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PNNL-35007

Riverine Plastic Pollution: Field Sampling Protocol and Implementation in U.S. Rivers

September 2023

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U.S. DEPARTMENT OF ENERGY

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Executive Summary

Riverine plastic pollution is increasingly being recognized as a serious environmental concern. The flux of plastic from the United States into the oceans is estimated to be on the order of one million metric tons per year. Plastic pollution has been detected in all major U.S. rivers. The Department of Energy is investigating riverine-energy-powered technology solutions to the problem of riverine plastic pollution with the Waterborne Plastics Resource Assessment and Debris Characterization (WaterPACT) project. Phase one of the WaterPACT project includes the development of a sampling protocol, field sampling events that implement the protocol, numerical modeling studies, impacted-communities engagement, and rigorous valorization of the total accessible market. To identify key opportunities for renewably-powered reclamation and remediation, the field sampling will quantify and characterize the plastic pollution and numerical modeling studies will analyze the movement of the plastic pollution by rivers.

This report details the WaterPACT sampling protocol and its implementation in four major U.S. rivers. The WaterPACT sampling protocol was implemented in the Mississippi, Columbia, Delaware, and Los Angeles rivers with at least three sampling events in each river. The rivers represent four types ranging from the large Mississippi with its vast agricultural watershed to the small Los Angeles with its highly engineered urban waterway. The three sampling events covered a variety of discharge conditions from low drought flow to extreme storm events. The data obtained by the WaterPACT sampling of the four rivers will be combined to provide invaluable data to researchers studying the source and chemical composition of plastic pollution and modelers estimating the flux of plastic being transported to and released into the oceans.

Acronyms and Abbreviations

NREL	National Renewable Energy Laboratory
PNNL	Pacific Northwest National Laboratory
USGS	United States Geological Survey
WaterPACT	Waterborne Plastics Assessment and Collection Technologies

Acknowledgments

This work is funded by the Department of Energy, Office of Energy Efficiency and Renewable Energy, Water Power Technologies Office under contract DE-AC05-76RL01830 to Pacific Northwest National Laboratory and the National Renewable Energy Laboratory. The WaterPACT team would like to thank the many people who collected samples, but especially Kelly Somers, Mike Mansolino, Todd Lutte, Mark Benfield, Andy Gray, Hannah Hapich, Elise Granek, Susanne Brander, and Win Cowger.

Contents

Figures

Tables

1.0 Introduction

The United States has been estimated to release around one million metric tons of plastic into the oceans every year (Law et al. 2020). Once the plastic is in the ocean it degrades slowly over long timescales and fragments into microplastics. The fragmentation process is driven by chemical and/or mechanical degradation that results in particles that exhibit remarkable environmental ubiquity and persistence (Chamas et al. 2020).

The United States contributes between 0.51 and 1.45 Mt of mismanaged plastic waste into watersheds (Law et al. 2020), some of which is concentrated into rivers and transported to the global oceans. Plastic pollution has been found in many U.S. rivers but very few studies reported the mass collected and therefore the data cannot be used to estimate the total U.S. plastic flux released into the oceans (Branch et al. 2022). The studies also do not report a consistent set of metrics to describe the shape, size, or chemical composition of the particles that were found, which makes it difficult to compare the findings (Cowger et al. 2020). To more effectively develop renewable-energy-powered technology solutions for sensing and collecting plastic debris, the Department of Energy is addressing this problem of understanding U.S. riverine plastic pollution with the Waterborne Plastics Resource Assessment and Debris Characterization (WaterPACT) project. The first phase of the project includes the development of a sampling protocol, a field study to collect samples, laboratory studies to analyze the samples, and modeling studies to investigate plastic transport and settling. This report details the WaterPACT field sampling protocol and how it was implemented in four U.S. rivers.

The objective of the WaterPACT field study was to implement a set of standardized sampling methods to measure the ranges of the current energy resource and waterborne plastic pollution. The standardized sampling methods produce data that can be compared across four U.S. rivers representing a broad set of limnological, meteorological, ecological, and anthropogenic forcing conditions. The WaterPACT sampling methods were designed to collect macroplastic (> 5 mm), microplastic (< 5 mm), and associated leachates. Net samples were used to capture plastic as large as the net mouth opening (0.79 m by 0.17 m) and as small as the mesh size (330 micron). Nets filtered large volumes of water (approx. 10-1000 m^3). Whole water samples were used to collect particles smaller than the net mesh size and to collect water for leachate analysis. Net and whole water samples measure different distributions and proportions of plastic particles even if they are sampled simultaneously at the same location (Barrows et al. 2017). Surface and mid-depth samples were collected to investigate the vertical distribution as modeled by the Lenaker et al. (2019) study. The vertical distribution of riverine plastic pollution may not be constant due to the low density of most plastics and the changes of particle weight with biofouling (Andrady 2011). Samples were collected during three different flow regimes: low flow, high flow, and an extreme event. An extreme event was defined as either a flow with a higher discharge than the climatological mean or a flow after a recent rapid increase in discharge. The extreme event sampling was designed to test the hypothesis that a rapid increase in discharge may increase the suspended sediment from the river bottom and banks where plastic has been previously deposited. If the rapid rise in discharge was correlated with a rain event, the rain may also wash plastic into the river from the surrounding watershed.

Four rivers were selected to study a range of sizes and seasonal discharge patterns across the United States. The river selections were based on the criteria of discharge, estimated plastics load, population in the watershed, terminus location, infrastructure, tidal influence, and co-location with simultaneous research projects (Table 1). The Mississippi River was selected due to its large hydroelectric energy capacity, discharge, estimated plastic flux to the ocean, and population in its watershed. The Columbia River was selected due to its agricultural watershed and existing hydropower infrastructure. The dams may currently be intercepting plastic or they may be used as plastic collection sites in the future. The Delaware River was selected because of a separate DOE-funded numerical modeling project that is currently being used to study the watershed dynamics around the sampling sites. The Los Angeles River was selected because it is heavily engineered and has a strongly episodic discharge pattern, punctuated by spikes generated from local storms.

Table 1. Four U.S. rivers sampled by WaterPACT (plastics estimated by Schmidt et al. 2017).

