Health Consultation

Per- and Polyfluoroalkyl Substances (PFAS) in the Pease Tradeport
Public Water System
EPA PWS ID: 1951020

PEASE AIR FORCE BASE

PORTSMOUTH, NEWINGTON, AND GREENLAND,
NEW HAMPSHIRE

EPA FACILITY ID: NH7570024847

MARCH 20, 2020

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.

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Prepared by:

U.S. Department of Health and Human Services
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Summary

Introduction

In April 2015, the U.S. Air Force asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate past and current exposures to per- and polyfluoroalkyl substances (PFAS) in the Pease Tradeport public water system (PWS). The Pease Tradeport PWS serves the Pease International Tradeport and the New Hampshire Air National Guard base at the former Pease Air Force Base (AFB). The source of PFAS in the Pease Tradeport PWS is assumed to be from aqueous film-forming foam (AFFF) used on the former Pease AFB, now known as the Pease International Tradeport. This evaluation focuses on exposures to persons who worked at the Pease International Tradeport and children who attended the two childcare centers at the Pease International Tradeport from 1993 to the present. However, ATSDR acknowledges that exposures to military and base personnel could have occurred before 1993 through drinking water and other sources.

Scientific information suggests an association between perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) exposure and various health endpoints, including effects on serum lipids, immune responses, fetal growth and development, and the liver. Several other PFAS were detected in the water, some of which have similar health endpoints as PFOA and PFOS (see Appendix A, Table A-1).

The Harrison, Haven, and Smith wells provided water to the Pease Tradeport PWS. The wells were sampled and analyzed for several PFAS in April and May 2014 [CB&I 2015]. PFAS were found in each of the wells. At that time, only the Haven well, where the maximum concentration of PFOS was 2.5 µg/L, exceeded the U.S. Environmental Protection Agency's (EPA) provisional health advisory level of 0.2 micrograms per liter (µg/L) for PFOS. The Haven well, located near the middle of the Pease AFB airstrip, was shut down on May 12, 2014, immediately after the results were known. Since the Haven well was shut down, the Harrison and Smith wells have continued to provide water for the Pease Tradeport PWS, supplemented by water from the City of Portsmouth PWS (ID 1951010).

ATSDR develops health-based comparison values (HBCVs) using available scientific findings about exposure levels and health effects. The HBCVs reflect an estimated contaminant concentration for a given chemical that is expected to cause no adverse health effects, assuming a standard daily water intake rate and body weight. To be conservative and protective of public health, HBCVs are generally based on contaminant concentrations many times lower than levels at which animal or human studies found no observable effects. ATSDR uses HBCVs in this health consultation to screen PFAS contaminant concentrations to determine if a further in-depth evaluation is needed which includes calculating an exposure dose and comparing these doses to ATSDR provisional minimal risk levels or MRLs.

Drinking water sampling from June 2014 through May 2017 indicated that the maximum detected PFOS concentration was equal to ATSDR's HBCV at the New Hampshire Department of Environmental Services (NHDES) office and above the HBCV at the water treatment plant. The treatment consists of corrosion control and then it is mixed to provide drinking water. A demonstration water treatment system (granular activated carbon filters) has been operational since September 2016. There were no exceedances of any other PFAS at any other sampling locations, which included two childcare centers and a fire station [City of Portsmouth 2017a]. A water treatment system to remove PFAS from the Smith and Harrison wells began operating on September 23, 2016. Tests of the treated water collected in October and November 2016 did not detect either PFOS or PFOA. Detection limits for PFAS typically range from 0.0026 µg/L for PFOS to 0.0046 µg/L for PFOA or 2.6 to 4.6 parts per trillion [Walton R. (Air Force Civil Engineer Center-BRAC Program Management Division) email to Gary Perlman (ATSDR), February 22, 2018, with datasheets, including Maxxam Analytics PFAS detection limits]. A few other PFAS occasionally were detected at very low concentrations. Both PFOA and PFOS were below EPA's lifetime health advisory in all samples analyzed since June 2014.

ATSDR evaluated PFAS exposures in the Pease Tradeport PWS for two timeframes. The first timeframe included the time when the Haven well was operational (1993 to May 2014). The second included the time when the Haven well was shut down (June 2014 to the present).

On April 1, 2019, ATSDR released this health consultation report for public comment. The comment period ended on June 3, 2019. ATSDR received 76 comments from individuals, agencies, and a consultant during the public comment period. Appendix C provides responses to the comments received.

Conclusions

ATSDR evaluated the public health implications of past and current PFAS exposure to the users of public water near the Pease International Tradeport and reached three 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 conservative 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 the PFAS that were measured in the water.

Conclusion 1

Drinking water exposures from the Pease Tradeport PWS from 1993 to May 2014, before the Haven Well was shut down, could have increased the risk for harmful non-cancer health effects to Pease International Tradeport workers and children attending the childcare centers. Other sources of PFAS exposure (e.g., from food and consumer products) to users of the Pease Tradeport PWS could increase the risk of harmful effects beyond the risk from the drinking water exposures alone. The cancer risk from past exposure to all PFAS in the Pease Tradeport PWS is uncertain.

Basis for Conclusion

The estimated exposures for PFOA, PFOS, and perfluorohexane sulfonic acid (PFHxS) from consuming the water were mostly below effect levels found in animal studies but were well above their respective ATSDR provisional MRL, indicating a potential for concern, especially for developmental and immune effects for exposure to PFOS. 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, development, endocrine (thyroid), and the liver. The combined exposures to a mixture of PFOS, PFOA, PFHxS, and perfluorononanoic acid (PFNA) could have increased the risk for developmental and immune effects above what might be expected from exposure to any of these PFAS alone. For other PFAS associations and health endpoints, however, the scientific information is far less certain. Food, consumer products, and mixtures of PFAS in the drinking water are all possible contributors to a person's overall PFAS exposure and body burden. Testing of exposed persons from the Pease Tradeport PWS by the New Hampshire Department of Health and Human Services (NH DHHS) indicate that PFOA, PFOS, and PFHxS blood levels are elevated as compared to national averages. Some pre-existing risk factors could increase the risk of harmful effects (see the Public Health Implications Section for details).

Epidemiologic data suggest a link between PFOA exposure and elevated rates of kidney, prostate, and testicular cancer. However, additional studies are needed to confirm the link between PFOA and other PFAS exposures and cancer to say they are the cause. 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 may be carcinogenic while some may not.

The EPA has developed an oral cancer slope factor (CSF) for PFOA based on testicular cancer from a rat study to evaluate the cancer risk. Based on these assumptions and assuming that the EPA CSF on testicular cancer from a rat study approximates the actual cancer risk for PFOA, then the estimated adult cancer risk from exposure to the maximum detected PFOA concentration in the public water supply system is 1.3×10^{-7}. This means that if 10 million people were similarly exposed, we might see an additional two cases of cancer. Please note this this is a theoretical estimate of cancer risk that is used by ATSDR 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. If the CSF 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 CSF has not been fully adopted and other cancers that were elevated in epidemiological studies of PFOA exposure were not evaluated. EPA does not have a CSF for PFOS or other PFAS. Therefore, ATSDR cannot calculate the estimated cancer risk from PFOS or other PFAS exposures and the actual cancer risk from exposure to all PFAS that may be cancer-causing from the Pease PWS is uncertain.

Next Steps

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

Consuming water containing low levels of PFAS from the Pease Tradeport PWS since June 2014 is not expected to cause harm to the public.

Basis for Conclusion

Except for two samples where PFOS was detected slightly above the ATSDR HBCV, data indicate that exposures were less than or equal to the ATSDR HBCVs, thereby indicating that no harmful effects are expected. In addition, exposures to children at the two childcare facilities were all below ATSDR HBCVs. Exposures to PFOS in the Pease Tradeport PWS since June 2014 are not above ATSDR provisional MRLs, thereby indicating that harmful non-cancer effects are unlikely. Further evaluation of the exposure to the mixture of PFOS, PFOA, PFHxS, and PFNA indicates that the risk for harmful developmental or immune effects is not likely to be more than what might be expected from exposure to any of these PFAS alone. Other PFAS were either below their HBCVs, maximally detected at low levels (single parts per trillion) and below ATSDR's most conservative HBCV, or not detected.

Next Steps

The treatment system being added to the Pease Tradeport PWS will help protect consumers of the drinking water. Operation of this treatment system will reduce exposure to PFAS contaminants. Treated water should continue to be sampled. The treatment system should be adjusted, as necessary, to prevent exposure above EPA or other applicable health-based drinking water guidelines and reduce exposures to PFAS compounds that have no HBCVs. As a prudent public health measure, ATSDR recommends that persons who have had long-term exposures to PFAS should be aware of ways to reduce exposures (see information available from https://www.atsdr.cdc.gov/pfas/pfas-exposure.html on ways to reduce exposures to all sources of PFAS).

Conclusion 3

Based on available scientific information, ATSDR concludes that the health and nutritional benefits of breastfeeding outweigh the risks associated with PFAS in breast milk.

Basis for Conclusion

Community members, particularly mothers who have historically been exposed to PFAS from the Pease Tradeport PWS, have expressed concern over the health implications of PFAS exposures to infants who breastfeed. Developmental effects are the most sensitive adverse health effects resulting from early life exposure to some PFAS. Studies have shown infants are exposed during pregnancy, through the mother to the fetus (maternal transfer) and occur to the nursing infant during breastfeeding. However, breastfeeding provides clear health and nutritional benefits, including protection from some illnesses and infections and reductions in the risks of developing asthma and sudden infant death syndrome. In general, the Centers for Disease Control and Prevention and the American Academy of Pediatrics recommend breastfeeding, despite the presence of chemicals in breast milk. Given what we know about PFAS exposure, the benefits of breastfeeding outweigh any risks. However, the science on the health effects of PFAS exposure on mothers and children continues to expand. A woman's decision to breastfeed is an individual choice, made after consideration of many different factors (many unrelated to PFAS exposure) and in consultation with her healthcare providers. Information developed by ATSDR to guide doctors (see https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf) can aid in this decision-making process.

Next Steps

Considering the many health benefits of breastfeeding for mother and child, ATSDR recommends that nursing mothers continue to breastfeed. ATSDR recommends that a nursing mother who has specific concerns should consult her healthcare provider. Moreover, women who plan on breastfeeding should attempt to reduce potential exposures to toxic substances as much as possible. ATSDR is available to consult with any healthcare provider, if needed.

Abbreviations and Acronyms used in this report

μg/L	micrograms per liter
6:2 FTS	6:2 fluorotelomer sulfonate
AFB	Air Force base
AFFF	aqueous film-forming foam
ATSDR	Agency for Toxic Substances and Disease Registry
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSF	oral cancer slope factor
CTE	central tendency exposure
EPA	United States Environmental Protection Agency
EtFOSE	N-ethyl perfluorooctane sulfonomidoethanol
HBCVs	health-based comparison values
HED	human equivalent dose
HI	hazard index
kg	kilogram
L	liter
LOAEL	lowest observed adverse effect level
MOE	margin of exposure
MEFOSE	N-methyl perfluorooctane sulfonomidoethanol
mg	milligram
MDH	Minnesota Department of Health
NA	not available
nc	not calculated
ND	not detected
NH DHHS	New Hampshire Department of Health and Human Services
NHANES	National Health and Nutrition Examination Survey
NHDES	NH Department of Environmental Services
NOAEL	no observed adverse effect level
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFCs	perfluorinated compounds
PFDeA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHpS	perfluoroheptane sulfonate
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFOSA	perfluorooctane sulfonamide
PFPeA	perfluoropentanoic acid
PFTeDA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUnA	perfluoroundecanoic acid
ppb	parts per billion
ppt	parts per trillion
PWS	public water supply
RME	reasonable maximum exposure
USAF	United States Air Force

Contents

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 Air Force Base (AFB). Pease AFB began operations in 1956 and closed in 1991 [ATSDR 1999]. The U.S. Air Force (USAF) transferred the Pease AFB property to the Pease Development Authority in October 1991. In February 1992, the site was named the Pease International Tradeport. The Pease Development Authority welcomed its first tenant in 1993 [Pease Development Authority 2017]. The EPA added the former Pease AFB 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]. There were no exposures to site-related contaminants in base drinking water above levels of concern [ATSDR 1999].

Under the National Priorities List, the USAF signed a federal facility agreement with the U.S. Environmental Protection Agency (EPA) and State of New Hampshire in 1991. The federal facility agreement identified the Installation Restoration Program sites at the former Pease AFB. It also identified the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (commonly known as Superfund) process. Sites included the former fire department Area 2 and the Installation Restoration Program sites within the Haven well vicinity. The past contamination issues were evaluated in a 1999 Public Health Assessment [ATSDR 1999].

As part of the EPA's evaluation of emerging contaminants, additional sampling[3] was conducted at Pease International Tradeport. In 2013, twenty-two monitoring wells located at Fire Department Area 2 (Site 8), known as AT008 on the Pease International Tradeport, were sampled for per- and polyfluoroalkyl substances (PFAS) (Appendix A, Figure A-2). Results were compared to EPA's health advisory level for perfluorooctane sulfonic acid (PFOS) and

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[1] The National Priorities List is the list of contaminated sites with known or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories. These sites are eligible for long-term clean up. Sites are listed 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. More details are available from https://www.epa.gov/superfund/superfund-national-priorities-list-npl.

[2] Volatile organic compounds are carbon-based compounds associated with photochemical reactions in the atmosphere. These compounds easily evaporate under normal atmospheric conditions. Some of these compounds can be harmful. 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°C). Samples extracted within 14 days of sample collection. Equipment rinsate blanks collected at a frequency of 10% using PFAS-free water supplied from the laboratory [CB&I 2014].

perfluorooctanoic acid (PFOA), which offers a margin of protection for all Americans including children and nursing infants throughout their lives from adverse health effects resulting from exposure to PFOA and PFOS in drinking water [EPA 2018a].

PFAS are a class of manufactured chemicals that are not regulated in public drinking water supplies. PFAS were used since the 1950s to make products resistant to heat, oil, stains, grease, and water [EPA 2017]. They are found in some fire-fighting foams and consumer products, including 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 exposure is common for the general U.S. population [NIEHS 2016; ATSDR 2015; EPA 2016a; CDC 2018].

PFAS persist in the environment. They are water-soluble and are found in soil, sediment, water, plants, and animals. Studies indicate that some PFAS move through the soil and easily enter groundwater, in which they can travel long distances [MDH 2017b, 2017c].

AFFF containing PFOS and PFOA was used at the former Pease AFB to respond to petroleum fires and during fire training exercises [CB&I 2014]. AFFF was first used at Pease around 1970 [NH DHHS 2015; Prevedouros et al. 2006; ATSDR 2015; NRL 2015]. Components of the AFFF, such as PFOA and PFOS, seeped into the soil and groundwater and migrated into the water supply wells that serve Pease Tradeport PWS.

At the time of sampling (2013), 19 monitoring wells at site 8 exceeded EPA's former provisional health advisory level of 0.2 microgram per liter (µg/L) for PFOS. Seventeen monitoring wells exceeded EPA's former provisional health advisory level of 0.4 µg/L for PFOA [CB&I 2014]. When those wells were compared to the current EPA lifetime health advisory of 0.070 µg/L [EPA 2016a, 2016b], 21 monitoring wells contained PFOS above 0.07 µg/L, and 18 contained PFOA above 0.07 µg/L [CB&I 2014].

The City of Portsmouth operates and maintains the Pease Tradeport PWS through an inter-municipal agreement with the Pease Development Authority (PDA). Three wells (identified as Harrison, Haven, and Smith) supplied or supply water to the Pease Tradeport PWS. Water from these wells are blended together and then three chemicals were added to the water: sodium hypochlorite (disinfection), hydrofluorosilicic acid (dental cavity prevention), and ortho/polyphosphate (iron and manganese sequestration and corrosion control). This water is then blended with supplemental water boosted from the Portsmouth PWS and sent to the distribution system. These wells were sampled and analyzed for several PFAS compounds in April and May 2014. Although PFAS were detected in each well, only the Haven well had elevated levels above the EPA provisional health advisory. PFOS in the Haven well was detected at a maximum concentration of 2.5 µg/L. This exceeded EPA's former provisional health advisory level of 0.2 µg/L. Advisory levels in place at that time reflected the current knowledge about amounts of a chemical a person might safely consume over a lifetime. When higher levels are detected, action should be taken to reduce exposure to those contaminants in drinking water. The EPA developed a Health Advisory for PFOS and PFOA (singly or combined at 0.07 ppb) on May 25, 2016.

The Haven well was shut down on May 12, 2014, immediately after the water testing results were known. The Harrison and Smith wells continue to provide public water for the Pease Tradeport PWS, supplemented by water from the City of Portsmouth PWS [CB&I 2014]. The Portsmouth and Pease Tradeport PWS are interconnected, which allows water to be transferred from Portsmouth to the Pease Tradeport as needed [Portsmouth Water Division 2014].

In April 2015, the USAF asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate exposures to PFAS in the Pease Tradeport PWS. ATSDR evaluated past and current exposures to on-site workers and children attending the two on-site childcare centers. ATSDR also examined two timeframes for these exposures.

- Water supply before the Haven well shut down; 1993 to May 2014
- Water supply after the Haven well was shut down; June 2014 to the present

ATSDR acknowledges that exposures to military and base personnel could have occurred through drinking water and other sources before 1993. However, this evaluation focuses on exposures to persons who worked at the Pease International Tradeport and children who attended the two childcare centers at the Pease International Tradeport from 1993 to present.

Pease Tradeport Public Water Supply

Water Supply Before Haven Well Shut Down, May 12, 2014

The Pease Tradeport PWS was built in the mid- to late 1950s as part of the construction of the former Pease AFB. The AFB operated the PWS while the base was open [CH2M Hill 1984]. The water system included three water supply wells (Harrison, Haven and Smith) and two water storage tanks (Hobbs Hill Landing and National Guard) (Appendix A, Figure A-3). Water from the three supply wells was chemically treated for corrosion control and introduced into the water distribution system. Water was routinely tested by the water system operators according to the monitoring plan set forth by the NHDES. Since 1985, water from these supply wells is mixed together and treated before being delivered to customers (before the date when the Pease International Tradeport welcomed its first tenants in 1993). The Harrison, Haven, and Smith wells provided the primary drinking water for the Pease International Tradeport. Table 1 presents the past and current water source contributions.

The Pease and Portsmouth water systems have always been interconnected. In fact, prior to the construction of the Pease Air Base, the Haven Well was one of the primary sources of supply for the City of Portsmouth, with a history of use dating back to the late 1700s. When the Newington Booster Station was built by the Army Corps of Engineers in the late 1950s to boost water that came from Madbury into the Portsmouth system they also installed pumps that could be used to pump water into the Pease Tradeport public water supply from the Newington Booster. The existing booster system at the Grafton Road facility was installed in the early 1990s to enable Portsmouth water to be blended with Pease Tradeport water to reduce nitrates that were in the Pease Tradeport wells because of the use of urea for a period at the airport. An online nitrate analyzer at the Grafton Road facility coordinated how much Portsmouth water was necessary to reduce the nitrate levels [B. Goetz, City of Portsmouth, New Hampshire, Public Works, email to Gary Perlman, ATSDR, March 8, 2018].

Table 1. Average pumping percentages for each water source, based on monthly reports, Pease Tradeport public water supply (PWS), 1994–2015

Years*	Water source†			
	Harrison	Haven	Smith	Portsmouth PWS‡
1994–1999	0%	56%	44%	NA
2000–2001	0%	88%	12%	NA
2003–2005	0%	53%	47%	NA
2006	26%§	48%	26%	NA
2007	51%	47%	2%	NA
2008–2013	29%	46%	25%	NA
Jan–May 2014¶	24%	47%	29%	NA
Jun 2014–Aug 2015	25%	0%	31%	44%

Note: See Appendix B for more details.

Abbreviation: NA = not available.

*Periods are discrete intervals and were determined by significant changes in amount of water provided.

†Normal operations involved all three wells turning on and off together based on demand and storage tank levels.

‡The Portsmouth PWS was only used occasionally to boost the water storage capacity until May 12, 2014, when this contribution was used to replace the contribution of the Haven well.

§A vote was held by the Portsmouth Planning Board to reactivate the Harrison well [2003] subsequently, the well was tested, designed and approved by the NH DES for reactivation in 2006.

¶Haven well taken out of service May 12, 2014.

When the Pease Tradeport PWS required supplemental water, it was pumped from the Portsmouth water system. In emergency situations, water from the Pease Tradeport water treatment facility was pumped to the Portsmouth system.

In 2014, based on the PFAS detections in monitoring wells located at AT008 (Site 8), the USAF sampled the three Pease Tradeport water supply wells. PFOS levels in the Haven well exceeded the former EPA provisional health advisory level of 0.2 µg/L. On May 12, 2014, the Haven well was shut down. The other two wells fell below the current EPA lifetime health advisory level.

Water Supply After 2014 Haven Well Shut Down

Since the Haven well was shut down on May 12, 2014, the Portsmouth PWS, Harrison, and Smith wells have provided water to the Pease Tradeport PWS.

In November 2015, the USAF, City of Portsmouth, and the Pease Development Authority reached an agreement to design and build a treatment system to remove PFAS from the Harrison, Haven, and Smith wells [City of Portsmouth 2015a, 2015b]. The City of Portsmouth led the design and construction. The USAF provided funding. Activities to reduce PFAS contamination in the aquifer beneath the Pease International Tradeport remain a priority of the

USAF, EPA, and New Hampshire Department of Environmental Services (NHDES) [City of Portsmouth 2015a, 2015b]. In April 2016, the USAF, City of Portsmouth, and the Pease Development Authority signed an agreement to install carbon filters to treat water from the Harrison and Smith wells. The activated carbon demonstration filters continue to filter the Harrison and Smith wells while the final treatment system for all three wells is constructed. The pilot testing of the Haven Well confirmed that resin filters in combination with activated carbon would provide the most efficient treatment of PFAS compounds. The construction project was bid in late 2018 and construction began in April 2019 with completion of the system scheduled for late 2021. Designs for the Haven well treatment continue [City of Portsmouth 2016a]. The treatment system for the two Pease Tradeport wells (Harrison, Smith) began operating September 23, 2016 [City of Portsmouth 2016b]. The treatment system will allow engineers to evaluate options for the Haven well. Pilot testing for the Haven well treatment system started in 2017 [City of Portsmouth 2016b, 2017c]. Water passing through the pilot filtration systems - from the period of October 2016 through October 2018 - has been mostly non-detect for 22 of 23 PFAS. PFBA was detected on several occasions at an estimated maximum value 0.01 ppb. Four other PFAS were estimated a low parts per trillion levels (detected only one time each), with one detection of PFOS at an estimated value of 0.017 ppb or 17 ppt). The detection limits for these 23 compounds ranged from 0.0026 ppb to 0.0066 ppb [see also http://files.cityofportsmouth.com/files/misc/PeaseWaterSupply20181024.pdf].

The USAF is developing two other PFAS treatment systems (systems A and B) to comply with the EPA's Administrative Order for addressing PFAS at the Pease International Tradeport [P. Sandin, New Hampshire Department of Environmental Services, email to Gary Perlman, ATSDR Branch, November 21, 2017].

Treatment system A: Site 8 is also known as the former fire training area at the north end of the airfield. The Administrative Order initially required the USAF to operate and optimize an existing groundwater treatment system at Site 8 until a more comprehensive system could be designed and installed. The existing system was designed and operated for more than 19 years to remove volatile organic compounds and other contaminants of concern identified at Site 8. After PFAS were found at Site 8 and EPA issued the Administrative Order, that system was operated in compliance with the Administrative Order from August 2015 to spring 2017. The system was then shut off so the new system could be built. The new system is expected to begin operation near the end of 2021.

Treatment System B: The Airfield Interim Mitigation System is expected to be built in 2019. It will pump and treat groundwater from several extraction wells in the middle of the airfield (roughly 2,500 feet upslope from the Haven well) and return the treated water to the aquifer. The system is also operating at a reduced flow rate as of the writing of this report.

Groundwater PFAS Contaminant History

1970-1991 AFFF in use at Pease AFB

Sampling for PFAS within Fire Department Area 2 (Site 8) began because some applied fire-suppression foams are known to have contained PFAS. AFFF is a fire-suppressant that was used on the base. Some AFFF contained PFAS. The fire suppressing foam was used at Pease AFB when responding to airplane fuel leaks, fires, and during training exercises conducted at Site 8 [CB&I 2015]. Pease AFB may have started using AFFF in 1970 [NH DHHS 2015; Prevedouros et al. 2006; ATSDR 2015; NRL 2015]. Site 8 is a known AFFF release area. Twenty additional AFFF areas were evaluated for potential releases (Appendix A, Figure A-4). Only 11 AFFF areas are subject to further evaluation [AMECFW 2016, 2017].

2013 Sampling

In 2013, monitoring wells located within the Pease Air Force Base Fire Department Area 2 (Site 8) were sampled for PFAS. Table A-2 (Appendix A) lists the PFAS that were monitored.

Monitoring Outcome

Based on the PFAS monitoring well results from Site 8, EPA and NHDES asked the USAF to sample the three Pease Tradeport PWS wells. USAF collected initial samples on April 16, 2014; USAF consultants and NHDES collected confirmatory samples on May 14, 2014. The Haven well was shut down two days before the confirmatory sampling. The samples were analyzed for 11 PFAS and the results are presented in Table A-3 (Appendix A).

Estimated Concentrations of PFAS in the Drinking Water before May 2014

Past exposures to PFAS in the public drinking water were from water supplied from the combination of the Harrison, Haven, and Smith wells. Because data for water at the distribution point were not available, ATSDR used a simple flow-weighted mixing model to estimate drinking water concentrations before June 2014 (see Appendix A Figure A-5, and Appendix B for more details). The simple mixing model assumed that the PFAS concentrations at Pease Tradeport PWS distribution points would be equal to those in any location where people drank the water. To calculate the estimated PFOS, PFOA, and other PFAS concentrations in the water, ATSDR used the monthly well pumping rates for several years and the highest PFOS and PFOA concentrations from the April and May 2014 supply well samples.

ATSDR used a simple mixing model to estimate average monthly concentrations of PFAS in the drinking water for the 11 compounds detected in the three water supply wells. The model used monthly pumping rates from January 2003–April 2014 (see Figure B-1) for each water supply well, along with PFAS concentrations measured at each well in April 2014 (Table B-3). To estimate average monthly concentrations of PFAS in drinking water, the model used pumping rates from May 2014–August 2015 for each water supply well and the highest PFAS concentrations measured at each well during the month. Figure B-3 shows the monthly estimated drinking water concentrations from January 2003–August 2015 for the 11 PFAS detected in the three water supply wells. The highest estimated concentration of PFOS in drinking water was 1.71 µg/L in December 2012 and January 2013. The highest estimated PFOA and perfluorohexane sulfonate (PFHxS) concentrations during the same months were 0.24 µg/L and 0.57 µg/L, respectively. Drinking water concentrations for the remaining eight PFAS detected were at or below 0.2 µg/L. In November 2007, December 2007, and January 2008, the estimated drinking water concentrations for all 11 PFAS were below 0.05 µg/L because the Haven well was shut down for service during these months. Because the Haven well was taken out of service on May 12, 2014, estimated concentrations of PFAS in drinking water during June 2014–August 2015 were less than 0.02 µg/L.

