

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

**Human health effects of drinking water exposures to per- and poly-fluoroalkyl
substances (PFAS): A multi-site cross-sectional study
Protocol**

December 6, 2019

Agency for Toxic Substances and Disease Registry
National Center for Environmental Health

This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by the Agency for Toxic Substances and Disease Registry. It does not represent and should not be construed to represent an agency determination or policy.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

Table of Contents

1. PROJECT OVERVIEW..... 5

 1.1 Summary..... 5

 1.1.1 Literature Review..... 5

 1.1.2 Health Study Feasibility Assessment..... 6

 1.1.3 Summary of Study Goals..... 7

 1.2 Study Investigators and Roles..... 9

2. INTRODUCTION..... 10

 2.1 Authority..... 10

 2.2 Background..... 11

 2.3 Selection of Sites..... 12

 2.4 General Approach for Study Recruitment..... 14

 2.5 Study Objectives and Study Questions..... 15

 2.5.1 Literature Review..... 16

 2.5.1.1 Health Effects in Children..... 16

 2.5.1.2 Health Effects in Adults..... 18

 2.5.2 Hypotheses..... 20

 2.6 Intended Use of Study Findings..... 21

3.1 Study Design..... 22

3.2 Study Populations and Eligibility..... 23

 3.2.1 Children..... 23

 3.2.2 Adults..... 24

3.3 Sample Size Considerations..... 24

1	3.3.1 Children.....	25
2	3.3.2 Adults.....	28
3	3.4 Study Roll Out and Communication Plan.....	32
4	3.5 Recruitment.....	32
5	3.5.3 Enrollment Procedures.....	33
6	3.6 Data Collection Procedures.....	34
7	3.6.1 Check-in Procedures.....	34
8	3.6.2 Informed Consent Process.....	35
9	3.6.2.1 Consent for Specimens and Data.....	35
10	3.6.2.2 Child Consent.....	35
11	3.6.2.3 Adult Consent.....	36
12	3.6.2.4 Risks and Benefits.....	36
13	3.6.3 Update Contact Information and Medication List.....	36
14	3.6.4 Body and Clinical Measurements.....	37
15	3.6.5 Questionnaire.....	38
16	3.6.5.1 Children and Parents.....	38
17	3.6.5.1.1 Child/Parent Neurobehavioral Assessments.....	39
18	3.6.5.2 Adults.....	42
19	3.6.6 Exit Procedures.....	42
20	3.6.6.1 Gift Cards as a Token of Appreciation for Participation.....	42
21	3.7 Biochemical Analyses.....	43
22	3.7.1 Children.....	44
23	3.7.2 Adults.....	45
24	3.7.3 Quality Control/Quality Assurance.....	45
25	3.7.4 Reference Values.....	46
26	3.8 Data Handling.....	46

1	3.8.1 Certificate of Confidentiality.....	46
2	3.8.3 Impact on Privacy.....	48
3	3.8.3.1 Access Controls and Security.....	49
4	3.8.4 Data Delivery.....	51
5	3.8.5 Data Ownership and Data Sharing.....	51
6	3.8.6 Storing Residual Blood for Future Use.....	52
7	3.8.7 Future Exploratory Analyses.....	53
8	3.9 Exposure Estimation.....	53
9	3.10 Statistical Analyses.....	56
10	4. RESULTS REPORTING.....	57
11	4.1 Notification of Individual Results.....	57
12	4.2 Disseminating Results to the Public.....	57
13	5. STRENGTHS AND LIMITATIONS.....	58
14	6. REFERENCES.....	60
15	7. LIST OF ATTACHMENTS.....	70
16		

1 1. PROJECT OVERVIEW

2 1.1 Summary

3 1.1.1 Literature Review

4 Per- and polyfluoroalkyl substances (PFAS) are a family of chemicals used in industrial applications and
5 consumer products. A number of PFAS chemicals including perfluorooctane sulfonate (PFOS),
6 perfluorooctanoate (PFOA), and perfluorohexane sulfonate (PFHxS) persist in the environment and have
7 long serum half-lives in humans (Wang 2017). PFAS contamination of drinking water is widespread in
8 the U.S. For example, one report indicated that at least six million residents were served by 66 public
9 water supplies that had at least one sample at or above the US EPA Lifetime Health Advisory for PFOA
10 and PFOS (individually or combined) of 70 ng/L (Hu 2016). Industrial facilities that manufacture or use
11 PFAS have contaminated drinking water in surrounding communities in West Virginia, Ohio, New York,
12 Minnesota, Alabama, Vermont, New Hampshire, and New Jersey (Kray 2018). An alternative method of
13 estimating PFAS drinking water contamination put the number of people potentially exposed to PFAS at
14 concentration over 2.5 ng/L at about 110 million (Environmental Working Group 2018). PFOS, PFOA,
15 PFHxS and other PFAS chemicals are constituents in aqueous film-forming foam (AFFF), used to
16 extinguish flammable liquid fires. Since the 1970s, military bases in the U.S. have used AFFF with PFAS
17 constituents for firefighting training as well as to extinguish fires. At some military bases, AFFF use has
18 resulted in the migration of PFAS chemicals through soils to ground water and/or surface water sources
19 of drinking water for the bases and/or surrounding communities (ATSDR 2017a). The Air Force and Navy
20 have identified at least 24 bases with contaminated drinking water in Alaska, California, Colorado,
21 Delaware, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Virginia, and
22 Washington (Kray 2018).

23 A detailed review of epidemiological studies published up through 2016 was included in the ATSDR
24 Feasibility Assessment for Epidemiological Studies at Pease International Tradeport, Portsmouth, New
25 Hampshire (ATSDR 2017a; released Nov 2017). Health effects of PFAS exposure in children were also
26 recently reviewed by Rapazzo (2017). The scientific evidence linking PFAS exposures with adverse
27 health effects is rapidly growing. Epidemiological studies have found associations with changes in lipids
28 (Steenland 2009; Zeng 2015, Mora 2018), levels of uric acid (Steenland 2010), thyroid and sex hormones
29 (Wen 2013; Lopez-Espinosa 2016, Preston 2018), liver (Darrow 2016, Mora 2018), and immune function
30 (Grandjean 2012, 2017), as well as reduced birth weight (Bach 2015, Verner 2015), reproductive effects
31 (Lopez-Espinosa 2011, Bach 2016) and some cancers (; Barry 2013). However, findings across studies

1 have been inconsistent for a variety of reasons, including differences in exposure levels, methods of
2 ascertaining diseases and the exposure and effect biomarkers measured. For some health endpoints,
3 only one or a few studies currently exist.

4 Most studies of the human health effects from PFAS exposures have focused on PFOA and PFOS. These
5 include studies that evaluated data from the National Health and Nutrition Examination Survey
6 (NHANES), occupational studies, and national surveys conducted in other countries where exposures to
7 PFAS were found mostly from consumption of food and beverages in PFAS-contaminated packaging.
8 Studies of West Virginia and Ohio residents and workers exposed to PFOA from a chemical plant (the
9 “C8” studies) have provided extensive and high quality information on PFOA (and to a lesser extent,
10 PFOS), studying a large cohort of highly exposed residents (60,000+) and workers living in the vicinity of
11 the production facility. However, other PFAS such as PFHxS and PFNA were not a primary focus of the
12 C8 studies. Except for the C8 studies, there is scant information on the health effects of exposures to
13 PFAS-contaminated drinking water.

14 **1.1.2 Health Study Feasibility Assessment**

15 In 2017, ATSDR published a feasibility assessment of possible future drinking water epidemiological
16 studies at the Pease International Tradeport, Portsmouth, New Hampshire (ATSDR 2017a). Drinking
17 water supply wells serving the Pease Tradeport were contaminated with PFAS from the use of AFFF at
18 the former Pease Air Force Base. As part of this feasibility assessment, ATSDR reviewed the available
19 information on the Pease Tradeport population and exposures (e.g., population size and demographics,
20 PFAS biomonitoring results, and drinking water data) as well as conducted sample size calculations. The
21 ATSDR feasibility assessment concluded that there was a need for additional epidemiological research
22 on the health effects of PFAS exposures to address several research gaps and issues: (1) the small
23 number of studies for some health endpoints, (2) the inconsistency of findings across studies for some
24 health endpoints, (3) the lack of drinking water studies other than the C8 studies, and (4) the need to
25 conduct studies that evaluate PFHxS and PFNA as well as other PFAS chemicals in addition to PFOA and
26 PFOS (ATSDR 2017a).

27 In addition, ATSDR determined that cross-sectional epidemiological studies of children and adults at one
28 site (e.g., at the Pease Tradeport) were feasible for some health endpoints (e.g., lipids, kidney function),
29 but the size of the populations would be insufficient for other important health endpoints (e.g., thyroid,
30 liver and immune function, autoimmune diseases). Therefore, the feasibility assessment concluded
31 that: (1) a multi-site PFAS study of children and adults was necessary, (2) the study should be cross-

1 sectional and involve separate evaluations of children (ages 4-17) and adults (ages ≥ 18), and (3) the
2 study should focus on communities impacted by PFAS-contaminated public drinking water supply wells
3 and/or private wells. A cross-sectional study design was chosen because this design is especially
4 suitable for assessing effect biomarkers and the prevalences of nonfatal diseases, in particular, diseases
5 with no clear point of onset (Checkoway 2004). Additionally, the cross-sectional design can generate
6 data for hypotheses that can be tested in subsequent longitudinal studies.

7 **1.1.3 Summary of Study Goals**

8 The main goal of the cross-sectional multi-site study is to evaluate associations between measured and
9 historically reconstructed serum levels of PFAS including PFOA, PFOS, and PFHxS (see **Section 3.10**), and
10 selected health outcomes as described below and detailed in study hypotheses (see **Section 2.5.2**). The
11 study will attempt to recruit at least 2,000 children and 6,000 adults (equally of both sexes for both
12 children and adults) from communities exposed to PFAS-contaminated drinking water. The criteria for
13 selecting study sites are detailed in **Section 2.3** and include:

- 14 1. Documented past or present PFAS drinking water concentrations at the tap,
- 15 2. The magnitude of past or present PFAS concentrations at the tap,
- 16 3. Size of the population exposed,
- 17 4. Geographic coverage;
- 18 5. The proposed researchers for a study site were experienced in conducting drinking water
19 epidemiological studies;
- 20 6. Amount of information available on the contaminated drinking water system or private wells,
21 and
- 22 7. If biomonitoring for PFAS has previously occurred at the site.

23 Possible candidate sites included communities whose drinking water was impacted by AFFF use at
24 military bases or by industrial PFAS emissions. The site selection process considered the levels of PFAS
25 drinking water concentrations at a site. The aim was to select sites so that a wide range in PFAS
26 exposures levels were included in the study in order to enable the evaluation of exposure-response
27 trends including effects at the lower range of exposures.

1 For those sites with complex drinking water systems (e.g., where individual supply wells serve particular
2 areas of the distribution system, or when there is uncertainty concerning which areas in the distribution
3 system received contaminated water) or sites with groundwater contamination affecting private wells
4 where there is uncertainty concerning which wells are contaminated, it may be necessary to use
5 modeling methods (e.g., ground water contaminant fate and transport models, water system
6 distribution system models) to identify the areas with contaminated drinking water. A targeted PFAS
7 biomonitoring approach is essential to confirm results from groundwater and/or distribution system
8 modeling approaches. Modeling may also be necessary to determine the period when the drinking
9 water was contaminated and to historically reconstruct PFAS contaminant concentrations during this
10 period (Shin 2011).

11 The study will obtain blood samples from participants to measure PFAS serum levels and several effect
12 biomarkers such as lipids, and thyroid, kidney, immune and liver function. The study will also obtain
13 urine samples from participants to measure PFAS levels and kidney function biomarkers. The study will
14 archive serum and urine samples in order to conduct analyses of additional PFAS chemicals and specific
15 effect biomarkers. Adult participants and a parent of the child participant will complete a questionnaire
16 that includes a residential history, medical history, occupational history and water consumption habits.
17 The study will access medical and school records to confirm adverse health outcomes reported in the
18 questionnaire. To facilitate access to these records, the recipient will reach out to local medical
19 societies, the public school system and private schools to enlist their cooperation with the study.

20 Participants will be categorized based on the measured serum concentration of PFAS compounds or on
21 modeled estimated historical serum levels (e.g., referent or low, medium, high). Estimated and
22 measured PFAS serum levels will also be evaluated as continuous variables. At sites with preceding PFAS
23 biomonitoring, the study will evaluate changes in PFAS concentration over time. The study will
24 reconstruct historic serum PFAS concentrations by estimating half-lives and elimination rates as well as
25 water contamination modeling to inform the pharmacokinetic (PK) or physiologically based
26 pharmacokinetic (PBPK) modeling. Historical serum PFAS reconstruction will enable the evaluation of
27 exposure lags and vulnerable periods as well as statistical analyses that can control for confounding and
28 reverse causation due to physiological factors (Dhingra 2017, Weisskopf 2017).

29 In order to restrict this study to drinking water exposures, adults occupationally exposed to PFAS will not
30 be eligible for the study (e.g., ever firefighters or worked in an industry using PFAS chemicals in its
31 manufacturing process). Likewise, children whose birth mothers were occupationally exposed will not

1 be eligible. Eligible females who are pregnant may enroll. The federal regulations do not allow people
2 who are prisoners or under house arrest to take part in this type of study.

3 Based on ATSDR's literature review of epidemiological studies of PFAS, the study will examine
4 associations between PFAS compounds and lipids, renal function and kidney disease, thyroid hormones
5 and disease, liver function and disease, glycemic parameters and diabetes, as well as immune response
6 and function in both children and adults. In addition, the study will investigate PFAS differences in sex
7 hormones and sexual maturation, vaccine response, and neurobehavioral outcomes in children. In
8 adults, additional outcomes of interest include cardiovascular disease, osteoarthritis and osteoporosis,
9 endometriosis, and autoimmune disease.

10 These health endpoints were not selected based on power calculations, but rather on epidemiological
11 and scientific bases: (1) endpoints that have been evaluated in previous PFAS research and need follow-
12 up; (2) endpoints observed to be elevated in studies of other chemicals with similar *in vitro/in vivo*
13 activity; and (3) results from toxicological and epidemiological studies of PFAS. With the proposed
14 sample sizes for the multi-site study there should be sufficient power to detect mean differences and
15 odds ratios in the ranges of those observed in other well designed epidemiologic studies.

16 **1.2 Study Investigators and Roles**

17 This cooperative research is being conducted under the ATSDR Notice of Funding Opportunity (NOFO)
18 No. CDC-RFA-TS-19-002, titled "Multi-Site Study of the Health Implications of Exposure to PFAS-
19 Contaminated Drinking Water." The expected number of research recipients¹ is six. The program will be
20 administered by the CDC Extramural Research Program Office (ERPO).

21 Given that the single IRB mandate under the revised 2018 Common Rule will take effect on January 19,
22 2020, this research program shall be managed under the review of a single IRB for cooperative research.
23 See [§46.114](#) (Cooperative Research).

24 Projects that involve the collection or generation of data with federal funds must develop, submit, and
25 comply with a Data Management Plan (DMP) prior to the collection or generation of public health data,
26 and, to the extent appropriate, provide public access to and archiving/long-term preservation of
27 collected or generated data.²

1 1 A "recipient" is defined as a "non-Federal entity that receives a Federal award directly from a Federal awarding
2 agency to carry out an activity under a Federal program." (see Grants.gov at [https://www.grants.gov/learn-
3 grants/grant-terminology.html#R](https://www.grants.gov/learn-grants/grant-terminology.html#R); accessed 02/04/2019).

4 ² <https://www.cdc.gov/grants/additional-requirements/ar-25.html>

1 This protocol also represents CDC-supported research in which identifiable, sensitive information is
2 collected and is issued a Certificate of Confidentiality (CoC). Thus, ATSDR and recipients are required to
3 protect the privacy of individuals who are subjects of such research in accordance with Section 301(d) of
4 the Public Health Service (PHS) Act.³

5 This protocol represents the core research that all recipients must conduct at their sites. Recipients will
6 tailor their site-specific informed consent forms based on the ATSDR template (**Attachment 7b**).

7 **ATSDR and NCEH Roles:** The health study team at ATSDR is responsible for the development of and for
8 external peer review requirements for the core protocol for the PFAS multi-site study. The study
9 protocol will be submitted by ATSDR for review and approval by the CDC Institutional Review Board (IRB)
10 under CDC's Federal wide Assurance (FWA) No. 00001413) and by the Office of Management and
11 Budget (OMB). ATSDR will also seek comments from community organizations involved with PFAS.

12 Serum specimens for PFAS analyses will be submitted to the CDC NCEH DLS, Atlanta, GA. Core clinical
13 and research effect biomarkers will be analyzed by commercial laboratories as specified in the protocol.
14 Urine specimens will be collected and stored for future analysis and study. ATSDR will conduct data
15 analyses of the combined core data from all the study sites with the recipient participation.

16 **Recipient Role:** Data collection at each study site will be conducted by the recipient via cooperative
17 agreement with the ATSDR. The recipient will conduct historical reconstruction of PFAS concentrations
18 in the drinking water at the specific site and will estimate historical PFAS serum levels. The recipient will
19 conduct participant sampling, obtain informed consent, and administer a questionnaire. The recipient
20 will verify reported health conditions with participant's health care providers and approach appropriate
21 school district to abstract special education records. The recipient will obtain a blood and urine sample
22 from each participant and will be responsible for specimen shipment to the CDC NCEH DLS and
23 commercial laboratories. The recipient will deliver the core data and personal identifier information
24 ("PII") such as social security number, full name and date of birth, to ATSDR. Each recipient may
25 conduct analyses of the data from the recipient's site. Each recipient shall maintain PII data in a secure
26 manner and delete PII data after the study is completed.

27

28 2. INTRODUCTION

1 ³<https://www.cdc.gov/grants/additional-requirements/ar-36.html>

1 **2.1 Authority**

2 ATSDR is authorized to conduct the PFAS multi-site study under Section 316(a) of the 2018 National
3 Defense Authorization Act (Public Law 115-91), as amended by Section 315 of the John S. McCain
4 National Defense Authorization Act for Fiscal Year 2019 (Pub. L. 115-232).

5

6 **2.2 Background**

7 **Starting in the 1950s, PFAS** have been used in a wide variety of products and applications including
8 fluoropolymer manufacturing, stain and water repellent coatings, cleaners, and paints. PFAS are also
9 components of aqueous film-forming foam (AFFF) used to extinguishing flammable liquid fires. From
10 approximately the early 1970s, AFFF was used for firefighting training and to extinguish fuel-based fires
11 at a number of military and non-military sites (e.g., airports) around the country. PFAS components of
12 AFFF include perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), and perfluorohexane
13 sulfonate (PFHxS).

14 PFAS contamination of drinking water is widespread with at least six million U.S. residents receiving
15 water having concentrations of PFOA and PFOS (individually or combined) exceeding the EPA's Lifetime
16 Health Advisory of 70 parts per trillion (Kray 2018). Sources of the drinking water contamination include
17 emissions from manufacturing facilities and the use of AFFF at military bases and airports. For example,
18 the Air Force and Navy have identified at least 24 bases with contaminated drinking water in several
19 states including Alaska, California, Colorado, Delaware, Michigan, New Hampshire, New Jersey, New
20 York, Ohio, Pennsylvania, Virginia and Washington (Kray 2018). At these bases, PFAS chemicals in the
21 AFFF likely leached into the soil and ground water and migrated to drinking water supply wells.

22 An example of a community drinking water supply contaminated via the use of AFFF at a military base is
23 the Pease International Tradeport, Portsmouth, New Hampshire. In 2014, a drinking water supply well
24 had measured PFOS, PFOA and PFHxS concentrations of 2.5 µg/L, 0.35 µg/L, and 0.96 µg/L, respectively.
25 The source of the contamination was use of AFFF at the former Pease Air Force Base. In 2015, NH DHHS
26 established a Pease biomonitoring program for PFAS. The program obtained blood specimens for PFAS
27 analyses from 1,578 persons (NH DHHS 2016, Daly 2018). The results from the blood-testing program
28 indicated that the exposed population had serum levels of PFOS and PFHxS that were about two to
29 three times higher than the U.S. population based on data from NHANES 2013-4 and from other

1 epidemiological studies in the U.S. In analyses conducted by NH DHHS (Daly 2018), geometric mean
2 PFHxS serum levels were higher for persons who drank ≥ 4 cups of water per day compared to those who
3 drank < 4 cups per day (4.76 $\mu\text{g/L}$ versus 3.77 $\mu\text{g/L}$). NH DHHS measured 8 to 14 PFAS congeners at 3
4 analytical laboratories. Among PFOA, PFOS, PFHxS and PFNA concentrations, water consumption had
5 the strongest effect on PFHxS serum levels. In particular, water consumption had the highest effect on
6 PFHxS serum levels among persons aged ≤ 19 years ($\beta = 0.31$, SE = 0.15, marginal effect = 36.4%).
7 Geometric mean PFOS and PFOA serum levels were also higher among persons who drank ≥ 4 cups of
8 water per day compared with those who drank < 4 cups per day (NH DHHS 2016, Daly 2018). Linear
9 trends were observed for geometric mean serum levels of PFOS, PFOA, and PFHxS and increasing time
10 spent at the Pease Tradeport. The trend was strongest for PFOS and PFHxS (NH DHHS 2016, Daly 2018).