	Mississippi	Delaware	Los Angeles	Columbia	Totals
Energy (GWhr/yr)	764	7	<1	52.7	824
Discharge (m^3/s)	13,300	340	6	3,592	17,238
Plastics (tons/yr)	699	15	8	13	735
Population (,000,000s)	76.7	7.5	5.0	7.3	96.5
Terminus	Gulf of Mexico	Atlantic	Pacific	Pacific	
Rationale	Magnitude	Watershed Study	Periodicity	Infrastructure	

Discharge data were acquired for the four rivers from the U.S. Geological Survey (USGS) station closest to the sampling site. Discharge data were averaged from 10/1/1963 to 10/12/2021 to obtain a climatology curve for the Columbia River. Discharge data were available for a longer time period for the Delaware River and averaged from 10/1/1912 to 12/9/2021. Discharge data were only available since 2008 at the USGS station closest to the Mississippi River sampling site. The climatology for the Mississippi River was calculated as the average from 10/29/2008 to 8/3/2022. The Los Angles River has been monitored for many years and its climatology curve was calculated from 10/1/1931 to 6/7/2022.

The WaterPACT sampling season occurred from October 2022 to July 2023.

2.0 Field Sampling Protocol

The objective of the WaterPACT field sampling protocol was to collect data that characterize the current energy resource and the type and quantity of riverine plastic pollution, leveraging methods that allow for comparison between different sizes of rivers. Directions describing the field sampling protocol will be released as a set of standard operating procedures. The WaterPACT field study included three sampling events in each river. Each event was classified as either low flow, high flow, or extreme. For each event, the sampling included the collection of both net and whole water samples at the surface and mid-depth (Fig. 1). Four net tows were completed at each depth and four whole water samples were collected at each depth. Sampling was conducted from boats in the Mississippi, Columbia, and Delaware and from a bridge over the Los Angeles River. The samples were stored in high-density polyethylene jars that had low-density polyethylene-lined polypropylene caps. Electrical tape was used to secure the caps (Fig. 2). The larger 4-liter jars were used for the whole water samples and the smaller 2-liter jars were used for the net samples. Blanks and spikes were also collected during each sampling event.

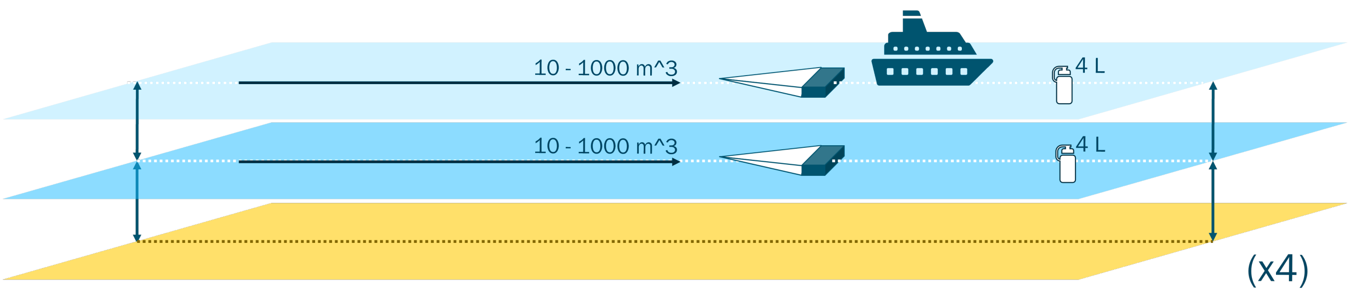

Figure 1. WaterPACT sampling method to collect both net and whole water samples.

Figure 2. Jars used to collect WaterPACT samples.

2.1 Net Sampling

The goal of the WaterPACT net sampling was to capture plastic pieces larger than the mesh size and smaller than the net opening. All of the rivers used a net mesh within the range of 295 to 335 microns. The nets used in the Mississippi, Columbia, and Delaware rivers were identical and manufactured by Ocean Instruments. They were 2.85 m long with cod ends at the bottom and metal frames at the top (Fig. 3). The net frames for both the surface and mid-depth tows had rectangular 0.79 m by 0.17 m openings (Figs. 4). The surface net had metal wings and a larger metal frame attached to the opening to enable it to be towed such that the net opening collected plastic from the water surface (Fig. 5). The nets were towed with synthetic rope and samples of the rope were kept to account for contamination. The net sampler used in the Los Angeles River was much smaller with a 0.20 m by 0.10 m opening (https://prph2o.com/elwha-river-sediment-sampler-us-er1/). The same sampler was used for both the surface samples and mid-depth samples (Fig. 6). The sampling protocol prescribed that the nets should tow through a volume of 10-1000 m^3. The nets were rinsed by spraying water from the outside to wash the contents down into the cod end (Fig. 7). The contents of the cod end were then rinsed into a 2-liter jar. The rinsing of the cod end was done with a spray bottle of deionized water.

Figure 3. Net and cod end.

Figure 4. Net frames: mid-depth (left) and surface (right).

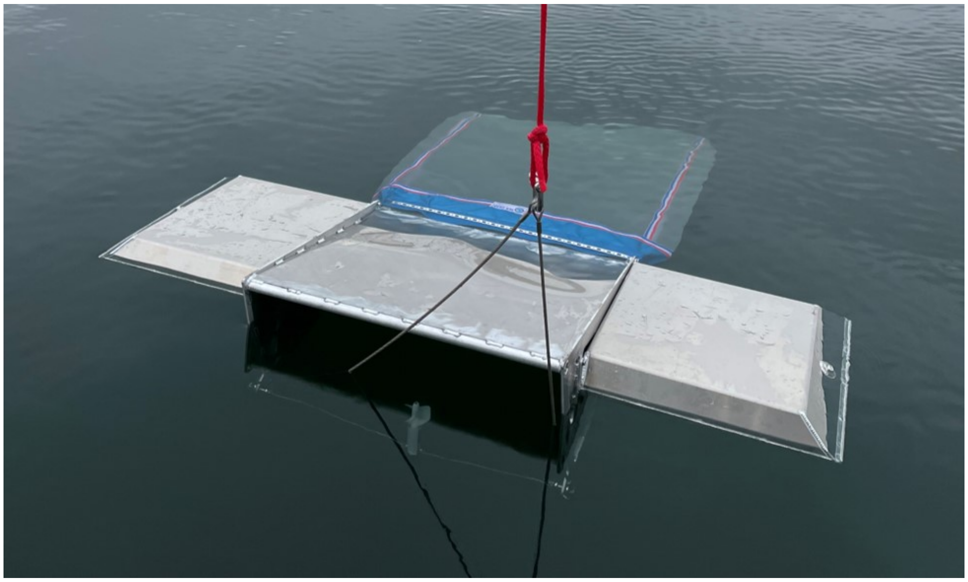

Figure 5. Surface net trawl configuration.

