Health Consultation

Dimock Groundwater Site

Carter Road and State Route 3023

Dimock, Susquehanna County, Pennsylvania

MAY 24, 2016

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

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Prepared By:

Agency for Toxic Substances and Disease Registry
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SUMMARY

Introduction:	Natural gas drilling and associated completion activities (e.g., hydraulic fracturing) began in approximately late summer/early fall of 2008 in the Carter Road area of Dimock, Susquehanna County, Pennsylvania. Some area residents began reporting groundwater quality and potability concerns beginning in the winter of 2008. Cabot Oil and Gas ("Cabot", the natural gas extraction company operating in the Carter Road area of Dimock) and the Pennsylvania Department of Environmental Protection (PADEP) tested residential water wells in the area. The results indicated that residential water wells in the Dimock area had significant concentrations of dissolved methane. PADEP subsequently determined that a number of residential water wells were impacted by Cabot natural gas activities (PADEP 2010). To address the situation, PADEP and Cabot executed a consent order and agreement (COSA) in 2009, which the parties modified several times before its final version was issued in 2010. The COSA required further well water testing, alternate water supplies and negotiations between Cabot and specific homeowners for installation of water treatment systems. By November 1, 2011, Cabot requested and was authorized by PADEP to stop supplying alternate water because the PADEP considered the steps taken by Cabot to be sufficient to meet the obligations of the COSA. Just before November 2011, Dimock residents requested that U.S. Environmental Protection Agency (EPA) and Agency for Toxic Substances and Disease Registry (ATSDR) assist with their ongoing groundwater concerns. ATSDR, following a 2011 request from EPA, conducted a preliminary screening of the historical data set (which included both a limited set of private water well sample results collected before natural gas activities commenced and a much larger set of groundwater data collected after natural gas activities began and following residents' reported water quality complaints). Based on limited screening of the historical data set, ATSDR recommended - in a 2011 ATSDR record of activity (AROA) document - that residents not use their well water until further notice and until further assessment was completed that provided for a better understanding of exposures in the Dimock site area. This health consultation completes the ATSDR assessment of the EPA 2012 private well water data and the conclusions and recommendations provided in this document supersede the ATSDR recommendations provided in the 2011 AROA. ATSDR reviewed the data EPA collected in 2012 from 64 Dimock private residential water wells. For this public health evaluation, ATSDR conservatively assumed ingestion of residential well water with the ***maximum*** detected chemical concentration(s) and included all detected contaminants in the evaluation ***regardless of the source of the contaminant*** in the residential well (e.g., naturally occurring or otherwise). Per ATSDR's health assessment process, ATSDR made conservative assumptions about exposures to the chemicals detected in the residential well water at this site, and made recommendations based on this information.

CONCLUSIONS	
Conclusion 1	ATSDR found some of the chemicals in the private water wells at this site at levels high enough to affect health (27 private water wells), pose a physical hazard (17 private water wells), or affect general water quality so that it may be unsuitable for drinking. Dimock residents who participated in EPA's 2012 sampling can review Appendix B of this document to understand what chemicals were identified by ATSDR as of potential health concern in their specific private water well.
Chemicals of Health Concern	• **Arsenic** (13 private water wells) - Some children may experience non-cancer health effects from chronic consumption of water from 10 wells; drinking water from 13 wells may lead to an increased risk of developing cancer over a lifetime. • **Cadmium** (1 private water well) - Chronic exposure may be of health concern for the most sensitive subpopulation (e.g., kidney disease, diabetic children). • **Copper** (2 private water wells) - Exposures may be of health concern for some children that may be sensitive to copper. • **Iron** (13 private water wells) – Chronic exposure may be of health concern for the most sensitive subpopulation (i.e., those with hemochromatosis). • **Lead** (20 private water wells) – The EPA has set a maximum contaminant goal of zero (0) for lead in drinking water because no health-based standard has been established. • **Lithium** (20 private water wells) – Exposures for children (and for adults for eight wells) exceed the EPA Provisional Peer Reviewed Toxicity Value. • **Manganese** (2 private water wells) - Chronic exposure may be of health concern for young children. • **Potassium** (1 private water well) – Chronic exposures may be of concern for people who are at risk for hyperkalemia (e.g., people with renal failure, severe heart failure, taking certain medications that impair potassium excretion, *etc*.). • **Sodium** (16 private water wells) – Exposure would exceed the drinking water advisory level of 20,000 µg/L. This level is intended to protect people who have high blood pressure or are on a sodium-restricted diet. Drinking water with a high level of sodium is a health concern for people who must limit how much salt they eat or drink. • **4-chlorophenyl phenyl ether** (2 private water wells) – There is not enough information on the toxicology of this chemical to determine its potential for adverse health effects. Non naturally-occurring chemicals (specifically bis(2-ethylhexyl) phthalate or DEHP, hexachlorobenzene, and 2,4-dinitrotoluene) were detected in EPA's 2012 sampling data set below levels of health concern. In the historical data set, non-naturally-occurring chemicals (specifically DEHP, ethylene glycol/other glycol compounds, and 2-methoxyethanol) were detected in post-drilling well water samples at higher concentrations than were found in EPA's 2012 sampling, and some of these higher detections were of public health concern.
Physical Hazard	**Methane** (17 private water wells) - An immediate risk of explosion or fire exists for five residences (methane >28 mg/L); cautionary level exceeded in 12 additional wells (methane >10 mg/L).
General Water Quality	Problems remain for a number of residential water wells that make water undesirable for consumption, including cloudiness and effervescence (from elevated methane), elevated metals/salts and total dissolved solids (e.g., discoloration, cloudiness, *etc*.), pH, and bacteriological contamination (including fecal coliform in one well).

Conclusion 2	Dimock residents' current exposures to chemicals in their well water remain unclear. Ultimately, due to a lack of data, it is not clear whether a resident is consuming treated or untreated groundwater or whether treatment was successful or remains effective.
Limitations	• The majority of the environmental sampling data reviewed in this document are limited temporally to a six month period of time in 2012 when a moratorium was in place for natural gas drilling and completion activities in the site area. This time- and condition-limited data may not represent past, current or future exposures for Dimock area residents consuming groundwater; therefore, ATSDR cannot make public health conclusions about current and future exposures. • There is a lack of pre-drilling data for comparison to post-drilling residential water well data, or for chronic exposure evaluations. Methane, industry-specific chemicals, and many metals were typically not assessed prior to the start of natural gas activities in the Dimock area. • Some of the analytical results, and particularly polycyclic aromatic hydrocarbons (PAHs), were "J" qualified by the laboratory, indicating the analyte was present in the field sample but the concentration reported may be inaccurate or imprecise. For this health consultation, ATSDR used the reported concentration of "J" qualified data when developing exposure doses. • The analytical data evaluated in this report are from field samples collected by the EPA in 2012 and provided to ATSDR through direct access to the EPA SCRIBE database. The original laboratory analytical packages were not reviewed by ATSDR. • Information on pH, total dissolved solids (TDS), and odor was not consistently collected and documented during EPA's 2012 assessment activities. • Information on potential pathways of exposure beyond the groundwater pathway (e.g., ambient air inhalation) is not available to ATSDR for this site at this time. • There is limited toxicological information on the effects of exposures to metal salt mixtures in drinking water, which, therefore, supports careful consideration of these exposures, especially to sensitive populations. Based on this lack of information, ATSDR suggests avoiding chronic exposures to metal salt mixtures.

Recommendations and Next Steps	
Chemicals of Health Concern	• **Arsenic** - ATSDR recommends continuing well water treatment to reduce arsenic exposure from well HW47 and regular monitoring of the treated well water to verify arsenic is below levels of health concern. ATSDR also recommends well water treatment to reduce lifetime arsenic exposures to twelve additional residential well water supplies: HW2, HW6, HW12, HW15a, HW17, HW18, HW22, HW29, HW32, HW49, HW57, and HW60. • **Cadmium** – ATSDR recommends well water treatment to reduce children's exposures to well HW57 well water. • **Copper** – ATSDR recommends steps, such as flushing the water pipes prior to use, to reduce children's exposure to copper at the tap in homes served by wells HW28a and HW33b. • **Iron** - ATSDR recommends that individuals with elevated iron in their well water that are on reduced-iron diets, including those with hemochromatosis, consult their health care provider to discuss this additional source of iron in their diet. • **Lead** - ATSDR recommends that homeowners with detectable lead in their drinking water take steps, such as well water treatment and flushing the water pipes prior to use, to reduce the lead before ingestion. Consistent with statewide childhood blood lead screening guidelines, every family is encouraged to discuss blood lead screening for children six years of age and under with their health care provider. • **Lithium** – Homeowners of the following water wells should take steps, such as installing an effective well water treatment system or choosing an alternative drinking water source, to reduce exposure to the lithium in their wells (HW1, HW2, HW5, HW6, HW12, HW15a, HW16, HW17, HW18, HW22, HW24, HW25, HW26, HW29, HW30, HW31, HW34a, HW39, HW47, and HW60). • **Manganese** - ATSDR recommends that homeowners of wells HW47 and HW8a install a well water treatment system to reduce exposure to manganese if it is being consumed by young children, particularly if the well water is being used for mixing infant formula. • **Potassium** - ATSDR recommends that individuals at risk for hyperkalemia, e.g., people with renal failure, severe heart failure, taking certain medications that impair potassium excretion, *etc.*, notify their health care provider about this additional source of potassium in their diet from well water. • **Sodium** - ATSDR recommends that individuals on sodium restricted diets or who have infants discuss the sodium in their residential well water with their health care provider. • **4-chlorophenyl phenyl ether** - Due to limited toxicological literature for 4-chlorophenyl phenyl ether and limited sampling information, ATSDR recommends that residents using wells HW8a and HW2 continue to monitor and/or take steps, such as installing an effective well water treatment system or choosing an alternative drinking water source, to reduce exposure to the chemicals in these private water wells.
Physical Hazard	• Concentrations of methane above 28 mg/L (28,000 µg/L) require immediate action, including wellhead ventilation and possibly treatment to remove the methane from the residential well water. • Take precautionary steps for dissolved methane concentrations that range from 10 mg/L (10,000 µg/L) to 28 mg/L (28,000 µg/L), including installation of a

	combustible gas monitor, ventilation of the home, ventilation of the well head, and removal of ignition sources in enclosed areas of the home. • Methane detected at a concentration below 10 mg/L (10,000 µg/L) does not warrant immediate action except for monitoring the appearance of the water and possibly ventilating the home. • For homes with dissolved methane in their well water exceeding 10 or 28 mg/L and that are not already being vented/treated, ATSDR recommends residents implement the protective actions described above.
Private Water Treatment Systems	• Dimock private water well users should carefully consider the information about their well water quality, as well as options about appropriate water treatment and operation and maintenance of any systems installed on their private water well. The Penn State Extension Program and the Master Well Owner Network can provide expert advice to help make decisions about appropriate water treatment and long term operation and maintenance. • All private well owners should test their drinking water on a regular basis. The Penn State Extension Program offers well water testing at low costs, and this program offers a specific gas/oil water testing package. The Penn State Extension lab testing web site is http://agsci.psu.edu/aasl/water-testing/drinking-water-testing, or the Susquehanna County Penn State Extension office can be reached at 570-278-1158 for more information on their private water well testing program.
Future Sampling	In addition to routine private well water quality monitoring by private well users, ATSDR recommends additional residential drinking water well sampling for further groundwater characterization purposes with an appropriate full analyte list following accepted sampling protocols in the Dimock site area either by the appropriate regulatory agency or under the supervision of the appropriate agency.
Next Steps	One primary role for public health agencies is to provide health education to community members to support protective health actions. In 2012, ATSDR participated in EPA's meetings with Dimock residents in their homes to review their individual residential well water results. ATSDR will continue to work with appropriate regulatory and public health agencies and community members to share information with the Dimock community about the public health implications of residential well water quality in the area. This educational effort will continue to include specific information related to ongoing well water potability concerns, appropriate treatment systems and operation and maintenance, and methane mitigation in wells with levels exceeding the 10-28 mg/L (10,000-28,000 µg/L) range.

Note: Site conditions have changed since the EPA January-July 2012 sampling. In August 2012, PADEP lifted the moratorium on completions (e.g., hydraulic fracturing) of previously drilled wells in the site area. In December 2012, subsequent to new completions in the site area, several residents filed complaints with the PADEP and one report was filed with the National Response Center regarding visual changes in their residential well water quality (turbidity, color changes, increased methane). Subsequently, PADEP conducted some additional investigation into potential well contamination in the moratorium area. During a July 2013 meeting between PADEP, ATSDR, and EPA, PADEP informed ATSDR that they continue to investigate groundwater concerns in Dimock. PADEP noted that they have collected and analyzed residential well water samples related to specific groundwater concerns but have not made a determination on these data or on additional lines of evidence related to the natural gas activities. To date, ATSDR has not received these newer Dimock private well water data.

I. Statement of Issues:

The U.S. Environmental Protection Agency (EPA) Region 3 requested ATSDR conduct a public health evaluation of the Dimock environmental data, including the EPA 2012 Dimock residential well water results. Access to EPA validated analytical sampling results is available at http://www.epaosc.org/site/doc_list.aspx?site_id=7555.

II. Background and Site History:

Natural gas drilling and completion activities began in approximately late summer/early fall of 2008 in the Carter Road area of Dimock, Susquehanna County, Pennsylvania, during the early stages of the recent natural gas boom in the Commonwealth. Some area residents began reporting groundwater quality and potability concerns beginning in the winter of 2008. Residents noted (1) orange, red, black and white groundwater discolorations; (2) increased sediment buildup that clogged their water treatment filters; and (3) radiator pipes that banged and rattled because of dissolved gases accumulating in their home heating systems. One residential well was reported to have exploded due to the elevated methane present in it (PADEP 2009). Because of residents' concerns, in 2008, the Pennsylvania Department of Environmental Protection (PADEP) and Cabot Oil and Gas (Cabot) began a residential groundwater sampling investigation in the Dimock area.

Post-drilling sampling by Cabot and PADEP since late in 2008 indicated that residential water wells in the Dimock area had elevated concentrations of dissolved methane. It is important to note that methane was not assessed in residential water wells prior to the initiation of natural gas drilling activities in the Dimock area. Following their groundwater investigation, PADEP determined that a number of residential water wells in the area were impacted by natural gas activities. The PADEP subsequently placed a moratorium on Cabot's drilling and completion activities in the Dimock area (PADEP 2009).

On November 4, 2009, Cabot and PADEP entered into a Consent Order and Agreement (COSA) regarding the Dimock groundwater contamination (PADEP 2009). Following a number of modifications, in December 15, 2010, the COSA between Cabot and PADEP was finalized (PADEP 2010). Under the COSA, Cabot was required to eliminate the unpermitted discharge of natural gas to waters of the Commonwealth by plugging or taking other remedial actions at certain Dimock/Carter Road natural gas wells, as well as to pay for or restore and/or replace affected drinking water supplies in the site area. Under this COSA, Cabot provided temporary whole house water supplies and provided funding and/or installed residential water well treatment systems for selected residents. The December 2010 final version of the order allowed Cabot to discontinue delivery of temporary whole house water supplies to residents who refused private water treatment systems by November 30, 2011 (PADEP 2010).

In October 2011, Dimock residents requested EPA and Agency for Toxic Substances and Disease Registry Region 3 (ATSDR) assistance with their ongoing concerns about the groundwater quality in Dimock and the implementation of private water treatment systems under the Commonwealth's order. In response, ATSDR and EPA participated in a listening session with concerned community members and area activists in November 2011, and conducted door-to-door visits at the Site to discuss these groundwater concerns with each available resident along Carter Road. In early December 2011, EPA requested that "ATSDR conduct a Health Consultation on the individual contaminant risks as well as the cumulative risk of the various compounds found in the residential water wells in and around the Dimock, PA area" (EPA 2011a). On December 30, 2011, ATSDR responded to EPA with a record of activity-technical assistance document (AROA) that provided ATSDR's initial public health evaluation of the large, historic data set (which included a limited pre-drilling groundwater data set, and post-drilling sampling analytical data from PADEP, Cabot and homeowners). In ATSDR's December 2011 review, ATSDR concluded that (1) there may be a public health threat from chronic exposure to the well water should exposures to the reported concentrations continue and (2) there were important data gaps for evaluating groundwater quality in residential water wells in the site area. At that time, ATSDR supported a “Do Not Use until Further Notice” action regarding the residential water wells sampled to date until the site could be characterized further. In the 2011 AROA, ATSDR recommended (1) further residential water well sampling using a full set of constituents (e.g., inorganic, organic, and potability parameters including total and fecal bacteriological samples), and (2) a full public health evaluation on the data from the site area (see Appendix A for the 2011 AROA).

In January 2012, based on elevated chemical concentrations observed in the historical sampling results from the site area, EPA began providing alternative drinking water to four private Dimock residences pending results from EPA’s sampling activities. From January through June 2012, EPA conducted an environmental sampling assessment of 64 residential water wells in the Dimock site area. The objective of the EPA sampling was to determine whether “any toxic substances were present in the residential water wells at this site that may pose a threat to the health of persons ingesting, contacting or engaging in typical residential uses of the groundwater to the extent that an EPA Removal Action should be continued, expanded or terminated” (EPA 2012). EPA noted that their analytical protocols were selected based in part on contaminants that may be present due to natural gas exploration, drilling or hydraulic fracturing activities occurring in the region. The EPA investigation included collecting multiple samples at each home to assess the water quality at the well, at the tap, and, where applicable, before and after any existing home water treatment system. Each sample was analyzed for approximately 225 parameters. The EPA “collected and analyzed approximately 300 discrete samples, yielding over 67,000 individual analytical results” (EPA 2012).

Environmental Data Sets

The **EPA 2012 data set** includes analytical data from 64 wells sampled by EPA between January and July 2012 during a natural gas moratorium.

The **historic data set** includes analytical data collected under the direction of Cabot, PADEP, and homeowners prior to 2012 (including pre-drilling and during drilling and completion activities). 18 wells are included in this data set.

As sampling activities progressed, EPA noted detections of lithium in some of their residential water well sampling results. Subsequently, on March 12, 2012, EPA requested consultation from ATSDR regarding what concentration of lithium in drinking water would represent an acute public health concern. ATSDR provided a technical assistance document responding to this request. In that document, ATSDR concluded that 1) lithium concentrations below 1,500 µg/L (1.5 mg/L) in drinking water would not likely result in adverse acute health effects for children and adults; and, 2) the lack of scientific information precluded making any health conclusions about chronic ingestion of drinking water containing 200 to 500 µg/L lithium (see Appendix A). ATSDR recommended that individuals using drinking water with these levels of lithium who are sensitive to lithium or concerned about lithium exposures should consult their personal health care provider and determine if it is prudent to follow their serum lithium levels.

EPA provided residents with their individual sampling results. Each sampled residence received a “toxicological memorandum” that summarized the EPA comparison of chemicals detected in the private drinking water supply to the EPA site-specific, risk-based levels. EPA found arsenic, barium or manganese in five residential water wells at levels that could present a health concern. Further toxicological review by ATSDR of exposures to arsenic, barium and manganese at the levels detected in EPA 2012 sampling data indicates exposures to the detected levels of arsenic and manganese could present a health concern to some individuals, but exposures to barium at the levels detected are not expected to present a health concern for adults or children. ATSDR generally concurred with the EPA toxicological reviews in these individual 2012 memoranda (see the public health evaluation section of this document for ATSDR’s detailed discussions for each of these chemicals). Some wells had chemicals present (such as sodium and iron) that exceeded EPA’s secondary drinking water quality standards. In April 2012 through May 2012, ATSDR also assisted EPA with home visits in Dimock to discuss EPA’s well water sampling results with each family. ATSDR participated in these individual meetings to discuss health-related questions or health concerns raised by the residents.

This health consultation provides an in-depth health evaluation of exposures to chemicals in Dimock residential well water identified in the EPA 2012 data set. Water quality is evaluated both pre- and post-treatment, when those data are available. When a specific detected chemical has relevance to water potability, such as discoloration, taste, or smell, it is specifically discussed in the document. ATSDR conducted a screen of the historic data set, which includes a large quantity of analytical results collected from 18 of the 64 Dimock residential water wells. When relevant for chronic exposures to specific chemicals detected in historic Dimock groundwater data, ATSDR provides comment in this document. Additional screening of the historic data set screening is provided in Appendix F.

Site conditions have changed since EPA's January-July 2012 sampling. PADEP lifted the moratorium on completion of previously drilled wells in the site area in August 2012. Subsequently, in December 2012 and February 2013, several residents reported to PADEP and one resident reported to the National Response Center visual changes in their private drinking water quality (turbidity, color changes, increased methane) (NRC 2012, verbal communications to ATSDR Region 3 from EPA Region 3 and residents). Subsequently, PADEP conducted an investigation into potential residential water well contamination in the moratorium area. PADEP collected and analyzed residential water well samples related to specific groundwater concerns, but has not made a determination on these data or on additional lines of evidence related to the natural gas activities.

Baseline and Background Environmental Data

Overall, the pre-drilling information on baseline (i.e., pre-drilling analytical data from residential water wells) and background groundwater quality (i.e., regional aquifer water quality) in the Dimock area is incomplete. Without sufficient pre-drilling groundwater analytical data, it is not possible for stakeholders (e.g., property owners, regulatory agencies) to determine with confidence whether groundwater quality changes have occurred in residential water wells or to fully understand residential water well quality prior to the start of natural gas activities in the area. Appendix C provides additional information about the baseline and background data available for the site area.

III. Discussion

In conducting a public health evaluation of environmental chemical exposures in a community, ATSDR follows its Public Health Assessment Guideline manual (ATSDR 2005). For this public health evaluation, ATSDR conservatively assumed ingestion of residential well water with the ***maximum*** detected chemical concentration(s) and included all detected contaminants in the evaluation ***regardless of the source of the contaminant*** in the residential well (e.g., naturally occurring or otherwise). Per ATSDR's health assessment process, ATSDR made conservative assumptions about exposures to the chemicals detected in the residential well water at this site, and made recommendations based on this information. For information about the ATSDR public health assessment process, see Appendix D.

This section covers the following: (1) specific data limitations for ATSDR's public health evaluation of the 2012 EPA Dimock data set; (2) potability of the residential well water; (3) determination of the contaminants of potential public health concern from the EPA 2012 Dimock data set; (4) the public health implications of exposure to chemicals of potential concern in Dimock; and, (5) community health concerns.

1. Data Limitations

There are important data limitations in ATSDR's public health evaluation of the environmental data from the Dimock site, including:

- The majority of the environmental sampling data reviewed in this document are limited temporally to a six month period of time in 2012 when a moratorium was in place for natural gas drilling and completion activities in the site area. This time- and condition-limited data may not represent past, current or future exposures for Dimock area residents consuming groundwater;

- There is a lack of pre-drilling data for comparison to post-drilling residential water well data, or for chronic exposure evaluations. Methane, industry-specific chemicals, and many metals were typically not assessed prior to the start of natural gas activities in the Dimock area;
- Some of the analytical results, and particularly polycyclic aromatic hydrocarbons (PAHs), were “J” qualified by the laboratory, indicating the analyte was present in the field sample but the concentration reported may be inaccurate or imprecise. For this health consultation, ATSDR used the reported concentration of “J” qualified data when developing exposure doses;
- The analytical data evaluated in this report are from field samples collected by the EPA in 2012 and provided to ATSDR through direct access to the EPA SCRIBE database. The original laboratory analytical packages were not reviewed by ATSDR;
- Information on pH, total dissolved solids (TDS), and odor was not consistently collected and documented during EPA 2012’s assessment activities;
- Information on potential pathways of exposure beyond the groundwater pathway (e.g., ambient air inhalation) is not available to ATSDR for this site at this time;
- There is limited toxicological information on the effects of exposures to metal salt mixtures in drinking water, which, therefore, supports careful consideration of these exposures, especially to sensitive populations. This lack of information suggests avoiding chronic exposures to metal salt mixtures.

A finding that is both a limitation and a conclusion of ATSDR’s work related to the Dimock site, is that a data gap exists regarding the existence and efficacy of home water well treatment systems that limits ATSDR’s ability to evaluate residential well water exposures in Dimock. The status of individual residential water well treatment systems has been difficult to document. In direct discussions with residents, many were not able to clearly describe their water purification systems or what their system is designed to treat. For example, EPA field records indicate some wells have both a methane wellhead vent and dissolved methane treatment, while other wells have no field notes indicating if either a vent or a treatment system is in place. For treatment systems that ATSDR has observed in the field, there is notable variability across homes. Some homes have installed whole-house systems, while others have point-of-use treatment for drinking water alone. Ultimately, it is not clear whether a resident is consuming treated or untreated groundwater or whether treatment was successful or remains effective.

2. General Water Quality and Potability

Potability is broadly defined as whether something is drinkable or not. For the purposes of this review, ATSDR uses the term potability to cover water quality characteristics that do not lend themselves to traditional environmental chemical exposure evaluation but that can negatively impact the desirability and drinkability of a water supply.

Some Dimock residents have been acquiring drinking water from local springs and surface waters of unknown water quality and composition because of their concerns about their residential well water quality. While these alternative surface water sources may be aesthetically acceptable (e.g., no odor, clear, no foul taste), it is not known whether these sources are safe for consumption regarding chemical or biological contaminant exposures. Some sensitive populations, such as those on sodium, chloride, or iron restricted diets may need to consume well water that exceeds secondary maximum contaminant levels due to a lack of alternative, potable water options.

A number of EPA secondary maximum contaminant levels (SMCLs) are available for evaluating groundwater potability. Some of the EPA 2012 sampling results include potability parameters that can be compared to SMCLs or other comparison values. However, water quality information in the EPA 2012 data set was inconsistent for some of the potability parameters. For example, information on pH, total dissolved solids (TDS), and odor was not consistently collected and documented during EPA's 2012 assessment activities. Further, not all of these potability parameters have a corresponding health-based comparison value.

Bacterial contamination was identified in 17 residential water wells in the EPA 2012 data set, but only one well was positive for fecal coliform bacteria (see Appendix B). We consider bacteriological contamination, and particularly fecal coliform contamination at any detectable level, a general water quality issue in this review. SMCL exceedances (e.g., the presence of high iron and other metals) along with the presence of organic materials can contribute to bacterial growth in residential water wells.

3. Determining Contaminants of Potential Health Concern

Starting in January 2012, EPA initiated field sampling of 64 residential water wells in the Dimock area using standardized field sampling protocols. The EPA sampling plan is available online: http://epaosc.org/sites/7555/files/Dimock_SAP_Rev01_Final.pdf. The laboratories selected to analyze the environmental samples are accredited and their analytical methods approved, including acceptable data quality controls and assurances. Some residential water wells were sampled by EPA more than once in 2012, and, if this was the case, these data are also included in this evaluation.

To evaluate exposures using the EPA 2012 data set, ATSDR used the maximum contaminant concentration detected in all wells sampled by EPA in 2012 to compare to the appropriate health-based comparison value (CV). CVs are substance and media-specific (air, water, soil) concentrations that are used by health assessors during the initial phase of ATSDR's Public Health Assessment process to select environmental contaminants that require further evaluation. It is important to note that if a chemical exceeds a health-based CV, it does not necessarily mean it is a health concern. Rather, it means the chemical and site-specific exposure scenario warrant further public health evaluation. If a chemical exceeds its CV, or if there is no appropriate CV for comparison, it will be held as a contaminant of potential concern (COPC) and will be further evaluated in the health consultation. For additional information about CVs used in this health consultation, see Appendix E.

ATSDR evaluated the available data for short, intermediate and long term exposure durations, assuming the following factors in estimating exposure doses: infant, child, and adult weights are 10, 16 and 70 kilograms, respectively; infants and children consume 1 liter of water per day; adults consume 2 liters of water per day; and, acute, intermediate and chronic exposure durations are 1 to 14 days, 15 to 364 days, and greater than 364 days, respectively. In this section, we screen the maximum contaminant detections in all residential water wells sampled against health-based CVs. This is followed by the public health implication section which evaluates in more detail exposures to each contaminant that exceeded a CV in the 2012 data set or for which no CV exists. Although other chemicals were detected in the EPA 2012 data set, the concentrations of these chemicals were below health-based comparison values for acute, intermediate or chronic exposures.

Contaminants of Potential Concern (COPCs)

A range of naturally occurring and man-made substances were detected in the residential water wells along Carter Road, Route 3023 and Meshoppen Creek Road in the Dimock site area in EPA's 2012 data set. This section highlights the chemicals that were detected at concentrations exceeding a CV, as well as the chemicals that were detected but for which no appropriate CV was identified. Table 1 summarizes the COPCs. Appendix B includes well-by-well details for specific chemicals detected above CVs or for which no CV is available.

A number of additional chemicals were detected at levels that did not exceed a CV, including acetone, bromoform, carbon disulfide, chloroethane, chloroform, dichloroethene-1,2 trans, xylenes, methyl acetate, methyl chloride, methyl ethyl ketone, tetrachloroethylene, toluene, and radionuclides. Therefore, these chemicals were eliminated from further analysis. Other chemicals were also detected in the historic data set that were not detected in the EPA 2012 sampling; see Appendix F for a summary of the historic data set.

Table 1
Summary of Contaminants of Potential Concern
2012 EPA-Sampled Residential Water Wells

Contaminant	**Number of wells exceeding CV, SMCL, or for which no CV available**	**Reason**
Fecal coliform	1	Exceeds CV
Methane	5	Exceeds CV
Polycyclic Aromatic Hydrocarbons (PAH)	6	Exceeds CV
Dibenzofuran	4	No CV
Di-ethylhexyl phthalate (DEHP)	2	Exceeds CV
4-Chlorophenyl phenyl ether	2	No CV
2,4-Dinitrotoluene	1	Exceeds CV
Hexachlorobenzene	4	Exceeds CV
Aluminum	6	Exceeds SMCL
Arsenic	27	Exceeds CV
Barium	2	Exceeds CV
Bromide	3	No CV
Cadmium	1	Exceeds CV
Copper	2	Exceeds CV
Iron	13	Exceeds SMCL
Lead	2	Exceeds CV
Lithium	20	No CV
Manganese	4	Exceeds CV
Phosphorus	5	Exceeds CV
Potassium	1	No CV
Sodium	16	Exceeds CV

Note: There were a total of 64 private residential wells assessed in Dimock by EPA in 2012. See Appendix E for comparison value (CV) information and well-by-well CV exceedances. SMCL = Secondary maximum contaminant level.

4. *Public Health Evaluation*

Exposure to environmental contamination does not occur 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. Based on the residential well water data available to ATSDR at this time, the relevant exposure pathways for residents are ingestion, dermal contact, and inhalation via use of groundwater from residential wells and local springs. A number of substances (dissolved gases, organic and inorganic chemicals, and biological contaminants) have been detected at levels exceeding health-based CVs or for which there are no CVs. The chemicals meeting these criteria are investigated further in this document.

