

Prepared in cooperation with the Massachusetts Department of Environmental Protection

# Concentrations of Per- and Polyfluoroalkyl Substances (PFAS) in Selected Rivers and Streams in Massachusetts, 2020

Data Report 1160  
Version 2.0, October 2023

U.S. Department of the Interior  
U.S. Geological Survey



**Cover.** U.S. Geological Survey streamgage station number 01185500, West Branch Farmington River near New Boston, Massachusetts. Photograph taken by Jennifer G. Savoie, U.S. Geological Survey.

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## Contents

Acknowledgments .....	iii
Abstract .....	1
Introduction .....	1
Study Design .....	3
Collection and Analysis of Environmental Samples .....	3
Collection and Analysis of Quality-Control Samples .....	4
Results of Analyses of Environmental and Quality-Control Samples .....	5
Summary .....	7
References Cited .....	8
Appendix 1. Alpha Analytical, Inc. Sample Processing Information and Data Qualifiers With Corresponding U.S. Geological Survey Remark and Value Qualifier Codes .....	18

## Figures

1. Map showing locations of wastewater treatment facilities, other sampling sites, and nearby gages used to monitor streamflow conditions in Massachusetts.....2

## Tables

1. Site number shown in figure 1, sampling site, and station information for water-quality-monitoring stations at selected rivers and streams in Massachusetts .....9
2. Sampling method and nearby U.S. Geological Survey (USGS) continuous streamgage used to determine flow conditions at sampling sites.....11
3. Information on analyses for per- and polyfluoroalkyl substances in samples collected from rivers and streams in Massachusetts, August to November 2020.....15
4. Statistical summary of per- and polyfluoroalkyl substances measured in samples collected from selected rivers and streams in Massachusetts from August to November 2020 .....6

## Conversion Factors

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per second (ft/s)	0.3048	meter per second (m/s)
liter (L)	0.2642	gallon (gal)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32.$$

## Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

## Supplemental Information

Concentrations of chemical constituents in water are given in nanograms per liter (ng/L).

## Abbreviations

MassDEP	Massachusetts Department of Environmental Protection
MDL	method detection limit
NWIS	National Water Information System
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoate
PFBS	perfluorobutanesulfonate
PFDA	perfluorodecanoate
PFHpA	perfluoroheptanoate
PFHxA	perfluorohexanoate
PFHxS	perfluorohexanesulfonate
PFNA	perfluorononanoate
PFOA	perfluorooctanoate
PFOS	perfluorooctanesulfonate
PFPeA	perfluoropentanoate
RL	reporting limit
QC	quality control
USGS	U.S. Geological Survey



# Concentrations of Per- and Polyfluoroalkyl Substances (PFAS) in Selected Rivers and Streams in Massachusetts, 2020

By Jennifer G. Savoie and Denise M. Argue

## Abstract

Water samples collected from 27 rivers and streams in Massachusetts were analyzed to characterize the presence and concentrations of per- and polyfluoroalkyl substances (collectively known as PFAS) in surface waters across the Commonwealth. Sampling sites were selected in urban rivers where PFAS were expected to be present, such as those that receive treated municipal wastewater, and in rural rivers that were not known to be affected by municipal wastewater. The samples were collected three times in 2020 from 64 sites, and were analyzed for 24 PFAS, 18 of which are included in the U.S. Environmental Protection Agency's Method 537.1.

Samples were collected when the instantaneous flow of the rivers and streams were at base-flow condition to minimize PFAS input or dilution from stormwater runoff and overland flow. The analyses detected PFAS in samples from all 27 rivers and streams. The number of PFAS detected in each sample ranged from 2 to 16. Concentrations of individual PFAS ranged from no detectable concentrations (less than 1.74 nanograms per liter) to 109 nanograms per liter. Samples from sites associated with wastewater treatment facilities in urban areas had a larger number and variety of PFAS present, and at higher concentrations, than in samples from the more rural rivers. This report includes a summary of the chemical data and physical properties of both environmental and quality-control samples, and a description of procedures for the collection and processing of the samples.

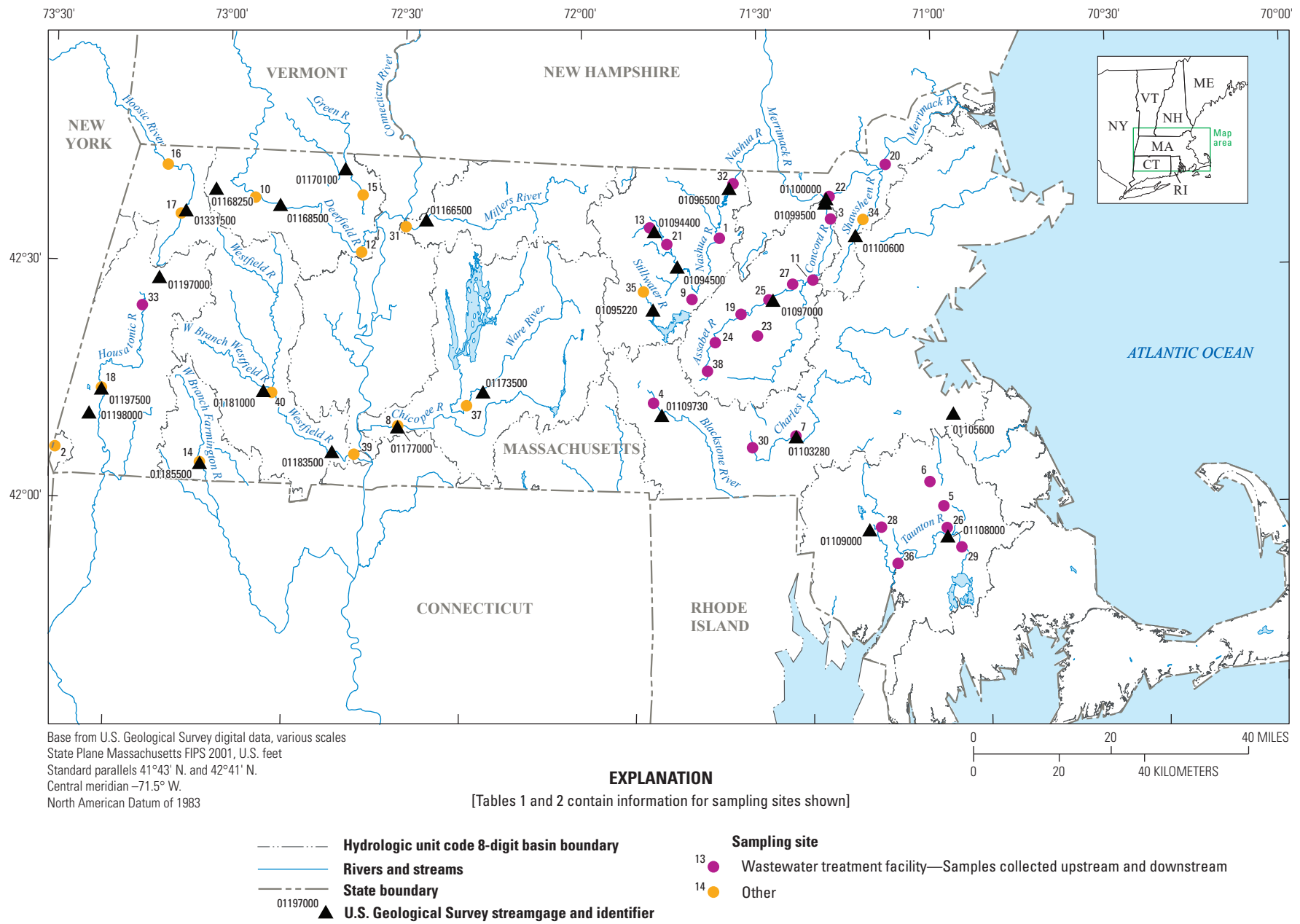
## Introduction

Per- and polyfluoroalkyl substances (collectively known as PFAS) are man-made chemicals that have been manufactured since the 1940s. These substances have been used in the United States for decades in many consumer and industrial products such as nonstick, stain-resisting, water-repelling agents, and in firefighting foams. PFAS are persistent in the environment and are known to have adverse effects on the health of humans and animals. Reduction in the manufacture and use of certain PFAS began in the late 1990s, and countries around the world have been working to both control PFAS in the environment and reduce human exposure pathways. PFAS have been detected throughout the world, with higher concentrations near areas where they are either manufactured

or used (such as fire-training areas), and in wastewater and sewage sludge (biosolids). PFAS are resistant to degradation and are known to migrate away from sources in groundwater and surface water, threatening human exposure through contaminated drinking water. Recent studies of PFAS in wastewater discharges to streams have shown decreases over time; however, wastewater discharges, biosolids disposal, and industrial sources continue to be a concern for drinking-water contamination (U.S. Environmental Protection Agency, 2022; Hu and others, 2016; Wang and others, 2017; Sunderland and others, 2018).