Figure 6. Net sampler used in the Los Angeles River.

Figure 7. Rinsing the net with pumped river water.

The amount of water sampled by the nets was measured with flowmeters that were mounted in the net openings (Fig.8). The flowmeters were manufactured by General Oceanics (https://www.generaloceanics.com/flowmeter-digital-7-cts-mech-w-one-way-clutch.html). The flowmeter data are a critical measurement because they allow quantification of the total plastic mass or total number of plastic particles per volume of water. Those values can then be used with discharge data to estimate a mass flux of plastic from each river into the ocean. The flowmeters failed during some of the tows. Data from the closest measurement in time was used for those tows and reported in italics in Sections 3.0.

Figure 8. Flowmeter mounted in the net opening of the mid-depth net.

2.2 Whole Water Sampling

The goal of the WaterPACT whole water sampling was to capture plastic pieces smaller than the mesh used in the net sampling and to collect water samples for leachate analysis. A Niskin sampler was used to collect the whole water samples in the Mississippi, Columbia, and Delaware rivers (Fig. 9). The Niskin sampler was manufactured by General Oceanics and it collected 1.7 liters of water (https://www.generaloceanics.com/model-1010-niskin-water-sampler-1.7l.html). It was lowered twice for each sample collection and the contents emptied into a 4-liter jar. It was lowered with synthetic ropes and samples of the rope were kept to check for contamination.

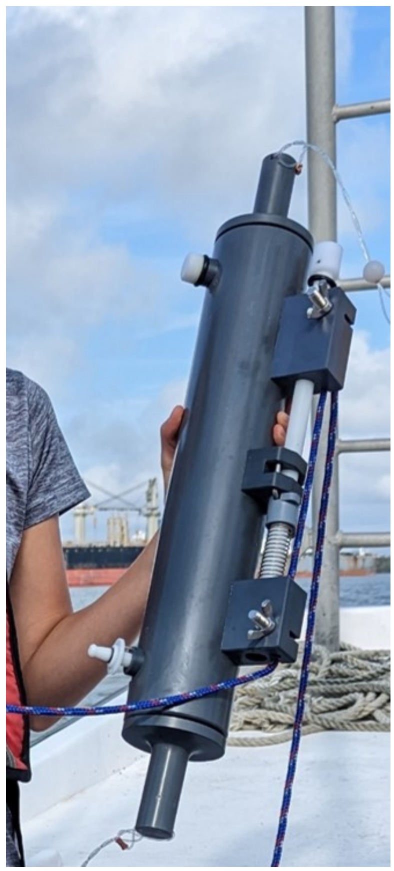

Figure 9. Niskin sampler used in the Mississippi, Columbia, and Delaware rivers.

A custom sampler was used to collect the whole water samples in the Los Angeles River. It was made of metal with a glass mason jar for storage and a small opening to collect the sample from a precise depth (Fig. 10). It was lowered from the bridge on a plastic-coated metal wire.

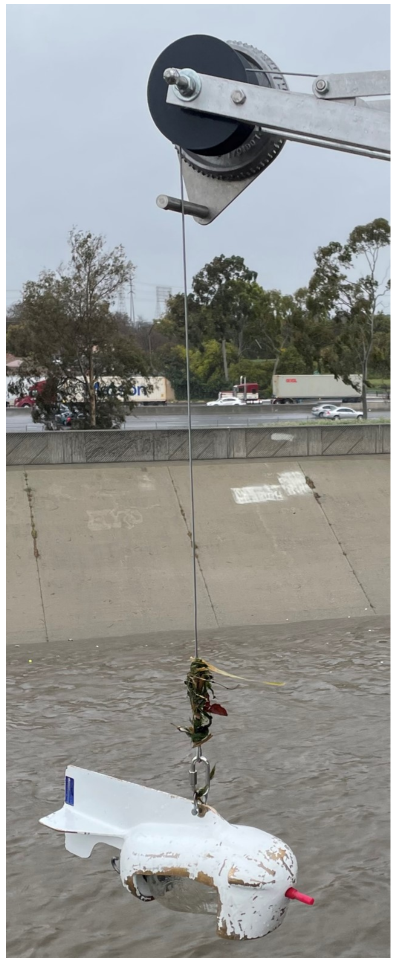

Figure 10. Whole water sampler used in the Los Angeles River.

2.3 Blanks and Spikes

Two blanks and two spiked samples were collected–one at the surface and one at mid-depth–for each sampling event. The whole water sampling blanks were collected by pouring 4 liters of deionized water into a 4-liter jar. The net sampling blanks were collected by spraying deionized water through the net, into the cod end, and then into a 2-liter bottle. The whole water spiked samples were collected by pouring 4 liters of deionized water into a 4-liter bottle, leaving the bottle open to the air for about 10 minutes, and then pouring the spike sample into it. The spike samples were swirled in the jar to make sure all of the spike was transferred (Fig. 11). The net spiked samples were collected by pouring 0.25 liters of deionized water into a 2-liter jar, adding the spike sample to that jar, pouring those contents into the net, rinsing the net into the cod end, rinsing the cod end back into the jar, and then leaving the jar open to the air for 10 minutes.

Figure 11. The addition of the spike sample.

3.0 Field Sampling in U.S. Rivers

3.1 Mississippi River

The Mississippi River was sampled downstream of New Orleans at Belle Chasse (Fig. 12). The discharge was measured by the USGS at station 07374525 approximately 2 miles upstream of the sampling site.