Some of the naturally occurring substances (e.g., calcium, chloride, iron, magnesium, manganese, potassium, sodium) are nutrients. The ATSDR evaluation focuses on the estimated dietary intake from residential well water alone. Total nutrient uptake includes all sources of the nutrient including food and drinks; typically, drinking water by itself is not considered a significant source of these nutrients. This health consultation used the tolerable upper intake levels (UL), as defined by the Institute of Medicine (IOM), for evaluating the health impacts from residential well water exposures to nutrients. The IOM defines a UL as the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population (IOM 1997). In the absence of health-based comparison values, ATSDR used the ULs as CVs.

Acute and chronic contaminant exposure dose estimates were calculated using the typical risk assessment default values of 2 liters of water/day and a 70 kg body weight for adults. For a child, two exposure doses were calculated: (1) 1 liter of water/day and a 16 kg body weight, and (2) 1 liter/day and a 10 kg body weight. ATSDR conducted the chronic (a year or more) exposure evaluation assuming the concentrations detected would remain consistent over the life of the residential water well use.

The health guidelines used in this evaluation are based on studies of animals and humans. The information from toxicological and epidemiological studies is used to determine the lowest amount of a substance that have resulted in adverse health effects (the Lowest Observed Adverse Effect Level, or LOAEL) and the highest amount of a substance that has not resulted in an adverse health effect (No Observed Adverse Health Effect Level, or NOAEL). ATSDR applies a number of uncertainty factors to the LOAEL and the NOAEL to derive non-cancer screening values called minimal risk levels (MRLs).

MRLs represent the daily dose of a chemical that people could be exposed to for a specified period of time (acute, intermediate and chronic) without experiencing non-cancer adverse health effects. Health effects at an exposure dose at or below the MRL are considered to be unlikely. If the MRL is exceeded, it does not mean the contaminant poses a health concern; it means further evaluation is needed to determine if health effects may occur. There could be concern if the estimated exposure dose approaches the LOAEL, e.g., within about an order of magnitude, although depending on the chemical, there may be concern at even lower levels.

To screen detected chemicals for lifetime cancer risk, ATSDR has developed Cancer Risk Evaluation Guides (CREG), which represent a concentration of a chemical in a media that if exposed to, could result in a chance of one person getting cancer out of a million people exposed for a lifetime, above and beyond the “background” level of cancer in the population. To assess cancer risk, ATSDR assumed exposure over a 78-year duration. ATSDR used this assumption in this case because a number of area residents reported lifetime and multi-generational use of their residential water wells. If cancer risk from 78 years of exposure exceeded EPA’s target risk of 1 in 10,000, then ATSDR calculated a 30-year cancer risk estimation (based on a more typical residency time at one dwelling). Estimated cancer risks that are between one in 10,000 and one in 1,000,000 are considered to fall within EPA’s target risk range.

Appendix B provides a well-by-well summary of comparison value and SMCL exceedances. If a particular chemical or analyte did not exceed its CV or SMCL, it is not included in the Appendix. If no CV was available, the chemical is included in the Appendix and considered a chemical of potential concern. The detailed review of potential health effects for all of the chemicals of potential concern (COPC) follows. Dimock residents who participated in EPA’s 2012 sampling may want to review Appendix B of this document to understand what chemicals were identified by ATSDR as potential health concern in their specific private water well.

Toxicological Implications of Exposure to COPCs

The following subsections evaluate non-radiological contaminants that exceed health-based CVs or for which no CVs have been determined.

Organic COPCs

Dissolved Gases (Methane)

Of the residential wells with dissolved gas detections, the primary volume of gas was methane. In the data set evaluated for this health consultation, combined concentrations of dissolved gases in residential water wells were only slightly higher than the total methane concentrations detected. Fluctuation in dissolved gas concentrations and variability in gas mixtures across individual water wells is expected over time.

The health risk from methane and related gases dissolved in residential well water is posed by their asphyxiant and explosive hazards when the gas migrates from the water into the air. There is insufficient toxicological or epidemiological information available to determine whether there may be health effects from drinking groundwater that contains methane and other similar dissolved gases (ethane, propane, n-butane, iso-butane, and ethene). Methane is odorless and tasteless.

Very high levels of methane in groundwater have the potential to become a simple asphyxiant (around 87% by volume in air) when released from the groundwater into ambient air. Asphyxiants, such as methane, displace oxygen; of particular concern in enclosed spaces. Reduced oxygen concentrations in the air can result in insufficient oxygen in the blood. Insufficient oxygen can produce symptoms of central nervous system depression including nausea, headache, dizziness, confusion, fatigue, and weakness. This can be of concern inside homes, especially in bathrooms, basements, and laundry rooms where well water enters and limited air circulation can allow rapid methane accumulation and oxygen displacement. This can also be a concern in well- or spring-houses where groundwater is accessed.

Methane's lower explosive limit (LEL) is 5% by volume in air and the upper explosive limit (UEL) is 15% by volume in air (NLM 2005). Methane levels within this range can lead to a fire or explosion if an ignition source is present. The saturation level for dissolved methane in water at standard room temperature and ambient atmospheric pressure (STP) is approximately 28,000 µg/L (28 mg/L). If residential well water contains methane above 28,000 µg/L (28 mg/L), the U.S. Department of the Interior, Office of Surface Mining, recommends taking immediate action to reduce this concentration to mitigate the potential buildup of methane gas in air.

Well water with dissolved methane concentrations above this threshold will off-gas and, if an ignition source is present, can create an immediate fire and explosion concern in confined areas (e.g., at the wellhead, springhouse, basement, crawlspace, *etc.*). Residential water wells with levels between 10,000 µg/L (10 mg/L) and 28,000 µg/L (28 mg/L) should be regularly monitored, and well owners may wish to consider treatment to lower the methane level (DOI 2001). Methane concentrations below 10,000 µg/L (10 mg/L) are generally considered safe.

Dissolved methane was detected in approximately 70% (45 out of 64 wells) of the residential wells tested by EPA in 2012. Five wells (HW3, HW12, HW25, HW26, and HW29) had methane concentrations in the untreated groundwater between 28,000 µg/L (28 mg/L) and 77,000 µg/L (77 mg/L), indicating an immediate safety hazard exists for these five residences. Two property owners (HW12 and HW29) with elevated methane in their well water indicated to ATSDR that their residential water wells are being addressed by Cabot for this issue (personal communication, November 20, 2012). The property owner for HW3 indicated they have a wellhead vent but no treatment to remove the dissolved methane before entering the home. ATSDR spoke with PADEP Office of Oil and Gas management representatives, who have indicated that well HW3 is eligible for a methane treatment system under the COSA between Cabot and PADEP, but that wells HW25 and HW26 are not considered a PADEP Oil and Gas issue and are not covered under agreement or considered directly related to Cabot operations (PADEP, personal communication, November 19, 2012). PADEP also noted that ambient air monitoring for methane gas at these three residences (HW3, HW25 and HW26) did not detect elevated methane in the air above their monitor's lower detection limit. As of January 2013, these remaining three wells (HW3, HW25 and HW26) did not have methane treatment systems in place.

EPA 2012 sampling identified 12 residential water wells (HW16, HW34a, HW6, HW11, HW60, HW52, HW2, HW22, HW31, HW15a, HW1, and HW47) with methane between 10,000 µg/L (10 mg/L) and 28,000 µg/L (28 mg/L). These wells require close monitoring and ATSDR suggests precautionary steps be taken to prevent unsafe methane and dissolved gas buildup in enclosed spaces.

Three residential water wells (HW9, HW13, and HW00) had methane levels under 10,000 µg/L (10 mg/L), the level generally considered as safe from explosive gas buildup. Two residential water wells, HW31 and HW34a, had much lower dissolved methane levels in treated water samples collected from their kitchen sink than untreated samples collected closest to their well pump, indicating both of these homes have effective methane treatment systems installed.

ATSDR recommends that homeowners that have dissolved methane above 28,000 (28 mg/L) in their residential water well water (HW3, HW12, HW25, HW26, and HW29), take immediate steps to treat and remove methane before the water enters their home. Two of these residential water wells (HW3 and HW12) have wellhead methane vents and treatment per the EPA/Cabot consent order. However, three of the five private water wells that exceed 28 mg/L are not part of the consent order (HW29, HW25 and HW26) and homeowners of these wells have indicated to ATSDR that beyond notification, the dissolved methane levels have not been addressed by industry, regulators or themselves to reduce the explosion or fire risk.

ATSDR recommends that all homeowners with dissolved methane exceeding 10,000 µg/L (10 mg/L) in their well water (HW1, HW2, HW6, HW11, HW15a, HW16, HW22, HW31, HW34a, HW47, HW52, HW60) install a methane detector in their home that will alarm if an unsafe level of methane has been detected in the indoor air.

Di-ethylhexyl phthalate (DEHP):

DEHP is a manufactured chemical that is commonly added to plastics to make them flexible. DEHP is a colorless liquid with almost no odor. It does not evaporate easily, and little will be present in the air even near sources of production. It dissolves more easily in materials such as gasoline, paint removers, and oils than it does in water. It is present in many plastics, especially vinyl materials, which may contain up to 40% DEHP, although lower levels are common. DEHP is present in plastic products such as wall coverings, tablecloths, floor tiles, furniture upholstery, shower curtains, garden hoses, swimming pool liners, rainwear, baby pants, dolls, some toys, shoes, automobile upholstery and tops, packaging film and sheets, sheathing for wire and cable, medical tubing, and blood storage bags (ATSDR 2002). DEHP is the most commonly used plasticizing agent for the widely used plastic polyvinylchloride (PVC) (Griffiths *et al.* 1995). Consequently, this compound is found everywhere in the environment of civilization, where it is in frequent contact with every person (Griffiths *et al.* 1995). In the April 2011 report by the Minority Staff of the U.S. House of Representatives Committee on Energy and Commerce, DEHP is listed as a chemical used in hydraulic fracturing (House 2011). This report noted that DEHP is a chemical component of three hydraulic fracturing products used between 2005 and 2009 (House 2011).

The estimated exposure doses from consuming groundwater with the maximum DEHP concentration (5.51 µg/L) is 0.0006 mg/kg/day and 0.0003 mg/kg/day for 10 kg and 16 kg children, respectively, and 0.00016 mg/kg/day for a 70 kg adult.

Non Cancer Exposure Evaluation

None of the DEHP detections in the EPA 2012 data set exceed the ATSDR non-cancer CV for this chemical or the PADEP health-based medium specific concentration (MSC) in groundwater of 6 µg/L (PADEP 2011). **Non-cancer health effects are not expected from exposures to DEHP at the levels detected in Dimock groundwater.**

Recently, attention has focused on the potential hazardous effects of certain chemicals on the endocrine system because of the ability of these chemicals to mimic or block endogenous hormones, or otherwise interfere with the normal function of the endocrine system. Chemicals with this type of activity are most commonly referred to as endocrine disruptors. While there is some controversy over the public health significance of endocrine disrupting chemicals, it is agreed that the potential exists for these compounds to affect the synthesis, secretion, transport, binding action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development, and/or behavior. Thus far, there is no evidence that DEHP is an endocrine disruptor in humans at the levels found in the environment (ATSDR 2002).

Cancer Exposure Evaluation

The ATSDR Cancer Risk Evaluation Guide (CREG) of 2.5 µg/L for DEHP was exceeded in two residential water wells (HW57 at 3.45 µg/L and HW39 at 5.51 µg/L) in the EPA 2012 data set. (*Note: the highest detected level of DEHP in Dimock groundwater was from the historic sampling data set; 22 µg/L was detected in HW00. HW00 was developed for residential use but has never been used to date*). No human studies have evaluated the potential for DEHP to cause cancer. Eating high doses of DEHP for a long time resulted in liver cancer in rats and mice. The Department of Health and Human Services (DHHS) has determined that DEHP may reasonably be anticipated to be a human carcinogen. EPA has determined that DEHP is a probable human carcinogen. These determinations were based entirely on liver cancer in rats and mice. The International Agency for Research on Cancer (IARC) has recently changed its classification for DEHP from "possibly carcinogenic to humans" to “cannot be classified as to its carcinogenicity to humans," because of the differences in how the livers of humans and primates respond to DEHP as compared with the livers of rats and mice (ATSDR 2002).

The maximum estimated adult DEHP exposure dose from the EPA 2012 Dimock data set is 0.00016 mg/kg/day. The EPA oral slope factor is 0.014 $(mg/kg/day)^{-1}$. By multiplying the maximum exposure dose by the oral slope factor, the estimated increased cancer risk from 78 years of exposure to DEHP at 5.51 µg/L in drinking water is approximately 2.2 additional cancers per one million exposed individuals. **The estimated cancer risk falls within EPA’s target risk range.**

4-Chlorophenyl phenyl ether:

Chlorinated diphenyl ethers (including 4-chloropheyl phenyl ether) are a growing environmental concern due to their increasing occurrence in lipophilic tissues such as human breast milk and blood and fish (TCEQ 2000). There are no ATSDR CVs or EPA screening values for 4-chlorophenyl phenyl ether, but the Texas Commission on Environmental Quality (TCEQ) has determined: (1) under the Texas Risk Reduction Program (TRRP), the protective concentration level (PCL) in residential groundwater is 0.06 µg/L, and (2) an oral cancer slope factor of 15 $(mg/kg/day)^{-1}$ will be applied in determining the potential lifetime carcinogenic risk. PCLs are default environmental cleanup standards in the TRRP. In 2000, due to limited toxicologic data for this group of chemicals, the TCEQ/Toxicology & Risk Assessment section selected octachlorodibenzodioxin (OCDD) as a toxicity surrogate (TCEQ 2013). Selection of OCDD as a surrogate was based on 4-chloropheyl phenyl ether’s potential interaction with the *ah*-receptor (TCEQ 2000). ATSDR has not conducted a comprehensive review of the Texas values referenced for this chemical.

4-Chlorophenyl phenyl ether was detected in two residential water wells, HW2 and HW8a at estimated concentrations of 0.096 µg/L and 0.029 µg/L, respectively. Using the maximum groundwater concentration of 0.096 µg/L, the estimated 10 kg and 16 kg child exposure doses are 0.00001 mg/kg/day and 0.000006 mg/kg/day, respectively, and 0.000003 mg/kg/day for a 70 kg adult.

Non Cancer Exposure Evaluation

As noted above, TCEQ uses 0.06 µg/L as their screening level for 4-chlorophenyl phenyl ether in drinking water based on the chemical surrogate, OCDD. Only well HW2 (0.096 µg/L) exceeds the TCEQ PCL for 4-chlorophenyl phenyl ether. **Due to limited toxicological literature for 4-chlorophenyl phenyl ether and the presence of other chemicals in the residential water well, ATSDR suggests residents take steps to reduce exposure to this chemical in both HW2 and HW8a.**

Cancer Exposure Evaluation

The maximum adult exposure dose to 4-chlorophenyl phenyl ether in Dimock drinking water is 0.000003 mg/kg/day. TCEQ, under their TRPP program, identified 15 (mg/kg/day)$^{-1}$ as the oral slope factor for 4-chlorophenyl phenyl ether. By multiplying the maximum adult exposure dose by the oral slope factor, the estimated increased cancer risk from 78 years of exposure to 4-chlorophenyl phenyl ether at 0.096 µg/L in drinking water is approximately 45 additional cancers per one million exposed individuals. **The estimated cancer risk falls within EPA's target risk range.**

2,4-Dinitrotoluene (2,4-DNT):

DNT (including 2,4-DNT and 2,6-DNT) is used to produce flexible polyurethane foams used in the bedding and furniture industry. DNT is also used to produce ammunition and explosives and to make dyes. It is also used in the air bags of automobiles. It has been found in the soil, surface water, and groundwater of at least 122 hazardous waste sites that contain buried ammunition wastes and wastes from manufacturing facilities that release DNT. DNT does not usually evaporate and is found in the air only in manufacturing plants. DNT also does not usually remain in the environment for a long time because it is broken down by sunlight and bacteria into substances such as carbon dioxide, water, and nitric acid. In water, DNT can be broken down by sunlight. Under conditions without oxygen or without light, DNT may be broken down by biological degradation, whereby microbes utilize the chemical as a source of energy and convert it into chemicals such as carbon dioxide and water. DNT in surface water from rivers and streams and groundwater from wells can result from releases of waste water from trinitrotoluene (TNT) manufacturing facilities and from buried munition wastes. The PADEP groundwater MSC for 2,4-DNT in a used aquifer is 2.1 µg/L (PADEP 2011).

2,4-DNT was detected in one residential water well, HW2, at an estimated concentration of 0.13 µg/L. The estimated exposure dose for a 10 and 16 kg child is 0.00001 and 0.000008 mg/kg/day, respectively. The estimated exposure dose for a 70 kg adult is 0.000004 mg/kg/day.

Non Cancer Exposure Evaluation

2,4-DNT did not exceed health-based non-cancer CVs. **Non-cancer health effects are not expected from exposures to 2,4-DNT at the level detected in HW2.**

Cancer Exposure Evaluation

2,4-DNT at the estimated concentration of 0.13 µg/L, exceeds the ATSDR CREG of 0.05 µg/L. IARC has classified 2,4-DNT as possibly carcinogenic to humans based on limited human evidence and less than sufficient evidence in animals (IARC 1997). EPA considers 2,4-DNT as a probable human carcinogen based on inadequate human evidence and sufficient animal studies (EPA 1993). EPA has not developed a cancer slope factor for 2,4-DNT. EPA and the New Jersey Department of Environmental Protection have identified an oral cancer slope factor of 0.68 (mg/kg/day)$^{-1}$ for mixtures of 2,4-DNT and 2,6-DNT (EPA 1990, NJDEP 2004). The California Office of Environmental Health Hazard Assessment (OEHHA) identifies a cancer slope factor of 0.31 (mg/kg/day)$^{-1}$ for 2,4-DNT (OEHHA 2009). ATSDR has not conducted a comprehensive review of the California or New Jersey values referenced for this chemical.

The maximum adult exposure dose to 2,4-DNT in Dimock drinking water is 0.000004 mg/kg/day. ATSDR selected the available CSF specific to 2,4-DNT by itself. OEHHA identifies a 2,4-DNT-specific cancer slope factor of 0.31 (mg/kg/day)$^{-1}$. By multiplying the maximum adult exposure dose by the oral slope factor, the estimated increased cancer risk from 78 years of exposure to 2,4-DNT at 0.13 µg/L in drinking water is approximately 1.3 additional cancers per one million exposed individuals. **The estimated cancer risk falls within EPA's target risk range.**

Dibenzofuran:

Dibenzofuran falls under the polycyclic aromatic hydrocarbon (PAH) structural class. It is a cyclic ether usually found as a white solid that is slightly soluble in water. Worker exposure to dibenzofuran may occur through inhalation and dermal contact at sites where coal tar, coal tar derivatives, or creosote are handled. The general population may be exposed to dibenzofuran through contact with creosote-treated wood or inhalation of fly ash particulates and emissions from municipal waste incinerators. Since dibenzofuran is a contaminant often found in waste dumps and in water supplies, exposure through ingestion of contaminated food products, e.g., fish, may also occur. Despite significant human exposure, very little information on the toxicity of dibenzofuran was found in the available literature (NTP 2000).

Dibenzofuran was detected in four residential water wells (HW2, HW61, HW36n, and HW28b) at estimated maximum concentrations of 0.038 µg/L, 0.022 µg/L, 0.014 µg/L, and 0.013 µg/L, respectively. The maximum estimated exposure dose based on the highest residential water well concentration of 0.0038 µg/L for a 10 and 16 kg child is 0.000004 and 0.0000024 mg/kg/day, respectively. The maximum estimated exposure dose for a 70 kg adult is 0.0000011 mg/kg/day.

Unlike other common PAHs, dibenzofuran is evaluated separately and not by comparing its toxicity to that of benzo(a)pyrene, and calculating a toxicity equivalency factor. The PADEP groundwater MSC for dibenzofuran in a used aquifer is 37 µg/L (PADEP 2011). More discussion on other PAHs is provided below.

Non Cancer Exposure Evaluation

ATSDR does not have a health-based comparison value for dibenzofuran. The EPA has also not determined a reference dose for oral exposure to dibenzofuran. The Texas Commission on Environmental Quality (TCEQ) has developed a chronic oral reference dose (RfD) of 0.004 mg/kg/day under the Texas Risk Reduction Program (TRPP) (TCEQ 2012). The TRPP identifies the toxicity values for chemicals which are then used as guidelines for hazardous site cleanups. ATSDR has not conducted a comprehensive review of the Texas value referenced for this chemical.

The maximum dibenzofuran exposure dose (0.000004 mg/kg/day) from drinking Dimock groundwater is below the Texas chronic oral RfD (0.004 mg/kg/day). **Non-cancer health effects are not expected from exposures to dibenzofuran at the levels detected in Dimock groundwater**.

Cancer Exposure Evaluation

There is insufficient animal or human study information to determine the carcinogenic risk from exposure to dibenzofuran.

Hexachlorobenzene:

Until 1965, hexachlorobenzene was widely used as a pesticide to protect the seeds of onions and sorghum, wheat, and other grains against fungus (ATSDR 2011). It was also used to make fireworks, ammunition, and synthetic rubber. Hexachlorobenzene is a white crystalline solid that is not very soluble in water. It does not occur naturally in the environment. It is formed as a by-product while making other chemicals, in the waste streams of chloralkali and wood-preserving plants, and when burning municipal waste (ATSDR 2011). The Hayes 2009 study has identified hexachlorobenzene in hydraulic fracturing flowback fluid in Pennsylvania (Hayes 2009). For hexachlorobenzene, the PADEP MSC for used aquifers is 1 µg/L (PADEP 2011).

Hexachlorobenzene was detected in four residential water wells in the EPA 2012 data set (HW2, HW8a, HW32 and HW61). The maximum estimated hexachlorobenzene exposure dose using the highest well concentration (0.217 µg/L) for a 10 and 16 kg child is 0.0000002 and 0.0000001 mg/kg/day, respectively. The maximum estimated hexachlorobenzene exposure dose for a 70 kg adult is 0.000006 mg/kg/day.

Non Cancer Exposure Evaluation

The maximum detected hexachlorobenzene concentration of 0.217 µg/L (well HW2) is below the ATSDR health-based non-cancer CVs of 0.5 µg/L and 2 µg/L for children and adults, respectively. **Non-cancer health effects are not expected from exposure to hexachlorobenzene in Dimock groundwater.**

Cancer Exposure Evaluation

The estimated concentrations of hexachlorobenzene detected in four residential water wells exceeded the ATSDR CREG of 0.02 µg/L (0.217 µg/L in HW2, 0.066 µg/L in HW8a, 0.08 µg/L in HW32 and 0.049 µg/L in HW61). The EPA cancer slope factor for hexachlorobenzene is 1.6 $(mg/kg/day)^{-1}$. By multiplying the maximum adult exposure dose (0.000006 mg/kg/day) by the oral slope factor, the estimated increased cancer risk from 78 years of exposure to hexachlorobenzene at 0.217 µg/L in drinking water is approximately 10 additional cancers per one million exposed individuals. **The estimated cancer risk falls within EPA's target cancer risk range.**

Polycyclic Aromatic Hydrocarbons (PAH):

PAHs are very common in the environment. They may occur naturally and also are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled/grilled meat. There are more than 100 different PAHs and they are generally found as mixtures, not as single compounds. While PAHs occur naturally, they also can be found in asphalt, crude oil, coal, coal tar pitch, creosote, and roofing tar. PAHs may be used by the natural gas industry in hydraulic fracturing fluids (EPA 2011a) and have been detected in hydraulic fracturing fluid flowback (Hayes 2009). In general, PAHs do not dissolve well in water; rather, they tend to stick tightly to solid particles - such as soil/sediment - that can settle at the bottom of lakes, rivers, and creeks (ATSDR 1995).

Because PAHs are so common in the environment, people are exposed to them every day. The most common sources of exposure to PAHs are tobacco smoke, food, wood smoke, and ambient air. Exposure to PAHs via inhalation is estimated to range from 0.02 to 3 micrograms/day (µg/day). Smoking one pack of unfiltered cigarettes per day increases this estimate by an additional 2 to 5 µg/day; chain smokers consuming three packs per day increase their exposure by an estimated 6 to 15 µg/day. The PADEP has identified health-based MSCs for many PAHs. See Table 2 for PADEP MSCs for PAHs identified in the EPA 2012 dataset.

PAHs generally have a low degree of acute toxicity to humans and the most significant endpoint for PAH toxicity is cancer. Some studies have shown non-carcinogenic effects from PAH exposures (ATSDR 1995). After chronic exposure, the non-carcinogenic effects of PAHs involve primarily the pulmonary, gastrointestinal, renal, and dermatologic systems. Many PAHs are only slightly mutagenic or even non-mutagenic in vitro; however, their metabolites or derivatives can be potent mutagens. Under some circumstances, PAHs can be harmful. The harmful effects observed often depend on the type of exposure or way that the contaminants enter the body. While there is little evidence to indicate a relationship between ingestion of PAHs and adverse health effects in humans, animal studies have shown that ingestion of PAHs causes gastrointestinal (digestive system), hepatic (liver), reproductive, and developmental effects. The lowest doses associated with these effects have ranged from 40 milligrams per kilogram of body weight per day (40 mg/kg/day) to 700 mg/kg/day (ATSDR 1995), exposure doses that are orders of magnitude greater than those likely to occur due to drinking the groundwater assessed in the EPA 2012 data set. The maximum estimated PAH exposure dose for Dimock groundwater is 0.00023 mg/kg/day (10 kg child consuming 1 liter of water per day with combined PAH concentration of 2.3 µg/L).

To assess the groundwater ingestion pathway, PAHs were converted to B(a)P toxicity equivalency quotients (TEQ) using established B(a)P toxicity equivalency factors (TEF). In order to assess PAHs for the overall Dimock site, a conservative approach was followed, assessing the highest concentrations of each PAH TEQ together to determine whether the highest PAH mixture exceeds B(a)P health-based CVs. Table 2 provides a summary of the highest PAH concentrations, the TEF and TEQ values, and the sum of maximum PAH values and TEQ values from those maximum PAH concentrations. HW2 had the most PAH compounds detected along with the highest concentrations; therefore, HW2 concentrations and TEQs are also included in Table 2 for the evaluation.

When combining the highest concentration of each PAH from all wells sampled, the maximum estimated PAH (see calculations below) exposure concentration for Dimock groundwater is 2.3 µg/L. The maximum PAH exposure concentration detected in a specific residential water well is 2.18 µg/L for HW2. Based on the combined PAH concentration of 2.3 µg/L, the maximum estimated exposure doses for 10 and 16 kg children are 0.00023 and 0.00014 mg/kg/day, respectively. The estimated exposure dose for a 70 kg adult is 0.000066 mg/kg/day. The estimated exposure dose for a 10 and 16 kg child is 0.00023 and 0.00014 mg/kg/day, respectively. The estimated exposure dose for a 70 kg adult is 0.000066 mg/kg/day.

Non Cancer Exposure Evaluation

Maximum concentrations of acenaphthylene, anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluroanthene, benzo(g,h,i)perylene, flourene, fluoranthene, phenanthrene, indeno(1,2,3,-cd)pyrene, and pyrene were detected in well HW2. PAHs were detected in other residential water wells at concentrations below health-based CVs (see Appendix B). The estimated total PAH exposure doses are below documented non-cancer effect levels for individual PAHs that have been studied, including B(a)P, benzo(a)anthracene, acenapthylene, anthracene, fluoranthene, and fluorine (ATSDR 1995). **Non-cancer health effects are not expected from exposures to the PAHs at the levels detected in Dimock groundwater.**

Table 2
Dimock EPA 2012 Polycyclic Aromatic Hydrocarbon (PAH) Data
Maximum Concentration, PADEP MSC, Toxicity Equivalency Quotient (TEQ) Summary

	PADEP		Sample ID HW1 to HW61		Sample ID HW2	
	MSC		Max value	TEQ Value	Max value	TEQ Value
Compound	(µg/L)	TEF*	Concentrations in micrograms per liter (µg/L)			
Acenaphthylene	2,200	0.001	0.013	0.000013	0.013	0.000013
Anthracene	66	0.010	0.231	0.00231	0.231	0.00231
Benzo(a)pyrene	0.2	1.000	0.196	0.196	0.196	0.196
Benzo(b)fluoranthene	0.29	0.100	0.15	0.015	0.15	0.015
Benzo(g,h,i)perylene	0.26	0.010	0.211	0.00211	0.211	0.0211
Benzo(k)fluoranthene	0.55	0.100	0.317	0.0317	0.317	0.0317
Fluoranthene	260	0.001	0.268	0.000268	0.268	0.000268
Fluorene	1,500	0.001	0.098	0.000098	0.098	0.000098
Indeno(1,2,3-cd)pyrene	0.29	0.100	0.205	0.0205	0.205	0.0205
2-Methylnaphthalene	150	0.001	0.06	0.00006	Not detected	Not detected
Naphthalene	100	0.001	0.06	0.00006	Not detected	Not detected
Phenanthrene	1,100	0.001	0.234	0.000234	0.234	0.000234
Pyrene	130	0.001	0.257	0.000257	0.257	0.000257
		Sum:	**2.30**	**0.269**	**2.18**	**0.287**

Note: *Toxicity equivalency factors (TEF) from ATSDR 2005. Max values reported above are from "J' qualified data, indicating the compound is present in the sample but the results are estimated. MSC = PADEP medium-specific concentration for drinking water aquifer with less than or equal to 2,500 micrograms of dissolved solids per liter of water. TEQ = Toxicity equivalency quotient

Cancer Exposure Evaluation

To evaluate lifetime cancer risk from exposure to PAHs, ATSDR converts the appropriate individual PAH concentrations into B(a)P TEQs, as discussed above, and sums those TEQs into a total B(a)P TEQ. This maximum estimated exposure concentration (0.27 µg/L) results in a daily exposure dose of 0.000008 mg/kg/day for an adult. By multiplying the daily exposure dose by the cancer slope factor of 7.3 $(mg/kg/day)^{-1}$, the estimated cancer risk from 78 years of exposure is determined to be 6 additional cancers per 100,000 individuals exposed over a lifetime. **This estimated cancer risk falls within EPA's target cancer risk range.**

Inorganic COPCs

In the following section, metals including aluminum, arsenic, barium, bromide, cadmium, copper, iron, lead, lithium, magnesium, manganese, phosphorus, potassium and sodium are evaluated for their public health implications because they either exceed a health-based CV or there is no available CV. When relevant, additional general water quality and potability issues are discussed for each COPC.

Aluminum:

Aluminum was detected at a wide range of concentrations in Dimock. However, none exceeded child or adult health-based CVs. Six residential water wells exceeded the SMCL for this chemical. Aluminum levels in excess of 50-200 µg/L, the EPA SMCL, may discolor well water (EPA 2012a).