The areal extent, presence and magnitude of PFAS concentrations in Massachusetts rivers and streams from point and nonpoint sources is unknown. Thus, a baseline characterization of those factors is needed so that PFAS in rivers and streams can be better quantified, and their sources and pathways managed. In 2020, the U.S. Geological Survey (USGS), in cooperation with the Massachusetts Department of Environmental Protection (MassDEP), conducted three sampling rounds at 64 sites on 27 rivers and streams across the Commonwealth. Water samples were collected upstream and downstream from 25 municipal wastewater treatment facilities (only downstream at one facility) that discharge to rivers, many of which are upstream from intakes for public drinking-water supplies. Samples also were collected from an additional 15 sites to represent nonmunicipal, wastewater-affected streams with other suspected nonpoint sources or where no upstream sources were suspected. Locations of the sampled stream sites are shown in [figure 1](#).

The information obtained from this study will provide MassDEP recent, comparable, and reliable data on concentrations of PFAS in rivers and streams in Massachusetts and will also help resource managers prioritize and better quantify the extent of PFAS concerns associated with wastewater treatment facilities that are upstream of intakes for public drinking-water supplies. Additionally, data from stream sites that were not known to be affected by wastewater discharges will fill spatial gaps in statewide characterization. This report describes the sample collection and analytical methods used in the study, provides a summary of the field and laboratory quality-assurance information collected, briefly describes the frequency of occurrence and magnitude of PFAS concentrations measured, and describes the publicly available results and metadata from this study and how to access them.



**Figure 1.** Map showing locations of wastewater treatment facilities, other sampling sites, and nearby gages used to monitor streamflow conditions in Massachusetts.

## Study Design

Water samples were collected from August 17 through November 9, 2020, upstream and downstream from 25 wastewater treatment facilities (except at site number 33 [fig. 1], where only downstream samples were collected) and at 15 river or stream sites that were not associated with wastewater discharges (table 1, in back of report). Samples were collected at each site three times over nearly 4 months, with the period between sampling rounds generally lasting 3 to 4 weeks. To ensure that the samples were representative of base-flow concentrations, thereby minimizing PFAS input or dilution from stormwater runoff and overland flow, samples were collected when the streams were at base-flow conditions. For this study, base-flow conditions were defined as those following three or more consecutive days of declining flow and an instantaneous flow less than the 25th percentile of annual daily mean flow (Rantz and others, 1982a, b).

The sampling sites included existing MassDEP monitoring sites, wastewater treatment facility ambient monitoring sites, USGS monitoring sites, and several new sites established for this project. All the sampling sites were assigned USGS station numbers and names. The sites were chosen so that they were only minimally affected by contributions from joining tributaries between the sample sites and the wastewater treatment facilities. Distances upstream and downstream from the wastewater treatment facility discharge points were generally less than (<) 1 mile. In some rivers, however, such as the Merrimack, downstream sampling sites were nearly 8 miles downstream from the discharge point owing to access limitations.

Flow conditions during sample collection were determined from the USGS WaterWatch website, which displays current streamflow conditions relative to the annual daily mean for a site and period of record (<https://waterwatch.usgs.gov/?m=real&r=ma&w=map>). The 64 sampling sites were spatially associated with an active USGS continuous streamgage (table 2, in back of report; fig. 1). In some cases, several PFAS sampling stations were associated with a single USGS streamgage, such as that on the Assabet River. The USGS streamgages were used as index stations to determine if streams met the sampling criteria for base-flow conditions defined previously.

Discrete measurements of water temperature, specific conductance, pH, and dissolved-oxygen concentration were made in-place and across the stream channel (with YSI 6920 V2-1 multiparameter probes) and the medians of these measurements were applied to the environmental samples. Turbidity also was measured (with a Hach 2100P turbidity meter), either in a grab sample collected from the river center or in the composited sample from a churn splitter. Depending on the width of the river, the USGS standard isokinetic, depth-integrated sampling method, or a modified version, was used to collect the samples (USGS, variously dated). At sites at which the water was shallow enough to wade, samples were collected using a DH-81 depth-integrated

hand sampler. At sites that were too deep to wade, samples were collected from bridges using either a DH-95 sampler that was lowered to the stream using a bridge board or by hand, or when flows were <1.5 feet per second (ft/s), samples were collected using a weighted-bottle sampler. If a bridge was not present at the site (such as the Taunton River), samples were collected from a boat using a weighted-bottle sampler. For sites with a cross-sectional width of <30 feet (ft) a single vertical, depth-integrated sample was collected using the DH-81 sampler (or weighted-bottle sampler if flows were <1.5 ft/s) at the center of the river. The sample water was then decanted directly into the sample bottles for analysis at the laboratory. At sites with cross-sectional widths ranging from 30 to 60 ft, three multivertical, depth-integrated subsamples were collected, one each at the center of the channel and at points equidistant from the center and the left and right banks; these subsamples were then decanted into a 4-liter polyethylene churn splitter, which is a compositing container. Sample bottles were filled directly from the churn while the composited sample was being mixed by the churn plunger. At sites where the channel was greater than (>) 60 ft wide, 10 equal-width increment samples were collected using the DH-95 and composited into an 8-liter polyethylene churn splitter, except at Deerfield River (station number 01170006) and Chicopee River (station number 01177000); at those sites, 10 equal-width transect multiple-vertical samples were collected using a weighted-bottle sampler instead of the DH-95 sampler because flows were <1.5 ft/s. At stations on the Nashua River (station number 01095920) and the Assabet River (station number 01097390), the only safe sample-collection locations were from the riverbank (by wading in near the edge) or from a dock. The sampling methods used at each site for the three sampling rounds are shown in table 2 (in back of report).

## Collection and Analysis of Environmental Samples

Although the USGS does not currently have published procedures for the collection of surface-water samples specifically for PFAS analysis, internal recommendations and a consensus of best practices provide guidance. The USGS best practices, or procedures, for the collection of surface-water samples for PFAS analysis were based on the policies and procedures for the collection of water-quality data described in the USGS national field manual (USGS, variously dated). The equipment and procedures used for sample collection include: (1) sample-handling equipment that is constructed of noncontaminating materials (for example, no Teflon-based or other equipment with “fluoro” in the construction material name is used); (2) handling equipment in a manner that minimizes the potential for altering ambient sample composition; (3) handling samples in a manner that prevents contamination; and (4) routinely collecting quality-control samples (USGS, variously dated). Sampling equipment was thoroughly cleaned prior to sample collection. Churns and 1-liter

sample-collection bottles and bottle nozzles were cleaned with a dilute soap and tap water solution, followed by three rinses of tap water, then by rinses of laboratory-grade deionized water until the specific conductance of the water collected from the churn spigot (or sample-collection bottle and nozzle) measured  $<1$  microsiemens per centimeter at 25 degrees Celsius. The equipment was then transferred to a fume hood, where it was rinsed with methanol and allowed to dry. After the equipment was clean and dry, it was double bagged in polyethylene bags to avoid contamination.

Sampling equipment was field rinsed with sample water prior to sample collection; however, 250-milliliter (mL) high-density polyethylene sample bottles supplied by the analyzing laboratory, Alpha Analytical, Inc., were not rinsed per recommendation by the laboratory. Each sample was collected into two 250-mL high-density polyethylene sample bottles, unfiltered and without chemical preservative. The sample bottles were filled to the shoulder, capped, double bagged, and stored at near 4 degrees Celsius until they were transferred to Alpha Analytical, Inc. in Mansfield, Mass.

The samples were analyzed for specific PFAS using a solid-phase extraction and liquid chromatography/tandem mass spectrometry isotope dilution method, which is a proprietary method modified from EPA Method 537.1. Results of the analyses by this method include concentrations of both the dissolved and sediment-bound PFAS. Alpha Analytical, Inc. first analyzes the liquid sample and then centrifuges the sample and extracts PFAS that are bound to any sediment in the sample. The two extracts (dissolved and sediment-bound) are combined for the final result. The method provided the concentrations for the linear isomers only for 19 of the selected PFAS and concentrations of linear and branched isomers for five substances, as indicated by the substance name, for a total of 24 analytes. Laboratory analyses of the selected PFAS include results of extracted internal standards (also known as surrogates) that were used to monitor the extraction efficiency of the selected analytes. The naming convention for individual PFAS used by Alpha Analytical, Inc. is different than that used by the USGS. Information about each analyte and results of the analyses of each is included in [table 3](#) (in back of report).

## Collection and Analysis of Quality-Control Samples

The collection and analysis of quality-control (QC) samples are prerequisite for evaluating the quality of techniques for the collection and processing of environmental samples, as well as data from the actual samples themselves. Environmental-sample data cannot be adequately interpreted if QC data, such as blanks and replicates, are not collected, because any errors associated with the sample data are unknown. In this study, QC samples were collected prior to and throughout the sampling period to ensure that the sampling equipment itself and methods used for cleaning the equipment, collecting the environmental samples,

and analyzing the samples were not inadvertently introducing PFAS into the samples. Data from the QC samples were considered to represent the same conditions of potential bias, variability, and random error that affect the environmental samples. Thus, the distribution and frequency of apparent contamination, bias, and random error in the QC samples (both as an ensemble and within analytical batches), were characterized and then used to infer the quality of the environmental samples (Mueller and others, 2015).

