Letter Health Consultation

Perfluorochemicals (PFCs) Contamination in Public and Private
Drinking Water Sources near the

FORMER NAVAL AIR WARFARE CENTER

WARMINSTER, BUCKS COUNTY, PENNSYLVANIA

JANUARY 20, 2016

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

Health Consultation: A Note of Explanation

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:

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January 20, 2016

Karen Melvin
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Dear Ms. Melvin:

On September 24, 2014, the United States Environmental Protection Agency (EPA) Region 3 Hazardous Site Cleanup Division requested a public health evaluation from the Agency for Toxic Substances and Disease Registry (ATSDR) on the perfluorochemicals (PFCs) contamination in public and private drinking water sources near the Former Naval Air Warfare Center (NAWC or also known as "the site"), Warminster, Bucks County, Pennsylvania ("the site"). The Department of the Navy (Navy) is the lead agency in the investigation. This Letter Health Consultation evaluates the public health implications of exposure to PFC contamination in these drinking water supplies, and supports the federal agency activities by the EPA and the Navy to further characterize and reduce exposures in the Warminster area.

Perfluorooctane sulfonate (PFOS) is the PFC of primary health concern in public and private water supplies at this site. Based on the current toxicological literature, which relies heavily on animal studies, ATSDR finds that exposure to the maximum levels of PFOS found in private and public drinking water supplies at this site were a past public health hazard. It is important to note that ATSDR used the maximum environmental sampling concentration at private and public wells to develop this conclusion. ATSDR used this conservative approach due to the uncertainty in the emerging science for this contaminant class, and the uncertainty in the historical sampling data and exposure duration at the site. ATSDR concurs with the EPA's and Navy's approach at this site to reduce exposures to PFCs in public and private drinking water sources at this site as a protective public health action.

At this time, neither ATSDR nor EPA have any chronic health-based comparison values for PFCs, with the exception of EPA's chronic value for PFBS. Most of the information regarding the effects of PFCs in animals is derived from oral studies; considerably less information is available from inhalation and dermal exposure studies. There is uncertainty in the potential health effects of people exposed to PFCs in their drinking water. The available epidemiology data identify several potential targets of toxicity of PFCs, and individuals with certain pre-existing health conditions (e.g., elevated blood pressure or cholesterol) may be unusually susceptible. We are not certain if children, infants, pregnant women, or lactating women have unique susceptibilities to exposure to PFCs.

Due to the preventative actions taken by the Navy, public and private water supply users in the site area are not currently being exposed to PFCs at or above the current EPA Provisional Health Advisory Level (PHAL) of 0.2 µg/L for PFOS and 0.4 µg/L for PFOA in drinking water. ATSDR recommends (1) EPA and the Navy should continue efforts to conduct additional characterization of the groundwater contaminated with PFCs at this site, as well as continuing the ongoing private well monitoring; (2) the Navy should continue to implement a long-term remedy at this site to permanently mitigate public exposures to PFC-contaminated public and private drinking water sources; (3) the Navy should conduct follow-up characterization of other non-drinking water potential environmental exposure pathways to PFCs in the site area (e.g., fish), if site information indicates these other exposures pathways might exist; (4) community members with private well water that exceeds the PHAL for PFOS should continue to reduce their exposure by using the provided bottled water for drinking and cooking, until they are connected to the public water supply; (5) to reduce potential exposure of formula-fed infants, caregivers should use pre-mixed baby formula or reconstitute dry formula using alternative water sources not containing PFCs; and (6) health education information related to PFCs and public health should continue to be developed and shared with community members and area health professionals.

The remainder of this letter details the supporting information of how we arrived at the conclusions above. Attachment A provides a summary of the available toxicological data and the potential health effects data for PFCs, and Attachment B provides summary tables and figures specific to this evaluation.

1. Background

Site Background

The former Naval Air Warfare Center (NAWC) is located in Warminster Township. The public water supply for customers of the Warminster Municipal Authority (WMA) is provided by 18 public water supply wells. The former NAWC site is located in proximity to only four of the 18 supply wells. The 824-acre former NAWC was used to research, develop and test naval aircraft systems from 1944 to 1996. The site is located in a populated suburban area surrounded by private homes, various commercial and industrial activities, and a golf course. The area encompassing the former NAWC includes various buildings and other structures connected by paved roads, mowed fields, and a small wooded area (EPA 2012). Wastes were generated during aircraft maintenance and repair, pest control, firefighting training, machine and plating shop operations, spray-painting, and various materials research and testing activities in laboratories. Wastes included paints, solvents, sludge from industrial wastewater treatment, and waste oils. In 1989, the NAWC site was added to the EPA National Priorities List (NPL) under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA, also known as Superfund) because of groundwater contamination with volatile organic compounds (VOCs) (ATSDR 2002). The Navy is charged with fulfilling the obligations under CERCLA. The Navy installed water treatment systems in more than 40 homes and connected more than 60 homes to public water systems in the early 1990s, and the EPA and the Navy installed groundwater treatment systems designed to remediate the primary VOC contaminants of concern (EPA 2012). In 2002, ATSDR published a public health assessment focusing on the VOC contamination at this site. This public health evaluation pre-dated the 2013 monitoring and detection of perfluorochemicals (PFCs) and therefore did not include an evaluation of PFC exposures (ATSDR 2002).

Aqueous film-forming foam (AFFF) containing PFCs appear to have been available since the mid 1960s or 1970s (Prevedouros et al 2006, ATSDR 2015, NRL 2015). Firefighting training activities have been conducted at NAWC for decades using AFFF. At the NAWC, PFCs were first tested for in groundwater as emerging contaminants in preparation for the CERCLA 2012 Five Year Review for this site. In summer 2013, levels of PFCs at or above the PHAL were first discovered in groundwater on the former Navy property (EPA 2015a).

Independent of the site activities related to the NPL listing for NAWC, at the national level EPA recently required many public water systems, including the WMA, to sample for 30 contaminants under EPA's Unregulated Contaminant Monitoring Rule 3 (UCMR3). As part of this initiative, sampling for PFCs in the Warminster water system first occurred in November 2013 (EPA 2014c). The six PFCs included in the UCMR3 sampling were perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanoic acid (PFHpA), and perfluorobutanesulfonic acid (PFBS) (EPA 2015d). Samples taken in the WMA system detected levels of PFOS, PFOA, PFHxS and/or PFHpA.

In response to the detections of PFCs in onsite monitoring wells and the offsite public drinking water wells, in 2014 the Navy requested that EPA provide technical expertise to determine if private drinking water wells in the area of NAWC were impacted. As of September 2015, 100 private wells (94 residential and 6 non-residential) were identified and sampled within an approximate 1-3 mile radius of the site. At least one PFC was detected in the majority (93 out of 100) of these private water wells.

As a result of the levels of PFCs detected in public and private drinking water supplies, interim actions were taken to reduce these exposures. In 2014, three public drinking water supply wells in the WMA system were taken off line and are no longer being used for drinking water. The Navy and EPA provided a limited number of residents whose private well water was at or above EPA's PHAL (with rounding up to one significant digit) with bottled water to use for drinking and cooking water, and is currently working to connect these locations to public water. A subset of additional private water wells with lower levels of PFCs (within 25% of the PFOS or PFOA PHALs) are being monitored through quarterly resampling. The Navy, EPA and WMA are currently implementing a long-term plan to address the PFC groundwater contamination in the public water wells at the site.

2. Results and Public Health Screening Evaluation

ATSDR conducted a three step process to evaluate the public health implications of the PFC contamination in drinking water supplies at this site. First, ATSDR conducted an exposure pathway analysis. Second, ATSDR conducted a screening analysis of the environmental sampling data against health-based comparison values. Third, ATSDR conducted a more detailed public health evaluation of contaminants of concern identified in the screening analysis.

