Health Consultation

BRADFORD DYEING ASSOCIATION:
PFAS IN FISH TISSUE

WESTERLY, WASHINGTON COUNTY, RHODE ISLAND

Prepared by the
Rhode Island Department of Health

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Westerly, Washington County, Rhode Island

Prepared By:

Environmental Health Risk Assessment Program
Rhode Island Department of Health

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LIST OF ABBREVIATIONS

4:2-FTS	4:2 Fluorotelomer sulfonic acid
6:2-FTS	6:2 Fluorotelomer sulfonic acid
8:2-FTS	8:2 Fluorotelomer sulfonic acid
ATSDR	Agency for Toxic Substances and Disease Registry
BW	Body weight
CDC	Centers for Disease Control
CSF	Cancer slope factor
CTE	Central tendency exposure
ED	Exposure duration
EF	Exposure frequency
EHRAP	Environmental Health and Risk Assessment Program
ELCR	Excess lifetime cancer risk
USEPA	Environmental Protection Agency
EPC	Exposure point concentration
FDA	Food and Drug Administration
FOSA	Perfluorooctanesulfonamide
g/day	Grams per day
GPP	Grills Preserve Pond (formerly the wastewater stabilization pond used by Bradford Dyeing Association)
HQ	Hazard quotient
HI	Hazard index
IR	Ingestion rate
LY	Lifetime
mg/kg/day	Milligrams per kilogram per day
MRL	Minimal risk level
N-EtFOSAA	N-ethylperfluorooctane sulfonamidoacetic acid
ng/L	Nanograms per liter
N-MeFOSAA	2-(N-methylperfluorooctane sulfonamido)acetic acid
PAH	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PFAS	Per- and polyfluorinated alkyl substances
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutane sulfonic acid
PFDA	Perfluorodecanoic acid
PFDoDA	Perfluorododecanoic acid
PFDS	Perfluorodecane sulfonic acid
PFHpA	Perfluoroheptanoic acid
PFHpS	Perfluoroheptane sulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFNS	Perfluorononane sulfonic acid
PFOA	Perfluorooctanoic acid

PFOS	Perfluorooctane sulfonic acid
PFPeA	Perfluoropentanoic acid
PFPeS	Perfluoropentane sulfonic acid
PFTeDA	Perfluorotetradecanoic acid
PFTrDA	Perfluorotridecanoic acid
PFUnDA	Perfluoroundecanoic acid
RIDEM	Rhode Island Department of Environmental Management
RIDOH	Rhode Island Department of Health
RME	Reasonable maximum exposure
PCE	Tetrachloroethylene (perchloroethylene)
TCE	Trichloroethylene
VOCs	Volatile organic compounds

SUMMARY

INTRODUCTION

The first mill in the current Bradford Dyeing Association complex was built in 1864 and produced uniforms and blankets during the Civil War.[1] The mill changed hands several times before it was purchased by Bradford Dyeing Association.[1] Bradford Dyeing Association, Inc., opened in 1911 as a fabric dyer and printer in Westerly, Rhode Island. During recent years, its primary product was textiles for the military and other government agencies.[2,3] During production, Bradford Dyeing Association generated thousands of gallons of waste likely contaminated with per- and polyfluorinated alkyl substances (PFAS), given their long-term history of use as waterproofing chemicals.[4] Starting in the mid-1980s, Bradford Dyeing Association waste management practices were out of compliance with Rhode Island Department of Environmental Management (RIDEM) regulations. In 2005, Bradford Dyeing Association was charged with violating the federal *Clean Air Act* and *Clean Water Act* for polluting the air and illegally dumping into the nearby Pawcatuck River. The company ended operations in 2012 after a major fire, disputes with clients, and a loss of government contracts. A variety of tenants occupied the manufacturing space until its sale to the Rockingham Estate in 2018.[5] Today, the mill building is vacant and the forested area is a nature preserve.

The site occupies 546 acres in total with a large mill complex (manufacturing space, outbuildings, and storage buildings), a forested area, and a series of wastewater lagoons leading to the waste stabilization pond. The waste stabilization pond (here referred to as the Grills Preserve Pond) is now a prominent feature of the Grills Nature Preserve. As of 2024, the land formerly owned by Bradford Dyeing Association has been divided and is managed by different parties. The manufacturing space is owned by the Rockingham Estate, the wastewater lagoons and an empty plot for telecommunications equipment is under the receivership of the Town of Westerly, and the forested area is owned by the Westerly Land Trust.

This health consultation was initiated based on a request from RIDEM. The Grills Nature Preserve occupies much of the land formerly owned by Bradford Dyeing Association. Both the Grills Preserve Pond and the Pawcatuck River (which borders the site) are frequently accessed through the nature preserve and used for fishing. Sunfish, chain pickerel, and largemouth bass were collected in the Grills Preserve Pond as well as upstream and downstream of its connection to the Pawcatuck River. The fish were analyzed for PFAS. Non-cancer hazard indices and hazard quotients were determined for the fish species sampled here. This analysis is important for the community near Bradford Dyeing Association, who frequently fish in the Pawcatuck River and the Grills Preserve Pond.

The Westerly community is also very interested in redeveloping the site for commercial or residential use. The only known currently complete exposure pathway is PFAS exposure through fish consumption. If the site is redeveloped, exposure to contaminants in soil and groundwater will become more important. Exposure to contaminants in soil and groundwater was evaluated at United States Environmental Protection Agency's (USEPA) request. Soil exposure could occur from accidentally eating or breathing in soil contaminated with polycyclic aromatic hydrocarbons (PAHs), cadmium, arsenic, and polychlorinated biphenyls (PCBs). Groundwater near Bradford Dyeing Association is contaminated with volatile organic chemicals. These chemicals prevent use of groundwater as a source of drinking water and can enter the basements of residences or businesses that may be constructed there.

CONCLUSIONS

1. PFAS were found at levels of concern in all fish in the Pawcatuck River and in Grills Preserve Pond. PFAS concentrations were highest in muscle tissue of all species collected in the Grills Preserve Pond.
2. The PFAS at the highest concentrations in fish muscle tissues were perfluorotridecanoic acid (PFTrDA) and perfluoroundecanoic acid (PFUnDA).
3. Our analysis of the area suggests that Bradford Dyeing Association is not the only source of PFAS in the area as fish collected upstream of the site were also contaminated. Further testing is necessary to confirm that upstream contamination contributes to PFAS levels in fish tissues.
4. Non-cancer hazard indices from PFAS ingestion were the highest for consumption of fish from the Grills Preserve Pond.
5. Our analysis indicates that fish from the Grills Preserve Pond should not be consumed and that fish from the Pawcatuck River downstream of Burdickville Road should be consumed no more than once per month. This recommendation includes stocked trout (see Next Steps). Figure 1 shows the map that will be posted at Grills Preserve indicating the areas where people should not be consuming caught fish. Figure 2 indicates the area of the Pawcatuck River where the 1 meal/month recommendation applies.
6. Upstream of Burdickville Road, RIDOH does not have data required to make a recommendation on a safe amount of fish to consume.
7. Health risks from exposure to contaminated soil and groundwater are currently negligible because Bradford Dyeing Association is no longer occupied.
8. Trichloroethylene and tetrachloroethylene were detected at levels that indicate increased risk for soil vapor intrusion into buildings onsite. This is concerning for potential site reuse (see Next Steps).

BASIS FOR CONCLUSION	In 2022, blue gill (*Lepomis macrochirus*), redbreast sunfish (*Lepomis auratus*), chain pickerel (*Esox niger*), and largemouth bass (*Micropterus salmoides*) were collected by Roger Williams University and RIDEM from the Pawcatuck River and Grills Preserve Pond. Muscle plugs from these fish were analyzed for 24 PFAS at the USEPA Office of Research and Development (ORD) laboratory in Narragansett, Rhode Island. Fish were sampled from two upstream locations on the Pawcatuck River, the Grills Preserve Pond, and two Pawcatuck River locations downstream from Bradford Dyeing Association. Samples were grouped as upstream, in the Grills Preserve Pond, and downstream. PFAS were detected in every fish sample, ranging 3-1340 ng/g. Longer chain PFAS (PFTrDA and PFUnDA) were more prevalent compared to shorter chain species. PFAS concentrations for all fish species were greater in the Grills Preserve Pond compared to the upstream and downstream sampling sites. Exposure estimates for the fishing community living close to the Pawcatuck River were quantified using central tendency exposure (CTE) and reasonable maximum exposure (RME) scenarios. CTE represents an estimate of the average person's exposure to a given contaminant, in this case, PFAS. RME is an estimate of the contaminant dose received by the most severely exposed people. The relationship between exposure to some types of PFAS and cancer is still being established, so only non-cancer hazard quotients (HQs) were calculated to assess health risks. PFOA has been classified by EPA as a likely carcinogen[6], but the other PFAS compounds detected here remain under study for their potential to cause cancer. HQs for each individual compound were summed to create a hazard index (HI). These values are used to indicate whether there is a need to evaluate the potential for negative toxicological effects. An HQ or an HI greater than 1 indicates the need for further examination of potential health effects. HIs were greater than 1 for every fish species and sampling location. This indicates that the consumption of fish under the rates assumed here should be evaluated for the potential to negatively impact health. Fish consumed less frequently from the Pawcatuck River would lower the potential risk of negative health effects. HIs were the highest for fish caught in the Grills Preserve Pond, leading to the recommendation not to consume fish from this area. Contaminants in surface soil and groundwater have been detected at concentrations greater than their health-based comparison values. Surface soil had cadmium, PCBs, and PAHs at levels of concern. In groundwater, trichloroethylene and tetrachloroethylene were detected at levels that indicate the potential for intrusion into buildings. While the risk of health

	effects from these chemicals is currently negligible, if residences or businesses are built at the site, they will become more important. New residences and business built in the area would increase the time that people spend interacting with soil and groundwater contaminants. This increases the potential risk of negative health effects. Remediation by capping or removal and replacement would reduce the risk from contaminants in surface soil to levels that are not of concern. Intrusion of trichloroethylene and tetrachloroethylene into buildings can be mitigated by vapor membranes or sub slab depressurization.
NEXT STEPS	• Official messaging should continue to discourage eating fish from the Grills Preserve Pond. • As the data stands, RIDOH does not have the data needed to make a health-based recommendation on the safety of consuming wild game and bird species around Bradford Dyeing Association. Individuals concerned about PFAS should know that these species can accumulate PFAS. People can be exposed to PFAS from a variety of sources and can lower their intake from one or more sources by limiting or replacing them.[7] • RIDOH recommends that RIDEM investigate sources of PFAS upstream of Bradford Dyeing Association that are contaminating fish muscle tissues. • RIDOH will communicate to the public that fish from the Grills Preserve Ponds should not be consumed and fish from the Pawcatuck River downstream of Burdickville Road should be consumed no more than once per month. This guidance extends to stocked trout until data can be produced indicating that stocked trout accumulate PFAS to a lesser extent compared to native species. • RIDEM, USEPA, and RIDOH should coordinate testing of stocked trout to determine the uptake rate of PFAS after release and better assess health risks. • RIDEM should test fish tissues for PFAS throughout the length of the Pawcatuck River, especially upstream of Burdickville Road and provide the results to RIDOH for analysis. • Messaging should discourage consumption of fish organs in the Pawcatuck River due to contamination with PFAS. • If residences are constructed onsite, contaminated soil should be removed or capped with a layer of soil/grass or an impervious material like asphalt or concrete. • Further testing may be necessary to understand the extent of soil contamination onsite. Surface soil samples were taken at 6-12 inches. Typically, people interact with the top three inches of soil. Sampling techniques should reflect that.

	• Groundwater should be remediated or soil vapor intrusion prevention should be employed in buildings constructed onsite. Remediation or soil vapor intrusion prevention would mitigate these risks. • The Bradford Dyeing Association waste lagoons should be fenced with locked gates to prevent access until remediation can occur.
FOR MORE INFORMATION	If you have concerns about your health, you should contact your local health care professional. Questions about this report or exposures associated with this site can be directed to the Environmental Health Risk Assessment Program at zachary.shepard@health.ri.gov.

OBJECTIVES AND HEALTH ISSUES

The Rhode Island Department of Health (RIDOH) Environmental Health Risk Assessment Program (EHRAP) evaluated potential public health concerns related to PFAS in fish from the Grills Preserve Pond and Pawcatuck River. Public health concerns related to redevelopment of Bradford Dyeing Association as a commercial or residential space were also evaluated. This health consultation (HC) was written to determine whether the PFAS levels in fish tissue posed a health hazard to nearby populations and whether the site could be used for future development.

The objectives of this HC were to:

1) Determine whether PFAS detected in fish collected from the Grills Preserve Pond and Pawcatuck River pose a public health hazard.
2) Determine whether contaminants in soil, surface water, groundwater, and sediment pose a health risk for future developments.
3) Recommend appropriate actions to protect public health currently and in a scenario where a residential or commercial development is constructed onsite.
4) Identify data gaps where additional sampling may be needed to better assess health risks.

Community health questions were not submitted as part of a formal ATSDR petition. The data contained in this HC was provided by the Environmental Protection Agency (USEPA) and various public records.

BACKGROUND

Site History

Bradford, Rhode Island, was colonized in 1732 and first marked as a manufacturing village in 1758.[1] At this time, a sawmill was constructed across the river from where Bradford Dyeing Association stands today.[1] The first textile mill in the current Bradford Dyeing Association complex was constructed in 1864.[1] It produced uniforms and blankets during the Civil War.[1] After the war, the mill had several owners.[1] In 1885 it was purchased by the Carmichael Manufacturing Company and in 1902 by James Pike.[1] After the death of Pike in 1910, the mill was purchased by the Bradford Dyeing Association.[1]

Bradford Dyeing Association operated a 500,000 square foot manufacturing space at 460 Bradford Road, Westerly, Rhode Island, as a dyer and printer of fabric for uniforms for the military and law enforcement.[3,5,8] The parcel of 546 acres was a functional textile finishing plant from 1911 to 2008.[3] The waste lagoons and Grills Preserve Pond were constructed in the 1950s after a study by the State of Rhode Island found that the mill was contaminating the Pawcatuck River.[9] The waste lagoons were operational until the 1970s.[9] In the mid-1980s, RIDEM determined Bradford Dyeing Association was out of compliance with hazardous waste (corrosives, halogenated solvents, and degreasing agents) disposal regulations.[5] Toxic sludge residue from the original biological wastewater treatment system also leached into the Pawcatuck River.[10] In 2005, Bradford Dyeing Association was charged with violating the federal *Clean Air Act* and *Clean Water Act*.[11]

In 2008, Bradford Dyeing Association closed after a major fire (in 2007), disputes with clients, and dwindling government contracts.[2] Bradford Dyeing Association reopened briefly under the name of Bradford Printing and Finishing Realty, LLC in 2009, but closed again in 2012.[3] Several tenants (a limousine service, radio station/cell service provider, machinery/equipment dealer, wood working shop, and a cultivator) occupied the main facility while it was under the name Bradford Industrial Park. The industrial park was operated by Bradford Printing and Finishing Realty, LLC, until the building was sold in 2018.[5,12] Prior to the sale, the property was subdivided into four lots: wastewater lagoons, 18-acre wooded wetland, main mill building, and empty plot for future telecommunications equipment.[13]

Bradford Dyeing Association's recent history involves frequently changing owners and concerns about PFAS and other possible contaminants. In July 2018, Bradford Printing & Finishing Realty, LLC ownership ended and the Town of Westerly began working to establish receivership of the mill building, empty plot, and the wastewater lagoons.[14] In 2019, the Rockingham Estate purchased the main mill building and wooded wetland.[15] Rockingham Estate planned to use the property as retail, restaurants, and residential properties.[15] After the sale, the wastewater lagoons and empty plot for future telecommunications equipment remained under receivership controlled by the Town of Westerly.[15] Rockingham Estate planned to gain control of all four lots after remediation of the lagoons.[16] Engineering and Land Development Services was hired as an environmental consultant to create a remediation plan before the lagoons were transferred into the control of the Rockingham Estate.[16] As of 2023, the four lagoons were still under receivership and the town was still seeking grant funds for cleanup.[17] Also in 2023, Rockingham Estate shifted away from planned residential use of the site.[17] This shift stems from the high water table in the area, which limits the capacity of an onsite sewage treatment system.[17]

A map of the site is shown in Figure 3. The Pawcatuck River borders the property to the north and west, Bradford Road/Main Street (Route 216) to the east, and residential homes on Bowling Lane and railroad tracks to the south. The large mill complex (Plat 15, Lot 14) houses the main facility, storage warehouses, outbuildings, parking areas, garages/sheds, a former groundwater system, and a pump house. The Grills Nature Preserve is located to the west of the site. Wastewater generated at Bradford Dyeing Association flowed through the waste lagoons and into the stabilization pond. During manufacturing, Bradford Dyeing Association utilized tens of thousands of gallons of water, which were discharged into the lagoons and stabilization pond.[10] The wastewater lagoons, canal, and stabilization pond run parallel to the Pawcatuck River and connect to the river through a weir at the end of the stabilization pond. During rainstorms, the canal connecting the wastewater lagoons and the stabilization pond overflows, creating a shortcut for contaminated water and sediment to enter the Pawcatuck River. Fish samples were collected in the Grills Preserve Pond as well as upstream and downstream of the connection between the pond and the Pawcatuck River. Sample sites can be found in Figure 4. Soil, sediment, surface water and groundwater samples were collected around the mill building, the wastewater lagoons, and areas of historic dumping (Figure 5-Figure 7)

Grills Nature Preserve History

The Grills Nature Preserve, owned by the Westerly Land Trust, was formed between 2003 to 2006.[9] The Westerly Land Trust purchased 482 acres in 2003 from the Grills family, who owned the Bradford Dyeing Association.[18] This purchase began the establishment of the Grills Nature Preserve, which was complete after smaller land purchases completed the parcel.[9] The acres are between the river, railroad tracks, and the former Bradford Dyeing Association mill.[18] The Grills financed the $2 million dollar purchase of the land allowing the Westerly Land Trust to finish payments by November 2008.[19] The Westerly Land Trust sold a conservation easement to the

RIDEM and The Nature Conservancy. This purchase sells any right to build and contributes to paying off a majority of the purchase.[19] The Grills Preserve is made of upland forest, wooded swamps, freshwater marsh, and 2.5 miles of riverfront.[19] Today, the Westerly Land Trust maintains several publicly-accessible trails on the preserve leading around the pond (Figure 1).

Nearby Demographics and River Use

Demographics data for the area was provided using the 2021 American Community Survey. Census Tracts 507.02 and 509.2 occupy the area around Bradford Dyeing Association (Figure 8). The population (~2,500 total) in these census tracts is white (100%) with a median household income of $65,000 (Table 1). In the village of Bradford, 13.5% of households are living below the poverty line. The downstream town of Westerly (which has easy access to the Grills Nature Preserve and the Pawcatuck River) is also majority white (91%). There are small Hispanic (3%) and Native American (1%) populations in Westerly as well. In Westerly, the median household income is $72,000 per year and 7.0% of the population lives below the poverty line.

The Pawcatuck River is widely used by the surrounding communities for boating, hiking, biking, etc.[20] Fishing in the Pawcatuck River and the Grills Preserve Pond also occurs frequently, and there are reports of hunting, particularly for waterfowl in the area. RIDEM stocks the Pawcatuck River with trout, including at a boat ramp just upstream of Bradford Dyeing Association. The Narragansett Indian Tribe (Tribe) is in this area and is heavily invested in the quality of the river. The Pawcatuck River is a culturally important resource for the Narragansett Indian Tribe. Narragansett tribal land is located near the Pawcatuck River (Figure 9). Community members indicate that the Pawcatuck River is an important source of fish for Tribe members.

Previous Investigations

RIDEM began investigating violations at Bradford Dyeing Association in the mid-1980s. In 1995, USEPA removed 160 cubic yards of soil contaminated with heavy metals and volatile organic compounds.[5] In 1998, a RIDEM investigation concluded that Bradford Dyeing Association had degraded the quality of the water in the adjacent Pawtucket River. This led to a lawsuit that was settled in 2006 for $150,000 and an agreement requiring Bradford Dyeing Association to make improvements dealing with air and water pollution.[11] In 2008, RIDEM issued violations related to aboveground chemical storage tanks.[5] RIDEM/USEPA investigations led to the removal of more containers of dyes, acids, oil-based products, and many other chemicals from the site in 2012.[5,21]

In 2018, Wood Environment & Infrastructure, Inc. (Wood) conducted Phase I and II environmental site assessments. The Phase I assessment examined the site history and performed a cursory reconnaissance.[5] This examination confirms that the site operated as a textile mill from 1911 to 2012. It also revealed the continued presence of chemical drums in the former manufacturing space and 22 above ground storage tanks used for oils, acids, gasoline, and peroxide, among others. Recognized environmental concerns onsite also included: use of the site for industrial purposes, presence of underground storage tanks with no closure records, and the onsite railway. The 2018 Phase II site assessment from Wood analyzed soil, sediment, and water samples from Bradford Dyeing Association.[22] This sampling showed some contaminant concentrations exceeding their respective standards.

Weston & Sampson conducted a more comprehensive Phase II environmental site assessment in 2020.[3] This investigation included soil borings, installation of temporary groundwater monitoring wells, soil and sediment field screening and analysis, groundwater and surface water sampling and analysis, and a groundwater flow survey. Four areas of concern (AOCs) were identified (Figure 3):

1. AOC-1: Main Facility – PFAS, lead, semi-volatile organic compounds (SVOCs), and chlorinated volatile organic compounds (VOCs) were detected in soil and groundwater samples near the main facility. Drums and totes labelled as fluorochemical oil and water repellent were inside the building.
2. AOC-2A: Wastewater Lagoons – Wastewater from dyeing, facility sewage, and stormwater were discharged into four onsite lagoons. The treatment process included settling, aerobic digestion, and aeration polishing. Treated water was then discharged into the Pawcatuck River through a diffuser. Arsenic, chromium, lead, and SVOCs were detected in the sediment and sludge. PFAS were detected in the shallow sediment, surface water, and groundwater surrounding the lagoons.
3. AOC-2B: Waste Stabilization Pond – Wastewater leaving the lagoons flows down the canal to the stabilization pond that overflows a weir into the Pawcatuck. Low concentrations of PFAS were detected in surface water samples in this area.
4. AOC-3: Waste Disposal Area 1 (Drums & Debris) – Partially buried drums, solid waste, and metal debris are located on a levee between the lagoons and the river. Arsenic, lead, and SVOCs were detected in the soil. PFAS compounds were detected in groundwater, surface water, and sediment samples.
5. AOC-4: Waste Disposal Area 2 (Landfill) – This area is a former landfill that contained metal debris, household items, and other solid waste scattered on the ground and dumped down an embankment into the wetland. AOC-4 had detections of arsenic, lead, polychlorinated biphenyls (PCBs), and SVOCs.

This report concludes that impacts of the Bradford Dyeing Association manufacturing facility on the environment are extensive.[3] Metals, VOCs, SVOCs, and PFAS compounds were confirmed in soil, sediment, surface water, and groundwater throughout the site.[3]

Community Health Concerns

The community around Bradford Dyeing Association is concerned about the potential health impacts of the site on visitors. From 2005 to 2007, community members lobbied Bradford Dyeing Association to reduce the amount of waste that it produced and to clean up the Pawcatuck River. The Grills Nature Preserve borders the former Bradford Dyeing Association manufacturing facility and the Pawcatuck River is frequently used for recreational fishing and boating. Trails in the area and fishing tackle found in multiple locations indicate that people fish in the Grills Preserve Pond (Figure 10).

EHRAP has met with several groups to gauge stakeholder interest in and concerns about fishing in the Pawcatuck River. The groups included local (Towns of Westerly and Hopkinton), state (RIDEM), federal (USEPA) government, nonprofit (Westerly Land Trust, Wood/Pawcatuck River Watershed Association, RI Rivers Council, and Southern RI Conservation District), and volunteer (Bradford Community Development) organizations.

Meetings with stakeholder groups have indicated that the land formerly owned by Bradford Dyeing Association may be used in some kind of development (residential or commercial) in the future.[17] If this land is slated for residential use, further consideration should be given to soil and groundwater contamination. Soil and groundwater around the mill building had concentrations of contaminants at levels of concern for human health (see Health Effects Evaluation: Other Exposure Pathways for details). Current risks posed by these contaminants are minimal because the mill is abandoned and the wetland is mostly a nature preserve. Soil remediation (capping or removal) and soil vapor intrusion mitigation should be considered if this area will be used for a residential development.

Some stakeholders were concerned that waterfowl could be contaminated with PFAS from the lagoons. This represents a potential source of exposure for hunters in the area. The science on PFAS in waterfowl is limited because of their migratory nature, which limits the ability to determine sources of PFAS.[23] Waterfowl that migrate are exposed to many different water bodies with varying levels of contamination. This makes it difficult to determine how much a single source (like the Bradford Dyeing Association) impacts the PFAS level in birds, but does not negate the fact that PFAS can accumulate in waterfowl.[23,24] Concentrations also vary depending on the way that the bird species of interest feeds.[24] Ingestion of contaminated sediment, vegetation, or animals would increase the PFAS level in the bird. Other game species, such as deer, have also been shown to accumulate PFAS.[23] Overall, there is no available data that would allow us to predict the level of PFAS in waterfowl species present at Bradford Dyeing Association. Given the lack of PFAS data around Bradford Dyeing Association, RIDOH cannot make a recommendation on whether to limit the consumption of game species. Individuals hunting in the area should be made aware of the risk so they can make an informed choice.

Stocked trout was also a source of significant concern from stakeholders and RIDEM. Trout are stocked in the Pawcatuck River, including at a point immediately upstream of Bradford Dyeing Association. The issue of PFAS in stocked trout is discussed in detail in the Health Effects Evaluation: Fish Consumption Exposure Pathway section.

SITE INVESTIGATION

Fish Sampling Locations

Fish samples were collected in July and November 2022 by Roger Williams University and RIDEM from 10 locations along the Pawcatuck River and in the Grills Preserve Pond. Fish upstream and downstream Bradford Dyeing Association were sampled (Figure 4). Samples were grouped into three categories: upstream, in the Grills Preserve Pond, and downstream. Fewer than eight samples of each species were collected at each location except for largemouth bass collected downstream (10 samples).

Fish Species

Fish tissue from bluegill (*Lepomis macrochirus*), redbreast sunfish (*Lepomis auritus*), largemouth bass (*Micropterus salmoides*), and chain pickerel (*Esox niger*) were collected in the Pawcatuck River and the Grills Preserve Pond. Largemouth bass were not collected upstream of the stabilization pond's connection with the Pawcatuck River. Dorsal muscle plugs were prepared at Roger Williams University for analysis by USEPA. These species were selected because they are abundant in the area, commonly consumed by the public, and are representative of the middle to upper levels of the food chain.

Analysis of PFAS in Fish Tissues

PFAS were extracted from fish tissues and analyzed using an approved Quality Assurance Project Plan (J-ACESD-0033695). Sample extraction followed USEPA Standard Operating Procedure J-ACESD-EEB-SOP-4251-1: Extraction of PFAS from aquatic organism tissues. 24 PFAS compounds were analyzed.[25] These compounds are listed in Table 1.

Soil, Sediment, and Water Investigations

Surface soil (0-6 inches below ground surface), subsurface soil (0-13 feet below ground surface), sediment, groundwater, and surface water samples were provided in a Phase II Environmental Site Assessment by Weston & Sampson.[3] Soil and sediment samples were evaluated for metals, polychlorinated biphenyls, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). Surface soil and soil borings were collected from the mill (AOC-1), waste disposal area (AOC-3) and the landfill area (AOC-4) (Figure 3). Groundwater (collected from the mill and the landfill) was analyzed for PFAS, barium, PCBs, VOCs, SVOCs. Surface water from the Pawcatuck River and the lagoons was analyzed for PFAS concentrations. Health effects were examined for people exposed to these chemicals in residential and occupational settings. Comparison values were from ATSDR or RIDEM.[26,27] Health risks (HQs and cancer risks) were calculated for contaminants that have health-based comparison values from ATSDR using the combined ingestion and dermal contact pathway. Dermal contact, inhaled particulates, and hand to mouth transfer of contaminated soil are expected to be the dominant pathways for exposure.

Current RIDOH Recommendations

RIDOH has posted signs in the area indicating that fish from the Grills Preserve Pond should not be eaten.

ATSDR EVALUATION METHODOLOGY

This section discusses details of ATSDR's methodology for evaluating the public health implications of contaminated fish, soil, sediment, groundwater and surface water in the Pawcatuck River, Grills Preserve Pond, and around the former Bradford Dyeing Association facility. This process involves two separate evaluations, one for exposure and one for health effects. Health risks from the consumption of PFAS contaminated fish are the major current health risk posed by Bradford Dyeing Association. These risks are evaluated separately from the potential future risk posed by contaminants in soil, sediment, groundwater, and surface water in the case the lot is further developed.

Assessment of Health Risks Posed by PFAS in Fish Tissues

The ATSDR *exposure evaluation* process has two steps: determine what hazards are at the site (*environmental data screen*) and evaluate how people may come into contact with these hazards (*exposure pathway analysis*). ATSDR identifies contaminants of concern by comparing site-specific concentrations to health-based *comparison values* (CVs) in an analysis of the potential for adverse health effects. An ATSDR CV is a contaminant concentration at which adverse health effects are not expected[28], based on animal studies and human epidemiological studies. In the case of PFAS, only non-cancer endpoints are evaluated. There is evidence of a relationship between some PFAS and cancer development, but this relationship has yet to be defined quantitatively. This means that cancer risks cannot be calculated for PFAS exposures.

For the exposure pathway analysis, the following five elements must all be present for an exposure to occur (i.e., completed exposure pathway):

- Contaminant source (e.g., hazardous waste site)
- Environmental medium (e.g., fish), which the contaminant moves through
- Exposure point (e.g., fish muscle tissue); where people contact a contaminated medium
- Exposure route (e.g., eating fish muscle tissue); how people contact the chemical
- Potentially exposed population (e.g., fishing population)

Even if all five elements are present, an adverse health effect may not necessarily occur because the chemical concentration <u>and</u> the amount of contact a human has with the chemical must both be high enough for harm to occur.[28] If data for one or more element is unknown, then it is considered a potential exposure pathway. An eliminated exposure pathway is one that poses no threat to the potentially exposed population in the past, present, or future.

If the initial evaluation indicated that an exposure may occur, then a more in-depth analysis is conducted to consider possible public health impacts. The ATSDR *health effects evaluation* has two steps: identify site-specific exposure dose estimates and determine public health implications for contaminants of concern. This evaluation calculates whether a public health hazard exists, depending on the site-specific contaminant levels. It also calculates whether people contact highly contaminated environmental media for long enough time periods to potentially contribute to cancer health risks.

Contact with a contaminant does not always result in harmful health effects. Some important factors that influence whether contact with a contaminant results in adverse health effects include:

- Dose (how much contaminant a person is exposed to)
- Duration (how long a person is exposed to a contaminant)
- Frequency (how often a person is exposed to a contaminant)
- Toxicity (what type of damage a contaminant can cause to a person)

Furthermore, different people or groups of people may respond differently to contaminant exposures. When exposed to the same concentration of a contaminant in the environment, children, the elderly, and people with other health conditions (i.e., sensitive subpopulations) may have more severe health outcomes compared to members of the general population.

All these factors are included when calculating an *exposure dose*. An exposure dose estimates the contaminant level that a person may come into contact with over time. When site-specific information is unavailable, several assumptions can be made for the ATSDR equation:

$$Estimated\ Exposure\ Dose = \frac{(C * IR * EF * ED)}{(BW * AT)}$$

C = Concentration of chemical in biota or soil (mg/kg)
IR = Ingestion rate (varies by age, see Table 4)

EF = Exposure frequency (365 d/y)
ED = Exposure duration (1 y for all age groups for non-cancer endpoints; varies by age for cancer endpoints)
BW = Body weight (varies by age, see Table 4)
AT = Averaging time (AT = ED × 365 days per year)

The concentration term (C) in the exposure dose equation is calculated from *exposure point concentrations* (EPCs).[28] The EPC used in the exposure dose calculation depends on the number of samples collected. With eight or more samples, the 95[th] upper confidence limit (95% UCL) of the arithmetic mean was used as the EPC to account for variability within the data. If there were fewer than eight fish samples, then the maximum concentration of a contaminant is used as the EPC. By overestimating the EPC, ATSDR and USEPA are conservative in calculating exposure doses. In this case, only largemouth bass collected downstream had more than 8 samples, so the 95% UCL was used for this sample set and the maximum concentration was used for all others.

Site-specific doses are derived by estimating the amount of contaminant intake (e.g., from eating fish) divided by a person's body weight. The dose is reported as nanograms of chemicals per kilogram body weight per day (or ng/kg/day). To protect public health, ATSDR and RIDOH assume a worst-case scenario to conservatively calculate exposure doses.

PFAS are usually detected in mixtures, making the determination of potential health risks more complicated. Cancer dose-response effects have not yet been rigorously associated with PFAS exposure, so this health consultation focuses on non-cancer health effects. The ratio of the estimated contaminant dose to the corresponding health guideline is called a *hazard quotient* (HQ). An HQ for each PFAS compound is calculated for each exposure scenario and fish species by dividing estimated exposure dose by a *minimum risk level (MRL)* or *reference dose (RfD)* (Table 17-Table 18).[29] The HQ calculation indicates whether there is a need for further evaluation of potential health effects and is shown here:

$$HQ = \frac{Dose_{non-cancer}}{RfD}$$

MRLs and RfDs are health guidelines that estimate the amount of contaminant intake that is not likely to have discernable non-cancer health effects.[28] The difference is that MRLs are established by ATSDR and RfDs are from USEPA or state agencies. Where an MRL or RfD was not available for a specific PFAS, a guideline was established using read-across. PFAS were grouped by carbon chain length and carboxylic/sulfonic acid head group. The color scheme in Table 17 and Table 18 coordinates with the Group # column, which shows how the PFAS were grouped for read across. The minimum RfD in the group was assigned to any PFAS that did not have an RfD established by another federal or state agency (Table 17-Table 18). If there were multiple RfDs for a single PFAS, the smallest value was chosen because that is the most protective of public health. The exceptions to this were PFOS and PFDA, which had minimum RfDs of 0.1 and 0.002 ng/kg/day, respectively.[26,30] Instead of these values, RfDs were set to 1.8 ng/kg/day and 2.0, for PFOS and PFDA respectively.[31–33] Less conservative RfDs were used here because of the nutritional benefits and cultural importance of catching fish for consumption.[34] RfDs are not generated considering the nutritional benefits of fish.[34] As discussed in the Context for Health Risk Results section, there are many health benefits to fish consumption. Recent work on this subject[34], indicates that these benefits need to be taken into account when considering the impact PFAS contamination in fish could have on public health.

