EPA Tools and Resources Webinar: 6PPD and 6PPD-quinone

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US EPA Office of Research and Development

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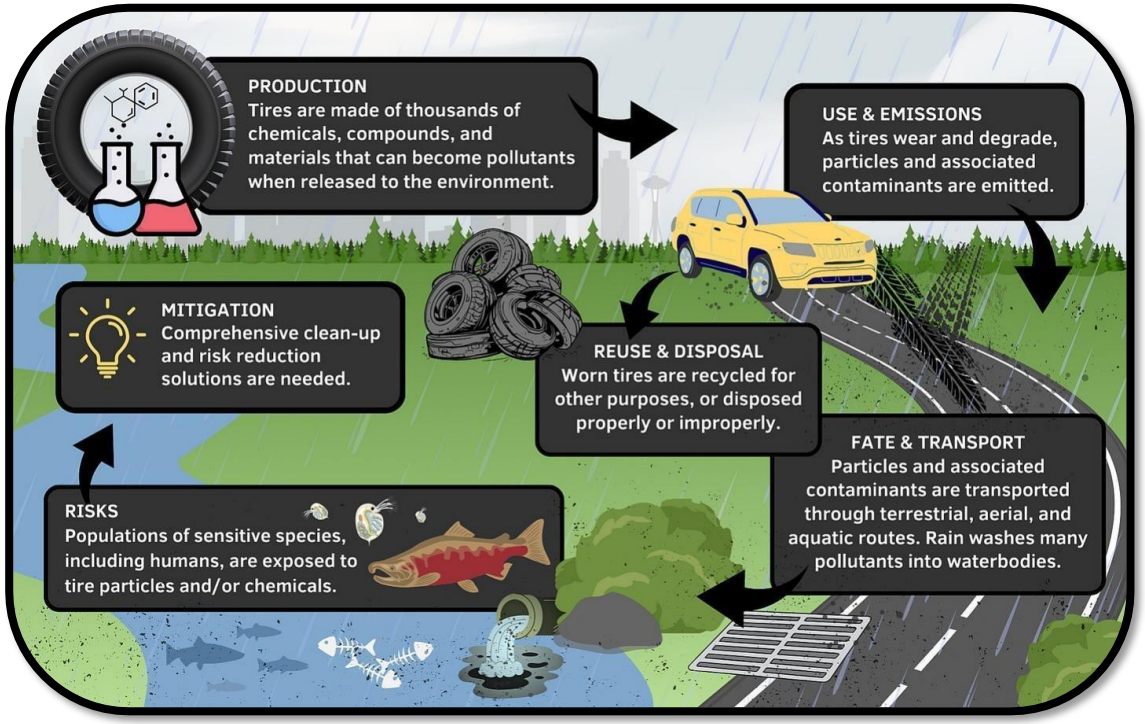
[3] *U.S. Geological Survey*

December 17, 2025

Problem: Background

- **6PPD-quinone** is a transformation product of the tire rubber antiozonant, 6PPD
- Present at toxic concentrations in roadway runoff and stormwater-affected creeks[1]
- Toxic to coho salmon[2,3,4], coastal cutthroat trout[5], brook trout[6], and rainbow trout[6]



Mayer et al., 2024

1) Mayer et al., 2024
2) Tian et al., 2021
3) Tian et al., 2022
4) Greer et al., 2023
5) Shankar et al., 2025
6) Brinkmann et al., 2022

Problem: Issue

- The potential of 6PPD-quinone to have ecotoxic effects and impact coho salmon populations is a key issue.
- These fish species have cultural, commercial, and ecological importance, and some coho salmon populations are threatened and endangered.
- Many Tribal Nations rely heavily on salmon and other aquatic resources for food and cultural practices.
- Limited information is available regarding release to the environment, fate and transport, and human health effects of 6PPD-quinone.
- **Needed: Data to inform timely decisions on protection of sensitive species.**

Approach

Collaborative research

- Since 2020, EPA has engaged in collaboration with other federal agencies, states, Tribal Nations, industry, and other partners and stakeholders to address information gaps and inform impact reduction through mitigation and identifying safer alternatives for use in tire manufacturing.
- EPA research on 6PPD and 6PPD-quinone includes work on fate and transport, ecotoxicity, and green infrastructure solutions for stormwater contamination.

Supported development of 6PPD alternatives (Small Business Innovation Research Program)

- Reduction or Replacement of 6PPD through Improved Ozonation-related Crack Resistance with Molecular Rebar (Final Report completed in 2024)
- Biorenewable Rubber Anti-Degradants (Final Report completed in 2025)

Results: Completed EPA ORD-Region Collaborative Research Projects

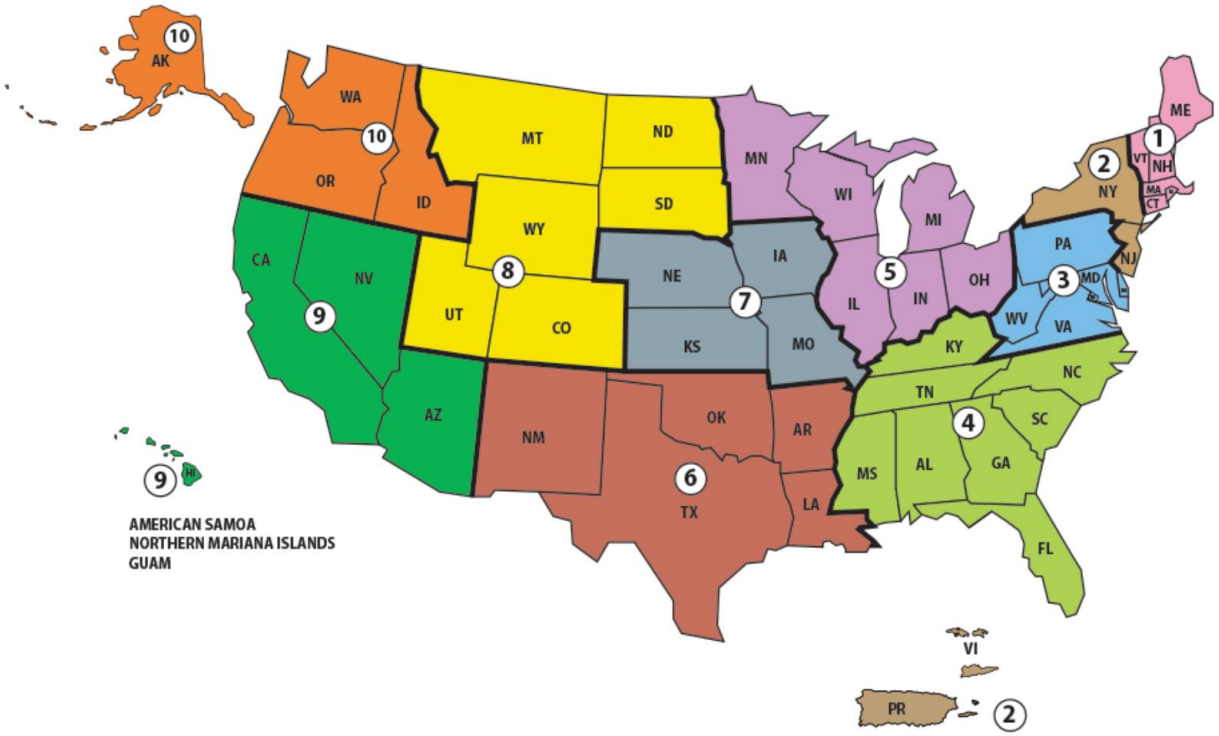
VELMA (Visualizing Ecosystem Land Management Assessments) modeling for salmonid and orca recovery in Puget Sound (Region 10)

Evaluating the bioactivity of 6PPD, 6PPD-quinone, and stream samples (Region 10)

Saving salmon and orca from stormwater pollutants through participatory decision science (Region 10)

The fate, transport, and treatment of tire-derived pollutants in stormwater (Regions 4 and 7)

Understanding airborne emissions and health impacts of 6PPD and 6PPD-quinone from tires (Region 3)



https://www.epa.gov/aboutepa/regional-and-geographic-offices

Results: Recent publications (1 of 3)

Contact:
Jonathan Halama
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Watershed analysis of urban stormwater 6PPD-quinone hotspots and stream concentrations using a process based ecohydrological model (Halama et al., 2024)

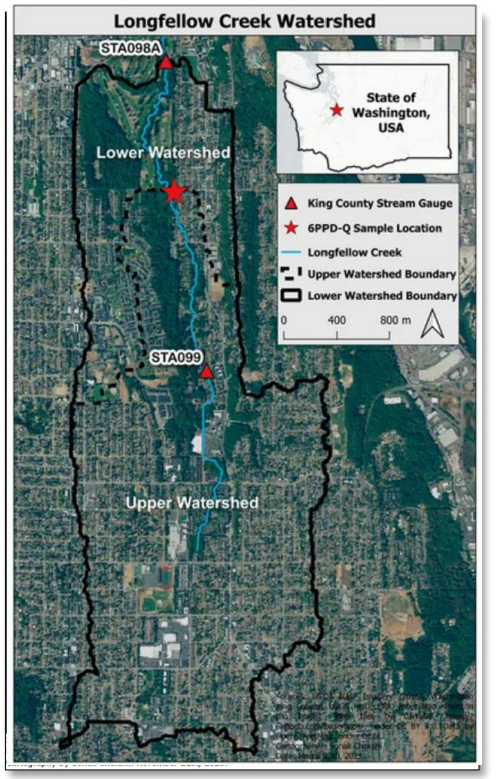
Objective: Understand the fate and transport of 6PPD/6PPD-quinone and mechanisms leading to salmon mortality in Puget Sound Estuary

Results:

- Highlights hydrological and biogeochemical controls on 6PPD-quinone flow paths and hotspots within the watershed and its stormwater infrastructure, that ultimately impact contaminant transport to Longfellow Creek and Puget Sound
- Simulated and sampled 6PPD-quinone concentrations corresponded within ±10 ng/L

Impact: Provides a tool for prioritizing locations and types of green infrastructure to reduce 6PPD-quinone stream concentrations

VELMA Modeling*



Halama et al., 2024

*Visualizing Ecosystem Land Management Assessments (VELMA) Model

Results: Recent publications (2 of 3)

