Health Consultation

Chesapeake ATGAS 2H Well Site

Leroy Hill Road, Leroy

Leroy Township, Bradford County, Pennsylvania

OCTOBER 29, 2013

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

An ATSDR Health Consultation is a verbal or written response from ATSDR 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 exposures studies to assess exposure; and providing health education for health care providers and community members.

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HEALTH CONSULTATION

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Leroy Hill Road, Leroy

Leroy Township, Bradford County, Pennsylvania

Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry (ATSDR)
Division of Community Health Investigations
Eastern Branch

Note:

This updated October 24, 2013 version of the Chesapeake ATGAS 2H Well Site Health Consultation replaces the original November 4, 2011 version of this document. The following table summarizes the revisions made in response to Chesapeake Energy Corporation's January 2012 Information Quality Request for Correction and follow-up May 2013 Information Quality Appeal submitted to the Agency for Toxic Substances and Disease Registry.

Summary of revisions made to the ATSDR Chesapeake ATGAS 2H Well Site Health Consultation

Request Comment Number (from the Chesapeake ATGAS Energy Corporation Information Quality Request for Correction)	**Error**	**Correction**
Appeal Item 1	None	To further emphasize the point made on page 18 of the original document, ATSDR added this clarification to Conclusion 1 on pages v and 19 of the updated document: "The available information indicates that the overland release following the ATGAS 2H incident did not appear to cause the water quality impacts observed in RW04."
Appeal Items 1 and 5	None	To emphasize that ATSDR did not attempt to conclusively determine the source of contamination, ATSDR added this language to the limitations sections on pages viii and 2 of the updated document: "In this document, ATSDR does not attempt to attribute conclusively the presence of the chemicals detected in the private wells at this site to a definitive source. ATSDR recognizes the expertise and authority of EPA and state environmental agencies to make final determinations about relevant sources of contamination."
2	Mislabeling of Table 3.	ATSDR removed the duplicate Table 3 header and re-labeled

Request Comment Number (from the Chesapeake ATGAS Energy Corporation Information Quality Request for Correction)	**Error**	**Correction**
		the tables on pages 15 and 18 of the updated document.
20	Incorrect sampling date for RW03 (April 27, 2011).	ATSDR corrected the sampling date for RW03 (April 28, 2011) on page 4 of the updated document.
22	ATSDR relied on "blank-qualified" data for Oil and Grease (HEM) to make unsupportable conclusions regarding the presence of hydrocarbons, especially in RW04.	ATSDR removed the parenthetical reference to HEM results in the Conclusions portions on pages v and 19 of the updated document.
23	The conversion of methane concentration of 87 percent in air to a concentration in µg/L is incorrect.	The appropriate conversion should be approximately 581,000 µg/L. ATSDR made this correction on p. 15 of the updated document.
27	ATSDR states on Page 3 that there is a notable increasing trend in strontium levels and warrant further consideration in future hydraulic fracturing-related groundwater sampling events.	ATSDR corrected the statement about an increasing trend in strontium levels on p. 3 of the updated document. The sentence now reads: "Although the detected levels of strontium did not exceed CVs and thus are not included in Table 1, site-specific and general industry-wide information for this chemical warrants further consideration in future hydraulic fracturing-related groundwater sampling events."
30	ATSDR states on page 7 that the iron concentration at RW02 is 500 µg/L and in Table 1 it is listed as 550 µg/L.	ATSDR corrected the RW02 value to 550 µg/L on page 7 of the updated document.

In addition, ATSDR revised the Public Health Action Plan on page 21 of the updated document to reflect the status at this site as of October 2013.

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Overview A Marcellus Shale formation natural gas well known as the Chesapeake ATGAS 2H Well Site in Leroy Township, Bradford County, Pennsylvania experienced a well head flange failure and uncontrolled flow-back fluid release on April 19, 2011. This acute event occurred while the well was undergoing hydraulic fracturing by the Chesapeake Energy Corporation (Chesapeake). Chesapeake and the Pennsylvania Department of Environmental Protection (PADEP) and the U.S. Environmental Protection Agency (EPA) concurrently completed an initial groundwater sampling event for the seven private wells closest to the well site on April 27 and 28, 2011. A comparison of the EPA and PADEP split samples showed consistency in the analytical results with the exception of the radionuclide results for one well. EPA requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate the environmental data collected from the seven private wells in order to determine whether harmful health effects would be expected from consuming and/or using the well water. Treated water or bottled water is currently being provided to three of the seven residences (RW02, RW03, and RW04). Based on the available data, it is not known if future chemical concentrations in the residential wells will change. Therefore, ATSDR evaluated the currently available data against a range of possible exposure durations (acute, intermediate and chronic).

Conclusion 1 The available environmental data and information for RW04 do not conclusively indicate but suggest that the groundwater near this site is impacted by natural gas activities. EPA is conducting further investigations at this site.

- Post-blowout sampling results for a number of analytes in residential drinking water well RW04 are notably higher than pre-blowout sampling results. Pre-blowout samples were collected approximately six months prior to any drilling activities at the Chesapeake ATGAS 2H Well Site.
- The methane concentration in residential well RW04 increased approximately 10-fold compared to the pre-blowout concentrations. This 10-fold increase in methane was accompanied by the presence of ethane along with approximately 10-fold increases in barium, calcium, chloride, magnesium, manganese, potassium, and sodium and a 7-fold increase in iron.
- It is unclear at this time why the levels in RW04 changed between the pre- and post-blowout sampling events. The available information indicates that the overland release following the ATGAS 2H incident did not appear to cause the water quality impacts observed in RW04. Further evaluation at the site is needed to characterize any relationship between the aquifers and drinking water wells under different operating scenarios at the well site or as a result of other changes in site conditions.

Conclusion 2	Adults consuming water from well RW04 would exceed the recommended dietary guideline for sodium for general and sensitive populations and the tolerable upper intake level for young children and adults. This exceedance does not include sodium intake from food, which is the primary source of sodium in our diet. Consuming water from the rest of the residential wells at this site with elevated sodium levels (RW02, RW03, RW05, RW06, and RW07) may also be of health concern to sensitive subpopulations, including individuals on sodium-restricted diets. Based on the maximum concentrations measured from the seven private wells, it is unlikely that healthy children or adults would be exposed to individual levels of inorganic salts, such as barium, calcium, magnesium, manganese, and/or potassium, at levels that would result in adverse health effects.
Conclusion 3	Two possible exposure scenarios were identified of health concern related to the maximum level of arsenic detected in a well at this site (30 µg/L in RW02). This level would result in an unacceptable cancer risk over a lifetime of exposure (i.e., 2 L water every day for 30 years). In addition, children who drink 1 liter of water at 30 ug/L arsenic for durations over a year could be at an increased risk for non-cancer health effects. Exposure to the maximum arsenic levels detected in groundwater at this site would be unlikely to produce adverse non cancer health effects in adults. Post-blowout and pre-blowout sampling results for arsenic in RW02 were similar.
Conclusion 4	Bromide was detected in RW04 at acceptable daily intake criteria for adults. A comparable guideline for bromide consumption in children is not available. Unless users of RW04 well had unusually high additional sources of bromide exposure beyond their well water (i.e., food), ATSDR expects that this exposure level likely did not produce adverse health effects in users of this well water.
Conclusion 5	In RW04 and RW06, lithium was detected at a level exceeding the EPA Regional Screening Level and the Pennsylvania Medium Specific Concentration. The estimated lithium exposures could be of concern to individuals currently undergoing lithium therapy. Lithium demonstrates a narrow therapeutic-toxic ratio and can induce adverse health effects, if slight changes in plasma levels occur. There is insufficient toxicological information available to determine the significance of these lithium exposures for individuals not undergoing lithium treatment. However, there are several groups of drugs that interact with lithium causing increased levels of lithium in the serum. These include diuretics (e.g., Hydrodiuril), nonsteroidal anti-inflammatory agents (e.g., Motrin), calcium channel blocking agents (e.g., Calan), and angiotensin-converting enzyme inhibitors (e.g., Capoten). The concurrent use of any drug associated with the aforementioned groups would increase the likelihood of toxic manifestations in a sensitive person.
Conclusion 6	Based on the maximum concentrations measured in wells RW01, RW03, RW05, RW06 (with the exception of lithium) and RW07 in April 2011,

ATSDR does not expect health effects for the users of these private wells.

Conclusion 7 Based on the information available from EPA's single groundwater sampling round, adverse health effects are not expected from drinking groundwater in RW03 with a gross alpha radiation level above EPA's MCL.

Recommendations and Next Steps

1. ATSDR supports actions to mitigate exposures to impacted groundwater from RW04. Chesapeake is installing a whole house reverse osmosis treatment system on RW04 and has been providing potable water in the interim. ATSDR recommends pre- and post-filtration water sampling of RW04 to determine whether the groundwater chemicals have remained elevated and whether the treatment system is removing chemical parameters as expected. ATSDR recommends that pre- and post- filtration system sampling results be shared with public health authorities.
2. ATSDR supports actions to mitigate exposures to the elevated levels of arsenic in RW02. EPA initially supplied bottled water to the residence with maximum level of arsenic detected (RW02), and recently installed a point of use filter at this residence.
3. EPA decided to provide bottled water to the residence with the exceedance of EPA's MCL for gross alpha radiation (RW03) until further testing and source evaluation is completed. ATSDR supports this action as a precaution until more information is available, however, ATSDR does not expect adverse health effects from the radionuclide levels detected in this private well.
4. ATSDR recommends that further sampling of the residential wells near this site be conducted to determine the current impacts to the local groundwater, to identify trends in chemical constituents, and to better assess chronic exposures to groundwater constituents related to natural gas drilling and hydraulic fracturing activities. Further evaluation at the site is needed to characterize any relationship between the aquifers and drinking water wells under different operating scenarios at the well site or as a result of other changes in site conditions.
5. ATSDR recommends that future environmental assessment at natural gas hydraulic fracturing sites in the Marcellus Shale formation address the following:
    a. Environmental exposure pathways in addition to groundwater should be included (e.g., fish in potentially impacted surface water bodies, livestock consuming potentially impacted surface water, air).
    b. In addition to the parameters commonly monitored and sampled in groundwater, ATSDR recommends that methane, ethane, lithium, strontium, and radiological parameter sampling should be included in "pre drilling" and "post drilling" private groundwater sampling events.
    c. Head space gas monitoring for methane and ethane and other volatile organic compounds should be conducted.
    d. Drinking water should also be tested for radon (and indoor air should be tested for radon). Many areas of Pennsylvania have elevated levels of naturally occurring radioactivity, including radon. Radon testing information would permit a more comprehensive consideration of total radioactive dose from gross alpha radiation for these locations. A more detailed future analysis of the water would be helpful to confirm if radiation levels are elevated, and if so if this is the result of naturally occurring radioactive material or technologically enhanced naturally occurring radioactive material.
6. ATSDR recommends that all private groundwater well users routinely sample their wells for biological, chemical and physical parameters at least annually, especially those in close proximity to natural gas drilling activities.

Data Limitations
The environmental sampling information reviewed in this health consultation is limited to groundwater exposures from seven residential wells and primarily reflects a specific timeframe one week after the Chesapeake ATGAS 2H natural gas well hydraulic fracturing blowout. Other scenarios in the lifecycle of natural gas hydraulic well development and use would potentially involve different considerations for groundwater and air quality over both acute and chronic exposure durations.

In this document, ATSDR does not attempt to attribute conclusively the presence of the chemicals detected in the private wells at this site to a definitive source. ATSDR recognizes the expertise and authority of EPA and state environmental agencies to make final determinations about relevant sources of contamination.