Non Cancer Exposure Evaluation

None of the 2012 EPA sample results exceeded health-based CVs for aluminum. **Non-cancer health effects are not expected from exposures to aluminum at the levels detected in Dimock groundwater.**

Note: Two residential water wells had maximum aluminum concentrations exceeding the ATSDR health-based CVs in the historic data set, but these concentrations were not detected again in EPA 2012 sampling: the first well (HW13), with a maximum aluminum concentration of 44,100 µg/L, exceeded both the child and adult chronic CVs of 10,000 µg/L and 40,000 µg/L, respectively; and, the second well (HW18), with a maximum aluminum value of 13,700 µg/L, exceeded the child chronic CV. For further toxicological information on aluminum ingestion exposures, see ATSDR Aluminum Toxicological Profile (ATSDR 2008a). A more detailed exposure evaluation on historic aluminum concentrations is provided in Appendix F.

Cancer Exposure Evaluation

Aluminum is not classified as carcinogenic.

Potability

Six residential water wells exceed the aluminum SMCL, including HW29 (51 µg/L), HW57 (1,670 µg/L), HW16 (102 µg/L), HW6 (2,020 µg/L), HW35 (240 µg/L) and HW22 (5,220 µg/L). These wells may have discolored water.

Arsenic:

Arsenic was detected in 27 of the residential water wells sampled by the EPA in 2012 ranging from 1 µg/L to 94.2 µg/L. ATSDR estimated a worst case exposure dose for chronic exposures to children and adults drinking water with the maximum arsenic concentration from the site (94.2 µg/L in HW47). The estimated exposure doses for a 10 kg and a 16 kg child consuming one liter of this well water per day is 0.0094 and 0.0059 mg/kg/day, respectively. The estimated exposure dose for an adult (70 kg body weight) consuming two liters of this well water is 0.0027 mg/kg/day.

Non Cancer Exposure Evaluation

The chronic MRL for arsenic (0.0003 mg/kg/day) is approximately 47 times lower than the chronic LOAEL (0.014 mg/kg/ day) and 3 times lower than the NOAEL (0.0008 mg/kg/day) (ATSDR 2000). The chronic MRL is derived from the NOAEL and includes an uncertainty factor of 3 for human variability. These health comparison values are based on Tseng *et al.* (1968) where people experienced long term exposure to high levels of naturally occurring arsenic in their drinking water. In that study, skin thickening (hyperkeratosis) and discoloration (hyperpigmentation) occurred in people with an estimated exposure of 0.014 mg/kg/day (Tseng *et al.* 1968).

Ten residential water wells had arsenic concentrations exceeding the child chronic exposure environmental media evaluation guideline (EMEG) of 3 µg/L. One well, HW47, with a maximum arsenic concentration of 94.2 µg/L, exceeded both the child chronic EMEG and the adult chronic EMEG (10 µg/L). The estimated child (0.0094 mg/kg/day) and adult (0.0027 mg/kg/day) arsenic exposure doses from well HW47 exceed the NOAEL, are within an order of magnitude of the LOAEL, and are of public health concern for non-cancer health effects. Daily exposures to the maximum arsenic concentration (94.2 µg/L) in well HW47 would be a public health concern for non cancer health effects (e.g., dermal effects) and ATSDR recommends exposure mitigation for this household. The arsenic concentration from the filtered tap sample collected at the same time from this well was only slightly lower: 90.7 µg/L. This slightly lower arsenic concentration would not significantly change the estimated chronic exposure dose calculation or the recommendations to reduce exposure. Shortly after the EPA 2012 data were validated, EPA and ATSDR discussed the high arsenic results with the family using this well. EPA also discussed providing an alternative water source for consumption and the installation of a treatment system for the well water; EPA was informed that Cabot is working with this family to address the treatment of this well water.

Nine additional wells (HW2, HW6, HW12, HW15a, HW22, HW29, HW32, HW57, and HW60), with arsenic concentrations ranging from 3.7 to 9.3 µg/L, exceed the child non-cancer CV of 3 µg/L. None of these wells exceed the adult chronic EMEG of 10 µg/L for arsenic. Estimated exposure doses for 10 kg children consuming one liter of water per day from these wells range from 0.00037 to 0.00093 mg/kg/day. Estimated exposure doses for 16 kg children consuming 1 liter of water per day from these wells range from 0.00023 to 0.00058 mg/kg/day. The estimated exposure doses for children exceed the MRL of 0.0003 mg/kg/day. The estimated exposures for children consuming water from these nine wells exceed the MRL but are more than ten times below the LOAEL. Although it is unlikely that children would experience arsenic-related non-cancer health effects from consuming water from these wells, some sensitive children may experience adverse health effects, such as skin thickening or discoloration.

In summary, ten Dimock residential water wells (HW2, HW6, HW12, HW15a, HW22, HW29, HW32, HW47, HW57, and HW60) have arsenic at concentrations exceeding the ATSDR child chronic MRL (0.0003 mg/kg/day), but below the LOAEL (0.014 mg/kg/day). **Although it is unlikely that individuals will experience health effects from consuming these well waters, some children may be more sensitive to arsenic and may experience adverse health effects.** Steps should be taken to reduce exposures, especially children's exposures, to arsenic in these wells.

Cancer Exposure Evaluation

Arsenic is classified as a human carcinogen. This classification is based on animal and human studies that indicate an increased risk for developing cancers of the skin, lung, bladder, kidney, liver, and prostate from consuming arsenic-containing water. A key parameter in estimating cancer risk is the EPA cancer slope factor, which was derived from arsenic exposures via drinking water and skin cancer cases reported in a Taiwanese study (ATSDR 2000, Tseng et al. 1968). Using the estimated doses from groundwater ingestion, an increased estimated risk of cancer can be derived for people drinking water every day for 30 years and 78 years. The estimated cancer risk is derived by multiplying the EPA cancer slope factor with the estimated chronic exposure dose.

Twenty-seven residential water wells had maximum arsenic detections exceeding the CREG of 0.02 µg/L. ATSDR conducted a cancer risk evaluation for the arsenic detected in these wells to determine if drinking this water over 30 or 78 years could result in increased cancer risk. Chemical concentrations in wells fluctuate and the appropriate estimated chronic exposure dose is based on the mean, or average, concentration in the well obtained over an extended period of sampling, when available. Data collected over an extended period is only available for a subset of the residential water wells, specifically wells HW1 to HW18. Due to the limited data available for most of these wells, the maximum arsenic concentrations are used to calculate the lifetime cancer risk for 30 and 78 year time periods.

A number of wells exceeded the CREG and are specifically discussed below. Except for the thirteen wells discussed next (HW47, HW32, HW60, HW2, HW6, HW12, HW15a, HW17, HW18, HW22, HW29, HW49, and HW57), cancer risks from lifetime exposures to arsenic detected in each of the other Dimock residential water wells sampled by EPA in 2012 are within the acceptable cancer risk range.

HW47

The chronic exposure dose for a 70 kg adult consuming two liters of water per day is 0.0027 mg/kg/day. Using the EPA cancer slope factor (1.5 $(mg/kg/day)^{-1}$) for 30 and 78 year durations, the estimated increased risk is 1.73 and 4 per 1,000 exposed individuals, respectively. **The estimated lifetime carcinogenic risk from exposure to arsenic in this water well (for 30 or 78 years) is above EPA's target cancer risk range.**

HW32

The chronic exposure dose for a 70 kg adult consuming two liters of water per day is 0.0003 mg/kg/day. Using the EPA cancer slope factor (1.5 $(mg/kg/day)^{-1}$) for 30 and 78 year durations, the estimated increased cancer risk is 1.93 and 4.5 per 10,000, respectively. **The estimated lifetime carcinogenic risk from exposure to arsenic in this water well (for 30 or 78 years) is above EPA's target cancer risk range.**

HW60

The chronic exposure dose for a 70 kg adult consuming two liters of water per day is 0.00027 mg/kg/day. Using the EPA cancer slope factor (1.5 $(mg/kg/day)^{-1}$) for 30 and 78 year durations, the estimated increased cancer risk is 1.71 and 3.9 per 10,000, respectively. **The estimated lifetime carcinogenic risk from exposure to arsenic in this water well (for 30 or 78 years) is above EPA's target cancer risk range.**

Additional wells

In addition to the three wells discussed above, ten additional wells (HW2, HW6, HW12, HW15a, HW17, HW18, HW22, HW29, HW49, and HW57) have arsenic concentrations in the 2012 data set ranging from 2.6 to 7.8 µg/L. Lifetime exposures (78 years) to this range of groundwater arsenic concentrations would result in estimated excess cancer risk ranging from 1.7 to 2.2 additional cancers per 10,000 exposed individuals. The historic arsenic data that is available for select wells (HW2, HW6, HW12, HW15a, HW17, and HW18) are consistent with the EPA 2012 data set and do not change the lifetime cancer estimate. **The estimated lifetime carcinogenic risks from exposure to arsenic in these ten wells are slightly higher than EPA's target cancer risk range.**

Barium:

ATSDR does not have sufficient information to determine the chemical form of the barium detected in Dimock groundwater sampling. Barium is present in a wide variety of food items including breads, peanut butter, cereals, pasta, fruits, vegetables, eggs, dairy products, and to a lesser extent meats, poultry, and fish at levels from 10 µg/kg up to 3,000 µg/kg (ATSDR 2007). The highest concentrations of barium in food have been noted in peanut butter and peanuts (2,900 µg/kg) and Brazil nuts (3,000-4,000 µg/kg). Barium is present in many public drinking water supplies at an average level of 30 µg/L, but can be as high as 300 µg/L in some regions of the United Sates (ATSDR 2007). Barium is used as a filler in many paints and other industrial coatings, plastics, rubber products, brake linings, and in some sealants and adhesives (ATSDR 2007, WHO 2001). In a 2009 study of Marcellus shale hydraulic fracturing flowback, total and dissolved barium was regularly detected in the flowback samples (Hayes 2009). Barite (a mineral composed primarily of barium sulfate with occasional traces of strontium and calcium) is used extensively in the oil industry as a constituent in drilling mud (ATSDR 2007, WHO 2001). Barium carbonate is often used as a rodenticide (ATSDR 2007). Barium sulfate is used extensively in the medical field as a contrast medium for diagnosing problems in the upper and lower GI tract (WHO 2001). As a medical contrast medium, it is often ingested in quantities of 400 grams or more. Since barium sulfate is virtually insoluble (only approximately 2,460 µg will dissolve in a liter of water at 25 ºC), it generally causes no adverse effects upon ingestion (except for occasional constipation) (ATSDR 2007, WHO 2001). However, some of the more soluble forms of barium, such as barium acetate, barium chloride, barium oxide, barium hydroxide, and barium carbonate can exhibit adverse effects after ingestion (ATSDR 2007). The ATSDR chronic EMEG for barium (2,000 µg/L for children and 7,000 µg/L for adults) is based on the more soluble forms of barium (soluble salts).

Barium was detected in 62 of 64 residential water wells and, ranged from 18.4 µg/L to 3,810 µg/L. Two residential water wells had barium concentrations exceeding the ATSDR child chronic EMEG (2,000 µg/L) and EPA MCL (2,000 µg/L): HW16 at 3,040 µg/L and HW39 at 3,810 µg/L. From the historical data set, HW16 was the only well to have a barium concentration (3,460 µg/L) exceeding the ATSDR child chronic EMEG and EPA MCL. No residential water wells exceeded the adult chronic EMEG of 7,000 µg/L. All other wells had maximum barium concentrations below CVs. The maximum barium exposure for the Dimock residential water wells is from well HW39, with a barium concentration of 3,810 µg/L. The daily exposure dose from consuming this water for an adult is 0.11 mg/kg/day, for a 10 kg child is 0.381 mg/kg/day, and for a 16 kg child is 0.238 mg/kg/day.

Non Cancer Exposure Evaluation

The majority of studies evaluating the health effects of barium is from oral exposure studies and includes numerous case reports and epidemiologic investigations of humans exposed to barium through accidental or intentional ingestion (ATSDR 2007). Other information on the health effects associated with exposure to barium was obtained from various animal studies involving acute, intermediate, or chronic exposure to barium either by gavage or by drinking water.

ATSDR has derived an intermediate-duration oral MRL of 0.2 mg/kg/day for barium (administered as barium chloride dehydrate). This MRL is based on a NOAEL of 65 mg/kg/day and a LOAEL of 115 mg/kg/day for increased kidney weight in female rats and an uncertainty factor of 100 (10 to account for animal to human extrapolation, and 10 for human variability) and modifying factor of 3 to account for the lack of an adequate developmental toxicity study. ATSDR has derived a chronic-duration oral MRL of 0.2 mg/kg/day for barium. The MRL is based on a benchmark dose 95% lower confidence level (BMDL05) of 61 mg/kg/day for nephropathy in male mice and an uncertainty factor of 100 (10 to account for animal to human extrapolation and 10 for human variability) and modifying factor of 3 to account for the lack of an adequate developmental toxicity study. EPA used the same study to derive an oral reference dose (RfD) for barium of 0.2 mg/kg/day, based on a benchmark dose level of 63 mg/kg/day for nephropathy in male mice and an uncertainty factor of 300 (10 to account for animal to human extrapolation, 10 for human variability, and 3 for database deficiencies, particularly the lack of a two-generation reproductive toxicity study and an adequate investigation of developmental toxicity) (EPA 2005, NTP 1994).

For adults, the estimated exposure dose does not exceed the MRL or RfD. For a 10 kg and 16 kg child, the estimated exposure doses (0.381 and 0.238 mg/kg/day) exceed the MRL and RfD, but are not at levels where children are expected to experience health effects. Further evaluation indicates children's doses do not exceed the adjusted dose where health effects might be expected (i.e., benchmark dose with relevant uncertainty factors applied). The MRL contains an uncertainty factor of 3 applied for database uncertainty because adequate developmental studies have not been conducted, which would apply to adults exposed during pregnancy. Adult doses did not exceed the MRL, which contains this uncertainty factor. **Non-cancer health effects are not expected from exposures to barium at the levels detected in Dimock groundwater.**

Cancer Exposure Evaluation

Barium has not been shown to cause cancer in humans or in experimental animals drinking barium in water. The Department of Health and Human Services (DHHS) has not classified barium as to its carcinogenicity (ATSDR 2007). EPA has determined that barium is not likely to be carcinogenic to humans following ingestion and that there is insufficient information to determine whether it will be carcinogenic to humans following inhalation exposure (ATSDR 2007). **Barium is not classified as carcinogenic via the ingestion route.**

Bromide:

This discussion applies specifically to inorganic bromide ion and not to bromate or other organic bromine compounds, for which individual health-based guideline values have been developed. Bromide (Br^-) is the anion of the element bromine, which is a member of the common halogen element series that includes fluorine, chlorine, bromine and iodine. Bromide commonly exists as salts with sodium, potassium and other cations, which are usually very soluble in water. Bromide is commonly found in nature along with sodium chloride, owing to their similar physical and chemical properties, but in smaller quantities. Bromide has been detected in hydraulic fracturing flowback (Hayes 2009). The typical daily dietary intake of bromide in the United States of America is 2–8 mg from grains, nuts and fish. Bromide and chloride are always present in body fluids in animals in steady state at levels dependent upon intake, and both are excreted readily. Increased chloride intake will increase the excretion of bromide (WHO 2009).

Inorganic bromide in drinking water was originally evaluated by the Joint FAO/WHO Meeting on Pesticide Residues in 1966, which recommended an acceptable daily intake (ADI) for humans of 0 - 1 mg/kg body weight, based on a minimum pharmacologically effective dosage in humans of about 900 mg of potassium bromide, equivalent to 600 mg of bromide ion (WHO 2009). This ADI of 0 - 1 mg/kg body weight was reaffirmed with new data in 1988 and in a subsequent second human study (WHO 2009). A conservative NOAEL (for marginal effect within normal limits of EEGs in females at 9 mg/kg body weight per day) of 4 mg/kg body weight per day suggests an ADI of 400 µg/kg body weight, including an uncertainty factor of 10 for population diversity (WHO 2009). An ADI of 400 µg/kg body weight yields an acceptable total daily intake of 28,000 µg/day for a 70 kg person, 4,000 µg/day for a 10 kg child, and 6,400 µg/day for a 16 kg child.

Bromide was detected in three of 62 residential water wells in the EPA 2012 data set. The maximum bromide concentrations detected in each of the three wells were 1,670 µg/L in HW29; 986 µg/L in HW39; and 857 µg/L in HW16.

Non Cancer Exposure Evaluation

Relative source contribution, used for risk assessment of chemicals in drinking water, is the proportion of the total daily exposure to a chemical that is attributed to tap water (accounting for multi-route exposures) in calculating acceptable levels of chemicals in the tap water. Assuming a relative source contribution of 50%, the maximum drinking water concentration before exceeding the ADI value for a 70 kg adult consuming 2 liters/day would be 7,000 µg/L; for a 10 kg child consuming 1 liter/day, the value would be up to 2,000 µg/L; and for a 16 kg child consuming 1 liter/day, the value would be up to 3,200 µg/L. Each of the three wells with bromide detections (HW29 at 1,670 µg/L, HW39 at 986 µg/L, and HW16 at 857 µg/L) are below the suggested ADI when assuming a 50% relative source contribution of bromide from well water.

With additional contributions of bromide from other sources including food, the total estimated daily intake of bromide for residents consuming water from these wells would not exceed the WHO ADI and is below the conservative NOAEL of 4 mg/kg/day. **Non-cancer health effects are not expected from exposures to bromide at the levels detected in Dimock groundwater.**

Cancer Exposure Evaluation

There is insufficient animal or human study information to determine the carcinogenic risk from exposure to bromide.

Cadmium:

Cadmium is an element that occurs naturally in the earth's crust. All soils and rocks, including coal and mineral fertilizers, contain some cadmium. Pure cadmium is a soft, silver-white metal. It is often found as part of small particles in air. It does not have a distinct taste or smell; therefore, it is not possible to taste or smell cadmium in water or air. In the United States most cadmium is extracted during the production of other metals such as zinc, lead, and copper. It has many uses in industry and consumer products, mainly batteries, pigments, metal coatings, and plastics.

Food and cigarette smoke are the largest potential sources of cadmium exposure for members of the general population. Average cadmium levels in U.S. foods range from 2 to 40 parts of cadmium per billion parts of food (ppb, equivalent to µg/L). Average cadmium levels in cigarettes range from 1,000 to 3,000 ppb. The level of cadmium in most drinking water supplies is less than 1 ppb (µg/L). The current average dietary intake of cadmium in adult Americans is about 0.0004 mg/kg/day; smokers receive an additional amount--about 0.0004 mg/kg/day--from cigarettes (ATSDR 2012a).

Numerous studies indicate that the kidney is the main target organ of cadmium toxicity following extended oral exposure to cadmium, with effects similar to those seen following inhalation exposure (ATSDR 2012). Elevated incidences of kidney effects (tubular proteinuria) have been found in numerous epidemiologic studies conducted on residents of cadmium-polluted areas in Japan (Nogawa *et al*. 1980, Nogawa *et al*. 1989), Belgium (Buchet *et al*. 1990, Roels *et al*. 1981), and China (Shiwen *et al*. 1990).

Cadmium was detected in only one residential water well (HW57). It was detected at 2.9 µg/L from a filtered sample collected at the kitchen tap. The cadmium level detected in HW57 exceeds the child chronic EMEG of 1 µg/L, but does not exceed the adult EMEG of 4 µg/L. The estimated daily exposure doses for consuming well water with cadmium at 2.9 µg/L are 0.0003 mg/kg/day for a 10 kg child, 0.00018 for a 16 kg child, and 0.00008 mg/kg/day for an adult. These estimated daily exposures assume children consume 1 liter of residential well water per day, and adults consume 2 liters per day.

Non Cancer Exposure Evaluation

The chronic oral MRL is 0.0001 mg/kg/day. The EPA RfD for cadmium in drinking water is 0.0005 mg/kg/day. Children consuming HW57 well water would exceed the ATSDR chronic MRL, but would fall below the EPA RfD. The maximum estimated cadmium exposure dose from drinking water from well HW57 is equal to the NOAEL of 0.0003 mg/kg/day (ATSDR 2012a). That is, children consuming one liter of water per day from residential well HW57 would be exposed to cadmium at a dose three times higher than the chronic MRL. Multiple studies (Buchet *et al*. 1990; Jarup *et al*. 2000; Suwazono *et al*. 2006) were used to determine the chronic MRL of 0.0001 mg/kg/day, which included an uncertainty factor of 3 for human variability. Due to this uncertainty, ATSDR concludes that the cadmium level in well HW57 may be of concern to some children consuming this well water on a daily basis.

Except for one well, ATSDR does not expect adverse non-cancer health effects from exposures to cadmium in Dimock wells. For well HW57, the estimated children's exposure dose exceeds the MRL, and may be of health concern for sensitive individuals.

Cancer Exposure Evaluation

The Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) consider cadmium to be a human carcinogen (ATSDR 2012a). The EPA classifies cadmium as a probable human carcinogen based on insufficient human data (ATSDR 2012a). Exposure of Wistar rats by inhalation to cadmium as cadmium chloride at concentrations of 12.5, 25 and 50 micrograms per cubic meter for 18 months, with an additional 13-month observation period, resulted in significant increases in lung tumors (Takenaka *et al*., 1983). Intratracheal instillation of cadmium oxide did not produce lung tumors in Fischer 344 rats but rather mammary tumors in males and tumors at multiple sites in males (Sanders and Mahaffey, 1984). Injection site tumors and distant site tumors (for example, testicular) have been reported by a number of authors as a consequence of intramuscular or subcutaneous administration of cadmium metal and chloride, sulfate, oxide and sulfide compounds of cadmium to rats and mice (EPA, 1985). Seven studies in rats and mice where cadmium salts (acetate, sulfate, chloride) were administered orally have shown no evidence of a carcinogenic response (EPA 1992). There is consistent evidence of carcinogenicity via inhalation of cadmium from occupational studies; neither the human nor the animal studies provide sufficient evidence to definitively conclude whether or not cadmium is a carcinogen specifically through ingestion (ATSDR 2012a).

Based on this information for the ingestion pathway, ATSDR does not expect carcinogenic effects from exposures to cadmium at the levels detected in Dimock groundwater. Due to human variability and the potential for fluctuation in the cadmium levels in groundwater, continued monitoring of well HW47 water quality, including the cadmium level, is suggested.

Copper:

Copper is essential for good health. However, exposure to higher doses can be harmful. If you drink water that contains higher than normal levels of copper, you may experience nausea, vomiting, stomach cramps, or diarrhea. Intentionally high intakes of copper can cause liver and kidney damage and even death. We do not know if copper can cause cancer in humans. EPA does not classify copper as a human carcinogen because there are no adequate human or animal cancer studies.

Only two samples exceed the child intermediate EMEG of 100 µg/L (HW33b at 166 µg/L and HW28a at 157 µg/L). Both of these samples were collected from the kitchen tap, and the corresponding samples for each of these water supplies that were collected closest to the wellhead had significantly lower copper concentrations (HW33b at 11 µg/L and HW28a at 27.9 µg/L), suggesting the groundwater does not contain elevated copper concentrations, but the plumbing system in the home may be contributing copper to the drinking water at the kitchen tap. The maximum copper concentrations detected at the kitchen tap in both of these homes (166 µg/L in HW33b and 157 µg/L in HW28a) are below EPA's maximum action level as well as the level suggested for enhanced water quality monitoring (1,300 µg/L).

The greatest potential source of copper exposure is through drinking water, especially in water that is first drawn in the morning after sitting in copper piping and brass faucets overnight (ATSDR 2004). To reduce exposure to copper in drinking water, run the water for at least 15-30 seconds before using it. Additionally, if there is concern about the concentration of copper in drinking water, the water should be regularly tested.

Non Cancer Exposure Evaluation

ATSDR has not developed a chronic EMEG or MRL for copper. In identifying the intermediate EMEG of 100 µg/L and 350 µg/L for children and adults, respectively, ATSDR used the Araya *et al*. study (2003), which identified a NOAEL of 0.042 mg/kg/day and a LOAEL of 0.091 mg/kg/day, based on two months of daily ingestion, resulting in the less serious LOAEL of gastrointestinal symptoms (ATSDR 2004). An intermediate MRL of 0.01 mg/kg/day was derived from the NOAEL with an uncertainty factor of 3 applied to account for human variability. The estimated daily exposure doses for children consuming water from wells HW33b and HW28a are below the NOAEL but above the MRL. Further evaluation indicates that children's estimated exposure doses fall within the area of uncertainty where health effects may occur (i.e., below the NOAEL but above the MRL).

Although it is unlikely that individuals will experience health effects from consuming drinking water at these maximum levels (166 µg/L in HW33b and 157 µg/L in HW28a), some children may be more sensitive to copper and may experience adverse health effects. Steps should be taken to reduce exposures, especially children's exposures, to copper in these water supplies.

Cancer Exposure Evaluation

We do not know if copper can cause cancer in humans. EPA does not classify copper as a human carcinogen because there are no adequate human or animal cancer studies (ATSDR 2004). **There is insufficient animal or human study information to determine the carcinogenic risk from exposure to copper.**

Iron:

Thirteen wells exceed the EPA SMCL of 300 µg/L in the EPA 2012 data set, and sixteen of 18 wells exceeded the SMCL in the historic data set. Iron levels above the SMCL may cause water to have bad taste and have a rusty color. This rusty color may stain clothes and dishes. This water may be unsuitable for drinking and cooking.

Non Cancer Exposure Evaluation

Iron is a required nutrient, and levels in residential well water are typically under 300 µg/L (WHO 1996). The recommended adequate intakes (AI) for iron 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 upper acceptable daily intake (UL) is 45 mg/day (IOM 2001).

Drinking water from the residential well with the highest level of iron (HW57 at 11,200 µg/L) would add approximately 22 mg of iron to an adult's daily diet (consuming 2 liters of water per day) and approximately 11 mg of iron to a 10-16 kg child's daily diet. These increased intakes of iron add sufficient iron to an individual's diet without any other source contribution, but are less than half the UL for iron recommended by the Institute of Medicine. **Exposures to the iron in Dimock residential water wells are not likely to result in adverse health effects in healthy residents.**

It should be noted that a rare inherited genetic disease called hemochromatosis is associated with iron overload in a small percentage of persons**. If any individuals with elevated iron in their well water are on reduced-iron diets to treat this condition, these individuals should consult their health professionals to discuss the additional iron exposures from consuming their well water.** Note that this disorder may not manifest until adulthood. Therefore, early consultation is recommended for families aware of their potential susceptibility because of relatives who have been told they have the disease.

The historic data set included the highest iron concentrations in Dimock residential water wells, with the maximum value of 24,100 µg/L in HW6. All of the residential water wells that exceeded the iron SMCL in the historic data set had lower iron concentrations in the EPA 2012 data, except for HW2. The iron concentration in well HW2 in 2012 is 1,580 µg/L, nearly four times higher than the maximum concentration detected in the historic data set (420 µg/L). HW6, which had the highest iron concentration in all data, had a much lower iron result in 2012 (2,970 µg/L) although it continues to be above the SMCL.

Cancer Exposure Evaluation

Iron is not classified as carcinogenic.

Potability

The SMCL for iron is based on adverse aesthetic and technical effects to the water system. Note that SMCLs are not health-based and for iron, this classification does not include the issue of hemochromatosis, which is discussed above. Adverse aesthetic effects from elevated iron concentrations include foul smelling water, rusty discoloration, and an unpleasant metallic taste. The technical effects of elevated iron include corrosion, which could cause increased system maintenance costs and reduced water flow, reddish or orange staining of household fixtures, and scaling and sedimentation causing buildup in pipes, boilers, heat exchangers, and other plumbing fixtures.

Lead:

Twenty wells had detectable levels of lead in the water (see Table 3), and two of those residential water wells, HW22 at 22.7 µg/L and HW35 at 21.2 µg/L, exceeded the EPA public water supply action level of 15 µg/L for lead (EPA 2009).

Non Cancer Exposure Evaluation

Chronic exposure to low lead levels in children has been shown to cause effects on the central nervous system, which can result in deficits in intelligence, behavior, and school performance. Health effects from lead exposure in children and unborn fetuses include both physical and mental impairments, hearing difficulties, impaired neurological development, and reduced birth weights and gestational age. Some health effects from lead exposure, such as impaired academic performance and motor skills, may become irreversible and persist, even when blood lead levels (BLL) return to below 5 micrograms per deciliter (µg/dL), the current CDC reference value. While there is some discrepancy in the scientific literature between the exact decreases in IQ points associated with a rise in BLL in children, the weight of scientific evidence supports that there is an inverse relationship. It has been hypothesized that the age of exposure (because younger children are more susceptible to neurological disorders), is a factor. More research is needed to further delineate the effect of low level lead exposure, particularly on children (CDC 2012a). Numerous studies have observed that low lead level exposure during the developmental stages can produce lifelong changes, including (but not limited to):

- Jusko, *et al.* found children's intellectual functioning at 6 years of age is impaired by blood lead concentrations well below 10 µg/dL (Jusko *et al*. 2008).
- A study by Canfield, R.L., *et al*. concluded that IQ declined by 7.4 points as lifetime average BLL concentrations increased from 1 to 10 µg/dL (Canfield *et al*. 2003).
- Lanphear, B.R. *et al*. found environmental lead exposure in children who have a BLL <7.5 µg/dL is associated with intellectual deficits (Lanphear *et al.* 2005).

There is no safe blood lead level in children. Any detectable level of lead in drinking water is of public health concern because of the potential neurological effects on the developing fetus and young children. EPA has established a health-based goal for lead in public drinking water supplies (MCLG) of zero.

Table 3
Lead Levels (µg/L) in Dimock Private Well Water (EPA 2012)

Well ID	Total Lead	Tap/Filtered Lead
HW2	1.9	Not available
HW4	2.2	Not available
HW6	2.9	Not available
HW7	3.2	Not available
HW8a	4.6	1.2
HW9	1.6	Not available
HW14	1.5	1.3
HW20	2.4	1.4
HW22	22.7	8.1
HW23	2	Not available
HW28b	3.3	3
HW33	1.7	Not available
HW35	21.2	2.4
HW38	1.4	Not available
HW40	3.1	1.7
HW51	1.1	Not available
HW57	3.5	Not available
HW59	1	1.2
HW62	1.8	2
HW64	1.4	Not available

µg/L: micrograms per liter

Water samples collected closest to the actual well at HW22 and HW35 exceed 15 µg/L, but the tap sample at HW22 (HW22-P) and the filtered sample at HW35 (HW35-F) are both lower. Tap sample HW22-P had a lead level of 8.1 µg/L and filtered sample HW35-F was 2.4 µg/L.

