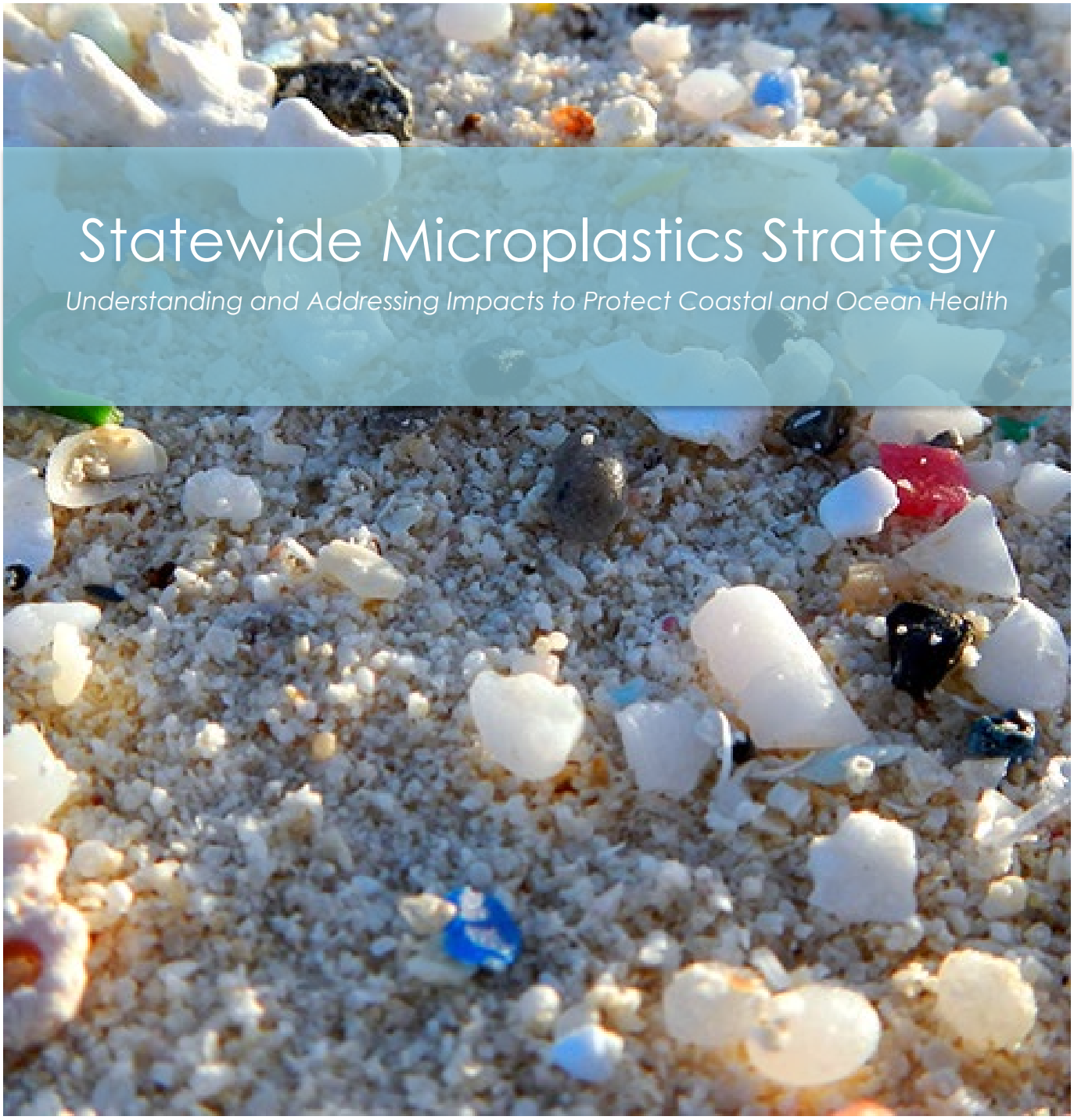

Statewide Microplastics Strategy

Understanding and Addressing Impacts to Protect Coastal and Ocean Health

February 2022

OCEAN PROTECTION COUNCIL

Acknowledgements

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Plastics are a global threat to ocean health. Worldwide, an estimated 11 million metric tons of plastic enter the ocean each year, with this amount expected to triple by 2040 if no intervention takes place. Microplastics, defined by the State Water Resources Control Board (SWRCB) as synthetic particles with at least three dimensions ranging from 1 nm to 5 mm in size, are considered pervasive and persistent global pollutants, with microplastics increasingly observed even in remote environments. The California Legislature recognized the need for a comprehensive plan to address this environmental challenge with the adoption of Senate Bill 1263 (Portantino) in 2018, requiring the California Ocean Protection Council (OPC) to adopt a statewide research strategy and identify early actions to reduce microplastic pollution in California's marine environment.

This Statewide Microplastic Strategy provides a multi-year roadmap for California to take a national and global leadership role in managing microplastics pollution. Multiple state agencies and external partners will work together to reduce the introduction of microplastics in California's coastal ocean and other aquatic systems. Foundational to this Strategy is a recognition that the state must take decisive, precautionary action to reduce microplastic pollution, while scientific knowledge and understanding of microplastics sources, impacts, and successful reduction measures continue to grow.

The Strategy outlines a two-track approach to comprehensively manage microplastics in California. The first track (**Chapter 2A**: **Solutions**) outlines immediate, 'no regrets' actions and multi-benefit solutions to reduce and manage microplastic pollution, while the second track (**Chapter 2B**: **Science to Inform Future Action**) outlines a comprehensive research strategy to enhance the scientific foundation for microplastic monitoring, source identification, risk assessment, and development of management solutions.

Solutions

multi benefit solutions the state can act upon now while the scientific knowledge of microplastics further develops.

- **Pollution Prevention**
  to eliminate plastic waste at the source (products or materials from which microplastics originate)
- **Pathway Interventions**
  to intervene within specific pathways that mobilize microplastics from a specific source into California waters
- **Education**
  to inform the public and industries of microplastics sources, impacts, and solutions

Science to Inform Future Action

research priorities to advance scientific knowledge of microplastics to develop and refine future solutions.

- **Monitoring**
  to understand and identify trends of microplastic pollution statewide
- **Risk**
  to improve understanding of critical thresholds at which aquatic life and humans are adversely impacted by microplastic exposure
- **Sources & Pathways Prioritization**
  to identify and prioritize future management solutions based on predominant ways microplastics enter California waters
- **Evaluating New Solutions**
  to develop and implement potential future solutions

Within the **Solutions** track, short-term management actions focus on eliminating plastic waste at its point of origin to prevent the introduction of plastics into the environment (**Pollution Prevention**) and implementing multi-benefit management interventions that can both reduce plastics loading and improve overall ecosystem health (**Pathway Interventions**). Also, **Solutions** include engaging the public, California Native American Tribes, and industries, and working to alter public behaviors and consumption, attitudes, and priorities around plastics use and waste reduction (**Outreach & Education**). Immediate actions outlined in this Strategy to reduce microplastic pollution include enaction of statewide comprehensive plastic source reduction goals, elimination of products that are among the highest contributors of both plastic and microplastic pollution, engagement with industry to identify alternative material sources and product designs, and improved stormwater management.

The research-focused **Science to Inform Future Action** track focuses on standardizing measurement approaches and building monitoring capacity to comprehensively assess the scale of, and trends in, microplastic pollution statewide (**Monitoring**), and implementing a risk assessment approach that identifies the types of microplastics having the greatest effect on aquatic life and human health. In addition, the **Science to Inform Future Action** track will enhance understanding of critical thresholds at which microplastics affect aquatic life and California communities now and into the future (**Risk Thresholds & Assessment**) and enhance understanding of the predominant pathways by microplastics enter aquatic environments (**Source & Pathways Prioritization**). Future actions include developing targeted management solutions based on research findings (**Evaluating New Solutions**). California will specifically prioritize the establishment of standardized methods, development of a statewide microplastic monitoring program, creation of a source emission inventory, and advancement of existing risk thresholds that can inform future regulatory and management actions by 2025.

This Strategy will adapt solutions to new science, as new information and approaches become available. To implement these research priorities, evaluate the efficacy of early actions, and inform future solutions, California will collaborate with scientific experts across academic institutions, federal and state agencies, and prioritize public engagement and transparency through direct community outreach and the use of the existing California Ocean Litter Strategy Project and the interagency projects and programs by the California Water Quality Monitoring Council.

Over the next four years, California can achieve reductions in microplastic pollution and catalyze increased scientific understanding by implementing the 22 recommended early actions and 13 research priorities outlined in the two tracks of this Strategy. As policy recommendations are implemented and scientific understanding advances, OPC, alongside state agency partners, will evaluate the findings and lessons learned to provide additional recommendations to the California Legislature by December 2025, to ensure that California takes action to reduce microplastic pollution that is informed by the best available science.

ACRONYMS

CalRecycle	California Department of Resources Recycling and Recovery
CCC	California Coastal Commission
CDFW	California Department of Fish and Wildlife
CTCP/CDPH	California Tobacco Control Program: California Department of Public Health
DGS	California Department of General Services
DOE	California Department of Education
DTSC	California Department of Toxic Substances Control
EPR	Extended Producer Responsibility
FGC	California Fish and Game Commission
LID	Low Impact Development
mm	millimeter
nm	nanometer
NOAA	National Oceanic and Atmospheric Administration
OEHHA	California Office of Environmental Health Hazard Assessment
OPC	California Ocean Protection Council
OPC SAT	California Ocean Protection Council, Science Advisory Team
OST	California Ocean Science Trust
PPSC	Plastic Pollution Steering Committee
RWQCB	Regional Water Quality Control Board
SPD	California State Parks Department
SFEI	San Francisco Estuary Institute
SLC	California State Lands Commission
SWRCB	California State Water Resources Control Board
SCCWRP	Southern California Coastal Water Research Project Authority
TMDL	Total Maximum Daily Load

1. BACKGROUND

Plastics are ubiquitous in both Californians' daily lives and in the environment. Worldwide, an estimated 11 million metric tons of plastic enter the ocean each year, and without any intervention, this amount is anticipated to triple by 2040.[1] Plastics are recognized globally as the most harmful and persistent fraction of marine litter, accounting for at least 85 percent of total marine waste.[2] Over time, plastics break down in aquatic environments into pieces of ever-decreasing size, with those less than 5 mm in size known as microplastics.