Exposure Pathway Analysis

To determine whether residents are exposed to contaminants migrating from the site, ATSDR evaluated the environmental and human components leading to human exposure. That pathways analysis consists of five elements: a source of contamination; transport through an environmental medium; a point of exposure; a route of human exposure; and an exposed population. ATSDR classifies exposure pathways as completed, potential, or eliminated. For a completed pathway to exist, five elements must be present, and there must be evidence exposure to a contaminant has occurred, is occurring, or will occur. In the case of a potential pathway at least one of the five elements is missing, but could exist. Potential pathways suggest that exposure to a contaminant could have occurred, could be occurring, or could occur. A pathway is eliminated when at least one of the five elements is missing and will never be present. PFCs are present in both public and private drinking water supplies at this site. Due to the preventative actions of the Navy, public and private water supply users in the site area are not currently being exposed to PFCs at or above the PHAL. Therefore, exposure to the levels of PFCs above the PHAL in public and private water supplies is considered a past completed exposure pathway at this site.

Screening Analysis

Following identification of a completed exposure pathway, ATSDR conducts a screening analysis of detected chemicals against health-based comparison values. There are health-based comparison values available for four of the six PFCs monitored for in drinking water supplies at this site.

In 2009, EPA's Office of Water established a PHAL of 0.2 µg/L for PFOS and 0.4 µg/L for PFOA in drinking water. These values are based on short-term exposure, assume a 20% relative source contribution of the contaminant from drinking water, and are protective of children for short-term exposures. Both of these PHAL values rely upon subchronic (e.g., 5-90 day durations of exposure) data (EPA 2009). EPA generally defines subchronic exposures as repeated exposures by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10 percent of the human lifespan (EPA 2015c). EPA's PHALs for PFOS and PFOA may not be protective of long-term exposures. EPA's PHAL values are provisional and under agency review.

In 2014, EPA developed provisional peer-reviewed toxicity values for chronic and subchronic exposure durations for PFBS. EPA's chronic value for PFBS is a provisional Reference Dose (RfD) of 0.02 mg/kg-day (EPA 2014d). Using this provisional RfD, EPA developed a tap water Risk-

Based Screening Level (RSL) of 380 µg/L using a child's intake parameters and a hazard index of 1 (EPA 2015e).

There are also state health-based screening values for PFCs. The New Jersey Department of Environmental Protection (NJ DEP) developed a guideline for chronic (lifetime) exposures to PFOA of 0.04 µg/L (New Jersey 2007), and a draft interim specific ground water criterion for PFNA of 0.01 µg/L (New Jersey 2015). The Minnesota Department of Health developed a chronic Health Risk Limits of 0.3 µg/L for PFOA and PFOS, and 7 µg/L for PFBS and PFBA (Minnesota 2015). In Michigan, the Michigan Department of Environmental Quality has established a standard of 0.42 µg/L for PFOA for surface water bodies used as a source of drinking water (Michigan 2015).

In 2015, ATSDR established a draft intermediate duration oral exposure dose called a Minimal Risk Levels (MRLs) for PFOS and PFOA of 3×10^{-5} mg/kg/day and 2×10^{-5} mg/kg/day, respectively.[1] An MRL is defined as an estimate of daily human exposure dose to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. ATSDR defines an intermediate duration of exposure as 15–364 days (ATSDR 2015). There is limited information on whether PFCs can cause cancer in humans. The International Agency for Research on Cancer and the Department of Health and Human Services have not yet evaluated the carcinogenicity of PFCs; EPA has begun an evaluation (ATSDR 2015). At this time, there are no cancer slope factors or cancer risk evaluation guidelines for these compounds. Therefore, we cannot quantitatively evaluate the cancer risk for PFCs.

To be consistent with the ongoing federal response by the Navy and EPA at this site, ATSDR screened the water sampling data at the Warminster site using the EPA PHAL values for PFOS and PFOA, and incorporated their rounding procedure. For the PFCs that do not have EPA PHALs, ATSDR used EPA's provisional RfD/RSL and available state screening values. Specifically, ATSDR used the New Jersey value for PFNA, and the EPA RfD/RSL value for PFBS. ATSDR was not able to locate any screening values (federal or state) for PFHxS or PFHpA.

The following sections describe in more detail ATSDR's screening analysis of the public and private water PFCs results at this site. This information is summarized in tabular format in Attachment B to this document (Table 1 summarizes the public water supplies, Table 2 summarizes the private residential water wells, and Table 3 summarizes the private non-residential water wells.)

PFOS levels above the health-based comparison value were detected in both public and private drinking water samples. Only one private well (an industrial non-residential well) had exceedances of other PFC health-based comparison values (i.e., PFOA and PFNA); this industrial well also had an exceedance of the PFOS comparison value. No public or private wells had

[1] ATSDR's Toxicological Profile for Perfluoroalkyls, including the PFOS and PFOA MRLs, are draft and undergoing public comment through December 1, 2015.

exceedances of the PFBS comparison value. There is only limited toxicological information available to further evaluate PFNA, PFHpA, and PFHxS. Only one industrial well with limited consumptive use had close to an exceedance of the PFOA PHAL (rounding up the result from this well equals the PFOA PHAL). Therefore, ATSDR selected PFOS only as a contaminant of concern for more detailed public health review in section 3 of this document.

Public Water Supplies

The WMA provides water to approximately 40,000 people. The water supplied to the customers is from 17 public water supply wells in the WMA system, and may be purchased from the North Wales Water Authority (NWWA), as well as the Upper Southampton Municipal Authority on an emergency basis. UCMR3 monitoring for PFCs is required at the entry point to the distribution system for each well and at any interconnection that is in operation. Accordingly, WMA conducted sampling in November 2013 and May 2014 for all wells and conducted sampling in November 2013 and February, May, and August 2014 for the interconnection with NWWA. WMA's water supply wells are connected individually to the distribution network. A generalized schematic of this type of system is shown in Figure 1. For the WMA system, contributions from the various public water supply wells are connected directly to the network and are blended within the distribution system. Therefore, customers located geographically closest to a given water supply well will likely receive more water from that well than users located further away. (PADEP 2005, Hoover 2015).

In November 2013, the Warminster public water supply was first sampled for PFCs under UCMR3. Three of WMA's public water wells were identified at that time with levels equal to or greater than EPA's PHAL for PFOS. In this sampling event, 17 samples covering 17 wells in the WMA and one sample of the NWWA interconnection were taken and analyzed for PFCs. One of the 17 WMA samples represents the combined water extracted from WMA Wells 43 and 44. Water from these two wells is combined for treatment and samples are taken after treatment at the entry point to the distribution system (Hoover 2014). PFOS was detected in 6 public wells and PFOA was detected in 8 public wells. PFOS was detected in Well 26 at 0.791 µg/L, more than three times the 0.2 µg/L PFOS PHAL value. Wells 10 and 13 had PFOS concentrations of 0.193 and 0.16 µg/L that can be rounded to 0.2 µg/L.[2] None of the PFOA detections exceeded the PFOA PHAL in the WMA wells. Well 26 had the highest detections for PFOA and PFOS.

Additional sampling was then conducted to follow up on the November 2013 results. In early spring 2014, one sample of the NWWA intertie (at a horizontal connecting location) was taken and analyzed for PFCs; results from the NWWA intertie were non-detect for all the PFCs sampled. In summer 2014, WMA again took 17 samples covering the same 18 wells and one sample of the NWWA intertie for PFCs. PFOS was detected in 4 public wells. PFOS was detected in Well 26 at 1.09 µg/L, more than five times the 0.2 µg/L PFOS PHAL value and there was a detection of 0.176 µg/L in Well 10. PFOA was detected in four wells, including Well 26 at 0.349 µg/L, close to the 0.4 µg/L PHAL for PFOA.

[2] Sampling data reported by EPA's laboratory with 3 significant figures.

Wells 13 and 26 were shut down in June 2014. Well 10 was shut down in September 2014. Water from Well 26 is currently being treated and pumped to the local wastewater treatment facility. Well 26 is serving as a groundwater extraction component for part of the CERCLA remedy.