The lead level in HW13, which had a lead concentration of 37 µg/L in the historic data set (the only well exceeding 15 µg/L in the historic data set), was not detected above 1 µg/L in the EPA 2012 sampling event, indicating lead exposures to this well water at the time of EPA 2012 sampling were considered to be low to none.

The filtered sample at HW35 indicates water filtration will remove lead from the residential drinking water, and **ATSDR suggests the homeowner use some form of filtration explicitly designed to reduce lead concentrations in this residential water supply.**

Lead levels in wells HW22 and HW13 were below the EPA action level set for public drinking water supplies, but lower level lead exposures are still possible in these homes. ATSDR suggests homeowners of well HW22 and HW13 (1) conduct periodic monitoring to verify the lead levels remain low, and, (2) consider filtration to remove even low levels of lead from their drinking water supply.

There is no safe blood lead level in children. ATSDR suggests homeowners with detectable lead (Table 3) in their drinking water take steps to reduce the lead before consumption.

Consistent with statewide childhood blood lead screening guidelines, all families are encouraged to discuss blood lead screening for children six years of age and under with their health care provider.

Cancer Exposure Evaluation

EPA, DHHS and IARC identify lead as possibly carcinogenic or reasonably anticipated to be carcinogenic to humans (ATSDR 2007a). Limited human and less than sufficient animal evidence is listed as the determination for this carcinogenic categorization. There is no conclusive proof that lead causes cancer in humans (ATSDR 2007a). **There is insufficient animal or human study information to determine the carcinogenic risk from exposure to lead.**

Lithium:

A wide range of estimates for daily dietary intake of lithium are reported. Some authors report estimates for the average daily dietary intake of lithium ranging from 0.24 to 1.5 µg/kg/day, while another reports an average of up to 33 to 80 µg/kg/day (EPA 2008). Literature reports lithium salts have been used therapeutically at adult doses varying between 900,000 µg /day (900 mg/day) to 1,800,000 µg/day (1,800 mg/day). The pharmacological dose is selected for individual patients to achieve therapeutic serum concentrations ranging from 0.6 to 1.4 millimoles per liter (mmol/L). Serum concentrations between 0.8 and 1.0 mmol/L are generally accepted as the optimally therapeutic range. A 900,000 µg (900 mg) dose of lithium carbonate medication contains 170,000 µg (170 mg) lithium; therefore, 170,000 µg (170 mg) of lithium for a 70 kg adult equates to roughly 2,500 µg/kg/day (2.5 mg/kg/day). It should be noted that the therapeutic range for lithium treatment has been shown to produce adverse health effects for some of the population.

Elevated lithium levels were consistently detected in a hydraulic fracturing flowback study of Marcellus shale completions ranging from non-detect to 153,000 µg/L (153 mg/L) with a median concentration in flowback of 43,700 µg/L (43.7 mg/L) (Hayes 2009).

Lithium, ranging from approximately 25 µg/L up to 533 µg/L, was detected in 20 of the 64 residential water wells (HW1, HW2, HW5, HW6, HW12, HW15a, HW16, HW17, HW18, HW22, HW24, HW25, HW26, HW29, HW30, HW31, HW34a, HW39, HW47, and HW60). The EPA Provisional Peer-Reviewed Toxicology Value (PPRTV) for lithium is 0.002 mg/kg/day (EPA 2008). By applying standard risk assessment inputs for body weight (10 and 70 kg body weight for children and adults, respectively) and daily water consumption (1 and 2 liters per day for children and adults, respectively), the drinking water-specific screening level based on the PPRTV is 20 and 70 µg/L for children and adult, respectively.

Eight residential water wells (see Appendix B for individual well concentrations) exceed the PADEP medium-specific concentration (MSC) of 73 µg/L (PADEP 2011).

Non Cancer Exposure Evaluation

None of the residential water wells exceed the ATSDR site-specific acute screening value of 1,500 µg/L (see ATSDR AROA-TA 2011 in Appendix A). ATSDR has not developed a site-specific screening value for chronic lithium exposures. The EPA PPRTV for lithium is used for evaluating chronic lithium exposures in Dimock. The PPRTV includes a composite uncertainty factor of 1000 to account for extrapolation from a LOAEL to a NOAEL (factor of 10), to protect susceptible individuals (factor of 10), and to account for database insufficiencies (factor of 10) (EPA 2008). There is very little toxicological data on lithium exposures in young children. The potential for adverse health effects in sensitive subpopulations is uncertain because of the lack of relevant study data. Potentially sensitive populations for lithium exposures include patients undergoing lithium treatment, children, pregnant women, and those with significant renal or cardiovascular disease, or dehydration or sodium depletion with concurrent long-term use of medications such as: diuretics (e.g., hydrochlorothiazide), nonsteroidal anti-inflammatory agents (e.g., ibuprofen), calcium channel blocking agents (e.g., verapamil), and angiotensin-converting enzyme inhibitors (e.g., captopril).

Children consuming water from any of the twenty wells with lithium concentrations above 20 µg/L (HW1, HW2, HW5, HW6, HW12, HW15a, HW16, HW17, HW18, HW22, HW24, HW25, HW26, HW29, HW30, HW31, HW34a, HW39, HW47, and HW60) would result in exposure doses exceeding the PPRTV. Adults consuming well water with concentrations exceeding 70 µg/L (HW6, HW16, HW18, HW24, HW29, HW34a, HW39, and HW47) would result in exposure doses exceeding the PPRTV. **Due to uncertainty in the PPRTV value, homeowners with water wells containing lithium levels exceeding 70 µg/L should take steps to reduce the level of lithium in their drinking water. Homeowners with children that have lithium levels in their well exceeding 20 µg/L, especially if those homes include sensitive subpopulation individuals such as those described above, should take steps to reduce the lithium in their drinking water.**

Cancer Exposure Evaluation

We do not know if lithium can cause cancer in humans. EPA does not classify lithium as a human carcinogen. Lithium is undergoing clinical trials as part of the treatment regime in clinical cancer studies. Additionally, Cohen *et al.* (1998) reported that patients undergoing lithium therapy have lower cancer prevalence than the general population and that lithium may have a protective effect. **There is insufficient animal or human study information to determine the carcinogenic risk from exposure to lithium.**

Manganese:

Manganese is a naturally occurring substance found in many types of rock and soil. Persons living near a coal or oil-burning factory may be exposed to higher levels of manganese since it is released into air when fossil fuels are burned. In addition to its natural origin, manganese can be found in groundwater as a result of its use in industrial activities and manufacturing, such as production of batteries, pesticides, and fertilizers. Elevated concentrations of manganese have been consistently detected in flowback from Marcellus shale completions (Hayes 2009). Several studies have found that mean levels of manganese in public drinking water ranging from 4 µg/L to 32 µg/L (ATSDR 2008). Analyzing data from the USGS National Water Quality Assessment (NAWQA) database, the EPA reported that the median concentration of manganese was 16 µg/L for surface water and 5 µg/L for groundwater from 20 watersheds and 16 drainage basins in the United States (ATSDR 2008).

Manganese is an essential dietary nutrient. The World Health Organization (WHO) has estimated the average dietary intake of manganese ranges from approximately 2 to 8.8 mg/day. EPA has estimated that the typical human intake of manganese from food is 1.28 micrograms per calorie (µg/calorie), which equates to 2.6 - 3.8 milligrams of manganese in 2000 - 3000 calorie diets (ATSDR 2008). The Food and Nutrition Board of the National Research Council has established Estimated Safe and Adequate Daily Dietary Intake Levels (ESADDI) for this nutrient that range from 0.3 mg/day for infants to 5 mg/day for adults (IOM 2001). IOM has a tolerable upper intake level (UL) of 2-3 mg/day for 1-8 year old children; 6 mg/day for 9-13 year old children; 9 mg/day for children under 18 years of age; and, 11 mg/day for adults. (Note, these ULs include manganese from all sources, including food, water, and supplements.) For most people, food is the primary source of manganese exposure.

Four residential water wells (HW8a at 942 µg/L, HW22 at 635 µg/L, HW32 at 301 µg/L, and HW47 at 947 µg/L) had maximum manganese concentrations exceeding the EPA manganese health advisory level of 300 µg/L (0.3 mg/l, EPA 2004). Three residential water wells (HW8a, HW22, and HW47) had maximum manganese concentrations exceeding the ATSDR remedial media evaluation guideline (RMEG) of 500 µg/L for children, but no wells exceeded the adult RMEG of 1,800 µg/L.

Non Cancer Exposure Evaluation

Excess exposure to manganese can be harmful to human health. An epidemiological study was conducted in Greece to investigate the possible correlation between long-term (i.e., more than 10 years) manganese exposure from drinking water and neurological effects in elderly people (Kondakis *et al*., 1989). The levels of manganese in the drinking water of 3 different geographical areas were 3.6-14.6 µg/L in the control area and 81-253 µg/L and 1800-2300 µg/L in the manganese-containing areas. The total population in the three areas being studied range from 3200 to 4350 people. The study included only individuals over the age of fifty drawn from a random sample of 10% of all households. The number of subjects sampled was 62, 49, and 77 for control, low-, and high-exposed groups. The authors performed a neurological examination of the subjects (weakness/fatigue, gait disturbances, tremors, dystonia, *etc*.) and expressed the results as composite scores. They found no differences in the manganese content in the blood, but a statistically-significant difference in both the manganese content in the hair and composite neurological scores between the high exposed area (concentrations 1800-2300 µg/L) and the control area, suggesting neurological impairment in the high exposed area. The investigators estimated a dietary intake of 5-6 mg/day (personal communication), but data were not provided. Because of the uncertainty in the amount of manganese in the diet, and possible exposure from other sources such as dust, and little information on nutritional status and other possible confounding variables, it is difficult to estimate the total exposure to manganese from this study (EPA 2004). Due to inherent limitations in the Kondakis *et al*., 1989 study, it could not be used to determine a quantitative dose response relationship for manganese in humans. In another report, a group of six Japanese families exposed to manganese in their well water at concentrations of approximately 14,000 µg/L developed manganism-like symptoms (ATSDR 2008).

Although ATSDR has not developed an MRL, the groundwater manganese data was compared to the ATSDR remedial media evaluation guideline (RMEG) of 500 and 1,800 ug/L for children and adults, respectively. The ATSDR RMEG is based on the EPA reference dose (RfD) of 0.14 mg/kg/day for food and 0.05 mg/kg/day for drinking water (EPA 1996). ATSDR also used the upper range of the ESADDI level for manganese of 5,000 µg/day (5 mg/day) from all exposure sources to estimate a site-specific health screening value of 0.07 mg/kg/day [(5 mg/day)/(70 kg)]. Lower ESADDI levels for manganese are identified in Table 4. Using the maximum ESADDI values for children (0.6-2 mg/day), interim guidance dose values for a 10 kg children would be 0.06 [(0.6 mg/day)/(10 kg)] to 0.12 mg/kg/day [(2 mg/day)/(16 kg)].

Table 4
Food and Nutrition Board of the National Research Council's Estimated Safe and Adequate Daily Dietary Intake Levels (ESADDIs) for Manganese

Age Range	Estimated Safe and Adequate Daily Dietary Intake Level
Birth to 6 months	0.3 to 0.6 mg/day
1 to 3 years	1.0 to 1.5 mg/day
4 to 6 years	1.0 to 2.0 mg/day
7 to 10 years	1.0 to 2.0 mg/day
Adolescents older than 11 years and Adults	2.0 to 5.0 mg/day

Source: (IOM 2001)
Notes: mg/day = milligrams manganese per day

Using standard drinking water exposure assumptions for children and adults consuming the highest manganese level detected by EPA in Dimock (947 µg/L), the daily manganese dose from the drinking water alone (not including food) is 0.95 mg/day and 1.9 mg/day, respectively. Corresponding exposure doses for the maximum manganese concentration detected in EPA 2012 data for 10 and 16 kg children are 0.095 and 0.059 mg/kg/day, respectively, and 0.027 mg/kg/day for an adult. Manganese exposures for adults in Dimock are not expected to be of public health concern. Manganese exposures for 10 kg children would exceed the interim guidance values for manganese through well water exposure alone. Food ingestion would add an additional 1.1-2.6 mg of manganese to a child's daily manganese exposure (based on 1.28 µg/calorie, and daily intake of 793 to 2000 calories for a child). It should be noted that the interim guidance levels are based on what is considered to be a safe and adequate dietary intake and that adverse health effects have not been observed at these levels.

Manganese exposures from two residential water wells would exceed the ATSDR interim guidance value of 0.07 mg/kg/day: HW47 (947 µg/L) and HW8a (942 µg/L). Estimated manganese exposures from HW22 (635 µg/L) and HW32 (301 µg/L) alone (excluding food) would not exceed the interim screening value of 0.07 mg/kg/day, although additional exposure from food intake (estimate of 3.8 mg of manganese per day for adults) would result in slightly exceeding the interim exposure dose for consumers of HW22 well water (5.1 mg/day or 0.073 mg/kg/day).

While a number of studies have determined average levels of manganese in various diets, the available toxicological information is insufficient to quantitatively identify toxic levels of manganese in the diet of humans. Because of the homeostatic control humans maintain over manganese, it is generally not considered to be very toxic when ingested in food and water. However recent studies suggest a negative relationship between ingestion of manganese in drinking water below 400 ug/L and childhood development, including possible effects on intelligence (Frisbie *et al*. 2012). The levels of manganese observed in the EPA 2012 residential water well data are not likely to pose a health concern for adults. However, there is more uncertainty with respect to young children's exposures. It is recognized that newborns may be at increased risk of toxicity resulting from exposure to manganese because of a higher level of uptake from the gastrointestinal tract and a decreased ability to excrete absorbed manganese. An additional concern for infants has been expressed because of the often high levels of manganese in infant formulas, particularly compared with breast milk (ATSDR 2008). The levels of manganese in two of the drinking water wells in the EPA 2012 data set, HW47 and HW8a, result in exposures for 10 kg children that exceed dietary guidelines for manganese via consumption of the water alone.

Based on the additional uncertainty regarding manganese exposures and young children, ATSDR concludes that the manganese levels in two residential water wells, HW47 and HW8a, would be a public health concern from ingestion by young children.

Cancer Exposure Evaluation

There is insufficient animal or human study information to determine the carcinogenic risk from exposure to manganese.

Potability

In 2012, nineteen residential water wells had manganese concentrations in excess of the EPA secondary maximum contaminant level (SMCL) for public drinking water supplies (50 µg/L). The manganese SMCL is based on aesthetic water quality parameters and is not a health-based level. EPA states that black to brown colored water, black staining, and a bitter metallic taste will be the noticeable effects when manganese levels exceed 50 µg/L (EPA 2012a).

Phosphorus:

Phosphorus is an essential nutrient. The Institute of Medicine (IOM) has identified recommended daily allowances (RDA) of phosphorus for infants, children and adults grouped by age. These RDAs range from a minimum of 460 mg/day for one to three year old children up to 1,250 mg/day for nine to eighteen year old children. The adult phosphorus RDA has been determined to be 700 mg/day (IOM 1997).

Non Cancer Exposure Evaluation

The concentration detected in Dimock groundwater (maximum concentration of 329 µg/L) would result in insignificant contributions of phosphorus to the daily diet, totaling no more than 1 mg/day for a child or an adult. **Non-cancer health effects are expected from exposures to phosphorus at the levels detected in Dimock groundwater.**

Cancer Exposure Evaluation

There is insufficient animal or human study information to determine the carcinogenic risk from exposure to phosphorus.

Potassium:

Potassium is an essential nutrient and adults in the U.S. typically consume 2.8 to 3.3 g of potassium/day. Only well HW46 (4,320 µg/L) exceeded the provisional health-based screening value of 4,000 µg/L in the EPA 2012 data set.

Non Cancer Exposure Evaluation

The potassium adequate intake (AI) for adults is 4.7 g/day (IOM 2005). There is no established upper acceptable daily intake (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 (IOM 2005).

The estimated daily potassium intake for adults consuming HW46 well water is approximately 8,640 µg/day and for children (10 or 16 kg) is 4,320 µg /day. This level of supplemental potassium is well below the typical daily intake for adults in the U.S. **Non-cancer health effects are not expected in healthy people from exposure to potassium at the levels detected in Dimock groundwater.**

The maximum level of potassium seen in Dimock might be of concern for people who are at risk for hyperkalemia (e.g., people with renal failure, severe heart failure, taking certain medications that impair potassium excretion, *etc*.). **If such sensitive persons were drinking water with this level of potassium, it would be appropriate for them to notify their health care provider about this additional source of potassium in their diet.**

Cancer Exposure Evaluation

Potassium is not classified as carcinogenic.

Sodium:

Sodium is an essential nutrient. It is needed for proper muscle and nerve function, and it is involved in the control of blood pressure. Excessive sodium intake is associated with high blood pressure. The Food and Nutrition Board of the National Research Council recommends that most healthy adults need to consume at least 500 mg/day, and that sodium intake be limited to no more than 2,400 mg/day. The U.S. Department of Health and Human Services (HHS) and Department of Agriculture (USDA) recommend consuming less than 2,300 mg/day for the general population and less than 1,500 mg/day for sensitive populations, including individuals with hypertension, African-Americans, and middle-aged and older adults (USDA 2010). The UL for sodium in adults is 2,300 mg/day (2.3 grams per day) (IOM 2005). It is estimated that approximately 75% of adults in the U.S. exceed the recommended daily sodium intake. People on low sodium diets should limit the total amount of sodium they consume to 2,000 mg (2 g) per day or less. One teaspoon of salt has about 2,300 mg sodium.

Sixteen residential water wells had sodium concentrations in the EPA 2012 data set that exceed 20,000 µg/L, the EPA drinking water guidance level (EPA 2003a). The taste of drinking water is generally offensive to users at levels of 20,000 mg/L or higher because of the salty taste.

Sodium is not considered to be carcinogenic and will only be evaluated for non-cancer end points. The maximum estimated daily exposure dose from the EPA 2012 data set is 20.1 and 12.6 mg/kg/day for 10 and 16 kg children and 5.7 mg/kg/day for 70 kg adults (based on the maximum sodium concentration of 201,000 µg/L, in well HW29).

Non Cancer Exposure Evaluation

Consuming well water with the highest sodium concentration, HW29 at 201,000 μg/L (201 mg/L), would result in an additional 402 mg of sodium per day for an adult and 201 mg per day for a child. This additional sodium ingestion would not result in individuals exceeding the HHS/USDA recommended dietary guideline for general and sensitive populations of 2,300 mg/day from their drinking water consumption alone (USDA 2010), but it is a relevant sodium source in an individual's daily diet. Consuming water from this well would not exceed the UL for sodium of 1,500 mg/day for young children (1-8 years old) or 2,300 mg/day for adults (14+ years old). It is important to note that the primary source of sodium intake is food, which is not included in the above daily sodium intake calculations.

Sodium in each of the other residential water wells sampled is at lower concentrations than the level found in HW29 and, sodium intake from well water alone is not expected to result in adverse health effects. However, it should be noted that each additional sodium intake adds to the already over-threshold burden for most Americans. These conclusions and recommendations are further complicated when well water users are on sodium restricted diets or are otherwise of a sensitive population for sodium consumption.

ATSDR recognizes bottle-fed infants as one particularly sensitive subpopulation for sodium exposures from well water. As stated above, sodium is essential for adequate functioning of human physiology, but our population is affected, in general, by too much rather than too little sodium consumption. The World Health Organization also notes that that the requirement for sodium in infants is lower than that for children and adults, and "…high sodium intake may lead to hypernatraemia. This is a problem for bottle-fed infants and is the reason why sodium levels in infant formulae have been reduced significantly over time" (WHO 2007).

Maximum sodium concentrations identified in historic sampling were also in excess of the EPA drinking water guidance level of 20,000 μg/L, but none were higher than the sodium level detected in well HW29 (201,000 μg/L), and no adverse health effects were expected from sodium exposures to that well water alone, not accounting for the additional sodium exposure from food ingestion.

Individuals on sodium restricted diets or individuals with infants should discuss their groundwater sodium results with their physician.

Radiological COPCs

The radiological results from EPA 2012 sampling and analysis were provided to an ATSDR radiation health expert (health physicist) for review. None of the radiological groundwater results in the EPA 2012 Dimock data set exceeded radiological health-based screening levels or EPA MCLs. **Non-cancer or cancer health effects are not expected from exposures to radiological constituents detected in Dimock groundwater.**

Chemical Mixtures

Residential water wells in Dimock include a variety of chemical mixtures, most often involving combinations of metal salts. For many chemicals, however, information on toxic interactions (chemical mixtures) is lacking, and the available literature focuses on the effects of chemical interactions at exposure doses that are much higher than those that are typically encountered in residential water wells. Furthermore, even though limited information for some chemical mixtures is available, there is not an empirical data set available that could account for the exact array of chemicals in varying proportions that was found in residential water wells at the Dimock site. ATSDR did review the scientific literature available specifically on mixtures of metal salts. Studies on metal salt mixtures were located for arsenic and cadmium; cadmium and lead; copper and lead; lead and arsenic; manganese and iron; and manganese and lead; and iron and lead (Roney *et al.* 2011, Pohl *et al.* 2011). Most of these available studies review mixtures information for metal combinations different from those found at Dimock. At Dimock, metals observed in drinking water samples above CVs alone or in combination included arsenic, manganese, lithium, potassium, sodium, and iron.

ATSDR finds that the limited available information on metal salt mixtures found in Dimock residential water well samples supports careful consideration of exposures to sensitive populations, consistent with the recommendations in this health consultation document.

5. Community Health Concerns

Dimock area residents have expressed specific concerns about their exposures to contaminants in their residential well water, including general water quality/potability issues, water treatment, methane in drinking water, blood barium tests, quality of provided water, and disease/cancer concerns. Appendix G discusses specific community health concerns raised to ATSDR by Dimock residents.

IV. Conclusions

Conclusion 1:

ATSDR found some of the chemicals in the private water wells at this site at levels high enough to affect health (27 private water wells), pose a physical hazard (17 private water wells), or make the water unsuitable for drinking. Dimock residents who participated in EPA's 2012 sampling may want to review Appendix B of this document to understand what chemicals were identified by ATSDR as of potential health concern in their specific private water well.

Chemicals of Health Concern:

- **Arsenic** - Chronic, daily ingestion of drinking water from thirteen (13) wells are of public health concern:
    - Drinking untreated water from well HW47 may result in non-cancer health effects and increased risk for cancer. Cabot has installed a treatment system on HW47 and continues to monitor arsenic levels in the treated water from this well
    - Although it is unlikely that individuals will experience health effects from consuming untreated water from these nine wells (HW2, HW6, HW12, HW15a, HW22, HW29, HW32, HW57, and HW60), some children may be more sensitive to arsenic and may experience non-cancer health effects from chronic consumption of water from these wells.
    - The excess lifetime cancer risk from drinking water from twelve residential wells (HW2, HW6, HW12, HW15a, HW17, HW18, HW22, HW29, HW32, HW49, HW57, and HW60) are estimated between 1.7 and 4.5 additional cancers in 10,000 exposed; slightly above EPA's target risk range of less than 1 in 10,000.
- **Cadmium** - Except for one well, ATSDR does not expect adverse non-cancer health effects from exposures to cadmium in untreated or treated drinking water. For well HW57, only the estimated children's exposure dose exceeds the minimal risk level (MRL), and may be of health concern for the most sensitive subpopulation (e.g., kidney disease, diabetic children).
- **Copper** - The estimated daily exposure doses for children consuming untreated or treated drinking water at homes served by wells HW33b and HW28a are below the no observed adverse effect level (NOAEL) but above the MRL and within the range of uncertainty due to human variability. Therefore, children's copper exposures to these two water supplies may be of health concern for some children that may be sensitive to copper.
- **Iron** - Exposures to the iron in Dimock residential water wells are not likely to result in adverse health effects in healthy residents. However, if any individuals with elevated iron in their well water are on reduced-iron diets they should consult their health professionals to discuss the additional iron exposures

from consuming their well water. Chronic exposure may be of health concern for the most sensitive subpopulation (i.e., those with hemochromatosis).

- **Lead** - Lead was detected in 20 of the 64 homes (see Table 3 for list of wells). The EPA has set a maximum contaminant goal of zero (0) for lead in drinking water because no health-based standard has been established.
- **Lithium** - Eight wells (HW6, HW16, HW18, HW24, HW29, HW34a, HW39, and HW47) have lithium concentrations that would result in child and adult exposure doses exceeding the EPA provisional peer-reviewed toxicology value (PPRTV). An additional twelve wells (HW1, HW2, HW5, HW12, HW15a, HW17, HW22, HW25, HW26, HW30, HW31, and HW60) have lithium concentrations that would result in child exposure doses exceeding the EPA PPRTV of 0.002 mg/kg/day.
- **Manganese** - Chronic, daily ingestion of water from two wells (HW47 and HW8a) may result in adverse non-cancer health effects for young children. Manganese exposures for small children (i.e., up to 10 kg or 22 pounds) would exceed ATSDR interim guidance values (i.e., above estimated safe and adequate daily dietary intake, or ESADDI levels) for manganese through well water exposure alone.
- **Potassium** – The levels found in Dimock wells are well below the typical daily intake for adults in the U.S., and are not likely to be associated with adverse health effects for healthy people. However, the maximum level of potassium seen in Dimock (well HW46 at 4,320 µg/L) might be of concern for people who are at risk for hyperkalemia (e.g., people with renal failure, severe heart failure, taking certain medications that impair potassium excretion, *etc*.).
- **Sodium** – Sixteen wells (HW6, HW15a, HW16, HW18, HW24, HW25, HW26, HW29, HW31, HW34a, HW35, HW39, HW40, HW41, HW47, and HW60) had sodium in excess of the drinking water advisory level of 20,000 µg/L.
- **4-chlorophenyl phenyl ether** - Two wells may be of public health concern (HW2 and HW8a) because there is not enough information on the toxicology of this chemical to determine its potential for adverse health effects.

Non naturally-occurring chemicals (specifically bis(2-ethylhexyl) phthalate or DEHP, hexachlorobenzene, and 2,4-dinitrotoluene) were detected in EPA's 2012 sampling data set below levels of health concern. In the historical data set, non naturally-occurring chemicals (specifically DEHP, ethylene glycol/other glycol compounds, and 2-methoxyethanol) were detected in post-drilling well water samples at higher concentrations than were found in EPA's 2012 sampling, and some of these higher detections were of public health concern.

Physical Hazard:

Methane - ATSDR identified an immediate risk of explosion or fire from dissolved methane exceeding 28 mg/L (28,000 µg/L, the saturation level of dissolved methane) in five residential water wells (HW3, HW12, HW25, HW26, and HW29). Twelve additional wells (HW1, HW2, HW6, HW11, HW15a, HW16, HW22, HW31, HW34a, HW47, HW52, and HW60) have methane over 10 mg/L (10,000 µg/L), the cautionary level for explosion or fire risk.

Some of these residential water wells have wellhead methane vents and treatment per the EPA/Cabot consent order. However, three of the five private water wells that exceed 28 mg/L are not part of the consent order (HW29, HW25 and HW26) and homeowners of these wells have indicated to ATSDR that beyond notification, the dissolved methane levels have not been addressed by industry, regulators or themselves to reduce the explosion or fire risk.

General Water Quality:

Problems remain for a number of residential water wells that make water undesirable for consumption, including cloudiness and effervescence (from elevated methane), elevated metals/salts and total dissolved solids (e.g., discoloration, cloudiness, *etc*.), pH, and bacteriological contamination (including fecal coliform in one well).

Conclusion 2:
Dimock residents' current exposures to chemicals in their well water remain unclear. Ultimately, it is not clear whether a resident is consuming treated or untreated groundwater or whether treatment was successful or remains effective.

V. Recommendations and Next Steps

Chemicals of Health Concern

- Arsenic - ATSDR recommends continuing well water treatment to reduce arsenic exposure from well HW47 and regular monitoring of the treated well water to verify arsenic is below levels of health concern. ATSDR also recommends well water treatment to reduce lifetime arsenic exposures to twelve additional residential well water supplies: HW2, HW6, HW12, HW15a, HW17, HW18, HW22, HW29, HW32, HW49, HW57, and HW60.
- Cadmium – ATSDR recommends steps to reduce children's exposures to well HW57 well water.
- Copper – ATSDR recommends steps, such as flushing of water pipes prior to use, to reduce children's exposure to copper at the tap in homes served by wells HW28a and HW33b.
- Iron - ATSDR recommends that individuals with elevated iron in their well water that are on reduced-iron diets, including those with hemochromatosis, consult their health care provider to discuss this additional source of iron in their diet.
- Lead - ATSDR recommends that homeowners with detectable lead (see Table 3 for private water wells with lead detections) in their drinking water take steps, such as well water treatment and flushing the water pipes prior to use, to reduce the lead before ingestion. Consistent with statewide childhood blood lead screening guidelines, every family is encouraged to discuss blood lead screening for children six years of age and under with their health care provider.
- Lithium – Homeowners of the following water wells should take steps, such as installing an effective well water treatment system or choosing an alternative drinking water source, to reduce exposure to the lithium in their wells (HW1, HW2, HW5, HW6, HW12, HW15a, HW16, HW17, HW18, HW22, HW24, HW25, HW26, HW29, HW30, HW31, HW34a, HW39, HW47, and HW60).
- Manganese - ATSDR recommends that homeowners of wells HW47 and HW8a treat their well water to reduce exposure to manganese if it is being consumed by young children, particularly if the well water is being used for mixing infant formula.
- Potassium - ATSDR recommends that individuals at risk for hyperkalemia, e.g., people with renal failure, severe heart failure, taking certain medications that impair potassium excretion, *etc*., notify their health care provider about this additional source of potassium in their diet from well water.
- Sodium - ATSDR recommends that individuals on sodium restricted diets or that have infants discuss the sodium in their residential well water with their health care provider.
- 4-chlorophenyl phenyl ether - Due to limited toxicological literature for 4-chlorophenyl phenyl ether, and limited sampling information for wells HW2 and HW8a, ATSDR recommends that residents of these homes continue to monitor and/or take steps, such as installing an effective well water treatment system or choosing an alternative drinking water source, to reduce exposure to the chemicals in this private water well.

Physical Hazard

- Concentrations of methane above 28 mg/L (28,000 µg/L) require immediate action, including wellhead ventilation and possibly treatment to remove the methane from the residential well water.
- Take precautionary steps for dissolved methane concentrations that range from 10 mg/L (10,000 µg/L) to 28 mg/L (28,000 µg/L), including installation of a combustible gas monitor, ventilation of the home, ventilation of the well head, and removal of ignition sources in enclosed areas of the home.

- Methane detected at a concentration below 10 mg/L (10,000 µg/L) does not warrant immediate action except for monitoring the appearance of the water and possibly ventilating the home.
- For homes with dissolved methane in their well water exceeding 10 or 28 mg/L and that are not already being vented/treated, ATSDR recommends residents implement the protective actions described above.

