Health Consultation

Public Comment Version

Evaluation of Per- and Polyfluoroalkyl Substances (PFAS) Detected in Private Residential Drinking Water Wells Located within 1 Mile of the Pease International Tradeport

PEASE AIR FORCE BASE

PORTSMOUTH, NEWINGTON, AND GREENLAND, NEW HAMPSHIRE

EPA FACILITY ID: NH7570024847

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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 exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Please address comments regarding this report to:

Agency for Toxic Substances and Disease Registry
Attn: Records Center
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Atlanta, Georgia 30333

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HEALTH CONSULTATION

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Prepared by the
U.S. Department of Health and Human Services
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Summary

Introduction

In April 2015, the U.S. Air Force (USAF) asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate per- and polyfluoroalkyl substances (PFAS) exposure in the private drinking water wells near Pease International Tradeport in Portsmouth, New Hampshire (NH). The source of PFAS is believed to be firefighting foam (aqueous film-forming foam: AFFF) used on the former Pease Air Force Base (AFB). Chemicals from the foam likely traveled from Pease AFB, now Pease International Tradeport, through soil and water to nearby private wells supplying residential drinking water.

Perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), and perfluoro-hexanesulfonic acid (PFHxS) are three forms of PFAS that were detected in several of the private wells tested. Scientific information suggests an association between PFOA, PFOS, and PFHxS exposures and various health endpoints, including effects on cholesterol (not PFHxS), immune responses, fetal growth and development, endocrine systems (e.g., thyroid), and the liver. Several other PFAS were detected in the water, some of which have may have similar health effects as PFOA and PFOS.

This report reviews data from June 2014 through December 2017 for 40 private wells near Pease International Tradeport. If any other private drinking water wells are identified in the PFAS exposure area, the USAF will include them in future sampling and assessment efforts. The USAF used “RES” followed by the well number to identify the wells sampled around Pease. ATSDR used the same designations in the health consultation to avoid confusion.

Conclusions

ATSDR evaluated the public health implications of past and current PFAS exposure to the users of private wells near the Pease International Tradeport and reached four conclusions. These conclusions are limited by several uncertainties. The specific PFAS formulation in the AFFF used at the former Pease AFB is not known. ATSDR used a health-protective approach to evaluate concentrations of 23 PFAS in drinking water wells. ATSDR’s conclusions are based on evaluation of the PFAS that were measured in the water. However, there might be other PFAS in the water that were not measured.

Conclusion 1—Wells with Possible PFAS Hazard/Risk

Past PFAS exposures may have increased the risk of harmful non-cancer health effects, especially to young children, who drank water from RES17, RES19, RES21, RES23, and RES37

or were born to mothers who did. The cancer risk from past exposures to all PFAS in these wells is uncertain. No current or future harmful exposures are expected for residents using these five water supply wells because actions have been taken to reduce or eliminate their exposures.

Basis for conclusion

The combined past exposures to PFOA, PFOS, and PFHxS to users of RES17, RES19, RES21, RES23, and RES37 may have increased the risk of harmful non-cancer health effects, especially for developmental, endocrine (e.g., thyroid), and immune effects, in young children. Harmful effects for other health outcomes shown to be associated with PFOA, PFOS, or PFHxS may also occur; such as, effects on cholesterol and the liver. Harmful non-cancer health effects for adults are only a concern for users of RES17. The risk of harmful effects to adult users of three other wells (RES19, RES21, and RES37) is uncertain because of the limited scientific information to evaluate the public health implications of exposures to other PFAS in these wells besides PFOS, PFOA, or PFHxS. Adult users of RES23 are not at risk because no other PFAS were detected.

Human and animal studies suggest a link between PFOA exposure and higher rates of several cancers. Animal studies suggest a link between PFOS exposure and several cancers; although, human studies have yet to confirm a link between cancer and PFOS exposures.

Limited data exist on the potential of other PFAS to cause cancer. ATSDR cannot calculate the estimated cancer risk for other past PFAS exposures or a total cancer risk from all potentially cancer-causing PFAS exposures. The total cancer risk from past PFAS exposures from these private wells is uncertain.

Exposure to PFAS from food and consumer products, and to other PFAS in the water, could contribute to the overall amount of PFAS in a person's body. Some pre-existing risk factors might increase the risk for harmful effects (e.g., persons with compromised immune systems or liver function).

Protective measures

Between October 2014 and August 2016, the USAF installed whole-house water treatment systems for wells RES17, RES19, RES21, and RES23. The USAF has monitored the treated water quarterly for contaminants. ATSDR considers the USAF installation of the treatment systems, quarterly monitoring, and provision of bottled water to the seasonal users at (RES37/GBNWR) to be protective public health actions. As a long-term remedy, the USAF prefers to connect the four residences with water treatment systems to the Pease Tradeport public water supply (identified as ID NH1951020).

Next steps — Inform and study

- ATSDR will present the findings of this report to the affected residents and community members.
- ATSDR will provide health education information related to PFAS in private residential drinking water wells to the affected residents and community members.
- ATSDR and the Centers for Disease Control and Prevention (CDC) are conducting a health study of children and adults exposed to PFAS-contaminated drinking water at the Pease International Tradeport and from nearby private wells. The study will evaluate associations between PFAS blood levels and signs of changes in the body (e.g., cholesterol levels, kidney and thyroid function, and the development of specific diseases), and will serve as the first site in CDC/ATSDR's Multi-site Health Study looking at the relationship between PFAS drinking water exposures and health outcomes. Sites in seven additional states will also participate in the Multi-site Health Study.
- ATSDR and CDC are working to address the concerns of community members regarding potential associations between PFAS exposure and cancer. We are conducting an analysis that uses previously collected data to look at rates of certain health outcomes, including many adult and pediatric cancers, in communities that have been exposed to PFAS through drinking water and those that have not.
- ATSDR and CDC are conducting exposure assessments in communities near current and former military bases and that are known to have had PFAS in their drinking water. The exposures assessments will provide information to communities about the levels of PFAS in their bodies. Using this information, public health professionals provide guidance to help people reduce or stop exposure.
- ATSDR is also providing technical assistance to tribal, state, and territorial health departments nationwide so they can effectively evaluate PFAS exposure in contaminated communities.

Conclusion 2 — Wells Where PFAS Hazard/Risk Cannot be Determined

The risk of harmful health effects (non-cancer and cancer) from past and current exposures to mixture of all PFAS in drinking water from 24 wells without treatment systems (see Table 5 for list of wells), now or in the past, cannot be determined.

Basis for conclusion

Exposure to PFOS, PFOA, and PFHxS individually or combined in untreated drinking water from RES03, RES20, RES22, and RES25 were evaluated and are not likely to result in an increased risk of harmful non-cancer health effects. The risk of harmful non-cancer health effects from past PFHxS exposures to users of RES09 cannot be determined because of uncertain exposure data. The cancer risk from past and current exposure to all PFAS in these wells is uncertain because of the limited data on the potential for these PFAS to cause cancer. In addition, drinking water from 19 other wells (see Table 5 for a listing) contained PFAS ranging from 2 in RES43 and RES50 to 14 different PFAS in a few wells. Sampling data indicate that RES01, RES03, RES15, RES20, RES22, and RES25 had the highest total PFAS concentrations and number of different PFAS detected (see Table A-1). However, the scientific community lack refined methods to evaluate the public health implications of exposure to the entire mixture of PFAS in all 24 of these wells. In addition to PFAS exposures from drinking water, PFAS exposure from food and consumer products might contribute to the overall amount of PFAS in a person's body.

Next steps

- ATSDR recommends that EPA, NHDES, and the USAF implement the following steps:
  - continue investigations to characterize PFAS groundwater contamination at the site. This is especially important since PFAS drinking water regulatory standards are continuing to evolve
  - continue monitoring the private drinking water supply wells
  - identify and sample any affected private drinking water wells that were not part of the original inventory plan

  These steps will allow the agencies to stop exposures to contaminated private drinking water sources containing PFAS above applicable health-based drinking water standards.

- The USAF preferred long-term remedy for the four residences currently with water treatment systems is to connect them to the Pease Tradeport public water supply. ATSDR recommends that the USAF with EPA and NHDES regulators continue their efforts to implement a long-term remedy, which will permanently stop exposure to contaminated private drinking water sources that have PFAS above EPA or other applicable health-based drinking water guidelines and reduce exposures to PFAS compounds that have no health-based comparison values (HBCVs).

- ATSDR recommends affected residents reduce their exposure to PFAS in their water by using an alternative or treated water source for drinking, food preparation, cooking, brushing teeth, and other uses by which they might consume well water. Using PFAS-contaminated water for bathing or showering, washing dishes, and doing laundry is not expected to result in significant PFAS exposure.

- During public availability sessions, ATSDR will consult with individual well users to provide additional health perspective on exposures to PFAS in their drinking water. Well users also may arrange a consultation with ATSDR scientists by calling ATSDR at 1-770-488-3731 or by email at gru1@cdc.gov.

Conclusion 3 — Wells Where PFAS Hazard/Risk Unlikely or No Hazard

Past and current exposure to PFAS in drinking water from 11 wells without treatment systems is unlikely to result in an increased risk of harmful health effects.

Basis for conclusion

No PFAS were detected in RES30, RES42, and RES52 — wells with no treatment systems — indicating that no exposures have occurred. Only a few PFAS (all with ATSDR HBCVs) were detected in wells RES07, RES08, RES27, and RES51, and all were below their respective ATSDR HBCVs. The risk for harmful health effects is likely low for RES10, RES12, RES13, and RES34, which had only a few detections of total PFAS at low parts-per-trillion concentrations, which were below ATSDR's lowest HBCV. Based on current scientific information, PFAS levels below the HBCV indicate that harmful health effects are not likely.

Conclusion 4 — Breastfeeding remains a healthy option

Scientific information suggests that the health and nutritional benefits of breastfeeding outweigh the potential risks associated with PFAS in breastmilk.

Basis for conclusion

Community members, particularly mothers who have been exposed to PFAS from the Pease International Tradeport site, have expressed concern about the health implications of PFAS exposures to breastfed infants. Developmental and immune effects may be the main adverse health effects resulting from early life exposure to some PFAS. Studies have shown that infants can be exposed to PFAS during pregnancy by transfer through the mother to the fetus and through breastfeeding. However, breastfeeding provides clear health and nutritional benefits. Some of the many benefits for infants include a reduced risk for ear and respiratory infections, asthma, obesity, and sudden infant death syndrome. Breastfeeding can also help lower a mother's risk for high blood pressure, type 2 diabetes, and ovarian and breast cancer. In general, CDC and the American Academy of Pediatrics recommend breastfeeding despite the potential presence of chemical contaminants in breast milk.

We continue to learn more about the health effects of PFAS exposure on mothers and children. From what we know about PFAS exposure through breastmilk, the benefits of breastfeeding outweigh the risks. A woman's decision to breastfeed is an individual choice considering different factors, many unrelated to PFAS exposure, and in consultation with her healthcare providers. ATSDR has developed information to guide healthcare providers in this decision-making process with their patients (see https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf [see also ATSDR 2019a]). Women should take steps to reduce exposure to toxic substances during childbearing years, especially while pregnant or breastfeeding (see https://www.atsdr.cdc.gov/pfas/pfas-exposure.html).

Next steps

Because of the mother and child health benefits of breastfeeding outweigh the known risk from PFAS exposure through breastmilk, ATSDR recommends nursing mothers continue to breastfeed and contact their healthcare providers with specific concerns. ATSDR is available to consult with healthcare providers as needed. To help protect formula-fed infants from potential exposure, ATSDR encourages caregivers to use pre-mixed baby formula or reconstitute dry formula using alternative water sources not containing PFAS.

Abbreviations used in this report

µg/L............. micrograms per liter
6:2 FTS .... 6:2 fluorotelomer sulfonate
8:2 FTS .... 8:2 fluorotelomer sulfonate
AFB.............. (Pease) Air Force Base
AFFF .... aqueous film-forming foam
ATSDR .... Agency for Toxic Substances and Disease Registry
CDC .... Centers for Disease Control and Prevention
CTE .... central tendency exposure
DHHS............ NH Department of Health and Human Services
EPA.............. Environmental Protection Agency
EtFOSA .... N-ethyl perfluorooctane sulfonamide
EtFOSE.......... N-ethyl perfluorooctane sulfonomidoethanol
GBNWR .... Great Bay National Wildlife Refuge
HBCVs .... health-based comparison values
HI .... hazard index
HQ............... hazard quotient
kg .... kilogram
L .... liter
LOAEL........... lowest observed adverse effect level
LOAEL HED ... Human Equivalent Dose for LOAEL
MeFOSA .... N-methyl perfluorooctane sulfonamide
MeFOSE .... N-methyl perfluorooctane sulfonomidoethanol
mg .... milligram
MDH............. Minnesota Department of Health
MOE .... margin of exposure
NH .... New Hampshire
NHANES .... National Health and Nutrition Examination Survey
NHDES.......... NH Department of Environmental Services
NOAEL.......... no observed adverse effect level
NOAEL HED .. no observed adverse effect level
nc .... not calculated
ND .... not detected
PFAS .... per and polyfluoroalkyl substances
PFBS .... perfluorobutanesulfonic acid
PFBA............ perfluorobutanoic acid
PFCA............ perfluoroalkyl carboxylic acids
PFCs .... perfluorochemicals
PFDS............ perfluorodecanesulfonic acid
PFDA .... perfluorodecanoic acid
PFDoA .... perfluorododecanoic acid
PFHpS........... perfluoroheptane sulfonate
PFHpA........ perfluoroheptanoic acid
PFHxS......... perfluorohexanesulfonic acid
PFHxA .... perfluorohexanoic acid
PFNA.......... perfluorononanoic acid
PFOSA .... perfluorooctane sulfonamide
PFOS .... perfluorooctanesulfonic acid
PFOA.......... perfluorooctanoic acid
PFPeA .... perfluoropentanoic acid
PFSAs .... perfluoroalkane sulfonates
PFTeDA ...... perfluorotetradecanoic acid
PFTrDA....... perfluorotridecanoic acid
PFUnA........ perfluoroundecanoic acid
PHAL .... provisional drinking water health advisory level
POE .... point of entry
ppt............... parts per trillion
RME .... reasonable maximum exposure
USAF .... United States Air Force

Table of Contents

1. Background and Statement of Issues

The Pease International Tradeport encompasses almost 4,300 acres in Greenland, Portsmouth, and Newington, New Hampshire (see Appendix A, Figure A-1). The Tradeport is on land formerly occupied by the Pease AFB. The Pease AFB began operations in 1956 and closed in 1991 [ATSDR 1999]. The USAF transferred the Pease AFB to the Pease Development Authority in October 1991. In February 1992, the facility was named the Pease International Tradeport. The Pease Development Authority welcomed its first tenant in 1993 [Pease Development Authority 2017]. The US Environmental Protection Agency (EPA) added the site to the National Priorities List[1] on February 21, 1990, because of groundwater and soil contamination by chlorinated volatile organic compounds, including trichloroethylene, petroleum-related volatile organic compounds[2], and metals [ATSDR 1999]. Under the National Priorities List, the USAF signed a federal facility agreement with the EPA and State of New Hampshire in 1991. The federal facility agreement identified the Installation Restoration Program sites and CERCLA process. Sites included the former fire department Area 2 and the Installation Restoration Program sites within the Haven well vicinity. ATSDR evaluated past contamination issues in a 1999 Public Health Assessment [ATSDR 1999].

In 2013, 22 monitoring wells located at Fire Department Area 2 (Site 8), known as AT008, on the Pease International Tradeport were sampled[3] for PFOA and PFOS (see Appendix A, Figure A-2). Fifteen monitoring wells had detections of PFOA exceeding the former EPA Provisional Health Advisory Level (PHAL) of 0.4 µg/L. Eighteen monitoring wells had detections of PFOS exceeding the PHAL of 0.2 µg/L. When those concentrations are compared to the current EPA health advisory of 0.070 µg/L, the exceedances increased to 17 wells for PFOA, and 20 wells for PFOS

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[1] The National Priorities List is the list of sites of national priority among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories. The EPA lists sites on the National Priorities List upon completion of Hazard Ranking System screening, public solicitation of comments about the proposed site, and after all comments have been addressed. For more details: https://www.epa.gov/superfund/superfund-national-priorities-list-npl.

[2] Volatile organic compounds are defined as any carbon compound, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides, or carbonates and ammonium carbonate, which participates in atmospheric photochemical reactions, except those designated by EPA as having negligible photochemical reactivity. Volatile organic compounds are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure. More details are available from: https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds.

[3] Sample collection parameters: 1-liter polycarbonate bottles and stored at 4 degrees Celsius (±2 degrees C). Samples extracted within 14 days of sample collection. Equipment rinsate blanks collected at a frequency of 10 percent using PFC-free water supplied from the laboratory [CB&I 2014]. Detection limits for PFAS typically range from 0.0026 µg/L for PFOS to 0.0046 µg/L for PFOA [Walton R. (Air Force Civil Engineer Center-BRAC Program Management Division) email to Gary Perlman (ATSDR), 2018 February 22.

[CB&I 2014]. Sampling was initiated because PFAS-containing aqueous film-forming foam (AFFF) was used at former Pease AFB to respond to airplane fuel leaks, fires, and training exercises conducted at Site 8 [CB&I 2014]. AFFF leached into the soil and groundwater and migrated into the water supply wells that serve the Pease International Tradeport.

AFFF was first used about 1970 [NH DHHS 2015; Prevedouros et al. 2006; NRL 2015]. In addition to Site 8, there are 21 other — potentially PFAS contaminated — areas that have been investigated (see Appendix A, Figure A-3). AFFF was reported to be stored, handled, used, or released in these areas [AMECFW 2016]. Eleven AFFF areas are subject to further evaluation. Ten sites currently are not the focus of additional investigations [AMECFW 2017].

Since about 2014, private drinking water wells located within one mile of the former Pease Air Force Base have been under investigation to determine if PFAS has migrated to the wells [AMEC 2014]. These wells are in the towns of Newington and Greenland, NH. Figure 1 depicts the areas where the private wells are located.

PFAS are a class of manufactured chemicals not currently regulated in public drinking water supplies. PFAS have been used since the 1950s to make products resistant to heat, oil, stains, grease, and water. They are found in some fire-fighting foams and consumer products such as nonstick cookware, stain-resistant carpets, fabric coatings, food packaging, cosmetics, and personal care products [EPA 2017]. People can be exposed to PFAS in the air, indoor dust, food, water, and consumer products. Because of their extensive use, PFAS are a common exposure for the general United States population [NIEHS 2016; EPA 2016a; CDC 2018].

PFAS persist in the environment. They are water soluble and may be detected in the soil, sediment, water, or biota. Studies indicate that some PFAS move through the soil and easily enter groundwater where they may travel long distances [MDH 2017a].

In April 2015, the USAF asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate past and current exposures to PFAS found in private wells near the former base [AMEC 2014]. The PFAS contamination source in groundwater likely came from AFFF used when Pease was an Air Force base [AMEC 2014]. It is important to note that the type of AFFF used at the former Pease AFB and the specific PFAS formulation is not known. The water sampling results for PFAS may not capture the full spectrum of exposures.

2. Groundwater PFAS Contaminant History

2.1 Private Drinking Water Well Monitoring

To determine whether PFAS in groundwater migrated beyond the former Pease AFB at concentrations that would be a public health concern, the USAF initiated an off-base private well sampling program in 2014. That program located and sampled private drinking water wells within one mile of the former Pease AFB boundaries.[4] The PFAS monitored are identified in Table A-2 (Appendix A). Figure 1 depicts the off-site well inventory zone boundaries. Figure 2 depicts the boundary of the Great Bay National Wildlife Refuge where RES37 is located. The private wells within one mile of the former Pease AFB boundaries are in the Towns of Newington and Greenland, NH.

2.2 Fate and transport of PFAS

Ongoing investigations by the USAF are designed to determine whether groundwater information may provide details on the depth of contamination, groundwater flow direction, and why some wells are more contaminated than others. The USAF is evaluating contaminant concentrations over time to learn more about how and when the contaminants are migrating [Walton R (USAF), email to Gary Perlman (ATSDR), 2018 December 6].

2.3 Surface Water and Biota Issues

Some community members noticed foam floating on the surface waterways where they used to play. ATSDR cannot confirm that the foam observed by the community was AFFF. If AFFF impacted the surface water bodies, residents in the area may have been exposed to PFAS while playing in the nearby waterways. In addition, surface or groundwater discharge to the Great Bay may have resulted in PFAS exposures and accumulation in fish and shellfish.

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[4] The plan included the identification and inventory of private wells in Newington and Greenland, NH within one mile of the former Pease AFB boundary. The contractor conducted a door-to-door survey in the neighborhoods within the survey areas. Property owners were interviewed, and well water usage data were collected. Follow-up visits were conducted if the contractor was unable to contact a property owner during outreach. In some cases, as many as six attempts were made. There is no indication that property owners refused to participate in the well inventory and sampling.