Five additional public wells in the vicinity of the site (not part of the WMA system) were sampled in July and August of 2014 by Weston Solutions, Inc. for EPA and there were no exceedances of the PHALs. Of the five wells, the well with the highest detections of PFCs (i.e., PFOS 0.151 µg/L and PFOA 0.0456 µg/L) that could have been considered to have a PFOS exceedance with rounding has never been brought into service.

Summary information for the public water sampling events at this site is presented in Attachment B, Table 1. In total, 23 locations were sampled. The 18 WMA locations were sampled twice. Of the 18 WMA well locations, 10 were non-detect for all 6 PFCs and eight wells had detections of one or more PFCs. Five samples from three locations exceeded the PFOS PHAL. Of the additional public well locations, one was non-detect for all PFCs and the other four wells had detections of three or four of the PFCs (PFOS, PFOA, PFHpA, and PFHxS). As stated earlier, contributions from the various public water supply wells in the WMA system are blended within the distribution system. Therefore, customers located geographically closest to the public water supply wells with PFC detections above PHALs received more water from those wells than users located further away. Some water customers could potentially have received the majority of their water from one of the contaminated wells in the past, but the majority of water customers likely received water that did not contain PFCs or contained PFCs less than the PHALs. To be conservative, for this evaluation ATSDR assumed that some public water users were exposed to the maximum levels of PFOS detected in the WMA well system.

<u>Private (Residential and Non Residential) Water Supplies</u>

Due to the PFCs detections in the WMA, the Navy requested EPA's support in evaluating whether PFCs are present in private water wells of properties adjacent to the NAWC. Based on available information on groundwater contamination and flow, sampling zones were identified within an approximate 1-3 mile radius of areas of concern identified at the site. The sampling plan included residential, irrigation, commercial, industrial and other supply, remediation or extraction wells (Weston 2014).

Properties for sampling were identified through database searches provided by local water authorities, and access agreements were obtained by EPA. Prior to sampling a drinking water well, the well system was purged to temperature stabilization for a minimum of 15 minutes to ensure that samples representative of the groundwater were collected. In the majority of cases, samples were collected from a faucet or tap that is at the main point of use. If there was a water treatment system, the sample was collected prior to the treatment system. On several occasions, samples were collected outside of the house at an outdoor spigot - either at the owner's insistence or because the owner was not at home at the time of sampling (Weston 2014).

One hundred and eighteen samples were taken from 100 private (residential and non-residential) water wells between July and November 2014. In a limited number of cases, a private well was sampled more than once or more than one sample was collected from multiple locations at the same address. Out of the 100 private water wells, 94 of these are residential water wells, and six of these are non-residential water wells (including industrial, commercial and irrigation wells). Of the 94 residential private water wells, five were non-detect for PFOA and PFOS, 18 had detections of PFOA only, and 71 had both PFOA and PFOS. Of the 6 non-residential private water wells, one had exceedances of both PFOS PHAL and PFNA NJ DEP screening value, and a level of PFOA that rounds up to the PHAL. Residents with private well water results exceeding the PHAL for PFOA or PFOS were provided bottled water for drinking and cooking purposes. Private wells that were below the PHAL but within 25% of this value continue to be monitored on a quarterly basis.

Of the 94 residential private water wells sampled, 11 had exceedances of the PFOS PHAL. For these 11 wells, these levels ranged from 0.152 µg/L (which rounds up to 0.2 µg/L) to 0.729 µg/L. There were no exceedances of the PFOA PHAL or PFBS value in the residential private water wells. One residential private well had a PFNA detection above the NJ DEP comparison value, and three other residential private water wells had PFNA detections that round up to the NJ DEP comparison value.

The summary information (based on the maximum detected concentration at each location) from the sampling and analysis of the six non-residential private water wells sampled is presented in Attachment B, Table 3. Of the four non-residential private water wells with detections of PFCs (six total wells sampled), only one well had exceedances of comparison values (based on the maximum detected concentrations). A commercial private water well used for industrial purposes had a PFOS level of 1.51 µg/L (which is more than seven times the PFOS PHAL); a level of PFNA of 0.0532 µg/L (about 2.7 times the NJ DEP comparison value); and a level of PFOA of 0.366 µg/L (rounding to equal the PFOA PHAL). There were no exceedances of the PFBS value in the non-residential private water wells.

The large majority of PFC detections in the private residential water wells were clustered close to or below detection limits and below the available screening values; this information is demonstrated for the private well sampling results in Figure 2. Figure 3 provides a map depicting the geographic distribution of PFCs detections and the PFOS PHAL exceedances in the private water wells. The PFOS PHAL exceedances are in two general locations. One location is south of the Jacksonville Road and East Bristol Road intersection. Six residential wells with PFOS levels that range from 0.102 to 0.109 µg/L (50% of the PHAL) are also in this location. The other location is in the area of York Rd and W Street.

3. Discussion – Public Health Implications

As stated previously, ATSDR focused on PFOS as a contaminant of concern for more detailed public health evaluation due to it exceeding a health-based comparison value in multiple public and private water wells (see Attachment B, Tables 1, 2, and 3).

For this more detailed exposure and health effects evaluation of the exposures to PFOS at this site, we used ATSDR's draft intermediate oral Minimal Risk Level (MRL) for PFOS and ATSDR's default exposure scenario assumptions (ATSDR 2015; ATSDR 2005). ATSDR's default exposure assumptions are defined by specific age ranges with corresponding estimated exposure doses for each age group. For this site, we used the highest concentration from each source of exposure (private well and public water sources) to estimate the central tendency exposure (CTE) as well as the reasonable maximum exposure (RME) that might be expected for each age group. The RME 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. Due to the lack of historical sampling data, emerging science of this contaminant class, and uncertainty in overall exposures information at this site, ATSDR used the highest concentration at each source for these calculations. Therefore, these values are conservative in nature. The CTE is the average or mean dose exposure that can be estimated for data available at this site assuming typical drinking water intake levels among each age group. Both the RME and CTE were calculated using the maximum exposure point concentrations detected in a private residential water well and a public water well. By calculating estimated exposure doses, ATSDR can better assess the possible public health implication for site-specific conditions among different age populations under different exposure durations.

ATSDR's (draft for public comment) oral intermediate MRL for PFOS is $3x10^{-5}$ (0.00003) mg/kg/day, or 0.03 µg/kg/day. ATSDR identified Seacat et al. (2002) as the critical study to derive this MRL. In this study, male and female monkeys were exposed to PFOS in their diet for six months. ATSDR identified increases in absolute liver weight as the most sensitive health endpoint in this study. However, using the dose levels directly from this animal study to derive an MRL for human exposures is problematic due to species differences in the toxicokinetics of PFOS. Therefore, ATSDR estimated the No Observed Adverse Effect Level (NOAEL) from this study using serum PFOS levels as a dose metric, and then estimated a Human Equivalent Dose (HED) of the 95% lower confidence limit of the bench mark dose (BMDL) using an empirical clearance model. ATSDR then divided this $NOAEL_{HED}$ value ($2.52x10^{-3}$ mg/kg/day) by applying an uncertainty factor of 90 (3 for animal to human extrapolation with dosimetric adjustment, 10 for human variability, and 3 for database deficiencies, particularly the lack of developmental and immunological studies in monkeys) to derive the MRL of $3x10^{-5}$ mg/kg/day. Additional detailed information on the derivation of ATSDR's draft oral intermediate MRL for PFOS can be found in Appendix A of the ATSDR Draft Toxicological Profile for Perfluoroalkyls (ATSDR 2015).

As presented in Attachment B, Table 4, public and private water users exceed the draft ATSDR PFOS MRL to varying degrees, with younger populations and pregnant and lactating women having higher levels of exposure. Specifically:

- The youngest age group evaluated (formula fed infants aged birth to less than one year) using *private or public* water at the maximum level of PFOS detected would exceed the ATSDR draft PFOS MRL using CTE (average drinking water intake levels) and RME (maximum drinking water intake levels) exposure. All age groups using the *public* water supply at the maximum level of PFOS detected would exceed the ATSDR draft PFOS MRL using RME (maximal) assumptions.
- Lactating women using *private or public* water and pregnant women using public water at the maximum level of PFOS detected would exceed the draft ATSDR PFOS MRL using RME (maximal) assumptions.
- Children younger than 11 years of age using *private* water at the maximum level of PFOS detected would exceed the draft ATSDR PFOS MRL using RME (maximal) assumptions.