Private Water Treatment Systems

- Dimock private water well users should carefully consider the information about their well water quality, as well as options about appropriate water treatment and operation and maintenance of any systems installed on their private water well. The Penn State Extension Program and the Master Well Owner Network can provide expert advice to help make decisions about appropriate water treatment and long term operation and maintenance.
- All private well owners should test their drinking water on a regular basis. The Penn State Extension Program offers well water testing at low costs, and this program offers a specific gas/oil water testing package. The Penn State Extension lab testing web site is http://agsci.psu.edu/aasl/water-testing/drinking-water-testing, or the Susquehanna County Penn State Extension office can be reached at 570-278-1158 for more information on their private water well testing program.

Future Sampling

- In addition to routine private well water quality monitoring by private well users, ATSDR recommends additional residential drinking water well sampling for further groundwater characterization purposes with an appropriate full analyte list following accepted sampling protocols in the Dimock site area either by the appropriate regulatory agency or under the supervision of the appropriate agency.

> Note: Site conditions have changed since the EPA January-July 2012 sampling. In August 2012, PADEP lifted the moratorium on completions (e.g., hydraulic fracturing) of previously drilled wells in the site area. In December 2012, subsequent to new completions in the site area, several residents filed complaints with the PADEP and one report was filed with the National Response Center regarding visual changes in their residential well water quality (turbidity, color changes, increased methane). Subsequently, PADEP conducted some additional investigation into potential well contamination in the moratorium area. During a July 2013 meeting between PADEP, ATSDR, and EPA, PADEP informed ATSDR that they continue to investigate groundwater concerns in Dimock. PADEP noted that they have collected and analyzed residential well water samples related to specific groundwater concerns but have not made a determination on these data or on additional lines of evidence related to the natural gas activities. To date, ATSDR has not received these newer Dimock private well water data.

Health Education

- One primary role for public health agencies is to provide health education to community members to support protective health actions. In 2012, ATSDR participated in EPA's meetings with Dimock residents in their homes to review their individual residential well water results. ATSDR will continue to work with appropriate regulatory and public health agencies and community members to share information with the Dimock community about the public health implications of residential well water quality in the area. This educational effort will continue to include specific information related to ongoing well water potability concerns, appropriate treatment systems and operation and maintenance, and methane mitigation in wells with levels exceeding the 10-28 mg/L (10,000-28,000 µg/L) range.

VI. Public Health Action Plan

On December 30, 2011, ATSDR responded to EPA with a record of activity-technical assistance document (AROA) that provided ATSDR's initial public health evaluation of the environmental data collected from 2009 through the end of 2011. In ATSDR's December 2011 review, ATSDR concluded that (1) there may be a chronic public health threat from exposure to the well water should exposures to the reported concentrations continue and (2) there were important data gaps for evaluating groundwater quality in private wells in the site area. At that time, ATSDR supported a "Do Not Use until Further Notice" action regarding the private wells sampled to date until the site could be characterized further. In ATSDR's 2011 review, ATSDR recommended (1) further private well sampling using a full set of constituents (e.g., inorganic, organic, and potability parameters including total and fecal bacteriological samples), and (2) a full public health evaluation on the data from the site area.

This document completes the public health evaluation of the EPA's 2012 environmental sampling of 64 wells. Appendix F provides a public health review of the environmental data made available to ATSDR from the limited number of Dimock area wells that were sampled before 2012.

ATSDR continues to communicate with the EPA and PADEP regarding Dimock groundwater public health implications. On July 9, 2013, ATSDR met with site managers from both EPA and PADEP in Williamsport, PA, to discuss this health consultation document and the conditions in Dimock following the 2013 resumption of well completion activities (e.g., hydraulic fracturing).

ATSDR will consider further public health review of any additional environmental sampling data or health concerns information formally submitted by residents or other stakeholders (e.g., EPA, PADEP) at this site on a case by case basis.

ATSDR will participate in additional individual discussions with interested community members and stakeholders as requested to discuss the conclusions and recommendations in this health consultation. ATSDR will provide consultation with individual health professionals as requested.

ATSDR will continue to work with PADOH and other public health partners to promote health education outreach related to concerns about potential air and water exposures and natural gas activities.

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Appendix A

ATSDR Records of Activity (AROA)

Dimock Groundwater Site

ATSDR Record of Activity/ Technical Assist

UID #: JBD7 Date: 12/28/2011 Time: 12:00 am pm X

Site Name: Dimock Area___ City: Dimock State: Pennsylvania

CERCLIS #:______ Cost Recovery #: 3ATA00 Region: 3

Site Status (1) NPL Non-NPL RCRA Non-Site specific Federal
(2) Emergency Response Remedial _Removal Other

Activities

Incoming Call
Outgoing Call
X Conference Call
Incoming Mail
Public Meeting*
Other Meeting
X Data Review
Other
X_Health Consult*
_ Health Referral
Written Response
Site Visit*
Info Provided
Training

Requestor: Jon Capacasa, EPA Region 3 Water Protection Division

NARRATIVE SUMMARY

On December 7, 2011, EPA Region 3 requested ATSDR conduct an evaluation of available Dimock private well data, stating that "residents are potentially in contact through dermal, inhalation and ingestion pathways, if you should identify any potential health threats please notify us as soon as possible." In order to conduct an immediate preliminary evaluation of the large data set as requested by EPA, on December 9, 2011, ATSDR Region 3 requested support from ATSDR Emergency Response in Atlanta. Home owners and numerous other concerned citizens contacted EPA and ATSDR in November 2011 asking for help in evaluating the well sampling data and requesting that alternative supplies of drinking water continue to be supplied to the residents. Following the residents' request, EPA acquired a large amount of summarized data tables regarding the Dimock site concern. After communicating with PADEP, EPA and ATSDR visited the Dimock homes along Carter Road and State Route 3023 on November 10, 2011 and were provided a large amount of well data. Based on the home visits and preliminary review of data, EPA and ATSDR raised the following concerns: the reliability of methane removal systems; the presence of other contaminants besides methane (metals, volatile organics and non-naturally occurring organics) for which the well treatment systems are not designed or in place to address; and homes/wells in Dimock that may have never been tested and may be contaminated. The multiple sampling efforts at this site to date were conducted by PADEP and private contractors not affiliated with EPA.

The site area is located in Dimock, a rural area of northeastern Pennsylvania in Susquehanna County. A map of the area is included as Attachment 1. Cabot began natural gas drilling in the Dimock area in 2008. Methane contamination was detected in private wells soon thereafter. The Pennsylvania Department of Environmental Protection (PADEP) has had the lead in investigating the environmental complaints in Dimock. After first calling for the provision of public water, which the State Public Utility Commission vetoed based on cost and feasibility, in November 2009 (last amended December 2010), PADEP issued a consent agreement with Cabot for methane and metals removal systems for eighteen private wells in the site area. The agreement calls for each well owner to enter into the agreement with Cabot. Until the treatment systems are installed, Cabot was to provide delivered water. There are eighteen wells that are part of the PADEP/Cabot agreement. Six well owners have signed agreements and have systems installed. However, most of them are buying bottled water because they do not have confidence that the treatment systems are working. Twelve well owners have not signed the agreement and are part of a civil suit. These 12 owners were being provided delivered water by Cabot. However on November 30, 2011, Cabot ceased delivering water to these homes.

PADEP approved the stoppage of water delivery scheduled for November 30, 2011 on the grounds that Cabot has allowed sufficient time for residents to sign the agreement and that a remedy for home owners has been provided. However, other private wells appear to exist in the site area. The exact number of these other private wells has not been confirmed by EPA or ATSDR at this time. These additional wells are not part of the existing PADEP/Cabot agreement, and very little if any sampling data are currently available for these wells.

DISCUSSION

ATSDR Division of Regional Operations received the water sampling data for the 18 properties that are part of the consent order between Cabot and PADEP. This information was provided to EPA and ATSDR Division of Regional Operations from PADEP and the legal representative for some of the residents. ATSDR Division of Regional Operations prepared a summary of this information for ATSDR Emergency Response. The data package provided to ATSDR Emergency Response for this review consisted of maximum concentrations reported over numerous sampling events over several years. It is not possible from this summary to evaluate the changes in conditions over time or determine if there is any potential synergism from the chemicals involved. Note, it is fairly unusual for metal contamination to be detected in field blanks, as was documented in the summary sampling data provided. Therefore, the quality control of the field sampling methods needs to be further evaluated. At this time, the full quality assurance/quality control information for these sampling data has not been provided to EPA or ATSDR.

Based on the maximum results for the approximately 18 wells sampled, levels of coliform bacteria, methane, ethylene glycol, bis(2-ethylhexyl) phthalate (DEHP), 2-methoxyethanol, aluminum, arsenic, lithium, manganese, sodium, and iron were elevated above comparison values (CVs).

Bacteriological/Coliform Results

CDC/NCEH (National Center for Environmental Health) reviewed the summary sampling results for bacteriological contamination. The review of the coliform data concluded that bacteria were detected in 9 of the 18 private wells. Any detection of coliform in drinking water supplies is of potential health concern. Total coliform bacteria are "indicators" used to determine if a pathway exists that might allow disease-causing bacteria to contaminate the water supply. E. coli bacteria are a subset of coliform bacteria that only occur in animal or human wastes and indicate more serious contamination. The coliform results were particularly elevated in five of the wells (in two cases noted by the laboratory as too high to count). Prior studies of private well water in Pennsylvania have found that approximately one third of private wells have total coliform detections Higher incidences of total coliform bacteria have been found in the southeast and southwest regions of Pennsylvania, while the lowest incidence was observed in the northwest and northeast regions (Swistock et al 2009).

Combustible Gas Results

In the summary data set provided, methane levels ranged from 79 µg/L dissolved in water to 64,300 µg/L dissolved in water. A level of 28,000 µg/L methane dissolved in water was used as a comparison level for the methane detections in these private wells. This level is based on the recommended action levels (RALs) from the Department of the Interior Office of Surface Mining Reclamation and Enforcement (DOI 2001). Elevated concentrations of methane can produce explosive environments. Additional combustible gases, including butanes, propane, ethane and ethene were also identified in many of the well sample results. Of the approximately 18 private wells in this data set, ten had maximum dissolved methane levels higher than 28,000 ug/L. Methane venting systems were offered to the 18 properties that are part of the Cabot/PADEP order. ATSDR and EPA do not have precise information at this time about which of the approximately 18 private wells for which sampling data are available have functioning methane venting systems at this time.

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 and eventual asphyxiation. Exposure to low oxygen environments (such as resulting from methane displacement) produces symptoms of central nervous depression, including nausea, headache, dizziness, confusion, fatigue, and weakness.

Organic Chemical Detections

Not all the private wells in this data set were analyzed for organic constituents. For the subset of these private wells that did have organic analyses conducted, a number of organic compounds were detected. These organic detections included glycols and phthalates, both used extensively in the natural gas field. Glycol detections included ethylene glycol, triethylene glycol, and 2,2'oxybisethanol (diethylene glycol). For ethylene glycol, ATSDR has identified an intermediate exposure duration (14 days to 364 days) drinking water ingestion CV of 8,000 µg/L for children and 30,000 µg/L for adults. EPA has identified an ethylene glycol lifetime health advisory (LTHA) value of 14,000 µg/L. Some wells had all three reported glycols present in their wells, including ethylene glycol, triethylene glycol and 2,2'oxybisethanol.

All of the glycol sampling detections (with the exception of the maximum ethylene glycol result of 8,410 ug/L) were data qualified with a "J" indicating the presence of the compound was confirmed but the concentration was estimated. These data qualifiers are likely a result of the difficulties in laboratory analysis for this class of compounds.

It is important to note that the maximum ethylene glycol result (8,410 ug/L) in this data set was from a sample collected after the treatment system on this private well. This maximum post-treatment ethylene glycol result exceeds the ATSDR child intermediate CV of 8,000 µg/L, but is below the EPA LTHA of 14,000 µg/L. It should also be noted that four additional samples may have exceeded the ATSDR EMEG of 8,000 µg/L with sample results indicated in the data package as less than 10,000 µg/L. Ethylene glycol is used to make antifreeze and de-icing solutions for cars, airplanes, and boats. It is also used in hydraulic brake fluids and inks used in stamp pads, ballpoint pens, and print shops.

Bis(2-ethylhexyl) phthlate (DEHP) is a manufactured chemical that is commonly added to plastics to make them flexible. DEHP is not toxic at the low levels usually present in the environment. In animals, high levels of DEHP can damage the liver and kidney and affect the ability to reproduce. Bis(2-ethylhexyl) phthalate (DEHP) was detected in five samples and ranged from 0.14 µg/L to 22 µg/L . These levels did not exceed the chronic health comparison values for non-cancer health effects; however four of the 5 samples exceeded the drinking water comparison value of 2 µg/L (ATSDR Cancer Risk Evaluation Guide (CREG) and one sample exceeded the EPA Maximum Contaminant Level (MCL) for public drinking water supplies for this chemical of 6 ug/L. A drinking water concentration of 22 µg/L would result in an exposure dose for an adult of 0.00063 mg/kg/day and 0.0022 mg/kg/day for a child.

Estimated 2-methoxyethanol concentrations (ranging from 880 µg/L to 1,300 µg/L) were detected in each of six wells assessed for this chemical, although all results were "J" qualified as estimated results. Each of these estimated results exceed the EPA Risk Screening Level (RSL) for 2-methoxyethanol of 110 µg/L. 2-Methoxyethanol is mainly used as a solvent and is found in the glycol ethers class. It is also used as an additive in deicing solutions.

Inorganic Chemical Detections

Aluminum was detected in each of the approximately 18 wells sampled, ranging from under 10 µg/L up to 44,100 µg/L. The two wells with the highest aluminum concentrations (13,700 µg/L and 44,100 µg/L) exceeded the ATSDR CV for chronic exposures (greater than 364 days) to children, set at 10,000 µg/L. The well with the maximum aluminum concentration (44,100 ug/L) also slightly exceeds the adult health-based CV for chronic exposures (40,000 µg/L).

Arsenic was detected in all of the wells, ranging from 0.67 µg/L to 37 µg/L. The two highest levels of arsenic detected were 37 µg/L and 25 µg/L; these were the only two arsenic concentrations that exceeded EPA's Maximum Contaminant Level (MCL) for this chemical in public drinking water supplies. The arsenic concentrations in approximately

12 of the samples from this data set were above the ATSDR Child EMEG (Environmental Media Evaluation Guide) of 3.0 µg/L for non-cancer effects. Arsenic has been classified as a known human carcinogen. This classification is based on animal and human studies which indicate an increased risk for developing cancers of the skin, lung, bladder, kidney, liver, and prostate from consuming water containing arsenic. All of the arsenic detections in the wells exceeded the estimated lifetime 10E-6 cancer risk level from exposure of 0.02 µg/L. A "B" data qualifier indicating this contaminant was also detected in blank quality control samples was assigned to four of the lower arsenic sampling results (ranging from 0.67-7.2 ug/L) in this summary.

Seven samples indicated lithium at concentrations ranging from 8.3 µg/L to 380 µg/L. Five of the 7 samples were above the child provisional Reference Dose Media Evaluation Guide (RMEG) of 20 µg/L. Therapeutically, lithium (lithium carbonate) is used to control manic episodes in manic depressive illness in doses of 900 to 1,800 mg/day. The estimated lithium intakes at the maximum concentrations at this site are well below reported therapeutic levels.

Manganese concentrations in the well water samples ranged from 2.4 µg/L to 1,920 µg/L. Although the concentrations of manganese in all but two of the samples in this data summary are greater than EPA's secondary drinking water standard for this contaminant (50 µg/L), this standard was set for aesthetic reasons and is not health based. Ten of the wells had maximum results exceeding EPA's health advisory level for manganese of 300 ug/L. Manganese is an essential mineral that occurs naturally; however excess exposure can cause health effects that include behavioral changes and other nervous system effects.

Sodium levels exceeded EPA's Drinking Water Advisory levels of 20,000 µg/L in ten of the samples. The highest concentration was detected at 131 mg/L. Drinking water from these wells would increase the amount of sodium consumption in a person's diet. This could be particularly problematic for sodium sensitive individuals.

Iron concentrations were found greater than EPA's secondary drinking water standard for this contaminant (300 µg/L) in 16 of the samples. This standard was set for aesthetic reasons and is not health based. The maximum level of iron in this data set was 24,100 ug/L, and this result is from a private well that is not known to have any treatment systems. At the levels detected, the taste of the water will be affected. Iron is an essential mineral with recommended average intakes of 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 Institute of Medicine Upper Tolerable Intake Level (UL) for iron is 45 mg/day. Drinking water from the well with the highest level of iron would add approximately 48.2 mg of iron to an adult's daily diet and add approximately 24.1 mg of iron to a 10-16 kg child's daily diet.

CONCLUSIONS

These sample results indicate that there is a possible chronic public health threat based on prolonged use of the water from at least some of these wells - assuming future exposure to these contaminants at these concentrations is not reduced. Based on the potential quality control issues, a potential health threat for the remaining wells cannot be disregarded. Additional characterization of the groundwater quality and a thorough review of any changes in concentration over time are indicated.

There are important data gaps for evaluating water quality in private wells that have been assessed and un-assessed in the site area. Further evaluation of all potentially impacted private wells in the site area and of treatment systems in use is needed.

RECOMMENDATIONS

ATSDR supports a "Do Not Use Until Further Notice" action regarding the private wells sampled to date at this site until the site can be characterized further. Distribution of alternative residential water supplies should be considered until potential exposures are further understood and mitigated as needed.

ATSDR and NCEH recommend that further sampling be conducted by EPA to ensure the highest quality sampling methodology possible, including appropriate quality assurance samples. Next steps, if implemented, should be focused on areas of primary concern delineated by EPA or the appropriate agency. Further sampling plans should consider a full set of appropriate inorganic, organic, and bacteriological (total and fecal) constituents.

A full public health evaluation should be conducted on the data from the site area. Because many of these compounds (e.g., metals) affect the same organ systems, ATSDR recommends evaluating the mixture for public health impacts using computational techniques or other suitable methods to evaluate the potential for synergistic actions. The cumulative concentration of all dissolved combustible gases should be considered to protect against the buildup of explosive atmospheres in all wells in the area.

PUBLIC HEALTH ACTION PLAN

ATSDR Division of Regional Operations in consultation with ATSDR/NCEH Headquarters has begun drafting a full health consultation on the available data set for the Dimock site, including Cabot, PADEP, and residents' consultant-collected samples over the past 2 years. ATSDR will review any follow up environmental monitoring being considered by EPA to assess current community exposures at the site and will continue to coordinate data reviews with Federal and Commonwealth public health and environmental authorities.

Signature:

Signature:________________________ Date: 12/29/11
Charles Edge, Health Scientist, ATSDR ERS

Signature:________________________ Date: 12·29·11
Robert Helverson, Regional Representative, ATSDR R3

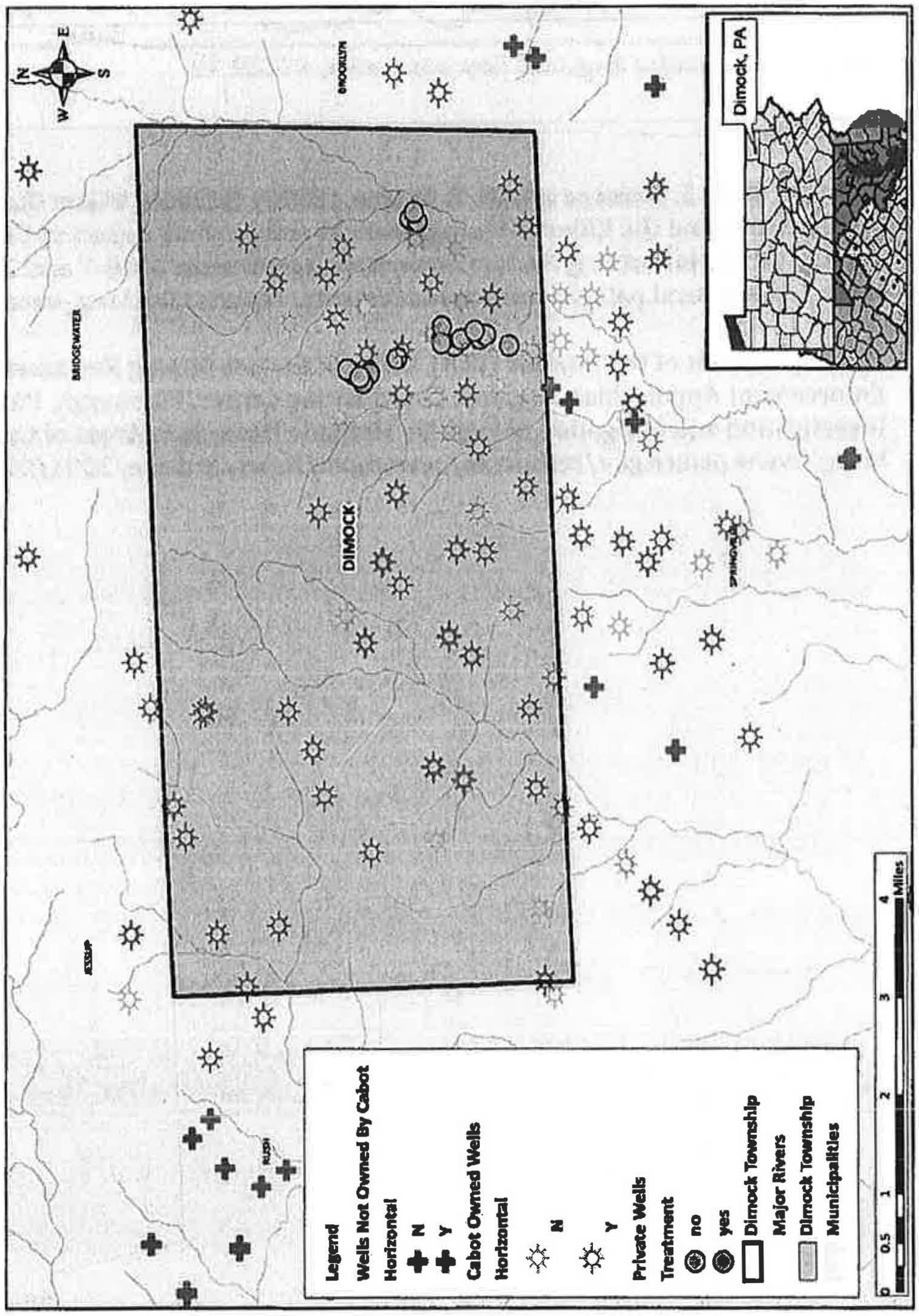
Concurrence:______________________ Date: 12/30/11
Lora Werner, Senior Regional Representative, ATSDR R3

References

Swistock, B. R., S. Clemens and W. E. Sharpe. (2009). Drinking Water Quality in Rural Pennsylvania and the Effect of Management Practices. Final report to The Center for Rural Pennsylvania, Harrisburg, PA for Cooperative Agreements 2006-7 and 2007-10. p. 24. (http://www.rural.palegislature.us/documents/reports/drinking_water_quality.pdf).

U.S. Department of the Interior (DOI), Office of Surface Mining Reclamation and Enforcement Appalachian Regional Coordinating Center, Pittsburgh, PA. 2001. Investigation and Mitigation of Fugitive Methane Hazards in Areas of Coal Mining. http://www.osmre.gov/resources/newsroom/News/Archive/2001/090601.pdf

Attachment 1.



ATSDR/DRO Activity Form

Preparer's First Name: Lora
Preparer's Last Name: Werner
Preparer's Affiliation: DRO

Site Name: Dimock Residential Groundwater Site
City: Dimock

State/Tribe: PA
Cost Recovery #: 3ATA
EPA ID:
Non-site-specific: ☐

Requester's Name: Dennis Carney, Branch Chief
Phone Number: 215-814-3241

Requester Category
EPA
Removal

Question or Request (full description)
Date of Request (mm/dd/yyyy): 3/12/2012

EPA R3 removal asked ATSDR R3 what concentration of lithium in drinking water would represent an acute public health concern. In addition, ATSDR R3 is interested in establishing whether lithium in the 200-500 ug/L range would represent a public health concern.

Activity (Select all that apply)

- ☐ Chemical Exposure
- ☐ Community Involvement
- ☒ Emergency Response
- ☐ Health Assessment
- ☐ Health Consultation
- ☐ Health Education (Public or Health Care Provider)
- ☐ Outreach Activity
- ☐ Public Meeting
- ☒ Removal
- ☐ Referrals (PEHSU, ACMT)
- ☐ Site Visit
- ☒ Technical Assistance
- ☐ Other (specify)

Special Initiative (Select all that apply)

- ☐ Brownfields
- ☐ CARE Pilot
- ☐ Day care
- ☐ Exercises
- ☐ Land Reuse Sites
- ☐ Mercury response
- ☐ Non-site related (HIA, asbestos, workgroups, etc)
- ☐ School Siting
- ☐ **Success Story**
- ☐ Toxicological data/PDA
- ☐ Training
- ☐ Tribal Activities
- ☐ Other (specify)

ATSDR Response (Detailed description of response)
Date of Response (mm/dd/yyyy): 3/23/2012

EPA R3 removal asked ATSDR R3 what concentration of lithium in drinking water would represent an acute public health concern. In addition, ATSDR R3 is interested in establishing whether lithium in the 200-500 microgram per liter or parts per billion (µg/L or ppb) range would represent a chronic public health concern. ATSDR R3 referred this request to ATSDR Emergency Response. ATSDR ER and the National Center for Environmental Health (NCEH) reviewed information from ATSDR, EPA, FDA, and other available literature on lithium toxicity.

RESPONSE TO QUESTION 1: What concentration of lithium in water would pose an acute human health threat?

Based on the literature reviewed, lithium concentrations in drinking water below 1,500 ug/L would likely not result in adverse acute health effects in children or adults. Based on clinical experience with acute toxicity, 1,500 ug/L represents a conservative level of concern for acute toxicity. There are a few epidemiologic studies associating varying levels of lithium in drinking water with behavioral effects and effects on thyroid functions. There is a wealth of literature on therapeutic use of lithium and adverse effects over time at doses that are much higher than these environmental exposures.

RESPONSE TO QUESTION 2: Are chronic (1 year or longer) exposures to lithium in drinking water at concentrations in the 200-500 ug/L range a public health concern?

ATSDR cannot determine if chronic consumption to 200-500 ug/L of lithium in drinking water represents a public health concern. ATSDR notes that these levels of ingestion are 1/3 as high as ATSDR's conservative level of concern for acute toxicity. ATSDR also notes that these levels are 10 to 20 fold higher than an EPA provisional reference dose (RfD) for children for chronic /subchronic lithium ingestion. The potential for adverse health effects in sensitive subpopulations is uncertain. There is very little data on lithium exposures in young children. Potentially sensitive populations for lithium exposures include children, pregnant women, and those with significant renal or cardiovascular disease, or dehydration or sodium depletion with concurrent long-term use of medications such as: diuretics (e.g., hydrochlorothiazide), nonsteroidal anti-inflammatory agents (e.g., ibuprofen), calcium channel blocking agents (e.g., verapamil), and angiotensin-converting enzyme inhibitors (e.g., captopril).

RECOMMENDATIONS:

ATSDR cannot predict the health consequences from chronic ingestion of drinking water containing 200 to 500 ug/L because there are not any scientific studies to support this. Individuals using drinking water with these levels of lithium who are sensitive or concerned should consult their personal health care provider and determine if it is prudent to follow their serum lithium levels. ATSDR will provide health education consultation on this issue to impacted residents. ATSDR will also consult with individual healthcare providers, if requested.

ATSDR ACTIVITIES:

ATSDR is in the process of conducting further public health evaluation of the available drinking water data from this site and will make additional conclusions and recommendations about this information as appropriate in a future health consultation document.

BASIS FOR CONCLUSIONS:

Conclusion 1: Lithium salts have been used therapeutically at adult doses varying between 900 mg (mg)/day to 1,800 mg/day to achieve therapeutic serum concentrations ranging from 0.6 to 1.4 millimoles per liter (mmol/L). Concentrations between 0.8 to 1.0 mmol/L are generally accepted as the optimally therapeutic range. A 900 mg dose of lithium carbonate medication contains 170 mg lithium; therefore, 170 mg of lithium for a 70 kg adult equates to roughly 2.5 mg lithium/kg body weight/day. If this is all ingested in 2 liters of water, it would amount to a lithium water concentration of 85,000 ug/L.

Conclusion 2: In general, lithium has a narrow therapeutic-toxic ratio and can induce adverse health effects, if slight changes in dosing or elimination occur. Lithium treatment is not recommended for patients with significant renal or cardiovascular disease, severe debilitation or dehydration or sodium depletion or for patients receiving certain other medications (e.g., diuretics) because the risk of lithium toxicity is very high in such patients. There are several groups of drugs that interact with lithium causing increased levels of lithium in the serum. These include diuretics (e.g., hydrochlorothiazide), nonsteroidal anti-inflammatory agents (e.g., ibuprofen), calcium channel blocking agents (e.g., verapamil), and angiotensin-converting enzyme inhibitors (e.g., captopril).

Thyroid impairments have been observed in individuals receiving lithium therapy, and possible thyroid effects from lithium in drinking water have been reported. Further, there is sufficient evidence available to conclude that therapeutic use of lithium causes developmental effects in offspring when maternal serum lithium concentrations are within the therapeutic range.

ATSDR cannot determine if chronic consumption to 200-500 ug/L of lithium in drinking water represents a public health concern. Note, these levels are unlikely to affect individuals already on lithium therapy as they would be very small (about 1,000 times less) compared to therapeutic doses; furthermore, these individuals should be having lithium levels measured periodically and doses adjusted accordingly.

A Lowest Observable Adverse Effect Level (LOAEL) has not been identified for lithium ingestion. In 2008, EPA developed a conservative provisional reference dose (RfD) for lithium ingestion of 2 ug/kg/day. In the absence of a LOAEL for lithium ingestion, EPA assigned the LOAEL to 2.1 mg/kg/day, which was estimated as the lowest value at which therapeutic effects were recognized, and then applied multiple uncertainty factors. Adverse effects in multiple organ systems have been noted at all therapeutic levels but are generally accepted to be related to increasing therapeutic serum levels. EPA used an uncertainty factor (UF) of 1,000 in this provisional RfD derivation (10 for LOAEL, 10 for human variability, and 10 for database uncertainty). The additional UF of 10 for database sufficiency is generally not used in ATSDR's derivations of health guidance values. Without the extra uncertainty factor of 10, a provisional guide for chronic exposures for a child would be approximately 200 ug/L of lithium in drinking water (i.e., 20 ug/kg/day X 10 kg child / 1 L/day) or 700 ug/L of lithium in drinking water for an adult (i.e., 20 ug/kg/day X 70 kg / 2 L/day). Using EPA's provisional RfD, screening value concentrations in drinking water can be calculated as 70 ug/L (for adults weighing 70 kg drinking 2 L/day), 20 ug/L for a 10 kg infant/child drinking 1 L/day, and 32 ug/L (for a 16 kg child drinking 1 L/day). It is very unlikely that levels of 200-500 ug/L of drinking water would be associated with acute toxicity. There are a few epidemiologic studies associating varying levels of lithium in drinking water with behavioral effects and effects on thyroid functions. There is a wealth of literature on therapeutic use of lithium and adverse effects over time at doses that are much higher than these environmental exposures. Further study would need to be done to fully understand the effect of chronic lithium drinking water exposure at environmental exposures less than therapeutic exposures.