Contact:
Mark Jankowski
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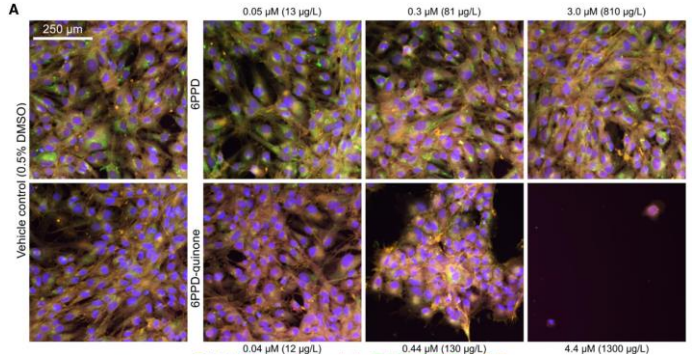
Bioactivity of the ubiquitous tire preservative 6PPD and degradant, 6PPD-quinone in fish- and mammalian-based assays (Jankowski et al., 2025)

Objective: Employed an array of high-throughput screening assays available within EPA to evaluate their suitability for detecting the toxicity of 6PPD-quinone

Results:

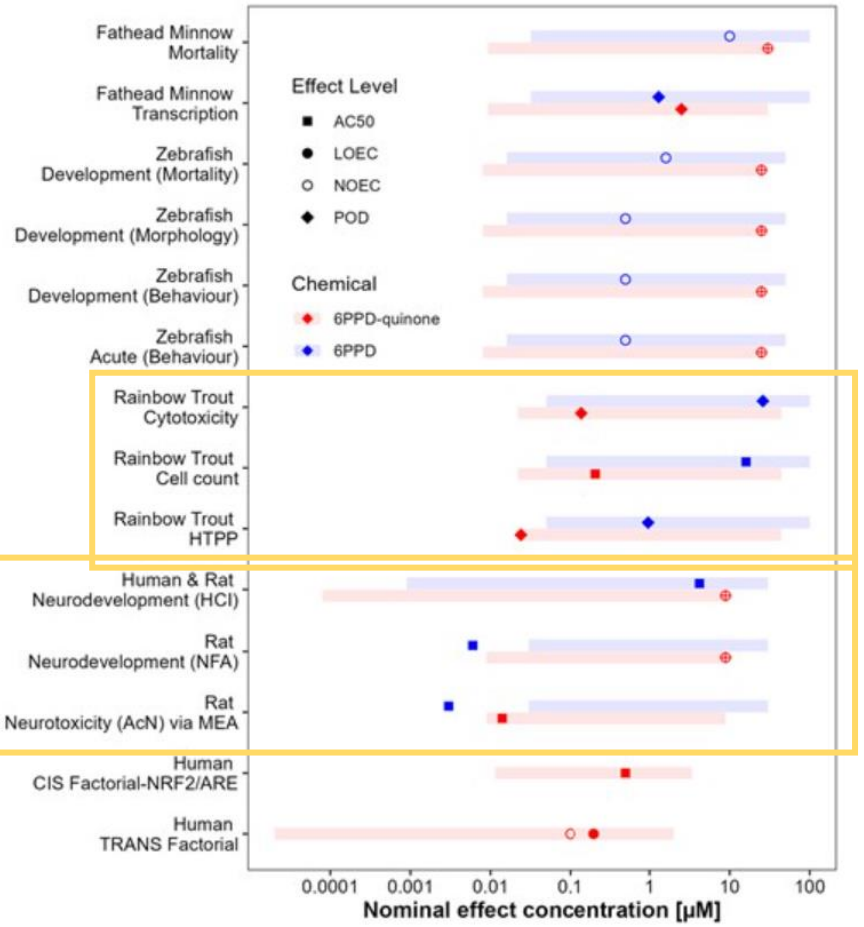
- 6PPD was bioactive in a broader set of assays than 6PPD-quinone
- 6PPD may be a developmental neurotoxicant
- 6PPD-quinone was much more potent than 6PPD in altering the intracellular phenotype of rainbow trout gill cells

Impact: High-throughput / high content bioactivity assays provide data to inform both ecological and human health assessments



Jankowski et al., 2025

Evaluating Bioactivity



Jankowski et al., 2025

Results: Recent publications (3 of 3)

Contact:
Felix Harris
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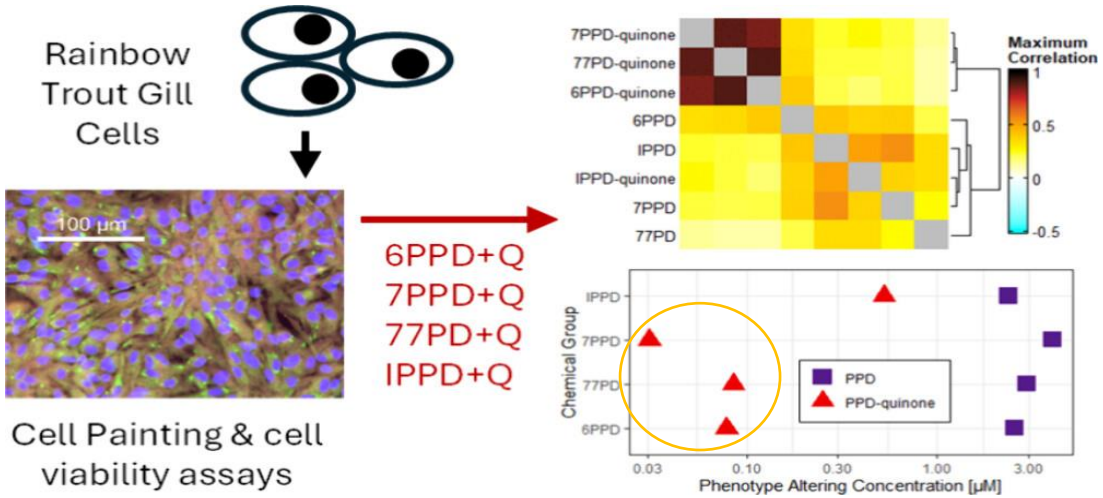
Evaluating Bioactivity

Phenotypic profiling of 6PPD, 6PPD-quinone and structurally diverse antiozonants in RTgill-W1 cells using the cell painting assay (Harris et al., 2025.)

- **Objective:** Characterize the biological activity of 6PPD, 6PPD-quinone and other antiozonants and transformation products in a rainbow trout gill cell line (RTgill-W1)
- **Results:** Quinones of 7PPD and 77PD exhibited similar bioactivity to 6PPD-quinone, suggesting these may not be suitable replacements for 6PPD in tires
- **Impact:** This work can be used to inform testing and identification of less toxic 6PPD alternatives



Harris et al., 2025

Impact: Other EPA activities

Key EPA Actions to Address 6PPD-quinone

- A cross-Agency technical review of 6PPD-quinone and the development of the 6PPD/6PPD-quinone Action Plan
- Publication of a draft laboratory testing method (EPA Method 1634) that will enable government agencies, Tribal Nations, and other groups to determine where and when 6PPD-quinone is present in local stormwater and surface waters
- Finalization of a rule under Section 8(d) of TSCA that requires manufacturers (including importers) of 6PPD to report lists and copies of unpublished health and safety studies on 6PPD and 6PPD-quinone to EPA
- Development of acute screening values for 6PPD-quinone and 6PPD to protect sensitive salmon and other aquatic life (Jarvis et al., 2025)

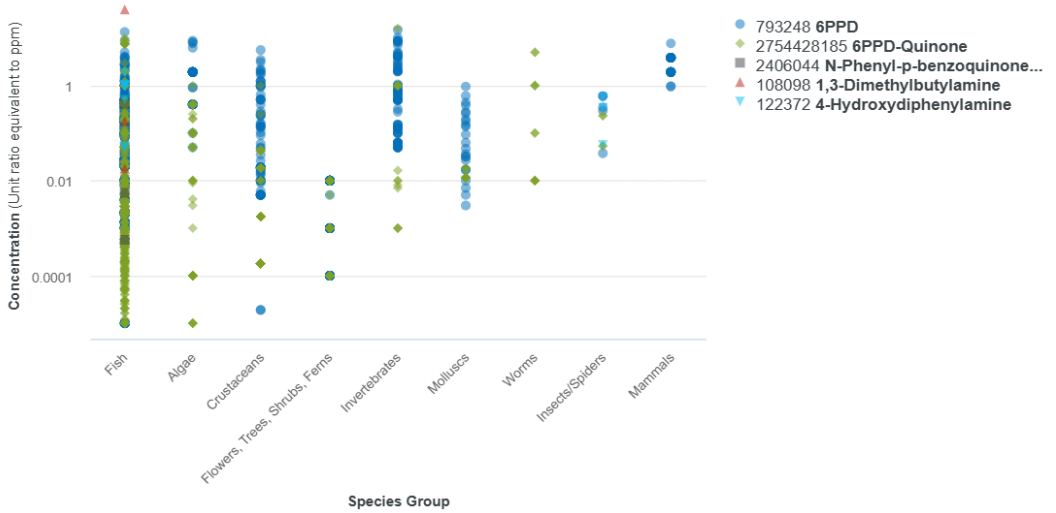
For more information, see EPA's 6PPD-quinone website

US EPA Resources

- CompTox Chemicals Dashboard (6PPD-quinone)
- ECOTOX Knowledgebase (6PPD-quinone)
- ChemExpo Knowledgebase (6PPD)
- Science Inventory (6PPD, 6PPD-quinone)

December 11th ECOTOX update

		In ECOTOX (Dec 11, 2025)	
CASRN	**Chemical Name**	**Publications**	**Records**
793-24-8	6PPD	62	1624
2754428-18-5	6PPD-Quinone	101	2781
122-37-2	4-Hydroxydiphenylamine	3	15
108-09-8	1,3-Dimethylbutylamine	1	9
2406-04-4	N-Phenyl-p-benzoquinone imine	1	9