Figure 12. Locations of the USGS discharge gauge and the sampling site.

The discharge of the Mississippi River has a strong seasonal signal with high values in the spring to early summer and low values in the fall and winter (Fig.13). The 2022-2023 sampling year had very low discharge values in the fall of 2022. The sampling began in December 2022 with the low-flow sampling event on 12/13/22 (Table 2). The low-flow event did not occur at the lowest flow of the year but did have a lower discharge value than the minimum value in the climatology. The high-flow sampling event occurred when the flow was close to the maximum discharge value in the climatology and a large amount of organic matter was captured by the nets (Fig. 14). The Mississippi River is so large that its discharge is barely affected by local storms. Therefore, the extreme flow sampling event did not occur during a local storm but instead after a rapid rise in discharge that was caused by multiple factors upstream in the watershed. A large amount of plastic was observed in the net collections of that sampling event.

Table 2. Mississippi River sample dates and discharge values.

	date	Q (m^3/s)
Low	12/13/22	7,932
High	3/27/23	23,314
Extreme	7/28/23	7,989

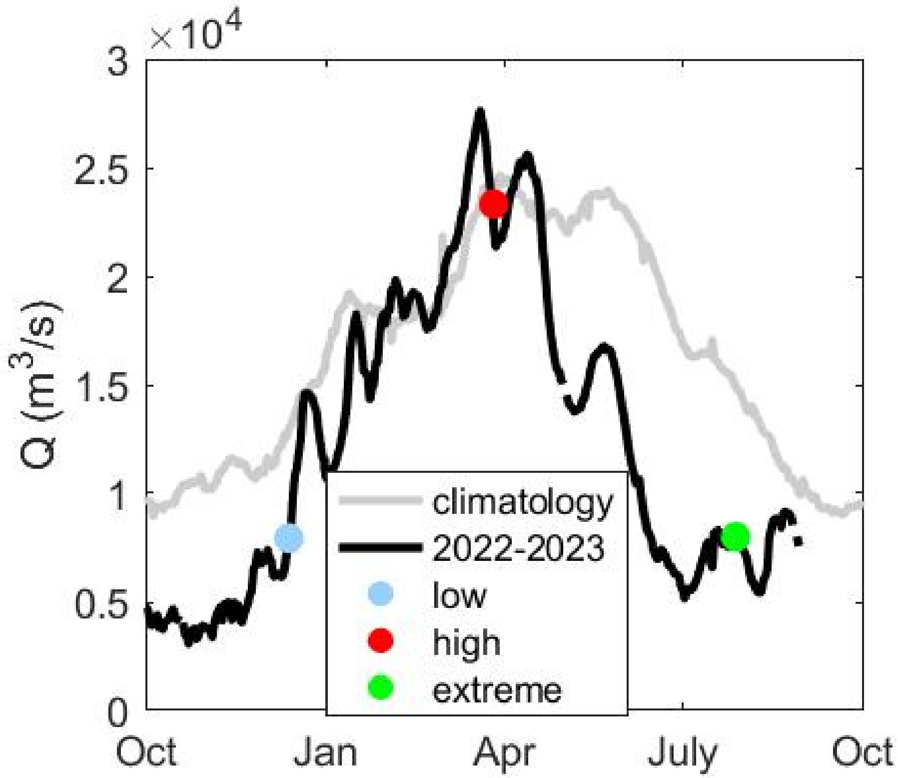

Figure 13. Mississippi River climatology, discharge, and WaterPACT sampling dates.

Table 3. Mississippi River net sampling water volumes.

	Tow #	Depth	Volume (m^3)
Low	1	surface	270
Low	2	surface	261
Low	3	surface	257
Low	4	surface	235
Low	1	mid	*256*
Low	2	mid	*256*
Low	3	mid	*256*
Low	4	mid	*256*
High	1	surface	344
High	2	surface	266
High	3	surface	264
High	4	surface	262
High	1	mid	428
High	2	mid	332
High	3	mid	368
High	4	mid	352
Extreme	1	surface	277
Extreme	2	surface	262
Extreme	3	surface	260
Extreme	4	surface	278
Extreme	1	mid	274
Extreme	2	mid	117
Extreme	3	mid	183
Extreme	4	mid	289

Figure 14. Material captured by the net during high-flow sampling of the Mississippi River.

3.2 Columbia River

The Columbia River was sampled near the city of Portland, Oregon, downstream of the confluence of the Columbia and Willamette Rivers (Fig. 15). The discharge was measured by USGS station 14144700 near Vancouver, Washington. Station 14144700 is upstream of the confluence of the two rivers.

The discharge of the Columbia River has a strong seasonal signal with the maximum usually occurring in May or June. The 2022-2023 sampling year had a narrow peak of higher discharge values (> 5000 m^3/s) from the last week of May to the first week of June (Fig. 16). The sampling began in December 2022 with the low-flow event. The extreme flow sampling event occurred in May when the discharge was above the climatological mean. The high-flow event occurred later in May when the flow had decreased but was still elevated above 5000 m^3/s.