If you have concerns about your health, you should contact your health care provider. For questions or concerns about the Chesapeake ATGAS 2H site, please contact the Agency for Toxic Substances and Disease Registry regional office at (215) 814-3140 or (215) 814 -3141.

Statement of Issues:

The U.S. Environmental Protection Agency (EPA) Region III requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate environmental data collected from seven private wells in Leroy Township, Bradford County, Pennsylvania to determine whether short-term or chronic health effects would be expected from consuming and/or using the well water (EPA 2011a). A Marcellus Shale formation natural gas well operated by the Chesapeake Energy Corporation (Chesapeake) known as the Chesapeake ATGAS 2H Well Site experienced a well head flange failure. An uncontrolled flow-back release occurred on April 19, 2011, while the well was undergoing hydraulic fracturing. Chesapeake and the Pennsylvania Department of Environmental Protection (PADEP), and EPA concurrently completed an initial groundwater sampling event for the seven private wells closest to the well site on April 27 and 28, 2011 (EPA 2011b). The focus of this health consultation document is the groundwater sampling information provided by EPA to ATSDR for these seven private wells. For additional context, EPA provided ATSDR with "pre-blowout" July 2010 sampling data collected by Chesapeake's contractor for four of these private wells, as well as PADEP's sampling information from April 20 and April 27-28, 2011 for these seven private wells. The pre-blowout samples were collected approximately six months prior to any drilling activities at the Chesapeake ATGAS 2H Well Site.

Background:

The seven wells sampled are located near the Chesapeake ATGAS 2H Well Site, a Marcellus Shale natural gas well located in Leroy Township, Bradford County, Pennsylvania. Leroy Township is a rural area in the northeast corner of Pennsylvania. Based on the 2010 Census, Leroy Township has a population of 718 residents, with an approximate population density over 48 square miles of 15 people per square mile (US Census 2010). There are approximately 126 residents within a one mile radius of the site. Appendix A includes a map of the well site location and summary demographics information for the site area, and Appendix B details the buildings in the well site area.

The Chesapeake ATGAS 2H well experienced a well head flange failure and release of flowback fluids and vapors on April 19, 2011, while the well was undergoing hydraulic fracturing by Chesapeake. The incident was reported to the PADEP on April 20, 2011. PADEP responded to assess the potential impacts of the release on Towanda Creek. Based on the water quality screening, the flow back water had elevated salinity and conductivity readings (EPA 2011b). Immediately after the uncontrolled release, lower explosive limit (LEL) readings were recorded at 100% at the well site. Therefore, as a precaution, the residents from the seven homes closest to the well site were given the option to relocate during the initial phase of the emergency. One resident chose to temporarily relocate. EPA dispatched an On-Scene Coordinator (OSC) to provide assistance to PADEP. During the first 10 hours of the spill, Chesapeake was unable to control the release of flow back fluids. The exact quantity of flow back fluids released onto nearby fields, the down gradient farm ponds, and into Towanda Creek has not been disclosed. Chesapeake was unable to control the well until April 25, 2011. Following well stabilization, LEL readings at the well head dropped to 0%. On April 27 and 28, 2011, EPA's contractor, PADEP, and Chesapeake's environmental consultants collected split samples from the seven residential wells nearest the Chesapeake ATGAS 2H well site (EPA 2011b).

Discussion

Private Well Sampling and Analysis:

EPA's April 2011 private well samples were analyzed for the following parameters: Target Compound List (TCL), Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Target Analyte List (TAL) total metals with the addition of lithium and strontium, HEM (n-hexane extractable material or oil and grease), methane and ethane, radiological constituents, and basic water quality parameters (alkalinity, turbidity, total dissolved and suspended solids, etc). Table 1 provides a summary of the analytes and compounds which exceed a health-based comparison value (CV) or for which no CV is available. Appendix C provides a summary of all non-radiological chemical detections in EPA's April 2011 sampling of residential private wells after the Chesapeake ATGAS 2H Well Site blowout. ATSDR compared PADEP split sample results to EPA's results. This comparison showed consistency in concentrations reported for the chemical analytes and compounds. Although slightly different methods were employed for radiological constituents, the PADEP and EPA radiologic results were also consistent, except for one well (RW03) which had differing alpha particle concentrations (EPA result was approximately 8 times higher than the PADEP result).

Data Limitations:

In this health consultation, ATSDR identified several limitations to the available environmental sampling data for this site. These limitations included:

- Information on potential pathways of exposure beyond the groundwater ingestion pathway is not available at the current time.
- The majority of the environmental sampling data reviewed in this document are limited temporally to a 7 to 8 day period after the blow-out began. Chemical concentrations in groundwater samples collected on a single day may not accurately represent year-round conditions or past, present and future exposure levels. Based on the available data, it is not known if future chemical concentrations in the residential wells will change.
- Limited July 2010 "pre-blowout" sampling information from Chesapeake for four of these private wells was provided to ATSDR for a subset of the analyte list used by EPA "post blowout" (see Appendix D, Comparison of EPA April 2011 Private Well Sampling Results With Chesapeake July 2010 Private Well Sampling Results for RW02, RW03, RW04, and RW06, Before and After Chesapeake ATGAS 2H Well Site Blowout).
- Reported concentrations for many of the chemicals detected in the environmental samples include contributions from naturally occurring sources. Relatively higher concentrations of naturally occurring chemicals (chloride, strontium, lithium, manganese, etc.) can be found in deep formations compared to surface soils. Many of these naturally occurring chemicals are readily mobilized in the environment by natural gas drilling and hydraulic fracturing activities.
- There is a lack of information at this site at this time regarding any relationship between the aquifers and drinking water wells under different operating scenarios at the well site or as a result of other changes in site conditions.
- ATSDR does not have information at this time regarding the horizontal delineation of the Chesapeake ATGAS 2H Well or any information about other natural gas wells in the immediate vicinity.

To account for some of these limitations, ATSDR assumed ingestion with the maximum detected chemical concentration(s) and included all detected contaminants in the evaluation regardless of source or possible background contributions. In addition, ATSDR evaluated the currently available data for both short and long term exposure durations.

In this document, ATSDR does not attempt to attribute conclusively the presence of the chemicals detected in the private wells at this site to a definitive source. ATSDR recognizes the expertise and authority of EPA and state environmental agencies to make final determinations about relevant sources of contamination.

Environmental Data:

ATSDR received the environmental data reviewed in this document from EPA. EPA's data consisted of field sample results, along with field blank, sample duplicate, and intra-laboratory check sample data. Each EPA sample underwent a quality control evaluation by the laboratory and was qualified by the EPA-approved data qualifiers. EPA provided ATSDR with a data package narrative and a secondary data validation package (quality assurance/quality control data package) for EPA's sample results. In addition, EPA provided ATSDR with PADEP's April 2011 private well sampling results and Chesapeake's July 2010 private well sampling results from the site area.

This health consultation uses the EPA private well sampling information as the primary basis for the public health analysis. However, the split sampling results from EPA and PADEP were consistent for the organic and inorganic parameter analyses, as well as the water quality parameters common to both data packages. The exception was the alpha particle concentrations reported for residential well RW03. EPA's alpha particle concentration for RW03 (24.3 ± 5.3 microcuries per liter) was considerably higher than the PADEP result (4.1 ± 1.7 microcuries per liter).

On September 13, 2011, ATSDR received a copy of Chesapeake's evaluation of residential well RW04 (SAIC 2011) from EPA. This report includes a large amount of additional sampling data and geophysical survey information from Chesapeake's investigation into possible water quality changes in this particular well, including zone-specific (packer) testing and borehole logging of this well. ATSDR does not attempt to comprehensively evaluate all of the information from this document in this Health Consultation. A preliminary evaluation of this document has not led to any technical changes in this ATSDR Health Consultation. ATSDR expects this will be the subject of further analysis by the environmental agencies.

Non-Radiological Parameters

ATSDR compared the levels of compounds detected in EPA's sampling information to available health-based comparison values (CVs). Health-based CVs were used to identify contaminants that should be further evaluated for their potential to produce adverse health effects (e.g., if a compound was detected at a level above the CV, it would be considered a compound of concern). For some of the naturally occurring substances (e.g., calcium and iron), information regarding the substance as a nutrient was employed to evaluate possible harmful effects associated with the substances. These evaluations typically considered the substance found in drinking water as nutrients, and focused the assessments around estimated dietary intakes. These assessments specifically utilized acceptable daily intakes, dietary reference intakes, and tolerable upper intake levels.

The following CVs were used in this review:

- Agency for Toxic Substances & Disease Registry Child/Adult Environmental Media Evaluation Guides (EMEG),
- U.S. Environmental Protection Agency Reference Dose Media Evaluation Guides (RMEG), Regional Screening Levels (RSLs), Health Advisory (HA) Levels, Maximum Contaminant Levels (MCL), Secondary Maximum Contaminant Levels (SMCL) and Drinking Water Advisory Levels,
- PA Department of Environmental Protection (PADEP) Medium Specific Concentrations (MSC),
- World Health Organization (WHO) Acceptable Daily Intakes (ADI),
- Institute of Medicine of the National Academies (IOM/NAS) Dietary Reference Intakes (DRI) and tolerable upper intake levels (UL), and
- ATSDR Cancer Risk Evaluation Guidelines (CREG).

Table 1 summarizes the results of ATSDR's screening of EPA's April 2011 sampling data of the seven residential private wells near the Chesapeake ATGAS 2H Well Site. The data are compared to health-based CVs and background concentrations of the selected chemicals. ATSDR-derived CVs are based on 10 kilogram body weight and 1 liter of water consumed per day for children and 70 kilogram body weight and 2 liters of water consumed per day for adults. The table includes all non-radiological chemical parameters that exceeded a CV or for which no CV is available. For context, information is provided from a joint Pennsylvania Department of Conservation and Natural Resources/ U.S. Geological Survey report for background levels of these parameters from groundwater in the area (USGS 1998). In addition, Table 1 summarizes EPA's sampling information for the radiological parameters in these private wells.

Although the detected levels of strontium did not exceed CVs and thus are not included in Table 1, site-specific and general industry-wide information for this chemical warrants further consideration in future hydraulic fracturing-related groundwater sampling events.