Microplastics fall into two general categories: primary microplastics manufactured at a small size (e.g., preproduction plastic pellets used in manufacturing or microbeads in personal care products) or secondary microplastics that result from the breakdown of larger plastics. Microplastics have a range of polymer types, sizes, shapes, and associated chemicals, with irregular shapes and fibers found increasingly in marine organisms, including mammals, fish, mollusks, and crustacea.[3] In toxicity studies, microplastic exposures have been shown to cause adverse effects, including tissue inflammation, impaired growth, developmental anomalies, and reproductive difficulties.[4]

Microplastics Definition.

In this Strategy, microplastics are defined as "solid polymeric materials to which chemical additives or other substances may have been added" and which have "at least three dimensions that range from 1 nm to 5 mm in size" consistent with the definition adopted by the State Water Resources Control Board in 2020. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded. Further, plastic particles larger than 5 mm in size are considered macroplastics.

In California, microplastics have been observed in Monterey Bay, San Francisco Bay, the Greater Farallones National Marine Sanctuary, Lake Tahoe, and in Southern California waterways, including preproduction plastic pellets ('nurdles') that spill from manufacturing facilities and reach California's beaches.

Microplastics are not only a marine pollution problem. Microplastics have been found nearly everywhere scientists have looked, from pristine mountain streams to agricultural soil, and within human placenta, stool samples, and lung tissue.[5] Microplastics can enter the food web, where plastic particles can transfer into tissue, and expose humans to plastic-associated and endocrine-disrupting chemicals from seafood consumption.[6]

In 2018, in response to rising concerns over the potential impacts of microplastics to ocean and human health in California, the California Legislature adopted Senate Bill 1422 and Senate Bill 1263,

[1] Lebreton & Andrady, 2020; Lau et al., 2020.
[2] United Nations Environment Programme, 2021.
[3] Barrows et al., 2018; Bucci et al., 2020; Sequeira et al., 2020.
[4] Gall & Thompson, 2015; Ziajahromi et al., 2017; Wilcox et al., 2018; Jacob et al., 2020.
[5] Amato-Lourenço et al., 2021; Ragusa et al., 2021; Schwabl et al., 2019; Rahman et al., 2021.
[6] Coffin et al., 2021.

requiring the State Water Resources Control Board (SWRCB) to address microplastics in drinking water and the California Ocean Protection Council (OPC) to develop a Statewide Microplastics Strategy to address microplastics in the ambient marine environment, respectively. This Statewide Microplastics Strategy was developed in response to Senate Bill 1263 to identify early actions and outline research priorities to address microplastics in the marine environment. Senate Bill 1263 requires that the Strategy include, but not be limited to: 1) a prioritized research plan; 2) standardized methods for sampling, detecting, characterizing, and monitoring microplastics; 3) an investigation of the sources, pathways, and impacts of microplastics on coastal and marine ecosystems; 4) a risk assessment framework based on the best available science on the exposure of microplastics to organisms; 5) research on pathway interventions; 6) an evaluation of source reduction and product stewardship techniques; and 7) policy recommendations.

To inform this Strategy, OPC collaborated with partner agencies and research institutions to enhance the scientific foundation of microplastics science. This has included the characterization of the predominant sources and pathways of microplastics in the San Francisco Bay; initiation of standardized sampling, detecting, characterization, and microplastic monitoring methods; and creation of a preliminary risk assessment framework that provides the foundation to sample, monitor, and evaluate microplastics statewide (see **Completed Studies**, **page 6**).

The final Statewide Microplastics Strategy, developed by OPC in coordination with state agency and external partners, provides a comprehensive and coordinated approach to identify early actions California can take to address microplastic pollution and advance existing microplastic research. The recommended actions outlined in the Strategy are organized into two basic categories: management actions that California can begin implementing immediately (**Chapter 2A**), and research priorities to inform future actions (**Chapter 2B**). The organizing framework and timeline to implement these actions are described in the final chapter (**Chapter 3**). As policy recommendations are implemented and scientific understanding advances, OPC alongside state agency partners, will evaluate the findings and lessons-learned to provide additional recommendations to the California Legislature by December 2025.

Senate Bill 1263 (Portantino, 2018)

The California Legislature directed the Ocean Protection Council, in close coordination with state agency partners, to develop the Statewide Microplastics Strategy, recognizing:

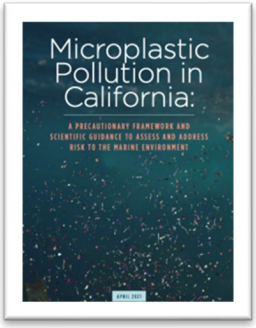
- Although substantial scientific research on microplastics exists, further research will complement and support continuing efforts to reduce microplastic pollution.
- Early actions to prevent and reduce known impacts of microplastics to the marine environment should be pursued.
- The need for a comprehensive prioritized research plan, including the development of risk assessments for microplastics in California.

Senate Bill 1263 requires the Ocean Protection Council to submit the Statewide Microplastics Strategy to the Legislature on or before December 31, 2021 and to report on the implementation of the Statewide Microplastics Strategy, the Council's findings, and recommendations to the Legislature on or before December 31, 2025.

Pub. Resources Code section 35635.

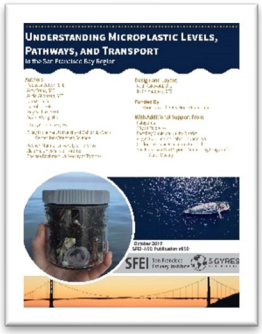
Completed Studies Informing the Statewide Microplastics Strategy

California is an emerging leader in microplastic research. Since the adoption of Senate Bill 1263 in 2018, OPC has collaborated with partner agencies and research institutions to enhance the scientific foundation for effective, informed management of microplastics. This body of work, coupled with global microplastics research and ongoing advancements in the field of microplastics science, provides the foundational knowledge necessary for California to develop and implement this Strategy.



Assessing the Risk of Microplastic Pollution in California. The OPC Science Advisory Team (OPC SAT) formed an interdisciplinary microplastics working group, convened by the California Ocean Science Trust (OST), that recommended precautionary management of microplastic pollution and emphasized upstream source reduction as the most effective response. The working group specifically identified high-priority and prevalent components of microplastic pollution (microfibers and road wear particles as dominant sources; stormwater runoff (urban, agricultural), aerial deposition, and wastewater as primary fate & transport pathways), priority endpoints, and recommended a particulate management approach to prevent the proliferation and risk of small particulates in the environment.

Microplastic Risk Quantification Framework. The State Water Resources Control Board (SWRCB) and Southern California Coastal Water Research Project Authority (SCCWRP) subsequently convened an expert workshop to identity critical thresholds at which biological effects become pronounced. The workshop focused on prioritizing microplastic characteristics (size, shape, polymer) of greatest biological concern, and developed an initial, tentative set of thresholds for aquatic life.



Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region. The San Francisco Estuary Institute (SFEI) conducted a comprehensive monitoring study of microplastic contamination in the San Francisco Bay area, which found stormwater was the primary pathway for microplastics to enter receiving waters, with tire wear particles and fibers potentially from textiles and cigarettes important sources of microplastics. SFEI made major field monitoring method improvements addressing stormwater and receiving water sampling methods, as well as recommendations for future microplastic monitoring study designs.

A Synthesis of Microplastic Sources and Pathways in Urban Runoff. SFEI developed conceptual models to inform source-specific management strategies for the most common particles in urban runoff – tire fragments, textile and cigarette fibers, and fragments of single-use plastic foodware.

Standardization of Microplastic Measurement Methods. SCCWRP conducted an international study to evaluate and standardize potential microplastic measurement methods. The State Water Resources Control Board used outcomes from that effort to develop a proposed standard method for measuring drinking water microplastics and laboratory accreditation procedures associated with the method, which will be the first of its kind worldwide. California can leverage outcomes from the SCCWRP study and SFEI's recommendations to develop standardized methods for measuring microplastics in ocean water, sediments and fish tissue, which will form the foundation of a statewide monitoring program.

National Call to Action

The National Academies of Sciences, Engineering, and Medicine released a consensus national report to Congress: Reckoning with the U.S. Role in Global Ocean Plastic Waste, on behalf of the National Oceanic and Atmospheric Administration (NOAA) in December 2021 highlighting the massive scale of the global plastics challenge impacting the ocean. The report concludes plastic waste in the United States is ubiquitous and increasing, with the United States having generated more plastic waste as of 2016 than any other country, exceeding that of all European Union member states combined. Recognizing no single solution will be sufficient to address the pervasive problem of plastic pollution, the report recommends:

- **Reduce Plastic Production**. The United States should substantially reduce solid waste generation (absolute and per person) to reduce plastic in the environment and environmental, economic, aesthetic, and health costs of managing waste and litter.
- **National Strategy**. A national strategy be created by the end of 2022 to employ a suite of interventions at every stage of plastics' flow into the ocean.
- **Coordinated Monitoring System**. The United States should establish a nationally coordinated and expanded monitoring system to track plastic pollution in order to better understand the scale and sources of the United States plastic waste problem, set reduction and management priorities, and measure progress.

The national report outlines six intervention strategies the United States should pursue: (1) reducing plastic production (with an emphasis on plastics that are not reusable or readily recyclable); (2) innovating design and materials to develop substitutes; (3) decreasing waste generation (including bans on specific products based on toxicity or necessity); (4) improving waste management (such as establishing regulatory limits for plastic or microplastic waste discharges into the ocean); (5) capturing waste in the environment (including ground litter and stormwater); and (6) minimizing at-sea disposal.

and Medicine (2021).

California's Statewide Microplastics Strategy embeds these intervention recommendations within the two-track approach, provides a framework to implement and advance the comprehensive recommendations of the national report, and can integrate microplastics science into federal monitoring and management of plastic waste as research and science advances.