We are not certain if children, infants, pregnant women, or lactating women have unique susceptibilities to exposure to PFCs. PFCs can be transferred to nursing infants. Studies that measured PFCs in maternal serum (or plasma) and breast milk in matched mother-infant pairs found highly variable correlations (ATSDR 2015). Transfer to breast milk appears to be a significant route of elimination of PFCs during breastfeeding (Mogensen 2015). Comparisons of serum concentrations of women who did or did not breastfeed their infants showed that breastfeeding significantly decreases maternal serum concentrations of PFCs. The decrease was estimated to be 2–3% decrease per month of breastfeeding. Concentrations of PFCs in breast milk also decrease with breastfeeding duration (ATSDR 2015). There are many clear health and nutritional benefits of breastfeeding. For example, breastfeeding protects babies from infections and illnesses that include diarrhea, ear infections and pneumonia; breastfed babies are less likely to develop asthma; children who are breastfed for six months are less likely to become obese; and breastfeeding also reduces the risk of sudden infant death syndrome (SIDS) (US HHS 2011). In contrast, there is a great deal of uncertainty regarding the health risk associated with PFCs contained in breast milk. In general, breastfeeding is still recommended despite the presence of chemical toxins (CDC 2015).

All of the estimated PFOS exposure doses for public and private water well users are below an estimated $NOAEL_{HED}$ ($1.9x10^{-3}$ mg/kg/day) and an estimated Lowest Observed Adverse Effect Level $(LOAEL)_{HED}$ ($6.2x10^{-3}$ mg/kg/day) for liver effects identified in the Seacat et al. 2002 animal study (EPA 2014b). Further, all the estimated exposure doses for PFOS for public and private water users at this site are below the ATSDR (2015) identified $NOAEL_{HED}$ value ($1.61x10^{-3}$ mg/kg/day) (with the highest estimated exposure dose at approximately $1/10^{th}$ of the estimated $NOAEL_{HED}$).

The available epidemiology data identify several potential targets of toxicity of PFCs, and individuals with certain pre-existing health conditions (e.g., elevated blood pressure or cholesterol) may be unusually susceptible. The liver has been shown to be a sensitive target in a number of animal species and there is some indication that it is also a target in humans. Therefore, individuals with compromised liver function may represent a susceptible population. It appears that exposure to PFOA or PFOS can result in changes in serum lipid levels, particularly cholesterol levels. Thus, an increase in serum cholesterol may result in a greater health impact in individuals with pre-existing high levels of cholesterol. Similarly, increases in uric acid levels have been observed in individuals with higher PFOS and PFOA levels; increased uric acid may be associated with an increased risk of high blood pressure (ATSDR 2015). Thus, individuals with hypertension may be at greater risk. The relationship between PFOA and PFOS exposure and increased risk of cardiovascular disease is currently mixed and inconclusive, and additional research is needed to understand how exposure to these chemicals may impact people with pre-existing risk factors (e.g., elevated cholesterol) for cardiovascular disease. Please refer to Attachment A for additional information regarding PFCs and their non cancer and cancer endpoints.

There is uncertainty about the threshold, or lowest, concentration where toxic effects in chronically exposed people might occur, that is, for persons who are exposed for longer than one year. ATSDR's draft for public comment PFOS MRL is based on an intermediate duration exposure (15–364 days). Given the uncertainties about effect levels for chronic exposures, and the duration (likely greater than one year) of past exposures at this site, as well as the public health implications for prenatal exposures and developmental endpoints and susceptible populations, ATSDR finds exposures to the highest levels of PFOS in private and public drinking water sources at this site were a past public health hazard. As stated previously, to address uncertainties in our understanding of past exposures at this site and the emerging science for this contaminant class, this conclusion is conservatively based on the maximum sampling concentrations detected in private and public drinking water sources.

Limitations

Only four of the six PFCs detected in the groundwater at the site have health-based screening values available to support a public health evaluation. At this time, neither ATSDR nor EPA have any *chronic* health-based comparison values for PFCs, with the exception of EPA's provisional chronic RfD value for PFBS. The New Jersey value for PFNA used in this document is a state-based value and has not been formally reviewed by ATSDR, and there is insufficient information available to further evaluate the public health significance of exposures exceeding this value. Most of the information regarding the effects of PFCs in animals is derived from oral studies; considerably less information is available from inhalation and dermal exposure studies. There are profound differences in the toxicokinetics of PFCs between humans and experimental animals. In general, a consistent finding across species is that the liver receives a relatively high fraction of the absorbed dose and may also experience relatively high tissue concentrations compared with other tissues, with blood (i.e., plasma) and kidney also showing relatively high concentrations. This finding supports ATSDR's use of liver effects in deriving the draft intermediate MRL. We do not have an approach for evaluating the levels of PFHpA or PFHxS detected in drinking water at this site, or an approach to evaluate the public health implications of exposures to the mixtures of PFCs detected.

There is uncertainty regarding how long and at what concentrations people in the community have been exposed to PFCs in their drinking water. However, it seems reasonable to assume that some residents could have been exposed for many years. This point is important because the detailed evaluation in this document regarding PFOS exposures above the ATSDR draft for public comment intermediate PFOS MRL is based on an animal study with an exposure duration of 6 months. PFCs not only accumulate in the body over time with exposure but also remain in the body for many years before being eliminated. There remains significant uncertainty about the lowest concentration where toxic effects might occur in people exposed to PFCs over multiple years. Therefore, persons who are exposed for many years could be at greater risk of harmful effects. There is uncertainty if subgroups of the community have additional exposures to PFCs from this site via other pathways of exposure (e.g., fish from local surface waters). The public water sampling data are based on sampling at the entry point to the distribution system for each well, and may not reflect public water user exposure at the tap.

Overall, scientific study is ongoing to better understand the health effects from human exposure to PFCs. Current health-based comparison values for PFOS in drinking water are based on the best available scientific research on the relationships between serum concentrations and adverse health effects and allow us to assess the potential risk from exposure to this chemical through drinking water. However, the body of knowledge on this relationship is constantly evolving. Further, there are currently no guidelines as to what is considered 'safe' or 'unsafe' levels of PFCs in blood.

4. Conclusions and Recommendations

Conclusions

1. Based on the current toxicological literature, which relies heavily on animal studies, ATSDR finds that exposures to the highest level of PFOS in private and public drinking water supplies at this site were a public health hazard in the past. The liver appears to be the most sensitive target in animals ingesting PFCs. It is important to note that ATSDR used the maximum environmental sampling concentration at private and public wells to develop this conclusion. ATSDR used this conservative approach due to the uncertainty in the emerging science for this contaminant class, and the uncertainty in the historical sampling data and exposure duration at the site.
2. Depending on the movement of the PFCs in the groundwater, some residents may have been exposed to PFCs in their drinking water for decades based on potential usage of PFCs at the site. Historical sampling data is not available and the first sampling for PFCs in drinking water at the site area started in 2013. Firefighting activities utilizing PFC-containing aqueous film-forming foam took place at NAWC for over 40 years.
3. People who use the municipal water supply are not currently exposed to elevated levels of PFCs. The wells that WMA currently uses are not contaminated with PFOS above

EPA's PHAL. Private well owners with exceedances of the PFOS PHAL and PFNA NJ value are not currently being exposed to PFCs in their drinking water at or above the PHAL, because they are being provided with bottled water for drinking and cooking and/or being connected to the public water supply.

4. There were detections of other PFCs at levels below state screening values or for which do not have state or federal screening values. Some of these drinking water supplies are still in use. The public health significance of exposure to these other PFCs singly and as a mixture in these drinking water supplies is an area of uncertainty.
5. ATSDR concludes that the clear health and nutritional benefits of breastfeeding far outweigh the uncertain risks associated with PFCs contained in breast milk.