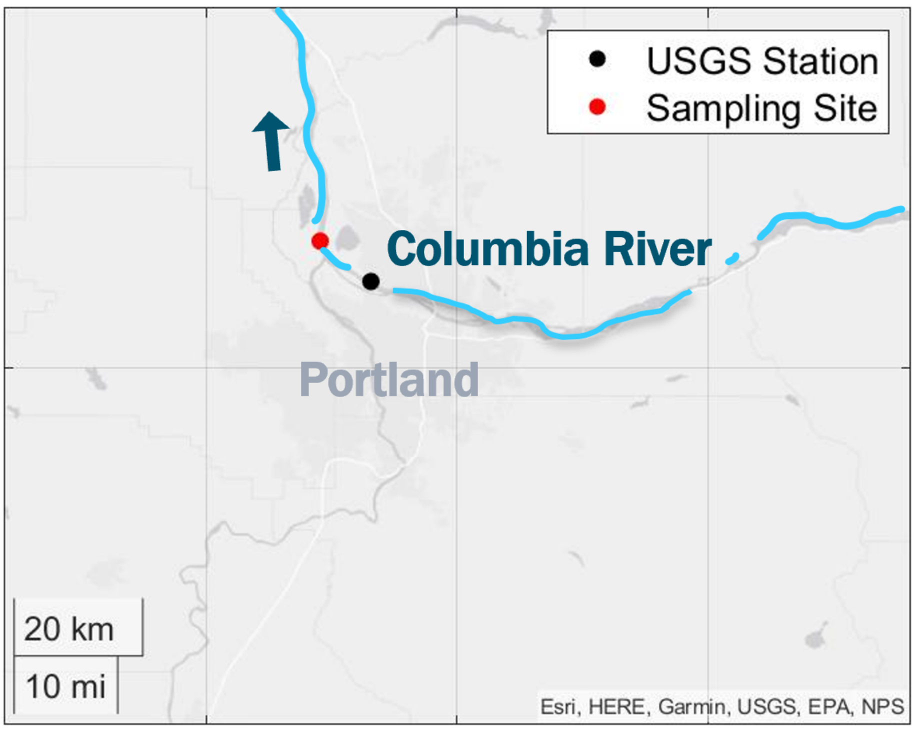

Figure 15. Locations of the USGS discharge gauge and the sampling site.

Table 4. Columbia River sample dates and discharge values.

	date	Q (m^3/s)
Low	12/7/22	3,428
High	5/30/23	7,790
Extreme	5/17/23	10,255

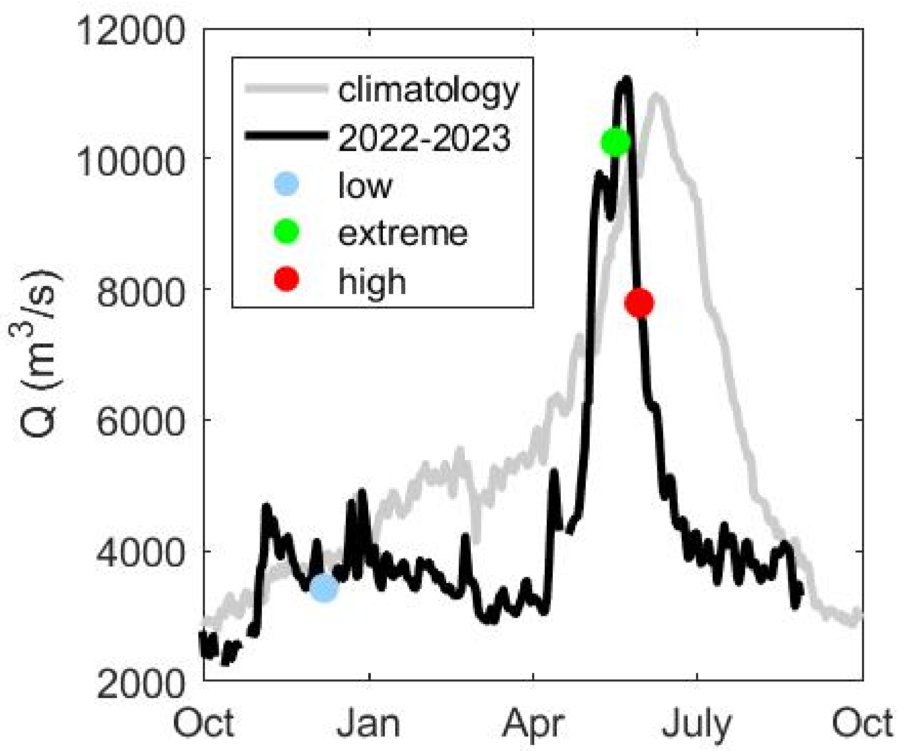

Figure 16. Columbia River climatology, 2022-2023 discharge, and WaterPACT sampling dates.

Table 5. Columbia River net sampling water volumes.

	Tow #	Depth	Volume (m^3)
Low	1	surface	*59*
Low	2	surface	*65*
Low	3	surface	*42*
Low	4	surface	*132*
Low	1	mid	59
Low	2	mid	65
Low	3	mid	42
Low	4	mid	132
High	1	surface	75
High	2	surface	76
High	3	surface	59
High	4	surface	89
High	1	mid	80
High	2	mid	24
High	3	mid	79
High	4	mid	67
Extreme	1	surface	56
Extreme	2	surface	44
Extreme	3	surface	44
Extreme	4	surface	45
Extreme	1	mid	52
Extreme	2	mid	37
Extreme	3	mid	26
Extreme	4	mid	28

3.3 Delaware River

The Delaware River was sampled at three sites (Fig. 17). The primary sampling site was downstream of Philadelphia. The secondary sites were upstream of Philadelphia at the Water Gap and Washington Crossing. The Water Gap site is within a national recreation area. Both the Water Gap and Washington Crossing sites are upstream of a drinking water intake at river mile 110. River discharge was measured by the USGS at station 01463500 near Trenton, New Jersey.

The Delaware River is smaller than the Mississippi and Columbia rivers and is therefore more influenced by local storms. Its hydrograph is not as smooth as those of the Mississippi and Columbia (Fig. 18). The hydrograph of the 2022-2023 sampling season has many peaks corresponding to storms rather than a wide, smooth peak in summer due to snow melt. Sampling began in the Delaware in October 2022 with the low-flow event near Philadelphia (Table 6). The high-flow sampling event near Philadelphia occurred when the discharge was higher in March than it had been in October, but it was lower than the climatological mean for that time of year. The extreme flow sampling event near Philadelphia occurred during a large storm in May 2023. The extreme flow sampling event at the Washington Crossing site occurred after a rapid rise in discharge during November 2022 (Fig. 19). An extreme flow was not sampled at the Water Gap site (Fig. 20). High flow was sampled at the Washington Crossing site in March 2023 (Table 8) and the Water Gap site in April 2023 (Table 10). Low-flow samples were collected at both the Washington Crossing and Water Gap sites in June 2023 (Figs. 19 and 20). Discharge during those two sampling events was close to the lowest flow of the year and below the climatological mean for that time of year.

Figure 17. Locations of the USGS discharge gauge, sampling sites, and an extraction point for a drinking water treatment facility.