2. TWO-TRACK APPROACH

The Statewide Microplastics Strategy takes a two-track approach to addressing microplastic pollution in California: (1) pursue solutions the state can immediately take while scientific knowledge of microplastics further develops (**Chapter 2A**: **Solutions**); and (2) continue to invest in and advance scientific knowledge of microplastics to inform and refine future solutions (**Chapter 2B**: **Science**). These two paths, taken together, reinforce and enhance each other. Immediate actions allow the state to move with the urgency this moment calls for, while future solutions are made possible only by advancing scientific knowledge. Jointly, this two-track approach empowers California to address microplastic pollution and reduce particulate loading of microplastics in a comprehensive manner.

Two Track Approach:

Solutions (Chapter 2A): pursue solutions the state will act upon now while the scientific knowledge of microplastics specific to California further develops.

Science to Inform Future Action (Chapter 2B): invest in and advance scientific knowledge of microplastics to develop and refine future solutions.

Underlying this Strategy is a recognition that California must take decisive, precautionary actions to address microplastic pollution. This Strategy specifically recognizes that once microplastics have entered the environment, it is difficult, if not impossible, to remove microplastics and action is needed to prevent microplastics from entering the environment in the first place. An OPC Science Advisory Team (OPC SAT) working group, convened by the California Ocean Science Trust, urged the state to take a precautionary approach to microplastics management in California to immediately curb the introduction of microplastics into the environment, as microplastics research continues to advance (See **Completed Studies**, **page 6**). To that end, the Strategy calls on California to take a series of immediate, 'no regrets' actions that will reduce microplastics as well as provide multiple environmental and societal benefits.

OPC collaborated with state agency partners to identify actionable priorities and solutions to prevent the proliferation of microplastics in the environment. These solutions are grouped into two broad categories – pollution prevention and pathway interventions – both aimed at reducing plastic waste that fragments into microplastics and preventing microplastics from mobilizing into California waters. Specific actions and recommended policy solutions are outlined in **Chapter 2A**.

This Strategy calls on California to simultaneously make strategic investments in scientific research to inform future management actions. The research priorities outlined in this Strategy will fill key knowledge gaps, thereby expanding the range of management solutions California can pursue in the future. Research priorities include the development of a statewide monitoring network, adaptation and implementation of the risk assessment framework as new data are collected, and the use of monitoring data and risk thresholds to prioritize new microplastic management actions. These research priorities are outlined in further detail in **Chapter 2B**.

2A. SOLUTIONS

Microplastics are persistent and the presence of microplastics in the environment will only be magnified if microplastic pollution remains unaddressed. The diverse sources and pathways from which microplastics enter the environment requires a comprehensive and systemic approach to prevent and manage microplastic pollution. Microplastics are extremely challenging, if not impossible, to effectively remove once in the aquatic environment. This Strategy therefore focuses on solutions to prevent microplastics from entering the marine environment in the first place. These solutions are grouped into three broad categories:

- **Pollution prevention** to eliminate plastic waste at the source, defined as the product, material, or industry from which microplastics originate. Strategies to achieve pollution prevention can include the elimination of specific products and materials through financial incentives to encourage product innovation and waste reduction; identifying alternate product actions, including alternate sourcing and design; and, where necessary, product and material prohibitions.
- **Pathway intervention** to intervene within specific pathways, such as stormwater or wastewater, that mobilize microplastics from a specific source into California waters. Pathway interventions should be pursued simultaneously and in addition to, not as substitutes for, pollution prevention actions that directly reduce plastic production and use.
- **Outreach & education** to engage impacted communities, raise awareness of microplastic pollution, and facilitate behavior, policy, systemic, and environmental change. Education campaigns and K-12 curriculum changes should be pursued as a targeted, strategic complement to other solutions that directly prevent and reduce plastic production, use, and waste.

Each of the recommended actions in this chapter addresses microplastic pollution in California as multi-benefit, 'no regrets' actions. 'No regrets' actions are identified based on a combination of factors, including feasibility, evidence to support those actions, available co-benefits, and overall benefit to our society and environment. These recommended actions are further consistent with the California Ocean Litter Prevention Strategy and build upon the Top 10 Recommendations to Address Plastic Pollution in California's Coastal and Marine Ecosystems, adopted by OPC in February 2021.

The rationale behind these recommended early actions is described in the following sections, while the individual recommended early actions are presented as a single list at the end of this chapter (see **Solutions**: **Recommended Early Actions**, **pages 19-21**). The recommended early actions are identified as actions that can be pursued immediately, as advances in scientific research are simultaneously pursued.

Objective 1. Pollution Prevention

Managing and preventing plastic pollution provides an important opportunity to prevent the proliferation of microplastics that fragment from larger plastics.[7] Microplastics are pervasive and persistent in the environment, with microplastics in the ocean anticipated to increase by almost 300 percent by 2030.[8] In the Southern California Bight alone, trash is pervasive within watersheds and on the seafloor with the majority of trash observed from 2013 to 2018 comprised of plastic, according to Southern California Bight Regional Monitoring Program findings.

Reducing plastic production and waste has the additional benefit of supporting national and California climate goals, given greenhouse gas emissions from plastics production have quadrupled since 1995, in part due to plastic demand in the European Union and United States.[9] Health impacts associated with the life cycle of plastics, including increased particulate matter pollution, are further recognized as a human rights issue that falls disproportionally on vulnerable communities.[10]

The OPC SAT working group, consistent with findings by national and international experts, has recommended source reduction of plastics as one of the most effective precautionary strategies to reduce and prevent microplastics pollution, given the lack of feasible microplastics cleanup strategies, persistence of microplastics that enter the environment, and the need to prevent the internalization of microplastics by marine organisms. This Strategy outlines three approaches to prevent microplastic pollution: (1) product and material regulations, (2) economic strategies, and (3) identifying and advancing product alternatives.

> *"The United States should substantially reduce solid waste generati*
> *(absolute and per person) to reduce plastic waste in the environment a*
> *the environmental, economic, aesthetic, and health costs of managi*
> *waste and litte*
>
> *National Academies, Reckoning with the U.S. Role in Global Ocean Plastic Waste* (2021)

Product & Material Regulations. Disincentivizing the production, sale, and use of plastic materials can prevent the proliferation of microplastics in the environment. California already has demonstrated its commitment to reducing plastic waste by enacting a series of product and material prohibitions and other laws aimed at reducing plastic waste (see box: **Examples of Existing California Plastic Waste Reduction Laws**). This Strategy calls on California to pursue additional product and material prohibitions to further curb the generation of plastic waste, advancing recommendations of the California Ocean Litter Prevention Strategy and Top 10 Recommendations to Address Plastic Pollution in California's Coastal and Marine Ecosystems.

[7] Kershaw & Rochman, 2016.
[8] Borrelle et al., 2020.
[9] Cabernard et al., 2021.
[10] United Nations Environment Programme, 2021.

Despite existing programs and requirements to reduce the use of specific single-use plastic items, California has not yet enacted a comprehensive approach to reducing plastic pollution. Efforts, such as the proposed California Recycling and Plastic Pollution Act of 2022 and the Plastic Pollution Producer Responsibility Act, seek to reduce single-use plastics by setting target reduction dates and require producer responsibility to help finance waste infrastructure improvements and help restore California's ocean, rivers, and beaches. Without consistent targets or comprehensive requirements to reduce plastic pollution, California remains limited to addressing plastic pollution and waste on a single-item or single-jurisdiction basis.

Elimination of specific single-use plastic products that are not readily recyclable should be pursued as more comprehensive programs and regulations are established. As one example, a statewide prohibition of expanded polystyrene in foodware and packaging can prevent the persistence of expanded polystyrene in the environment, as it easily breaks apart, mixes with coastal sand and sediment, and is often unable to be recycled due to food contamination.[11] Additionally, prohibiting the sale and distribution of cigarette filters, which are among the top littered plastic items globally on a per-item basis and contain damaging chemicals, and other tobacco products that contribute to microplastic pollution can reduce the presence of microplastics from tobacco products in the aquatic environment.[12] California can additionally act on international recommendations to restrict the use of intentionally added microplastics in specific consumer products, such as cosmetics, household and industrial detergents, and cleaning products.[13]

Economic Strategies. Economic strategies and programs by both state and federal partners can drive innovation in product design and materials, incentivize consumer habits, and improve the overall life cycle management of products that contribute to microplastic pollution. Economic strategies may include the use of taxes, fees, subsidies, consumer rebates, or extended producer responsibility (EPR) to drive innovation and improve management.

EPR can support a circular economy and assign producers responsibility for the end-use management of specific products. EPR can specifically advance solutions that recognize the entire life cycle of products, and help fund research, environmental monitoring, and waste management improvements. In California, EPR programs are in place for products such as paint, mattresses, carpet, and pesticide containers. The California Department of Resources Recycling and Recovery (CalRecycle) has developed an EPR Framework and Checklist to guide statutory proposals that would allow CalRecycle and other stakeholders to implement additional product stewardship programs.

Financial incentives and programs can additionally target specific consumer products, such as home clothing appliances, to reduce microplastic pollution caused by textile shedding that enter the environment through clothing dryer vents or washing machines.[14] Requirements for improved filters inside home appliances may be pursued as technology continues to advance.

[11] Sutton et al., 2019.
[12] Miller et al., 2019; Sutton et al., 2019; Wright et al., 2015; Sutton et al., 2019; Belzagui et al., 2021.
[13] European Chemicals Agency, 2020.
[14] De Falco et al., 2019; McIlwraith et al., 2019; Erdle et al. 2021; Geyer et al., 2022.

Examples of Recently Enacted California Plastic Waste Reduction Laws

- **Microplastic Bead Ban**. Chapter 594 of 2015 (AB 888, Bloom) prohibits the sale of personal care products with plastic microbeads.

- **Single-Use Plastic Bag Ban**. Chapter 850 of 2014 (SB 270, Padilla) and Proposition 67 (2016) established a statewide single-use carryout bag ban, requiring a fee for paper and reusable bag in grocery stores, food marts, liquor stores, and retail stores with a pharmacy.

- **State Foodware Requirements**. Chapter 610 of 2018 (SB 1335, Allen) requires a food service facility located in a state-owned facility, operating on state-owned property, or otherwise contracted by the state to use reusable, recyclable, or compostable food service packaging.

- **Single-Use Plastic Straws Upon Request.** Chapter 576 of 2018 (AB 1884, Calderon) requires full-service restaurants to only provide single-use plastic straws upon request of the customer.