DRO Rep: Dir DRO	Regional Rep: Lora Werner	DRO Concurrence: ✓
DRO Rep Signature:	Regional Rep Signature:	

Appendix B

Detailed Well by Well Review of Chemicals Exceeding Health-Based Comparison Values or Without a Comparison Value

(EPA 2012 Data Set Only)

Dimock Groundwater Site

The following appendix provides specific information about the environmental data collected by EPA in 2012 from 64 private wells in Dimock, PA. The first table (D-1) provides a summary of all parameters that exceeded a screening threshold, including health based comparison values, maximum contaminant levels, and secondary maximum contaminant levels. Table D-1 is designed to inform homeowners of what we found in their private water well that required further review. For more in depth assessment of these screening level exceedances, please refer to the main body of the health consultation.

Additional well-by-well contaminant information is also provided in this Appendix, including bacterial well contamination information, dissolved methane, and organic and inorganic contaminants detected in the 64 private wells sampled by EPA in 2012.

Table B-1
Well-by-Well Summary of Chemicals Exceeding Health-Based Comparison Values or Without a Comparison Value
EPA 2012 Data

Well: Parameter	HW-01	HW-02	HW-03	HW-04	HW-05	HW-06	HW-08a	HW-09	HW-11	HW-12	HW-13	HW-15a	HW-16	HW-17	HW-18	HW-19	HW-20
Total/Fecal Coliform		X/ND					X/ND				X/ND				X/ND	X/ND	X/ND
Methane	P	P	Exp			P			P	Exp		P	P				
Benzo(a)pyrene		C		C													
Other PAHs		X															
Chlorophenyl-4-phenyl ether		TP															
2,4-Dinitrotoluene		C															
Hexachlorobenzene		C					C										
Aluminum						S							S				
Arsenic		C, A1				C, A1		C		C, A1		C, A1		C	C		
Barium													M, A1				
Bromide													X				
Iron		S	S		S	S				S	S		S				
Lithium	T	T				T				T		T	T	T	T		
Manganese							S, L, R1										
Phosphorus						X											
Sodium						Adv						Adv	Adv		Adv		

Table B-1 (Continued)
Well-by-Well Summary of Chemicals Exceeding Health-Based Comparison Values or Without a Comparison Value
EPA 2012 Data

Well: Parameter	HW-21	HW-22	HW-23	HW -24	HW-25	HW-26	HW-27	HW-28	HW-28a	HW-29	HW-30	HW-31	HW-32	HW-33b	HW-34a	HW-35	HW-36
Total/Fecal Coliform					X/ND											X/X	
Methane		P			Exp	Exp				Exp		Exp			P		
Other PAHs													X				
Dibenzofuran								Xc									Xc
Hexachlorobenzene													C				
Aluminum		S								S						S	
Arsenic		C, A1	C				C			C/ A1		C	C, A1		C		
Bromide										X							
Copper									A1					A1			
Iron	S	S														S	
Lead		E														E	
Lithium		T		T	T	T				T	T	T			T		
Manganese		S, L, R1											S, L				
Phosphorus		X															
Sodium				Adv	Adv	Adv				Adv		Adv			Adv	Adv	

Table B-1 (Continued)
Well-by-Well Summary of Contaminants Exceeding a Screening Value or without a Screening Value

Well: **Parameter**	**HW -39**	**HW -40**	**HW -43**	**HW -43**	**HW -46**	**HW -47**	**HW -48**	**HW -49**	**HW-50**	**HW-51**	**HW-52**	**HW -53**	**HW -55**	**HW-56**	**HW -57**	**HW -58**	**HW -60**	**HW -61**
Total/Fecal Coliform									X/ND					X/ND			X/ND	X/ND
Methane						P					P						P	
Other PAHs																		X
Di-ethylhexyl phthalate, or DEHP	C														C			
Dibenzofuran																		Xc
Hexachlorobenzene																		C
Aluminum															S			
Arsenic		C		C		C, A2	C	C	C	C		C	C	C	C, A1	C	C, A1	
Barium	M, A1																	
Bromide	X																	
Cadmium															A1			
Iron						S									S		S	
Lithium	T					T											T	
Manganese						S, L, R1												
Phosphorus				X		X									X			
Potassium					D													
Sodium	Adv	Adv	Adv			Adv											Adv	

Notes:

A1 = Exceeds ATSDR child non-cancer Environmental Media Evaluation Guideline (EMEG)
A2 = Exceeds ATSDR child and adult non-cancer EMEG
Adv = Exceeds EPA guidance level for drinking water
C = Exceeds Cancer Risk Evaluation Guideline (CREG)
D = Exceeds Derived potassium screening value from MS Canyon Oil Spill
E = Exceeds EPA Action level for lead
Exp = Explosion hazard exists
L = Exceeds EPA Lifetime Health Advisory
M = Exceeds EPA Maximum Contaminant Level (MCL)
ND = Not detected
R1 = Exceeds child ATSDR remedial media evaluation guideline (RMEG);
P = Potential hazard
S = Exceeds EPA secondary MCL
T = Exceeds EPA trigger level for 2012 EPA Removal Program in Dimock
TP = Exceeds Texas Risk Reduction Program Protective Concentration Level
X = Contaminant detected in sample, but there is no comparison value
Xc = Contaminant detected in sample, but there is no cancer comparison value

Total/Fecal Coliform and Heterotrophic Plate Count (HPC)

Coliform bacteria are microbes found in the digestive systems of warm-blooded animals, in soil, on plants, and in surface water. These microbes typically do not make you sick; however, because microbes that do cause disease are hard to test for in the water, "total coliforms" are tested instead. If the total coliform count is high, then it is very possible that harmful germs like viruses, bacteria, and parasites might also be found in the water. Fecal coliforms and E. coli in well water are usually harmless. However, a positive test may mean that feces and harmful germs have found their way into a private water system. These harmful germs can cause diarrhea, dysentery, and hepatitis (CDC 2012).

Heterotrophs are broadly defined as microorganisms that require organic carbon for growth. Microorganisms recovered through heterotrophic plate count (HPC) tests generally include those that are part of the natural (typically non-hazardous) microbiota of water; in some instances, they may also include organisms derived from diverse pollutant sources. Abrupt increases in HPC levels might sometimes concurrently be associated with fecal contamination; tests for E. coli or other fecal-specific indicators and other information are essential for determining whether a health risk exists (WHO 2003).

Only one well in the EPA 2012 data set (HW35) was reported with detectable levels of fecal. Five wells were positive for total coliform bacteria. Eleven wells were positive for heterotrophic plate count (HPC). Table D-2 provides a well-by well summary of coliform and HPC detections.

Table B-2
Dimock EPA 2012 Coliform Results
Wells with Positive Detections

Well ID	Analyte	Result	Units
HW35	**Fecal Coliform Bacteria**	**1**	**Present**
HW02	Total Coliform Bacteria	82	cfu/100mL
HW08a	Total Coliform Bacteria	54	cfu/100mL
HW35	Total Coliform Bacteria	34	cfu/100mL
HW62	Total Coliform Bacteria	200 J	cfu/100 mL
HW64	Total Coliform Bacteria	200 J	Cfu/100 mL
HW13	Heterotrophic Plate Count	**560**	cfu/mL
HW18	Heterotrophic Plate Count	73	cfu/mL
HW19	Heterotrophic Plate Count	24	cfu/mL
HW20	Heterotrophic Plate Count	67	cfu/1mL
HW25	Heterotrophic Plate Count	42	cfu/mL
HW50	Heterotrophic Plate Count	2	cfu/mL
HW56	Heterotrophic Plate Count	22	cfu/mL
HW60	Heterotrophic Plate Count	14	cfu/mL
HW61	Heterotrophic Plate Count	71	cfu/mL
HW62	Heterotrophic Plate Count	300 J	cfu/ mL
HW63	Heterotrophic Plate Count	300 J	cfu/ mL

Notes: cfu = Colony forming units; mL = Milliliters; J= Estimated value

Dissolved Gases

EPA sampled for dissolved methane and ethane in the 62 Dimock groundwater wells in 2012. Forty six of the 62 wells had detectable levels of methane dissolved in the well water. Detectable methane concentrations ranged from an estimated 0.6 µg/L in well HW50 up to 77,000 µg/L in well HW29. Seventeen wells had methane levels exceeding 10,000 µg/L, the level at which enhanced screening for explosivity is recommended by the Department of Interior (DOI 2011). Five of those wells exceeded 28,000 µg/L, the saturation level for methane in water (HW29, HW25, HW12, HW26, and HW03). Table D-3 provides a summary of wells that had methane levels exceeding 10,000 µg/L in the EPA 2012 sampling results.

Table B-3
Dimock EPA 2012 Methane Results
Wells Exceeding Recommended Screening Levels of 10,000 and 28,000 µg/L

Well ID	Result
HW29	77,000
HW25	65,000
HW12	52,000
HW26	43,000
HW03	28,000
HW16	26,000
HW34a	26,000
HW06	23,000
HW11	22,000
HW60	21,000
HW52	19,000
HW02	18,000
HW22	17,000
HW31	17,000
HW15a	14,000
HW01	12,000
HW47	10,000

Notes: Results in micrograms per liter; µg/L = Micrograms per liter

Twenty-six of 62 wells had detectable levels of ethane dissolved in the groundwater. Ethane levels ranged from an estimated 0.6 µg/L in well HW47 up to 4,700 µg/L in well HW29. Well HW29 had the highest level of both methane and ethane in the EPA 2012 data set.

Organics

In addition to dissolved combustible gas detections (methane and ethane), the only organic compounds detected at levels exceeding health-based comparison values in the EPA 2012 data set were semi-volatile organic compounds (SVOC). Table D-4 provides a summary of the organic chemicals detected in residential groundwater wells that exceed a health-based CV or for which no CV is available. No volatile organic compounds were detected in the EPA 2012 data set.

Polycyclic Aromatic Hydrocarbons (PAH):

Benzo(a)pyrene or B(a)P was detected in two wells at estimated concentrations of 0.196 µg/L in HW02 and 0.049 µg/L in HW04.

Acenaphthylene (0.013 µg/L), Benzo(b)fluoranthene (0.15 µg/L), Benzo(k)fluoranthene (0.317 µg/L), Benzo(ghi)perylene (0.211 µg/L), and indeno(1,2,3-cd)pyrene (0.205 µg/L) was detected in only one well, HW02.

Phenanthrene was detected in three wells, including HW02, HW32, and HW61 at estimated concentrations of 0.234 µg/L, 0.09 µg/L, and 0.07 µg/L, respectively. It was not detected in the duplicate samples collected from HW02 or HW61.

Table B-4
Dimock EPA 2012 Semi-Volatile Organic Compounds
Compounds Detected Which Exceed CVs or for Which No CV is Available

	Benzo(a)pyrene	**Acenaphthylene**	**Benzo(b)fluoranthene**	**Benzo(k)fluoranthene**	**Benzo(ghi)perylene**	**Phenanthrene**	**Indeno(1,2,3-cd) pyrene**	**Dibenzofuran**	**Bis(2-ethylhexyl)phthalate**	**4-Chlorophenyl phenyl ether**	**2,4-Dinitrotoluene**	**Hexachlorobenzene**
Class	PAH	PAH	PAH	PAH	PAH	PAH	PAH	PAH	Phthalate		Explosive Precursor	Pest.
CV	0.005								2		0.05	0.02
CV Source	CREG								CREG		CREG	CREG
Well ID	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result
HW02	0.196 J	0.013 J	0.15 J	0.317 J	0.211 J	0.234 J	0.205 J	0.038 J		0.096 J	0.13 J	0.217 J
HW04	0.049 J											
HW08a										0.029 J		0.066 J
HW28b								0.013 J				
HW32						0.09 J						0.08 J
HW36n								0.014 J				
HW39									5.51			
HW57									3.45 J			
HW61						0.07 J		0.022 J				0.049 J

Note: Results in micrograms per liter (µg/L); CREG = Cancer risk evaluation guideline; J indicates analyte is present and the reported value is estimated; PAH = polycyclic aromatic hydrocarbon; Exp. = Explosive; Pest. = pesticide

Dibenzofuran:

Dibenzofuran was detected in four wells, including HW02, HW61, HW36n, and HW28b at estimated maximum concentrations of 0.038 µg/L, 0.022 µg/L, 0.014 µg/L, and 0.013 µg/L, respectively. HW36n is a sample collected from the new well installed at the HW36 residence.

Bis(2-ethylhexyl)phthalate or Diethylhexyl phthalate (DEHP):

DEHP was detected in five residential wells. Only two residential well samples exceeded a health-based CV for DEHP. The concentrations in these wells were an estimated 3.45 µg/L in well HW57 and 5.51 µg/L in HW39. Neither well exceeds the EPA MCL of 6 µg/L. DEHP is not naturally occurring and is a known carcinogen. Both wells exceed the ATSDR CREG of 2 µg/L. None of the wells had DEHP concentrations exceeding the ATSDR non-cancer CV (600 µg/L for children and 2,000 µg/L for adults).

4-Chlorophenyl phenyl ether:

4-Chlorophenyl phenyl ether was detected in two wells, HW02 and HW08a at estimated concentrations of 0.096 µg/L and 0.029 µg/L, respectively. There are no health-based CVs for 4-chlorophenyl phenyl ether.

2,4-Dinitrotoluene (2,4-DNT):

2,4-DNT was detected in one well, HW02, at an estimated concentration of 0.13 µg/L, exceeding the ATSDR CREG of 0.05 µg/L. 2,4-DNT was not detected in the duplicate sample from this well. 2,4-DNT does not exceed the non-cancer chronic exposure CVs of 20 µg/L and 70 µg/L for children and adults, respectively.

Hexachlorobenzene:

Hexachlorobenzene was detected in four wells exceeding the ATSDR CREG of 0.02 µg/L. Each of these results were "J" qualified as estimated concentrations, including 0.217 µg/L in HW02, 0.066 µg/L in HW8a, 0.08 µg/L in HW32 and 0.049 µg/L in HW61.

Inorganics

Metals were detected in all of the residential wells sampled by EPA, but only those wells with metal concentrations exceeding health-based CVs or for which there is no CV are listed in Table D-4. Some of the metals listed in Table D-4 are essential to a healthy diet. There are no traditional ATSDR health-based CVs to determine whether the concentrations could result in adverse health effects for these nutrients. Therefore, for this health consultation ATSDR utilizes the tolerable upper intake levels (UL) as defined by the National Institute of Medicine (IOM) to further evaluate exposures to these chemicals in the 2012 EPA Dimock private well data set (IOM 1997, 2001, 2005).

Arsenic:

Arsenic was detected in 27 of the 62 Dimock residential wells sampled by the EPA in 2012 ranging from 1 µg/L to 94.2 µg/L. Each of the 27 wells with arsenic detections had concentrations exceeding the arsenic CREG of 0.02 µg/L. Ten wells had maximum results exceeding the child chronic exposure environmental media evaluation guideline (EMEG) of 3 µg/L. One well, HW47, with a maximum arsenic concentration of 94.2 µg/L, exceeded the adult chronic EMEG and the EPA MCL public drinking water standard for arsenic.

Barium:

Barium was detected in 62 of 64 residential wells sampled for barium ranging from 18.4 µg/L to 3,810 µg/L. Two wells had barium concentrations exceeding the ATSDR children's chronic EMEG and EPA MCL of 2000 µg/L: HW16 at 3,040 µg/L and HW39 at 3,810 µg/L. No wells exceeded the adult chronic EMEG of 7,000 µg/L. All other wells had maximum barium concentrations below health-based CVs.

Bromide:

There is no health based CV for bromide, which was detected in three of 62 wells. The maximum bromide concentrations detected in each of the three wells were 1,670 µg/L in HW29, 986 µg/L in HW39, and 857 µg/L in HW16.

Cadmium:

Cadmium was detected in one well, HW57, from a filtered sampled at 2.9 µg/L. No other wells had detectable levels of cadmium. The cadmium level detected in HW57 exceeds the child chronic EMEG of 1 µg/L, but does not exceed the adult EMEG of 4 µg/L.

Copper:

Copper was detected in 49 of the 62 residential wells sampled. Only two samples exceed the child intermediate EMEG of 100 µg/L, including HW33b at 166 µg/L and HW28a at 157 µg/L. Both of these samples were collected from the kitchen tap, and the corresponding samples for each water supply collected closest to the wellhead was at a significantly lower concentration (HW33 at 11 µg/L and HW28a at 27.9 µg/L), suggesting the groundwater does not contain elevated copper concentrations. No samples contained copper exceeding the adult intermediate EMEG of 400 µg/L.

Iron:

Iron was detected in 23 of 64 residential wells ranging from 106 µg/L to 11,200 µg/L. The EPA SMCL for iron (300 µg/L) is not a health-based value but a value set for aesthetic water qualities. The Institute of Medicine (IOM) Upper Tolerable Intake Level (UL) for iron is 45 mg/day. Drinking water from the well with the maximum iron concentration from EPA 2012 sampling (11,200 µg/L in well HW57) would add approximately 22.4 mg of iron to an adult's daily diet (assuming 2 liters of water consumed per day) and approximately 11.2 mg of iron to a 10-16 kg child's daily diet (assuming 1 liter of water consumed per day). Thirteen wells exceed the secondary MCL of 300 µg/L and none would result in an exceedance of the IOM UL for iron, not accounting for other sources of iron in the diet.

Lead:

Lead was detected in 20 of 62 Dimock site residential wells sampled by EPA in 2012, ranging from 1 µg/L to 22.7 µg/L. Two wells, HW22 at 22.7 µg/L and HW35 at 21.2 µg/L, exceed the EPA action level for lead (15 µg/L) in public water supplies. Both of these samples were collected from the nearest point accessible to the wellhead.

Lithium:

Lithium was detected in 24 of the 62 wells for which it was analyzed ranging from approximately 25 µg/L up to 533 µg/L. Twenty wells exceed the EPA site-specific trigger level of 31 µg/L. Eight wells exceed the PADEP medium-specific concentration (MSC) of 73 µg/L. Three wells had maximum lithium concentrations in excess of 200 µg/L (HW29 at 533 µg/L, HW06 at 356 µg/L and HW24 at 211.1 µg/L). None of the wells exceed the ATSDR site-specific acute screening value of 1,500 ug/L (ATSDR 2012).

Manganese:

Manganese was detected in 54 of the 62 wells sampled by EPA in 2012. Nineteen wells had maximum manganese concentrations exceeding the EPA manganese SMCL of 50 µg/L. Four wells (HW08a at 942 µg/L, HW22 at 635 µg/L, HW32 at 301 µg/L, and HW47 at 947 µg/L) had maximum manganese concentrations exceeding the EPA manganese health advisory level of 300 ug/L. Three wells (HW08a at 942 µg/L, HW22 at 635 µg/L and HW47 at 947 µg/L) had maximum manganese concentrations exceeding the RMEG of 500 µg/L for children, but no wells exceeded the adult RMEG of 2,000 µg/L.

Phosphorus:

There is no health-based CV for total phosphorus. The total phosphorus test measures all the forms of phosphorus in the sample (orthophosphate, condensed phosphate, and organic phosphate), and it was detected in five Dimock site residential wells, ranging from 79 µg/L to 329 µg/L.

Potassium:

There is no ATSDR health-based CV for potassium in drinking water, however a provisional value of 4,000 µg/L was determined by ATSDR during the Deepwater Horizon incident and is also used here for screening. Seven wells had detectable levels of potassium ranging from 2,100 µg/L (HW16) to 4,320 µg/L (HW46). Only well HW46 exceeded the provisional value of 4,000 µg/L.

Sodium:

Sixteen wells had sodium concentrations in the EPA 2012 data set that exceed the EPA drinking water advisory level of 20,000 µg/L. Not accounting for other sources of sodium in food and drinks, consuming water from any of the wells assessed would not result in exceeding the UL for children and adults.

Table B-4

Dimock EPA 2012 Inorganics Results - Wells with Results Exceeding CVs or for Which No CV is Available

	Aluminum	**Arsenic**	**Barium**	**Bromide**	**Copper**	**Iron**	**Lead**	**Lithium**	**Manganese**		**Phosphorus**	**Potassium**	**Sodium**
CV	50 to 200	3/10 (0.02)	2000/7000 (2000)		100/400	300	15	31.5	50 300	500/ 2000		4000	20,000
CV Source	SMCL	Ch/A Chron EMEG (CREG)	Ch/A Chron EMEG (MCL)		Inter EMEG	SMCL	EPA AL	EPA Trigger Level	SMCL LTHA	RMEG		Derived (MS Canyon Oil Spill)	EPA Drinking Advisory Level
Well ID	Result	Result	Result	Result	Result	Result	Result	Result	Result		Result	Result	Result
HW01								41					
HW02		4				1620		39.6					
HW03						711							
HW04													
HW05						620		31					
HW06	2,020	7.8				2970		356			98		110,000
HW08a									942				
HW09		1											
HW12		6				1240		36.8					
HW13						2870							
HW15a		5.1						33.5					66,000
HW16	102		3040	857		464		105					52,000
HW17		2.7						31.9					
HW18		2.2						100					45,600
HW21						366							
HW22	5,220	7.1				8530	22.7	33.5	635		103		
HW23		1.3											
HW24								211.1					88,000
HW25								51.1					24,700
HW26								61.6					27,800
HW27		1.7											
HW28a					157								
HW29	51	3.7		1670				533					201,000
HW30								32.1					
HW31		1.3						43.8					27,000
HW32		10.5							301				

Table B-4 (Continued)
Dimock EPA 2012 Inorganics Results - Wells with Results Exceeding CVs or for Which No CV is Available

	Aluminum	**Arsenic**	**Barium**	**Bromide**	**Cadmium**	**Copper**	**Iron**	**Lead**	**Lithium**	**Manganese**		**Phosphorus**	**Potassium**	**Sodium**
CV	50 to 200	3/10 (0.02)	2000/ 7000 (2000)		1/4	100/400	300	15	31.5	50 (300)	500/ 2000		4000	20,000
CV Source	SMCL	Ch/A Chron EMEG (CREG)	Ch/A Chron EMEG (MCL)		Ch/A Chron EMEG	Ch/A Inter EMEG	SMCL	EPA AL	EPA Trigger Level	SMCL (LTH A)	Ch/A RMEG		Derived (MS Canyon Oil Spill)	EPA Drinking Advisory Level
Well ID	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result		Result	Result	Result
HW33b						166								
HW34a		1.1							87.2					39,700
HW35	240						478	21.2						28,700
HW39			3810	986					138					49,300
HW40		1.1												21,700
HW41														23,600
HW43		1.3										79		
HW46													4320	
HW47		94.2					4550		128	947		329		93,900
HW48		1.1												
HW49		2.9												
HW50		1.9												
HW51		1.1												
HW53		1.8												
HW55		2.1												
HW56		1.5												
HW57	1,670	5.8			2.9		11200					215		
HW58		1.7												
HW59														
HW60		9.3					754		47.7					20,300
HW63														

Notes: All results in micrograms per liter (μg/L); AL = EPA action level for lead; Ch/A = Child/Adult; Chron EMEG = chronic exposure environmental media evaluation guideline (EMEG); CREG = Cancer risk evaluation guideline; CV = Comparison value; Inter EMEG = ATSDR Intermediate EMEG; LTHA = EA lifetime health advisory; MCL = EPA maximum contaminant level; RMEG = EPA child/adult remedial evaluation guideline; SMCL = EPA Secondary maximum contaminant level

Appendix C

Baseline and Background Data

Dimock Groundwater Site

It can be helpful to have information on background and baseline groundwater quality for context when reviewing private well water sampling information. Limited, pre-drilling, background groundwater quality data for the specific geological formation in the Dimock area are available. ATSDR obtained information on regional background groundwater quality for the Dimock site area primarily from two references:

1. United States Geological Survey (USGS). 1998. Williams, J.H., Taylor, L.E., Low, D.J. 1998. Hydrogeology and groundwater quality of the glaciated valleys of Bradford, Tioga, and Potter Counties, Pennsylvania, Fourth Series. Pennsylvania Geologic Survey. Water Resource Report 68. Harrisburg.

The USGS report is for neighboring counties, including Bradford County. Specific data were acquired from this report for the Devonian Catskill (Dck) formation, which extends into Susquehanna County, and is understood to be the formation accessed by the residential wells in the site area. Much of the information available in the USGS report is for dissolved concentrations, which have been provided in this report, when appropriate, and only for comparison. These are not health-based values, but instead are background geological formation chemical concentrations based on actual field samples collected from wells accessing the Dck formation.

2. Boyer, W.B., Swistock, B.R., Clark, J., Madden, M., Rizzo, D.E. 2012. The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies. Penn State University. March. Accessed online at: http://www.rural.palegislature.us/documents/reports/Marcellus_and_drinking_water_2012.pdf

The Boyer *et al.* study provides pre-drilling water quality information, including median and maximum values for the major natural gas drilling areas of Pennsylvania (primarily northeast and southwest PA). The data compiled in the Boyer *et al.* study are from actual field sampling throughout the state, and is not for a specific geologic formation. The concentrations referenced from 2012 Boyer *et al.* are dissolved and not total chemical concentrations.

A limited set of pre-drilling, baseline private water well testing data are also available. In Pennsylvania, baseline private water well testing data are voluntarily collected by industry prior to the initiation of natural gas drilling activities and may be submitted to the private water well owner and PADEP. These data can be used to try to establish whether private well water quality or quantity has changed significantly following drilling and completion activities in the area.

Cabot and other natural gas companies have conducted baseline private well water sampling at a large number of residential properties in Susquehanna County. ATSDR received baseline, pre-drilling data collected by Cabot for some 18 private water wells in the Dimock site area. This information was provided to ATSDR by residents and by EPA. The baseline sampling information ATSDR reviewed for the Dimock private water wells is limited. Early in the natural gas boom in the Commonwealth, a relatively limited list of analytical parameters was typically used in pre-drilling water quality testing. Cabot's baseline sampling in Dimock included chloride, methylene blue active substance (MBAS), pH, sulfide, total dissolved solids (TDS), total suspended solids (TSS), iron and magnesium. Of particular note, natural gas parameters (including methane, ethane, ethene, propane, and butane), and chemicals used by the natural gas drilling industry that do not naturally occur in groundwater aquifers (*e.g.*, phthalates, glycols, biocides) were not included in the Dimock baseline private well water sampling. Although this is not standardized via any regulations, more recent baseline testing in the Commonwealth has generally been expanded to include additional relevant analytical parameters.

Appendix D

The ATSDR Public Health Assessment Process

Dimock Groundwater Site

ATSDR's public health assessment process involves the review of **environmental data, exposure data, health effects data** (toxicologic, epidemiologic, medical, and health outcome data), and **community health concerns**. Starting early in the assessment process, ATSDR begins to gather relevant scientific data to support the assessment. ATSDR also needs to learn what people in the area know about a site and site-related exposures and what concerns they may have about its impact on their health. Therefore, ATSDR actively gathers information and comments from the people who live or work near the site, including area residents, civic leaders, health professionals, and community groups. Throughout the public health assessment process, the agency communicates with the public about the purpose, approach, and results of its public health activities.

The public health assessment process involves two primary scientific evaluations—the exposure evaluation and the health effects evaluation.

1. Exposure Evaluation: Exposure assessment is the hallmark of the public health assessment process. ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by federal and state government agencies and/or their contractors, potentially responsible parties, and the public. The exposure evaluation begins with a comparison of the maximum chemical concentration detected in an exposure pathway to health-based comparison values (CV). If the maximum detected concentration is below the appropriate CV, then exposures to the maximum concentration detected and any lower concentration of this chemical are not expected to be of public health concern. Although the maximum detected value is used to conduct the initial exposure evaluation, it may not represent the maximum chemical concentration at the site, it is only the maximum value observed from the sample data set. When the maximum chemical value exceeds a health-based CV, further evaluation of the chemical is conducted in the health effects evaluation. When adequate environmental or exposure information is not available to evaluate exposure, ATSDR will indicate what further environmental sampling may be needed and may collect environmental and biologic samples when appropriate.

2. Health Effects Evaluation: If the exposure evaluation shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether this contact may result in harmful effects. ATSDR uses existing scientific information, which can include the results of medical, toxicologic, and epidemiologic studies and data collected in disease registries, to determine what health effects may result from exposures. ATSDR recognizes that children, because of their behavior, size and growing bodies, may be particularly vulnerable to site-related exposures. Developing fetuses also may be more vulnerable to such exposures. Thus, the impact to children is considered first when evaluating the health threat to a community. The health impacts to other potentially high-risk groups within the community (such as the elderly, the chronically ill, other sensitive sub-populations and people who may have higher exposure potential) also receive special attention during the evaluation.

The public health assessment process is iterative and dynamic and may lead to a variety of products or outcomes. The findings may be communicated in public health assessment or public health consultation documents or an issued public health advisory (if there is an urgent health threat). All of these products serve as an aid for developing public health actions.

Appendix E

Overview of ATSDR Comparison Values

Dimock Groundwater Site

Comparison values (CVs) are substance and media-specific (air, water, soil) concentrations that are used by health assessors during the initial phase of ATSDR's Public Health Assessment Process to select environmental contaminants that require further evaluation. CVs are derived from human and animal studies for which uncertainty factors have been applied to ensure that they are adequately protective of public health. Therefore, contaminants present in concentrations less than CVs are unlikely to pose a health threat. CVs incorporate standard default exposure assumptions and are not site-specific. They may be based on cancer or non-cancer health effects. CVs should not be used to determine whether exposures could result in harmful effects. Rather, they are used to identify substances that require further, in-depth evaluation as part of ATSDR's Public Health Assessment Process which may include calculation of site-specific exposure doses, cancer risk estimates, and review of the available scientific literature.

ATSDR considers many sources of relevant toxicological information for evaluation of chemical exposures, following a specific hierarchy for this screening process. If no CV can be determined, the chemical is carried into the next step of the evaluation process. The following hierarchy defines this critical screening process for the first step in ATSDR's public health assessment:

- Hierarchy 1 includes screening environmental data against ATSDR chronic exposure environmental media evaluation guidelines (EMEG), ATSDR minimal risk levels (MRL), and cancer risk evaluation guidelines (CREG);
- Hierarchy 2 includes screening environmental data against intermediate exposure EMEGs, ATSDR remedial media evaluation guidelines (RMEG), which are based on EPA reference doses, and EPA lifetime health advisories (LTHA);
- Hierarchy 3 includes screening environmental data against maximum contaminant levels (MCL, and maximum contaminant level goals (MCLG);
- Additional sources include screening environmental data against other relevant and valid sources to identify CVs.