Every sample of fish tissue that was analyzed had multiple PFAS HQs > 0.1.[29] Samples had between 5 and 14 PFAS with HQs > 0.1. This indicates that each sample has to be evaluated as a mixture using a *hazard index* (HI).[29] The HI is calculated by adding together the HQs for each individual compound[29]:

$$HI = HQ_1 + HQ_2 + HQ_3 + \cdots$$

The HI is the value that is used to make decisions about the toxicity of the mixture. Generally, an HI less than 1.0 means that it is unlikely an exposed person would experience adverse non-cancer health effects, while an HI equal to or greater than 1.0 means that the risk should be evaluated further.

Health Risks Posed by Contaminants in Soil, Sediment, Surface Water, and Groundwater

As the site stands currently, health risks posed by contaminants in soil, sediment, surface water, and groundwater are minimal. If the site is redeveloped into a residential or commercial space, then health risks would likely change. Health risk analyses were performed under the assumption that Bradford Dyeing Association was redeveloped into a residential or commercial site. Non-cancer health risks were calculated using the HQ process described in the previous section. HQs > 1 indicate the need for further toxicological evaluation to determine if estimated doses approach or exceed doses that might cause harmful noncancer effects. The analysis did not include an HI calculation because these contaminants were evaluated individually.

The increased cancer risk from a lifetime (t=78 years) of exposure to a contaminant by ingestion or inhalation was calculated using a cancer slope factor (CSF).[28] When the cancer-specific exposure dose is multiplied by a contaminant's CSF, the resulting *excess lifetime cancer risk* (ELCR) describes the risk of cancer health effects in excess of the "background" risk:

$$ELCR = D_{cancer} * CSF * \frac{ED}{LY}$$

ELCR = excess lifetime cancer risk
D_{cancer} = dose
ED = Exposure duration (varies by age)
LY = Lifetime (78 y)

<u>The ELCR does not estimate the number of expected cancer cases in a community</u>. Instead, the ELCR measures the probability that a group of similarly exposed people may develop cancer sometime in their lifetime following exposure to a particular contaminant. Everyone has some baseline risk of developing cancer, and the ELCR shows the increase in risk of cancer after exposure to a contaminant. RIDOH/ATSDR uses the following ranges to characterize cancer risk estimates:

1. An ELCR below $1.0x10^{-6}$ (one in one million) is "no concern for increased cancer risk".

2. An ELCR between $1.0x10^{-6}$ and $1.0x10^{-4}$ (one in ten thousand) is "possible concern for increased cancer risk" depending on the situation, and
3. An ELCR $\geq 1.0x10^{-4}$ (one in one thousand) is "a concern for increased cancer risk".[16]

HQs and cancer risks for these pathways were calculated using ATSDR's standard age groups in the Public Health Assessment Site Tool.

EXPOSURE PATHWAY ANALYSIS

Contaminants of Concern

The contaminants of concern in this health consultation are PFAS, PCBs, cadmium, arsenic, PAHs, and volatile organic compounds (VOCs). PFAS is the primary contaminant of concern in fish in the Grills Preserve Pond and in the Pawcatuck River. PCBs, cadmium, arsenic, and PAHs have been detected at levels of concern in soil. Volatile organic compounds (tri and tetrachloroethylene) have been detected in groundwater. This section will describe the chemistry and health risks determined in the literature for each of these contaminants. Later sections will discuss the health risks assessed at Bradford Dyeing Association, specifically.

PFAS

<u>Chemistry</u>

The main contaminants of concern for this health consultation are PFAS. The term "PFAS" encompasses a large family of chemicals with a similar structure: a carbon chain with attached fluorine atoms.[35] These compounds are man-made and highly resistant to degradation.[36] PFAS persist in the environment and eventually make their way into humans.[36] Major applications for PFAS include stainproof and waterproof fabrics and carpeting, nonstick pots and pans, and grease resistant take out containers.[37,38] They have also been used in aqueous film forming foams (AFFF), which were used for firefighting.[38]

The individual compounds within the PFAS class differ based on the head group and the length of the carbon chain. There are two common types of PFAS encountered in the environment based on their head groups: carboxylates and sulfonates.[39] Other PFAS, known as precursor compounds, have different structures, but these typically transform into carboxylates and sulfonates in the environment.[40]

PFAS can also be categorized based on their chain length. Carboxylated PFAS are considered "long chain" when they have seven or more carbons with attached fluorine atoms.[41] Long chain sulfonated PFAS have six or more carbons with attached fluorine atoms.[41] The fate and transport of PFAS in the environment and the human body are dictated by the chain length. Longer chain PFAS are less water soluble[40,42] and are more prevalent adhered to sediment[43] or taken up into fish[44–49]. Most PFAS compounds have low volatility, meaning that they do not evaporate easily. However, PFAS precursors, like fluorotelomer alcohols are easily evaporated.[50] PFAS precursors also do not follow the long chain/short chain naming convention.

People can be exposed to PFAS from a variety of sources. Point sources of PFAS contamination include airports, firefighting training areas, textile mills (like Bradford Dyeing Association), and former PFAS manufacturing plants.[38,51,52] Long chain PFAS have been phased out of many consumer products in the United States based on the potential health risks, but they are still being manufactured abroad. Short chain PFAS continue to be used in a wide variety of products.

The chemistry of PFAS helps scientists understand how people are exposed to these chemicals and how they move through the human body. Most PFAS exposure stems from food and water consumption or inhalation of volatile PFAS precursors.[35,38,39,53] Volatile PFAS precursors are the compounds that would be most concerning for contaminating air. Breathing in air contaminated with PFAS is most important for people who work directly with these chemicals.[39] Since Bradford Dyeing Association is closed, this is not an important mechanism for this investigation.

Currently, the major pathway of concern for PFAS exposure is eating fish contaminated with PFAS caught near Bradford Dyeing Association. As mentioned previously, PFAS (especially long chain PFAS) are taken up into fish.[44–49] When people eat the contaminated fish, PFAS is absorbed through the lining of their stomachs and intestines.[35,39] From there, PFAS enters the blood stream and binds to proteins that can be found in blood serum.[39] PFAS is distributed throughout the body by blood, but the highest concentrations can be found in the liver and the kidneys.[39] Once in the body, longer chain PFAS are eliminated more slowly compared to shorter chains.[39]

The structure of PFAS allows them to bind to proteins, for example: human serum albumin.[54–56] Serum albumin regulates blood pressure and transports large molecules through the body.[57] Proteins are made up of units called amino acids. Each type of amino acid has a different structure that interacts with PFAS compounds differently. Some amino acids interact with the carbon-fluorine chain of a PFAS compound and others interact with the head group.[58] The carbon-fluorine chain is hydrophobic, meaning that it repels water. The head group is charged and is hydrophilic, meaning that it is attracted to water. Hydrophobic and hydrophilic amino acids are attracted to their respective parts of a PFAS molecule. Interactions between the amino acids and a PFAS compound can change the structure of a protein, which, in turn, changes the ability of the protein to function.[56,58]

Health Risks

The health effects caused by PFAS are still being studied, but the current literature indicates that PFAS are associated with a number of health outcomes.[35,59] The most widely studied health effects are on the liver, kidneys, immune system, thyroid, reproductive system, and development.[39,59,60]

Liver:
PFOA, PFOS, PFHxS, and PFNA have been linked to liver damage and disruption of normal liver function.[35,59,61,62] Injury to the liver from PFAS exposure is associated with an increase in total and LDL cholesterol in blood serum.[35] An increase in lipid accumulation in the liver is another established health outcome.[59]

Kidney:
Exposure to PFAS can lead to decreased kidney health. Previous studies have shown an increased risk for kidney hyperplasia, kidney disease, and diminished kidney function.[35,64] In some cases, highly exposed individuals can have an increased risk for kidney cancer.[35,64–66]

Immune system:
PFAS exposure can negatively impact the immune system's ability to respond to vaccines and infections.[59] The goal of a vaccine is to challenge the immune system so it produces antibodies designed to fight a later infection. The response of the immune system to a vaccine can be measured by the production of antibodies. In children and adolescents, increased PFAS concentration in blood serum leads to a reduction in the antibodies produced in response to vaccines.[67,68] This has been shown for several vaccines including tetanus, rubella, mumps, *Hemophilus* influenza, and diphtheria.[35,69] Increased blood serum concentrations of PFDA and PFOA are related to reduced immune response to tetanus and diphtheria vaccines.[67,68]

Suppression of the immune system by PFAS can also increase the risk for infections. Exposure to PFAS prenatally can increase the risk for immune effects during childhood.[70,71] Concentrations of PFOS in maternal plasma have been shown to increase the risk for the development of infection in children less than four years old.[70] PFHxS concentrations in maternal plasma were associated with increased risk for the development of infection in girls (also less than four years old).[70] Cord blood concentrations of PFOS, PFOA, FOSA, PFNA, and PFUnDa are associated with increased risk of lower respiratory tract infections.[71] Ulcerative colitis is a chronic immune condition causing the intestines to become overactive. Prevalence of ulcerative colitis has been shown to increase with increasing PFOA concentrations in serum.[72,73]

Overall, the literature indicates that exposure to PFAS can modify immune response.[74,75] This means that people with elevated PFAS concentrations in the bodies have a higher risk for lowered antibody production and being more prone to infection and conditions related to the immune system.

Thyroid:
Scientific studies have shown that PFAS can interact with thyroid hormone binding proteins, which can interfere with the ability of the thyroid to regulate metabolic changes (such as changes in temperature and energy regulation within the body).[76,77] PFOS, PFDA, and PFUnDA in blood are associated with changes in the concentrations of thyroid hormones in pregnant women.[76] PFOS and PFOA have been shown to bind to major thyroid hormone transport proteins.[77] There is some evidence showing that PFAS exposure can lead to hypothyroidism in women and children.[59] PFAS exposure has also been linked to thyroid disease in women.[78]

Reproductive system:
Impacts to the reproductive systems of both men and women have been documented with PFAS exposures. Pregnant people exposed to PFOA and PFOS have a higher risk for pregnancy induced hypertension and pre-eclampsia.[35,59] PFOA exposure has been shown to reduce sperm count and mobility.[35,59] In people who are exposed to a lot of PFOA through their occupation, there can also be an increased the risk for testicular cancer.[39,65,66,79]

Development:
PFAS compounds have been shown to increase the risk of negative outcomes in studies examining developmental health.[39] PFAS can move across the placenta, exposing the developing fetus.[80,81] PFOA and PFOS exposure in the womb increases the risk for small reductions in birth

weight.[35,39,59,81,82] Other developmental metrics can also be affected, such as early puberty onset and delayed mammary gland development.[35,59]

The literature shows that PFAS increase the risk for negative health effects, but the risks depend on a variety of factors. The type of PFAS, concentration, and time a person is exposed all effect the potential health risks. PFOA and PFOS are the most widely studied PFAS compounds. Longer chain compounds (PFUnDA, PFDoDA, etc.) have not been studied as widely, so the health risks posed by these compounds are less clear.

PCBs

PCBs are a group of man-made chemicals that were widely used in the United States until the mid-1970s, when their production was banned and their use was greatly restricted. As good insulators, PCBs were applied to a wide variety of products, including hydraulic fluids, fluorescent light fixtures, flame retardants, inks, adhesives, paints, and electrical transformers. Manufacturing of PCBs was stopped due to concerns about PCB persistence and toxicity. Humans are most frequently exposed to PCBs from contaminated food and soil, but inhalation of volatile PCBs is also a concern.[83] PCBs can accumulate in body fat and the liver and persist in the human body for many years.[83,84] Adverse health outcomes associated with PCB exposures have included liver, reproductive, and developmental effects, as well damage to the thyroid, endocrine, and immune systems.[83] Liver and biliary tract cancer have also been associated with PCB exposures in humans.[85]

Cadmium

Cadmium is a metal that is used in batteries, pigments, and coatings.[86] While cadmium can be found naturally in the environment, it is also associated with pollution from industry. Cadmium can be released into the environment through the settling of particles created during high heat manufacturing or through dumping (likely the case for Bradford Dyeing Associates).[86] Eating food, soil, or plants and breathing air that is contaminated with cadmium are the primary ways that people are exposed to cadmium.[86] A large percentage of inhaled cadmium enters the blood stream (5-50%).[86] A smaller amount (1-10%) of cadmium in food and water enters through the digestive tract.[86] If the exposed person does not have enough iron, they tend to take up more cadmium.[86] Once in the body, cadmium can interfere with gene expression and prevents DNA from being able to repair itself.[87] Most cadmium that enters the body ends up stored in the kidney and liver and can remain there for years.[86,88] Exposure to small doses of cadmium over a long time can increase risk for bone fragility.[86,88] Workers in industries that are exposed to cadmium in the air are at a higher risk for lung cancer.[86] Anemia, liver disease, and nerve/brain damage have been seen in animals exposed to cadmium in laboratory studies.[86]

PAHs

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that are formed when oil, gas, coal, or other organic materials are burned.[89] When organic materials are burned, a mixture of PAHs with different structures are created.[89] The structure of PAHs dictates what happens to them in the environment. Smaller PAHs are more easily evaporated than the larger varieties, which tend to remain attached to particles (like soil or dust).[90] Exposure is usually through breathing in cigarette smoke, wood smoke, or car exhaust or through eating foods contaminated with PAHs. Long term exposure to PAHs can lead to health effects, such as difficulty with reproduction, harmful skin effects, and lung cancer.[89]

Volatile organic compounds

Volatile organic compounds (VOCs) are a group of chemicals known to easily evaporate. The two VOCs that were detected in groundwater at levels of concern were tetrachloroethylene (also called perchloroethylene and abbreviated as PCE) and trichloroethylene (TCE). They are frequently used in industry as cleaners and degreasers.[91–93] PCE and TCE are introduced to the environment from industry.[91–93] Historically, workers would dispose of PCE and TCE by dumping it on the ground and allowing it to evaporate. Some of the chemical would evaporate and the rest would stick to the soil and sink into the ground, eventually contaminating the water table.[91] At Bradford Dyeing Association today, exposure to PCE and TCE would be primarily through accidentally eating or breathing in contaminated soil or drinking contaminated groundwater.[91] Most of the PCE or TCE that a person breathes in, eats, or drinks goes quickly into the bloodstream. This is then broken down by the body or breathed out.[91–93] The compounds that are created when the body breaks down PCE and TCE are also toxic.[91]

When people are exposed to large amounts of PCE, they can experience dizziness, headaches, and sleepiness.[92] Exposure to small amounts of PCE over a longer period of time can lead to changes in mood, memory, attention, reaction time, and vision in people.[92] Animal studies of PCE exposure have shown changes in liver and kidney function and brain chemistry.[92] Health effects to pregnant people and unborn children are extremely important.[92] PCE can increase the risk of miscarriage, birth defects, and delayed growth of the baby.[92] Bladder cancer, multiple myeloma, and non-Hodgkin lymphoma are linked to PCE exposure.[91,92]

Similarly to PCE, exposure to large amounts of TCE can lead to dizziness, headaches, and sleepiness.[93] TCE has also been shown to lead to nervous system damage (changes in heartbeat rhythm, hearing, seeing, and balance).[93] In small doses over a long period of time, TCE can increase risk for kidney cancer.[93,94] There is some evidence to suggest that it also leads to liver cancer and malignant lymphoma.

Completed, Potential, and Eliminated Pathways at Bradford Dyeing Association

EHRAP considered logical exposure pathways at Bradford Dyeing Association and whether contaminants could have an adverse public health effect in the present or future.

<u>Completed current</u> human exposure pathways for the site included and <u>quantitatively</u> evaluated:

- **On-site biota** – Ingestion of contaminated fish from the stabilization pond for nearby fishing community (past, present, future)

<u>Completed future</u> human exposure pathways for the site evaluated assuming a future residential development with no remediation:

- **Ingestion/inhalation of contaminated soil –** People living or working in a development onsite would be exposed to contaminated soil if the site was not remediated.

- **Indoor air** – In the event of a residential or commercial development onsite, soil vapor intrusion could lead to contamination in indoor air.

Eliminated current and future exposure pathways for the site included:

- **Surface water** – Surface water PFAS concentrations in the Pawcatuck River and Grills Preserve Pond are low. Neither water body is used for drinking water, and dermal contact (from swimming or wading) is not considered an important route of exposure to PFAS in water.[95]
- **Groundwater** – This is not a concern because the main facility is shut down and is no longer using its groundwater well. Also, the closest residential groundwater wells are located far enough away to effectively limit their risk. Finally, groundwater in the area flows toward the Pawcatuck and away from residences preventing contamination of nearby wells and there is no evidence of contamination in wells on the other side of the Pawcatuck River.
- **Sediment** – Contaminants in sediment are not likely to affect health if water levels in the lagoons remain constant. Sediment contaminated with PFAS could uptake in fish and eventual exposure in humans.
- **Outdoor air** – Health risks from outdoor air are minimal.

HEALTH EFFECTS EVALUATION

Fish Consumption Exposure Pathway

PFAS in Fish Tissue Results

PFAS were detected in 100% of the fish tissue samples. The highest concentrations were onsite, in the Grills Preserve Pond (Figure 11). Total PFAS loading varied greatly between the collected fish tissues and was highest in largemouth bass collected in the Grills Preserve Pond (Figure 11, Table 3). PFAS concentrations in fish from the Pawcatuck River are at levels concerning for health upstream and downstream of Bradford Dyeing Association (Figure 11). PFTrDA, PFUnDA, PFDoDA, and PFOS were detected at the highest concentrations, making up 80-90% of the total PFAS in the fish (Figure 12).

USEPA National Rivers and Streams Assessments (NRSAs) in 2008-2009 (Figure 13), 2013-2014 (Figure 14), and 2018-2019 (Figure 15) contain PFAS data for fish collected around the country.[96] The locations of the NRSA samples and samples for the current study collected in the Pawcatuck River can be found in Figure 4. All samples (collected by RIDEM, Roger Williams University, and USEPA) were collected upstream of the Town of Westerly. The NRSA results support the major PFAS signature/fingerprint and concentrations detected during this analysis. NRSA results are based on composite samples where the specimens prepared here were single samples.

The major PFAS contributor in fish sourced from the Pawcatuck River was PFTrDA in the 2018-2019 NRSA report (Figure 15), supporting the results found in this study, which found that long chain PFAS were the major contributors. Previous NRSA studies (2008-2009 and 2013-2014) showed that the major PFAS contributors in fish tissue were PFOS, PFUnDA, and PFDoDA. These studies did not quantify PFTrDA. In the Seekonk River and most waterbodies around the country, the major PFAS in fish tissues is PFOS. This difference may stem from the type of textile treatments being performed around the Pawcatuck River, but not the Seekonk River.[51]

The NRSA data sets reported total PFAS concentrations ranging approximately 40-90 ng/g in Pawcatuck River fish tissues (Figure 13-Figure 15). These concentrations are similar to those quantified in fish tissues sourced from the Pawcatuck River in this report (30-160 ng/g ww). The comparison between rivers is limited because of the differences in fish species sampled, the number of samples, and collection and method analysis, but the USEPA NRSA study shows that fish collected from the Pawcatuck River typically have higher concentrations of PFAS than fish collected from other rivers in Rhode Island (Figure 13-Figure 15).

Figure 11 shows that PFAS concentrations in sunfish collected upstream of Bradford Dyeing Association are higher compared to the downstream samples. This is due to the high concentrations of PFAS in detected in the bluegill samples collected upstream of the site (Figure 16). Variations in PFAS concentrations are to be expected in wild-caught specimens.[97] This can be caused by a number of factors including the metabolism of the species (and the individual specimen), the time of year, and where the specimen was acquired.[97,98] Large sample sets (30-50 specimens) are required to fully capture the variability of PFAS concentrations in fish tissues.[99] Due to budget and time constraints, our partners were not able to collect and analyze that many samples.

While there is no data to support a reason for the variations in sunfish PFAS concentrations, literature reports suggest that differences in the time of sampling could be an important factor. Samples 12922 and 12920 were collected by Roger Williams University in July 2022 (Figure 16). Samples 11520, 11594, and 11591 were collected by RIDEM in November 2022 (Figure 16). Sunfish behavior is different depending on the time of year.[100] The fall is the time of year sunfish start to spawn.[100] Males will create a nest in the sediment and attract a mate.[100] They then use their tails to prevent sediment from covering their eggs.[100] This means that when the RIDEM collected samples in November, male sunfish would have spent more time interacting with sediment compared to the sunfish collected in July. This would increase interaction with longer chain PFAS (such as those found at Bradford Dyeing Associates) adhered to sediment.[101,102] Changing interactions with sediment is just one example of a behavioral change that could have led to variations in PFAS loading depending on the time of year. Egg laying is another seasonal behavior that could have impacted tissue concentrations in the collected sunfish. This phenomenon has been documented in fish and turtles.[103,104]

The relatively high concentration of PFAS in fish collected upstream suggests that Bradford Dyeing Association is not the only source of PFAS contamination in the Pawcatuck River. PFAS would not move against the current of the Pawcatuck and fish migration upstream is limited by the presence of a dam. Results of the 2018 USEPA NRSA also support the conclusion that Bradford Dyeing Association is not the only source of PFAS on the Pawcatuck River. Fish in the USEPA NRSA were collected much further upstream than fish collected in the RIDEM/Roger Williams University sampling (Figure 4). The PFAS concentrations in the NRSA were similar to the results presented here (Figure 15). This indicates a similar concentration of PFAS in fish tissues throughout most of the Pawcatuck River. Also, Dunn *et al* 2023 indicates that PFAS concentrations in the surface water are ubiquitous throughout the Pawcatuck River.[52] This provides an additional indication that there are other sources of PFAS in the area contributing to contamination of the Pawcatuck River. Other potential sources of PFAS on the Pawcatuck River upstream of Bradford Dyeing Association include Charbert and Kenyon Mill, now owned by Brookwood Finishing, (Figure 9). Charbert and Kenyon are other former or current textile mills that have been associated with PFAS releases into the Pawcatuck River.[52,105] Further testing of fish upstream of Bradford Dyeing Association should be performed to confirm that upstream sources of contamination exist.

Fish Consumption Scenarios

Two sets of calculations were conducted based on different fish consumption rates to create two exposure scenarios: the central tendency exposure (CTE, an estimate of the average exposure to a contaminant) and reasonable maximum exposure (RME, an estimate of the highest reasonable exposure). CTE fish meal sizes were half of the fish meal sizes for the RME scenario. RME values were calculated using guidance from various state health departments.[106–108] These departments recommend 1 oz fish for every 20 lbs body weight.[106–108] The recommended meal size was 8 oz for an adult weighing 160-210 lbs.[106–108] The amount of fish per meal was scaled based on body weights in the ATSDR age group categories. The intake rates are presented in Table 4. Fish meals per week for the United States average lifetime (78 years) were based on FDA recommendations and assumed to be one (1) for the CTE scenario and three (3) for the RME to calculate the exposure factors under both scenarios. The calculations are performed assuming that 100% of the fish meals come from sunfish, chain pickerel, or largemouth bass harvested from the Pawcatuck River or Grills Preserve Pond.

Non-cancer HQs and HIs were calculated to evaluate health risks posed by PFAS in fish tissue. Cancer risks were not calculated for PFAS. PFAS exposure is suspected of increasing risks for certain cancers, such as kidney and testicular cancer.[35] This potential association has not been defined quantitatively yet, so we do not have the numbers required for a quantitative assessment. ATSDR's *Framework for Assessing Health Impacts of Multiple Chemicals and Other Stressors* was used to calculate the HQs and HIs presented here.[29] The exposure factor for each scenario was set to 1.[109] An exposure factor expresses the amount of time and the frequency with which a person comes into contact with a contaminant in their environment within a certain period of time.[28] An exposure factor of 1 indicates daily contact with a contaminant and is the default value in examinations for non-cancer health effects.[109]

Health Risk Results

Non-cancer HQs and HIs were calculated based on the doses presented in Table 5-Table 16. Dose values were calculated for any PFAS compound with at least one detection greater than the method detection limit. The PFAS with no detections greater than the method detection limit (PFPeA, PFOA, PFBS, PFPeS, 4:2 FtS, 8:2-FTS) were not included. Reference doses were provided from ATSDR, and various state governments/agencies (Table 17-Table 18). When multiple reference doses were available, the lowest was used to calculate the HQ as a conservative estimate for exposure. PFNS, 6:2 FtS, N-Et FOSAA, and N-Me FOSAA had no available reference dose. Reference doses for these compounds were established using read across with PFAS of a similar structure. There is some uncertainty in this approach because the RfDs established using read across are for compounds that are not widely studied.[110,111] This means that data supporting the similarity of their mechanisms of toxicity is lacking. The literature indicates that multiple PFAS compounds elicit similar health effects (see Health Risks Section for PFAS under Contaminants of Concern). Based on this and the similarity of the chemical structures, we used read across to establish RfDs for the PFAS without experimentally determined values.

In Tier 1 of ATSDR's framework for assessing the toxicity of mixtures, HQs are calculated for each component (Table 19-Table 30). Figure 17 & Figure 18 summarize the HQs for each PFAS, fish species, and exposure scenario in heat maps. HQs in the RME scenario (Figure 18) are larger than the CTE (Figure 17) scenario because fish consumption is greater in the RME scenario. Intake rates and fish meal frequencies for RME are larger than the CTE. Higher HQs for PFUnDA, PFTrDA, and PFOS indicate that they are the major contributors to the toxicity of the mixture.

Non-cancer HIs for the CTE and RME scenarios are summarized in Figure 19 and Figure 20, respectively. These values are also presented along with the HQs for each compound in Tables Table 19-Table 30. HIs were greater than 1.0 for every scenario and largest in the Grills Preserve Pond. For the CTE scenario, HIs range 5-48 in the Pawcatuck River and 36-125 in the Grills Preserve Pond. In the RME scenario, HIs are much larger. RME scenario HIs range 23-160 in the river and 199-755 in the Grills Preserve Ponds.

Overall, the results indicate that HIs are generally greater than 1 and that consuming fish from study areas (the Pawcatuck River and Grills Preserve Pond) at the rates in Table 4 need to be evaluated for potential to cause harmful noncancer health effects. The following discussion provides further analysis for these results.

Context for Health Risk Results

The HQs and HIs presented here are calculated by making a set of assumptions that are protective of public health. The first set of assumptions is that 100% of the fish meals being consumed are sunfish, chain pickerel, and largemouth bass. Actual PFAS exposure will vary depending on the species consumed (evidenced by the differences in total PFAS between this report and the USEPA NRSA data). Another assumption is that all the fish consumed by an individual are harvested from the Pawcatuck River or Grills Preserve Pond. This is unlikely because grocery stores stocking fish and other freshwater/marine sources are readily available in Rhode Island.

The fish consumption rates (Table 4) are based on those recommended by various state governments [106–108] and the number of fish meals recommended by the FDA.[112] The consumption rates and fish meal frequencies assumed in this study likely overestimate the amount of fish consumed by the average stakeholder. The CTE and RME intake rates are within the range of the 50^{th} and 97^{th}-99^{th} percentiles, respectively, of total finfish and shellfish consumption as measured by the USEPA.[113] The number of fish meals per week was set to 1 and 3 for the CTE and RME, respectively.

In addition to environmental contaminants, fish also contain high-quality protein and omega-3 fatty acids, which have numerous long-term health benefits: decreased risk of stroke, decreased rates of coronary heart disease, and improved fetal neurodevelopment during pregnancy.[34,114,115] Some studies suggest that these fish lipids partially offset methylmercury neurodevelopmental adverse outcomes.[34,116,117] Others have stated that the risks posed by organic contaminants (dioxins, PCBs, etc.) are small compared to the benefits associated with fish consumption.[118] This health consultation deals with the risks posed from consumption of fish contaminated with PFAS. While PFAS has been linked to negative health effects, fish is still a source of essential nutrients.[34] Consumers should consider the source of their fish and weigh the benefits of fish consumption against potential contamination.[34] Stores stocking fish and other sources of freshwater and saltwater fish are plentiful in Rhode Island.

Fish Consumption Recommendation
EHRAP recommends that people limit the amount of fish consumed from the Pawcatuck River downstream of Burdickville Road to one meal per month. This is based on fish consumption guidelines from other states and an effort to balance the benefits of fish consumption with the harms from PFAS.[119] Fish from the Grills Preserve Pond should not be consumed. This is due to the hazard indices for fish caught from the pond, which were 7-26 times higher than those in fish caught in the Pawcatuck River (Figure 17 & Figure 18). People consuming fish from the Grills Preserve Pond or the Pawcatuck River at the rates in Table 4 could be at risk for the health effects described in the Contaminants of Concern section for PFAS. People can lower their risk for adverse health effects by limiting consumption of fish from the river to one meal per month. The goal of this recommendation is to help people balance healthy fish consumption with the risk posed by PFAS at this site. Fish is still a very healthy food and should be consumed. Consumption of fish from the Pawcatuck River should be balanced with fish from other sources that are lower in PFAS. The recommendation is limited to downstream of Burdickville Road because of the limited geographic scope of the sampling that was performed. Due to budget and time constraints, RIDOH only has data for a small section of the Pawcatuck River. More data is required to make a recommendation for the rest of the river. RIDEM will be collecting this data and should provide the results to RIDOH for analysis.

The fish consumption recommendation is complex for people who are pregnant, nursing, or may become pregnant. The most important route for PFAS exposure in infants is through breast milk.[120] PFAS (especially PFOA and PFOS[121,122]) have been detected in breastmilk at levels exceeding ATSDR's drinking water quality guidelines for infants.[123] Infants are particularly susceptible to health effects from PFAS exposure because they are growing so rapidly. The current recommendation from ATSDR is that people should breast feed if they choose despite potential environmental contaminants, as the benefits from breastfeeding outweigh the potential risks.[124] People who are or might become pregnant should not consume fish from the Grills Preserve Pond and should limit consumption of fish from the Pawcatuck River to reduce PFAS intake as much as possible. If substitution with another source of fish is available, people who are pregnant or might become pregnant should avoid consumption of fish from the Pawcatuck River entirely.

Stocked Trout
Stocked trout is a topic of major concern for this area. RIDEM stocks trout just upstream of Bradford Dyeing Association and at other locations along the Pawcatuck River. Stakeholders have expressed interest in whether stocked trout can safely be consumed from the area. Guidance in other states recommends that stocked trout not be consumed in areas contaminated with PFAS. Connecticut recently recommended that stocked trout should not be consumed from the Hockanum River due to elevated PFAS concentrations.[125] Massachusetts originally recommended eating stocked trout instead of native species, but now advises against consuming all fish in PFAS contaminated areas, including trout.[126,127]

The argument for the consumption of stocked trout over native species stems from their residence time in a contaminated waterbody. Stocked trout were assumed to spend too little time in the environment to uptake enough of other contaminants to be of any concern. A literature review was conducted to evaluate how quickly PFAS is taken up into fish. Experimental studies have examined PFAS uptake in a variety of fish species and experimental conditions (Table 31). Uptake of PFAS in fish occurs quickly, with PFOS levels reaching Do Not Eat Classification within 21-28 days of exposure (Table 32).[128–130] The rate at which PFAS is taken up into fish depends on the concentration in the environment and chain length. The laboratory studies summarized in Table 31 tend to expose fish to higher concentrations of PFAS compared to what is typically seen in the Pawcatuck River. Higher exposure concentrations can lead to an increase in the rate of PFAS uptake.[46] The literature shows that the concentrations of PFOA[131–133], PFHpA[132], PFBS[132,133], and linear PFOS[47] tend to stabilize in fish tissue within 28 days of exposure.[46,47,131–133]

Chain length also factors in to the rate at which PFAS are taken up into fish, with longer chain PFAS reaching a steady-state concentration in fish faster compared to shorter chain PFAS.[44–46,48,49] This is of particular concern at Bradford Dyeing Associates because of the prevalence of long chain PFAS, like PFUnDA, PFDoDA, PFTrDA (Figure 12) in fish. The toxicity of these longer chain compounds is less widely studied. Given the literature indicating the rapid uptake of PFAS in fish, RIDOH is extending the fish consumption recommendation to stocked trout. Stocked trout consumption should be limited to one meal per month from the Pawcatuck River downstream of Burdickville Road. Trout are not stocked in the Grills Preserve Pond; no fish should be consumed from this pond.

The scientific literature indicates that PFAS uptake in fish occurs quickly, but this is limited because the data does not come directly from fish in the Pawcatuck River. RIDOH is recommending that a study examining PFAS uptake in stocked trout in this ecosystem or similar be performed. This will provide direct evidence of the rate of PFAS uptake in the Pawcatuck River and be useful in determining whether stocked trout can be safely consumed.

Mercury in Fish Tissues

Mercury in fish tissues in the Pawcatuck River and the Grills Preserve Pond was quantified by collaborators at Roger Williams University. Concentrations of mercury in fish tissues were similar in the river and the ponds. Similarly sized bluegills from the ponds and the river had statistically similar mercury concentrations ($p = 0.31$). The same trend was reported for largemouth bass ($p = 0.63$). The data indicates that release of mercury from Bradford Dyeing Associates is not contaminating fish tissues. Mercury uptake in fish is a function of local ecology and depends on nutrient availability in the water body of interest, upwind air pollution, and the size and diet of the specific fish species.[134–136]

Other Exposure Pathways:

Exposure pathways other than fish do not currently pose a threat to human health but could pose a risk in the event that a residential development is constructed onsite, which is the preferred outcome of many stakeholders. In this section, HQs and cancer risks will be calculated for each contaminant individually. Although a residential development is a preferred outcome, a commercial development is also being considered. Health risks will be calculated for potential residential and commercial redevelopments. HQs greater than 1.0 and cancer risks greater than 1×10^{-6} indicate the need for further evaluation.

Soil

Contaminants in surface (6-12 in below ground surface) and subsurface (0-13 feet below ground surface) soil were evaluated to determine if contaminants could pose a threat to people living (residential) or working (occupational) onsite. Right now, soil contamination does not represent a major health risk because the land is used as a nature preserve. If residences are constructed onsite, exposure to contaminants through soil would be more important. Exposure parameters from the ATSDR default residential (Table 33) and occupational (Table 41) soil/sediment exposure scenarios were used for this analysis.

Surface Soil

Exposure to contaminants in surface soil comes from a variety of mechanisms. People can breathe in or accidentally swallow contaminated soil in the form of dust. Swallowing contaminated soil is of particular concern for children, who often play in soil and frequently put their hands or dirty objects in their mouths. They might also engage in pica behavior, which can include eating soil. People might also be working in soil (for example, digging in a garden) and get that soil on their skin. Contaminants may migrate through the skin or later accidentally be swallowed if proper handwashing does not occur.