Radiological Parameters

The method used by ATSDR to evaluate the radiological sampling data involved reviewing the QA/QC package and comparing the identified radionuclides and the uncertainty for each evaluation, the method used by laboratory for analysis, the minimum detectable activity or concentration, and finally the EPA MCL. Those samples marked by the laboratory as non-detects ("U" qualified) were determined to be unusable by ATSDR. Table 1 summarizes EPA's radiologic data for the residential wells sampled near Chesapeake ATGAS 2H Well site above MCLs. The residential well data from near the Chesapeake ATGAS 2H Well Site were compared to several parameters, including the sample minimal

Table 1
EPA April 2011 Sampling of Residential Private Wells Post-Chesapeake ATGAS 2H Well site Blowout
Compounds Detected Which Exceed CVs or For Which No CV is Available

Analyte	Background Concentration*	Comparison Value	Date Sampled: CV Source	RW01 4/27/11	RW02 4/27/11	RW03 4/28/11	RW04 4/27/11	RW05 4/28/11	RW06 4/27/11	RW07 4/28/11
Methane	NA	None		ND	120	ND	6,200	7.4	240	17
Ethane	NA	None		ND	ND	ND	2.6	ND	ND	ND
Arsenic	9	10; 3/10; 0.02	EPA MCL; ATSDR Child/Adult Chronic EMEG; ATSDR CREG	0.73 J	30	9.4	1.8 J	2.1 J	4.2 J	2.1 J
Barium	1,620† [560-98,000][1]	2,000/7,000	ATSDR Child/Adult Chronic EMEG	180	370	220	2,600	200	660	250
Bromide	NA	2,000/6,000	WHO Child/Adult ADI	ND	120 J	ND	15,000	110 J	1,700	340
Calcium	39,000	*See Table 2*	IOM Upper Tolerable Intake (UL)	76,000	43,000	40,000	170,000	29,000	26,000	24,000
Chloride	12,000 (560,000)[2]	250,000 *See Table 2*	EPA SMCL; IOM Upper Tolerable Intake (UL)	8,600	15,000	10,000	1,900,000+	12,000	220,000+	45,000
Iron	270 (1,200)[2]	300	EPA SMCL	ND	550	3,100	600	170	80 J	190
Lithium	NA	73 20/70	EPA RSL/PADEP MSC; Child/Adult derived provisional RMEG	13	11 L	17	1,900	38	87	60
Magnesium	10,000	*See Table 2*	IOM Upper Tolerable Intake (UL)	12,000	6,000	4,200	21,000	5,400	3,600	3,900
Manganese	50 (490)[2]	50; 500/2000; 300	EPA SMCL; EPA RMEG Child/Adult; EPA HA	200	400	130	260	130	95	110
Potassium	1,100	None		1,500 J	1,700 B	1,700 J	13,000	1,200 J	1,900 B	1,200 J
Sodium	28,000	20,000 *See Table 2*	EPA Drinking Water Advisory; IOM Upper Tolerable Intake (UL)	8,600	46,000 K	22,000	2,100,000 K	56,000	120,000 K	74,000
Gross Alpha Radiation	NA	15	EPA MCL	5.2±3.2	ND	24.3±5.3	ND	ND	ND	ND

Notes: All concentrations reported as µg/L (ppb), except radionuclides data which are reported in picocuries per liter
* Unless otherwise noted, values are the median concentration from DCNR/USGS study (1998) of Devonian Lock Haven (Dlh) formation in Bradford County
\+ = Result reported from diluted analysis

† = Concentration detected from nearby well (BR 205) from DCNR/USGS study (1998) in the Devonian Lock Haven (Dlh) formation in Bradford County (USGS 1998)
[1] = Range of values reported from DCNR/USGS study (1998) of Devonian Lock Haven (Dlh) formation in Bradford County wells
[2] = Only 10% of the wells in the Lock Haven formation samples reported in the DCNR/USGS study (1998) exceeded this concentration
ATSDR Child/Adult Chronic EMEG= Agency for Toxic Substances & Disease Registry Child/Adult Chronic Environmental Media Evaluation Guide
B = Compound found in the blank
EPA HA, RSL, RMEG, MCL, SMCL= U.S. Environmental Protection Agency Health Advisory, Regional Screening Level, EPA Reference Dose Media Evaluation Guide, Maximum Contaminant Level, and Secondary Maximum Contaminant Level
J = Result is less than the reporting limit but equal or greater than the method detection limit; concentration reported is approximate
K = Analyte present. Reported value may be high. Actual value expected to be lower.
L = Analyte present. Sample value biased low. Actual value expected to be higher.
NA= Not available
ND = Not detected above method detection limit
PADEP MSC = PA Department of Environmental Protection Medium Specific Concentration
RDA = Recommended Daily Allowance
WHO ADI = World Health Organization Acceptable Daily Intake (for Bromide in Drinking Water) (WHO 2009)

Table 2
Extrapolated Upper Tolerable Intake Levels (UL) in Water for Sodium, Chloride, Calcium and Magnesium

Age (in years)	Volume of water ingested	Sodium UL	Sodium (µg/L)	Chloride UL	Chloride (µg/L)	Calcium UL	Calcium (µg/L)	Magnesium UL	Magnesium (µg/L)
Infants (0-12 months)	1 L/day	NE	NE	NE	NE	NE	NE	NE	NE
1-3 years	1 L/day	1.5 g/day	1,500,000	2.3 g/day	2,300,000	2.5 g/day	2,500,000	0.065 g/day	65,000
4-8 years	1 L/day	1.9 g/day	1,900,000	2.9 g/day	2,900,000	2.5 g/day	2,500,000	0.110 g/day	110,000
9-13 years	1 L/day	2.2 g/day	2,200,000	3.4 g/day	3,400,000	3.0 g/day	3,000,000	0.350 g/day	350,000
14-18 years	2 L/day	2.3 g/day	1,150,000	3.6 g/day	1,800,000	3.0 g/day	1,500,000	0.350 g/day	175,000
19-50 years	2 L/day	2.3 g/day	1,150,000	3.6 g/day	1,800,000	2.5 g/day	1,250,000	0.350 g/day	175,000
51+ years	2 L/day	2.3 g/day	1,150,000	3.6 g/day	1,800,000	2.0 g/day	1,000,000	0.350 g/day	175,000

Sources: Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride (IOM 1997) and Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate (IOM 2005).
Notes: **Values above does not include additional exposures from food and non tap water.**
Upper Tolerable intake levels (UL) for sodium, chloride, calcium and magnesium for infants are not established; source of intake for infants should be from human milk (or formula) and food only.
NE = Not established
UL = Upper tolerable intake level reported in grams per day (g/day)
L = Liter
µg/L = micrograms per liter

detection limits (MDL), and whether the reported activity exceeded the individual MCL for the particular analyte. To be evaluated, the sample had to exceed the MDL and the reported uncertainty levels could not exceed the reported values.

Contaminants of Concern

As noted above, when determining the contaminants of concern, ATSDR screened 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.

Non-Radiological Contaminants of Concern

Arsenic:
Arsenic was detected in all seven wells. In five of the wells, low levels were found (0.73-4.2 µg/L) and qualified as below the reporting limit, but equal to or greater than the method detection limit. In two wells, arsenic was detected above the detection limit (9.4 µg/L in RW03 and 30 µg/L in RW02). All of the arsenic detections in the seven private wells exceeded the ATSDR *cancer* health based CV (0.02 µg/L). In the Bradford County Devonian Lockhaven (Dlh) formation, the median arsenic concentration is 9 µg/L (USGS 1998).

The concentration of arsenic in RW03 (9.4 µg/L) is above one ATSDR health-based *non cancer* chronic CV for children (3 ppb child for non-cancer effects). For RW03, in the post-blowout sample the arsenic concentration was 9.4 µg/L, and in the pre-blowout sample arsenic was not found above the detection limit.

The concentration of arsenic in RW02 (30 µg/L) is above EPA's MCL (10 µg/L) and ATSDR's health-based *non cancer* chronic CVs for children and adults (3 ppb child; 10 ppb adult for non-cancer effects). Post-blowout (30 µg/L) and pre-blowout (29 µg/L) sampling results for arsenic in RW02 were very similar.

Barium:
Barium was detected in each of the seven wells, ranging from 180 µg/L to 2,600 µg/L. The maximum result detected (2,600 µg/L) exceeded ATSDR's chronic ingestion CV for a child (2,000 µg/L). In the Bradford County Dlh formation, the median barium concentration is 1,620 µg/L (USGS 1998).

Bromide:
Bromide was detected in five of seven wells ranging from 110 to 15,000 µg/L. Only well RW04, with a bromide concentration of 15,000 µg/L, would result in exceedances of the World Health Organization (WHO) acceptable daily intake (ADI) for children (weighing 10 kg and consuming 1 liter/day) and adults (weighing 70 kg and consuming 2 liters/day) (WHO 2009).

Calcium:
Calcium was detected in each of the seven wells, at concentrations ranging from 24,000-170,000 µg/L. Calcium is a natural constituent in water as well as a required nutrient. In the Bradford County Dlh formation, the median calcium concentration is 39,000 µg/L (USGS 1998). By itself (not accounting for other sources of calcium in food and drinks), the maximum calcium concentration detected (170,000 µg/L) would not result in calcium ingestion exceeding the upper tolerable intake level (UL) for this nutrient (IOM 1997).

Chloride:
Chloride was detected in each of the seven wells, at concentrations ranging from 8,600-1,900,000 µg/L. Chloride is naturally present in groundwater, particularly in deep bedrock aquifers. Background concentrations of chloride in drinking water wells are highly variable, ranging from less than 10 mg/L in some glacial aquifers to more than 500 mg/L in deeper bedrock wells. In the Bradford County Dlh formation, the median chloride concentration is 12,000 µg/L (USGS 1998). Chloride is an element found in most common salts, such as road salt, table salt, and water-softener salt (USGS 2004). EPA has set a SMCL of 250,000 µg/L for chloride. This limit is an aesthetic not health-based level. It was established because water with chloride concentrations greater than this level tastes salty to most people. The maximum

detected level in a residential well at this site (1,900,000 µg/L) exceeds the EPA SMCL and would result in exceedances of the UL of 3.6 g/day for individuals consuming 2 liters or more of this water per day (IOM 2005).

Iron:
Iron levels were detected in six of seven wells, ranging from 80 to 3,100 µg/L. In the Bradford County Dlh formation, the median iron concentration is 270 µg/L (USGS 1998). Three of the wells (RW02 at 550 µg/L, RW03 at 3,100 µg/L and RW04 at 600 µg/L) had iron levels exceeding the EPA SMCL of 300 µg/L.

Lithium:
Lithium was detected in all seven wells ranging from approximately 11 µg/L up to 1,900 µg/L. Two of the wells exceeded the EPA regional screening level (RSL) and PADEP medium-specific concentration (MSC) of 73 µg/L. Lithium concentrations in four wells (RW04, RW05, RW06, and RW07) exceed the child Reference Dose Media Evaluation Guide (RMEG) of 20 µg/L derived from EPA's provisional reference dose (RfD).

Magnesium:
Magnesium was detected in each of the seven private wells ranging from 3,600- 21,000 µg/L. In the Bradford County Dlh formation, the median magnesium concentration is 10,000 µg/L (USGS 1998). By itself, the maximum level of magnesium detected in all the drinking water samples would not result in a person (children and adults) exceeding the UL for magnesium, not accounting for other sources of magnesium in food and drinks.

Manganese:
Manganese was detected in each of the seven wells tested, ranging from 95 to 400 µg/L. All of the manganese detections in the seven private wells exceeded EPA's manganese SMCL (50 µg/L). In addition, the maximum detected level of manganese (400 µg/L, RW02) exceeds EPA's manganese health advisory level of 300 ug/L. None of the levels detected are above the EPA reference dose media evaluation guideline (RMEG) of 500 µg/L for children and 2,000 µg/L for adults. In the Bradford County Dlh formation, the median manganese concentration is 50 µg/L (USGS 1998).

Methane and Ethane:
Dissolved methane and ethane were detected in groundwater at this site. Dissolved methane was detected in five of the seven wells in concentrations ranging from 7.4 µg/L to 6,200 µg/L. Ethane was detected in one well at 2.6 µg/L. The methane concentration in RW04 increased approximately ten times post-blowout compared to pre-blowout. The methane concentrations in the other three wells for which pre-blowout comparison information is available are more variable. For example, for RW02 the methane result was 340 ug/L pre blowout and 120 ug/L post blowout. For RW03, methane was not detected in either sampling round. For RW06, methane was 440 ug/L pre blowout, and was found at 240 ug/L post blowout. There are no health based comparison values for consumption of methane and ethane in drinking water. For well water containing 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 to mitigate the potential buildup of methane gas. Methane concentrations below 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 (DOI 2001).

Potassium:
Potassium was detected in each of the seven wells tested, ranging from an estimated 1,200 µg/L to 13,000 µg/L. There is no CV for potassium in drinking water. In the Bradford County Dlh formation, the median potassium concentration is 1,100 µg/L (USGS 1998). Only RW04, at 13,000 µg/L, substantially exceeds this median background level for potassium.