Quality-control samples consisted of several types of blank samples and include: (1) three blanks prepared using deionized water produced at the USGS laboratory in Massachusetts and used to clean sampling equipment, (2) three source-solution blanks prepared using Fisher Chemical Optima water manufactured for high-performance liquid chromatography that was used for the field blanks, (3) two preliminary equipment blanks prepared on July 30, 2020, in the USGS laboratory in Massachusetts using the churn splitters and 1-liter sample-collection bottles and bottle nozzles prior to collection of environmental samples, and (4) 23 field blanks collected by passing the Fisher Chemical Optima water through the sample-collection bottle and nozzle into the churn splitter and filling the sample bottles from the churn spigot before the environmental samples were collected. Quality-control samples also included replicates of 22 environmental samples that were either split concurrently, when taken from a churn splitter; or split sequentially, when decanted directly from the 1-liter sample-collection bottles.

Laboratory QC samples were analyzed by Alpha Analytical, Inc. to ensure the precision and accuracy of the laboratory results. Laboratory QC samples included 33 laboratory method blanks, 33 laboratory control sample pairs, 24 laboratory matrix spikes, and 23 laboratory duplicates. Alpha Analytical, Inc. requires that these five types of laboratory QC samples be prepared and analyzed for every batch (no more than 20 samples per batch) of environmental samples processed. If the results of the analysis of a laboratory QC sample did not meet either the percent recovery limits of the analytical method or the extracted internal standard acceptance criteria, then Alpha Analytical, Inc. either repeated the analysis until satisfactory results were obtained or assigned data qualifiers to describe the performance issue.

Laboratory method blanks were analyzed to confirm that potential background contaminants were not interfering with the identification or quantitation of the method analytes. Laboratory control samples were analyzed to assess the performance of the analysis and were prepared by fortifying deionized water with known concentrations of selected analytes in low (2 nanograms per liter [ng/L]), medium (40 ng/L), and high (500 ng/L) concentrations that were rotated from batch to batch. The laboratory control samples were analyzed in pairs, and the relative percent differences of the two results had to be less than or equal to ( $\leq$ ) 30 percent for medium- and high-concentration replicates, and  $\leq$ 50 percent for low-concentration replicates for the batch analysis results to be considered acceptable.



Laboratory matrix spikes were completed to assess the extent that sample matrix may interfere with the method accuracy. The matrix spikes were created by spiking a random environmental sample with a known concentration of selected analytes. Similar to the laboratory control samples, the matrix spike samples were spiked with low, medium, and high concentrations of selected analytes and the percent recoveries of the added spike analytes were determined. Percent recoveries for matrix spikes had to range between 70 and 130 percent for medium- and high-concentration spiked samples, and 50 to 150 percent for low-concentration spiked samples for the batch analysis results to be considered acceptable. If recoveries were outside these criteria, the results were qualified by Alpha Analytical, Inc.

Laboratory duplicates were analyzed to verify the precision associated with the sample storage and laboratory procedures. Alpha Analytical, Inc. analyzed at least one laboratory duplicate per every 20 samples analyzed either by randomly reanalyzing one of the USGS environmental samples in the batch or by analyzing a sample from another client that was included in the same batch. Results of the two analyses were compared, and relative percent differences between the initial analysis and the duplicate analysis had to be  $\leq 30$  percent for the laboratory replication of analyses to be considered acceptable.

## Results of Analyses of Environmental and Quality-Control Samples

A total of 192 discrete environmental water samples and 53 field QC samples were collected for the 64 sites during the study period (August to November 2020). The water-quality data for the environmental samples are available to the public online from the USGS National Water Information System (NWIS) web interface (USGS, 2020). The data for the environmental samples and the associated field and laboratory QC samples are available in a data release (Savoie and Argue, 2022).

Measurable concentrations of PFAS were detected in samples from all 27 rivers and streams; however, the number of different substances and their concentrations varied across the State and site types. Nineteen of the 24 PFAS for which samples were analyzed were detected at least once. Five PFAS: fluorotelomersulfonate (8:2 FTS), fluorotelomersulfonate (4:2 FTS), perfluorodecanesulfonate (PFDS), perfluorononanesulfonate (PFNS), and perfluorooctanesulfonamide (PFOSA, also called FOSA) were not detected in any of the samples. A statistical summary of PFAS detected in samples collected from August to November 2020 at 64 sites (192 samples) is shown in [table 4](#). Summary statistics for the minimum, median, mean, and maximum concentrations of each analyte do not include the results that were reported as less than the reporting limit ([table 1](#)).

The number of PFAS detected in each sample ranged from a low of one substance, measured in samples from Wright Brook, to a high of 16 PFAS, measured in samples from the Shawsheen River. Concentrations of individual PFAS ranged from estimated concentrations that were greater than the method detection limit (MDL) and less than the reporting limit (RL) to 109 ng/L. Six PFAS were detected in 90 percent or more of the samples analyzed; these included the substances perfluorooctanoate (PFOA), perfluorooctanesulfonate (PFOS), perfluoroheptanoate (PFHpA), perfluoropentanoate (PFPeA), perfluorobutanoate (PFBA), and perfluorobutanesulfonate (PFBS). PFPeA and perfluorohexanoate (PFHxA) had the highest overall median concentrations, at 10.9 and 10.7 ng/L, respectively. The highest maximum concentrations reported were for PFPeA and PFBS, at 106 and 109 ng/L, respectively. The highest maximum concentrations of PFOA, PFHpA, PFBA, and PFBS (42, 19, 54, and 109 ng/L, respectively) were measured in samples from the North Nashua River. The highest PFOS concentration (55 ng/L) was measured in the Shawsheen River and the highest PFPeA concentration (106 ng/L) was measured in Sawmill Brook ([table 4](#)). Concentrations typically increased from sampling sites upstream to sites downstream from the wastewater treatment facilities, although at some downstream sites concentrations decreased. At sampling sites with associated wastewater treatment facilities, more PFAS were detected and at higher concentrations than at sampling sites on rivers without wastewater treatment facilities.

Field replicate samples were collected at sites that included a wide range of PFAS concentrations, from less than the RL to more than 100 ng/L. The relative percent difference for the field replicate samples was  $< 20$  percent for all substances. The relative percent difference between laboratory control sample pairs was  $< 30$  percent for all pairs except for Fluorotelomersulfonate (6:2 FTS) in work group WG1414858. The laboratory control sample pair in work group WG1414858 (WG1414858-3 and WG1414858-2) differed by 46 percent, however 6:2 FTS was not detected in the environmental samples analyzed in work group WG1414858. The percent recovery of all the matrix spike samples fell within the set recovery limits for each analyte measured. Data from field and laboratory quality control samples are included as tables in the accompanying data release (Savoie and Argue, 2022).

Perfluorohexanoate (PFHxA) was detected frequently in the QC samples at concentrations greater than the MDL and less than the RL and ranged from 0.305 to 0.513 ng/L. The QC samples with detections of PFHxA included three field source-solution blanks, 80 percent of the field blank samples, two of three deionized water blanks, and 44 percent of the laboratory method blanks. In response to the frequent detection of PFHxA in both field and laboratory blanks, two measures were employed to identify and describe the observed low-level systematic bias for PFHxA results. First, all detections greater than the MDL and less than the RL were reported as less than the RL. Second, a subset of environmental results was qualified with a “V” remark code, indicating that the concentrations

**Table 4.** Statistical summary of per- and polyfluoroalkyl substances measured in samples collected from selected rivers and streams in Massachusetts from August to November 2020.

[Abbreviations of analytes are shown in parenthesis after analyte name. USGS, U.S. Geological Survey; wu, water unfiltered; E, estimated; V, value affected by systematic contamination, which is attributed in this study to laboratory contamination for PFHxA; —, no data]

USGS parameter code	Analyte	Percent of samples with detections	Number of detections	Concentration (nanograms per liter)			
				Minimum	Median	Mean	Maximum
54116	Perfluorooctanoate (PFOA), linear and branched, wu	99	191	E0.24	7.5	8.7	42
54117	Perfluorooctanesulfonate (PFOS), linear and branched, wu	95	183	E0.52	6.3	7.0	E55
54229	Perfluoroheptanoate (PFHpA), linear, wu	95	182	E0.24	3.3	4.1	19
54235	Perfluoropentanoate (PFPeA), linear, wu	95	182	E0.44	10.9	14.4	106
54224	Perfluorobutanoate (PFBA), linear, wu	94	180	E0.43	4.9	6.7	54
54223	Perfluorobutanesulfonate (PFBS), linear, wu	90	173	E0.33	4.0	8.0	109
54113	Perfluorohexanesulfonate (PFHxS), linear and branched, wu	88	169	E0.40	2.6	3.1	26
54230	Perfluorohexanoate (PFHxA), linear, wu	87	166	V1.85	10.7	15.4	91
54232	Perfluorononanoate (PFNA), linear, wu	87	167	E0.29	E1.31	E1.58	10
54226	Perfluorodecanoate (PFDA), linear, wu	65	124	E0.28	E0.64	E0.85	4.8
54234	Perfluoropentanesulfonate (PFPeS), linear, wu	64	123	E0.24	E0.43	E0.53	2.9
54238	Perfluoroundecanoate (PFUnA), linear, wu	21	40	E0.24	E0.36	E0.53	E1.84
54222	6:2 Fluorotelomersulfonate (6:2 FTS), linear, wu	13	25	E1.27	3.0	4.6	E18
53961	N-Methylperfluorooctanesulfonamidoacetate (N-MeFOSAA), linear and branched, wu	5	10	E0.68	E0.74	E0.87	E1.48
54236	Perfluorotetradecanoate (PFTeA), linear, wu	5	10	E0.23	E0.26	E0.28	E0.37
53962	N-Ethylperfluorooctanesulfonamidoacetate (N-EtFOSAA), linear and branched, wu	5	9	E0.82	E0.95	E1.17	2.3
54237	Perfluorotridecanoate (PFTrDA), linear, wu	2	3	E0.31	E0.35	E1.01	2.4
54227	Perfluorododecanoate (PFDoA), linear, wu	1	1	E0.56	E0.56	E0.56	E0.56
54228	Perfluoroheptanesulfonate (PFHpS), linear, wu	1	1	E1.56	E1.56	E1.56	E1.56
54220	8:2 Fluorotelomersulfonate (8:2 FTS), linear, wu	0	0	—	—	—	—
54221	4:2 Fluorotelomersulfonate (4:2 FTS), linear, wu	0	0	—	—	—	—
54225	Perfluorodecanesulfonate (PFDS), linear, wu	0	0	—	—	—	—
54231	Perfluorononanesulfonate (PFNS), linear, wu	0	0	—	—	—	—
54233	Perfluorooctanesulfonamide (PFOSA, also called FOSA), linear, wu	0	0	—	—	—	—