ITRC Overview of the tire-derived chemicals 6PPD & 6PPD-quinone

Interstate Technology & Regulatory Council (ITRC)

https://6ppd.itrcweb.org/

Meet the ITRC Team Leads

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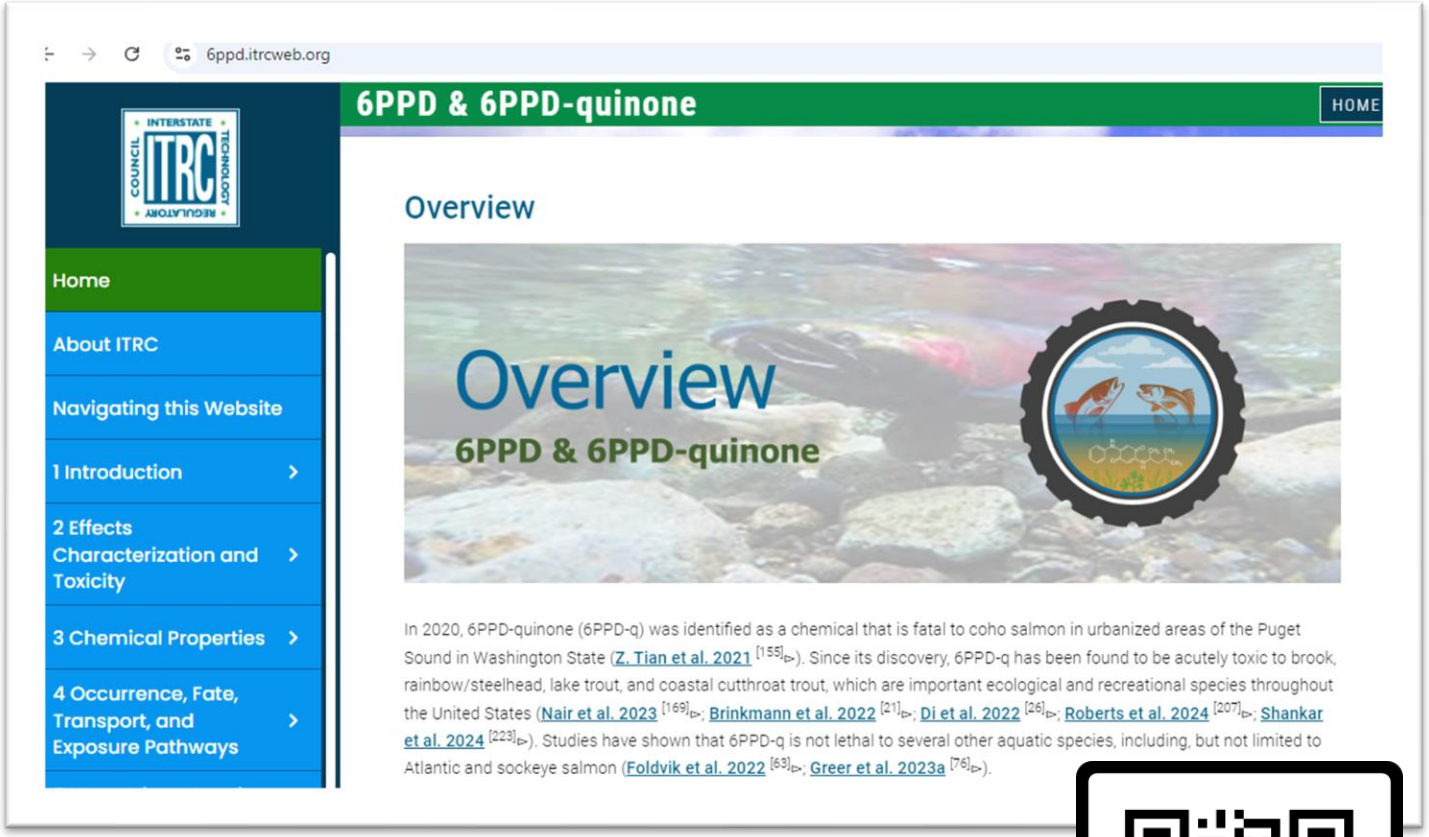
Guidance Document



https://6ppd.itrcweb.org

SCAN ME

- Overview
- Introduction
- Effects Characterization and Toxicology
- Chemical Properties
- Occurrence, Fate, Transport, & Exposure
- Measuring, Mapping, and Modeling
- Mitigation Measures and Solutions
- Policies, Regulations, and Laws
- Information Gaps and Research Needs
- References
- Acronyms, Glossary, Team Contacts

Road Map

Effects Characterization and Toxicology

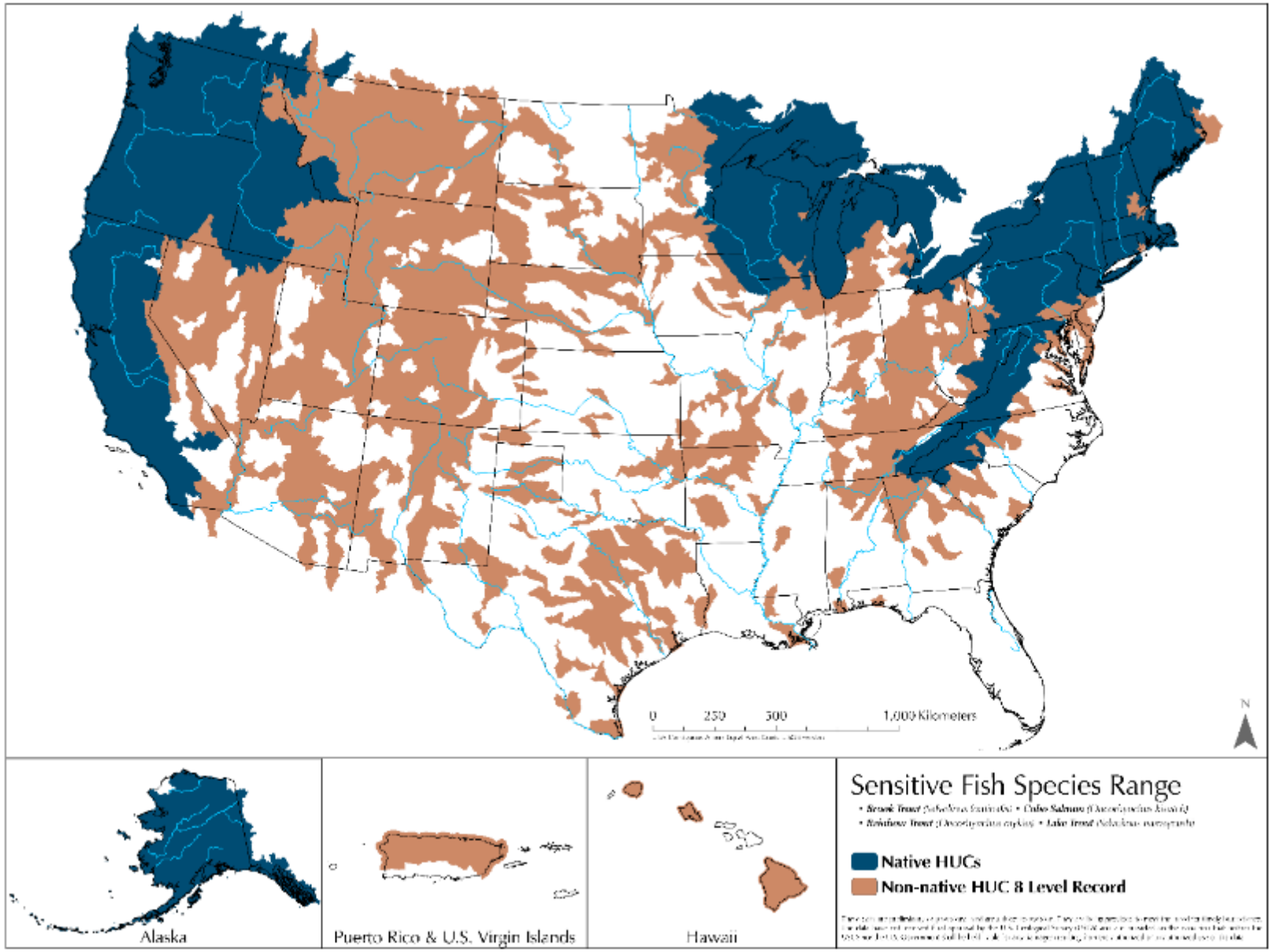
Occurrence

Measuring, Mapping, and Modeling

Mitigation Measures

Policies, Regulations, and Laws

6PPD-q – Toxic to Some Salmonids



Coho salmon

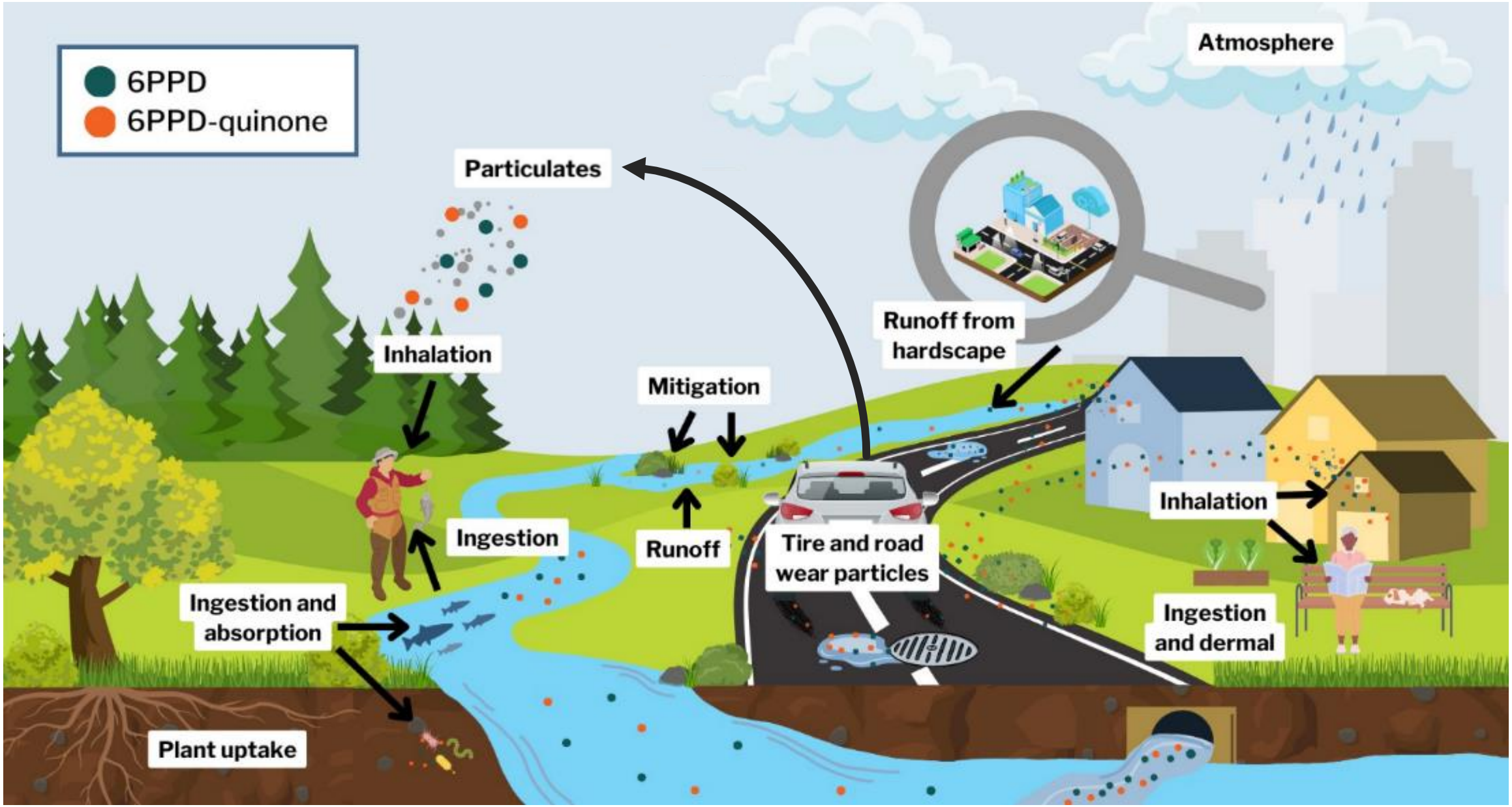
Brook trout

Lake trout

Rainbow trout/steelhead

Coastal cutthroat trout

Conceptual Exposure Model



Road Map

Effects Characterization and Toxicology

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Species-Specific Acute Toxicity in Salmonids