Recommendations

1. ATSDR recommends EPA and the Navy continue efforts to conduct additional characterization of the PFCs groundwater contamination at this site as well as continuing the ongoing private well monitoring.
2. ATSDR recommends the Navy continue with implementing a long-term remedy to permanently mitigate public exposures to contaminated public and private drinking water sources at this site.
3. ATSDR recommends that the Navy conduct follow-up characterization of other non-drinking water potential environmental exposure pathways to PFCs in the site area (e.g., fish), if site information indicates these other exposures pathways might exist.
4. ATSDR recommends that community members with private well water at or above the PHAL for PFOS continue to reduce their exposure by using the bottled water provided by the Navy for drinking and cooking, until they are connected to the public water supply.
5. ATSDR recommends women make their own personal choices about breastfeeding. ATSDR recommends that, to reduce potential exposure of formula-fed infants, caregivers should use pre-mixed baby formula or reconstitute dry formula using alternative water sources not containing PFCs.
6. ATSDR recommends that health education information related to PFCs and public health continue to be developed and shared with community members and the health professional community serving the site area.

Sincerely,

Lora Siegmann Werner, MPH
Regional Director
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cc Dr. Sharon Williams Fleetwood, ATSDR Eastern Branch Chief
Dr. Farhad Ahmed, Pennsylvania Department of Health
Willington Lin, Navy

Attachment A: Background on Chemicals of Concern (PFCs)

PFCs, also known as perfluoroalkyls, are an emerging class of chemicals that are not currently regulated in public drinking water supplies, but are beginning to be tested for in public water systems.

PFCs are a family of man-made chemicals that have been used for decades as ingredients to make products that resist heat, oil, stains, grease and water. Commercial and consumer products containing or degrading to these compounds were introduced in the 1950s, including the use at the site. They have been used in a variety of products such as nonstick cookware, stain-resistant carpets, fabric coatings, some food packaging, aqueous film-forming foam (AFFF), makeup and personal care products. PFCs can also be found in many industrial applications such as floor care and cleaning products (ATSDR 2009).

AFFF is used to extinguish highly flammable or combustible liquid fires such as fires involving gas tankers and oil refineries. The biggest users of AFFF are the US military, petrochemical and aviation industries. In the late 1990s, EPA received information indicating that PFOS was widespread in the blood of the general population, and presented concerns for persistence, bioaccumulation, and toxicity. Following discussions between EPA and 3M, the manufacturer of PFOS and PFOS-related chemicals, the company terminated production of these chemicals. In 2006, EPA and 8 major companies committed to reduce global facility emissions and product content of PFOA and related chemicals by 95% by 2010 and to work toward eliminating emissions and product content by 2015 (EPA 2015b).

PFCs are very persistent in the environment. They are water soluble and may be found in soil, sediments, water or biota. Studies indicate that some PFCs move through soil and easily enter groundwater where they may travel long distances. Some experts suggest that PFCs can also travel in air, deposit on soil and then leach into groundwater (Eschauzier, C., et al., 2013). PFOS and PFOA have been detected in a number of US cities in surface water and sediments downstream from former fluorochemical production facilities and in wastewater treatment plant effluent, sewage sludge and landfill leachate (ATSDR, 2009).

Drinking water treatment for PFCs is complex and can be difficult to implement at a household level. However, a study by the Minnesota Department of Health found that some water filtration devices (point-of-use devices at a single tap, faucet, or outlet) may remove *some* PFCs from water (Olsen and Paulson, 2008). However, household treatment systems need to be carefully maintained to be effective, and guidance for private well owners is not currently available regarding appropriate filter change out and maintenance for residential drinking water treatment for PFCs.

PFOA and PFOS have been detected in the blood of humans, wildlife and fish. PFCs have the potential to bioaccumulate and biomagnify in wildlife. Studies show that nearly all people have some PFCs in their blood, regardless of age (Wu, X.M., et al, 2015); Kato, K., et al, 2011; Calafat, A.M., et al, 2007). People are most likely exposed to PFCs by consuming contaminated water and food and by using some consumer products that contain PFCs (Fromme, H., et al, 2009). PFCs are readily absorbed after oral exposure and accumulate primarily in the serum, kidney and liver. Once PFCs are in a person's body, it takes on average 5.4 years, 3.8 years, and 8.5 years for PFOS, PFOA, and PFHS, respectively, before levels go down by half, even if no more is taken in (Bartell, S.M., et al, 2010; Olsen, G.W., et al, 2007; ATSDR 2009, EPA 2014a). CDC's National Health and Nutrition Examination Survey (NHANES) is a program of studies designed to assess the health and nutritional status of adults and children in the United States. As part of NHANES, CDC monitors the levels of 12 different PFCs in the blood of U.S. residents. CDC scientists have found four PFCs (PFOS, PFOA, PFHxS, and PFNA) in the blood of nearly all of the people tested (CDC 2015). Based on NHANES data for the U.S. population, mean concentrations for PFOA, PFOS, and PFHxS in human blood declined by 10–30% in the 2003–2004 survey, while PFNA values doubled from 0.5 to 1.0 ng/mL. NHANES survey data from 2005–2006, 2007–2008, and 2009–2010, have generally continued to show declining levels of PFOA and PFOS in human serum samples (CDC 2013).

Non-Cancer Toxicity

Studies of the general population, communities with exposures to drinking water with elevated PFCs, and workers exposed to PFCS, suggest that PFCs increase the risk of a number of non-cancer health effects. The most consistent human health effect findings for PFOA – the most studied of the PFCs – are increases in cholesterol and uric acid levels (Gleason, J.A., et al, 2015; Fletcher, T., et al, 2013; Fitz-Simon, N., et al, 2013; Sakr, C.J., et al, 2007; Olsen, G.W. & Zobel, L.R., 2007 ; ATSDR 2009). In humans, exposure to PFCs before birth or in early childhood may result in decreased birth weight (Verner, M.A. 2015; Darrow, L.A., Stein, C.R., & Steenland, K., 2013; Olsen, G.W., Butenhoff, J.L, & Zobel, L.R., 2009; Fei, C., 2008, 2009), decreased immune responses (Looker, C., et al, 2014; Dong, G.H., 2013), and hormonal effects later in life. More research is needed to understand the role of PFCs and effects in human development. A recent study found that PFC exposures in children at levels similar to the National Health and Nutrition Examination Survey average were associated with lower antibody responses to childhood immunizations and an increased risk of antibody concentrations below the level needed to provide long-term protection (Grandjean et al 2012).

Reports by the C8 Science Panel have noted a probable link between exposure to PFOA and several health effects, including pregnancy-induced hypertension, thyroid disease, ulcerative colitis, and increases in cholesterol and uric acid levels (C8 Science Panel 2015).

Laboratory animals exposed to PFC levels well above the levels of exposure seen in humans experience developmental (Abbott, B.D. et al, 2009; Lau, C. et al 2006; Lau, C, Butenhoff, J.L. & Rogers, J.M. et al 2004), immune, neurobehavioral, liver, endocrine, and metabolic toxicity (Butenhoff, J.L, et al 2012; Cui, L et al, 2009; Seacat, A.M. et al, 2002; ATSDR 2009). The National Toxicology Program is conducting research involving a variety of short-term and long-term rodent toxicology studies, using internal dose, based on plasma levels, to identify a potential relationship between exposure and health effects (NIEHS 2012). The liver appears to be the most sensitive target in animals ingesting PFCs. The effects include increases in liver weight, changes in the liver cells, and changes in blood cholesterol and triglyceride levels (Elcombe, C.R. et al, 2012; Perkins, R.G. et al 2004;Butenhoff, J. et al, 2002). Studies in mice also found that the immune system is a sensitive target of PFOA and PFOS; the effects include decreases in the size of the spleen and thymus (Qazi, M.R. et al, 2009). However, humans and rodents react differently to PFOA and PFOS and not all of the effects observed in rats and mice may occur in humans (Albrecht, P.P. et al 2013). Many of the adverse health effects observed in laboratory animals result from the ability of these compounds (with some structural restrictions) to activate the peroxisome proliferator-activated receptor α (PPARα). Species differences in the response to PPARα agonists have been found. Rodents are the most sensitive species and guinea pigs, nonhuman primates, and humans are less responsive. Although humans are less response to PPARα agonists, they do have a functional PPARα (Albrecht, P.P. et al, 2013; Guyton, K.Z. et al, 2009; ATSDR 2009).