Surface soil samples were collected from around the mill (AOC-1) and in the landfill area (AOC-4) (Figure 5 - Figure 7). Contaminants detected above their ATSDR comparison values were cadmium, Aroclor 1254, and PAHs (evaluated as benzo(a)pyrene, BaP, equivalents) (Table 34). Aroclor 1254 is a trade name for a mixture of PCBs used in transformers, hydraulic fluids, and synthetic resins.[137]

HQs and cancer risks in surface soil collected around the mill indicate a slightly increased concern for health effects from exposure to PAHs for children under the age of 6. This scenario assumes that the children are living at the mill with unremediated soil. Under the CTE residential scenario, HQs range 1.4-2.5 and cancer risks were 5.50×10^{-6} for children 0-6 years old (Table 35). In the RME residential scenario, increased concern extends to children less than 11 years old (Table 36). In the landfill area, HQs for cadmium and Aroclor 1254 are greater than 1.0 for all age groups (Table 38). Under the RME scenario, concern for noncancer health effects in children under the age of 2 is slightly elevated (HQs were 1.4-1.6). The results of this analysis show that there are contaminants in surface soil at Bradford Dyeing Associates that could pose a risk to people living onsite.

Occupational exposures to surface soil onsite are unlikely to lead to increased concern of negative health effects (Table 42 - Table 43). HQs for contaminants in the mill and landfill are less than 1.0 and cancer risks are below 1×10^{-4}. Normal precautions, like washing hands and soiled clothing, are enough to reduce health risks posed by contaminants in onsite surface soil for workers.

The health risk analysis uses the maximum potential exposure that could be experienced through surface soil. Soil samples were collected from the most contaminated areas at Bradford Dyeing Associates: the mill and landfill (Figure 5-Figure 7). The maximum values were used in the calculation of the exposure point concentrations and the quantification of health risks. If the surface soil around the mill building and in the landfill is removed or appropriately remediated health risks from surface soil on the site should be negligible for residential and occupational exposure.

Subsurface soil

Subsurface soil samples were acquired for the mill, waste disposal area, and landfill area (Figure 5 - Figure 7). Exposure to subsurface soil is unlikely during day-to-day activities. If construction is to occur onsite, digging for foundations or utilities could expose workers to subsurface soil. Cadmium, arsenic, pentachlorophenol, and PAHs exceeded their comparison values in subsurface soil samples and were evaluated for adverse health effects. Health risks were low (HQs<1.0 and cancer risks less than 1×10^{-4}) for most contaminants. Near the landfill, the health risks posed by exposure to arsenic for heavy soil contact workers are slightly elevated. This risk can be mitigated by limiting exposure to soil through normal precautions like washing hands and soiled clothing. Workers may consider wearing a face mask to prevent the inhalation of contaminated dust. Given that contact with subsurface soil is low for all groups, risks from this pathway are minimal for workers.

Groundwater

Soil Vapor Intrusion

Soil vapor intrusion is the movement of volatile chemicals from groundwater or soil pore gas into buildings.[138] Dichloroethene, PCE, and TCE were measured in groundwater near the mill (Table 48). PCE and TCE were also detected in soil near the mill building. Concentrations of these contaminants were at levels of concern in groundwater (ranging 270-640 µg/L), but not at levels of concern in soil (Table 44). The concentrations of PCE and TCE were greater than their respective ATSDR comparison values in soil, indicating an increased risk for intrusion. No health risks can be calculated for these contaminants in PHAST. This is because of the complex pathway that groundwater contaminants must undergo to infiltrate into a building.

The soil vapor intrusion pathway is concerning for potential site reuse. Groundwater should be remediated in the area before basement structures are built. If remediation is not feasible, mitigation techniques such as vapor membranes or sub slab depressurization should be considered.

Drinking Water

Data around Bradford Dyeing Association indicates that the groundwater is contaminated with PFAS (Table 49). Drinking water is supplied to the area by a public water system, so health impacts from an untreated PFAS contaminated groundwater as a source of drinking water are negligible.

Sediment

Sediment samples were collected from the waste lagoons and the Pawcatuck River (Figure 5 - Figure 7). Health risks posed by contaminated sediment in the wastewater lagoons are not likely to be significant. A few of the measured compounds had concentrations greater than the comparison values established by RIDEM, but contaminants with health-based ATSDR comparison values were not in exceedance (Table 50). Comparison values from RIDEM are not health-based. The sediment in the Pawcatuck River and the waste lagoons are also usually underwater. Their mobility and their ability to enter the human body are limited as long as water levels remain constant.

The collected sediments show that the former waste lagoons are contaminated with PFAS (Table 51). Movement of contaminated sediment into the Grills Preserve Pond likely occurs when it rains, making this a pathway for PFAS uptake in fish (Table 31). PFAS uptake in fish occurs quickly and poses a threat to people consuming fish from the pond.[46,47,131,132] Treatment or removal of the sediment are possible options to prevent further contamination.

Surface Water
Surface water samples were collected from the Pawcatuck River, the Grills Preserve Pond, and Bradford Dyeing Association's waste lagoon (Table 52). Surface water samples were taken in the wastewater lagoons, near outfalls from the wastewater lagoons and the Grills Preserve Pond to the Pawcatuck River, and in the pond upstream of the weir marking the connection to the Pawcatuck River.[3] The data focuses on PFAS and shows that concentrations were higher in the lagoons (1252 ± 1803 ng total PFAS/L) compared to the Pawcatuck River (15 ± 3 ng total PFAS/L). Dunn *et al* 2023 used a passive sampling technique to examine the flow of PFAS in the Pawcatuck River monthly.[52] This study showed that concentrations of PFAS in surface water tend to increase downstream of the waste lagoons at Bradford Dyeing Association compared to upstream.[52] The largest increases were seen for long chain PFCAs such as PFNA, PFDA, and PFUnDA.[52] This indicates that waste lagoons from former mill sites are contributing to the PFAS concentrations and signature/fingerprint in the Pawcatuck River.[52]

The health implications of PFAS in surface water are limited. The major exposure route for PFAS is consumption of food or water containing PFAS. Swimming in contaminated water is not considered an important exposure pathway for PFAS. The river and lagoon will not be used as sources of water for any planned developments, so this pathway was not explored further.

LIMITATIONS

Limited Number of Samples

Due to budget and time constraints, our collaborators were only able to collect a small number of fish specimens in a limited area. Only five samples were analyzed for each species and sampling location except for largemouth bass (no largemouth were collected upstream of Bradford and ten were collected downstream). In order to capture the natural variations in PFAS concentrations in wild caught specimens, previous literature recommends 30-50 samples.[99] Public health was protected by using the maximum PFAS concentration in fish tissues to calculate health risks (except for downstream largemouth bass, which used the 95% upper confidence limit). More regular sampling of freshwater fish in Rhode Island would address this limitation.

Sample Collection Timing

Large variations in PFAS concentrations were reported for sunfish collected upstream of Bradford Dyeing Association. As mentioned previously, these variations could be due to the timing of collection. Fish behavior and PFAS flux in the Pawcatuck River depending on the time of sample collection.[52,100] The timing of collection and low number of specimens could introduce some variability into the data set. A larger number of samples collected over a longer period of time would more appropriately characterize temporal changes in the concentrations of PFAS in fish tissue.[99]

Lack of Data on Stocked Trout

RIDOH's fish recommendation of one meal per month from the Pawcatuck River downstream of Burdickville Road extends to stocked trout. The recommendation is based on scientific literature indicating that fish can take up PFAS to levels of concern within the expected residence time of stocked trout. A study examining the uptake of PFAS in stocked trout in an ecosystem with lower concentrations of PFAS would provide more conclusive evidence confirming/denying the risk of PFAS contamination. RIDOH has issued a recommendation based on the currently available evidence to protect public health. RIDOH, RIDEM, and USEPA should coordinate to pursue a study examining the uptake of PFAS in stocked trout in a contaminated water body.

Lack of Data on the Health Effects of Longer Chain PFAS

The major PFAS contributors in the collected fish tissues were very long chain compounds. The toxic effects of longer chain PFAS, such as PFTrDA, PFDoDA, PFTeDA, etc., have yet to be studied with the rigorous attention others have received (such as PFOS and PFOA). Of the major contributors in the fish tissues analyzed here, ATSDR has the best data about PFOS and PFUnDA toxicity. PFOS exposure has been tied to negative cardiovascular, gastrointestinal, hematological, musculoskeletal, hepatic, renal, endocrine, immunological, and reproductive health effects.[39] PFUnDA and PFDoDA have been linked to cardiovascular, hepatic, endocrine, and immune effects.[39] The structures of PFUnDA (carbon chain length 11) and PFDoDA (12) are closer to PFTrDA (13) than PFOS (8), so we would expect the health effects to be similar for PFTrDA, PFUnDA, and PFDoDA.

PFAS have been linked to increased risk of cancer (liver and kidney, especially)[59], but the associations have yet to be quantitatively defined. As our understanding of PFAS toxicity improves, these results will need to be updated with cancer risk values.

Fish Tissue Type

PFAS concentrations were determined from muscle plugs taken from the fillet of the fish. Fish take up PFAS into their blood, organs, and muscles at different rates.[46,49] In fish, PFAS is found at the highest concentrations in the liver, kidneys, and blood.[46,49] Muscle (like that found in a fish fillet) has some of the lowest concentrations of PFAS in fish.[46,49] If people use fish organs in their meal, the calculations performed here could underestimate the amount of PFAS consumed and the health risk.

Fish Species in the Human Diet

While the fish species sampled (sunfish, chain pickerel, and largemouth bass) are eaten in the US, other species may be caught as frequently. For example, northern pike and smaller fish (e.g., yellow perch), can be legally fished in Rhode Island.[139] These species interact with the environment differently and would take up PFAS at different rates. For future studies, nearby communities can provide detailed information about the species, sizes, and seasons when they fish, enabling a more complete health effects evaluation.

Human Behavior

The CTE and RME scenarios are estimates of freshwater fish ingestion based on previous research.[113,140] These estimates rely on consistent and predictable human behavior in occupational and residential situations, but human activities can have large variability, and chemical exposures are unique to each individual person. Therefore, estimates were used for the calculation of the dose values, HQs, and HIs.

Surface Soil Data Limitations
The surface soil samples collected by Weston & Sampson were 6-12 inches below ground surface, which is deeper than people typically interact with soil. ATSDR defines surface soil as 0-3 inches below ground surface. It is unclear what the contaminant concentrations are at soil depths that people interact with. If residential buildings are constructed on site, surface sampling should reflect typical human exposure.

Potential Future Site Application
At the time of writing this health consultation, the future of the Bradford Dyeing Association is unclear. Potential redevelopment into commercial or residential space is possible. Assumptions regarding potential site reuse were made here, but health risks could be different depending on what happens to the site in the future.

CONCLUSIONS
For this health consultation, EHRAP evaluated PFAS concentrations in fish tissues collected around Bradford Dyeing Association. The amount of PFAS in fish tissues is at a level of concern for non-cancer health effects. Based on the data provided by USEPA and the exposure scenarios evaluated, EHRAP concludes:

1. PFAS were found at levels of concern in all fish in the Pawcatuck River and in Grills Preserve Pond. PFAS concentrations were highest in muscle tissue of all species collected in the Grills Preserve Pond.
2. The PFAS at the highest concentrations in fish muscle tissues were perfluorotridecanoic acid (PFTrDA) and perfluoroundecanoic acid (PFUnDA).
3. Our analysis of the area suggests that Bradford Dyeing Association is not the only source of PFAS in the area as fish collected upstream of the site were also contaminated. Further testing is necessary to confirm that upstream contamination contributes to PFAS levels in fish tissues.
4. Non-cancer hazard indices from PFAS ingestion were the highest for consumption of fish from the Grills Preserve Pond.
5. Our analysis indicates that fish from the Grills Preserve Pond should not be consumed and that fish from the Pawcatuck River downstream of Burdickville Road should be consumed no more than once per month. This recommendation includes stocked trout (see Next Steps). Figure 1 shows the map that will be posted at Grills Preserve indicating the areas where people should not be consuming caught fish. Figure 2 indicates the area of the Pawcatuck River where the 1 meal/month recommendation applies.
6. Upstream of Burdickville Road, RIDOH does not have data required to make a recommendation on a safe amount of fish to consume.
7. Health risks from exposure to contaminated soil and groundwater are currently negligible because Bradford Dyeing Association is no longer occupied.
8. Trichloroethylene and tetrachloroethylene were detected at levels that indicate increased risk for soil vapor intrusion into buildings onsite. This is concerning for potential site reuse (see Next Steps

RECOMMENDATIONS

- Official messaging should continue to discourage eating fish from the Grills Preserve Pond.
- As the data stands, RIDOH does not have the data needed to make a health-based recommendation on the safety of consuming wild game and bird species around Bradford Dyeing Association. Individuals concerned about PFAS should know that these species can accumulate PFAS. People can be exposed to PFAS from a variety of sources and can lower their intake from one or more sources by limiting or replacing them.[7]
- RIDOH recommends that RIDEM investigate sources of PFAS upstream of Bradford Dyeing Association that are contaminating fish muscle tissues.
- RIDOH will communicate to the public that fish from the Grills Preserve Ponds should not be consumed and fish from the Pawcatuck River downstream of Burdickville Road should be consumed no more than once per month. This guidance extends to stocked trout until data can be produced indicating that stocked trout accumulate PFAS to a lesser extent compared to native species.
- RIDEM, USEPA, and RIDOH should coordinate testing of stocked trout to determine the uptake rate of PFAS after release and better assess health risks.
- RIDEM should test fish tissues for PFAS throughout the length of the Pawcatuck River, especially upstream of Burdickville Road and provide the results to RIDOH for analysis.
- Messaging should discourage consumption of fish organs in the Pawcatuck River due to contamination with PFAS.
- If residences are constructed onsite, contaminated soil should be removed or capped with a layer of soil/grass or an impervious material like asphalt or concrete.
- Further testing may be necessary to understand the extent of soil contamination onsite. Surface soil samples were taken at 6-12 inches. Typically, people interact with the top three inches of soil. Sampling techniques should reflect that.
- Groundwater should be remediated or soil vapor intrusion prevention should be employed in buildings constructed onsite. Remediation or soil vapor intrusion prevention would mitigate these risks.

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FIGURES

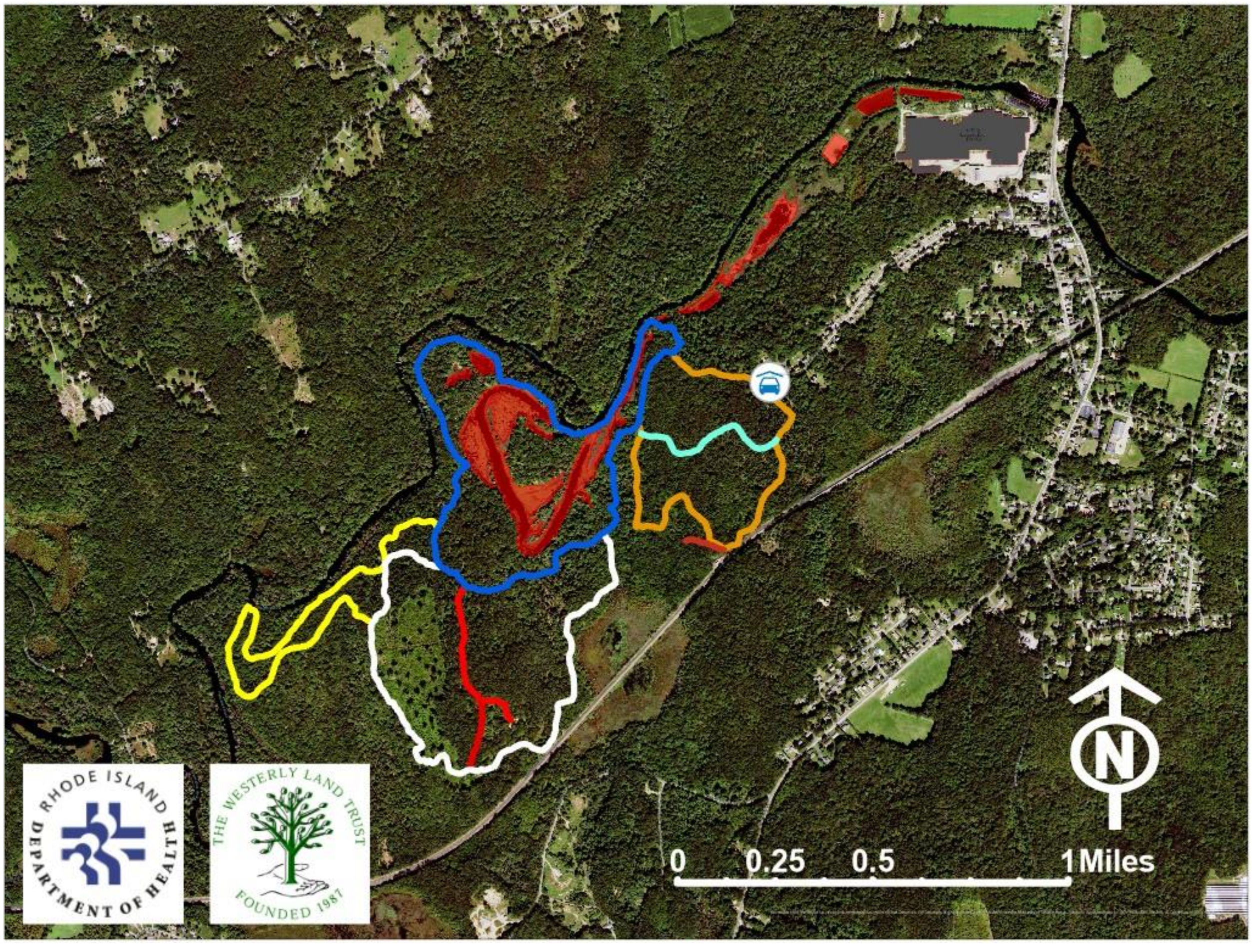

Figure 1: Map of Grills Preserve clarifying where fish should not be eaten. The Grills Preserve Ponds and wastewater lagoons are highlighted in red. Fish collected from these areas should not be consumed. The Grills Preserve trails are bolded in white, orange, teal, blue, red, and yellow to indicate how the ponds and river can be accessed. This map will be posted in Grills Preserve with more information on fishing guidance for the area.

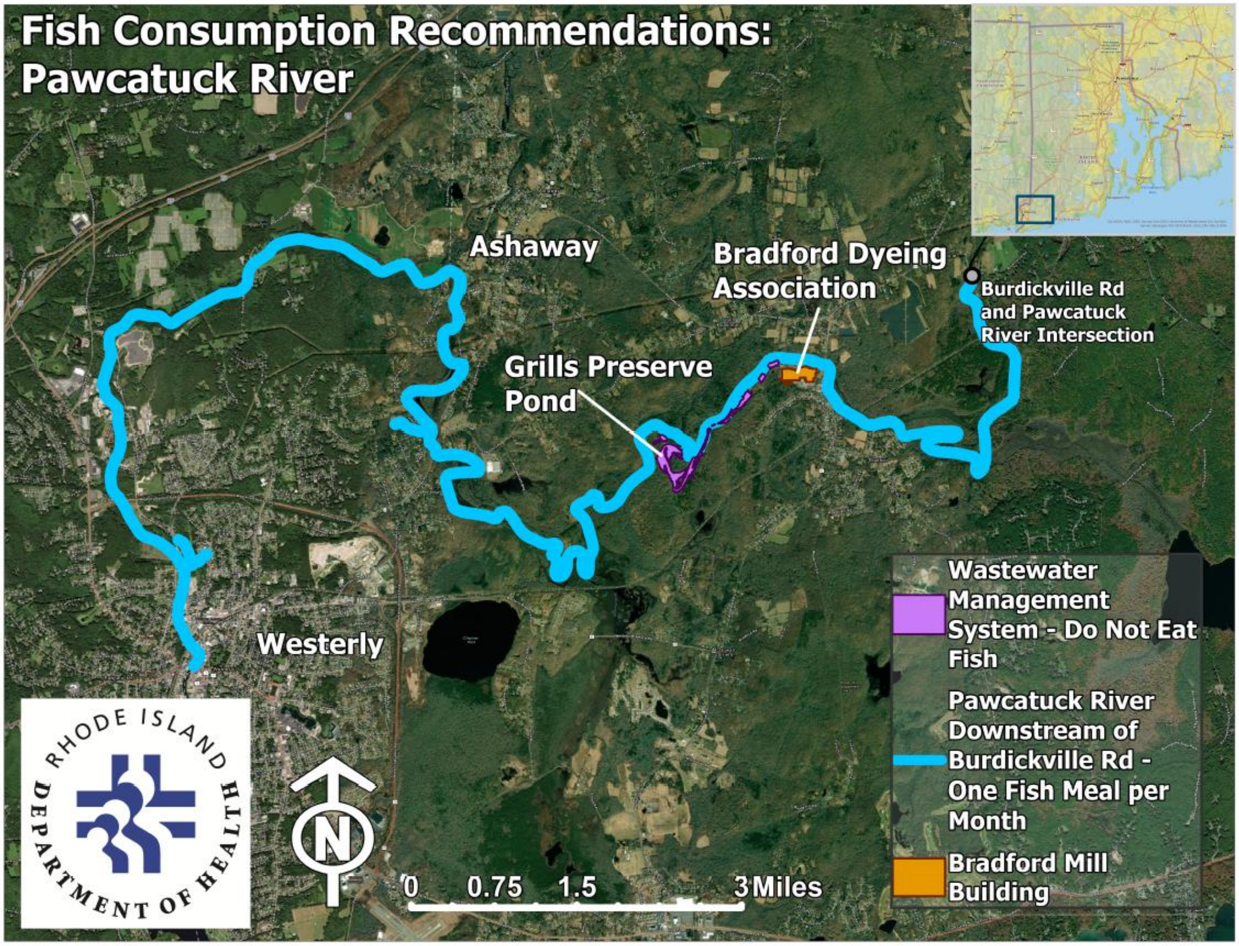

Figure 2: Map of the Pawcatuck River indicating where the 1 meal per month advisory is in place.The highlighted section of the Pawcatuck River (downstream of the intersection with Burdickville Road) indicates where the 1 meal per month advisory is in place. The purple highlighted bodies of water are the Grills Preserve Pond. Bradford Dyeing Association is highlighted in orange.

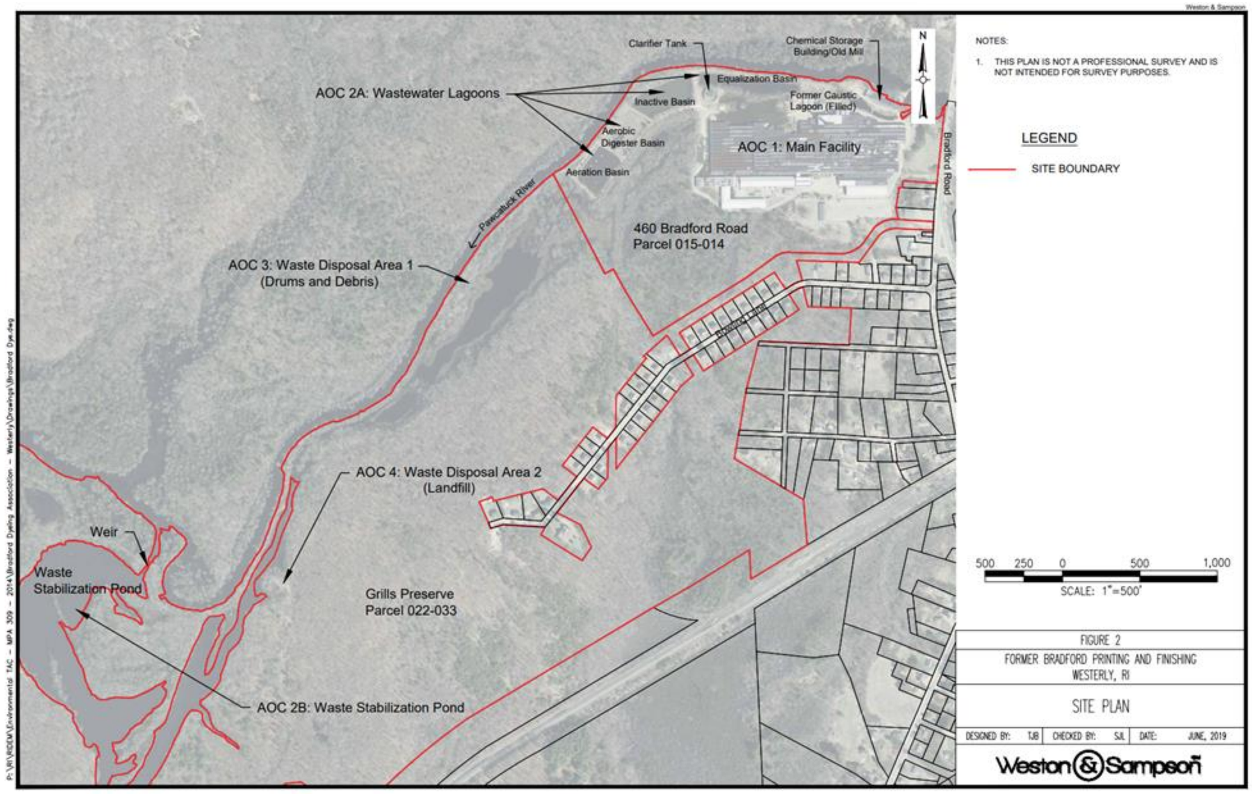

Figure 3: Bradford Dyeing Association site map. Red lines indicate site boundaries. Map provided by Weston & Sampson.[3]

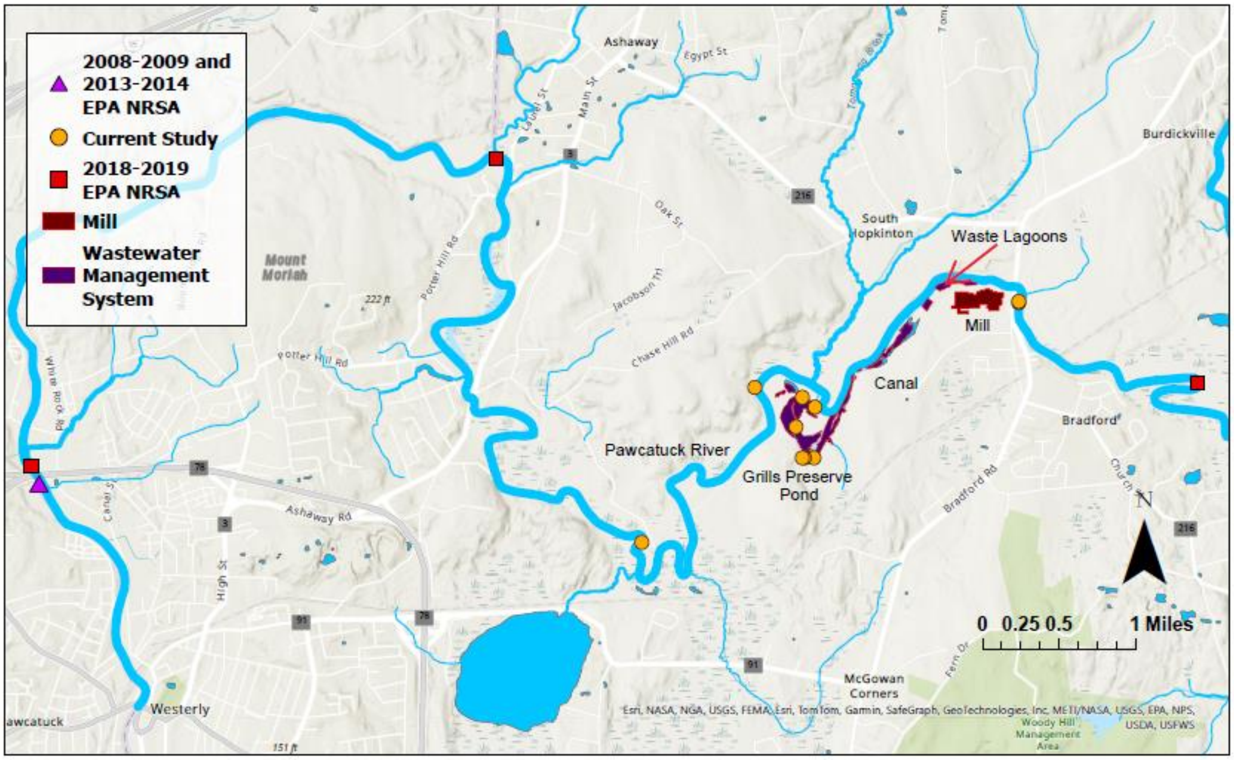

Figure 4: Fish sampling locations. Pink triangles are the sampling locations for the 2008-2009 and 2013-2014 NRSA studies. Yellow squares are the locations for the 2022 sampling. Red squares are locations for the 2018 USEPA NRSA sampling. The mill formerly occupied by Bradford Dyeing Association is indicated in dark brown and the wastewater treatment system (lagoons and stabilization pond) are a dark blue.

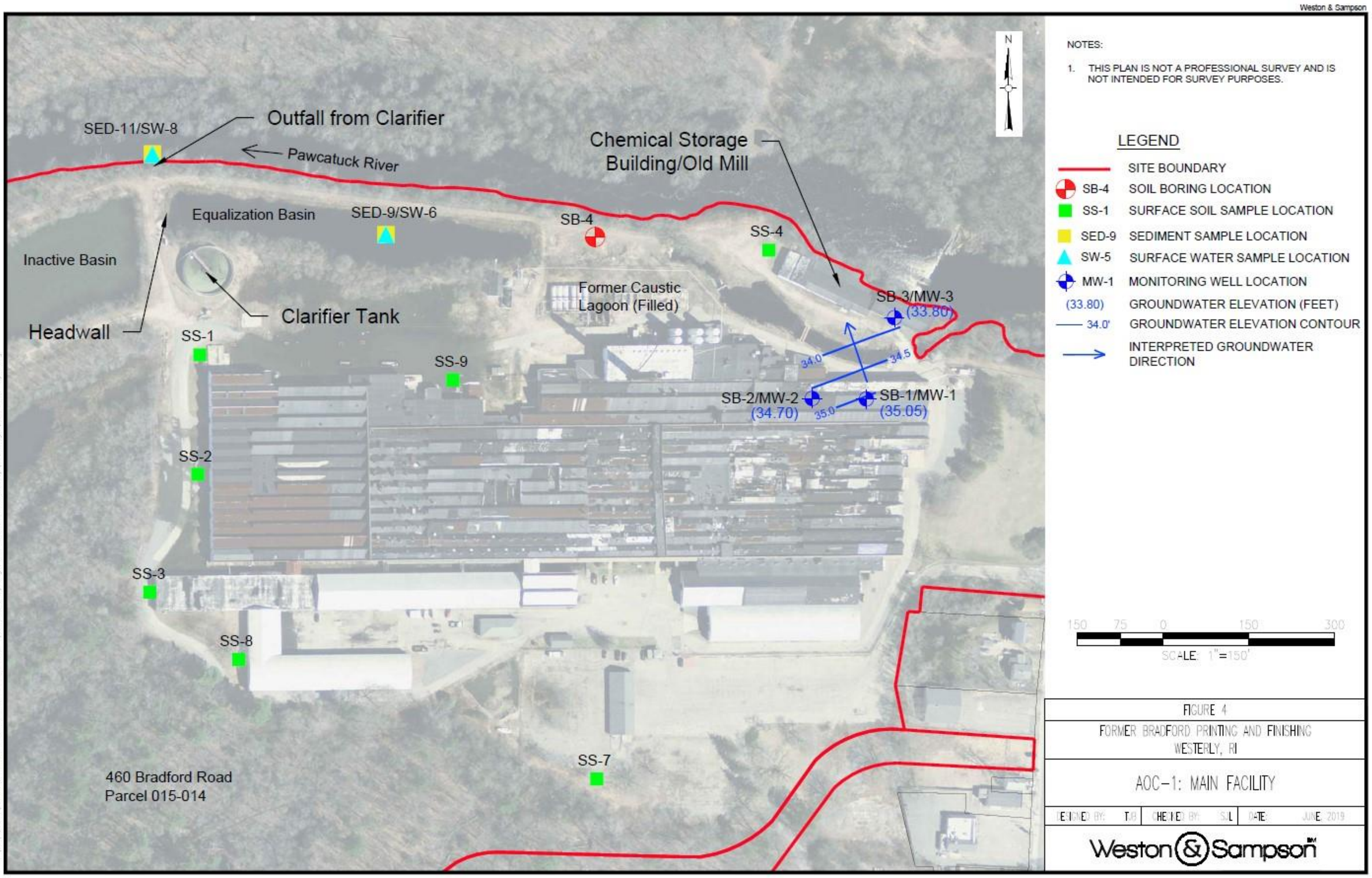

Figure 5: Sampling around the Bradford Dyeing Association mill (AOC-1).[3] This map shows the locations of surface (SS) and subsurface (SB) soil samples taken around the mill (AOC-1). Blue arrows show the direction of groundwater flow. Yellow squares and teal trials show the locations of sediment and surface water samples.Map provided by Weston & Sampson.[3]