The following four PFAS were estimated at maximum concentrations from May 2012 to May 2014:

- perfluoroheptanoic acid (PFHpA) — 0.08 µg/L
- perfluorohexanoic acid (PFHxA) — 0.23 µg/L
- perfluorohexane sulfonic acid (PFHxS) — 0.57 µg/L
- perfluoropentanoic acid (PFPeA) — 0.19 µg/L

Drinking water testing results, June 2014 to the present

Since May 12, 2014, the Harrison and Smith wells have provided approximately 52% of the public water to the Pease Tradeport PWS; the City of Portsmouth provides the other 48%.[4]

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[4] The City of Portsmouth, NH conducted tap water sampling for PFAS in June 2016. The samples were collected at two NHDES sites: Sagamore Road and the Portsmouth Library. PFOA and PFOS were non-detect. Five other compounds were detected at low levels: perfluorobutanesulfonic acid (PFBS), perfluoroheptane sulfonate (PFHpS), perfluoropentanoic acid (PFPeA), perfluorotetradecanoic acid (PFTeDA), and perfluorotridecanoic acid (PFTrDA). The

Since June 2014, USAF consultants have sampled the Smith well once a week and the Harrison well twice a month, analyzing for 23 PFAS. Among Pease Tradeport PWS locations, the water treatment plant and the NHDES Office have been sampled quarterly, and Fire Station No. 3, Great Bay Kids' Company, and Discovery Child Enrichment Center have been sampled occasionally. The weekly sampling of the wells was changed to monthly sampling after the demonstration filters were installed on the Smith and Harrison wells in September 2018--that sampling frequency continues.

Table A-4 (Appendix A) presents results of water samples from the Harrison and Smith wells from June 2014 through May 2017 (only the minimum and maximum for that period are included). Table A-5 (Appendix A) presents results of samples from the Pease Tradeport distribution points for that period. Table A-6 (Appendix A) presents results from the childcare centers. Seventeen PFAS were detected in either the Harrison or Smith wells and nine PFAS were detected in the Pease Tradeport distribution point water samples. Water samples were collected from March 2015 through December 2015 at Great Bay Kids' Company and the Discovery Child Enrichment Center. Table A-6 (Appendix A) presents data for those samples. Seven PFAS were detected in the water supplying the two childcare centers.

Sentry Wells

In addition to periodic Pease Tradeport PWS sampling, 12 monitoring wells, called sentry wells, are sampled regularly. The sentry wells are used to check whether PFAS contamination affecting the Haven well might migrate to the southern well field [AMECFW 2016]. The southern well field includes two operating Pease Tradeport wells; the Harrison and Smith wells; and the Collins and Portsmouth wells, two wells closest to the Pease International Tradeport that are part of the Portsmouth PWS. The Portsmouth well, located about 2,800 feet south of the Pease International Tradeport boundary, is the closest Portsmouth PWS well. The Haven well is located about 5,300 feet north (upgradient) from the Harrison well, the closest of the four wells in the southern well field.

The results from the sentry wells, through May 2017, are being closely evaluated for potential PFAS migration in groundwater south toward the southern well field [AMECFW 2016; City of Portsmouth 2017a]. The highest PFOS and PFOA concentrations detected in the sentry wells are 0.05 µg/L (November 2015) and 0.022 µg/L (May 2017), respectively [City of Portsmouth 2017a]. The USAF has proposed installing additional sentry wells to increase monitoring

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levels of these compounds were equivalent to the sources that served the sample location, except for PFHpS, which was not detected at any of the sources, thus likely associated with facility plumbing or a laboratory analysis issue [City of Portsmouth 2017b, 2018].

capability and identify potential PFAS migration toward the public wells. These sentry wells have never supplied public water. No one has nor will be drinking water from the sentry wells.

ATSDR's Evaluation Process

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.

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 conservative and 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.

Identifying Chemicals of Concern

Screening values are ATSDR's health-based comparison values[5] (HBCVs). ATSDR develops HBCVs to screen environmental contamination for further evaluation. If contaminant concentrations are above these HBCVs, ATSDR reviews exposure variables (such as duration and frequency), the toxicology of the contaminant, and epidemiology studies to determine likelihood of possible health effects. During this part of the evaluation process, ATSDR estimates site-specific exposure doses and compares those to health guideline values. This comparison allows ATSDR to assess the possible public health effects of site-specific conditions. Health-based comparison values are developed based on data drawn from the epidemiologic and toxicological literature. Many uncertainty factors, sometimes known as safety factors, are applied to ensure that the health-based comparison values amply protect human health.

ATSDR's MRLs [ATSDR 2018b] and EPA's reference doses and oral cancer slope factors (CSFs) are the health guidelines used in the screening process. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. A CSF (also known as an oral slope factor) is an EPA derived estimate of the increased cancer risk from oral exposure

[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.

to a dose of 1 milligram per kilogram per day (mg/kg-day) for a lifetime. Estimated doses that are below health guidelines are not expected to cause adverse health effects. When no federal HBCVs are available, ATSDR used applicable state values for further comparison in the screening process. Data on contaminants for which there were no federal or state HBCVs were retained for further evaluation.

The following sections describe the evaluation process in more detail, focusing first on who was potentially exposed (the exposure pathway analysis). ATSDR then consider the chemicals identified for further evaluation (the screening analysis). Then we discuss the public health implications of exposure.

Exposure Pathway Analysis

The Pease Development Authority welcomed its first tenant in 1993. Therefore, people who worked at the Pease International Tradeport from 1993 to the present consumed in the past or are now consuming drinking water from the Pease Tradeport PWS. Two childcare centers operate at the Pease Tradeport. The Discovery Child Enrichment Care opened in 1994, and the Great Bay Kids' Company opened in 2010. Both childcare centers are open every day. Children who attend the childcare centers range in age from 6 weeks to 5 years. Both childcare centers received drinking water from the Pease Tradeport PWS.

Exposure to contaminants in water, in general, occurs by drinking (ingesting) and showering (skin contact and breathing in vapors or mists). Skin exposure studies report very limited PFAS absorption through the skin [Prevedouros 2006]. Moreover, exposure through water use, such as bathing or showering, is not a pathway of concern for either inhalation or skin absorption of PFAS at typical drinking water concentrations [NH DHHS 2016a; Emmett et al. 2006]. Because people who use water at the Pease International Tradeport are typically workers and other non-residents, bathing and showering would likely occur only where people exercise or swim. Children at the childcare centers might use the water for play: infants might sit in tubs of water and older children might run through sprays of water outside. However, the dermal exposure pathway is minor, because skin absorption is slow. Skin exposures to PFAS do not result in significant absorption.

Persons exposed include adults working on-site and children attending on-site childcare centers who consume drinking water with PFAS from the Pease Tradeport PWS. Pregnant women who consume or have consumed drinking water with PFAS from the Pease Tradeport PWS would pass PFAS to the developing fetus through the placenta and to infants by breast feeding. Exposure pathways are presented in Table A-7 (Appendix A).

Screening Analysis

ATSDR screened all drinking water data against available HBCVs to select PFAS for further evaluation. Table A-8 in Appendix A summarizes the HBCVs selected for screening. Data on PFAS lacking HBCVs were retained for further in-depth evaluation. For some of the PFAS compounds without HBCVs, concentrations in the water were very low and adequate toxicological data were unavailable. ATSDR will consider the possible contributing effects of these PFAS compounds as part of mixtures.

Sampling from the Pease Tradeport Public Water Supply before June 2014

Table 2 describes the PFAS levels in the supply wells screened against HBCVs. Table 2 also includes concentrations from the Haven well when it was operational.

Table 2. Water quality data from supply wells for 2014, screened by available health-based comparison values, concentrations in micrograms per liter (µg/L) for eight compounds: PFOS, PFOA, PFHxS, PFHpA, PFHxA, PFNA, and PFPeA

Specific PFAS	HBCV	Haven well		Harrison well		Smith well	
		April 16	May 14	April 16	May 14	April 16	May 14
PFHpA	None*	0.12	0.12	0.0046†	0.0042†	0.0025†	0.002†
PFBS	2§	0.051	0.051	0.00094†	0.00087†	0.002†	0.0019†
PFHxA	None*	0.33	0.35	0.0087	0.01	0.0039†	0.004†
PFHxS	0.14‡	0.83	0.96	0.036	0.032	0.013	0.013
PFNA	0.021‡	0.017	0.017	ND	ND	ND	ND
PFOA	0.021‡	0.35	0.32	0.009	0.0086	0.0035†	0.0036†
PFOS	0.014‡	2.5¶	2.4¶	0.048	0.041	0.018	0.015
PFPeA	None*	0.27	0.26	0.0079	0.0084	0.0035†	0.0034†

Source: City of Portsmouth [2014].

Abbreviations: ND = not detected; PFAS = per- and polyfluoroalkyl substances; PFOS = perfluorooctanesulfonic acid; PFOA = perfluorooctanoic acid; PFHxS = perfluorohexane sulfonic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFPeA = perfluoropentanoic acid; HBCV = health-based comparison value.

Note: Shaded = Concentrations are above a health-based comparison value.

* Although lacking health-based comparison values, these were selected for further in-depth analysis because they were detected at higher concentrations. Other PFAS with no HBCV and detected at low concentrations will be included as part of the overall evaluation of mixtures.

† Indicates an estimated value. This flag is used when the mass spectral data indicate the presence of an analyte meeting all the identification criteria, but the result is less than the Contract Required Quantitation Limit but greater than zero.

‡ ATSDR derived value 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 provisional MRLs and conservative 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.

§MDH developed a guidance value of 2 ppb for PFBS in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017d].

¶ These represent the maximum PFOS concentration in samples collected during April and May 2014 from the Haven well. Sampling from the same well during November 16 and 28, 2016, indicated that the PFOS concentrations were 1.0 µg/L and 1.4 µg/L, respectively. Data from 2014 remain valid and were selected for further analysis and modeling by ATSDR (see Appendix B for modeling report).

During April 2014, PFAS were detected in each of the three wells (Harrison, Haven, and Smith) that originally comprised the Pease Tradeport PWS. Because the water from these three wells was blended before being supplied as drinking water, ATSDR needed to use a mathematical model to estimate drinking water exposure levels from January 2003 through March 2015 (before and after the Haven well shut down in May 2014). The PFAS which were analyzed prior to June 2014 include the eight PFAS listed in Table 2. After June 2014, additional laboratory methods were available, and the list of PFAS expanded to include 23. The additional fourteen PFAS are listed below:

6:2 Fluorotelomer sulfonate (6:2 FTS)
8:2 Fluorotelomer sulfonate (8:2 FTS)
N-Ethyl perfluorooctane sulfonamide (EtFOSA)
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)
N-Methyl Perfluorooctane Sulfonamide (MEFOSA)
N-Methyl Perfluorooctane Sulfonamidoethanol (MEFOSE)
Perfluorodecane sulfonate (PFDS)
Perfluorodecanoic acid (PFDA)
Perfluorododecanoic acid (PFDoA)
Perfluorononanoic acid (PFNA)
Perfluorotetradecanoic acid (PFTeDA)
Perfluorotridecanoic acid (PFTrDA)
Perfluoroundecanoic acid (PFUnA)
Perfluoroheptanoic acid (PFHpA)

The values in Table 3 show maximum estimated drinking water PFAS concentrations.

Table 3. Maximum modeled per- and polyfluoroalkyl substances (PFAS) concentrations in blended Pease Tradeport PWS drinking water for the indicated period. All units displayed in micrograms per liter (µg/L)

Specific PFAS	HBCV	Modeled time frames: Jan 2003–Oct 2007	Nov 2007–Jan 2008	Feb 2008–Aug 2010	Sep 2010–Apr 2012	May 2012–May 2014	Jun 2014–Mar 2015
PFHpA	None*	0.08	<0.01	0.07	0.06	0.08	<0.01
PFHxA	None*	0.22	0.01	0.18	0.17	0.23	0.01
PFHxS	0.14†	0.57	0.04	0.46	0.44	0.57	0.02
PFOA	0.021†	0.24	0.01	0.19	0.18	0.24	<0.01
PFOS	0.014†	1.7	0.05	1.37	1.29	1.71	0.02
PFPeA	None*	0.18	0.01	0.15	0.14	0.19	0.01

Abbreviations: HBCV = health-based comparison value; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctanesulfonic acid; PFPeA = perfluoropentanoic acid.

*Although lacking health-based comparison values, these were selected for further in-depth analysis because they were modeled at higher concentrations. Other PFAS with no HBCV and detected at low concentrations will be included as part of the overall evaluation of mixtures.

†ATSDR derived value 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 provisional MRLs and conservative 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.

Note: ATSDR used the maximum PFOS concentration from the Haven well collected in April and May 2014. Subsequent sampling from the same well during November 16 and 28 of 2016 indicated that the PFOS concentration was 1.0 µg/L and 1.4 µg/L, respectively. The data from 2014 remain valid and were selected for modeling by ATSDR (see Appendix B for modeling report). Shaded = Concentrations are above a health-based comparison value.

Table A-9 (Appendix A) shows more of the data summarized in Table 3. Table A-9 includes the maximums and geometric means (a form of averaging) for the estimated drinking water PFAS concentrations. To be conservative, ATSDR used the maximum estimated concentrations from the water modeling to further evaluate the public health implications of PFAS exposures (see Appendix B for modeling report).

Sampling from the Pease PWS after June 2014

Since May 2014, a mixture of water from the Harrison well, Smith well, and the Portsmouth PWS comprised the drinking water supply. People were exposed to low levels of PFAS until the water treatment system to treat the Harrison and Smith wells began operating on September 22, 2016 [City of Portsmouth 2016c]. The permanent water treatment system design is expected to remove PFAS contaminants. The City of Portsmouth will follow all federal and state guidelines and requirements to ensure the treated water meets current water quality standards.

Drinking water sampling for PFAS was conducted at several distribution points from June 2014 through December 2015. Table 4 highlights the concentrations of PFAS after the Haven well was shut down, using three locations: DES office, water treatment plant, and Fire Station No. 3. The maximum detected PFOS and PFOA concentrations in the distribution points were 0.016 µg/L and 0.0073 µg/L respectively. The sampling indicated that the maximum detected PFOS concentration was equal to the HBCV at the NHDES office and slightly above the HBCV at the water treatment plant. There were no exceedances of any other PFAS at any other sampling locations, which included two childcare centers and a fire station [City of Portsmouth 2017a]. For more details on those samples, see Table A-5 (Appendix A).

Table 4. Summary of per- and polyfluoroalkyl substances in the Pease Tradeport water supply (New Hampshire Department of Environmental Services (NHDES) office, water treatment plant distribution point, and Fire Station No. 3) from June 2014 through May 2017, Pease International Tradeport, Portsmouth, New Hampshire, concentrations in micrograms per liter (µg/L)

		NHDES office (13 samples)		Water treatment plant distribution point (9 samples)		Fire Station No. 3 (2 samples)	
Specific PFAS	HBCV	Min	Max	Min	Max	Min	Max
PFHpA	None*	ND	ND	ND	ND	ND	ND
PFHxA	None*	0.003	0.0081	0.003	0.006	ND	0.007
PFHxS	0.14†	0.006	0.019	0.006	0.019	0.012	0.019
PFOA	0.021†	ND	0.0073	ND	ND	0.0055	0.0061
PFOS	0.014†	0.006	0.014	0.006	0.016	0.012	0.013
PFPeA	None*	0.003	0.0083	0.004	0.007	0.0037	0.009

Abbreviations: HBCV = health-based comparison value; Max = maximum value detected; Min = minimum value detected; ND = not detected; PFAS = per- and polyfluoroalkyl substances; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctanesulfonic acid; PFPeA = perfluoropentanoic acid.

*Although lacking health-based comparison values, these were selected for further in-depth analysis because they were detected at higher concentrations. Other PFAS with no HBCV and detected at low concentrations will be included as part of the overall evaluation of mixtures.

†ATSDR derived value 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 provisional MRLs and conservative 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.

Note: Shaded = Concentrations are above a health-based comparison value.

Table 5 highlights the PFAS concentrations in the on-site childcare center (Great Bay Kids' Company and Discovery Child Enrichment Center) sample locations after the Haven well was taken off-line. Table A-6 in Appendix A shows additional, low level PFAS detections. The maximum detected PFOS and PFOA concentrations in the childcare distribution points were 0.012 µg/L and 0.005 µg/L, respectively. Those concentrations, both individually and combined, are below the current EPA lifetime health advisory (0.070 µg/L) and below ATSDR health-based comparison values. Other PFAS were detected at low levels below ATSDR's lowest HBCV or did not exceed available ATSDR HBCVs. For more details on those samples, see Table A-6 (Appendix A).

Table 5. Summary of per- and polyfluoroalkyl substances (PFAS) detected in the Pease Tradeport public water supply at two childcare centers, March 2015, September 2015, and October 2015, Pease International Tradeport, Portsmouth, New Hampshire; concentrations in micrograms per liter (μg/L)

		Great Bay Kids' Company*		Discovery Child Enrichment Center†	
Specific PFAS	HBCV	Min	Max	Min	Max
PFHpA	None‡	ND	ND	ND	ND
PFHxA	None‡	0.004	0.005	ND	ND
PFHxS	0.14§	0.01	0.014	0.01	0.014
PFOA	0.021§	ND	0.005	ND	ND
PFOS	0.014§	0.011	0.012	0.007	0.012
PFPeA	None‡	0.005	0.006	0.006	0.006

Abbreviations: HBCV = health-based comparison value; Max = maximum value detected; Min = minimum value detected; ND = not detected; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctanesulfonic acid; PFPeA = perfluoropentanoic acid.

*Results from two untreated samples from the Pease Tradeport Water Supply at Great Bay Kids' Company location.

†Results from two untreated samples from the Pease Tradeport Water Supply at Discovery Child Enrichment Center location.

‡Although lacking health-based comparison values, these were selected for further in-depth analysis because they were detected at higher concentrations. Other PFAS with no HBCV and detected at low concentrations will be included as part of the overall evaluation of mixtures.

§ATSDR derived value 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 provisional MRLs and conservative 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.

Summary of Screening Analysis

For data obtained before June 2014, PFOS, PFOA, and PFHxS were selected for further in-depth evaluation because their estimated maximum modeled concentrations were above their respective HBCVs. Neither the modeled nor measured levels of PFNA were above an HBCV indicating that no further evaluation is needed. However, PFNA was included as part of the mixture evaluation. Three PFAS that lacked HBCVs (PFHpA, PFHxA, and PFPeA) were selected for further in-depth evaluation because they occurred in significant concentrations in the water and some scientific information on health effects were available to evaluate exposure. 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 A-1 in Appendix A.

For data collected after June 2014, the maximum detected PFOS concentration was equal to the HBCV at the NHDES office and above the HBCV at the water treatment plant (see Table A-5). There were no exceedances of any other PFAS at any other sampling locations, which included two childcare centers and a fire station (see Table A-6) [City of Portsmouth 2017a].

Public Health Implications of Exposure to PFAS in Drinking Water

A MRL is an estimate of the amount of a chemical a person can eat, drink, or breathe each day without a detectable non-cancer risk to health. MRLs serve as a tool to help public health professionals determine areas and populations potentially at risk for health effects from exposure to a particular chemical.

MRLs are a screening tool that help identify exposures that could be *potentially* hazardous to human health. Exposure above the MRLs does not mean that health problems will occur. Instead, it serves as a signal to health assessors to look more closely at a particular 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 type and quality of data available. MRLs can be set for 3 different time periods (the length of time people are exposed to the substance): acute (about 1 to 14 days), intermediate (from 15-364 days), and chronic (exposure for more than 365 days). MRLS are also calculated for different exposure routes (for example: inhalation and ingestion). ATSDR has developed over 400 human health MRLs. MRLs are developed for health effects other than cancer. For PFAS, ATSDR has developed provisional MRLs for ingestion for PFOS, PFOA, PFHxS, and PFNA based on intermediate duration oral animal studies. ATSDR is using these intermediate provisional oral MRLs to also screen and evaluate chronic exposures [ATSDR 2018a]. As the fetus/neonate is the most sensitive group, the provisional MRLs developed for the four PFAS are protective for the entire population and for health endpoints that may occur at higher concentrations. In addition, ATSDR considered immune effects in the development of our provisional MRLs as these effects may be a more sensitive effect 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, the MRLs go 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 EPA, before being submitted for public comment [ATSDR 2018a].

Many studies have examined possible relationships between levels of per- and polyfluoroalkyl substances (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 weights (<20 grams (0.7 ounces) decrease in birth weight per 1 ng/mL increase in PFOA or PFOS in blood);
- increased risk of kidney or testicular cancer (ATSDR, 2018a)

Currently, scientists are still learning about the health effects of exposures to mixtures of PFAS.

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. In addition, investigators are actively studying whether being exposed to multiple PFAS chemicals at the same time increases the risk of health effects. 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.

It is important to remember that the likelihood of adverse health effects depends on several factors, such as the concentrations of different PFAS, as well as the frequency and duration of exposure. More frequent exposure can increase risk. Higher concentration and length of time exposed can lead to increased risk.

Exposure from 1993 to May 2014

Because the data collected in 2014 were from water supply wells, ATSDR must rely on computer-modeled concentrations for the distribution points to estimate past exposures. Using these data, ATSDR considered the following lines of evidence to evaluate the likelihood of health effects from past exposures:

- Potential effects of individual exposures to PFOA, PFOS, and PFHxS (PFAS with ATSDR provisional MRLs)
- Potential effects of individual exposures to PFHxA, PFHpA, and PFPeA (PFAS with no ATSDR provisional MRLs)
- Potential effects of exposures to a mixture of PFAS
- Biological measurements from past exposure
- Potential contributions from other sources

- Potential effects on susceptible populations: persons with pre-existing conditions and early development

Given all the uncertainties related to evaluating PFAS compounds in general, ATSDR used the maximum modeled concentration as a conservative approach. The selection of the maximum values not only enabled the evaluation of long-term exposures but also exposures of less than 1 year (including young children at childcare centers). To estimate the exposure doses from past consumption of the water, ATSDR used default exposure scenario assumptions [ATSDR 2016a, 2016b]. ATSDR's default exposure assumptions are defined by specific age ranges, resulting in estimated exposures for each age group. ATSDR used the maximum estimated modeled concentrations from the distribution points to estimate the central tendency exposure (CTE) and the reasonable maximum exposure (RME) that might be expected for each age group (see Equations 2 and 3 in Appendix A). The central tendency exposure is the average water intake. The reasonable maximum exposure is the maximum estimated exposure dose that might occur at this site, based on the available data and assuming maximum water intake in each age group. To account for less than residential exposures, ATSDR applied an exposure frequency factor of 71% (5 days divided by 7 days) to the exposure dose calculations to match a typical employee workplace and a year-round childcare attendance frequency [ATSDR 2016a].

Exposures to PFOA and PFOS

Exposure doses were compared with the ATSDR provisional MRLs for PFOA and PFOS. The MRL is 100% of a total daily exposure below which no adverse health effects are expected. ATSDR derived an intermediate duration (15-364 days) oral provisional MRL of 3×10^{-6} mg/kg/day for PFOA. This MRL is based on neurodevelopmental effects (i.e., altered activity at 5–8 weeks of age and skeletal alterations at 13 and 17 months of age) in the offspring of mice fed a diet containing PFOA [Koskela et al. 2016]. The PFOA provisional MRL is calculated using a human equivalent dose (HED), lowest observed effect level (LOAEL) of 0.000821 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. This MRL is 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 calculated with an HED no observed adverse effect level (NOAEL) of 0.000515 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 to account for concern that immunotoxicity may be a more sensitive endpoint than developmental toxicity [ATSDR 2018a]. The HED LOAEL for developmental effects from the Luebker et al. (2005) study was estimated to be 0.0021 or 2.1×10^{-3} mg/kg/day.

Adverse health effects from PFOS and PFOA exposure in animals that are the same in humans include changes in total cholesterol and decreased birth weight. In animal studies, there are common effects to the liver, neonatal development, and immune system. PFOS and PFOA provisional MRLs are based on developmental endpoints. The maximum estimated modeled PFOS and PFOA concentrations for any one month in the Pease Tradeport PWS was 1.71 µg/L and 0.24 µg/L, respectively. These values were used to calculate exposure doses. In Appendix A, Tables A-10 and A-11 present the exposure assumptions and exposure doses of PFOS and PFOA for each age group, along with hazard quotients (HQ). An HQ is the ratio of the exposure doses for PFOA and PFOS divided by their provisional MRLs.

An RME scenario assumes a higher than average water intake and, thus, that people have more exposure to a contaminant. In this scenario, PFOA and PFOS HQs for all age groups, for a pregnant woman, and for a lactating woman using the Pease Tradeport PWS estimated water concentrations before May 12, 2014, exceeded 1.0. Assuming an average water intake rate (referred to as a central tendency exposure or CTE scenario), all HQs for PFOS were above 1.0; however, for PFOA, all were above 1.0 except for older children (6-21 years), adults and pregnant women. The highest HQs were for young children (birth to less than 1 year).

If the HQ is greater than 1.0, concern for the potential hazard of the mixture increases as the HQ increases. As can be seen from Tables A-10 and A-11, the HQs for PFOS were particularly high and much greater than for PFOA. To put these HQs into perspective, ATSDR calculated a margin-of-exposure (MOE). The MOE is the effect level, developed from animal studies, used to derive the ATSDR provisional MRL divided by the dose from exposure to Pease public water. In contrast to the HQ, the lower the MOE, the closer the exposure was to effect levels which indicates more concern. Assuming 100% of the PFAS exposure is from drinking water, the PFOS exposure dose for the most exposed Pease Tradeport PWS user, a child younger than 1 year, is 1.7×10^{-4} mg/kg/day. The MOE between the exposure dose and the lowest observed adverse effect level human equivalent dose $(LOAEL)_{HED}$ (2.1×10^{-3} mg/kg/day) for developmental effects was about 25 and 12 for the CTE and RME scenarios, respectively. To provide additional perspective to exposure doses and immune effect levels found in the scientific literature, MOEs were also calculated based on the Dong et al. (2011) and the Guruge et al. (2009) studies for a RME scenario. The MOEs ranged from <1 to 2.4 for the Guruge et al. and Dong et al. studies, respectively. Based on the current scientific literature, ATSDR understands that the immune effect levels from PFOS exposures lies somewhere between the HED LOAELs for these two studies (i.e., 4.1×10^{-4} for the Dong study and 3.1×10^{-5} for the Guruge et al. study). These exposure doses are near or exceed the lower HED LOAEL from the Guruge et al. (2009) study and would be considered potentially harmful. Therefore, PFOS exposures before May 2014 may result in harmful immune effects.

The MOE between the exposure dose and the estimated PFOA lowest observed adverse effect level human equivalent dose $(LOAEL)_{HED}$ (8.2×10^{-4} mg/kg/day) for neurodevelopmental effects shown in the Koskela et al. 2016 animal studies was 74 and 33 for the CTE and RME scenarios, respectively. Based on the above, past exposures to PFOS and PFOA from the Pease Tradeport PWS are of concern and the estimated exposures do not include PFOA and PFOS exposures from non-drinking water sources.

Exposure to PFHxS

An intermediate-duration oral provisional MRL of 2×10^{-5} mg/kg/day was derived for PFHxS based on thyroid follicular cell damage (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 HED NOAEL of 0.0047 mg/kg/day and 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. The modifying factor for database limitations was added to account for the small number of studies examining the toxicity of PFHxS following intermediate-duration exposure and the limited scope of these studies in particular studies examining immune effects, a sensitive endpoint for other PFAS, and general toxicity [ATSDR 2018a]. The HED LOAEL from these studies is estimated to be 0.0073 or 7.3×10^{-3} mg/kg/day.