Special considerations for younger populations exposed to PFCs in drinking water include:

- 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.
- A study of people, including children, in an area of southeastern Ohio, whose drinking water was contaminated with PFOA found no short-term adverse health effects associated with PFOA. However, the study found the highest levels of PFOA in the blood of young children and older adults (Emmett et al 2006).
- There is evidence to suggest 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 for birth weight. Although significant associations were found, decreases in birth weight were small and may not be biologically relevant (ATSDR 2015).
- Based on both animal and human study reports, developmental effects are of concern in regards to potential adverse effects from PFOA exposure. Birth defects were seen in mice born to females exposed to relatively high amounts of PFOS during pregnancy (Thibodeaux et al 2003). Exposure to PFOA and PFOS has resulted in increased early death and delayed development of mice and rat pups (e.g., Abbott et al. 2007; Lau et al. 2003), but this did not occur in animals exposed to PFBA or PFHxS (Butenhoff et al. 2009a; Das et al. 2008).
- PFCs can be transferred to nursing infants. Studies that measured PFCs in maternal serum (or plasma) and breast milk in matched mother-infant pairs found highly variable correlations (ATSDR 2015). Transfer to breast milk appears to be a significant route of elimination of PFCs during breastfeeding (Mogensen 2015). Comparisons of serum concentrations of women who did or did not breastfeed their infants showed that breastfeeding significantly decreases maternal serum concentrations of PFCs. The decrease was estimated to be 2–3% decrease per month of breastfeeding. Concentrations of PFCs in breast milk also decrease with breastfeeding duration (ATSDR 2015).

Carcinogenicity

Under the EPA 2005 cancer guidelines, the evidence for the carcinogenicity of PFOS is considered "suggestive of carcinogenicity," but not sufficient to assess human carcinogenicity potential. On the basis of limited evidence in humans that PFOA causes testicular and renal cancer, and limited evidence in experimental animals, a working group of the International Agency for Research on Cancer (IARC) recently classified PFOA as possibly carcinogenic to humans. The workgroup found that an increased risk of kidney cancer with a statistically significant exposure–response trend was reported in workers in a fluoropolymer production plant in West Virginia, and in an exposed community near the plant. Increases of about threefold in the risk of testicular cancer were reported in the most highly exposed residents of communities near the same plant (Benbrahim-Talllaa et al, 2014). Carcinogenicity of other PFCs has not yet been evaluated.

Studies of animals given large amounts of PFOA found liver, testicular, and pancreatic cancers but more studies are needed to determine the risk of cancer for people (Butenhoff, J.L. et al, 2012; Perkins R.G., et al 2004) . From 2005 to 2013, the C8 Science Panel conducted an epidemiologic study of approximately 70,000 people in the Ohio River Valley examining a possible link between PFOA and testicular and kidney cancer (Vaughn, B., Winquist, A., & Steenland, K., 2013)]. Additional studies are needed to evaluate this possible link. Occupational studies examining whether PFCs are linked to prostrate, bladder and liver cancer in PFC manufacturing workers have not found a link. Additional studies are underway (C8 Science Panel 2015, ATSDR 2009).

In a chronic oral toxicity and carcinogenicity study of PFOS in rats, liver, thyroid and mammary fibroadenomas were identified. The biological significance of the mammary fibroadenomas and thyroid tumors was questionable as a true dose-dependent response was not identified. The liver tumors also had a questionable dose-response with slight but statistically significant increases only in high-dose males and females. Genotoxicity data are uniformly negative (Thomford, 2002 as reviewed in EPA 2014b). Human epidemiology studies did not find a direct correlation between PFOS exposure and the incidence of carcinogenicity in worker-based populations (Alexander, B.H. et al, 2003; Gilliland, F.D. & Mandel, J.S. 1993). The weight of evidence for the carcinogenic potential to humans of these tumors was judged to be too limited to support a quantitative cancer assessment.

Combined Exposure to Multiple PFCs

At this time, there is not sufficient information to evaluate the public health implications of exposures to mixtures of PFCs.

Attachment B: Tables and Figures

Table 1. Summary of Warminster public water sampling results for PFCs (2013-2014)

			Warminster Municipal Authority public water wells (17 wells)							Other public water wells (5 wells)			
				11/19/2013			6/9/2014			7/22 - 8/7/2014			
Contaminant	Health Based Comparison Value (CV)		Detection Limit	Minimum µg/L	Maximum µg/L	Wells Above CV	Minimum µg/L	Maximum µg/L	Wells Above CV	Detection Limit	Minimum µg/L	Maximum µg/L	Wells Above CV
PFOS	0.2	US EPA PHAL	0.04	0.0553	0.791	3*	0.0413	1.09	2**	0.037–0.04	0.0209	0.151^	0
PFOA	0.4	US EPA PHAL	0.02	0.0203	0.291	0	0.0201	0.349	0	0.0185–0.0185	0.011	0.0456^	0
PFHpA	not available		0.01	0.0105	0.0561	-	0.0159	0.071	-	0.00926–0.01	0.00418	0.0127^	-
PFHxS	not available		0.03	0.0308	0.334	-	0.0595	0.389	-	0.0278	0.00529	0.0484^	-
PFNA	0.01	NJ DEP	0.02	non-detect		0	non-detect		0	0.0185–0.02	non-detect		0
PFBS	380	US EPA RSL	0.09	non-detect		0	non-detect		0	0.0833–0.09	non-detect		0

Results rounded to 1 significant figure for purposes of estimating wells exceeding the CV, per the Navy's and EPA's approach at this site.

Data include 17 samples covering 17 wells in the WMA and one sample of the North Wales Water Authority (NWWA interconnection). * The three exceedances include two wells with 0.193 and 0.16 µg/L concentrations that round up to 0.2 µg/L.

**The exceedances include a well with 0.176 µg/L concentration that rounds up to 0.2 µg/L. ^The well with the maximum levels was not in service.

PFOS = Perfluorooctane sulfonate

PFOA = Perfluorooctanoic acid

PFHpA = Perfluoroheptanoic acid

PFHxS = Perflurorohexylsulfonic acid

PFNA = Perflurornonanoic acid

PFBS = Perfluorobutanesulfonic acid

US EPA PHAL = US Environmental Protection Agency Provisional Health Advisory Level, NJ DEP = New Jersey Department of Environmental Protection

US EPA RSL = US Environmental Protection Agency Risk-Based Screening Level

Table 2. Summary of Warminster private residential water well sampling results for PFCs (July-November 2014)

July to November 2014 (94 wells)						
Contaminant	Detection Limit	Minimum (µg/L)	Maximum (µg/L)	Health-based Comparison Value (CV) (µg/L)		Wells Exceeding the CV
PFOS	0.0357–0.04	0.0108	0.729	0.2	US EPA PHAL	11
PFOA	0.0179–0.02	0.00326	0.337	0.4	US EPA PHAL	0
PFHpA	0.00893–0.01	0.00255	0.0906	not available		-
PFHxS	0.0268–0.03	0.00479	0.416	not available		-
PFNA	0.0179–0.02	0.00408	0.019	0.01	NJ DEP	1*
PFBS	0.0804–0.09	0.0101	0.0912	380	US EPA RSL	0

* With rounding to 1 significant figure, 1 private residential water well exceeds the PFNA CV and 3 other private residential water wells equal the CV.