may be affected by contamination. Environmental results less than or equal to 10 times the 95-percent upper confidence limit for the 95th percentile of the PFHxA concentrations measured in blanks (Mueller and others, 2015) were qualified with a “V” remark code. The 95-percent upper confidence limit of the 95th percentile of PFHxA concentrations measured in blank samples was 0.513 ng/L. Therefore, all environmental and replicate samples with concentrations of PFHxA reported above the RL and below 5.13 ng/L were qualified with a “V” remark code. The rationale was that potential contamination for this subset of samples could be as great as 10 percent of the measured value; thus, the effect of the contamination bias on the environmental value may be of significance for the measured PFHxA concentrations in these samples. For concentrations

in environmental samples >5.13 ng/L, the potential contamination bias would be <10 percent of the reported concentration and is less significant to the environmental values; thus, these values were not qualified with a “V” remark code but were flagged with value qualifier “v” in NWIS, indicating that PFHxA was detected in the laboratory method blank. The PFHxA contamination bias resulted in 36 samples (29 environmental and 7 replicate samples) with PFHxA concentrations greater than the RL and <5.13 ng/L qualified with a “V” remark code.

Selected additional results were also qualified with a “V” remark code because the laboratory method blank completed during the analysis had one or more detections of PFAS. Perfluorononanoate (PFNA) concentrations for six



environmental samples (L2046360-01, -02, -03, -06, -08, and -09) were qualified with a “V” remark code because the laboratory method blank in the work group WG1429821 had an estimated PFNA concentration (E1.2 ng/L) that was nearly equal to values reported in the environmental samples. Perfluorohexanesulfonic acid (PFHxS) and PFOS were detected in the laboratory method blank associated with work group WG1432858. PFHxS concentration values for four environmental samples (L2048824-01, -02, -04, and -05) were qualified with a “V” remark code because the environmental sample concentrations were nearly four times the concentration detected in the laboratory method blank (E0.728 ng/L). The PFOS concentration values for the environmental samples in WG1432858 were >10 times the concentration in the laboratory method blank and therefore were not qualified with a remark code but were flagged with value qualifier “v” in NWIS, indicating that PFOS was detected in the laboratory method blank. The PFOS concentration in the field blank in WG1432858 (L2048824-03) was also qualified with a “V” remark code because the field blank concentration was similar to the concentration in the laboratory method blank (E0.728 ng/L). The PFOS concentrations for the environmental samples in WG1432858 were >10 times the concentration in the laboratory method blank and therefore were not qualified with a remark code but were flagged with value qualifier “v” in NWIS, indicating that PFOS was detected in the laboratory method blank.

Selected additional results were “V” qualified because the field blank associated with the environmental sample had one or more detections of PFAS. The PFOA concentration for environmental sample L2039415-24 (7.34 ng/L) was qualified with a “V” remark code because the associated field blank (L2039415-23) had a detection of PFOA at a concentration of 3.54 ng/L. PFOA, PFOS, perfluorodecanoate (PFDA), and perfluorononanoate (PFNA) were detected in the field blank associated with environmental sample L2048824-02. The “V” remark code was applied to the environmental results for PFDA and PFNA for sample L2048824-02 because the concentrations in sample L2048824-02 were within 10 times the concentrations in the field blank. The PFOA and PFOS concentrations for sample L2048824-02 were >10 times the concentrations in the field blank and therefore were not qualified. For samples that were assigned value qualifiers, result-level comments were also added in the NWIS database to indicate that concentrations were associated with detections in field or laboratory blanks. The other detections in the field or laboratory blanks (perfluorotridecanoate [PFTrDA], perfluoroundecanoate [PFUnA], and 6:2 fluorotelomersulfonate [6:2 FTS]) were not associated with detections in the environmental samples, and therefore the associated environmental samples were not qualified with remark or qualifier codes.

Overall, the field and laboratory QC data indicate that the environmental data collected and reported are of known and definable quality and suitable to meet the objectives of the project. The analytical results provided by Alpha Analytical, Inc. included data qualifiers related to the method sensitivity

and performance for each sample and substance analyzed. The USGS used those data qualifiers related to the method sensitivity and performance, combined with the distribution and frequency of contamination, bias, and random error measured in the QC samples analyzed for this project, to describe the quality of the data. The USGS has many metadata tools available to describe the quality of data; for this dataset, however, remark codes and value qualifier codes defined by NWIS were used to describe the quality of the results. The Alpha Analytical, Inc. sample labeling convention and data qualifiers with corresponding USGS remark and value qualifiers codes are described in [appendix 1](#). Although selected results were qualified or remark codes were added on the basis of field or laboratory quality-assurance information, all data are published and available. The USGS recommends that data users review and consider the assigned remark codes and value qualifier codes when interpreting these data.

## Summary

Water samples collected during three sampling rounds at 64 sites in 27 rivers and streams in Massachusetts were analyzed to determine the occurrence and concentrations of 24 per- and polyfluoroalkyl substances (PFAS). The samples were collected when the instantaneous flow of the rivers and streams were at base-flow conditions (flow less than the 25th percentile of annual daily mean flow) to minimize PFAS input or dilution from stormwater runoff and overland flow. The data collected show that measurable concentrations of PFAS were observed in all rivers and streams sampled. The number of PFAS detected in each sample ranged from a low of 1 substance, measured in samples from Wright Brook, to a high of 16 PFAS, measured in samples from the Shawsheen River. The PFAS detected most frequently—in 90 percent or more of the samples analyzed—included perfluorooctanoate (PFOA), perfluorooctanesulfonate (PFOS), perfluoroheptanoate (PFHpA), perfluoropentanoate (PFPeA), perfluorobutanoate (PFBA), and perfluorobutanesulfonate (PFBS).

Concentrations of individual PFAS ranged from estimated levels that were greater than the method detection limit and less than the reporting limit to 109 nanograms per liter (ng/L). The highest maximum concentrations reported were measured in samples from the North Nashua River, Shawsheen River, and Sawmill Brook. Concentrations typically increased from sampling sites upstream to downstream of the wastewater treatment facilities, although at some sites downstream concentrations decreased. At sampling sites associated with wastewater treatment facilities, more PFAS were detected and at higher concentrations than at sampling sites on rivers without wastewater treatment facilities.

Quality-control data demonstrated that concentrations of perfluorohexanoate (PFHxA) less than 5.13 ng/L may have been affected by a systematic positive bias in the analytical method. The positive bias reduced the ability to characterize

low concentrations (less than 5.13 ng/L) of PFHxA. However, the median concentration of PFHxA was 10.7 ng/L and the maximum value 91 ng/L, indicating that more than 50 percent of the distribution of concentrations was high enough to overcome the potential systematic bias. All data are published and available and users are advised to review and consider the assigned remark and value qualifier codes when interpreting the data.

The data collected in this study provide information on PFAS occurrence and concentrations in Massachusetts rivers and streams that receive wastewater discharge from wastewater treatment and industrial facilities, and those that have no known or suspected sources of PFAS. This information can be used for watershed planning and wastewater discharge permitting in Massachusetts, particularly at facilities that discharge upstream from public water supplies. The results of the study will provide the Massachusetts Department of Environmental Protection with documentation of baseline water-quality conditions with respect to PFAS, and will help the U.S. Geological Survey assess sources, transport, and delivery of PFAS in rivers and streams on a nationwide basis.

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**Table 1.** Site number shown in [figure 1](#), sampling site, and station information for water-quality-monitoring stations at selected rivers and streams in Massachusetts.