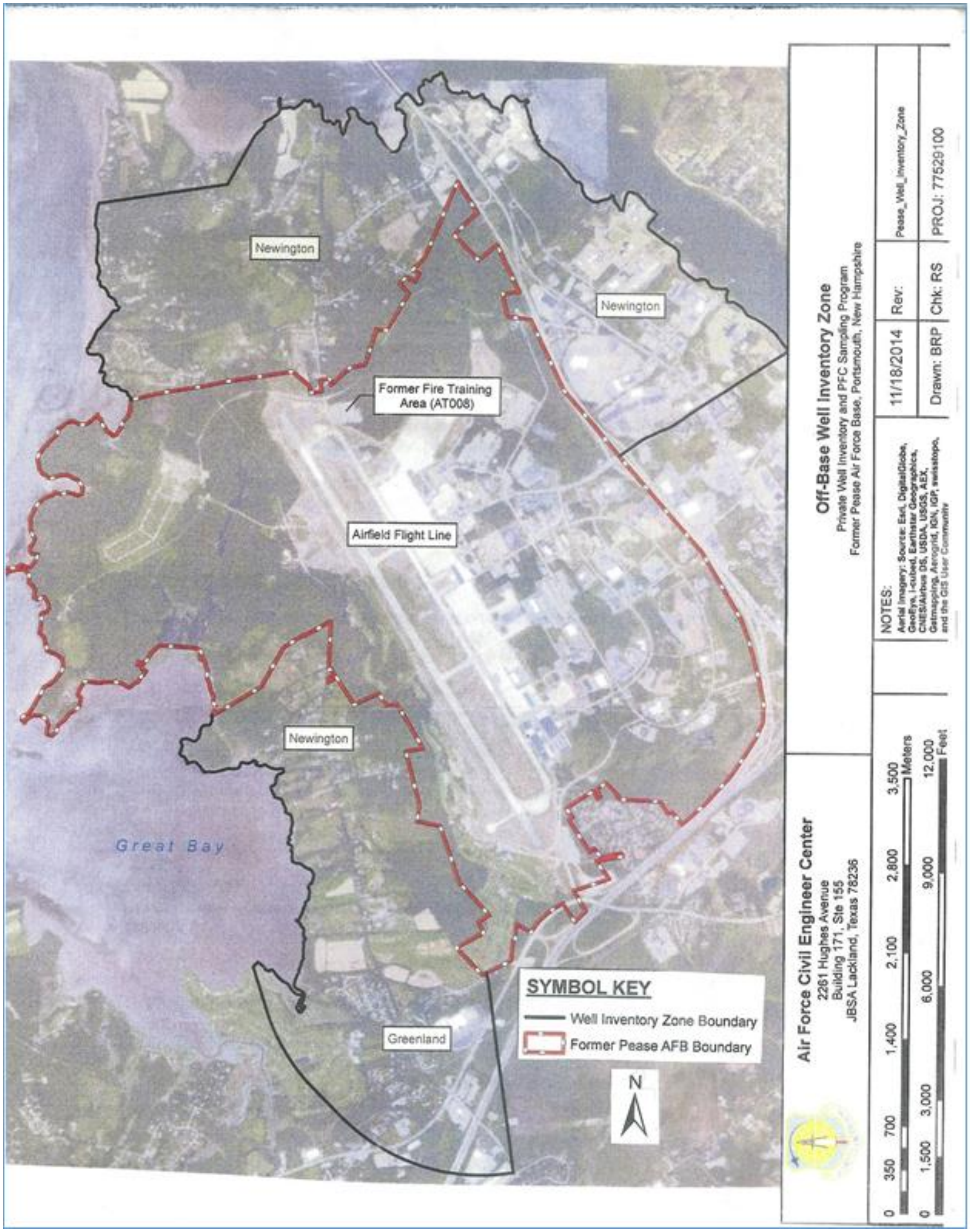

Figure 1 Off-site well inventory zone (adapted from AMEC 2014)

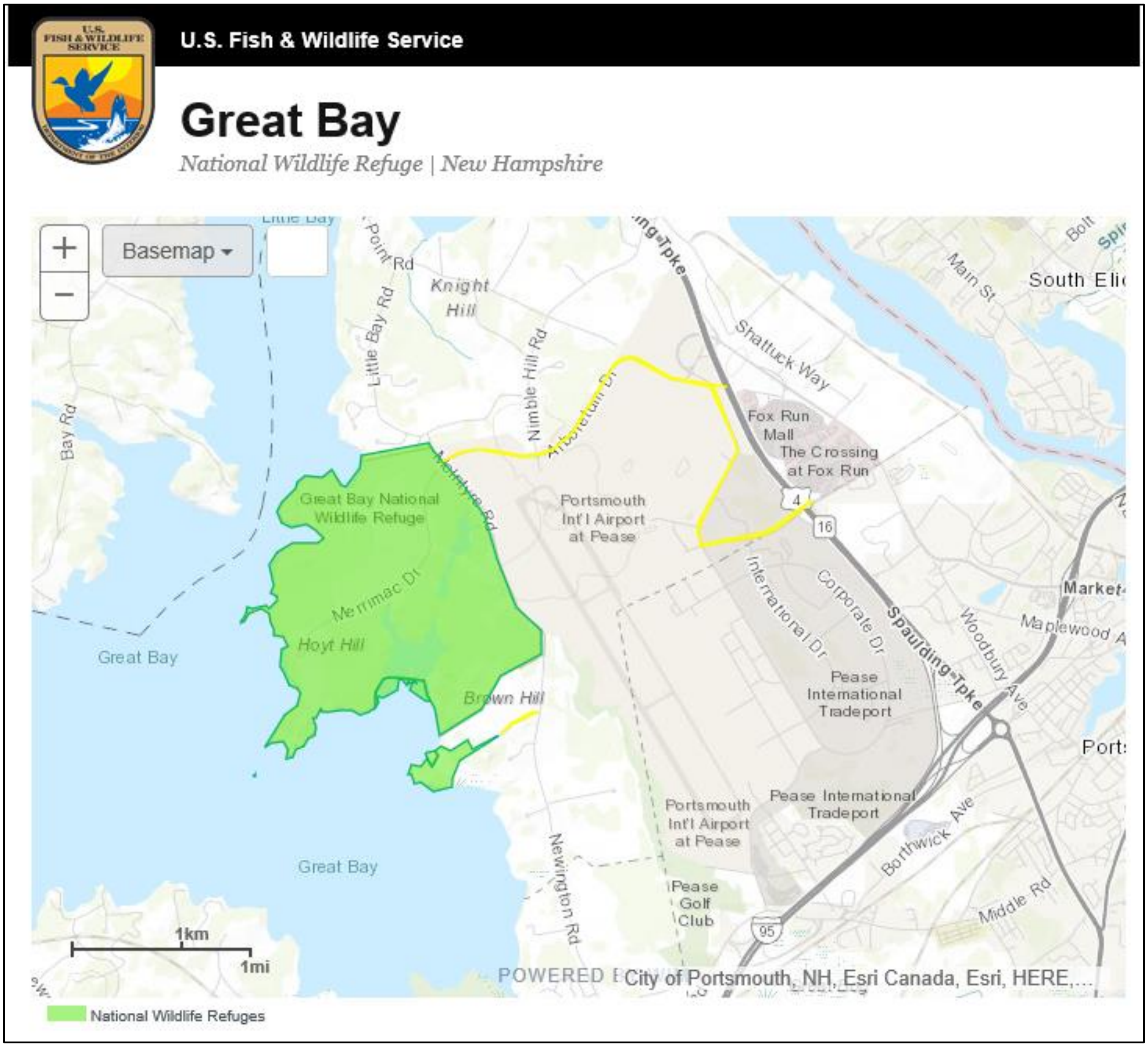

Figure 2 Great Bay National Wildlife Refuge (adapted from U. S. Fish & Wildlife Service, Base map of Great Bay National Wildlife Refuge, New Hampshire, available from: https://www.fws.gov/refuge/Great_Bay/map.html)

The USAF is coordinating an investigation regarding potential effects on surface water from springs and brooks that lead to the Great Bay. Great Bay sampling is planned [Walton R (USAF), email to Gary Perlman (ATSDR), 2018 December 6].

2.4 Private Well Monitoring Outcome

Between June 2014 and December 2017, 40 residential wells in Newington and Greenland, NH were sampled for 23 PFAS, including PFBA, PFBS, PFHxS, PFNA, PFOS and PFOA. Table A-3 (Appendix A) lists the maximum detected perfluoroalkyl substances concentrations in these wells. PFAS were detected in 37 private wells [AMEC 2014; AMECFW 2016; Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 16, includes one file attachment with private well PFAS data from 2014–2017]. Twenty-five wells had PFOA, PFOS, or both. Depicted below (figure 3) is a summary of the wells with various number of PFAS detections. The range of PFAS was from none to a maximum of 14. Three wells had no PFAS detections. One well had a maximum of fourteen PFAS.

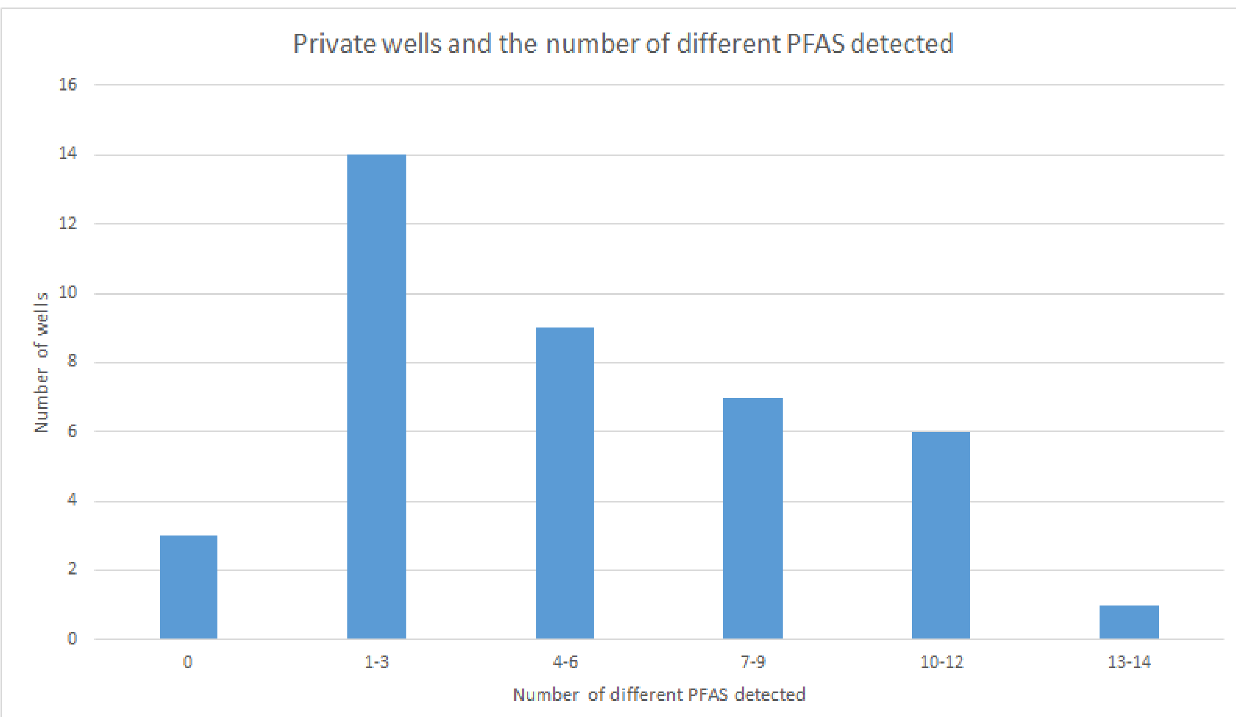

Figure 3. Private wells with various number of PFAS detections

In September 2014, one private residential drinking water well — designated as RES17 and located in Newington, NH — exceeded the former EPA PHAL for PFOS of 0.2 µg/L. On October 18, 2014, in response, the USAF installed an activated carbon whole-home water treatment system [AMEC 2014]. The USAF has monitored the treated water from RES17 quarterly for breakthrough. The USAF maintains the activated carbon whole-home water treatment system [Hilton S (NHDES), email to Dave Gordon (NHDES), 2015 September 28].

EPA announced the health advisory for PFOA and PFOS (0.07 µg/L; individually or combined) in May 2016. Four private wells exceeded (RES19 and RES21) or nearly exceeded (RES23 and RES37) this level. In response, the USAF immediately provided bottled water to the users of these drinking water wells as a prudent public health action.

Between July and August 2016, the USAF installed whole-home water treatment systems in, RES19, RES21, and RES23. The treatment system for RES17 was installed in October 2014.

In June 2016, the USAF and the State of New Hampshire first learned that a well located at the Great Bay National Wildlife Refuge (GBNWR; also referred to as RES37/GBNWR) was used seasonally by two volunteer workers who connected to it from their recreational vehicle [Sandin P (NHDES), email to Dave Gordon (NHDES), 2016 June 8]. The summed PFOS and PFOA concentrations for that well exceeded the EPA health advisory. The seasonal users were provided bottled water from June through October 2016 when they moved off the property [Forbes P (USAF), email to Dave Gordon (NHDES), 2016 June 24; Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 22]. The well has remained unused since 2016. The USAF will reevaluate if it is used again. Since the well at the Great Bay National Wildlife Refuge has been inactive, the USAF has checked with staff each spring to determine whether they expect the well will be used. They have confirmed each spring (2017, 2018, and 2019) that they do not expect the well to be used by seasonal employees. The well is in a portion of the site that is behind a locked gate and is not accessible to the public [Libby Bowen (John Wood Group PLC), email to Gary Perlman (ATSDR), 2019 June 6].

3. ATSDR's Evaluation Process

3.1 Identifying Exposure

People near an environmental release are exposed to a contaminant only if they contact the contaminant. Exposure might occur by eating food, breathing air, skin contact with a substance, or drinking a substance containing the contaminant. A release does not always result in exposure.

ATSDR evaluates site conditions to determine if people could have been (a past scenario), are (a current scenario), or could be (a future scenario) exposed to site-related contaminants. ATSDR also considers the route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact (or get exposed) to it. This is an exposure pathway. An exposure pathway has five elements:

1) a source of contamination (for example spill or release)
2) an environmental media and transport mechanism (groundwater)
3) a point of exposure (tap water)
4) a route of exposure (drinking)
5) a receptor population (people potentially or actually exposed)

When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (such as drinking water) has occurred, is occurring, or might occur. ATSDR also identifies an exposure pathway as completed or potential or eliminates the pathway from further evaluation. Exposure pathways are complete if all five elements of a human exposure pathway are present. A potential pathway occurs when one or more pathway elements cannot be proved or disproved. A pathway is eliminated if at least one element is missing. (See Appendix A, Table A-4 for a description of the exposure pathways.)

3.2 Exposure and Health Effects

At sufficient exposure levels, chemicals in the environment can cause harmful health effects. The type and severity of effects are influenced by complex factors such as

- concentration (how much)
- the frequency or duration of exposure (how often and how long)
- the way the chemical enters the body
- combined exposure to other chemicals

Age, gender, nutritional status, genetics, health status, and other characteristics can affect how a person’s body responds to an exposure and whether the exposure harms their health. When a completed exposure pathway is identified, ATSDR evaluates chemicals in that pathway by comparing exposure levels to screening values. Screening values are developed from available scientific findings about exposure levels and health effects. They reflect an estimated contaminant concentration that is not expected to cause adverse health effects for a given chemical, assuming a standard daily contact rate (such as amount of water consumed) and body weight. To be protective of public health, screening values are generally based on contaminant concentrations many times lower than levels at which no effects were observed in experimental animals or human studies. ATSDR does not use screening values to predict the occurrence of adverse health effects, but rather to serve as a health protective first step in the evaluation process.

3.3 Identifying Chemicals of Concern

As a first step in the evaluation process, ATSDR uses health-based comparison values[5] (HBCVs) as screening values. HBCVs are developed based on data from the epidemiologic and toxicological literature. Many uncertainty factors[6], sometimes known as safety factors, are applied to ensure that the health-based comparison values amply protect human health. Estimated doses that are below health guidelines are not expected to cause adverse health effects. When no federal HBCVs are available, ATSDR uses applicable state values. Data on contaminants for which there were no federal or state HBCVs are retained for further evaluation.

ATSDR used six HBCVs in the evaluations of PFAS exposures. Four of the ATSDR-derived HBCVs (PFHxS, PFNA, PFOA, and PFOS) were used. The remaining two HBCVs were derived by the Minnesota Department of Health (PFBA and PFBS). Table A-5 shows the HBCVs used in this evaluation.

3.4 Summary of Screening Analysis

Table 1 summarizes the PFAS exceeding HBCVs in private water supply wells within 1 mile of the former Pease Air Force Base. Three PFAS (PFHxS, PFOA, and PFOS) were identified as chemicals of concern for past and current exposures. Ten of the 40 sampled wells had PFAS detections that exceeded a HBCV. Some PFAS lacking an HBCV were also retained for further evaluation. For some of the PFAS without HBCVs, concentrations in the water were very low and adequate toxicological data were unavailable. These PFAS compounds were included in the evaluation of exposure to PFAS mixtures. Several private wells will not be further evaluated as water from these wells either did not contain any PFAS (RES30, RES42, and RES52) or the only PFAS detected were ones with an ATSDR HBCVs, and all the levels in these wells (RES07, RES08, RES27, and RES51) were below the HBCVs. In addition, based on post-treatment sampling for RES19, RES21, and RES23, no PFAS have been detected. For RES17, the maximum levels of three PFAS, with no HCBVs, were each detected at low parts per trillion. Three PFAS with HBCV

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[5] Not all comparison values used to screen data were from ATSDR or other federal agency sources, because there were no federal comparison values available. As the state of science on these compounds progresses, more values may become available. Some values might be revised from their current values.

[6] Uncertainty factors are used to account for uncertainties associated with extrapolations from animal to human data as well as adjustments for intraspecies variability

(PFOS, PFOA, and PFHxS) in RES17 have not been detected since treatment has been installed. No current exposures are occurring to water from the seasonal well RES37 as the well has been abandoned.

Only two wells (RES01 and RES03) had detectable levels of PFNA and neither were above an HBCV indicating that no further evaluation is needed. However, PFNA was included as part of the mixture evaluation for RES03 (see Public Health Implications of Exposure to PFAS in Private Drinking Water Section below). Other PFAS that lacked HBCVs (6:2 FTS, EtFOSE, PFHpA, PFHpS, PFHxA, PFOSA, and PFPeA) were further evaluated to the extent possible based on available toxicological data. Other PFAS with no HBCVs, detected at low concentrations and with limited toxicological data, will be included as part of the overall public health evaluation of the PFAS mixture. These are summarized in Table 3 in Public Health Implications of Exposure to PFAS in Private Drinking Water Section.

Table 1. Summary of results in private drinking water wells with at least one exceedance of an ATSDR health-based comparison value located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exceedance of PFAS HBCV (yes/no)		
Well ID	PFHxS†	PFOA†	PFOS†
RES03	No	No	Yes
RES09	Yes	No	No
RES17‡	Yes	Yes	Yes
RES19‡	No	No	Yes
RES20	No	No	Yes
RES21‡	No	Yes	Yes
RES22	No	No	Yes
RES23‡	No‡	No‡	Yes‡
RES25	No	No	Yes
RES37/GBNWR inactive*	No	No	Yes

Notes: For those residential wells with maximum values above ATSDR screening values (no wells had levels of PFBA nor PFBS above the Minnesota HBCV * The RES37/GBNWR well is for a seasonal trailer on the Great Bay National Wildlife Refuge. Users were provided bottled water, but no treatment was installed. The well is no longer active. † ATSDR health-based comparison values [ATSDR 2018a]. ‡ Wells with treatment systems. RES23 was provided an alternative water supply when the wellhead had detections of 0.067 ppb for PFOS. Samples from an interior faucet, however, was much lower than the wellhead.
Sources AMEC 2014, AMECFW 2016, and Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 16. Includes one file attachment with private well PFAS data from 2014–2017.
No = no exceedances were detected.
Yes = at least one exceedance was detected.

4. New Hampshire release of new PFAS Ambient Groundwater Quality Standards

For this Health Consultation, ATSDR used our scientifically based standard approach to screen and subsequently evaluate exposure doses. On September 30, 2019, New Hampshire released new Ambient Groundwater Quality Standards for four PFAS that include: 0.012 µg/L for perfluorooctanoic acid (PFOA), 0.015 µg/L for perfluorooctane sulfonic acid (PFOS), 18 µg/L for perfluorohexane sulfonic acid (PFHxS), and 0.011 µg/L for perfluorononanoic acid (PFNA). Additional information regarding those values may be obtained from https://www4.des.state.nh.us/nh-pfas-investigation/?p=1126. The New Hampshire Ambient Groundwater Quality Standards are water concentrations established by the state. ATSDR used our Health-based Comparison Values to screen the well water concentration data for additional evaluation. If the New Hampshire Ambient Groundwater Quality Standards had been used to screen the data, rather than the ATSDR HBCVs, the dose calculations and conclusions in this Health Consultation would remain unchanged.

5. Public Health Implications of Exposure to PFAS in Drinking Water

If contaminant concentrations exceed an HBCVs, ATSDR reviews exposure variables (such as duration and frequency), the toxicology of the contaminant, and epidemiology studies to determine the likelihood of possible health effects.

5.1. Evaluating Health Effects: Introduction

5.1.1. What are Non-Cancer Health Effects of PFAS?

Many studies have examined possible relationships between levels of PFAS in blood and harmful health effects in people. However, not all studies involved the same groups of people, the same type of exposure, or the same PFAS, resulting in a variety of observed health outcomes. Research in humans suggests that high levels of certain PFAS may lead to

- increased cholesterol levels;
- changes in liver enzymes;
- decreased vaccine response in children;
- increased risk of high blood pressure or pre-eclampsia in pregnant women;
- small decreases in infant birth weight [ATSDR 2018a]

One way to learn about whether PFAS will harm people is to do studies on lab animals.

- Most of these studies have tested doses of PFOA and PFOS that are higher than levels found in the environment
- These animal studies have found that PFOA and PFOS can cause damage to the liver and the immune system
- PFOA and PFOS have also caused birth defects, delayed development, and newborn deaths in lab animals

Humans and animals react differently to PFAS, and not all effects observed in animals may occur in humans. Scientists have ways to estimate how the exposure and effects in animals compare to what they would be in humans.

Some PFAS build up in the human body. The levels of some PFAS go down slowly over time when exposure is reduced or stopped. Scientists in multiple federal agencies are studying how different amounts of PFAS in the body might affect human health over time. Most existing research has focused on long-chain PFAS. These persist in the environment; bioaccumulate in wildlife and humans; and are toxic to laboratory animals, producing reproductive, developmental, and systemic effects in laboratory tests.

Long-chain PFAS comprise two sub-categories:

- perfluoroalkyl carboxylic acids (PFCAs) with eight or more carbons, including PFOA, and
- perfluoroalkane sulfonic acids (PFSAs) with six or more carbons, including
  - perfluorohexane sulfonic acid (PFHxS) and
  - perfluorooctane sulfonic acid (PFOS).

While persistent in the environment, PFCAs with fewer than eight carbons, such as perfluorohexanoic acid (PFHxA), and PFSAs with fewer than six carbons, such as perfluorobutane sulfonic acid (PFBS), are generally less bioaccumulative in wildlife and humans [EPA 2018b]. However, health effects of many short-chained PFAS and new PFAS alternatives have not been fully researched. See Table A-2 for a listing of PFAS chemical formulas and designated chain length.

5.1.2. What are Cancer Health Effects of PFAS?

Epidemiologic data suggest a link between PFOA exposure and elevated rates of kidney, prostate, and testicular cancers. Additional studies are needed to confirm the link between PFOA and other PFAS exposures and cancer. EPA considers the evidence that PFOA has the potential to be carcinogenic in humans to be suggestive, and the International Agency for Research on Cancer has determined that PFOA is possibly carcinogenic to humans [EPA 2016b]. Animals given PFOA have shown higher rates of liver, testicular, and pancreatic tumors. We do not know if cancer at these three sites in animals results from a mode of action that is relevant to humans. Epidemiology studies of PFOS-exposed workers reported an increased risk for some cancers; however, because of small sample sizes, the results were not statistically significant [Alexander et al. 2003; Alexander and Olsen 2007; Grice et al. 2007; Olsen et al. 2004]. A causal link between cancer and PFOS exposures, based on human studies, remains uncertain. Animal studies have found limited but suggestive evidence of PFOS exposure and increased incidence of liver, thyroid, and mammary tumors. Although current data are very limited, other PFAS might be carcinogenic and some might not.