PFOS = Perfluorooctane sulfonate
PFOA = Perfluorooctanoic acid
PFHpA = Perfluoroheptanoic acid
PFHxS = Perflurorohexylsulfonic acid
PFNA = Perflurornonanoic acid
PFBS = Perfluorobutanesulfonic acid
US EPA PHAL = US Environmental Protection Agency Provisional Health Advisory Level
NJ DEP = NJ DEP = New Jersey Department of Environmental Protection
US EPA RSL = US Environmental Protection Agency Risk-Based Screening Level

If a private water well was sampled more than once, the maximum value detected was used for the purposes of this table summary.
One home on public water was mistakenly identified has having a private well; the sample results from this residence were not included in this summary.
Results rounded to 1 significant figure for purposes of estimating wells exceeding the CV, per the Navy's and EPA's approach at this site.

Table 3. Summary of Warminster private non-residential water well sampling results for PFCs (July-October 2014)

July to October 2014 (6 wells)						
Contaminant	Detection Limit	Minimum (µg/L)	Maximum (µg/L)	Health-based Comparison Value (CV) (µg/L)		Wells Exceeding the CV
PFOS	0.04	0.0218	1.51	0.2	US EPA PHAL	1
PFOA	0.02	0.0202	0.366	0.4	US EPA PHAL	0
PFHpA	0.01	0.00516	0.255	not available		-
PFHxS	0.004	0.00458	0.716	not available		-
PFNA	0.0192–0.02	0.0041	0.0532	0.01	NJ DEP	1*
PFBS	0.0865–0.09	0.0116	0.0912	380	US EPA RSL	0

PFOS = Perfluorooctane sulfonate
PFOA = Perfluorooctanoic acid
PFHpA = Perfluoroheptanoic acid
PFHxS = Perflurorohexylsulfonic acid
PFNA = Perflurornonanoic acid
PFBS = Perfluorobutanesulfonic acid
US EPA PHAL = US Environmental Protection Agency Provisional Health Advisory Level
NJ DEP = New Jersey Department of Environmental Protection
US EPA RSL = US Environmental Protection Agency Risk-Based Screening Level

Results rounded to 1 significant figure for purposes of estimating wells exceeding the CV, per the Navy's and EPA's approach at this site and consistent with EPA Water Supply Guidance (WSG-21) 21, Procedures for Rounding-Off Analytical Data to Determine Compliance with Maximum Contaminant Levels Present in NIPDWR (1981).
**The same single industrial well had exceedances of PFOS and PFNA, and a level of PFOA that rounds up to the PHAL.*

Table 4. Warminster PFOS Environmental Exposure Assumptions and Estimated Exposure Doses

	Exposure Assumptions			Estimated Exposure Dose			
	Drinking Water Intake		Body Wt	private well maximum exposure point 0.729 µg/L		public well maximum exposure point 1.09 µg/L	
	Upper Percentile	Mean		RME	CTE	RME	CTE
Age groups	L/day	L/day	kg	mg/kg/day	mg/kg/day	mg/kg/day	mg/kg/day
Birth to < 1 yr	1.113	0.504	7.8	**1.04E-04**	**4.71E-05**	**1.56E-04**	**7.04E-05**
1 to < 2 yr	0.893	0.308	11.4	**5.71E-05**	1.97E-05	**8.54E-05**	2.94E-05
2 to < 6 yr	0.977	0.376	17.4	**4.09E-05**	1.58E-05	**6.12E-05**	2.36E-05
6 to < 11 yr	1.404	0.511	31.8	**3.22E-05**	1.17E-05	**4.81E-05**	1.75E-05
11 to <16 yr	1.976	0.637	56.8	2.54E-05	8.20E-06	**3.79E-05**	1.22E-05
16 to <21 yr	2.444	0.77	71.6	2.49E-05	7.80E-06	**3.72E-05**	1.17E-05
Adults ≥ 21 yr	3.092	1.227	80	2.82E-05	1.12E-05	**4.21E-05**	1.67E-05
Lactating Women	3.588	1.665	73	**3.60E-05**	1.70E-05	**5.40E-05**	2.50E-05
Pregnant Women	2.589	0.872	73	2.60E-05	9.00E-06	**3.90E-05**	1.30E-05

Notes: **Yellow highlight** indicates exceedance of ATSDR draft intermediate oral MRL of 0.00003 mg/kg/day, CTE = central tendency of exposure, L = Liter, mg/kg/day = milligrams of chemical per kilogram of body weight per day, RME = reasonable maximum exposure concentration, µg/L = micrograms per liter, yr = year

RME = Upper Percentile Drinking Water Intake (L/day) x Exposure point concentration (µg/L)/1000
Body wt (kg)

CTE = Mean Drinking Water Intake (L/day) x Exposure point concentration (µg/L)/1000
Body wt (kg)

Figure 1. Generalized schematic of a decentralized drinking water distribution network with water supply well connections throughout