- **Single-Use Foodware Upon Request**. Chapter 505 of 2021 (AB 1276, Carrillo) expands the plastic straws upon request law to other single-use foodware items, such as utensils, straws, and condiments, requiring that these items only be provided upon request of the customer.

- **Local Ordinances.** The Berkeley Single-Use Foodware and Litter Reduction Ordinance, enacted in 2019, is designed to reduce single-use foodware, including cups, lids, straws, and other disposable items that contribute to street litter, marine pollution, and waste sent to landfills. Similar ordinances have been initiated in San Diego, Santa Monica, and other cities throughout California.

Implementing Pollution Prevention Strategies:
Reusable California Policy Playbook

The Reusable California Policy Playbook, an OPC sponsored project by UPSTREAM, released in November 2021 as part of a toolkit and resource hub to inform and help local governments, policymakers, and businesses develop foodware ordinances to reduce single use plastics and achieve reuse goals in food service operations. The Playbook and resource hub will help advance OPC's Top 10 Recommendations to Address Plastic Pollution in California's Coastal and Marine Ecosystems, by providing technical assistance and tools to assist with the implementation of local comprehensive foodware ordinances. The Playbook includes:

- Policy tools & key provisions
- Sample model policies and language (where available)
- Real-world examples to guide implementation

As the project continues to roll out resources and trainings in Spring 2022, the Reusable California Policy Playbook and resource hub can help local governments pursue more comprehensive reuse and reduction strategies rather than continuing to address single use plastics in foodware on an item by item basis.

Identifying & Advancing Product Alternatives. Effective pollution prevention requires specific industries and diverse stakeholders to advance innovation, identify actions to advance alternative products, and pilot plastic waste reduction solutions. This Strategy calls for advancements in technology to identify alternative products, sourcing, design, and overall plastic reduction strategies that may be voluntarily taken up by targeted industries – and influence domestic and global markets with improved products, design, or materials.

Targeted, sector-specific workshops should be held to investigate, conduct an alternatives analysis, and identify sector-specific recommendations to reduce microplastic pollution from the following priority industries: (1) vehicle tires, (2) textiles, (3) single-use foodware and packaging, (4) agriculture, and (5) fisheries & aquaculture.[15] Alternative materials and design of pre-production plastics, granules of plastic less than 5 mm in size known as 'nurdles,' should also be explored. These workshops should result in explicit sector-specific recommendations and immediate actions to enact plastic pollution prevention strategies, based on the use, cost-effectiveness, and benefit of each product and product alternative, life cycle assessments that incorporate global climate, social, and food security impacts consistent with the United Nations Sustainable Development Goals,[16] and chemical additive safety to avoid regrettable substitutions.

Table 1. Possible Sector-Specific Topics for Investigation

Vehicle Tires	• Evaluate tire tread abrasion rates and product design alternatives under a variety of surface and environmental conditions. • Evaluate and promote policies to increase use of pervious pavement in roadways. • Propose a policy framework and recommendations to advance product design alternatives, roadway and pavement design, best management practices, and behavior, such as reducing vehicle miles traveled.
Textiles	• Evaluate existing technologies and recommend advancements in textiles and home appliances to reduce synthetic microfiber emissions. • Develop fiber fragmentation and/or shedding standards for textiles. • Develop textile product labeling standards. • Investment in natural textile processing and manufacturing systems in California. • Evaluate potential toxicity of dyes and additives used on textile fibers. • Evaluate and propose a policy framework to reduce synthetic fiber production and waste. • Develop extended producer responsibility strategies for the release of synthetic microfibers.

[15] Verschoor et al., 2016; Boucher & Friot, 2017; Unice et al., 2019a; Unice et al., 2019b; Parker et al., 2020; Brander et al., 2021; Tian et al., 2021; Werbowski et al., 2021; Geyer et al., 2022; Turner et al., 2022.
[16] United Nations, 2015.

Single-use Foodware & Packaging	• Evaluate available plastic product and material alternatives and identify future opportunities for innovation. • Evaluate biodegradability and compostability of alternatives to petroleum-based plastics. • Evaluate ecotoxicity of plastic alternative products and materials. • Recommend updated product labeling standards. • Evaluate and propose a policy framework to bring alternatives materials and products to scale.
Agriculture	• Evaluate the scale of agricultural plastic use, including plastic mulch, seed coatings, and coverings that prevent crop damage, and identify alternative practices and materials. • Evaluate lifespan and degradation of plastic products used in agriculture. • Evaluate microplastics concentrations in agricultural soils, applied biosolids, and compost materials that contain biosolids. • Evaluate and propose a policy framework or standards to reduce degradation of plastic products used in agriculture. • Identify incentives to reduce plastic product use in agriculture.
Fisheries & Aquaculture	• Evaluate degradation of plastic materials used in recreational and commercial fishing, and in aquaculture. • Evaluate and propose a policy framework or standards to reduce degradation of plastic fishing and aquaculture gear. • Provide recommendations for operations and maintenance Best Management Practices for fishing and aquaculture to reduce gear loss. • Identify and advance recycling capabilities and/or a recycling program to recover, reuse, and remanufacture fishing and aquaculture gear. • Evaluate fate, transport, and effects of microplastics caused by marine coating and antifouling paints. • Identify policy recommendations to remediate and prevent microplastic emissions from antifouling paint originated from boatyards, marinas, and abandoned boats.

Objective 2. Pathway Interventions

California must prioritize management solutions that intercept large plastic debris and microplastic pollution before it reaches the marine environment. Scientific studies completed in San Francisco Bay identified urban runoff as a major pathway for microplastics,[17] with average concentration and overall load of microplastics in urban stormwater approximately two orders of magnitude higher than in treated wastewater effluent.[18] Additional statewide studies are needed to assess whether urban stormwater runoff has similarly high contributions of microplastics in other regions of the state, and to what extent agricultural runoff and aerial deposition transport microplastics into California waters to identify additional pathway interventions.

[17] Sutton et al., 2019; Werbowski et al., 2021; Zhu et al., 2021; Moran et al., 2021.
[18] Sutton et al., 2019; Moran et al., 2021.

As research advances to identify the full range of pathways by which microplastics enter the environment, California should pursue immediate pathway interventions that have multiple benefits for water quality and the overall management of California's water system.

Stormwater. In many California urban areas, rainfall washes particles into stormwater collection systems that discharge directly into receiving waters, such as California's rivers, estuaries, and ocean.[19] Comprehensive studies of microplastics in California urban runoff outside of the San Francisco Bay area have not yet been conducted, although the relatively high microplastic concentrations measured in San Francisco Bay stormwater are generally consistent with limited observations of microplastics in stormwater in international locations.[20] The importance and prevalence of microplastics in urban stormwater runoff observed in the San Francisco Bay should be confirmed as a predominant pathway in other urban areas in the state; however, existing studies demonstrate improved stormwater management as a viable and available management strategy to reduce the flow of microplastic pollution from municipalities into the marine environment.

Trash and marine debris, which are largely comprised of plastic, have become a policy focus throughout California, with several policies and management actions implemented to reduce the amount of trash that reach state waters. These existing policies include local bans of specific items that contribute to plastic pollution, establishing Total Maximum Daily Loads (TMDLs) in specific watersheds, and implementation of the statewide Trash Provisions (discussed in more detail below) and the California Ocean Litter Prevention Strategy to mitigate plastic trash and debris.

Trash capture, such as full-capture devices, can be used to interfere and remove debris from stormwater. These strategies can help prevent the flow of large plastic pollution into receiving waters and help mitigate microplastic pollution by reducing large plastic debris that can fragment into microplastics.[21] Low impact development (LID), such as bioretention rain gardens, high-flow bioretention systems, and infiltration trenches, offers opportunities to capture both large plastic debris and microplastics and provide additional pollution reduction and groundwater augmentation benefits.

California has existing requirements to prevent the discharge of preproduction plastics ('nurdles') and to manage trash larger than 5 mm that mobilizes in stormwater runoff through the statewide Trash Provisions adopted by the State Water Resources Control Board in 2015. The Trash Provisions further established a water quality objective of no trash present in state waters, in amounts that adversely affect beneficial uses or cause nuisance, by 2030. Timely implementation of the Trash Provisions and achievement of this implementation deadline is a priority to reduce the amount of plastic that enters California rivers, lakes and ocean, prevent the fragmentation of plastic into microplastics, and prevent impacts to aquatic life and public health.

Wastewater. Wastewater is a known pathway of microplastic and microfiber pollution, whether directly through wastewater effluent or as indirect discharge through the land application of

[19] Moore et al., 2011; Sutton et al., 2019.
[20] Moran K. et al., 2021.
[21] Werbowski et al., 2021.

biosolids.[22] Available data indicate that microplastic concentrations and loads from wastewater are significantly smaller than those in urban runoff in San Francisco Bay; however, comparison data for other locations in California are absent.[23] Additional research is needed to determine the consistency of these findings in other California regions. OPC initiated a study in 2020 to assess the efficacy of microplastic removal in California wastewater treatment plants, with anticipated completion in early 2023. Numerous studies demonstrate that wastewater treatment plants with only primary and secondary treatment levels release higher concentrations of microplastics than wastewater treatment plants with tertiary or advanced levels of treatment, which release negligible levels of microplastics.[24]

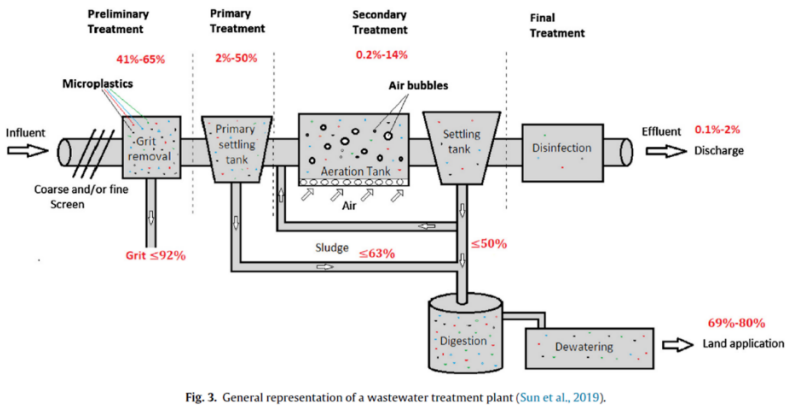


Fig. 3. General representation of a wastewater treatment plant (Sun et al., 2019).