Table 6. Delaware River sample dates and discharge values for samples collected near Philadelphia.

	date	Q (m^3/s)
Low	10/26/22	154
High	3/27/23	487
Extreme	5/4/23	1,181

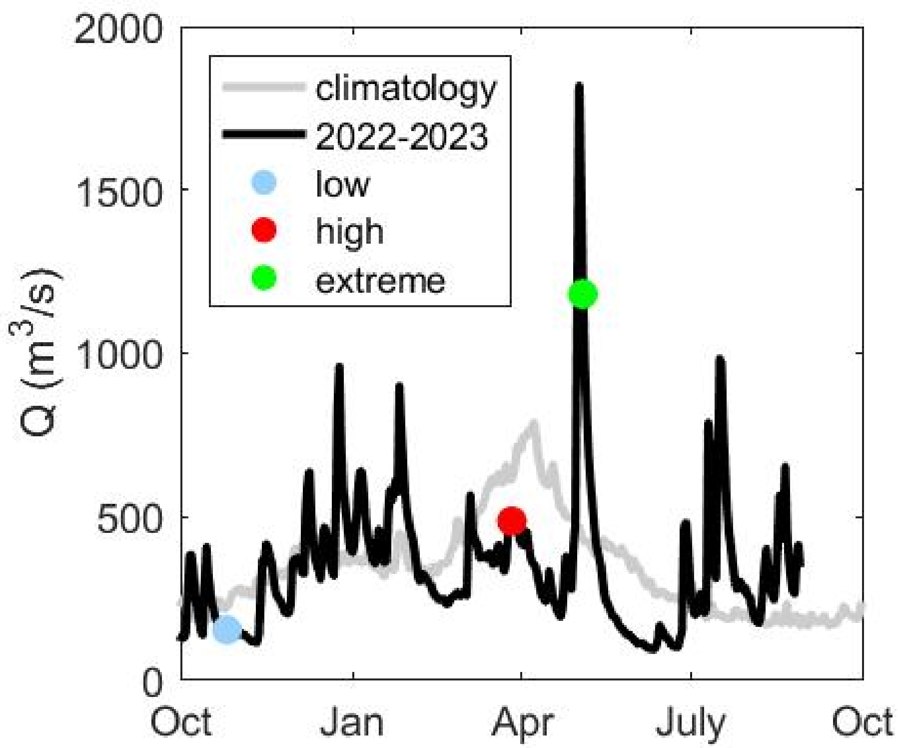

Figure 18. Delaware River climatology, 2022-2023 discharge, and sampling dates for collections near Philadelphia.

Table 7. Delaware River net sampling water volumes collected near Philadelphia.

	Tow #	Depth	Volume (m^3)
Low	1	surface	89
Low	2	surface	88
Low	3	surface	*88*
Low	4	surface	174
Low	1	mid	*89*
Low	2	mid	114
Low	3	mid	*88*
Low	4	mid	241
High	1	surface	83
High	2	surface	112
High	3	surface	118
High	4	surface	174
High	1	mid	118
High	2	mid	97
High	3	mid	108
High	4	mid	182
Extreme	1	surface	192
Extreme	2	surface	208
Extreme	3	surface	211
Extreme	4	surface	190
Extreme	1	mid	192
Extreme	2	mid	184
Extreme	3	mid	205
Extreme	4	mid	163

Table 8. Delaware River sample dates and discharge values for samples collected at the Washington Crossing site.

	date	Q (m^3/s)
Low	6/21/23	106
High	3/29/23	490
Extreme	11/16/22	416

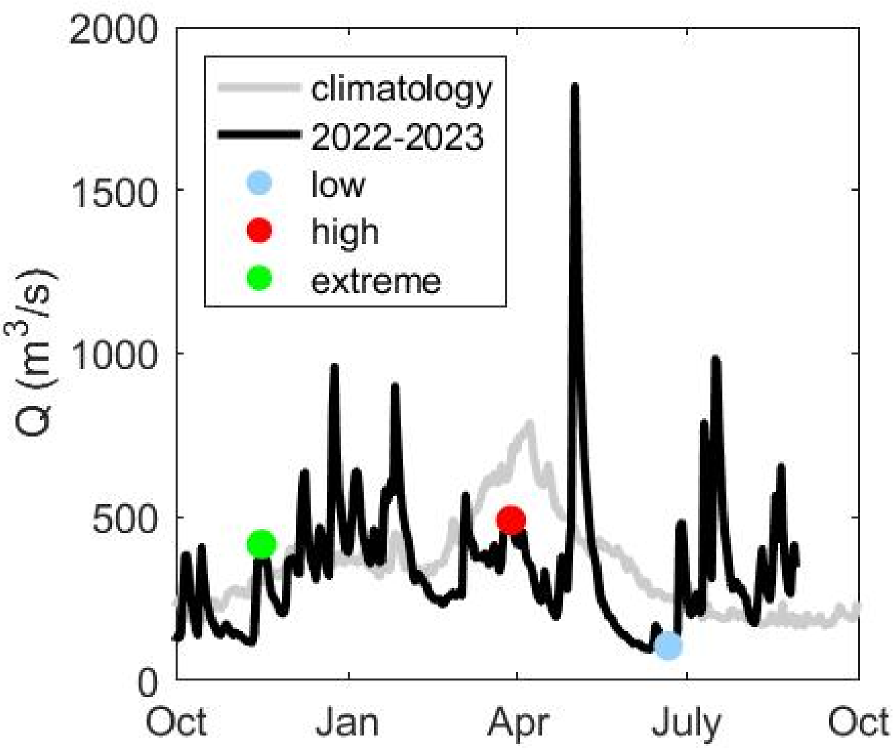

Figure 19. Delaware River climatology, 2022-2023 discharge, and dates for the sampling at the Washington Crossing site

Table 9. Delaware River net sampling water volumes for the samples collected at the Washington Crossing site.