5.1.3. How does ATSDR Evaluate Non-Cancer and Cancer Health Effects?

For those residential wells with maximum PFAS values above ATSDR HBCVs, ATSDR compared estimated doses to the ATSDR provisional Minimal Risk Levels (MRL). An MRL is an estimate of the amount of a chemical a person can eat, drink, or breathe each day without a detectable risk to health for non-cancer health effects. MRLs are a screening tool that help identify exposures that could be potentially hazardous to human health. MRLs help public health professionals determine areas and populations potentially at risk for health effects from exposure to a chemical. ATSDR has developed more than 400 human health MRLs.

Exposure above the MRLs does not mean that health problems will occur. Instead, it signals health assessors to look more closely at a site where exposures may be identified. MRLs do not define regulatory or action levels for ATSDR.

The way the MRL is calculated can change depending on the type and quality of data available. MRLs can be set for three different lengths of time people are exposed to the substance:

- Acute — about 1-14 days
- Intermediate — from 15-364 days
- Chronic — more than 365 days

MRLs are calculated for different exposure routes, for example: inhalation and ingestion. MRLs are developed for non-cancer health effects — ATSDR uses available EPA oral cancer slope factors and other information to evaluate cancer effects. For PFAS, ATSDR developed provisional MRLs for PFOS, PFOA, PFHxS, and PFNA ingestion based on intermediate duration oral animal studies. ATSDR is using these provisional oral MRLs to screen and evaluate chronic exposures also [ATSDR 2018a]. ATSDR's provisional MRLs are developed for the most sensitive population (the fetus/neonate) and are protective for the entire population. In addition, ATSDR considered immune effects as these effects may be more sensitive than developmental effects. Because of this, ATSDR added in a modifying factor of 10 for concern that immunotoxicity may be a more sensitive endpoint than developmental toxicity for some of the provisional oral MRLs [ATSDR 2018a].

Proposed MRLs undergo a rigorous review process. Following internal review by ATSDR's expert toxicologists and before being submitted for public comment, they are sent to an expert panel of external peer reviewers, an interagency MRL workgroup, with participation from federal agencies, such as CDC's National Center for Environmental Health and National Institute of Occupational Safety and Health, the National Institutes of Health's National Toxicology Program, and the EPA [ATSDR 2018a].

An intermediate-duration (15 to 364 days), oral provisional MRL of 3×10^{-6} mg/kg/day was derived for PFOA based on neurodevelopmental effects (i.e., altered activity at age 5–8 weeks and skeletal alterations at age 13 to 17 months) in the offspring of mice fed a diet containing PFOA [Koskela et al. 2016]. The provisional MRL is based on a human equivalent dose, lowest observed effect level ($LOAEL_{HED}$) of 8.21×10^{-4} mg/kg/day, and a total uncertainty factor of 300 (10 for use of a LOAEL, 3 for extrapolation from animals to humans, and 10 for human variability). For PFOS, ATSDR derived an intermediate-duration oral provisional MRL of 2×10^{-6} mg/kg/day based on developmental effects (i.e., delayed eye opening and transient decrease in body weight during lactation) in the offspring of rats administered PFOS [Luebker et al. 2005]. The provisional MRL is based on a human equivalent dose for the no observed adverse effect level ($NOAEL_{HED}$) of 5.15×10^{-4} mg/kg/day and a total uncertainty factor of 30 (3 for extrapolation from animals to humans with dosimetric adjustments and 10 for human variability) and a modifying factor of 10 for concern that immunotoxicity may be a more sensitive endpoint than developmental toxicity) [ATSDR 2018a]. The estimated $LOAEL_{HED}$ based on the Koskela et al. 2006 study is 2.1×10^{-3} mg/kg/day.

For PFHxS, ATSDR derived an intermediate-duration oral provisional MRL of 2×10^{-5} mg/kg/day based on thyroid follicular cell damage, which is considered the most sensitive health outcome, in adult male rats administered PFHxS for a minimum of 42 days [Butenhoff et al. 2009;

Hoberman and York 2003]. The provisional MRL is based on a human equivalent dose NOAEL of 4.7×10^{-3} mg/kg/day, a total uncertainty factor of 30 (3 for extrapolation from animals to humans and 10 for human variability), and a modifying factor of 10 for database limitations. ATSDR added the modifying factor for database limitations to account for the small number and limited scope of studies examining PFHxS toxicity following intermediate-duration exposure, particularly studies examining immune effects, a sensitive endpoint for other PFAS, and general toxicity [ATSDR 2018a]. ATSDR estimates that the HED LOAEL for the above studies to be 7.3×10^{-3} mg/kg/day.

Currently, scientists are still learning about the health effects of exposures to mixtures of PFAS. In addition, investigators are actively studying whether being exposed to multiple PFAS chemicals at the same time increases the risk of health effects. Only two studies [Carr et al. 2013; Wolf et al. 2014] have shown that binary pairs of PFAS (i.e., comparing only two PFAS) show concentration and response additivity at lower concentrations, but deviate from additivity at higher concentrations [Wolf et al. 2014]. These possible interactions or dose additivity complicate the interpretation of the epidemiology data.

In the absence of data, chemical component-based approaches are used in risk assessment of chemical mixtures. Component chemicals, that are judged to be toxicologically similar, are evaluated by dose additive risk assessment methods that include the hazard index, relative potency factors, and toxicity equivalency factors. These methods are based on potency weighted dose addition and assume that there are no greater than or less than additive interactions among the chemicals in the dose region of interest. Because data are limited, ATSDR cannot assume any mixture effect besides additivity. ATSDR also conducted a qualitative analysis of the scientific literature to determine which PFAS might have similar target organ effects.

ATSDR considered several factors in evaluating if health effects are likely from current and past exposures, including the following:

- Potential effects of exposures to PFOA, PFOS, and PFHxS (individually)
- Potential effects of exposures to 6:2 FTS, EtFOSE, PFHpA, PFHpS, PFHxA, PFOSA, and PFPeA (individually)
- Potential effects of exposures to a mixture of PFAS
- Potential contributions from other sources
- Potential effects on susceptible populations: persons with pre-existing conditions and early development

ATSDR used the maximum detected concentration in each well as a health-protective approach when evaluating exposure from contaminated wells (see Appendix A, Table A-3). To estimate the exposure doses from past and current water consumption, ATSDR used default exposure scenario assumptions [ATSDR 2016a, 2016b]. ATSDR calculates exposure doses for each age group using average estimates of drinking water intake rates to determine the central tendency exposure (CTE). ATSDR also calculates the reasonable maximum exposure (RME) using reasonable maximum estimates of drinking water intake for each age group (see Appendix A, Table A-6 for description of exposure assumptions, and Equations 2 and 3 in Appendix A for how the CTE and RME were calculated).

5.2. Wells with Potential PFAS Hazards/Risks (RES17, RES19, RES21, RES23, and RES37)

5.2.1 Evaluation of Past Exposures with HBCVs

ATSDR used several measures to evaluate whether harmful effects are possible (i.e., an increased risk) from exposure to PFOA, PFOS, or PFHxS alone or combined. These include the hazard index (HI), hazard quotient (HQ), and margin-of-exposure (MOE). The following public health evaluation discusses these measures and how they were used to determine whether harmful effects are possible for an individual PFAS exposure and exposure to a mixture of PFAS in each well evaluated. Table 2 summarizes the calculated measures for each of the residential wells with at least one of the maximum PFOA, PFOS, or PFHxS levels above an ATSDR HBCV (see Table 1). These measures are based on a health-protective scenario for a child (birth to 1 year old), based on an upper-percentile water intake (the reasonable maximum exposure or RME). The maximum concentrations detected in RES23 were collected at the wellhead. The PFOS, PFOA, and PFHxS levels detected in the faucet sample for RES23 were below ATSDR's HBCVs. However, exposures to the maximum levels detected could have occurred; therefore, ATSDR is evaluating these as actual exposures.

Table 2. Public health implication evaluation measures for users of private wells that have perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA), or perfluorohexanesulfonic acid (PFHxS) above a health-based comparison value (HBCV), based on a reasonable maximum exposure (RME) dose for children ages birth to 1 year

Well ID	Hazard Quotient (HQ)			Margin-of-Exposure (MOE)*				Mixture Hazard Index (HI) †
	PFOS	PFOA	PFHxS	PFOS (developmental)	PFOS (immune)	PFOA	PFHxS	
RES03	1	<1	<1	970	14-180	283	4581	3
RES09‡	<1	<1	<1/7	2100	32-410	727	53/5824	<1/8
RES17	41	5	3	25	<1-5	52	137	49
RES19	6	<1	<1	170	3-22	830	504	7
RES20	2	<1	<1	540	8-100	315	672	3
RES21	3	1	<1	340	5-64	270	690	5
RES22	2	<1	<1	540	8-100	900	900	3
RES23	4	<1	<1	280	4-53	380	16796	5
RES25	1	<1	<1	1000	15-200	333	2519	2
RES37	9	<1	<1	110	2-21	400	512	11

Notes: *The MOEs are based on either developmental effects (PFOA and PFOS), immune effects (PFOS) or thyroid effects (PFHxS). Immune MOEs are based on the HED LOAELs from the Guruge et al. (2009) and Dong et al. (2011) animal studies of 3.1×10^{-5} mg/kg/day and 4.1×10^{-4} mg/kg/day, respectively.

† The mixture hazard index measures whether there is an increased risk of harmful effects beyond what might be expected from exposures to PFOS, PFOA, or PFHxS alone.

‡For RES09, evaluation measures reported for both the maximum PFHxS value (which may be an anomaly) and for the next highest level. The value before the "/" is based on the second highest PFHxS level and the value after the "/" is based on the maximum PFHxS level.

Abbreviations: HI = the sum of the hazard quotients for PFOS, PFOA, and PFHxS to evaluate mixtures; HQ = ratio of exposure dose divided by the provisional MRL. For the mixture HI and HQ, if greater than 1.0, as the HI and HQ increase, so does the concern for potential mixture or individual health effects, respectively; MOE = health effect level used to derive the provisional MRL divided by the exposure dose. The MOE measures how close a residential exposure is to effect levels from animal studies used to derive the provisional MRL; an individual measure not applicable as water level not above a HBCV.

PFOA and PFOS. ATSDR compared estimated exposure doses with the provisional MRLs for PFOA and PFOS. ATSDR calculated PFOS and PFOA exposure doses for each well using the maximum detected values. ATSDR used age group-specific exposure assumptions and calculated hazard quotients (HQ) for each estimated dose. An HQ is the ratio of the exposure dose divided by the provisional MRL.

If the HQ is greater than 1.0, then ATSDR further evaluates the public health implications of the exposure. As the HQ increases, so does concern for the potential hazard of exposure to that chemical. If the HQ is equal to or less than 1.0, then harmful effects of exposure to that chemical along is not likely. HQs for PFOS were greater than for PFOA. For RES17, all PFOS HQs for both the CTE and RME scenarios were elevated (HQ > 1.0) for all age groups and for pregnant and lactating women. For RES17, HQs for PFOA exposures were elevated for young children (birth to < 1 year) for both the CTE and RME scenarios but elevated only for the RME scenario for the other age and exposure groups. PFOA exposure HQs were all less than 1.0 for users of RES19, RES21, RES23, and RES37. However, the HQ of 1.01 was slightly elevated for young children using the RME scenario for RES21.

(See Appendix A tables for HQ calculations: RES17-Tables A-7 to A-9; RES19-Table A-10; RES21-Tables A-11 and A12; RES23-Tables A-13 and A-14; RES37-Tables A-15 and A-16)

To put these HQs into perspective, ATSDR calculated margins-of-exposure (MOE). The MOE is the effect level from the study used by ATSDR to derive the provisional MRL, divided by the estimated exposure dose. The MOE measures how close an estimated residential exposure is to effect levels in animal studies used to derive ATSDR's provisional MRL or other studies.
The smaller the MOE, the closer the exposure dose is to an effect level. ATSDR calculated the MOE for RES17, RES19, RES21, RES23, and RES37.

For RES17, the PFOS MOE for developmental effects was about 57 for the CTE scenario and 25 for the RME scenarios for the birth to < 1 year age group. To provide perspective to exposure doses and immune effects levels found in the scientific literature, MOEs were also calculated based on the Dong et al. (2011) and the Guruge et al. (2009) studies and an RME scenario (Table 2). Based on the current scientific literature, ATSDR believes that the immune effect levels from PFOS exposures lies somewhere between the HED LOAELs for these two studies (i.e., 4.1×10^{-4} mg/kg/day for the Dong study and 3.1×10^{-5} mg/kg/day for the Guruge study). Exposure doses near or exceeding the lower LOAEL HED from the Guruge et al. (2009) study would be considered potentially harmful. Therefore, exposures to young children (birth to < 1 year) exposed to PFOS in the past from RES17 may result in harmful immune effects.

For RES17, the PFOA MOE for neurodevelopmental effects was about 120 for the CTE scenario and 52 for the RME scenario for a child, birth to < 1 year. The PFOS MOEs for adults and lactating and pregnant women ranged from 75 to 100 for the RME scenario and 160 to 300 for the CTE scenario.

Based on this analysis, PFOS exposures to all ages and exposed groups using RES17 could have increased the risk for non-cancer health effects. These estimated exposures exclude possible PFOA and PFOS exposures from non-drinking water sources.

For RES19, RES21, RES23, and RES37, the PFOS developmental effect MOEs for young children (birth to < 1 year) ranged from 110 to 340 for the RME scenario which is well below effect levels. As above, the MOEs for immune effects ranged from 2 to 5 when using the Guruge study and 21 to 64 when using the Dong study. Therefore, PFOS exposures to young children using these wells may increase the risk for non-cancer immune health effects, but other age groups and pregnant and lactating women are at a low increased risk.

(See Appendix A tables for MOE calculations based on studies used to derive the ATSDR intermediate provisional MRL and for HQ calculations see RES17-Tables A-7 to A-9; RES19-Table A-10; RES21-Tables A-11 and A12; RES23-Tables A-13 and A-14; RES37-Tables A-15 and A-16)

PFHxS. Only RES17 exceeded ATSDR's HBCV for PFHxS. The HQs for all exposed groups and ages were below 1.0 except for young children for the CTE (birth to < 1 year) and RME (birth to < 6 years) scenarios (see Appendix A, Table A-7). ATSDR calculated a PFHxS MOE to put these HQs into perspective. For RES17, assuming 100% of the PFAS exposure is from drinking water, a child younger than 1 year of age will have the highest PFHxS exposure doses. The MOE was about 307 for the CTE scenario and 137 for the RME scenario (see Appendix A, Table A-7). Based on this analysis, young children who consumed water at a higher daily intake rate (the RME scenario) would have a low increased risk of harmful non-cancer effects. However, the conclusions for PFHxS human health effects are limited as the number and scope of intermediate study duration studies are limited, especially for studies examining immune effects, a sensitive endpoint for other PFAS, and general toxicity [ATSDR 2018a].

Mixture of PFOS, PFOA, and PFHxS. ATSDR evaluated the potential risk from cumulative exposures to PFOA, PFOS, PFHxS, and PFNA (the PFAS with ATSDR-derived provisional MRLs) by calculating a hazard index. A hazard index (HI) is used to assess non-cancer health effects of a mixture. The HI assumes dose additivity. It is the sum of the quotients of the estimated dose of a chemical divided by its MRL. If the HI is less than 1.0, significant additive or toxic interactions are considered unlikely, and no further evaluation is necessary. If the hazard index is greater than 1.0, concern about the potential hazard of the mixture increases.

For RES17, the HIs (based on an RME scenario) were greater than 1.0 for all age groups and pregnant and lactating women. The HIs for the other wells were greater than 1.0 only for young children (birth to < 1 year). Therefore, because of combined exposures to PFOA, PFOS, and PFHxS, all age groups that used RES17 might have increased risk for developmental, endocrine (thyroid), and immune effects greater than what might be expected from any one of these chemicals. Among users of other wells, only young children would have risk greater than what might be expected from exposure to any one of these PFAS alone. Harmful effects for other health outcomes shown to be associated with PFOA, PFOS, or PFHxS might also occur. The risk for harmful non-cancer effects to adult users of RES19, RES21, and RES37 from past exposure to the total mixture of PFAS (beyond PFOA, PFOS, and PFHxS) is uncertain because ATSDR lacks scientific information to evaluate this mixture. Adult users of RES23 are not at additional risk beyond their exposure to PFOS because no other PFAS were detected in this well.

(See Appendix A tables for HI calculations: RES17-Table A-23; RES19-Table A-24; RES21-Table A-25; RES23-Table A-26; RES37-Table A27)

5.2.2 Evaluation of Past Exposures without HBCVs

In addition to PFOA, PFOS, and PFHxS exposures above HBCVs, people using wells RES17, RES19, RES21, RES23, and RES37 were exposed to the other PFAS at the maximum concentrations shown in Table 3. None of these wells had levels of PFBA nor PFBS above the Minnesota HBCVs. This section evaluates these PFAS individually; it does not evaluate the mixture. ATSDR could not fully evaluate PFAS without ATSDR provisional MRLs that were detected in wells with no treatment systems because of the lack of scientific data. However, ATSDR provides some health perspective below to owners of wells with no treatment systems. ATSDR will be available to consult with individual well users on PFAS exposures in their wells.

Table 3. Maximum detected PFAS concentrations (other than PFOA, PFOS, and PFHxS) in Greenland and Newington, New Hampshire, private wells within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire; concentrations in micrograms per liter (µg/L) 2014 to 2017

Well Identifier	6:2 FTS	EtFOSE	PFHpA	PFHpS	PFHxA	PFOSA	PFPeA
RES03	ND	0.009	0.013	0.0047	0.01	ND	0.0076
RES09	ND	ND	0.012	ND	0.014	0.0048	0.024
RES17	0.041	ND	0.038	0.015	0.23	ND	0.094
RES19	ND	ND	ND	ND	0.022	ND	0.024
RES20	0.0059	ND	0.0038	0.0076	0.016	0.028	0.011
RES21	ND	ND	ND	ND	0.011	ND	0.0066
RES23	ND	ND	ND	ND	ND	ND	ND
RES25	ND	ND	0.0063	ND	0.0073	0.017	0.0086

Note: ND = Not detected

Sources AMEC 2014, AMECFW 2016, and Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 16. Includes one file attachment with private well PFAS data from 2014–2017.

Abbreviations: 6:2 FTS = 6:2 fluorotelomer sulfonate; EtFOSE = N-ethyl perfluorooctane sulfonamidoethanol; PFHpA = perfluoroheptanoic acid; PFHpS = perfluoroheptane sulfonate; PFHxA = perfluorohexanoic acid; PFOSA = perfluorooctane sulfonamide; PFPeA = perfluoropentanoic acid.

PFAS besides those shown in Table 3 also were found in these and other wells but were generally detected less frequently and at lower levels (see Appendix A, Table A-3). A description, based on the best available scientific information, of the likely health effects for exposure to each compound shown in Table 3 is discussed below.

PFHxA. Very limited information is available relating to the health effects of ingesting perfluorohexanoic acid (PFHxA). One study evaluated the chronic oral (ingestion) toxicity of PFHxA in laboratory animals [Klaunig et al. 2015]. Exposure of female rats to 200 mg/kg/day resulted in changes in blood (decreases in red blood cells and hemoglobin levels, and increases in reticulocyte counts), kidney effects (tubular degeneration, necrosis, increased urine volume, and reduced specific gravity), and liver effects (necrosis). No adverse changes were seen in females given doses of 30 mg/kg/day or in males given 100 mg/kg/day doses. A major uncertainty related to this study is that researchers did not measure serum PFHxA levels.

Based on the maximum detected concentration of PFHxA from RES17, the estimated RME dose for a child (birth to less than 1 year old) is 5.4×10^{-5} mg/kg/day (see Appendix A, Table A-22). This dose is about 500,000 times lower than the lowest NOAEL from the Klaunig et al. (2015)

study. Exposures from other private wells with the highest detected levels of PFHxA (RES19) would produce even higher margins between exposure doses and effect levels, which would indicate less risk. Based on this study, harmful effects are unlikely. PFHxA has not been studied as extensively as the PFAS with ATSDR provisional MRLs, especially for the most sensitive health endpoints, such as developmental and immune effects, and the only identified chronic study has limitations.

PFHpA, PFPeA, 6:2 FTS, PFHpS, PFOSA, and EtFOSE. The scientific literature has very limited information from human or animal studies relating to the health effects of exposure to perfluoroheptanoic acid (PFHpA), perfluoropentanoic acid (PFPeA), 6:2 fluorotelomer sulfonate (6:2 FTS), and perfluoroheptane sulfonate (PFHpS).

For PFHpA, ATSDR identified several human studies (e.g., for cardiovascular disease, serum lipids, immune system) that were either limited or found no association between exposure and adverse health effects [ATSDR 2018a].

For perfluorooctane sulfonamide (PFOSA), there is one animal study for acute oral exposure. No animal studies for intermediate or chronic exposures are available. Human studies of PFOSA exposures generally showed no associations with developmental and reproductive effects. One study did show an association with neurological effects in children; others showed no effects. One human study showed an associated with breast cancer [ATSDR 2018a].

Studies have shown that n-ethyl perfluorooctane sulfonamidoethanol (EtFOSE) is metabolized and degrades in the environment to PFOS. In animal studies, EtFOSE caused developmental effects similar to those associated with PFOS [DeWitt 2015]. Persons exposed to both PFOS and EtFOSE might have an increased risk for developmental effects, but ATSDR is unable to quantify this mixture effect with current knowledge.

No human studies were identified for exposures to 6:2 FTS. 6:2 FTS has been detected at low levels in some consumer products, drinking water, air, and fish. Human exposure might occur through any of these pathways. Some animal studies have shown that 6:2 FTS can cause kidney and liver toxicity, but it does not 1) cause damage to DNA, 2) act as a skin sensitizer, and 3) cause toxicity to reproductive organs or to the developing fetus [NASF 2019]. However, these studies are very limited, and no definitive conclusions can be drawn relating to potential effects of 6:2 FTS exposures in humans.

For all the PFAS discussed in this section, no animal or other studies were identified to allow ATSDR to compare the exposure dose from drinking private well water to effect levels (i.e., NOAELs or LOAELs). Therefore, ATSDR cannot evaluate these PFAS using its standard public health assessment approach. Additional analysis of the PFAS mixture in each well is provided below.