As seen in Table A-12, for the CTE scenario, only a child (birth to less than 1 year) had a dose above the ATSDR provisional MRL. No other age groups for the to the CTE scenario were at or above an HQ of 1.0. However, for the upper water intake scenario (RME), children 1 to 6 years old and lactating women were at or above an HQ of 1.0. As for PFOA and PFOS above, to put these HQs into perspective, ATSDR calculated MOEs for PFHxS. Assuming 100% of the PFAS exposure is from drinking water, the PFHxS exposure dose for the most exposed Pease Tradeport PWS user, a child younger than 1 year, is 5.85×10^{-5} mg/kg/day. The MOE between the exposure dose and the lowest observed adverse effect level human equivalent dose $(LOAEL)_{HED}$ for thyroid effects was about 125 and 278 for the CTE and RME scenarios, respectively. Any 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]. For a child younger than 1 year, the HQ was about 3 indicating that the dose received by this age group could have been 3 times higher than ATSDR's MRL. Based on exposures to PFHxS alone, ATSDR would expect only a slight increased risk of harmful effects only for young children less than 1 year that consumed more than average amounts of water on a daily basis (see the Exposure to a Mixture of PFAS section below for more health perspective on this exposure).

Exposure to Other Individual PFAS

Before June 2014, people also were exposed to other PFAS. PFHxA (0.23 µg/L), PFPeA (0.19 µg/L), and PFHpA (0.08 µg/L) were detected at the highest estimated concentrations. The likely health effects for each of these compounds, based on the best available scientific information, are discussed below.

Exposure to PFHxA

Very limited information is available about the health effects of PFHxA exposure. One study evaluated the chronic oral (ingestion) toxicity of PFHxA in laboratory animals [Klaunig et al. 2015]. Female rats exposed to 200 mg/kg/day had changes to their blood, such as decreased red blood cells and hemoglobin levels and increased reticulocyte counts. Exposure also caused renal effects (tubular degeneration, necrosis, increased urine volume, and reduced specific gravity) and liver effects (necrosis). No adverse alterations (NOAELs) were seen in female rats at 30 mg/kg/day or in male rats at 100 mg/kg/day. One major uncertainty related to this study is that serum PFHxA levels were not measured. Based on the maximum estimated concentration of PFHxA in the Pease Tradeport PWS, the estimated reasonable maximum exposure dose for a young child is 2.3×10^{-5} mg/kg/day (Table A-13). This dose is about a million times lower than the lowest NOAEL from the Klaunig et al. [2015] study. Based on this study alone, harmful effects are unlikely. However, although this PFAS has not been studied as extensively as the PFAS with ATSDR MRLs (especially for the most sensitive health endpoints such as developmental and immune effects) and the only identified chronic study has limitations, as previously stated, PFCA chemicals with fewer than eight carbons, such as perfluorohexanoic acid (PFHxA) are generally less toxic and less bioaccumulative in wildlife and humans [EPA, 2018a].

Exposure to PFHpA and PFPeA (individually)

Very little scientific information is available from either human or animal studies about the health effects of exposure to PFHpA and PFPeA. However, for PFHpA, ATSDR identified several human studies for cardiovascular disease, serum lipids, immune response, and other effects that found either limited or no association. No studies for PFHpA and PFPeA were identified to allow ATSDR to compare the exposure dose from the Pease Tradeport PWS and effect levels (i.e., NOAELs or LOAELs) [ATSDR 2018a]. Therefore, ATSDR can make no health conclusions for PFHpA and PFPeA. However, although PFHpA and PFPeA have not been studied as extensively as the PFAS with ATSDR provisional MRLs, these PFAS are short-chained and not sulfonated indicating they may bioaccumulate relatively less than longer-chained and sulfonated PFAS. However, health effects of many short-chained PFAS and new PFAS alternatives have not been fully researched.

Exposure from June 2014 to the Present (individual PFAS)

Because PFOS was the only PFAS above an ATSDR HBCV in distribution samples taken after May 2014, it was further evaluated. As seen in Table A-14, none of the estimated PFOS exposure doses after June 2014 was above an HQ of 1.0 indicating that exposures to PFOS alone are not expected to be harmful. In addition, because PFOA, PFHxS, and PFNA were below ATSDR's HBCVs, we do not expect harmful effects from individual exposures to these PFAS. Other PFAS detected in the distribution system since June 2014 could not be evaluated individually because of the lack of scientific data. However, further evaluation of the mixture of all PFAS exposures after June 2014 was conducted and is explained below.

Exposure to a Mixture of PFAS

To evaluate the potential risk for cumulative exposures to PFOA, PFOS, PFHxS, and PFNA (those PFAS with ATSDR-derived provisional MRLs), ATSDR calculated a hazard index. The hazard index approach assumes dose additivity to assess the non-cancer health effects of a mixture. The hazard index is the sum of the HQs for each of the four PFAS with ATSDR provisional MRLs. If the hazard index is less than 1.0, it is unlikely that significant additive or toxic interactions would occur; so no further evaluation is necessary. If the hazard index is greater than 1.0, concern for the potential hazard of the mixture increases. Only two studies [Carr et al. 2013; Wolf et al. 2014] have shown binary pairs of PFAS (i.e., comparing only two PFAS together) demonstrate 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 of these limited data, ATSDR cannot assume any mixture effect except additivity.

With the exception of the hazard index approach for PFOA, PFOS, PFHxS, and PFNA, there is not a broadly accepted scientific method to quantitatively evaluate the possible health effects of combined exposures to PFAS. In addition, as stated previously, not all PFAS share the same health outcomes. Therefore, ATSDR evaluated the scientific literature to determine what health effects from the chemicals in the PFAS mixture found in the Pease Tradeport PWS might have similar health endpoints.

Exposures from 1993 to May 2014

For PFOA, PFOS, and PFNA (see Table A-15 for individual PFNA doses used in the mixture evaluation), ATSDR derived its provisional MRLs based on developmental effects, and for PFHxS based on thyroid effects. However, other studies show that developmental effects may occur from exposure to PFHxS (see Table A-1). Therefore, ATSDR will evaluate if additional risk of developmental effects is possible from the combined exposure to these four PFAS in the Pease Tradeport PWS. Table A-16 shows the hazard indices for the combined exposures to these four PFAS. The hazard indices for the CTE and RME scenarios for infants are 44 and 98 which are well above 1.0. These numbers show a potential for additional risk for developmental effects beyond what might be expected from exposure to any one of these PFAS alone. Three of the PFAS for which ATSDR has derived provisional MRLs (PFOS, PFOA, and PFHxS) have also been shown to have possible immune system effects (see Table A-1). Although ATSDR could not derive a provisional MRL based on immune effects, the agency added a modifying factor of 10 to the derivation of the provisional MRLs for PFOS and PFHxS to account for immune effects. Therefore, in addition to developmental effects, increased immune effects are also possible.

Each of the effects to target organ systems in Table A-1, has at least two PFAS compounds found to be associated with them in animal or human epidemiological studies. Moreover, at least four PFAS compounds are associated with developmental, liver, immune, and serum lipid effects. Therefore, although we lack refined evaluation methods, the combined exposures to PFAS compounds from the Pease Tradeport PWS might have increased the risk for some of these non-cancer health outcomes.

Exposures from June 2014 to Present

ATSDR used a similar approach as above to evaluate the cumulative exposure to PFAS with derived ATSDR provisional MRLs for exposures since June 2014. As seen in Table A-17, only the HI for children[6] less than one year (for the RME scenario) was above 1.0 (1.17). Given that the HI is only slightly above 1.0, that it represents conservative assumptions (i.e., using the maximum concentration represent longer-term intermediate and chronic exposures), and that none of the PFOA, PFOS, PFHxS, and PFNA levels were above HBCVs for the childcare centers,

[6] please note that the individual HQs summed in this table are shown in Tables A-14, A-19, A-20 and that PFNA was not included since it was not detected in water samples analyzed since June 2014

it is unlikely that the combined exposures to these four PFAS would increase the risk of harmful effects higher than what was predicted by exposures to each alone. As with the mixtures evaluation above, we lack refined methods to evaluate the combined exposures to other PFAS without HBCVs detected in the Pease Tradeport PWS since June 2014. However, as stated above, all the maximum levels were either not detected or, if present, were only detected in low ppt levels and below ATSDR's most conservative HBCV. Moreover, at least half of the PFAS detected with no ATSDR MRLs were short-chain and non-sulfonated. Generally, these PFAS bioaccumulate less in wildlife and humans. However, health effects of many short-chained PFAS and new PFAS alternatives have not been fully researched.

Biomonitoring results for Pease International Tradeport — New Hampshire Department of Health & Human Services Blood Sampling Program

Biomonitoring has been increasingly used to assess people's exposure to environmental chemicals. Serum levels of PFAS tend to reflect cumulative exposure over several years from all sources. Although there is no current guideline that tell us what levels of PFAS in blood are "safe" or "unsafe" and body burden levels reflect overall exposure from all sources and routes, monitoring PFAS in blood can help physicians and public health officials determine whether or not people have been exposed to higher levels of PFAS than are found in the general population and also help scientists plan and conduct research on exposure and health effects. Background levels of 16 PFAS in the blood serum of the United States population are monitored at regular intervals through the National Health and Nutrition Examination Survey (NHANES) [CDC 2018]. The trend for PFOA and PFOS levels in serum has been declining for several years, most likely because of reductions in their use [CDC 2013].

Responding to requests from the affected public, the New Hampshire Department of Health and Human Services (NH DHHS) began a biomonitoring program to determine blood serum PFAS levels for those exposed at Pease International Tradeport. [NH DHHS 2015, 2016a, 2016b, 2016c, 2017a]. Between April and October 2015, 1,578 members of the Pease Tradeport community had their blood tested for PFAS exposure. An additional 258 persons from the Pease Tradeport community had their blood tested in 2016-2017 [NH DHHS 2017b]. The results of the first round of biomonitoring were analyzed and presented in a NH DHHS report [NH DHHS 2015]. The results from that report were presented to the public at a community meeting held June 16, 2016. About 23% of the samples were from children ages 11 years or younger. Three PFAS (PFOS, PFOA, and PFHxS) were detected in more than 94% of all samples. The geometric means of these three PFAS were also significantly higher than for the population tested in the 2011 to 2012 NHANES. PFNA was detected in 85% of the blood samples, but its geometric mean was significantly lower in the Pease International Tradeport population than those in the NHANES data.

The other PFAS tested for in blood were detected in less than half of the Pease International Tradeport population and at much lower concentrations than PFOS, PFOA, PFHxS, and PFNA. NH DHHS therefore concluded that a meaningful analysis and comparison of the other PFAS was not possible. PFOS, PFOA, and PFHxS geometric means in the Pease International Tradeport children's group were also significantly elevated compared with the 2011–2012 NHANES data, but the PFNA geometric mean did not differ significantly between the two. Only PFOA had a significantly different geometric mean level between the Pease International Tradeport children's group and the Pease International Tradeport adolescent/adult population. (see NH DHHS 2017a for additional resources).

Before the release of the 2013–2014 NHANES data, children ages less than 12 years were not included in the NHANES data. Initially, because there was no ideal comparison for the Pease International Tradeport children's group (ages less than 12 years), the NH DHHS compared children's serum levels to 2011–2012 NHANES results for Pease International Tradeport adolescents and adults to put the Pease International Tradeport children (ages less than 12 years) serum levels into context, as noted above. However, since the release of the 2013–2014 NHANES data, which does include data for children less than 12 years, the NH DHHS revised their age-specific comparisons, which are available from https://wisdom.dhhs.nh.gov/wisdom.

NH DHHS also evaluated the data for the 258 persons who participants in the blood sampling in 2016-2017. For PFOA, only blood levels for persons 12 years and older were statistically significantly higher (by 0.5 µg/L) than for the general U.S. population. For PFOS, levels for all age groups were higher than for the general U.S. population and were statistically significant (3.6 and 5.2 µg/L higher for the 3-11 and 12 and older age groups, respectively). Finally, for PFHxS, levels for all age groups were higher than for the general U.S. population (2.6 and 3.1 µg/L higher for the 3-11 and 12 and older age groups, respectively) and the results were statistically significant [NH DHHS 2017c]. The 2016-2017 results are consistent with the 2015 sampling [NH DHHS 2017b].

Health outcomes cannot be determined from the testing results. A person's risk for developing health effects from PFAS exposure is unknown. Currently, no PFAS serum levels in humans have been identified at which adverse health effects are expected. The Pease Biomonitoring program implemented by NH DHHS was based on convenience sampling, while NHANES uses a statistically based approach. Convenience sampling collects information from population members who are readily available to participate and volunteer and is inherently biased towards participants with the greatest interest in the study. Statistically based sampling uses the power of statistics to generate unbiased findings that represent an entire community, even people that did not get their blood tested. Therefore, direct comparison of the Pease Biomonitoring Program results to NHANES data has limitations.

Contributions from Other Sources

We do not have enough information to identify individual exposure sources nor to estimate the background exposure level in the PWS water users. Those sources might include PFAS-contaminated food (certain types of fish and shellfish if nearby streams, rivers, lakes, or other water bodies are affected), hand-to-mouth transfer from surfaces previously treated with PFAS-containing stain protectants (carpet being most significant for infants and toddlers), or eating food packaged in material containing PFAS, such as popcorn bags, fast food containers, or pizza boxes.

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

The available epidemiology data identify several potential targets of toxicity of PFAS, and people with pre-existing conditions may be unusually susceptible. For example, it appears that exposure to PFOA or PFOS can increase serum lipid levels, particularly cholesterol levels. Thus, an increase in serum cholesterol may result in a greater health impact in persons with high levels of cholesterol or with 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 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 2015, 2018a]. Finally, human studies have indicated that some PFAS may affect immune function [ATSDR 2018a]. Therefore, persons who are immunocompromised may also be a susceptible population to PFAS exposures. The relationship between PFOA and PFOS exposure and increased risk for cardiovascular disease is currently 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.

ATSDR recognizes that the unique vulnerabilities of the unborn, infants, and children demand 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. Reducing exposures to sources of PFAS, in infants and young children, are extremely important because of their unique vulnerabilities. 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 (human blood) 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 with birth weight. However, although significant associations were found for the high serum group, decreases in birth weight were small and may not be biologically relevant [ATSDR 2018a].

Cancer Evaluation

Epidemiologic data suggest a link between PFOA exposure and elevated rates of kidney, prostate, and testicular cancer. However, additional studies are needed to confirm the link between PFOA and other PFAS exposures and cancer to say they are the cause. Currently, EPA considers the evidence suggestive that PFOA has the potential to be carcinogenic in humans and the 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 observed an increased risk for some cancers; however, because of the small sample size, they were not statistically significant [Alexander et al. 2003; Alexander and Olsen 2007; Grice et al. 2006; Olsen et al. 2004]. 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 may be carcinogenic while some may not.

EPA calculated a PFOA oral cancer slope factor (CSF)[7] as a comparison to the safety of their reference dose against carcinogenic effects, not as an official CSF for inclusion on their Integrated Risk Information System [EPA 2016b][8]. Using the testicular cancer data from a 2012 rat study [Butenhoff et al. 2012], EPA calculated a CSF of 0.07 $mg/kg/day^{-1}$ [EPA 2016b].

To estimate the potential cancer risk from exposure to PFOA, ATSDR used the maximum modeled levels of PFOA in public water wells (0.2 µg/L). Table A-18 shows the estimated cancer risk calculations, by age, for PFOA exposure. 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 public and private water supply wells. As an estimate, ATSDR used an exposure time of 26 years (from the opening of the Pease International Tradeport to 2017). ATSDR assumed that persons were exposed to the maximum estimated PFOA concentration for these 26 years which is likely to overestimate the estimated cancer risk. Based on these assumptions and assuming that the EPA CSF on testicular cancer from a rat study approximates the actual cancer risk for PFOA, then the estimated adult cancer risk from exposure to the maximum detected PFOA concentration in the public water supply system is 1.3×10^{-7}. This means that if 10 million people were similarly exposed, we might see an additional two cases of cancer. Please note that this is a theoretical estimate of cancer risk that is used by ATSDR 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. This estimated cancer risk level is considered a very low cancer risk. However, this theoretical cancer risk must be viewed with caution because the EPA CSF is not an official one 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).

Currently, 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 and the actual cancer risk from all PFAS exposures from private wells is uncertain.

[7] EPA defines oral cancer slope factor (CSF) 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.

[8] The EPA IRIS assessment process is a rigorous seven-step process that includes development of a draft assessment, agency and interagency review, public and peer-review, and then agency and interagency review before finalization.

Summary of Public Health Implications Evaluation

We must deal with several limitations and uncertainties when evaluating human health implications from PFAS exposures in drinking water (see below). Because of these limitations and until better methods are developed, ATSDR used a conservative approach to evaluate the possibility for harmful health effects for noncancerous exposures. ATSDR's approach considering 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 that could contribute to overall health effects of PFAS exposures. Even assuming a 100% contribution from drinking water, PFOA, PFOS, and PFHxS exposures were mostly below health effect levels reported in the scientific literature. Nonetheless, many of the estimated doses were well above ATSDR's provisional MRLs, indicating a potential for concern, especially for PFOS.

ATSDR evaluated the risk from drinking water with levels of PFOS, PFOA, and PFHxS above ATSDR's provisional MRLs before the Haven well was shut down on May 12, 2014, in combination with other PFAS found in the Pease Tradeport PWS and other nondrinking water sources. ATSDR concluded that drinking that water could have increased the possibility of harmful non-cancer health effects in adults and particularly for young children (especially for developmental and immune effects). Harmful non-cancer effects were likely greater for young children who attended the childcare or were born to mothers who worked at the Pease International Tradeport. Except for PFOA, PFOS, PFHxS, and PFNA, well-accepted scientific methods to calculate the possible health effects of the combined exposures to PFAS compounds (the mixture) have not been developed. The combined exposures to the mixture of PFOS, PFOA, PFHxS and PFNA[9], before the Haven well was closed, may have increased the risk of developmental and immune effects beyond what might be expected from exposure to any one of these PFAS alone. However, several other PFAS adversely affect the same general organ systems. Therefore, the combined exposures to PFAS compounds from the Pease Tradeport PWS might have increased the risk for some non-cancer health outcomes.

Since June 2014, no PFAS were detected above available HBCVs in water samples from the two childcare centers served by the Pease Tradeport PWS. Sampling data from other points in the water distribution system showed that only PFOS was detected slightly above ATSDR's HBCV at a maximum value of 0.016 µg/L. None of the estimated exposures doses for PFOS exposures since June 2014 were above an HQ of 1.0 indicating that harmful exposures to PFOS alone are not expected. ATSDR used a similar approach as above to evaluate the cumulative exposure to

[9] PFNA was below ATSDR's HBCV so further evaluation of individual exposures to this PFAS are not indicated. However, PFNA was included as part of the mixture evaluation from exposure to all four PFAS with ATSDR MRLs.

PFAS for exposures since June 2014. Only the HI for children infants (for the RME scenario) was above 1.0 (1.17). Given that the HI is only slightly above 1.0, that it represents conservative assumptions (i.e., using the maximum concentration from one sample to represent longer-term intermediate and chronic exposures), and that none of the PFOA, PFOS, PFHxS, and PFNA levels were above HBCVs for the childcare exposures, it is unlikely that the combined exposures to these four PFAS would result in a higher risk of harmful effects than what was predicted by exposures to each alone. We lack refined methods to evaluate the combined exposures to other PFAS without HBCVs detected in the Pease Tradeport PWS since June 2014. However, all the maximum levels were either not detected or, if present, were only detected in low ppt levels and below ATSDR's most conservative HBCV. Moreover, most of the PFAS detected with no ATSDR MRLs were short-chain and non-sulfonated indicating that they may bioaccumulate less than the longer-chain and sulfonated PFAS. However, health effects of many short-chained PFAS and new PFAS alternatives have not been fully researched.

Additional supporting information leading to this conclusion includes the following:

- Scientific information suggests an association between PFOA, PFOS, and PFHxS exposure and various health effects on serum lipids (not PFHxS), immune responses, development, endocrine (thyroid), and the liver.

- A review of the scientific literature indicated that newborns and children are more sensitive to PFAS exposures. In addition, people with certain pre-existing health conditions (risk factors), such as elevated cholesterol or elevated blood pressure, and those with compromised livers or who are immunocompromised might be unusually susceptible to PFAS exposures.

- Other sources of exposure (background contributions and body burden) to users of the Pease Tradeport PWS could increase the risk of harmful effects beyond the risk from the drinking water exposures alone. Because of this, ATSDR considered possible contributions from other sources, such as food and PFAS-treated furnishings.

- Effects from exposure to PFHxA, PFHpA, and PFPeA could not be determined with certainty because the information on health effects of exposure to these PFAS compounds is very limited. Moreover, most of the PFAS detected with no ATSDR MRLs were short-chain and non-sulfonated indicating that they may bioaccumulate less than the longer-chain and sulfonated PFAS. However, health effects of many short-chained PFAS and new PFAS alternatives have not been fully evaluated.

- Results from New Hampshire's Biomonitoring Program show that the levels of PFOA, PFOS, and PFHxS in persons who drank water from the Pease Tradeport PWS were significantly higher than national levels reported in the 2011–2012 and 2013–2014 CDC NHANES reports.

- 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. The EPA has developed an oral cancer slope factor (CSF) for PFOA based on testicular cancer from a rat study to evaluate the cancer risk. If the CSF 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 CSF has not been fully adopted and other cancers that were elevated in epidemiological studies of PFOA exposure were not evaluated. EPA does not have a CSF 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 all cancer-causing PFAS exposures from the Pease PWS is uncertain.

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. Such exposures might occur through the mother to the fetus (maternal transfer) during pregnancy, or to the infant during breastfeeding. Studies that measured PFAS in maternal blood and breast milk in matched mother-infant pairs found highly variable correlations [ATSDR 2018a]. Over time, PFAS levels in women decrease through breastfeeding. 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 (SIDS). 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 2015a; 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 (See https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf). Moreover, women who plan on breastfeeding should attempt to reduce potential exposures to toxic substances as much as possible.

Limitations and Uncertainties of Human Health Risks from PFAS Exposures

Several limitations and uncertainties affect efforts to evaluate human health risks from PFAS exposures in drinking water. These are discussed in detail below.

Multiple Exposure Sources

In addition to drinking water exposures, community members likely have exposures to PFAS from other sources. These could include food, dust, air, and consumer products. Exposures might also occur when people touch surfaces treated with a stain protector then touch their mouths or food. All sources add to the amount of chemicals in the body and potential health effects.

Lack of Historical Exposure Data

We do not know exactly how long people drank the water, how much they drank, or the precise PFAS concentrations workers and children were exposed to in Pease Tradeport PWS drinking water. Historical sampling data are unavailable. Exposures might have occurred for years because of PFAS movement in groundwater. PFAS compounds accumulate and remain in the body for years before elimination. Past and current exposures contribute to the overall health risks from PFAS. It is uncertain whether reducing the frequency of exposure by about 30% might underestimate the exposures. ATSDR used this approach because workers and childcare attendees did not spend as much time at Pease International Tradeport as at their homes. ATSDR typically uses this type of the adjustment factor used for such a scenario. These assumptions match typical workplace and childcare attendance frequencies. Additional uncertainties relate to the usage of 2014 data to estimate exposure before 2014, including 1993 when the Tradeport opened.

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 the municipal 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 added 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 assessment methods have limitations. Only six of the 17 different PFAS detected in the Pease Tradeport PWS have HBCVs to support a public health evaluation. ATSDR has HBCVs only for PFOS, PFOA, PFHxS, and PFNA. ATSDR has not formally reviewed the Minnesota values for PFBS and PFBA that are used in this document. ATSDR has included those values for perspective (to show that the levels are much below an HBCV). Since ATSDR did not verify those values, they will therefore not be included in the mixture analyses.

Other General Limitations

Humans and experimental animals differ in how their bodies absorb and react to PFAS. This leaves questions about how relevant effects in animals are to humans. ATSDR also has limited toxicity data for many PFAS compounds from human and animal studies [Butenhoff and Rodricks 2015]. The health consequences of PFAS in the body are uncertain. Significant uncertainty remains 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.

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

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 of the PFAS constituents and that these constituents have changed over time. Data on AFFF-impacted groundwater indicate that about 25 percent 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 [Brazen-Hanson et al. 2017].

Because of these limitations, ATSDR used a conservative approach to evaluate health risks for noncancerous exposures until better methods are developed. ATSDR evidence on exposures and other factors for the evaluations. For noncancerous health effects, we calculated hazard quotients for PFOS, PFOA, PFHxS, and PFNA, the most thoroughly investigated PFAS compounds. If the hazard quotient exceeded one, we considered a potential exposure to be of concern. In evaluating health risks, we also considered other source contributions, other PFAS compounds in the mixture, and past exposures. We reviewed the available literature for likely health consequences from these exposures.

Conclusions

ATSDR evaluated the public health implications of past and current PFAS exposure to the users of public water near the Pease Tradeport and reached three 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 conservative 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 the PFAS that were measured in the water.

ATSDR develops health-based comparison values (HBCVs) using available scientific findings about exposure levels and health effects. The HBCVs reflect an estimated contaminant concentration for a given chemical that is expected to cause no adverse health effects, assuming a standard daily water intake rate and body weight. To be conservative and protective of public health, HBCVs are generally based on contaminant concentrations many times lower than levels at which animal or human studies found no observable effects. ATSDR uses HBCVs in this health consultation to screen PFAS contaminant concentrations to determine if a further in-depth evaluation is needed which includes calculating an exposure dose and comparing these doses to ATSDR provisional minimal risk levels or MRLs.

1. Drinking water exposures from the Pease Tradeport PWS from 1993 to May 2014, before the Haven Well was shut down, could have increased the risk for non-cancer harmful health effects to Pease International Tradeport workers and children attending the childcare centers. Other sources of PFAS exposure (e.g., from food and consumer products) to users of the Pease Tradeport PWS could increase the risk of harmful effects beyond the risk from the drinking water exposures alone. The cancer risk from past exposure to all PFAS in the Pease Tradeport PWS is uncertain.

The estimated exposures for PFOA, PFOS, and perfluorohexane sulfonic acid (PFHxS) from consuming the water were mostly below effect levels found in animal studies but were well above their respective ATSDR provisional minimal risk levels (MRL), indicating a potential for concern, especially for developmental and immune effects for exposure to PFOS. 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, development, endocrine (thyroid), and the liver. The combined exposures to a mixture of PFOS, PFOA, PFHxS, and perfluorononanoic acid (PFNA) could have increased the risk for developmental and immune effects above what might be expected from exposure to any of these PFAS alone. For other PFAS associations and health endpoints, however, the scientific information is far less certain. Food, consumer products, and mixtures of PFAS in the drinking water are all possible contributors to a person's overall PFAS exposure and body burden. Testing of exposed persons from the Pease Tradeport PWS by the NH DHHS indicate that PFOA, PFOS, and PFHxS blood levels are elevated as compared to national averages. Some pre-existing risk factors could increase the risk of harmful effects (see the Public Health Implications Section for details).

Epidemiologic data suggest a link between PFOA exposure and elevated rates of kidney, prostate, and testicular cancer. However, additional studies are needed to confirm the link between PFOA and other PFAS exposures and cancer to say they are the cause. 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 may be carcinogenic while some may not.