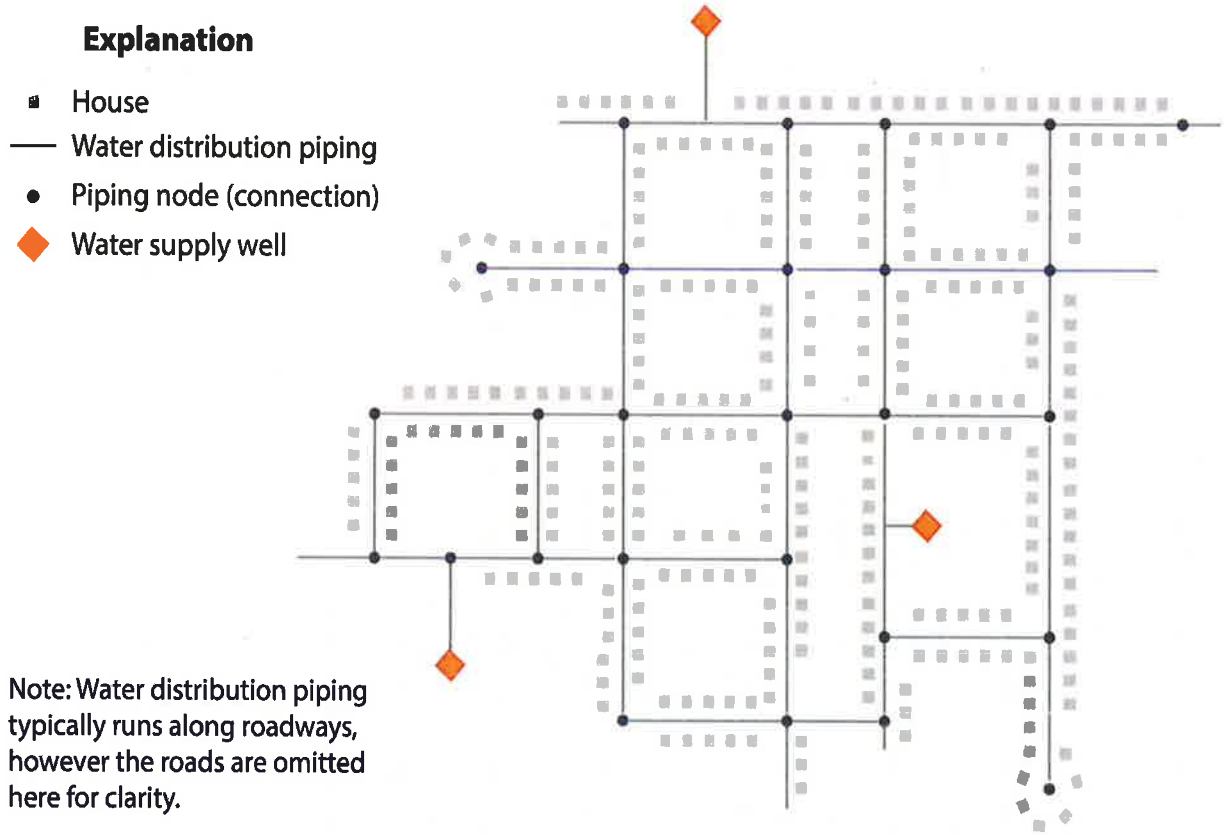
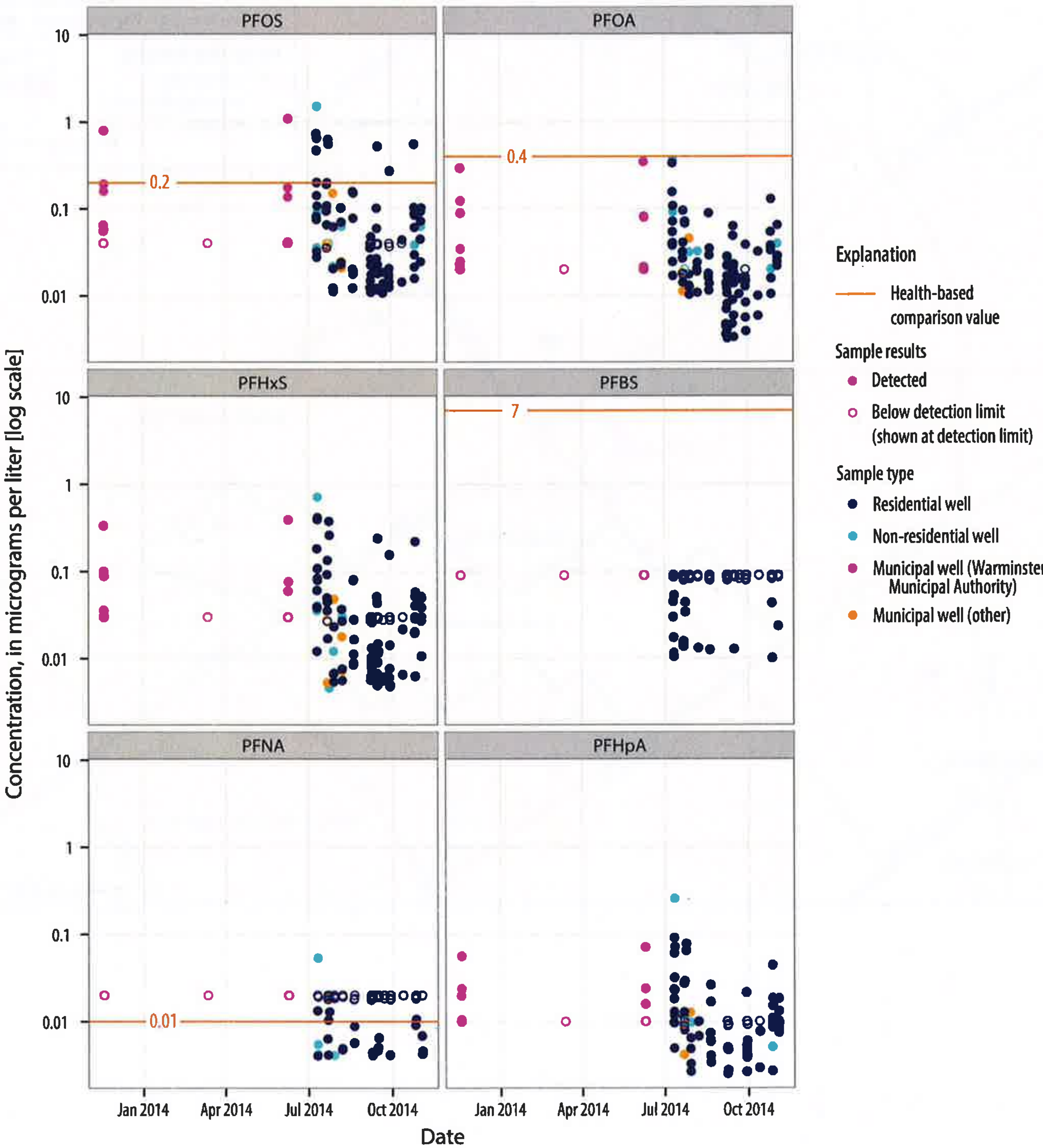
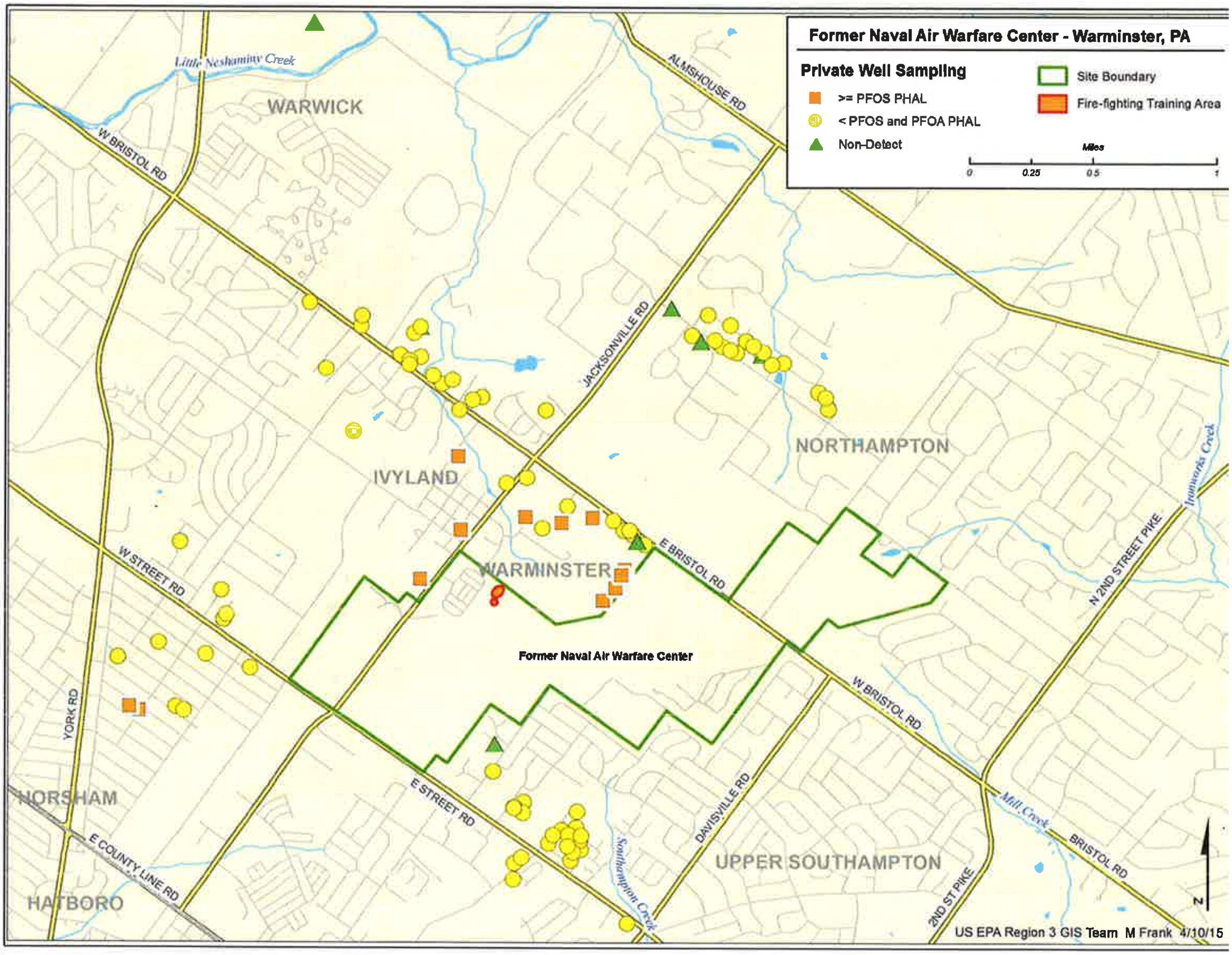


Figure 2. Scatter plot of PFCs detected in μg/L in Warminster, PA 2014 EPA water sampling *



* The PFBS scatterplot incorporates the MN screening value of 7 μg/L instead of the EPA screening value of 380 μg/L to maintain the scale.

Figure 3. Map of Warminster, PA site area and summary of 2014 EPA private water well PFCs sampling information



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