5.2.3 Evaluation of Cancer Health Effects from Past Exposures

EPA calculated a PFOA oral cancer slope factor [7] as a comparison to the safety of their reference dose against carcinogenic effects. EPA did not include this oral cancer slope factor in its Integrated Risk Information System [EPA 2016b]. Using the testicular cancer data from a 2012 rat study [Butenhoff et al. 2012], EPA calculated an oral cancer slope factor of 0.07 $(mg/kg/day)^{-1}$ [EPA 2016b].

To estimate potential cancer risk from PFOA exposure, ATSDR used the maximum detected levels of PFOA in private well water (RES17 at 0.11 µg/L). Table A-33 shows the estimated cancer risk calculations, by age, for PFOA exposure at this drinking water concentration. The estimated lifetime excess cancer risk calculations were based on Equation 1 in Appendix A. We do not know when PFAS contaminated the groundwater and reached the private water supply wells. To be more protective, ATSDR calculated an exposure time of 33 years for adults, based on EPA's 95th percentile residential occupancy period. Based on these assumptions, the estimated adult cancer risk from exposure to the maximum detected PFOA concentration in water from private wells is 1.3×10^{-7}. In other words, if 10 million people were similarly exposed, one additional case of cancer might occur. Exposures of other private wells users to lower levels of PFOA would result in a lower estimated additional cancer risk. For users of all private wells with the highest levels of PFOA, the estimated cancer risk level is considered very low. Note that this is a theoretical estimate of cancer risk that ATSDR uses as a tool for deciding whether public health actions are needed to protect health — it is not an actual estimate of cancer cases in a community. Moreover, this theoretical cancer risk must be viewed with caution because the EPA oral cancer slope factor is not official for inclusion in IRIS, and other cancers that were elevated in epidemiological studies of PFOA exposure were not evaluated (i.e., kidney and prostate cancer).

EPA does not have an oral cancer slope factor for PFOS or other PFAS because the animal data do not show a measurable or dose-response relationship. Therefore, ATSDR cannot calculate

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[7] EPA defines a cancer slope factor as "An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime oral exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg-day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100." See also https://www.epa.gov/fera/risk-assessment-carcinogenic-effects.

the estimated cancer risk from PFOS or other potentially carcinogenic PFAS exposures and the actual cancer risk from all PFAS exposures from private wells is uncertain.

5.2.4 Evaluation of Current Exposures with HBCVs

No exposures above HBCVs have occurred since treatment systems were installed on wells RES17, RES19, RES21, and RES23, or since RES37 was abandoned. Therefore, no harmful effects are expected from current exposure to these PFAS.

5.2.5 Evaluation of Current Exposures without HBCVs

Post-treatment sampling for RES19, RES21, and RES23, detected no PFAS. For RES17, the maximum levels of three PFAS, with no HCBVs, were each detected at low parts per trillion, with the total PFAS concentration close to ATSDR's most health protective HBCV. Three PFAS with HBCV (PFOS, PFOA, and PFHxS) in RES17 have not been detected since treatment has been installed. Therefore, the risk for harmful non-cancer health effects to current exposures to users of RES17 is low. No harmful exposures are occurring from seasonal well RES37, which has been abandoned.

5.2.6 Evaluation of Cancer Health Effects for Current Exposures

EPA does not have an oral cancer slope factor for PFAS, other than for PFOA, because the animal data do not show a measurable or dose-response relationship. Therefore, ATSDR cannot calculate the estimated cancer risk from other potentially carcinogenic PFAS exposures, and the actual cancer risk from all PFAS exposures from private wells is uncertain. However, because no PFAS have been detected in water from RES19, RES21, and RES23 since treatment systems were installed, ATSDR would not expect an increased risk for cancer. The cancer risk for users of RES17 for current exposures is likely low. No harmful exposures are occurring from seasonal well RES37, which has been abandoned.

5.3. Wells Where PFAS Hazard/Risk Cannot be Determined

5.3.1 Evaluation of Exposures with HBCVs (RES03, RES09, RES20, RES22, and RES25)

Four wells (RES03, RES20, RES22, and RES25) had a maximum detection that exceeded the ATSDR HBCV for PFOS. None had maximum PFOA or PFNA levels that exceeded ATSDR's HBCV. None had combined PFOA and PFOS levels that exceeded the EPA health advisory. One well (RES09) had a maximum PFHxS detection that exceeded ATSDR's HBCV. The maximum detection in RES09 might be an anomaly. The concentration was never duplicated at that well. ATSDR evaluated the public health implication of the highest value and the next highest value detected in water from RES09 to give users of the well some health perspective related to each of these exposure levels. Table 2 shows the measures used to evaluate PFOS and PFHxS below.

PFOS. All CTE scenario HQs for all ages and exposure groups who consumed water from RES03, RES20, RES22, and RES25 were below 1.0. Exposures below an HQ of 1.0 indicate that no harmful effects from exposures to PFOS alone are expected. However, the RME scenario HQs for RES03, RES20, RES22, and RES25 were slightly elevated (1.0 to 2.0) for a young child (birth to < 1 year). ATSDR also evaluated the MOE for each of these PFOS exposures. The RME scenario MOE for these wells ranged from 540 to 1,000 for young children (birth to < 1 year). The MOEs for all other age groups and pregnant and lactating women all exceeded 990. Based on this analysis, no harmful non-cancer health effects are likely from PFOS exposures to users of these wells.

(See Appendix A tables for HQ and MOE calculations: RES03-Table A-17; RES20-Table A-18; RES22-no table, exposures are similar to RES20; RES25-Table A-19)

PFHxS. For RES09, the exposure HQs exceeded 1.0 for all exposed groups and ages for the RME scenario. The intermediate exposure HQs exceeded 1.0 only for young children (birth to < 6 years) and lactating women for the CTE scenario (see Appendix A, Table A-20). The MOE for birth to less than 1 year old, the most-exposed group, and was 118 times below effect levels found in animal studies for the CTE scenario and 53 for the RME scenario. MOEs for all other age groups and pregnant and lactating women were around 100 or greater. Therefore, if this exposure occurred, an increased risk of harmful thyroid effects for young children might be expected. However, any conclusions from this evaluation are uncertain because the PFHxS detection in this well may be an anomaly and may have been an artifact of improper sampling or analytical technique. That is, PFHxS was never detected in this well in any other samples at these levels, and PFHxS in other samples were either not detected or detected at levels well below ATSDR's HBCV. Moreover, the conclusions for PFHxS human health effects are limited as the number and scope of studies are limited, especially for studies examining immune effects, a sensitive endpoint for other PFAS, and general toxicity [ATSDR 2018a].

ATSDR also calculated the HQs for the next highest PFHxS levels detected in RES09. All the PFHxS HQs were well below 1.0, indicating that no harmful effects are likely if these were the exposure levels (see Appendix A, Table A-21).

If the single high PFHxS level in RES09 is an anomaly, ATSDR's evaluation indicates no harmful effects are likely to users of 24 wells with no treatment systems as a result of PFOA, PFOS, and PFHxS exposures. However, water from these wells also contained other PFAS for which limited scientific information on human health effects is available. Therefore, ATSDR is unable to assess whether exposures to those PFAS might result in harmful effects.

Mixture of PFOS and PFHxS. Except for the HIs calculated for the single, possibly anomalous, high PFHxS level found in RES09, no HI was elevated for the CTE scenario. For RES03 and RES20, the HIs were slightly elevated between 2.7 to 3.4 for the RME scenario (see Table 2). These data do not provide enough evidence that the combined PFOS, PFOA, and PFHxS exposures to users of wells RES03 and RES20 significantly increase the risk of harmful non-cancer effects except for what might be expected from exposure to any one of these PFAS alone. However, these wells also contained other PFAS. Further health perspective for the total mixture of PFAS found in these wells is provided below, and ATSDR is available to discuss these findings with the users.

(See Appendix A tables for HI calculations: RES03-Table A-28, RES09-Tables A-29 and A-30, RES 20-Table A-31, RES25-Table A-32. Although RES22 is not shown, HIs would be slightly less than for RES20).

5.3.2 Evaluation of Exposures without HBCVs (See Table 5 below for listing of 19 wells)

In addition to PFOA, PFOS, and PFHxS exposures above HBCVs, people using wells RES03, RES09, RES20, RES23, and RES25 are also exposed to the other PFAS at the maximum concentrations shown in Table 3. None of these wells had levels of PFBA nor PFBS above the Minnesota HBCVs. This section evaluates these PFAS individually; it does not evaluate the mixture. See above for the discussion of the known public health implications of exposure to PFAS without HBCVs. For all the PFAS discussed in that section, no animal or other studies were identified to allow ATSDR to compare the exposure dose from drinking private well water to effect levels (i.e., NOAELs or LOAELs).

5.3.3 Evaluation of Mixtures without HBCVs

Aside from the HI approach for PFOA, PFOS, PFHxS, and PFNA, well-accepted scientific methods to calculate possible health effects of exposures to PFAS mixtures do not yet exist. In addition, not all PFAS share the same health outcomes nor have the same toxicity. Therefore, ATSDR evaluated the scientific literature to determine what health effects from the PFAS mixture found in these private wells might have similar health endpoints (see Table 4 below).

Table 4. PFAS and possible effects on organ systems

Specific PFAS	Cardiovascular	Developmental	Endocrine	Liver	Immune	Reproductive	Serum Lipid
6:2 FTS	No	No	No	No	No	No	No
8:2 FTS	No	No	No	No	No	No	No
EtFOSA	No	No	No	No	No	No	No
EtFOSE	No	Yes	No	No	No	No	No
PFBA	No	No	Yes	Yes	No	No	No
PFBS	No	Yes	Yes	No	No	Yes	No
PFDS	No	No	No	No	No	No	No
PFHpA	No	No	No	No	No	No	No
PFHpS	No	No	No	No	No	No	No
PFHxA	No	Yes	No	Yes	No	No	No
PFHxS	No	Yes	Yes	Yes	Yes	No	No
PFNA	No	Yes	No	No	No	No	Yes
PFOA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PFOS	Yes	Yes	Yes	Yes	No	Yes	Yes
PFOSA	No	No	No	No	No	No	No
PFPeA	No	No	No	No	No	No	No
PFTeDA	No	No	No	No	No	No	No
PFTrDA	No	No	No	No	No	No	No

Notes: Yes = Indicates possible effects on this target organ system. No=Indicates no effects/insufficient information. Only PFAS that have at least one detection in private wells are included in this table.

Abbreviation	Definition	Citation(s) for effects (if applicable)
6:2 FTS	6:2 fluorotelomer sulfonate	no effects or insufficient information on target organ systems
8:2 FTS	8:2 fluorotelomer sulfonate	no effects or insufficient information on target organ systems
EtFOSA	n-ethyl perfluorooctane sulfonamide	no effects or insufficient information on target organ systems
EtFOSE	n-ethyl perfluorooctane sulfonamidoethanol	DeWitt 2015
PFBA	perfluorobutanoic acid	[MDH] Minnesota Department of Health 2017a
PFBS	perfluorobutane sulfonic acid	[MDH] Minnesota Department of Health 2017a
PFDS	perfluorodecanesulfonic acid	no effects or insufficient information on target organ systems
PFHpA	perfluoroheptanoic acid	no effects or insufficient information on target organ systems
PFHpS	perfluoroheptane sulfonate	no effects or insufficient information on target organ systems
PFHxA	perfluorohexanoic acid	Klaunig et al. 2015; Iwai and Hoberman 2014
PFHxS	perfluorohexanesulfonic acid	Gleason et al. 2015; Grandjean et al. 2012; Morgensen et al. 2015; Viberg et al. 2013; Butenhoff et al. 2009
PFNA	perfluorononanoic acid	ATSDR 2018a
PFOA	perfluorooctanoic acid	ATSDR 2018a
PFOS	perfluorooctane sulfonic acid	ATSDR 2018a
PFOSA	perfluorooctane sulfonamide	no effects or insufficient information on target organ systems
PFPeA	perfluoropentanoic acid	no effects or insufficient information on target organ systems
PFTeDA	perfluorotetradecanoic acid	no effects or insufficient information on target organ systems
PFTrDA	perfluorotridecanoic acid	no effects or insufficient information on target organ systems

As shown in Table 4, animal studies or human epidemiological studies have indicated that adverse health outcomes of concern for PFAS compounds are typically associated with two or more compounds in the class. Except for cardiovascular and serum lipid health outcomes, all target organ systems have at least three of the PFAS associated with that health outcome. Therefore, the combined exposures to PFAS from private wells may have increased the risk for some of these non-cancer health outcomes, but refined methods to evaluate these combined exposures are lacking.

ATSDR cannot evaluate these PFAS using its standard public health assessment approach. ATSDR used EPA's definition of long-chained PFAS [EPA 2018b] to calculate the percentage of long-chained PFAS, which are generally considered to be more bioaccumulative than short-chained PFAS (see Table A-1). The number of PFAS detected in the remaining wells ranged from one or two (RES12, RES13, RES34, RES43, and RES50) up to 11-14 in a few wells (RES01, RES03, and RES20). Table A-1 shows that RES01, RES03, RES15, RES20, RES22, and RES25 had the highest total PFAS concentrations and number of different PFAS detected (based on at least nine PFAS detected and a total PFAS concentration greater than 0.1 microgram per liter or 100 ppt).

This information offers users of these wells some perspective on total PFAS concentrations, number of PFAS, and percentage of long-chained PFAS detected in their wells. Owners should also consider whether young children and women of childbearing age are being exposed to PFAS through the drinking water in their homes. ATSDR will be available to consult with individual homeowners to explain the meaning of these results. However, we lack scientific information on the health effects of the combined exposures to these PFAS and refined methods to evaluate them. Therefore, ATSDR will not be able to definitively say if harmful effects are possible from exposures to users of these wells.

5.3.4. Evaluation of cancer health effects

EPA does not have an oral cancer slope factor for PFOS or other PFAS because the animal data do not show a measurable or dose-response relationship. Therefore, ATSDR cannot calculate the estimated cancer risk from PFOS or other potentially carcinogenic PFAS exposures. The actual cancer risk from all PFAS exposures from these 24 private wells is uncertain.

5.4. Wells Where PFAS Hazard/Risk Unlikely or No Hazard (see Table 6 below for listing of 11 wells)

5.4.1 Evaluation of Exposures with HBCVs

No PFAS with HBCVs were detected in RES30, RES42, and RES52; therefore, no harmful effects are expected. Only PFAS with HBCVs were detected in RES07, RES08, RES27, and RES51. All PFAS were below HBCVs, indicating that no harmful effects are expected.

5.4.2. Evaluation of Exposures without HBCVs

No PFAS without HBCVs were detected in RES30, RES42, and RES52; therefore, no harmful effects are expected. For wells with only a few detections of PFAS (e.g., RES10, RES12, RES13, and RES34), the risk of harmful health effects is likely low as they were detected at low parts per trillion concentrations below ATSDR’s lowest HBCV.

5.4.3. Evaluation of cancer health effects

No increased risk of cancer is expected for exposures to user of RES30, RES42, and RES52 because no PFAS were detected. Although EPA does not have an oral cancer slope factor for PFOS because the animal data do not show a measurable or dose-response relationship, the cancer risk from PFAS exposures to users of RES 07, RES08, RES27, and RES51 is likely to be low.

5.5. Other Public Health Considerations

5.5.1 Contributions from Other Sources

ATSDR does not have enough information to identify individual exposure sources and to estimate the background exposure level in persons whose private wells are contaminated. Those sources might include PFAS-contaminated food, such as certain types of fish and shellfish if nearby streams, rivers, or lakes are affected; hand-to-mouth transfer from surfaces previously treated with PFAS-containing stain protectants, with carpet being most significant for infants and toddlers; or eating food packaged in PFAS-containing material, such as popcorn bags, fast food containers, or pizza boxes).

5.5.2 Susceptible Populations: Persons with Pre-existing Health Conditions and Early Development

The available epidemiology data identify several potential targets of PFAS toxicity; people with pre-existing conditions may be unusually susceptible. For example, it appears that exposure to PFOA or PFOS may increase serum lipid levels, particularly cholesterol levels. Thus, an increase in serum cholesterol may result in greater health impact to persons with high levels of cholesterol or other existing cardiovascular risk factors. Similarly, increases in uric acid levels have been observed in persons with higher PFAS levels; increased uric acid may be associated with an increased risk of high blood pressure. Thus, people with hypertension may be at greater risk. The relationship between PFOA and PFOS exposure and increased risk for cardiovascular disease is inconclusive. Additional research is needed to understand how exposure to these chemicals might affect people with pre-existing risk factors (such as elevated cholesterol) for cardiovascular disease. The liver is a sensitive target in many animal species and might be a target in humans. Therefore, people with compromised liver function could be a susceptible population [ATSDR 2018a]. Human studies have indicated that some PFAS may affect immune function [ATSDR 2018a]. Therefore, immunocompromised persons may also be a susceptible population to PFAS exposures. In general, the clinical significance of the impact of PFAS exposures on people with pre-existing conditions is not well understood.

ATSDR recognizes that the unique vulnerabilities of fetuses, infants, and children merit special emphasis in communities affected by environmental contamination. A child's developing body systems can sustain damage if toxic exposures occur during critical growth stages. Children ingest a larger amount of water relative to body weight than adults, resulting in a higher intake of pollutants in proportion to body size. In addition, children exhibit hand-to-mouth behavior and could be exposed to PFAS from previously treated carpet materials and other treated fabrics. Reducing exposures to sources of PFAS in infants and young children is extremely important. As evidence for this concern:

- Formula-fed infants consuming formula mixed with contaminated water would have a higher exposure compared to adults as a result of formula being their sole or primary food source and their smaller body weight.
- Evidence suggests that high serum PFOA or PFOS levels are associated with lower birth weights. Studies of populations with lower serum PFOA or PFOS levels have not found significant associations for birth weight. Although significant associations were found for the high serum group, decreases in birth weight were small and may not be biologically relevant [ATSDR 2018a].

PFAS can be transferred from breast milk to nursing infants. Studies that measured PFAS in maternal serum and breast milk in matched mother-infant pairs found highly variable correlations [ATSDR 2018a]. Information on breastfeeding is included elsewhere in this report.

5.5.3 Biomonitoring results – New Hampshire Department of Health and Human Services Blood Sampling Program

The New Hampshire Department of Health & Human Services offered biomonitoring (blood testing) for any persons exposed to PFAS in drinking water at Pease International Tradeport, including those exposed to either PFOS or PFOA above their former EPA provisional health advisory levels (PHALs) from private wells tested because of the Pease PFAS investigation. All blood testing for PFAS is no longer available through the NH Department of Health and Human Services. NH DHHS has and will continue to provide information and recommendations to healthcare providers to help providers and patients make informed decisions about what PFAS exposure might mean for an individual's health (see also https://www.dhhs.nh.gov/dphs/pfcs/blood-testing.htm).

Results from New Hampshire's Biomonitoring Program show that body burdens of PFOA, PFOS, and PFHxS in persons who consumed water from the Pease Tradeport public water system and private wells were significantly higher than national levels reported in CDC's 2011–2012 National Health and Nutrition Examination Survey (NHANES) report [NH DHHS 2015]. In addition, since the release of the 2013–2014 NHANES data, NH DHHS revised its age-specific comparisons. Please see the ATSDR Public Water Health Consultation for a summary of these findings [ATSDR 2020]. It is important to note that the result of biomonitoring data is indicative of exposures received from all sources of PFAS in a person's environment including their drinking water.

5.6. Summary of Public Health Implications Evaluation

There are several limitations and uncertainties when evaluating human health implications from PFAS exposures in drinking water (see below). Because of these limitations, ATSDR used a health-protective approach to evaluate the possibility for harmful non-cancer and cancer health effects. ATSDR used an approach that considered multiple exposures and factors. These included consideration of past body burdens, length of exposure, multiple PFAS in the water, contributions from other non-water sources, and similarity of health effects for various PFAS—all sources or factors which could contribute to the overall health effects of PFAS exposures. Although most of the PFOA, PFOS, and PFHxS exposures were below health effect levels seen in the scientific literature (assuming a 100% contribution from drinking water), some of the estimated doses were above ATSDR's provisional MRLs indicating a potential for concern and some doses approached effect levels. The following table summarizes the bottom-line findings from ATSDR's evaluation of the 40 private wells sampled and the following sections provide the basis for these determinations.

Table 5. Summary of Non-Cancer Public Health Findings for Private Drinking Water Wells in Newington and Greenland, NH sampled Near the Pease International Tradeport, Portsmouth, New Hampshire

Hazard (Risk) Determination	Private Drinking Water Wells
Wells with possible PFAS hazard/risk—see Conclusion 1	**5 Wells**: RES17, RES19, RES21, RES23, and RES37
Wells where PFAS hazard/risk cannot be determined—see Conclusion 2	**24 Wells**: RES01, RES02, RES03, RES04, RES05, RES06, RES09, RES11, RES14, RES15, RES18, RES20, RES22, RES24, RES25, RES29, RES31, RES38, RES43, RES41, RES45, RES48, RES49, and RES50
Wells where PFAS hazard/risk unlikely--Exposure—see Conclusion 3	**8 Wells**: RES07, RES08, RES10, RES12, RES13, RES27, RES34, and RES51
Wells with no PFAS hazard/risk—No Exposure—see Conclusion 3	**3 Wells**: RES30, RES42, and RES52

5.6.1. Wells with Possible PFAS Hazard/Risk

After evaluating multiple factors, ATSDR concludes that past exposure to drinking water with levels of PFOA, PFOS, and PFHxS measured in well RES17 in combination with exposure to other PFAS found in the RES17 water and other potential non-drinking water sources, could have increased the risk for harmful non-cancer health effects in all age and exposure groups, particularly young children and infants. The risks for harmful non-cancer effects were likely greater for young children who lived at RES17 or were born to mothers who used this well long-term for drinking water.

Adult users of wells RES19, RES21, RES23, and RES37/GBNWR are not likely to have increased risk for harm from their past exposures to PFOA, PFOS, and PFHxS in their private wells. However, the risk of harmful non-cancer effects to adult users of RES19, RES21, and RES37 from past exposure to the total mixture of PFAS (beyond PFOA, PFOS, and PFHxS) is uncertain. Adult users of RES23 are not at an additional risk beyond their exposure to PFOS because no other PFAS were detected in this well. There is a concern for exposures to young children who used water from these wells because of the combined PFOS, PFOA, and PFHxS exposures and other PFAS in their water. For some of these wells, especially RES17, the estimated exposure doses for PFOS were close to or above effect levels found in the animal studies ATSDR used to derive its provisional MRL and from other animal studies of immune effects. Therefore, because PFOA and PFOS levels in RES19, RES21, RES23, and RES37/GBNWR were near or above the EPA health advisory, ATSDR agrees with actions to provide these residents with treatment systems. No other private wells had PFOA and PFOS levels above the EPA health advisory.