The EPA has developed an oral cancer slope factor (CSF) for PFOA based on testicular cancer from a rat study to evaluate the cancer risk. Based on these assumptions and assuming that the EPA CSF on testicular cancer from a rat study approximates the actual cancer risk for PFOA, then the estimated adult cancer risk from exposure to the maximum detected PFOA concentration in the public water supply system is 1.3×10^{-7}. This means that if 10 million people were similarly exposed, we might see an additional two cases of cancer. Please note this this is a theoretical risk that is used by ATSDR 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. If the CSF 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 CSF has not been fully adopted and other cancers that were elevated in epidemiological studies of PFOA exposure were not evaluated. EPA does not have a CSF 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 all exposures to cancer-causing PFAS that may be cancer-causing from the Pease PWS is uncertain.

2. Consuming water containing low levels of PFAS from the Pease Tradeport PWS since June 2014 is not expected to cause harm to the public.

Except for two samples where PFOS was detected slightly above the ATSDR HBCV, data indicate that exposures were less than or equal to the ATSDR HBCVs, thereby indicating that no harmful effects are expected. In addition, exposures to children at the two childcare facilities were all below ATSDR HBCVs. Exposures to PFOS in the Pease Tradeport PWS since June 2014 are not above ATSDR provisional MRLs, thereby indicating that harmful non-cancer effects are unlikely. Further evaluation of the exposure to the mixture of PFOS, PFOA, PFHxS, and PFNA indicates that the risk for harmful developmental or immune effects is not likely to be more than what might be expected from exposure to any of these PFAS alone. Other PFAS were either below their HBCVs, maximally detected at low levels (single ppt) and below ATSDR's most conservative HBCV, or not detected.

3. Based on available scientific information, ATSDR concludes that the health and nutritional benefits of breastfeeding outweigh the risks associated with PFAS in breast milk.

Community members, particularly mothers who have historically been exposed to PFAS from the Pease PWS, have expressed concern over the health implications of PFAS exposures to infants who breastfed. Developmental effects are the most sensitive adverse health effects resulting from early life exposure to some PFAS. Studies have shown infants are exposed during pregnancy, through the mother to the fetus (maternal transfer) and occur to the nursing infant during breastfeeding. However, breastfeeding provides clear health and nutritional benefits, including protection from some illnesses and infections and reductions in the risks of developing asthma and sudden infant death syndrome. In general, the Centers for Disease Control and Prevention recommends breastfeeding, despite the presence of chemicals in breast milk. Given what we know about PFAS exposure, the benefits of breastfeeding outweigh any risks. However, the science on the health effects of PFAS exposure on mothers and children continues to expand. A woman's decision to breastfeed is an individual choice, made after consideration of many different factors (many unrelated to PFAS exposure) and in consultation with her healthcare providers. Information developed by ATSDR to guide doctors (see https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf) can aid in this decision-making process.

Recommendations

ATSDR recommends that EPA, NHDES, and the USAF continue their investigations to characterize PFAS groundwater contamination at the site and continue their periodic monitoring of the Pease Tradeport PWS for PFAS concentration trends. In addition, the USAF should consider prioritizing their efforts and research into better understanding the types and the formulations of AFFF used at Pease and other facilities to better inform future monitoring efforts and health evaluations.

While the Pease Tradeport PWS treatment system is operating and being adjusted to provide the maximum temporary removal of PFAS. The EPA issued Administrative Order SDWA-01-

2015-016 to the Air Force in August 2018 which required the Air Force to treat the Haven Well and the effected aquifer at the former Pease Air Base. Subsequently, actions have been taken by the Air Force to implement the order.

The treatment system being added to the Pease Tradeport PWS will help protect consumers of the drinking water. Operation of this treatment system will reduce exposure to PFAS contaminants. Treated water should continue to be sampled. The treatment system should be adjusted, as necessary, to prevent exposure above EPA or other applicable health-based drinking water guidelines and reduce exposures to PFAS compounds that have no HBCVs. As a prudent public health measure, ATSDR recommends that persons who have had long-term exposures to PFAS should be aware of ways to reduce exposures (see information available from https://www.atsdr.cdc.gov/pfas/pfas-exposure.html on ways to reduce exposures to all sources of PFAS).

Breastfeeding provides clear health and nutritional benefits to infants. These include protection from some illnesses and infections, and reductions in the risks for developing asthma and sudden infant death syndrome. In general, CDC recommends breastfeeding despite the presence of chemical toxins in breast milk. From what we know, the benefits of breastfeeding outweigh risk. However, the science on the health effects of PFAS exposure to mothers and children continues to grow. A woman's decision to breastfeed must be an individual choice — one that is made after consideration of many different factors, many unrelated to PFAS exposure, specific to the mother and the child. Information developed by ATSDR to guide doctors (see https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf) can aid in this decision-making process. Moreover, women who plan on breastfeeding should attempt to reduce potential exposures to toxic substances as much as possible.

We recommend that health education information related to PFAS in drinking water continue to be developed and provided to affected residents, community members, and health professionals in the site area.

Public Health Action Plan

Completed Actions

The Haven well, the one well with PFAS detected above HBCVs, was shut down. Water from the City of Portsmouth PWS has replaced some of the water volume lost by the Haven well shutdown.

The USAF, City of Portsmouth, and Pease Development Authority signed an Environmental Services Cooperative Agreement for the design and construction of a water treatment system as a short-term remedy to reduce exposure to PFAS in the Pease Tradeport PWS. The treatment system for the Harrison and Smith wells began operation on September 23, 2016. New well locations to replace the Haven well have been investigated and tested.

The NH DHHS developed a document that provides health information about PFAS, titled *Frequently Asked Questions: Perfluorochemicals (PFCs) in the Pease International Tradeport Water System*. This document can be found on the NH DHHS "Investigation into Contaminant Found in Pease Tradeport Water System" webpage at http://www.dhhs.nh.gov/dphs/investigation-pease.htm.

NH DHHS offered blood testing (biomonitoring) for people who were exposed to PFAS in the drinking water at the Pease International Tradeport. NH DHHS sent results to people as it received those from the laboratories. NH DHHS summarized the biomonitoring results in its report and presented that information to the public in a June 16, 2016 meeting.

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 International Tradeport. The report is available on the ATSDR website, https://www.atsdr.cdc.gov/sites/pease/documents/ Pease_Feasibility_Assessment_November-2017_508.pdf.

In June 2018, ATSDR released a draft for public comment Toxicological Profile for Perfluoroalkyls. This report contains information on the derivation of provisional MRLs used in this health consultation to evaluate exposures to PFOA, PFOS, PFHxS, and PFNA.

In April 2019 after the release of this health consultation for public comment, ATSDR representatives met with officials from the city of Portsmouth and town of Newington to discuss the findings of this Health Consultation. Additionally, ATSDR conducted a 12-hour availability session (at the Great Bay community College) for residents, workers, and others to drop by and ask questions about our report.

Ongoing Actions

PFAS levels in the Pease Tradeport PWS are being monitored periodically by sampling the Harrison well, Smith well, and selected distribution points of the Pease Tradeport PWS.

PFAS levels in the treated water are being sampled regularly, and the treatment system will be adjusted as necessary to provide the most effective removal of PFAS contaminants.

PFAS levels in area groundwater and potential migration of PFAS toward operating Pease Tradeport and Portsmouth PWS wells are being periodically monitored by sampling sentry monitoring wells.

The USAF is investigating potential PFAS contaminant source area and PFAS migration pathways at the former Pease Air Force Base to determine the most effective groundwater contaminant containment and mitigation strategies.

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 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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All website links in this Health Consultation were tested and accessed on the date indicated. Websites may undergo changes that cause one or more links to no longer work. The web address are provided for archival purposes (especially for those links that may no longer work).

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Appendix A – Figures, Tables, and Equations

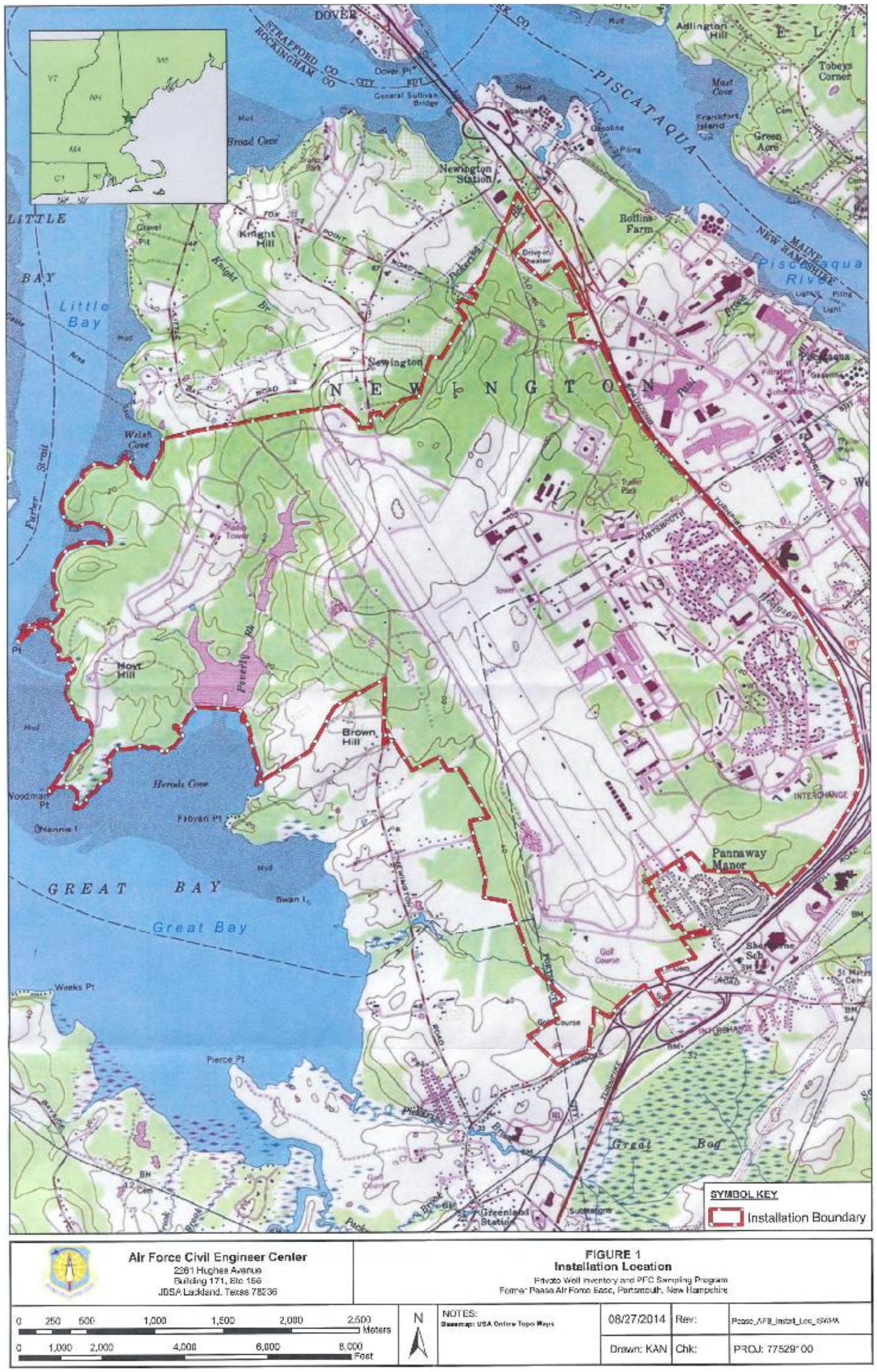

Figure A-1. Location and vicinity of Pease International Tradeport (former Pease Air Force Base), New Hampshire. Source: AMEC 2014.

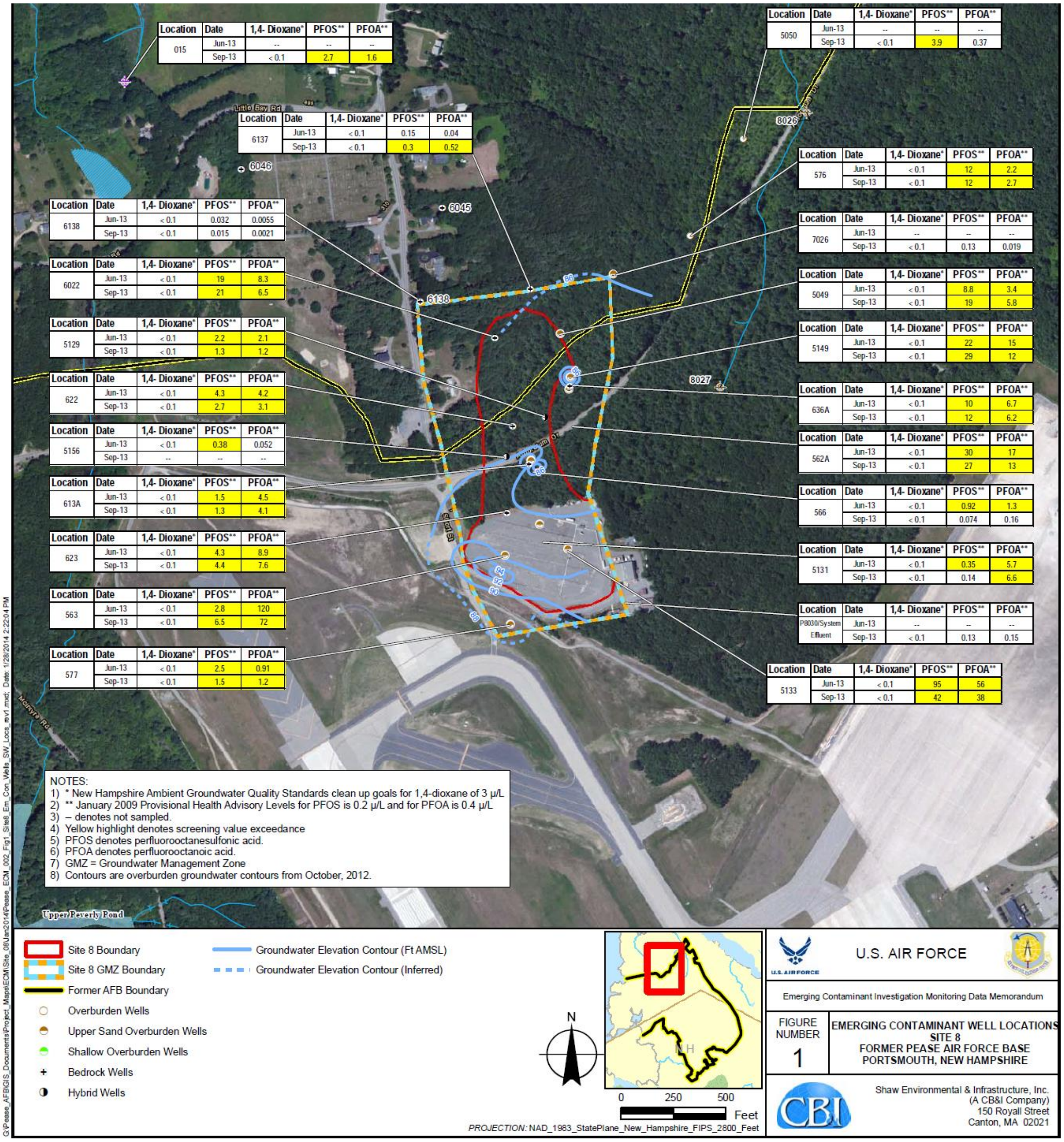

Figure A-2. Former Pease Air Force Base/Pease International Tradeport detail and location of site 8, the former fire training area. Source: CB&I 2015.

Figure A-3. Location of the Pease International Tradeport public water supply wells

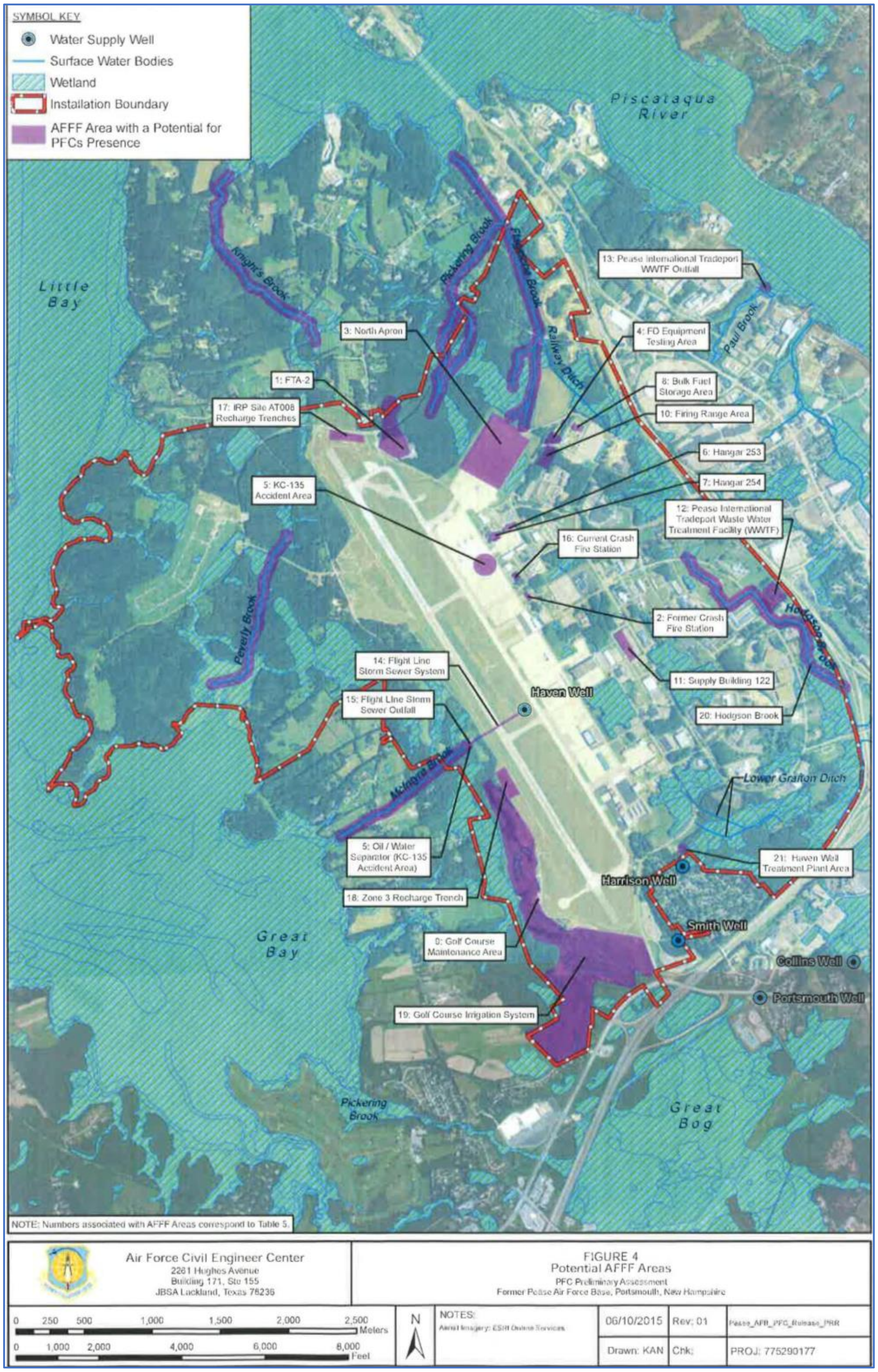

Figure A-4. Areas where aqueous film-forming foam might have been used. **Source**: AMECFW 2015.

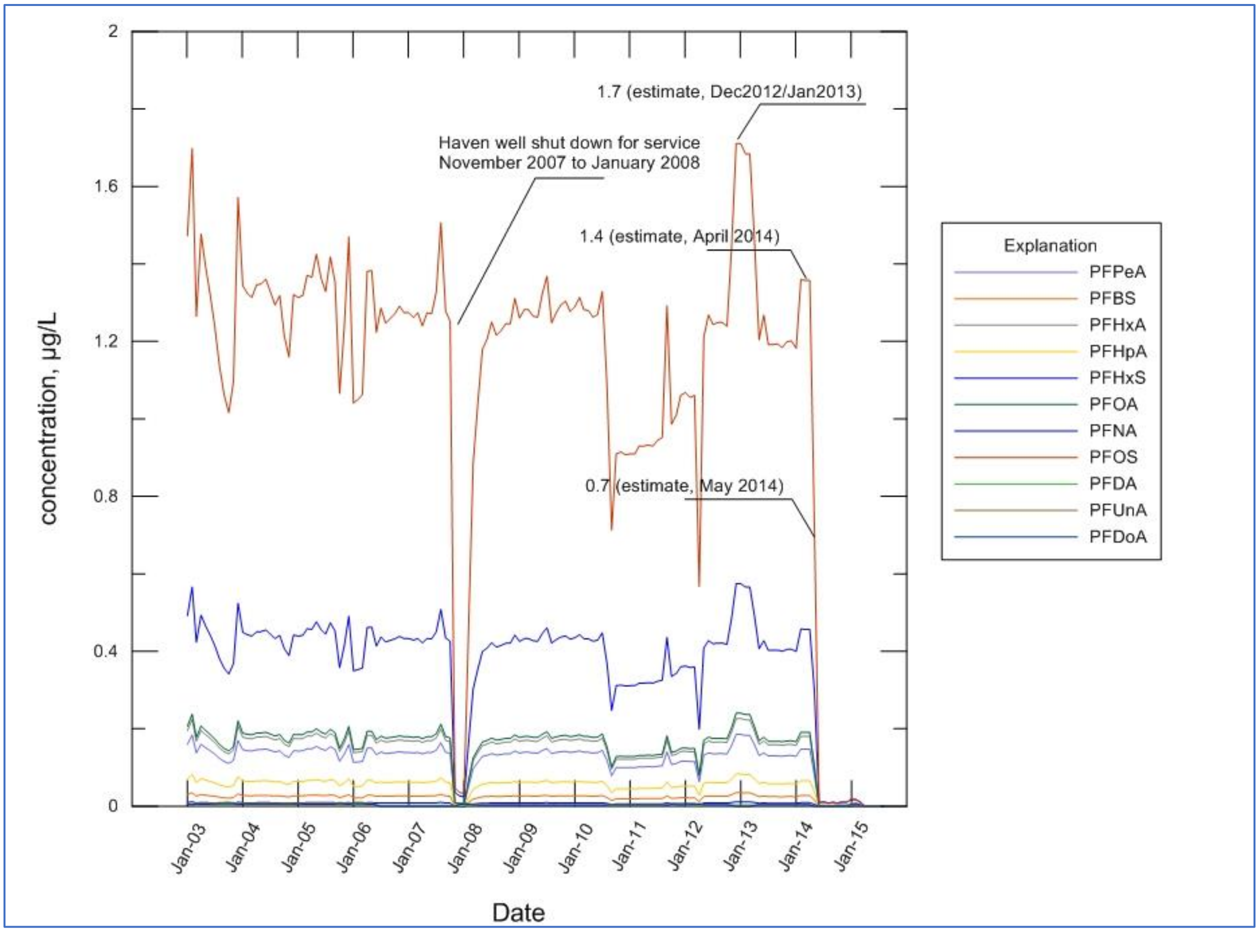

Figure A-5. Monthly estimated drinking water concentrations between January 2003 and August 2015 for 11 per- and polyfluoroalkyl substances (PFAS) detected in the water supply wells. Estimated values derived by using flow-weighted mixing model approach and measured PFAS concentrations in April 2014.

Note: see Appendix B for more details.

Abbreviations: µg/L = micrograms per liter; PFBS = perfluorobutane sulfonic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

Table A-1. Per- and polyfluoroalkyl substances (PFAS) and possible effects on organ systems

Specific PFAS	Cardiovascular	Developmental	Endocrine	Liver	Immune	Reproductive	Serum lipid
PFBS	○	●	●	○	○	●	○
PFDeA	○	●	○	○	●	○	●
PFDoA	○	○	○	○	○	○	○
PFHpA	○	○	○	○	○	○	○
PFHxA	○	●	○	●	○	○	○
PFHxS	○	●	●	●	●	○	○
PFNA	○	●	○	○	○	○	●
PFOA	●	●	●	●	●	●	●
PFOS	●	●	●	●	●	●	●
PFPeA	○	○	○	○	○	○	○
PFUnA	○	●	○	○	○	○	○

NOTES:
● = Indicates possible impacts on this target organ system
○ = Indicates no impacts or insufficient information

Abbreviation		**Citation(s) for effects (if applicable)**
PFBS	perfluorobutane sulfonic acid	Minnesota Department of Health [MDH 2017a]
PFDeA	perfluorodecanoic acid	Fu et.al. 2014; Grandjean et al. 2012; Harris and Birnbaum 1989; Starling, et al. 2014
PFDoA	perfluorododecanoic acid	No effects or insufficient information on target organ systems
PFHpA	perfluoroheptanoic acid	No effects or insufficient information on target organ systems
PFHxA	perfluorohexanoic acid	Iwai and Hoberman 2014; Klaunig et al. 2015
PFHxS	Perfluorohexane sulfonic acid	Butenhoff et al. 2009; Gleason et al. 2015; Grandjean et al. 2012; Morgensen et al. 2015; Viberg et al. 2013
PFNA	perfluorononanoic acid	Das et al. 2015; Starling et al. 2014; Zeng, et al. 2015
PFOA	perfluorooctanoic acid	ATSDR 2018a
PFOS	perfluorooctane sulfonic acid	ATSDR 2018a
PFPeA	perfluoropentanoic acid	No effects or insufficient information on target organ systems
PFUnA	perfluoroundecanoic acid	Takahashi et al. 2014

Table A-2. Per- and polyfluoroalkyl substances (PFAS) analyzed in Pease Tradeport water supply wells during April and May 2014

Specific PFAS	Abbreviation	Chemical formula	Type†
perfluorobutanesulfonic acid	PFBS	$C_4HF_9O_3S$	Short
perfluorodecanoic acid	PFDeA	$C_{10}HF_{19}O_2$	Long
perfluoroheptanesulfonic acid	PFHpS	$C_7HF_{15}O_3S$	Long
perfluoroheptanoic acid	PFHpA	$C_7HF_{13}O_2$	Short
perfluorohexane sulfonic 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
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
perfluoroundecanoic acid	PFUnA	$C_{11}HF_{21}O_2$	Long
perfluorododecanoic acid	PFDoA	$C_{12}HF_{23}O_2$	Long

Note*:* PFAS = perfluoroalkyl substances

† 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 2018b].

Table-A-3. Water quality data from Pease Tradeport supply wells (collected in 2014) screened by health-based comparison values; concentrations in micrograms per liter (µg/L)

Specific PFAS	HBCV	HBCV Source	Haven well		Harrison well		Smith well	
			April 16	May 14	April 16	May 14	April 16	May 14
PFBS	2	MDH§	0.051	0.051	0.002*	0.0019*	0.00094*	0.00087*
PFDeA	None	None	0.0049*	0.0043*	ND	ND	0.0044	ND
PFDoA	None	None	ND	ND	ND	ND	0.012	ND
PFHpA	None	None	0.12	0.12	0.0046*	0.0042*	0.0025*	0.002*
PFHxA	None	None	0.33	0.35	0.0087	0.01	0.0039*	0.004*
PFHxS	0.14	ATSDR‡	0.83	0.96	0.036	0.032	0.013	0.013
PFNA	0.021	ATSDR	0.017	0.017	ND	ND	ND	ND
PFOA	0.021	ATSDR	0.35	0.32	0.009	0.0086	0.0035*	0.0036*
PFOS	0.014	ATSDR	2.5†	2.4†	0.048	0.041	0.018	0.015
PFPeA	None	None	0.27	0.26	0.0079	0.0084	0.0035*	0.0034*
PFUnA	None	None	ND	ND	ND	ND	0.017	ND

Abbreviations: µg/L = micrograms per liter; ATSDR = Agency for Toxic Substances and Disease Registry's derived children's health-based comparison value; HBCV = Health-based comparison value; ND = not detected; PFAS = per- and polyfluoroalkyl substances; PFBS = perfluorobutane sulfonic acid; PFDeA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

*Estimated value.