Species	LC_{50} (µg/L)	Test duration (h)
Coho salmon *(Oncorhynchus kisutch)*	**0.08 (median)**	**24**
Coastal Cutthroat trout *(Oncorhynchus clarkii clarkii)*	**0.14 (median)**	**24**

- LC_{50} = lethal concentration to half the population
- Coho LC_{50} frequently exceeded in stormwater runoff
- Observed concentrations in surface waters up to 2.85 µg/L

Guidance Document Table 1-1

Species-Specific Acute Toxicity in Salmonids

Species	LC_{50} (µg/L)	Test duration (h)
Coho salmon *(Oncorhynchus kisutch)*	**0.08 (median)**	**24**
Coastal Cutthroat trout *(Oncorhynchus clarkii clarkii)*	**0.14 (median)**	**24**
Brook trout *(Salvelinus fontinalis)*	**0.4 (median)**	**24**
Lake trout *(Salvelinus namaycush)*	**0.51**	**24**
White-spotted char *(Salvelinus leucomaenis pluvius)*	**0.51**	**24**
Rainbow trout/steelhead *(Oncorhynchus mykiss)*	**1.0 (median)**	**96**

Guidance Document Table 1-1

Hypotheses for 6PPD-q's Mode of Action

Leakage from blood vessels

- Blood-brain barrier failure

Mitochondrial dysfunction

- Breakdown of the process cells use to make energy

Metabolic differences between sensitive and tolerant species

- Tolerant species may biotransform 6PPD-q more effectively

6PPD-q Can Cause Sublethal Effects

Developmental malformations

- Coho & lake trout

Altered gill morphology

- Brook trout

Behavior and swimming

- Coastal cutthroat trout
- Zebrafish

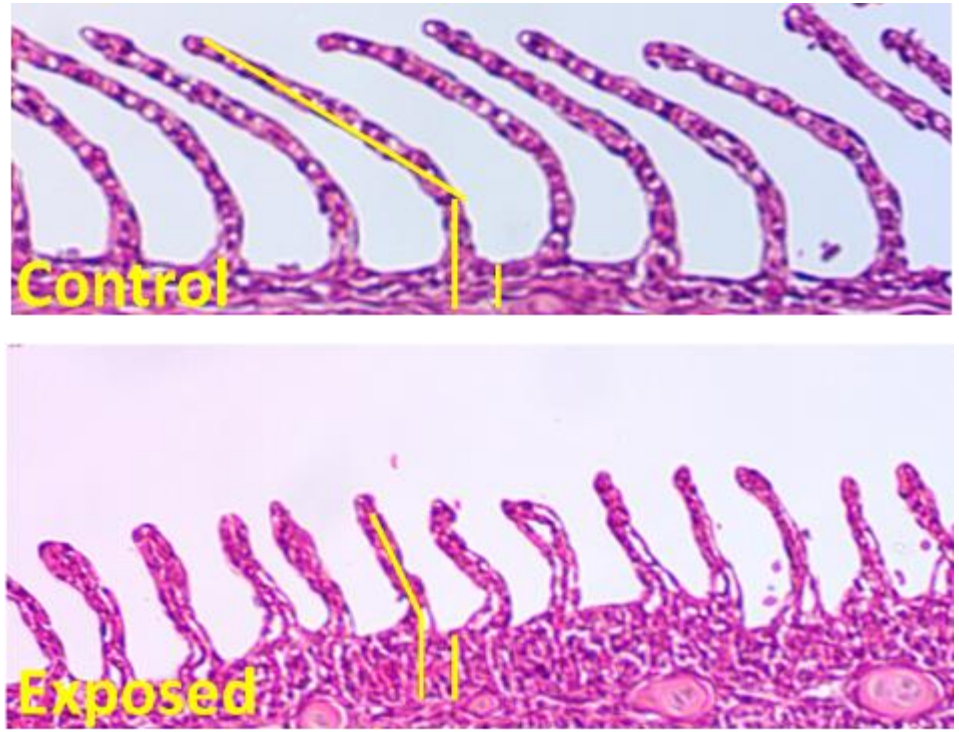


Image Courtesy: Danielle Philibert

Human Exposure & Toxicokinetics

Human Biomonitoring:

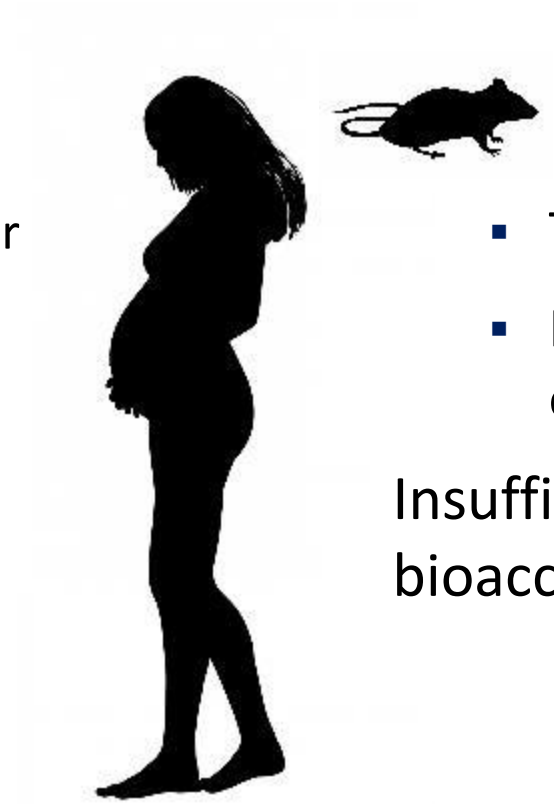
6PPD & 6PPD-q in urine

- Pregnant people's urine had higher levels; unclear whether greater exposure or differences in metabolism

6PPD & 6PPD-q in blood serum

6PPD & 6PPD-q in breastmilk

Only 6PPD-q in cerebrospinal fluid, ovarian follicles



Mouse models:

- Transmitted through the placenta
- Pass through the blood-brain barrier of adult and fetus

Insufficient information on bioaccumulation in mammals

Human Health Hazards

New

Summary of toxicological hazard traits of 6PPD and 6PPD-q

6PPD

- Liver toxicity
- Skin sensitizer (causes skin allergies)
- Reproductive toxicant, potential for developmental toxicity
- Anemia
- Possible neurotoxicant
- Oxidative stress

6PPD-q

- Liver toxicity
- Reproductive toxicity (testes, ovaries, endometrium)
- Possible intestinal toxicity
- Oxidative stress

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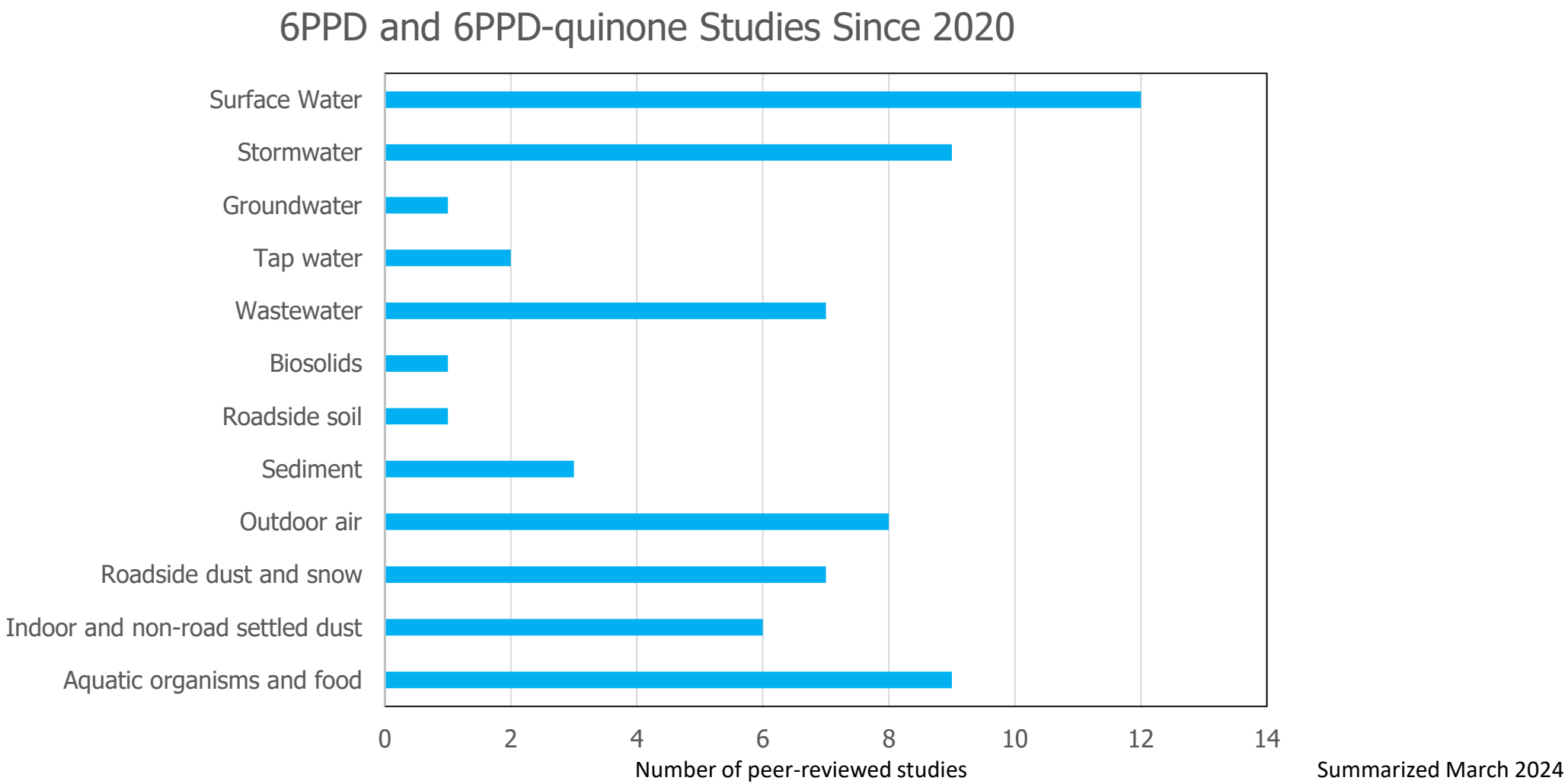
Peer-Reviewed Occurrence Studies



https://6ppd.itrcweb.org/section-4-tables-occurrence-fate-transport-and-exposure-pathways/