5.6.2. Wells Where PFAS Hazard/Risk Cannot be Determined

For RES 03, RES09, RES20, RES22, and RES25, a least one maximum value was detected above the ATSDR HBCV for PFOS. None of the maximum PFOA or PFNA levels for these wells were above ATSDR's HBCV. In addition, none of the combined PFOA and PFOS levels for these wells exceeded the EPA health advisory. RES09 had the highest detected PFHxS concentration (0.96 µg/L) which exceeded ATSDR's HBCV, but PFHxS was not above its HBCVs in any other wells. The one high PFHxS level may be an anomaly because that concentration was never duplicated at that well. ATSDR's evaluation indicates that if this were an actual PFHxS exposure, young children may experience a slight increased risk of thyroid effects. If it were not an actual exposure, then ATSDR expects no harmful non-cancer effects to anyone using this well. ATSDR's evaluation of exposures to PFOS alone indicate that no harmful effects are likely because the HQs were either below 1.0 or only slightly elevated and the estimated exposure doses were well below health effect levels shown in animals studies used to derive ATSDR's provisional MRLs. ATSDR's evaluation of the exposure to the PFOA, PFOS, PFHxS, and PFNA mixture in these wells provided little information that the combined exposures to these PFAS appreciably increased the risk of harmful effects. Further health perspective for the total mixture of PFAS found in these wells is provided in the next section below. ATSDR is available to discuss these findings with the users of these wells.

For residential wells with no treatment systems, no harmful health effects are likely for exposures to PFOA, PFOS, PFHxS, or PFNA, either alone or combined. However, water from these wells also contained other PFAS with no HBCVs. We lack refined methods to evaluate the public health implications of exposure to the entire mixture of PFAS in water from these wells. For most of these other PFAS, except for those with HBCVs, little toxicological information is available to understand what harmful effects they might cause and at what exposure levels.

The number of PFAS detected in the remaining 19 wells ranged from one or two (RES12, RES13, RES34, RES43, and RES50) up to 11 to 14 different PFAS in a few wells. Sampling data indicates that RES01, RES03, RES15, RES20, RES22, and RES25 had the highest total PFAS concentrations and highest number of different PFAS detected (see Table A-1).

This health consultation includes the limited information on what is known about the health effects of some of these PFAS. Longed-chained PFAS are generally considered to be more bioaccumulative than short-chained PFAS. (See Table A-1 for more information on which PFAS are short- or long-chained.) To help owners of wells with no treatment systems better understand what is in the water from their wells, ATSDR calculated the percentage of long-chained PFAS for the summed concentrations of all detected PFAS in water from each well (see Table A-1). Although that is a health-protective assumption, ATSDR is uncertain about the validity of adding these PFAS, because we do not know if they all have the same health endpoints. Besides PFAS exposures from drinking water, PFAS exposure from food and consumer products are possible contributors to the overall PFAS body burden.

5.6.3. Wells where PFAS Hazard/Risk Unlikely or No Hazard

A few of the wells with no treatment systems had no PFAS detected (RES30, RES42, and RES52) or all the PFAS detected had HBCVs and were below them (RES07, RES08, RES27, and RES51), indicating that no harmful PFAS are expected. For some wells with only a few PFAS detections (i.e., RES10, RES12, RES13, and RES34), the risk for harmful health effects is likely low as they were detected at low parts–per-trillion concentrations below ATSDR's lowest HBCV.

5.6.4 Additional Supporting Information

- Scientific information suggests an association between PFOA, PFOS, and PFHxS exposure and various health endpoints, including effects on serum lipids (not for PFHxS), immune responses, fetal growth and development, endocrine systems (thyroid), and the liver.
- A review of the scientific literature indicated children and neonates are considered sensitive to PFAS exposures and are the age group is likely to receive the highest exposures. In addition, persons with certain pre-existing health conditions (risk factors) such as elevated cholesterol or elevated blood pressure and those with compromised livers or who may be immunocompromised may be unusually susceptible to health effects associated with PFAS exposures. In general, the clinical significance of the impact of PFAS exposures on people with pre-existing conditions is not well understood.
- Well-accepted scientific methods to quantitatively evaluate the possible health impacts of the combined exposures to mixtures of PFAS do not exist. ATSDR determined that combined exposure to PFOA, PFOS, PFHxS and PFNA in these wells could have increased the risk of developmental, endocrine (thyroid) and immune effects. Several other PFAS may adversely affect the same organ systems. Harmful effects for other health outcomes shown to be associated with PFOA, PFOS, or PFHxS may also occur. Therefore,

the combined exposures to PFAS measured in these private wells may have increased the risk for some non-cancer health outcomes.

- Exposures to PFAS from non-drinking water sources, combined with exposure to other PFAS in private well water with limited scientific information, could increase the risk for some associated health effects.
- Epidemiologic data suggest a link between PFOA exposure and elevated rates of kidney, prostate, and testicular cancer. Animals given PFOA have shown higher rates of liver, testicular, and pancreatic tumors. A causal link based on human studies between cancer and PFOS exposures remains uncertain. Animal studies have found limited, but suggestive evidence of PFOS exposure and increased incidence of liver, thyroid, and mammary tumors. Although current data are very limited, other PFAS might be carcinogenic and some may not. EPA has developed an oral cancer slope factor only for PFOA based on testicular cancer from a rat study. If the oral cancer slope factor approximates the actual cancer risk for PFOA, then the estimated cancer risk level is considered a very low risk. This estimated cancer risk must be viewed with caution because the EPA oral cancer slope factor has not been fully adopted, and other cancers that were elevated in epidemiological studies of PFOA exposure were not evaluated. EPA does not have an oral cancer slope factor for PFOS or other PFAS. Therefore, ATSDR cannot calculate the estimated cancer risk from PFOS or other potentially carcinogenic PFAS exposures, and the actual cancer risk from most PFAS exposures from the Pease private wells is uncertain.

6. Community Concern: Breastfeeding Exposures and Health Implications

Community members, especially mothers who were exposed to PFAS from the Pease International Tradeport site, have expressed concerns about the health implications of PFAS exposure to infants who breastfeed. Developmental effects are the most sensitive adverse health effect resulting from any early life exposure. Studies have shown PFAS to transfer to nursing infants. Studies that measured PFAS in maternal blood and breast milk in matched mother-infant pairs found highly variable correlations [ATSDR 2018a]. Comparisons of serum concentrations of women who breastfed their infants with those who did not showed that breastfeeding significantly decreases maternal serum concentrations of PFAS [Mogensen et al. 2015]. The decrease was estimated to be 2% to 3% per month of breastfeeding. Concentrations of PFAS in breast milk also decrease with breastfeeding duration [ATSDR 2018a].

Breastfeeding provides many health and nutritional benefits to a child; such as, a reduced risk of ear and respiratory infections, asthma, obesity, and sudden infant death syndrome. In addition, breastfeeding can also help lower a mother's risk of high blood pressure, type 2 diabetes, and ovarian and breast cancer [CDC 2019].

In general, CDC and the American Academy of Pediatrics recommend breastfeeding, despite the presence of chemical toxicants [CDC 2015; AAP 2012]. A woman's decision to breastfeed is a personal choice, made in consultation with her healthcare provider. It is a choice made after consideration of many different factors, many unrelated to PFAS exposure, specific to the mother and child. ATSDR has developed information to guide doctors and aid in this decision-making process.

7. Limitations and Uncertainties of Human Health Risks from PFAS Exposures

7.1 Multiple Exposure Sources

In addition to drinking water exposures, community members likely have additional PFAS exposures from other sources. These could include food, dust, air, and consumer products. Exposures might also occur by touching surfaces treated with a stain protector and then touching one's mouth or touching food that is eaten. All sources add to the amount of chemicals in one's body and potential health effects. ATSDR was not able to assess the impact of these sources on possible health effects.

7.2 Lack of Historical Exposure Data

ATSDR does not know exactly how long and at what concentrations workers and children were exposed to PFAS in private wells near the Pease International Tradeport. Historical sampling data are unavailable. Exposures might have occurred for years through PFAS movement in groundwater. PFAS compounds accumulate and remain in the body for years before they are eliminated. Past and current exposures contribute to the overall health risks from PFAS.

7.3 Inadequate Methods to Fully Assess Human Health Implications

Methods are available to evaluate the public health implications of exposure to PFOA, PFOS, PFHxS, and PFNA (all PFAS with ATSDR-derived provisional MRLs). People who use private well water are potentially exposed to a mixture of PFAS compounds. Methods used to assess exposure to other environmental mixtures have not been developed for PFAS or might be appropriate only for PFOA, PFOS, PFHxS, and PFNA. ATSDR used the approach of adding hazard quotients to get a hazard index which is often used to assess risk to multiple chemicals. However, this approach may not provide an appropriate solution for all PFAS. Only compounds with similar toxicological endpoints should be combined (i.e., PFOS, PFOA, PFHxS, and PFNA). Moreover, standard risk assessments methods have limitations. Only six of the 23 different PFAS detected in the private wells have HBCVs available to support a traditional ATSDR public health evaluation. ATSDR does not have HBCVs other than for the four PFAS that include PFOS, PFOA, PFHxS, and PFNA. ATSDR has not formally reviewed the Minnesota HBCVs for two PFAS that include PFBS and PFBA used in this document.

7.4 Other General Limitations

Humans and experimental animals differ in how their bodies absorb and react to PFAS. That leaves questions about the relevance of effects in animals to humans. ATSDR also has limited toxicity data for many PFAS compounds from human and animal studies [Butenhoff JL and Rodricks JV 2015]. The health consequences of PFAS in the body are uncertain. Significant uncertainty exists about the lowest concentration at which toxic effects might occur in people exposed to PFAS for many years. Therefore, people exposed for many years could be at increased health risk.

The HBCVs for PFOS, PFOA, PFHxS, and PFNA in drinking water were calculated by ATSDR using the best available scientific information. These values allow ATSDR to assess the potential risk from drinking water exposures. ATSDR HBCVs and provisional MRLs are based on the most current PFAS science; however, the overall scientific knowledge on PFAS is still evolving. Toxicity information for other PFAS compounds is limited.

Because of these limitations, ATSDR used a health-protective approach to evaluate health risks for non-cancer health effects until better methods are developed. For non-cancer health effects, ATSDR calculated hazard quotients for PFOS, PFOA, PFHxS, and PFNA, the most thoroughly investigated PFAS compounds. If the hazard quotient exceeded one, ATSDR considered a potential exposure of concern. In a qualitative way, ATSDR considered other source contributions, other PFAS compounds in the mixture, and past exposures in evaluating health risks.

7.5 Incomplete information on the type of AFFF used at the former Pease AFB and specific PFAS formulations

One of the challenges to evaluating exposures from an AFFF source is that we do not know all the PFAS constituents and that these constituents have changed over time. Data on AFFF-impacted groundwater indicate that about 25% of the PFAS species remain unidentified [Houtz et al. 2013]. A study by Barzen-Hanson et al. (2017) resulted in the discovery of 40 novel classes of PFAS and the detection of 17 classes of previously reported PFAS, adding over 240 individual PFAS to the previous list that can now be associated with AFFF. Little is known about the newly discovered PFAS regarding the subsurface remediation strategies, transport, and toxicity [Barzen-Hanson et al. 2017].

8. Conclusions

ATSDR evaluated the public health implications of past and current PFAS exposure to the users of private wells near the Pease Tradeport and reached four conclusions. These conclusions are limited by several uncertainties. The specific PFAS formulation in the AFFF used at the former Pease AFB is not known. ATSDR used a health-protective approach to evaluate concentrations of 23 PFAS in drinking water wells. However, there may be PFAS in the water that were not measured. ATSDR's conclusions are based on evaluation of other PFAS that were measured in the water.

Conclusion 1—Wells with Possible PFAS Hazard/Risk

Past PFAS exposures may have increased the risk of harmful non-cancer health effects, especially to young children, who drank water from RES17, RES19, RES21, RES23, and RES37 or were born to mothers who did. The cancer risk from past exposures to all PFAS in these wells is uncertain. No current or future harmful exposures are expected for residents using these five water supply wells because actions have been taken to reduce or eliminate their exposures. However, there might be PFAS in the water that were not measured.

Basis for conclusion

The combined past exposures to PFOA, PFOS, and PFHxS to users of RES17, RES19, RES21, RES23, and RE37 may have increased the risk of harmful non-cancer health effects, especially for developmental, endocrine (e.g., thyroid), and immune effects, in young children. Harmful effects for other health outcomes shown to be associated with PFOA, PFOS, or PFHxS may also occur; such as, effects on cholesterol and the liver. Harmful non-cancer health effects for adults are only a potential concern for users of RES17. The risk of harmful effects to adult users of three other wells (RES19, RES21, and RES37) is uncertain because of the lack of scientific information to evaluate the health implications of exposures to other PFAS in these wells besides PFOS, PFOA, or PFHxS. Adult users of RES23 are not at risk because no other PFAS were detected.

Human and animal studies suggest a link between PFOA exposure and higher rates of several cancers. Animal studies suggest a link between PFOS exposure and several cancers; although, human studies have yet to confirm a link between cancer and PFOS exposures.

Limited data exist on the potential of other PFAS to cause cancer. ATSDR cannot calculate the estimated cancer risk for other past PFAS exposures or a total cancer risk from all potentially cancer-causing PFAS exposures. The total cancer risk from past PFAS exposures from these private wells is uncertain.

Exposure to PFAS from food and consumer products, and to other PFAS in the water, could contribute to the overall amount of PFAS in a person's body. Some pre-existing risk factors might increase the risk for harmful effects (e.g., persons with compromised immune systems or liver function).

Conclusion 2 — Wells Where PFAS Hazard/Risk Cannot be Determined

The risk of harmful health effects (non-cancer and cancer) from past and current exposures to mixture of all PFAS in drinking water from 24 wells without treatment systems (see Table 5 for list of wells), now or in the past, cannot be determined.

Basis for conclusion

Exposure to PFOS, PFOA, and PFHxS individually or combined in untreated drinking water from RES03, RES20, RES22, and RES25 were evaluated and not likely to result in an increased risk of harmful non-cancer health effects. The risk of harmful non-cancer health effects from past PFHxS exposures to users of RES09 cannot be determined because of uncertain exposure data. The cancer risk from current and past exposure to all PFAS in these wells is uncertain because of limited data on the potential for these PFAS to cause cancer. In addition, drinking water from 19 other wells (see Table 5 for list) contained PFAS ranging from 2 in RES43 and RES50 to 14 different PFAS in a few wells. Sampling data indicate that RES01, RES03, RES15, RES20, RES22, and RES25 had the highest total PFAS concentrations and number of different PFAS detected (see Table A-1). However, the scientific community lack refined methods to evaluate the public health implications of exposure to the entire mixture of PFAS in all 24 of these wells. In addition to PFAS exposures from drinking water, PFAS exposure from food and consumer products might contribute to the overall amount of PFAS in a person's body.

Conclusion 3 — Wells where PFAS Hazard/Risk Unlikely or No Hazard

Past and current exposure to PFAS in drinking water from 11 wells without treatment systems is unlikely to result in an increased risk of harmful health effects.

Basis for conclusion

No PFAS were detected in RES30, RES42, and RES52 — wells with no treatment systems — indicating that no exposures have occurred. Only a few PFAS (all with ATSDR HBCVs) were detected in wells RES07, RES08, RES27, and RES51, and all were below their respective ATSDR HBCVs. The risk for harmful health effects is likely low for RES10, RES12, RES13, and RES34, which had only a few detections of total PFAS at low parts-per-trillion concentrations, which were below ATSDR's lowest HBCV. Based on current scientific information, PFAS levels below the HBCV indicate that harmful health effects are not likely.

Conclusion 4 — Breastfeeding remains a healthy option

Scientific information suggests that the health and nutritional benefits of breastfeeding outweigh the potential risks associated with PFAS in breastmilk.

Basis for conclusion

Community members, particularly mothers who have been exposed to PFAS from the Pease International Tradeport site, have expressed concern about the health implications of PFAS exposures to breastfed infants. Developmental and immune effects may be the main adverse health effects resulting from early life exposure to some PFAS. Studies have shown that infants can be exposed to PFAS during pregnancy by transfer through the mother to the fetus and through breastfeeding. However, breastfeeding provides clear health and nutritional benefits. Some of the many benefits for infants include a reduced risk for ear and respiratory infections, asthma, obesity, and sudden infant death syndrome. Breastfeeding can also help lower a mother's risk for high blood pressure, type 2 diabetes, and ovarian and breast cancer. In general, CDC and the American Academy of Pediatrics recommend breastfeeding despite the potential presence of chemical contaminants in breast milk.

We continue to learn more about the health effects of PFAS exposure on mothers and children. From what we know about PFAS exposure through breastmilk, the benefits of breastfeeding outweigh the risks. A woman's decision to breastfeed is an individual choice considering different factors, many unrelated to PFAS exposure, and in consultation with her healthcare providers. ATSDR has developed information to guide healthcare providers in this decision-making process with their patients (see https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf). Women should take steps to reduce exposure to toxic substances during childbearing years, especially while pregnant or breastfeeding (see https://www.atsdr.cdc.gov/pfas/pfas-exposure.html).

9. Recommendations

ATSDR recommends that EPA, NHDES, and the USAF continue their investigations to characterize PFAS groundwater contamination at the site and continue monitoring the private drinking water supply wells, including the identification of any affected wells that were not part of the original inventory plan.

The USAF preferred long-term remedy for the four residences currently with water treatment systems is to connect them to the Pease Tradeport public water supply. ATSDR recommends that the USAF with EPA and NHDES regulators continue their efforts to implement a long-term remedy, which will permanently stop exposure to contaminated private drinking water sources that have PFAS above EPA or other applicable health-based drinking water guidelines and reduce exposures to PFAS compounds that have no HBCVs. In addition, because the PFAS drinking water regulatory standards are continuing to evolve, these agencies should implement a long-term monitoring program that evaluates PFOS, PFOA, PFHxS and other PFAS that may be found in private wells. This will allow the agencies to stop exposures to contaminated private drinking water sources containing PFAS above applicable health-based drinking water standards.

If individuals want to reduce their exposure to PFAS in their water, they can use an alternative or treated water source for drinking, food preparation, cooking, brushing teeth, and any activity that might result in ingestion of water. Using contaminated water for bathing or showering, washing dishes, and doing laundry is not expected to result in significant exposure to PFAS.

ATSDR recommends, based on several health benefits of breastfeeding for both mother and child, that nursing mothers continue to breastfeed. ATSDR recommends caregivers use pre-mixed baby formula or reconstitute dry formula with water sources not containing PFAS to reduce any potential exposure. More Information to guide healthcare providers is available from: https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf.

10. Public Health Action Plan

10.1 Completed Actions

The USAF tested private wells located within one mile of the former Pease AFB boundary for PFAS.

The USAF installed whole house activated carbon treatment systems at RES17, RES19, and RES21 to treat water with exceedances of the EPA health advisory. As a health-protective action, the USAF also installed a whole house activated carbon treatment system at RES23 because the combined PFOA and PFOS concentrations in the most recent sample taken in April 2016 was close to reaching the EPA health advisory. The USAF also provided bottled water for the seasonal users of RES37/GBNWR and this well is no longer in use.

NHDES collaborated with the New Hampshire Department of Health & Human Services (DHHS) to provide health information about PFAS in a document titled *Frequently Asked Questions: Perfluorochemicals (PFCs) in the Pease Tradeport Water System.* This can be found on the DHHS webpage: Investigation into Contaminant Found in Pease Tradeport Water System available from: http://www.dhhs.nh.gov/dphs/investigation-pease.htm.

In November 2017, ATSDR released a feasibility assessment for conducting a study to evaluate potential health effects of the population exposed to PFAS at the Pease Tradeport. The report is available from:
https://www.atsdr.cdc.gov/sites/pease/documents/Pease_Feasibility_Assessment_November-2017_508.pdf.

ATSDR developed health education information related to PFAS in drinking water for residents, community members, and health professionals which is available from:
https://www.atsdr.cdc.gov/PFAS/

10.2 Ongoing Actions

Drinking water wells RES19 and RES21 will be connected to public water lines. The USAF will maintain whole house activated carbon treatment system at RES17. The users of well RES23 have opted to take over their filter system.

The New Hampshire Department of Health & Human Services offered biomonitoring (blood testing) for any persons exposed to PFAS in drinking water at Pease International Tradeport, including those exposed to either PFOS or PFOA above their former EPA PHALs from private wells tested because of the Pease PFAS investigation. All blood testing for PFAS is no longer available through the NH Department of Health and Human Services. NH DHHS has and will continue to provide information and recommendations to healthcare providers to help providers and patients make informed decisions about what PFAS exposure might mean for an individual's health (see also https://www.dhhs.nh.gov/dphs/pfcs/blood-testing.htm).

The USAF is investigating the source and migration pathway of PFAS from former Pease AFB Site 8 to off-site wells to determine strategies to mitigate contaminant migration.

ATSDR and the Centers for Disease Control and Prevention (CDC) are conducting a health study of children and adults exposed to PFAS-contaminated drinking water at the Pease International Tradeport and from nearby private wells. The study will evaluate associations between PFAS blood levels and signs of changes in the body (e.g., cholesterol levels, kidney and thyroid function, and the development of specific diseases), and will serve as the first site in CDC/ATSDR's Multi-site Health Study looking at the relationship between PFAS drinking water exposures and health outcomes. Sites in seven additional states will also participate in the Multi-site Health Study.

ATSDR and CDC are working to address the concerns of community members regarding potential associations between PFAS exposure and cancer. We are conducting an analysis that uses previously collected data to look at rates of certain health outcomes, including many adult and pediatric cancers, in communities that have been exposed to PFAS through drinking water and those that have not.

ATSDR and CDC are conducting exposure assessments in communities near current and former military bases and that are known to have had PFAS in their drinking water. The exposures assessments will provide information to communities about the levels of PFAS in their bodies. Using this information, public health professionals provide guidance to help people reduce or stop exposure.

ATSDR is also providing technical assistance to tribal, state, and territorial health departments nationwide so they can effectively evaluate PFAS exposure in contaminated communities.

ATSDR will be available during the public availability sessions planned in the community to consult with individual well users to provide them additional health perspective on the PFAS exposures in their drinking water. In addition, well users may call ATSDR at 1-770-488-3731 or by e-mail at gru1@cdc.gov to arrange a consultation with ATSDR scientists.

ATSDR recognizes that additional information is needed about the types of PFAS in AFFF and the type of AFFF used at Pease. Standard laboratory methods capable of detecting a broader range of PFAS in environmental samples are also needed. As more information becomes available, ATSDR will incorporate it into future assessments of exposure to PFAS from sites associated with the use of AFFF.