Site number ( <a href="#">fig. 1</a> )	Sampling site	Station number	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)
1	Upstream	01095862	NASHUA RIVER NEAR MCPHERSON ROAD, SHIRLEY, MA	42.555	-71.611
1	Downstream	01095920	NASHUA RIVER NEAR AYER, MA	42.578	-71.609
2	Other	01362147	WRIGHT BROOK NEAR MOUNT WASHINGTON, MA	42.107	-73.483
3	Upstream	423506071171401	CONCORD R POLLAND ST	42.585	-71.287
3	Downstream	01099000	CONCORD RIVER AT LOWELL, MA	42.628	-71.298
4	Upstream	01109650	BLACKSTONE RIVER RT 146 AT WORCESTER, MA	42.228	-71.788
4	Downstream	01109660	BLACKSTONE RIVER NEAR MILLBURY, MA	42.208	-71.781
5	Upstream	01107100	TOWN RIVER AT BRIDGEWATER, MA	41.997	-70.973
5	Downstream	01107102	TOWN RIVER AT HAYWARD ST, BRIDGEWATER, MA	41.998	-70.954
6	Upstream	01106438	SALISBURY PLAIN R AT SARGENT'S WAY, BROCKTON, MA	42.054	-71.010
6	Downstream	01106444	SALISBURY PLAIN R NR MATFIELD ST E BRIDGEWATER, MA	42.038	-70.984
7	Upstream	01103280	CHARLES RIVER AT MEDWAY, MA	42.140	-71.390
7	Downstream	01103305	CHARLES RIVER NEAR MILLIS, MA	42.133	-71.362
8	Other	01177000	CHICOPEE RIVER AT INDIAN ORCHARD, MA	42.161	-72.514
9	Upstream	01095505	NASHUA RIVER 0.4 MI UPSTREAM RT 110 AT CLINTON, MA	42.429	-71.680
9	Downstream	01095506	NASHUA RIVER AT ROUTE 110, CLINTON, MA	42.433	-71.680
10	Other	01168305	COLD RIVER NEAR CHARLEMONT, MA	42.636	-72.934
11	Upstream	01098880	CONCORD RIVER NEAR LOWELL ROAD, CONCORD, MA	42.467	-71.356
11	Downstream	423033071185001	CONCORD R RT225 CARLISLE-BEDFORD, MA	42.509	-71.314
12	Other	01170006	DEERFIELD R, STILLWATER BR, AT WEST DEERFIELD, MA	42.527	-72.633
13	Upstream	01094445	NORTH NASHUA R NR LANIDES LN, E. FITCHBURG, MA	42.550	-71.751
13	Downstream	01094450	NORTH NASHUA RIVER AT NORTH LEOMINSTER, MA	42.542	-71.746
14	Other	01185500	WEST BRANCH FARMINGTON RIVER NEAR NEW BOSTON, MA	42.079	-73.073
15	Other	01170150	GREEN RIVER NEAR GREENFIELD, MA	42.647	-72.620
16	Other	01332500	HOOSIC RIVER NEAR WILLIAMSTOWN, MA	42.700	-73.159
17	Other	01331393	HOOSIC RIVER NEAR GROVE STREET, ADAMS, MA	42.601	-73.138
18	Other	01197500	HOUSATONIC RIVER NEAR GREAT BARRINGTON, MA	42.232	-73.355
19	Upstream	01096870	ASSABET RIVER AT COX ST NEAR HUDSON, MA	42.400	-71.546
19	Downstream	01096876	ASSEBET RIVER AT ROUTE 62, HUDSON, MA	42.404	-71.526
20	Upstream	01100500	MERRIMACK RIVER AT LAWRENCE, MA	42.705	-71.153
20	Downstream	011006712	MERRIMACK RIVER NEAR HAVERHILL, MA	42.770	-71.087
21	Upstream	01094455	NORTH NASHUA RIVER AT LEOMINSTER, MA	42.526	-71.737

**Table 1.** Site number shown in [figure 1](#), sampling site, and station information for water-quality-monitoring stations at selected rivers and streams in Massachusetts.  
—Continued

Site number ( <a href="#">fig. 1</a> )	Sampling site	Station number	Station name	Latitude (decimal degrees)	Longitude (decimal degrees)
21	Downstream	01094465	NORTH NASHUA RIVER AT MECHANIC ST, LEOMINSTER, MA	42.520	-71.727
22	Upstream	01100000	MERRIMACK RIVER BL CONCORD RIVER AT LOWELL, MA	42.646	-71.298
22	Downstream	01100475	MERRIMACK R AT ABE BASHARA BOAT HOUSE LAWRENCE, MA	42.693	-71.177
23	Upstream	01098704	WARD BROOK NEAR MARLBOROUGH, MA	42.352	-71.495
23	Downstream	01098705	SEWAGE BROOK NEAR MARLBOROUGH, MA	42.351	-71.491
24	Upstream	01096720	ASSABET RIVER AT BOUNDARY ST. NR NORTHBOROUGH, MA	42.341	-71.616
24	Downstream	01096725	ASSABET RIVER, DS MARLBOROUGH WWTP	42.345	-71.614
25	Upstream	01097000	ASSABET RIVER AT MAYNARD, MA	42.432	-71.450
25	Downstream	01097026	ASSABET RIVER AT POWDERMILL RD AT ACTON, MA	42.441	-71.429
26	Upstream	01108050	SAWMILL BROOK AT CONANT ST BRIDGEWATER, MA	41.959	-70.959
26	Downstream	01108055	SAWMILL BROOK AT ROUTE 28, BRIDGEWATER, MA	41.949	-70.969
27	Upstream	01097050	ASSABET RIVER AT MAIN ST NEAR CONCORD, MA	42.456	-71.390
27	Downstream	01097390	ASSABET RIVER AT RT 2 NEAR CONCORD, MA	42.466	-71.392
28	Upstream	01109043	THREEMILE RIVER AT CRANE ST, TAUNTON, MA	41.947	-71.160
28	Downstream	01109048	THREEMILE RIVER AT NORTON AVE, TAUNTON, MA	41.933	-71.154
29	Upstream	01107798	NEMASKET R AT OLIVER MILL PARK, MIDDLEBOROUGH, MA	41.907	-70.914
29	Downstream	01107799	NEMASKET RIVER AT PLYMOUTH ST, MIDDLEBOROUGH, MA	41.922	-70.923
30	Upstream	01103138	CHARLES RIVER AT MILFORD SEWER PLANT, MILFORD, MA	42.120	-71.507
30	Downstream	01103139	CHARLES RIVER AT MELLEN STREET, MILFORD, MA	42.117	-71.501
31	Other	01166630	MILLERS RIVER AT BRIDGE STREET, MILLERS FALLS, MA	42.580	-72.497
32	Upstream	010965042	NASHUA RIVER UPSTREAM, PEPPERELL, MA	42.673	-71.563
32	Downstream	010965043	NASHUA RIVER DOWNSTREAM, PEPPERELL, MA	42.676	-71.560
33	Downstream	01197134	HOUSATONIC RIVER AT NEW LENOX, MA	42.394	-73.240
34	Other	011006065	SHAWSHEEN RIVER AT BRIDGE STREET NR TEWKSBURY, MA	42.595	-71.195
35	Other	01094950	STILLWATER RIVER AT WEST STERLING, MA	42.447	-71.818
36	Upstream	01108414	TAUNTON RIVER UPSTREAM, TAUNTON, MA	41.878	-71.093
36	Downstream	01108415	TAUNTON RIVER DOWNSTREAM, TAUNTON, MA	41.872	-71.103
37	Other	01173515	WARE RIVER NEAR PALMER, MA	42.205	-72.319
38	Upstream	01096603	ASSABET RIVER NEAR WESTBOROUGH, MA	42.280	-71.638
38	Downstream	421700071381901	ASSABET RIVER DS FROM WESTBOROUGH WTP AT ROUTE 9	42.283	-71.639
39	Other	01183610	WESTFIELD RIVER AT BRIDGE ST AT NORTH AGAWAM, MA	42.099	-72.636
40	Other	01181008	WESTFIELD RIVER AT HUNTINGTON, MA	42.226	-72.871

**Table 2.** Sampling method and nearby U.S. Geological Survey (USGS) continuous streamgage used to determine flow conditions at sampling sites.

[Sampling method: C, centroid, single vertical sample; L, left edge of river single sample; R, right edge of river single sample; EWI, equal-width incremental (10 samples collected from the river using a DH-95 and composited into a churn splitter); EWT, equal-width transect (10 samples collected from the river using a weighted-bottle sampler and composited into a churn splitter); L-C-R, left, center, right (3 to 5 samples composited into a churn splitter)]