11 **2.3 Selection of Sites**

12 Possible candidate sites included communities whose drinking water was impacted by AFFF use at
13 military bases or by industrial PFAS emissions. The criteria for selecting study sites included:

- 14 1. Documented past or present PFAS drinking water concentrations at the tap,
- 15 2. The magnitude of past or present PFAS concentrations at the tap,
- 16 3. Size of the population exposed,
- 17 4. Geographic coverage;
- 18 5. The proposed researchers for a study site were experienced in conducting drinking water
19 epidemiological studies;
- 20 6. Amount of information available on the contaminated drinking water system or private wells,
21 and
- 22 7. If biomonitoring for PFAS has previously occurred at the site.

23 In order to determine the feasibility of a site for inclusion in the multi-site study, information on the
24 following parameters were included in the application

- 25 1. For public water systems using ground water sources, enumeration of supply wells that
26 provided drinking water to the site. Information on each supply well should include years of
27 operation, well capacity, and daily or monthly pumping rates. This information can be used to

- 1 determine the monthly proportion of the total water supply provided by each well during the
2 period when PFAS contamination occurred. Information is also necessary about changes to the
3 water system (e.g., closure of contaminated supply wells) after the contamination was detected.
- 4 2. For a water system supplied by surface water, characteristics of this source.
 - 5 3. For a water system purchasing water from another system, characteristics of this source, the
6 period of time purchased, and daily or monthly amount purchased in order to determine the
7 proportion of the total water supply provided by the purchased water.
 - 8 4. Characteristics of the drinking water distribution system. For example, for systems using supply
9 wells, it is important to obtain information on whether mixing from the supply wells occurred at
10 the treatment plant before entering the distribution system or if each supply well served a
11 specific area in the system. If water was purchased from another system, then information on
12 the area of the distribution system served by purchased water is necessary. For systems in
13 which PFAS concentrations throughout the distribution system cannot be assumed to be similar
14 (e.g., if all water is not mixed at the treatment plant before distribution), then It may be
15 necessary to obtain sufficient information on the distribution system (e.g., pipe network,
16 elevation and water demand at each node, pipe length and diameter, etc.) so that preliminary
17 modeling using software such as EPANET can be used to estimate PFAS concentrations at
18 various areas in the distribution system.
 - 19 5. Description of when and how PFAS samples from monitoring or supply wells (or surface water)
20 were obtained, the location of the wells, and the measured concentrations of PFAS including
21 description of analytical methods used by the laboratory.
 - 22 6. If the distribution system was sampled, which PFAS were detected, when, and the measured
23 levels of concentration.
 - 24 7. For sites involving private well contamination, the number and locations of the wells, periods of
25 operation, any information on the source of contamination and the PFAS groundwater plume,
26 and the dates of PFAS sampling and the measured concentrations.
 - 27 8. Any information on the historical use of AFFF (e.g., amount purchased/used, location and
28 frequency of training exercises, fire incidents, spills, etc.) at the site or in the vicinity of the site
29 (e.g., military base airstrip) which was the source of the drinking water contamination. Any
30 information on the soil and ground water characteristics in the vicinity of AFFF use. Any
31 information on the groundwater PFAS plume.
 - 32 9. If previous human PFAS biomonitoring program was conducted, the PFAS serum results, dates of
33 blood or urine collection, and possible descriptive/predictive factors of the serum

1 concentrations (e.g. volume of water consumed, length of residence at site, differences in age,
2 race, or other population characteristics).

3 For those sites with complex drinking water systems (e.g., where individual supply wells serve particular
4 areas of the distribution system, or when there is uncertainty concerning which areas in the distribution
5 system received contaminated water) or sites with groundwater contamination affecting private wells
6 where there is uncertainty concerning which wells are contaminated, a targeted PFAS biomonitoring
7 approach may be useful to confirm results from groundwater and/or distribution system modeling
8 approaches. Possible candidate sites included communities whose drinking water was impacted by AFFF
9 use at military bases or by industrial PFAS emissions.

10 On September 23, 2019, ATSDR awarded cooperative agreements with seven partners to study the
11 human health effects of exposures to PFAS through drinking water at locations across the nation.
12 Information regarding the multi-site study cooperative agreement partners and the location where they
13 each will conduct their work are as follows:

14 •Colorado School of Public Health, University of Colorado Anschutz Medical Campus, to look at
15 exposures in El Paso County, CO

16 •Michigan State Department of Health and Human Services to look at exposures in Parchment/Cooper
17 Township, MI, and North Kent County, MI

18 •RTI International and the Pennsylvania Department of Health to look at exposures in Montgomery and
19 Bucks Counties, PA

20 •Rutgers Biomedical and Health Sciences – School of Public Health to look at exposures in Gloucester
21 County, NJ

22 •Silent Spring Institute to look at exposures in Hyannis, MA, and Ayer, MA

23 •University at Albany, SUNY and New York State Department of Health to look at exposures in Hoosick
24 Falls, NY, and Newburgh, NY

25 •University of California – Irvine to look at exposures in communities near the UC Irvine Medical Center

26

1 2.4 General Approach for Study Recruitment

2 In considering possible study designs, ATSDR focused on the methods used in previous epidemiological
3 research of PFAS exposures (ATSDR 2017a). Adopting study design methods consistent with previous
4 research facilitates the interpretation and synthesis of findings across studies. Most of the
5 epidemiological studies of PFAS exposures were cross-sectional and evaluated serum PFAS
6 measurements. Some studies also evaluated cumulative PFAS serum levels estimated from historical
7 reconstruction models. ATSDR concluded that the multi-site study should be cross-sectional and
8 evaluate measured serum PFAS measurements as well as historically reconstructed estimates of
9 cumulative PFAS serum levels. ATSDR also concluded that methods used to evaluate health-related
10 endpoints in the study should be consistent with methods used in previous epidemiological research of
11 PFAS exposures, given adequate sample size and power. In the future, the follow up to the cross-
12 sectional studies of health-related outcomes proposed to be studied in the longitudinal studies.

13 The recipient should work closely with local and state agencies (e.g., public school systems, local and
14 state health departments), local community organizations, and local media to conduct outreach about
15 the study to encourage participation and community engagement with all local stakeholders. For those
16 sites involving a contaminated public water system, the recipient should request that the water
17 purveyor include a flyer about the study in its billing mailings and email notices.

18 If feasible, the recipients were encouraged to identify and enumerate all households served by the
19 contaminated drinking water supply in the selected community in order to recruit potential participants
20 to meet the sample size requirements for children and adults. If the selected community is served by a
21 PFAS-contaminated public water system, then the recipient was encouraged to obtain a list of
22 households served by the water purveyor from its billing records, if available. If the community is served
23 by contaminated private wells, then the recipient was encouraged to obtain a list of households with
24 contaminated wells from the local and/or state health and environmental agencies, if available.

25 Recipients could use statistical sampling methods (e.g., a two stage cluster sample) for recruitment of
26 study participants if all the affected households can be enumerated. However, it was recognized that a
27 simple random sample may not be appropriate if the PFAS drinking water concentrations vary widely
28 across the community. In these situations, a random sample of households stratified by PFAS
29 concentration levels might be more appropriate. However, although a recruitment process based on a
30 statistically-based sampling approach may be theoretically ideal, in practice it may not be feasible. For
31 example, enumeration of all households may not be possible. Moreover, if participation rates are not

1 high, then in order to achieve the sample size objective, it will be necessary to recruit volunteers (i.e.,
2 include a “convenience sample”). Therefore the recipient could consider non-probabilistic sampling
3 approaches such as “judgement” and “snowballing” sampling approaches (Tyrrer 2016).

4 Regardless of sampling method used, the recruitment strategy should achieve a wide distribution of
5 exposure levels among study participants, i.e., it should be exposure-driven, in order to effectively
6 assess exposure-response relationships. Therefore, the recipient should consider a targeted sampling
7 approach, e.g., oversampling areas with higher PFAS drinking water concentrations. If the PFAS
8 concentrations in drinking water are generally uniform throughout the community (e.g., if drinking
9 water from all sources is mixed at the treatment plant prior to distribution), then a targeted sampling
10 approach may not be necessary. On the other hand, if PFAS concentrations are not likely to be uniform
11 throughout the distribution system or among private wells in the affected area, then a targeted
12 sampling approach will probably be necessary with oversampling in areas with higher PFAS drinking
13 water concentrations. To enable a targeted sampling approach, the recipient should use available
14 information and, if necessary, preliminary modeling methods, to classify households in the community
15 by past or present PFAS concentration levels in the drinking water. For contaminated public water
16 systems, the recipient should request distribution system information from the water purveyor in order
17 to identify areas with higher and lower PFAS concentrations in the drinking water. For contaminated
18 private wells, the recipient should request information on the ground water PFAS contamination plume
19 affecting the wells from the local or state environmental agency. Each cooperative agreement recipient
20 is developing their recruitment strategy based on the above recommendations.

21 The recipient should request assistance from local and state health departments in its recruitment
22 efforts. In addition, the recipient should engage community organizations to assist in conducting
23 outreach about the study and recruitment of participants. In addition, the recipient may establish a
24 community assistance panel (“CAP”) to review and provide comments on the study protocol and to
25 facilitate the involvement of the affected community in decisions related to outreach about the study,
26 participant recruitment strategies, and study logistics. The CAP would also assist the recipient in the
27 dissemination of study findings to the community.

28 **2.5 Study Objectives and Study Questions**

29 The main goal of the multi-site study of children and adults is to evaluate the associations between
30 specific health effects and serum PFAS concentrations among those exposed to PFAS-contaminated
31 drinking water.

1 **2.5.1 Literature Review**

2 A literature review was conducted for the Pease feasibility assessment and can be accessed in the final
3 feasibility report (ATSDR 2017a). The literature review from the Pease feasibility assessment concluded
4 that most information on potential health effects concerned exposures to PFOA. In particular,
5 numerous studies have been conducted of West Virginia and Ohio residents and workers exposed to
6 PFOA from a chemical plant via contaminated drinking water and occupationally, respectively (the “C8”
7 studies) (Frisbee 2009). Studies of other workforces also focused primarily on PFOA exposures. The
8 literature review found that less information was available about the potential health effects of PFOS
9 exposures, and little information was available on the potential health effects of exposures to PFHxS.
10 PFHxS and PFOS are often major contaminants in drinking water impacted by AFFF. Except for the C8
11 studies, there is scant information on the health effects of exposures to PFAS-contaminated drinking
12 water.

13 The literature review identified many health-related endpoints evaluated in previous epidemiological
14 studies of PFAS exposures. These included cancers, changes in lipids, effects on thyroid and immune
15 function, and developmental delays. They also included effects on kidney and liver function and sex
16 hormones, and diseases such as endometriosis, ulcerative colitis and osteoporosis (ATSDR 2017a).

17 The literature review found that most of the epidemiological studies of PFAS exposures were cross-
18 sectional and evaluated serum PFAS measurements. Some studies also evaluated cumulative PFAS
19 serum levels estimated from modeling methods. ATSDR concluded that studies of populations exposed
20 to the PFAS-contaminated drinking water should be initially be cross-sectional to be comparable with
21 other studies and to establish a baseline for potential follow-up longitudinal studies. Studies should also
22 evaluate measured serum PFAS measurements as well as estimated cumulative PFAS serum levels and
23 use methods for the evaluation of health-related endpoints that are consistent with methods used in
24 previous epidemiological research of PFAS exposures.

25 **2.5.1.1 Health Effects in Children**

26 There is some evidence that PFAS exposures are associated with decreased birth weight, small birth size
27 for gestational age, measures of intrauterine growth retardation, and preterm birth. In particular,
28 several meta-analyses have found an overall decrease in birthweight associated with PFOA and PFOS
29 (Johnson 2014, Negri 2017, Verner 2015; Bach 2015). However, the findings across studies are
30 inconsistent for adverse birth outcomes, and few studies have evaluated PFHxS. Several studies of

1 infants have found that prenatal PFAS exposures affect thyroid function, but only two studies have
2 evaluated thyroid function in older children (Lopez-Espinosa 2012; Lin 2013, Preston 2018).

3 A few studies of children have found elevated uric acid with PFAS exposures, but the possibility of
4 reverse causation exists (Geigere 2013; Kataria 2015; Qin 2016). Positive findings occurred in some of
5 the four studies of PFAS exposures and testosterone and other sex hormones, but the findings were not
6 consistent across studies and further research is necessary (Maisonet 2015; Lopez Espinosa 2016, Zhou
7 2016). Growing evidence suggests that exposure to per- and polyfluoroalkyl substances (PFASs) may
8 disrupt lipid homeostasis and liver function, but data in children are limited. Indicators of adiposity and
9 glucose metabolism were also linked with PFAS in a large follow up study of children and adolescents
10 (Domazet 2016). Recent study (Mora, 2018) suggests that prenatal and mid-childhood PFAS exposure
11 may be associated with modest, but somewhat conflicting changes in the lipid profile and ALT levels in
12 children.

13 There is some evidence from four studies that PFAS exposures might be associated with attention deficit
14 hyperactivity disorder (ADHD), but findings have not been consistent across studies (Stein 2011; Liew
15 2015; Ode 2014; Hoffman 2010). In the Stein (2011) study, the ORs for ADHD and PFOS and PFHxS were
16 1.3 and 1.6, so there was some evidence of an increased risk, although not strong. A study using
17 NHANES data obtained an OR of 1.6 for PFOS and ADHD (Hoffman 2010). Other studies have found
18 conduct and coordination problems associated with PFOS (Fei 2011) and executive function deficits with
19 PFOS and PFHxS (Vuong 2016). Evaluating the evidence for PFAS exposures and neurobehavioral
20 outcomes is difficult for several reasons: 1) the studies used different methods to measure the
21 outcomes, 2) studies are inconsistent in the outcomes evaluated, and 3) too few studies exist. For
22 example, there is little evidence that PFAS affects IQ, primarily because only two studies evaluated it;
23 one in Taiwan, which observed deficits (Lien 2016), and one at C8 which did not (Stein 2011). We believe
24 it is worth evaluating whether the PFAS mixture at individual sites with contamination due to AFFF use is
25 associated with IQ deficits or other neurobehavioral outcomes. A few studies have found associations
26 between PFAS exposures and a decline in antibody response to specific vaccines (Grandjean 2012,
27 2016), but only two studies evaluated the same vaccine (i.e., rubella; Granum 2013, Stein 2016).

28 In summary, there are considerable data gaps concerning the health effects in children of PFAS
29 exposures. This is because of the small number of studies conducted, inconsistencies in methods and
30 findings across studies, and limited sample sizes in some studies. As for other adverse outcomes, few
31 studies have evaluated the effects on children of PFHxS exposures. A recent systematic review of PFAS

1 studies of children concluded that there was "...generally consistent evidence for PFAS' association with
2 dyslipidemia, immunity including vaccine response and asthma, renal function, and age at menarche"
3 (Rappazzo 2017). The review noted the limited number of studies for any one particular health
4 outcome, the variability in outcome measurement, and the need for longitudinal studies.

5

6 2.5.1.2 Health Effects in Adults

7 Based on its detailed assessment of the epidemiological literature, ATSDR concluded that there was
8 limited information concerning associations with PFAS exposures and most cancers and other adult
9 diseases (ATSDR 2017a).

10 Epidemiologic studies of subjects exposed to PFOA and PFOS at background levels and at occupational
11 settings have reported positive associations with number of health outcomes and conditions. Lipid and
12 cholesterol concentrations were associated with increased PFOA or PFOS (Frisbee 2010; Nelson 2010;
13 Fletcher 2011; Steenland 2015), as were increased uric acid levels (Costa et al., 2009; Steenland 2010;
14 Shankar 2011; Geiger 2013; Gleason 2015), concentrations of thyroid and sex hormones (Olsen and
15 Zobel 2007; Knox 2011; Jain 2013; Wen 2013; Winqvist and Steenland 2014), immune parameters
16 (Dalsager 2016), and reproductive effects (Joensen 2013; Kristensen 2013; Crawford 2017).

17 Associations with liver enzymes were found with PFAS in most cross-sectional studies (Olsen 2000;
18 Sakr 2007; Lin 2010; Gallo 2012; Gleason 2015) but were weaker or found no association in the cohort
19 studies of liver enzymes (Sakr 2007b, Darrow 2016). Structural protein cytokeratin 18 (CK-18) and its
20 components have been used as a new non-invasive serum biomarker for non-alcoholic fatty liver disease
21 and suspected steatohepatitis for adults and children (Fieldstein 2013, Shen 2012, Vos 2008). Prevalent
22 coronary heart disease was positively associated in a cross sectional examination of NHANES (Shankar
23 2012) but not in cohort designs (Winqvist 2014b; Mattsson 2015).

24 Two studies of osteoarthritis show association with PFOA in cross sectional analyses (Innes 2011, Uhl
25 2013) but no association in longitudinal analyses (C8 Science Panel 2012a). Another cross-sectional
26 NHANES study (Khalil 2016) found an association with osteoporosis among women for PFHxS. Two
27 NHANES studies (Lin 2014, Khalil 2016) also found associations with bone mineral density. Although,
28 these studies are cross-sectional, they provide important evidence for a link between PFAS exposures
29 and osteoarthritis and osteoporosis unless there is evidence that confounding or reverse causation can
30 explain these results.

1 In evaluation of kidney function, data from Watkins (2013) and Dhingra (2017) showed that while
2 measured PFOA showed positive association, modeled PFOA concentrations had no relation to eGFR
3 illustrating example of potential reverse causality. C8 Science panel found no association with the
4 nonmalignant renal disease in their cohort study (2021b)

5 There is increasing evidence showing associations between PFAS and markers of glucose homeostasis
6 and insulin resistance, and associations with adult type 2 diabetes risk in men and women (Cardenas
7 2017; He 2018; Sun 2018); strengthening the case for adverse metabolic activity of these compounds.

8 Roles of inflammatory cytokines and adipokines have been explored several studies of liver disease such
9 as non-alcoholic fatty liver disease/steatohepatitis and in atherosclerosis (Hennig 2007, Wahlang 2016,
10 Clair 2018). Proinflammatory responses, alteration in leptin signaling, and increases in TNF-alpha and IL-
11 2 were reported in mechanistic studies with various persistent organohalogen pollutants in relation to
12 diabetes and metabolic syndrome (Ferrante 2014; Wieser 2013). These associations have not yet been
13 explored specifically with PFAS compounds.

14 Some positive associations have also been found for cancer outcomes; with C8 studies finding strong
15 associations for liver, kidney, and testicular cancer (Alexander and Olsen 2007; Barry2013; Bonefeld-
16 Jorgensen2014; Hardell2014; Steenland2015).

17 Some studies have found no association between PFAS exposure and health effects such as specific
18 cancers (Alexander and Olsen 2007; Lundin 2009), lipids or metabolic function (Fisher, 2013). Effects of
19 confounding, bias, and chance on observed associations with PFAS compounds were explored in
20 reviews of immune and cancer outcomes (Chang 2014, Chang 2015) and in studies of PFAS and
21 menopause and endometriosis (Dhingra 2017, Ruark 2017, Ngueta 2017).

22 Few studies have evaluated PFHxS exposures and the risk of cancers and other adult diseases. Although
23 epidemiological studies have primarily evaluated PFOA and PFOS, there remain considerable data gaps
24 concerning the health effects of exposures to these chemicals in adults. There have been
25 inconsistencies in findings across studies and limited sample sizes in some studies. For some adverse
26 outcomes, only one or a few studies have been conducted. Finally, except for the C8 studies, there are
27 no published individual-level epidemiological studies in adults that have evaluated the health effects
28 from exposures to PFAS-contaminated drinking water. Therefore, additional research is necessary to
29 determine whether drinking water exposures to PFHxS, PFOS, and PFOA increase the risk of non-cancer

1 diseases. The proposed scope of the funding and sample size estimated for this health study would be
2 too small and insufficient to evaluate cancer health outcomes.