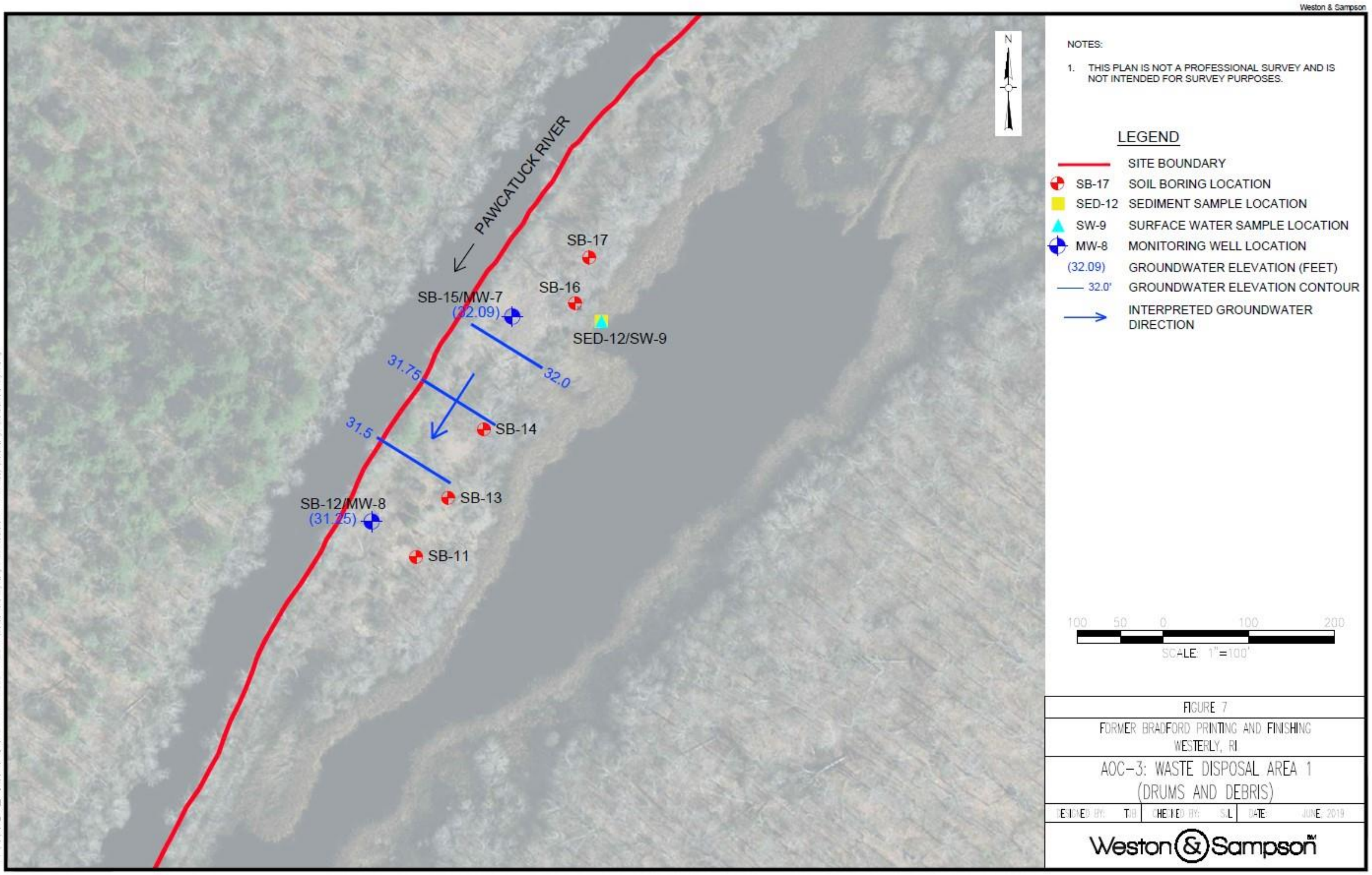

Figure 6: Sampling around the Bradford Dyeing Association waste disposal area/drums and debris (AOC-3).[3] This map shows the locations of surface (SS) and subsurface (SB) soil samples taken around the mill (AOC-1). Blue arrows show the direction of groundwater flow. Yellow squares and teal trials show the locations of sediment and surface water samples.Map provided by Weston & Sampson.[3]

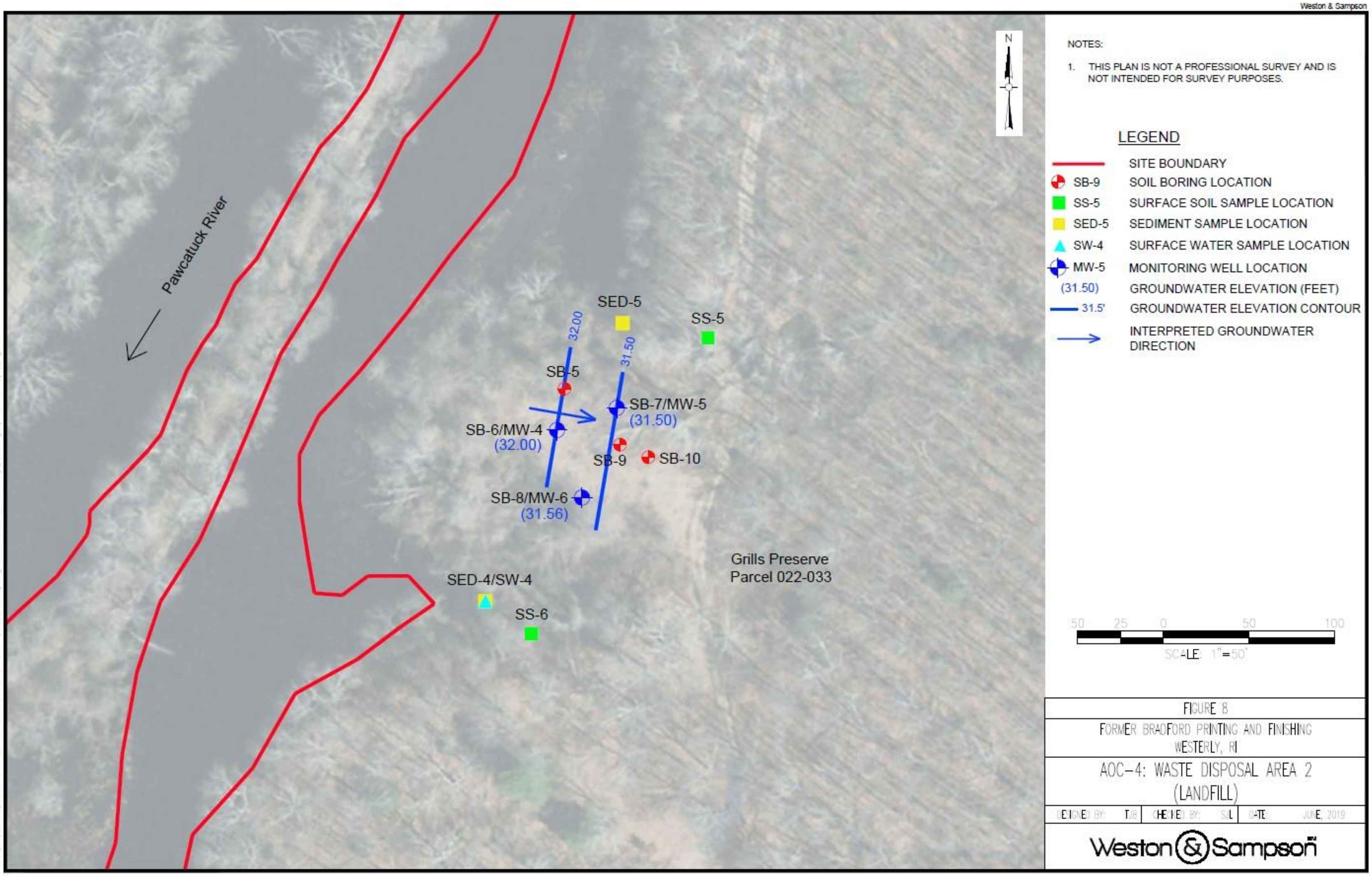

Figure 7: Sampling around the Bradford Dyeing Association landfill (AOC-4).[3] This map shows the locations of surface (SS) and subsurface (SB) soil samples taken around the mill (AOC-1). Blue arrows show the direction of groundwater flow. Yellow squares and teal trials show the locations of sediment and surface water samples. Map provided by Weston & Sampson.[3]

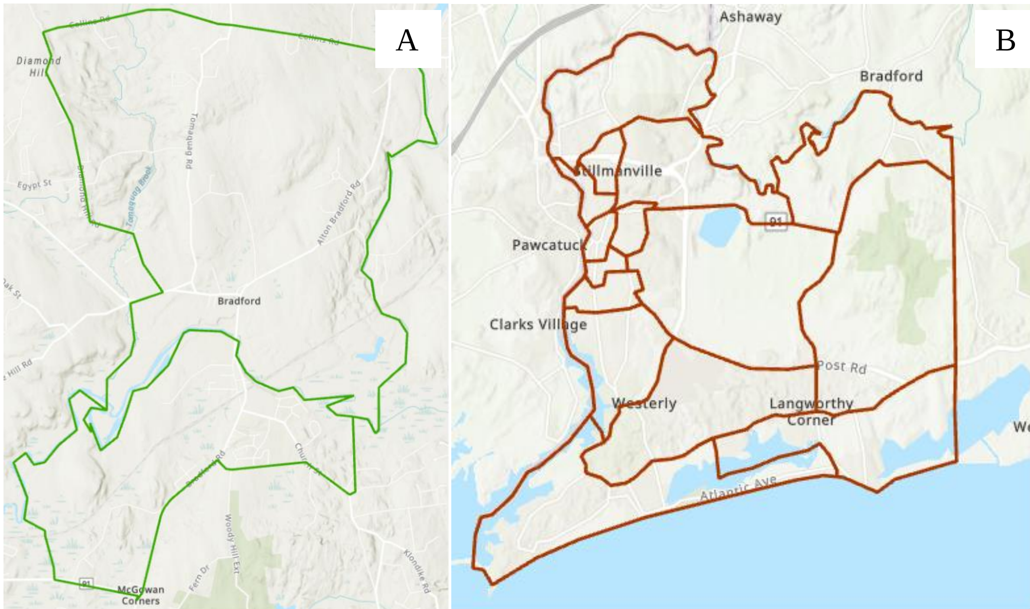

Figure 8: Census tracts analyzed for demographic data. (A) Census tracts 507.02 and 509.02 (block groups 4 and 1, respectively) encompassing Bradford and Bradford Dyeing Association (B) Census tracts 508.01 (block groups 1-5), 508.02 (block groups 1&2), 509.01 (block groups 1-3), and 510 (block groups 1 &2), encompassing Westerly.

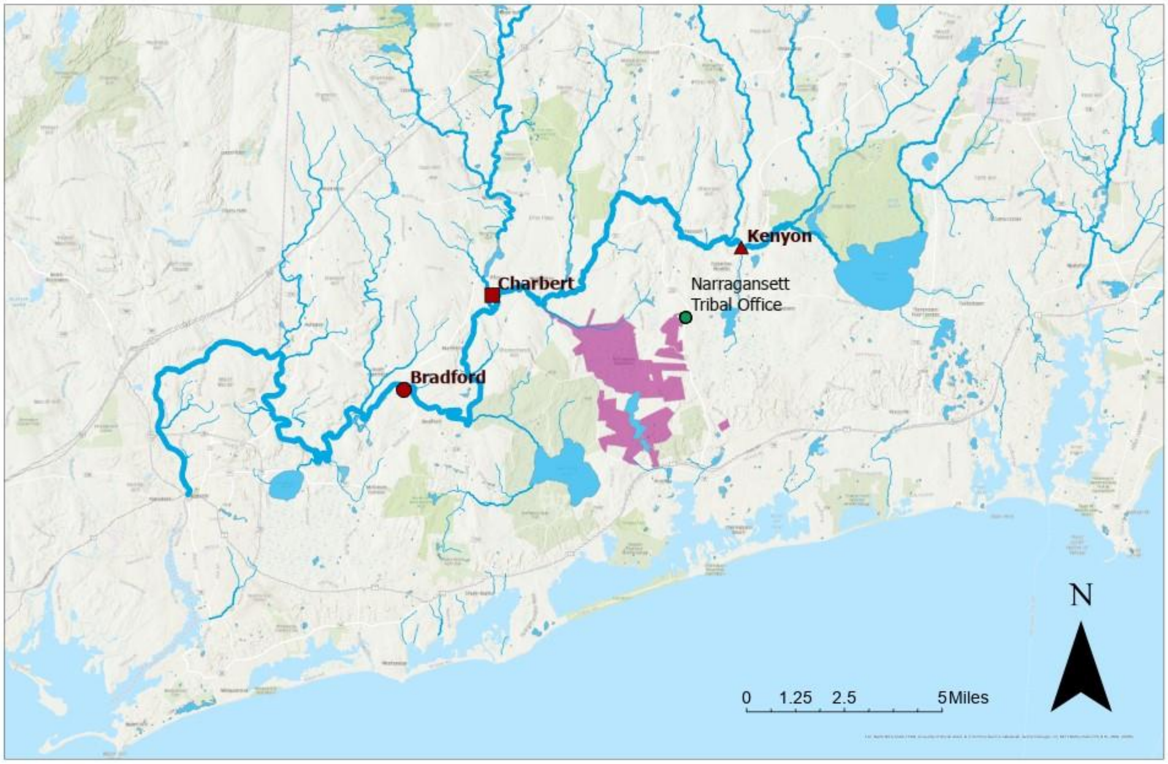

Figure 9: Pawcatuck River with associated mills and Narragansett Indian Tribe land. Bradford Dyeing Associated (Bradford, red circle), Charbert, Inc. (Charbert, red square), and Kenyon Industries (Kenyon, red triangle) are current and former textile mills on the Pawcatuck River. The green circle indicates the location of the Narragansett Indian Tribal Office. The pink regions on the map are Narragansett Indian Tribal lands.

Figure 10: A fishing lure found on the shore of the Grills Preserve Pond taken as an example of fishing activity in the area.

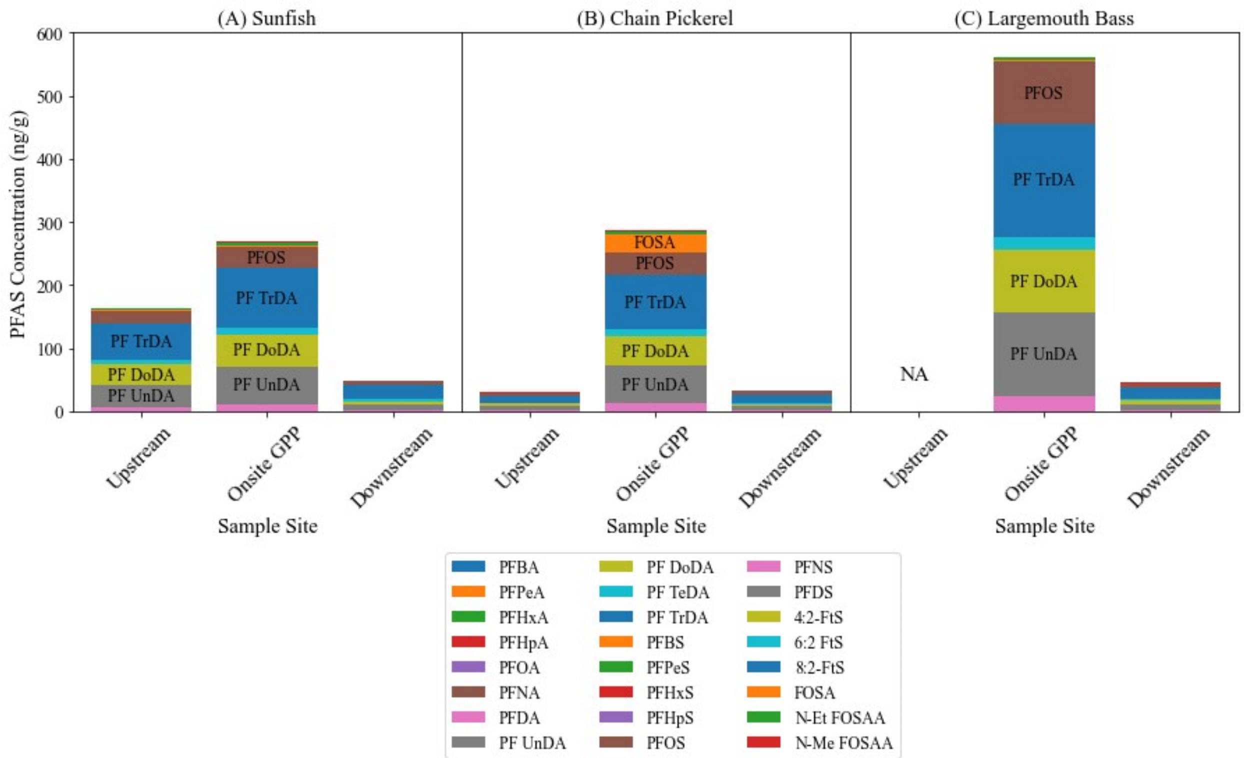

Figure 11: PFAS concentrations in (A) sunfish, (B) chain pickerel, and (C) largemouth bass. Samples were collected upstream and downstream of Bradford Dyeing Association and onsite in the Grills Preserve Pond (onsite GPP). Each compound is averaged across the fish specimens sampled. Major contributors (>25 ng/ g ww) are labelled with the compound name.

Onsite GPP – Grills Preserve Pond; NA – not applicable, no largemouth bass were collected upstream; 4:2-FTS - 4:2 fluorotelomer sulfonic acid; 6:2-FTS - 6:2 fluorotelomer sulfonic acid; 8:2-FTS - 8:2 fluorotelomer sulfonic acid; FOSA - Perfluorooctanesulfonamide; N-EtFOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-MeFOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid; PFBA - Perfluorobutanoic acid; PFBS - Perfluorobutane sulfonic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFDS - Perfluorodecane sulfonic acid; PFHpA - Perfluoroheptanoic acid; PFHpS - Perfluoroheptane sulfonic acid; PFHxA - Perfluorohexanoic acid; PFHxS - Perfluorohexane sulfonic acid; PFNA - Perfluorononanoic acid;PFNS - Perfluorononane sulfonic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFPeA - Perfluoropentanoic acid; PFPeS - Perfluoropentane sulfonic acid; PFTeDA - Perfluorotetradecanoic acid; PFTrDA - Perfluorotridecanoic acid; PFUnDA - Perfluoroundecanoic acid.

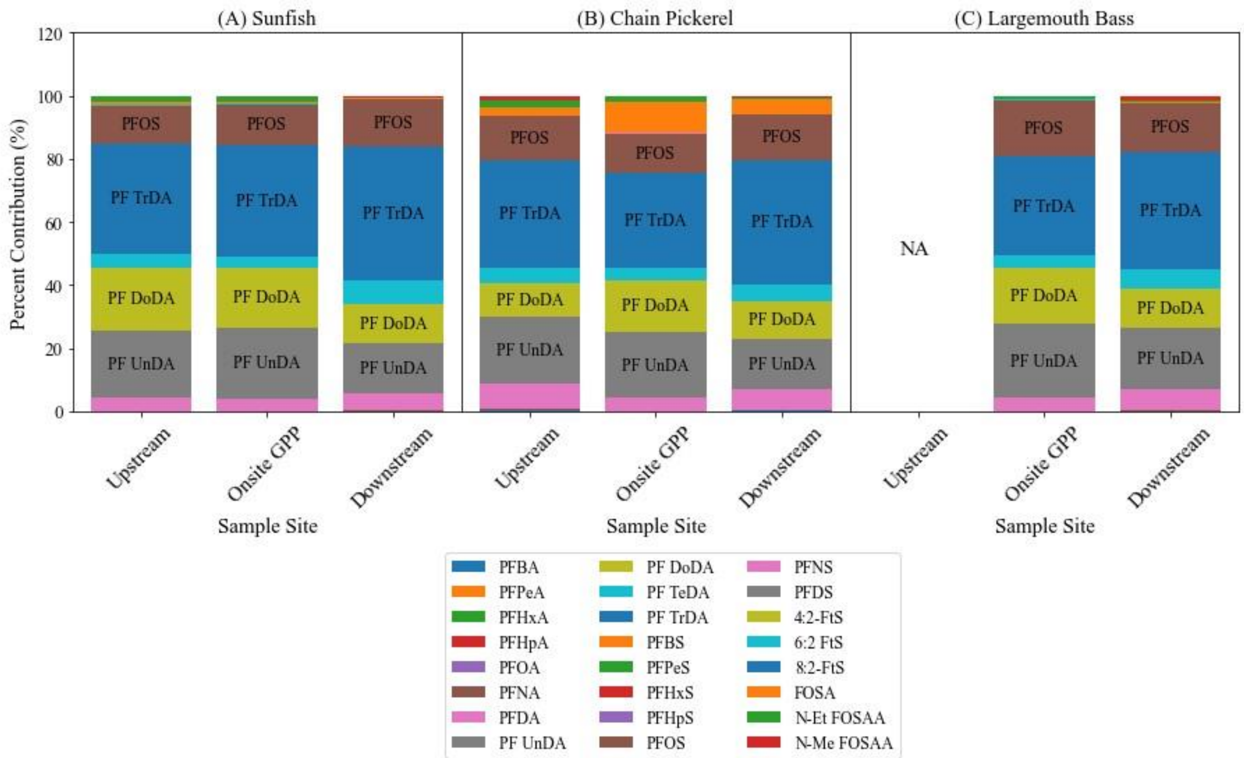

Figure 12: PFAS contributors in (A) sunfish, (B) chain pickerel, and (C) largemouth bass. Each compound is averaged across the fish specimens sampled. Samples were collected upstream and downstream of Bradford Dyeing Association and onsite in the Grills Preserve Pond (onsite GPP). Major contributors (>10%) are labelled with the compound name.

Onsite GPP – Grills Preserve Pond; NA – not applicable, no largemouth bass were collected upstream; 4:2-FTS - 4:2 fluorotelomer sulfonic acid; 6:2-FTS - 6:2 fluorotelomer sulfonic acid; 8:2-FTS - 8:2 fluorotelomer sulfonic acid; FOSA - Perfluorooctanesulfonamide; N-EtFOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-MeFOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid; PFBA - Perfluorobutanoic acid; PFBS - Perfluorobutane sulfonic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFDS - Perfluorodecane sulfonic acid; PFHpA - Perfluoroheptanoic acid; PFHpS - Perfluoroheptane sulfonic acid; PFHxA - Perfluorohexanoic acid; PFHxS - Perfluorohexane sulfonic acid; PFNA - Perfluorononanoic acid;PFNS - Perfluorononane sulfonic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFPeA - Perfluoropentanoic acid; PFPeS - Perfluoropentane sulfonic acid; PFTeDA - Perfluorotetradecanoic acid; PFTrDA - Perfluorotridecanoic acid; PFUnDA - Perfluoroundecanoic acid.

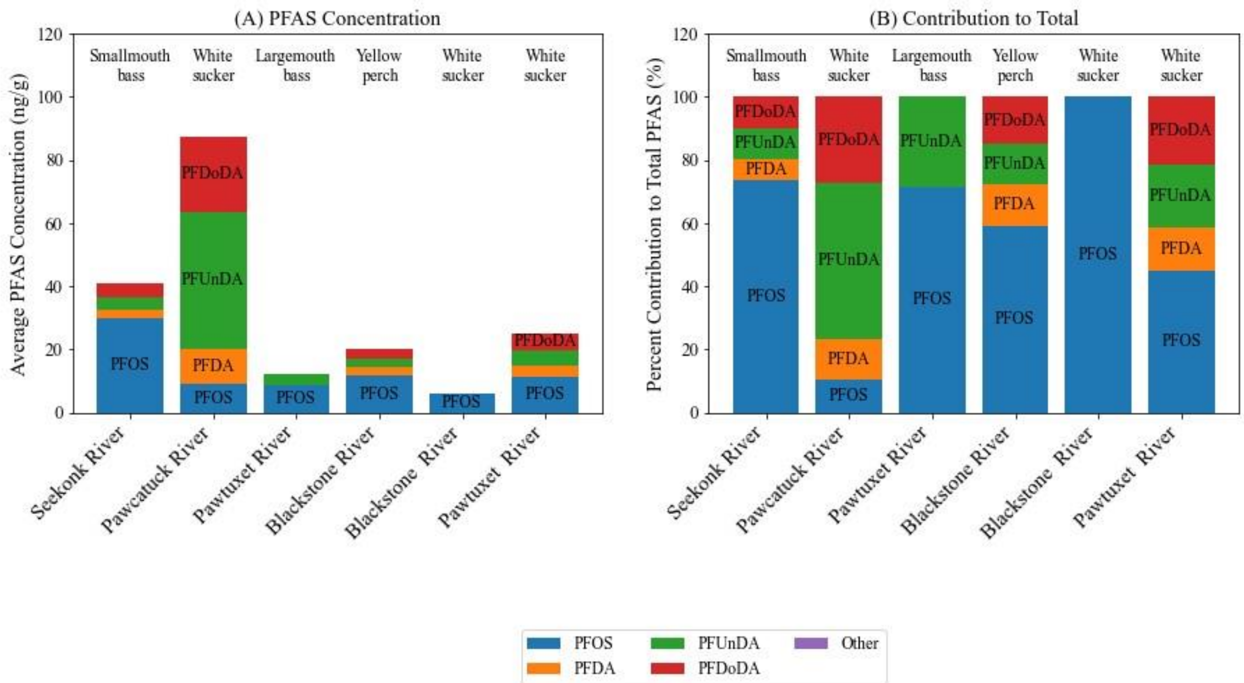

Figure 13: PFAS concentrations in fish tissue in Rhode Island rivers provided in the 2008-2009 National Rivers and Streams Assessment (NRSA) by USEPA. (A) Average PFAS concentrations in white sucker and yellow perch composite samples (B) PFAS contributions by compound. Fish species are identified above their respective columns. Multiple fish specimens were composited for each sample.

PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFOS - Perfluorooctane sulfonic acid; PFUnDA - Perfluoroundecanoic acid.

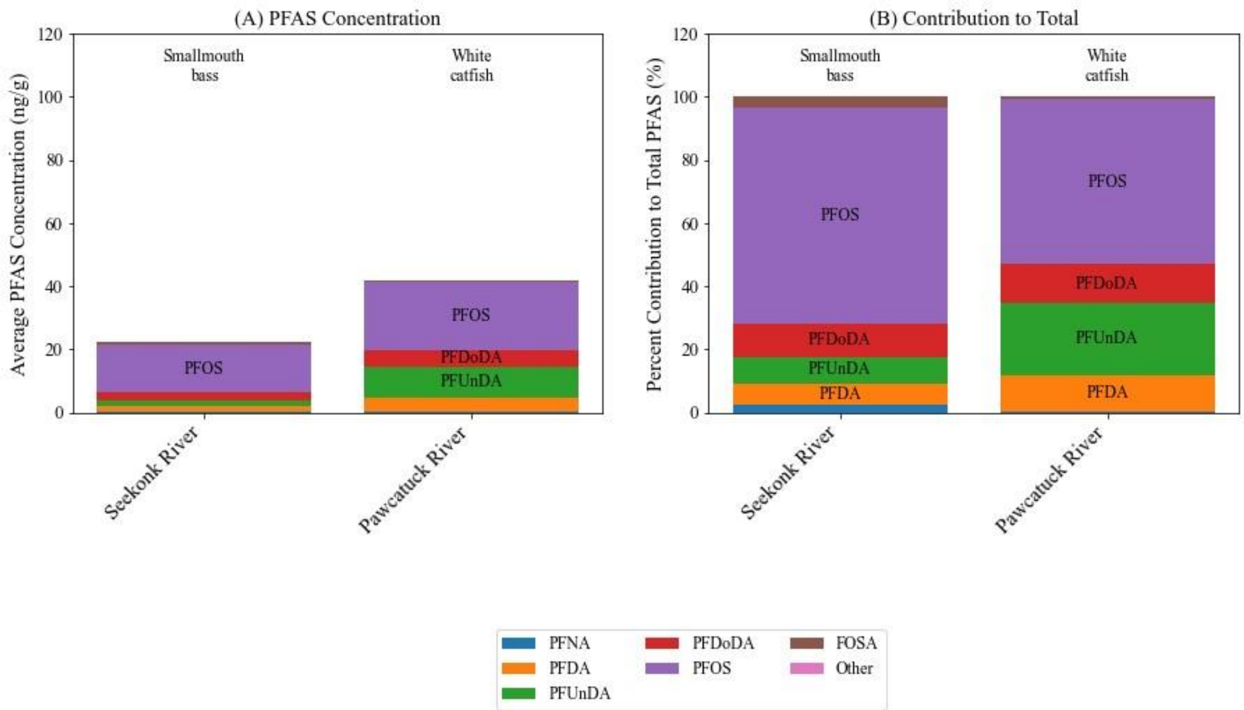

Figure 14: PFAS concentrations in fish tissue in Rhode Island rivers provided in the 2013-2014 National Rivers and Streams Assessment (NRSA) by USEPA. (A) Average PFAS concentrations in white sucker and yellow perch composite samples (B) PFAS contributions by compound. Fish species are identified above their respective columns. Multiple fish specimens were composited for each sample.

FOSA - Perfluorooctanesulfonamide; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFNA - Perfluorononanoic acid; PFOS - Perfluorooctane sulfonic acid; PFUnDA - Perfluoroundecanoic acid.

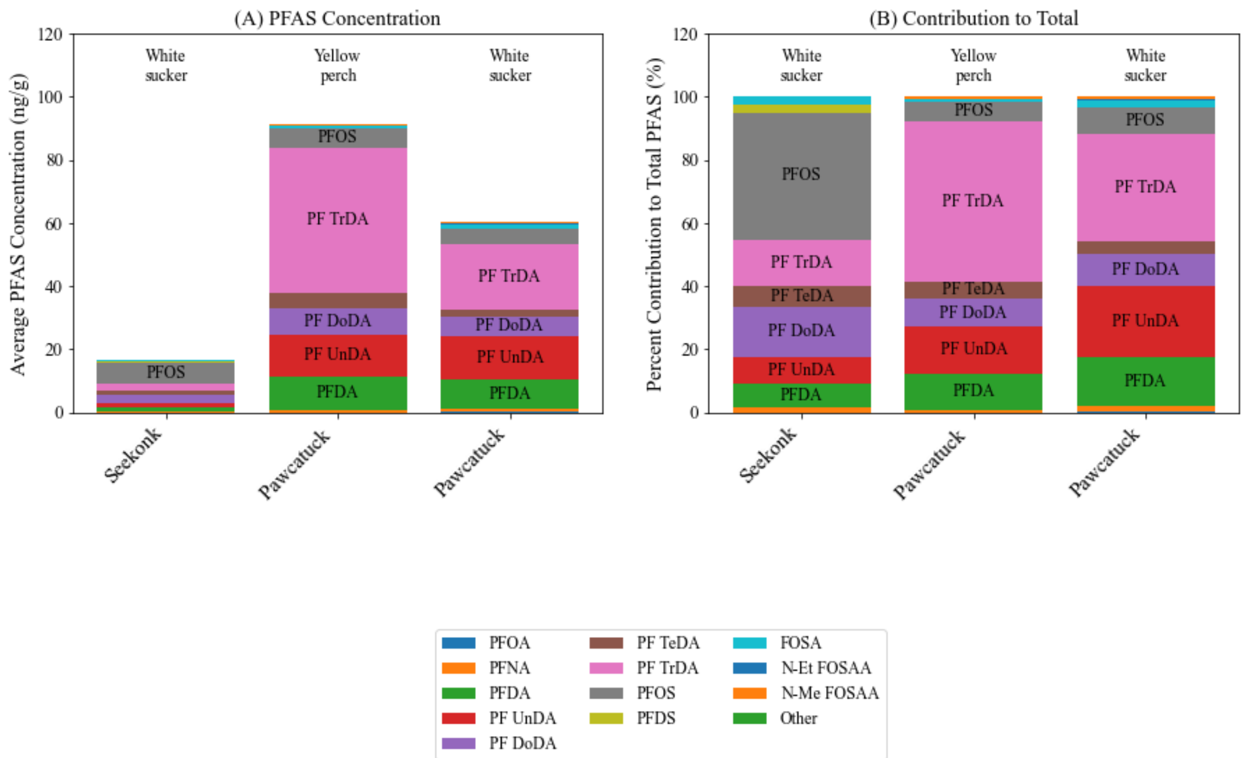

Figure 15: Average PFAS concentrations in fish tissue provided in the 2018-2019 National Rivers and Streams Assessment (NRSA) by USEPA. (A) Average PFAS concentrations in composite fish tissue samples. (B) PFAS contributions by compound. Fish species are identified above their respective columns. Multiple fish specimens were composited for each sample. Downstream white sucker is an average of two composite samples. Sample sites were named based on their location relative to Bradford Dyeing Association.

FOSA - Perfluorooctanesulfonamide; N-EtFOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-MeFOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFDS - Perfluorodecane sulfonic acid; PFNA - Perfluorononanoic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFTeDA - Perfluorotetradecanoic acid; PFTrDA - Perfluorotridecanoic acid; PFUnDA - Perfluoroundecanoic acid.

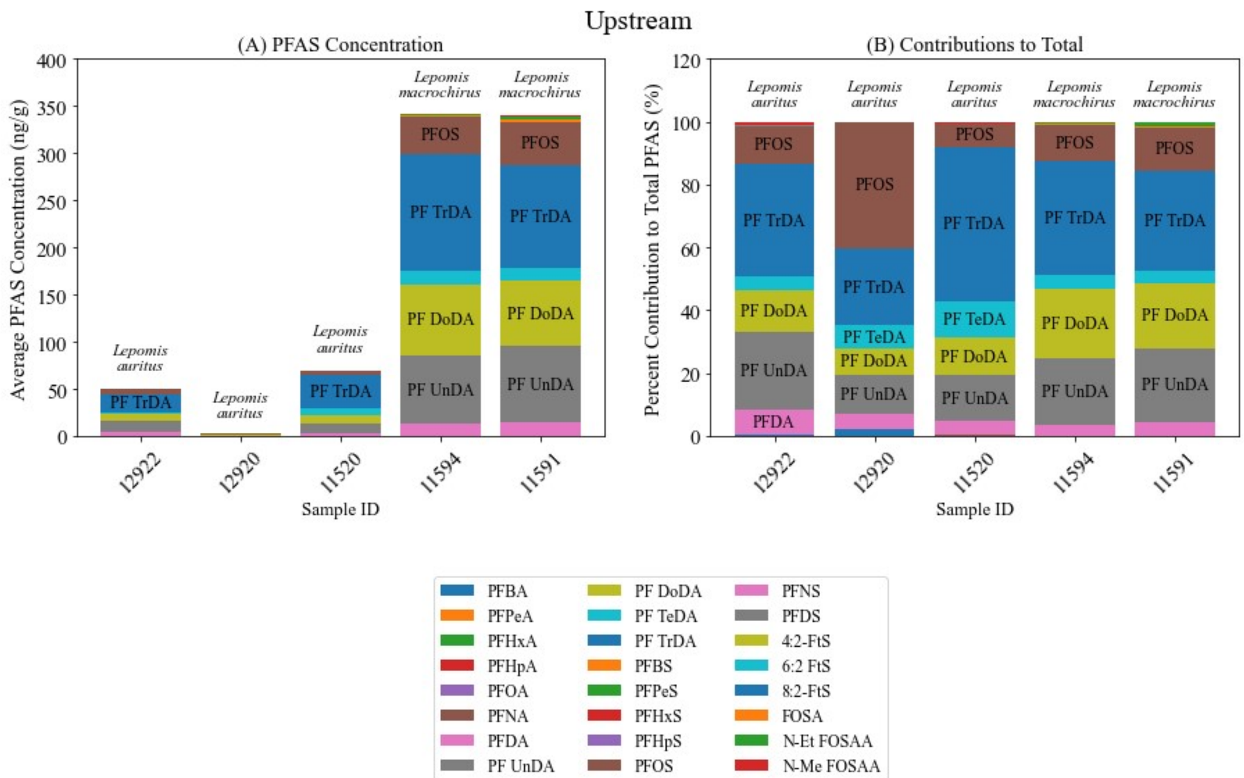

Figure 16: PFAS concentrations in sunfish samples collected upstream of Bradford Dyeing Association. (A) Average PFAS concentrations (ng/g ww); (B) Contribution of each PFAS to the total concentration. Each sample is labelled with the species: *Lepomis auritus* (redbreast sunfish) or *Lepomis macrochirus* (bluegill).