Sodium:
Each of the seven wells had detections for sodium, ranging from 8,600 µg/L to an estimated 2,100,000 µg/L. Six of the seven wells had detections exceeding EPA's drinking water advisory level for individuals on a 500 mg/day sodium restricted diet (20,000 µg/L) and five of seven wells exceeded the median background sodium concentration (28,000 µg/L) in the Bradford County Dlh formation (U.S.G.S. 1998). The three highest detections were "K" qualified, indicating sodium is present, but the reported value is biased high and expected to be lower. Consuming water from residential well

RW04 would result in exceeding the UL for children and adults, not accounting for other sources of sodium in food and drinks.

Radiological Contaminants of Concern

Of the samples ATSDR determined to be above the required detection limits, only RW03 had an exceedance above a radiologic comparison value. RW03's gross alpha value in EPA's sampling was 24.3± 5.3 picocuries per liter (pCi/L), which exceeds EPA's MCL for gross alpha radiation of 15 pCi/L. EPA and PADEP's results differed for the gross alpha particle concentration in RW03 (EPA's result was approximately 8 times higher than the PADEP result). None of the wells included in this dataset exceeded EPA's 50 pCi/L screening value for beta emitters.

Public Health Implications of Exposure to Chemicals of Concern in Private Wells Near the Chesapeake ATGAS 2H Well Site

Exposure to environmental contamination cannot 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 data available to ATSDR at this time, the relevant pathway for analysis for residents near the Chesapeake ATGAS 2H Well Site is exposure to contaminants through ingestion of drinking water. A number of substances were found in nearby drinking water wells near the Chesapeake ATGAS 2H Well Site at levels that exceeded health-based comparison values (CV) or had no CV. These were labeled "chemicals of concern" (COC) and were investigated further.

For some of the naturally occurring substances (e.g., calcium and iron), information regarding the substance as a nutrient was employed to evaluate possible harmful effects associated with the substances. These evaluations typically considered the substance found in drinking water as nutrients, and focused the assessments around estimated dietary intakes. These assessments specifically utilized "adequate intake" levels (AI) and the tolerable upper intake levels (UL).

To evaluate potential public health implications for the contaminants of concern, exposure estimates are based on a daily intake of 2 liters of water/day and a 70 kg body weight for adults. For a child, two exposure doses were calculated, including (1) daily intake of 1 liter of water/day and a 16 kg body weight, and (2) daily intake of 1 liter/day and a 10 kg body weight. Due to the limited amount of data available, ATSDR conducted this evaluation assuming the concentrations detected would remain at these levels. Therefore, a chronic exposure evaluation along with an evaluation of potential acute exposure impacts was performed for these data. Table 3 provides a well by well summary of the chemical constituents of potential public health concern. The detailed review of potential health effects for all of the chemicals of concern follows.

Table 3
Well by Well Summary of Potential Public Health Concerns

	RW02	RW03	RW04	RW05	RW06	RW07
Arsenic	Cancer; Non-cancer (Child only)					
Iron	Sensitive sub-populations	Sensitive sub-populations	Sensitive sub-populations			
Lithium			Sensitive sub-populations	Sensitive sub-populations	Sensitive sub-populations	Sensitive sub-populations
Potassium			Sensitive sub-populations			
Sodium/ Chloride	Sensitive sub-populations	Sensitive sub-populations	Sensitive sub-populations	Sensitive sub-populations	Sensitive sub-populations	Sensitive sub-populations

Non-Radiological Contaminants of Concern

Arsenic:
Arsenic was detected in all seven wells. In five of the wells, low levels were found (0.73-4.2 µg/L) and qualified as below the reporting limit but equal to or greater than the method detection limit. In two wells, arsenic was detected above the detection limit: 9.4 µg/L in RW03 and 30 µg/L in RW02.

Arsenic Non Cancer Exposure Evaluation
The estimated exposure doses of both children and adults were compared to health guideline values to determine if the users of the well with the maximum level of arsenic (RW02 at 30 ug/L) were at risk for non-cancer health effects. ATSDR assumed that this exposure was ongoing because the pre-blow out sampling information available for this well indicated a similar concentration of arsenic (29 ug/L). The health guidelines used in this evaluation are based on studies of animals and humans exposed to arsenic. The information from these 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 safety factors to the LOAEL and the NOAEL to develop a non-cancer screening value called a minimal risk level (MRL). The MRL represents the daily dose of a chemical that people could be exposed to for a specified period of time without experiencing adverse health effects. There should be no risk for developing non-cancer health effects at an exposure dose less than the MRL. If the MRL is exceeded, further evaluation is needed to determine if health effects may occur. There could be concern if the estimated exposure dose approaches the LOAEL (within an order of magnitude).

ATSDR estimated an exposure dose for long term exposures for children and adults drinking water with the maximum arsenic concentration of 30 µg/L. The estimated exposure doses for an adult is 0.00086 mg/kg/day, for a 10 kg child is 0.003, and for a 16 kg child is 0.0019 mg/kg/day. The child’s exposure doses exceed the chronic minimal risk level (MRL) of 0.0003 mg/kg/day and the NOAEL (0.0008 mg/kg/day). The chronic MRL is approximately 47 times lower than the chronic LOAEL for arsenic (0.014 mg/kg/day) and approximately 3 times lower than the NOAEL (0.0008 mg/kg/day). These values are based on studies in Taiwan where people had long term exposure to high levels of naturally occurring arsenic in their drinking water. Skin thickening (hyperkeratosis) and discoloration (hyperpigmentation) occurred in people with an estimated exposure of 0.014 mg/kg/day.

At 30 ppb of arsenic, the adult exposure dose is approximately 16 times lower than the LOAEL and slightly above the NOAEL. Therefore, it is unlikely that an adult would experience non-cancer health effects from daily exposure to 30 ppb arsenic in drinking water. The estimated children’s exposure doses are approximately 4.5-7 times lower than the LOAEL and 2- 3.75 times above the NOAEL. Therefore, the exposure dose for children who drink 1 liter of water containing 30 ppb for durations over a year is approaching the LOAEL (as such a 16 kg child would need to drink >7 liters of water/day at 30 ppb arsenic to reach the LOAEL or at 0.5 L/day this estimated exposure dose is approximately at the NOAEL). ATSDR concludes that, because the estimated arsenic exposure doses for infant/children are within an order of magnitude of the LOAEL, children/infants drinking 1 liter of water/day with 30 ppb of arsenic for over a year are at an increased risk of non-cancer adverse health effects.

Arsenic Cancer Exposure Evaluation
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 arsenic-containing water. 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 one in a million chance of an additional cancer in a population (interpreted as a slight cancer risk). All of the April 2011 arsenic detections in the seven private wells at this site exceeded the ATSDR cancer health based guideline (CREG) for arsenic of 0.02 µg/L. Therefore, ATSDR conducted a cancer risk evaluation for the arsenic concentrations detected in these private wells to determine if drinking the water in these wells over many years could result in additional increased risks for cancer.

A theoretical cancer risk is estimated which is the number of additional cancer cases that would occur in a population, if they are exposed to a chemical at a specific level over a lifetime. These calculated values may not represent actual risk, but allows regulatory and public health officials a way to identify potential cancer risks. This hypothetical cancer risk is derived using an EPA cancer slope factor with the estimated exposure dose. Cancer risks are explained in terms of the likelihood that an additional case of cancer will occur in a population. As an example, one additional cancer case in 10,000 exposed individuals indicates that there is a low increased cancer risk.

A key parameter in estimating cancer risk is the EPA cancer slope factor, which, for arsenic, 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 dose from groundwater ingestion, an increased hypothetical risk of cancer can be derived for people drinking water every day for 30 years and 70 years. Using EPA's standard cancer risk evaluation methodology and the maximum measured arsenic concentration at this site in April 2011 (30 µg/L in RW02), a theoretical additional cancer risk of approximately 6 in 10,000 for 30 years of exposure and approximately 1 in 1,000 for 70 years of exposure can be derived. The estimated long term cancer risks at this maximum level of arsenic detected are considered to be unacceptable. People drinking water with arsenic at the next highest arsenic concentration detected at this site (9.4 ug/L in RW03) for 30 years of exposure would have a theoretical additional cancer risk of approximately 2 in 10,000, and for 70 years of exposure this would result in an estimated theoretical additional cancer risk of approximately 4 in 10,000. This can be considered within an acceptable cancer risk range. Further, given that arsenic was not found above the detection limit in the pre blowout result for this well, overall lifetime exposures to arsenic via this drinking water well would be less than assumed in this calculation. Lifetime exposure to the remaining even lower levels of arsenic found in the other wells sampled is not expected to result in unacceptable theoretical cancer risks.

Barium:
The estimated exposure dose from consuming the maximum concentration of barium detected in the residential wells (2,600 µg/L) for an adult is 0.074 mg/kg/day, for a 10 kg child is 0.260 mg/kg/day, and for a 16 kg child is 0.163 mg/kg/day.

Barium is a naturally occurring element and is found in most soils at concentrations ranging from about 15,000 to 3,500,000 µg/kg with mean values ranging between 265,000 and 835,000 µg/kg. 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. 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).

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 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). Barium carbonate often is 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 majority of studies evaluating the health effects of barium is 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. 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 has derived 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 and children weighing 16 kg, the estimated exposure doses to the maximum level of barium (2,600 µg/L) detected in the private wells at this site do not exceed the ATSDR MRLs or EPA RfD. For a 10 kg child, the estimated exposure dose (0.260 mg/kg/day) very slightly exceeds the MRL (0.2 mg/kg/day). ATSDR does not expect adverse non cancer health effects from this concentration of barium for children or adults.

Bromide:
Well RW04 has a bromide concentration (15,000 µg/L) exceeding the extrapolated WHO Acceptable Daily Intake (ADI) of 2,000 and 7,000 µg/L for children and adults, respectively. The estimated exposure doses from consuming water with the highest detected bromide concentration (15,000 µg/L) for an adult is 0.43 mg/kg/day, for a 10 kg child is 1.5 mg/kg/day, and for a 16-kg child is 0.94 mg/kg/day.

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. 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. This ADI of 0 - 1 mg/kg body weight was reaffirmed with new data in 1988 and in a subsequent second human study. A conservative no-observed-effect level (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 0.4 mg/kg body weight, including a safety factor of 10 for population diversity (WHO 2009). An ADI of 0.4 mg/kg body weight yields an acceptable total daily intake of 28 mg/day for a 70 kg person, 4 mg/day for a 10 kg child, and 6.4 mg/day for a 16 kg child. Assuming a relative source contribution of 50%, the drinking water value for a 70 kg adult consuming 2 liters/day would be up to 7,000 µg/L; for a 10 kg child consuming 1 liter/day, the value would be up to 1,000 µg/L; and for a16 kg child consuming 1 liter/day, the value would be up to 3,200 µg/L. However, the dietary bromide contribution for a child would probably be less than that for an adult.

With additional contributions of bromide from other sources including food, the total estimated daily intake of bromide from RW04 would exceed the WHO ADI for an adult and for 10 kg and 16 kg children, but is not expected to be above the conservative NOAEL of 4 mg/kg/day. Therefore, health effects are unlikely from this exposure. All other well results are at least one magnitude below the maximum value detected and bromide exposure from consuming these well waters are not expected to exceed the WHO ADI (or NOAEL) nor result in acute or chronic health effects.

Calcium:
Assessments of environmental exposures to nutrients such as calcium typically consider the estimated dietary intakes of the nutrient. These assessments utilize “adequate intake” levels (AI) and tolerable upper intake levels (UL). The AI for calcium is 1,000 mg/day for adults and 1,200 mg/day for those over 50 years of age. Using standard exposure inputs, the calcium UL would be exceeded when concentrations are greater than 2,500,000 and 1,250,000 µg/L, for children and adults, respectively (IOM 1997).