3 **2.5.2 Hypotheses**

4 For children (aged 4-17 years), the Multi-site Study will evaluate the following main hypotheses,
5 following the outline of the biochemical analytical plan (**Attachment 2**):

6 Higher serum levels of PFOA, PFOS, PFHxS, or other PFAS are associated with:

- 7 1. Lipids (higher total cholesterol, low-density lipoprotein, and triglycerides, and higher prevalence
8 of hypercholesterolemia; obesity).
- 9 2. Impaired renal function (a higher level of uric acid, a higher prevalence of hyperuricemia, and a
10 lower estimated glomerular filtration rate (eGFR).
- 11 3. Liver function/damage biomarkers (alanine transaminase (ALT), aspartate aminotransferase
12 (AST), alkaline phosphatase (ALP), γ -glutamyltransferase (GGT), albumin, direct bilirubin,
13 cytokeratin-18 (CK-18)), and non-alcoholic fatty liver disease/steatohepatitis (determined by CK-
14 18 levels).
- 15 4. Glycemic parameters (glucose, insulin, glycosylated hemoglobin (HbA1c), auto-antibodies (GAD-
16 65 and IA-2), C-peptide, pro-insulin; and diabetes (type 1 and 2).
- 17 5. Measures of thyroid function (differences in thyroid stimulating hormone - TSH, total thyroxin -
18 TT4, free T4, and total triiodothyronine (TT3); thyroglobulin antibody, thyroid peroxidase
19 antibodies (TPO); higher prevalence of hypothyroidism/hyperthyroidism).
- 20 6. Differences in sex hormones, growth and sexual maturation (testosterone, estradiol, and sex
21 hormone-binding globulin (SHBG); insulin-like growth factor - 1 (IGF-1), age at menarche,
22 delayed puberty).
- 23 7. Immune response including prevalence of hypersensitivity-related outcomes (e.g., asthma,
24 atopic dermatitis; higher levels of immunoglobulins (IgG, IgA, IgE, and IgM) and lower antibody
25 responses to rubella, mumps, and diphtheria vaccines).
- 26 8. Neurodevelopmental outcomes (lower intelligence quotient (full scale IQ), attention-deficit and
27 hyperactivity disorder [ADHD]).

28

- 1 For adults (aged ≥ 18 years), the Multi-site Study will evaluate the following main hypotheses.
- 2 Higher serum levels of PFOA, PFOS, PFHxS, or other PFAS are associated with:
 - 3 1. Lipids (higher total cholesterol, low-density lipoprotein and triglycerides) and a higher
4 prevalence of hypercholesterolemia).
 - 5 2. Higher prevalence of coronary artery disease and hypertension (including hypertensive
6 disorders of pregnancy).
 - 7 3. Renal function (higher level of uric acid and a higher prevalence of hyperuricemia, lower
8 estimated glomerular filtration rate (eGFR)) and higher prevalence of kidney disease.
 - 9 4. Glycemic parameters (glucose, insulin, glycosylated hemoglobin (HbA1c), auto-antibodies (GAD-
10 65 and IA-2), C-peptide, pro-insulin) and diabetes (type 1 and 2).
 - 11 5. Differences in thyroid hormones (thyroid stimulating hormone (TSH), TT4, free T4, and TT3,
12 thyroglobulin antibody, thyroid peroxidase antibodies (TPO)); and higher prevalence of
13 hypothyroidism/hyperthyroidism.
 - 14 6. Liver function/damage biomarkers (e.g. alanine transaminase (ALT), aspartate aminotransferase
15 (AST), alkaline phosphatase (ALP), γ -glutamyltransferase (GGT), albumin, direct bilirubin,
16 cytokeratin-18 (CK-18)) and liver disease.
 - 17 7. Higher prevalence of osteoarthritis
 - 18 8. Higher prevalence of osteoporosis.
 - 19 9. Higher prevalence of endometriosis.
 - 20 10. Measures of immune response and inflammation (serum levels of IgA, IgE, IgG, IgM, C - reactive
21 protein (CRP), rheumatoid factor, antinuclear antibodies (ANA), inflammatory cytokines and
22 adipokines (interleukin 1- β (IL-1 β), interleukin 4 (IL-4), interleukin 6 (IL-6), interleukin 8 (IL-8),
23 interleukin 12 (IL-12), monocyte chemotactic protein-1 (MCP-1), tumor necrosis factor α (TNF α),
24 leptin, adiponectin, resistin, plasminogen activator inhibitor-1 (PAI-1).
 - 25 11. Higher prevalence of autoimmune diseases such as ulcerative colitis, rheumatoid arthritis, lupus,
26 and multiple sclerosis.

27

1 2.6 Intended Use of Study Findings

2 Given that epidemiological research on the health effects of drinking water exposures to PFAS other
3 than PFOA is at an early stage, the Multi-site Study should make an important contribution to the
4 scientific literature, expand knowledge in this field, and help addressing concerns about past exposure.

5 Additionally, the Multi-site Study will provide the PFAS serum level and the results of the clinical tests
6 and effect biomarker tests to each study participant. The participant can use this information for
7 medical decision-making. Advice and assistance (e.g. workshops and or training programs) to clinicians
8 in each community be provided by recipients and ATSDR as a part of the community engagement efforts
9 to be able to answer questions about the potential effects of elevated PFAS levels on health,
10 interpreting results, additional test or treatments. ATSDR will provide summaries of the study findings
11 to the participating affected communities and will also provide assistance in interpreting each of these
12 results.

13

14 3. METHODS

15 3.1 Study Design

16 The Multi-site study will be cross-sectional with separate evaluation of children (ages 4 - 17 years) and
17 adults (aged ≥ 18 years). The participants will be recruited from lists of residences served by PFAS-
18 contaminated drinking water.

- 19 • The recipient will obtain adult consent and parental permission (ages 4-17) and child assent
20 (ages 7 -17), to participate in this research study (including consent to be contacted for any
21 future studies).
- 22 • The recipient will administer adult and child questionnaires and seek medical records
23 verification of self-reported diseases and medical histories (including neurobehavioral diseases).
- 24 • The recipient will administer neurobehavioral test batteries to the children and their parents
25 and seek to abstract children's school records, in particular, special education records.
- 26 • The recipient will obtain blood samples from each participant for analyses of PFAS and a number
27 of effect biomarkers.
- 28 • As part of the current protocol, both children and adults will be asked to provide a urine sample
29 for future analyses of PFAS and relevant effect biomarkers. The recipient will ship the urine

- 1 samples to CDC biorepository for analysis at a later time when more knowledge is gained about
2 urinary PFAS and effect biomarkers and until the laboratory methods are developed.
- 3 • The recipient will seek consent to store residual blood and urine samples for future analyses of
4 other PFAS and/or relevant effect biomarkers yet to be identified.

5 **3.2 Study Populations and Eligibility**

6 The target areas for the Multi-site Study are those served in the present or past by public water systems
7 and/or private wells with documented past or present PFAS concentrations at the tap. The target
8 populations consist of those residing in households in the target areas. Those eligible for the study
9 include individuals aged ≥ 4 years at the start of the study who reside in a household in the target area
10 and whose last exposure to drinking water exceeding the EPA Lifetime Health Advisory Level for PFOS
11 and PFOA was no more than 15 years prior to the start of the study. In addition to those who resided in
12 households served by contaminated drinking water, individuals exposed in utero and during
13 breastfeeding when the mother resided in the household would also be eligible if the exposure occurred
14 within 15 years of the start of the study. The limit of 15 years since last exposure was chosen to take
15 into account the estimated half-lives in the body of PFOA, PFOS and PFHxS and to ensure that exposures
16 to the contaminated drinking water are relatively recent.

17 Firefighters and others with occupational PFAS exposure from sources other than the drinking water will
18 not be included in the study. In addition, children whose birth mothers had occupational exposures to
19 PFAS from sources other than drinking water will be excluded. The goal is to enroll at least 2,000
20 children (ages 4-17) and 6,000 adults aged ≥ 18 years with drinking water exposure to PFAS.

21 **3.2.1 Children**

22 The eligibility criteria for children is as follows:

- 23 1. Aged 4 – 17 years at the start of the study,
- 24 2. Resided in areas with documented past or present PFAS drinking water concentrations at the
25 tap, or were exposed in utero or during breastfeeding when the mother consumed the
26 contaminated drinking water,
- 27 3. Drinking water exposure occurred within 15 years of the start of the study.
- 28 4. Children will be excluded if their birth mothers were ever employed as a firefighter, ever
29 participated in fire training exercises using AFFF foam, or were ever employed at industrial
30 facilities that used PFAS chemicals in the manufacturing process.

1 The requirement that the child's last exposure be within 15 years of the start of the study takes into
2 account the half-lives of about 3 years for PFOA and PFOS, and about 5 years for PFHxS, observed in a
3 recent study of drinking water exposures caused by AFFF use at a military facility in Sweden (Li 2017).
4 Slightly longer half-lives for individual PFAS (5 to 8 years) were derived in the draft ATSDR toxicological
5 profile (ATSDR 2018). Based on these half-lives, those last exposed more than 15 years ago will have
6 greatly diminished current serum levels of these PFAS chemicals, making the use of these serum
7 measurements to predict past exposures more problematic.

8 The age range for the child study (4-17 years) was determined by taking into account the age ranges in
9 previous PFAS studies and the age range appropriate for the candidate endpoints. The study will limit
10 inclusion to those ≥ 4 years of age because most of the neurobehavioral tests that will be used in the
11 study are appropriate for children aged ≥ 4 years of age.

12 **3.2.2 Adults**

13 The eligibility criteria for adults is as follows:

- 14 1. Aged ≥ 18 years at the start of the study.
- 15 2. Resided in areas with documented past or present PFAS drinking water concentrations at
16 the tap,
- 17 3. Drinking water exposure occurred within 15 years of the start of the study.
- 18 4. Persons ever employed as a firefighter, ever participated in fire training exercises using AFFF
19 foam, or ever employed at industrial facilities that used PFAS chemicals in the
20 manufacturing process will be excluded.

21 **3.3 Sample Size Considerations**

22 The Pease feasibility assessment included sample size calculations for a wide range of health related
23 outcomes (ATSDR 2017a). Sample size calculations selected a type 1 (" α error") of .05 and type 2 error
24 (" β error") of .20. The tables present sample sizes per stratum for specific outcomes for children (Table
25 1) and for adults (Table 2). To determine effect sizes that are reasonable to detect, we selected
26 epidemiological studies using NHANES data. For those outcomes not included in NHANES studies, the
27 C8 studies were used. The C8 results were considered more representative of U.S. populations (e.g., in
28 background disease rates and prevalence of non-PFAS risk factors) than studies conducted in other
29 countries, although the PFOS, and especially the PFOA, serum levels in the C8 studies were higher than
30 might occur at other sites. For outcomes not evaluated by NHANES or C8 studies, it was necessary to use

1 studies conducted in other countries. The total sample sizes for children and adults should allow for the
2 categorization of PFAS serum levels (or cumulative PFAS serum levels) into e.g. quartiles of exposure:
3 reference level, low, medium and high.

4 **Attachment 3** includes additional information and assumptions pertinent to selected health outcomes
5 to be studied.

6 **3.3.1 Children**

7 For children, **Table 1** (and **Attachment 3a**) provide the sample size calculations for several health
8 outcomes of interest assuming a type 1 (“ α error”) of .05 and type 2 error (“ β error) of .20. It was
9 considered important that a study have a total sample size so that exposures could be categorized into
10 tertiles (i.e., reference, medium, and high) or preferably into quartiles (i.e., reference, low, medium and
11 high). Per stratum estimates of needed sample size have been calculated based on different prevalence
12 of outcomes and detected odds ratios or mean difference.

13 The proposed minimum sample size of 2,000 children (equally of both sexes) is large enough to
14 effectively evaluate many of the health outcomes identified in the Pease Feasibility Assessment
15 literature review and the recent systematic review (Rapazzo 2017) as potentially associated with PFAS in
16 children. The health outcomes and biomarkers studied would include mean difference in total
17 cholesterol (ranging from 156 to 637 per stratum), uric acid levels (556 per stratum), estimated
18 glomerular filtration rate (eGFR; 275 per stratum), testosterone (about 400 per stratum) and insulin
19 growth factor-1 (IGF-1; 146 per stratum). Based on our estimations, we would also be able to detect
20 differences in risk for obesity and atopic dermatitis. A sample size of 2,000 children would be larger
21 than many of the PFAS studies that evaluated neurobehavioral outcomes such as IQ and ADHD (Wang
22 2015, Stein 2013, 2014, Fei 2011, Hoffman 2010, Strom 2014).

23 An NHANES study of estimated glomerular filtration rate observed statistically significant findings with a
24 total sample size of just under 2,000 children (Kataria 2015). For thyroid function, estradiol, delayed
25 puberty, and asthma, a total sample sizes of 2,000 children may be sufficient, although larger sample
26 sizes would be optimal (Lopez-Espinosa 2011, 2012; Stein 2016).

27 In summary, a total sample size of $\geq 2,000$ would be sufficient to evaluate a wide range of biomarkers
28 and outcomes including lipids (and hypercholesterolemia), uric acid (and hyperuricemia), estimated
29 glomerular filtration rate, testosterone, IGF-1, neurobehavioral measures (executive function, attention,

- 1 IQ) and ADHD, rhinitis, and obesity. Each cooperative agreement recipient will attempt to meet a target
- 2 recruitment of 300 children.
- 3 **Table 1.** Sample size estimations for selected health-related endpoints in Child Study (ages 4-17 years)

Health-related Endpoint	Relevant Study	Observed Effect Size	Assumptions	Sample Size/Stratum α error = .05 β error = .20
Total Cholesterol (mg/dL)	Frisbee 2010, C8 Study 1,971 boys <12 yrs 2,773 boys 12-18 yrs 1,886 girls <12 yrs 2,520 girls 12-18 yrs	PFOS: 5 th vs 1 st quintile Age: <12 yrs 12-18 Boys: +6.2 +9.3 Girls: +4.6 +9.4	Mean PFOS serum levels were about 20 μ g/L. SD for total cholesterol=29.3 mg/dL	+4.6: 637/stratum +9.3: 156/stratum
High cholesterol		OR = 1.6	Prevalence=34.2%	300/stratum
Thyroid function TT ₄	Lopez-Espinosa 2012, C8 1,078 1-5 yrs 3,132 6-10 yrs 6,447 >10 - 17 yrs	PFOS, 4 th vs 1 quartile: 2.3% change (mean difference = 0.17 μ g/dL)	Mean PFOS serum levels were about 20 μ g/L. SD for TT ₄ as estimated at 1.4. Percent change in TT ₄ was converted to mean difference assuming the median TT ₄ was ref. level.	1,080/stratum
Thyroid disease		PFOA: OR=1.44 (PFOS: OR < 1.0)	Prevalence=0.6% (used PFOA results)	>16,000/stratum
Uric Acid	Kataria 2015, NHANES 1,960; 12-18 yrs	PFOS: 4 th vs 1 st quartile = +0.19 mg/dL	Mean PFOS serum level = 12.8 μ g/L. SD = 1.19.	556/stratum
Hyperuricemia	Geiger 2013, NHANES 1,772; 12-18 years	PFOS: 4 th vs 1 st quartile, OR=1.65	Mean PFOS serum level =16.6. Prevalence=16%	400/stratum
eGFR	Kataria 2015	PFOA mean serum level	Standard	275/stratum

	1,960; 12-18 yrs	=3.5 µg/L. mean difference= -6.6	deviation=27.6	
Testosterone	Lopez-Espinosa 2016, C8 1,169 boys; 6-9 yrs 1,123 girl; 6-9 yrs	PFOS (IQR): -5.8% boys (diff=1.9) -6.6% girls (diff=2.45)	Percent change was converted to mean difference assuming median testosterone level was ref. level. SD estimated at 11.85 for girls and 9.63 for boys.	Boys: 404/stratum Girls: 368/stratum
IGF-1 (Insulin-like growth factor - 1)	Lopez-Espinosa 2016, C8	PFHxS (IQR): Boys: -2.5% (diff=17.3) Girls: -2.1%	Percent change was converted to mean difference assuming median IGF-1 in boys as ref. level. SD estimated as 52.6	146/stratum
Delayed Puberty	Lopez-Espinosa 2011. C8 3,072 boys, 8-18 yrs 2,903 girls, 8-18 yrs	PFOS: mean serum level was about 19 µg/L.	OR for delayed puberty and the number of days delayed puberty had narrow CIs	Insufficient information to calculate sample size, but sample sizes in this study were enough for sufficient precision.
ADHD	Stein 2011, C8 10,546; aged 5-18 yrs.	PFHxS mean serum level was 5.2 µg/L. 4 th vs 1 st quartile, OR=1.5	Prevalence: ADHD Dx: 12.4%	764/stratum
Asthma	Stein 2016, NHANES 640; 12-19 yrs	PFOA mean serum level = 3.6 µg/L. OR=1.2	Prevalence = 11%	2,400/stratum
Atopic dermatitis	Wang 2011 (Taiwan) 244; infants, 2 yrs	PFOS mean serum level=5.5 µg/L., 4 th quartile OR=2.19	Prevalence=10.7%	220/stratum
Obesity	Karlsen 2017 (Faroes)	PFOA mean serum level=2.22 µg/L. OR=1.88	Prevalence=17%	250/stratum

1 Note: Observed effect sizes focused on the results for serum levels of PFOS and/or PFHxS.

1 [†] eGFR –estimated glomerular filtration rate, TT4 – total thyroxine; IGF-1 – insulin-like growth factor 1; ADHD – attention-deficit
2 and hyperactivity disorder.

3

4 **3.3.2 Adults**

5 For adults, **Table 2** (and **Attachment 3b**) provide the sample size calculations for several health
6 outcomes of interest assuming a type 1 (“ α error”) of .05 and type 2 error (“ β error”) of .20. In this
7 exposure based study, we assume an appropriate coverage of range of exposures that will enable
8 stratification/categorization to tertiles or quartiles of exposure. Per stratum estimates of needed sample
9 size (e.g. first vs. fourth quartile) have been calculated based on different measures of association such
10 as odds ratios or detected mean difference.

11 The proposed minimum sample size of 6,000 adults (equally of both sexes) is large enough to effectively
12 evaluate many of the health outcomes identified in the Pease Feasibility Assessment literature review.
13 For example, for outcomes like elevated lipids levels (cholesterol) or uric acid, the range of 229 to 660
14 participants per stratum (i.e. quartile) or 200 to 550 per stratum, respectively, given observed
15 differences would be needed. That would translate to overall sample size of about 800 to 2,600
16 participants being sufficient to detect differences at the specified level of precision and power
17 (Steenland, 2009, 2010; Fisher 2013; Shankar 2011). Similar sample sizes would also be required to
18 compare other common health outcomes such as cardiovascular disease (Shankar 2012). Larger samples
19 sizes would be needed for liver function or osteoarthritis, with a total sample in the range of 3,000 to
20 4,000 subjects (Uhl 2013; Gallo 2012; Steenland 2010).

21 For thyroid disease and thyroid function, a total sample size of 6,000 may be sufficient although
22 probably not optimal. However, NHANES studies of thyroid function and thyroid disease obtained
23 statistically significant findings with total sample sizes considerably less than 6,000 (Melzer 2010; Wen
24 2013). NHANES studies of liver function also obtained statistically significant findings with total sample
25 sizes considerably less than 6,000 (Gleason 2015; n=4333). For biomarkers of immune function (e.g.,
26 immunoglobulins, C-reactive protein and cytokines) and fatty liver disease, there was insufficient
27 information to calculate sample sizes. However, a total sample size of 6,000 should be sufficient to
28 evaluate these biomarkers as we assumed similar endpoint differences of those outcomes.

29 For ulcerative colitis, a sample size of 6,000 might be sufficient if the effect size in the C8 study (i.e.,
30 OR=3.05) was consistent for PFOA serum levels considerably lower than those in the C8 study. For more
31 modest effect sizes (e.g., ORs < 2.75), a total sample size of 6,000 would not be adequate to evaluate
32 associations with ulcerative colitis.

1 In addition, several epidemiological studies of adults exposed to PFAS that reported robust statistical
 2 associations with these health outcomes had smaller sample sizes than the one proposed for the Multi-
 3 site Study, e.g., NHANES studies (Nelson 2010, Wen 2013), a C8 longitudinal study (Fitz-Simon 2013), a
 4 C8 immune study (Looker 2014), and studies in China (Fu 2014) and Korea (Ji 2012).

5 In summary, a total sample size of $\geq 6,000$ in multi-site study should be sufficient to evaluate a broad
 6 range of biomarkers and outcomes such as lipids (and hypercholesterolemia), uric acid (and
 7 hyperuricemia), cardiovascular disease, osteoarthritis, immune biomarkers and biomarkers for fatty liver
 8 disease. It also may be sufficient to evaluate thyroid disease, thyroid function and liver function. Each
 9 cooperative agreement recipient will attempt to meet a target recruitment of 1,000 adults.