†These represent the maximum PFOS concentration from the Haven well collected in April and May 2014. Subsequent sampling from the same well during November 16 and 28, 2016, indicated that the PFOS concentration was 1.0 µg/L and 1.4 µg/L, respectively. The data from 2014 remain valid. ATSDR used these for further analysis and modeling (see Appendix B for modeling report).

§MDH developed a guidance value of 2 ppb for PFBS in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017d].

‡ ATSDR derived value 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 provisional MRLs and conservative 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.

Note: Shaded = concentrations are above a health-based comparison value.

Table-A-4. Summary of per- and polyfluoroalkyl substances (PFAS) detected in the Pease Tradeport public water supply (Harrison and Smith wells) from June 2014 through May 2017, Pease International Tradeport, Portsmouth, New Hampshire; concentrations in micrograms per liter (µg/L)

Specific PFAS	HBCV	HBCV source	Harrison well (74 samples)		Smith well (125 samples)	
			Min	Max	Min	Max
6:2 FTS	None	None	0.0068	0.01	ND	ND
EtFOSE	None	None	ND	ND	ND	0.0075
MEFOSE	None	None	ND	ND	0.006	0.006
PFBA	7	MDH¶	ND	0.014	ND	0.0100
PFBS	2	MDH§	ND	0.01	ND	0.01
PFDeA	None	None	ND	ND	0.0035	0.0038
PFHpA	None	None	ND	0.0089	ND	0.0082
PFHpS	None	None	ND	0.0096	ND	0.0099
PFHxA	None	None	ND	0.018	ND	0.01
PFHxS	0.14	ATSDR‡	0.010	0.038	0.0061	0.031
PFNA	0.021	ATSDR	ND	0.0074	ND	0.007
PFOA	0.021	ATSDR	ND	0.014	ND	0.011
PFOS	0.014	ATSDR	0.011	0.038	ND	0.026
PFOSA	None	None	ND	ND	0.003	0.006
PFPeA	None	None	ND	0.019	ND	0.01
PFUnA	None	None	ND	0.005	ND	0.0053

Source: City of Portsmouth 2017a.

Abbreviations: µg/L = micrograms per liter; ATSDR = Agency for Toxic Substances and Disease Registry's derived children's health-based comparison value; HBCV = Health-based comparison value; Max = maximum value detected; MDH = Minnesota Department of Health; Min = minimum value detected; ND = not detected; 6:2 FTS = 6:2 fluorotelomer sulfonate; EtFOSE = N-ethyl perfluorooctane sulfonomidoethanol; MEFOSE = N-methyl perfluorooctane sulfonomidoethanol; PFBA = perfluorobutanoic acid; PFHpS = perfluoroheptane sulfonate; PFBS = perfluorobutane sulfonic acid; PFDeA = perfluorodecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

¶MDH developed a guidance value of 7 ppb for PFBA in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017e].

§MDH developed a guidance value of 2 ppb for PFBS in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017d].

‡ ATSDR derived value 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 provisional MRLs and conservative 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.

Table A-5. Summary of per- and polyfluoroalkyl substances (PFAS) detected in the Pease Tradeport water supply (New Hampshire Department of Environmental Services (NHDES) office, distribution point, and Fire Station No. 3) from June 2014 through May 2017, Pease International Tradeport, Portsmouth, New Hampshire; concentrations in micrograms per liter (µg/L)

Specific PFAS	HBCV	HBCV Source	Pease Tradeport Water Supply at NHDES office (13 samples)		Pease Tradeport water supply at water treatment plant (9 samples)		Pease Tradeport Water Supply at Fire Station No. 3 (2 samples)	
			Min	Max	Min	Max	Min	Max
PFBA	7	MDH[¶]	ND	0.013*	ND	0.0059*	0.0075*	0.013*
PFBS	2	MDH[§]	ND	0.0066*	ND	ND	0.0051*	0.0065*
PFHpA	None	None	ND	ND	ND	ND	ND	ND
PFHxA	None	None	ND	0.0081*	ND	0.0062*	ND	0.007*
PFHxS	0.14	ATSDR[‡]	0.006*	0.019*	ND	0.012*	0.013*	0.019*
PFNA	0.021	ATSDR	ND	ND	ND	ND	ND	ND
PFOA	0.021	ATSDR	ND	0.0073*	ND	ND	ND	0.0055*
PFOS	0.014	ATSDR	0.006*	0.014*	ND	0.016*	0.0095*	0.013*
PFPeA	None	None	ND	0.0083*	ND	0.0066*	0.0037*	0.0091*

Source: City of Portsmouth 2017a.

Abbreviations: µg/L = micrograms per liter; ATSDR = Agency for Toxic Substances and Disease Registry's derived children's health-based comparison value; HBCV = Health-based comparison value; Max = maximum value detected; MDH = Minnesota Department of Health; Min = minimum value detected; ND = not detected; PFBA = perfluorobutanoic acid; PFBS = perfluorobutane sulfonic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid.

Note: Shaded = concentrations are at or above a health-based comparison value. The following PFAS were analyzed and not detected: 6:2 Fluorotelomer sulfonate (6:2 FTS); 8:2 Fluorotelomer sulfonate; N-Ethyl perfluorooctane sulfonamide; N-Ethyl perfluorooctane sulfonamidoethanol ; N-Methyl Perfluorooctane Sulfonamide; N-Methyl Perfluorooctane Sulfonamidoethanol; Perfluorodecane sulfonate ; Perfluorodecanoic acid; Perfluorododecanoic acid); Perfluorononanoic acid; Perfluorotetradecanoic acid; Perfluorotridecanoic acid; Perfluoroundecanoic acid; Perfluoroheptanoic acid*Estimated values.

[¶]MDH developed a guidance value of 7 ppb for PFBA in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017e].

[§]MDH developed a guidance value of 2 ppb for PFBS in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017d].

[‡] ATSDR derived value 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 provisional MRLs and conservative 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.

Table A-6. Summary of per- and polyfluoroalkyl substances (PFAS) detected in the Pease Tradeport public water supply (at two childcare centers), March–October 2015, Pease International Tradeport, Portsmouth, New Hampshire; concentrations in micrograms per liter (µg/L)

Specific PFAS	HBCV	HBCV source	Great Bay Kids' Company*		Discovery Child Enrichment Center†	
			Min	Max	Min	Max
PFHpA	None	None	ND	ND	ND	ND
PFHpS	None	None	ND	0.0044‡	ND	ND
PFHxA	None	None	ND	0.0052‡	ND	ND
PFHxS	0.14	ATSDR§	ND	0.014‡	ND	0.014‡
PFNA	0.021	ATSDR	ND	ND	ND	ND
PFOA	0.021	ATSDR	ND	0.005‡	ND	ND
PFOS	0.014	ATSDR	ND	0.012‡	ND	0.012‡
PFOSA	None	None	ND	0.0026‡	ND	ND
PFPeA	None	None	ND	0.006‡	ND	0.0064‡

Sources: City of Portsmouth 2017a, 2018.

Abbreviations: µg/L = micrograms per liter; ATSDR = Agency for Toxic Substances and Disease Registry's derived children's health-based comparison value; HBCV = Health-based comparison value; Max = maximum value detected; Min = minimum value detected; ND = not detected; PFHpA = perfluoroheptanesulfonic acid; PFHpS = perfluoroheptane sulfonate; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFPeA = perfluoropentanoic acid.

*Two untreated samples from the Pease Tradeport Water Supply at Great Bay Kids' Company location.

†Two untreated samples from the Pease Tradeport Water Supply at Discovery Child Enrichment Center location.

‡Estimated values.

§ ATSDR derived value 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 provisional MRLs and conservative 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.

Note: The following PFAS were analyzed and not detected: 6:2 Fluorotelomer sulfonate (6:2 FTS); 8:2 Fluorotelomer sulfonate; N-Ethyl perfluorooctane sulfonamide; N-Ethyl perfluorooctane sulfonamidoethanol ; N-Methyl Perfluorooctane Sulfonamide; N-Methyl Perfluorooctane Sulfonamidoethanol; Perfluorodecane sulfonate ; Perfluorodecanoic acid; Perfluorododecanoic acid); Perfluorononanoic acid; Perfluorotetradecanoic acid; Perfluorotridecanoic acid; Perfluoroundecanoic acid; Perfluoroheptanoic acid*Estimated values.

Table-A-7. Exposure pathways, Pease International Tradeport, Portsmouth, New Hampshire

Pathway	Source	Media	Exposure point	Exposed population	Exposure route	Time	Completed pathway status (see notes below)
Pease Tradeport Public Water Supply	Pease Air Force Base Fire Dept. Training Area 2 (Site 8)	Drinking water	Pease Tradeport water supply distribution points (businesses, childcare centers)	Workers (since 1993) and children attending childcare (since 1994 and 2010)	Ingestion	Past, present, and future	Completed Completed*
					Skin absorption and inhalation of PFAS as vapors	Past, present, and future	Completed† Completed‡
Pease Tradeport Public Water Supply	Pease Air Force Base Fire Dept. Training Area 2 (Site 8)	Drinking water	Pease Tradeport water supply distribution points (businesses, childcare centers)	Pregnant women and women of child-bearing age who breastfeed	Ingestion	Past, present, and future	Completed
				Breast feeding infants	Ingestion	Past, present, and future	Completed

*Treatment system to remove per- and polyfluoroalkyl substances from Harrison and Smith wells began operating on September 22, 2016. Perfluorooctane sulfonic acid and perfluorooctanoic acid were not detected in six samples of treated water collected through mid-November 2016. Other per- and polyfluoroalkyl substances occasionally detected at very low levels. Treatment system will be adjusted to maximize removal of per- and polyfluoroalkyl substances.

†Dermal and inhalation exposure routes contributed negligible additional intake based on past concentrations in drinking water.

‡Water treatment system is removing PFAS to either non-detect levels or very low concentrations. The two drinking water exposure routes contribute negligible additional intake based on current concentrations in the treated drinking water.

Table A-8. Health-based comparison values used to screen water quality for per- and polyfluoroalkyl substances (PFAS); concentrations in micrograms per liter (µg/L)

Specific PFAS	Health-based comparison value source	Value (µg/L)
PFBA	MDH¶	7
PFBS	MDH§	2
PFDeA	NA	NA
PFDoA	NA	NA
PFHxA	NA	NA
PFHxS	ATSDR*	0.14
PFNA	ATSDR	0.021
PFOA	ATSDR	0.021
PFOS	ATSDR	0.014
PFPeA	NA	NA
PFUnA	NA	NA

Abbreviations: µg/L = micrograms per liter; ATSDR = Agency for Toxic Substances and Disease Registry's derived children's health-based comparison value; HBCV = Health-based comparison value; NA = not available (no health-based comparison value is available for this compound); PFBA = perfluorobutanoic acid; PFBS = perfluorobutane sulfonic acid; PFDeA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

*ATSDR derived value 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 provisional MRLs and conservative 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.

¶MDH developed a guidance value of 7 ppb for PFBA in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017e].

§MDH developed a guidance value of 2 ppb for PFBS in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017d].

Table A-9. Per- and polyfluoroalkyl substances (PFAS) modeled maximums and geometric means values compared with health-based comparison values; all units in micrograms per liter (µg/L)

Specific PFAS	HBCV	Jan 2003–Oct 2007 MAX	Jan 2003–Oct 2007 GM	Nov 2007–Jan 2008 MAX	Nov 2007–Jan 2008 GM	Feb 2008–Aug 2010 MAX	Feb 2008–Aug 2010 GM	Sep 2010–Apr 2012 MAX	Sep 2010–Apr 2012 GM	May 2012–May 2014 MAX	May 2012–May 2014 GM	Jun 2014–Mar 2015 MAX	Jun 2014–Mar 2015 GM
PFBS[§]	2	0.03	0.03	<0.01	<0.01	0.03	0.02	0.03	0.02	0.04	0.03	<0.01	<0.01
PFDeA	none	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PFDoA	none	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0	0
PFHpA*	none	0.08	0.06	<0.01	<0.01	0.07	0.06	0.06	0.05	0.08	0.06	<0.01	<0.01
PFHxA*	none	0.22	0.17	0.01	0.01	0.18	0.16	0.17	0.13	0.23	0.17	0.01	<0.01
PFHxS*	0.14[†]	0.57	0.43	0.04	0.03	0.46	0.41	0.44	0.32	0.57	0.44	0.02	0.01
PFNA	0.021[†]	0.01	0.01	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01
PFOA*	0.021[†]	0.24	0.18	0.01	0.01	0.19	0.17	0.18	0.13	0.24	0.18	<0.01	<0.01
PFOS*	0.014[†]	1.7	1.29	0.05	0.04	1.37	1.2	1.29	0.94	1.71	1.29	0.02	0.01
PFPeA*	none	0.18	0.14	0.01	0.01	0.15	0.13	0.14	0.1	0.19	0.14	0.01	<0.01
PFUnA	none	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01

Abbreviations: µg/L = micrograms per liter; HBCV = health-based comparison values. GM = geometric mean; MAX = maximum value; PFBS = perfluorobutane sulfonic acid; PFDeA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

*These compounds were selected for further review.

[†]ATSDR derived children's health-based comparison value; [§]MDH developed a guidance value of 2 ppb for PFBS in drinking water to protect people who are most vulnerable to the potentially harmful effects of a contaminant [MDH 2017d].

Notes Shaded = above HBCV. ATSDR used the maximum PFOS concentration from the Haven well collected in April and May 2014. Subsequent sampling from the same well during November 16 and 28 of 2016 indicated that the PFOS concentration was 1.0 µg/L and 1.4 µg/L respectively. The data from 2014 remain valid. ATSDR used the data for modeling (see Appendix B for modeling report).

Table A-10. Perfluorooctane sulfonic acid (PFOS) environmental exposure assumptions, estimated exposure doses, and hazard quotients for Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - 1993 to May 2014

	Exposure Assumptions						
	Daily drinking water intake rate			Dose based on the maximum modeled concentration of PFOS = 1.7 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate provisional MRL)	
Age groups	CTE L/day	RME L/day	Body weight kg	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless
Birth to <1 year	0.36	0.80	7.8	7.8E-05	1.7E-04	39.5	87.7
1 to <2 years	0.22	0.64	11.4	3.3E-05	9.5E-05	16.5	48.0
2 to <6 years	0.27	0.70	17.4	2.6E-05	6.8E-05	13.3	34.4
6 to <11 years	0.37	1.00	31.8	2.0E-05	5.4E-05	9.9	26.9
11 to <16 years	0.46	1.41	56.8	1.4E-05	4.2E-05	6.9	21.2
16 to <21 years	0.55	1.75	71.6	1.3E-05	4.1E-05	6.6	20.9
Adults (≥21 years)	0.88	2.21	80	1.9E-05	4.7E-05	9.4	23.6
Pregnant women	0.62	1.85	73	1.5E-05	4.3E-05	7.3	21.7
Lactating women	1.19	2.56	73	2.8E-05	6.0E-05	13.9	30.0

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.
Notes: Shaded = exceedance of or equivalence to the ATSDR intermediate minimal risk level for PFOS.

Table A-11. Perfluorooctanoic acid (PFOA) environmental exposure assumptions, estimated exposure doses, and hazard quotients for Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - 1993 to May 2014

	Exposure Assumptions			Dose based on the maximum modeled concentration of PFOA = 0.2 µg/L		Hazard quotient for PFOA (dose divided by the Intermediate provisional MRL)	
	Daily drinking water intake rate		Body weight				
Age groups	CTE L/day	RME L/day	kg	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless
Birth to <1 year	0.36	0.80	7.8	9.2E-06	2.0E-05	3.08	6.84
1 to <2 years	0.22	0.64	11.4	3.9E-06	1.1E-05	1.29	3.74
2 to <6 years	0.27	0.70	17.4	3.1E-06	8.0E-06	1.03	2.68
6 to <11 years	0.37	1.00	31.8	2.3E-06	6.3E-06	0.78	2.10
11 to <16 years	0.46	1.41	56.8	1.6E-06	5.0E-06	0.54	1.65
16 to <21 years	0.55	1.75	71.6	1.5E-06	4.9E-06	0.51	1.63
Adults (≥21 years)	0.88	2.21	80	2.2E-06	5.5E-06	0.73	1.84
Pregnant women	0.62	1.85	73	1.7E-06	5.1E-06	0.57	1.69
Lactating women	1.19	2.56	73	3.3E-06	7.0E-06	1.09	2.34

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.
Notes: Shaded = exceedance of or equivalence to the ATSDR intermediate minimal risk level for PFOA.

Table A-12. Perfluorohexane sulfonic acid (PFHxS) environmental exposure assumptions, estimated exposure doses, and hazard quotients for Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - 1993 to May 2014

	Exposure Assumptions			Dose based on the maximum modeled concentration of PFHxS= 0.57 µg/L		Hazard quotient for PFHxS (dose divided by the Intermediate provisional MRL)	
	Daily drinking water intake rate		Body weight				
Age groups	CTE L/day	RME L/day	kg	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless
Birth to <1 year	0.36	0.80	7.8	2.63E-05	5.85E-05	1.32	2.92
1 to <2 years	0.22	0.64	11.4	1.10E-05	3.20E-05	0.55	1.60
2 to <6 years	0.27	0.70	17.4	8.84E-06	2.29E-05	0.44	1.15
6 to <11 years	0.37	1.00	31.8	6.63E-06	1.79E-05	0.33	0.90
11 to <16 years	0.46	1.41	56.8	4.62E-06	1.41E-05	0.23	0.71
16 to <21 years	0.55	1.75	71.6	4.38E-06	1.39E-05	0.22	0.70
Adults (≥21 years)	0.88	2.21	80	6.27E-06	1.57E-05	0.31	0.79
Pregnant women	0.62	1.85	73	4.84E-06	1.44E-05	0.24	0.72
Lactating women	1.19	2.56	73	9.29E-06	2.00E-05	0.46	1.00

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

Notes: Shaded = exceedance of or equivalence to the ATSDR intermediate minimal risk level for PFHxS.

Table A-13. Perfluorohexanoic acid (PFHxA) environmental exposure assumptions and estimated exposure doses for Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - 1993 to May 2014

	Exposure assumptions			Dose based on the maximum modeled concentration of 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	0.36	0.80	7.8	1.1E-05	2.3E-05
1 to <2 years	0.22	0.64	11.4	4.4E-06	1.3E-05
2 to <6 years	0.27	0.70	17.4	3.6E-06	9.2E-06
6 to <11 years	0.37	1.00	31.8	2.6E-06	7.3E-06
11 to <16 years	0.46	1.41	56.8	1.8E-06	5.7E-06
16 to <21 years	0.55	1.75	71.6	1.8E-06	5.6E-06
Adults (≥21 years)	0.88	2.21	80	2.5E-06	6.3E-06
Pregnant women	0.62	1.85	73	2.0E-06	5.8E-06
Lactating women	1.19	2.56	73	3.7E-06	8.1E-06

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

Table A-14. Perfluorooctane sulfonic acid (PFOS) environmental exposure assumptions, estimated exposure doses, and hazard quotients for NH DES office, fire station and treatment plant sampling locations Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - June 2014 through May 2017

	Exposure Assumptions						
	Daily drinking water intake rate			Dose based on the maximum modeled concentration of PFOS = 0.016 µg/L		Hazard quotient for PFOS (dose divided by the Intermediate provisional MRL)	
	CTE	RME	Body weight	CTE	RME	CTE	RME
Age groups	L/day	L/day	kg	mg/kg/day	mg/kg/day	unitless	unitless
Birth to <1 year	0.36	0.80	7.8	7.4E-07	1.6E-06	0.4	0.8
1 to <2 years	0.22	0.64	11.4	3.1E-07	9.0E-07	0.2	0.4
2 to <6 years	0.27	0.70	17.4	2.5E-07	6.4E-07	0.1	0.3
6 to <11 years	0.37	1.00	31.8	1.9E-07	5.0E-07	0.1	0.3
11 to <16 years	0.46	1.41	56.8	1.3E-07	4.0E-07	0.1	0.2
16 to <21 years	0.55	1.75	71.6	1.2E-07	3.9E-07	0.1	0.2
Adults (≥21 years)	0.88	2.21	80	1.8E-07	4.4E-07	0.1	0.2
Pregnant women	0.62	1.85	73	1.4E-07	4.1E-07	0.1	0.2
Lactating women	1.19	2.56	73	2.6E-07	5.6E-07	0.1	0.3

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

Table A-15. Perfluorononanoic acid (PFNA) environmental exposure assumptions, estimated exposure doses, and hazard quotients for Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - 1993 to May 2014

	Exposure Assumptions			Dose based on the maximum modeled concentration of PFNA = 0.012 µg/L		Hazard quotient for PFNA (dose divided by the Intermediate provisional MRL)	
	Daily drinking water intake rate		Body weight				
Age groups	CTE L/day	RME L/day	kg	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless
Birth to <1 year	0.36	0.80	7.8	5.54E-07	1.23E-06	0.18	0.41
1 to <2 years	0.22	0.64	11.4	2.32E-07	6.74E-07	0.08	0.22
2 to <6 years	0.27	0.70	17.4	1.86E-07	4.83E-07	0.06	0.16
6 to <11 years	0.37	1.00	31.8	1.40E-07	3.77E-07	0.05	0.13
11 to <16 years	0.46	1.41	56.8	9.72E-08	2.98E-07	0.03	0.10
16 to <21 years	0.55	1.75	71.6	9.22E-08	2.93E-07	0.03	0.10
Adults (≥21 years)	0.88	2.21	80	1.32E-07	3.32E-07	0.04	0.11
Pregnant women	0.62	1.85	73	1.02E-07	3.04E-07	0.03	0.10
Lactating women	1.19	2.56	73	1.96E-07	4.21E-07	0.07	0.14

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

Table A-16. Combined perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) hazard index for Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - 1993 to May 2014

	Exposure assumptions			Hazard index (HI) for combined PFHxS, PFNA, 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	0.36	0.80	7.8	43.81	97.35
1 to <2 years	0.22	0.64	11.4	18.32	53.29
2 to <6 years	0.27	0.70	17.4	14.73	38.18
6 to <11 years	0.37	1.00	31.8	11.04	29.85
11 to <16 years	0.46	1.41	56.8	7.69	23.56
16 to <21 years	0.55	1.75	71.6	7.29	23.20
Adults (≥21 years)	0.88	2.21	80	10.44	26.22
Pregnant women	0.62	1.85	73	8.06	24.05
Lactating women	1.19	2.56	73	15.47	33.29

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure multiplied by 5/7 to account for less than residential exposures; HI = hazard index is the combined hazard quotients for PFOA and PFOS combined (all drinking water intake rates are assumed to be 5/7 of a residential intake rate); kg = kilogram; L = liter; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

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

Table A-17. Combined perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA=all non detect), perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) hazard index for NH DES office, fire station and treatment plant sampling locations Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - June 2014 through May 2017

	Exposure assumptions				
	Daily drinking water intake rate		Body weight	Hazard index (HI) for combined PFHxS, PFNA, PFOA and PFOS	
	CTE	RME		CTE	RME
Age groups	L/day	L/day	kg	unitless	unitless
Birth to <1 year	0.36	0.80	7.8	0.53	1.17
1 to <2 years	0.22	0.64	11.4	0.22	0.64
2 to <6 years	0.27	0.70	17.4	0.18	0.46
6 to <11 years	0.37	1.00	31.8	0.13	0.36
11 to <16 years	0.46	1.41	56.8	0.09	0.28
16 to <21 years	0.55	1.75	71.6	0.09	0.28
Adults (≥21 years)	0.88	2.21	80	0.13	0.31
Pregnant women	0.62	1.85	73	0.10	0.29
Lactating women	1.19	2.56	73	0.19	0.40

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure multiplied by 5/7 to account for less than residential exposures; HI = hazard index is the combined hazard quotients for PFOA and PFOS combined (all drinking water intake rates are assumed to be 5/7 of a residential intake rate); kg = kilogram; L = liter; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

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

Table A-18. Perfluorooctanoic acid (PFOA) cancer risk calculations for Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire

Exposure assumptions		Estimated exposure doses*		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	9.2E-06	2.0E-05	4.7×10^{-8}	1.3×10^{-7}
1 to <2 years		3.9E-06	1.1E-05		
2 to <6 years		3.1E-06	8.0E-06		
6 to <11 years		2.3E-06	6.3E-06		
11 to <16 years		1.6E-06	5.0E-06		
16 to <21 years		1.5E-06	4.9E-06		
Adults (≥21 years)	26	2.2E-06	5.5E-06	5.1×10^{-8}	1.3×10^{-7}
Pregnant women	nc	1.7E-06	5.1E-06	nc	nc
Lactating women	nc	3.3E-06	7.0E-06	nc	nc

Abbreviations: µg/L = micrograms per liter; CTE = central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; nc = not calculated; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

* Dose based on maximum modeled PFOA concentration (0.2 µg/L).

†Exposure duration for children is from birth through age 20 years (21 years). The exposure duration for adults is 26 years (from the opening of the Pease Tradeport to 2017).

Table A-19. Perfluorooctanoic acid (PFOA) environmental exposure assumptions, estimated exposure doses, and hazard quotients for NH DES office, fire station and treatment plant sampling locations Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - June 2014 through May 2017

	Exposure Assumptions						
	Daily drinking water intake rate			Dose based on the maximum modeled concentration of PFOA = 0.0073 µg/L		Hazard quotient for PFOA (dose divided by the Intermediate provisional MRL)	
	CTE	RME	Body weight	CTE	RME	CTE	RME
Age groups	L/day	L/day	kg	mg/kg/day	mg/kg/day	unitless	unitless
Birth to <1 year	0.36	0.80	7.8	3.37E-07	7.49E-07	0.11	0.25
1 to <2 years	0.22	0.64	11.4	1.41E-07	4.10E-07	0.05	0.14
2 to <6 years	0.27	0.70	17.4	1.13E-07	2.94E-07	0.04	0.10
6 to <11 years	0.37	1.00	31.8	8.49E-08	2.30E-07	0.03	0.08
11 to <16 years	0.46	1.41	56.8	5.91E-08	1.81E-07	0.02	0.06
16 to <21 years	0.55	1.75	71.6	5.61E-08	1.78E-07	0.02	0.06
Adults (≥21 years)	0.88	2.21	80	8.03E-08	2.02E-07	0.03	0.07
Pregnant women	0.62	1.85	73	6.20E-08	1.85E-07	0.02	0.06
Lactating women	1.19	2.56	73	1.19E-07	2.56E-07	0.04	0.09

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

Table A-20. Perfluorohexane sulfonic acid (PFHxS) environmental exposure assumptions, estimated exposure doses, and hazard quotients for NH DES office, fire station and treatment plant sampling locations Pease Tradeport public water system users, Pease International Tradeport, Portsmouth, New Hampshire - June 2014 through May 2017

Exposure Assumptions				Dose based on the maximum modeled concentration of PFHxS= 0.019 µg/L		Hazard quotient for PFHxS (dose divided by the Intermediate provisional MRL)	
	Daily drinking water intake rate		Body weight				
Age groups	CTE L/day	RME L/day	kg	CTE mg/kg/day	RME mg/kg/day	CTE unitless	RME unitless
Birth to <1 year	0.36	0.80	7.8	8.77E-07	1.95E-06	0.04	0.10
1 to <2 years	0.22	0.64	11.4	3.67E-07	1.07E-06	0.02	0.05
2 to <6 years	0.27	0.70	17.4	2.95E-07	7.64E-07	0.01	0.04
6 to <11 years	0.37	1.00	31.8	2.21E-07	5.97E-07	0.01	0.03
11 to <16 years	0.46	1.41	56.8	1.54E-07	4.72E-07	0.01	0.02
16 to <21 years	0.55	1.75	71.6	1.46E-07	4.64E-07	0.01	0.02
Adults (≥21 years)	0.88	2.21	80	2.09E-07	5.25E-07	0.01	0.03
Pregnant women	0.62	1.85	73	1.61E-07	4.82E-07	0.01	0.02
Lactating women	1.19	2.56	73	3.10E-07	6.66E-07	0.02	0.03

Abbreviations: µg/L = micrograms per liter; CTE =central tendency exposure multiplied by 5/7 to account for less than residential exposures; kg = kilogram; L = liter; mg = milligram; mg/kg/day = milligrams of chemical per kilogram of body weight per day; RME = reasonable maximum exposure multiplied by 5/7 to account for less than residential exposures.