***Figure 2**. Representation of microplastic removal at various treatment stages within a wastewater treatment plant. (Sun et al., 2019).*

While tertiary and advanced treatment have demonstrated efficacy in preventing microplastic pollution from entering receiving waters, microplastics may be applied to land and impact soils through the biosolid byproduct of wastewater treatment plants.[25] Preventing microplastics from entering wastewater treatment systems reduces the risk of direct or indirect microplastics discharges.[26] An all-of-the-above approach, including pollution prevention and wastewater facility upgrades, where feasible and practicable to prevent microplastics from entering the marine environment through another wastewater stream, should be taken to manage microplastics in wastewater. Advancing recycling of wastewater that would otherwise be discharged directly into the ocean and promoting tertiary wastewater treatment are examples of multi-benefit actions that can have the potential to improve coastal water quality, advance California's water recycling goals, and manage microplastic pollution.

Aerial Transport. Atmospheric transport drives the widespread distribution of microplastics in the global environment, particularly in remote regions.[27] Microplastics have been found to be transported from distances of up to 95 km away,[28] with road and tire wear particles known to contribute to airborne microplastics that enter urban stormwater.[29] Aerial transport is a potentially significant pathway of microplastics into the marine environment,[30] and further research is needed

[22] Geyer R. et al., 2022.
[23] Moran K. et al., 2021; Zhu et al., 2019.
[24] Hou et al., 2021.
[25] Liu et al., 2020; Koutnik et al., 2021; Food and Agriculture Organization of the United Nations, 2021.
[26] Fendall et al., 2009.
[27] Zhang et al., 2019; Hernández-Arenas et al., 2021.
[28] Allen et al., 2019.
[29] Moran et al., 2021.
[30] Dris et al., 2016; Evangeliou et al., 2020; Brahney et al., 2021.

to understand the full implications of the transport, deposition, and exposure to both human and marine health from microplastics in air.

The sector-specific workshops outlined under **Objective 2. Identifying & Advancing Product Alternatives** provide the opportunity to evaluate and identify recommendations to reduce road and tire wear particle emissions. Dryers are further identified as a potentially significant source of textile fiber emissions in outdoor air.[31] Improving lint capture technology on dryers provides an opportunity to intervene with microparticles and microfibers and prevent these particles from becoming airborne. Moving toward the capture of microfibers from dryers and encouraging use of alternatives such as hanging textiles to dry can abate one source of microplastic pollution, while research is pursued to advance understanding of emissions from this pathway (see **Chapter 2B**: **Science**).

Objective 3. Outreach & Education

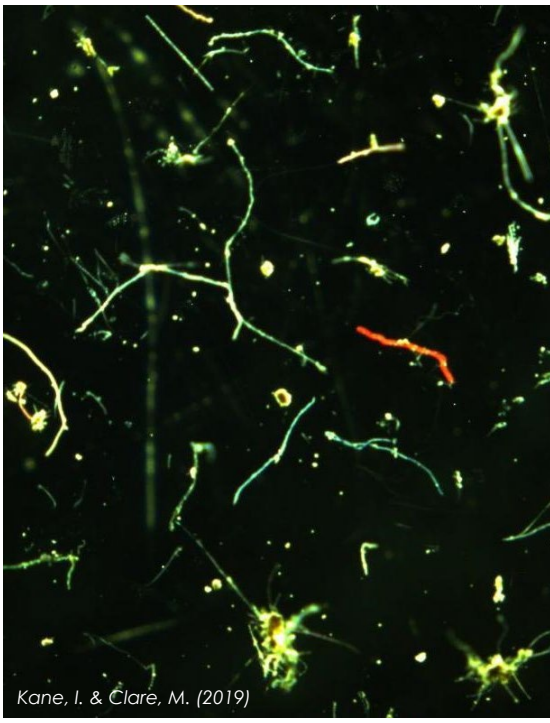
Meaningful public engagement is a cornerstone to reducing and preventing large plastic and microplastic pollution. Public awareness, engagement, and education are an important and overarching component of this Strategy to raise awareness about microplastic pollution and facilitate public behavior, policy, systemic, and environmental change.

Public outreach and engagement play an important role in evaluating impacts of microplastic exposure and ensuring individual projects and pollution prevention strategies are informed by local community needs. California has existing requirements and commitments to implement effective government-to-government consultation with California Native American Tribes on the development of legislation, regulations, rules, and policies on matters that may affect tribal communities. Further, OPC is committed to enhancing tribal stewardship of ancestral lands and waters and protecting tribal cultural resources. Impacts of microplastic pollution on tribal ancestral lands and resources should be evaluated and considered, with individual strategies to address microplastic pollution evaluated and informed by impacted tribes. California should additionally prioritize local engagement with vulnerable populations, such as communities disproportionately burdened by environmental injustice and those historically excluded from decision-making processes, to evaluate specific strategies to reduce microplastic pollution and exposure.

Raising public awareness of microplastic pollution complements the solutions and research priorities presented in this Strategy. Education campaigns can reduce desirability, accessibility, and acceptability of plastic products, increase consumer demand for plastic alternatives or reuse, and improve understanding of microplastic impacts on human and environmental health. Developing and advancing a coordinated, strategic public awareness campaign that educates the public to understand the sources, impacts, and available solutions to reduce macro and microplastic pollution is needed to enact the recommended early actions outlined in this Strategy.

[31] Kapp K. J. & Miller, R. Z., 2020; Tao et al., 2022.

Coordinated public awareness and education campaigns are needed to advance multiple, cross-cutting statewide policies and goals. Campaigns may include, but are not limited to, working with the California Air Resources Board to elevate public awareness of the tire wear pollution prevention benefits associated with reducing vehicle miles traveled, working with the California Department of Public Health's Tobacco Control Program to develop messaging on toxic tobacco product waste and strategies for reducing tobacco product waste in the environment, and advancing multi-benefit Low Impact Development and green infrastructure solutions to capture stormwater. OPC, as facilitator of the interagency Plastic Pollution Steering Committee (PPSC), can additionally work with agency partners to promote informal and formal education programs. Priority actions include partnering with the Department of Education and CalRecycle in its capacity as lead of the California Education and the Environment Initiative to update pertinent environmental principles and concepts, standards, teacher training efforts, and/or curricula to educate K-12 students on microplastic environmental and public health impacts and pollution prevention solutions.



Kane, I. & Clare, M. (2019)

SOLUTIONS: RECOMMENDED EARLY ACTIONS

Each of the recommended early actions are suggested below to address microplastic pollution in California as multi-benefit, 'no regrets' actions.

Objective 1. Pollution Prevention

Product & Material Regulations

- ☐ **2A.1.1** Implement the statewide requirement that single-use foodware and condiments be provided only upon request, consistent with Assembly Bill 1276 (Carrillo, 2021) by 2022.
- ☐ **2A.1.2** Encourage state purchasing and service contracts to require reusable foodware whenever feasible and reduce the state's reliance on single-use foodware by 2022.
- ☐ **2A.1.3** Enact comprehensive statewide plastic source reduction, reuse, and refill goals by 2023.
- ☐ **2A.1.4** Prohibit the sale and distribution of expanded polystyrene foodware and packaging by 2023.
- ☐ **2A.1.5** Expand the statewide microbead ban enacted by Assembly Bill 888 (Bloom, 2015) to include microplastics that are intentionally added to specific consumer products, such as cosmetics, household and industrial detergents, and cleaning products by 2023.
- ☐ **2A.1.6** Prohibit the sale and distribution of single-use tobacco products that demonstrably contribute to tobacco product plastic pollution, including but not limited to cigarette filters, electronic cigarettes, plastic cigar tips, and unrecyclable tobacco product packaging by 2022.

Economic Strategies

- ☐ **2A.1.7** Identify Extended Producer Responsibility (EPR) strategies for recycling or disposal of plastic packaging and foodware by 2022.
- ☐ **2A.1.8** Promote, or otherwise require, the sale and use of ENERGY STAR condenser dryers and washing machines with filtration rates of 100 microns or smaller and develop a program to incentivize post-market retrofits or purchases through rebates and other mechanisms by 2024.

Identifying & Advancing Product Alternatives

- ☐ **2A.1.9** Convene representatives from targeted industries (e.g., vehicle tires, textiles, agriculture, foodware and packaging, and/or fisheries & aquaculture) and scientific experts to identify alternative products and other sector-specific plastic pollution prevention strategies by 2023.

Objective 2. Pathway Interventions

Stormwater

- **2A.2.1** Promote the multiple benefits of green infrastructure by prioritizing LID retrofit projects for existing development that generate or have the potential to generate microplastic loading in receiving waters beginning in 2022.
- **2A.2.2** Evaluate microplastic removal efficacy of LID structural Best Management Practices, including operations & maintenance strategies, and identify sites where LID implementation should be required based on environmental characteristics and available co-benefits by 2023.
- **2A.2.3** Consistent with findings of microplastic removal efficacy under **2A.2.2**, consider inclusion of LID requirements for new and redevelopment projects to address microplastic loading in municipal, industrial, construction, and highway water quality permits, in local coastal programs, and in coastal development permits adopted or reissued after December 31, 2023.
- **2A.2.4** Prioritize compliance assurance, and conduct enforcement actions as necessary, for preproduction plastic pellets ('nurdles') discharge prohibitions consistent with the Trash Provisions and local Trash TMDLs beginning in 2022.
- **2A.2.5** Prioritize the interception of trash and plastic debris with trash receptacles and trash services in 'trash hot spots' (high use beaches, recreational areas, & encampments adjacent to waterways) outside of the scope of the statewide Trash Provisions beginning in 2022.
- **2A.2.6** Implement the statewide Trash Provisions and assure compliance with the final deadline of no trash in state surface waters by 2030.