Site number (fig. 1)	USGS station number	USGS station name	Sampling method round 1	Sampling method round 2	Sampling method round 3	Nearby continuous streamgage USGS station number	Nearby continuous streamgage USGS station name
1	01095862	NASHUA RIVER NEAR MCPHERSON ROAD, SHIRLEY, MA	L-C-R	L-C-R	L-C-R	01096500	NASHUA RIVER AT EAST PEPPER-ELL, MA
1	01095920	NASHUA RIVER NEAR AYER, MA	L	L	L	01096500	NASHUA RIVER AT EAST PEPPER-ELL, MA
2	01362147	WRIGHT BROOK NEAR MOUNT WASHINGTON, MA	C	C	C	01198000	GREEN RIVER NEAR GREAT BARRINGTON, MA
3	423506071171401	CONCORD R POLLAND ST	EWI	EWI	EWI	01099500	CONCORD R BELOW R MEADOW BROOK, AT LOWELL, MA
3	01099000	CONCORD RIVER AT LOWELL, MA	EWI	EWI	EWI	01099500	CONCORD R BELOW R MEADOW BROOK, AT LOWELL, MA
4	01109650	BLACKSTONE RIVER RT 146 AT WORCESTER, MA	C	C	L-C-R	01109730	BLACKSTONE RIVER, W. MAIN ST., AT MILLBURY, MA
4	01109660	BLACKSTONE RIVER NEAR MILLBURY, MA	EWI	EWI	EWI	01109730	BLACKSTONE RIVER, W. MAIN ST., AT MILLBURY, MA
5	01107100	TOWN RIVER AT BRIDGEWATER, MA	C	C	C	01105600	OLD SWAMP RIVER NEAR SOUTH WEYMOUTH, MA
5	01107102	TOWN RIVER AT HAYWARD ST, BRIDGEWATER, MA	C	C	C	01105600	OLD SWAMP RIVER NEAR SOUTH WEYMOUTH, MA
6	01106438	SALISBURY PLAIN R AT SARGENT'S WAY, BROCKTON, MA	C	C	C	01105600	OLD SWAMP RIVER NEAR SOUTH WEYMOUTH, MA
6	01106444	SALISBURY PLAIN R NR MATFIELD ST E BRIDGEWATER, MA	C	C	C	01105600	OLD SWAMP RIVER NEAR SOUTH WEYMOUTH, MA
7	01103280	CHARLES RIVER AT MEDWAY, MA	C	C	L-C-R	01103280	CHARLES RIVER AT MEDWAY, MA
7	01103305	CHARLES RIVER NEAR MILLIS, MA	L-C-R	C	L-C-R	01103280	CHARLES RIVER AT MEDWAY, MA
8	01177000	CHICOPEE RIVER AT INDIAN ORCHARD, MA	EWT	EWT	EWT	01177000	CHICOPEE RIVER AT INDIAN ORCHARD, MA
9	01095505	NASHUA RIVER 0.4 MI UPSTREAM RT 110 AT CLINTON, MA	C	C	C	01094500	NORTH NASHUA RIVER NEAR LEOMINSTER, MA
9	01095506	NASHUA RIVER AT ROUTE 110, CLINTON, MA	C	C	C	01094500	NORTH NASHUA RIVER NEAR LEOMINSTER, MA
10	01168305	COLD RIVER NEAR CHARLEMONT, MA	C	C	C	01168250	COLD RIVER AT FLORIDA, MA



**Table 2.** Sampling method and nearby U.S. Geological Survey (USGS) continuous streamgage used to determine flow conditions at sampling sites.—Continued

[Sampling method: C, centroid, single vertical sample; L, left edge of river single sample; R, right edge of river single sample; EWI, equal-width incremental (10 samples collected from the river using a DH-95 and composited into a churn splitter); EWT, equal-width transect (10 samples collected from the river using a weighted-bottle sampler and composited into a churn splitter); L-C-R, left, center, right (3 to 5 samples composited into a churn splitter)]

Site number (fig. 1)	USGS station number	USGS station name	Sampling method round 1	Sampling method round 2	Sampling method round 3	Nearby continuous streamgage USGS station number	Nearby continuous streamgage USGS station name
11	01098880	CONCORD RIVER NEAR LOWELL ROAD, CONCORD, MA	EWI	EWI	EWI	01099500	CONCORD R BELOW R MEADOW BROOK, AT LOWELL, MA
11	423033071185001	CONCORD R RT225 CARLISLE-BEDFORD, MA	EWI	EWI	EWI	01099500	CONCORD R BELOW R MEADOW BROOK, AT LOWELL, MA
12	01170006	DEERFIELD R, STILLWATER BR, AT WEST DEERFIELD, MA	EWT	EWT	EWT	01168500	DEERFIELD RIVER AT CHAR-LEMONT, MA
13	01094445	NORTH NASHUA R NR LANIDES LN, E. FITCH-BURG, MA	C	C	C	01094400	NORTH NASHUA RIVER AT FITCH-BURG, MA
13	01094450	NORTH NASHUA RIVER AT NORTH LEOMINSTER, MA	EWI	EWI	EWI	01094400	NORTH NASHUA RIVER AT FITCH-BURG, MA
14	01185500	WEST BRANCH FARMINGTON RIVER NEAR NEW BOSTON, MA	L-C-R	C	L-C-R	01185500	WEST BRANCH FARMINGTON RIVER NEAR NEW BOSTON, MA
15	01170150	GREEN RIVER NEAR GREENFIELD, MA	C	C	C	01170100	GREEN RIVER NEAR COLRAIN, MA
16	01332500	HOOSIC RIVER NEAR WILLIAMSTOWN, MA	C	C	C	01331500	HOOSIC RIVER AT ADAMS, MA
17	01331393	HOOSIC RIVER NEAR GROVE STREET, ADAMS, MA	C	C	C	01331500	HOOSIC RIVER AT ADAMS, MA
18	01197500	HOUSATONIC RIVER NEAR GREAT BARRINGTON, MA	EWI	EWI	EWI	01197500	HOUSATONIC RIVER NEAR GREAT BARRINGTON, MA
19	01096870	ASSABET RIVER AT COX ST NEAR HUDSON, MA	L-C-R	L-C-R	L-C-R	01097000	ASSABET RIVER AT MAYNARD, MA
19	01096876	ASSEBET RIVER AT ROUTE 62, HUDSON, MA	L-C-R	L-C-R	L-C-R	01097000	ASSABET RIVER AT MAYNARD, MA
20	01100500	MERRIMACK RIVER AT LAWRENCE, MA	EWI	EWI	EWI	01100000	MERRIMACK RIVER BL CONCORD RIVER AT LOWELL, MA
20	011006712	MERRIMACK RIVER NEAR HAVERHILL, MA	EWI	L-C-R	EWI	01100000	MERRIMACK RIVER BL CONCORD RIVER AT LOWELL, MA
21	01094455	NORTH NASHUA RIVER AT LEOMINSTER, MA	C	C	C	01094500	NORTH NASHUA RIVER NEAR LEOMINSTER, MA
21	01094465	NORTH NASHUA RIVER AT MECHANIC ST, LEOMINSTER, MA	L-C-R	L-C-R	L-C-R	01094500	NORTH NASHUA RIVER NEAR LEOMINSTER, MA
22	01100000	MERRIMACK RIVER BL CONCORD RIVER AT LOWELL, MA	EWI	EWI	EWI	01100000	MERRIMACK RIVER BL CONCORD RIVER AT LOWELL, MA



**Table 2.** Sampling method and nearby U.S. Geological Survey (USGS) continuous streamgage used to determine flow conditions at sampling sites.—Continued

[Sampling method: C, centroid, single vertical sample; L, left edge of river single sample; R, right edge of river single sample; EWI, equal-width incremental (10 samples collected from the river using a DH-95 and composited into a churn splitter); EWT, equal-width transect (10 samples collected from the river using a weighted-bottle sampler and composited into a churn splitter); L-C-R, left, center, right (3 to 5 samples composited into a churn splitter)]

Site number (fig. 1)	USGS station number	USGS station name	Sampling method round 1	Sampling method round 2	Sampling method round 3	Nearby continuous streamgage USGS station number	Nearby continuous streamgage USGS station name
22	01100475	MERRIMACK R AT ABE BASHARA BOAT HOUSE LAWRENCE, MA	R	R	R	01100000	MERRIMACK RIVER BL CONCORD RIVER AT LOWELL, MA
23	01098704	WARD BROOK NEAR MARLBOROUGH, MA	C	C	C	No nearby continuous streamgage	No nearby continuous streamgage
23	01098705	SEWAGE BROOK NEAR MARLBOROUGH, MA	C	C	C	No nearby continuous streamgage	No nearby continuous streamgage
24	01096720	ASSABET RIVER AT BOUNDARY ST. NR NORTHBOROUGH, MA	C	C	C	01097000	ASSABET RIVER AT MAYNARD, MA
24	01096725	ASSABET RIVER, DS MARLBOROUGH WWTP	C	C	C	01097000	ASSABET RIVER AT MAYNARD, MA
25	01097000	ASSABET RIVER AT MAYNARD, MA	L-C-R	L-C-R	L-C-R	01097000	ASSABET RIVER AT MAYNARD, MA
25	01097026	ASSABET RIVER AT POWDERMILL RD AT ACTON, MA	L-C-R	L-C-R	L-C-R	01097000	ASSABET RIVER AT MAYNARD, MA
26	01108050	SAWMILL BROOK AT CONANT ST BRIDGEWATER, MA	C	C	C	01108000	TAUNTON RIVER NEAR BRIDGEWATER, MA
26	01108055	SAWMILL BROOK AT ROUTE 28, BRIDGEWATER, MA	C	C	C	01108000	TAUNTON RIVER NEAR BRIDGEWATER, MA
27	01097050	ASSABET RIVER AT MAIN ST NEAR CONCORD, MA	L-C-R	L-C-R	EWI	01097000	ASSABET RIVER AT MAYNARD, MA
27	01097390	ASSABET RIVER AT RT 2 NEAR CONCORD, MA	L	L	L	01097000	ASSABET RIVER AT MAYNARD, MA
28	01109043	THREEMILE RIVER AT CRANE ST, TAUNTON, MA	C	C	C	01109000	WADING RIVER NEAR NORTON, MA
28	01109048	THREEMILE RIVER AT NORTON AVE, TAUNTON, MA	L-C-R	C	C	01109000	WADING RIVER NEAR NORTON, MA
29	01107798	NEMASKET R AT OLIVER MILL PARK, MIDDLEBOROUGH, MA	C	C	C	01108000	TAUNTON RIVER NEAR BRIDGEWATER, MA
29	01107799	NEMASKET RIVER AT PLYMOUTH ST, MIDDLEBOROUGH, MA	C	C	C	01108000	TAUNTON RIVER NEAR BRIDGEWATER, MA