The following CVs were used in this review:

- ATSDR child/adult acute, intermediate and chronic exposure duration EMEGs,
- ATSDR CREGs,
- ATSDR RMEGs, EPA Regional Screening Levels (RSLs), EPA LTHAs, MCLs, Secondary Maximum Contaminant Levels (SMCL) and Drinking Water Equivalent Levels (DWEL),
- PA Department of Environmental Protection (PADEP) Medium Specific Concentrations (MSC) or other similar state health-based screening values,
- Institute of Medicine of the National Academies (IOM/NAS) Dietary Reference Intakes (DRI) and tolerable upper intake levels (UL), and Estimated safe and adequate daily dietary intake (ESADDI)
- World Health Organization (WHO) Acceptable Daily Intakes (ADI)
- State risk screening values, including Texas Commission on Environmental Quality (TCEQ) protective concentration levels and oral reference doses, California Office of Environmental Health Hazard Assessment (OEHHA) and New Jersey Department of Environmental Protection cancer slope factors (CSF),

When conducting this initial screening against health-based CVs, ATSDR uses the highest detected concentration for each chemical. When the maximum chemical concentration in the data set exceeds the CV, it is held as a chemical of potential concern (COPC) and included in the health effects evaluation. When a chemical that has been detected does not have a health-based CV, it is also included as a COPC to be included in the health effects evaluation.

Appendix F

Summary Screening of Historical Dimock Data Set
Dimock Groundwater Site

ATSDR considers the data collected before 2012 as the "historical data set." This data set was compiled by ATSDR and EPA. ATSDR received some of these data directly from residents, and the rest from EPA. EPA requested these data from stakeholders, including Cabot, PADEP, and Dimock residents and their representatives. The historical data set includes a number of analytical parameters collected over more than two years by multiple field sampling companies and individuals. Those samples were analyzed by multiple analytical laboratories using a variety of analytical methods. All of these variables make the historical data set difficult to interpret as a whole. It is important to note that some of the historical data (i.e., PADEP data) meets standards for field and laboratory quality controls while other data do not. Due to variability in sampling protocols and parameters, ATSDR considered the historical data on a well-by-well basis only.

A. Contaminants of Potential Concern (COPC) in the Historical Data Set

Historical residential well sample data from the Dimock site area were collected by a variety of Cabot contractors, by PADEP, by environmental consultants working for residents and their law firms, and by research institutions, such as Duke University. These data sets are highly variable in their analytical parameters and detection limits. Very little is known about the field sampling methods employed, such as purge times and volumes, sample collection points (i.e., kitchen tap, outdoor faucet, basement expansion tank, directly from well), and sample glassware and preservatives. Slightly more is known about the analytical laboratories that performed these analyses.

ATSDR screened all of the historical data and identified the maximum concentrations for each analytical parameter in each residential well. Data from 18 separate wells are included in the historical data set. When a specific analytical result was considerably different than data for the same well or for the entire dataset, ATSDR requested additional information from the EPA, who coordinated these requests with PADEP. A number of transcription errors were identified and corrected during this early review. The maximum concentration for each parameter which exceeds a health-based comparison value in each well is provided in Table F-1. Table F-2 is the first screening process used in the public health review of the historical data set, and is used specifically to identify the contaminants of potential concern (COPC) for past exposures at the Dimock Site. All of the environmental sampling data that was made available to ATSDR through the variety of sources identified above was considered in this first screening process.

The second step in the evaluation process was an evaluation of the COPCs on a well-by-well basis. At this stage, data quality was considered before continuing with the public health review process. When determining the contaminants of potential concern (COPC), ATSDR compares the maximum concentration detected in drinking water to health-based comparison values using conservative exposure factors: a body weight of 10 kilograms (22 pounds) and a daily intake of 1 liter per day for an infant/child, and a body weight of 70 kilograms (154 pounds) and a daily intake of 2 liters per day for an adult.

i. Non-Radiological COPCs

A number of naturally occurring and man-made substances were detected in the residential wells along Carter Road, Route 3023 and Meshoppen Creek Road in the Dimock site area. This section discusses the concentrations of chemical parameters for which there is no health-based comparison value (CV) or for which the concentration exceeds a CV. Although other chemicals were detected, the concentrations were below health-based comparison values for acute, intermediate or chronic exposures. The non-radiological COPCs include:

- Total and fecal coliform;
- Dissolved gases (methane and ethane, ethene, propane, iso-butane, n-butane);
- Organic chemicals, including total petroleum hydrocarbons (TPH), bis(2-ethylhexyl)phthalate or DEHP, ethylene glycol and other glycol compounds, 2-methoxyethanol, and phenols;
- Methylene blue active substance (MBAS); and,
- Inorganic chemicals, including aluminum, arsenic, barium, iron, lead, lithium, magnesium, manganese, potassium, sodium, and, silicon.

In addition to the chemicals specifically used in gas field operations, natural gas drilling and completion activities mobilize naturally occurring substances from deep formations, including the brine water contained in deep geologic

Table F-1
Dimock Historical Environmental Data
Compounds Detected Which Exceed CVs or For Which No CV is Available

Chemical/ Analyte	**Total Coliform/ Fecal Coliform**	**Methane***	**Bis(2-ethylhexyl)phthalate**	**Ethylene glycol**	**2-Methoxyethanol**
Units	MPN/100mL	ug/L	ug/L	ug/L	ug/L
CV	2 MPN/100mL (Total) 0 MPN/100 mL (Fecal)	10,000-28,000	600/2,000 (2) {6}	8,000/30,000 {14,000}	110
CV Source	EPA MCL	RAL from Office of Surface Mining Reclamation and Enforcement	ATSDR Child/Adult Chronic EMEG (CREG) {LTHA}	ATSDR Child/Adult Intermediate EMEG {LTHA}	EPA RSL (drinking water)
EPA Well ID	**Maximum Detection>CV**	**Result**	**Result**	**Result**	**Result**
HW-01		42,700	2.3		1,300 J
HW-02		33,340			
HW-03		39,600			1,100 J
HW-04	46/46	29,400			880 J
HW-05	300/250	19,170			
HW-06	"Confluent growth"/ND	64,300	3.1		
HW-07	7/7	15,500			
HW-08a	208/208	25,000	2.61	<10,000	
HW-9	11/11				
HW-10		56,900			
HW-11		39,300			
HW-12	THTC/THTC	61,200		<10,000	
HW-13				8,410 (post-treatment)	
HW-14	14/1	19,000			
HW-15		36,000		<10,000	
HW-16		51,900		<10,000	
HW-17		11,500			
HW-18	THTC/THTC				
HW-00			22		1,000 J

Notes:

* = No screening level established for other light gasses (ethane, propane, iso-butane, n-butane and ethene). These gases are co-located with methane detections in wells and will be further discussed for wells with methane levels exceeding 10,000 ug/L.

ATSDR = Agency for Toxic Substances and Disease Registry
CV = Comparison value
CREG = Cancer risk evaluation guideline
EMEG = Environmental media evaluation guideline
EPA = U.S. Environmental Protection Agency
HW = Home well
J = Analyte is present in the sample. The result is estimated.
LTHA = EPA Lifetime health advisory

MPN = Most probable number of colony forming units
mL = milliliter
MCL = EPA maximum contaminant level for public drinking water supplies
ND = Not detected
ug/L = Micrograms per liter
RAL = Recommended Action Level
RSL = Risk Screening Level
THTC = Too high to count

Table F-1 (Continued)
Dimock Historical Environmental Data
Compounds Detected Which Exceed CVs or No CV Available

Chemical/ Analyte	Aluminum	Arsenic	Barium	Iron	Lead
Units	ug/L	ug/L	ug/L	ug/L	ug/L
CV	10,000/40,000	3/10 (0.02)	2,000/7,000	300	15
CV Source	ATSDR Child/Adult Chronic EMEG	ATSDR Child/Adult Chronic EMEG (CREG)	ATSDR Child/Adult Chronic EMEG	EPA SMCL	EPA Action Level
EPA Well ID	**Result**	**Result**	**Result**	**Result**	**Result**
HW-01				4,020	
HW-02		1.8		420	
HW-03		2.4		3,161	
HW-04				4,517	
HW-05		1.3		8,720	
HW-06		6.5		24,100	
HW-07		3.1		2,680	
HW-08a		2.7		15,500	
HW-9					
HW-10		4.3			
HW-11				541	
HW-12		4.2		5,340	
HW-13	44,100	25		18,700	
HW-14		3.1		3,380	
HW-15		6		3,430	
HW-16		3.0	3,460	694	
HW-17		3.3		610	
HW-18	13,700	3.3		16,060	
HW-00					

Notes:

* = No screening level established for other light gasses (ethane, propane, iso-butane, n-butane and ethene). These gases are co-located with methane detections in wells and will be further discussed in the following subsections.

ATSDR = Agency for Toxic Substances and Disease Registry
CV = Comparison value
CREG = Cancer risk evaluation guideline
EMEG = Environmental media evaluation guideline
EPA = U.S. Environmental Protection Agency
HW = Home well

PADEP = PA Department of Environmental Protection
MSC = Medium specific concentration
RMEG = Remedial media evaluation guideline
RSL = Risk Screening Level
ug/L = Micrograms per liter

Table F-1 (Continued)
Dimock Historical Environmental Data
Compounds Detected Which Exceed CVs or For Which No CV is Available

Chemical/Analyte	**Lithium**	**Magnesium**	**Manganese**		**Potassium**	**Silicon**
Units	ug/L	ug/L	ug/L		ug/L	ug/L
CV	31/73	65,000	50	500/2000 {300}	4,000	
CV Source	EPA RSL/ PADEP MSC	IOM Upper Tolerable Intake (UL)	EPA SMCL	RMEG Child/Adult {LTHA}	Derived (MS Canyon Oil Spill)	None available
EPA Well ID	**Result**	**Result**	**Result**		**Result**	**Result**
HW-01						
HW-02	33.18					5,000
HW-03			76			
HW-04			628		6,973	
HW-05	28.24		212			5,210
HW-06	380		669			5,600
HW-07			1,360			5,350
HW-08a			413			7,140
HW-9						
HW-10		125,600	84			
HW-11			583			
HW-12	32.8		242			5,520
HW-13			1,920		9,340	
HW-14			362			
HW-15			381			
HW-16			666			
HW-17	26.5		118			4,620
HW-18			374		4,433	
HW-00						

Notes:

ATSDR = Agency for Toxic Substances and Disease Registry
CV = Comparison value
CREG = Cancer risk evaluation guideline
EPA = U.S. Environmental Protection Agency
HW = Home well
IOM = Institute of Medicine
LTHA = EPA Lifetime health advisory
MPN = Most probable number
mL = milliliter
MCL = EPA maximum contaminant level
RSL = Risk Screening Level
SMCL = EPA secondary maximum contaminant level
ug/L = Micrograms per liter

Table F-1 (Continued)
Dimock Historical Environmental Data
Compounds Detected Which Exceed CVs or For Which No CV is Available

Chemical/ Analyte	Sodium	Total Petroleum Hydrocarbons (TPH)	Methylene Blue Active Substance (MBAS)
Units	ug/L	ug/L	ug/L
CV	20,000	None	None
CV Source	EPA Drinking Water Advisory		
EPA Well ID	**Result**	**Result**	**Result**
HW-01			13 JHB
HW-02			
HW-03	110,000		
HW-04	82,900 (post-treatment)	210	
HW-05			
HW-06	131,000		
HW-07			22 JHB
HW-08a	36,800 (Post treatment)		
HW-9			
HW-10	39,400		
HW-11			
HW-12	56,000		
HW-13			
HW-14	70,600	150	
HW-15			
HW-16	70,700		
HW-17			
HW-18	65,800		
HW-00	100,000		18 JHB

Notes:

ATSDR = Agency for Toxic Substances and Disease Registry.
B = Chemical detected in the blank sample
CV = Comparison value
CREG = Cancer risk evaluation guideline
EPA = U.S. Environmental Protection Agency
H = Sampled exceeded its hold time
HW = Home well
IOM = Institute of Medicine
j = Analyte present; result may not be accurate or precise.
LTHA = EPA Lifetime health advisory
MPN = Most probable number
mL = milliliter
MCL = EPA maximum contaminant level
RSL = Risk Screening Level
SMCL = EPA secondary maximum contaminant level
ug/L = Micrograms per liter

Table F-2
Well-by-Well Summary of Comparison Value Exceedance in Historical Data Set

Well: Parameter	HW-01	HW -02	HW-03	HW-04	HW-05	HW-06	HW-07	HW-08a	HW-09	HW-10	HW-11	HW-12	HW-13	HW-14	HW-15	HW-16	HW-17	HW-18	HW-00
Total/Fecal Coliform				X/X	X/X	X/ND	X/X	X/X	X/X			X/X		X/X				X/X	
Aluminum													A2					A1	
Arsenic		C	C		C	C, A1	C, A1	C				C, A1	C, A2	C, A1	C, A1	C, A1	C, A1	C, A1	
Barium																A1, M			
Bis(2-ethylhexyl) phthalate	C					C		C											C, M
Methane	Exp	Exp	Exp	Exp	P	Exp	P	P		Exp	Exp	Exp		P	Exp	Exp	P		
Glycols	Pr		Pr				Pr						A1						Pr
Iron	S	S	S	S	S	S	S	S			S	S	S	S	S	S	S	S	
Lithium		T			T	T						T							
Magnesium										UL									
Manganese			S	S, R1, L	S	S, R1, L	S, R1, L	S, L		S	S, R1, L	S	S, R1, L	S, L	S, L	S, R1, L	S	S, L	
2-Methoxyethanol	X		X	X															X
Silicon (No CV)		X			X	X	X	X				X					X		
Sodium			S	S		S		S		S		S		S		S		S	S

Notes:

A1 = Exceeds ATSDR child non-cancer Environmental Media Evaluation Guideline (EMEG)
A2 = Exceeds ATSDR child and adult non-cancer EMEG
C = Exceeds Cancer Risk Evaluation Guideline (CREG)
L = Exceeds EPA Lifetime Health Advisory (LHA)
M = Exceeds EPA Maximum Contaminant Level (MCL)
ND = Not detected
Exp = Explosion hazard
R1 = Exceeds child remedial media evaluation guideline (RMEG)
R2 = Exceeds child and adult RMEG
P = Potential hazard
Pr = Present in sample
S = Exceeds EPA secondary MCL
UL = Exceeds Institute of Medicine Upper Tolerable Intake Level for particular age group
X = Contaminant detected in sample, but there is no comparison value

formations. Because many of the chemical compounds (*e.g.*, arsenic, chloride, lithium, manganese, sodium) are naturally present in these regions, a comparison of background concentrations in local groundwater aquifers (i.e., pre-drilling data or hydro-geological reports such as USGS reports) to post-drilling concentrations in residential wells accessing the same groundwater formations is helpful. Background concentrations were obtained from three sources: baseline data from the residential wells in Dimock, USGS 1998, and Boyer *et al.* 2012.

TOTAL/FECAL COLIFORM

Total coliform was detected in 9 of the 19 wells assessed (HW-04 to HW-09, HW-12, HW-14 and HW-18), ranging from seven colony forming units per 100 milliliters (CFU/100 mL) to well above the ability to differentiate individual colony forming units (*i.e.,* "confluent plate growth" and "too high to count"). Each of the nine wells with detectable CFUs exceed the PADEP drinking water standard of less than 1 CFU/100 mL. Four wells (HW-04, HW-07, HW-08a, and HW-12) had the same maximum total and fecal coliform counts in their respective well, and five wells had zero or less fecal coliform counts than their respective positive total coliform results (HW-05, HW-06, HW-09, HW-14, HW-18).

A 2012 study of drinking well water quality in Pennsylvania noted that the median total coliform and median fecal coliform values were less than 1 cfu/100 mL (Boyer *et al.* 2012). Boyer *et al.* found that 33 and 8 percent of the wells tested exceeded the state's drinking water standard of 1 cfu/100 mL for total and fecal coliform, respectively (Boyer *et al.* 2012).

DISSOLVED GASES

Dissolved gases (methane, propane, ethane, ethene, iso-butane and n-butane) were detected in all Dimock groundwater site residential wells. Only three of the nineteen wells had no detections of methane above 10,000 µg/L, the recommended screening level for additional assessment of explosivity. There are no health based comparison values for consumption of methane, propane, ethane, ethene, iso-butane and n-butane that is dissolved in drinking water. For well water containing methane concentrations above 28,000 µg/L, the U.S. Department of the Interior, Office of Surface Mining, suggests that you take immediate action to reduce this concentration to mitigate the potential buildup of methane gas. Wells with levels between 10,000 and 28,000 µg/L should be regularly monitored, and well owners may wish to consider treatment to lower the methane level (DOI 2001). The cumulative concentration of all the dissolved combustible gases detected in a well should be considered when evaluating the potential for explosive atmospheres.

Methane

Dissolved methane was detected in all 19 wells at maximum concentrations ranging from 79 µg/L to 64,300 µg/L. Fifteen of the 19 wells have methane above 10,000 µg/L and 10 of those wells had maximum methane levels exceeding 28,000 µg/L. The Boyer *et al.* 2012 study determined that the median and maximum dissolved methane concentrations in 189 Pennsylvania drinking water wells sampled was 10 µg/L and 58,300 µg/L, respectively (Boyer *et al.* 2012). Two wells (HW-06 at 64,300 µg/L and HW-12 at 61,200 µg/L) exceeded the maximum methane levels detected in background sampling from the Boyer *et al.* 2012 study.

Ethane

Dissolved ethane was detected in 18 of 18 wells assessed at maximum concentrations ranging from 0.69 µg/L to 2,780 µg/L. The maximum ethane values for well HW-14 (979 µg/L) and HW-08a (1,280 µg/L) were from samples collected after treatment by the home water treatment.

Ethene

Dissolved ethene was detected in 3 of the 13 wells sampled for ethene, including HW-14 at 27.40 µg/L, HW-04 at 58.60 µg/L, and HW-02 at 520 µg/L. The maximum ethene value detected in HW-14 (27.40 µg/L) was from a sample collected after treatment by the home water treatment installed by Cabot.

Iso-butane

Dissolved iso-butane was detected in 13 of the 17 wells assessed for iso-butane, with maximum concentrations in these wells ranging from 0.04 µg/L to 1.7 µg/L. One well, HW-18, had a maximum iso-butane (0.04 µg/L) level detected in the post-treatment system water.

n-butane

Dissolved n-butane was detected in 13 of 17 wells assessed for n-butane with maximum concentrations in these wells ranging from 0.05 µg/L to 6.30 µg/L.

Propane

Dissolved propane was detected in 14 of 17 wells assessed for propane with maximum concentrations in these wells ranging from 0.17 µg/L to 126 µg/L. The maximum propane value for one well, HW-04 at 39.2 µg/L, was in the post-treatment system sample.

METHYLENE BLUE ACTIVE SUBSTANCE (MBAS):

MBAS is an indicator of the concentration of anionic-type surface active materials (surfactants) in a water sample. ATSDR does not have a CV for MBAS. MBAS was detected in three samples, although it is not clear whether these detections were due to laboratory contamination or actual presence of surfactants in the field sample: HW-01 at 13 µg/L (JHB), HW-07 at 22 µg/L (JHB), and HW-00 at 18 µg/L (JHB). Each of the results were "J" qualified, indicating the results is an estimated value; "H" qualified, indicating the sample exceeded its hold time, and "B" qualified, indicating that MBAS was detected in the blank sample. The blank sample has not been provided with the data. Further evaluation of MBAS detections is not performed in this document.

ORGANICS

Total Petroleum Hydrocarbons (TPH):

Two of eleven wells, HW-04 at 210 µg/L and HW-14 at 150 µg/L, had total petroleum hydrocarbons detected in the water. The nine wells reported as not detected had a wide range of minimum detection limits, ranging from 10 µg/L up to 5,100 µg/L. There are no health-based CVs for TPH.

Bis(2-ethylhexyl)phthalate or Diethylhexyl phthalate (DEHP):

DEHP was detected in the five wells that had been sampled for this compound, with maximum values ranging from 0.14 µg/L to 22 µg/L. DEHP is not naturally occurring and is a known carcinogen. One well, HW-00 (22 µg/L), exceeded the EPA MCL of 6 µg/L. All four wells (HW-01, HW-06, HW-08a, HW-00) exceeded the ATSDR cancer risk evaluation guideline (CREG) of 2 µg/L. None of the wells had DEHP concentrations exceeding the ATSDR non-cancer CV (600 µg/L for children and 2,000 µg/L for adults).

Glycols:

Glycols were reported by PADEP and Cabot under different terms, including GLYCOL, ethylene glycol, triethylene glycol, and 2,2'Oxybisethanol (diethylene glycol). For ethylene glycol, ATSDR has identified an intermediate exposure duration (14 days to 364 days) drinking water CV of 8,000 µg/L for children and 30,000 µg/L for adults. EPA has identified an ethylene glycol lifetime health advisory (LTHA) value of 14,000 µg/L. For this evaluation, the ATSDR CVs for ethylene glycol were used as surrogate CVs for triethylene glycol and 2,2'Oxybisethanol. Glycols are not naturally occurring and are commonly used in natural gas site activities. Some wells have had all three reported glycols present in the historic data set, including ethylene glycol, triethylene glycol and 2,2'Oxybisethanol. Further discussion of glycols are provided below.

Ethylene Glycol/GLYCOL

Nine of 19 wells were sampled for ethylene glycol/GLYCOL. Four of the nine wells (HW-8a, HW-12, HW-15, and HW-16) sampled did not report results below the minimum detection limit of 10,000 µg/L. Four of the nine wells had "J" qualified ethylene glycol/GLYCOL results due to the concentrations being estimated between the reporting limit and the method detection limit: HW-01 at 1,600 µg/L (J), HW-03 at 1000 µg/L (J), HW-07 at 1,300 µg/L (J), and HW-00 at 1,600 µg/L (J). Well HW-13 had the only unqualified ethylene glycol/GLYCOL result at 8,410 µg/L, and this result was from a sample collected after the water passed through the treatment system at this residence. The ethylene glycol/GLYCOL concentration in HW-13 exceeds the ATSDR child intermediate CV of 8,000 µg/L, but is below the EPA LTHA of 14,000 µg/L.

Triethylene Glycol

Three of 19 wells were analyzed for triethylene glycol, and in each well triethylene glycol was identified. All results were "J" qualified as estimated results, including well HW-07 at 2,100 µg/L (J), well HW-01 at 1,900 µg/L (J), and well HW-00 at 4,000 µg/L (J). None of these reported concentrations exceed ATSDR CVs or EPA's LTHA.

2,2'Oxybisethanol (aka Diethylene glycol)

Four of the 19 wells were analyzed for 2,2'Oxybisethanol, and this chemical was shown to be present in each of them. All results were "J" qualified as estimated values, including HW-04 at 630 µg/L (J), HW-01 at 1200 µg/L (J), HW-00 at 3,600 µg/L (J), and HW-03 at 620 µg/L (J). None of these estimated results exceed ATSDR CVs or EPA's LTHA.

2-Methoxyethanol

2-methoxyethanol concentrations were detected in each of four wells assessed for this chemical ranging from 880 µg/L to 1,300 µg/L, although all results were "J" qualified as estimated concentrations. Estimated 2-methoxyethanol concentrations were detected in HW-01 at 1,300 µg/L (J), HW-03 at 1,100 µg/L (J), HW-04 at 880 µg/L (J), and HW-00 at 1,000 µg /L (J). Each of these estimated results exceed the ATSDR 2-methoxyethanol CV of 110 µg/L, which is based on the EPA drinking water Risk Screening Level (RSL).

INORGANICS

Aluminum:

Aluminum was detected in each of the 19 wells sampled, ranging from under 10 µg/L up to 44,100 µg/L. Two wells had maximum aluminum concentrations exceeding the ATSDR health-based CVs in the historic data set, but these concentrations were not detected again in the EPA 2012 data set. Therefore, these maximum exposures are evaluated in more detail here.

Two of 19 wells (HW-13 at 44,100 µg/L and HW-18 at 13,700 µg/L) in the historic data set exceeded the ATSDR CV for chronic exposures to children (10,000 µg/L). The maximum aluminum concentration (HW-13) also exceeds the adult health-based chronic exposure CV (40,000 µg/L).

The maximum estimated aluminum exposure doses for both children and adults were compared to health-based guidelines to determine whether there is any risk for adverse health effects from drinking the well water. By using the maximum concentration of aluminum in water at the site (44,100 ug/L in well HW13) to develop the intermediate and chronic exposure dose, the most conservative, or worst case exposure can be evaluated.

Non Cancer Exposure Evaluation
Estimated children's exposure doses from drinking 1 liter of water per day are 4.41 mg/kg/day for a 10 kg child and 2.76 mg/kg/day for a 16 kg child. The estimated adult exposure dose from consuming 2 liters of water per day is 1.26 mg/kg/day for a 70 kg adult. A minimal risk level (MRL) of 1 mg/kg/day has been derived for intermediate (15-364 days) and chronic (greater than 365 days) duration oral exposure to aluminum. The maximum children and adult estimated exposure dose for this site exceeds both the intermediate and chronic exposure MRL, suggesting further evaluation is necessary for aluminum in Dimock drinking water.

The intermediate (1 mg/kg/day) MRL was developed using the NOAEL of 26 mg/kg/day from the Golub and Germann 2001 Swiss Webster mouse study (Golub and Germann 2001). The intermediate NOAEL identified by Golub and Germann (2001) was divided by an uncertainty and modifying factor of 30 (10 for extrapolation from animals to humans, 10 for human variability, and 0.3 to account for possible differences in the bioavailability of the specific aluminum compound used in the study [aluminum lactate] as compared to the aluminum compounds typically found in drinking water and the U.S. diet) (ATSDR 2008a).

The chronic (1 mg/kg/day) MRL was developed using the LOAEL of 100 mg/kg/day from Golub *et al.*, 2000, Swiss Webster mouse study (Golub *et al.* 2000). The chronic LOAEL was modified by 100 for uncertainty and modifying factors (3 for use of minimal LOAEL, 10 for extraction from animals to humans, 10 for human variability, and 0.3 to account for possible differences in the bioavailability of the specific aluminum compound used in the study [aluminum lactate] as compared to the aluminum compounds typically found in drinking water and the U.S. diet) (ATSDR 2008a).

The highest NOAEL (26 mg/kg/day) identified in intermediate duration animal studies is approximately six times higher than the maximum estimated exposure dose at the Dimock Groundwater site (HW13 at 44,100 µg/L resulting in 4.41 mg/kg/day maximum exposure dose). The residential well with this maximum concentration, HW13, was sampled for aluminum more than 25 times between November 2008 and June 2011. The average pre-treatment aluminum concentration in HW13 was approximately 4,650 µg/L. The second highest pre-treatment aluminum concentration in this well was 8,720 µg/L, below health-based CVs. The average concentration of 4,650 µg/L is below the chronic CV and would result in an estimated exposure dose of 0.465 mg/kg/day for a 10 kg child. This estimated exposure dose is more than 50 times below the highest NOAEL and is not expected to result in any adverse health effects. **Additional information, including EPA's 2012 sampling results (<30 µg/L) and post-treatment sampling data (maximum of 1,080 µg/L on June 20, 2011) indicate that chronic exposures to the aluminum in HW13 well water is not expected to result in adverse health effects.**

The second well exceeding health-based CVs, HW18, had a maximum concentration of 13,700 µg/L and an average concentration of approximately 2,476 µg/L. Based on historic data, the approximate chronic exposure dose (0.25 mg/kg/day) for a 10 kg child is more than 100 times below the highest NOAEL. The 2012 concentration detected by EPA in this well was 34.6 µg/L. **Chronic exposures to aluminum in HW18 well water is not expected to result in adverse health effects.**

All other wells had aluminum concentrations below health-based CVs and are not expected to result in adverse health effects.

Arsenic:
Arsenic was detected in 17 of the 19 wells for which arsenic was assessed. Arsenic levels for three wells were qualified as non-detect due to blank contamination. Arsenic concentrations in the 14 wells with arsenic ranged from 1.3 µg/L to 25 µg/L. The maximum arsenic level of 25 µg/L was from dissolved arsenic analysis and was detected in HW-13. All of the arsenic detections in the private wells exceeded the ATSDR *cancer* health based CV (0.02 µg/L).

The concentrations of arsenic in 11 of the 19 wells are above the ATSDR health-based *non cancer* chronic CV for children (3 µg/L), and arsenic concentrations in one well exceeds the ATSDR health-based *non cancer* chronic CV for adults (10 µg/L), HW-13 at 25 µg/L. Only HW-13 in exceeded the EPA MCL for arsenic (10 µg/L).

The Boyer *et al.* 2012 study of drinking well water quality in Pennsylvania determined that the median and maximum dissolved arsenic concentrations in 115 Pennsylvania drinking water wells sampled was 2.5 µg/L and 27.7 µg/L, respectively, with only 4 percent of the wells tested exceeding the EPA MCL of 10 µg/L (Boyer *et al.* 2011).

Barium:
Barium was detected in each of the nineteen wells assessed, ranging from 100 µg/L to 3,460 µg/L. The maximum result (HW-16 at 3,460 µg/L) was the only well to have a barium concentration exceeding the ATSDR's chronic ingestion CV for a child (2,000 µg/L). Two wells had barium levels exceeding 1,000 µg/L, including HW-03 at 1,360 µg/L and HW-14 with a maximum barium level of 1,123 µg/L detected after the water had been treated. All other wells had barium concentrations below 1,000 µg/L.

The Boyer *et al.* 2012 study of drinking well water quality in Pennsylvania noted that the median and maximum dissolved barium concentrations in 218 Pennsylvania drinking water wells sampled was 130 µg/L and 7,380 µg/L, respectively, with only one percent of the wells tested exceeding the EPA MCL of 2,000 µg/L (Boyer *et al.* 2011).

Iron:
Iron was detected in 18 of the 19 wells assessed, ranging from 38 µg/L (HW-09) to 24,100 µg/L (HW-06). The EPA SMCL for iron (300 µg/L) is not a health-based value but a value set for aesthetic water qualities. The Institute of Medicine (IOM) Upper Tolerable Intake Level (UL) for iron is 45 mg/day. Drinking water from well HW-06 with iron at 24,100 µg/L would add approximately 48.2 mg of iron to an adult's daily diet (assuming 2 liters of water consumed per day) and add approximately 24.1 mg of iron to a 10-16 kg child's daily diet (assuming 1 liter of water consumed per day). Except for well HW-06, all other wells would not result in an exceedance of the IOM UL for iron. Sixteen of 18 wells exceed the EPA SMCL of 300 µg/L.