Wastewater

- **2A.2.7** Based on the results of existing studies regarding microplastic removal efficacy in wastewater treatment plants, further promote recycling of tertiary-treated wastewater that would otherwise be discharged to the ocean beginning in 2022.
- **2A.2.8** Based on the results of existing studies and the following completion of the ongoing SCCWRP study on wastewater treatment plant process removal efficacy, further develop microplastics reduction strategies, and monitoring recommendations based on each level of treatment, including primary, secondary, tertiary, and advanced treatment beginning in 2023.
- **See Pollution Prevention, Product and Material Regulations: 2A.1.5** Expand the microbead ban to include microplastics that are intentionally added to specific consumer products, such as cosmetics, household and industrial detergents, cleaning products, and paints by 2023.
- **See Pollution Prevention, Economic Strategies: 2A.1.8** Promote, or otherwise require, the sale and use of washing machines with a filtration rate of 100 microns or smaller and develop a program to incentivize post-market retrofits or purchases by 2024.

Aerial Transport

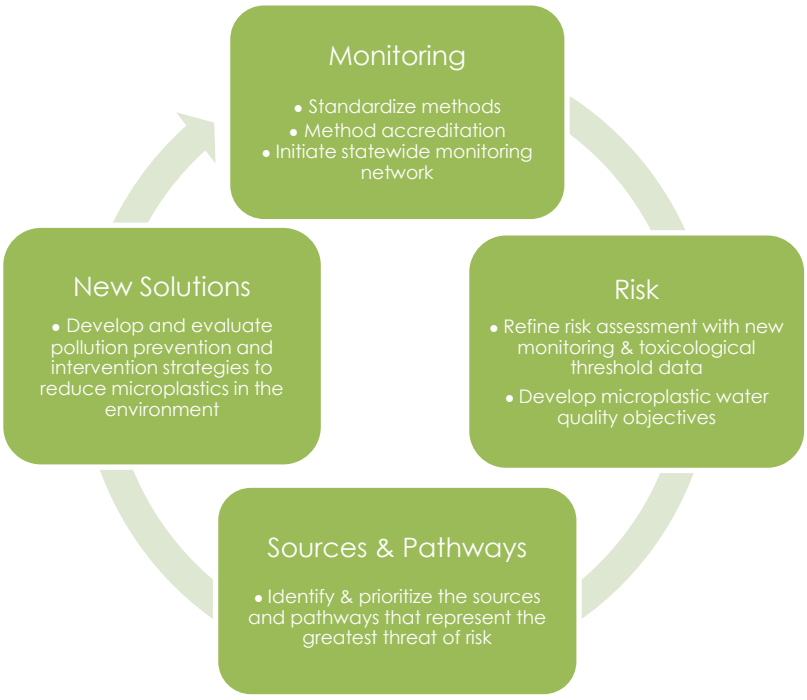
- **See Pollution Prevention, Economic Strategies: 2A.1.8** Promote, or otherwise require, the sale and use of ENERGY STAR condenser dryers and develop a program to incentivize post-market retrofits or purchases by 2024.

Objective 3. Outreach & Education

- **2A.3.1** Engage with California Native American Tribes to initiate outreach, monitoring, and immediate plastic and microplastic pollution reduction efforts beginning in 2022.
- **2A.3.2** Engage with underserved or communities disproportionately burdened by environmental injustice to ensure inclusion in decision-making processes, and to identify and pursue immediate solutions to reduce plastic and microplastic pollution beginning in 2022.
- **2A.3.3** Develop a public campaign to raise awareness of microplastic pollution, and to facilitate behavior, policy, systemic, and environmental change by 2023.
- **2A.3.4** Promote informal and formal educational programs with updated principles, concepts, standards, teacher training efforts, and/or curricula to educate K-12 students of microplastic sources, impacts, and solutions by 2024.
- **2A.3.5** Promote industry engagement and outreach to advance sector-specific microplastic pollution prevention strategies by 2024.

2B. SCIENCE TO INFORM FUTURE ACTION

This Strategy builds from recent advancements in microplastic science and details an overarching research strategy to advance proposed solutions (**Chapter 2A**) and shape the next generation of management solutions. The research priorities outlined in this chapter call for coordinated, simultaneous investments across four main areas that embed the research elements outlined in Senate Bill 1263: (1) Collect data on levels of microplastic contamination across the state (**Monitoring**); (2) Improve understanding of critical thresholds at which aquatic life and humans are adversely impacted by various microplastic exposures (**Risk Thresholds & Assessment**); (3) Identify and prioritize future management solutions based on the predominant ways that microplastics enter California's marine ecosystems (**Sources & Pathways Prioritization**); and (4) Develop and evaluate new mitigation strategies (**Evaluating New Solutions**). The philosophy and rationale behind each of these investment areas are described in greater detail below; specific recommended research investments are summarized as a list at the end of this section (see **Science to Inform Future Action: Research Priorities** on **page 27**).



Objective 1. Monitoring

Effective management of microplastics begins with understanding the extent of microplastic pollution within the state. California has the opportunity to build from existing monitoring studies, including methods developed by SFEI to collect and identify microplastics from a variety of environments, comprised of surface waters, sediments, stormwater runoff and treated wastewater

effluent. SCCWRP has additionally conducted large-scale laboratory intercalibration studies that developed and quantified the effectiveness of laboratory measurement methods for processing water, sediment, and tissue samples. Priority research to advance microplastic monitoring include: (1) transitioning the foundational work performed by SFEI and SCCWRP into standardized methods; (2) acquiring laboratory accreditation to ensure standardized monitoring methods are employed properly and to confirm that data submitted are of acceptable quality and comparable; and (3) creating a statewide monitoring network with willing partners to design, implement, and sustain long-term operations of the network.

Monitoring provides crucial information regarding how much and what types of microplastic (e.g., particle sizes, morphologies, polymer types) are in California waters and provides the foundation for tracking future changes in response to management action. Monitoring information also provides context for exposure in various environmental matrices (e.g., water, air, sediment, biological tissue) and habitats (e.g., marine, estuary, freshwater), to directly inform which areas are most contaminated and which organisms and biological communities may be at greatest risk from microplastics.

California has several existing monitoring programs that may incorporate microplastic sampling, including the Surface Water Ambient Monitoring Program (SWAMP), the San Francisco Bay Regional Monitoring Program, and Southern California Bight Regional Monitoring Program. These programs, alongside representative sampling efforts and potential microplastic monitoring requirements in permits, can be leveraged to form the foundation of a statewide monitoring network. The California Water Quality Monitoring Council is well positioned to engage these programs, as well as other willing partners, to develop an integrated monitoring network, develop a proposed monitoring plan, and determine the most appropriate means for collating and sharing data from the monitoring network.

Objective 2. Risk Thresholds & Assessment

Microplastics are ubiquitous in the California ocean, and determining the urgency for implementing specific management action requires a risk assessment to quantify the number and type of biota that are affected now, and are likely to be affected in the future, under different management scenarios. Senate Bill 1263 called for development of such a risk assessment, which was initiated through the OPC SAT working group and completed in Spring 2021 (See **Completed Studies**, **page 6**). The State Water Resources Control Board (SWRCB) and SCCWRP subsequently expanded on this through an expert workshop to identify critical thresholds at which biological effects from microplastics exposure become pronounced. The expert workshop developed a framework for assessing risks of microplastics with confidence in its ability to assess risks based on available studies. Data availability to assess risk is increasing rapidly, which will only strengthen risk assessment outcomes in the future.

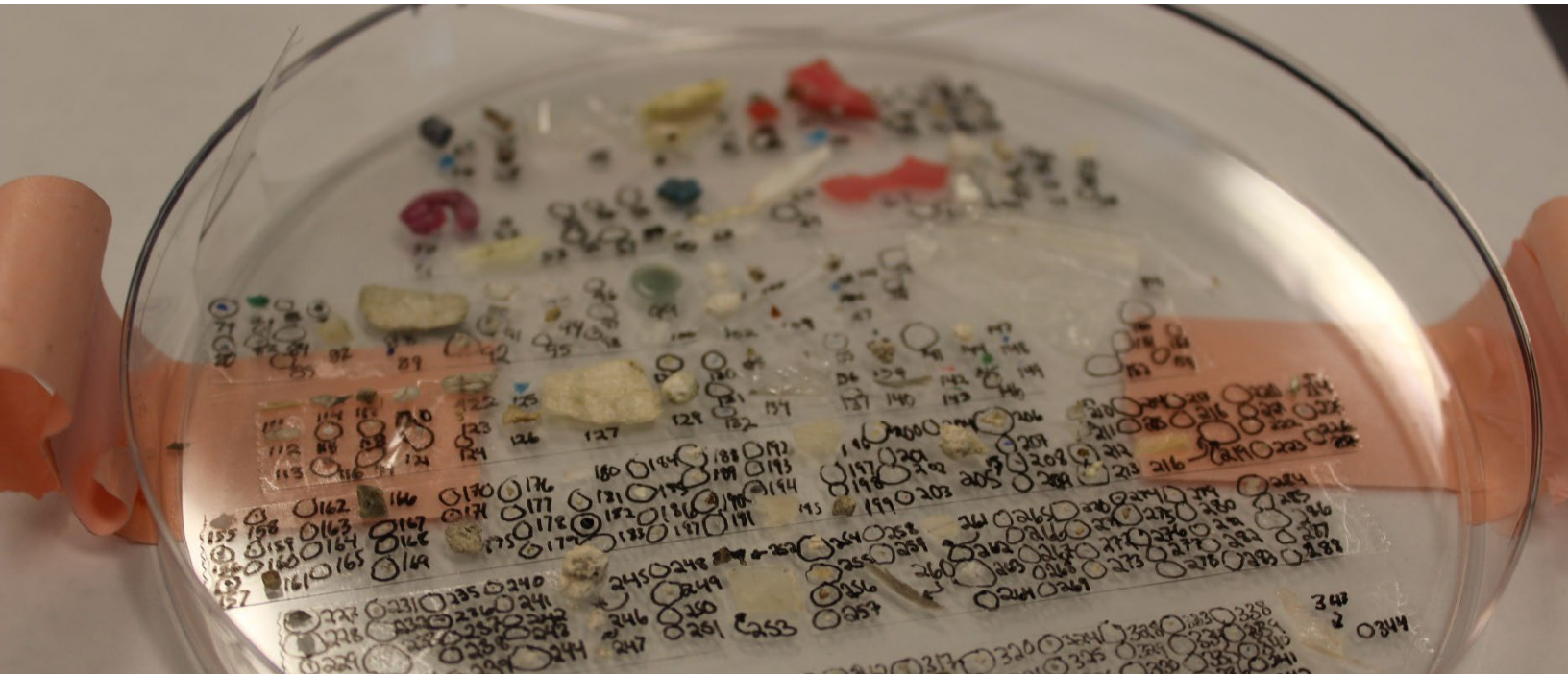
Using updated and strengthened thresholds to quantify both existing and future risks from microplastics exposure, including whether risks would change under a range of management scenarios (e.g., pathway interventions, source control, and/or no action), will help California identify the habitats and/or communities that may be most affected by plastic pollution, and

provide insight as to which management actions are most needed to reduce microplastic exposure. Risk evaluations should address the probability of exposure, the magnitude, duration and frequency of exposure, and the magnitude of adverse impacts or consequences that could result from microplastic exposure to environmental and human health. Information acquired from future monitoring and reporting of microplastics in drinking water, as required by Health and Safety Code section 116376, can further inform risk assessment of the potential exposure risk of microplastics for human health.