10

11 **Table 2.** Sample size estimations for selected health-related endpoints in Adult Study.

Health-related Endpoint	Relevant Study	Observed Effect Size	Assumptions	Sample Size/Stratum α error = .05 β error = .20
Total Cholesterol (mg/dL)	Steenland 2009, C8 46,294 aged ≥ 18 yrs	PFOS, mean serum level = 19.6 $\mu\text{g/L}$, 10 th vs 1 st decile: +11 mg/dL	SD=41.9	228/stratum
High cholesterol		4 th vs 1 st quartile, OR=1.51	Prevalence=15%	660/stratum
High Cholesterol	Fisher 2013, Canada	PFHxS, mean serum level = 2.2 $\mu\text{g/L}$, 4 th vs 1 st quartile, OR=1.57	Prevalence=44%	290/stratum
Cardiovascular disease	Shankar 2012, NHANES 1,216 aged ≥ 40 years	PFOA mean serum level = 4.2 $\mu\text{g/L}$, 4 th vs 1 st quartile: OR=2.01	Prevalence = 13%	250/stratum
Uric Acid	Steenland 2010, C8 53,458 aged ≥ 20 yrs	PFOS mean serum level = 20.2 $\mu\text{g/L}$, 10 th vs 1 st decile: +0.22 mg/dL	SD=1.55	780/stratum

		Hyperuricemia, 5 th vs 1 st quintile: OR=1.26	Prevalence:24%	1,525/stratum
Uric Acid	Shankar 2011, NHANES 3,883 aged ≥20 yrs	PFOA mean serum level = 3.5 µg/L, 4 th vs 1 st quartile: +0.44 mg/dL Hyperuricemia, 4 th vs 1 st quartile: OR=1.97 PFOS mean serum level = 17.9 µg/L Hyperuricemia, 4 th vs 1 st quartile: OR=1.5	SD = 2.5 Prevalence: 19.2%	507/stratum 200/stratum 550/stratum
Liver function Elevated ALT	Gallo 2012, C8 46,452 aged ≥18 yrs	PFOA and PFOS mean serum levels were 28 µg/L and 20.3 µg/L, respectively. PFOA: OR=1.54 PFOS: OR=1.25	Prevalence = 11.2%	725/stratum 2,917/stratum
Liver function ALT (µIU/mL)	Gallo 2012, C8 46,452 aged ≥18 yrs	The top quintile of serum PFOS in the Pease population was 15 µg/L. This would approximately correspond to a mean difference in ALT of +1.8 µIU/mL	SD=1.47	1,958/stratum
Liver function Elevated ALT	Gleason 2015, NHANES 4,333 aged ≥12 yrs	PFHxS mean serum level = 1.8 µg/L. 4 th vs 1 st quartile: OR=1.37	Assumed similar prevalence as in the C8 study	1,570/stratum
Thyroid disease	Melzer 2010, NHANES 1,900 men, aged ≥20 yrs 2,066 women, aged ≥20 yrs	PFOA, mean serum level=3.5 µg/L, 4 th vs 1 st quartile: Thyroid disease ever: Women, OR=1.64 Men, OR=1.58 Thyroid disease with current meds	Prevalences: 16.18% 3.06%	410/stratum 2,035/stratum

		Women, OR=1.86 Men, OR=1.89	9.89% 1.88%	365/stratum 1,575/stratum
Subclinical hypothyroidism	Wen 2013, NHANES 672 males aged ≥20 yrs 509 females aged ≥20 yrs	PFHxS mean serum level averaged about 2 µg/L. Unit increase in Ln(PFHxS): Women, OR=3.10 Men, OR=1.57	Prevalences: 1.6% 2.2%	475/stratum 2,918/stratum
Osteoarthritis	Innes 2011, C8 49,432 aged >20 yrs	OR=1.42	Prevalence=7.6%	1,580/stratum
Osteoarthritis	Uhl 2013, NHANES 4,102 aged 20-84	PFOA mean serum level = 5.4 µg/L, 4 th vs 1 st quartile: OR=1.55 PFOS mean serum level = 24.6 µg/L, 4 th vs 1 st quartile: OR=1.77	Assumed similar prevalence as in the C8 study	978/stratum 550/stratum
Ulcerative colitis	Steenland 2013, C8 28,541 community and 3,713 worker cohorts	OR=3.05	Prevalence=0.5%	1,480/stratum

- 1 For rare health outcomes such as ulcerative colitis, other autoimmune diseases, or cancer the sample size
- 2 of 6,000 adults is too small to detect reasonably expected increases in the ORs.
- 3 It should be noted that the number of PFAS epidemiological studies available for each of the outcomes is
- 4 limited, and the actual differences in clinical and research parameters may be quite different in the
- 5 Multi-site study than have been observed in the PFAS literature. Sample size estimates provide
- 6 guidance and may be useful for planning purposes but should be interpreted with caution, especially
- 7 given the limited nature of the PFAS literature.
- 8 **Attachment 3** provides further information and details on the derivation of the sample size calculations
- 9 for Table 2 and also estimates of detectable mean difference and odds ratios for selected clinical tests
- 10 and health outcomes.

1 3.4 Study Roll Out and Communication Plan

2 The recipient will work with local and state health and environmental agencies as well as local and state-
3 wide community groups in conducting outreach to encourage participation in the study. The recipient
4 may establish a community assistance panel (CAP) at each site, (or covering several nearby sites), to
5 assist in outreach efforts. The recipient may also establish a multi-site “umbrella” CAP, with community
6 representatives from each of the sites included in the study, to develop a coordinated, across-site,
7 approach to conducting outreach about the study.

8 Community involvement via a CAP or an alternative participatory mechanism will be crucial in achieving
9 a high participation rate at each site and the sample size requirements of the study. In advance of the
10 start of the study, outreach and engagement will involve announcements to local elected officials,
11 medical societies/community health clinics, local media, community organizations, local unions, the
12 public school system, and local private schools (**Attachment 5**). Outreach may also involve meetings with
13 community representatives, medical societies, school officials, and/or public meetings. Although active
14 in outreach, state and local agencies, CAPs, unions and community organizations will not directly obtain
15 consent, intervene, or interact with research participants. As part of the outreach, the recipient will
16 prepare a factsheet for distribution to state and local agencies, unions, and community groups
17 (**Attachment 5, Attachment 7c**).

18 3.5 Recruitment

19 For sites with a contaminated public water supply, the recipient will request a list of residences served
20 by the water purveyor. The information requested will include the name of the person on the
21 residential account and the street address of the residence. The recipient will also request information
22 from the water purveyor on the distribution system characteristics, in particular, whether the PFAS
23 concentrations can be assumed to be relatively uniform throughout the system or whether the system
24 had specific areas with substantially higher or lower PFAS concentrations. If uniform PFAS
25 concentrations can be assumed, then a random sample of households may be conducted and
26 recruitment letters mailed to these households. If the system has specific areas with substantially
27 higher PFAS concentrations, then households in these areas will be targeted (oversampled) for
28 recruitment letters.

29 For sites with contaminated private wells, the recipient will request information on the impacted
30 residences and the results of PFAS sampling of their private wells from the state and/or local health and

1 environmental agencies. Sampling will target households based on the magnitude of the PFAS
2 concentrations in their private wells - i.e., wells with higher concentrations will be oversampled.

3 Recruitment letters will provide a phone number to call for information about the study and to accept
4 the invitation to participate in the study. The recipient will screen each interested caller using an
5 eligibility screening script (**Attachment 4**). If necessary to achieve a high participation rate and the
6 sampling size goal for the site, study staff may visit the sampled households to recruit participants.

7 Sampled households may have more than one eligible adult and/or child, and some parents may want to
8 enroll in both of the adult and child studies. Trained study staff will use the recruitment tracking form
9 (**Attachment 6**) to track recruitment success and to calculate non-response bias.

10 **3.5.3 Enrollment Procedures**

11 Once potential recruits express interest and are screened for eligibility, study staff will schedule
12 appointments for them at the central study office, or alternatively for a home visit for some who are
13 unable or unwilling to attend an office visit and who live a reasonable distance to the office. The study
14 staff will establish a toll-free telephone line for interested recruits to schedule appointments at their
15 convenience. Once the appointment is scheduled, study staff will mail an Appointment Packet
16 (containing an Appointment Reminder Card (**Attachment 7a**), the Informed Consent materials
17 (**Attachment 7b**), a Study Fact Sheet (**Attachment 7c**) with a description to arrive fasting, and to bring
18 medications and a urine sample to the appointment. Interested recruits will be mailed urine collection
19 supplies. They will be instructed to collect a first-morning voided urine sample on the day of their
20 appointment. An advance copy of the Informed Consent Form will provide an extra opportunity for the
21 interested recruit to read and more fully understand his or her rights in the study and to ask any
22 questions before the scheduled appointment.

23 Study staff will give the interested recruit a reminder telephone call and send a text one to two days
24 before the scheduled appointment (**Attachment 8**). The study protocol will provide the flexibility to
25 schedule or re-schedule office or home visits within the study period. Interested recruits who are unable
26 or unwilling to come to the study office and live within a one-hour drive of the study office, will be
27 offered an in-home appointment by trained study staff to complete the study. Interested recruits who
28 request or require a home interview, blood draw, and urine collection, should reside within a one-hour
29 drive from the study office. The study staff will make up to five contact attempts to an interested recruit

1 who misses an appointment in order to reschedule the appointment and maximize the number of
2 completed appointments (**Attachment 9**).

3 **3.6 Data Collection Procedures**

4 The study will establish a central office in each study site to obtain informed consent, blood and urine
5 specimens, administering the neurobehavioral batteries to parents and children, and providing a space
6 for completion of the questionnaire. Study staff will be available to answer any questions concerning the
7 study. All study staff will receive training on the goals and purposes of informed consent, administration
8 of the questionnaire, administration of the neurobehavioral test batteries, collection methods for the
9 blood specimens, and on proper documentation of data collection procedures. Study staff will receive
10 certified training on Human Subjects Protection (e.g., Collaborative Institutional Training Initiative [CITI]
11 Program) and sign a confidentiality agreement prior to contact with potential recruits and enrolled
12 participants.

13 Trained study staff will attend dedicated telephone lines to respond to questions and to address
14 concerns from potential recruits, enrolled participants, and the public. Study staff will ask participants to
15 attend their appointment in at least an eight-hour fasting state; therefore, most recruits will likely
16 schedule appointments in the early morning. The steps of the data collection will include:

- 17 1. Check-in procedures;
- 18 2. Informed consent;
- 19 3. Data collection procedures;
- 20 4. Exit procedures; including provision of a gift card as a token of appreciation for participation.

21 **3.6.1 Check-in Procedures**

22 Trained study staff will document the completion of each step from check-in to the provision of gift
23 cards on a hard copy form (**Attachment 9**). This hardcopy form will be stored with the participant's
24 signed Informed Consent Form (**Attachment 7b**) in locked files and in secure rooms. Staff will securely
25 ship all files to ATSDR at the end of data collection. All files and biological samples will be securely stored
26 at the study office prior to shipment.

1 **3.6.2 Informed Consent Process**

2 The informed consent includes a description of study procedures and risks and benefits of participation
3 (**Attachment 7b**), including a Privacy Act Statement (**Attachment 7b1**). A study factsheet will inform the
4 adult participant and the child participant and parent of the chemical tests and clinical outcomes to be
5 measured (**Attachment 7c**). Study staff will emphasize the voluntary nature of participation and will
6 answer any questions the participant, or parent of the child participant, has prior to obtaining
7 signatures.

8 3.6.2.1 Consent for Specimens and Data

9 The recipient will obtain fasting blood specimens from each participant for analyses of PFAS and several
10 effect biomarkers. In addition, all participants will be asked to provide a morning void urine sample on
11 the same day as their blood draw. After all the current laboratory analyses on blood are completed, the
12 recipient will ask for permission to archive any residual blood specimens and the urines for future
13 analyses of PFAS and/or effect biomarkers.

14 If a study participant previously had a PFAS serum measurement, the recipient will ask the participant
15 for the results.

16 3.6.2.2 Child Consent

17 Before any data collection can begin in the child study, trained study staff will review the hardcopy
18 Parental Permission and Assent Form (**Attachment 7b2**) with the parent who is interested in having the
19 child participate. The study staff will explain to the parent and child the purpose of the study and
20 request that the parent sign the permission forms. If the child is seven years of age or older, the study
21 staff will request that the child give an assent to participate in the study.

22 The recipient will request that the parent complete a questionnaire about the child and complete a
23 parental neurobehavioral test battery on behalf of the child. The permission form will request that the
24 parent allow the child to donate a fasting blood specimen and store any residual specimens for future
25 analyses. The parental permission form will allow the investigators to administer a neurobehavioral test
26 battery to the child, access the child's medical and school records (including special education records)
27 (**Attachments 7b2, 7b3 & 7b5**), and to contact the child and parent for possible future studies. Once the

1 parent signs the consent and permission forms (and the child aged ≥ 7 years gives assent to participate),
2 the parent and/or the child become study participants in the future.

3 3.6.2.3 Adult Consent

4 Before any data collection can begin in the adult study, trained study staff will review the hardcopy
5 Adult Consent Form with the interested recruit (**Attachment 7b4**). The study staff will explain the
6 purpose of the study and obtain written informed consent for the completion of a questionnaire, the
7 collection of a new fasting blood specimen, the storage of this blood specimen for future analyses,
8 access to medical records (**Attachment 7b5**), and permission to contact the participant in the future for
9 a possible study . After signing the consent form, the adult will become a study participant.

10 3.6.2.4 Risks and Benefits

11 As further described in **Section 3.8.1**, the recipient will inform the participant that his or her
12 participation is protected by a Certificate of Confidentiality under Section 301(d) of the Public Health
13 Service Act as amended by Section 2012 of the 21st Century Cures Act. The recipient will further inform
14 the participant that access to identifiable occupational history, private medical records, and to school
15 records are protected from certain disclosures under Section 301(d) of the PHSA.

16 The risks of participation in this study are minimal (defined in 45 CFR 46.110). In-home urine collections
17 are minimal risk. This study plans for a one-time 30-ml volume of fasting blood collected from the child
18 and a one-time 40-ml volume of fasting blood collected from the adult. These amounts of blood are the
19 minimum necessary to conduct analyses for PFAS and the effect biomarkers (**Attachment 2**). After the
20 blood draw, the participant will be offered a small snack, thereby allowing monitoring of adverse events
21 due to phlebotomy.

22 Participants in this study will not receive any direct benefit from taking part in this research. Their taking
23 part in this research will provide the scientific community and the public a better understanding of how
24 exposures to PFAS-contaminated drinking water may affect human health. Each adult participant and
25 the parent of the child participant will receive the results of the analyses of serum PFAS levels and effect
26 biomarkers. They will receive the results of their urine PFAS and effect biomarker levels, if ATSDR
27 identifies meaningful urinary analyses to perform.

1 **3.6.3 Update Contact Information and Medication List**

2 The adult participant and the parent of the child participant will be asked to verify and update his or her
3 current contact information for results reporting and potential future contact (**Attachment 10**).

4 The study staff will request that the adult participant and the parent of the child participant bring all
5 current prescription and over the counter medications prior to the study office. This will help the study
6 staff to complete the medications list (**Attachment 11**).

7 **3.6.4 Body and Clinical Measurements**

8 Trained study staff will perform the body and clinical measurements and specimen collections as
9 described in the Manual of Procedures (**Attachment 12**).

10 *Body Measurements:* Trained study staff will perform body measurements, blood pressure
11 measurements, and blood draws. Three blood pressure (BP) measurements will be taken and averaged.
12 The measured BP level is subject to biological and observer variability; therefore, the study will use
13 three different sizes of the manual cuffs in the measurements; the appropriate cuff size will be selected
14 for each participant and administered 3 times. The purpose of a specific measurement protocol, or
15 training and certifications of technicians and of ongoing quality control is to minimize variability due to
16 known exogenous factors and to reduce imprecision and biases in measurement. Measurement of
17 resting blood pressure, height, weight, and waist and hip circumference can occur in any order, but the
18 BP measurement should occur after the subject has been in the seated position for at least five minutes.
19 BP measurement will occur before venipuncture if the activities are scheduled consecutively. Trained
20 study staff will record the measurements in the Body and Blood Pressure Measures Form (**Attachment**
21 **13**).

22 *Fasting Blood Specimen and First Morning Urine Void Collection:* Participants will transport their urine
23 sample to study office for collection. Trained staff will collect and record the urine specimen intake
24 (**Attachment 14**). The blood collection procedure consists of administering and recording responses to a
25 blood draw screening questionnaire for conditions that exclude the participant from the blood draw
26 (hemophilia, skin condition, or chemotherapy in the past four), ask about having diabetes, taking blood
27 thinning medications, participant's weight, pregnancy, and fasting status (**Attachment 14**). Next,
28 phlebotomists will draw 30-ml (about 1.0 ounce or about 6 teaspoons) of blood from the child
29 participant and 40-ml (1.3 ounces or about 8 teaspoons) of blood from the adult participant using

1 standard venipuncture techniques (**Attachment 12**) and record the outcome (**Attachment 14**). If a
2 person is unable to provide the desired volume of blood, a smaller amount can be drawn and
3 documented. Trained study staff will record the phlebotomy and urine collection result on the Blood
4 Draw and Urine Collection Form (**Attachment 14**).

5 Common adverse events from blood draws include bruising, bleeding, and fainting. No serious adverse
6 events are anticipated in drawing these volumes of blood. Fasting diabetic participants who use insulin
7 will receive priority appointments for their blood draw. Light snacks will be provided following blood
8 collection. While each participant will be asked to provide a fasting sample, it is recognized that some
9 may not be able to fast. Variations in lipids levels due to fasting will affect PFAS compounds
10 measurements to a lesser extent as PFAS in serum are bound to proteins not the lipid fraction. . In the
11 C8 Science Panel studies, about 25% of participants fasted – but they were not asked to do so (Frisbee
12 2009).

13 Phlebotomists will extract serum, and label and prepare the serum and urine specimens for secure
14 storage and transport from the study office to the CDC NCEH laboratory in Atlanta, GA (**Attachment 12**).

15 The NCEH laboratory will perform the analyses of serum PFAS according to the biochemical analytical
16 plan (**Attachment 2**) and approved laboratory methods (Kuklenyik 2015). The NCEH laboratory staff will
17 also aliquot and ship blood and serum specimens to participating laboratories for the analyses of the
18 effect biomarkers according to the plan. The recipient will store the urine samples and conduct analyses
19 at a later date when more knowledge is gained about urinary PFAS and effect biomarkers and until the
20 laboratory methods are developed. Residual blood and urines will be archived at NCEH so that
21 additional PFAS or effect biomarkers can be analyzed as new knowledge and analytical methods become
22 available.

23 **3.6.5 Questionnaire**

24 Each adult participant, and a parent of the child participant, will complete a questionnaire during the
25 appointment for the blood draw.

26 **3.6.5.1 Children and Parents**

27 Study staff will request that the parents of the child participant complete the questionnaire. The
28 questionnaire will obtain demographic information (e.g., education, primary occupation), residential

1 history, water consumption habits, medical history of the mother and child, the child's medications, the
2 mother's reproductive history (including maternal age at birth of the participating child) and any
3 occupational exposures the mother may have had to PFAS. The questionnaire will be administered in
4 two formats: a form for the child whose parent is not also a participant (**Attachment 15**), and an
5 abbreviated form for the child whose parent is also an adult participant (**Attachment 15a**).

6 The questionnaire will obtain the mother's and child's residential history in the study area, and the dates
7 and length of time of the pregnancy and breastfeeding of the child. The questionnaire will also obtain
8 information on the water consumption habits (including use of water for formula, juices, etc., bottled
9 water use) of the mother and child when they resided in the study area. Information on the mother's
10 workplaces in the study area (location and dates) and the child's daycare and schools in the study area
11 (location and dates) will be obtained.

12 The questionnaire will request information on the child's height and weight, vaccination history, and
13 whether the child regularly exercises, currently smokes (and the number of cigarettes/day) or consumes
14 alcohol (and the number of drinks/week). The questionnaire will ask when the female child first began
15 to menstruate. The questionnaire will include specific questions addressing health outcomes of interest.
16 For example, for ADHD, the questionnaire will ask, "Has a doctor or health professional ever told your
17 child that your child has/had ADD or ADHD?" If the answer is "yes," a second question will ask for a list
18 of medications the child took for the condition. The questionnaire will ask if the child had learning or
19 behavioral problems, and if so, the type of problem and the treatment used. Questions would be
20 included for the hypersensitivity-related outcomes, asthma, atopic dermatitis (or atopic eczema), and
21 allergies. The study will attempt to confirm diseases and conditions reported in the questionnaire by
22 accessing medical records sending abstraction forms (**Attachments 17&17a**) to the medical care
23 provider identified by the participants on their consent forms (**Attachment 7b5**).