The estimated exposure intake for an adult drinking the maximum level of calcium detected in the well water at this site, at a concentration of 170,000 µg/L, is 340 mg/day. For a child (10 kg or 16 kg), the estimated exposure intake is 170 mg/day. The estimated daily intake for both adults and children is below the UL for calcium. Therefore, ingesting the calcium in the well water at this site is not likely to result in adverse health effects.

It is worth noting that elevated calcium intakes, such as involved with therapy use to treat osteoporosis, can result in a total calcium intake of 2,400 mg/day (IOM 1997). Some researchers suggest that daily intakes of 5 mg/day are commonly provided in dietary supplements and that a level of approximately 5 mg/day represents a LOAEL for total calcium intake. The LOAEL of 5 mg/day was based on the critical effects of kidney stone formation or milk-alkali syndrome (hypercalcemia and renal insufficiency) (IOM 1997). Individuals drinking well water containing elevated levels of calcium, and also taking calcium supplements, should discuss their calcium intakes with their physicians.

Chloride:
The cation sodium and the anion chloride are normally found in most foods together as sodium chloride, also termed salt. EPA has set a secondary Maximum Contaminant Level (SMCL) for chloride of 250,000 µg/L. Chloride was detected in each of the seven wells sampled by EPA. The maximum detected result in RW04 (1,900,000 µg/L) exceeds the EPA SMCL for chloride and would result in exceeding the UL of 3.6 g/day for individuals consuming 2 liters or more of this water per day (IOM 2005). All other drinking water chloride results are below the EPA SMCL and would not result in exceeding the UL for adults or children.

The Institute of Medicine has established an acceptable intake (AI) for chloride at a level equivalent on a molar basis to that of sodium, since almost all dietary chloride comes with the sodium added during processing or consumption of foods. The AI for chloride for young children is 1.5 g/day or 1,500 mg/day, for younger adults is 2.3 g/day or 2,300 mg/day, and for older adults and the elderly, the AI is 2,000 and 1,800 mg/ day respectively (IOM 2005).

The estimated exposure intake for an adult drinking two liters per day of water with the maximum level of chloride detected at this site (1,900,000 µg/L) is 3,800,000 µg/day, or 3,800 mg/day. For children (10 kg and 16 kg) consuming one liter of water per day, the estimated exposure intake is 1,900 mg/day. For adults and young children, the estimated daily chloride intake from consuming water from the well with the maximum detected concentration exceeds the AI.

The major adverse effect of increased sodium chloride intake is elevated blood pressure, which has been shown to be an etiologically related risk factor for cardiovascular and renal diseases. On average, blood pressure rises progressively with increased sodium chloride intake. The dose-dependent rise in blood pressure appears to occur throughout the spectrum of sodium intake. However, the relationship is nonlinear in that the blood pressure response to changes in sodium intake is greater at sodium intakes below 2.3 g (100 mmol)/day than above this level. While blood pressure, on average, rises with increased sodium intake, there is well-recognized heterogeneity in the blood pressure response to changes in sodium chloride intake. Individuals with hypertension, diabetes, and chronic kidney disease, as well as older-age persons and African Americans, tend to be more sensitive to the blood pressure-raising effects of sodium chloride intake than their counterparts. Genetic factors also influence the blood pressure response to sodium chloride. The adverse effects of higher levels of sodium intake on blood pressure provide the scientific rationale for setting the Tolerable Upper Intake Level (UL). Because the relationship between sodium intake and blood pressure is progressive and continuous without an apparent threshold, it is difficult to precisely set a UL, especially because other environmental factors (weight, exercise, potassium intake, dietary pattern, and alcohol intake) and genetic factors also affect blood pressure. For adults, a UL of 2.3 g (100 mmol)/day is set. It is well-recognized that the current intake of sodium for most individuals in the United States and Canada greatly exceeds both the AI and UL (IOM 2005). The high concentration of chloride detected in residential well RW04 and the elevated chloride concentrations in wells near the Chesapeake ATGAS 2H well may be of health concern for individuals on sodium chloride restricted diets. Individuals drinking water with elevated sodium chloride levels should consult their physician to discuss these elevated levels in their drinking water.

Iron:
Iron is a required nutrient, and levels in well water are typically in the range of 10-250 µg/L. The recommended AIs 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 UL is 45 mg/day (IOM 2001).

Iron was detected in three of the seven wells sampled, with the highest level at 3,100 µg/L. Three of the wells with iron detections exceeded the CV of 300 µg/L (EPA SMCL). Drinking water from the well with the highest level of iron would add approximately 6.2 mg of iron to an adult's daily diet and add approximately 3.1 mg of iron to a 10-16 kg child's daily diet. These increased intakes of iron are not likely to result in adverse health effects in healthy residents. It should be noted that a disease called hemochromatosis is associated with iron overload in a small percentage of persons. If 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.

Lithium:
In EPA's sampling near the Chesapeake ATGAS 2H Well Site, lithium was detected in all seven wells ranging from 11 to 1,900 µg/L. Two of the wells exceeded the EPA regional screening level (RSL) and PADEP medium-specific concentration (MSC) of 73 µg/L. EPA has derived a provisional lithium reference dose (RfD) of 0.002 mg/kg-day. This provisional reference dose is based on a Lowest Observable Adverse Effect Level (LOAEL) of 2.1 mg/kg-day for adverse effects in several organs and systems. EPA applied an uncertainty factor of 1000 in determining the RfD, which includes a factor of 10 to extrapolate from a LOAEL to a NOAEL, a factor of 10 to protect susceptible individuals and a factor of 10 to account for database insufficiencies (EPA 2008). Using this 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. Four of the wells (RW04, RW05, RW06, and RW07) are above the lowest child RMEG of 20 ug/L and two wells (RW04 and RW06) are above the adult RMEG of 70 ug/L.

A wide range of estimates for daily dietary intake of lithium have been 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 daily dietary intake range of up to 33 to 80 µg Li/kg-day (EPA 2008). Based on the ranges of lithium detected in the seven wells, ATSDR calculated adult exposure doses of 0.000314 to 0.0543 mg/kg/day and daily intakes of 0.022 to 3.8 mg lithium/day. For a 10 kg child, the range of lithium exposure doses from these wells is 0.00110-0.190 mg/kg/day with daily intakes of 0.011-1.9 mg lithium/day. For a 16 kg child, the range of lithium exposure doses from these wells is 0.00069-0.119 mg/kg/day with daily intakes of 0.011-1.9 mg lithium/day. Therapeutically, lithium (lithium carbonate) is used to control manic episodes in manic-depressive illness in doses of 900 - 1,800 mg/day. The estimated lithium intakes at the maximum concentrations at this site are well below reported therapeutic levels.

There is a great deal of uncertainty regarding the public health significance of environmental exposures to sub-therapeutic doses of lithium. Numerous pharmacokinetic studies of lithium have reported large inter-individual variability in response to lithium administration. 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. In general, lithium demonstrates a narrow therapeutic-toxic ratio and can induce adverse health effects, if slight changes in dosing or elimination occur. There are several groups of drugs that interact with lithium causing increased levels of lithium in the serum. These include diuretics (e.g., Hydrodiuril), nonsteroidal anti-inflammatory agents (e.g., Motrin), calcium channel blocking agents (e.g., Calan), and angiotensin-converting enzyme inhibitors (e.g., Capoten). The concurrent use of any drug associated with the aforementioned groups would increase the likelihood of toxic manifestations (PADOH 1994).

Some of the signs of lithium toxicity include diarrhea, vomiting, tremors, mild ataxia, drowsiness, or muscular weakness. Thyroid impairments have been observed in individuals receiving lithium therapy (Grandjean and Aubry 2009; Lazarus 2009), and possible thyroid effects from lithium in drinking water have been reported (Broberg et al. 2011). 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 (EPA 2008).

Using the maximum concentration of lithium (1,900 ppb) detected in RW04, the ingestion exposure exceeds EPA's provisional chronic RfD for children and adults. Given the safety factors employed in developing the provisional RfD, ATSDR concludes that exposure to lithium at the level detected in RW04 is not likely to cause adverse health effects to the general population. However, this maximum drinking water concentration would be of health concern for any individuals receiving lithium therapy, and there remains uncertainty regarding the potential for health effects of elevated but sub-therapeutic doses of lithium, particularly for sensitive subpopulations (e.g., children, pregnant women, people with significant cardiovascular disease, sodium depletion, and people on medications previously discussed).

Lithium is not routinely sampled for in inorganic drinking water analyses. ATSDR believes that given the trend of increasing lithium concentrations as observed in an industry flow-back water study (GTI 2009) and the suggestive impacts on lithium concentrations in RW04, lithium sampling should be included in future environmental sampling events related to hydraulic fracturing.

Magnesium:
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).

The median magnesium concentration in the Devonian LockHaven formation (Dlh) in Bradford County is 10,000 µg/L (USGS 1998). Magnesium was detected in three of seven residential wells sampled in this investigation. The highest level of magnesium detected was 21,000 µg/L. At this concentration the estimated daily intake for adults is approximately 42 mg/day, and for children (10 or 16 kg) this is 21 mg/day. The estimated daily intakes of magnesium due to drinking the maximum level detected in the wells near the Chesapeake ATGAS 2H Well Site are below the daily intakes of magnesium associated with gastrointestinal discomfort in children and adults. Therefore, the magnesium in the drinking water wells is not likely to result in adverse health effects.

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. Manganese can be found in groundwater as a result of its use in the production of batteries, pesticides, and fertilizers. The average levels of manganese in drinking water have been reported to range from approximately 4 µg/L to 32 µg/L (ATSDR 2008).

The maximum concentration of manganese in water from the residential wells at this site was reported at 400 µg/L, which using standard drinking water exposure assumptions for a 10 kg and 16 kg child results in a manganese dose of approximately 0.4 mg/day, and for an adult results in a manganese dose of 0.8 mg/day.

Although the concentration of manganese in the water is greater than the EPA's secondary drinking water standard for this contaminant (50 µg/L), this standard was set for aesthetic reasons and is not health based. This concentration exceeds EPA's health advisory level for manganese of 300 ug/L.

Manganese is an essential dietary nutrient. The World Health Organization (WHO) has estimated the average dietary intake of manganese to range from approximately 2 to 8.8 mg/day. The Food and Nutrition Board of the National Research Council has established "estimated safe and adequate daily dietary intake levels" for this nutrient that range from 0.3 mg/day for infants to 5 mg/day for adults (see Table4) (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. EPA has estimated that the typical human intake of manganese from food is 3.8 mg/day (ATSDR 2008).

At the maximum manganese concentration detected in a private well at this site, it is possible that these tolerable upper intake levels could be exceeded depending on the levels of other dietary sources of manganese.

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 > 11 years and Adults	2.0 to 5.0 mg/day

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

Excess exposure to manganese can be harmful to human health. It is not known whether eating or drinking too much manganese can cause manganism. There is one study indicating a statistically significant difference in neurologic test scores between people from one area with high levels of manganese in well water compared with people from another area with low levels of manganese in well water. The concentration of manganese in the water from the high concentration area ranged from 1.8 to 2.3 mg/L; however, because of other limitations this study could not be used to determine a quantitative dose response relationship for the toxicity of manganese in humans. In another report, a group of six Japanese families exposed to manganese in their well water at concentrations of approximately 14 mg/L developed manganism like symptoms (ATSDR 2008).