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Appendix A–Figures, Tables, and Equations

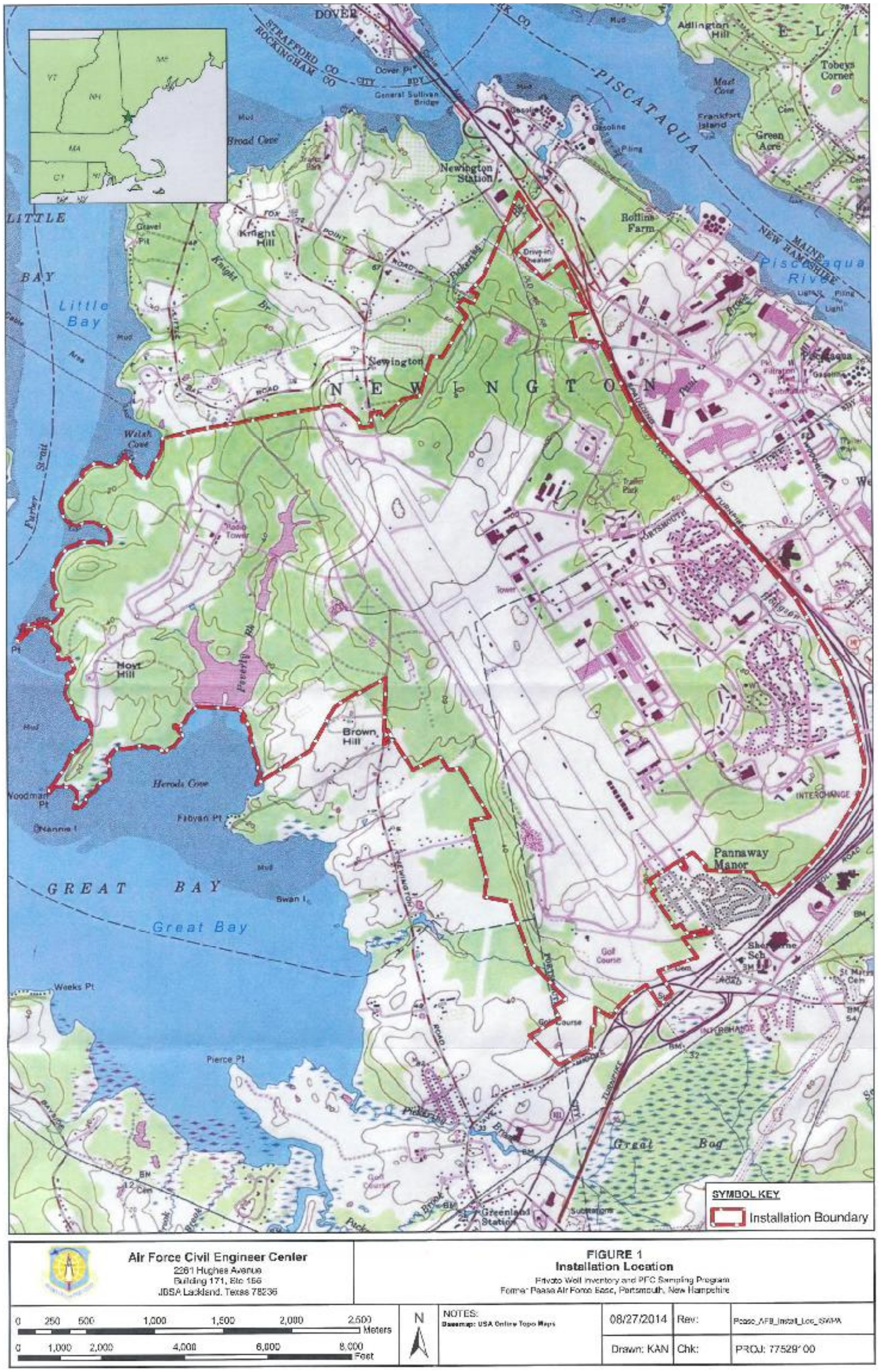

Figure A-1. Location and vicinity of Pease International Tradeport (former Pease Air Force Base). **Source**: AMEC. 2014.

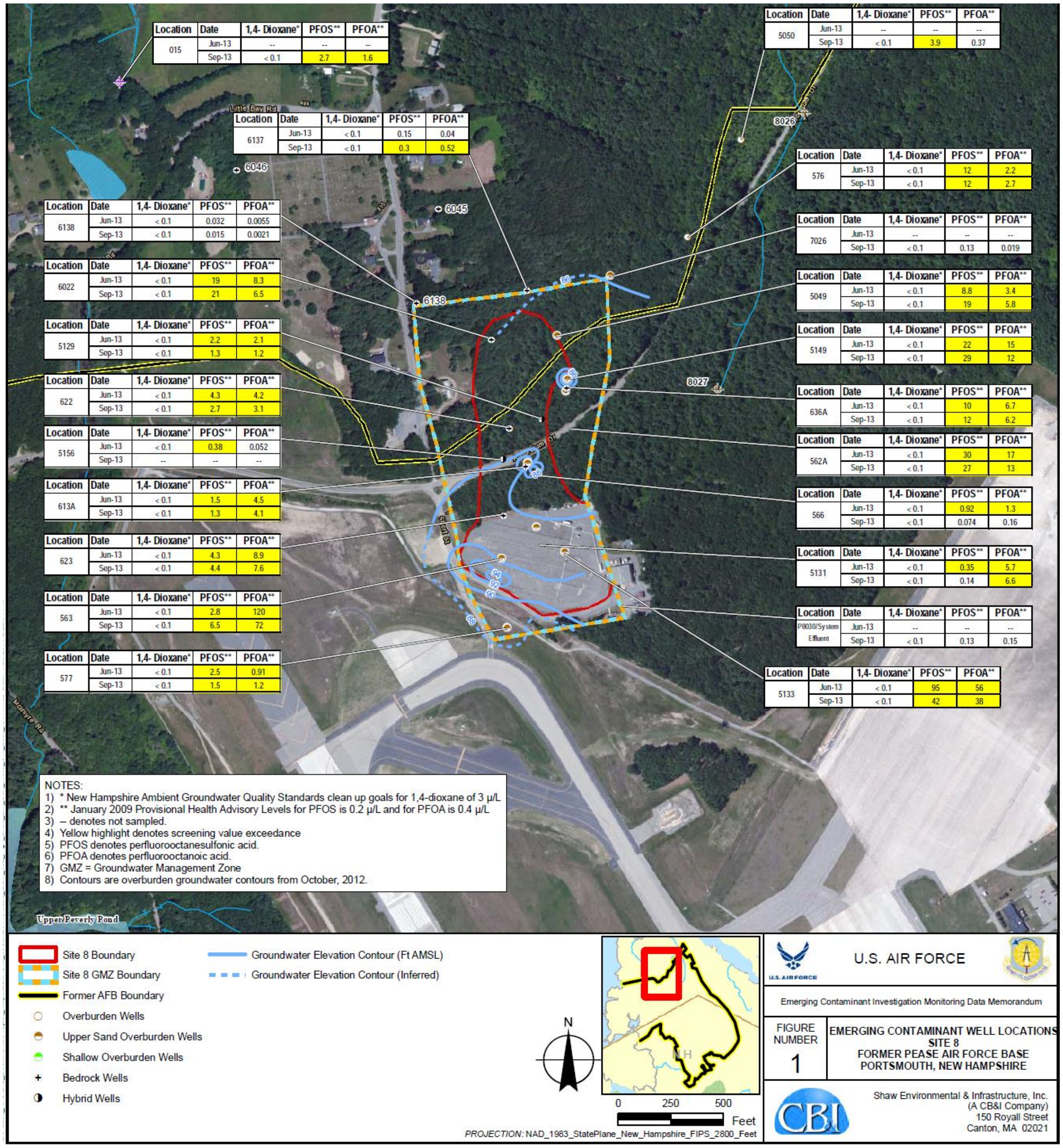

Figure A-2. Former Pease Air Force Base/Pease International Tradeport detail and location of site 8. **Source**: CB&I. 2015.

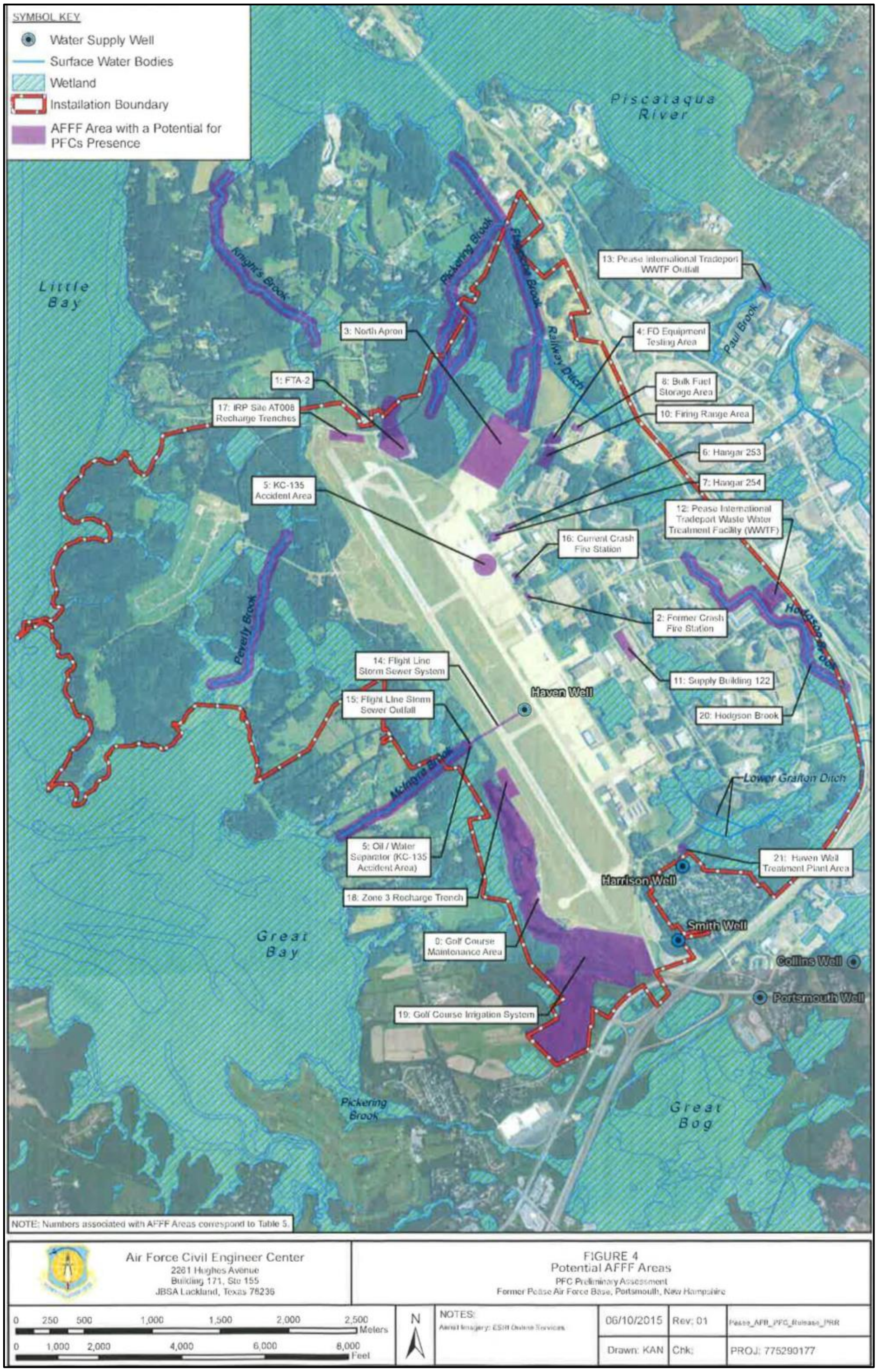

Figure A-3. Potential aqueous film-forming foam areas. **Source**: AMECFW 2015.

Table A-1. Total PFAS concentration (Including and excluding the perfluorohexanesulfonic acid (PFHxS), perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), number of different PFAS detected, and percentage of detected PFAS that were long chain from Untreated Private drinking water wells located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire. Concentrations in micrograms per liter (µg/L)

	Includes PFHxS, PFNA, PFOA, PFOS			Excludes PFHxS, PFNA, PFOA, PFOS		
Well ID	Total PFAS concentration	# PFAS	% Long Chain*	Total PFAS concentration	# PFAS	% Long Chain*
RES01	0.1029	14	64%	0.0627	10	50%
RES02	0.0779	9	44%	0.0425	6	17%
RES03	0.1130	11	55%	0.0631	7	29%
RES04	0.0199	4	75%	0.0102	2	50%
RES05	0.0294	4	100%	0.0173	2	100%
RES06	0.0762	9	44%	0.0488	6	17%
RES07	0.0059	1	100%	0	0	
RES08	0.0079	1	100%	0	0	
RES09	1.0414	8	50%	0.0668	5	20%
RES10	0.0136	2	100%	0.0084	1	100%
RES11	0.0359	4	75%	0.0189	2	50%
RES12	0.0117	2	100%	0.0117	2	100%
RES13	0.0139	2	100%	0.0139	2	100%
RES14	0.0468	5	40%	0.0291	3	0%
RES15	0.1203	9	44%	0.0349	6	17%
RES17	1.5706	12	58%	0.5206	9	44%
RES18-W1	0.0241	5	60%	0.0083	2	0%
RES19	0.2488	6	50%	0.056	3	0

Note: *% Long Chain = percent of PFAS detected in this well that are classified as long chain PFAS. Long-chain PFAS comprise two sub-categories: long-chain perfluoroalkyl carboxylic acids with eight or more carbons, and perfluoroalkane sulfonates with six or more carbons [EPA 2018].

Table A-1. (continued)

Well ID	Includes PFHxS, PFNA, PFOA, PFOS			Excludes PFHxS, PFNA, PFOA, PFOS		
	Total PFAS concentration	# PFAS	% Long Chain*	Total PFAS concentration	# PFAS	% Long Chain*
RES20	0.2145	11	55%	0.0945	8	38%
RES21	0.1579	6	50%	0.0209	3	0%
RES22	0.1392	9	56%	0.0454	6	33%
RES23	0.0700	3	100%	0	0	0%
RES24-W1	0.0263	4	75%	0.0206	3	67%
RES25	0.1090	9	44%	0.0580	6	17%
RES27	0.0059	1	0%	0.0059	1	0%
RES29	0.0438	7	29%	0.0278	5	0%
RES30	0	0		0	0	
RES31	0.0311	5	60%	0.0236	4	50%
RES34	0.0070	1	100%	0.0070	1	100%
RES37	0.2743	7	57%	0.0313	4	25%
RES38	0.0319	5	80%	0.0116	2	50%
RES41	0.0590	6	50%	0.0294	3	0%
RES42	0	0		0	0	
RES43	0.0157	2	100%	0.0083	1	100%
RES45	0.0507	6	50%	0.0264	3	0%
RES48	0.0744	6	50%	0.0417	3	0%
RES49	0.0345	4	100%	0.0146	2	100%
RES50	0.0199	2	100%	0.0100	1	100%
RES51	0.0082	1	100%	0	0	
RES52	0	0		0	0	

Note: *% Long Chain = percent of PFAS detected in this well that are classified as long chain PFAS. Long-chain PFAS comprise two sub-categories: long-chain perfluoroalkyl carboxylic acids with eight or more carbons, and perfluoroalkane sulfonates with six or more carbons [EPA 2018].

Table A-2. Perfluoroalkyl substances analyzed in water supply wells during April 2014 to December 2017

Specific PFAS	Abbreviation	Chemical Formula*	Type†
8:2 fluorotelomer sulfonate	8:2 FTS	$C_{10}H_4F_{17}O_3S$	Long
6:2 fluorotelomer sulfonate	6:2 FTS	$C_8H_4F_{13}O_3S$	Long
n-ethyl perfluorooctane sulfonamide	EtFOSA	$C_{10}H_6F_{17}NO_2S$	Long
n-ethyl perfluorooctane sulfonamidoethanol	EtFOSE	$C_{12}H_{10}F_{17}NO_3S$	Long
n-methyl perfluorooctane sulfonamide	MeFOSA	$C_9H_4F_{17}NO_2S$	Long
n-methyl perfluorooctane sulfonamidoethanol	MeFOSE	$C_{11}H_8F_{17}NO_3S$	Long
perfluorobutanesulfonic acid	PFBS	$C_4HF_9O_3S$	Short
perfluorobutanoic acid	PFBA	$C_4HF_7O_2$	Short
perfluorodecanesulfonic acid	PFDS	$C_{10}HF_{21}O_3S$	Long
perfluorodecanoic acid	PFDA	$C_{10}HF_{19}O_2$	Long
perfluorododecanoic acid	PFDoA	$C_{12}HF_{23}O_2$	Long
perfluoroheptane sulfonate	PFHpS	$C_7HF_{15}SO_3$	Long
perfluoroheptanoic acid	PFHpA	$C_7HF_{13}O_2$	Short
perfluorohexanesulfonic acid	PFHxS	$C_6HF_{13}O_3S$	Long
perfluorohexanoic acid	PFHxA	$C_6HF_{11}O_2$	Short
perfluorononanoic acid	PFNA	$C_9HF_{17}O_2$	Long
perfluorooctane sulfonamide	PFOSA	$C_8H_2F_{17}NO_2S$	Long
perfluorooctanesulfonic acid	PFOS	$C_8HF_{17}O_3S$	Long
perfluorooctanoic acid	PFOA	$C_8HF_{15}O_2$	Long
perfluoropentanoic acid	PFPeA	$C_5HF_9O_2$	Short
perfluorotetradecanoic acid	PFTeDA	$C_{14}HF_{27}O_2$	Long
perfluorotridecanoic acid	PFTrDA	$C_{13}HF_{25}O_2$	Long
perfluoroundecanoic acid	PFUnA	$C_{11}HF_{21}O_2$	Long

Note*:* PFAS = per and polyfluoroalkyl substances

*available from: https://pubchem.ncbi.nlm.nih.gov/ and https://comptox.epa.gov/dashboard/chemical_lists/pfastrier

†Long-chain PFAS comprise two sub-categories: long-chain perfluoroalkyl carboxylic acids with eight or more carbons, and perfluoroalkane sulfonates with six or more carbons [EPA 2018].

Table A-3. Maximum detected perfluoroalkyl substances concentrations in Greenland and Newington, NH private wells within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire. Concentrations in micrograms per liter (µg/L) 2014 to 2017

Sample ID	Specific PFAS ==> HBCV ==>	PFOS (0.014)*	PFOA (0.021)*	6:2FTS (none)	8:2FTS (none)	EtFOSA (none)	EtFOSE (none)	PFBA (7.0)†	PFBS (2.0)†
RES01		0.013 J	0.011 J	ND	0.0059 J	ND	ND	0.0087 J	0.011 J
RES02		0.013 J	0.0094 J	ND	ND	ND	ND	0.0091 J	0.0054 J
RES03		0.015 J	0.02 J	ND	ND	ND	0.009 J	0.0068 J	0.012 J
RES04		0.0045 J	ND	ND	ND	ND	ND	ND	0.0055 J
RES05		0.0043 B	ND	ND	ND	0.0063 J	ND	ND	ND
RES06		0.0068 J	0.011 J	ND	ND	ND	ND	0.0079 J	0.0057 J
RES07		ND	ND	ND	ND	ND	ND	ND	ND
RES08		ND	ND	ND	ND	ND	ND	ND	ND
RES09		0.0068 J	0.0078 J	ND	ND	ND	ND	0.012 J	ND
RES10		0.0052 B	ND	ND	ND	0.0084 J	ND	ND	ND
RES11		0.0074 J	ND	ND	ND	ND	ND	ND	0.011 J
RES12		ND	ND	ND	ND	ND	ND	ND	ND
RES13		ND	ND	0.009 J	ND	ND	ND	ND	ND
RES14		0.0047 B	ND	ND	ND	ND	ND	0.0093 J	ND
RES15		0.0094 J	0.014 J	ND	ND	ND	ND	0.0037 J	0.01 J
RES17‡		0.57	0.11	0.041 J	ND	ND	ND	0.032	0.06
RES17TRT		ND	ND	ND	ND	ND	ND	ND	ND
RES18-W1		0.0053 B	0.0068 J	ND	ND	ND	ND	ND	0.0027 J
RES19		0.086	0.0068	ND	ND	ND	ND	ND	0.01 J
RES19TRT		ND	ND	ND	ND	ND	ND	ND	ND
RES20		0.027	0.018 J	0.0059 J	ND	ND	ND	0.0092 J	0.013 J

Notes: Only PFAS with at least one detection are shown in this table. ND = Not detected. RES17 = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on October 18, 2014. RES17TRT = Samples after the treatment system were ND. RES19 = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on July18, 2014. RES19TRT = Samples after the treatment system were ND. Shaded indicate concentration of individual PFAS or summed PFAS exceeds a HBCV.

Sources AMEC 2014, AMECFW 2016, and Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 16. Includes one file attachment with private well PFAS data from 2014 to 2017.

*ATSDR HBCV. †MDH Minnesota Department of Health Risk Limit. ‡Gaps in numbering between residential wells indicates the numbers are attached to non-potable wells used for irrigation or open springs. B = This compound was detected in an associated blank by the laboratory.
J = Analyte was identified, but the concentration was estimated.

Table A-3. (CONTINUED)

Sample ID	Specific PFAS ==> HBCV ==>	PFOS (0.014)*	PFOA (0.021)*	6:2FTS (none)	8:2FTS (none)	EtFOSA (none)	EtFOSE (none)	PFBA (7.0)†	PFBS (2.0)†
RES21		0.043	0.021	ND	ND	ND	ND	0.0033	ND
RES21TRT		ND	ND	ND	ND	ND	ND	ND	ND
RES22		0.029	0.0088 J	ND	ND	ND	0.0079 B	ND	0.014 J
RES23		0.052	0.015	ND	ND	ND	ND	ND	ND
RES23TRT		ND	ND	ND	ND	ND	ND	ND	ND
RES24-W1		ND	ND	0.011 J	ND	ND	0.0051 B	ND	0.0045 J
RES25		0.014 J	0.017 J	ND	ND	ND	ND	0.0068 J	0.012 J
RES27‡		ND	ND	ND	ND	ND	ND	ND	0.0059 J
RES29		ND	0.0083 J	ND	ND	ND	ND	0.0072 J	0.0046 J
RES30		ND	ND	ND	ND	ND	ND	ND	ND
RES31		ND	ND	ND	ND	0.0089 J	ND	ND	0.0054 J
RES34		ND	ND	0.007 J	ND	ND	ND	ND	ND
RES37/GBNWR		0.13	0.014 J	ND	ND	ND	ND	ND	0.0054 J
RES38		0.005 J	0.01 J	ND	ND	ND	ND	0.0074 J	ND
RES41		0.0066 J	0.01 J	ND	ND	ND	ND	ND	0.0087 J
RES42		ND	ND	ND	ND	ND	ND	ND	ND
RES43		ND	ND	0.0083 J	ND	ND	ND	ND	ND
RES45		0.0079 J	0.0095 J	ND	ND	ND	ND	0.012 J	0.0082 J
RES48		0.0041 B	0.0066 J	ND	ND	ND	ND	ND	0.0086 J
RES49		ND	0.0099 J	0.007 J	ND	0.0076 J	ND	ND	ND
RES50		ND	ND	ND	ND	ND	0.01 J	ND	ND
RES51		ND	ND	ND	ND	ND	ND	ND	ND
RES52		ND	ND	ND	ND	ND	ND	ND	ND

Notes: Only PFAS with at least one detection are shown in this table. ND = Not detected. RES21F = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on September 1, 2016. RES21TRT = Samples after the treatment system were ND. RES23 = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on July 18, 2016. RES23TRT = Samples after the treatment system were ND. Shaded indicate concentration of individual PFAS or summed PFAS exceeds a HBCV.