24 3.6.5.1.1 Child/Parent Neurobehavioral Assessments

25 **Table 3** provides the neurobehavioral test battery for children enrolled in the Multi-site Study.

26 Trained professionals will administer the following tests to children:

- 27 • The Wechsler Abbreviated Scale of Intelligence – 2nd Edition (WASI – II) test will be administered
28 to measure Full Scale IQ (FSIQ) among children 6-17 years (15 minutes). Intelligence testing of
29 children aged 4 – 5 years will not be conducted.

- Each child 4-16 years will complete the NEPSY-II selected tests. Except for Theory of Mind, these additional tests are short and useful to assess memory and inhibition. For all the NEPSY - II tests, children 4 years would take about 52 minutes, and children ≥ 5 years, about 70 minutes.
- Children aged 4 - 7 years will complete the Connors Kiddie Continuous Performance Test (K-CPT - 2) (8 minutes), and children aged >7 years will complete the Connors CPT - 3 (14 minutes).

Trained professionals will administer the following tests to parents about their children:

- Strengths and Difficulties Questionnaire (SDQ) (5 minutes).
- Behavior Rating Inventory of Executive Function[®] (BRIEF[®]) to assess the child's emotional, conduct, and peer relationship problems as well as problems with hyperactivity, inattention and executive function.
 - Parents of children aged 4 - 5 years will complete the preschool version (BRIEF[®]-P) (10 minutes).
 - Parents of children aged >5 years will complete the BRIEF[®] (10 minutes).

A summary of the neurobehavioral test battery is found in **Attachment 18**. Each child will spend an average of 90 minutes to complete the child battery of tests. Each parent will spend an average of 15 minutes to complete the parent battery of tests. Overall, each parent/child pair will take 105 minutes to complete the neurobehavioral test battery (**Attachment 18a**).

Table 3. Neurobehavioral Test Battery for Children

Neurobehavioral Test	Domain	Age	Administration	Time to Administer
Wechsler Abbreviated Scale of Intelligence - 2 nd Edition (WASI - II)	Two Subtest Form (FSIQ)	6 - 17 [*]	Child	15 minutes
A Developmental Neuropsychological Assessment - 2 nd edition (NEPSY - II) subtests	Comprehension of Instructions* (receptive language, trouble following multi-step commands)	4 - 16	Child	6 - 8 minutes
	Speeded Naming* (expressive language, processing speed)	4 - 16	Child	2 - 7 minutes
* from Core Assessment				

	Narrative Memory* (comprehension, verbal memory)	4 - 16	Child	6 - 11 minutes
	Design Copying* (visuospatial processing)	4 - 16	Child	7 - 10 minutes
	Affect Recognition (social perception)	4-16	Child	5 - 7 minutes
	Stature (inhibitory control)	4 - 6	Child	3 minutes
	Word Generation (expressive language, executive control)	4 - 16	Child	4 - 6 minutes
Conners Kiddie Continuous Performance Test, 2 nd Edition (Conners K-CPT 2)	Inattentiveness, Impulsivity, Sustained Attention, Vigilance	4-7	Child	8 minutes
Conners Continuous Performance Test 3 rd edition (CPT 3)	Inattentiveness, Impulsivity, Sustained Attention, Vigilance	8-17	Child	14 minutes
Strengths and Difficulties Questionnaire [®] (SDQ [®])	Double-sided form with impact supplement (behavioral problems)	4 - 17	Parent about Child	5 minutes
Behavior Rating Inventory of Executive Function [®] (BRIEF [®])	Executive Function	6-17	Parent about Child	10 minutes
Behavior Rating Inventory of Executive Function [®] - Preschool Version (BRIEF [®] -P)	Executive Function - Preschool	4-5	Parent about Child	10 minutes

1

2 For each child, the recipient will also review and abstract school records, including special education
3 records, to identify learning problems and behavioral problems (**Attachments 18b&18c**). If the parent
4 reports that the child has a developmental disability (e.g., ADHD, autism, or a learning disability), then
5 the recipient shall obtain and abstract the special education records for the child including the

1 individualized education program (IEP), the IEP evaluation report (“Full Individual Evaluation” or “FIE”),
2 and if available, the Independent Educational Evaluation.

3 3.6.5.2 Adults

4 Each adult participant will complete a questionnaire requesting demographic information, residential
5 history, water consumption habits, occupational history, medical history and reproductive history
6 (**Attachment 16**). In particular, the questionnaire will ask if the participant ever had kidney disease, liver
7 disease, cardiovascular disease, hypertension, high cholesterol, thyroid disease, diabetes, autoimmune
8 diseases, osteoporosis, osteoarthritis, pregnancy-induced hypertension, infertility, and endometriosis.
9 For each reported disease or condition, the questionnaire will ask about the date of diagnosis, the
10 medical provider who made the diagnosis, and the medications used for treatment the questionnaire
11 will ask the participant about conditions that might affect PFAS serum levels such as date of menopause,
12 menstrual cycle information, blood transfusions, and blood donations. The study will attempt to confirm
13 diseases and conditions reported in the questionnaire by medical records review (**Attachments**
14 **17&17a**).

15 3.6.6 Exit Procedures

16 At the end of the data collection, study coordinators or staff will review recorded items in the
17 participant’s Appointment Tracking Form for completeness (**Attachment 9**).

18 The adult participant or the parent of the child participant will receive a copy of the participant’s Body
19 and Blood Pressure Measures Report (**Attachment 19**). These results will be immediately available and
20 will require no further evaluation or interpretation with two exceptions. The adult participant or the
21 parent of the child participant will receive a supplemental notice if the participant has a critical blood
22 pressure measure (diastolic blood pressure > 120 mm Hg, or systolic blood pressure >180 mm Hg). In
23 this case, a Critical Hypertension Notice will be appended to the Body and Blood Pressure
24 Measurements Report along with written and verbal recommendations to obtain immediate medical
25 attention. If the participant does not have a personal physician, the study coordinator will provide a
26 referral. If the participant has an elevated but non-critical blood pressure measure (resting blood
27 pressure > 140/90), an Elevated Hypertension Notice will be appended to the Body and Blood Pressure
28 Measures Report with written and verbal recommendations to obtain clinical follow-up.

1 3.6.6.1 Gift Cards as a Token of Appreciation for Participation

2 As a token of thanks for participation, the recipient will offer gift cards according to the following
3 schedule:

- 4 • \$25 for body and blood pressure measures, and for blood and urine collection;
- 5 • \$25 for completed questionnaire; and
- 6 • \$25 for child/parent completion of the neurobehavioral test battery

7 Trained study staff will document provision of gift cards on the hard copy form (**Attachment 9**). As part
8 of the exit procedures, the participant will sign this form to document receiving the gift card.

9 **3.6.7 Adverse Events**

10 The risks associated with this study are minimal. There is a small chance of unexpected or adverse
11 events occurring during the course of this project. Unanticipated problems involving risk to the subjects
12 or others will be reported to the CDC Human Institutional Review Board (IRB) in accordance with
13 institutional policies and procedures.

14 The most likely adverse event is a participant feeling lightheaded or fainting during blood collection. The
15 phlebotomist will receive training to respond to such situations. The tests and procedures conducted by
16 trained study staff are for research purposes only and are not diagnostic exams. They are not a
17 substitute for an evaluation by a medical professional. The study will not perform any clinical treatments
18 or health interventions as part of the study.

19 If a participant loses consciousness, falls, is unable to stand, or experiences chest pain the study staff will
20 decide whether to advise the adult participant or the parent of the child participant to seek immediate
21 medical treatment or to contact emergency medical services. Study staff have identified appropriate
22 local medical care providers that participants may be referred to if clinical results suggest medical
23 attention is needed (**Attachment 12**).

24 **3.7 Biochemical Analyses**

25 *Serum PFAS*: The study's biochemical analytical plan is found in **Attachment 2**. The study will analyze 12
26 PFAS in fasting serum including PFOA (linear and the sum of branched isomers of PFOA), PFOS (linear
27 and the sum of perfluoromethylheptane sulfonate isomers, and PFHxS (Kuklenyik 2015). Other PFAS

1 analyzed will include: perfluorooctane sulfonamide (PFOSA), 2-(N-methyl-perfluorooctane sulfonamido)
2 acetic acid (Me-PFOSA-AcOH), 2-(N-ethyl-perfluorooctane sulfonamido) acetic acid (Et-PFOSA-AcOH),
3 perfluorobutane sulfonic acid (PFBS), perfluoroheptanoic acid (PFHpA), perfluorononanoic acid (PFNA),
4 perfluorodecanoic acid (PFDeA), perfluoroundecanoic acid (PFUA), and perfluorododecanoic acid
5 (PFDoA).

6 {Note: the study may include measurement of additional PFAS if methods become available by the start
7 of the study. Addition of new analytes will be submitted to the CDC IRB for approval of amendments}

8 *Urinary PFAS:* The study will also analyze PFAS compounds in first morning void urines at later time on
9 stored urine samples. Urine is an important excretion pathway for human metabolism and PFAS urine
10 elimination may be important influencing serum concentrations (Harada 2005, Zhang 2015). The PFAS
11 compounds to be measured in the future are listed in **Attachment 2**.

12 **3.7.1 Children**

13 The study will analyze fasting serum for the following biomarkers of lipids, thyroid, glycemic, liver, and
14 kidney function, sex hormones, and immune function (**Attachment 2**):

- 15 • Total cholesterol, low density lipoprotein, high density lipoprotein, total triglycerides,
- 16 • Uric acid, creatinine,
- 17 • Total thyroxine (TT4), free T4, TT3, thyroid stimulating hormone (TSH), thyroglobulin antibodies,
18 thyroid peroxidase antibodies (TPO),
- 19 • Glucose, insulin, glycosylated hemoglobin (HbA1c), auto-antibodies (GAD-65 and IA-2), C-
20 peptide, pro-insulin,
- 21 • Alanine transaminase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), γ -
22 glutamyltransferase (GGT), direct bilirubin, albumin, and cytokeratin-18 (CK-18),
- 23 • Testosterone, estradiol, sex hormone-binding globulin (SHBG), follicle stimulating hormone,
24 insulin-like growth factor,
- 25 • Immunoglobulin G (IgG), IgA, IgE, and IgM; antibodies to measles, mumps, rubella, tetanus, and
26 diphtheria.

27 The child study will use the cut points of 50 ng/dL of total testosterone and 20 pg/mL of estradiol to
28 identify sexual maturation in boys and girls, respectively (Lopez-Espinosa 2011). The child study will
29 measure IgG antibodies for measles, rubella, and diphtheria to determine vaccine responses. It will

1 analyze allergen-specific IgE (mold, dust mites, dog, cat, cow's milk, peanut, hen's egg, and birch). The
2 study will analyze serum levels of thyroid stimulating hormone (TSH) and total/free T4 separately and
3 use these measurements to determine clinical and subclinical hypothyroidism and hyperthyroidism. The
4 study will measure uric acid, total cholesterol, low-density and high-density lipoprotein, and
5 triglycerides. We also propose to measure liver enzymes and CK-18 (Feldstein 2013, Mora 2018, and
6 Santoro 2013).

7 **3.7.2 Adults**

8 The study will analyze the following biomarkers in the adult fasting serum (**Attachment 2**):

- 9 • Total cholesterol, low density lipoprotein, high density lipoprotein, total triglycerides,
- 10 • Uric acid, creatinine,
- 11 • Total thyroxine (TT4), free T4, TT3, thyroid stimulating hormone (TSH), thyroglobulin antibody,
12 thyroid peroxidase antibodies (TPO),
- 13 • Glucose, insulin, glycosylated hemoglobin (HbA1c), auto-antibodies (GAD-65 and IA-2), C-
14 peptide, pro-insulin,
- 15 • Alanine transaminase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), γ -
16 glutamyltransferase (GGT), direct bilirubin, albumin, and cytokeratin-18 (CK-18),
- 17 • Immunoglobulin G (IgG), IgA, IgE, and IgM; C reactive protein, rheumatoid factor, and
18 antinuclear antibodies (ANA),
- 19 • Cytokines and adipokines (e.g. IL-1 β , IL-4, IL-6, IL-8, IL-12, MCP-1, TNF α , leptin, adiponectin,
20 resistin, PAI-1).

21 **3.7.3 Quality Control/Quality Assurance**

22 To maintain the integrity of the lab results, a backup generator will be available for the refrigerator and
23 freezer at the study office. All serum, blood, and urine specimens will be securely stored at the study
24 office until shipped to the NCEH laboratory.

25 The NCEH and other participating laboratories will fulfill quality assurance/quality control criteria
26 (QA/QC) including a documented quality assurance plan and adherence to required quality control
27 procedures specified in an approved method. The laboratories will ensure that the analytical data are
28 scientifically valid, defensible, and of known and acceptable precision and accuracy. QA/QC procedures,
29 including appropriate calibration of instruments, running standards and blanks, reporting limits of
30 detection, and other parameters will be in place before specimens are tested. Specimen collection,

1 storage, and transportation techniques are specified in the Manual of Procedures to ensure the integrity
2 of the specimens (**Attachment 12**). Specimens will be stored at the proper temperature and isolated
3 from potential sources of contamination.

4 The Standard Operating Procedure (SOP) for each analytical method will be kept on file by the PI and will
5 be available for review upon request.

6 **3.7.4 Reference Values**

7 The participating laboratories will provide reference values and action levels for the effect biomarkers
8 which will be reported in **Attachments 20&21**. The recipient will report the participant's PFAS results
9 using reference values from the most recent NHANES report (**Attachment 22**). Currently, the 2013-14
10 report is available and provides reference values for children. **Section 4** provides additional descriptions
11 of the procedures for advance and final results reporting.

12 **3.8 Data Handling**

13 **3.8.1 Certificate of Confidentiality**

14 ATSDR requests to issue a Certificate of Confidentiality (CoC) under Section 301(d) of the Public Health
15 Service (PHS) Act, as amended by Section 2012 of the 21st Century Cures Act, P.L. 114-255 (42 U.S.C.
16 241(d)), states that the Secretary shall issue CoCs to persons engaged in biomedical, behavioral, clinical,
17 or other research activities in which identifiable, sensitive information is collected. In furtherance of this
18 provision, CDC research commenced or ongoing after December 13, 2016 and in which identifiable,
19 sensitive information is collected, as defined by Section 301(d), is deemed issued a CoC and therefore
20 researchers are required to protect the privacy of individuals who are subjects of such research in
21 accordance with Section 301(d) of the PHSA.

22 Consistent with Section 301(d), ATSDR determined that a CoC applies to this research by answering the
23 following questions:

- 24 1. Is the activity biomedical, behavioral, clinical, or other research? YES
- 25 2. Does the research involve Human Subjects as defined by 45 CFR Part 46? YES
- 26 3. Is ATSDR collecting or using biospecimens that are identifiable to an individual as part of the
27 research? YES

1 4. If collecting or using biospecimens as part of the research, is there a small risk that some
2 combination of the biospecimen, a request for the biospecimen, and other available data
3 sources could be used to deduce the identity of an individual? YES

4 5. Does the research involve the generation of individual level, human genomic data? NO

5 Since the answer to any one of Questions 2-5 is YES, ATSDR determined that a CoC will apply to the
6 research; therefore, in accordance with subsection 301(d) of the Public Health Service Act, ATSDR and
7 any of its cooperative agreement recipients shall not:

- 8 • Disclose or provide, in any Federal, State, or local civil, criminal, administrative, legislative, or
9 other proceeding, the name of such individual or any such information, document, or
10 biospecimen that contains identifiable, sensitive information about the individual and that was
11 created or compiled for purposes of the research, unless such disclosure or use is made with the
12 consent of the individual to whom the information, document, or biospecimen pertains; or
- 13 • Disclose or provide to any other person not connected with the research the name of such an
14 individual or any information, document, or biospecimen that contains identifiable, sensitive
15 information about such an individual and that was created or compiled for purposes of the
16 research.

17 Disclosure is permitted only when:

- 18 • Required by Federal, State, or local laws (e.g., as required by the Federal Food, Drug, and
19 Cosmetic Act, or state laws requiring the reporting of communicable diseases to State and local
20 health departments), excluding instances of disclosure in any Federal, State, or local civil,
21 criminal, administrative, legislative, or other proceeding;
- 22 • Necessary for the medical treatment of the individual to whom the information, document, or
23 biospecimen pertains and made with the consent of such individual;
- 24 • Made with the consent of the individual to whom the information, document, or biospecimen
25 pertains; or
- 26 • Made for the purposes of other scientific research that is in compliance with applicable Federal
27 regulations governing the protection of human subjects in research.

28 ATSDR and its cooperative agreement recipients conducting this research are required to establish and
29 maintain effective internal controls (e.g., policies and procedures) that provide reasonable assurance
30 that the research contract is managed in compliance with Federal statutes, regulations, and the terms
31 and conditions of the award (**Attachment 12**). Recipients are also required to ensure: 1) that any

1 investigator or institution not funded by CDC/ATSDR who receives a copy of identifiable, sensitive
2 information protected by this CoC, understands that it is also subject to the requirements of subsection
3 301(d) of the PHS Act; and 2) that any subrecipient that receives funds to carry out part of this CDC
4 award involving a copy of identifiable, sensitive information protected by a Certificate understands that
5 it is subject to subsection 301(d) of the PHS Act.

6 For studies in which informed consent is sought, ATSDR and its cooperative agreement recipients shall
7 inform research participants of the protections and the limits to protections provided by this CoC
8 (**Attachment 7b**). Therefore, all study staff will receive training on the importance of protecting the
9 confidentiality of human research subjects and of personal information acquired, including the
10 collection of biological specimens. The study will minimize the risk of loss of confidentiality and privacy
11 through careful attention to procedures for such protections in the collection, handling, and reporting of
12 individually identifiable and sensitive data (**Attachment 12**).

13 **3.8.2 Data Management and Security**

14 Data management for this study described below includes guidance on:

- 15 1. Use and protection of information in identifiable form (IIF);
- 16 2. Security access (physical, technical, and administrative) controls for ATSDR and its contractor;
- 17 3. Appropriate data delivery; and
- 18 4. Data ownership and data sharing.

19 *Collection of IIF.* The study staff will collect, manage and store IIF in an already established record system
20 (System of Records Notice [SORN] No. 09-19-0001 titled "Records of Persons Exposed to Toxic or
21 Hazardous Substances"). ATSDR will use IIF to report results to each parent of a child participant or adult
22 participant. ATSDR will be the final recipient of the IIF (to keep for potential re-contacting of
23 participants).

24 The study staff will deliver all field-collected records to ATSDR headquarters at the end of the study.
25 ATSDR will retain IIF such as name, Social Security Number (SSN), current address, phone number, email
26 address, date of birth, and the date of the participant's blood draw and questionnaire completion.
27 ATSDR will store the IIF in a separate master key dataset along with a study-generated ID. This dataset
28 will be separate from the dataset containing the questionnaire data and other data used in the statistical
29 analyses. The study-generated ID will be the variable that can link the two datasets if necessary. IIF will

1 not be linked with files used for statistical analysis and will not appear in any reports generated from this
2 data set.

3 **3.8.3 Impact on Privacy**

4 Because the study staff will collect, store, manage, and maintain IIF on an already established record
5 system, there would be a likely effect on the participant's privacy if a breach of data security occurred.
6 Therefore, its established record system has stringent safeguards in place as described in the following
7 section. Research datasets will include only coded information that might be sensitive, such as questions
8 on reproductive outcomes, fertility, or fecundability. These files will not have associated information
9 that might directly identify these participants. IIF will be stored in a separate master key dataset, which
10 will enable ATSDR investigators to link the participant's research data with his or her IIF via a study-
11 generated ID. Maintaining this contact information is necessary to provide results of the tests or re-
12 contact them in the future for a longitudinal study. Therefore, stringent data security measures will be in
13 place, including administrative, physical, and technical controls as described below.

14 All laboratories involved in biochemical analyses will receive biological specimens with participants'
15 study-generated ID only. Nondisclosure agreements will be executed between the recipient and
16 laboratories that will not be engaged in research.

17 **3.8.3.1 Access Controls and Security**

18 The recipient PI and Project Manager will be responsible for all required staff training and certification,
19 periodic checks of procedures and data collection methods, privacy, and security of data, as well as
20 access of assigned personnel to different types of data. For this information collection, all study staff will
21 be under the direct supervision of the ATSDR on-site supervisor. The study staff will obtain appropriate
22 office space for the blood draws, clinical assessments, questionnaire, neurobehavioral batteries
23 administration, secure storage of questionnaires, medical and school records, and storage of blood
24 specimens (including refrigeration) prior to shipment to the NCEH laboratory. All data and biological
25 specimens collected in the study are the property of ATSDR. Methods to ensure least privilege access to
26 the study information will be in place; therefore, access to identifiable information will be role-based on
27 a need-to-know basis for the recipient investigators.