In the neighboring Bradford County Dck formation, the median dissolved iron concentration is 90 µg/L (USGS 1998). The 2012 Boyer *et al.* study found median and maximum iron concentrations of 50 µg/L and 20,460 µg/L from the 222 Pennsylvania drinking water wells sampled (Boyer *et al.* 2012).

Lead:
Lead was detected in seven of the eleven wells assessed for lead, ranging from 0.53 µg/L (HW-02) to 37 µg/L (HW-13). The EPA action level for lead in public water supplies is 15 µg/L. Only HW-13 exceeds the EPA action level for lead, and the next highest maximum value detected was in well HW-07 (11.9 µg/L). Four of the eleven wells had blank qualified results that were also below the EPA action level.

The 2012 Boyer *et al.* study found median and maximum lead concentrations of 2.5 µg/L and 325 µg/L from 104 Pennsylvania drinking water wells sampled in the study (Boyer *et al.* 2012).

Lithium:

Lithium was detected in each of the seven wells for which it was analyzed ranging from approximately 8.3 µg/L up to 380 µg/L. Three wells (HW-02 at 33.18 µg/L, HW-06 at 380 µg/L, and HW-12 at 32.8 µg/L) exceed the EPA site-specific trigger level of 31 µg/L, and one of those well samples (HW-06) exceeds the PADEP medium-specific concentration (MSC) of 73 µg/L. None of the wells exceed the ATSDR site-specific acute screening value of 1,500 ug/L (ATSDR 2012).

Magnesium:

Magnesium was detected in all wells ranging from 160 µg/L (HW-00) to 125,600 µg/L (HW-10). Not accounting for other sources of magnesium in food and drinks, only one well (HW-10 at 125,600 µg/L) had a magnesium concentration that would result in an exceedance of the IOM UL. None of the other wells had a maximum magnesium result that would result in an IOM UL magnesium exceedance from daily consumption.

In the neighboring Bradford County Dck formation, the median dissolved magnesium concentration is 5,500 µg/L (USGS 1998). In the 2012 Boyer *et al.* study, median and maximum magnesium levels of 6,980 µg/L and 70,000 µg/L, respectively, were determined from the 140 wells sampled in that study (Boyer *et al.* 2012).

This essential nutrient is not considered to be carcinogenic and will only be evaluated for non-cancer end points.

Non Cancer Exposure Evaluation

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 females of 320 mg/day. The UL for magnesium is 350 mg/day for adults and 65 mg/day for young children (*i.e.*, 1-3 years of age) (IOM 1997).

None of the magnesium concentrations in wells assessed by the EPA in 2012 would result in an exceedance of the magnesium UL for adults or children drinking the water. Only one well from the historic data set (HW-10 at 125,600 µg/L) had a magnesium concentration that would result in an exceedance of the IOM UL. HW10 was not assessed by the EPA in 2012. At the historic concentration of 125,600 µg/L, the estimated daily intake for adults is approximately 251 mg/day, and for children (10 or 16 kg) this is 126 mg/day. These estimated daily intakes from the historic data set would result in levels below the level of daily magnesium intake (360 mg/day from nonfood sources for adults and an adjusted value of 65 mg/day for small children) associated with gastrointestinal discomfort in children and adults (IOM 1997). Therefore, the maximum magnesium detected in HW10 prior to 2012 was not likely to have resulted in adverse health effects for adults, but may have caused gastrointestinal discomfort in children, including diarrhea.

Manganese:

Manganese was detected in 18 of the 19 wells, ranging from 2.4 µg/L (HW-00) to 1,920 µg/L (HW-13). Only three wells (HW-01, HW-02, HW-00) had no manganese concentrations exceeding the EPA manganese SMCL of 50 µg/L. Ten wells exceeded the EPA manganese health advisory level of 300 ug/L. Six wells (HW-04, HW-06, HW-07, HW-11, HW-13, HW-16) had maximum manganese concentrations exceeding the RMEG of 500 µg/L for children, but no wells exceeded the adult RMEG of 2,000 µg/L.

In the neighboring Bradford County Dck formation, the median dissolved manganese concentration is 30 µg/L (USGS 1998). The 2012 Boyer *et al.* study found a median manganese level of 10 µg/L for the 203 PA wells sampled with a maximum detection of 6,640 µg/L (Boyer *et al.* 2012).

Potassium:
Potassium was detected in 18 of the 19 wells tested, ranging from 1,404 µg/L (HW-11) to 9,340 µg/L (HW-13). There is no ATSDR health-based CV for potassium in drinking water, however a provisional value of 4,000 µg/L was determined by ATSDR during the Deepwater Horizon incident and is also used here for screening. Three wells (HW-04 at 6,973 µg/L, HW-18 at 4,433 µg/L, and HW-13 at 9,340 µg/L) exceed the ATSDR provisional value.

In the neighboring Bradford County Dck formation, the median dissolved potassium concentration is 2,000 µg/L (USGS 1998). The 2012 Boyer *et al.* study found median and maximum potassium concentrations of 1,270 µg/L and 4,060 µg/L, respectively, for the 107 Pennsylvania wells sampled (Boyer *et al.* 2012).

Silicon:
Eight wells were assessed for silicon, with maximum concentrations for these wells ranging from 4,620 µg/L (HW-17) to 7,140 µg/L (HW-08a). ATSDR does not have a CV for silicon. Because silicon was not assessed in residential groundwater during the EPA 2012 sampling events, this exposure is evaluated in more detail in this appendix.

Non Cancer Exposure Evaluation
A functional role for silicon in humans has not yet been identified (NRC 2001). Silicon appears to be involved in the formation of collagen and bone in animals. Based on the Food and Drug Administration Total Diet Study, the mean intakes of silicon in adult men and women were 40 and 19 mg/day, respectively (Pennington, 1991). Concentrations of silicon are higher in plant-based foods than in animal-derived food products. Based on the Total Diet Study, beverages, including beer, coffee, and water, are the major contributors of silicon (55 percent), followed by grains and grain products (14 percent), and vegetables (8 percent) (Pennington, 1991).

There is no evidence that silicon that occurs naturally in food and water produces adverse health effects. Limited reports indicate that magnesium trisilicate (6.5 mg of elemental silicon per tablet) when used as an antacid in large amounts for long periods (i.e., several years) may be associated with the development of urolithiasis due to the formation, in vivo, of silicon-containing stones (Haddad and Kouyoumdjian, 1986). Less than 30 cases of urolithiasis reported to be associated with intake of silicates (in the form of antacids) could be found even though antacids containing silicon have been sold since the 1930s.

The concentrations detected in historic samples are many times lower than the mean daily intakes of silicon identified by the FDA Total Diet Study, and are not expected to be of public health concern from past exposures. Additionally, silicon has not been identified as causing adverse health effects, except when used as an antacid for many years (although there were very few cases reported over 60 years of use). We do not have information on children's exposures and silicon.

Cancer Exposure Evaluation
Takizawa and coworkers (1988) examined the carcinogenicity of amorphous silica ($SiO2$) given by the oral route to rats and mice for approximately 2 years. There was no evidence that orally administered silica induced tumors. Although there is insufficient evidence to determine the carcinogenicity of

ingested silicon from drinking water, past exposures to silicon in Dimock groundwater would result in exposures well below the mean daily intakes identified by FDA and, therefore, are not expected to be of public health concern.

Sodium:

Sodium was detected in each of the 19 wells sampled with maximum concentrations in the wells ranging from 9,900 (HW-11) to 132,000 µg/L (HW-06). Ten wells had maximum sodium levels exceeding the EPA drinking water advisory level of 20,000 µg/L. Not accounting for other sources of sodium in food and drinks, consuming water from any of the wells assessed would not result in exceeding the UL for children and adults.

In the neighboring Bradford County Dck formation, the median sodium concentration is 11,000 µg/L (USGS 1998). The 2012 Boyer *et al.* study found median and maximum sodium concentrations of 10,650 µg/L and 255,000 µg/L, respectively, for the 199 Pennsylvania wells sampled (Boyer *et al.* 2012).

ii. Radiological COPCs

No radiological contaminants were identified in the historic data set at or above levels of public health concern. A limited number of samples were collected for radiological analyses in the historic data set. These samples were analyzed for thorium 228, thorium 230, thorium 232, uranium 234, uranium 234/235, and uranium 238. None of the results from these samples exceeded health-based screening levels.

Appendix G

Community Health Concerns

Dimock Groundwater Site

1. Residents have expressed health concerns (adults, children, elderly) regarding exposure to chemicals and compounds in their water:

ATSDR has reviewed EPA-collected groundwater data, PADEP-collected data, and Cabot-provided data (forwarded from EPA) for multiple drinking water wells in the Dimock area. The public health review of this information is provided in this health consultation. Our findings may address some of the health concerns??

2. What are the health effects of methane gas in drinking water?

Studies have not linked ingestion of water containing methane to any short term (acute) or long term (chronic) health effects; however, very little research has been done. Methane rapidly escapes from water out into the air. This leaves much less methane in the water used for drinking. Methane is not usually considered to present a health threat from ingestion. Even though dissolved methane in drinking water is not currently considered a health hazard for ingestion, it is potentially an asphyxiant, but this requires a high concentration of methane buildup to displace the air in an enclosed spaces. Airborne methane levels might also build up and be a fire and explosion hazard in poorly ventilated or confined areas.

When present at high concentrations, methane gas can act as an asphyxiant by displacing air and causing breathing and other health problems. Another risk at high concentrations is a fire and explosion danger. Methane typically forms an explosive/fire mixture in the air at concentrations of 5% to 15% of methane in air by volume. Other factors such as water temperature, ventilation at the wellhead, air movement inside the home, and the percent composition of the gas determine the exact concentration that is capable of producing an explosive/fire hazard.

If your well water contains methane concentrations above 28 milligrams per liter (mg/L), the U.S. Department of the Interior, Office of Surface Mining suggests that you take immediate action to reduce this concentration (DOI 2001). Methane concentrations below about 10 mg/L are generally considered safe. Wells with levels between 10 and 28 mg/L should be regularly monitored, and well owners may wish to consider treatment to lower the methane level in water before it enters their home.

3. What causes changes in color (*e.g.*, from clear to chalky, milky, orange, and black), odor and/or taste in drinking water and is it a health concern?

ATSDR is aware of these concerns and has personally witnessed discoloration and odor in some of the Dimock well waters. In many cases, variations in water quality will not result in observable changes in color, odor, and/or taste. For instance, in situations where health-significant chemical levels are increasing, there may be no apparent change in color, odor, and/or taste of the water. For some chemicals, and particularly those found in Dimock area groundwater at relatively higher levels than in other regions, observable changes are easily noted. The chemicals in Dimock area groundwater which may be causing these changes in residential well water include aluminum, iron, manganese, sodium, and dissolved methane. For more specific details on the health significance of these chemicals, refer to the previous sections in this health consultation.

EPA has established National Secondary Drinking Water Regulations that set non-mandatory water quality standards for 15 contaminants (EPA 2012a). EPA does not enforce these "secondary maximum contaminant levels" or "SMCLs." They are established only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color and odor. These contaminants are not considered to present a risk to human health at the SMCL. The absence of an MCL for a chemical listed with an SMCL does not mean the chemical is not of health significance from high exposure levels. Exceeding an SMCL is likely to make that water undesirable for drinking (non-potable). For this reason, particular chemicals exceeding SMCLs were evaluated for their public health significance in the preceding sections of this document.

There are a wide variety of problems related to secondary contaminants. These problems can be grouped into three categories: *Aesthetic effects* -- undesirable tastes or odors; *Cosmetic effects* – effects, such as color and clarity which do not damage the body but are still undesirable; and *Technical effects* -- damage to water equipment or reduced effectiveness of treatment for other contaminants. The secondary MCLs related to each of these effects are given in Table 1.

Aesthetic Effects:

Odor and Taste are useful indicators of water quality even though odor-free water is not necessarily safe to drink. Odor is also an indicator of the effectiveness of different kinds of treatment. However, present methods of measuring taste and odor are still fairly subjective and the task of identifying an unacceptable level for each chemical in different waters requires more study. Also, some contaminant odors are noticeable even when present in extremely small amounts. It is usually very expensive and often impossible to identify, much less remove, the odor-producing substance. *Standards related to odor and taste:* chloride, copper, foaming agents, iron, manganese, pH, sulfate, Threshold Odor Number (TON), Total Dissolved Solids (TDS), and zinc.

- Chloride - In drinking water, the salty taste produced by chloride depends upon the concentration of the chloride ion. Water containing 250 milligrams per liter (mg/L) of chloride may have a detectable salty taste if the chloride came from sodium or potassium chloride.
- Foaming agents - bitter and/or detergent taste
- Iron - Iron is mainly present in water in two forms: either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air in the pressure tank or atmosphere, the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of iron that will not dissolve in water. Dissolved ferrous iron gives water a disagreeable metallic taste. When the iron combines with tea, coffee and other beverages, it produces an inky, black appearance and a harsh, unacceptable taste. Vegetables cooked in water containing excessive iron turn dark and look unappealing. When iron exists along with certain kinds of bacteria, a smelly biofilm can form. To survive, the bacteria use the iron, leaving behind a reddish brown or yellow slime that can clog plumbing and cause an offensive odor. This slime or sludge is noticeable in the toilet tank when the lid is removed.
- Manganese – Iron and manganese are two similar elements that can be a nuisance in a drinking water supply. Iron is more common than manganese, but they often occur together. Dissolved manganese can give water a bitter metallic taste.
- pH - The term "pH" is the measure for the level of acidity or alkalinity in water. The hydrogen ion, H+, is the basis or building block of all acids and the pH scale means the negative logarithm of the H+ concentration. Values range from zero (extremely strong acid) to 14 (extremely strong base or alkali), with the neutral point in the middle at pH 7.0. It is a logarithmic scale, so values differing by one unit indicate ten-fold differences. Acidity of pH 5 is ten times more acidic then pH 6, and 100 times more acidic than pH 7. Carbonated beverages are usually pH 3-4, wines slightly lower, and stomach acid is pH 1. Blood and body fluids are pH 7.4, drinking water is usually pH 7-9, antacids are pH 10 or so, and lye or drain cleaners are pH 12-14. The pH of drinking water is important because "acidic water" (pH less than 7) is a major cause of corrosion, which may leach toxic levels of lead, copper, zinc, and cadmium from the plumbing. Scaling is prominent when pH values exceed 8.5 in combination with high hardness and alkalinity.
- Sulfate – Few studies are available that report on the organoleptic properties (i.e., taste and odor) of sulfate. None of the studies reported an odor threshold; therefore, all of the reported values are based on taste thresholds. It is not possible to precisely identify a specific taste threshold for sulfates in drinking water because the taste threshold concentration varies among individuals. In addition, the associated cations, different water matrices, and temperatures also influence taste. On the basis of the available data, no significant taste effects have been found to occur at sulfate concentrations of about 200-300 mg/L (EPA 2003). In general, sulfate concentrations above 300 mg/L may have a salty taste. Although, sodium sulfate has a taste threshold between 180-500 mg/L so depending on predominant ions in water a person may notice saltiness below SMCL of 250 mg/L. It should be noted that under anaerobic conditions, such as in an groundwater aquifer, sulfates can produce hydrogen sulfide and other reduced sulfur compounds that may be accompanied by a rotten egg or sulfur-type odor.
- Threshold Odor Number (TON) - Given the presence of certain chemicals (including petroleum hydrocarbons, iron, and sulfate) and bacteria indicated in the EPA sampling, odor issues are plausible. 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 Dimock domestic wells. Almost all taste and odor in water is microbial in origin. Common earthy-musty-fishy-moldy taste and odor is produced by algae in reservoirs,

filamentous bacteria called actinomycetes, and also molds. Rotten egg odor is hydrogen sulfide produced by anaerobic bacteria deep in wells or in stagnant, dead-end pipes. Sometimes combinations of iron and sulfur bacteria produce strange "septic" smells. Finally, it is possible for marginal disinfection with chlorine or ozone to produce traces of phenol or phenolic compounds, which combine with the remaining traces of chlorine to produce chlorophenols, which are producers of "medicinal" taste and odor.

- Total Dissolved Solids (TDS) - TDS concentrations above 500 mg/L can give an unpleasant mineral taste and/or saltiness to water.
- Zinc - The Zn++ ion occurs in drinking water only as a corrosion by-product from galvanized (zinc-coated) steel pipe or from fittings made of brass (a copper and zinc alloy). Zinc is one of the few metals that are dissolved by strong base as well as by acid, and a water pH of 10 higher can produce a metallic, astringent taste.

Cosmetic Effects:

Color and clarity may be indicators of dissolved organic material, inadequate treatment, high disinfectant demand and the potential for the production of excess amounts of disinfectant by-products. Inorganic contaminants such as metals are also common causes of color. In general, the point of consumer complaint is variable over a range from 5 to 30 color units, though most people find color objectionable over 15 color units. Rapid changes in color levels may provoke more citizen complaints than a relatively high, constant color level. *Standards related to color:* Aluminum, Color, Copper, Foaming Agents, Iron, Manganese, and Total Dissolved Solids.

- Aluminum – Aluminum in water has no taste or odor. However, very high aluminum levels can sometimes cause water to have a bluish color. The only way to know if your drinking water has elevated levels of aluminum is to have it tested by a state-certified water testing laboratory.
- Copper - A blue-green color is generally a result of copper in your water supply, or copper pipes and corrosive water. The copper can cause staining of your fixtures and your laundry. Copper has a taste threshold of approximately 5.0 mg/L.
- Foaming agents – frothy and/or cloudy.
- Iron – Concentrations of iron as low as 0.3 mg/L will leave reddish brown stains on laundry, porcelain, dishes, utensils, glassware, sinks, fixtures and concrete that are very hard to remove. When these deposits break loose from water piping, rusty water will flow through the faucet.
- Manganese - Manganese causes brownish-black stains on laundry, porcelain, dishes, utensils, glassware, sinks, fixtures and concrete. Manganese may become noticeable in water at levels greater than 50 micrograms per liter of water (µg/L). At this level, the water will have a brown color and might start to leave black deposits mentioned above.
- Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulfate and, particularly in groundwater, nitrate (from agricultural use). TDS concentrations above 500 mg/L can give an unpleasant mineral taste and/or saltiness to water.

Technical Effects:

Corrosivity, and *staining* related to corrosion, not only affect the aesthetic quality of water, but may also have significant economic implications. Other effects of corrosive water, such as the corrosion of iron and copper, may stain household fixtures, and impart objectionable metallic taste and red or blue-green color to the water supply as well. Corrosion of distribution system pipes can reduce water flow. *Standards related to corrosion and staining include* chloride, copper, corrosivity, iron, manganese, pH, total dissolved solids, and zinc. *Scaling* and *sedimentation* are other processes which have economic impacts. Scale is a mineral deposit which builds up on the insides of hot water pipes, boilers, and heat exchangers, restricting or even blocking water flow. Sediments are loose deposits in the distribution system or home plumbing. *Standards related to scale and sediments:* Iron, pH, Total Dissolved Solids, Aluminum.

Table G-1
EPA Secondary Maximum Contaminant Levels (SMCL)

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL
Aluminum	0.05 to 0.2 mg/L*	colored water
Chloride	250 mg/L	salty taste
Color	15 color units	visible tint
Copper	1.0 mg/L	metallic taste; blue-green staining
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste
Odor	3 TON (threshold odor number)	"rotten-egg", musty or chemical smell
pH	6.5 - 8.5	*low pH:* bitter metallic taste; corrosion *high pH:* slippery feel; soda taste; deposits
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye
Sulfate	250 mg/L	salty taste
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	metallic taste
** mg/L is milligrams of substance per liter of water; SOURCE: EPA 2012a*		

How can these problems be corrected?

Although state health agencies and public water systems often decide to monitor and treat their supplies for secondary contaminants, federal regulations do not require them to do this. Where secondary contaminants are a problem, the types of removal technologies discussed below are corrective actions which the water supplier can take. They are usually effective depending upon the overall nature of the water supply.

Corrosion control is perhaps the single most cost-effective method a system can use to treat for iron, copper and zinc due to the significant benefits in (1) reduction of contaminants at the consumer's tap, (2) cost savings due to extending the useful life of water mains and service lines, (3) energy savings from transporting water more easily through smoother, un-corroded pipes, and (4) reduced water losses through leaking or broken mains or other plumbing. This treatment is used to control the acidity, alkalinity or other water qualities which affect pipes and equipment used to transport water. By controlling these factors, the public water system can reduce the leaching of metals such as copper, iron, and zinc from pipes or fixtures, as well as the color and taste associated with these contaminants. It should be noted that corrosion control is not used to remove metals from contaminated source waters.

Conventional treatments will remove a variety of secondary contaminants. *Coagulation/flocculation* and *filtration* removes metals like iron, manganese and zinc. *Aeration* removes odors, iron and manganese. *Granular activated carbon* will remove most of the contaminants which cause odors, color, and foaming.

Non-conventional treatments like *distillation, reverse osmosis* and *electro dialysis* are effective for removal of chloride, nitrates, total dissolved solids and other inorganic substances. However, these are fairly expensive technologies and may be impractical for smaller systems.

Non-treatment options include blending water from the principal source with uncontaminated water from an alternative source.

If you are concerned about the presence of secondary contaminants in your drinking water supply, you can have your water tested by a certified laboratory. A list of certified labs is available via PADEP website.

4. **Residents have expressed concerns regarding media reports that people have had elevated blood barium levels associated with natural gas activities.**

While testing and laboratory analysis can be performed to determine a barium concentration at the time of the test in the blood or urine of an individual, it cannot provide information about the source of exposure and there are limitations for each test in evaluating the actual barium exposure scenario due to its biological half-life in humans. For example, besides the potential for barium exposure from drinking groundwater, individuals may also be exposed by ingesting common foods, such as breads, peanut butter, cereals, pasta, fruits, vegetables, eggs, dairy products, and to a lesser extent meats, poultry, and fish. A blood or urine test will not determine whether the barium detected in a blood or urine sample is from groundwater or food. Additional limitations to interpreting barium data from either a blood or urine sample are discussed below.

Biomonitoring efforts for non-occupational exposure to barium in humans have been conducted most commonly in urine. The National Health and Nutrition Examination Survey (NHANES) conducted by the Centers for Disease Control and Prevention's (CDC's) National Center for Health Statistics measured chemicals or their metabolites in blood, serum, and urine samples from random subsamples of about 2500 participants. NHANES is a series of surveys designed to collect data related to the health and nutritional status of the U.S. population.

The CDC reported urinary barium measurements. Levels of urinary barium reflect recent exposure. Studies reporting urinary levels of barium in general populations have found values generally similar to those reported in NHANES 1999–2000, 2001–2002, and 2003–2004 (CDC 2012b). Barium levels determined in clinically submitted specimens were broadly comparable (CDC 2012b) to levels in NHANES 1999–2000 and 2001–2002.

Additionally, a "White Paper on Measurement and Analysis of Exposures to Environmental Pollutants and Biological Agents during the National Children's Study," the authors noted that "...for metals that do not bioaccumulate in humans like barium, blood (whole, serum, or plasma) is considered "not an important matrix for assessing exposure for chemicals in the category" for any of the life stages (adult or child) (NCS 2004).

When evaluating blood results for any parameter, *e.g*, biological (red blood cells) or chemical (iron, barium), a reference range is necessary. Interpreting any clinical laboratory test involves comparing the patient's results to the test's "reference range" also commonly called the "normal range" or "reference interval."

What is a reference range? Some tests provide a simple yes or no (positive or negative, reactive or non-reactive) answer. Was the urine or blood pregnancy test positive for pregnancy (indicating the presence of a hormone called HCG) or negative (absence of HCG)? Did the test find antibodies to a virus or bacterium that indicates an infection? Some labs report these tests as reactive (positive) or non-reactive (negative). More commonly, the meaning of test results depends on their context. A typical lab report will provide your results followed by a reference range.
A reference range is established by testing a large number of healthy people and observing what is "normal" for that group. The first step in determining a given reference range is to define the population to which the reference range will apply – for example, healthy females aged 20-30 years old. A large number of individuals from this category would be tested for a specific laboratory test. The results would yield a normal" distribution and a reference range (plus or minus 2 standard deviations of the average) of normally distributed values would be established. The term "reference range" is preferred over "normal range" because the reference population can be clearly defined. Rather than implying that the test results are being compared with some vague definition of "normal," the reference range means the results are being considered in the most relevant context. When you examine test results from different populations, you quickly discover that what is "normal" for one group is not necessarily normal for another group. For example, pregnancy changes many aspects of the body's chemistry, so pregnant women have their own "normal range" for many lab tests that vary greatly from non-pregnant women of the same age. Finally, reference ranges are specific to the laboratory that produces the test results. For many test specimens ("analytes"), different laboratories

use different kinds of equipment and different methods of testing. This means that each laboratory must establish its own reference ranges using data from its own equipment and methods. The laboratory must supply your test result with an accompanying reference range on the laboratory report. Consequently, there is no such thing as a standard reference range.

The media has reported elevated blood barium levels when compared to the reference range provided with results from two commercial laboratories. Neither of these labs has established a reference range by testing a large number of healthy people and observing what is "normal" for that group. In actuality, they're sending the blood sample to the NMS Laboratory in Pennsylvania for analysis. Under the reference comments" section of their report you will find the following: "Barium is present in trace amounts in all human tissue, and some studies indicate it is an element essential to proper growth. The concentration in normal human blood is 2 – 400 mcg/L, most of which is found in the plasma fraction".

ATSDR agrees that the "reference range" for barium in blood is likely within that range provided in text from the NMS Laboratory in Pennsylvania (2-400 mcg/L or µg/L). The scientific literature regarding serum (blood) barium levels in humans suggests that the "normal range" of serum barium levels has some variability depending on reference material. A range of 30-200 µg/L is provided by Jacobs *et al.* (2002) and Hung *et al.* (2004). However, other sources have reported the "normal range" to be 30-290 µg/L (Glauser 2001) and 80-400 µg/L (Leiken and Paloucek (1998); and National Medical Services provides a range of 2-400 µg/L (NMS 2006)).

5. What is the quality of the water that was supplied to residents via water buffalos?
ATSDR is not aware of any sampling results for the supplied water (i.e., water buffalos), with the exception of limited results reported in the historical data set. One arsenic anomaly was reported for a sample of provided water in the data provided to the EPA by the PADEP as part of the historical data set. The maximum historic data set arsenic detection of 37 µg/L was identified in water provided by Cabot to a resident in the site area. It is not clear whether this provided water was for drinking or other household use as it was labeled as "provided water" in the summary tables the PADEP provided. This arsenic concentration is more than three times the EPA MCL and exceeds ATSDR health-based CVs for children and adults. Provided water not intended for ingestion should be clearly identified as such when provided to residents as an alternative water source.

6. What about an interaction between the arsenic and Coumadin (an anticoagulant blood thinner)?
There is limited information regarding this interaction but in one study (Alam et al. 2008), the arsenic concentration reported to effect the protein binding of Coumadin in blood was approximately 8,000 ppb. The resident asking this question had arsenic levels approximately 1,000 times below this level and ATSDR would not expect drug interactions at this low level.

7. Residents have expressed concerns regarding disease and/or cancer clusters resulting from natural gas activities in area. Is anyone investigating this?
ATSDR is aware of these concerns not only in the Dimock, PA, area but also throughout the Marcellus region.
At this time, ATSDR and PADOH are not collecting health data in the Dimock, PA area.

8. Can chlorine, bromine, and organic matter interact in my well water? Bromide compounds can be formed during reactions between chlorine and naturally occurring organic matter in drinking water. These reactions can form brominated and mixed chloro-bromo byproducts, such as trihalomethanes or halogenated acetic acids, some of which are carcinogenic. Some Dimock residents are using chlorination to address bacteriological contamination in their private water wells. The EPA 2012 sampling information did not include brominated and mixed chloro-bromo byproducts, therefore these compounds were not part of ATSDR's public health evaluation in this health consultation document.

Appendix H

Acronyms and Definitions

Dimock Groundwater Site

µg/L	Micrograms per liter
ADI or AI	Acceptable daily intake or acceptable intake
AROA	ATSDR record of activity
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
B(a)P	Benzo(a)pyrene, a polycyclic aromatic hydrocarbon
BMDL05	benchmark dose with 95% lower confidence level
CDC	U.S. Centers for Disease Control and Prevention
COPC	Contaminant of potential concern
COSA	Consent Order and Settlement Agreement
CREG	ATSDR cancer risk evaluation guideline
CV	Health based comparison value
DEHP	bis(2-ethylhexyl) phthalate or diethyhexyl phthalate
DHHS or HHS	U.S. Department of Health and Human Services
DOI	U.S. Department of Interior
EMEG	Environmental media evaluation guideline
EPA	U.S. Environmental Protection Agency
EPA SCRIBE	EPA database software used for managing all EPA-collected analytical results ATSDR accessed the Dimock SCRIBE database for analytical data evaluated in this document
ESADDI	National Academy of Science estimated safe and adequate daily dietary intake
Hyperkalemia	Elevated potassium in the blood
Hypernatraemia	Elevated sodium in the blood
IARC	International Agency for Research on Cancer
IOM	Institute of Medicine
kg	Kilogram
LEL	Lower explosive limit
LOAEL	Lowest observed adverse effect level
MCL	Maximum contaminant level
mg/kg/day	Milligrams of chemical per kilogram body weight per day
mg/L	Milligrams per liter
MRL	Minimal risk level
NJDEP	New Jersey Department of Environmental Protection
NOAEL	No observed adverse effect level
NTP	National Toxicology Program
OCDD	Octachlorodibenzodioxin
OEHHA	California Office of Environmental Health Hazard Assessment
PADEP	Pennsylvania Department of Environmental Protection
PADOH	Pennsylvania Department of Health
PAH	polycyclic aromatic hydrocarbon
PCL	TCEQ protective concentration levels
PHAP	Public Health Assessment Process. For more information, go to
ppb	parts per billion
RDA	Recommended daily dietary allowance
RfD	EPA reference dose
RMEG	ATSDR remedial media evaluation guideline, based on the EPA reference dose
SMCL	Secondary maximum contaminant level

TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TEF	Toxicity equivalence factor
TEQ	Toxicity equivalence quotient
TRRP	Texas Risk Reduction Program
WHO	World Health Organization

Greetings,

You are receiving a document from the Agency for Toxic Substances and Disease Registry (ATSDR). We are very interested in your opinions about the document you received. We ask that you please take a moment now to complete the following ten question survey. You can access the survey by clicking on the link below.

Completing the survey should take less than 5 minutes of your time. If possible, please provide your responses within the next two weeks. All information that you provide will remain confidential.

The responses to the survey will help ATSDR determine if we are providing useful and meaningful information to you. ATSDR greatly appreciates your assistance as it is vital to our ability to provide optimal public health information.

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