Risk evaluations for vulnerable communities, such as those underserved, historically excluded from decision-making processes, and disproportionately burdened by environmental injustice, should be prioritized, as these communities may be at greater risk from microplastic pollution due to disproportionate community exposure from a variety of possible pathways, such as inequitable distribution of plastic products, plastic manufacturing facilities, higher densities of trucks, other vehicles, and associated tire degradation particles and fibers, and emissions of plastics particles and fibers from fixed sources. Advancing and conducting risk assessments can evaluate the potential socioeconomic factors that magnify the risk of microplastic exposure and help identify future solutions to reduce the risk of exposure.

California can support comprehensive risk assessments and inform future regulatory action by: (1) identifying ambient exposure concentrations generated through the statewide monitoring program; (2) applying risk thresholds; and (3) updating the risk assessment framework developed by the OPC SAT and SWRCB/SCCWRP microplastics working groups by incorporating new ambient concentration data and toxic effects data as they become available, and quantifying risk based on these new values.

Investing in and prioritizing additional research that advances the foundational advancements and findings made by the OPC SAT working group, SWRCB/SCCWRP, and international research community will provide California with information needed to guide future management decisions. Advancing the research priorities of this Strategy will provide actionable risk thresholds and identify future source control actions needed to inform a water quality objective and program of implementation, to ensure protection of aquatic life and beneficial uses of California waters.



Microplastic Water Quality Objectives

California's water quality regulatory framework relies on water quality objectives to protect and maintain beneficial uses of California waters and the health of aquatic ecosystems. Developing a water quality objective for microplastics will provide a key regulatory mechanism to monitor and control the prevalence of microplastics in California waters and in the organisms that ingest or otherwise are exposed to microplastics. Water quality objectives are an important precursor to many potential management actions and provide a target level for management action. Failure to achieve the objective can lead to listing of a water body as impaired under Section 303(d) of the Clean Water Act and adoption of Total Maximum Daily Load allocations (TMDLs).

In the absence of water quality objectives for microplastics, California has implemented preliminary regulations to control plastics and microplastics, including requirements to manage preproduction plastics (small, granular plastic less than 5 mm in size known as 'nurdles') and trash larger than 5 mm through the Trash Provisions adopted by the State Water Resources Control Board in 2015. California, however, will need specific microplastic water quality objectives to propel the development and implementation of future regulatory actions.

Objective 3. Sources & Pathways Prioritization

To reduce microplastic pollution in aquatic environments, management actions must target and prioritize the predominant sources and pathways by which microplastics accumulate and pose ecological and human health risks. Sources are the original products and manufacturing processes that can trigger the generation and initial release of microplastics; meanwhile, pathways are the transport mechanisms (e.g., runoff, air) through which microplastics reach aquatic environments. SFEI has conducted a comprehensive assessment of microplastics in the San Francisco Bay, finding average concentrations and estimated total annual discharge of microplastics in stormwater are approximately two orders of magnitude higher than those in treated wastewater effluent. This insight has helped focus local management activities on stormwater runoff and other solutions outlined in **Chapter 2A**.

California can build on this foundational work to assess pathways not yet fully studied (e.g., agricultural runoff, air deposition) and confirm the prominence of microplastic transport in stormwater in other regions of the state. Future research priorities may include an assessment of windborne microplastics and the quantification of macro and microplastic contributions from agriculture to the marine environment, including monitoring microplastics in agricultural soils, biosolids, and runoff.

For each pathway, particles should be characterized (according to size, morphology, polymer type) in addition to quantifying the total amount of microplastics present. Additionally, advancing source identification methods can provide insights to inform industry-specific source control measures. Research in California should focus on investigating sources for which viable management remediation strategies can be readily developed. Preliminary priorities include identifying solutions and strategies to reduce microplastic discharges from tire and road wear, laundry and textiles, tobacco products, and agricultural runoff. Based on the OPC SAT working group findings, California should prioritize the development of a source emissions inventory, dependent on the availability of necessary data, to quantify the top sources that contribute to microplastics in California's marine environment and to refine and inform future management actions. A key consideration of this work should include selecting sources that may disproportionately affect marginalized or frontline communities.

Investments in existing research to advance source identification and application of this technology, once proven successful, could allow California to identify and work with individual product manufacturers that are yielding the largest contributions and risk caused by microplastics in the environment.

Objective 4. Evaluating New Solutions

Once the occurrence, risks, priority sources and pathways associated with microplastics have been identified in specific localities in California, targeted solutions to mitigate microplastic contamination can be prioritized and implemented. Feasibility and efficacy studies, and future risk assessments, can inform future management actions as new innovations are identified and developed in California, nationally, and abroad. Future management actions and solutions should include life cycle assessments that incorporate global climate, social, and food security impacts, evaluations of a range of possible alternatives, including an evaluation of no action, cost-effectiveness, and chemical additive safety to avoid regrettable solutions.

This Strategy will identify new solutions and management actions as new information and approaches become available, through OPC's facilitation of the iterative process between plastic pollution reduction and intervention strategies (**Chapter 2A**: **Solutions**) and research (**Chapter 2B**: **Science to Inform Future Action**). To implement these research priorities, evaluate the efficacy of early actions, and inform future solutions, California will collaborate with scientific experts across academic institutions, federal and state agencies, and other organizations over the next four years.

SCIENCE TO INFORM FUTURE ACTION
RESEARCH PRIORITIES

Each research priority and action presented below are contingent upon available funding and personnel resources.

Objective 1. Monitoring

- ☐ **2B.1.1** Establish standardized microplastic monitoring methods (sampling and analysis of environmental samples, including marine, river, and estuarine waters, sediment, and fish tissue) with accreditation by 2023.
- ☐ **2B.1.2** Develop a model microplastics monitoring program and establish an ongoing integrated statewide ambient monitoring network to quantify microplastic occurrence and effectiveness of management actions for microplastic pollution by 2024.
- ☐ **2B.1.3** Based on the results of existing studies regarding microplastic removal efficacy in wastewater treatment plants, require microplastic monitoring for California wastewater treatment plant permittees, as needed, as permits are renewed or revised beginning in 2024.
- ☐ **2B.1.4** Following completion of standardized monitoring methods and accreditation, require microplastic monitoring for municipal stormwater permittees as permits are renewed or revised beginning in 2024.
- ☐ **2B.1.5** Following completion of standardized monitoring methods, implement a pilot monitoring program to evaluate microplastics in agricultural soils, biosolids, and runoff, beginning in 2024.

Objective 2. Risk Thresholds & Assessment

- ☐ **2B.2.1** Develop toxicological studies that provide greater certainty of microplastics risk thresholds for marine life and human health, and determine recommended actions when thresholds are exceeded by 2024.
- ☐ **2B.2.2** Update the existing microplastics risk assessment framework and execute risk assessments that incorporate local environmental loads of microplastics and risk thresholds to quantify the risk of microplastics to marine life and human health by 2025.
- ☐ **2B.2.3** Engage with California Native American Tribes to conduct a risk assessment of microplastic pollution exposure and impacts to ancestral lands and waters, tribal cultural resources, and tribal beneficial uses to inform and prioritize future solutions by 2025.
- ☐ **2B.2.4** Engage with California communities disproportionately burdened by environmental injustice, underserved, and/or economically disadvantaged to conduct a risk assessment of microplastic pollution exposure and impacts to inform and prioritize future solutions by 2025.
- ☐ **2B.2.5** Prioritize the development of microplastic water quality objectives for state ocean waters, estuarine waters, and freshwaters beginning in 2024.
- ☐ **2B.2.6** Identify water body impairments in the California Integrated Report based on best available science, known thresholds, and available data beginning in 2024.

Objective 3. Sources & Pathways Prioritization

- ☐ **2B.3.1** Quantify and characterize relative inputs from the primary pathways (e.g., urban stormwater, agricultural runoff, wastewater, aerial deposition) of microplastics statewide to the ocean by 2024.
- ☐ **2B.3.2** Create a source emissions inventory to quantify the most prevalent California-specific sources (i.e., specific materials and products) contributing microplastics into the environment to inform future regulatory action by 2024.

Objective 4. Evaluating New Solutions

- ☐ **2B.4.1** Based on findings from actions completed under Science to Inform Future Action (**Chapter 2B**), provide additional policy recommendations consistent with subsection (g)(2) of Senate Bill 1263 by December 2025.

3. IMPLEMENTATION

Implementation of the Statewide Microplastic Strategy requires a comprehensive and coordinated effort between California state agencies, California Native American Tribes, federal, local, and industry partners. The recommendations and research priorities of the Statewide Microplastic Strategy will be integrated into existing initiatives and working groups established to address plastic pollution, including the California Ocean Litter Strategy Project, the interagency Plastic Pollution Steering Committee (PPSC), existing regional water quality monitoring programs, and interagency programs and projects by the California Water Quality Monitoring Council.

Federal and state partnerships, including those between OPC and the National Oceanic and Atmospheric Administration (NOAA), can further advance the research priorities of this Strategy by leveraging capabilities and resources to increase microplastics science and understanding.