4:2-FTS - 4:2 fluorotelomer sulfonic acid; 6:2-FTS - 6:2 fluorotelomer sulfonic acid; 8:2-FTS - 8:2 fluorotelomer sulfonic acid; FOSA - Perfluorooctanesulfonamide; N-EtFOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-MeFOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid; PFBA - Perfluorobutanoic acid; PFBS - Perfluorobutane sulfonic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFDS - Perfluorodecane sulfonic acid; PFHpA - Perfluoroheptanoic acid; PFHpS - Perfluoroheptane sulfonic acid; PFHxA - Perfluorohexanoic acid; PFHxS - Perfluorohexane sulfonic acid; PFNA - Perfluorononanoic acid;PFNS - Perfluorononane sulfonic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFPeA - Perfluoropentanoic acid; PFPeS - Perfluoropentane sulfonic acid; PFTeDA - Perfluorotetradecanoic acid; PFTrDA - Perfluorotridecanoic acid; PFUnDA - Perfluoroundecanoic acid.

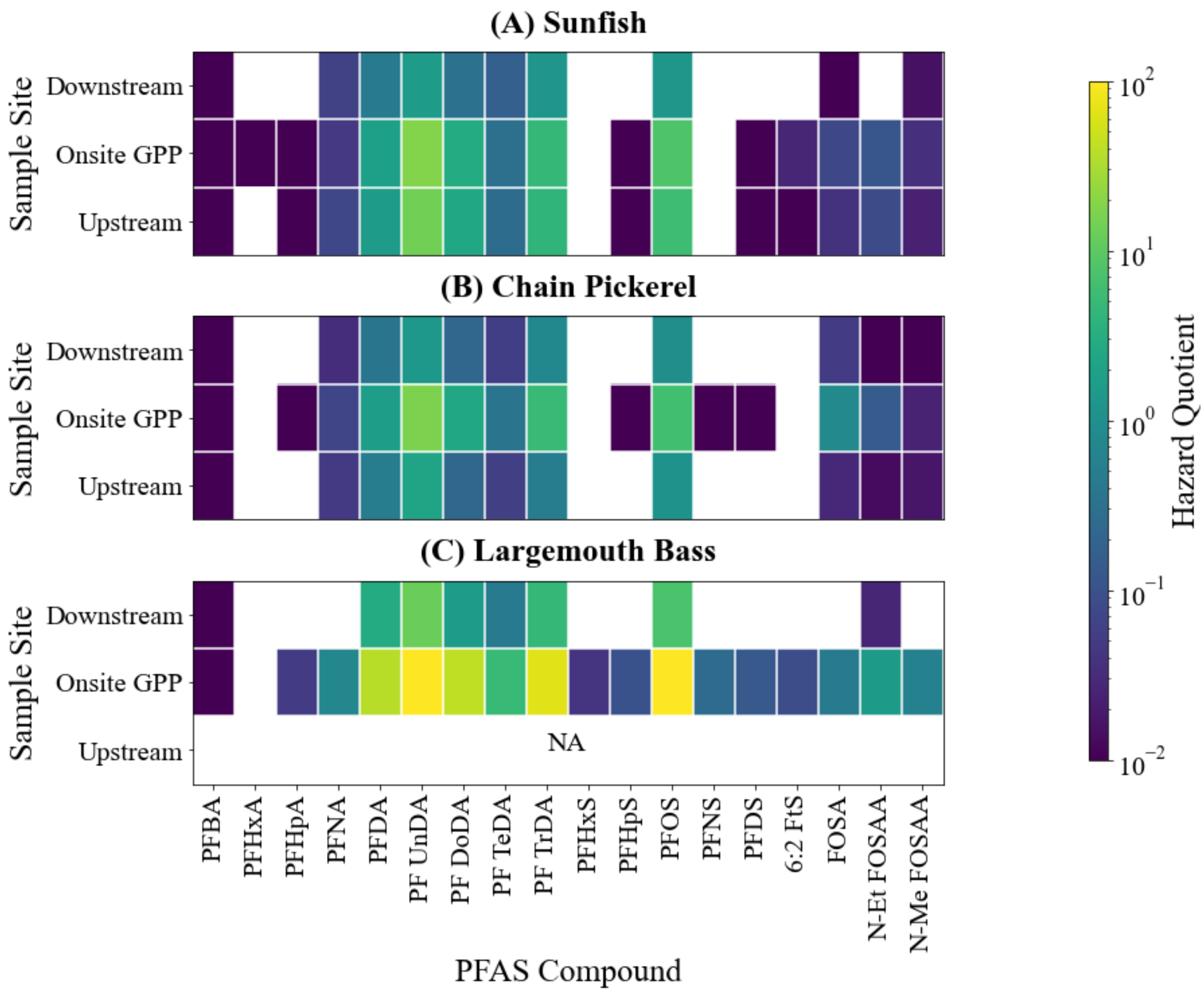

Figure 17: HQs in the CTE consumption scenario. Lighter colors indicate higher HQs. HQs < 0.01 shown as white. GPP is the Grills Preserve Pond. Largemouth bass were not collected upstream of Bradford Dyeing Association (NA).

Onsite GPP – Grills Preserve Pond; NA – not applicable, no largemouth bass were collected upstream; 4:2-FTS - 4:2 fluorotelomer sulfonic acid; 6:2-FTS - 6:2 fluorotelomer sulfonic acid; 8:2-FTS - 8:2 fluorotelomer sulfonic acid; FOSA - Perfluorooctanesulfonamide; N-EtFOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-MeFOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid; PFBA - Perfluorobutanoic acid; PFBS - Perfluorobutane sulfonic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFDS - Perfluorodecane sulfonic acid; PFHpA - Perfluoroheptanoic acid; PFHpS - Perfluoroheptane sulfonic acid; PFHxA - Perfluorohexanoic acid; PFHxS - Perfluorohexane sulfonic acid; PFNA - Perfluorononanoic acid;PFNS - Perfluorononane sulfonic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFPeA - Perfluoropentanoic acid; PFPeS - Perfluoropentane sulfonic acid; PFTeDA - Perfluorotetradecanoic acid; PFTrDA - Perfluorotridecanoic acid; PFUnDA - Perfluoroundecanoic acid.

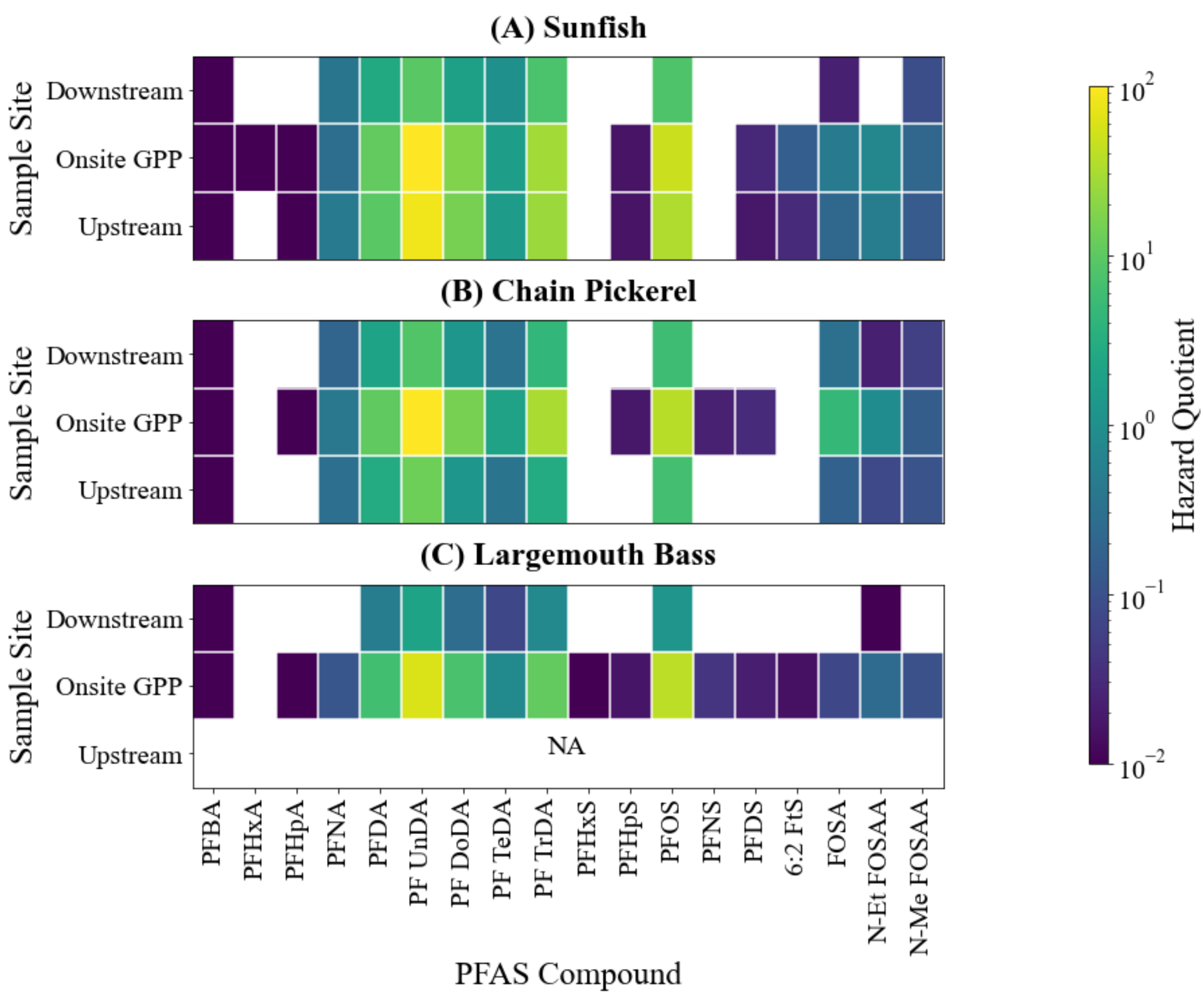

Figure 18: HQs in the RME consumption scenario. Darker colors indicate lower HQs. HQs < 0.01 shown as white. GPP is the Grills Preserve Pond. Largemouth bass were not collected upstream of Bradford Dyeing Association (NA).

Onsite GPP – Grills Preserve Pond; NA – not applicable, no largemouth bass were collected upstream; 4:2-FTS - 4:2 fluorotelomer sulfonic acid; 6:2-FTS - 6:2 fluorotelomer sulfonic acid; 8:2-FTS - 8:2 fluorotelomer sulfonic acid; FOSA - Perfluorooctanesulfonamide; N-EtFOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-MeFOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid; PFBA - Perfluorobutanoic acid; PFBS - Perfluorobutane sulfonic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFDS - Perfluorodecane sulfonic acid; PFHpA - Perfluoroheptanoic acid; PFHpS - Perfluoroheptane sulfonic acid; PFHxA - Perfluorohexanoic acid; PFHxS - Perfluorohexane sulfonic acid; PFNA - Perfluorononanoic acid;PFNS - Perfluorononane sulfonic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFPeA - Perfluoropentanoic acid; PFPeS - Perfluoropentane sulfonic acid; PFTeDA - Perfluorotetradecanoic acid; PFTrDA - Perfluorotridecanoic acid; PFUnDA - Perfluoroundecanoic acid.

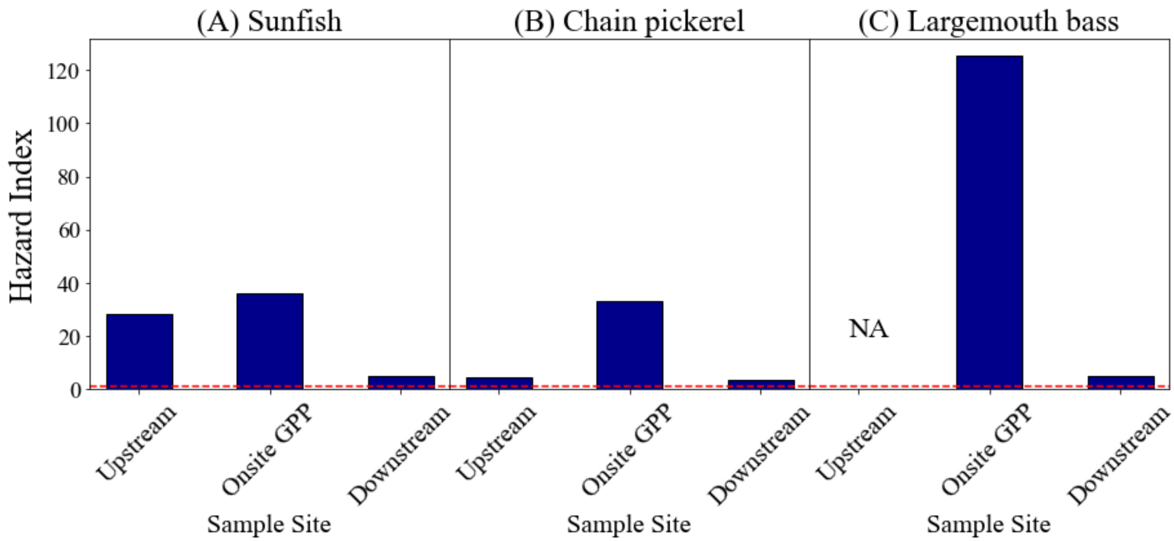

Figure 19: Hazard indices (HIs) for (A) sunfish, (B) chain pickerel, and (C) largemouth bass under the CTE consumption scenario. Horizontal red line marks an HI = 1.0. GPP is the Grills Preserve Pond. No largemouth bass were collected upstream, this is marked NA ("not applicable").

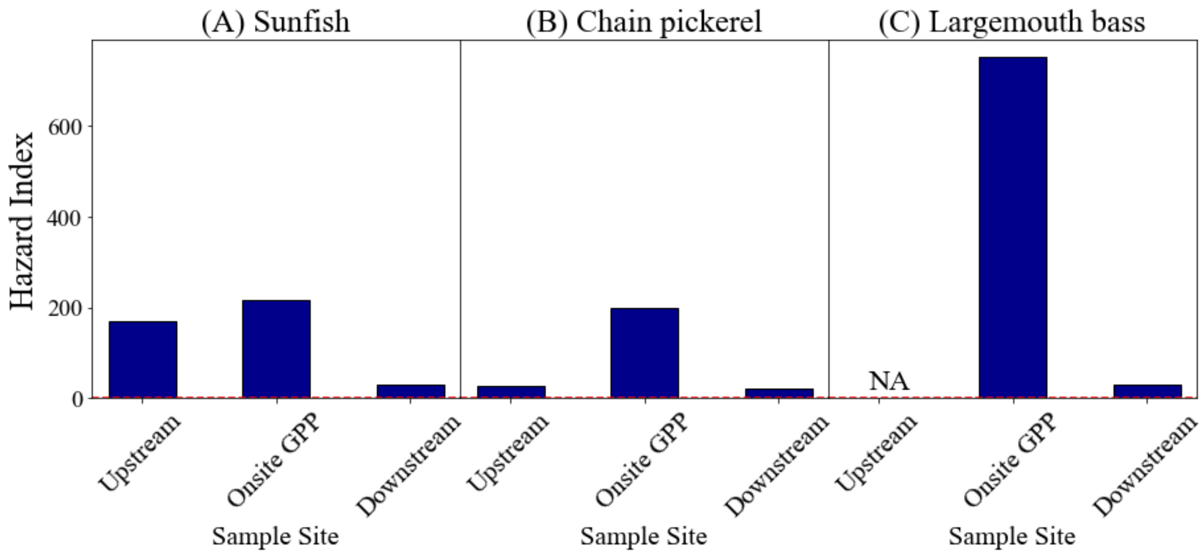

Figure 20: Hazard indices (HIs) for (A) sunfish, (B) chain pickerel, and (C) largemouth bass under the RME consumption scenario. Horizontal red line marks an HI = 1.0. No largemouth bass were collected upstream, this is marked NA (“not applicable”).

TABLES

Table 1: Demographics data for Bradford and surrounding areas

Population	Bradford Count	Bradford Percent	Westerly Count	Westerly Percent	Rhode Island Count	Rhode Island Percent
Total Population	2478.0	100.0	23352.0	100.0	1091949.0	100.0
Male (under 5 years old)	31.0	1.3	245.0	1.0	28236.0	2.6
Female (under 5 years old)	0.0	0.0	470.0	2.0	27134.0	2.5
Population over 65 years old	312.0	12.6	5231.0	22.4	181153.0	16.6
Population under 18 years old	518.0	20.9	3310.0	14.2	212049.0	19.4
High school graduate over the age of 25	617.0	24.9	4931.0	21.1	178129.0	16.3
White	2478.0	100.0	21333.0	91.4	841181.0	77.0
Black	0.0	0.0	208.0	0.9	69398.0	6.4
Hispanic	0.0	0.0	786.0	3.4	178673.0	16.4
Population below the poverty line	335.0	13.5	1627.0	7.0	118257.0	10.8
Median household income	65439.50	NA	72500.00	NA	78648.50	NA
Native American	0.0	0.0	246.0	1.1	14451.0	1.3
Non-English speakers at home	10.0	0.4	1711.0	7.3	232168.0	21.3

Table 2: PFAS Analytes and Acronyms

Acronym	Chemical Name	Formula	CAS Registry Number
4:2-FTS	4:2 Fluorotelomer sulfonic acid	$C_{6}H_{5}F_{9}O_{3}S$	757124-72-4
6:2-FTS	6:2 Fluorotelomer sulfonic acid	$C_{8}H_{5}F_{13}O_{3}S$	27619-97-2
8:2-FTS	8:2 Fluorotelomer sulfonic acid	$C_{10}H_{5}F_{17}O_{3}S$	39108-34-4
FOSA	Perfluorooctanesulfonamide	$C_{8}H_{2}F_{17}NO_{2}S$	754-91-6
N-EtFOSAA	N-ethylperfluorooctane sulfonamidoacetic acid	$C_{12}H_{8}F_{17}NO_{4}S$	2991-50-6
N-MeFOSAA	2-(N-methylperfluorooctane sulfonamido)acetic acid	$C_{11}H_{6}F_{17}NO_{4}S$	2355-31-9
PFBA	Perfluorobutanoic acid	$C_{4}HF_{7}O_{2}$	375-22-4
PFBS	Perfluorobutane sulfonic acid	$C_{4}HF_{9}O_{3}S$	375-73-5
PFDA	Perfluorodecanoic acid	$C_{10}HF_{19}O_{2}$	335-76-2
PFDoDA	Perfluorododecanoic acid	$C_{12}HF_{23}O_{2}$	307-55-1
PFDS	Perfluorodecane sulfonic acid	$C_{10}HF_{21}O_{3}S$	335-77-3
PFHpA	Perfluoroheptanoic acid	$C_{7}HF_{13}O_{2}$	375-85-9
PFHpS	Perfluoroheptane sulfonic acid	$C_{7}HF_{15}O_{3}S$	375-92-8
PFHxA	Perfluorohexanoic acid	$C_{6}HF_{11}O_{2}$	307-24-4
PFHxS	Perfluorohexane sulfonic acid	$C_{6}HF_{13}O_{3}S$	355-46-4
PFNA	Perfluorononanoic acid	$C_{9}HF_{17}O_{2}$	375-95-1
PFNS	Perfluorononane sulfonic acid	$C_{9}HF_{19}O_{3}S$	68259-12-1
PFOA	Perfluorooctanoic acid	$C_{8}HF_{15}O_{2}$	335-67-1
PFOS	Perfluorooctane sulfonic acid	$C_{8}HF_{17}O_{3}S$	1763-23-1
PFPeA	Perfluoropentanoic acid	$C_{5}HF_{9}O_{2}$	2706-90-3
PFPeS	Perfluoropentane sulfonic acid	$C_{5}HF_{11}O_{3}S$	2706-91-4
PFTeDA	Perfluorotetradecanoic acid	$C_{14}HF_{27}O_{2}$	376-06-7
PFTrDA	Perfluorotridecanoic acid	$C_{13}HF_{25}O_{2}$	72629-94-8
PFUnDA	Perfluoroundecanoic acid	$C_{11}HF_{21}O_{2}$	2058-94-8

CAS – Chemical abstract service number

Table 3: Total PFAS average, standard deviation, maximum, and minimum values for each fish species and sampling location.

Species	Sampling Location	Average (ng/gww)	Standard deviation (ng/gww)	Maximum (ng/gww)	Minimum (ng/gww)
Sunfish	Upstream Grills	161.2	165.8	342.1	3.5
Sunfish	Preserve Pond	268.1	119.3	441.5	121.5
Sunfish	Downstream	48.6	15.2	73.8	33.5
Chain pickerel	Upstream Grills	29.8	13.1	49.7	13.8
Chain pickerel	Preserve Pond	285.8	103.2	455.3	198.3
Chain pickerel	Downstream	34.0	11.5	53.3	24.2
Largemouth	Upstream Grills	NA	NA	NA	NA
Largemouth	Preserve Pond	561.0	449.8	1341.2	212.1
Largemouth	Downstream	45.4	17.4	70.5	9.1

*NA-no largemouth bass were collected upstream of Bradford Dyeing Association

ng/gww – nanograms PFAS per gram wet fish weight

Table 4. Age-specific exposure dose variables for fish consumption.

Exposure group	ATSDR body weight categories (kg)	CTE intake rate (g/day)*	RME intake rate (g/day)**
1-2 years	11.4	3	15
2-6 years	17.4	4	23
6-11 years	31.8	7	43
11-16 years	56.8	13	76
16-21 years	71.6	16	96
Adult	80.0	18	107

**The CTE fish meal size is ½ the fish meal size.
**RME intake rate was determined based on fish consumption guidance from the Minnesota Dept. of Health, Washington Dept. of Health, and Oregon Health Authority [106–108].

kg – kilograms; CTE – central tendency exposure; RME – reasonable maximum exposure; g/day – grams fish per day

Table 5: Dose (ng/kg/day) values for carboxylated PFAS compounds detected in sunfish under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	3.23E-02	0.00E+00	2.69E-02	5.23E-02	3.18E+00	1.80E+01	1.68E+01	3.16E+00	2.76E+01
Upstream	2-6	3.23E-02	0.00E+00	2.70E-02	5.24E-02	3.19E+00	1.80E+01	1.68E+01	3.17E+00	2.77E+01
Upstream	6-11	3.23E-02	0.00E+00	2.70E-02	5.24E-02	3.19E+00	1.80E+01	1.68E+01	3.16E+00	2.76E+01
Upstream	11-16	3.23E-02	0.00E+00	2.70E-02	5.24E-02	3.19E+00	1.80E+01	1.68E+01	3.16E+00	2.76E+01
Upstream	16-21	3.23E-02	0.00E+00	2.70E-02	5.24E-02	3.19E+00	1.80E+01	1.68E+01	3.17E+00	2.76E+01
Upstream	>21	3.23E-02	0.00E+00	2.70E-02	5.24E-02	3.19E+00	1.80E+01	1.68E+01	3.16E+00	2.76E+01
On site	1-2	3.47E-02	1.27E-02	2.74E-02	3.40E-02	3.65E+00	2.38E+01	1.92E+01	3.54E+00	3.12E+01
On site	2-6	3.48E-02	1.27E-02	2.74E-02	3.41E-02	3.66E+00	2.39E+01	1.92E+01	3.55E+00	3.12E+01
On site	6-11	3.48E-02	1.27E-02	2.74E-02	3.41E-02	3.65E+00	2.38E+01	1.92E+01	3.54E+00	3.12E+01
On site	11-16	3.48E-02	1.27E-02	2.74E-02	3.41E-02	3.65E+00	2.38E+01	1.92E+01	3.54E+00	3.12E+01
On site	16-21	3.48E-02	1.27E-02	2.74E-02	3.41E-02	3.66E+00	2.38E+01	1.92E+01	3.54E+00	3.12E+01
On site	>21	3.48E-02	1.27E-02	2.74E-02	3.41E-02	3.65E+00	2.38E+01	1.92E+01	3.54E+00	3.12E+01
Downstream	1-2	3.67E-02	0.00E+00	0.00E+00	4.34E-02	8.81E-01	2.07E+00	2.10E+00	2.04E+00	8.10E+00
Downstream	2-6	3.68E-02	0.00E+00	0.00E+00	4.35E-02	8.83E-01	2.08E+00	2.11E+00	2.04E+00	8.12E+00
Downstream	6-11	3.68E-02	0.00E+00	0.00E+00	4.34E-02	8.82E-01	2.07E+00	2.10E+00	2.04E+00	8.11E+00
Downstream	11-16	3.68E-02	0.00E+00	0.00E+00	4.34E-02	8.82E-01	2.07E+00	2.10E+00	2.04E+00	8.11E+00
Downstream	16-21	3.68E-02	0.00E+00	0.00E+00	4.35E-02	8.83E-01	2.08E+00	2.10E+00	2.04E+00	8.11E+00
Downstream	>21	3.68E-02	0.00E+00	0.00E+00	4.35E-02	8.83E-01	2.07E+00	2.10E+00	2.04E+00	8.11E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 6: Dose values (ng/kg/day) for sulfonated and total PFAS compounds detected in sunfish under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	Total
Upstream	1-2	0.00E+00	2.69E-02	1.01E+01	0.00E+00	3.03E-02	1.91E-02	4.56E-01	8.35E-01	2.34E-01	8.05E+01
Upstream	2-6	0.00E+00	2.70E-02	1.02E+01	0.00E+00	3.03E-02	1.92E-02	4.57E-01	8.36E-01	2.34E-01	8.07E+01
Upstream	6-11	0.00E+00	2.70E-02	1.02E+01	0.00E+00	3.03E-02	1.92E-02	4.57E-01	8.36E-01	2.34E-01	8.06E+01
Upstream	11-16	0.00E+00	2.70E-02	1.02E+01	0.00E+00	3.03E-02	1.92E-02	4.57E-01	8.35E-01	2.34E-01	8.06E+01
Upstream	16-21	0.00E+00	2.70E-02	1.02E+01	0.00E+00	3.03E-02	1.92E-02	4.57E-01	8.36E-01	2.34E-01	8.07E+01
Upstream	>21	0.00E+00	2.70E-02	1.02E+01	0.00E+00	3.03E-02	1.92E-02	4.57E-01	8.36E-01	2.34E-01	8.07E+01
On site	1-2	0.00E+00	2.74E-02	1.44E+01	0.00E+00	4.70E-02	1.01E-01	8.90E-01	1.17E+00	3.43E-01	9.85E+01
On site	2-6	0.00E+00	2.74E-02	1.45E+01	0.00E+00	4.71E-02	1.01E-01	8.92E-01	1.18E+00	3.44E-01	9.87E+01
On site	6-11	0.00E+00	2.74E-02	1.45E+01	0.00E+00	4.70E-02	1.01E-01	8.91E-01	1.17E+00	3.43E-01	9.86E+01
On site	11-16	0.00E+00	2.74E-02	1.45E+01	0.00E+00	4.70E-02	1.01E-01	8.91E-01	1.17E+00	3.43E-01	9.86E+01
On site	16-21	0.00E+00	2.74E-02	1.45E+01	0.00E+00	4.70E-02	1.01E-01	8.92E-01	1.17E+00	3.43E-01	9.86E+01
On site	>21	0.00E+00	2.74E-02	1.45E+01	0.00E+00	4.70E-02	1.01E-01	8.91E-01	1.17E+00	3.43E-01	9.86E+01
Downstream	1-2	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	4.56E-02	0.00E+00	1.50E-01	1.78E+01
Downstream	2-6	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	4.57E-02	0.00E+00	1.50E-01	1.78E+01
Downstream	6-11	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	4.57E-02	0.00E+00	1.50E-01	1.78E+01
Downstream	11-16	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	4.57E-02	0.00E+00	1.50E-01	1.78E+01
Downstream	16-21	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	4.57E-02	0.00E+00	1.50E-01	1.78E+01
Downstream	>21	0.00E+00	0.00E+00	2.34E+00	0.00E+00	0.00E+00	0.00E+00	4.57E-02	0.00E+00	1.50E-01	1.78E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 7: Dose (ng/kg/day) values for carboxylated PFAS compounds detected in sunfish under the RME consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	1.94E-01	0.00E+00	1.62E-01	3.14E-01	1.91E+01	1.08E+02	1.01E+02	1.90E+01	1.66E+02
Upstream	2-6	1.94E-01	0.00E+00	1.62E-01	3.15E-01	1.91E+01	1.08E+02	1.01E+02	1.90E+01	1.66E+02
Upstream	6-11	1.94E-01	0.00E+00	1.62E-01	3.14E-01	1.91E+01	1.08E+02	1.01E+02	1.90E+01	1.66E+02
Upstream	11-16	1.94E-01	0.00E+00	1.62E-01	3.14E-01	1.91E+01	1.08E+02	1.01E+02	1.90E+01	1.66E+02
Upstream	16-21	1.94E-01	0.00E+00	1.62E-01	3.14E-01	1.91E+01	1.08E+02	1.01E+02	1.90E+01	1.66E+02
Upstream	>21	1.94E-01	0.00E+00	1.62E-01	3.14E-01	1.91E+01	1.08E+02	1.01E+02	1.90E+01	1.66E+02
On site	1-2	2.08E-01	7.61E-02	1.64E-01	2.04E-01	2.19E+01	1.43E+02	1.15E+02	2.12E+01	1.87E+02
On site	2-6	2.09E-01	7.63E-02	1.65E-01	2.05E-01	2.19E+01	1.43E+02	1.15E+02	2.13E+01	1.87E+02
On site	6-11	2.09E-01	7.62E-02	1.64E-01	2.05E-01	2.19E+01	1.43E+02	1.15E+02	2.13E+01	1.87E+02
On site	11-16	2.09E-01	7.62E-02	1.64E-01	2.05E-01	2.19E+01	1.43E+02	1.15E+02	2.13E+01	1.87E+02
On site	16-21	2.09E-01	7.62E-02	1.64E-01	2.05E-01	2.19E+01	1.43E+02	1.15E+02	2.13E+01	1.87E+02
On site	>21	2.09E-01	7.62E-02	1.64E-01	2.05E-01	2.19E+01	1.43E+02	1.15E+02	2.13E+01	1.87E+02
Downstream	1-2	2.20E-01	0.00E+00	0.00E+00	2.60E-01	5.29E+00	1.24E+01	1.26E+01	1.22E+01	4.86E+01
Downstream	2-6	2.21E-01	0.00E+00	0.00E+00	2.61E-01	5.30E+00	1.25E+01	1.26E+01	1.22E+01	4.87E+01
Downstream	6-11	2.21E-01	0.00E+00	0.00E+00	2.61E-01	5.29E+00	1.24E+01	1.26E+01	1.22E+01	4.87E+01
Downstream	11-16	2.21E-01	0.00E+00	0.00E+00	2.61E-01	5.29E+00	1.24E+01	1.26E+01	1.22E+01	4.87E+01
Downstream	16-21	2.21E-01	0.00E+00	0.00E+00	2.61E-01	5.30E+00	1.25E+01	1.26E+01	1.22E+01	4.87E+01
Downstream	>21	2.21E-01	0.00E+00	0.00E+00	2.61E-01	5.30E+00	1.24E+01	1.26E+01	1.22E+01	4.87E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 8: Dose values (ng/kg/day) for sulfonated and total PFAS compounds detected in sunfish under the RME consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	Total
Upstream	1-2	0.00E+00	1.62E-01	6.09E+01	0.00E+00	1.82E-01	1.15E-01	2.74E+00	5.01E+00	1.40E+00	4.83E+02
Upstream	2-6	0.00E+00	1.62E-01	6.10E+01	0.00E+00	1.82E-01	1.15E-01	2.74E+00	5.02E+00	1.41E+00	4.84E+02
Upstream	6-11	0.00E+00	1.62E-01	6.10E+01	0.00E+00	1.82E-01	1.15E-01	2.74E+00	5.01E+00	1.40E+00	4.84E+02
Upstream	11-16	0.00E+00	1.62E-01	6.10E+01	0.00E+00	1.82E-01	1.15E-01	2.74E+00	5.01E+00	1.40E+00	4.84E+02
Upstream	16-21	0.00E+00	1.62E-01	6.10E+01	0.00E+00	1.82E-01	1.15E-01	2.74E+00	5.02E+00	1.40E+00	4.84E+02
Upstream	>21	0.00E+00	1.62E-01	6.10E+01	0.00E+00	1.82E-01	1.15E-01	2.74E+00	5.01E+00	1.40E+00	4.84E+02
On site	1-2	0.00E+00	1.64E-01	8.67E+01	0.00E+00	2.82E-01	6.05E-01	5.34E+00	7.04E+00	2.06E+00	5.91E+02
On site	2-6	0.00E+00	1.65E-01	8.69E+01	0.00E+00	2.82E-01	6.06E-01	5.35E+00	7.05E+00	2.06E+00	5.92E+02
On site	6-11	0.00E+00	1.64E-01	8.68E+01	0.00E+00	2.82E-01	6.06E-01	5.35E+00	7.05E+00	2.06E+00	5.92E+02
On site	11-16	0.00E+00	1.64E-01	8.68E+01	0.00E+00	2.82E-01	6.06E-01	5.35E+00	7.04E+00	2.06E+00	5.91E+02
On site	16-21	0.00E+00	1.64E-01	8.68E+01	0.00E+00	2.82E-01	6.06E-01	5.35E+00	7.05E+00	2.06E+00	5.92E+02
On site	>21	0.00E+00	1.64E-01	8.68E+01	0.00E+00	2.82E-01	6.06E-01	5.35E+00	7.05E+00	2.06E+00	5.92E+02
Downstream	1-2	0.00E+00	0.00E+00	1.40E+01	0.00E+00	0.00E+00	0.00E+00	2.74E-01	0.00E+00	8.99E-01	1.07E+02
Downstream	2-6	0.00E+00	0.00E+00	1.41E+01	0.00E+00	0.00E+00	0.00E+00	2.74E-01	0.00E+00	9.01E-01	1.07E+02
Downstream	6-11	0.00E+00	0.00E+00	1.40E+01	0.00E+00	0.00E+00	0.00E+00	2.74E-01	0.00E+00	9.00E-01	1.07E+02
Downstream	11-16	0.00E+00	0.00E+00	1.40E+01	0.00E+00	0.00E+00	0.00E+00	2.74E-01	0.00E+00	9.00E-01	1.07E+02
Downstream	16-21	0.00E+00	0.00E+00	1.40E+01	0.00E+00	0.00E+00	0.00E+00	2.74E-01	0.00E+00	9.00E-01	1.07E+02
Downstream	>21	0.00E+00	0.00E+00	1.40E+01	0.00E+00	0.00E+00	0.00E+00	2.74E-01	0.00E+00	9.00E-01	1.07E+02