Sources AMEC 2014, AMECFW 2016, and Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 16. Includes one file attachment with private well PFAS data from 2014 to 2017.

*ATSDR HBCV. †MDH Minnesota Department of Health Risk Limit. ‡Gaps in numbering between residential wells indicates the numbers are attached to non-potable wells used for irrigation or open springs.

B = This compound was detected in an associated blank by the laboratory.

J = Analyte was identified, but the concentration was estimated.

Table A-3. (CONTINUED)

Sample ID	Specific PFAS ==> HBCV ==>	PFDS (none)	PFHpA (none)	PFHpS (none)	PFHxA (none)	PFHxS (0.14)*	PFNA (0.021)*	PFOSA (none)	PFPeA (none)	PFTeDA (none)	PFTrDA (none)
RES01		ND	0.0039 J	0.005 J	0.0043 J	0.0095 J	0.0067 J	0.007 J	0.0058 J	0.006 J	0.0051 J
RES02		ND	0.0047 J	0.0048 B	0.0075 J	0.013 J	ND	ND	0.011 J	ND	ND
RES03		ND	0.013 J	0.0047 J	0.01 J	0.011 J	0.0039 J	ND	0.0076 J	ND	ND
RES04		ND	ND	0.0047 B	ND	0.0052 J	ND	ND	ND	ND	ND
RES05		ND	ND	ND	ND	0.0078 J	ND	0.011 J	ND	ND	ND
RES06		ND	0.007 J	0.0044 B	0.0098 J	0.0096 J	ND	ND	0.014 J	ND	ND
RES07		ND	ND	ND	ND	0.0059 J	ND	ND	ND	ND	ND
RES08		ND	ND	ND	ND	0.0079 J	ND	ND	ND	ND	ND
RES09		ND	0.012 J	ND	0.014 J	0.96†	ND	0.0048 J	0.024 J	ND	ND
RES10		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES11		ND	ND	ND	ND	0.0096 J	ND	0.0079 J	ND	ND	ND
RES12		ND	ND	0.0045 B	ND	ND	ND	ND	ND	0.0072 J	ND
RES13		ND	ND	0.0049 J	ND	ND	ND	ND	ND	ND	ND
RES14		ND	ND	ND	0.011 J	0.013 J	ND	ND	0.0088 J	ND	ND
RES15		ND	0.0059 J	ND	0.0065 J	0.062	ND	0.0053 J	0.0035 J	ND	ND
RES17‡		0.0056 J	0.038	0.015 J	0.23	0.37	ND	ND	0.094	0.005 J	ND
RES17TRT		0.0056 J	ND	0.0049 J	ND	ND	ND	ND	ND	0.005 J	ND
RES18-W1		ND	0.0056 J	ND	ND	0.0037 J	ND	ND	ND	ND	ND
RES19		ND	ND	ND	0.022	0.1	ND	ND	0.024	ND	ND
RES19TRT		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES20		ND	0.0038 J	0.0076 J	0.016 J	0.075	ND	0.028	0.011 J	ND	ND

Notes: Only PFAS with at least one detection are shown in this table. ND = Not detected. RES17F = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on October 18, 2014. RES17TRT = Samples after the treatment system were ND. RES19F = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on July18, 2014. RES19TRT = Samples after the treatment system were ND. Shaded indicate concentration of individual PFAS or summed PFAS exceeds a HBCV.

Sources AMEC 2014, AMECFW 2016, and Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 16. Includes one file attachment with private well PFAS data from 2014 to 2017.

*ATSDR HBCV. †This well had an apparent anomaly–an elevated concertation of 0.96 µg/L. That concentration was never duplicated at that well. ‡Gaps in numbering between residential wells indicates the numbers are attached to non-potable wells used for irrigation or open springs.

B = This compound was detected in an associated blank by the laboratory.

J = Analyte was identified, but the concentration was estimated.

Table A-3. (CONTINUED)

Sample ID	Specific PFAS ==> HBCV ==>	PFDS (none)	PFHpA (none)	PFHpS (none)	PFHxA (none)	PFHxS (0.14)*	PFNA (0.021)*	PFOSA (none)	PFPeA (none)	PFTeDA (none)	PFTrDA (none)
RES21		ND	ND	ND	0.011	0.073	ND	ND	0.0066	ND	ND
RES21TRT		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES22		ND	0.0056 J	0.0041 J	0.0099 J	0.056	ND	ND	0.0039 J	ND	ND
RES23		ND	ND	ND	ND	0.0031	ND	ND	ND	ND	ND
RES23TRT		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES24-W1		ND	ND	ND	ND	0.0057 J	ND	ND	ND	ND	ND
RES25		ND	0.0063 J	ND	0.0073 J	0.02 J	ND	0.017 J	0.0086 J	ND	ND
RES27†		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES29		ND	0.0065 J	ND	0.0055 J	0.0077 J	ND	ND	0.004 J	ND	ND
RES30		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES31		ND	ND	0.0045 B	ND	0.0075 J	ND	ND	0.0048 J	ND	ND
RES34		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES37/GBNWR		ND	ND	0.0078 J	0.013 J	0.099	ND	ND	0.0051 J	ND	ND
RES38		ND	ND	ND	ND	0.0053 J	ND	0.0042 J	ND	ND	ND
RES41		ND	ND	ND	0.014 J	0.013 J	ND	ND	0.0067 J	ND	ND
RES42		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RES43		ND	ND	ND	ND	0.0074 J	ND	ND	ND	ND	ND
RES45		ND	ND	ND	ND	0.0069 J	ND	ND	0.0062 J	ND	ND
RES48		ND	ND	ND	0.028	0.022	ND	ND	0.0051 J	ND	ND
RES49		ND	ND	ND	ND	0.01 J	ND	ND	ND	ND	ND
RES50		ND	ND	ND	ND	0.0099 J	ND	ND	ND	ND	ND
RES51		ND	ND	ND	ND	0.0082 J	ND	ND	ND	ND	ND
RES52		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: Only PFAS with at least one detection are shown in this table. ND = Not detected. RES21F = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on September 1, 2016. RES21TRT = Samples after the treatment system were ND. RES23F = Samples collected at the faucet before the activated carbon whole house treatment system which was installed on July 18, 2016. RES23TRT = Samples after the treatment system were ND.

Sources AMEC 2014, AMECFW 2016, and Walton R (Air Force Civil Engineer Center), email to Gary Perlman (ATSDR), 2018 February 16. Includes one file attachment with private well PFAS data from 2014 to 2017.

*ATSDR HBCV. †Gaps in numbering between residential wells indicates the numbers are attached to non-potable wells used for irrigation or open springs.

B = This compound was detected in an associated blank by the laboratory.

J = Analyte was identified, but the concentration was estimated.

Table A-4. Exposure Pathways, Off-Site Private Wells, Surface Water and Biota, Former Pease Air Force Base, Newington, NH

Pathway	Source	Media	Exposure Point	Exposure Route	Exposed Population	Time	Pathway Completion Status
Private Wells	Pease AFB–Fire Dept. Training Area 2 (Site 8)	Drinking Water	Off-Base Residential Wells	Ingestion	Residents with Contaminated Private Wells	Past	Complete-But we do not know when exposure began because there are no well sampling data before June 2014
Private Wells	Pease AFB–Fire Dept. Training Area 2 (Site 8)	Drinking Water	Off-Base Residential Wells	Ingestion	Residents with Contaminated Private Wells	Present and Future	Complete-PFAS detected in 37 wells. Five wells above HBCVs However, a point-of-entry (POE) water treatment system was installed at RES17 in October 2014, eliminating their exposure. POEs were installed at three other residences in July and August 2016; the two with exceedances and another slightly below the EPA health advisory. Bottled water was provided to seasonal users of Great Bay National Wildlife Refuge well.
Private Wells	Pease AFB–Fire Dept. Training Area 2 (Site 8)	Shower or Bath Water	Off-Base Residential Wells	Dermal Absorption and Inhalation of PFAS as vapors	Residents with Contaminated Private Wells	Past	Incomplete. PFAS are not volatile and inhalation of PFAS as vapor is an incomplete pathway
Private Wells	Pease AFB–Fire Dept. Training Area 2 (Site 8)	Shower or Bath Water	Off-Base Residential Wells	Dermal Absorption and Inhalation of PFAS as vapors	Residents with Contaminated Private Wells	Present and Future	Incomplete. PFAS are not volatile and inhalation of PFAS as vapor is an incomplete pathway. The 22 residential wells and the seasonal Refuge well users without POEs– But the non-drinking water exposure routes contribute negligible additional intake based on current concentrations in drinking water [ATSDR 2018a, ATSDR 2018b]
Private Wells	Pease AFB–Fire Dept. Training Area 2 (Site 8)	Drinking Water	Off-Base Residential Wells	Ingestion	Pregnant Women and Women of child bearing age who breastfeed	Past	Completed
Private Wells	Pease AFB–Fire Dept. Training Area 2 (Site 8)	Drinking Water	Off-Base Residential Wells	Ingestion	Breast feeding infants	Past, Present, and Future	Completed

Table A-4. (CONTINUED)

Pathway	Source	Media	Exposure Point	Exposure Route	Exposed Population	Time	Pathway Completion Status
Biota (Fish Deer)	Pease AFB–Fire Dept. Training Area 2 (Site 8)	Biota	On or off base where fish, shellfish, or deer are caught	Ingestion	Consumers of fish, shellfish, or deer meat	Past, Present, and Future	Potential
Surface Water	Surface water-Great Bay	Surface Water	Swimming, wading	Dermal, ingestion	Recreational swimmers/wader	Past, Present, and Future	Potential

Table A-5. Health-based comparison values used to screen water quality for PFAS. Concentrations in micrograms per liter (µg/L)

Specific PFAS	Health-Based Comparison Value Source	Value (µg/L)
PFBA	MDH	7
PFBS	MDH	2
PFHxS	ATSDR	0.14
PFNA	ATSDR	0.021
PFOA	ATSDR	0.021
PFOS	ATSDR	0.014

Notes: There were no HBCVs for the following: PFOSA, 6:2 FTS, 8:2 FTS, EtFOSA, EtFOSE, MeFOSA, MeFOSE, PEPeA0, PFDA, PFDoA, PFDS, PFHpA, PFHpS, PFHxA, PFTeDA, PFTrDA, or PFUnA

Abbreviations: ATSDR = These values were derived by ATSDR for children's exposures. This value is called an Environmental Media Evaluation Guide (EMEG) and is an estimated contaminant concentration that is not expected to result in adverse noncarcinogenic health effects based on ATSDR evaluation. EMEGs are based on ATSDR MRLs and health-protective assumptions about exposure, such as intake rate, exposure frequency and duration, and body weight. Child drinking water EMEGs are based on an infant (age birth to one year old) weighing 7.8 kg and an intake rate of 1.113 liters per day; HBCV = health-based comparison value; MDH = Minnesota Department of Health Risk Limit [MDH 2017a, 2017b, 2017c. 2017d].

Table A-6 Exposure assumptions used for dose calculations

	Exposure Assumptions		
	Daily drinking water intake rate		Body weight
	CTE	RME	
Age groups	L/day	L/day	kg
Birth to <1 year	0.504	1.13	7.8
1 to <2 years	0.308	0.893	11.4
2 to <6 years	0.376	0.977	17.4
6 to <11 years	0.511	1.404	31.8
11 to <16 years	0.637	1.976	56.8
16 to <21 years	0.77	2.444	71.6
Adults (≥21 years)	1.227	3.092	80
Pregnant women	0.872	2.589	73
Lactating women	1.665	3.588	73

Abbreviations: kg = kilogram; L = liter.

Table A-7. Environmental exposure assumptions and estimated exposure doses for perfluorohexanesulfonic acid (PFHxS) from private drinking water well identified as RES17 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFHxS= 0.37 µg/L		Hazard quotient for PFHxS (dose divided by the Intermediate MRL)		Margin of exposure for PFHxS (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	2.4E-05	5.4E-05	1.20	2.68	307	137
1 to <2 years	1.0E-05	2.9E-05	0.50	1.45	734	253
2 to <6 years	8.0E-06	2.1E-05	0.40	1.04	918	353
6 to <11 years	5.9E-06	1.6E-05	0.30	0.82	1235	449
11 to <16 years	4.1E-06	1.3E-05	0.21	0.64	1769	570
16 to <21 years	4.0E-06	1.3E-05	0.20	0.63	1845	581
Adults (≥21 years)	5.7E-06	1.4E-05	0.28	0.72	1293	513
Pregnant women	4.4E-06	1.3E-05	0.22	0.66	1661	559
Lactating women	8.4E-06	1.8E-05	0.42	0.91	870	404

Note: Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFHxS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-8. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES17 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose* based on the maximum concentration of PFOS= 0.57 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)		Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)†	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	3.7E-05	8.3E-05	18.4	41.3	57	25
1 to <2 years	1.5E-05	4.5E-05	7.7	22.3	140	47
2 to <6 years	1.2E-05	3.2E-05	6.2	16.0	170	66
6 to <11 years	9.2E-06	2.5E-05	4.6	12.6	230	83
11 to <16 years	6.4E-06	2.0E-05	3.2	9.9	330	110
16 to <21 years	6.1E-06	1.9E-05	3.1	9.7	340	110
Adults (≥21 years)	8.7E-06	2.2E-05	4.4	11.0	240	95
Pregnant women	6.8E-06	2.0E-05	3.4	10.1	310	100
Lactating women	1.3E-05	2.8E-05	6.5	14.0	160	75

Notes: Shaded = Exceedance of health-based comparison value. *The maximum value was from samples collected at the faucet before the whole house activated carbon treatment system was installed on October 18, 2014.

†Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-9. Environmental exposure assumptions and estimated exposure doses for perfluorooctanoic acid (PFOA) from private drinking water well identified as RES17 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose* based on the maximum concentration of PFOA= 0.11 µg/L		Hazard quotient for PFOA (dose divided by the Intermediate MRL)		Margin of exposure for PFOA (effect level used to derive MRL divided by the dose)†	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	7.1E-06	1.6E-05	2.37	5.31	120	52
1 to <2 years	3.0E-06	8.6E-06	0.99	2.87	280	95
2 to <6 years	2.4E-06	6.2E-06	0.79	2.06	350	130
6 to <11 years	1.8E-06	4.9E-06	0.59	1.62	460	170
11 to <16 years	1.2E-06	3.8E-06	0.41	1.28	670	210
16 to <21 years	1.2E-06	3.8E-06	0.39	1.25	690	220
Adults (≥21 years)	1.7E-06	4.3E-06	0.56	1.42	490	190
Pregnant women	1.3E-06	3.9E-06	0.44	1.30	620	210
Lactating women	2.5E-06	5.4E-06	0.84	1.80	330	150

Notes: *The maximum value was from samples collected at the faucet before the whole house activated carbon treatment system was installed on October 18, 2014. Shaded = Exceedance of health-based comparison value.

†Margin of exposure for PFOA (based on HED effect level from study used to derive MRL divided by the dose).

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-10. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES19 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFOS= 0.086 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)		Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	5.6E-06	1.2E-05	2.8	6.2	380	170
1 to <2 years	2.3E-06	6.7E-06	1.2	3.4	900	310
2 to <6 years	1.9E-06	4.8E-06	0.9	2.4	1100	430
6 to <11 years	1.4E-06	3.8E-06	0.7	1.9	1500	550
11 to <16 years	9.6E-07	3.0E-06	0.5	1.5	2200	700
16 to <21 years	9.2E-07	2.9E-06	0.5	1.5	2300	720
Adults (≥21 years)	1.3E-06	3.3E-06	0.7	1.7	1600	630
Pregnant women	1.0E-06	3.1E-06	0.5	1.5	2000	690
Lactating women	2.0E-06	4.2E-06	1.0	2.1	1100	500

Note: Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-11. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES21 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Dose based on the maximum concentration of PFOS= 0.043 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)		Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)*	
Age groups	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	2.8E-06	6.2E-06	1.4	3.1	760	340
1 to <2 years	1.2E-06	3.4E-06	0.6	1.7	1800	620
2 to <6 years	9.3E-07	2.4E-06	0.5	1.2	2300	870
6 to <11 years	6.9E-07	1.9E-06	0.3	0.9	3000	1100
11 to <16 years	4.8E-07	1.5E-06	0.2	0.7	4400	1400
16 to <21 years	4.6E-07	1.5E-06	0.2	0.7	4500	1400
Adults (≥21 years)	6.6E-07	1.7E-06	0.3	0.8	3200	1300
Pregnant women	5.1E-07	1.5E-06	0.3	0.8	4100	1400
Lactating women	9.8E-07	2.1E-06	0.5	1.1	2100	990

Note: Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-12. Environmental exposure assumptions and estimated exposure doses for perfluorooctanoic acid (PFOA) from private drinking water well identified as RES21 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFOA= 0.021 µg/L		Hazard quotient for PFOA (dose divided by the Intermediate MRL)		Margin of exposure for PFOA (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	1.4E-06	3.0E-06	0.45	1.01	610	270
1 to <2 years	5.7E-07	1.6E-06	0.19	0.55	1400	500
2 to <6 years	4.5E-07	1.2E-06	0.15	0.39	1800	700
6 to <11 years	3.4E-07	9.3E-07	0.11	0.31	2400	890
11 to <16 years	2.4E-07	7.3E-07	0.08	0.24	3500	1100
16 to <21 years	2.3E-07	7.2E-07	0.08	0.24	3600	1100
Adults (≥21 years)	3.2E-07	8.1E-07	0.11	0.27	2500	1000
Pregnant women	2.5E-07	7.4E-07	0.08	0.25	3300	1100
Lactating women	4.8E-07	1.0E-06	0.16	0.34	1700	800

Note: Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFOA (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-13. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES23 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Dose based on the maximum concentration of PFOS= 0.052 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)		Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)*	
Age groups	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	3.4E-06	7.5E-06	1.7	3.8	630	280
1 to <2 years	1.4E-06	4.1E-06	0.7	2	1500	520
2 to <6 years	1.1E-06	2.9E-06	0.56	1.5	1900	720
6 to <11 years	8.4E-07	2.3E-06	0.42	1.1	2500	910
11 to <16 years	5.8E-07	1.8E-06	0.29	0.9	3600	1200
16 to <21 years	5.6E-07	1.8E-06	0.28	0.89	3800	1200
Adults (≥21 years)	8.0E-07	2.0E-06	0.4	1	2600	1000
Pregnant women	6.2E-07	1.8E-06	0.31	0.92	3400	1100
Lactating women	1.2E-06	2.6E-06	0.59	1.3	1800	820

Notes: Shaded = Exceedance of health-based comparison value. Sample obtained from the wellhead. The faucet concentrations were lower. This calculation was conducted since the wellhead data drove the decision to provide an alternative water source for RES23.
*Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-14. Environmental exposure assumptions and estimated exposure doses for perfluorooctanoic acid (PFOA) from private drinking water well identified as RES23 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFOA= 0.015 µg/L		Hazard quotient for PFOA (dose divided by the Intermediate MRL)		Margin of exposure for PFOA (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	9.7E-07	2.2E-06	0.32	0.72	850	380
1 to <2 years	4.1E-07	1.2E-06	0.14	0.39	2000	700
2 to <6 years	3.2E-07	8.4E-07	0.11	0.28	2500	970
6 to <11 years	2.4E-07	6.6E-07	0.08	0.22	3400	1200
11 to <16 years	1.7E-07	5.2E-07	0.06	0.17	4900	1600
16 to <21 years	1.6E-07	5.1E-07	0.05	0.17	5100	1600
Adults (≥21 years)	2.3E-07	5.8E-07	0.08	0.19	3600	1400
Pregnant women	1.8E-07	5.3E-07	0.06	0.18	4600	1500
Lactating women	3.4E-07	7.4E-07	0.11	0.25	2400	1100

Note: Sample obtained from the wellhead. The faucet concentrations were lower. This calculation was conducted since the wellhead data drove the decision to provide an alternative water source for RES23.
*Margin of exposure for PFOA (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-15. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES37/GBNWR located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFOS= 0.13 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)		Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	8.4E-06	1.9E-05	4.2	9.4	250	110
1 to <2 years	3.5E-06	1.0E-05	1.8	5.1	600	210
2 to <6 years	2.8E-06	7.3E-06	1.4	3.6	750	290
6 to <11 years	2.1E-06	5.7E-06	1.0	2.9	1000	370
11 to <16 years	1.5E-06	4.5E-06	0.7	2.3	1400	460
16 to <21 years	1.4E-06	4.4E-06	0.7	2.2	1500	470
Adults (≥21 years)	2.0E-06	5.0E-06	1.0	2.5	1100	420
Pregnant women	1.6E-06	4.6E-06	0.8	2.3	1400	460
Lactating women	3.0E-06	6.4E-06	1.5	3.2	710	330

Notes: The intermediate exposure scenario for these well users include the following: seven days per week for eight weeks. This was established since the supplied residents is only seasonal (i.e., eight summer weeks). Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-16. Environmental exposure assumptions and estimated exposure doses for perfluorohexanesulfonic acid (PFHxS) from private drinking water well identified as RES37/GBNWR located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Dose based on the maximum concentration of PFHxS= 0.099 µg/L		Hazard quotient for PFHxS (dose divided by the Intermediate MRL)		Margin of exposure for PFHxS (effect level used to derive MRL divided by the dose)*	
Age groups	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	6.4E-06	1.4E-05	0.32	0.72	1147	512
1 to <2 years	2.7E-06	7.8E-06	0.13	0.39	2744	946
2 to <6 years	2.1E-06	5.6E-06	0.11	0.28	3431	1320
6 to <11 years	1.6E-06	4.4E-06	0.08	0.22	4614	1679
11 to <16 years	1.1E-06	3.4E-06	0.06	0.17	6611	2131
16 to <21 years	1.1E-06	3.4E-06	0.05	0.17	6894	2172
Adults (≥21 years)	1.5E-06	3.8E-06	0.08	0.19	4834	1918
Pregnant women	1.2E-06	3.5E-06	0.06	0.18	6207	2091
Lactating women	2.3E-06	4.9E-06	0.11	0.24	3251	1508

Note: The intermediate exposure scenario for these well users include the following: seven days per week for eight weeks. This was established since the supplied residents is only seasonal (i.e., eight summer weeks).