Equations

Equation 1. Estimating the lifetime excess cancer risk for perfluorooctanoic acid (PFOA) in drinking water.

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

Equation 2. Reasonable maximum exposure concentration calculation approach.

$$\text{Reasonable maximum exposure} = \frac{\frac{5}{7} \times \text{Upper percentile drinking water intake}\left(\frac{\text{L}}{\text{day}}\right) \times \text{Exposure point concentration}\left(\frac{\mu\text{g}}{\text{L}}\right)}{\text{Body weight (kg)} \times 1{,}000}$$

Equation 3. Central tendency exposure concentration calculation approach.

$$\text{Central tendency exposure} = \frac{\frac{5}{7} \times \text{Mean drinking water intake}\left(\frac{\text{L}}{\text{day}}\right) \times \text{Exposure point concentration}\left(\frac{\mu\text{g}}{\text{L}}\right)}{\text{Body weight (kg)} \times 1{,}000}$$

Appendix B. Estimating Concentrations of Per- and Polyfluoroalkyl Substances (PFAS) in the Pease Tradeport Public Drinking Water

Prepared by:

Agency for Toxic Substances and Disease Registry
U.S. Department of Health and Human Services
Atlanta, Georgia

List of Abbreviations and Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
EPA	(United States) Environmental Protection Agency
gpm	gallons per minute
µg/L	micrograms per liter
NHDES	New Hampshire Department of Environmental Services
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutane sulfonate
PFDeA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PFPeA	perfluoropentanoic acid
PFUnA	perfluoroundecanoic acid
PWTF	Pease Water Treatment Facility

Abstract

The New Hampshire Department of Environmental Services (NHDES) Bureau of Hazardous Waste Remediation asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate past and current exposures to per- and polyfluoroalkyl substances (PFAS) in the Pease Tradeport public water supply. ATSDR used the estimated concentrations of PFAS from Appendix B to conduct the health consultation presented in the main section of this report.

Three water supply wells have been the primary sources of drinking water for the Pease International Tradeport at Portsmouth, New Hampshire. Before 1985, when the Pease Water Treatment Facility (PWTF) was built, water from each well was chemically treated and introduced directly into the Pease water distribution system. After the PWTF was built, water from all three water supply wells was mixed at the water treatment facility. PWTF added chlorine and fluoride to the water before delivery to customers. This appendix summarizes ATSDR's analyses of estimated concentrations of PFAS in public drinking water delivered by the PWTF to the public between January 2003 and August 2015. The approach used to estimate average monthly concentrations of PFAS in drinking water at Pease International Tradeport during the past 13 to 14 years included computing flow-weighted average concentrations of PFAS using a materials mass balance (simple mixing) model.

Background

(see main report)

Historical Operation

The Pease Tradeport water system takes water from three wells (Haven, Smith, and Harrison), chemically treats it, and pumps it directly into the distribution system. The PWTF, built in 1985, combines water from supply wells, adds chlorine and fluoride, and pipes the treated water to customers. The water system was transferred from the U.S. Air Force to the Pease Development Authority in the early 1990s. The City of Portsmouth, New Hampshire, assumed operation responsibilities through an agreement with the authority in 1993. The system type is non-transient non-community water system with a commercial population of customers. A non-transient non-community water system is a public water system that regularly supplies water to at least 25 of the same people at least six months per year. The system did not serve residential customers until early May 2014, when service was extended to a portion of the Town of Newington, just before shutdown of the Haven well.

On May 12, 2014, the NHDES shut down the Haven well because levels of perfluorooctane sulfonate (PFOS) were above the 2009 EPA provisional health advisory level of

0.2 µg/L for PFOS. The science has evolved since 2009, and EPA replaced the provisional advisories with new, lifetime health advisories in 2016. The Haven, Smith, and Harrison water supply wells were the primary sources of drinking water for the Pease Tradeport water system. The Harrison well was offline for several years until it was redeveloped and new equipment was installed in 2006 to reactivate the well. During water supply well maintenance and when the Pease system needed more water, water was pumped from the Portsmouth water system. On occasion, when emergency backup water was needed, valves were opened to provide water from the PWTF to the Portsmouth system. After the Haven well was taken out of service in May 2014, water from the Smith and Harrison wells has been supplemented with water from the Portsmouth system via booster pumps at the PWTF where the water is mixed.

In 1953, the Army Corps of Engineers rebuilt the Haven well, which was initially developed in 1870. The Haven well has a rated capacity of about 450 gallons per minute (gpm), but is no longer being used. Pump testing in the 1990s set the well's sustained capacity at 534 gpm. The Smith well was installed in 1958 as part of the water system for Pease Air Force Base. The Smith well capacity is approximately 250 gpm. It supplies nearly 31% of the drinking water to the PWTF. The Harrison well, originally built in 1957, was redeveloped in June 2006. The Harrison well has a capacity of around 225 gpm. It provides about 25% of the drinking water to the PWTF. The remaining 44% of Pease public drinking water comes from two 450 gpm booster pumps that supply the Pease PWTF with drinking water from the Portsmouth water system (B. Goetz, City of Portsmouth Department of Public Works, email to Jason Sautner, ATSDR Division of Community Health Investigations, Science Support Branch, May 11, 2015). Table B-1 lists the average percent of drinking water provided to the PWTF from each source for distinct intervals between 1994 and 2014.

Table B-1. Average percent of drinking water provided by water supply wells to the Pease Water Treatment Facility, 1994–2015, Portsmouth, New Hampshire

Period*	Haven well	Smith well	Harrison well	Portsmouth booster pumps
1994–1999	56%	44%	0%	NA
2000–2001	88%	12%	0%	NA
2002‡	NA	NA	NA	NA
2003–2005	53%	47%	0%	NA
2006	48%	26%	26%	NA
2007	47%	2%	51%	NA
2008–2013	46%	25%	29%	NA
Jan–May 2014†	47%	29%	24%	NA
Jun 2014–Aug 2015	0%	30%	25%	45%

Source: B. Goetz, City of Portsmouth, email to Jason Sautner, ATSDR Division of Community Health Investigations, Science Support Branch, May 11, 2015.

Abbreviation: NA = not available.

*Periods are discrete intervals determined by significant changes in amount of water provided.

†The Haven well was taken out of service May 12, 2014.

‡Incomplete electronic data for 2002; electronic files not backed up for all months in 2002.

The City of Portsmouth Department of Public Works provided monthly pumping records for all three water supply wells for January 2003–August 2015 (B. Goetz, City of Portsmouth Department of Public Works, email to Jason Sautner, ATSDR Division of Community Health Investigations, Science Support Branch, May 11, 2015). Figure B-1 shows the continuous monthly pumping rates for each well between January 2003 and August 2015. The Harrison well was replaced and put back into service in June 2006. The Smith well was taken out of service in July 2006. Between November 2007 and January 2008, the Haven well was shut down for service. During April 2014, water samples collected from the Haven well were found to contain PFOS at a level above the 2009 EPA provisional health advisory level screening level of 0.2 µg/L. At that time, the Haven well supplied about 6.3 million gallons (54%) of the total drinking water delivered to the PWTF; the Smith well provided about 3.0 million gallons (25%); and the Harrison well provided about 2.4 million gallons (21%). In May 2014, water from the Haven well also contained PFOS concentration levels above the 2009 EPA provisional health advisory level. During May 2014, the Haven well supplied 3.6 million gallons (29%), the Smith well supplied 4.7 million gallons (38%), and the Harrison well supplied 4.0 million gallons (32%) of the drinking water to the PWTF. On May 12, 2014, the Haven well was shut down because water samples collected from the well contained PFOS at a level above the 2009 EPA provisional health advisory level.

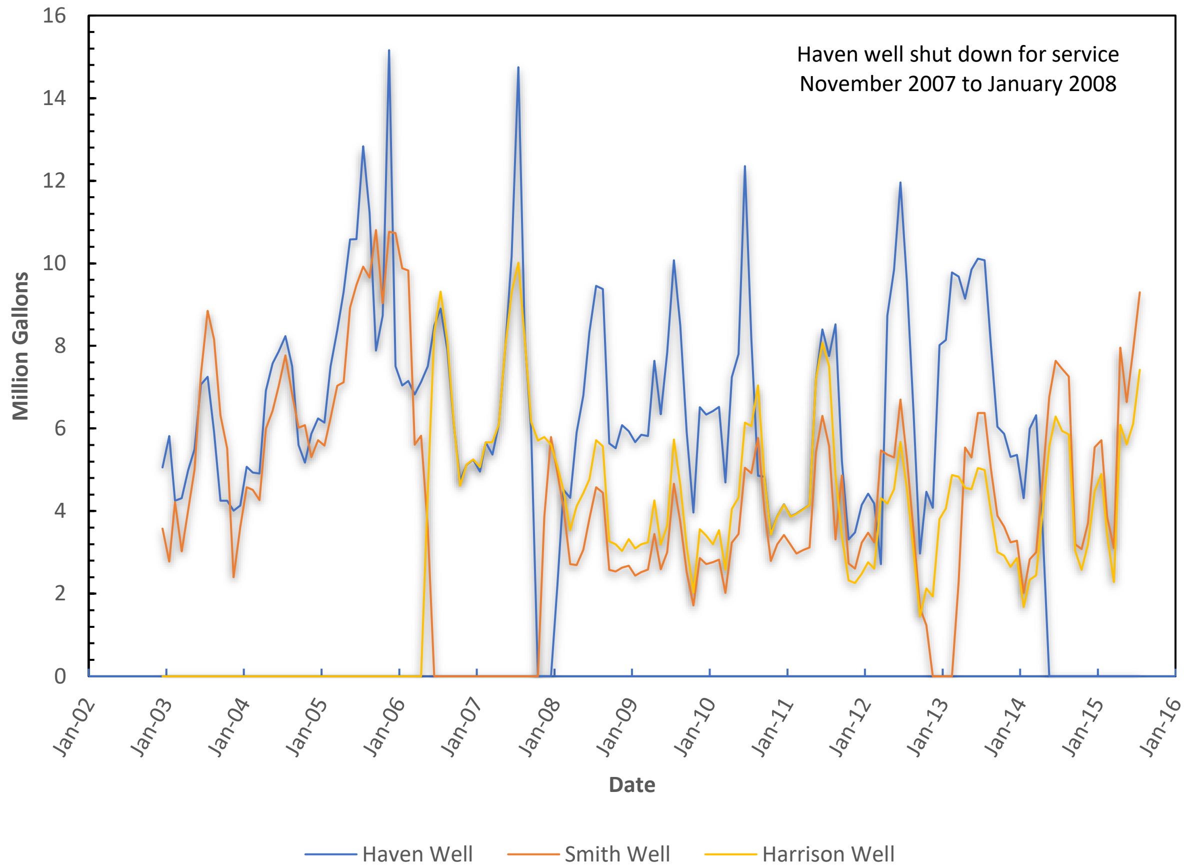

Figure B-1. Monthly pumping rates for Pease International Tradeport water supply wells, January 2003–August 2015, Portsmouth, New Hampshire.

Modeling Approach to Estimate PFAS Concentrations

From 1985 until May 12, 2014, when the Haven well was shut down, groundwater from the Haven, Smith, and Harrison water supply wells was mixed at the PWTF before distribution to customers. Therefore, ATSDR used a materials mass balance (simple mixing) model to compute levels of PFAS in drinking water delivered to Pease International Tradeport customers during April and May 2014. The model is based on the principles of continuity and conservation of mass [Masters 1998]. Application of the simple mixing model presumes that the computed PFAS concentrations of water at the PWTF are nearly equal to those at any location throughout the water distribution system. Figure B-2 shows a schematic diagram of the mixing model approach. The model is a sufficiently accurate and useful method to compute drinking water concentrations at the PWTF and at locations serviced by the PWTF for any given month. Maslia et al. [2009] provide further details and comparison of mixing models and complex, numerical water distribution system models.

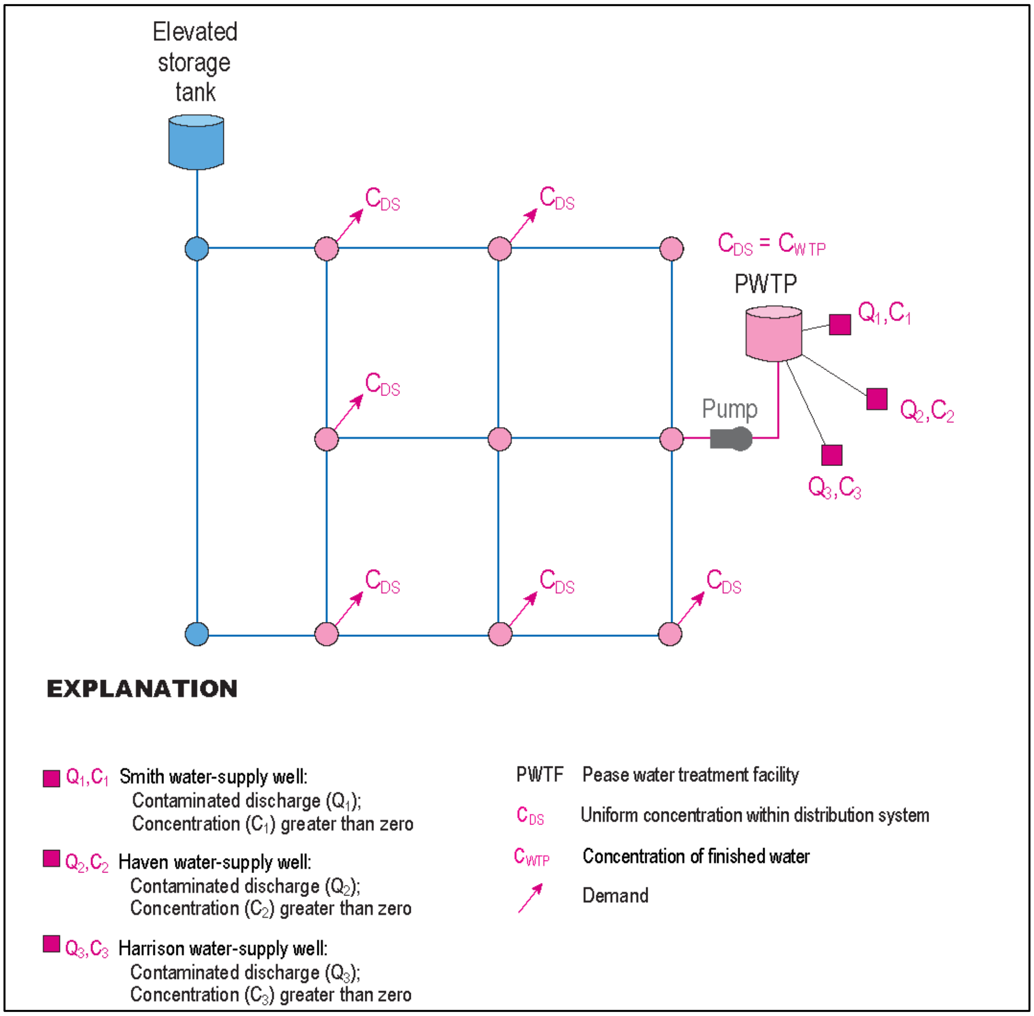

Figure B-2. Schematic representation of the mixing model approach used for the Pease International Tradeport water system analysis (modified from Maslia et al. 2013)

To compute weighted-average PFAS concentrations, ATSDR weighted PFAS concentrations measured in April and May 2014 at each water supply well by the respective well discharge during the month. These weighted-average concentrations are the likely average concentrations of PFAS distributed through the Pease water system for any day during April and May 2014.

Using the concentrations of PFAS at the three water supply wells and well pumping rates, ATSDR calculated levels of PFAS at the PWTF and locations serviced by the PWTF with the following mixing model:

$$C_i = \frac{\sum_{j=1}^{n} q_{ij} c_{ij}}{Q_{Ti}},$$

where C_i = the concentration of PFAS at the PWTF for month i (ML^{-3});
n = the total number of active water supply wells for month i;
q_{ij} = the pumping rate of well j for month i (L^3T^{-1});
c_{ij} = the concentration of PFAS at water supply well j for month i (ML^{-3}); and
Q_{Ti} = is the total water demand for month i (L^3T^{-1}).

Within those factors, M = mass (e.g., µg), L = length (e.g., meter or foot), and T = time (e.g., day).

Table B-2 lists estimated average monthly concentrations of PFAS calculated for April and May 2014 at the PWTF and locations serviced by the PWTF. The calculated combined perfluorooctanoic acid (PFOA) and PFOS average monthly concentration of 1.55 µg/L in drinking water at any location throughout the Pease water distribution system during April 2014 exceeded the EPA lifetime health advisory level of 0.07 µg/L. The computed combined PFOA and PFOS average monthly concentration of 0.82 µg/L during May 2014 also exceeded the EPA lifetime health advisory.

Table B-2 Estimated concentrations of per- and polyfluoroalkyl substances (PFAS) in the Pease International Tradeport water distribution system, April and May, 2014, Portsmouth, New Hampshire; concentrations in micrograms per liter (µg/L)*

Specific PFAS	Sample date	
	April 16, 2014	May 14, 2014
PFBS	0.03	0.02
PFDeA	0.00	0.00
PFDoA	0.00	0.00
PFHpA	0.07	0.04
PFHxA	0.18	0.11
PFHxS	0.46	0.30
PFNA	0.01	0.00
PFOA	0.19	0.10
PFOA + PFOS	1.55†	0.82‡
PFOS	1.36	0.72
PFPeA	0.15	0.08
PFUnA	0.00	0.00

Abbreviations: µg/L = micrograms per liter; PFBS = perfluorobutane sulfonic acid; PFDeA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

* Derived using the flow-weighted mixing model approach described in text. † The Haven well operated May 1–12, 2014 and was shut down the rest of the month. The values reported in this table are the estimated average monthly concentrations of PFAS in the water distribution system. ‡ Indicates concentration exceeds the Environmental Protection Agency lifetime health advisory level of 0.07 µg/L.

Groundwater samples taken from the Haven well in April and May 2014 generally contained higher concentrations of PFAS than did samples from the Smith and Harrison wells. The calculated levels of PFAS in the public drinking water system were higher for April 2014 than those calculated for May 2014. The Haven well provided 54% of the total drinking water delivered to the PWTF during April 2014, but only 29% of the total during May 2014 because it was shut down on May 12. From the middle of 2010 until about April 2012, the Haven well supplied an average of 37% of the public drinking water to the PWTF. The Smith and Harrison wells provided the other 63%. From May 2012 to April 2014, the Haven well provided more than half of the drinking water to the PWTF, and the Smith and Harrison wells provided the rest. The Haven well no longer provides drinking water to the PWTF.

Estimated Past Concentrations of PFAS in Drinking Water

ATSDR used a simple mixing model to estimate average monthly concentrations of PFAS in the drinking water for the 11 compounds detected in the three water supply wells. The model used monthly pumping rates from January 2003–April 2014 (see Figure B-1) for each water supply well, along with PFAS concentrations measured at each well in April 2014 (Table B-3). To estimate average monthly concentrations of PFAS in drinking water, the model used pumping rates from May 2014–August 2015 for each water supply well and the highest PFAS concentrations measured at each well during the month. Figure B-3 shows the monthly estimated drinking water concentrations from January 2003–August 2015 for the 11 PFAS detected in the three water supply wells. The highest estimated concentration of PFOS in drinking water was 1.71 µg/L in December 2012 and January 2013. The highest estimated PFOA and perfluorohexane sulfonate (PFHxS) concentrations during the same months were 0.24 µg/L and 0.57 µg/L, respectively. Drinking water concentrations for the remaining eight PFAS detected were at or below 0.2 µg/L. In November 2007, December 2007, and January 2008, the estimated drinking water concentrations for all 11 PFAS were below 0.05 µg/L because the Haven well was shut down for service during these months. Because the Haven well was taken out of service on May 12, 2014, estimated concentrations of PFAS in drinking water during June 2014–August 2015 were less than 0.02 µg/L.

Table B-3. April and May 2014 water supply well concentration levels for per- and polyfluoroalkyl substances (PFAS); concentrations in µg/L

Specific PFAS	Haven well		Smith well		Harrison well	
	April 16	May 14	April 16	May 14	April 16	May 14
PFBS	0.051	0.051	0.00094*	0.00087*	0.002*	0.0019*
PFDeA	0.0049*	0.0043*	0.0044*	ND	ND	ND
PFDoA	ND	ND	0.012	ND	ND	ND
PFHpA	0.12	0.12	0.0025*	0.002*	0.0046*	0.0042*
PFHxA	0.33	0.35	0.0039*	0.004*	0.0087	0.01
PFHxS	0.83	0.96	0.013	0.013	0.036	0.032
PFNA	0.017	0.017	ND	ND	ND	ND
PFOA	0.35	0.32	0.0035*	0.0036*	0.009	0.0086
PFOS	2.5†	2.4†	0.018	0.015	0.048	0.041
PFPeA	0.27	0.26	0.0035*	0.0034*	0.0079	0.0084
PFUnA	ND	ND	0.017	ND	ND	ND

Source: Scott Hilton, New Hampshire Department of Environmental Services, email to Jason Sautner, ATSDR Division of Community Health Investigations, Science Support Branch, May 2015.

Abbreviations: µg/L = micrograms per liter; ND = not detected; PFBS = perfluorobutane sulfonic acid; PFDeA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

*Estimated value.

†Concentration level above U.S. Environmental Protection Agency provisionary health advisory level of 0.2 µg/L.

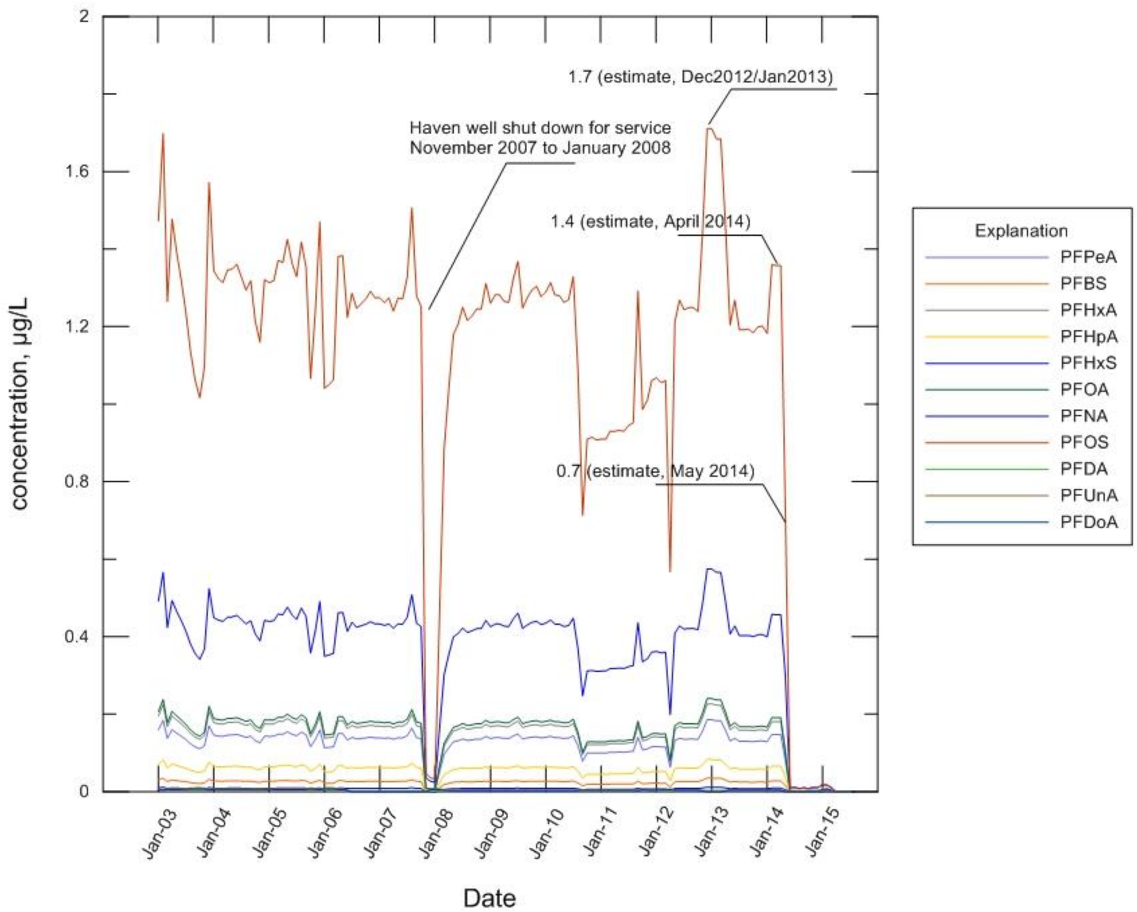

Figure B-3. Monthly estimated drinking water concentrations in the Pease water distribution system between January 2003 and August 2015 for the 11 per- and polyfluoroalkyl substances (PFAS) detected in water supply wells. Estimated values derived by using flow-weighted mixing model approach and measured concentrations of PFAS in Pease water supply wells during April 2014.

Abbreviations: µg/L = micrograms per liter; PFBS = perfluorobutane sulfonic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

Based on estimated values derived by using the flow-weighted mixing model approach and measured concentrations of PFAS from April 2014, ATSDR estimated the combined PFOA and PFOS concentrations at the PWTF and in public drinking water for 2003 through 2015 (Figure B-3). Estimates for the last 3 to 4 years are the most reliable. The average monthly flow concentration peaked at about 2.0 µg/L in December 2012 and January 2013.

The flow-weighted mixing model approach is effective and efficient in estimating recent concentrations of PFOA and PFOS because water from all three supply wells was mixed at the PWTF during April 2014 before being delivered to Pease customers. The flow-weighted mixing model is also effective in estimating concentrations of PFOA and PFOS in the public drinking water from 2003 through 2011 because PFOA and PFOS are extremely resistant to breakdown.

The concentrations of PFOA and PFOS measured in the water supply wells in April 2014 are thought to represent concentrations between 2003 and 2011 because PFOA and PFOS persist in the environment [MDH 2005]. These estimations are based on measured concentrations of PFAS in April 2014. Having detailed historical water system operational data and measured PFAS concentrations closer to the year 2003 could help verify the reliability of the model and might help improve the model results. ATSDR currently lacks all the information needed to improve the model results, thus has not committed to additional modeling.