28 The study staff will provide details on its data security technology and methods including password
29 protection, desktop firewalls, daily backups and server based storage, intrusion detection, vulnerability

1 scans of personal computers and server, laptop security, and computer encryption procedures to the
2 CDC security office.

3 Once collected from the participant, all hardcopy informed consents and data collection forms will be
4 stored in locked files in locked rooms in the study office and at ATSDR. Informed consent will also be
5 scanned into electronic form and transferred to ATSDR to provide backup in the case of incidental
6 damage to the paper forms.

7 Upon completion of the project and once the ATSDR has received all approved study related paper
8 documents, the recipient will destroy those hardcopy documents not necessary to complete the study
9 analyses or to contact study participants.

10 Data security measures at ATSDR will comply with the *CDC/ATSDR Protection of Information Resources*
11 *Policy* and the *CDC/ATSDR IT Security Program Implementation Standards*. These policies apply to all
12 authorized ATSDR employees. All incidents involving a suspected or confirmed breach of IIF must be
13 reported to OCISO according to the policy titled *OCISO/CDC Standard for Responding to Breaches of*
14 *Personally Identifiable Information (PII)*.

15 *Physical controls* - The CDC/ATSDR issues identity credentials based on the Federal Information
16 Processing Standards (FIPS) Publication 201 for Personal Identity Verification (PIV) authentication of
17 government employees' identities. Security measures for physical access to secured facilities include the
18 use of PIV Cards, security guards, and closed circuit TV monitoring.

19 *Technical Controls* - CDC/ATSDR policy requires employees to gain authorized logical access to its
20 information systems through a unique electronic identity (User ID). The computer-controlled limits on
21 what can be done by the user are assigned based on program roles and privilege requirements.

22 *Administrative Controls* - Authorized recipient researchers and CDC/ATSDR employees are required to:

- 23 • Complete required privacy and information security refresher training.
- 24 • Read, acknowledge, sign (if online completion is not available), and comply with the HHS Rules
25 of Behavior, as well as other applicable CDC/ATSDR- and system-specific rules of behavior
26 before gaining access to the CDC/ATSDR's systems and networks.

- 1 • Adhere to the requirements set forth in the *CDC/ATSDR IT Security Program Implementation*
2 *Standards*, and other security policies and procedures that minimize the risk to CDC systems,
3 networks, and data from malicious software and intrusions.
- 4 • Abide by all applicable acceptable use policies and procedures regarding use or abuse of
5 CDC/ATSDR IT resources.

6 All study records are subject to the ATSDR Comprehensive Record Control Schedule (CRCS), B-371,
7 which contains authorized disposition instructions for ATSDR's administrative and program records.
8 ATSDR is legally required to maintain its program-related records in accordance with disposition
9 instructions contained in this comprehensive records control schedule. These retention periods have a
10 direct impact on completing Freedom of Information Act (FOIA) requests and in applying the
11 requirements of the Privacy Act. The current schedule requires ATSDR to retain and archive program
12 records for a period of 75 years after the end of the study activities.

13 **3.8.4 Data Delivery**

14 Study staff will follow checks and quality control procedures for data entry. Only authorized study staff
15 will receive permission to enter or manipulate the study data. Data entry from hardcopy documents will
16 involve double entry with discrepancies compared and corrected.

17 Study staff will prepare draft datasets to record questionnaire responses and medical record/school
18 record data to send to ATSDR for review and approval. ATSDR will work with the study staff to resolve
19 missing values and other data issues. The study staff will also keep and deliver a shipping log of blood
20 specimens sent to the NCEH laboratory in Microsoft Excel format (**Attachment 12**). The log will include
21 the include vial type, volume, ID code, date, and carrier details. ATSDR will receive lab results from the
22 participating laboratories. The lab dataset will be merged by study ID with the questionnaire data to
23 create a combined questionnaire and lab dataset.

24 All dataset formats will be transformed to SAS datasets (SAS 9.3, Cary NC). All final data management
25 will be performed on this platform. Site investigators may also use other CDC approved statistical
26 software before converting to SAS. Final datasets will be sent to ATSDR using encrypted, password
27 coded spreadsheets through a password protected data sharing facility. The contractor will deliver to
28 ATSDR the code and the master key dataset by which the response data are potentially relinkable to PII.

1 Consent forms that collect the signatures of participants will be paper instruments and the adult
2 participant or parent of the child participant will receive a copy of the consent form; scanned electronic
3 copy will be sent to CDC. Height, weight, and other applicable body measures and blood pressure will be
4 recorded on a paper form and transferred to an electronic form.

5 **3.8.5 Data Ownership and Data Sharing**

6 Coded research datasets will be available to all ATSDR study investigators listed in **Attachment 1**. We will
7 produce coded datasets by removing the following: name, SSN, date of birth, address, former address
8 (es), phone number, and date of completion of the blood draw and questionnaire. SSN will be collected
9 at enrollment for linkage to medical records and school records. Once the linkage has occurred, the SSN
10 will be kept with other PII in a separate access restricted secure database. Age will replace date of birth
11 in the data analysis file because it is the necessary variable in exposure and health outcome analyses.

12 Release of de-identified multi-site combined data to outside investigators including recipients must be
13 approved by ATSDR. A data use agreement (DUA) will be prepared, detailing the condition of use of the
14 data and proposed analyses for each outside project. The DUA condition of use will specify that ATSDR
15 will not release the link between the study IDs and the participants' PII to the outside researchers. The
16 DUA will also specify that:

- 17 1. Our data cannot be merged with public data in such a way that individuals may be identified;
- 18 2. Our data cannot be enhanced with public data sets with identifiable, or potentially identifiable,
19 data;
- 20 3. One of the study investigators listed in **Attachment 1** must be a co-investigator on any outside
21 research project to guarantee adherence to the agreed conditions of use; and
- 22 4. Each data release will be cleared by a specific IRB request to the investigator's home institution
23 prior to data release.

24 After the approved project with the outside researchers is completed, further or secondary analyses of
25 electronic datasets can only be undertaken with additional approval(s) from ATSDR. Written
26 confirmation of understanding the conditions of use will be required from the lead scientist and
27 institution. Copies of statistical code and datasets used in statistical analyses by the outside investigators
28 will be kept by ATSDR.

1 **3.8.6 Storing Residual Blood for Future Use**

2 After performing the chemical and clinical tests, there may be some residual blood. In the consent form,
3 we will ask participant's permission to save this residual blood for additional future analyses of PFAS and
4 possibly additional effect biomarkers. We will only store blood of those participants who will consent to
5 have their blood archived for additional PFAS and effect biomarker analyses (**Attachment 7b**).

6 The residual blood specimens will be stored with the study-generated ID only. ATSDR will keep a
7 separate dataset that can link the study ID with the participant's name. If participants change their
8 minds later about letting their blood used for additional analyses, they can contact ATSDR and we will
9 remove their specimens. We do not plan to provide participants the results of these future tests, but we
10 may contact them if we learn something that is important.

11 We will consent participants at enrollment and not recontact them for the additional analyses of stored
12 biospecimens related to this PFAS research: Because new scientific knowledge, tests, or methods may
13 arise, we would like to save this leftover biospecimens for additional analyses on exposures or health
14 conditions related to PFAS. In addition, ATSDR or recipients may release de-identified research datasets
15 or de-identified biospecimens for future studies related to PFAS to outside investigators under a data
16 use agreement that will prohibit any attempt to identify you or your child as a research subject. In this
17 case, your individual test results will not be reported to you.

18 After we complete this study ATSDR or recipients may conduct new research studies. At that time, we
19 may ask for additional consent to include participants' data or leftover biospecimens from this current
20 study.

21 For all future use, the stored biospecimens will not be used for any commercial activities for profit. In
22 addition, we do not anticipate the collected biospecimens to be used for whole genome sequencing
23 (you would need to be recontacted to consent for such tests). All future analyses and studies must
24 adhere to IRB review requirements.

25 **3.8.7 Future Exploratory Analyses**

26 CDC IRB approval will be sought for this additional research either as a protocol amendment or under a
27 new research protocol prior to undertaking this plan.

1 3.9 Exposure Estimation

2 The study will use the fasting serum PFAS measurements obtained from study participants to estimate
3 exposures. In addition, the study will estimate each participant's cumulative PFAS serum level, using:

- 4 • PFAS serum measurements obtained in the study,
- 5 • Historical reconstruction of PFAS concentrations in the drinking water consumed by the
6 participant,
- 7 • Questionnaire data on the participant's consumption of PFAS-contaminated drinking water and
8 factors that might affect PFAS serum levels,
- 9 • Age-, sex-, and calendar year-specific "background" PFAS serum levels from NHANES, and
- 10 • Physiologically based pharmacokinetic (PBPK) models.

11 If previous PFAS serum measurements are available for some of the participants (e.g., from a
12 biomonitoring program), then these results will be used to validate the modeled historical PFAS serum
13 estimates.

14 The C8 studies used PBPK modeling to estimate cumulative serum levels of PFOA and PFOS (Shin 2011).
15 The model incorporated information from the historical reconstruction of PFAS concentrations in the
16 drinking water serving the C8 areas, questionnaire data on each participant's water consumption, and
17 the serum levels of PFOA and PFOS obtained from study participants. A recent effort to reconstruct
18 historical exposures worked well for PFOA and PFOS; but less well for PFHxS (Gomis 2017). Low
19 environmental concentrations, lack of decline in older population, possible ongoing exposure in
20 children/younger adults, and scarcity of time-trend data in consumer products were cited as reason for
21 poor prediction characteristics of PFHxS models (Gomis 2017). However, if there are high correlations in
22 serum levels between PFHxS and PFOS and/or PFOA, then it may be possible to estimate cumulative
23 PFHxS serum levels based on the historical estimates for serum PFOS and/or PFOA.

24 Recently, an online serum PFOA calculator for adults became available using a modified one-
25 compartment exponential decay model to estimate PFOA serum levels from PFOA concentrations in
26 drinking water (Bartell 2017). Developing a similar calculation for serum PFOS is possible. The studies of
27 children and adults by ATSDR and recipients will explore this approach to estimate serum PFOA, PFOS,
28 PFHxS and PFNA levels and make comparisons with serum levels from the blood specimens obtained in
29 this study (and if available, previous PFAS serum measurements). The recipient may consider the use of

1 a one-compartment PBPK model similar to one used by Shin (2011) and Avanas (2016), and also used as
2 the basis for a recent PFOA serum calculator (Bartell SM 2017).

3 A number of improvements in PBPK modeling approaches, especially as related to multi-compartment
4 models, have been developed recently and the recipient should take those into consideration (Loccisano
5 2013, Fabrega 2014, 2016; Verner 2015, 2016).

6 The recipient should attempt to integrate a broad range of information on individuals'
7 sociodemographics (birth year, age, sex, ethnicity), PFAS pharmacokinetics (e.g. tissue partitioning and
8 distribution volumes, elimination rates), as well as exposure sources as pertain for the general
9 population (e.g. breastfeeding, water consumption, blood transfusion) and secretion routes (e.g. parity,
10 breastfeeding history, and menstruation in women; donating blood) which will be collecting in the adult
11 and child questionnaire. Questionnaires also includes detailed information on menstruation cycles for
12 women (regular/irregular, length, heavy/light flow, last menstruation before blood draw; Wong 2015,
13 Verner and Longnecker 2015). The recipient can assume the contributions from dietary intake,
14 cookware, cleaning supplies, etc. to be similar to the background US population (Domingo 2012,
15 Christensen 2017). The recipient can also assume that NHANES calendar year-, age- and sex-specific
16 PFAS serum concentrations reflect these background exposures (Calafat 2007, Ye 2017).

17 In order to estimate historical concentrations of PFAS in the drinking water and historical PFAS serum
18 levels, it is necessary to obtain as much information as possible on the source of the PFAS
19 contamination. If the source is environmental emissions from an industrial facility, then the recipient
20 should request information from the facility about these emissions (e.g., periods, locations, frequencies
21 and amounts of emissions, and whether the emissions are to surface water, ground water and/or air). If
22 the source is AFFF use at a military base, airport or fire training area, then the recipient should seek
23 information on the period and location of use, the annual amount of AFFF used, and any accidental or
24 non-routine use (e.g., to extinguish a major fire, or a major spill) and the date, location and amount
25 used.

26 Once information on the source is obtained, the recipient should seek information on how the PFAS
27 contamination migrated from the source to the drinking water supply. For example, the recipient should
28 request information on the soil, ground water and/or surface water characteristics in the vicinity of the
29 industrial emissions or AFFF use, as well as the location of drinking water intakes, supply wells (and
30 nearby monitoring wells), and/or private wells serving the study area. If the PFAS contamination

1 migrated from the source via ground water, then the recipient should seek information on the extent of
2 the contamination plume from the state environmental agency, EPA, and/or the industrial facility.

3 If the contaminated drinking water is from a municipal system, then the characteristics of the
4 distribution system will be obtained from the water purveyor. If supply wells are used, then the
5 recipient will request historical and current information on these wells including monthly or daily
6 production logs and dates of operation. If a surface water source is used or if water is purchased from
7 another purveyor, then the recipient will request information about this source.

8 The recipient will also request the results of all relevant PFAS sampling: in the surface water near the
9 drinking water intakes, in the distribution system, in the supply wells and nearby monitoring wells, in
10 purchased water from other water purveyors, and in the private wells in the study area.

11 **3.10 Statistical Analyses**

12 ATSDR staff will perform statistical analyses with the participation of the recipients using SAS, R and
13 STATA on the combined multi-site study dataset. ATSDR staff may also use SPSS for data management.
14 ATSDR staff will calculate descriptive statistics (including means, geometric means, medians, standard
15 deviations, and percentiles) to identify the presence and distribution of PFAS and effect biomarker
16 analytes. Statistical methods will include multiple linear regression of continuous (untransformed and
17 natural log transformed) effect biomarkers on continuous (untransformed and natural log transformed)
18 PFAS serum levels and categorized PFAS serum levels, and logistic regression of categorized effect
19 biomarkers (e.g., hypercholesterolemia) or disease prevalence on continuous (untransformed and
20 natural log transformed) and categorical PFAS serum levels. ATSDR staff will use restricted cubic spline
21 methods (or generalized additive models using cubic regression splines) for linear and logistic regression
22 to obtain flexible, smoothed exposure-response curves. To identify risk factors that may act as
23 confounders for a particular health outcome, the analysis will implement a “10% change in the
24 estimate” rule (Maldonado 1993).

25 Primary analyses will focus on estimated cumulative PFAS serum levels. Supplemental analyses will
26 evaluate PFAS serum levels in the blood specimens obtained in the study as well as estimated maximum
27 and average PFAS serum levels. The primary analyses will evaluate each PFAS chemical separately; sum
28 of PFAS measures may also be considered. Statistical analyses using prevalent cases in a cohort design
29 which takes into consideration the times of diagnosis will also be conducted. ATSDR will explore the use
30 of methods for evaluating multi-pollutant mixtures, such as the hierarchical Bayesian model, to analyze

1 the effects of exposures to the PFAS mixtures. ATSDR will use quantitative methods to assess the impact
2 of possible selection bias and possible confounding due to unmeasured risk factors (Lash 2009). There
3 are several caveats and recommendations in conducting analyses of mixtures to determine the optimal
4 method that avoids amplifying bias due to confounding (Weisskopf et al 2018). For the bias analyses,
5 ATSDR will identify “negative control” diseases with no known association with PFAS exposures (Lipsitch
6 2010). ATSDR conducted a literature search to identify these negative control diseases and included
7 them in the questionnaire. To gauge the potential and magnitude of possible selection bias and
8 information biases, two approaches will be taken. First, quantitative methods described in Lash et al
9 (2009) will be used to estimate the possible magnitude of selection and informational biases. Second,
10 “negative control” diseases will be used to also estimate the potential and magnitude of these biases
11 (Lipsitch et al 2010). Negative control diseases are those diseases not known to be associated with the
12 exposures of interest. In the multi-site study, the exposures of interest are PFAS serum levels. The
13 negative control diseases for children included in the questionnaire are celiac disease, scleroderma,
14 lupus, and Crohn’s disease. In addition to these diseases, negative control diseases for adults include
15 Parkinson disease, emphysema, chronic bronchitis, multiple sclerosis, and fibromyalgia.

16 ATSDR will interpret the findings from this study based on the magnitude of the effect estimates (e.g.,
17 the linear regression coefficient for continuous outcomes or the odds ratio for categorical outcomes) of
18 the exposure-response relationship, consistency with findings from other studies, and the possible
19 sources of bias (Rothman 2014). The analyses will construct confidence intervals to indicate the level of
20 precision (or uncertainty) in the effect estimates.

21 The studies will use statistical significance testing to interpret findings but will not use it as a sole factor
22 in determining scientific and public health significance (Rothman et al. 2008, 2010; Stang et al. 2010). A
23 finding that fails to achieve statistical significance can still provide evidence for a causal association, and
24 a finding that achieves statistical significance can lack any such significance (Porta 2014).

25 **4. RESULTS REPORTING**

26 **4.1 Notification of Individual Results**

27 Some of the clinical tests may include results that indicate disease or serious medical condition. Due to
28 the scheduled timespan between blood specimen collection and the actual laboratory analyses, we are
29 unable to report study results in a short period. Study staff will report to the participant the result of a
30 clinical test that clearly indicates the potential for a serious health consequence immediately after

1 receiving the result from the laboratory. An advance notification phone call from the study investigators
2 (**Attachment 22**) with a subsequent letter of clinical tests results will be sent to the participant when the
3 abnormal results are identified, processed, and checked for accuracy (**Attachment 22a**). Study staff will
4 advise the participants to consult his/her physician, or to contact the physician associated with the study
5 for explanation of clinical findings.

6 Participants will also receive results of their effect biomarker tests after the study is completed. Contract
7 labs will provide their clinical reference abnormal or 'high' levels, if available, for interpretation of
8 clinical test results (**Attachment 23**). Participants will receive their PFAS test results. The recipient will
9 provide to the 50th and 95th percentiles from NHANES for comparison to the U.S. population (CDC, 2018).
10 Study staff will advise participants to consult ATSDR with questions about their results if they wish to do
11 so.

12 **4.2 Disseminating Results to the Public**

13 The recipient will consult with the local and/or state health agency, local community groups, and the
14 National PFAS Contamination Coalition to determine the most effective method of disseminating the
15 results to the participants and the public. If the recipient establishes a community assistance panel
16 (CAP) in the study area, then the CAP will participate in study community outreach and recruitment
17 activities as well as provide advice on effective methods of results dissemination.

18 The recipient may consider using a user-centered digital interface developed by the Silent Spring
19 Institute for reporting results to each participant. The recipient will present study results to the
20 community in public meetings, printed community handout materials, participating in local radio
21 programs and in informal activities. The recipient also will provide a study website with information
22 about the study findings and general information about any future follow up studies.

23 Generally, ATSDR will publish study results only as group data analyses in peer-reviewed scientific
24 journals or government reports. If individual data are presented, those will not be linked to participants'
25 identities. In the event that some other exceptional characteristics would enable personal identification,
26 those would be masked or modified as needed to protect individual privacy. ATSDR will use manuscripts
27 published in peer-reviewed scientific journals and presentations at major scientific meetings to inform
28 the scientific community about the results of the Multi-site studies.

1 5. STRENGTHS AND LIMITATIONS

2 Cross-sectional studies are especially suitable for assessing effect biomarkers and the prevalences of
3 nonfatal diseases, in particular, diseases with no clear point of onset (Checkoway 2004). However, if the
4 cross-sectional study concurrently measures the exposure and the outcome (i.e., the disease or effect
5 biomarker), it might be difficult to determine whether the exposure caused the outcome or whether the
6 outcome influenced the measured exposure level (Flanders 1992, 2016). For example, as discussed
7 above, the concurrent measurement of serum PFAS levels and kidney function biomarkers might raise
8 the question of “reverse causation” because kidney function can affect the levels of PFAS in serum. One
9 approach to minimize the problem of reverse causation or possible confounding due to health outcomes
10 that affect PFAS serum levels is by estimating exposures based on the historical reconstruction modeling
11 of serum PFAS levels. In addition, it might be possible to estimate exposures during critical vulnerable
12 periods (e.g., in utero exposure) through the modeling of historical serum PFAS levels. However, the
13 modeling of historical PFAS serum levels is subject to uncertainties and data limitations, and published
14 methods currently are available only to model serum levels of PFOA and PFOS.