Surface water & stormwater

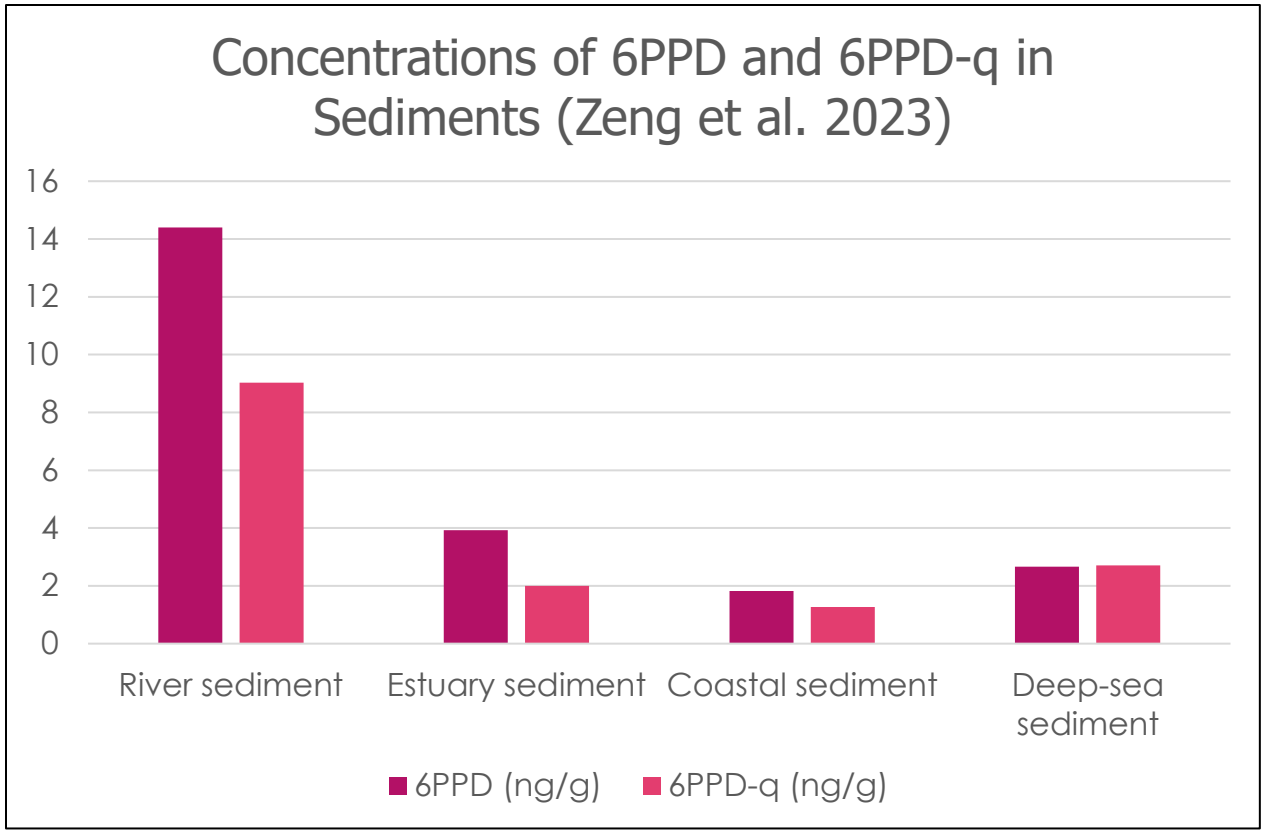
Surface runoff and stormwater are major mechanisms for transporting TRWP, 6PPD, and 6PPD-Q to surface water.

- Stormwater
  - **6PPD:** ND - 0.075 ug/L
  - **6PPD-Q:** ND - 5.58 ug/L
- Surface water
  - **6PPD:** ND - 0.099 ug/L
  - **6PPD-Q:** ND - 2.85 ug/L

https://6ppd.itrcweb.org/4-occurrence-fate-transport-and-exposure-pathways/#4_1

Soil & Sediment

- Tire, road, and soil particles are transported by stormwater and surface water.
- The allocation between what stays suspended in water and what is deposited in the sediments and soils is unknown.
- Biodegradation of 6PPD and 6PPD-q in soil has been observed.



Potential Food Sources

Vegetables

Seafood

Property	6PPD	6PPD-q	Comments
Bioconcentration (BCF; unitless)	617 - 801	20.9	Below US EPA Sustainable Futures / P2 Framework Manual bioaccumulation risk value of 1,000 for fish.

See Section 4.5 for additional information and references: https://6ppd.itrcweb.org/4-occurrence-fate-transport-and-exposure-pathways/#4_5

Road Map

Effects Characterization and Toxicology

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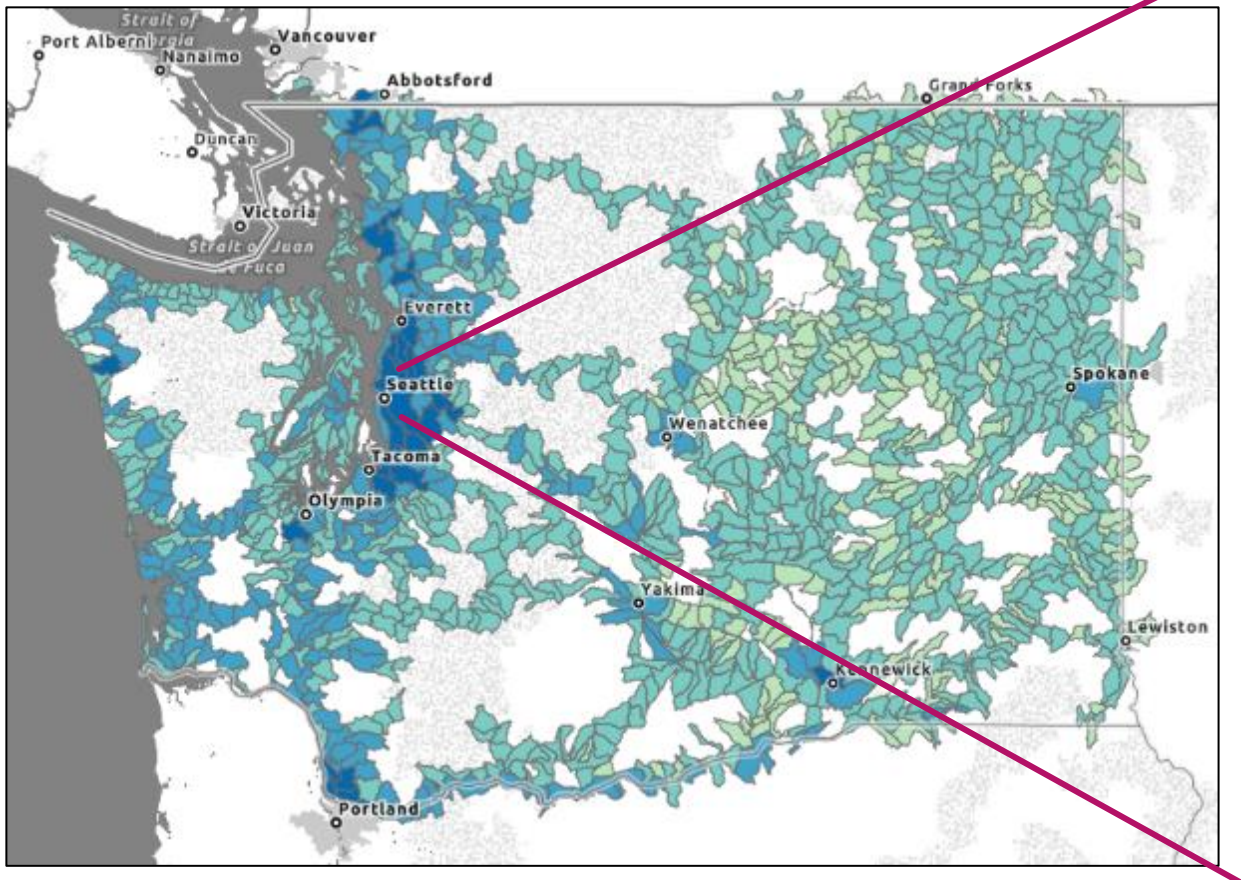
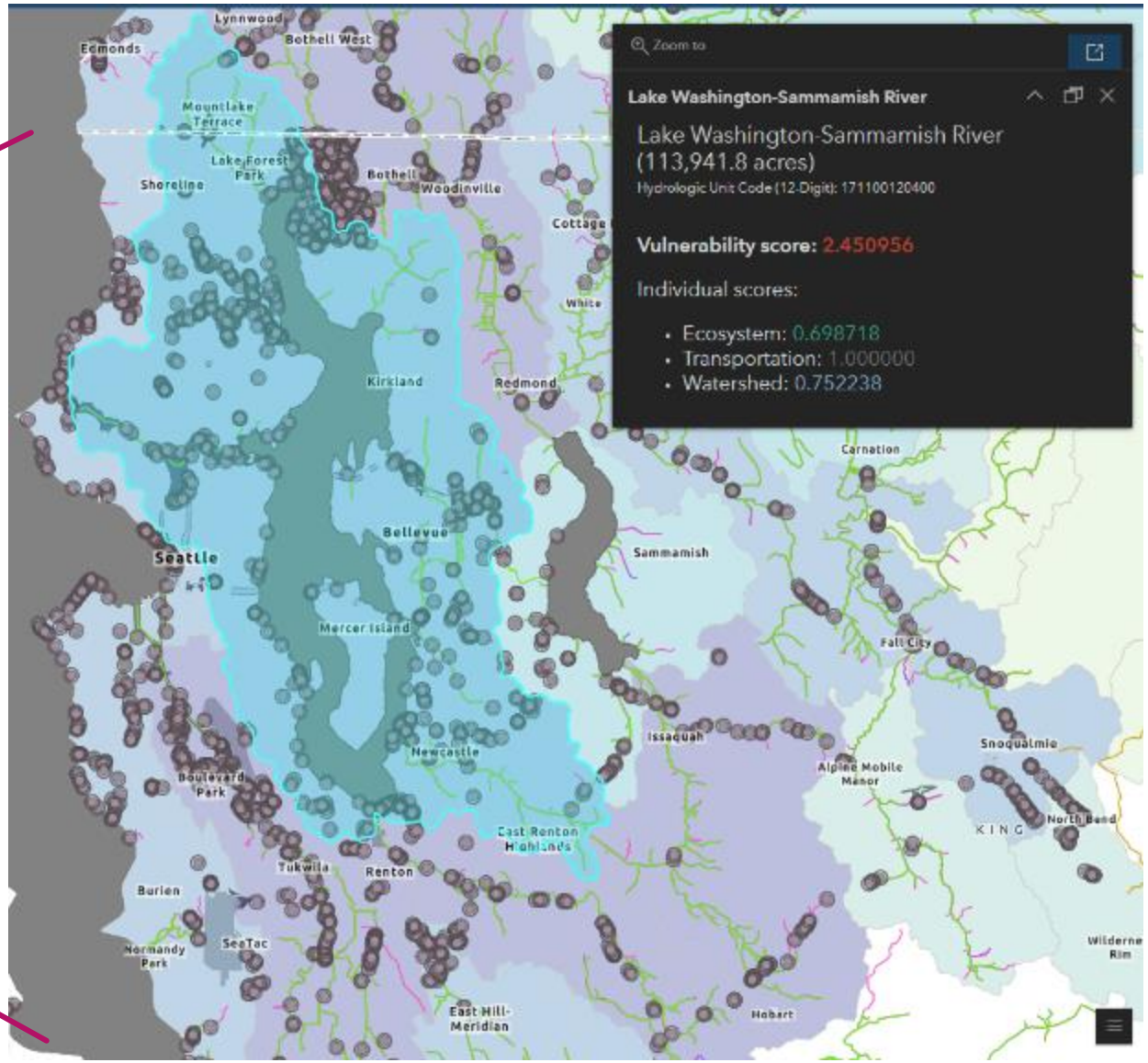
Mitigation Measures