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 9: Dose (ng/kg/day) values for carboxylated PFAS compounds detected in chain pickerel under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	8.23E-02	0.00E+00	0.00E+00	3.58E-02	9.64E-01	2.85E+00	1.40E+00	6.88E-01	3.27E+00
Upstream	2-6	8.25E-02	0.00E+00	0.00E+00	3.59E-02	9.66E-01	2.86E+00	1.40E+00	6.89E-01	3.28E+00
Upstream	6-11	8.24E-02	0.00E+00	0.00E+00	3.59E-02	9.65E-01	2.85E+00	1.40E+00	6.88E-01	3.28E+00
Upstream	11-16	8.24E-02	0.00E+00	0.00E+00	3.59E-02	9.65E-01	2.85E+00	1.40E+00	6.88E-01	3.27E+00
Upstream	16-21	8.25E-02	0.00E+00	0.00E+00	3.59E-02	9.65E-01	2.85E+00	1.40E+00	6.89E-01	3.28E+00
Upstream	>21	8.25E-02	0.00E+00	0.00E+00	3.59E-02	9.65E-01	2.85E+00	1.40E+00	6.89E-01	3.28E+00
On site	1-2	2.89E-02	0.00E+00	2.98E-02	5.01E-02	3.52E+00	2.13E+01	1.68E+01	4.07E+00	3.40E+01
On site	2-6	2.90E-02	0.00E+00	2.99E-02	5.02E-02	3.52E+00	2.14E+01	1.68E+01	4.08E+00	3.41E+01
On site	6-11	2.90E-02	0.00E+00	2.99E-02	5.01E-02	3.52E+00	2.13E+01	1.68E+01	4.08E+00	3.41E+01
On site	11-16	2.90E-02	0.00E+00	2.99E-02	5.01E-02	3.52E+00	2.13E+01	1.68E+01	4.08E+00	3.41E+01
On site	16-21	2.90E-02	0.00E+00	2.99E-02	5.02E-02	3.52E+00	2.14E+01	1.68E+01	4.08E+00	3.41E+01
On site	>21	2.90E-02	0.00E+00	2.99E-02	5.01E-02	3.52E+00	2.14E+01	1.68E+01	4.08E+00	3.41E+01
Downstream	1-2	3.58E-02	0.00E+00	0.00E+00	2.45E-02	7.05E-01	1.79E+00	1.39E+00	6.65E-01	4.92E+00
Downstream	2-6	3.59E-02	0.00E+00	0.00E+00	2.45E-02	7.07E-01	1.79E+00	1.39E+00	6.67E-01	4.93E+00
Downstream	6-11	3.59E-02	0.00E+00	0.00E+00	2.45E-02	7.06E-01	1.79E+00	1.39E+00	6.66E-01	4.92E+00
Downstream	11-16	3.59E-02	0.00E+00	0.00E+00	2.45E-02	7.06E-01	1.79E+00	1.39E+00	6.66E-01	4.92E+00
Downstream	16-21	3.59E-02	0.00E+00	0.00E+00	2.45E-02	7.07E-01	1.79E+00	1.39E+00	6.66E-01	4.93E+00
Downstream	>21	3.59E-02	0.00E+00	0.00E+00	2.45E-02	7.06E-01	1.79E+00	1.39E+00	6.66E-01	4.93E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 10: Dose values (ng/kg/day) for sulfonated and total PFAS compounds detected in chain pickerel under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	Total
Upstream	1-2	0.00E+00	0.00E+00	1.94E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-01	1.29E-01	1.75E-01	1.19E+01
Upstream	2-6	0.00E+00	0.00E+00	1.95E+00	0.00E+00	0.00E+00	0.00E+00	3.44E-01	1.29E-01	1.76E-01	1.19E+01
Upstream	6-11	0.00E+00	0.00E+00	1.94E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-01	1.29E-01	1.76E-01	1.19E+01
Upstream	11-16	0.00E+00	0.00E+00	1.94E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-01	1.29E-01	1.76E-01	1.19E+01
Upstream	16-21	0.00E+00	0.00E+00	1.94E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-01	1.29E-01	1.76E-01	1.19E+01
Upstream	>21	0.00E+00	0.00E+00	1.94E+00	0.00E+00	0.00E+00	0.00E+00	3.43E-01	1.29E-01	1.76E-01	1.19E+01
On site	1-2	0.00E+00	2.98E-02	1.10E+01	3.83E-02	5.23E-02	0.00E+00	9.21E+00	1.44E+00	2.54E-01	1.02E+02
On site	2-6	0.00E+00	2.99E-02	1.11E+01	3.84E-02	5.24E-02	0.00E+00	9.23E+00	1.45E+00	2.54E-01	1.02E+02
On site	6-11	0.00E+00	2.99E-02	1.11E+01	3.83E-02	5.24E-02	0.00E+00	9.22E+00	1.45E+00	2.54E-01	1.02E+02
On site	11-16	0.00E+00	2.99E-02	1.11E+01	3.83E-02	5.24E-02	0.00E+00	9.22E+00	1.45E+00	2.54E-01	1.02E+02
On site	16-21	0.00E+00	2.99E-02	1.11E+01	3.83E-02	5.24E-02	0.00E+00	9.23E+00	1.45E+00	2.54E-01	1.02E+02
On site	>21	0.00E+00	2.99E-02	1.11E+01	3.83E-02	5.24E-02	0.00E+00	9.23E+00	1.45E+00	2.54E-01	1.02E+02
Downstream	1-2	0.00E+00	0.00E+00	1.70E+00	0.00E+00	0.00E+00	0.00E+00	5.94E-01	3.81E-02	9.50E-02	1.19E+01
Downstream	2-6	0.00E+00	0.00E+00	1.70E+00	0.00E+00	0.00E+00	0.00E+00	5.96E-01	3.81E-02	9.52E-02	1.20E+01
Downstream	6-11	0.00E+00	0.00E+00	1.70E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-01	3.81E-02	9.51E-02	1.20E+01
Downstream	11-16	0.00E+00	0.00E+00	1.70E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-01	3.81E-02	9.51E-02	1.20E+01
Downstream	16-21	0.00E+00	0.00E+00	1.70E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-01	3.81E-02	9.52E-02	1.20E+01
Downstream	>21	0.00E+00	0.00E+00	1.70E+00	0.00E+00	0.00E+00	0.00E+00	5.95E-01	3.81E-02	9.52E-02	1.20E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 11: Dose (ng/kg/day) values for carboxylated PFAS compounds detected in chain pickerel under the RME consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	4.94E-01	0.00E+00	0.00E+00	2.15E-01	5.78E+00	1.71E+01	8.40E+00	4.13E+00	1.96E+01
Upstream	2-6	4.95E-01	0.00E+00	0.00E+00	2.15E-01	5.79E+00	1.71E+01	8.42E+00	4.14E+00	1.97E+01
Upstream	6-11	4.95E-01	0.00E+00	0.00E+00	2.15E-01	5.79E+00	1.71E+01	8.41E+00	4.13E+00	1.97E+01
Upstream	11-16	4.95E-01	0.00E+00	0.00E+00	2.15E-01	5.79E+00	1.71E+01	8.41E+00	4.13E+00	1.96E+01
Upstream	16-21	4.95E-01	0.00E+00	0.00E+00	2.15E-01	5.79E+00	1.71E+01	8.41E+00	4.13E+00	1.97E+01
Upstream	>21	4.95E-01	0.00E+00	0.00E+00	2.15E-01	5.79E+00	1.71E+01	8.41E+00	4.13E+00	1.97E+01
On site	1-2	1.74E-01	0.00E+00	1.79E-01	3.00E-01	2.11E+01	1.28E+02	1.01E+02	2.44E+01	2.04E+02
On site	2-6	1.74E-01	0.00E+00	1.79E-01	3.01E-01	2.11E+01	1.28E+02	1.01E+02	2.45E+01	2.05E+02
On site	6-11	1.74E-01	0.00E+00	1.79E-01	3.01E-01	2.11E+01	1.28E+02	1.01E+02	2.45E+01	2.05E+02
On site	11-16	1.74E-01	0.00E+00	1.79E-01	3.01E-01	2.11E+01	1.28E+02	1.01E+02	2.45E+01	2.05E+02
On site	16-21	1.74E-01	0.00E+00	1.79E-01	3.01E-01	2.11E+01	1.28E+02	1.01E+02	2.45E+01	2.05E+02
On site	>21	1.74E-01	0.00E+00	1.79E-01	3.01E-01	2.11E+01	1.28E+02	1.01E+02	2.45E+01	2.05E+02
Downstream	1-2	2.15E-01	0.00E+00	0.00E+00	1.47E-01	4.23E+00	1.07E+01	8.33E+00	3.99E+00	2.95E+01
Downstream	2-6	2.15E-01	0.00E+00	0.00E+00	1.47E-01	4.24E+00	1.08E+01	8.35E+00	4.00E+00	2.96E+01
Downstream	6-11	2.15E-01	0.00E+00	0.00E+00	1.47E-01	4.24E+00	1.07E+01	8.34E+00	4.00E+00	2.95E+01
Downstream	11-16	2.15E-01	0.00E+00	0.00E+00	1.47E-01	4.24E+00	1.07E+01	8.34E+00	4.00E+00	2.95E+01
Downstream	16-21	2.15E-01	0.00E+00	0.00E+00	1.47E-01	4.24E+00	1.08E+01	8.35E+00	4.00E+00	2.96E+01
Downstream	>21	2.15E-01	0.00E+00	0.00E+00	1.47E-01	4.24E+00	1.08E+01	8.34E+00	4.00E+00	2.96E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 12: Dose values (ng/kg/day) for sulfonated and total PFAS compounds detected in chain pickerel under the RME consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	Total
Upstream	1-2	0.00E+00	0.00E+00	1.16E+01	0.00E+00	0.00E+00	0.00E+00	2.06E+00	7.73E-01	1.05E+00	7.13E+01
Upstream	2-6	0.00E+00	0.00E+00	1.17E+01	0.00E+00	0.00E+00	0.00E+00	2.06E+00	7.75E-01	1.05E+00	7.14E+01
Upstream	6-11	0.00E+00	0.00E+00	1.17E+01	0.00E+00	0.00E+00	0.00E+00	2.06E+00	7.74E-01	1.05E+00	7.13E+01
Upstream	11-16	0.00E+00	0.00E+00	1.17E+01	0.00E+00	0.00E+00	0.00E+00	2.06E+00	7.74E-01	1.05E+00	7.13E+01
Upstream	16-21	0.00E+00	0.00E+00	1.17E+01	0.00E+00	0.00E+00	0.00E+00	2.06E+00	7.74E-01	1.05E+00	7.14E+01
Upstream	>21	0.00E+00	0.00E+00	1.17E+01	0.00E+00	0.00E+00	0.00E+00	2.06E+00	7.74E-01	1.05E+00	7.14E+01
On site	1-2	0.00E+00	1.79E-01	6.62E+01	2.30E-01	3.14E-01	0.00E+00	5.53E+01	8.67E+00	1.52E+00	6.11E+02
On site	2-6	0.00E+00	1.79E-01	6.64E+01	2.30E-01	3.15E-01	0.00E+00	5.54E+01	8.69E+00	1.53E+00	6.13E+02
On site	6-11	0.00E+00	1.79E-01	6.63E+01	2.30E-01	3.14E-01	0.00E+00	5.53E+01	8.68E+00	1.52E+00	6.12E+02
On site	11-16	0.00E+00	1.79E-01	6.63E+01	2.30E-01	3.14E-01	0.00E+00	5.53E+01	8.68E+00	1.52E+00	6.12E+02
On site	16-21	0.00E+00	1.79E-01	6.63E+01	2.30E-01	3.14E-01	0.00E+00	5.54E+01	8.68E+00	1.52E+00	6.12E+02
On site	>21	0.00E+00	1.79E-01	6.63E+01	2.30E-01	3.14E-01	0.00E+00	5.54E+01	8.68E+00	1.52E+00	6.12E+02
Downstream	1-2	0.00E+00	0.00E+00	1.02E+01	0.00E+00	0.00E+00	0.00E+00	3.57E+00	2.28E-01	5.70E-01	7.17E+01
Downstream	2-6	0.00E+00	0.00E+00	1.02E+01	0.00E+00	0.00E+00	0.00E+00	3.57E+00	2.29E-01	5.71E-01	7.19E+01
Downstream	6-11	0.00E+00	0.00E+00	1.02E+01	0.00E+00	0.00E+00	0.00E+00	3.57E+00	2.29E-01	5.71E-01	7.18E+01
Downstream	11-16	0.00E+00	0.00E+00	1.02E+01	0.00E+00	0.00E+00	0.00E+00	3.57E+00	2.29E-01	5.71E-01	7.18E+01
Downstream	16-21	0.00E+00	0.00E+00	1.02E+01	0.00E+00	0.00E+00	0.00E+00	3.57E+00	2.29E-01	5.71E-01	7.18E+01
Downstream	>21	0.00E+00	0.00E+00	1.02E+01	0.00E+00	0.00E+00	0.00E+00	3.57E+00	2.29E-01	5.71E-01	7.18E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 13: Dose (ng/kg/day) values for carboxylated PFAS compounds detected in largemouth bass under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA
On site	1-2	2.45E-02	0.00E+00	1.70E-01	8.81E-02	1.24E+01	7.70E+01	4.67E+01	9.72E+00	7.41E+01
On site	2-6	2.45E-02	0.00E+00	1.71E-01	8.83E-02	1.25E+01	7.72E+01	4.68E+01	9.75E+00	7.43E+01
On site	6-11	2.45E-02	0.00E+00	1.70E-01	8.82E-02	1.25E+01	7.71E+01	4.68E+01	9.74E+00	7.42E+01
On site	11-16	2.45E-02	0.00E+00	1.70E-01	8.82E-02	1.25E+01	7.71E+01	4.68E+01	9.74E+00	7.42E+01
On site	16-21	2.45E-02	0.00E+00	1.71E-01	8.83E-02	1.25E+01	7.71E+01	4.68E+01	9.74E+00	7.42E+01
On site	>21	2.45E-02	0.00E+00	1.70E-01	8.83E-02	1.25E+01	7.71E+01	4.68E+01	9.74E+00	7.42E+01
Downstream	1-2	2.70E-02	0.00E+00	0.00E+00	0.00E+00	9.49E-01	2.70E+00	1.79E+00	8.76E-01	5.09E+00
Downstream	2-6	2.71E-02	0.00E+00	0.00E+00	0.00E+00	9.51E-01	2.71E+00	1.79E+00	8.78E-01	5.10E+00
Downstream	6-11	2.71E-02	0.00E+00	0.00E+00	0.00E+00	9.50E-01	2.70E+00	1.79E+00	8.77E-01	5.09E+00
Downstream	11-16	2.71E-02	0.00E+00	0.00E+00	0.00E+00	9.50E-01	2.70E+00	1.79E+00	8.77E-01	5.09E+00
Downstream	16-21	2.71E-02	0.00E+00	0.00E+00	0.00E+00	9.51E-01	2.70E+00	1.79E+00	8.78E-01	5.09E+00
Downstream	>21	2.71E-02	0.00E+00	0.00E+00	0.00E+00	9.51E-01	2.70E+00	1.79E+00	8.78E-01	5.09E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 14: Dose values (ng/kg/day) for sulfonated and total PFAS compounds detected in largemouth bass under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	Total
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
On site	1-2	2.63E-02	1.70E-01	7.30E+01	4.09E-01	2.15E-01	5.67E-02	8.81E-01	2.54E+00	9.68E-01	2.99E+02
On site	2-6	2.63E-02	1.71E-01	7.32E+01	4.10E-01	2.15E-01	5.69E-02	8.83E-01	2.54E+00	9.70E-01	2.99E+02
On site	6-11	2.63E-02	1.70E-01	7.31E+01	4.10E-01	2.15E-01	5.68E-02	8.82E-01	2.54E+00	9.69E-01	2.99E+02
On site	11-16	2.63E-02	1.70E-01	7.31E+01	4.10E-01	2.15E-01	5.68E-02	8.82E-01	2.54E+00	9.69E-01	2.99E+02
On site	16-21	2.63E-02	1.71E-01	7.31E+01	4.10E-01	2.15E-01	5.68E-02	8.83E-01	2.54E+00	9.70E-01	2.99E+02
On site	>21	2.63E-02	1.70E-01	7.31E+01	4.10E-01	2.15E-01	5.68E-02	8.83E-01	2.54E+00	9.69E-01	2.99E+02
Downstream	1-2	0.00E+00	0.00E+00	2.17E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E-02	0.00E+00	1.36E+01
Downstream	2-6	0.00E+00	0.00E+00	2.18E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-02	0.00E+00	1.37E+01
Downstream	6-11	0.00E+00	0.00E+00	2.18E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-02	0.00E+00	1.37E+01
Downstream	11-16	0.00E+00	0.00E+00	2.18E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-02	0.00E+00	1.37E+01
Downstream	16-21	0.00E+00	0.00E+00	2.18E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-02	0.00E+00	1.37E+01
Downstream	>21	0.00E+00	0.00E+00	2.18E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-02	0.00E+00	1.37E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).
***No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 15: Dose (ng/kg/day) values for carboxylated PFAS compounds detected in largemouth bass under the RME consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA
On site	1-2	1.47E-01	0.00E+00	1.02E+00	5.29E-01	7.46E+01	4.62E+02	2.80E+02	5.83E+01	4.45E+02
On site	2-6	1.47E-01	0.00E+00	1.02E+00	5.30E-01	7.48E+01	4.63E+02	2.81E+02	5.85E+01	4.46E+02
On site	6-11	1.47E-01	0.00E+00	1.02E+00	5.29E-01	7.47E+01	4.63E+02	2.81E+02	5.84E+01	4.45E+02
On site	11-16	1.47E-01	0.00E+00	1.02E+00	5.29E-01	7.47E+01	4.63E+02	2.81E+02	5.84E+01	4.45E+02
On site	16-21	1.47E-01	0.00E+00	1.02E+00	5.30E-01	7.48E+01	4.63E+02	2.81E+02	5.84E+01	4.45E+02
On site	>21	1.47E-01	0.00E+00	1.02E+00	5.30E-01	7.47E+01	4.63E+02	2.81E+02	5.84E+01	4.45E+02
Downstream	1-2	1.62E-01	0.00E+00	0.00E+00	0.00E+00	5.69E+00	1.62E+01	1.07E+01	5.26E+00	3.05E+01
Downstream	2-6	1.63E-01	0.00E+00	0.00E+00	0.00E+00	5.71E+00	1.62E+01	1.08E+01	5.27E+00	3.06E+01
Downstream	6-11	1.62E-01	0.00E+00	0.00E+00	0.00E+00	5.70E+00	1.62E+01	1.07E+01	5.26E+00	3.05E+01
Downstream	11-16	1.62E-01	0.00E+00	0.00E+00	0.00E+00	5.70E+00	1.62E+01	1.07E+01	5.26E+00	3.05E+01
Downstream	16-21	1.62E-01	0.00E+00	0.00E+00	0.00E+00	5.70E+00	1.62E+01	1.08E+01	5.27E+00	3.06E+01
Downstream	>21	1.62E-01	0.00E+00	0.00E+00	0.00E+00	5.70E+00	1.62E+01	1.08E+01	5.27E+00	3.06E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**NA – not applicable. No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 16: Dose values (ng/kg/day) for sulfonated and total PFAS compounds detected in largemouth bass under the RME consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	Total
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
On site	1-2	1.58E-01	1.02E+00	4.38E+02	2.46E+00	1.29E+00	3.40E-01	5.29E+00	1.52E+01	5.81E+00	1.79E+03
On site	2-6	1.58E-01	1.02E+00	4.39E+02	2.46E+00	1.29E+00	3.41E-01	5.30E+00	1.53E+01	5.82E+00	1.80E+03
On site	6-11	1.58E-01	1.02E+00	4.38E+02	2.46E+00	1.29E+00	3.41E-01	5.29E+00	1.52E+01	5.82E+00	1.79E+03
On site	11-16	1.58E-01	1.02E+00	4.38E+02	2.46E+00	1.29E+00	3.41E-01	5.29E+00	1.52E+01	5.81E+00	1.79E+03
On site	16-21	1.58E-01	1.02E+00	4.39E+02	2.46E+00	1.29E+00	3.41E-01	5.30E+00	1.52E+01	5.82E+00	1.79E+03
On site	>21	1.58E-01	1.02E+00	4.39E+02	2.46E+00	1.29E+00	3.41E-01	5.30E+00	1.52E+01	5.82E+00	1.79E+03
Downstream	1-2	0.00E+00	0.00E+00	1.30E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-01	0.00E+00	8.19E+01
Downstream	2-6	0.00E+00	0.00E+00	1.31E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.68E-01	0.00E+00	8.21E+01
Downstream	6-11	0.00E+00	0.00E+00	1.31E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-01	0.00E+00	8.20E+01
Downstream	11-16	0.00E+00	0.00E+00	1.31E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-01	0.00E+00	8.20E+01
Downstream	16-21	0.00E+00	0.00E+00	1.31E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-01	0.00E+00	8.20E+01
Downstream	>21	0.00E+00	0.00E+00	1.31E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-01	0.00E+00	8.20E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).
***NA-Not applicable. No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

ng/kg/day – nanograms PFAS per kilogram body weight per day

Table 17: Reference doses (RfDs, ng/kg/day) used to calculate HQs.[26,31–33,38,128,141–148] Group numbers indicate grouping for read across.

Compound Name	Group #	Carbon chain length	**USEPA**	**ATSDR**	**New Jersey Department of Health**	**Texas Council for Environmental Quality**	**Zeilmaker et al 2018**	**Michigan Department of Health & Human Services**	**Hawai'i Department of Health**	**Wisconsin Department of Health Services**
PFBA	1	4	1000.0			1000	400		3800	1000
PFPeA*	1	5				500	400		400	
PFHxA	1	6	500.0			500	2000	8300000	2000	15000
PFHpA	2	7				23	20.0		20	
PFOA*	2	8	0.03		1.8	12	20.0	3.9	20	
PFNA	2	9		3.0	0.74	12	2	2.2	2.2	3
PFDA	2	10	0.002			15	2.0		2	30
PF UnDA	2	11			1.3	12.0	5		5	300
PF DoDA	2	12				12.0	6.7		6.7	50
PF TeDA	2	14				12	67.0		67	30
PF TrDA	2	13				12.0			6.7	
PFBS*	3	4	3000			1400.0		300	300	45000
PFPeS*	3	5								-
PFHxS	3	6		20.0		3.8	33	9.7	9.7	4
4:2 FTS*	3	6								-
PFHpS	4	7					10.0		10	-
PFOS	4	8	0.1	2.0	1.8	23	10	2.9	20	
PFNS	4	9								
PFDS	4	10				12	10.0		10	
6:2 FtS	4	8								-
8:2 FtS*	4	10								-
FOSA	4	8				12.0			12	
N-Et FOSAA	4	12								
N-Me FOSAA	4	11								

Table 18: Reference doses (RfDs, ng/kg/day) used to calculate HQs (continued).[26,31–33,38,128,141–148] Group numbers indicate grouping for read across.

Compound Name	Group #	Carbon chain length	**Minnesota Department of Health**	**New Hampshire**	**Washington State**	**California**	**Selected RfD****
PFBA	1	4	3800				400.0
PFPeA*	1	5					400.0
PFHxA	1	6					500.0
PFHpA	2	7					20.0
PFOA*	2	8		6.1		20	0.03
PFNA	2	9		4.3			0.7
PFDA	2	10					2.0
PF UnDA	2	11					1.3
PF DoDA	2	12					6.7
PF TeDA	2	14					12.0
PF TrDA	2	13					6.7
PFBS*	3	4					300.0
PFPeS*	3	5					3.8
PFHxS	3	6	9.7	4			3.8
4:2 FTS*	3	6					**3.8**
PFHpS	4	7					10.0
PFOS	4	8	3.1	3	3	30	1.8
PFNS	4	9					**10.0**
PFDS	4	10					10.0
6:2 FtS	4	8					**10.0**
8:2 FtS*	4	10					**10.0**
FOSA	4	8					12.0
N-Et FOSAA	4	12					**10.0**
N-Me FOSAA	4	11					**10.0**

*Compounds marked with an asterisk (*) were detected at less than the method detection limit in every sample.

**Reference doses shown in bold were established using read across. If a reference dose could not be established through a literature search, it was supplied by read across using a member of the same group. PFAS were grouped based on structure (carboxylic short/long chain and sulfonic short/long chain).

4:2-FTS - 4:2 fluorotelomer sulfonic acid; 6:2-FTS - 6:2 fluorotelomer sulfonic acid; 8:2-FTS - 8:2 fluorotelomer sulfonic acid; FOSA - Perfluorooctanesulfonamide; N-EtFOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-MeFOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid; PFBA - Perfluorobutanoic acid; PFBS - Perfluorobutane sulfonic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFDS - Perfluorodecane sulfonic acid; PFHpA - Perfluoroheptanoic acid; PFHpS - Perfluoroheptane sulfonic acid; PFHxA - Perfluorohexanoic acid; PFHxS - Perfluorohexane sulfonic acid; PFNA - Perfluorononanoic acid;PFNS - Perfluorononane sulfonic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFPeA - Perfluoropentanoic acid; PFPeS - Perfluoropentane sulfonic acid; PFTeDA - Perfluorotetradecanoic acid; PFTrDA - Perfluorotridecanoic acid; PFUnDA - Perfluoroundecanoic acid; ng/kg/day – nanograms PFAS per kilograms body weight per day; RfD – reference dose; USEPA – Environmental Protection Agency; ATSDR – Agency for Toxic Substances and Disease Registry.

Table 19: Hazard quotients for carboxylated PFAS compounds in sunfish under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	8.07E-05	0.00E+00	1.35E-03	7.07E-02	1.59E+00	1.38E+01	2.50E+00	2.63E-01	4.12E+00
Upstream	2-6	8.09E-05	0.00E+00	1.35E-03	7.08E-02	1.59E+00	1.38E+01	2.51E+00	2.64E-01	4.13E+00
Upstream	6-11	8.08E-05	0.00E+00	1.35E-03	7.08E-02	1.59E+00	1.38E+01	2.51E+00	2.64E-01	4.12E+00
Upstream	11-16	8.08E-05	0.00E+00	1.35E-03	7.07E-02	1.59E+00	1.38E+01	2.51E+00	2.64E-01	4.12E+00
Upstream	16-21	8.08E-05	0.00E+00	1.35E-03	7.08E-02	1.59E+00	1.38E+01	2.51E+00	2.64E-01	4.13E+00
Upstream	>21	8.08E-05	0.00E+00	1.35E-03	7.08E-02	1.59E+00	1.38E+01	2.51E+00	2.64E-01	4.12E+00
On site	1-2	8.68E-05	2.54E-05	1.37E-03	4.60E-02	1.82E+00	1.83E+01	2.86E+00	2.95E-01	4.65E+00
On site	2-6	8.70E-05	2.54E-05	1.37E-03	4.61E-02	1.83E+00	1.84E+01	2.87E+00	2.96E-01	4.66E+00
On site	6-11	8.69E-05	2.54E-05	1.37E-03	4.61E-02	1.83E+00	1.83E+01	2.87E+00	2.95E-01	4.66E+00
On site	11-16	8.69E-05	2.54E-05	1.37E-03	4.61E-02	1.83E+00	1.83E+01	2.87E+00	2.95E-01	4.66E+00
On site	16-21	8.69E-05	2.54E-05	1.37E-03	4.61E-02	1.83E+00	1.83E+01	2.87E+00	2.95E-01	4.66E+00
On site	>21	8.69E-05	2.54E-05	1.37E-03	4.61E-02	1.83E+00	1.83E+01	2.87E+00	2.95E-01	4.66E+00
Downstream	1-2	9.18E-05	0.00E+00	0.00E+00	5.86E-02	4.41E-01	1.59E+00	3.14E-01	1.70E-01	1.21E+00
Downstream	2-6	9.20E-05	0.00E+00	0.00E+00	5.88E-02	4.42E-01	1.60E+00	3.14E-01	1.70E-01	1.21E+00
Downstream	6-11	9.19E-05	0.00E+00	0.00E+00	5.87E-02	4.41E-01	1.60E+00	3.14E-01	1.70E-01	1.21E+00
Downstream	11-16	9.19E-05	0.00E+00	0.00E+00	5.87E-02	4.41E-01	1.60E+00	3.14E-01	1.70E-01	1.21E+00
Downstream	16-21	9.19E-05	0.00E+00	0.00E+00	5.87E-02	4.41E-01	1.60E+00	3.14E-01	1.70E-01	1.21E+00
Downstream	>21	9.19E-05	0.00E+00	0.00E+00	5.87E-02	4.41E-01	1.60E+00	3.14E-01	1.70E-01	1.21E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

Table 20: Hazard quotients for sulfonated PFAS and hazard indices for the mixture detected in sunfish under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	HI
Upstream	1-2	0.00E+00	2.69E-03	5.64E+00	0.00E+00	3.03E-03	5.04E-03	3.80E-02	8.35E-02	2.34E-02	2.82E+01
Upstream	2-6	0.00E+00	2.70E-03	5.65E+00	0.00E+00	3.03E-03	5.05E-03	3.81E-02	8.36E-02	2.34E-02	2.82E+01
Upstream	6-11	0.00E+00	2.70E-03	5.64E+00	0.00E+00	3.03E-03	5.04E-03	3.81E-02	8.36E-02	2.34E-02	2.82E+01
Upstream	11-16	0.00E+00	2.70E-03	5.64E+00	0.00E+00	3.03E-03	5.04E-03	3.81E-02	8.35E-02	2.34E-02	2.82E+01
Upstream	16-21	0.00E+00	2.70E-03	5.65E+00	0.00E+00	3.03E-03	5.04E-03	3.81E-02	8.36E-02	2.34E-02	2.82E+01
Upstream	>21	0.00E+00	2.70E-03	5.65E+00	0.00E+00	3.03E-03	5.04E-03	3.81E-02	8.36E-02	2.34E-02	2.82E+01
On site	1-2	0.00E+00	2.74E-03	8.02E+00	0.00E+00	4.70E-03	2.65E-02	7.42E-02	1.17E-01	3.43E-02	3.63E+01
On site	2-6	0.00E+00	2.74E-03	8.04E+00	0.00E+00	4.71E-03	2.66E-02	7.44E-02	1.18E-01	3.44E-02	3.64E+01
On site	6-11	0.00E+00	2.74E-03	8.03E+00	0.00E+00	4.70E-03	2.66E-02	7.43E-02	1.17E-01	3.43E-02	3.63E+01
On site	11-16	0.00E+00	2.74E-03	8.03E+00	0.00E+00	4.70E-03	2.66E-02	7.43E-02	1.17E-01	3.43E-02	3.63E+01
On site	16-21	0.00E+00	2.74E-03	8.04E+00	0.00E+00	4.70E-03	2.66E-02	7.43E-02	1.17E-01	3.43E-02	3.63E+01
On site	>21	0.00E+00	2.74E-03	8.04E+00	0.00E+00	4.70E-03	2.66E-02	7.43E-02	1.17E-01	3.43E-02	3.63E+01
Downstream	1-2	0.00E+00	0.00E+00	1.30E+00	0.00E+00	0.00E+00	0.00E+00	3.80E-03	0.00E+00	1.50E-02	5.10E+00
Downstream	2-6	0.00E+00	0.00E+00	1.30E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-03	0.00E+00	1.50E-02	5.11E+00
Downstream	6-11	0.00E+00	0.00E+00	1.30E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-03	0.00E+00	1.50E-02	5.11E+00
Downstream	11-16	0.00E+00	0.00E+00	1.30E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-03	0.00E+00	1.50E-02	5.11E+00
Downstream	16-21	0.00E+00	0.00E+00	1.30E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-03	0.00E+00	1.50E-02	5.11E+00
Downstream	>21	0.00E+00	0.00E+00	1.30E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-03	0.00E+00	1.50E-02	5.11E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**HIs are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

Table 21: Hazard quotients for carboxylated PFAS compounds in sunfish under the RME consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	4.84E-04	0.00E+00	8.08E-03	4.24E-01	9.55E+00	8.29E+01	1.50E+01	1.58E+00	2.47E+01
Upstream	2-6	4.85E-04	0.00E+00	8.10E-03	4.25E-01	9.57E+00	8.31E+01	1.51E+01	1.58E+00	2.48E+01
Upstream	6-11	4.85E-04	0.00E+00	8.09E-03	4.25E-01	9.56E+00	8.30E+01	1.50E+01	1.58E+00	2.47E+01
Upstream	11-16	4.85E-04	0.00E+00	8.09E-03	4.24E-01	9.56E+00	8.30E+01	1.50E+01	1.58E+00	2.47E+01
Upstream	16-21	4.85E-04	0.00E+00	8.09E-03	4.25E-01	9.56E+00	8.30E+01	1.51E+01	1.58E+00	2.48E+01
Upstream	>21	4.85E-04	0.00E+00	8.09E-03	4.25E-01	9.56E+00	8.30E+01	1.50E+01	1.58E+00	2.47E+01
On site	1-2	5.21E-04	1.52E-04	8.21E-03	2.76E-01	1.09E+01	1.10E+02	1.72E+01	1.77E+00	2.79E+01
On site	2-6	5.22E-04	1.53E-04	8.23E-03	2.77E-01	1.10E+01	1.10E+02	1.72E+01	1.77E+00	2.80E+01
On site	6-11	5.21E-04	1.52E-04	8.22E-03	2.76E-01	1.10E+01	1.10E+02	1.72E+01	1.77E+00	2.79E+01
On site	11-16	5.21E-04	1.52E-04	8.22E-03	2.76E-01	1.10E+01	1.10E+02	1.72E+01	1.77E+00	2.79E+01
On site	16-21	5.22E-04	1.52E-04	8.22E-03	2.77E-01	1.10E+01	1.10E+02	1.72E+01	1.77E+00	2.79E+01
On site	>21	5.21E-04	1.52E-04	8.22E-03	2.76E-01	1.10E+01	1.10E+02	1.72E+01	1.77E+00	2.79E+01
Downstream	1-2	5.51E-04	0.00E+00	0.00E+00	3.52E-01	2.64E+00	9.56E+00	1.88E+00	1.02E+00	7.25E+00
Downstream	2-6	5.52E-04	0.00E+00	0.00E+00	3.53E-01	2.65E+00	9.58E+00	1.89E+00	1.02E+00	7.27E+00
Downstream	6-11	5.51E-04	0.00E+00	0.00E+00	3.52E-01	2.65E+00	9.57E+00	1.88E+00	1.02E+00	7.26E+00
Downstream	11-16	5.51E-04	0.00E+00	0.00E+00	3.52E-01	2.65E+00	9.57E+00	1.88E+00	1.02E+00	7.26E+00
Downstream	16-21	5.52E-04	0.00E+00	0.00E+00	3.52E-01	2.65E+00	9.58E+00	1.88E+00	1.02E+00	7.27E+00
Downstream	>21	5.52E-04	0.00E+00	0.00E+00	3.52E-01	2.65E+00	9.58E+00	1.88E+00	1.02E+00	7.26E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