*Margin of exposure for PFHxS (based on HED effect level from study used to derive MRL divided by the dose).

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-17. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES03 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFOS = 0.015 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)		Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	9.7E-07	2.2E-06	0.5	1.1	2200	970
1 to <2 years	4.1E-07	1.2E-06	0.2	0.6	5200	1800
2 to <6 years	3.2E-07	8.4E-07	0.2	0.4	6500	2500
6 to <11 years	2.4E-07	6.6E-07	0.1	0.3	8700	3200
11 to <16 years	1.7E-07	5.2E-07	0.1	0.3	12000	4000
16 to <21 years	1.6E-07	5.1E-07	0.1	0.3	13000	4100
Adults (≥21 years)	2.3E-07	5.8E-07	0.1	0.3	9100	3600
Pregnant women	1.8E-07	5.3E-07	0.1	0.3	12000	3900
Lactating women	3.4E-07	7.4E-07	0.2	0.4	6100	2800

Note: Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-18. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES20 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Dose based on the maximum concentration of PFOS= 0.027 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)			Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)*	
Age groups	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless		CTE unitless	RME unitless
Birth to <1 year	1.7E-06	3.9E-06	0.9	2.0	3.0E+02	1200	540
1 to <2 years	7.3E-07	2.1E-06	0.4	1.1	7.1E+02	2900	990
2 to <6 years	5.8E-07	1.5E-06	0.3	0.8	8.8E+02	3600	1400
6 to <11 years	4.3E-07	1.2E-06	0.2	0.6	1.2E+03	4800	1800
11 to <16 years	3.0E-07	9.4E-07	0.2	0.5	1.7E+03	6900	2200
16 to <21 years	2.9E-07	9.2E-07	0.1	0.5	1.8E+03	7200	2300
Adults (≥21 years)	4.1E-07	1.0E-06	0.2	0.5	1.2E+03	5100	2000
Pregnant women	3.2E-07	9.6E-07	0.2	0.5	1.6E+03	6500	2200
Lactating women	6.2E-07	1.3E-06	0.3	0.7	8.4E+02	3400	1600

Note: Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-19. Environmental exposure assumptions and estimated exposure doses for perfluorooctane sulfonic acid (PFOS) from private drinking water well identified as RES25 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFOS= 0.014 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate MRL)		Margin of exposure for PFOS (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	9.0E-07	2.0E-06	0.5	1.0	2300	1000
1 to <2 years	3.8E-07	1.1E-06	0.2	0.5	5600	1900
2 to <6 years	3.0E-07	7.9E-07	0.2	0.4	6900	2700
6 to <11 years	2.2E-07	6.2E-07	0.1	0.3	9300	3400
11 to <16 years	1.6E-07	4.9E-07	0.1	0.2	13000	4300
16 to <21 years	1.5E-07	4.8E-07	0.1	0.2	14000	4400
Adults (≥21 years)	2.1E-07	5.4E-07	0.1	0.3	9800	3900
Pregnant women	1.7E-07	5.0E-07	0.1	0.2	13000	4200
Lactating women	3.2E-07	6.9E-07	0.2	0.3	6600	3100

Note: Shaded = Exceedance of health-based comparison value.
*Margin of exposure for PFOS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-20. Environmental exposure assumptions and estimated exposure doses for perfluorohexanesulfonic acid (PFHxS) from private drinking water well identified as RES09 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose* based on the maximum concentration of PFHxS= 0.96 µg/L		Hazard quotient for PFHxS (dose divided by the Intermediate MRL)		Margin of exposure for PFHxS (effect level used to derive MRL divided by the dose)†	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	6.2E-05	1.4E-04	3.10	6.95	118	53
1 to <2 years	2.6E-05	7.5E-05	1.30	3.76	283	98
2 to <6 years	2.1E-05	5.4E-05	1.04	2.70	354	136
6 to <11 years	1.5E-05	4.2E-05	0.77	2.12	476	173
11 to <16 years	1.1E-05	3.3E-05	0.54	1.67	682	220
16 to <21 years	1.0E-05	3.3E-05	0.52	1.64	711	224
Adults (≥21 years)	1.5E-05	3.7E-05	0.74	1.86	499	198
Pregnant women	1.1E-05	3.4E-05	0.57	1.70	640	216
Lactating women	2.2E-05	4.7E-05	1.09	2.36	335	156

Notes: *This well had an apparent anomaly–an elevated concertation of 0.96 µg/L. That concentration was never duplicated at that well. ATSDR assumed that the concentration of 0.96 µg/L was exposure point concentration from the day after the previous sample date (when the concertation was 0.0063 µg/L) through the day prior the next sampling round (when the concentration was ND). The resultant exposure duration is approximately 174 days. Shaded = Exceedance of health-based comparison value.

†Margin of exposure for PFHxS (based on HED effect level from study used to derive MRL divided by the dose).

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-21. Environmental exposure assumptions and estimated exposure doses for perfluorohexanesulfonic acid (PFHxS) from private drinking water well identified as RES09 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Age groups	Dose based on the maximum concentration of PFHxS= 0.0087 µg/L		Hazard quotient for PFHxS (dose divided by the Intermediate MRL)		Margin of exposure for PFHxS (effect level used to derive MRL divided by the dose)*	
	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless	CTE unitless	RME unitless
Birth to <1 year	5.6E-07	1.3E-06	0.0280	0.0630	13057	5824
1 to <2 years	2.4E-07	6.8E-07	0.0120	0.0340	31227	10770
2 to <6 years	1.9E-07	4.9E-07	0.0094	0.0240	39043	15026
6 to <11 years	1.4E-07	3.8E-07	0.0070	0.0190	52503	19109
11 to <16 years	9.8E-08	3.0E-07	0.0049	0.0150	75229	24251
16 to <21 years	9.4E-08	3.0E-07	0.0047	0.0150	78451	24717
Adults (≥21 years)	1.3E-07	3.4E-07	0.0067	0.0170	55008	21829
Pregnant women	1.0E-07	3.1E-07	0.0052	0.0150	70629	23789
Lactating women	2.0E-07	4.3E-07	0.0099	0.0210	36990	17165

*Margin of exposure for PFHxS (based on HED effect level from study used to derive MRL divided by the dose).
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-22. Environmental exposure assumptions and estimated exposure doses for perfluorohexanoic acid (PFHxA) from private drinking water well identified as RES17F located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure Assumptions			Dose Based on the Maximum Concentration PFHxA 0.23 µg/L*	
	Daily Drinking Water Intake Rate		Body Weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	mg/kg/day	mg/kg/day
Birth to < 1 year	0.504	1.113	7.8	1.49E-05	5.4E-05
1 to < 2 years	0.308	0.893	11.4	6.21E-06	2.9E-05
2 to < 6 years	0.376	0.977	17.4	4.97E-06	2.1E-05
6 to < 11 years	0.511	1.404	31.8	3.70E-06	1.6E-05
11 to < 16 years	0.637	1.976	56.8	2.58E-06	1.3E-05
16 to < 21 years	0.77	2.444	71.6	2.47E-06	1.3E-05
Adults (≥21 years)	1.227	3.092	80	3.54E-06	1.4E-05
Pregnant Women	0.872	2.589	73	2.75E-06	1.3E-05
Lactating Women	1.665	3.588	73	5.26E-06	1.8E-05

Note: *The maximum value was from samples collected at the faucet before the whole house activated carbon treatment system was installed.

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-23. Combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) hazard index for private drinking water well identified as RES17F located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure assumptions				
	Daily drinking water intake rate		Body weight	Hazard index (HI) for combined PFHxS, PFOA, and PFOS	
Age groups	CTE L/day	RME L/day	kg	CTE unitless	RME unitless
Birth to <1 year	0.504	1.13	7.8	21.98	49.28
1 to <2 years	0.308	0.89	11.4	9.19	26.65
2 to <6 years	0.376	0.98	17.4	7.35	19.10
6 to <11 years	0.511	1.4	31.8	5.47	15.02
11 to <16 years	0.637	1.98	56.8	3.81	11.83
16 to <21 years	0.77	2.44	71.6	3.66	11.61
Adults (≥21 years)	1.227	3.09	80	5.22	13.15
Pregnant women	0.872	2.59	73	4.06	12.06
Lactating women	1.665	3.59	73	7.76	16.72

Notes: Shaded = exceedance of an HI of 1. Estimated exposure doses assume 100% of exposure is from drinking water ingestion.

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; HI = hazard index is the combined hazard quotients for PFHxS, PFOA and PFOS combined; kg = kilogram; L = liter; RME = reasonable maximum exposure.

Table A-24. Environmental exposure assumptions and calculated hazard indexes for combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) for private drinking water well identified as RES19 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure Assumptions			Hazard Indexes (HI) for combined PFHxS, PFOA, and PFOS	
	Daily Drinking Water Intake Rate		Body Weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to < 1 year	0.504	1.113	7.8	3.25	7.28
1 to < 2 years	0.308	0.893	11.4	1.36	3.94
2 to < 6 years	0.376	0.977	17.4	1.09	2.82
6 to < 11 years	0.511	1.404	31.8	0.81	2.22
11 to < 16 years	0.637	1.976	56.8	0.56	1.75
16 to < 21 years	0.77	2.444	71.6	0.54	1.72
Adults (≥21 years)	1.227	3.092	80	0.77	1.94
Pregnant Women	0.872	2.589	73	0.60	1.78
Lactating Women	1.665	3.588	73	1.15	2.47

Note: Shaded = Exceedance of health-based comparison value.
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-25. Environmental exposure assumptions and calculated hazard indexes for combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) for private drinking water well identified as RES21 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure Assumptions			Hazard Index (HI) for combined PFHxS, PFOA, and PFOS	
	Daily Drinking Water Intake Rate		Body Weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to < 1 year	0.504	1.113	7.8	2.08	4.66
1 to < 2 years	0.308	0.893	11.4	0.87	2.52
2 to < 6 years	0.376	0.977	17.4	0.69	1.81
6 to < 11 years	0.511	1.404	31.8	0.52	1.42
11 to < 16 years	0.637	1.976	56.8	0.36	1.12
16 to < 21 years	0.77	2.444	71.6	0.35	1.10
Adults (≥21 years)	1.227	3.092	80	0.49	1.24
Pregnant Women	0.872	2.589	73	0.38	1.14
Lactating Women	1.665	3.588	73	0.73	1.58

Note: Shaded = Exceedance of health-based comparison value.
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-26. Environmental exposure assumptions and calculated hazard indexes for combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) for private drinking water well identified as RES23 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure Assumptions			Hazard Index (HI) for combined PFHxS, PFOA, and PFOS	
	Daily Drinking Water Intake Rate		Body Weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to < 1 year	0.504	1.113	7.8	2.013	4.513
1 to < 2 years	0.308	0.893	11.4	0.842	2.440
2 to < 6 years	0.376	0.977	17.4	0.673	1.749
6 to < 11 years	0.511	1.404	31.8	0.501	1.375
11 to < 16 years	0.637	1.976	56.8	0.349	1.084
16 to < 21 years	0.77	2.444	71.6	0.335	1.063
Adults (≥21 years)	1.227	3.092	80	0.478	1.204
Pregnant Women	0.872	2.589	73	0.372	1.105
Lactating Women	1.665	3.588	73	0.710	1.531

Notes: Shaded = Exceedance of health-based comparison value. Sample obtained from the wellhead. The faucet concentrations were lower. This calculation was conducted since the wellhead data drove the decision to provide an alternative water source for RES23.

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-27. Environmental exposure assumptions and calculated hazard indexes for combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) for private drinking water well identified as RES37/GBNWR located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure Assumptions			Hazard Index (HI) for combined PFHxS, PFOA, and PFOS	
	Daily Drinking Water Intake Rate		Body Weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to < 1 year	0.504	1.113	7.8	4.82	10.81
1 to < 2 years	0.308	0.893	11.4	2.02	5.84
2 to < 6 years	0.376	0.977	17.4	1.61	4.19
6 to < 11 years	0.511	1.404	31.8	1.20	3.29
11 to < 16 years	0.637	1.976	56.8	0.84	2.60
16 to < 21 years	0.77	2.444	71.6	0.80	2.55
Adults (≥21 years)	1.227	3.092	80	1.14	2.88
Pregnant Women	0.872	2.589	73	0.89	2.65
Lactating Women	1.665	3.588	73	1.70	3.67

Notes: The intermediate exposure scenario for these well users include the following: seven days per week for eight weeks. This was established since the supplied residents is only seasonal (i.e., eight summer weeks). Shaded = Hazard index exceeded 1.0.

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-28. Combined perfluorohexanesulfonic acid (PFHxS), perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) hazard index for private drinking water well identified as RES03 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure assumptions			Hazard index (HI) for combined PFHxS, PFOA, PFNA, and PFOS	
	Daily drinking water intake rate		Body weight		
Age groups	CTE L/day	RME L/day	kg	CTE unitless	RME unitless
Birth to <1 year	0.504	1.13	7.8	1.19	2.66
1 to <2 years	0.308	0.89	11.4	0.50	1.44
2 to <6 years	0.376	0.98	17.4	0.40	1.03
6 to <11 years	0.511	1.4	31.8	0.30	0.81
11 to <16 years	0.637	1.98	56.8	0.21	0.64
16 to <21 years	0.77	2.44	71.6	0.20	0.63
Adults (≥21 years)	1.227	3.09	80	0.28	0.71
Pregnant women	0.872	2.59	73	0.22	0.65
Lactating women	1.665	3.59	73	0.42	0.90

Notes: Shaded = exceedance of an HI of 1. Estimated exposure doses assume 100% of exposure is from drinking water ingestion.
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; HI = hazard index is the combined hazard quotients for PFHxS, PFNA, PFOA and PFOS combined; kg = kilogram; L = liter; RME = reasonable maximum exposure.

Table A-29. Combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) hazard index for private drinking water well identified as RES09 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure assumptions				
	Daily drinking water intake rate		Body weight	Hazard index (HI) for combined PFHxS, PFOA, and PFOS	
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to <1 year	0.504	1.13	7.8	3.49	7.82
1 to <2 years	0.308	0.89	11.4	1.46	4.23
2 to <6 years	0.376	0.98	17.4	1.17	3.03
6 to <11 years	0.511	1.4	31.8	0.87	2.38
11 to <16 years	0.637	1.98	56.8	0.61	1.88
16 to <21 years	0.77	2.44	71.6	0.58	1.84
Adults (≥21 years)	1.227	3.09	80	0.83	2.09
Pregnant women	0.872	2.59	73	0.65	1.92
Lactating women	1.665	3.59	73	1.23	2.65

Notes: Shaded = exceedance of an HI of 1. Estimated exposure doses assume 100% of exposure is from drinking water ingestion.
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; HI = hazard index is the combined hazard quotients for PFHxS, PFOA and PFOS combined; kg = kilogram; L = liter; RME = reasonable maximum exposure.

Table A-30. Combined perfluorohexanesulfonic acid* (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) hazard index for private drinking water well identified as RES09 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure assumptions			Hazard index (HI) for combined PFHxS, PFOA, and PFOS	
	Daily drinking water intake rate		Body weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to <1 year	0.504	1.13	7.8	0.42	0.93
1 to <2 years	0.308	0.89	11.4	0.17	0.50
2 to <6 years	0.376	0.98	17.4	0.14	0.36
6 to <11 years	0.511	1.4	31.8	0.10	0.28
11 to <16 years	0.637	1.98	56.8	0.07	0.22
16 to <21 years	0.77	2.44	71.6	0.07	0.22
Adults (≥21 years)	1.227	3.09	80	0.10	0.25
Pregnant women	0.872	2.59	73	0.08	0.23
Lactating women	1.665	3.59	73	0.15	0.32

Notes: Estimated exposure doses assume 100% of exposure is from drinking water ingestion. *The second highest detected level of PFHxS (0.0087 µg/L) was used since the highest detected level appeared to be an anomaly.

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; HI = hazard index is the combined hazard quotients for PFHxS, PFOA and PFOS combined; kg = kilogram; L = liter; RME = reasonable maximum exposure.

Table A-31. Environmental exposure assumptions and calculated hazard indexes for combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) for private drinking water well identified as RES20 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure Assumptions			Hazard Indexes (HI) for combined PFHxS, PFOA, and PFOS	
	Daily Drinking Water Intake Rate		Body Weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to < 1 year	0.504	1.113	7.8	1.50	3.37
1 to < 2 years	0.308	0.893	11.4	0.63	1.82
2 to < 6 years	0.376	0.977	17.4	0.50	1.31
6 to < 11 years	0.511	1.404	31.8	0.37	1.03
11 to < 16 years	0.637	1.976	56.8	0.26	0.81
16 to < 21 years	0.77	2.444	71.6	0.25	0.79
Adults (≥21 years)	1.227	3.092	80	0.36	0.90
Pregnant Women	0.872	2.589	73	0.28	0.82
Lactating Women	1.665	3.588	73	0.53	1.14

Note: Shaded = Exceedance of health-based comparison value.
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-32. Environmental exposure assumptions and calculated hazard indexes for combined perfluorohexanesulfonic acid (PFHxS), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) for private drinking water well identified as RES25 located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

	Exposure Assumptions			Hazard Index (HI) for combined PFHxS, PFOA, and PFOS	
	Daily Drinking Water Intake Rate		Body Weight		
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to < 1 year	0.504	1.113	7.8	0.88	1.98
1 to < 2 years	0.308	0.893	11.4	0.37	1.07
2 to < 6 years	0.376	0.977	17.4	0.30	0.77
6 to < 11 years	0.511	1.404	31.8	0.22	0.60
11 to < 16 years	0.637	1.976	56.8	0.15	0.48
16 to < 21 years	0.77	2.444	71.6	0.15	0.47
Adults (≥21 years)	1.227	3.092	80	0.21	0.53
Pregnant Women	0.872	2.589	73	0.16	0.48
Lactating Women	1.665	3.588	73	0.31	0.67

Note: Shaded = Exceedance of health-based comparison value.
Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure.

Table A-33. Environmental exposure assumptions and estimated cancer risk calculation for perfluorooctanoic acid (PFOA) from private drinking water well identified as RES17F located within 1 mile from the former Pease Air Force Base, Portsmouth, New Hampshire

Exposure Assumptions		Dose Based on Maximum PFOA Concentration 0.11 µg/L*		Cancer Risk Calculations	
Exposure Group Age groups	Exposure Duration Years†	CTE mg/kg/day	RME mg/kg/day	CTE Risk	RME Risk
Birth to < 1 year	21	7.1E-06	1.6E-05	3.6×10^{-8}	1.0×10^{-7}
1 to < 2 years		3.0E-06	8.6E-06		
2 to < 6 years		2.4E-06	6.2E-06		
6 to < 11 years		1.8E-06	4.9E-06		
11 to < 16 years		1.2E-06	3.8E-06		
16 to < 21 years		1.2E-06	3.8E-06		
Adults (≥21 years)	33	1.7E-06	4.3E-06	5.0×10^{-8}	1.3×10^{-7}
Pregnant Women	nc	1.3E-06	3.9E-06	nc	nc
Lactating Women	nc	2.5E-06	5.4E-06	nc	nc

Notes: *The maximum value was from samples collected at the faucet before the whole house activated carbon treatment system was installed on October 18, 2014. †Exposure duration for children is from birth through age 20 (21 years). The exposure duration for adults is 33 years.

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure; kg = kilogram; L = liter; mg/kg/day = milligrams of chemical per kilogram of body weight per day; nc = not calculated; RME = reasonable maximum exposure.

Equations

Equation 1. Estimating lifetime excess cancer risk for PFOA in drinking water.

$$\text{Lifetime excess cancer risk} = \frac{\text{Exposure dose}\left(\frac{\frac{\text{mg}}{\text{kg}}}{\text{day}}\right) \text{x Exposure time (years) x oral cancer slope factor} \left(\frac{\frac{\text{mg}}{\text{kg}}}{\text{day}}\right)^{-1}}{\text{78 years}}$$

Equation 2. Reasonable maximum exposure (RME) concentration calculation approach.

$$\text{Reasonable maximum exposure} = \frac{\text{Upper Percentile Drinking Water Intake } \left(\frac{\text{L}}{\text{day}}\right) \text{x Exposure point concentration } \left(\frac{\mu\text{g}}{\text{L}}\right)}{\text{Body weight (kg) x 1,000}}$$

Equation 3. Central tendency exposure (CTE) concentration calculation approach.

$$\text{Central tendency exposure} = \frac{\text{Mean Drinking Water Intake } \left(\frac{\text{L}}{\text{day}}\right) \text{x Exposure point concentration } \left(\frac{\mu\text{g}}{\text{L}}\right)}{\text{Body weight (kg) x 1,000}}$$

Appendix B–Chemical Specific Health-Based Comparison Values Discussion

Perfluorobutanoate (PFBA)

In 2017, Minnesota developed a health risk value for PFBA of 7 µg/L for chronic non-cancerous health effects. This PFBA health risk value is based on a reference dose of 0.0014 mg/kg/day and NOAEL of 60 mg/kg/day. The critical effects end point observed in laboratory animals include liver weight changes, morphological changes in liver and thyroid gland, decreased T4, decreased red blood cells, decreased hematocrit and hemoglobin. The Minnesota health risk value includes an uncertainty factor of 300 (3 for interspecies differences, 10 for intraspecies variability, and 10 for database uncertainty) [MDH 2017c].

Perfluorobutane sulfonate (PFBS)

In 2011, Minnesota developed a health risk value for PFBS of 2 µg/L for chronic non-cancerous health effects. This health risk value for PFBS is based on a reference dose of 0.0043 mg/kg/day and human equivalent dose of 0.129 mg/kg/day. The critical effects were kidney epithelial and tubular/ductal hyperplasia. The co-critical effects include focal papillary edema and necrosis in the kidney The Minnesota health risk value includes an uncertainty factor of 300 (3 for interspecies differences (for toxicodynamics), 10 for intraspecies variability, 3 for database uncertainty (concerns regarding neurological effects and persistent effects observed following in utero only exposure), and 3 for use of a subchronic study for the chronic duration [MDH 2017d, 2017e].