15 Other issues concerning cross-sectional study designs are similar to those that confront other
16 observational study designs, such as cohort studies. These issues include: 1) the ability to clearly define,
17 enumerate and recruit (without introducing selection bias) the exposed and comparison populations, 2)
18 the comparability of the exposed and comparison populations on risk factors other than the PFAS
19 exposures, 3) accurate exposure assessment, and 4) accurate measurement of effect biomarkers and
20 ascertainment of diseases. In addition, a bias similar to the “healthy worker survival effect” bias could
21 occur in a cross-sectional study because the study population consists of those who remained in the
22 study area (and, for example, did not leave the study area due to health problems caused by exposure
23 to the PFAS contaminated drinking water). While the resulting cohort is a ‘survivor cohort’, the studies
24 have shown that the only if survival after incidence differs by exposure level can results be biased (Barr
25 2015) for the non-fatal and even in the case of fatal disease...

26 All epidemiological studies of environmental exposures and health outcomes have limitations and
27 uncertainties. Whether a study will find an association between an environmental exposure and health
28 effects is unknown prior to conducting the study. No single study will provide definitive answers to the
29 community about whether their exposures to the PFAS-contaminated drinking water caused their health
30 problems. The ability of the multi-site study to provide useful information will depend largely on the

- 1 success of recruiting a sufficient number of study participants and obtaining sufficient information on
- 2 the PFAS contamination to estimate historical PFAS serum levels with reasonable accuracy.

1 6. REFERENCES

- 2 Agency for Toxic Substances and Disease Registry (ATSDR). Feasibility Assessment for Epidemiological
3 Studies at Pease International Tradeport. Portsmouth, New Hampshire. November 2017a. Available at:
4 [https://www.atsdr.cdc.gov/sites/pease/documents/Pease_Feasibility_Assessment_November-](https://www.atsdr.cdc.gov/sites/pease/documents/Pease_Feasibility_Assessment_November-2017_508.pdf)
5 [2017_508.pdf](https://www.atsdr.cdc.gov/sites/pease/documents/Pease_Feasibility_Assessment_November-2017_508.pdf)
- 6 Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR's PFAS Exposure Assessment
7 Technical Tools (PEATT). Atlanta, Georgia. November 2017b. Available at: on request ATSDR/DCAI
- 8 Alexander BH, Olsen GW. Bladder cancer in perfluorooctanesulfonyl fluoride manufacturing workers.
9 *Ann Epidemiol.* 2007;17(6):471-8.
- 10 Avanasì R, Shin HM, Vieira VM, Savitz DA, Bartell SM. Impact of Exposure Uncertainty on the Association
11 between Perfluorooctanoate and Preeclampsia in the C8 Health Project Population. *Environ Health*
12 *Perspect.* 2016;124(1):126-32
- 13 Bach CC, Bech BH, Brix N, Nohr EA, Bonde JP, Henriksen TB. Perfluoroalkyl and polyfluoroalkyl
14 substances and human fetal growth: a systematic review. *Crit Rev Toxicol* 2015;45(1):53-67.
- 15 Barry V, Winquist A, Steenland K. Perfluorooctanoic Acid (PFOA) Exposures and Incident Cancers among
16 Adults Living Near a Chemical Plant. *Environ Health Perspect* 2013;121:1313-1318.
- 17 Bartell SM. Online serum PFOA calculator for adults. *Environ Health Perspect* 2017; 125:104502.
- 18 Bonfeld-Jørgensen EC, Long M, Fredslund SO, Bossi R, Olsen J. Breast cancer risk after exposure to
19 perfluorinated compounds in Danish women: a case-control study nested in the Danish National Birth
20 Cohort. *Cancer Causes Control.* 2014;25(11):1439-48.
- 21 C8 Science Panel 2012a.
22 http://c8sciencepanel.org/pdfs/Probable_Link_C8_Osteoarthritis_29Oct2012v2.pdf.
- 23 C8 Science Panel 2012b. http://c8sciencepanel.org/pdfs/Probable_Link_C8_Kidney_29Oct2012.pdf.
- 24 Cardenas et al. Plasma concentrations of per- and polyfluoroalkyl substances at baseline and
25 associations with glycemic indicators and diabetes incidence among high-risk adults in the diabetes
26 prevention program trial. *Environ Health Perspect* 2017;125(10):107001.
- 27 Calafat AM, Wong LY, Kuklennyik Z, Reidy JA, Needham LL. Polyfluoroalkyl chemicals in the U.S.
28 population: data from the National Health and Nutrition Examination Survey (NHANES) 2003-2004 and
29 comparisons with NHANES 1999-2000. *Environ Health Perspect.* 2007;115(11):1596-602.
- 30 Centers for Disease Control and Prevention (CDC). Fourth Report on Human Exposure to Environmental
31 Chemicals, Updated Tables, (January 2017). Atlanta, GA: U.S. Department of Health and Human Services,
32 Centers for Disease Control and Prevention. <https://www.cdc.gov/exposurereport/>
- 33 Centers for Disease Control and Prevention. Fourth Report on Human Exposure to Environmental
34 Chemicals, Updated Tables, (March 2018). Atlanta, GA: U.S. Department of Health and Human Services,
35 Centers for Disease Control and Prevention. <https://www.cdc.gov/exposurereport/>.

- 1 Chang ET, Adami HO, Boffetta P, Wedner HJ, Mandel JS. A critical review of perfluorooctanoate and
2 perfluorooctanesulfonate exposure and immunological health conditions in humans. *Crit Rev Toxicol.*
3 2016;46(4):279-331.
- 4 Chang ET, Adami HO, Boffetta P, Cole P, Starr TB, Mandel JS. A critical review of perfluorooctanoate and
5 perfluorooctanesulfonate exposure and cancer risk in humans. *Crit Rev Toxicol.* 2014;44 Suppl 1:1-81.
- 6 Checkoway H, Pearce N, Kriebel D. *Research Methods in Occupational Epidemiology*, Second Edition.
7 Oxford U. Press 2004.
- 8 Christensen et al. Perfluoroalkyl substances and fish consumption. *Environ Res* 2017; 154:145-151.
- 9 Clair HB, Pinkston C, Pavuk M, Dutton ND, Brock G, Prough RA, Falkner CK, Wahlang B, McClaine CJ, and
10 Cave MC. High Prevalence of Environmental Liver Disease and Suspected Toxicant Associated
11 Steatohepatitis in a Large United States Residential Cohort With High Polychlorinated Biphenyl
12 Exposures. *Toxicol Sci.* 2018; 164(1):39-49.
- 13 Crawford NM, Fenton SE, Strynar M, Hines EP, Pritchard DA, Steiner AZ. Effects of perfluorinated
14 chemicals on thyroid function, markers of ovarian reserve, and natural fertility. *Reprod Toxicol.*
15 2017;69:53-59.
- 16 Dalsager L, Christensen N, Husby S, Kyhl H, Nielsen F, Høst A, Grandjean P, Jensen TK. Association
17 between prenatal exposure to perfluorinated compounds and symptoms of infections at age 1-4years
18 among 359 children in the Odense Child Cohort. *Environ Int.* 2016 Nov;96:58-64.
- 19 Daly ER, Chan BP, Talbot EA et al. Per- and polyfluoroalkyl substance (PFAS) exposure assessment in a
20 community exposed to contaminated drinking water, New Hampshire, 2015. *Int J Hyg Environ Health*
21 2018;221:569-577.
- 22 Darrow LA, Groth AC, Winquist A, Shin HM, Bartell SM, Steenland K. Modeled perfluorooctanoic acid
23 (PFOA) exposure and liver function in a Mid-Ohio Valley Community. *Environ Health Perspect*
24 2016;124:1227-1233.
- 25 Dhingra R, Winquist A, Darrow LA, Klein M, Steenland K. A Study of Reverse Causation: Examining the
26 Associations of Perfluorooctanoic Acid Serum Levels with Two Outcomes. *Environ Health Perspect.*
27 2017;125(3):416-421.
- 28 Domazet SL, Grøntved A, Timmermann AG, Nielsen F, Jensen TK. Longitudinal associations of exposure
29 to perfluoroalkylated substances in childhood and adolescence and indicators of adiposity and glucose
30 metabolism 6 and 12 years later: The European Youth Heart Study. *Diabetes Care* 2016;39(10):1745-51.
- 31 Domingo et al. Human dietary exposure to perfluoroalkyl substances in Catalonia, Spain. *Food Chemistry*
32 2012;135:1575-1582.
- 33 Emmett, EA, Shofer FS, Zhang H, Freeman D, Desai C, Shaw LM. Community Exposure to
34 Perfluorooctanoate: Relationships Between Serum Concentrations and Exposure Sources. *J Occ Environ*
35 *Med* 2006; 48(8):759-770.
- 36 Emmett, EA, Shofer FS, Freeman D, Desai C, Shaw LM. Community Exposure to Perfluorooctanoate:
37 Relationships Between Serum Levels and Certain Health Parameters. *J Occ Environ Med* 2006;48(8):771-
38 779.

- 1 Environmental Working Group. [https://www.ewg.org/research/report-110-million-americans-could-](https://www.ewg.org/research/report-110-million-americans-could-have-pfas-contaminated-drinking-water)
2 [have-pfas-contaminated-drinking-water](https://www.ewg.org/research/report-110-million-americans-could-have-pfas-contaminated-drinking-water). Accessed Nov 28, 2018.
- 3 Fàbrega F, Kumar V, Schuhmacher M, Domingo JL, Nadal M. PBPK modeling for PFOS and PFOA:
4 validation with human experimental data. *Toxicol Lett*. 2014 ;230(2):244-51.
- 5 Fàbrega F, Nadal M, Schuhmacher M, Domingo JL, Kumar V. Influence of the uncertainty in the
6 validation of PBPK models: A case-study for PFOS and PFOA. *Regul Toxicol Pharmacol*. 2016;77:230-9.
- 7 Fei C, Olsen J. Prenatal exposure to perfluorinated chemicals and behavioral or coordination problems at
8 age 7 years. *Environ Health Perspect*. 2011;119:573-578.
- 9 Feldstein AE, Alkhoury N, De Vito R, Alisi A, Lopez R, Nobili V. Serum cytokeratin-18 fragment levels are
10 useful biomarkers for nonalcoholic steatohepatitis in children. *Am J Gastroenterol*. 2013;108(9):1526-31.
- 11 Ferrante MC, Amero P, Santoro A, Monnolo A, Simeoli R, Di Guida F, Mattace Raso G, Meli R.
12 Polychlorinated biphenyls (PCB 101, PCB 153 and PCB 180) alter leptin signaling and lipid metabolism in
13 differentiated 3T3-L1 adipocytes. *Toxicol Appl Pharmacol*. 2014; 279(3):401-8.
- 14 Fisher M, Arbuckle TE, Wade M, Haines DA. Do perfluoroalkyl substances affect metabolic function and
15 plasma lipids?—Analysis of the 2007–2009, Canadian Health Measures Survey (CHMS) Cycle1. *Environ*
16 *Res* 2013;121:95-103.
- 17 Fitz-Simon N, Fletcher T, Luster MI, Steenland K, Calafat AM, Kato K, Armstrong B. Reductions in serum
18 lipids with a 4-year decline in serum perfluorooctanoic acid and perfluorooctanesulfonic acid.
19 *Epidemiology* 2013;24:569-76.
- 20 Flanders WD, Lin L, Pirkle JL, Caudill SP. Assessing the direction of causality in cross-sectional studies. *Am*
21 *J Epidemiol* 1992;135:926-935.
- 22 Flanders WD, Klein M, Mirabelli MC. Conditions for valid estimation of causal effects on prevalence in
23 cross-sectional and other studies. *Ann Epidemiol* 2016;26:389-394.
- 24 Fleisch AF, Rifas-Shiman SL, Mora AM, Calafat AM, Ye X, Luttmann-Gibson H, Gillman MW, Oken E, Sagiv
25 SK. Early-Life Exposure to Perfluoroalkyl Substances and Childhood Metabolic Function. *Environ Health*
26 *Perspect*. 2017;125(3):481-487.
- 27 Frisbee SJ, Brooks Jr AP, Maher A, et al. The C8 health project: design, methods, and participants.
28 *Environ Health Perspect* 2009;117:1873-1882.
- 29 Frisbee SJ, Shankar A, Knox SS, Steenland K, Savitz DA, Fletcher T, Ducatman AM. Perfluorooctanoic acid,
30 perfluorooctanesulfonate, and serum lipids in children and adolescents: Results from the C8 Health
31 Project. *Arch Pediatr Adolesc Med* 2010;164:860-869.
- 32 Fu Y, Wang T, Fu Q, Wang P, Lu Y. Associations between serum concentrations of perfluoroalkyl acids
33 and serum lipid levels in a Chinese population. *Ecotoxicol Environ Saf* 2014;106:246-52.
- 34 Gallo V, Leonardi G, Genser B, Lopez-Espinosa MJ, Frisbee SJ, Karlsson L, Ducatman AM, Fletcher T.
35 Serum perfluorooctanoate (PFOA) and perfluorooctane sulfonate (PFOS) concentrations and liver
36 function biomarkers in a population with elevated PFOA exposure. *Environ Health Perspect*
37 2012;120:655–660.

- 1 Geiger SD, Xiao J, Shankar A. Positive association between perfluoroalkyl chemicals and hyperuricemia in
2 children. *Am J Epidemiol* 2013;177:1255-1262.
- 3 Gleason JA, Post GB, Fagliano JA. Associations of perfluorinated chemical serum concentrations and
4 biomarkers of liver function and uric acid in the US population (NHANES), 2007-2010. *Environ Res.*
5 2015;136:8-14 Gomis MI, Vestergren R, MacLeod M, Mueller JF, Cousins IT. Historical human exposure to
6 perfluoroalkyl acids in the United States and Australia reconstructed from biomonitoring data using
7 population-based pharmacokinetic modelling. *Environ Int* 2017;108:92-102.
- 8 Gomis MI, Vestergren R, MacLeod M, Mueller JF, Cousins IT. Historical human exposure to perfluoroalkyl
9 acids in the United States and Australia reconstructed from biomonitoring data using population-based
10 pharmacokinetic modelling. *Environ Int.* 2017;108:92-102.
- 11 Grandjean P, Andersen EW, Budtz-Jørgensen E, Nielsen F, Mølbak K, Weihe P, Heilmann C. Serum
12 Vaccine Antibody Concentrations in Children Exposed to Perfluorinated Compounds. *JAMA* 2012;307:
13 391-397.
- 14 Grandjean P, Heilmann C, Weihe P, Nielsen F, Mogensen UB, Budtz-Jørgensen E. Serum vaccine antibody
15 concentrations in adolescents exposed to perfluorinated compounds. *Environ Health Perspect*
16 2017;125(7):077018.
- 17 Granum, Haug LS, Namork E, Stølevik SB, Thomsen C, Aaberge IS, van Loveren H, Løvik M, Nygaard UC.
18 Pre-natal exposure to perfluoroalkyl substances may be associated with altered vaccine antibody levels
19 and immune-related health outcomes in early childhood. *J Immunotoxicol* 2013; 10:4, 373-379.
- 20 Harada K, Inoue K, Morikawa A, Yoshinaga T, Saito N, Koizumi A. Renal clearance of perfluorooctane
21 sulfonate and perfluorooctanoate in humans and their species-specific excretion. *Environ Res* 2005;
22 99:253-261
- 23 He X, Liu Y, Xu B, Gu L, Tang W. PFOA is associated with diabetes and metabolic alteration in US men:
24 National Health and Nutrition Examination Survey 2003-2012. *Sci Total Environ* 2018;625:566-74.
- 25 Hennig, B., Oesterling, E., & Toborek, M. Environmental toxicity, nutrition, and gene interactions in the
26 development of atherosclerosis. *Nutr Metab Cardiovasc Dis.* 2007; 17(2):162-169.
- 27 Hoffman K, Webster TF, Weisskopf MG, Weinberg J, Vieira VM. Exposure to polyfluoroalkyl chemicals
28 and attention deficit/hyperactivity disorder in U.S. children 12-15 years of age. *Environ Health Perspect*
29 2010;118(12):1762-7.
- 30 Innes KE, Ducatman AM, Luster MI, Shankar A. Association of osteoarthritis with serum levels of the
31 environmental contaminants perfluorooctanoate and perfluorooctane sulfonate in a large Appalachian
32 population. *Am J Epidemiol.* 2011;174(4):440-50.
- 33 Jain RB. Association between thyroid profile and perfluoroalkyl acids: data from NHANES 2007-2008.
34 *Environ Res.* 2013 Oct;126:51-9.
- 35 Ji K, Kim S, Kho Y, Paek D, Sakong J, Ha J, Kim S, Choi K. Serum concentrations of major perfluorinated
36 compounds among the general population in Korea: Dietary sources and potential impact on thyroid
37 hormones. *Environ Int* 2012;45:78-85.

- 1 Joensen UN, Veyrand B, Antignac JP, Blomberg Jensen M, Petersen JH, Marchand P, Skakkebaek NE,
2 Andersson AM, Le Bizec B, Jørgensen N. PFOS (perfluorooctanesulfonate) in serum is negatively
3 associated with testosterone levels, but not with semen quality, in healthy men. *Hum Reprod*.
4 2013;28(3):599-608.
- 5 Karlsen M, Grandjean P, Weihe P, Steuerwald U, Oulhote Y, Valvi D. Early-life exposures to persistent
6 organic pollutants in relation to overweight in preschool children. *Reprod Toxicol* 2017;68:145-153.
- 7 Kataria A, Trachtman H, Malaga-Dieguez L, Trasande L. Association between perfluoroalkyl acids and
8 kidney function in a cross-sectional study of adolescents. *Environ Health* 2015;14:89.
- 9 Khalil N, Chen A, Lee M, Czerwinski SA, Ebert JR, DeWitt JC, Kannan K. Association of Perfluoroalkyl
10 Substances, Bone Mineral Density, and Osteoporosis in the U.S. Population in NHANES 2009-2010.
11 *Environ Health Perspect*. 2016;124(1):81-7.
- 12 Knox SS, Jackson T, Frisbee SJ, Javins B, Ducatman AM. Perfluorocarbon exposure, gender and thyroid
13 function in the C8 Health Project. *J Toxicol Sci*. 2011;36(4):403-10.
- 14 Kristensen SL, Ramlau-Hansen CH, Ernst E, Olsen SF, Bonde JP, Vested A, Halldorsson TI, Becher G, Haug
15 LS, Toft G. Long-term effects of prenatal exposure to perfluoroalkyl substances on female reproduction.
16 *Hum Reprod*. 2013;28(12):3337-48.
- 17 Kray JB, Wightman SJ. Contaminants of emerging concern: A new frontier for hazardous waste and
18 drinking water regulation. *Natural Resources & Environment* 2018;32:36-40.
- 19 Kuklennyik Z, Needham LL, Calafat AM. Measurement of 18 perfluorinated organic acids and amides in
20 human serum using on-line solid-phase extraction. *Anal Chem*. 2005;77(18):6085-91.
- 21 Lash TL, Fox MP, Fink AK. *Applying Quantitative Bias Analysis to Epidemiologic Data*. Springer (NY, 2009).
- 22 Lavrakas PJ ed. *Encyclopedia of Survey Research Methods*. Sage Publication, 2008.
- 23 Lien GW, Huang CC, Shiu JS, Chen MH, Hsieh WS, Guo YL, Chen PC. Perfluoroalkyl substances in cord
24 blood and attention deficit/hyperactivity disorder symptoms in seven-year-old children. *Chemosphere*.
25 2016;156:118-27.
- 26 Liew Z, Ritz B, von Ehrenstein OS, Bech BH, Nohr EA, Fei C, Bossi R, Henriksen TB, Bonefeld-Jørgensen EC,
27 Olsen J. Attention deficit/hyperactivity disorder and childhood autism in association with prenatal
28 exposure to perfluoroalkyl substances: a nested case-control study in the Danish National Birth Cohort.
29 *Environ Health Perspect* 2015;123(4):367-73.
- 30 Lin CY, Wen LL, Lin LY, Wen TW, Lien GW, Hsu SH, Chien KL, Liao CC, Sung FC, Chen PC, Su TC. The
31 associations between serum perfluorinated chemicals and thyroid function in adolescents and young
32 adults. *J Hazard Mater* 2013;244-245:637-644.
- 33 Lipsitch M, Tchetgen Tchetgen E, Cohen T. Negative controls: A tool for detecting confounding and bias
34 in observational studies. *Epidemiol* 2010;21:383-388.
- 35 Loccisano AE, Longnecker MP, Campbell JL Jr, Andersen ME, Clewell HJ 3rd. Development of PBPK
36 models for PFOA and PFOS for human pregnancy and lactation life stages. *J Toxicol Environ Health A*.
37 2013;76(1):25-57