	Tow #	Depth	Volume (m^3)
Low	1	surface	*73*
Low	2	surface	*73*
Low	3	surface	77
Low	4	surface	76
Low	1	mid	*73*
Low	2	mid	73
Low	3	mid	*77*
Low	4	mid	65
High	1	surface	128
High	2	surface	60
High	3	surface	174
High	4	surface	159
High	1	mid	148
High	2	mid	*60*
High	3	mid	82
High	4	mid	*65*
Extreme	1	surface	140
Extreme	2	surface	137
Extreme	3	surface	170
Extreme	4	surface	147
Extreme	1	mid	137
Extreme	2	mid	104
Extreme	3	mid	*170*
Extreme	4	mid	*147*

Table 10. Delaware River sample dates and discharge values for samples collected at the Water Gap site.

	date	Q (m^3/s)
Low	6/20/23	111
High	4/10/23	314

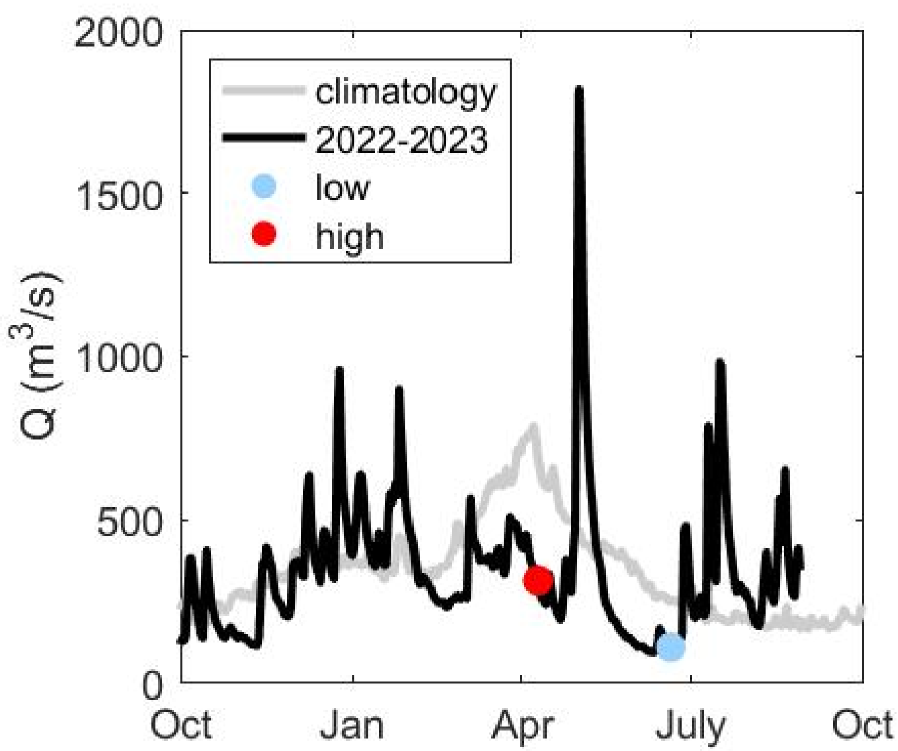

Figure 20. Delaware River climatology, 2022-2023 discharge, and dates for the sampling at the Water Gap site

Table 11. Delaware River net sampling water volumes for the samples collected at the Water Gap site.

	Tow #	Depth	Volume (m^3)
Low	1	surface	21
Low	2	surface	79
Low	3	surface	*62*
Low	4	surface	*60*
Low	1	mid	53
Low	2	mid	70
Low	3	mid	62
Low	4	mid	60
High	1	surface	*61*
High	2	surface	80
High	3	surface	84
High	4	surface	89
High	1	mid	61
High	2	mid	32
High	3	mid	52
High	4	mid	22

3.4 Los Angeles River

The Los Angeles River was sampled from the Wardlow Street Bridge in an urban area of Long Beach, California, which is south of the city of Los Angeles (Fig. 21). The sampling site was downstream of USGS station 11092450 and 1.5 miles upstream of where the river discharges into the ocean.

The Los Angeles River is the smallest river sampled by the WaterPACT project in terms of hydroelectric energy capacity, discharge, and estimated plastic flux. Its hydrograph is dominated by storm peaks (Fig. 22). The first sampling event occurred during a storm on 2/24/23. The team was able to begin sampling and completed two surface tows and two mid-depth tows before the flood surge arrived with a clearly visible hydraulic jump. The flood surged during the third mid-depth tow and the net sampler had to be removed. A fourth mid-depth tow was attempted but the net was only in the water for one minute before the conditions were deemed unsafe and it was removed. Only 0.5 m^3 of water was sampled during that tow (Table 13). That sampling event was classified as an extreme event. The high- and low-flow sampling events took place in March and June 2023 (Table 12).

Figure 21. Locations of the USGS discharge gauge and the sampling site.

Table 12. Los Angeles River sample dates and discharge values.