Table 22: Hazard quotients for sulfonated PFAS and hazard indices for the full mixture in sunfish under the RME consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	HI
Upstream	1-2	0.00E+00	1.62E-02	3.38E+01	0.00E+00	1.82E-02	3.02E-02	2.28E-01	5.01E-01	1.40E-01	1.69E+02
Upstream	2-6	0.00E+00	1.62E-02	3.39E+01	0.00E+00	1.82E-02	3.03E-02	2.29E-01	5.02E-01	1.41E-01	1.69E+02
Upstream	6-11	0.00E+00	1.62E-02	3.39E+01	0.00E+00	1.82E-02	3.03E-02	2.28E-01	5.01E-01	1.40E-01	1.69E+02
Upstream	11-16	0.00E+00	1.62E-02	3.39E+01	0.00E+00	1.82E-02	3.03E-02	2.28E-01	5.01E-01	1.40E-01	1.69E+02
Upstream	16-21	0.00E+00	1.62E-02	3.39E+01	0.00E+00	1.82E-02	3.03E-02	2.28E-01	5.02E-01	1.40E-01	1.69E+02
Upstream	>21	0.00E+00	1.62E-02	3.39E+01	0.00E+00	1.82E-02	3.03E-02	2.28E-01	5.01E-01	1.40E-01	1.69E+02
On site	1-2	0.00E+00	1.64E-02	4.81E+01	0.00E+00	2.82E-02	1.59E-01	4.45E-01	7.04E-01	2.06E-01	2.18E+02
On site	2-6	0.00E+00	1.65E-02	4.83E+01	0.00E+00	2.82E-02	1.60E-01	4.46E-01	7.05E-01	2.06E-01	2.18E+02
On site	6-11	0.00E+00	1.64E-02	4.82E+01	0.00E+00	2.82E-02	1.59E-01	4.46E-01	7.05E-01	2.06E-01	2.18E+02
On site	11-16	0.00E+00	1.64E-02	4.82E+01	0.00E+00	2.82E-02	1.59E-01	4.46E-01	7.04E-01	2.06E-01	2.18E+02
On site	16-21	0.00E+00	1.64E-02	4.82E+01	0.00E+00	2.82E-02	1.59E-01	4.46E-01	7.05E-01	2.06E-01	2.18E+02
On site	>21	0.00E+00	1.64E-02	4.82E+01	0.00E+00	2.82E-02	1.59E-01	4.46E-01	7.05E-01	2.06E-01	2.18E+02
Downstream	1-2	0.00E+00	0.00E+00	7.79E+00	0.00E+00	0.00E+00	0.00E+00	2.28E-02	0.00E+00	8.99E-02	3.06E+01
Downstream	2-6	0.00E+00	0.00E+00	7.81E+00	0.00E+00	0.00E+00	0.00E+00	2.29E-02	0.00E+00	9.01E-02	3.07E+01
Downstream	6-11	0.00E+00	0.00E+00	7.80E+00	0.00E+00	0.00E+00	0.00E+00	2.28E-02	0.00E+00	9.00E-02	3.06E+01
Downstream	11-16	0.00E+00	0.00E+00	7.80E+00	0.00E+00	0.00E+00	0.00E+00	2.28E-02	0.00E+00	9.00E-02	3.06E+01
Downstream	16-21	0.00E+00	0.00E+00	7.80E+00	0.00E+00	0.00E+00	0.00E+00	2.28E-02	0.00E+00	9.00E-02	3.07E+01
Downstream	>21	0.00E+00	0.00E+00	7.80E+00	0.00E+00	0.00E+00	0.00E+00	2.28E-02	0.00E+00	9.00E-02	3.07E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

Table 23: Hazard quotients for carboxylated PFAS compounds in chain pickerel under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	2.06E-04	0.00E+00	0.00E+00	4.84E-02	4.82E-01	2.19E+00	2.09E-01	5.73E-02	4.88E-01
Upstream	2-6	2.06E-04	0.00E+00	0.00E+00	4.85E-02	4.83E-01	2.20E+00	2.09E-01	5.74E-02	4.89E-01
Upstream	6-11	2.06E-04	0.00E+00	0.00E+00	4.85E-02	4.82E-01	2.19E+00	2.09E-01	5.74E-02	4.89E-01
Upstream	11-16	2.06E-04	0.00E+00	0.00E+00	4.85E-02	4.82E-01	2.19E+00	2.09E-01	5.74E-02	4.89E-01
Upstream	16-21	2.06E-04	0.00E+00	0.00E+00	4.85E-02	4.83E-01	2.19E+00	2.09E-01	5.74E-02	4.89E-01
Upstream	>21	2.06E-04	0.00E+00	0.00E+00	4.85E-02	4.82E-01	2.19E+00	2.09E-01	5.74E-02	4.89E-01
On site	1-2	7.23E-05	0.00E+00	1.49E-03	6.77E-02	1.76E+00	1.64E+01	2.50E+00	3.39E-01	5.08E+00
On site	2-6	7.25E-05	0.00E+00	1.49E-03	6.78E-02	1.76E+00	1.64E+01	2.51E+00	3.40E-01	5.09E+00
On site	6-11	7.24E-05	0.00E+00	1.49E-03	6.77E-02	1.76E+00	1.64E+01	2.51E+00	3.40E-01	5.09E+00
On site	11-16	7.24E-05	0.00E+00	1.49E-03	6.77E-02	1.76E+00	1.64E+01	2.51E+00	3.40E-01	5.09E+00
On site	16-21	7.24E-05	0.00E+00	1.49E-03	6.78E-02	1.76E+00	1.64E+01	2.51E+00	3.40E-01	5.09E+00
On site	>21	7.24E-05	0.00E+00	1.49E-03	6.78E-02	1.76E+00	1.64E+01	2.51E+00	3.40E-01	5.09E+00
Downstream	1-2	8.96E-05	0.00E+00	0.00E+00	3.31E-02	3.53E-01	1.38E+00	2.07E-01	5.54E-02	7.34E-01
Downstream	2-6	8.98E-05	0.00E+00	0.00E+00	3.32E-02	3.54E-01	1.38E+00	2.08E-01	5.56E-02	7.36E-01
Downstream	6-11	8.97E-05	0.00E+00	0.00E+00	3.31E-02	3.53E-01	1.38E+00	2.08E-01	5.55E-02	7.35E-01
Downstream	11-16	8.97E-05	0.00E+00	0.00E+00	3.31E-02	3.53E-01	1.38E+00	2.07E-01	5.55E-02	7.35E-01
Downstream	16-21	8.97E-05	0.00E+00	0.00E+00	3.31E-02	3.53E-01	1.38E+00	2.08E-01	5.55E-02	7.35E-01
Downstream	>21	8.97E-05	0.00E+00	0.00E+00	3.31E-02	3.53E-01	1.38E+00	2.08E-01	5.55E-02	7.35E-01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

Table 24: Hazard quotients for sulfonated PFAS and hazard indices for the full mixture in chain pickerel under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	HI
Upstream	1-2	0.00E+00	0.00E+00	1.08E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-02	1.29E-02	1.75E-02	2.82E+01
Upstream	2-6	0.00E+00	0.00E+00	1.08E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-02	1.29E-02	1.76E-02	2.82E+01
Upstream	6-11	0.00E+00	0.00E+00	1.08E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-02	1.29E-02	1.76E-02	2.82E+01
Upstream	11-16	0.00E+00	0.00E+00	1.08E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-02	1.29E-02	1.76E-02	2.82E+01
Upstream	16-21	0.00E+00	0.00E+00	1.08E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-02	1.29E-02	1.76E-02	2.82E+01
Upstream	>21	0.00E+00	0.00E+00	1.08E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-02	1.29E-02	1.76E-02	2.82E+01
On site	1-2	0.00E+00	2.98E-03	6.13E+00	3.83E-03	5.23E-03	0.00E+00	7.68E-01	1.44E-01	2.54E-02	3.63E+01
On site	2-6	0.00E+00	2.99E-03	6.15E+00	3.84E-03	5.24E-03	0.00E+00	7.70E-01	1.45E-01	2.54E-02	3.64E+01
On site	6-11	0.00E+00	2.99E-03	6.14E+00	3.83E-03	5.24E-03	0.00E+00	7.69E-01	1.45E-01	2.54E-02	3.63E+01
On site	11-16	0.00E+00	2.99E-03	6.14E+00	3.83E-03	5.24E-03	0.00E+00	7.69E-01	1.45E-01	2.54E-02	3.63E+01
On site	16-21	0.00E+00	2.99E-03	6.14E+00	3.83E-03	5.24E-03	0.00E+00	7.69E-01	1.45E-01	2.54E-02	3.63E+01
On site	>21	0.00E+00	2.99E-03	6.14E+00	3.83E-03	5.24E-03	0.00E+00	7.69E-01	1.45E-01	2.54E-02	3.63E+01
Downstream	1-2	0.00E+00	0.00E+00	9.42E-01	0.00E+00	0.00E+00	0.00E+00	4.95E-02	3.81E-03	9.50E-03	5.10E+00
Downstream	2-6	0.00E+00	0.00E+00	9.44E-01	0.00E+00	0.00E+00	0.00E+00	4.96E-02	3.81E-03	9.52E-03	5.11E+00
Downstream	6-11	0.00E+00	0.00E+00	9.43E-01	0.00E+00	0.00E+00	0.00E+00	4.96E-02	3.81E-03	9.51E-03	5.11E+00
Downstream	11-16	0.00E+00	0.00E+00	9.43E-01	0.00E+00	0.00E+00	0.00E+00	4.96E-02	3.81E-03	9.51E-03	5.11E+00
Downstream	16-21	0.00E+00	0.00E+00	9.44E-01	0.00E+00	0.00E+00	0.00E+00	4.96E-02	3.81E-03	9.52E-03	5.11E+00
Downstream	>21	0.00E+00	0.00E+00	9.43E-01	0.00E+00	0.00E+00	0.00E+00	4.96E-02	3.81E-03	9.52E-03	5.11E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

Table 25: Hazard quotients for carboxylated PFAS compounds detected in chain pickerel under the RME consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	1.24E-03	0.00E+00	0.00E+00	2.90E-01	2.89E+00	1.31E+01	1.25E+00	3.44E-01	2.93E+00
Upstream	2-6	1.24E-03	0.00E+00	0.00E+00	2.91E-01	2.90E+00	1.32E+01	1.26E+00	3.45E-01	2.94E+00
Upstream	6-11	1.24E-03	0.00E+00	0.00E+00	2.91E-01	2.89E+00	1.32E+01	1.26E+00	3.44E-01	2.93E+00
Upstream	11-16	1.24E-03	0.00E+00	0.00E+00	2.91E-01	2.89E+00	1.32E+01	1.25E+00	3.44E-01	2.93E+00
Upstream	16-21	1.24E-03	0.00E+00	0.00E+00	2.91E-01	2.90E+00	1.32E+01	1.26E+00	3.44E-01	2.93E+00
Upstream	>21	1.24E-03	0.00E+00	0.00E+00	2.91E-01	2.89E+00	1.32E+01	1.26E+00	3.44E-01	2.93E+00
On site	1-2	4.34E-04	0.00E+00	8.95E-03	4.06E-01	1.05E+01	9.84E+01	1.50E+01	2.04E+00	3.05E+01
On site	2-6	4.35E-04	0.00E+00	8.97E-03	4.07E-01	1.06E+01	9.86E+01	1.51E+01	2.04E+00	3.06E+01
On site	6-11	4.34E-04	0.00E+00	8.96E-03	4.06E-01	1.06E+01	9.85E+01	1.50E+01	2.04E+00	3.05E+01
On site	11-16	4.34E-04	0.00E+00	8.96E-03	4.06E-01	1.06E+01	9.85E+01	1.50E+01	2.04E+00	3.05E+01
On site	16-21	4.35E-04	0.00E+00	8.96E-03	4.07E-01	1.06E+01	9.86E+01	1.51E+01	2.04E+00	3.05E+01
On site	>21	4.35E-04	0.00E+00	8.96E-03	4.07E-01	1.06E+01	9.85E+01	1.50E+01	2.04E+00	3.05E+01
Downstream	1-2	5.37E-04	0.00E+00	0.00E+00	1.98E-01	2.12E+00	8.26E+00	1.24E+00	3.33E-01	4.40E+00
Downstream	2-6	5.39E-04	0.00E+00	0.00E+00	1.99E-01	2.12E+00	8.28E+00	1.25E+00	3.33E-01	4.41E+00
Downstream	6-11	5.38E-04	0.00E+00	0.00E+00	1.99E-01	2.12E+00	8.27E+00	1.25E+00	3.33E-01	4.41E+00
Downstream	11-16	5.38E-04	0.00E+00	0.00E+00	1.99E-01	2.12E+00	8.27E+00	1.24E+00	3.33E-01	4.41E+00
Downstream	16-21	5.38E-04	0.00E+00	0.00E+00	1.99E-01	2.12E+00	8.27E+00	1.25E+00	3.33E-01	4.41E+00
Downstream	>21	5.38E-04	0.00E+00	0.00E+00	1.99E-01	2.12E+00	8.27E+00	1.25E+00	3.33E-01	4.41E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

Table 26: Hazard quotients for sulfonated PFAS and hazard indices for the mixtures in chain pickerel under the RME consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	HI
Upstream	1-2	0.00E+00	0.00E+00	6.47E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-01	7.73E-02	1.05E-01	2.77E+01
Upstream	2-6	0.00E+00	0.00E+00	6.48E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-01	7.75E-02	1.05E-01	2.77E+01
Upstream	6-11	0.00E+00	0.00E+00	6.48E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-01	7.74E-02	1.05E-01	2.77E+01
Upstream	11-16	0.00E+00	0.00E+00	6.48E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-01	7.74E-02	1.05E-01	2.77E+01
Upstream	16-21	0.00E+00	0.00E+00	6.48E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-01	7.74E-02	1.05E-01	2.77E+01
Upstream	>21	0.00E+00	0.00E+00	6.48E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-01	7.74E-02	1.05E-01	2.77E+01
On site	1-2	0.00E+00	1.79E-02	3.68E+01	2.30E-02	3.14E-02	0.00E+00	4.61E+00	8.67E-01	1.52E-01	1.99E+02
On site	2-6	0.00E+00	1.79E-02	3.69E+01	2.30E-02	3.15E-02	0.00E+00	4.62E+00	8.69E-01	1.53E-01	2.00E+02
On site	6-11	0.00E+00	1.79E-02	3.68E+01	2.30E-02	3.14E-02	0.00E+00	4.61E+00	8.68E-01	1.52E-01	2.00E+02
On site	11-16	0.00E+00	1.79E-02	3.68E+01	2.30E-02	3.14E-02	0.00E+00	4.61E+00	8.68E-01	1.52E-01	2.00E+02
On site	16-21	0.00E+00	1.79E-02	3.69E+01	2.30E-02	3.14E-02	0.00E+00	4.61E+00	8.68E-01	1.52E-01	2.00E+02
On site	>21	0.00E+00	1.79E-02	3.68E+01	2.30E-02	3.14E-02	0.00E+00	4.61E+00	8.68E-01	1.52E-01	2.00E+02
Downstream	1-2	0.00E+00	0.00E+00	5.65E+00	0.00E+00	0.00E+00	0.00E+00	2.97E-01	2.28E-02	5.70E-02	2.26E+01
Downstream	2-6	0.00E+00	0.00E+00	5.67E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-01	2.29E-02	5.71E-02	2.26E+01
Downstream	6-11	0.00E+00	0.00E+00	5.66E+00	0.00E+00	0.00E+00	0.00E+00	2.97E-01	2.29E-02	5.71E-02	2.26E+01
Downstream	11-16	0.00E+00	0.00E+00	5.66E+00	0.00E+00	0.00E+00	0.00E+00	2.97E-01	2.29E-02	5.71E-02	2.26E+01
Downstream	16-21	0.00E+00	0.00E+00	5.66E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-01	2.29E-02	5.71E-02	2.26E+01
Downstream	>21	0.00E+00	0.00E+00	5.66E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-01	2.29E-02	5.71E-02	2.26E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

Table 27: Hazard quotients for carboxylated PFAS compounds detected in largemouth bass under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA
On site	1-2	6.12E-05	0.00E+00	8.51E-03	1.19E-01	6.22E+00	5.92E+01	6.97E+00	8.10E-01	1.11E+01
On site	2-6	6.13E-05	0.00E+00	8.53E-03	1.19E-01	6.23E+00	5.94E+01	6.99E+00	8.12E-01	1.11E+01
On site	6-11	6.13E-05	0.00E+00	8.52E-03	1.19E-01	6.23E+00	5.93E+01	6.98E+00	8.11E-01	1.11E+01
On site	11-16	6.13E-05	0.00E+00	8.52E-03	1.19E-01	6.23E+00	5.93E+01	6.98E+00	8.11E-01	1.11E+01
On site	16-21	6.13E-05	0.00E+00	8.53E-03	1.19E-01	6.23E+00	5.93E+01	6.99E+00	8.12E-01	1.11E+01
On site	>21	6.13E-05	0.00E+00	8.52E-03	1.19E-01	6.23E+00	5.93E+01	6.99E+00	8.12E-01	1.11E+01
Downstream	1-2	6.76E-05	0.00E+00	0.00E+00	0.00E+00	4.75E-01	2.08E+00	2.67E-01	7.30E-02	7.59E-01
Downstream	2-6	6.77E-05	0.00E+00	0.00E+00	0.00E+00	4.76E-01	2.08E+00	2.68E-01	7.32E-02	7.61E-01
Downstream	6-11	6.76E-05	0.00E+00	0.00E+00	0.00E+00	4.75E-01	2.08E+00	2.67E-01	7.31E-02	7.60E-01
Downstream	11-16	6.76E-05	0.00E+00	0.00E+00	0.00E+00	4.75E-01	2.08E+00	2.67E-01	7.31E-02	7.60E-01
Downstream	16-21	6.77E-05	0.00E+00	0.00E+00	0.00E+00	4.75E-01	2.08E+00	2.68E-01	7.31E-02	7.60E-01
Downstream	>21	6.77E-05	0.00E+00	0.00E+00	0.00E+00	4.75E-01	2.08E+00	2.67E-01	7.31E-02	7.60E-01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

Table 28: Hazard quotients for sulfonated PFAS and hazard indices for the mixture detected in largemouth bass under the CTE consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	HI
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
On site	1-2	6.91E-03	1.70E-02	4.06E+01	4.09E-02	2.15E-02	1.49E-02	7.34E-02	2.54E-01	9.68E-02	1.25E+02
On site	2-6	6.93E-03	1.71E-02	4.06E+01	4.10E-02	2.15E-02	1.50E-02	7.36E-02	2.54E-01	9.70E-02	1.26E+02
On site	6-11	6.92E-03	1.70E-02	4.06E+01	4.10E-02	2.15E-02	1.50E-02	7.35E-02	2.54E-01	9.69E-02	1.26E+02
On site	11-16	6.92E-03	1.70E-02	4.06E+01	4.10E-02	2.15E-02	1.49E-02	7.35E-02	2.54E-01	9.69E-02	1.26E+02
On site	16-21	6.92E-03	1.71E-02	4.06E+01	4.10E-02	2.15E-02	1.50E-02	7.36E-02	2.54E-01	9.70E-02	1.26E+02
On site	>21	6.92E-03	1.70E-02	4.06E+01	4.10E-02	2.15E-02	1.50E-02	7.35E-02	2.54E-01	9.69E-02	1.26E+02
Downstream	1-2	0.00E+00	0.00E+00	1.21E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E-03	0.00E+00	4.86E+00
Downstream	2-6	0.00E+00	0.00E+00	1.21E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-03	0.00E+00	4.87E+00
Downstream	6-11	0.00E+00	0.00E+00	1.21E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-03	0.00E+00	4.87E+00
Downstream	11-16	0.00E+00	0.00E+00	1.21E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-03	0.00E+00	4.87E+00
Downstream	16-21	0.00E+00	0.00E+00	1.21E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-03	0.00E+00	4.87E+00
Downstream	>21	0.00E+00	0.00E+00	1.21E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.46E-03	0.00E+00	4.87E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).
***No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

Table 29: Hazard quotients for carboxylated PFAS compounds detected in largemouth bass under the RME consumption scenario.*

Sampling Location	Age group (years)	PFBA	PFHxA	PFHpA	PFNA	PFDA	PF UnDA	PF DoDA	PF TeDA	PF TrDA
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA
On site	1-2	3.67E-04	0.00E+00	5.11E-02	7.15E-01	3.73E+01	3.55E+02	4.18E+01	4.86E+00	6.64E+01
On site	2-6	3.68E-04	0.00E+00	5.12E-02	7.16E-01	3.74E+01	3.56E+02	4.19E+01	4.87E+00	6.65E+01
On site	6-11	3.68E-04	0.00E+00	5.11E-02	7.15E-01	3.74E+01	3.56E+02	4.19E+01	4.87E+00	6.64E+01
On site	11-16	3.68E-04	0.00E+00	5.11E-02	7.15E-01	3.74E+01	3.56E+02	4.19E+01	4.87E+00	6.64E+01
On site	16-21	3.68E-04	0.00E+00	5.12E-02	7.16E-01	3.74E+01	3.56E+02	4.19E+01	4.87E+00	6.65E+01
On site	>21	3.68E-04	0.00E+00	5.11E-02	7.16E-01	3.74E+01	3.56E+02	4.19E+01	4.87E+00	6.65E+01
Downstream	1-2	4.05E-04	0.00E+00	0.00E+00	0.00E+00	2.85E+00	1.25E+01	1.60E+00	4.38E-01	4.55E+00
Downstream	2-6	4.06E-04	0.00E+00	0.00E+00	0.00E+00	2.85E+00	1.25E+01	1.61E+00	4.39E-01	4.56E+00
Downstream	6-11	4.06E-04	0.00E+00	0.00E+00	0.00E+00	2.85E+00	1.25E+01	1.60E+00	4.39E-01	4.56E+00
Downstream	11-16	4.06E-04	0.00E+00	0.00E+00	0.00E+00	2.85E+00	1.25E+01	1.60E+00	4.39E-01	4.56E+00
Downstream	16-21	4.06E-04	0.00E+00	0.00E+00	0.00E+00	2.85E+00	1.25E+01	1.61E+00	4.39E-01	4.56E+00
Downstream	>21	4.06E-04	0.00E+00	0.00E+00	0.00E+00	2.85E+00	1.25E+01	1.60E+00	4.39E-01	4.56E+00

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFBA – perfluorobutanoic acid; PFHxA – perfluorohexanoic acid; PFHpA – perfluoroheptanoic acid; PFNA – perfluorononanoic acid; PFDA – perfluorodecanoic acid; PFUnDA – perfluoroundecanoic acid; PFDoDA – perfluorododecanoic acid; PFTeDA – perfluorotetradecanoic acid; PFTrDA – perfluorotridecanoic acid

Table 30: Hazard quotients for sulfonated PFAS and hazard indices for the mixture detected in largemouth bass under the RME consumption scenario.*

Sampling Location	Age group (years)	PFHxS	PFHpS	PFOS	PFNS	PFDS	6:2 FtS	FOSA	N-Et FOSAA	N-Me FOSAA	HI
Upstream	1-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	2-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	6-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	11-16	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	16-21	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
Upstream	>21	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00E+00
On site	1-2	4.15E-02	1.02E-01	2.43E+02	2.46E-01	1.29E-01	8.96E-02	4.41E-01	1.52E+00	5.81E-01	7.53E+02
On site	2-6	4.16E-02	1.02E-01	2.44E+02	2.46E-01	1.29E-01	8.98E-02	4.42E-01	1.53E+00	5.82E-01	7.55E+02
On site	6-11	4.15E-02	1.02E-01	2.44E+02	2.46E-01	1.29E-01	8.97E-02	4.41E-01	1.52E+00	5.82E-01	7.54E+02
On site	11-16	4.15E-02	1.02E-01	2.44E+02	2.46E-01	1.29E-01	8.97E-02	4.41E-01	1.52E+00	5.81E-01	7.54E+02
On site	16-21	4.15E-02	1.02E-01	2.44E+02	2.46E-01	1.29E-01	8.97E-02	4.41E-01	1.52E+00	5.82E-01	7.54E+02
On site	>21	4.15E-02	1.02E-01	2.44E+02	2.46E-01	1.29E-01	8.97E-02	4.41E-01	1.52E+00	5.82E-01	7.54E+02
Downstream	1-2	0.00E+00	0.00E+00	7.24E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-02	0.00E+00	2.92E+01
Downstream	2-6	0.00E+00	0.00E+00	7.26E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.68E-02	0.00E+00	2.92E+01
Downstream	6-11	0.00E+00	0.00E+00	7.25E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-02	0.00E+00	2.92E+01
Downstream	11-16	0.00E+00	0.00E+00	7.25E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-02	0.00E+00	2.92E+01
Downstream	16-21	0.00E+00	0.00E+00	7.26E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-02	0.00E+00	2.92E+01
Downstream	>21	0.00E+00	0.00E+00	7.25E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-02	0.00E+00	2.92E+01

*Not all PFAS compounds analyzed appear in the table. Compounds that were reported at concentrations less than the method detection limit for all samples are not included here.
**Total doses are based on the combination of all PFAS (carboxylic and sulfonated).
***No largemouth bass were sampled upstream of Bradford Dyeing Association.

PFHxS - Perfluorohexane sulfonic acid; PFHpS - Perfluoroheptane sulfonic acid; PFOS - Perfluorooctane sulfonic acid; PFNS - Perfluorononane sulfonic acid; PFDS - Perfluorodecane sulfonic acid; 6:2 FtS - 6:2 Fluorotelomer sulfonic acid; FOSA – Perfluorooctanesulfonamide; N-Et FOSAA - N-ethylperfluorooctane sulfonamidoacetic acid; N-Me FOSAA - 2-(N-methylperfluorooctane sulfonamido)acetic acid

Table 31: PFAS Uptake in Fish: Experimental Studies

Study	Uptake period duration	Species	Sample	PFAS exposure route	PFAS	Exposure concentration	Maximum concentration in fish	Key takeaways
Falk 2015[44]	28 days	Rainbow trout	Muscle	Food	PFBS	185 ng/g	73 ng/g	Fish exposed to contaminated food during the 28 d uptake period They have PFAS quantified in the muscle, liver, kidneys, gills, blood, skin, and carcass Sorption potential increases with an increase in chain length Dissolved PFAS considered negligible Liver is the target organ Elimination half life ranges 2-20 days Elimination half-life increases with increasing chain length and varies depending on the organ of interest
					PFOA	299 ng/g	86 ng/g	
					PFHxS	308 ng/g	632 ng/g	
					PFNA	347 ng/g	298 ng/g	
					PFOS	172 ng/g	237 ng/g	
Fang 2016[45]	28 days	Carp	Muscle	Water Sediment	PFOA	74100 ng/L 314 ng/g	131 ng/g	Uptake constant increases with chain length Elimination constant decreases with chain length increase Suspended particulates are an important source of PFAS for aquatic organisms 2 days to detection of all compounds Linear PFOS partitions into liver, kidney, and muscle from blood circulation Uptake follows the K_{oc} value
					PFNA	21100 ng/L 735 ng/g	899 ng/g	
					PFDA	1800 ng/L 1130 ng/g	846 ng/g	
					PFUnDA	100 ng/L 1050 ng/g	569 ng/g	
					PFDoDA	40 ng/L 939 ng/g	272 ng/g	

Study	Uptake period duration	Species	Sample	PFAS exposure route	PFAS	Exposure concentration	Maximum concentration in fish	Key takeaways
					PFOS	800 ng/L 1068 ng/g	2059 ng/g	Linear PFOS accumulates more than branched isomers
Huang 2022[46]	28 days	Zebrafish	Whole body	Water	PFHxS	3700 ng/L	30 ng/g	Longer chain PFAS have a higher accumulation rate Muscle has lower concentrations compared to blood/liver PFAS bind well to proteins in the liver
					PFOS	1200 ng/L	$5.0*10^{2}$ ng/g	
					F53B	1150 ng/L	755 ng/g	
					OBS	1560 ng/L	517 ng/g	
					PFBS	4300 ng/L	20 ng/g	
					PFHxS	13500 ng/L	$4.0*10^{2}$ ng/g	
					PFOS	9600 ng/L	$6.0*10^{3}$ ng/g	
					F53B	8630 ng/L	$6.6*10^{3}$ ng/g	
					OBS	6180 ng/L	$4.3*10^{3}$ ng/g	
					PFBS	14400 ng/L	40 ng/g ng/g	
					PFHxS	117300 ng/L	$7*10^{3}$ ng/g	
					F53B	102310 ng/L	$5.2*10^{4}$ ng/g	
					OBS	86070 ng/L	$1.7*10^{4}$ ng/g	
					PFOS	107100 ng/L	$5.2*10^{4}$ ng/g	
					PFBS	114900 ng/L	$5.7*10^{2}$ ng/g	
Martin 2003a[49]	12 days	Rainbow trout	Muscle	Water	PFDA	710.0 ng/L	7 ng/g	PFAS accumulate in blood>kidney>liver>gall bladder (order of concentration) Uptake rate increases with increasing chain length Rates vary depending on the compound and the target organ
					PFOA	1500.0 ng/L	4 ng/g	
					PFUnDA	480.0 ng/L	11 ng/g	
					PFDoDA	200.0 ng/L	16 ng/g	
					PFTeDA	14.0 ng/L	45 ng/g	
					PFHxS	1400.0 ng/L	6 ng/g	

Study	Uptake period duration	Species	Sample	PFAS exposure route	PFAS	Exposure concentration	Maximum concentration in fish	Key takeaways
					PFOS	350.0 ng/L	12 ng/g	Sulfonates have increased uptake compared to carboxylates No detection for PFAS with less than 6-7 carbons Muscle has some of the lowest concentrations of PFAS
Hassel 2019	21 days	Blue spot gobies	Whole body	Food	PFOA	500 ng/g each (about 500 ng/g, actual concentrations varied during the 3 weeks of the experiment)	28 ng/g ww	GenX doesn't bioaccumulate as much as PFOA 14 days to steady state GenX was hexafluoropropylene oxide dimer acid PFOS is synthesized in a way that creates a mixture of linear (70%) and branched (30%) species Linear and branched PFOS are eliminated differently Linear PFOS is eliminated more slowly
					Linear PFOS		101 ng/g ww	
					Total PFOS		108 ng/g ww	
					GenX		Non detect	
Zhong 2019[48]	28 days	Carp	Whole fish	Water	PFBS	600 ng/L	9 ng/g	Fish serum protein binding constant and bioconcentration factor increase with increase in chain length Proteins in blood, liver, kidney mediate the accumulation of PFAAs in fish Uptake rate constant increases with an increase in carbon chain length
					PFHxS	998 ng/L	84 ng/g	
					PFOS	1000 ng/L	710 ng/g	
					PFOA	828 ng/L	442 ng/g	
					PFNA	928 ng/L	654 ng/g	
					PFDA	1028 ng/L	1511 ng/g	
					PFUnDA	1128 ng/L	2549 ng/g	
					PFDoDA	1228 ng/L	3186 ng/g	
Martin 2003b[131]	34 days	Rainbow trout	Whole fish	Food	PFPeA	500 ng/g	ND	Time to steady state: PFOA-10 days PFDA-33 days PFUnDA-38 days PFDoDA-49 days PFTA-120 days PFOS-43 days PFHxS-30 days
					PFOA	420 ng /g	100 ng/g	
					PFDA	390 ng/g	300 ng/g	
					PFUnDA	570 ng/g	700 ng/g	
					PFDoDA	1100 ng/g	270 ng/g	
					PFTeA	1200 ng/g	650 ng/g	
					PFOS	540 ng/g	150 ng/g	

Study	Uptake period duration	Species	Sample	PFAS exposure route	PFAS	Exposure concentration	Maximum concentration in fish	Key takeaways
					PFHxS	510 ng/g	45 ng/g	Depuration rate decreased with increasing chain length Sulfonates bioaccumulate to a greater extent compared to carboxylates Negligible transfer of PFAS from food to water Half-lives range 3-35 days Steady state is when the concentration of PFAS in fish/concentration in food approaches 90% of the bioaccumulation factor
					PFHxA	520 ng/g	ND	
					PFHpA	460 ng/g	ND	
					PFBS	320 ng/g	50 ng/g	
Goeritz 2013[133]	28 days	Rainbow trout	Whole body	Food	PFBS	185 ng/g	7.03 ng/g	Most uptake from food, not water Half-lives range 7 to 16 days Biomagnification less than 1, so they say that the compounds aren't biomagnifying Equilibrium uptake not attained within 28 days Target tissues liver, blood kidney, skin PFAS concentrations in muscle tissue are relatively low compared to liver, blood, kidney, and gills
					PFHxS	309 ng/g	49.7 ng/g	
					PFOS	172 ng/g	49.0 ng/g	
					PFOA	303 ng/g	15.4 ng/g	
					PFNA	347 ng/g	62.7 ng/g	
Goloso-vskaia 2024[132]	32 days	Zebrafish	Whole body	Water	PFHpA	9600 ng/L	37 ng/g ww	Physiologically based kinetic modelling for co-exposures Transfer of PFAS from mother to eggs FOSA and 6:2 eliminated from embryos quickly No accumulation from food
					PFOA	8900 ng/L	291 ng/g ww	
					PFNA	7800 ng/L	1725 ng/g ww	
					PFBS	8700 ng/L	10 ng/g ww	
					PFHxS	11400 ng/L	228 ng/g ww	
					FOSA	9600 ng/L	Not reported	
					6:2 FTSA	10500 ng/L	35 ng/g ww	

6:2-FTS - 6:2 fluorotelomer sulfonic acid; FOSA - Perfluorooctanesulfonamide; PFBS - Perfluorobutane sulfonic acid; PFDA - Perfluorodecanoic acid; PFDoDA - Perfluorododecanoic acid; PFHpA - Perfluoroheptanoic acid; PFHxA - Perfluorohexanoic acid; PFHxS - Perfluorohexane sulfonic acid; PFNA - Perfluorononanoic acid; PFOA - Perfluorooctanoic acid; PFOS - Perfluorooctane sulfonic acid; PFPeA - Perfluoropentanoic acid; PFTeDA - Perfluorotetradecanoic acid; PFUnDA - Perfluoroundecanoic acid; F-53B – Perfluorinated ether sulfonate; OBS – sodium *p*-perfluorous nonenoxybenzenesulfonate.