Policies, Regulations, and Laws

State Mapping Example Tool

Storymap Washington Department of Ecology
Visualizing the potential occurrence of 6PPD-quinone along roadways near salmon-bearing waterbodies



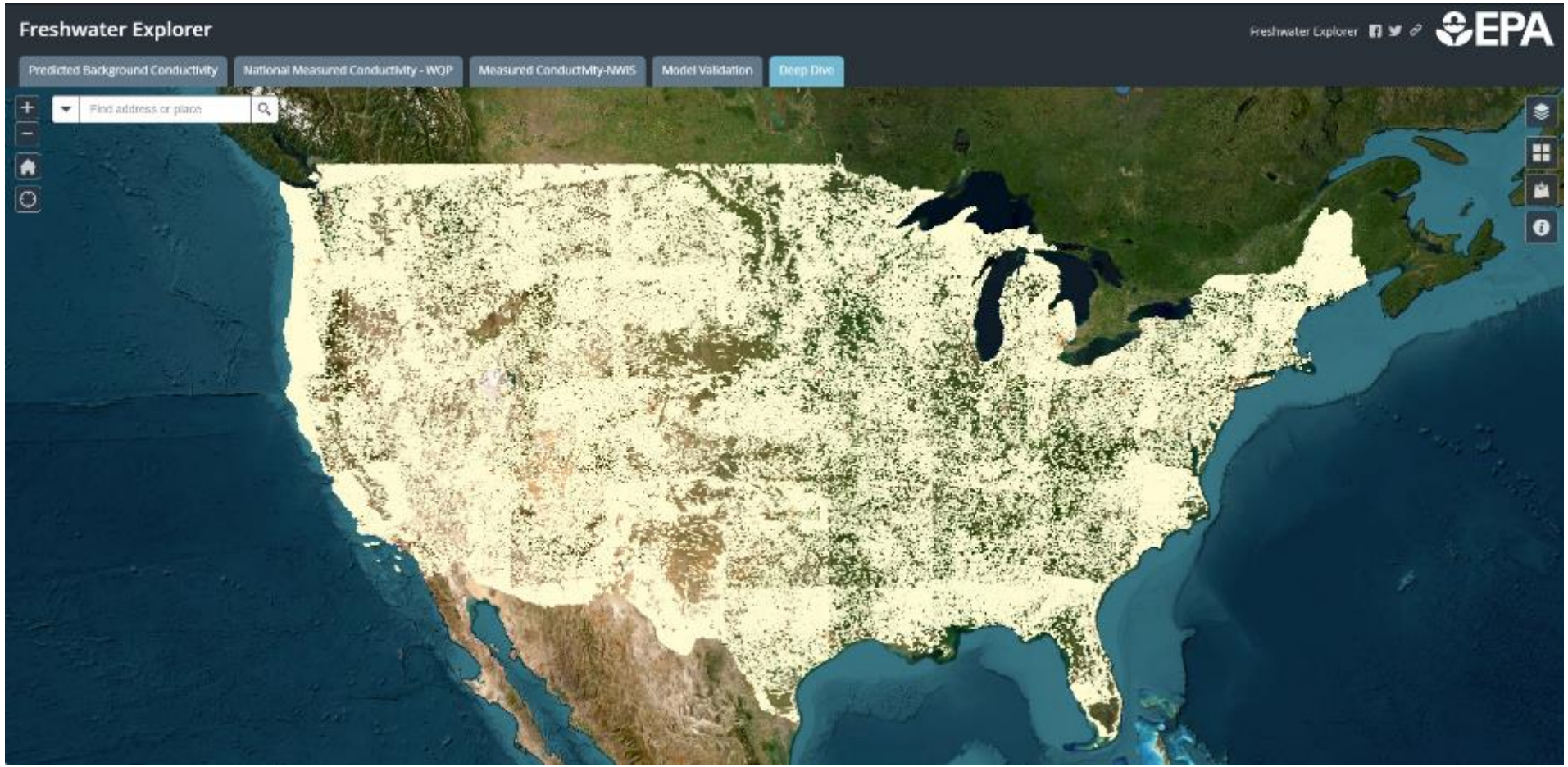


The Washington Department of Ecology Source: Washington Department of Ecology website, Tire Contaminants (wa.gov)

Federal Mapping Example Tool

USEPA Freshwater Explorer

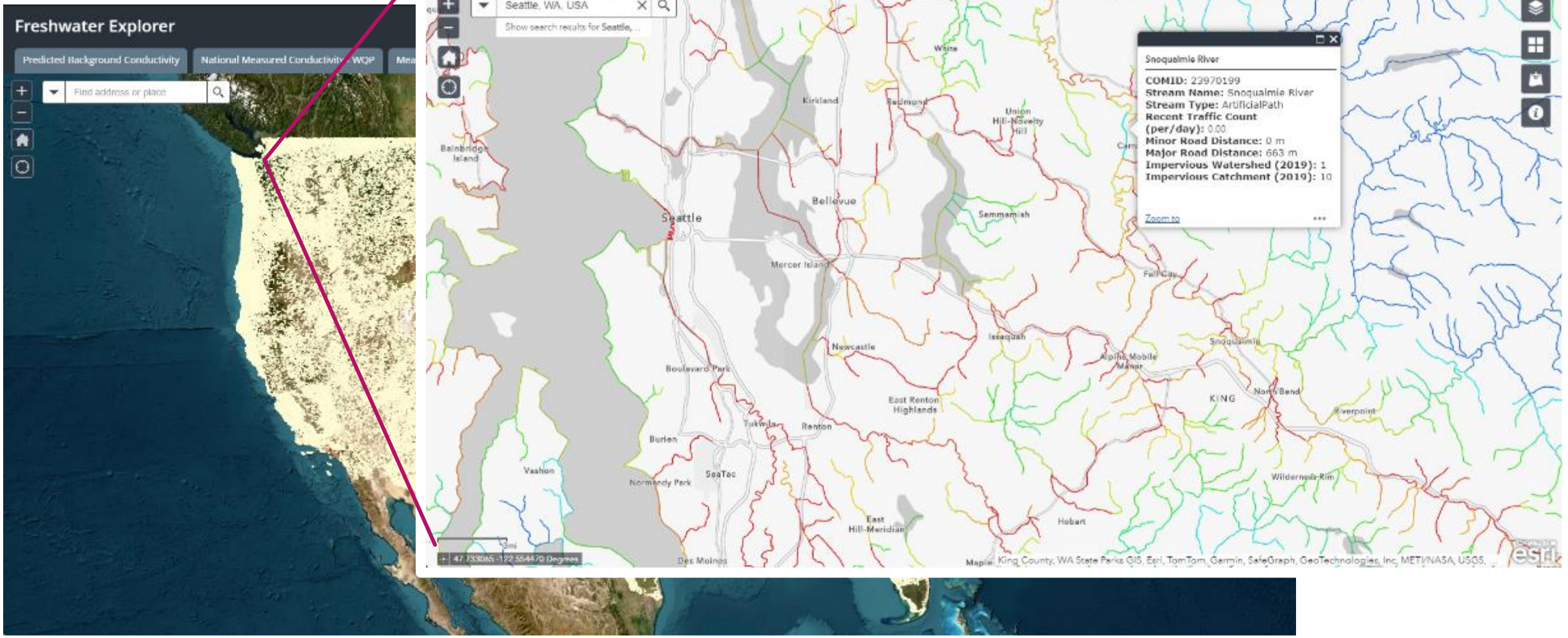
Visualizing impervious surfaces, traffic, and road proximity to streams



Source: Screenshot from USEPA Freshwater Explorer, https://www.epa.gov/water-research/freshwater-explorer