- 1 Looker C, Luster MI, Calafat AM, Johnson VJ, Burleson GR, Burleson FG, Fletcher T. Influenza Vaccine
2 Response in Adults Exposed to Perfluorooctanoate and Perfluorooctanesulfonate. *Toxicol Sci* 2014;
3 138(1): 76–88.
- 4 Lopez-Espinosa MJ, Fletcher T, Armstrong B, Genser B, Dhatariya K, Mondal D, Ducatman A, Leonardi G.
5 Association of Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonate (PFOS) with age of puberty
6 among children living near a chemical plant. *Environ Sci Technol* 2011;45:8160-8166.
- 7 Lopez-Espinosa MJ, Mondal D, Armstrong B, Bloom MS, Fletcher T. Thyroid function and perfluoroalkyl
8 acids in children living near a chemical plant. *Environ Health Perspect* 2012;120:1036-1041.
- 9 Lopez-Espinosa MJ, Mondal D, Armstrong BG, Eskenazi B, Fletcher T. Perfluoroalkyl substances, sex
10 hormones, and insulin-like growth factor-1 at 6–9 years of age: a cross-sectional analysis within the C8
11 Health Project. *Environ Health Perspect* 2016;124:1269-1275.
- 12 Maisonet M, Näyhä S, Lawlor DA, Marcus M. Prenatal exposures to perfluoroalkyl acids and serum lipids
13 at ages 7 and 15 in females. *Environ Int* 2015a;82:49-60.
- 14 Maisonet M, Calafat AM, Marcus M, Jaakkola JJ, Lashen H. Prenatal exposure to perfluoroalkyl acids and
15 serum testosterone concentrations at 15 years of age in female ALSPAC study participants. *Environ*
16 *Health Perspect* 2015b;123:1325-1330.
- 17 Maldonado G, Greenland S. Simulation Study of Confounder-Selection Strategies. *Am J Epidemiol*
18 1993;138: 923–36.
- 19 Mattsson K, Rignell-Hydbom A, Holmberg S, Thelin A, Jönsson BA, Lindh CH1, Sehlstedt A, Rylander L.
20 Levels of perfluoroalkyl substances and risk of coronary heart disease: Findings from a population-based
21 longitudinal study. *Environ Res* 2015;142:148-54.
- 22 Melzer D, Rice N, Depledge MH, Henley WE, Galloway TS. Association between serum perfluorooctanoic
23 acid (PFOA) and thyroid disease in the U.S. National Health and Nutrition Examination Survey. *Environ*
24 *Health Perspect* 2010;118:686–692.
- 25 Mora AM, Fleisch AF, Rifas-Shiman SL, Woo Baidal JA, Pardo L, Webster TF, Calafat AM, Ye X, Oken E,
26 Sagiv SK. Early life exposure to per- and polyfluoroalkyl substances and mid-childhood lipid and alanine
27 aminotransferase levels. *Environ Int.* 2018;111:1-13.
- 28 Nelson JW, Hatch EE, Webster TF. Exposure to polyfluoroalkyl chemicals and cholesterol, body weight,
29 and insulin resistance in the general U.S. population. *Environ Health Perspect* 2010;118:197-202.
- 30 New Hampshire Division of Public Health Services, Department of Health and Human Services (NH
31 DHHS). Pease PFC Blood-testing Program: April 2015 – October 2015. Pease Tradeport, Portsmouth, NH,
32 June 2016. <http://www.dhhs.nh.gov/dphs/documents/pease-pfc-blood-testing.pdf>
- 33 Ngueta G, Longnecker MP, Yoon M, Ruark CD, Clewell HJ Rd, Andersen ME, Verner MA. Quantitative bias
34 analysis of a reported association between perfluoroalkyl substances (PFAS) and endometriosis: The
35 influence of oral contraceptive use. *Environ Int.* 2017;104:118-121.
- 36 Ode A, Kallen K, Gustafsson P, Rylander L, Jonsson BA, Olofsson P, Ivarsson SA, Lindh CH, Rignell-
37 Hydbom A. Fetal Exposure to Perfluorinated Compounds and Attention Deficit Hyperactivity Disorder in
38 Childhood. *PLoS ONE* 2014; 9(4): e95891.

- 1 Olsen GW, Zobel LR. Assessment of lipid, hepatic, and thyroid parameters with serum
2 perfluorooctanoate (PFOA) concentrations in fluorochemical production workers. *Int Arch Occup*
3 *Environ Health*. 2007;81(2):231-46. Epub 2007 Jun 29.
- 4 Oulhote Y, Steuerwald U, Debes F, et al. Behavioral difficulties in 7-year old children in relation to
5 developmental exposure to perfluorinated alkyl substances. *Environ Int* 2016;97:237-245.
- 6 Porta M. ed. *A Dictionary of Epidemiology, Sixth Edition*, Edited for the International Epidemiological
7 Association. Oxford University Press (2014, NY) pp. 200, 246.
- 8 Qin XD, Qian Z, Vaughn MG, Huang J, Ward P, Zeng XW, Zhou Y, Zhu Y, Yuan P, Li M, Bai Z, Paul G, Hao
9 YT, Chen W, Chen PC, Dong GH, Lee YL. Positive associations of serum perfluoroalkyl substances with
10 uric acid and hyperuricemia in children from Taiwan. *Environ Pollution* 2016;212:519-524.
- 11 Rappazzo KM, Coffman E, Hines EP. Exposure to Perfluorinated Alkyl Substances and Health Outcomes in
12 Children: A Systematic Review of the Epidemiologic Literature. *Int. J. Environ. Res. Public Health* 2017,
13 14, 691
- 14 Rothman KJ, Greenland S, Lash TL. *Modern Epidemiology*, 3rd Edition. Walters Kluwer/ Lippincott
15 Williams & Wilkins, Philadelphia, PA. 2008.
- 16 Rothman KJ. Curbing type I and type II errors. *Eur J Epidemiol* 2010;25:223-224.
- 17 Rothman KJ. Six persistent research misconceptions. *J Gen Intern Med*. 2014;29:1060-4.
- 18 Ruark CD, Song G, Yoon M, Verner MA, Andersen ME, Clewell HJ 3rd, Longnecker MP. Quantitative bias
19 analysis for epidemiological associations of perfluoroalkyl substance serum concentrations and early
20 onset of menopause. *Environ Int*. 2017;99:245-254.
- 21 Sakr CJ, Kreckmann KH, Green JW, Gillies PJ, Reynolds JL, Leonard RC. Cross-sectional study of lipids and
22 liver enzymes related to a serum biomarker of exposure (ammonium perfluorooctanoate or APFO) as
23 part of a general health survey in a cohort of occupationally exposed workers. *J Occup Environ Med*.
24 2007a;49(10):1086-96.
- 25 Sakr CJ, Leonard RC, Kreckmann KH, Slade MD, Cullen MR. Longitudinal study of serum lipids and liver
26 enzymes in workers with occupational exposure to ammonium perfluorooctanoate. *J Occup Environ*
27 *Med*. 2007b;49(8):872-9
- 28 Santoro N, Feldstein AE, Enoksson E, Pierpont B, Kursawe R, Kim G, Caprio S. The association between
29 hepatic fat content and liver injury in obese children and adolescents: effects of ethnicity, insulin
30 resistance, and common gene variants. *Diabetes Care*. 2013;36(5):1353-60.
- 31 Shankar A, Xiao J, Ducatman A. Perfluoroalkyl chemicals and elevated serum uric acid in US adults. *Clin*
32 *Epidemiol* 2011;3:251-258.
- 33 Shankar A, Xiao J, Ducatman A. Perfluorooctanoic acid and cardiovascular disease in US adults. *Arch*
34 *Intern Med* 2012;172:1397-403.
- 35 Shen J, Chan HL, Wong GL, Choi PC, Chan AW, Chan HY, Chim AM, Yeung DK, Chan FK, Woo J, Yu J, Chu
36 WC, Wong VW. Non-invasive diagnosis of non-alcoholic steatohepatitis by combined serum biomarkers.
37 *J Hepatol*. 2012;56(6):1363-70.

- 1 Shin HM, Vieira VM, Ryan PB et al. Retrospective exposure estimation and predicted versus observed
2 serum perfluorooctanoic acid concentrations for participants in the C8 Health Project. *Environ Health*
3 *Perspect* 2011;119:1760-1765.
- 4 Stang A, Poole C, Kuss O: The ongoing tyranny of statistical significance testing in biomedical research.
5 *Eur J Epidemiol* 2010, 25:225-30.
- 6 Steenland K, Tinker S, Frisbee S, Ducatman A, Vaccarino V. Association of perfluorooctanoic acid and
7 perfluorooctane sulfonate with serum lipids among adults living near a chemical plant. *Am J Epidemiol*
8 2009;170:1268-1278.
- 9 Steenland K Association of perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) with uric
10 acid among adults with elevated community exposure to PFOA. *Environ Health Perspect* 2010;118:229-
11 233.
- 12 Steenland K, Zhao L, Winqvist A, Parks C. Ulcerative colitis and perfluorooctanoic acid (PFOA) in a highly
13 exposed population of community residents and workers in the mid-Ohio valley. *Environ Health*
14 *Perspect*. 2013;121(8):900-5.
- 15 Steenland K, Zhao L, Winqvist A. A cohort incidence study of workers exposed to perfluorooctanoic acid
16 (PFOA). *Occup Environ Med*. 2015;72(5):373-80.
- 17 Stein CR, Savitz DA. Serum perfluorinated compound concentration and attention deficit/hyperactivity
18 disorder in children 5-18 years of age. *Environ Health Perspect* 2011;119:1466-1471.
- 19 Stein CR, Savitz DA, Bellinger DC. Perfluorooctanoate and neuropsychological outcomes in children.
20 *Epidemiology* 2013;24:590-599.
- 21 Stein CR, Savitz DA, Elston B, Thorpe PG, Gilboa SM. Perfluorooctanoate exposure and major birth
22 defects. *Reprod Toxicol*. 2014a;47:15-20.
- 23 Stein CR, Savitz DA, Bellinger DC. Perfluorooctanoate exposure in a highly exposed community and
24 parent and teacher reports of behavior in 6-12-year-old children. *Paediatr Perinat Epidemiol*
25 2014b;28:146-156. Stein CR, McGovern KJ, Pajak AM, Maglione PJ, Wolff MS. Perfluoroalkyl and
26 Polyfluoroalkyl Substances and Indicators of Immune function in children aged 12-19 y: National Health
27 and Nutrition Examination Survey. *Pediatr Res*. 2016a; 79(2):348-57.
- 28 Stein CR, Ge Y, Wolff MS et al. Perfluoroalkyl substance serum concentrations and immune response to
29 FluMist vaccination among healthy adults. *Environ Res* 2016b;149:171-178.
- 30 Sun Q, Zong G, Valvi D, Nielsen F, Coull B, Grandjean P. Plasma concentrations of perfluoroalkyl
31 substances and risk of type 2 diabetes: A prospective investigation among US Women. *Environ Health*
32 *Perspect* 2018;126(3):037001.
- 33 Trochim WMK. *Research Methods Knowledge Base*. 2006.
34 <https://socialresearchmethods.net/kb/samprnon.php>.
- 35 Tyrer S, Heyman B. Sampling in epidemiological research: issues, hazards and pitfalls. *BJPsych Bull*.
36 2016;40(2):57-60.

- 1 Uhl SA, James-Todd J, Bell ML. Association of Osteoarthritis with Perfluorooctanoate and
2 Perfluorooctane Sulfonate in NHANES 2003–2008. *Environ Health Perspect* 2013;121:447-452.
- 3 U.S. Environmental Protection Agency (EPA). Provisional Health Advisories for Perfluorooctanoic Acid
4 (PFOA) and Perfluorooctyl Sulfonate (PFOS); 2009. Available from
5 http://water.epa.gov/action/advisories/drinking/upload/2009_01_15_criteria_drinking_pfoa_pfos.pdf
6 PFOA_PFOS.pdf
- 7 U.S. Environmental Protection Agency (EPA). Fact Sheet – PFOS & PFOA Drinking Water Health
8 Advisories. Ground Water and Drinking Water; 2016a. Available from:
9 https://www.epa.gov/sites/production/files/2016-06/documents/drinkingwaterhealthadvisories_pfoa_pfos_updated_5.31.16.pdf
10 pfos_updated_5.31.16.pdf
- 11 U.S. Environmental Protection Agency (EPA). Third Unregulated Contaminant Monitoring Rule, July
12 2016b. Available from: <https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule#3>
13 monitoring-rule#3
- 14 Verner MA, Longnecker MP. Comment on "enhanced elimination of perfluorooctanesulfonic Acid by
15 menstruating women: evidence from population-based pharmacokinetic modeling". *Environ Sci Technol*.
16 2015;49(9):5836-7.
- 17 Verner MA, Loccisano AE, Morken NH, Yoon M, Wu H, McDougall R, Maisonet M, Marcus M, Kishi R,
18 Miyashita C, Chen MH, Hsieh WS, Andersen ME, Clewell HJ 3rd, Longnecker MP. Associations of
19 perfluoroalkyl substances (PFAS) with lower birth weight: an evaluation of potential confounding by
20 glomerular filtration rate using a physiologically based pharmacokinetic model (PBPK). *Environ Health*
21 *Perspect* 2015;123(12):1317-24.
- 22 Verner MA, Ngueta G, Jensen ET, Fromme H, Völkel W, Nygaard UC, Granum B, Longnecker MP. A
23 Simple Pharmacokinetic Model of Prenatal and Postnatal Exposure to Perfluoroalkyl Substances (PFASs).
24 *Environ Sci Technol*. 2016; 19;50(2):978-86
- 25 Vos MB, Barve S, Joshi-Barve S, Carew JD, Whittington PF, McClain CJ. Cytokeratin 18, a marker of cell
26 death, is increased in children with suspected nonalcoholic fatty liver disease. *J Pediatr Gastroenterol*
27 *Nutr*. 2008 Oct;47(4):481-5.
- 28 Vuong AM, Yolton K, Webster GM, Sjödin A, Calafat AM, Braun JM, Dietrich KN, Lanphear BP, Chen A.
29 Prenatal polybrominated diphenyl ether and perfluoroalkyl substance exposures and executive function
30 in school-age children. *Environ Res*. 2016;147:556-64
- 31 Wahlang B, Prough RA, Falkner KC, Hardesty JE, Song M, Clair HB, Clark BJ, States JC, Arteel GE, Cave
32 MC. Polychlorinated Biphenyl-Xenobiotic Nuclear Receptor Interactions Regulate Energy Metabolism,
33 Behavior, and Inflammation in Non-alcoholic-Steatohepatitis. *Toxicol Sci*. 2016;149(2):396-410.
- 34 Wang JJ, Hsieh WS, Chen CY, Fletcher T, Lien GW, Chiang HL, Chiang CF, Wu TN, Chen PC. The effect of
35 prenatal perfluorinated chemicals exposures on pediatric atopy. *Environ Res* 2011; 111:785–791.
- 36 Wang Z, DeWitt JC, Higgins CP, Cousins IT. A never-ending story of per- and polyfluoroalkyl substances
37 (PFASs)? *Environ Sci Technol* 2017;51:2508-2518.

- 1 Weisskopf MG, Webster TF. Trade-offs of personal versus more proxy exposure measures in
2 environmental epidemiology. *Epidemiol* 2017;28:635-643.
- 3 Weisskopf MG, Seals RM, Webster TF. Bias Amplification in Epidemiologic Analysis of Exposure to
4 Mixtures. *Environ Health Perspect* 2018;126:047003.
- 5 Wen LL, Lin LY, Su TC, Chen PC, Lin CY. Association between serum perfluorinated chemicals and thyroid
6 function in U.S. adults: The National Health and Nutrition Examination Survey 2007–2010. *J Clin*
7 *Endocrinol Metab* 2013;98:E1456-E1464.
- 8 Winquist A, Steenland K. Perfluorooctanoic acid exposure and thyroid disease in community and worker
9 cohorts. *Epidemiology* 2014a;25:255-264.
- 10 Winquist A, Steenland K. Modeled PFOA exposure and coronary artery disease, hypertension, and high
11 cholesterol in community and worker cohorts. *Environ Health Perspect* 2014b; 122:1299-1305.
- 12 Wieser V, Moschen AR, Tilg H. Inflammation, cytokines and insulin resistance: a clinical perspective. *Arch*
13 *Immunol Ther Exp (Warsz)*. 2013; 61(2):119-25.
- 14 Wong F, MacLeod M, Mueller JF, Cousins IT. Enhanced elimination of perfluorooctane sulfonic acid by
15 menstruating women: evidence from population-based pharmacokinetic modeling. *Environ Sci Technol*.
16 2014;48(15):8807-14.
- 17 Worley RR, Yang X, Fisher J. Physiologically based pharmacokinetic modeling of human exposure to
18 perfluorooctanoic acid suggests historical non drinking-water exposures are important for predicting
19 current serum concentrations. *Toxicol Appl Pharmacol*. 2017a;330:9-21.
- 20 Worley RR, Moore, SM, Tierney BC, Ye X, Calafat AM, Campbell S, Woudneh MB, Fisher J. Per- and
21 polyfluoroalkyl substances in human serum and urine samples from a residentially exposed community.
22 *Environ Int*. 2017b;106:135-143.
- 23 Ye X, Kato K, Wong LY, Jia T, Kalathil A, Latremouille J, Calafat AM. Per- and Polyfluoroalkyl Substances in
24 Sera from Children 3 to 11 Years of Age Participating in the National Health and Nutrition Examination
25 Survey 2013–2014. *Int J Hyg Environ Health* 2017;Sep29: S1438-4639(17)30588-6 [Epub ahead of print]
- 26 Zeng XW, Qian Z, Emo B, Vaughn M, Bao J, Qin XD, Zhu Y, Li J, Lee YL, Dong GH. Association of
27 polyfluoroalkyl chemical exposure with serum lipids in children. *Sc Total Environ* 2015;512-513:364-370.
- 28 Zhang T, Sun H, Qin X, Gan Z, Kannan K. PFOS and PFOA in paired urine and blood from general adults
29 and pregnant women: assessment of urinary elimination. *Environ Sci Pollut Res Int*. 2015;22(7):5572-9.
- 30 Zhou Y, Hu LW, Qian ZM, Chang JJ, King C, Paul G, Lin S, Chen PC, Lee YL, Dong GH. Association of
31 perfluoroalkyl substances exposure with reproductive hormone levels in adolescents: By sex status.
32 *Environ International* 2016;94:189-195.

1 **7. LIST OF ATTACHMENTS**

2

3 Attachment 1. Investigators and Key Study Personnel

4 Attachment 2. Biochemical Analytical Plan in Children and Adults

5 Attachment 3. Justification for Sample Size Calculations

6 Attachment 3a. Sample Size for Child Study

7 Attachment 3b. Sample Size for Adult Study

8 Attachment 4. Eligibility Screening Script

9 Attachment 5 –Recruitment Materials

10 Attachment 6 – Recruitment Tracking Form

11 Attachment 7 – Appointment Packet

12 Attachment 7a – Appointment Reminder Card

13 Attachment 7b – Informed Consent Packet

14 Attachment 7b1 – Privacy Act Statement

15 Attachment 7b2 – Parental Permission and Child Assent Forms

16 Attachment 7b3 – Parental Consent to Release Student Information

17 Attachment 7b4 – Adult Consent Form

18 Attachment 7b5 – Parent/Child/Adult Permission for Medical Record Abstraction

19 Attachment 7c – Study Fact Sheet

20 Attachment 8 – Appointment Reminder Telephone Script

21 Attachment 9 – Appointment Tracking Form

22 Attachment 10 – Update Contact Information Hardcopy Form

23 Attachment 11 – Medication List

24 Attachment 12 – Manual of Procedures

25 Attachment 13 – Body and Blood Pressure Measures Form

26 Attachment 14 – Blood Draw and Urine Collection Form

27 Attachment 15 – Child Questionnaire – Long Form

28 Attachment 15a – Child Questionnaire – Short Form

29 Attachment 16 – Adult Questionnaire

30 Attachment 17 – Request for Medical Record Abstraction

31 Attachment 17a – Medical Record Abstraction Form

32 Attachment 17b – Medical Record Abstraction Form

33 Attachment 18 – Child/Parent Neurobehavioral Test Battery

34 Attachment 18a – NBT Time Estimation Table, by Age in Years

35 Attachment 18b – Request for Child School Record Abstraction

36 Attachment 18c – Child School Record Abstraction Form

37 Attachment 19 – Body and Blood Pressure Measurements Report

38 Attachment 20 – Advance Reporting Script for Clinical Tests

39 Attachment 20a – Advance Clinical Test Report Tracking Form

40 Attachment 20b – Letter Report of Critical Values

41 *Attachment 21 – Clinical Test Results Report*

42 Attachment 22 – PFAS Results Report

43 Attachment 22a – ATSDR PFAS Factsheet

44