**Table 2.** Sampling method and nearby U.S. Geological Survey (USGS) continuous streamgage used to determine flow conditions at sampling sites.—Continued

[Sampling method: C, centroid, single vertical sample; L, left edge of river single sample; R, right edge of river single sample; EWI, equal-width incremental (10 samples collected from the river using a DH-95 and composited into a churn splitter); EWT, equal-width transect (10 samples collected from the river using a weighted-bottle sampler and composited into a churn splitter); L-C-R, left, center, right (3 to 5 samples composited into a churn splitter)]

Site number (fig. 1)	USGS station number	USGS station name	Sampling method round 1	Sampling method round 2	Sampling method round 3	Nearby continuous streamgage USGS station number	Nearby continuous streamgage USGS station name
30	01103138	CHARLES RIVER AT MILFORD SEWER PLANT, MILFORD, MA	C	C	C	01103280	CHARLES RIVER AT MEDWAY, MA
30	01103139	CHARLES RIVER AT MELLEN STREET, MILFORD, MA	C	C	C	01103280	CHARLES RIVER AT MEDWAY, MA
31	01166630	MILLERS RIVER AT BRIDGE STREET, MILLERS FALLS, MA	L-C-R	L-C-R	L-C-R	01166500	MILLERS RIVER AT ERVING, MA
32	010965042	NASHUA RIVER UPSTREAM, PEPPERELL, MA	EWI	EWI	EWI	01096500	NASHUA RIVER AT EAST PEPPERELL, MA
32	10965043	NASHUA RIVER DOWNSTREAM, PEPPERELL, MA	EWI	EWI	EWI	01096500	NASHUA RIVER AT EAST PEPPERELL, MA
33	01197134	HOUSATONIC RIVER AT NEW LENOX, MA	EWI	EWI	EWI	01197000	EAST BRANCH HOUSATONIC RIVER AT COLTSVILLE, MA
34	011006065	SHAWSHEEN RIVER AT BRIDGE STREET NR TEWKSBURY, MA	L-C-R	L-C-R	C	01100600	SHAWSHEEN RIVER NEAR WILMINGTON, MA
35	01094950	STILLWATER RIVER AT WEST STERLING, MA	C	C	C	01095220	STILLWATER RIVER NEAR STERLING, MA
36	01108414	TAUNTON RIVER UPSTREAM, TAUNTON, MA	L-C-R	L-C-R	L-C-R	01108000	TAUNTON RIVER NEAR BRIDGEWATER, MA
36	01108415	TAUNTON RIVER DOWNSTREAM, TAUNTON, MA	L-C-R	L-C-R	L-C-R	01108000	TAUNTON RIVER NEAR BRIDGEWATER, MA
37	01173515	WARE RIVER NEAR PALMER, MA	EWI	EWI	EWI	01173500	WARE RIVER AT GIBBS CROSSING, MA
38	01096603	ASSABET RIVER NEAR WESTBOROUGH, MA	C	C	C	01097000	ASSABET RIVER AT MAYNARD, MA
38	421700071381901	ASSABET RIVER DS FROM WESTBOROUGH WTP AT ROUTE 9	C	C	C	01097000	ASSABET RIVER AT MAYNARD, MA
39	01183610	WESTFIELD RIVER AT BRIDGE ST AT NORTH AGAWAM, MA	L-C-R	L-C-R	L-C-R	01183500	WESTFIELD RIVER NEAR WESTFIELD, MA
40	01181008	WESTFIELD RIVER AT HUNTINGTON, MA	EWI	L-C-R	EWI	01181000	WEST BRANCH WESTFIELD RIVER AT HUNTINGTON, MA

**Table 3.** Information on analyses for per- and polyfluoroalkyl substances in samples collected from rivers and streams in Massachusetts, August to November 2020.

[Abbreviations of analytes are shown in parenthesis after analyte name. USGS, U.S. Geological Survey; NWIS, National Water Information System; EIS, extracted internal standard (also known as surrogate); wu, water unfiltered; LM105, mass-dependent determination of selected alkyl substances by solid phase extraction and liquid perfluorinated chromatography/tandem mass spectrometry isotope dilution; MA-AALM, Massachusetts–Alpha Analytical, Inc., laboratory, Mansfield; NA, not applicable]

Alpha Analytical, Inc. analyte name	Alpha Analytical, Inc. analyte percent recovery limits	Alpha Analytical, Inc. associated EIS analyte name	Alpha Analytical, Inc. EIS percent recovery acceptance criteria	Data published in USGS NWIS	USGS NWIS parameter code	USGS NWIS method code	USGS NWIS analyzing agency code	USGS NWIS analyte name
N-Methyl Perfluorooctanesulfonamidoacetic acid (N-MeFOSAA)	60–166	N-Deuteriomethylperfluoro-1-octanesulfonamidoacetic acid (d3-N-MeFOSAA)	1–181	Yes	53961	LM105	MA-AALM	N-Methylperfluorooctanesulfonamidoacetate (N-MeFOSAA), linear and branched, water, unfiltered, recoverable, nanograms per liter
N-Methyl Perfluorooctanesulfonamidoacetic acid-Linear (L_N-MeFOSAA)	60–166	N-Deuteriomethylperfluoro-1-octanesulfonamidoacetic acid (d3-N-MeFOSAA)	1–181	No	NA	NA	NA	NA
N-Methyl Perfluorooctanesulfonamidoacetic acid-Branched (Br_N-MeFOSAA)	60–166	N-Deuteriomethylperfluoro-1-octanesulfonamidoacetic acid (d3-N-MeFOSAA)	1–181	No	NA	NA	NA	NA
N-Ethyl Perfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	45–170	N-Deuterioethylperfluoro-1-octanesulfonamidoacetic acid (d5-N-EtFOSAA)	23–146	Yes	53962	LM105	MA-AALM	N-Ethylperfluorooctanesulfonamidoacetate (N-EtFOSAA), linear and branched, water, unfiltered, recoverable, nanograms per liter
N-Ethyl Perfluorooctanesulfonamidoacetic acid-Linear (L_N-EtFOSAA)	45–170	N-Deuterioethylperfluoro-1-octanesulfonamidoacetic acid (d5-N-EtFOSAA)	23–146	No	NA	NA	NA	NA
N-Ethyl Perfluorooctanesulfonamidoacetic acid-Branched (Br_N-EtFOSAA)	45–170	N-Deuterioethylperfluoro-1-octanesulfonamidoacetic acid (d5-N-EtFOSAA)	23–146	No	NA	NA	NA	NA
Perfluorohexanesulfonic acid (PFHxS)	69–177	Perfluoro[1,2,3-13C3]Hexanesulfonic acid (M3PFHxS)	47–153	Yes	54113	LM105	MA-AALM	Perfluorohexanesulfonate (PFHxS), linear and branched, water, unfiltered, recoverable, nanograms per liter
Perfluorohexanesulfonic acid-Linear (L_PFHxS)	69–177	Perfluoro[1,2,3-13C3]Hexanesulfonic acid (M3PFHxS)	47–153	No	NA	NA	NA	NA
Perfluorohexanesulfonic acid-Branched (Br_PFHxS)	69–177	Perfluoro[1,2,3-13C3]Hexanesulfonic acid (M3PFHxS)	47–153	No	NA	NA	NA	NA

**Table 3.** Information on analyses for per- and polyfluoroalkyl substances in samples collected from rivers and streams in Massachusetts, August to November 2020.—Continued

[Abbreviations of analytes are shown in parenthesis after analyte name. USGS, U.S. Geological Survey; NWIS, National Water Information System; EIS, extracted internal standard (also known as surrogate); wu, water unfiltered; LM105, mass-dependent determination of selected alkyl substances by solid phase extraction and liquid perfluorinated chromatography/tandem mass spectrometry isotope dilution; MA-AALM, Massachusetts–Alpha Analytical, Inc., laboratory, Mansfield; NA, not applicable]