Federal Mapping Example Tool

USEPA Freshwater Explorer

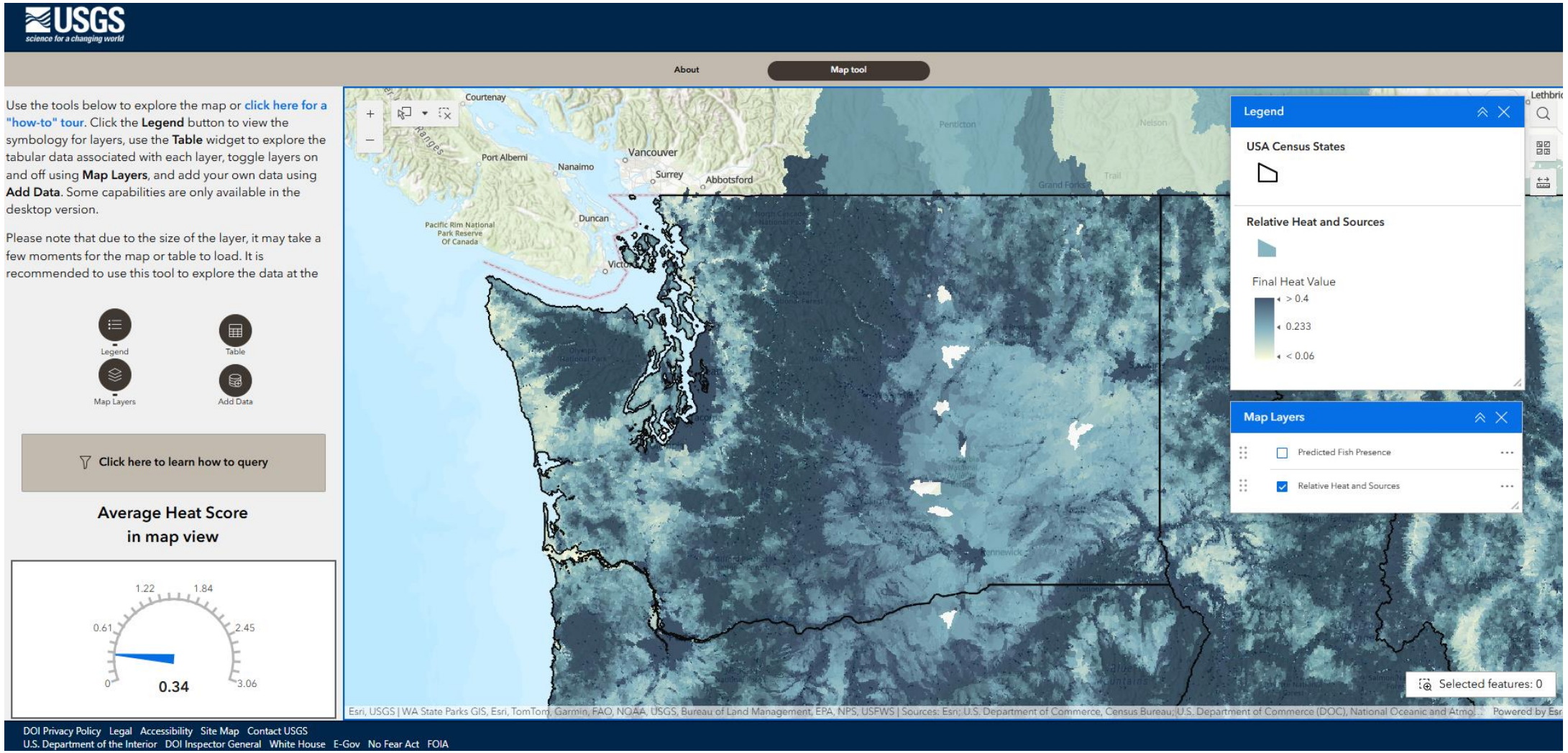


Source: Screenshot from USEPA Freshwater Explorer, 20240806, Seattle, Washington
https://www.epa.gov/water-research/freshwater-explorer

Federal Mapping Example Tool

USGS Mapping 6PPD-quinone sources across the conterminous U.S.

geonarrative.usgs.gov/6ppdqsourcedashboard/



Federal Mapping Example Tool

USGS
science for a changing world

Use the tools below to explore the map or click here for a "how-to" tour. Click the **Legend** button to view the symbology for layers, use the **Table** widget to explore the tabular data associated with each layer, toggle layers on and off using **Map Layers**, and add your own data using **Add Data**. Some capabilities are only available in the desktop version.

Please note that due to the size of the layer, it may take a few moments for the map or table to load. It is recommended to use this tool to explore the data at the

Legend
Table
Map Layers
Add Data

Click here to learn how to query

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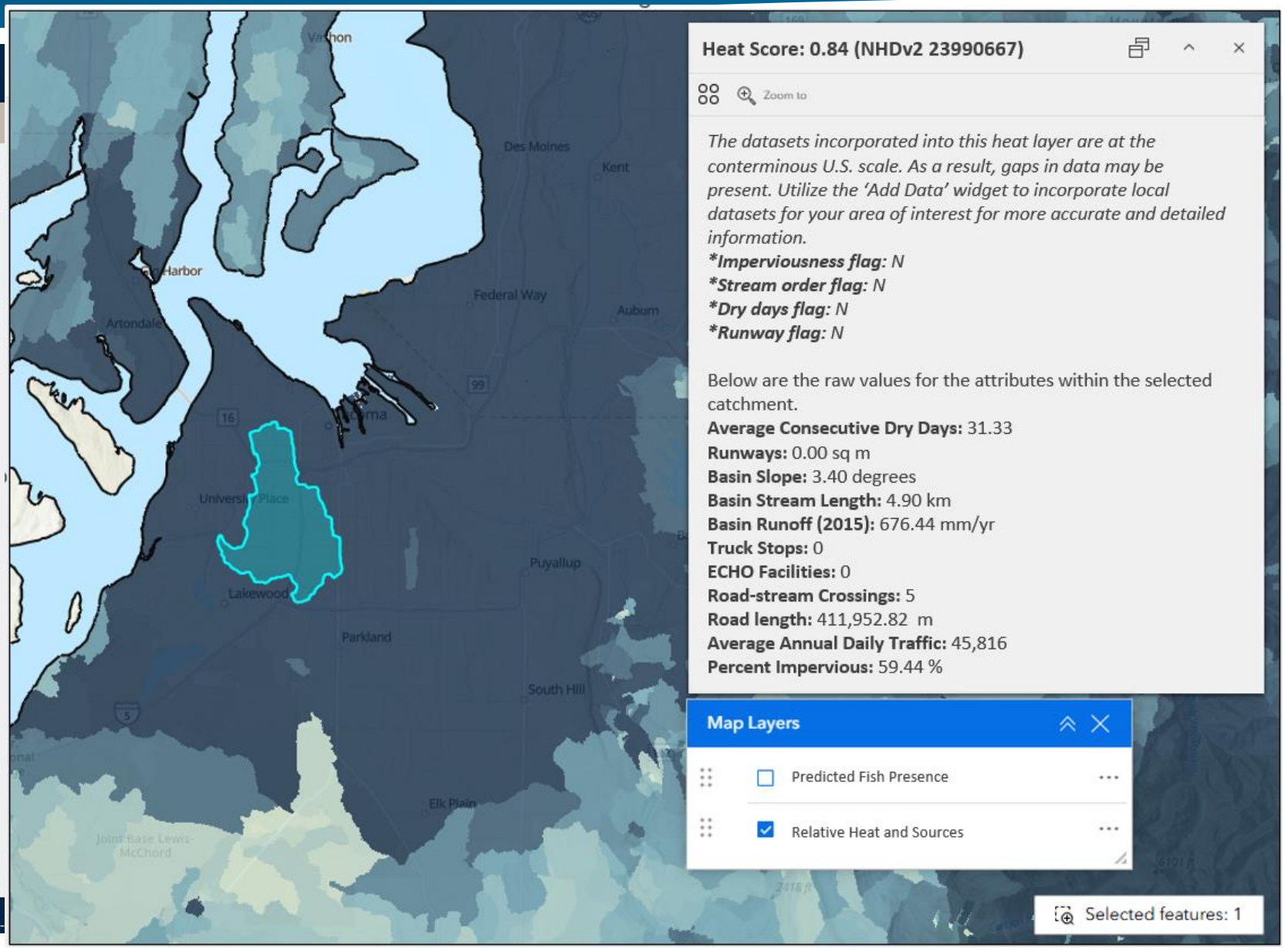
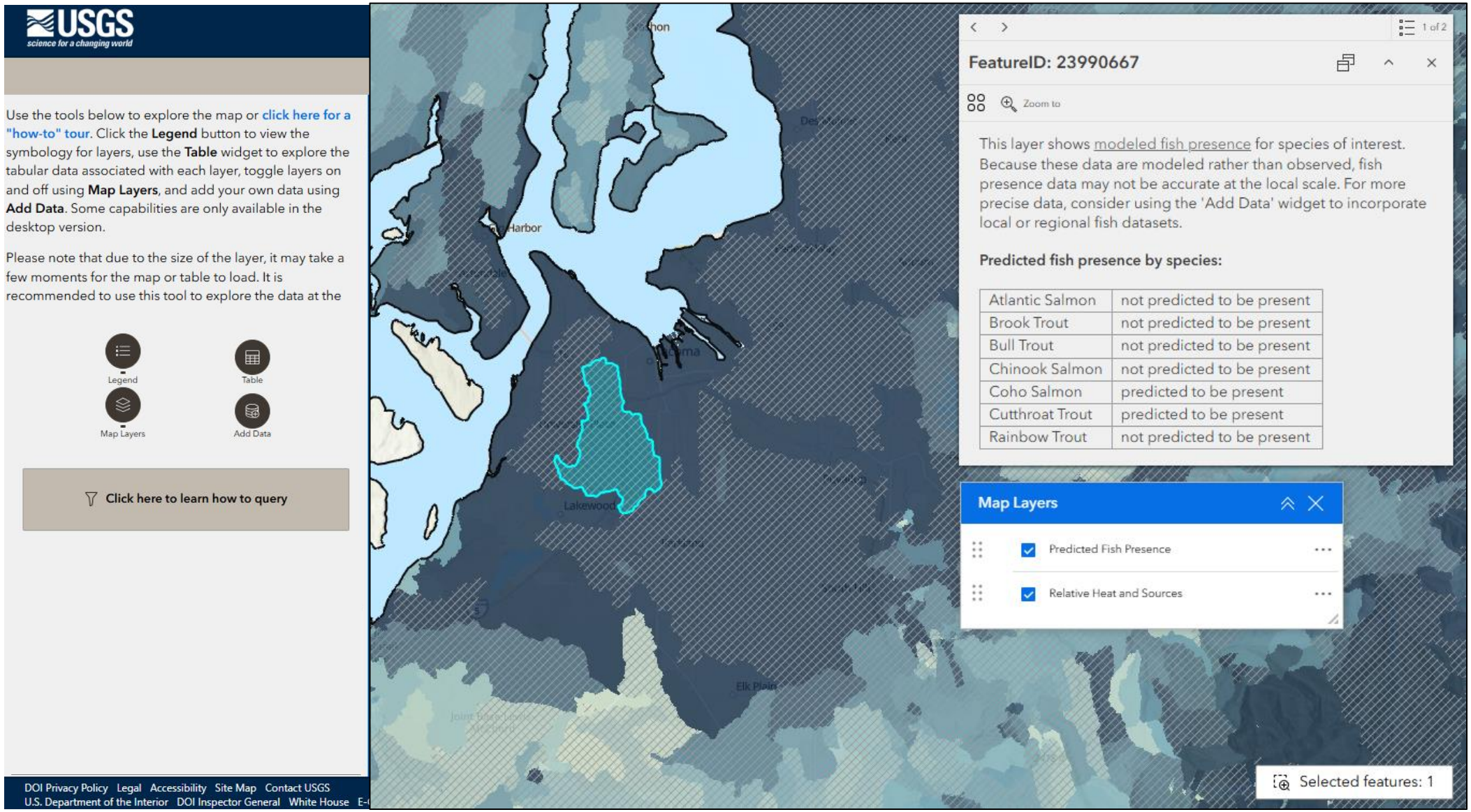
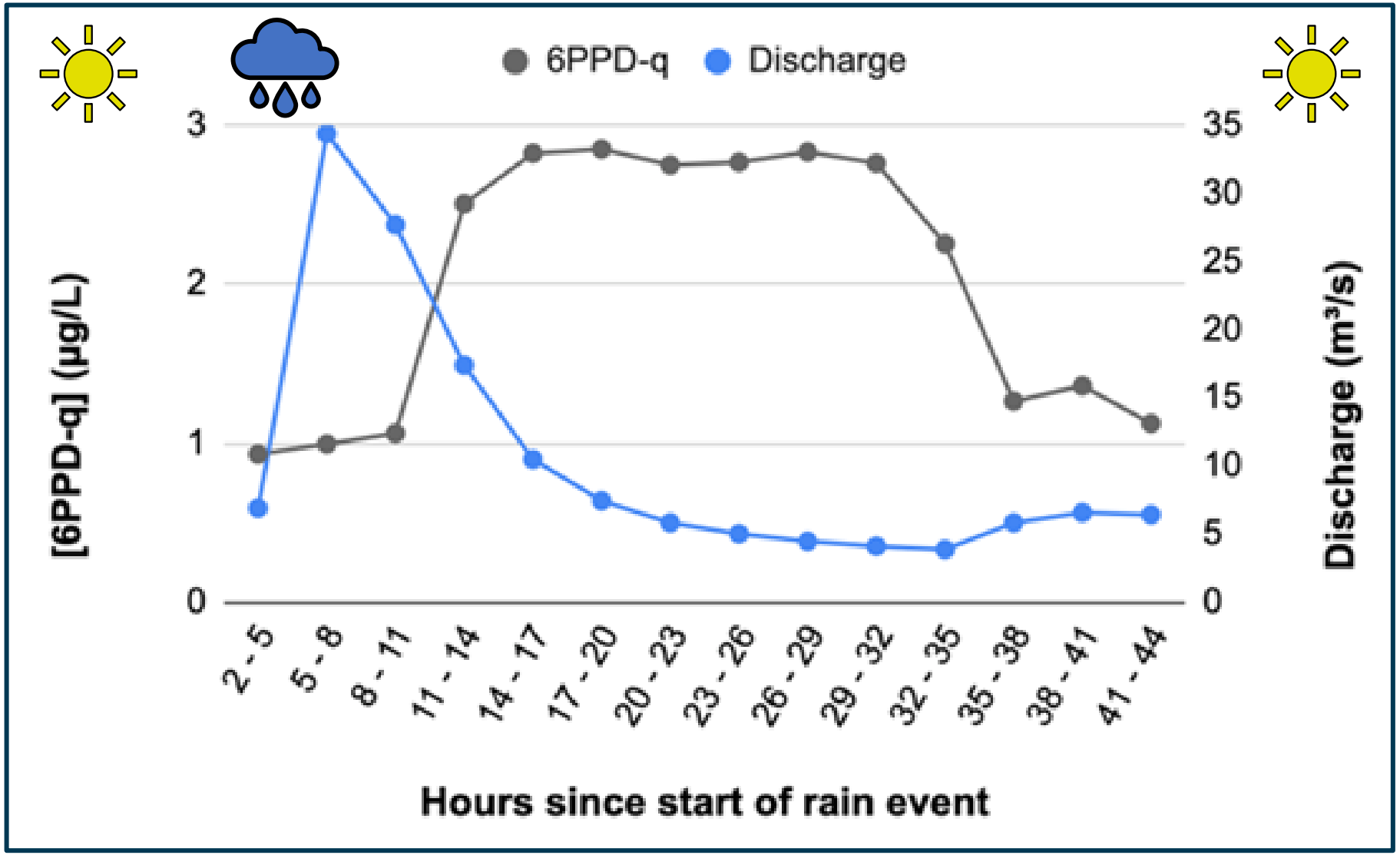