Figure B-4 shows the monthly estimated combined drinking water concentrations of PFOA and PFOS during January 2003–August 2015. The highest estimated combined concentration was 2.0 µg/L in December 2012 and January 2013. The only times the combined concentrations of PFOA and PFOS were below the EPA lifetime health advisory of 0.7 µg/L were when the Haven well was shut down during November 2007–January 2008, and when the Haven well was taken out of service in May 2014.

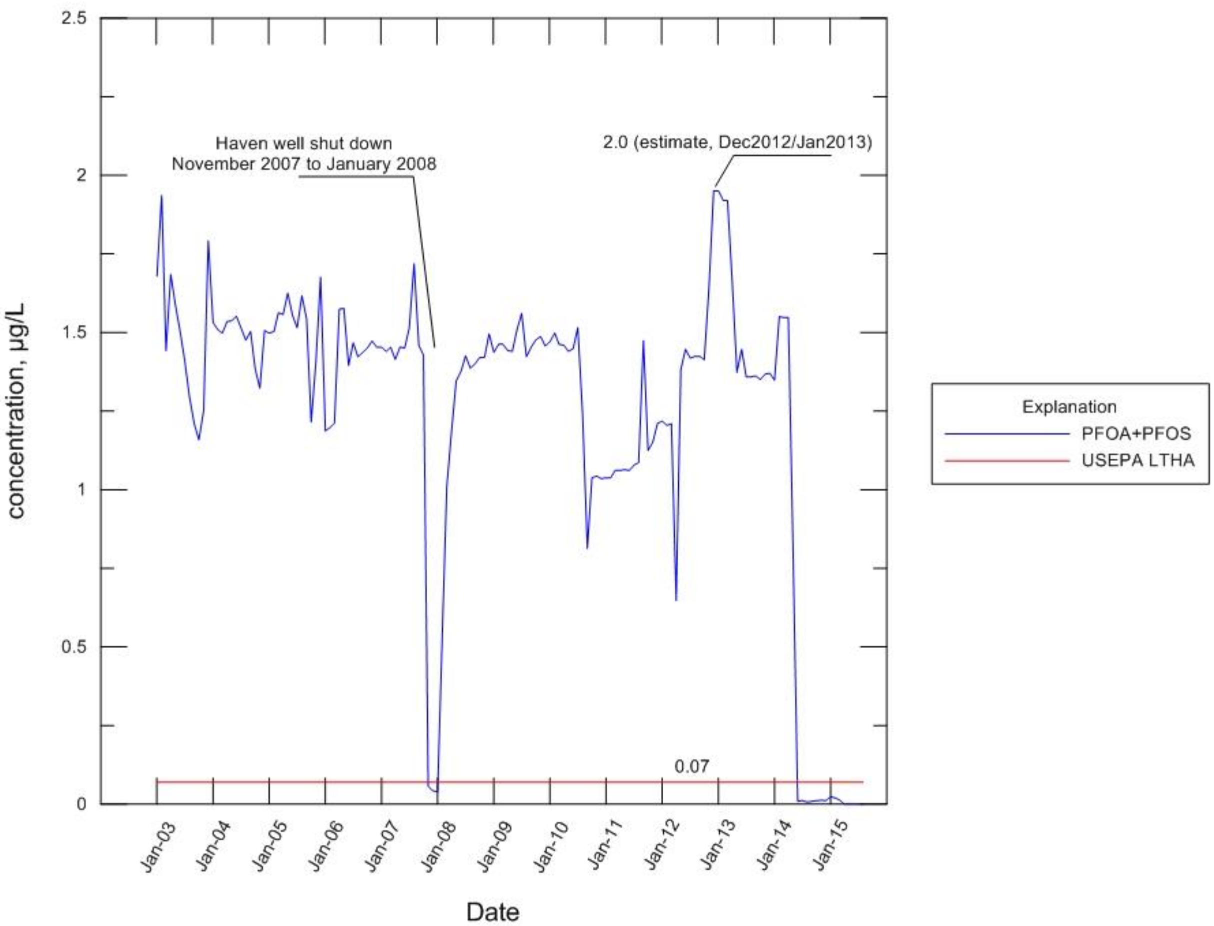

Figure B-4. Monthly estimated combined drinking water concentrations in the Pease water distribution system for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) detected in water supply wells, January 2003–August 2015, Portsmouth, New Hampshire. Estimated values derived by using flow-weighted mixing model approach and measured concentrations of per- and polyfluoroalkyl substances (PFAS) in Pease International Tradeport water supply wells during April 2014. USEPA LTHA = U.S. Environmental Protection Agency lifetime health advisory level of 0.07 µg/L.

Abbreviations: µg/L = micrograms per liter; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; USEPA LTHA = U.S. Environmental Protection Agency Lifetime Health Advisory.

Table B-4 lists the average percent of drinking water provided to the PWTF from each of the wells for discrete intervals during 2003–2015. The discrete periods shown in the tables reflect significant changes in the percent of drinking water the Haven well supplies to the Pease water system. New periods were selected when a significant change occurred in the amount of water the Haven well supplied to the PWTF. The Haven well was shut down on May 12, 2014, immediately after NHDES notified the City of Portsmouth that water samples collected from the well contained PFOS at a level above the 2009 EPA provisional health advisory level.

Table B-5 lists estimated maximum concentrations and estimated geometric mean concentrations for the 11 compounds detected in drinking water at Pease International Tradeport. The highest estimated PFAS concentrations were when the Haven well supplied around 50% of the drinking water to the PWTF. The highest estimated combined concentration of PFOA and PFOS in drinking water was 2.0 µg/L in December 2012 and January 2013. Between June 2014 and August 2015, estimated concentrations of PFAS in drinking water were less than 0.02 µg/L because the Haven well was taken out of service on May 12, 2014. ATSDR estimated the values by using the flow-weighted mixing model approach and measured concentrations of PFAS in Pease water supply wells during April 2014.

Table B-4. Average percent of drinking water provided by water sources to the Pease Water Treatment Facility, January 2003–August 2015, Portsmouth, New Hampshire

Water Source	Period*					
	Jan 2003 – Oct 2007	Nov 2007 – Jan 2008	Feb 2008 – Aug 2010	Sep 2010 – Apr 2012	May 2012 – May 2014†	Jun 2014 – Aug 2015‡
Haven	51%	0%	48%	37%	52%	0%
Smith	35%	30%	23%	30%	23%	30%
Harrison	14%	70%	29%	33%	25%	25%
Portsmouth Booster	NA	NA	NA	NA	NA	45%

Source: B. Goetz, City of Portsmouth Department of Public Works, email to Jason Sautner, ATSDR Division of Community Health Investigations, Science Support Branch, May 11, 2015.

Abbreviation: NA = not available.

* Periods are discrete intervals determined by significant changes in amount of water provided.

† Haven well taken out of service May 12, 2014.

‡ Pease water system supplemented with water from Portsmouth water system.

Table B-5. Estimated maximum and geometric mean concentrations of per- and polyfluoroalkyl substances (PFAS) in the Pease water distribution system, January 2003–August 2015, Portsmouth, New Hampshire; concentrations in micrograms per liter (µg/L)*

Specific PFAS	Period†											
	Jan 2003 – Oct 2007		Nov 2007 – Jan 2008		Feb 2008 – Aug 2010		Sep 2010 – Apr 2012		May 2012 – May 2014‡		Jun 2014 – Aug 2015§	
	MAX¶	GM¶	MAX	GM	MAX	GM	MAX	GM	MAX	GM	MAX	GM
PFBS	0.03	0.03	<0.01	<0.01	0.03	0.02	0.03	0.02	0.04	0.03	<0.01	<0.01**
PFDeA	<0.01	<0.01	<0.01	<0.01**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01**
PFDoA	0.01	<0.01**	0.01	<0.01**	<0.01	<0.01	0.01	<0.01	<0.01	<0.01**	0.00	0.00
PFHpA	0.08	0.06	<0.01	<0.01	0.07	0.06	0.06	0.05	0.08	0.06	<0.01	<0.01**
PFHxA	0.22	0.17	0.01	0.01	0.18	0.16	0.17	0.13	0.23	0.17	0.01	<0.01
PFHxS	0.57	0.43	0.04	0.03	0.46	0.41	0.44	0.32	0.57	0.44	0.02	0.01
PFNA	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01**
PFOA	0.24	0.18	0.01	0.01	0.19	0.17	0.18	0.13	0.24	0.18	<0.01	<0.01
PFOA + PFOS	1.94††	1.47††	0.06	0.05	1.56††	1.37††	1.47††	1.07††	1.95††	1.47††	0.02	0.01
PFOS	1.70	1.29	0.05	0.04	1.37	1.20	1.29	0.94	1.71	1.29	0.02	0.01
PFPeA	0.18	0.14	0.01	0.01	0.15	0.13	0.14	0.10	0.19	0.14	0.01	<0.01
PFUnA	0.01	<0.01**	0.01	<0.01**	0.01	<0.01	0.01	0.01	0.01	<0.01**	<0.01	<0.01**

Abbreviations: MAX = maximum concentration; GM = geometric mean concentration; PFBS = perfluorobutane sulfonic acid; PFDeA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid; PFHxS = perfluorohexane sulfonic acid; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonic acid; PFPeA = perfluoropentanoic acid; PFUnA = perfluoroundecanoic acid.

***** Derived using the flow-weighted mixing model approach described in text.

† Periods are discrete intervals determined by significant changes in amount of water provided.

‡ Haven well taken out of service May 12, 2014.

§ Pease water system supplemented with water from Portsmouth water system.

¶ Estimated.

** The geometric mean was assumed to be <0.01 µg/L if the compound was detected in at least one sample but at a level lower than 0.01 µg/L.

†† Indicates concentration exceeds the U.S. Environmental Protection Agency lifetime health advisory level of 0.07 µg/L.

Discussion

ATSDR used measured concentrations of PFAS in the Pease water supply wells to estimate concentrations of PFAS in drinking water for April and May 2014. ATSDR used a flow-weighted mixing model to estimate average monthly concentrations in the drinking water for 2003 through 2014. The model used April 2014 measured concentrations of PFAS in the water supply wells and monthly water supply well pumping rates from 2003–2014. Use of the simple mixing model presumes that the computed concentrations at the PWTF are nearly equal to the concentrations at any location throughout the water distribution system. The mixing model is appropriate because the PWTF mixes water from the supply wells before distribution to customers.

The mass balance (simple mixing) approach ATSDR used to compute PFAS concentrations in drinking water delivered to Pease customers is based on the principles of continuity and conservation of mass [Masters 1998]. Although the approach is efficient and simple to use, it does include some simplifying assumptions. These assumptions include the following:

1) Groundwater containing PFAS is uniformly and instantly mixed in a storage tank (storage tank flow dynamics are not considered)
2) Measures of PFAS or any constituent are conservative and do not include changes such as decay or biodegradation
3) Estimated concentrations of PFAS delivered to the distribution system represent likely values or an average occurring on any day of the month

Having concentrations of PFAS measured closer to 2003 and detailed historical water system operational data could help verify the reliability of the model and perhaps improve the model results. Because all of the information needed to verify and improve the model results is not available, no additional modeling is scheduled.

Conclusions

In April and May 2014, water from the Pease water system was tested and found to contain several PFAS. Water from the Haven well contained 0.35 µg/L of PFOA and 2.5 µg/L of PFOS during April 2014. Water from the Smith and Harrison wells contained PFOA and PFOS concentration levels below the EPA lifetime health advisory of 0.07 µg/L. PFOA and PFOS were also detected in water from the three water supply wells during both sampling dates, but at levels below the EPA lifetime health advisory.

ATSDR used a flow-weighted mixing model to estimate average monthly concentrations of PFAS in public drinking water. In December 2012 and January 2013, the highest estimated

PFOA and PFOS concentration in the drinking water were 0.24 µg/L and 1.71 µg/L, respectively. The highest estimated combined PFOA and PFOS concentration of 2.0 µg/L exceeds the EPA lifetime health advisory level of 0.07 µg/L. The highest estimated PFHxS concentration in drinking water was 0.57 µg/L in December 2012 and January 2013, and the highest estimated PFNA concentration was 0.012 µg/L in February 2003, December 2012, and January 2013. The estimated drinking-water concentrations of PFAS in this modeling report will be used in the ATSDR Pease Tradeport PWS health consultation.

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Appendix C - Responses to public comments

Comment 1: After reading the article in today's Seacoast Online I find it interesting as I worked on Pease at 2 International Drive and on New Hampshire Dr. from 1993 to 2008. Ironically, one of my colleagues that had worked in the same office along with myself have both been diagnosed with hyperthyroidism with Graves' disease. I have no family history of thyroid disease so this was a shocking diagnose. I'm currently being treated by an Endocrinologist. I also am a very healthy, active 52 yr old that has a slightly high liver function but no know (sic) cause of it per my Drs. further testing was also done to seek answers. It is very ironic that in a very small office of maybe 10 of us that 2 of us have the same exact thyroid disease. Knowing this can be triggered by environmental PFAS is concerning and could be linked to that exposure for the many years we worked there.

Response:
Scientific studies indicate that exposures to the three primary PFAS (PFOA, PFOS, and PFHxS) found in the Pease PWS have been associated with endocrine disorders, such as thyroid disease and effects on the liver (see Table A-1). ATSDR is conducting a study of persons exposed to PFAS from the Pease PWS and this study, along with our other nationwide multi-site study, should provide exposed persons and the scientific community a better understanding of the association between drinking water exposures to these PFAS and the health effects described by the commenter as well as other effects.

Comment 2*: The following comments have been placed together as they all related to our lack of understanding of the full spectrum of PFAS contained in the AFFF used at Pease:*

a. **The greatest weakness of the ATSDR analysis is the relatively few PFAS compounds that are addressed, and why.**

b. **Site 8 is said to be the major source of pollutants in the Portsmouth drinking water supply, but there is no discussion of which PFASs (or other chemicals and surfactants, etc.) were in the fire-fighting foams or other solvents used at site 8. It is a black box.**

c. **There is no discussion of why the 19 or so PFAS compounds listed in the abbreviations list were selected for study, nor of which ones were excluded. It is a black box. Just because a PFAS does not have a known "test" for measuring it does not mean that the contaminant can be ignored as if it does not exist in our water.**

d. **Conclusion #2 says that treated water is safe to drink based on the testing of only a dozen PFAS compounds, when it is clear that thousands of PFASs exist and any particular fire-fighting foam may have contained hundreds of different PFASs, even though the primary component was PFOA or PFOS. ATSDR should not make such a broad, open-ended conclusion without limiting its scope to the actual chemicals tested, disclosing what else was in the fire-fighting foams, and addressing those chemicals that were not tested. For example, which PFASs are not removed by treatment with activated charcoal and resin columns?**

e. **This report by ATSDR says it will "conclude the health consultation process for this site." But it provides the public with no information about the "black boxes" just mentioned and addresses only a dozen or so compounds selected by an unknown entity (USAF?) with no disclosure/discussion of the selection process. It requires a leap of faith to believe Conclusion #2. Newington deserves better – especially because we have believed the experts about the drinkability of the Haven well water and have been twice burned by our blind faith.**

Response:
ATSDR has collected all available information to evaluate exposures to PFAS from the Pease Tradeport PWS. However, incomplete information exists on the type of AFFF used at the former Pease AFB and specific PFAS formulations. ATSDR reviewed the PFAS water results provided and acknowledges that there are potentially other PFAS which were not analyzed and that exposures to other PFAS could have occurred. Previous PFAS water analyses were based on available laboratory methods and data availability at the time of sampling. ATSDR has added a statement to the final health consultation about this uncertainty in our conclusions and a new section under the Limitations and Uncertainties of Risk Assessment of PFAS Exposures. Any additional PFAS exposures prior to June 2014 would have increased the risk of harmful effects and ATSDR acknowledges this in the public comment version of this health consultation several times. After June 2014, because of the availability of additional laboratory methods, the number of PFAS analyzed increased from 9 to 23. These additional analysis helps ATSDR to better understand the past exposures between the time the Haven Well was shutdown (May 2014) and when the new water treatment system for the Smith and Harrison Wells was installed (September 2016). The Haven well was operated until it was shut down in May 2014. A granular activated carbon system was installed in September 2016. The Harrison and Smith Wells have been treated by that system ever since that time. Additional protection is expected when the dual granular activated carbon and resin treatment system is installed.

Comment 3: The following comments relate to whether the treated water from the City of Portsmouth supplied to the Pease Tradeport and residents is safe to drink.

Newington has been twice burned with experts telling us the water treated at Pease was OK to drink, first due to TCE/VOC contamination and then due to PFAS contamination. For sure, the USAF and Portsmouth Water Dept. will point to this report and its recommendations as a rubber stamp of approval, full steam ahead…. But continuing to rely on a drinking water well in the middle of a superfund site and an operating airfield seems a recipe for another disaster.

Conclusion #2 is especially worrisome. Especially because the analysis at Pease will be used across the country for other contaminated drinking water supplies next to military bases. Why should the public believe the treated water is now safe to drink when this was not true for TCE, nor for decades with PFASs?

Already we are hearing:
"We can only test for what we can test for." – Portsmouth Water Department
"We only know what we know." – NH DES
"There is nothing special about Pease, this is the state-of-the-art for how contaminated water systems are cleaned up." – EPA
The ATSDR should exercise its authority and compel the USAF to compile information on the components of fire-fighting foams and share it with all of us, so we will know a lot more about what needs to be cleaned up and if the suggested processes are sufficient to produce water that is safe to drink. Until we know the full extent of what we are dealing with, how can the ATSDR conclude that the treated water is safe to drink and will do no harm.
Newington does not want to drink treated Haven Well water for the next 20 years only to learn that the experts got it all wrong, FOR A THIRD TIME.
For more on the Pease RAB see: https://www.afcec.af.mil/Home/BRAC/Pease.aspx

Response:
As stated in the response to Comment 1 above, ATSDR agrees that there is some uncertainty regarding all of the PFAS that may be present in the wells that have and will be providing the primary source of water to the Pease Tradeport community. However, ATSDR reviewed at least 8 monthly rounds the post-filter samples from the currently installed filter system and it appears to be effectively removing 23 PFAS from the Harrison and Smith wells. This system appears to be removing both long-chain and short-chained PFAS. Only a few samples after treatment have detected any PFAS, with only one sample that detected PFOS at levels slightly above ATSDR's HBCV and similar to the level detected in the distribution system samples at the

water treatment system distribution point (see Table 4). ATSDR has added a recommendation to the USAF to prioritize their research and efforts to determine the AFFF usage and formulation at Pease and other facilities to help inform future monitoring efforts around sites where AFFF has been used. This additional monitoring will help to also inform future health evaluations of exposures to communities who live around bases that have used AFFF.

Comment 4: The following comments relate to ATSDR recommendations:

a. **The back of the front page of this report states: "An ATSDR health 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." But the Recommendations in this study are especially weak. They are a gift to the USAF, a pat on the back for a job well done. There is no attempt to hold their feet to the fire so the experts and public can understand the full extent of what is really in the water supply, what is being removed, and what is not being removed by the GAC/resin treatment process.**

b. **As a minimum, the recommendations should compel the USAF to disclosure all the surfactants and chemicals, including different PFASs, their components and degradation products, and relative concentrations that were in the fire-fighting foams used at Pease, especially at Site 8. The USAF is waving its hands in the air and arguing about trade secrets, patents, and confidentiality of foam components. OK, so disclose the chemical components in the foams and their relative proportions but do not disclose the brand names or their manufacturers. The USAF is arguing that it cannot find a record of all the fire-fighting foams used at Pease over the last 50 years. OK, so identify all the foams that were on the market during those years, whether or not the USAF purchased them, and disclose what is in them and go from there.**

c. **During discussion of the water treatment proposals for cleaning the Haven Well water, the Pease Restoration Advisory Board first heard that charcoal filters were all that were needed to remove PFASs from the contaminated water. That was not true. Soon it became apparent that an ion exchange resin was also needed for removing certain PFASs, such as those that are short chains. The Portsmouth Water Department has been doing a great job in monitoring 23 PFAS compounds (that have available tests) in the current water treatment process. But there is no information about the hundreds of PFASs and other chemicals presumably present in the fire-fighting foams used at Pease and whether those 23 PFASs/chemicals will be effectively removed by the GAC/resin treatment process. Ignoring these other PFASs/chemicals and declaring**

the water safe to drink based on testing only a select few PFASs is frightening. The recommendations in this report should compel the USAF to undertake studies of broad classes and types of different PFAS compounds to determine which ones will, or will not, be removed by the proposed treatment process.

Response: See responses to Comments 2 and 3 above.

Comment 5:
Water in Newington is contaminated with many different PFASs. USAF data for testing the water in Watering Springs is shown in the figure below. These springs are located off the old base in the Newington residential area, which is down gradient from the old Site 8 fire training area at Pease. I am using this data as a proxy for the Pease public drinking water data. Though these springs have higher PFAS concentrations than contaminated drinking water wells in Newington, the relative concentrations of the contaminants are likely similar in the springs, the wells, and the Pease public drinking water because the water all comes from the same contaminated underground aquifer close to Site 8.

My husband kept a plastic pitcher of Watering Springs water in our refrigerator so all of us could enjoy the cold fresh water. All our ducks, geese, turkeys for the local 4-H group, pigs, and beef that we grew when our children were young drank this water at full strength (not 120X diluted). We ate the duck and goose eggs and the meat from the ducks, geese, turkeys, pigs, and beef. Our exposure was not to any particular PFAS in the water but to all of the PFASs in the water, eggs, and meat. The impact on human health is the combined impact from exposure to PFAS cocktails, not just to individual PFAS chemicals.

Response: ATSDR agrees that persons exposed to PFAS from the Pease PWS are also likely to have exposures to PFAS from other sources like food. These exposures will likely vary depending on the source of a family's food. ATSDR does not have data on the foodstuffs mentioned by the commenter to evaluate the public health implications beyond past PFAS exposures from the Pease PWS. ATSDR will evaluate the potential exposures and health effects related to the shellfish data from the Great Bay. ATSDR acknowledges in this health consultation that total PFAS body burden for persons exposed to the Pease Tradeport PWS in the past is a result of these exposures and other non-drinking water sources.

Comment 6: Watering springs is also contaminated with 6:2FTS, which had the third highest concentration of the 13 PFASs tested. Although this PFAS was listed in the Abbreviations Table on page vii of your health consultation, no other analysis is presented in the report. It is not possible to understand the impact of 6:2 FTS to human health in the untreated and

treated Portsmouth Drinking water supply because no data is included in this health consultation. Since all these chemicals likely came from the Site 8 fire training area, 6:2 FTS is likely also in the Haven Well. Newington needs to understand the importance of 6:2FTS on human health because it is present at high levels in our water. Deeming water treated at Pease to be safe (Conclusion #2) without including information on 6:2 FTS is not reassuring.

The Watering Springs figure includes data on 13 PFAS contaminants that were tested. We have no idea how many other PFAS chemicals are in this water. I divided the PFAS levels in the water by 120 to obtain values that would be below the new drinking water standards proposed by NH DES. Thus, the water (120x dilution) would be considered safe to drink if similar levels were found in someone's well:

— 13.3 ppt PFOA < 38 ppt proposed PFOA standard
— 50 ppt PFOS < 70 ppt proposed PFOS standard
— 63.3 ppt PFOA+PFOS < 70 ppt proposed PFOA+PFOS standard
— 0.2 ppt PFNA < 23 ppt proposed PFNA standard
— 29.2 ppt PFHxS < 85 ppt proposed PFHxS standard

BUT look at the combined total of 139.5 ppt for the 13 PFASs that were tested and found to be present in the 120X diluted water. Certainly, drinking water that has such high levels of PFASs cannot be good for you. In addition, there could be many other PFAS chemicals in this water (some worse than others) that were not tested, so the combined PFAS exposure is actually higher than 139.5 ppt.

Response: ATSDR cannot determine the exposure levels to 6:2 FTS before June 2014 because it was not analyzed. After May 2014, when the list of PFAS analyzed was expanded, 6:2 FTS was analyzed in the distribution system water samples and in samples of the treated water after the treatment system was installed in September 2016. This PFAS was not detected in the distribution water samples nor in drinking water supplied after the treatment system was installed in September 2016. ATSDR has updated this health consultation to include this information. In addition, ATSDR did some additional research and determined the following regarding possible health effects of 6:2 FTS:

> *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 may occur those any of these pathways. Some animal studies have shown that 6:2 FTS can cause kidney and liver toxicity, but 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, overall, these studies are very limited and no definitive conclusions can be drawn relating to potential effects in humans.

Comment 7: Mixtures of PFASs are more important to study/regulate than any one PFAS alone. Fire-fighting foams are not homogenous and are likely comprised of hundreds of chemicals, including many different PFASs, foaming agents, solvents, foam stabilizers, unreacted ingredients, and degradation products. Most contaminated water supplies from military bases and old fire training areas will have many (dozens? hundreds?) of different contaminants from the release of these foams. This report should include a fourth conclusion that specifically addresses PFAS mixtures. Assessing the impacts of PFAS exposure on human health requires understanding the exposure of people to "cocktails" of multiple PFASs (and the other chemicals present in the foams). Impacts from any one PFAS will inform such a study, but the total impact to human health will arise from exposure to the total PFAS cocktail.

Response: To the extent possible, ATSDR has evaluated the mixture of the PFAS exposures related to the Pease PWS. ATSDR has already make conclusions about the possible health effects of the mixture of PFAS exposures at Pease, both before and after May 2014. As stated in other responses to public comments, ATSDR agrees that a major uncertainty of this evaluation is the lack of information on the type of AFFFs used, formulations, and exposures to other related chemicals. ATSDR has added in this additional uncertainty statement to the final health consultation.

Comment 8: "I agree with the following statement in Conclusion #1 about past PFAS exposures:
"The combined exposures to a mixture of PFOS, PFOA, PFHxS, and perfluorononanoic acid (PFNA) could have increased the risk for developmental and immune effects above what might be expected from exposure to any of these PFAS alone." I do not agree with the statement in Conclusion #2 about the safety of treated water: "Further evaluation of the exposure to the mixture of PFOS, PFOA, PFHxS, and PFNA indicates that the risk for harmful developmental or immune effects is not likely to be more than what might be expected from exposure to any of these PFAS alone." This statement may be true on the face of it for these four compounds. But these 4 PFASs occurred in a cocktail of many other PFASs, some identified and most not. It is misleading to imply that PFASs mixtures in treated water are safe when only one subset of four PFASs was assessed.

Response: See responses to comments 2, 3, and 6 above.

Comment 9: Tables 2, 3, 4, and 5 indicate that PFHpA, PFHxA, and PFPeA lack health-based comparison values and will be included as part of the overall evaluation of mixtures. Is this analysis in the report? I couldn't find information on the mixture of these three PFASs.

Response: ATSDR could not do a complete mixtures health evaluation for these PFAS as was conducted for the four PFAS with provisional MRLs. However, we did research the scientific literature to determine what health information might be available. ATSDR discussed the common health outcomes associated with exposure to these PFAS and presented the results on Table A-1. In addition, as stated in this health consultation, ATSDR can make no definitive health conclusions for exposures to PFHxA, PFHpA and PFPeA. However, although PFHxA, PFHpA and PFPeA have not been studied as extensively as the PFAS with ATSDR provisional MRLs. Moreover, most of the PFAS detected with no ATSDR MRLs were short-chain and non-sulfonated indicating that they may bioaccumulate less than the longer-chain and sulfonated PFAS. However, health effects of many short-chained PFAS and new PFAS alternatives have not been fully researched.