Although no MRLs or RfDs have been established for manganese, ATSDR has used the upper range of the Estimated Safe and Adequate Daily Dietary Intake Levels (ESADDI) for manganese of 5 mg/day to establish an interim guidance value of 0.07 mg/kg/day [(5 mg/day) /(70 kg)]. Using the maximum reported concentration of manganese at the site, an adult would have to drink more than 12 liters of water per day before exceeding the interim guidance level. It should be noted that the interim guidance is 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. The estimated exposure doses to the maximum level of manganese detected in the private wells at this site are not expected to result in adverse health effects.

Methane and Ethane:
The health risk from these light gases in drinking water is posed by their explosive and asphyxiant hazards. Methane is odorless and tasteless. EPA detected dissolved methane (6,200 µg/L maximum value) in the water of five residential wells and ethane (2.6 µg/L maximum value) dissolved in the water of one residential well sampled at this site. Methane is a simple asphyxiant (at around 87% by volume, or approximately 581,000 µg/L). Asphyxiants displace oxygen from air primarily in enclosed spaces. This can result in insufficient oxygen in the blood. Methane exposure can also produce symptoms of central nervous depression including nausea, headache, dizziness, confusion, fatigue, and weakness. Methane's lower explosive limit (LEL) is 5% and the upper explosive limit (UEL) is 15%. Methane levels below 5% by volume in air and above 15% by volume in air are not explosive (NLM 2005).

In the private well sampling at this site, EPA did not detect measurements of *dissolved* methane or ethane in the samples above the lower explosive limit (LEL) for each compound. The presence of dissolved methane at 6,200 µg/L together with ethane at 2.6 µg/L in well RW04 suggests the groundwater has been impacted by natural gas.

Potassium:
Potassium is an essential nutrient and adults in the U.S. typically consume 2.8 to 3.3 g of potassium/day. The potassium AI for adults is 4.7 g/day. There is no UL for potassium, because there is no evidence that food can supply an excessive level of potassium. Initial gastrointestinal discomfort with potassium supplements is seen with intake rates of 1.6 to 2.3 g/day. One study added 5.6 g/day to diets of adults without altering normal-range producing plasma sodium concentrations (IOM 2005). The median level of potassium in the Bradford County area Devonian Lock Haven formation groundwater is 1,100 µg/L (USGS 1998). It was detected in three of seven wells sampled in this investigation.

The highest level of potassium detected in residential wells during this investigation near the Chesapeake ATGAS 2H Well was 13,000 µg/L. At this concentration, the estimated daily intake for adults is approximately 26 mg/day and for children (10 or 16 kg) is 13 mg/day. This level of supplemental potassium that could be ingested in the Chesapeake ATGAS 2H Well site area drinking water is well below the typical daily intake for adults in the U.S., and is not likely to be associated with adverse health effects for healthy people. However, the maximum level of potassium seen in RW04 at this site 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.

Sodium:
The median sodium concentration in the Bradford County Dlh formation is 28,000 µg/L (USGS 1998). Sodium levels in surface and ground waters can be affected by human activities. The extent to which any of these activities may affect the groundwater quality in the area of the Chesapeake ATGAS 2H Well Site is unknown. Sodium was detected in all of the residential wells sampled by EPA at this site, ranging from 8,600 ug/L to 2,100,000 ug/L.

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. The UL for sodium in adults is 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.

Adults consuming water from well RW04, with an estimated dose of 4,200 mg/day, would exceed the HHS/USDA recommended dietary guideline for general and sensitive populations of 2,300 mg/day from their drinking water consumption alone. Consuming water from this well would also exceed the UL for sodium of 1,500 mg/day for young children (1-8 years old) and 2,300 mg/day for adults (14+ years old). This intake does not include sodium intake from other sources including food, which is the primary source of sodium in our diet.

If adults have a daily intake of water with a sodium concentration of 8,600 to 2,100,000 µg/L, those residents would consume approximately 17 to 4,200 mg of sodium per day in addition to the sodium contained in food. If residents use water softeners, the sodium level consumed by drinking water could be even higher. Thus, in addition to the sodium consumed with food, drinking RW04 well water with the highest levels of sodium detected at the site (2,100,000 ug/L) would result in sodium intake above the recommended HHS/USDA recommended level and the ULs for children and adults, and is of health concern for sensitive populations. The next highest residential well sodium concentration was more than 10 times lower (RW06 at 120,000 ug/L) than the maximum detected concentration in RW04. Exposures to sodium in all other residential wells sampled are not expected to result in adverse health effects, unless users are on sodium restricted diets or are otherwise sensitive populations for sodium consumption.

Radiological Contaminants of Concern:

EPA's MCL for gross alpha radiation is 15 pCi/L, which is legally enforceable and used to screen public water supplies for radioactivity levels. If the MCL is exceeded, then additional steps must be taken to determine the source of the elevated gross alpha radiation. Some people who drink water containing alpha emitters in excess of the MCL for many years may have an increased risk of developing cancer. ATSDR's chronic MRL for non cancer and cancer health effects from ionizing radiation is 100 mrem per year. The population is simultaneously exposed to radiation through oral, inhalation, and external routes of exposure, and ATSDR's chronic MRL is applicable to the cumulative exposure by all routes. ATSDR's Toxicological Profile for Ionizing Radiation refers to average annual effective dose to the U.S. population of 360 mrem/year, which is obtained mainly by naturally occurring radiation from external sources, medical uses of radiation, and radiation from consumer products. This annual dose of 360 mrem/year has not been associated with adverse non cancer health effects or increases in the incidences of any type of cancers in humans or other animals (ATSDR 1999). With the expanding use of nuclear medical procedures, estimates of average annual effective doses in the U.S. are increasing. The National Council on Radiation Protection and Measurements estimated more recently that the effective dose per individual in the U.S. population is now approximately 620 mrem/year (NCRP 2009).

ATSDR developed its chronic ionizing radiation MRL of 100 mrem/year using the 360 mrem/year level, after applying an uncertainty factor of three for human variability (ATSDR 1999). The estimated radiation dose from consuming two liters of water per day at EPA's MCL for gross alpha radiation in drinking water is substantially lower than ATSDR's chronic ionizing radiation MRL. Therefore, based on the information available from EPA's single groundwater sampling round, adverse health effects are not expected from drinking groundwater in RW03 with a gross alpha radiation level slightly above EPA's MCL. Because EPA and PADEP's alpha particle radiological sampling results differed for RW03, future sampling will assist in determining the alpha particle radiological concentrations in this well. If well users wish to reduce their exposures to these radiological constituents, gross alpha radiation is easily removed by properly maintained water softeners.

Water Quality Changes in RW04

Post-blowout sampling results for residential drinking water well RW04 are notably higher than pre-drilling sampling results. Pre-drilling samples were collected approximately six months prior to any drilling activities at the Chesapeake ATGAS 2H Well Site. The methane concentration in residential well RW04 increased approximately 10-fold compared to the pre-drilling concentrations. This 10-fold increase in methane was accompanied by the presence of ethane along with approximately 10-fold increases in barium, calcium, chloride, magnesium, manganese, potassium, and sodium and a 7-fold increase in iron. An evaluation of the purge volumes and corresponding analytical data appears to rule out changes in purge volume as the sole cause of the highly increased concentrations of salts and methane in this well in April/May 2011 and the return to pre-drill water quality in July 2011. The available information instead suggests that some event occurred between the baseline data sampling date of July 15, 2010 and the April 27, 2011 sampling event that produced the changes in water quality. Interpretation of the information in the SAIC (2011) report and the available baseline sampling data for RW04 is complicated by several factors, including: (1) different purge volumes were employed at each sampling event at this well; and (2) the field temperature measured at the baseline sampling was higher than all other sampling temperatures, indicating the baseline sample may not have been collected following standard operating procedures. It is unclear at this time why the levels in RW04 changed between the pre-drilling and post-blowout sampling events. Table 5 provides a comparison of purge volumes and well water quality for pre-drilling and post-drilling sampling dates at RW04.

Table 5
Comparison of Selected Purge Volume, Specific Conductivity, Methane, Chloride, Sodium and Strontium in RW04

Sample Date	Purge volume (gallons)	Laboratory Specific conductivity (µmhos/cm)	Methane (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Strontium (mg/L)
July 15, 2010 (pre-drill)	15	704	0.763	116	132	NA
April 20, 2011	39	6,160	5.87	1,750	1,120	9.09
April 27, 2011	75	7,530	8.18	1,900	2,100	14.9
May 14, 2011	30	6,170	4.97	778	1,080	8.23
July 6, 2011	350	838	0.38	151	159	0.625

Source: (SAIC 2011)
Note: NA = Not available

Further evaluation at this site is needed to characterize any relationship between the aquifers and drinking water wells under different operating scenarios at the well site or as a result of other changes in site conditions. It appears that the available data in the various reports concerning pre-drilling and post-blowout monitoring of RW04 well are inconclusive with regard to the source of elevated organic and inorganic constituents (post-blowout).

The homeowner of RW04 has stated to EPA and ATSDR that the well driller found water with higher salt content at the bottom of the residential well when it was originally drilled, and the available sampling data verify that the deepest fracture at approximately 172 feet below ground surface in RW04 has a water quality signature that is markedly different than the water in the fractures above it. Sodium, chloride, total dissolved solids, and methane concentration levels are all greater than those found in other well intervals isolated during the packer testing and the baseline sample. The SAIC report hypothesizes that post blowout increases in groundwater contaminants from RW04 are due to a high purge volume preceding the post blowout sampling and selective groundwater intrusion from the high salt (172-174 ft. depth) zone. Using this hypothesis, in August 2011 Chesapeake sealed the lower portion of the well to reduce exposure to the higher contaminant concentrations.

Available data from the SAIC report contradict this hypothesis about selective saltwater intrusion into RW04, including: (1) analysis of purge volumes and effects on water quality parameters (e.g., on July 6, 2011, the most water was purged of any of the sampling events – however, specific conductivity, methane, chloride and sodium levels are again consistent with the concentrations determined from the July 15, 2010 baseline sampling event when the least water was purged); and (2) statements about the relative contributions of groundwater to the well from fractures at various depths, particularly at 172 feet below ground surface (e.g, statements about inflow of salt water in the body of the report versus the finding of possible visible outflow at 172' as reported in actual borehole geophysical logging report in Appendix B). Further, the methane concentrations found at this site need to be considered. It appears that methane was less than 1 mg/l in RW04 prior to the drilling of the ATGAS well. Methane concentrations were at 2 mg/l or less for the shallower packed intervals and the baseline sample and slightly above 8 mg/l in the deepest interval tested after drilling was conducted. No discussion of the significance of the methane levels is presented in the SAIC report.

The SAIC report focuses on the question of whether RW04 was impacted by the ATGAS 2H well incident (the well blowout and uncontrolled flowback release in April 2011). ATSDR agrees with the SAIC report to the extent that the data currently available do not appear to support the conclusion that contaminants from the uncontrolled flowback release (surface overland flow) caused impacts to RW04. The SAIC report does not discuss the potential for impacts to well RW04 from other natural gas activities, including drilling activities and hydraulic fracturing. Therefore, the ultimate source of the elevated groundwater contaminants has not been conclusively determined and it is unknown whether the completed well remediation will improve water quality. If there is a problem related to the integrity of the ATGAS 2H well and communication with fractures in the drinking water aquifer, modifications to the RW04 well will not resolve the potential issues for local groundwater quality. ATSDR finds that the currently available data and information for RW04 do not conclusively indicate, but suggest that the groundwater near this site is impacted by natural gas activities. EPA is conducting further investigations at this site.

Interim Steps Currently in Place

EPA and ATSDR met with the private well owners sampled near this site, and discussed the findings in each well with each family.