	date	Q (m$^3/s$)
Low	6/7/23	1.3
High	3/11/23	14
Extreme	2/24/23	166

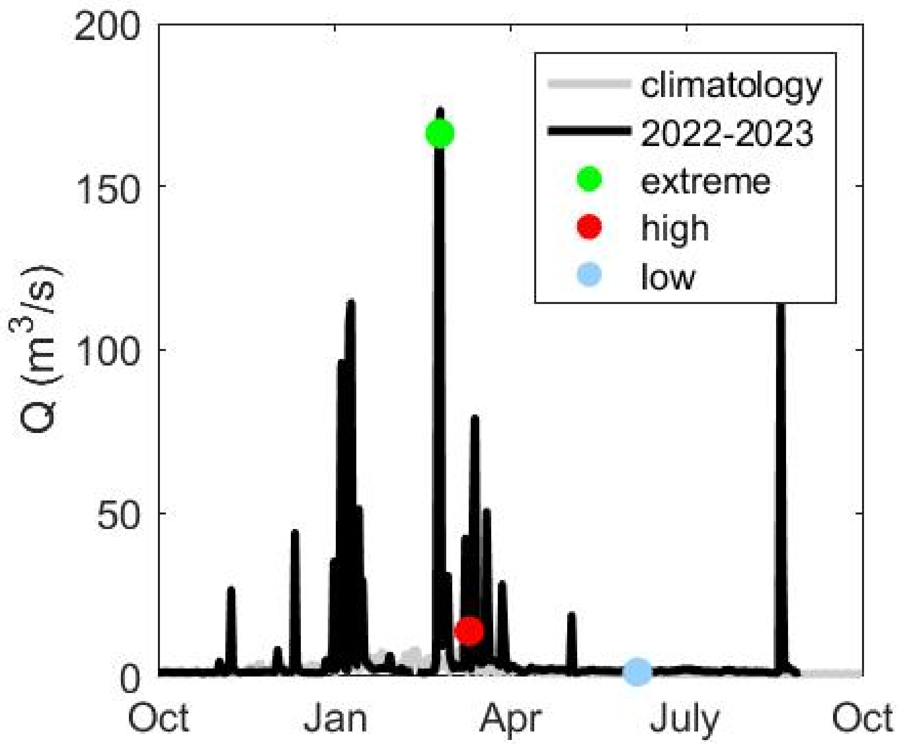

Figure 22. Climatology, discharge, and sampling dates in the Los Angeles River.

Table 13. Los Angeles River net sampling water volumes.

	Tow #	Depth	Volume (m^3)
Low	1	surface	25
Low	2	surface	28
Low	3	surface	23
Low	4	surface	11
Low	1	mid	45
Low	2	mid	8
Low	3	mid	7
Low	4	mid	11
High	1	surface	20
High	2	surface	19
High	3	surface	17
High	4	surface	25
High	1	mid	11
High	2	mid	7
High	3	mid	7
High	4	mid	5.4
Extreme	1	surface	11
Extreme	2	surface	26
Extreme	3	surface	*26*
Extreme	4	surface	*26*
Extreme	1	mid	8
Extreme	2	mid	13
Extreme	3	mid	15
Extreme	4	mid	0.5

4.0 Summary

The WaterPACT field project successfully sampled for plastic pollution in four major U.S. rivers over a wide range of discharge conditions. Seventeen sampling events took place from October 2022 to July 2023. Twelve sampling events occurred at primary sites and five at secondary sites. The primary sites were downstream of major cities and the secondary sites were in the Delaware River upstream of Philadelphia and a drinking water intake site. The four rivers sampled were the Mississippi, Columbia, Delaware, and Los Angeles. Each of the rivers was sampled three times to cover a range of discharge conditions: low flow, high flow, and an extreme event. Low flow, high flow, and one extreme event samples were also collected at the secondary sites. The comparison between the urban primary site and rural secondary sites in the Delaware River will quantify the strength of pollution from Philadelphia as a source term and support model development. The discharge conditions sampled throughout the year ranged from normal conditions to record low flow in the Mississippi River and an unusually large storm in the Los Angeles River.

The WaterPACT sampling protocol was designed to collect data that could be compared across the wide range of river sizes. The volume of water sampled during the net collections varied between the four rivers but was within the range described in the WaterPACT protocol for all of the collections except for a few tows in the Los Angeles River. Identical sampling equipment was used whenever possible. The Mississippi, Columbia, and Delaware used identical nets, Niskin samplers, and collection jars. Identical red polyethylene rope was used to tow the nets whenever possible. If a different rope was used, a section of it was sent to the laboratory along with the samples.

The Los Angeles River was different than the three large rivers because of its shallow depth and bridge sampling. The net mesh used in the Los Angeles was standardized with the large rivers and the samples were stored in the same collection jars. The same red polyethylene rope was used on the net sampler when it was collecting surface samples.

All of the rivers collected whole water and net samples at two depths. Net and whole water samples were used to collect particles as small as laboratory analysis could detect and as large as the net opening. The liquid water in the whole water samples was also collected for leachate analysis. The data collected with the WaterPACT sampling protocol will provide information about the quantity and characteristics of leachates, microplastics, and macroplastics at the surface and mid-depth. Although the sampling methods varied slightly between the rivers, all of the same metrics of mass, particle number, volume flux, and chemical composition will be derived from the data and compared across the four rivers.

The discharge conditions sampled by the WaterPACT project ranged from normal to record levels. The Mississippi was sampled when it was well below the climatological mean during a year of record low levels. The Columbia and Delaware low discharge samples were collected very near their fall climatological means and the Los Angeles low-flow sampling took place during the summer period when the flow could be described as ”urban drool.” The high-flow sampling in the Mississippi occurred very close to the climatological mean. The high-flow samplings in the Columbia and Delaware were below the climatological means for the time of year they were sampled but elevated above the climatological mean for the rest of the year. The Los Angeles high flow was significantly above the climatological mean but lower than the extreme event level. The extreme event sampled in the Los Angeles River was so strong that the net sampler could not operate during the peak flow. The range of conditions sampled during the WaterPACT field project will result in data covering normal to extreme conditions.

Site-specific USGS flowrates, ship-based speeds in combination with flowmeter readings, and intricate bathymetric- and stream-gauge-based numerical models of riverine flow during the testing episodes will be used to assess the available hydrokinetic energy resource, ultimately identifying areas of co-located energy and remediable plastics ”resource”. The data collected under WaterPACT are intended be used in late phases of this project as the engineering basis to guide development of renewable-energy-powered sensor and collector technologies.

Additionally, the WaterPACT data will be used to inform a variety of plastic pollution studies. The metric of grams per m^3 will be used in large-scale studies such as Schmidt et al. (2017) to estimate the total flux of plastic that U.S. rivers release to the oceans. The shape and chemical composition of the particles may provide insight into the sources of the pollution. The comparison between samples from the Mississippi with its massive agricultural watershed and the Los Angeles with its highly engineered urban environment will also inform studies working to identify pollution sources. The comparison between the Columbia (> 60 dams) and the Delaware (0 dams) will inform future studies of dams as possible plastic collection sites. The secondary sampling in the Delaware River upstream of Philadelphia will provide a valuable comparison of the contributions from urban and rural areas. The wide range of river sizes, discharge conditions, and watershed types sampled during the WaterPACT field project will result in an invaluable dataset for studies of riverine plastic pollution. The WaterPACT sampling protocol will be used for future field campaigns to collect comparable datasets for process studies at specific sites or trends over time as our climate, population, and land usage changes.

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