Alpha Analytical, Inc. analyte name	Alpha Analytical, Inc. analyte percent recovery limits	Alpha Analytical, Inc. associated EIS analyte name	Alpha Analytical, Inc. EIS percent recovery acceptance criteria	Data published in USGS NWIS	USGS NWIS parameter code	USGS NWIS method code	USGS NWIS analyzing agency code	USGS NWIS analyte name
Perfluorooctanoic acid (PFOA)	63–159	Perfluoro[13C8]Octanoic acid (M8PFOA)	36–149	Yes	54116	LM105	MA-AALM	Perfluorooctanoate (PFOA), linear and branched, water, unfiltered, recoverable, nanograms per liter
Perfluorooctanoic acid-Linear (L_PFOA)	63–159	Perfluoro[13C8]Octanoic acid (M8PFOA)	36–149	No	NA	NA	NA	NA
Perfluorooctanoic acid-Branched (Br_PFOA)	63–159	Perfluoro[13C8]Octanoic acid (M8PFOA)	36–149	No	NA	NA	NA	NA
Perfluorooctanesulfonic acid (PFOS)	52–151	Perfluoro[13C8]Octanesulfonic acid (M8PFOS)	42–146	Yes	54117	LM105	MA-AALM	Perfluorooctanesulfonate (PFOS), linear and branched, water, unfiltered, recoverable, nanograms per liter
Perfluorooctanesulfonic acid-Linear (L_PFOS)	52–151	Perfluoro[13C8]Octanesulfonic acid (M8PFOS)	42–146	No	NA	NA	NA	NA
Perfluorooctanesulfonic acid-Branched (Br_PFOS)	52–151	Perfluoro[13C8]Octanesulfonic acid (M8PFOS)	42–146	No	NA	NA	NA	NA
1H,1H,2H,2H-Perfluorodecanesulfonic acid (8:2 FTS)	56–173	1H,1H,2H,2H-Perfluoro[1,2-13C2]Decanesulfonic acid (M2-8:2FTS)	7–170	Yes	54220	LM105	MA-AALM	8:2 Fluorotelomersulfonate (8:2 FTS), linear, water, unfiltered, recoverable, nanograms per liter
1H,1H,2H,2H-Perfluorohexanesulfonic acid (4:2 FTS)	37–219	1H,1H,2H,2H-Perfluoro[1,2-13C2]Hexanesulfonic acid (M2-4:2FTS)	1–313	Yes	54221	LM105	MA-AALM	4:2 Fluorotelomersulfonate (4:2 FTS), linear, water, unfiltered, recoverable, nanograms per liter
1H,1H,2H,2H-Perfluorooctanesulfonic acid (6:2 FTS)	49–187	1H,1H,2H,2H-Perfluoro[1,2-13C2]Octanesulfonic acid (M2-6:2FTS)	1–244	Yes	54222	LM105	MA-AALM	6:2 Fluorotelomersulfonate (6:2 FTS), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorobutanesulfonic acid (PFBS)	65–157	Perfluoro[2,3,4-13C3]Butanesulfonic acid (M3PFBS)	31–159	Yes	54223	LM105	MA-AALM	Perfluorobutanesulfonate (PFBS), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorobutanoic acid (PFBA)	67–148	Perfluoro[13C4]Butanoic acid (MPFBA)	2–156	Yes	54224	LM105	MA-AALM	Perfluorobutanoate (PFBA), linear, water, unfiltered, recoverable, nanograms per liter

**Table 3.** Information on analyses for per- and polyfluoroalkyl substances in samples collected from rivers and streams in Massachusetts, August to November 2020.—Continued

[Abbreviations of analytes are shown in parenthesis after analyte name. USGS, U.S. Geological Survey; NWIS, National Water Information System; EIS, extracted internal standard (also known as surrogate); wu, water unfiltered; LM105, mass-dependent determination of selected alkyl substances by solid phase extraction and liquid perfluorinated chromatography/tandem mass spectrometry isotope dilution; MA-AALM, Massachusetts–Alpha Analytical, Inc., laboratory, Mansfield; NA, not applicable]

Alpha Analytical, Inc. analyte name	Alpha Analytical, Inc. analyte percent recovery limits	Alpha Analytical, Inc. associated EIS analyte name	Alpha Analytical, Inc. EIS percent recovery acceptance criteria	Data published in USGS NWIS	USGS NWIS parameter code	USGS NWIS method code	USGS NWIS analyzing agency code	USGS NWIS analyte name
Perfluorodecanesulfonic acid (PFDS)	38–156	Perfluoro[13C8]Octanesulfonic acid (M8PFOS)	42–146	Yes	54225	LM105	MA-AALM	Perfluorodecanesulfonate (PFDS), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorodecanoic acid (PFDA)	63–171	Perfluoro[1,2,3,4,5,6-13C6]Decanoic acid (M6PFDA)	38–144	Yes	54226	LM105	MA-AALM	Perfluorodecanoate (PFDA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorododecanoic acid (PFDoA)	67–153	Perfluoro[1,2-13C2]Dodecanoic acid (MPFDOA)	24–161	Yes	54227	LM105	MA-AALM	Perfluorododecanoate (PFDoA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluoroheptanesulfonic acid (PFHpS)	61–179	Perfluoro[13C8]Octanesulfonic acid (M8PFOS)	42–146	Yes	54228	LM105	MA-AALM	Perfluoroheptanesulfonate (PFHpS), linear, water, unfiltered, recoverable, nanograms per liter
Perfluoroheptanoic acid (PFHpA)	58–159	Perfluoro[1,2,3,4-13C4]Heptanoic acid (M4PFHpA)	30–139	Yes	54229	LM105	MA-AALM	Perfluoroheptanoate (PFHpA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorohexanoic acid (PFHxA)	69–168	Perfluoro[1,2,3,4,6-13C5]Hexanoic acid (M5PFHxA)	21–145	Yes	54230	LM105	MA-AALM	Perfluorohexanoate (PFHxA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorononanesulfonic acid (PFNS)	48–150	Perfluoro[13C8]Octanesulfonic acid (M8PFOS)	42–146	Yes	54231	LM105	MA-AALM	Perfluorononanesulfonate (PFNS), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorononanoic acid (PFNA)	68–171	Perfluoro[13C9]Nonanoic acid (M9PFNA)	34–146	Yes	54232	LM105	MA-AALM	Perfluorononanoate (PFNA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorooctanesulfonamide (FOSA)	46–170	Perfluoro[13C8]Octanesulfonamide (M8FOSA)	1–87	Yes	54233	LM105	MA-AALM	Perfluorooctanesulfonamide (PFOSA, also called FOSA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluoropentanesulfonic acid (PFPeS)	52–156	Perfluoro[1,2,3-13C3]Hexanesulfonic acid (M3PFHxS)	47–153	Yes	54234	LM105	MA-AALM	Perfluoropentanesulfonate (PFPeS), linear, water, unfiltered, recoverable, nanograms per liter
Perfluoropentanoic acid (PFPeA)	63–161	Perfluoro[13C5]Pentanoic acid (M5PFPeA)	16–173	Yes	54235	LM105	MA-AALM	Perfluoropentanoate (PFPeA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorotetradecanoic acid (PFTA)	59–182	Perfluoro[1,2-13C2]Tetradecanoic acid (M2PFTEDA)	33–143	Yes	54236	LM105	MA-AALM	Perfluorotetradecanoate (PFTA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluorotridecanoic acid (PFTrDA)	48–158	Perfluoro[1,2-13C2]Dodecanoic acid (MPFDOA)	24–161	Yes	54237	LM105	MA-AALM	Perfluorotridecanoate (PFTrDA), linear, water, unfiltered, recoverable, nanograms per liter
Perfluoroundecanoic acid (PFUnA)	60–153	Perfluoro[1,2,3,4,5,6,7-13C7]Undecanoic acid (M7PFUDA)	40–144	Yes	54238	LM105	MA-AALM	Perfluoroundecanoate (PFUnA), linear, water, unfiltered, recoverable, nanograms per liter

## Appendix 1. Alpha Analytical, Inc. Sample Processing Information and Data Qualifiers With Corresponding U.S. Geological Survey Remark and Value Qualifier Codes

The 192 environmental samples and 53 field quality-control samples submitted to Alpha Analytical, Inc. for this study were assigned unique laboratory sample identifiers (such as L2035871-13). The samples were analyzed in 16 batches, and each batch, depending on the number of samples, was separated into one to four work groups for analysis and assigned a work-group number (such as WG1396002). Each work group typically included associated laboratory quality control samples with laboratory sample identifiers that included the work-group number followed by suffixes “-1” through “-5.” Laboratory method blanks were assigned suffix “-1” (example WG1396002-1), laboratory control sample pairs were assigned suffixes “-2” and “-3” (examples WG1396002-2 and WG1396002-3), laboratory matrix spikes were assigned suffix “-4” (example WG1396002-4), and laboratory duplicate were assigned suffix “-5” (example WG1396002-5).

Data qualifiers from Alpha Analytical, Inc. were translated into appropriate U.S. Geological Survey (USGS) remark and value qualifier codes. The Alpha Analytical, Inc. data

qualifiers were modified to conform to USGS remark and data qualifiers codes as follows: (1) for analytes not detected, the USGS remark code “<” was used in place of Alpha Analytical, Inc. code “U”; (2) for estimated values below the reporting level but at or above the detection level, remark code “E” and value qualifier “n” was used in place of Alpha Analytical, Inc. code “J”; (3) for estimated values extrapolated at the high end, the remark code “E” and value qualifier code “a” was used in place of Alpha Analytical, Inc. code “F”; (4) for estimated values below the reporting level but at or above the detection level and extrapolated at the high end, remark code “E” and value qualifiers “a” and “n” were used in place of the Alpha Analytical, Inc. code “JF”; (5) for estimated values where the analyte was detected in associated the laboratory method blank, remark code “E” and value qualifier “v” were used in place of the Alpha Analytical, Inc. code “JB”; and (6) for values outside of the laboratory control acceptance criteria, value qualifier “\” was used in place of Alpha Analytical, Inc. code “Q.”



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