EPA and ATSDR informed the residential property owner of well RW04 that barium, bromide, calcium, chloride, iron, lithium, magnesium, manganese, potassium, and sodium are elevated in their groundwater. The residential property owner informed EPA and ATSDR that Chesapeake Energy provided an alternate drinking water source via an on-site water buffalo at their residence. Additionally, the resident noted that Chesapeake Energy is building a reverse osmosis system to treat their well water for future use.

EPA and ATSDR informed the residential property owner of RW02 that their well water has an elevated arsenic concentration. EPA initially supplied bottled water to the residence with maximum level of arsenic detected (RW02), and recently installed a point of use filter at this residence.

EPA decided to provide bottled water to the residence with a slight exceedance of EPA's MCL for gross alpha radiation (RW03) action until further testing and source evaluation is completed.

Follow up environmental sampling is being conducted at this site by PADEP, Chesapeake, and EPA. EPA will participate in the additional groundwater sampling at the private wells closest to the well site.

Conclusions

1. The available environmental data and information for RW04 do not conclusively indicate but suggest that the groundwater near this site is impacted by natural gas activities. EPA is conducting further investigations at this site. Post-blowout sampling results for a number of analytes in drinking water well RW04 are notably higher than pre-blowout sampling results. Pre-blowout samples were collected approximately six months prior to any drilling activities at the Chesapeake ATGAS 2H Well Site. The methane concentration in residential well RW04 increased approximately 10-fold compared to the pre-blowout concentrations. This 10-fold increase in methane was accompanied by the presence of ethane along with approximately 10-fold increases in barium, calcium, chloride, magnesium, manganese, potassium, and sodium and a 7-fold increase in iron. It is unclear at this time why the levels in RW04 changed between the pre- and post-blowout sampling events. The available information indicates that the overland release following the ATGAS 2H incident did not appear to cause the water quality impacts observed in RW04. Further evaluation at the site is needed to characterize any relationship between the aquifers and drinking water wells under different operating scenarios at the well site or as a result of other changes in site conditions.

2. Adults consuming water from well RW04 would exceed the recommended dietary guideline for sodium for general and sensitive populations and the tolerable upper intake level for young children and adults. This exceedance does not include sodium intake from food, which is the primary source of sodium in our diet. Consuming water from the additional residential wells at this site with elevated sodium levels may also be of health concern to sensitive subpopulations, including individuals on sodium-restricted diets. Based on the maximum concentrations measured from the seven private wells, it is unlikely that children or adults would be exposed to individual levels of inorganic salts, such as barium, calcium, magnesium, manganese, and/or potassium, at levels that would result in adverse health effects.

3. The maximum level of arsenic detected in a well at this site (30 µg/L in RW02) would result in an unacceptable cancer risk over a lifetime of exposure. Exposure to the maximum arsenic levels detected in private wells at this

site would be unlikely to produce adverse non cancer health effects in adults; children who drink water at 30 ug/L arsenic for durations over a year could be at an increased risk for non-cancer health effects.

4. Bromide was detected in RW04 at the World Health Organization (WHO) acceptable daily intake criteria for adults. A comparable guideline for bromide consumption in children is not available. Unless users of RW04 well had unusually high additional sources of bromide exposure beyond their well water (i.e., food), ATSDR expects that this exposure level likely did not produce adverse health effects in users of this well water.

5. In RW04 and RW06, lithium was detected at a level exceeding the EPA Regional Screening Level and the Pennsylvania Medium Specific Concentration. The estimated lithium exposures could be of concern to individuals currently undergoing lithium therapy because lithium demonstrates a narrow therapeutic-toxic ratio and can induce adverse health effects, if slight changes in plasma levels occur. There are several groups of drugs that interact with lithium causing increased levels of lithium in the serum. The concurrent use of certain drug classes, including diuretics, nonsteroidal anti-inflammatory agents, calcium channel blockers, and angiotensin-converting enzyme inhibitors, could increase the likelihood of toxic manifestations. There is insufficient toxicological information available to determine the significance of these lithium exposures for individuals not undergoing lithium treatment.

6. Based on the maximum concentrations measured in wells RW01, RW03, RW05, RW06 (with the exception of lithium), and RW07 in April 2011, ATSDR does not expect health effects for the users of these private wells.

7. Based on the information available from EPA's single groundwater sampling round, adverse health effects are not expected from drinking groundwater in RW03 with a gross alpha radiation level slightly above EPA's MCL.

Recommendations and Next Steps

1. ATSDR supports actions to mitigate exposures to impacted groundwater from RW04. Chesapeake is installing a whole house reverse osmosis treatment system on RW04, and has been providing potable water in the interim. In addition, Chesapeake sealed the lower portion of the well. ATSDR recommends pre- and post-filtration water sampling of RW04 to determine whether the groundwater chemicals have remained elevated and whether the treated water is removing chemical parameters as predicted. ATSDR recommends that pre- and post- filtration system sampling results be shared with public health authorities.

2. ATSDR supports actions to mitigate exposures to the elevated levels of arsenic in RW02. EPA initially supplied bottled water to the residence with maximum level of arsenic detected (RW02), and recently installed a point of use filter at this residence.

3. EPA decided to provide bottled water to the residence with a slight exceedance of EPA's MCL for gross alpha radiation (RW03), and is continuing to provide bottled water to this residence until further testing and source evaluation is completed. ATSDR supports this action as a precaution until more information is available, however, ATSDR does not expect adverse health effects from the radionuclide levels detected in this private well.

4. ATSDR recommends that further sampling of the residential wells near this site be conducted to determine the current impacts to the local groundwater, to identify trends in chemical constituents, and to better assess chronic exposures to groundwater constituents related to natural gas drilling and hydraulic fracturing activities. Further evaluation at the site is needed to characterize any relationship between the aquifers and drinking water wells under different operating scenarios at the well site or as a result of other changes in site conditions.

5. ATSDR recommends that future environmental assessment at natural gas hydraulic fracturing sites in the Marcellus Shale formation address the following:

a. Environmental exposure pathways in addition to groundwater should be included (e.g., fish in potentially impacted surface water bodies, livestock consuming potentially impacted surface water, air).
b. In addition to the parameters commonly monitored and sampled in groundwater, ATSDR recommends that methane, ethane, lithium, strontium, and radiological parameter sampling should be included in "pre drilling" and "post drilling" private groundwater sampling events.
c. Head space gas monitoring for methane and ethane and other volatile organic compounds should be conducted.
d. Drinking water should be tested for radon (and indoor air should be tested for radon). Many areas of Pennsylvania have elevated levels of naturally occurring radioactivity, including radon. Radon testing information would permit a more comprehensive consideration of total radioactive dose from gross alpha radiation for these locations. A more detailed future analysis of the water would confirm if radiation levels are elevated, and if so if this is due to naturally occurring radioactive material or technologically enhanced naturally occurring radioactive material.

6. ATSDR recommends that all private groundwater well users sample their wells for biological, chemical and physical parameters at least annually, especially those in close proximity to natural gas drilling activities.

Public Health Action Plan

[Updated as of October 2013] Follow up environmental sampling was conducted at this site by PADEP, Chesapeake, and EPA. PADEP collected surface water and fish samples from the site area. EPA participated in the additional groundwater sampling at the private wells closest to the well site, and shared these results with ATSDR. Chesapeake officials shared their final site reports with ATSDR as well. ATSDR reviewed this additional sampling information, and discussed these results with EPA and the individual residents, as needed.

ATSDR will continue to answer questions from community members as needed. ATSDR will provide consultation with individual health professionals as requested.

ATSDR will work with PADOH to promote health education outreach related to air, water, and biota exposures related to natural gas hydraulic fracturing activities as needed. In particular, ATSDR will consider general health professional outreach to address sensitive subpopulations and a potential additive exposure related to lithium in private groundwater supplies.

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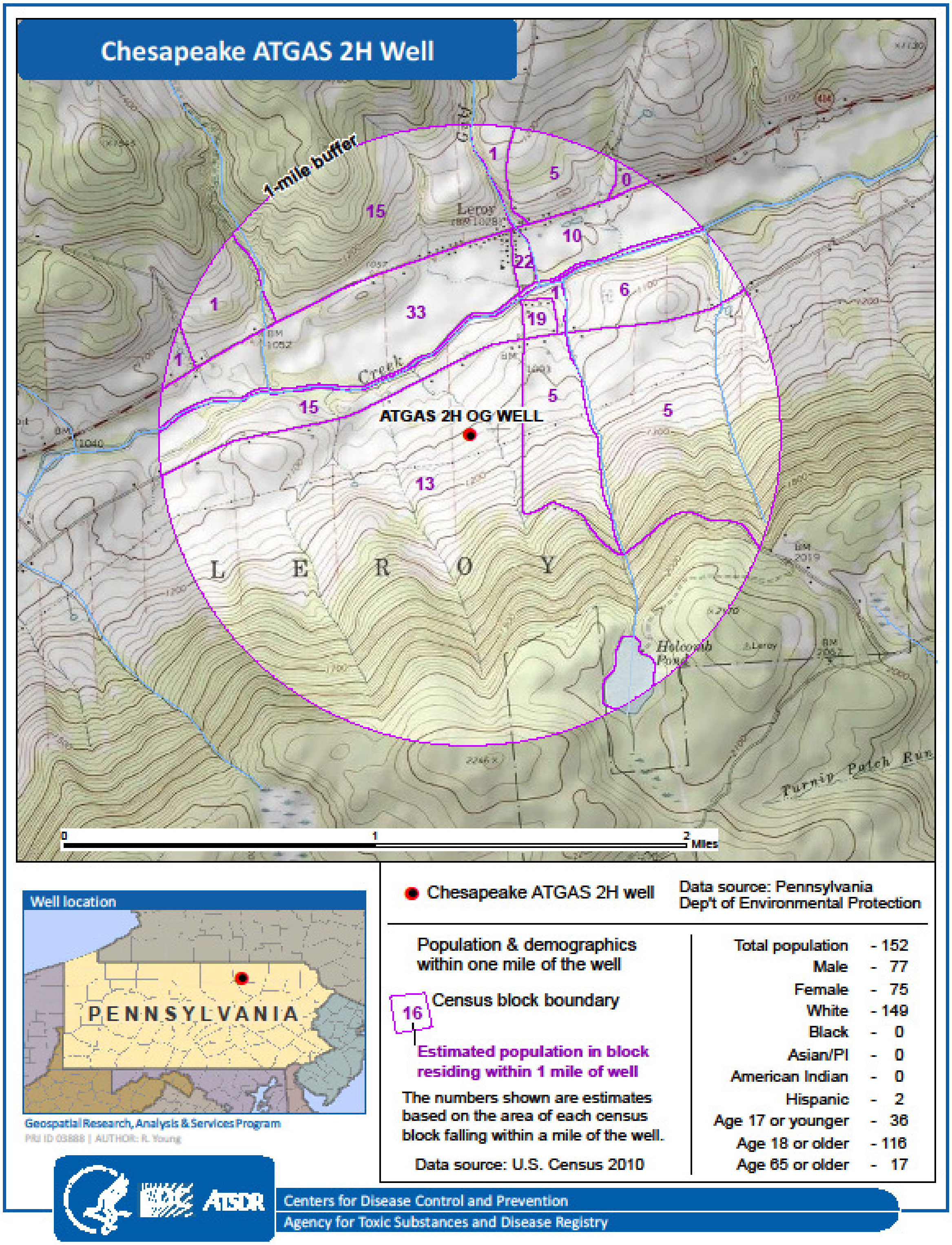
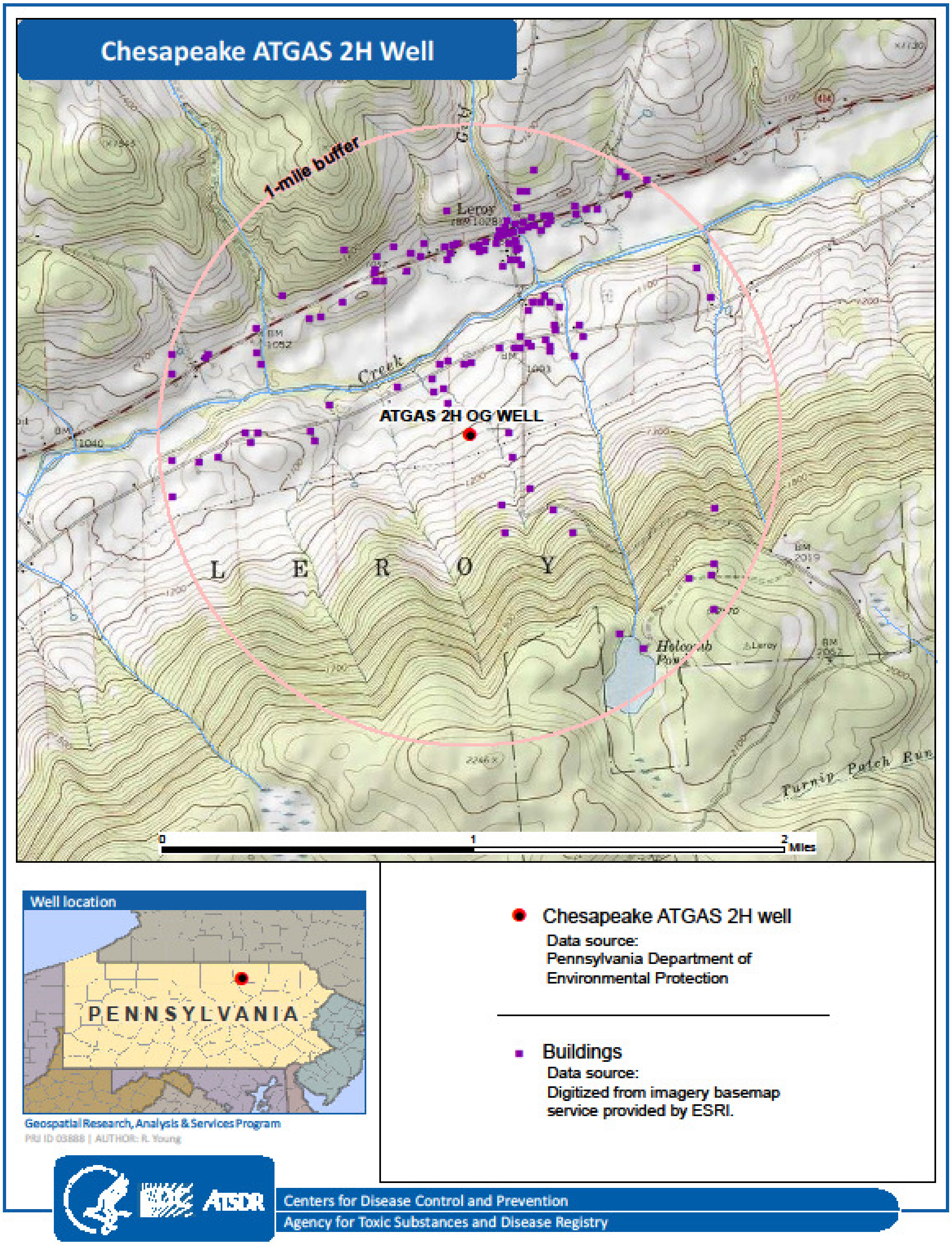
Appendix A. Chesapeake ATGAS 2H Well Site Location and Demographics Information