Comment 10: Many states are wrestling with setting water standards for PFASs, with Massachusetts and Connecticut proposing a standard of 70 ppt for the sum of PFOS, PFOA, PFNA, PFHxS, PFHpA, and PFBS. It would be helpful if the ATSDR could give further discussion on the impacts of combined totals of PFASs. It is highly unlikely that drinking water will have only one or two of these compounds. Newington is already contaminated with a broad mixture of PFASs so addressing exposure to PFAS cocktails in our water is likely more important than addressing any one PFAS alone.

Response: At this time, ATSDR can only conduct a full mixtures evaluation of the four PFAS with provisional MRLs. To the extent possible, ATSDR discussed the available literature for other PFAS found in the Pease PWS and also discussed the relative toxicity of the most predominate PFAS detected in the Pease PWS as discussed in the response above.

Comment 11: Conclusion #3 on Breastfeeding. This conclusion is based on a general knowledge that breast feeding is beneficial and ignores any real analysis of PFAS bioaccumulation in breast milk. At best, the conclusion is preliminary and needs further analysis. Please take into consideration the following two milk-related PFAS reports:

- **Careful attention needs to be given to the Minnesota Department of Health's (MDH) study (Goeden et al., Journal of Exposure Science & Environmental Epidemiology 29:183–195, 2019) that shows that nursing babies and fetuses are exposed to the PFASs that are present in the mother and then pass on to the fetus during pregnancy and to the baby while nursing.**

Because mothers are bioaccumulating PFASs, the amount measured in drinking water alone is not indicative of deleterious health effects.

Response: ATSDR recognizes and discusses in this health consultation the well-known fact that PFAS are transferred from a nursing mother to her infant. Breastfeeding provides clear health and nutritional benefits to infants. These include protection from some illnesses and infections, and reductions in the risks for developing asthma and sudden infant death syndrome. In general, CDC recommends breastfeeding despite the presence of chemical toxins in breast milk. From what we know, the benefits of breastfeeding outweigh risk. However, the science on the health effects of PFAS exposure to mothers and children continues to grow. A woman's decision to breastfeed must be an individual choice — one that is made after consideration of many different factors, many unrelated to PFAS exposure, specific to the mother and the child. Information developed by ATSDR to guide doctors (see https://www.atsdr.cdc.gov/pfas/index.html) can aid in this decision-making process. Moreover, women who plan on breastfeeding should attempt to reduce potential exposures to toxic substances as much as possible. The American Academy of Pediatrics has made similar recommendations [AAP 2012]. The article cited in this comment provides similar conclusions and recommendations, as follows:

> ***Although PFOA, PFHxS, and PFOS can be excreted through breastmilk, MDH recognizes the important short- and long-term health benefits of breastfeeding for both mother and infant. MDH recommends that women currently breastfeeding, and pregnant women who plan to breastfeed, continue to do so. Exclusive breastfeeding is recommended by doctors and other health professionals for the first 6 months. It is unlikely that potential health concerns from infant PFOA exposure exceed the known benefits of breastfeeding.***

ATSDR recognizes that 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 (See https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf)

ATSDR has revised the health consultation to recommend that women who plan on breastfeeding should attempt to reduce potential exposures to toxic substances as much as possible and we have added a reference to the American Academy of Pediatrics policy on breastfeeding.

Comment 12:
In 2017, PFAS testing at Stoneridge Farm in Arundel, Maine found PFAS contamination of 50 ppt in the farm well, 7.93 ppt in the stream, 41.07 ppt in the pond, and 690 ppt in the milk produced by cows on the farm. I do not know the breakdown of specific PFAS chemicals (PFOA, PFOS,….) in this analysis but certainly the analysis demonstrates that cows that drink water with levels of PFASs less than 70 ppt can concentrate PFAS in their milk at concentrations at least 10 times higher than that found in the drinking water. Of course, part of the milk contamination on this farm may have come from cows eating contaminated grass, hay, or dirt in the fields. These other sources of contaminants must also be studied when assessing the impacts on human health from drinking milk (or eating beef).

Response: ATSDR acknowledges that PFAS contamination in milk and other food is an additional potential source of PFAS exposures. Persons who drank water from the Pease PWS in the past could have additional PFAS exposure if they drink milk from this farm or consumed other food containing PFAS. However, these exposures will likely vary depending on the source of a family's food. In general, ATSDR agrees that other sources of PFAS exposures in food is a growing concern and needs further investigation and we do not have data to evaluate these exposures in the community.

Comment 13: Other potential exposure pathways to human health. I appreciate the work the ATSDR has put into the PFAS issue in this health consultation on the Pease public drinking water system. Some other equally important health consultations include the following:

- **Drinking from contaminated well water – Health Consultation expected by end of 2019.**
- **Eating contaminated wildlife (turkeys, deer, fowl) – Health Consultation needed (see attached Appendix).**
- **Eating agricultural products, such as eggs, meat, and milk that were produced on fields close to the contaminated water table – Health Consultation needed.**
- **The potential of inhalation exposure from the operation of the vapor extraction system at the two fire training sites at Pease. These systems ran for over ten years, and pumped water having extremely high levels of PFAS from multiple ground wells before discharging the treated water back into recharge trenches. Though the system was mostly closed, no analysis has been done to assess when, if, or how 8 PFASs may have been released into the air. Site 8 is very close to the Air National Guard facility – Health Consultation needed.**

Response: ATSDR will release a health consultation of PFAS exposures to users of private wells in Newington and Greenland. ATSDR does not have any exposure data on the various food products discussed in this comment to evaluate the public health implications. PFAS do not readily evaporate into the air. ATSDR does not expect any significant inhalation exposures to PFAS from the operating extraction system on the base as compared to other pathways. However, ATSDR does not have any exposure data to confirm this conclusion.

Comment 25:

It should be noted that this study is extremely conservative in its approach and does not accurately reflect the conditions encountered at Pease. For example, the study looks at 100% of PFAS exposure originating from drinking water. As PFAS have historically been used in numerous consumer products that an average population would come into frequent contact with, a 100% relative source contribution from drinking water is a false representation of the environment we live in. While the conclusions in the report include the language of uncertainty, such as "…could have increased the risk for harmful health effect…", these conclusions, based on highly conservative calculations, may have unintended ramifications for public water suppliers. The conclusions should be bracketed with the assumptions and short fallings of the study to further elaborate on the uncertainty associated with this work. These uncertainties, if presented clearly and concisely, help to prevent the study's conclusions from being interpreted carte blanche.

Response: The assumption of a 100% relative source contribution is the standard approach taken by ATSDR when evaluating site-related exposures in our health assessment documents. The goal of this health consultation is to better understand site exposures and to determine if harmful effects are possible. To do that, ATSDR must compare estimated PFAS exposures from the Pease PWS to various health-based comparison values and health effect levels. ATSDR acknowledges that persons exposed through the Pease PWS could have PFAS exposures from other sources in their homes or through their food. These other exposures are evaluated in a qualitative way in this health consultation.

ATSDR has included an extensive list of uncertainties related to this health consultation in the public comment version and has added in additional uncertainty statements to address public comments. These uncertainties may under- or over-estimate actual exposures, so no additional caveats on our conclusions are needed.

Comment 26:

It is recommended that a cover letter be added to accompany the report. The cover letter should clearly explain the findings of the study and explain the significance of the various findings. The assumptions associated with the study should also be highlighted. This cover letter should be written in such a manner to allow the general public, with a vast array of scientific and non-scientific backgrounds, to understand.

Response:
The accompanying factsheet was developed to assist the reader understand the key findings of the health consultation.

Comment 27:
While the study does show some potentially concerning findings associated with PFAS exposure at Pease, the commenter would like to highlight a few relevant statements regarding the Pease water system moving forward:

a. **Since the shutdown of the Haven Well, water from the Harrison and Smith Wells, either blended to lower PFAS concentrations or filtered through temporary granular activated carbon filters, is not expected to have harmful effects on human health.**

   Response: Comment noted.

b. **Not all PFAS appear to have the same health outcomes. Short chain compounds and those with non-sulfonated head groups may be less toxic based on current research and the focus of treatment should be on the longer chain compounds with known negative health outcomes. To quote the EPA: "While persistent in the environment, PFCA chemicals with fewer than eight carbons, such as perfluorohexanoic acid (PFHxA), and PFSA chemicals with fewer than six carbons, such as perfluorobutane sulfonic acid (PFBS), are generally less toxic and less bioaccumulative in wildlife and humans. Additional health studies may be required to confirm this understanding. Additionally, short chain PFAS do not appear to have significant bioaccumulation properties, with a human half-life of less than a week. This is highlighted in MDH's Toxicological Summary for: Perfluorobutanoate (https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw /pfba2summ.pdf).**

   Response: ATSDR generally agrees with the statements in the comment and these findings are already in the public comment version of the Pease PWS Health Consultation. ATSDR agrees that 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 more persistent in the environment and generally less bioaccumulative in wildlife and humans. However, health effects of many short-chained PFAS and new PFAS alternatives have not been fully researched. The health consultation was updated to make this clear.

c. **The permanent water treatment system design is expected to remove all PFAS contaminants. Portsmouth water operators will follow all federal and state guidelines and requirements to ensure the treated water meets current water quality standards.**

   Response: This is also ATSDR's understanding.

Comment 30:
While the commenter acknowledges that additional testing and research is required to understand the health effects of the vast majority of PFAS in the environment, the limitations associated with this lack of knowledge and the calculations conducted in this study should be presented and explained so that all reading the report may better understand the conclusions.

Response: The public comment version of the Pease PWS Health Consultation contains a section that describes all of the limitations and uncertainties of evaluating the human health risk from PFAS exposures. In addition, based on other public comments received, ATSDR has also added in the uncertainty regarding the AFFF formulation and what other PFAS chemicals might have been present in the drinking water.

Comment 31:
Page ii states: "Since the Haven well was shut down, the Harrison and Smith wells have continued to provide water for the Pease Tradeport PWS, supplemented by water from the City of Portsmouth PWS (ID 1951020)." The PWS ID number for the Pease Tradeport is 1951020 and the PWS ID number for the City of Portsmouth is 1951010. This should be clarified in the report.

Response: Updated as suggested.

Comment 32:
Page ii states: "Drinking water sampling from June 2014 through May 2017 indicated that the maximum detected PFOS concentration was equal to ATSDR's health-based comparison value (HBCV) at the New Hampshire Department of Environmental Services (NHDES) office and above the HBCV at the water treatment plant." The demonstration GAC filters were operational in September 2016. The dates in the report should reflect this.

Response: Updated as suggested.

Comment 33:

On page iii, the laboratory used to analyze PFAS samples is spelled incorrectly. The laboratory is Maxxam Analytics and not Maxxim Laboratory.

Response: Updated as suggested.

Comment 34:

Page 2 provides an overview of PF AS compounds. Background information regarding the preliminary and updated health advisories for PFOA and PFOS would be helpful for the drinking water system regulatory perspective. An explanation of health advisory versus Maximum Contaminant Level (MCL) regulations would be useful as well (see https://www.epa.gov/dwstandardsregulations/drinking-water-contaminant-human-health-effects-information for more information).

Response:
Added: The EPA developed a Lifetime Health Advisory for PFOS and PFOA (singly or combined at 0.07 ppb) on May 25, 2016.

Comment 35:

Page 2 states: "The City of Portsmouth operates ... " This sentence should be updated to say, "The City of Portsmouth operates and maintains the Pease Tradeport PWS through an intermunicipal agreement with the Pease Development Authority (PDA)."

Response: Updated as suggested.

Comment 36:

Page 2 states: "Three wells (identified as Harrison, Haven, and Smith) supplied or supply water to the Pease Tradeport PWS. Water from these wells is disinfected and iron is removed. The water is then treated for corrosion control and mixed to provide drinking water." The _ proposes this section read as follows: "Three wells (identified as Harrison, Haven, and Smith) supplied or supply water to the Pease Tradeport PWS. Water from these wells are blended together and then three chemicals were added to the water: sodium hypochlorite (disinfection), hydrofluorosilicic acid (dental cavity prevention), and ortho/polyphosphate (iron and manganese sequestration and corrosion control). This water is then blended with supplemental water boosted from the Portsmouth PWS and sent to the distribution system."

Response: Updated as suggested.

Comment 37:
Page 2 states: "Although PFAS were detected in each well, only the Haven well had elevated levels." The reference to elevated levels should be clarified as "levels above the EPA provisional health advisory."

Response: Updated as suggested.

Comment 38:
Page 3 footnote should be updated to say that, "The Pease and Portsmouth water systems have always been interconnected. In fact, prior to the construction [of the Pease Air Base, the Haven Well was one of the primary sources of supply for the City of Portsmouth, with a history of use dating back to the late 1700's."

Response: Updated as suggested.

Comment 39:
Page 4 should add the statement that, "Water was routinely tested by the water system operators according to the monitoring plan set for by the NHDES."

Response: Updated as suggested.

Comment 40:
Page 4 footnote that says, "A vote was held by the Portsmouth Planning Board to reactivate the Harrison well." Additional information should be added to say, subsequently, the well was tested, designed and approved by the NHDES for reactivation in 2006."

Response: Updated as suggested.

Comment 41:
Page 5 states: "Pilot testing for the Haven well treatment system started in 2017..." The pilot testing at the Haven Well concluded in 2019 and should be included in the report. It is also recommended that the report mention in this section that construction of the permanent treatment system is currently underway with an anticipated completion date in 2021.

Response: Updated as suggested.

Comment 42:

Page 5 should be updated to state that "the activated carbon demonstration filters continue to filter the Harrison and Smith wells while the final treatment system for all three wells is constructed. The pilot testing of the Haven Well confirmed that resin filters in combination with activated carbon would provide the most efficient treatment of PFAS compounds. The construction project was bid in late 2018 and construction began in April 2019 with completion of the system scheduled for late 2021."

Response: Updated as suggested.

Comment 43:

Page 5 states: "The Airfield Interim Mitigation System is expected to be built in 2019." The system is also operating at a reduced flow rate as of the writing of this report.

Response: Updated as suggested.

Comment 44:

Page 8 should add the comment that, "the weekly sampling of the wells was changed to monthly sampling after the demonstration filters were installed on the Smith and Harrison wells in September 2018. That sampling continues."

Response: Updated as suggested.

Comment 45:

Page 8 refers to Table A-4 for sampling results of the Haven Well. Additional information on subsequent sampling was provided by the City of Portsmouth to Gary Perlman via email on March 17, 2019.

Response: It is unclear what the first part of this comment is referring to as page 8 of the public comment version of this health consultation refers to sampling results from the Harrison and Smith wells which was summarized in Table A-4. ATSDR did receive and review subsequent sampling results provided by the City of Portsmouth on March 17, 2019.

Comment 46: The following comments relate to differences in PFOS levels found in the Haven well in 2014 and in subsequent sampling:

a. **PFOS Levels at the Haven Well. The Haven Well, while off-line from the drinking water system, has periodically been sampled for PFOS as part of the treatment system design and piloting effort since 2014. This data has previously been submitted to the ATSDR, showing results that are almost half of what they were as sampled in 2014 prior to the shut-down of this well. This may be due to the dilution factor and methods of the testing analysis in 2014. As pointed out in the information the City has provided the other compounds all have similar levels. Only PFOS is significantly different. We believe that this is not due to a reduction in PFOS levels but more accurate laboratory methods.**

b. **The original round of sampling by the Air Force's consultant in April and May 2014 had an average PFOS concentration of 2,450 ppb. A follow-up sample in May 2014 taken by the New Hampshire Department of Environmental Services resulted in a concentration of 1,900 ppb for PFOS. Subsequently, the City's consultant pump-tested the well to do some comprehensive water quality analysis in 2016 and the PFOS results averaged 1,200 ppb. Finally, 13 rounds of testing from November 2017 to June 2018 during their treatment system piloting (Granular Activated Carbon and Resin comparison testing) and had an average result for PFOS of 1,377 ppb. As shown in the data, except for PFOS, all the other compounds were fairly consistent from the 2014 sampling event.**

c. **It is our understanding that the Air Force's sampling as part of their AIMS water treatment system design and construction project has seen PFOS levels closer to the 1,200 to 1,400 ppb results that we have seen since the original samples were taken in 2014. We recommend that ATSDR check with the Air Force to confirm.**

Response: ATSDR confirmed with the USAF that the PFOS levels were in the range of 1,200 to 1,400 parts per trillion (not ppb as indicated in the comment). Although there is some uncertainty about the validity of the 2014 PFOS sampling as indicated by the commenter, it is ATSDR's understanding that the laboratory still considers these results valid. In addition, one reason why the PFOS levels were reduced in later sampling could be because of the effects on groundwater hydrology after the shutdown of the Haven Well.

Comment 47:
Page 16, Table 5, provides a footnote describing how ATSDR derived value for children's exposures. Did this value take into account that those drinking this water were only doing so when at Pease and not 24/7?

Response:
Yes, ATSDR adjusted the exposure scenario to account for non-residential exposures. ATSDR uses an exposure factor of 5/7 to adjust for exposures in a school or occupational setting as was the case for PFAS exposures from the Pease PWS drinking water.

Comment 48:
Page 17, Public Health Implication of Exposure to PFAS in Drinking Water. Please explain what "lifetime exposures" mean in the realm of drinking water health advisories and regulations.

Response: ATSDR cannot locate the phrase "lifetime exposures" in the section referenced in the comment. In other sections, the document refers to EPA's health advisory or HA which may be what the comment is relating to. If so, a Health Advisory refers to a concentration that is not expected to cause adverse health effects over a lifetime of consistent daily exposure at that level.

Comment 49:
Page 38. The statement that "the USAF continue working with EPA and NHDES to implement a long-term remedy," should be updated. The EPA issued Administrative Order SDWA-01-2015-016 to the Air Force in August 2018 which required the Air Force to treat the Haven Well and the effected aquifer at the former Pease Air Base. Subsequently, actions have been taken by the Air Force to implement the order.

Response: Updated as suggested.

Comment 50: One commenter provided some additional comments regarding the overall study regarding the history of fire-fighting foam use at Pease, as follows:

a. **The commenter has been actively involved with the hydrogeological and scientific review of the PFAS contamination at the Pease Tradeport since the sampling event in 2014 that resulted in shutting down the Haven Well. The technical team of Hydrogeologist, scientists and regulators have performed an extensive amount of field sampling and analysis throughout the former Pease Air Base. One of the assessments of this group is that contamination of the Pease wells from the former fire training center and other sites away from the Haven well likely did not have much contribution to the PFAS levels. Other than the 90,000 gallons of fire-fighting foam used to put out the KC-135E Fire at Pease AFB in January 1990 there are if any unknowns regarding the past use, makeup and volumes of fire-fighting foam that may have been discharged on the ground and eventually absorbed into the aquifer.**

b. **It would be most helpful from an historical perspective if this study were to further investigate the history, types and volumes of PFAS contaminant events at the former Pease Air Base to be able to reconstruct what the levels may have been years ago. It is possible that prior to the fire in 1990 the Haven Well may have had lower PF AS levels than found in 2014 and that people living and drinking the water when on the base were not exposed to significant levels of PF AS in the drinking water.**

c. **Questions have also arisen as part of the Pease Restoration Advisory Board (RAB) about what compounds and volumes of fire-fighting foam, and other potential contaminants, were used at the base and the airport. This information would also be most helpful in gaining more insight to the response to contamination as part of the RAB's work.**

Response: ATSDR agrees that there are many uncertainties relating to the amount, type, and formulation of the AFFF used at the former Pease AFB. For this health consultation, we must rely on the results of our modeling to provide a reasonable estimate of what past exposures between 1993 and May 2014 might have been. Additional work to better understand these past exposures is being conducted in relation to the ATSDR Pease Health Study. In addition, ATSDR has revised the health consultation to recommend to the USAF that they should consider doing additional work and research to better understand the type and formulations of AFFF used at Pease and other facilities to inform future monitoring efforts and health assessments.

Comment 51: The commenter would like to thank the ATSDR for consideration of these comments. The commenter would also like to thank the ATSDR for their work on this important and rapidly developing issue.

Response: Comment noted.

Comment 52:

Summary of Key Findings/Bullet point #2. Stating the phrase: "…can depress the immune system….", implies definitive evidence for a causal relationship between PFAS exposure and health effects. Update the bullet point to: "…may or have the potential to depress the immune system…".

Response: The National Toxicology Program (NTP) concludes that PFOA and PFOS are *presumed to be an immune hazard to humans* based on a high level of evidence that PFOA suppressed the antibody response from animal studies and a moderate level of evidence from studies in humans (NTP, 2016). Based on these determinations, "can" is an appropriate word to use in this context. No change made.

Comment 53:

The document is difficult to understand in a general sense and requires revision that would improve its readability - especially for the public. For example, on page iii the Basis for Conclusion section contains language that is redundant and can be streamlined. More specifically for example, "the estimated exposure doses" should be revised to "the estimated exposure. Revise the overall report language for understanding and readability, such as the example provided in the comment.

Response: ATSDR will make the changes as suggested in the comment. The health consultation summary and fact sheet that accompanied the release of this document is intended for a lay audience.

Comment 54:

There are several technical points that are incorrect or make broad assumptions that should be corrected. For example, it is incorrect to state on page iii that "the cancer risk from past exposure to all PFAS ...is uncertain" while not necessarily incorrect, implies that all PFAS are carcinogens. Which is not the case. So the statement is highly misleading. In fact the document goes on to acknowledge that there is only a slope factor for PFOA. Revise the report language with regard to technical points to ensure there are no unclear, incorrect, or misleading statements such as the example provided.

Response: ATSDR will add in a statement that clarifies that not all PFAS are carcinogenic.

Comment 55:

The document is burdened with jargon such as references to screening values such as MRLs and HBCVs. The document should be rewritten to exchange these acronyms with a description of the sensitive population they are developed to protect. For example, regarding HBCVs the document should describe that be values are protective of children of less than one year old. Revise the report language with regard to screening values in order to provide clarity in the applicability of the screening values to the populations (public) reading this document.

Response: ATSDR's public health assessment documents are intended for both a technical and lay audience. The ATSDR fact sheet that accompanied the release of this health consultation is written for the general public. ATSDR defined all terms and explained how they were used in the evaluation process. No change is indicated.

Comment 56:

On page iii and iv there are contradicting statements regarding discussion of the risk associated with exposure to mixtures. Pg. iii. "The combined exposures to a mixture of PFOS, PFOA, PFHxS, and perfluorononanoic acid (PFNA) could have increased the risk for developmental and immune effects above what might be expected from exposure to any of these PFAS alone." Pg. iv. "Further evaluation of the exposure to the mixture of PFOS, PFOA, PFHxS, and PFNA indicates that the risk for harmful developmental or immune effects is not likely to be more than what might be expected from exposure to any of these PFAS alone. Revise the language in these sections, and any corresponding sections in the report, to clarify which of these statements is correct. Make the needed corrections.

Response: ATSDR was able to locate the language on page iii that the commenter refers to, but not the language on page iv. The language referred to in this comment is on page v under Conclusion 2. These statements are correct as the first refers to the evaluation of exposure from 1993 to May 2014, which is part of the basis for Conclusion 1. The second statement refers to exposures after May 2014 and is part of the basis for that conclusion. No changed indicated.

Comment 57:

The last sentence in this paragraph states the new system is expected to begin operation near the end of 2018. This period has past. Update with the appropriate data of operation.

Response: Updated to 2021.

Comment 58:
Monitoring Outcome... Add a period at the end of the sentence, following May 14, 2014.

Response: Updated as stated

Comment 59:
The section does not provide enough information on the sources for and the development of the HBCVs. Revise this section to more clearly state the process for selecting and/or developing the HBCVs.

Response: Beyond ATSDR's HBCVs which are based on the provisional MRLs and well-documented in the ATSDR draft PFAS Toxicological Profile, ATSDR generally will use the most conservative HBCV from other reliable sources if they are peer-reviewed. As more states and federally derived health-based and peer-reviewed values become available, ATSDR will consider adding more HBCV to use in our health assessment work.

Comment 60:
Firstly, the commenter would like to commend the ATSDR for the thorough and well-written health consultation it has provided for public comment, as well as thank the agency for the time permitted to review the document.

Response: Thank you for the comment.

Comment 61:

"Conclusion 1: As a part of the basis for this conclusion, ATSDR described some of the epidemiological and animal data used to consider carcinogenic potential of PFAS exposure. _ understands that the existing toxicological database is limited in regards to definitively classifying PFOA (or other PFAS) as carcinogens. However, the text on page iv appears to lack precision in describing the uncertainty around findings from animal studies. The commenter appreciates the difficulty in communicating the technical interpretation of these findings in animal studies as they relate to unknown cancer risk. Nevertheless, as presently written this could lead to the perception that ATSDR is drawing a link between two animal studies and a definitive risk for cancer in humans. As a part of its public comment, the commenter recommends a review of this paragraph and consideration of more appropriate risk communication that conveys: 1) the limits (essentially 2 studies) that inform this statement, 2) the evolving nature of the science around the scientific community's understanding of PFAS and cancer, and 3) an understanding of the region's specific concerns to cancer(s). With regards to this last point, the Seacoast region and its communities have concerns about potential cancer clusters due to previous reports (NHDHHS 2016, 2017) and statistics offered to the CDC (https://www.cdc.gov/cancer/dcpc/data/index.htm). Thus, it is recommended that this point is clarified to avoid unintentional conflation with any cancer concerns in this community. While there is clear uncertainty surrounding the cancer risks of PFAS, it would be beneficial for the major conclusions of the ATSDR to be more clear given their authority and trust from the public"

Response: The basis for the first conclusion on the cancer risk related to PFAS exposures is a summary of the full description of the state of scientific knowledge relating to animal and human studies which is contained in the body of the health consultation report. ATSDR believes that the full description of the cancer evaluation in the text lays out the primary points and uncertainty in relation to how animal and human studies inform our knowledge on PFOA and PFOS exposures and cancer in humans. ATSDR does not believe any further explanation is needed for this report. ATSDR is aware of the concerns in the Seacoast Region regarding childhood central nervous system and other cancers. This report does not evaluate any health statistics in relation to cancer risk for the exposed Pease population. However, it does estimate what a cancer risk may be in relation to PFOA exposures and describes all the uncertainty related to estimating a cancer risk for PFOA, PFOS, and other PFAS that may be carcinogenic. 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. Since the health consultation explains what cancer evaluation may be undertaken, ATSDR does not see the need for any further explanation of what was reported in the health consultation and what is being attempted in the Pease Health Study or other studies being conducted to look at childhood cancers in the Seacoast Region.

Comment 62:

"Conclusion #3: The commenter agrees with this statement and does not dispute the benefits of breastfeeding relative to the existing body of knowledge regarding early-life risk associated with PFAS exposure. _ believes that the later discussion on this issue (page 32 - Community Concern: Breastfeeding Exposures and Health Implications) should provide further details on this as recent risk assessment tools (i.e., Goeden et al. 2019) suggest that breastfeeding not only results in elevated infant serum levels of PFAS, but may result in chronically elevated serum levels through adolescence. Again, the benefits of breastfeeding on an infant's health and well-being are clear. Yet, relative to the ATSDR MRLs, the discussion at this point should reflect the knowledge that PFAS have extraordinary half-lives (i.e., protracted serum levels into adolescence) and that the ATSDR considered not only infant but the subsequent benefits of breastfeeding on childhood."

Response: Please see response to Comment 11.