Public engagement and transparency will be promoted through the existing California Ocean Litter Strategy Project structure, which includes publicly available video webinars and remote meetings to share information and report on progress between participating stakeholders. The California Water Quality Monitoring Council's Trash Monitoring Working Group, Microplastics Subcommittee established in November 2021 will provide additional opportunities for public engagement and opportunities to elevate microplastics research between scientific experts, local environmental managers, and interested stakeholders. California agencies will additionally engage and consult with California Native American Tribes and vulnerable communities to advance understanding of microplastic impacts on individual communities and to identify local solutions to reduce microplastic pollution.

Continued statewide collaboration through both the OPC-facilitated interagency PPSC and California Water Quality Monitoring Council, and convenings of interdisciplinary scientific experts through the OPC SAT, will facilitate information sharing and coordination to advance this Strategy, evaluate management strategies as new information is generated, and provide new recommendations to the California Legislature by December 31, 2025, consistent with Public Resources Code section 35635, subsection (g)(2) (Senate Bill 1263).

The following three pages contain a timeline and partner information associated with each of the recommended actions in **Chapters 2A: Solutions** & **2B: Science to Inform Future Action**. Specifically, each recommended action is listed alongside the state partners that are be best suited to advance the action, and a timeline to implement the action.

TIMELINE & PARTNERS

2022

CHAPTER 2A. SOLUTIONS

Objective 1. Pollution Prevention

2A.1.1 Implement the statewide requirement that single-use foodware and condiments be provided only upon request, consistent with Assembly Bill 1276 (Carrillo, 2021) by 2022. **Partners: Local Governments**

2A.1.2 Encourage state purchasing and service contracts to require reusable foodware whenever feasible and reduce the state's reliance on single-use foodware by 2022. **Partners: DGS, PPSC Agencies**

2A.1.6 Prohibit the sale and distribution of single-use tobacco products that demonstrably contribute to tobacco product plastic pollution, including but not limited to cigarette filters, electronic cigarettes, plastic cigar tips, and unrecyclable tobacco product packaging by 2022.

2A.1.7 Identify Extended Producer Responsibility (EPR) strategies for recycling or disposal of plastic packaging and foodware by 2022.

Objective 2. Pathway Interventions

2A.2.1 Promote the multiple benefits of green infrastructure by prioritizing LID retrofit projects for existing development that generate or have the potential to generate microplastic loading in receiving waters beginning in 2022. **Partners: Local Governments, CCC, SWRCB, RWQCB**

2A.2.4 Prioritize compliance assurance, and conduct enforcement actions as necessary, for preproduction plastic pellets ('nurdles') discharge prohibitions consistent with the Trash Provisions and local Trash TMDLs beginning in 2022. **Partners: SWRCB, RWQCB**

2A.2.5 Prioritize the interception of trash and plastic debris with trash receptacles and trash services in 'trash hot spots' (high use beaches, recreational areas, & encampments adjacent to waterways) outside of the scope of the statewide Trash Provisions beginning in 2022. **Partners: Local Governments, SWRCB, RWQCB**

2A.2.7 Based on the results of existing studies regarding microplastic removal efficacy in wastewater treatment plants, further promote recycling of tertiary-treated wastewater that would otherwise be discharged to the ocean beginning in 2022. **Partners: Local Governments, SWRCB, RWQCB**

Objective 3. Outreach & Education

2A.3.1 Engage with California Native American Tribes to initiate outreach, monitoring, and immediate plastic and microplastic pollution reduction efforts beginning in 2022. **Partners: PPSC Agencies**

2A.3.2 Engage with underserved or communities disproportionately burdened by environmental injustice to ensure inclusion in decision-making processes, and to identify and pursue immediate solutions to reduce plastic and microplastic pollution beginning in 2022. **Partners: PPSC Agencies**

2023

CHAPTER 2A. SOLUTIONS

Objective 1. Pollution Prevention

2A.1.3 Enact comprehensive statewide plastic source reduction, reuse, and refill goals by 2023.

2A.1.4 Prohibit the sale and distribution of expanded polystyrene foodware and packaging by 2023.

2A.1.5 Expand the statewide microbead ban enacted by Assembly Bill 888 (Bloom, 2015) to include microplastics that are intentionally added to specific consumer products, such as cosmetics, household and industrial detergents, and cleaning products by 2023.

2A.1.9 Convene representatives from targeted industries (e.g., vehicle tires, textiles, agriculture, foodware and packaging, and/or fisheries & aquaculture) and scientific experts to identify alternative products and other sector-specific plastic pollution prevention strategies by 2023. **Partners: PPSC Agencies**

Objective 2. Pathway Interventions

2A.2.2 Evaluate microplastic removal efficacy of LID structural Best Management Practices, including operations and maintenance strategies, and identify sites where LID implementation should be required based on environmental characteristics and available co-benefits by 2023. **Partners: CCC, SWRCB, RWQCB**

2A.2.8 Based on the results of existing studies and the following completion of the ongoing SCCWRP study on wastewater treatment plant process removal efficacy, further develop microplastics reduction strategies, and monitoring recommendations based on each level of treatment, including primary, secondary, tertiary, and advanced treatment beginning in 2023. **Partners: SWRCB, RWQCB**

Recommended Actions | Research Priorities

Objective 3. Outreach & Education

2A.3.3 Develop a public campaign to raise awareness of microplastic pollution, and to facilitate behavior, policy, systemic, and environmental change by 2023. **Partners: PPSC Agencies**

CHAPTER 2B. SCIENCE TO INFORM FUTURE ACTION

Objective 1. Monitoring

2B.1.1 Establish standardized microplastic monitoring methods (sampling and analysis of environmental samples, including marine, river, and estuarine waters, sediment, and fish tissue) with accreditation by 2023. **Partner: SWRCB**

2024

CHAPTER 2A. SOLUTIONS

Objective 1. Pollution Prevention

2A.1.8 Promote, or otherwise require, the sale and use of ENERGY STAR condenser dryers and washing machines with filtration rates of 100 microns or smaller, and develop a program to incentivize post-market retrofits or purchases through rebates and other mechanisms by 2024.

Objective 2. Pathway Interventions

2A.2.3 Consistent with findings of microplastic removal efficacy under **2A.2.2**, consider inclusion of LID requirements for new and redevelopment projects to address microplastic loading in municipal, industrial, construction, and highway water quality permits, in local coastal programs, and in coastal development permits adopted or reissued after December 31, 2023. **Partners: CCC, SWRCB, RWQCB**

Objective 3. Outreach & Education

2A.3.4 Promote informal and formal educational programs with updated principles, concepts, standards, teacher training efforts, and/or curricula to educate K-12 students of microplastic sources, impacts, and solutions by 2024. **Partners: DOE, PPSC Agencies**

2A.3.5 Promote industry engagement and outreach to advance sector-specific microplastic pollution prevention strategies by 2024. **Partners: PPSC Agencies**

CHAPTER 2B. SCIENCE TO INFORM FUTURE ACTION

Objective 1. Monitoring

2B.1.2 Develop a model microplastics monitoring program and establish an ongoing integrated statewide ambient monitoring network to quantify microplastic occurrence and effectiveness of management actions for microplastic pollution by 2024. **Partners: SWRCB, RWQCB**

CHAPTER 2B. SCIENCE TO INFORM FUTURE ACTION

Objective 1. Monitoring

2B.1.3 Based on the results of existing studies regarding microplastic removal efficacy in wastewater treatment plants, require microplastic monitoring for California wastewater treatment plant permittees, as needed, as permits are renewed or revised beginning in 2024. **Partners: SWRCB, RWQCB**

2B.1.4 Following completion of standardized monitoring methods and accreditation, require microplastic monitoring for municipal stormwater permittees as permits are renewed or revised beginning in 2024. **Partners: SWRCB, RWQCB**

2B.1.5 Following completion of standardized monitoring methods, implement a pilot monitoring program to evaluate microplastics in agricultural soils, biosolids, and runoff, beginning in 2024. **Partners: SWRCB, RWQCB**

Objective 2. Risk Thresholds & Prioritization

2B.2.1 Develop toxicological studies that provide greater certainty of microplastics risk thresholds for marine life and human health, and determine recommended actions when thresholds are exceeded by 2024. **Partners: SWRCB, RWQCB, OEHHA**

2B.2.5 Prioritize the development of microplastic water quality objectives for state ocean waters, estuarine waters, and freshwaters beginning in 2024. **Partners: SWRCB, RWQCB**

2B.2.6 Identify water body impairments in the California Integrated Report based on best available science, known thresholds, and available data beginning in 2024. **Partners: SWRCB, RWQCB**

Objective 3. Sources & Prioritization

2B.3.1 Quantify and characterize relative inputs from the primary pathways (e.g., urban stormwater, agricultural runoff, wastewater, aerial deposition) of microplastics statewide to the ocean by 2024. **Partners: SWRCB, RWQCB**

2B.3.2 Create a source emissions inventory to quantify the most prevalent California-specific sources (i.e., specific materials and products) contributing microplastics into the environment to inform future regulatory action by 2024. **Partners: SWRCB, RWQCB**

2025

CHAPTER 2B. SCIENCE TO INFORM FUTURE ACTION

Objective 2. Risk Thresholds & Assessment

2B.2.2 Update the existing microplastics risk assessment framework and execute risk assessments that incorporate local environmental loads of microplastics and risk thresholds to quantify the risk of microplastics to

marine life and human health by 2025. **Partners: SWRCB, OEHHA**

2B.2.3 Engage with California Native American Tribes to conduct a risk assessment of microplastic pollution exposure and impacts to ancestral lands and waters, tribal cultural resources, and tribal beneficial uses to inform and prioritize future solutions by 2025 **Partners: PPSC Agencies**

2B.2.4 Engage with California communities disproportionately burdened by environmental injustice, underserved, and/or economically disadvantaged to conduct a risk assessment of microplastic pollution exposure and impacts to inform and prioritize future solutions by 2025. **Partners: PPSC Agencies**

Objective 4. Evaluating New Solutions

2B.4.1 Based on findings from actions completed under Science to Inform Future Action (**Chapter 2B**), provide additional policy recommendations consistent with subsection (g)(2) of Senate Bill 1263 by December 2025. **Partners: PPSC Agencies**

2030

CHAPTER 2A. SOLUTIONS

Objective 2. Pathway Interventions

2A.2.6 Implement the statewide Trash Provisions and assure compliance with the final deadline of no trash in state surface waters by 2030. **Partners: SWRCB, RWQCB**

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