Table 32: PFOS Screening Levels

Maine Center for Disease Control and Prevention, 2023[129]		Michigan Department of Health and Human Services, 2016[149]		Great Lakes Consortium for Fish Consumption Advisories, 2019[3]		Washington Department of Health, 2022[128]	
Meal Category	PFOS Concentration (ng/g)	Meal Category (meals/month)	PFOS Concentration (ng/g)	Meal Category	PFOS Concentration (ng/g)	Meal Category	PFOS (ng/g)
1 meal/week	3.5	16	≤9.0	Unrestricted	≤10	No advisory	<1.8
2 meals/month	7.5	12	9.0-13.0	2 meals/week	10-20	8 meals/month	1.8-2.3
1 meal/month	15	8	13.0-19.0	1 meal/week	20-50	4 meals/month	2.4-4.7
6 meals/year	30	4	19-38	1 meal/month	50-200	2 meals/month	4.8-9.4
3 meals/year	60	2	38-87	Do Not Eat	>200	1 meal/month	9.5-28.2
Do Not Eat	>60	1	75-150	-	-	Do Not Eat	>28.2
-	-	6 meals per year	150-300	-	-	-	-
-	-	Do Not Eat	>300	-	-	-	-

ng/g – nanograms PFOS per gram fish

Table 33: Exposure parameters and constants used to calculate residential soil exposure dose.

Age Group (years)	Body Weight (kg)	CTE Exposure Duration (years)	CTE Intake Rate (mg/day)	RME exposure duration (years)	RME Intake Rate (mg/day)	Soil-pica intake rate (mg/day)	Adherence factor to skin (mg/cm^2/event)	Combined Skin Surface Area (cm^2)
0-1	7.8	1	55	1	150	-	0.2	1772
1-2	11.4	1	90	1	200	5000	0.2	2299
2-6	17.4	4	60	4	200	5000	0.2	2592
6-11	31.8	5	60	5	200	-	0.2	3824
11-16	56.8	1	30	5	100	-	0.2	5454
16-21 years	71.6	0	30	5	100	-	0.2	6083
Total Child	-	12	-	21	-	-	-	-
Adult	80	12	30	33	100	-	0.07	6030

All parameters are from PHAST (version 2.3.3.0), which was accessed 2/1/24.[26]

kg – kilograms

mg/day – milligrams day

mg/cm^2/event – milligrams per centimeter squared per event

cm^2 – centimeter squared

Table 34: Concentrations of various contaminants in surface soil (6-12 inch depth) at Bradford Dyeing Associates*

Contaminant	Mill (AOC-1) Concentration (mg/kg)	Landfill (AOC-4) Concentration (mg/kg)	Comparison value (mg/kg)	Source[26,27]
Arsenic		5.8	16	ATSDR PHAST
Barium	83	3,000	10000	ATSDR PHAST
Cadmium	0.46	120	5.2	ATSDR PHAST
Lead	370	1,000	1000	RIDEM
Aroclor 1248		0.74	NA	NA
Aroclor 1254	0.21	19	19	ATSDR PHAST
Aroclor 1260		0.44	NA	NA
PCBs (Total)	0.21	20.18	10	RIDEM
Benzo(ghi)perylene	44	14	0.8	RIDEM
Fluoranthene	62	26	2100	ATSDR PHAST
Phenanthrene	24	15	40	RIDEM
Pyrene	58	22	1600	ATSDR PHAST
Benzo(a)pyrene	59	19	0.065	ATSDR PHAST

*Data provided by Weston & Sampson.

AOC-1 – Area of concern 1 (main mill building); AOC-4 – Area of concern 4 (landfill); mg/kg – milligram contaminant per kilogram soil; ATSDR PHAST – Agency for Toxic Substances and Disease Registry Public Health Assessment Site Tool; RIDEM – Rhode Island Department of Environmental Management; PCBs – polychlorinated biphenyls; NA-Not applicable. ATSDR does not provide a cancer slope factor for Aroclor 1248 and 1260. RIDEM regulates PCBs like Aroclor 1248 and 1260 as a sum, which is presented as PCBs (Total).

Table 35: Contaminant doses and health risks under the CTE mill (AOC-1) surface soil exposure scenario (risk from combined ingestion and dermal contact)

Exposure period	Age group (years)	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP Cancer Risk	Exposure Duration (years)
Chronic	0-1	0.00076	2.5	-	1
Chronic	1-2	0.00077	2.6	-	1
Chronic	2-6	0.00043	1.4	-	4
Chronic	6-11	0.00029	0.98	-	5
Chronic	11-16	1.80E-04	0.59	-	1
Chronic	16-21	1.50E-04	0.51	-	0
Chronic	Total Child	-	-	5.50E-04	12
Chronic	>21	6.20E-05	0.21	1.60E-05	12
Intermediate	0-1	0.00076	-		
Intermediate	1-2	0.00077	-		
Intermediate	2-6	0.00043	-		
Intermediate	6-11	0.00029	-		
Intermediate	11-16	0.00018	-		
Intermediate	16-21	0.00015	-		
Intermediate	>21	6.20E-05	-		

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents

Table 36: Contaminant doses and health risks under the RME mill (AOC-1) surface soil exposure scenario (risk from combined ingestion and dermal contact)

Exposure period	Age group (years)	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP Cancer Risk	Exposure Duration (years)
Chronic	0-1	0.0015	4.9	-	1
Chronic	1-2	0.0013	4.5	-	1
Chronic	2-6	0.0009	3	-	4
Chronic	6-11	0.00055	1.8	-	5
Chronic	11-16	2.50E-04	0.83	-	5
Chronic	16-21	2.10E-04	0.71	-	5
Chronic	Total Child	-	-	1.10E-03	21
Chronic	>21	1.10E-04	0.38	8.20E-05	33
Chronic	0-33	-	-	1.20E-03	33
Intermediate	0-1	0.0015	-	-	-
Intermediate	1-2	0.0013	-	-	-
Intermediate	2-6	0.0009	-	-	-
Intermediate	6-11	0.00055	-	-	-
Intermediate	11-16	0.00025	-	-	-
Intermediate	16-21	0.00021	-	-	-
Intermediate	>21	0.00011	-	-	-

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents

Table 37: Contaminant doses and health risks under the pica mill (AOC-1) surface soil exposure scenario (risk from combined ingestion and dermal contact)

Age group (years)	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient
1-2	0.011	-
2-6	0.0075	-

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents

Table 38: Contaminant doses and health risks under the CTE landfill (AOC-4) surface soil exposure scenario (risk from combined ingestion and dermal contact)

Exposure period	Age group (years)	Cadmium Dose (mg/kg/day)	Cadmium Non-cancer Hazard Quotient	Cadmium Cancer Risk	Arochlor 1254 Dose (mg/kg/day)	Arochlor 1254 Non-cancer Hazard Quotient	Arochlor 1254 Cancer Risk	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP Cancer Risk	Exposure Duration (years)
Chronic	0-1	0.0011	11	-	0.00025	13	-	0.00025	0.82	-	1
Chronic	1-2	0.0011	11	-	0.00026	13	-	0.00025	0.84	-	1
Chronic	2-6	0.00056	5.6	-	0.00014	7.2	-	0.00014	0.47	-	4
Chronic	6-11	0.00034	3.4	-	0.0001	5	-	9.60E-05	0.32	-	5
Chronic	11-16	0.00016	1.6	-	6.10E-05	3.1	-	5.80E-05	0.19	-	1
Chronic	16-21	0.00013	1.3	-	5.30E-05	2.7	-	5.00E-05	0.17	-	0
Chronic	Total Child	-	-	-	-	-	-	-	-	1.80E-04	12
Chronic	>21	7.00E-05	0.7	-	2.10E-05	1.1	-	2.00E-05	0.067	5.30E-06	12
Intermediate	0-1	0.0011	2.1	-	0.00025	8.5	-	-	-	-	-
Intermediate	1-2	0.0011	2.3	-	0.00026	8.6	-	-	-	-	-
Intermediate	2-6	0.00056	1.1	-	0.00014	4.8	-	-	-	-	-
Intermediate	6-11	0.00034	0.68	-	0.0001	3.3	-	-	-	-	-
Intermediate	11-16	0.00016	0.31	-	6.10E-05	2	-	-	-	-	-
Intermediate	16-21	0.00013	0.26	-	5.30E-05	1.8	-	-	-	-	-
Intermediate	>21	7.00E-05	0.14	-	2.10E-05	0.71	-	-	-	-	-

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents

Table 39: Contaminant doses and health risks under the RME landfill (AOC-4) surface soil exposure scenario (risk from combined ingestion and dermal contact)

Exposure period	Age group (years)	Cadmium Dose (mg/kg/day)	Cadmium Non-cancer Hazard Quotient	Cadmium Cancer Risk	Aroclor 1254 Dose (mg/kg/day)	Aroclor 1254 Non-cancer Hazard Quotient	Aroclor 1254 Cancer Risk	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP Cancer Risk	
Chronic	0-1	0.0025	25	-	0.00049	24	-	0.00048	1.6	-	1
Chronic	1-2	0.0023	23	-	0.00044	22	-	0.00043	1.4	-	1
Chronic	2-6	0.0015	15	-	0.0003	15	-	0.00029	0.98	-	4
Chronic	6-11	0.00087	8.7	-	0.00018	9.2	-	0.00018	0.6	-	5
Chronic	11-16	0.0003	3	-	8.50E-05	4.2	-	8.10E-05	0.27	-	5
Chronic	16-21	0.00025	2.5	-	7.20E-05	3.6	-	6.90E-05	0.23	-	5
Chronic	Total Child	-	-	-	-	-	-	-	-	3.70E-04	21
Chronic	>21	0.00018	1.8	-	3.80E-05	1.9	-	3.70E-05	0.12	2.70E-05	33
Chronic	0-33	-	-	-	4.90E-04	16	-	-	-	3.80E-04	
Intermediate	0-1	0.0025	5.1	-	0.00044	15	-	-	-	-	-
Intermediate	1-2	0.0023	4.6	-	0.0003	9.9	-	-	-	-	-
Intermediate	2-6	0.0015	3	-	0.00018	6.1	-	-	-	-	-
Intermediate	6-11	0.00087	1.7	-	8.50E-05	2.8	-	-	-	-	-
Intermediate	11-16	0.0003	0.61	-	7.20E-05	2.4	-	-	-	-	-
Intermediate	16-21	0.00025	0.5	-	3.80E-05	1.3	-	-	-	-	-
Intermediate	>21	0.00018	0.35	-	-	-	-	-	-	-	-

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents

Table 40: Contaminant doses and health risks under the pica landfill (AOC-4) surface soil exposure scenario (risk from combined ingestion and dermal contact)

Age group (years)	Cadmium Dose	Cadmium Non-cancer Hazard Quotient	Aroclor 1254 Dose	Aroclor 1254 Non-cancer Hazard Quotient	BaP Dose	BaP Non-cancer Hazard Quotient
1-2	0.023	45	0.0037	120	-	-
2-6	0.015	30	0.0024	81	-	-

BaP – benzo(a)pyrene equivalents

Table 41: Exposure parameters and constants used to calculate occupational soil exposure dose.

Exposure Group	Body Weight (kg)	CTE Exposure Duration (yrs)	RME Exposure Duration (yrs)	Intake Rate (mg/day)	Adherence Factor to Skin (mg/cm^2/event)	Combined Skin Surface Area (cm^2)
Workers - outdoor (low intensity soil contact)	80.6	5	20	100	0.07	3470
Workers - outdoor (high intensity soil contact)	80.6	5	20	330	0.07	3470

kg – kilograms; yrs – years; mg/day – milligrams contaminant per day; mg/cm^2/event – milligrams per centimeter squared per event; cm^2 – centimeter squared

Table 42: Non-cancer hazard quotients and cancer risks for surface soil contaminants near the mill (AOC-1) under occupational exposure.

Exposure	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP CTE Cancer Risk*	BaP RME Cancer Risk**
Low soil contact workers	6.60E-05	0.22	7.20E-06	2.90E-05
High soil contact workers	0.00018	0.6	2.00E-05	7.90E-05

*CTE cancer risk was calculated for 5 years of exposure.

**RME cancer risk was calculated for 20 years of exposure.

Boxes highlighted in yellow indicate values that have exceeded either 1.0 for non-cancer HQs or $1.0*10^{-6}$ for cancer risks.

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents; CTE – central tendency exposure; RME – reasonable maximum exposure

Table 43: Non-cancer hazard quotients and cancer risks for surface soil contaminants near the landfill (AOC-4) under occupational exposure.

Exposure	Cadmium Dose (mg/kg/day)	Cadmium Non-cancer Hazard Quotient	Cadmium CTE Cancer Risk*	Cadmium RME Cancer Risk**	Aroclor 1254 Dose (mg/kg/day)	Aroclor 1254 Non-cancer Hazard Quotient	Aroclor 1254 CTE Cancer Risk*	Aroclor 1254 RME Cancer Risk**	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP CTE Cancer Risk*	BaP RME Cancer Risk**
Low soil contact workers	1.10E-04	1.1	-	-	2.20E-05	1.1	-	-	2.10E-05	0.071	2.30E-06	9.30E-06
High soil contact workers	0.00035	3.5	-	-	5.90E-05	2.9	-	-	5.90E-05	0.2	6.40E-06	2.60E-05

*CTE cancer risk was calculated for 5 years of exposure.

**RME cancer risk was calculated for 20 years of exposure.

Boxes highlighted in yellow indicate values that have exceeded either 1.0 for non-cancer HQs or $1.0*10^{-6}$ for cancer risks.

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents; CTE – central tendency exposure; RME – reasonable maximum exposure

Table 44: Contaminants in soil borings (up to 13 feet below ground surface) at Bradford Dyeing Associates.*

Class	Contaminant	Mill (AOC-1)	Waste Disposal Area (AOC-3)	Landfill (AOC-4)	Comparison value (mg/kg)	Source
Volatile Organic Compounds	Benzene	-	0.0045	0.024	7	ATSDR PHAST
	P-Isopropyltoluene	-	0.019	-	-	NA
	Tetrachloroethylene	80	-	0.19	180	ATSDR PHAST
	Trichloroethylene	1.2	-	-	5.6	ATSDR PHAST
	Toluene	-	-	0.0069	4200	ATSDR PHAST
Polychlorinated biphenyls	PCB 1254	-	0.15		-	NA
	PCB 1260	-	-	0.23	-	NA
	PCB 1248	-	-	0.19	-	NA
	PCBs (Total)	0	0.15	0.42	10	RIDEM
Metals	Arsenic	2.7	15	200	16	ATSDR PHAST
	Barium	83	570	2200	10000	ATSDR PHAST
	Cadmium	0.73	4.4	39	5.2	ATSDR PHAST
	Chromium	270	60	53	390	RIDEM
	Lead	190	880	8800	1000	RIDEM
	Mercury	0.39	0.31	42	23	RIDEM
	Silver	-	3.1	9	260	ATSDR PHAST
Semivolatile organic compounds	1-Methylnaphthalene	-	1.9	0.23	3600	ATSDR PHAST
	2-Methylnaphthalene	-	2.5	0.77	2100	ATSDR PHAST
	Acenaphthene	-	9.6	-	3100	ATSDR PHAST
	Acenaphthylene	-	0.34	-	23	RIDEM
	Anthracene	-	19	1.2	1600	ATSDR PHAST
	Benzo(g,h,i)perylene	-	19	2	0.8	RIDEM
	Carbazole	-	8.4	0.27	-	NA
	Cresol	-	-	0.9	-	NA
	Dibenzofuran	-	6.5	1.1	-	NA
	Fluoranthene	0.24	73	4.8	2100	ATSDR PHAST
	Fluorene	-	10	-	2100	ATSDR PHAST
	Naphthalene	-	3.9	1.1	54	RIDEM
	Pentachlorophenol	-	1.3	-	0.97	ATSDR PHAST
	Phenanthrene	-	77	7.1	40	RIDEM
	Phenol	-	-	1.1	6000	RIDEM
	Pyrene	0.27	69	4.8	1600	ATSDR PHAST
	BaP Equivalent	0.8001	49.93	5.443	0.065	ATSDR PHAST

*Data provided by Weston & Sampson, 2020.[3]

Comparison values are for the soil/sediment ingestion and dermal pathways.
mg/kg – milligram contaminant per kilogram soil; PCB – polychlorinated biphenyls; BaP – benzo(a)pyrene; ATSDR PHAST – Agency for Toxic Substances and Disease Registry Public Health Assessment Site Tool; RIDEM – Rhode Island Department of Environmental Management;

AOC-1 – Area of concern 1 (main mill building); AOC-3 – Area of concern 3 (waste disposal area); AOC-4 – Area of concern 4 (landfill); NA – not applicable

Table 45: Non-cancer hazard quotients and cancer risks for subsurface (up to 13 feet below ground surface) soil contaminants near the mill (AOC-1) under occupational exposure.

Exposure	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP CTE Cancer Risk	BaP RME Cancer Risk
Workers outdoor (low intensity soil contact)	6.80E-07	0.0023	7.40E-08	3.00E-07
Workers outdoor (high intensity soil contact)	2.20E-06	0.0075	2.40E-07	9.80E-07

*CTE cancer risk was calculated for 5 years of exposure.

**RME cancer risk was calculated for 20 years of exposure.

Boxes highlighted in yellow indicate values that have exceeded either 1.0 for non-cancer HQs or $1.0*10^{-6}$ for cancer risks.

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents; CTE – central tendency exposure; RME – reasonable maximum exposure

Table 46: Non-cancer hazard quotients and cancer risks for subsurface (up to 13 feet below ground surface) soil contaminants near the waste disposal area (AOC-3) under occupational exposure.

Exposure	Pentachlorophenol Dose (mg/kg/day)	Pentachlorophenol Non-cancer Hazard Quotient	Pentachlorophenol CTE Cancer Risk*	Pentachlorophenol RME Cancer Risk**	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP CTE Cancer Risk*	BaP RME Cancer Risk**
Low soil contact workers	1.80E-06	0.00036	4.60E-08	1.80E-07	5.60E-05	0.19	6.10E-06	2.40E-05
High soil contact workers	4.30E-06	0.00086	1.10E-07	4.40E-07	1.50E-04	0.51	1.70E-05	6.70E-05

*CTE cancer risk was calculated for 5 years of exposure.

**RME cancer risk was calculated for 20 years of exposure.

Boxes highlighted in yellow indicate values that have exceeded either 1.0 for non-cancer HQs or $1.0*10^{-6}$ for cancer risks.

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents; CTE – central tendency exposure; RME – reasonable maximum exposure

Table 47: Non-cancer hazard quotients and cancer risks for subsurface (up to 13 feet below ground surface) soil contaminants near the landfill (AOC-4) under occupational exposure.

Exposure	Arsenic Dose (mg/kg/day)	Arsenic Non-cancer Hazard Quotient	Arsenic CTE Cancer Risk*	Arsenic RME Cancer Risk**	BaP Dose (mg/kg/day)	BaP Non-cancer Hazard Quotient	BaP CTE Cancer Risk*	BaP RME Cancer Risk**	Cadmium Dose (mg/kg/day)	Cadmium Non-cancer Hazard Quotient	Cadmium CTE Cancer Risk*	Cadmium RME Cancer Risk**
Low soil contact workers	1.10E-04	0.38	1.10E-05	4.40E-05	6.10E-06	0.02	6.60E-07	2.70E-06	3.40E-06	0.011	3.70E-07	1.50E-06
High soil contact workers	0.00035	1.2	3.40E-05	1.30E-04	1.70E-05	0.056	1.80E-06	7.30E-06	9.20E-06	0.031	1.00E-06	4.00E-06

*CTE cancer risk was calculated for 5 years of exposure.

**RME cancer risk was calculated for 20 years of exposure.

Boxes highlighted in yellow indicate values that have exceeded either 1.0 for non-cancer HQs or $1.0*10^{-6}$ for cancer risks.

mg/kg/day – milligrams contaminant per kilogram body weight per day; BaP – benzo(a)pyrene equivalents; CTE – central tendency exposure; RME – reasonable maximum exposure

Table 48: Contaminant concentrations in groundwater near the mill (AOC-1)

Contaminant	Concentration (µg/L)	Comparison value (µg/L)	Source
cis-1,2-dichloroethene	360	NA	NA
Tetrachloroethylene	640	5.3	ATSDR PHAST
Trichloroethylene	270	0.52	ATSDR PHAST

*CTE cancer risk was calculated for 5 years of exposure.

**RME cancer risk was calculated for 20 years of exposure.

Boxes highlighted in yellow indicate values that have exceeded their comparison values. The only potential pathway for groundwater contaminants is soil-vapor intrusion. Dose calculations for this pathway are not supported by ATSDR PHAST at this time.

ATSDR PHAST – Agency for Toxic Substances and Disease Registry Public Health Assessment Site Tool; RIDEM – Rhode Island Department of Environmental Management; NA – not applicable; µg/L – micrograms per liter

Table 49: PFAS concentrations in groundwater.*

Monitoring Well Identifier	MW-1 (ng/L)	MW-2 (ng/L)	MW-3 (ng/L)	MW-4 (ng/L)	MW-5 (ng/L)	DUP-1 (ng/L)	MW-6 (ng/L)	MW-7 (ng/L)	MW-8 (ng/L)	EMW-01 (ng/L)	EMW-02 (ng/L)
Area of concern	AOC-1	AOC-1	AOC-1	AOC-4	AOC-4	AOC-4	AOC-4	AOC-3	AOC-3	AOC-2A	AOC-2A
PFBS	NT	NT	NT	NT	NT	NT	NT	5.1	2.9	4.7	<2.0
PFHxA	NT	NT	NT	NT	NT	NT	NT	71	34	470	490
PFHpA	NT	NT	NT	NT	NT	NT	NT	120	53	720	930
PFBA	NT	NT	NT	NT	NT	NT	NT	4.5	3.0	41	30
PFHpS	NT	NT	NT	NT	NT	NT	NT	7.5	4.4	6.6	3.0
FOSA	NT	NT	NT	NT	NT	NT	NT	84	4.7	31	16
PFPeA	NT	NT	NT	NT	NT	NT	NT	47	33	310	250
6:2 FTS	NT	NT	NT	NT	NT	NT	NT	<2.0	2.7	8.9	21
8:2 FTS	NT	NT	NT	NT	NT	NT	NT	<2.0	2.1	54	120
PFHxS	NT	NT	NT	NT	NT	NT	NT	13	8.4	14	5.5
PFOA	NT	NT	NT	NT	NT	NT	NT	320	170	2,000	3,400
PFOS	NT	NT	NT	NT	NT	NT	NT	730	320	470	290
PFNA	NT	NT	NT	NT	NT	NT	NT	96	68	1,300	2,100
PFDA	NT	NT	NT	NT	NT	NT	NT	110	47	1,000	2,600
N-MeFOSAA	NT	NT	NT	NT	NT	NT	NT	<2.0	<2.0	75	26
PFUnDA	NT	NT	NT	NT	NT	NT	NT	16	11	630	2,100
N-EtFOSAA	NT	NT	NT	NT	NT	NT	NT	31	5.1	160	61
PFDoA	NT	NT	NT	NT	NT	NT	NT	<2.0	<2.0	4.8	110
PFTrDA	NT	NT	NT	NT	NT	NT	NT	<2.0	<2.0	<2.0	15

*Data provided by Weston & Sampson, 2020.[3]

MW – monitoring well identifier; ng/L – nanograms per liter; AOC-1 – Area of concern 1 (main mill building); AOC-2A – Area of concern 2A (lagoon); AOC-3 – Area of concern 3 (waste disposal area); AOC-4 – Area of concern 4 (landfill); PFBS – Perfluorobutane sulfonic acid; PFHxA – Perfluorohexanoic Acid; PFBA – Perfluorobutanoic Acid; PFHpS - Perfluoroheptane Sulfonate Acid; FOSA – Perfluorooctanesulfonamide; PFPeA - Perfluoropentanoic Acid; 6:2-FTS – 6:2 Fluorotelomer sulfonic acid; 8:2-FTS – 8:2 Fluorotelomer sulfonic acid; PFHxS - Perfluorohexane sulfonic acid; PFOA - Perfluorooctanoic Acid; PFOS - Perfluorooctane Sulfonate; PFNA - Perfluorononanoic Acid; PFDA - Perfluorodecanoic Acid; N-MeFOSAA – 2-(N-Methyl Perfluorooctane Sulfonamido)acetic Acid; PFUnDA - Perfluoroundecanoic Acid; N-EtFOSAA - N-Ethyl Perfluorooctane Sulfonamidoacetic Acid; PFDoA - Perfluorododecanoic Acid; PETrDA - Perfluorotetradecanoic Acid

Table 50: Contaminant concentrations in sediment.*

Contaminant	Area of Concern	Exposure Point Concentration (mg/kg)	Comparison Value (mg/kg)	CV Source
Arsenic	Lagoon (AOC-2A)	13.00	16	ATSDR PHAST
Barium	Lagoon (AOC-2A)	476.11	10000	ATSDR PHAST
Cadmium	Lagoon (AOC-2A)	4.20	5.2	ATSDR PHAST
Chromium	Lagoon (AOC-2A)	618.76	390	RIDEM
Lead	Lagoon (AOC-2A)	1405.11	1000	RIDEM
Mercury	Lagoon (AOC-2A)	0.82	23	RIDEM
Silver	Lagoon (AOC-2A)	4.20	260	ATSDR PHAST
PCB 1254	Lagoon (AOC-2A)	0.26	10	RIDEM
Benzo(g,h,i)perylene	Lagoon (AOC-2A)	2.10	0.8	RIDEM
Fluoranthene	Lagoon (AOC-2A)	6.50	2100	ATSDR PHAST
Phenanthrene	Lagoon (AOC-2A)	3.20	40	ATSDR PHAST
Pyrene	Lagoon (AOC-2A)	6.60	1600	ATSDR PHAST
Bis(2-ethylhexyl)phthalate	Lagoon (AOC-2A)	1.00	46	RIDEM
Arsenic	Pawcatuck River	4.30	16	ATSDR PHAST
Barium	Pawcatuck River	140.00	10000	ATSDR PHAST
Cadmium	Pawcatuck River	0.76	5.2	ATSDR PHAST
Chromium	Pawcatuck River	27.00	390	RIDEM
Lead	Pawcatuck River	400.00	1000	RIDEM
Mercury	Pawcatuck River	0.09	23	RIDEM
Silver	Pawcatuck River	0.74	260	ATSDR PHAST
Benzo(g,h,i)perylene	Pawcatuck River	NA	10	RIDEM
Fluoranthene	Pawcatuck River	NA	0.8	RIDEM
Phenanthrene	Pawcatuck River	NA	2100	ATSDR PHAST
Pyrene	Pawcatuck River	NA	40	ATSDR PHAST
Bis(2-ethylhexyl)phthalate	Pawcatuck River	NA	1600	ATSDR PHAST

*Data provided by Weston & Sampson, 2020.[3]

NA-not applicable. No Pawtucket River sediment samples had detections of benzo(g,h,i)perylene, fluoranthene, phenanthrene, pyrene, or bis(2-ethylhexyl)phthalate.

AOC-2A – Area of concern 2A (lagoons); mg/kg – milligram per kilogram; ATSDR PHAST – Agency for Toxic Substances and Disease Registry Public Health Assessment Site Tool; RIDEM – Rhode Island Department of Environmental Management;

Table 51: PFAS concentrations in sediment (µg/kg)*

Compound	SED-1 (Lagoon)	SED-4 (Lagoon)	SED-5 (Lagoon)	SED-6 (Lagoon)	SED-7 (Lagoon)	SED-8 (Lagoon)	SED-9 (Lagoon)	SED-3 (River)	SED-10 (River)	DUP-3 (River)	SED-11 (River)	SED-12 (River)
PFHxA	<3.3	<5.4	<2.3	20	20	52	390	<3.8	<1.6	<1.6	<1.5	<1.6
PFHpS	<3.3	<5.4	<2.3	<3.9	40	16	<12	<3.8	<1.6	<1.6	<1.5	<1.6
FOSA	<3.3	<5.4	<2.3	28	<11	<14	<12	<3.8	<1.6	<1.6	<1.5	<1.6
6:2 FTS	<4.0	<6.5	<2.7	<4.7	<13	<17	<14	<4.6	<1.9	<1.9	<1.8	ND
8:2 FTS	<3.3	<5.4	<2.3	<3.9	<11	<14	<12	<3.8	<1.6	<1.6	1.6	<1.6
PFOA	<3.3	<5.4	<2.3	4.7	47	57	14	<3.8	<1.6	<1.6	<1.5	<1.6
PFOS	<3.3	10	2.7	19	<11	<14	16	<3.8	<1.6	<1.6	<1.5	3.6
PFNA	<3.3	<5.4	<2.3	5.2	100	170	20	<3.8	<1.6	<1.6	<1.5	<1.6
PFDA	<3.3	9.3	<2.3	23	170	720	49	<3.8	<1.6	<1.6	<1.5	3.4
PFUnDA	<3.3	35	6.4	150	370	4100.00	92	<3.8	<1.6	<1.6	1.7	6.3
N-EtFOSAA	<3.3	<5.4	<2.3	9.6	<11	<14	<12	<3.8	<1.6	<1.6	<1.5	<1.6
PFDoA	<3.3	8.7	2.7	72	65	110	14	<3.8	<1.6	<1.6	<1.5	2.9
PFTrDA	<3.3	<5.4	<2.3	63	56	55	<12	<3.8	<1.6	<1.6	<1.5	<1.6

*Data provided by Weston & Sampson, 2020.[3]

µg/kg – micrograms kilogram; SED – sediment; PFHxA – Perfluorohexanoic Acid; PFHpS - Perfluoroheptane Sulfonate; 6:2-FTS – 6:2 Fluorotelomer sulfonic acid; 8:2-FTS – 8:2 Fluorotelomer sulfonic acid; PFOA - Perfluorooctanoic Acid; PFOS - Perfluorooctane Sulfonate; PFNA - Perfluorononanoic Acid; PFDA - Perfluorodecanoic Acid; PFUnDA - Perfluoroundecanoic Acid; ; N-EtFOSAA - N-Ethyl Perfluorooctane Sulfonamidoacetic Acid; PFDoA - Perfluorododecanoic Acid; PETrDA - Perfluorotetradecanoic Acid; SED – Sediment sample

Table 52: Surface water PFAS concentrations (ng/L)*

Compound	Carbon chain length	SW-1 Lagoon	SW-4 Lagoon	SW-5 Lagoon	SW-6 Lagoon	SW-3 River	SW-7 River	SW-8 River	DUP-4 River	SW-9 Lagoon	SW-10 River
PFBS	4	<2.0	2.5	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.5	<2.0
PFBA	4	<2.0	<2.0	68	12	<2.0	<2.0	<2.0	<2.0	7.6	<2.0
PFPeA	5	5.4	6.9	160	50	4.3	6.0	5.9	5.7	13	4.7
PFHxA	6	7.4	9.8	340	130	3.1	3.5	4.5	4.3	21	3.4
PFHxS	6	<2.0	2.6	2.1	3.6	<2.0	<2.0	<2.0	<2.0	4.7	<2.0
PFHpA	7	8.0	14	520	120	<2.0	2.0	<2.0	2.2	28	<2.0
FOSA	8	<2.0	<2.0	3.4	<2.0	<2.0	<2.0	<2.0	<2.0	2.4	<2.0
PFOA	8	27	41	1,500	690	4.7	4.2	5.0	4.9	90	3.7
PFOS	8	16	26	51	69	2.8	<2.0	<2.0	<2.0	110	<2.0
PFNA	9	12	19	600	58	<2.0	<2.0	<2.0	2.1	31	<2.0
PFDS	10	<2.0	<2.0	2.4	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
8:2 FTS	10	<2.0	2.8	18	5.3	<2.0	<2.0	<2.0	<2.0	9.5	<2.0
PFDA	10	14	16	620	49	<2.0	<2.0	<2.0	<2.0	32	<2.0
N-MeFOSAA	11	<2.0	<2.0	4.7	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
PFUnDA	11	17	12	450	14	<2.0	<2.0	<2.0	<2.0	21	<2.0
PFDoDA	12	4.0	<2.0	18	2.9	<2.0	<2.0	<2.0	<2.0	6.7	<2.0
PFTrDA	13	<2.0	<2.0	5.0	<2.0	<2.0	<2.0	<2.0	<2.0	6.5	<2.0
N-EtFOSAA	13	5.0	5.8	18	2.7	<2.0	<2.0	<2.0	<2.0	12	<2.0
PFTeDA	14	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.2	<2.0

*Data provided by Weston & Sampson, 2020.[3]

ng/L – nanograms per liter, PFBS – Perfluorobutane sulfonic acid; PFBA – Perfluorobutanoic Acid; ; PFPeA - Perfluoropentanoic Acid; PFHxA - Perfluorohexanoic Acid; PFHxS - Perfluorohexane sulfonic acid; PFHpA - Perfluoroheptanoic acid; FOSA – Perfluorooctanesulfonamide; PFOA - Perfluorooctanoic Acid; PFOS - Perfluorooctane Sulfonate; PFNA - Perfluorononanoic Acid; PFDS - Perfluorodecane sulfonic acid; 8:2-FTS – 8:2 Fluorotelomer sulfonic acid; PFDA - Perfluorodecanoic Acid; N-MeFOSAA – 2-(N-Methyl Perfluorooctane Sulfonamido)acetic Acid; PFUnDA - Perfluoroundecanoic Acid; PFDoDA -Perfluorododecanoic acid;

PETrDA - Perfluorotetradecanoic Acid; N-EtFOSAA - N-Ethyl Perfluorooctane Sulfonamidoacetic Acid; PFTeDA - Perfluorotetradecanoic acid; SW – surface water sample

APPENDIX A. ATSDR GLOSSARY OF TERMS

ATSDR is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency. By contrast, the USEPA develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public, last reviewed on January 1, 2009. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-800-CDC-INFO (232-4636).

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Ambient
Surrounding (for example, *ambient* air).

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Antagonistic effect
A biologic response to exposure to multiple substances that is **less** than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Dose
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often

and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

mg/kg
Milligram per kilogram.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), non-cancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or **NPL)**
USEPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An USEPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Synergistic effect
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].