Appendix B. Buildings Near the Chesapeake ATGAS 2H Well Site



Appendix C. Summary of All Non-Radiological Chemical Detections in EPA April 2011 Sampling of Residential Private Wells Post-Chesapeake ATGAS 2H Well Site Blowout

Analyte	Blank	RW01	RW02	RW03	RW04	RW05	RW06	RW07	
Methane		ND	120	ND	6,200	7.4	240	17	Organics
Ethane		ND	ND	ND	2.6	ND	ND	ND	
HEM	2,900 b	1,700 B	2,200 B	1,700 B	3,200 B	1,300 B	2,800 B	2,100 B	
Tetrachloroethene		ND	ND	ND	ND	ND	ND	0.36 J	
Aluminum	ND	ND	ND	2,400	ND	ND	ND	ND	Inorganics
Antimony	ND	ND	ND	0.11 J	0.085 J	ND	ND	ND	
Arsenic	ND	0.73 J	30	9.4	1.8 J	2.1 J	4.2 J	2.1 J	
Barium	ND	180	370	220	2,600	200	660	250	
Beryllium	ND	ND	ND	0.14 J	ND	ND	ND	ND	
Cadmium	ND	ND	ND	0.043 J	0.090 J	ND	ND	ND	
Calcium	ND	76,000	43,000	40,000	170,000	29,000	26,000	24,000	
Chromium	ND	ND	ND	2.4	ND	ND	ND	ND	
Cobalt	ND	0.062 J	0.030 B	1.1	0.10 J	0.019 J	0.039 B	0.026 J	
Copper	ND	20	ND	12	2.9 J	ND	8	ND	
Iron	ND	ND	550	3,100	600	170	80 J	190	
Lead	ND	0.48 J	0.20 J	1.7	ND	ND	0.60 J	0.66	
Lithium	ND	13	11 L	17	1,900	38	87	60	
Magnesium	ND	12,000	6,000	4,200	21,000	5,400	3,600	3,900	
Manganese	ND	200	400	130	260	130	95	110	
Nickel	ND	0.70 J	0.35 J	3.5	1.1 J	ND	1 J	ND	
Potassium	240 B	1,500 J	1,700 B	1,700 J	13,000	1,200 J	1,900 B	1,200 J	
Silver	ND	ND	0.026 B	ND	0.038 B	ND	ND	ND	
Sodium	320 B	8,600	46,000 K	22,000	2,100,000 K	56,000	120,000 K	74,000	
Strontium	ND	220	610	380	15,000	1,100	1,100	1,000	
Thallium	0.020 B	0.032 B	ND	0.047 B	0.030 B	ND	0.020 B	ND	

Analyte	Blank	RW01	RW02	RW03	RW04	RW05	RW06	RW07	
Uranium	ND	5.1	2.9	9.3	0.023 B	0.049 J	0.14 J	0.16 J	
Vanadium	ND	ND	ND	5.4	0.17 J	ND	ND	3.9 J	
Zinc	ND	5.4 J	ND	15	2.7 J	ND	5.8 J	ND	
Total Phosphate	ND	ND	27 J	120 J	ND	ND	ND	16 J	Water Quality
Bromide	ND	ND	120 J	ND	15,000+	110 J	1,700	340	
Chloride	ND	8,600	15,000	10,000	1,900,000+	12,000	220,000+	45,000	
Sulfate	ND	32,000	6,900	12,000	1,200+	16,000	4,500 J	12,000	
Alkalinity	ND	220,000	210,000	130,000	110,000	180,000	140,000	170,000	
Bicarbonate alkalinity (as CaCO3)	ND	220,000	210,000	130,000	110,000	180,000	140,000	170,000	
Turbidity (in NTU)	ND	0.11	3.8	190+	0.71	0.65	0.52	0.54	
Specific conductance (in unhos/cm)	ND	480	660	330 L	5,900	410 L	1,000	470 L	
Hardness	ND	240,000	130,000	120,000	510,000	96,000	81,000	76,000	
Total Dissolved Solids	ND	270	230,000	210,000	4,700,000+	230,000	520,000	270,000	
Total Suspended Solids	ND	ND	2,000 J	80,000+	ND	ND	ND	ND	

Notes: Data are in µg/L
Most detection limits were higher for pre-drilling than post-drilling analyses
+ = result reported from diluted analysis
B = Compound found in the blank
J = Result is less than the reporting limit but equal or greater than the method detection limit; concentration reported is approximate
K = Analyte present, Reported value may be high. Actual value expected to be lower.
L = Analyte present. Sample value is biased low. Actual value is expected to be higher.
MBAS = Methylene blue active substance
NA = Data not available
ND = Not detected above method detection limit
NTU = Nephelometric turbidity units
RSL = Regional screening level
RW = Residential well
umhos/cm = micromhos per centimeter

Appendix D. Comparison of EPA April 2011 Private Well Sampling Results With Chesapeake July 2010 Private Well Sampling Results for RW02, RW03, RW04, and RW06, Before Drilling and After Chesapeake ATGAS 2H Well Site Blowout

		Before Drilling	After Blowout
Location	**Analyte**	**Date Sampled: 7/14/2010**	**Date Sampled: 4/27/2011**
RW02	Methane	349	120
RW02	Arsenic	29.3	30
RW02	Barium	365	370
RW02	Calcium	41000	43,000
RW02	Iron	521	550
RW02	Lithium	NA	11 L
RW02	Magnesium	6570	6,000
RW02	Manganese	366	400
RW02	Potassium	1,300	1,700 B
RW02	Sodium	45,800	46,000 K
RW02	Strontium	NA	610
RW02	Uranium	NA	2.9

		Before Drilling	After Blowout
Location	**Analyte**	**Date Sampled: 7/13/2010†**	**Date Sampled: 4/28/2011**
RW03	Methane	ND/ND	ND
RW03	Arsenic	ND/ND	9.4
RW03	Barium	41.5/157	220
RW03	Calcium	46,100/42,700	40,000
RW03	Iron	514/ND	3,100
RW03	Lithium	NA	17
RW03	Magnesium	8,240/4,090	4,200
RW03	Manganese	242/ND	130
RW03	Potassium	ND/ND	1,700 J
RW03	Sodium	27,100/17,000	22,000
RW03	Strontium	NA	380
RW03	Uranium	NA	9.3

		Before Drilling	After Blowout
Location	**Analyte**	**Date Sampled: 7/15/2010**	**Date Sampled: 4/27/2011**
RW04	Methane	763	6,200
RW04	Ethane	ND	2.6
RW04	Arsenic	ND	1.8 J
RW04	Barium	247	2,600
RW04	Calcium	15,400	170,000
RW04	Iron	87.7	600
RW04	Lithium	NA	1,900
RW04	Magnesium	2,430	21,000
RW04	Manganese	32.4	260
RW04	Potassium	1,780	13,000
RW04	Sodium	132,000	2,100,000 K
RW04	Strontium	NA	15,000
RW04	HEM (Oil and Grease)	ND	3.2 JB

		Before Drilling	After Blowout
Location	**Analyte**	**Date sampled: 7/15/2010**	**Date sampled: 4/27/2011**
RW06	Methane	440	240
RW06	Arsenic	ND	4.2 J
RW06	Barium	876	660
RW06	Calcium	29,100	26,000
RW06	Iron	77.2	80 J
RW06	Lithium	NA	87
RW06	Potassium	1,780	1,900 B
RW06	Magnesium	4,610	3,600
RW06	Manganese	106	95
RW06	Sodium	136,000	120,000 K
RW06	Strontium	NA	1,100
RW06	HEM (Oil and Grease)	ND	2.8 JB

Notes: Data are in µg/L
Most detection limits were higher for pre-drilling than post-drilling analyses
B = Compound found in the blank
J = Result is less than the reporting limit but equal or greater than the method detection limit; concentration reported is approximate
K = Analyte present, Reported value may be high. Actual value expected to be lower.
L = Analyte present. Sample value is biased low. Actual value is expected to be higher.
NA = Data not available
ND = Not detected above method detection limit
RW = Residential well