Federal Mapping Example Tool



Considerations for Watershed and Stormwater Sampling



Reference C. Johannessen, 2021
10.1007/s00244-021-00878-4
Provided by Rhea Smith

6PPD-q Field and Laboratory Methods

WA Ecology SOP Sampling 6PPD-quinone in Receiving Waters

EPA Draft Method 1634 Determination of 6PPD-quinone in Aqueous Matrices Using Liquid Chromatography with Tandem Mass Spectrometry (LC/MS/MS)

Photos Courtesy of WA Dept of Ecology

Modeling

Modeling tools to predict the occurrence of 6PPD and 6PPD-quinone

Atmospheric fate and transport modeling

US EPA's MOtor Vehicle Emission Simulator (MOVES)

US EPA's AERMOD Modeling System

Modeling 6PPD-quinone Stormwater Transport to Surface Water

US EPA's VELMA tool (Visualizing Ecosystem Land Management Assessments)

Modeling Stormwater Best Management Practice (BMP) Effectiveness

USGS Stochastic Empirical Loading and Dilution Model (SELDM)

Road Map

Effects Characterization and Toxicology

Occurrence

Measuring, Mapping, and Modeling

Mitigation Measures

Policies, Regulations, and Laws

Stormwater Control Measures

Source Control

Flow Control

Runoff Treatment

Photos Courtesy of BioCycle 2021, WA State Department of Ecology
Resource: https://stormwater-1.itrcweb.org/

Stormwater Control Measures Research

- Longevity of bioretention media
- Soils and sorbents effectiveness
- Street sweeping effectiveness
- Vegetated and non-vegetated bioretention mixes

Photo Courtesy of Washington State Department of Transportation
https://6ppd.itrcweb.org/6-mitigation-measures-and-solutions/#6_3

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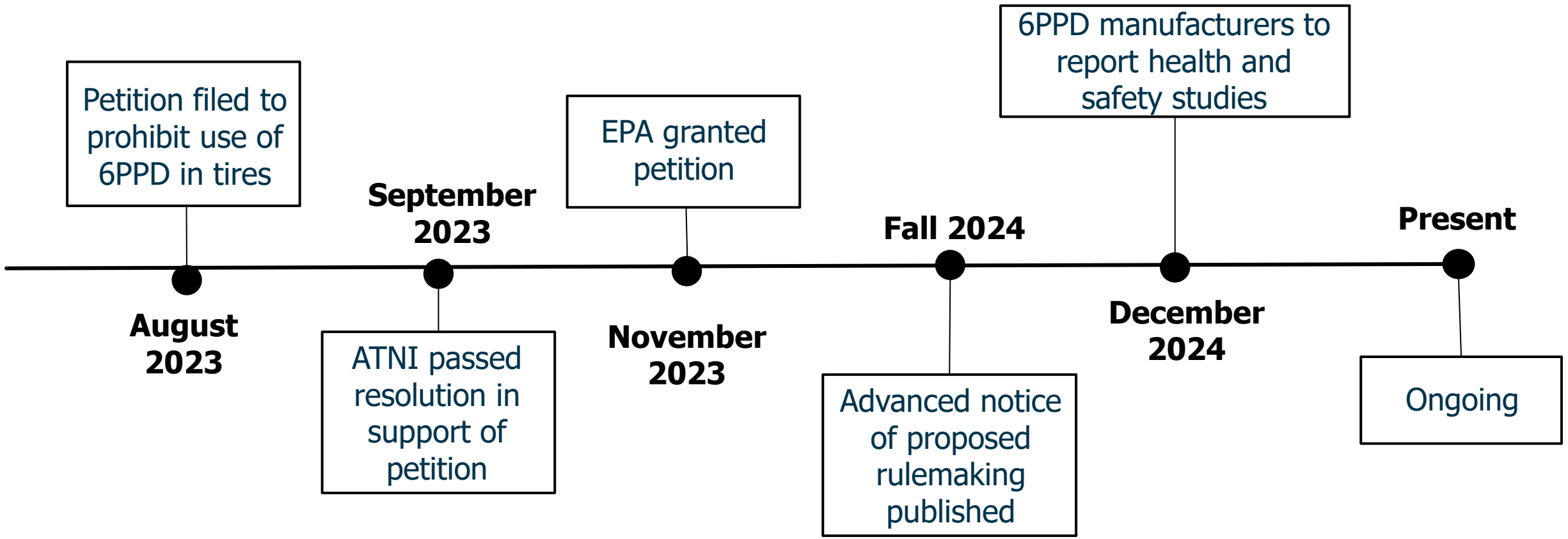
TSCA – Section 21 Petition



Clean Water Act: Water Quality Thresholds

EPA freshwater acute screening values (non-regulatory)

- 6PPD-q: 0.011 µg/L
- 6PPD: 8.9 µg/L

WA State Acute Aquatic Life Criteria (regulatory)

- 6PPD-q: 0.012 µg/L

State Actions for 6PPD Alternatives

California Safer Consumer Products Regulation

75 tire manufacturers have completed Preliminary Alternatives Analyses with 20 possible alternatives to 6PPD.

Safer Products for Washington Program

Completing an Alternatives Assessment using hazard criteria developed specifically for 6PPD, including data requirements for sensitive species and other trophic levels.

Take home messages

- Information on 6PPD and 6PPD-quinone is evolving rapidly
- The chemicals are widely dispersed in the environment
- Acute aquatic toxicity of 6PPD-quinone seems limited to trout and salmon
- Understanding risks to humans is still preliminary
- Governments and partners have developed tools to sample, measure, map, and address 6PPD and 6PPD-quinone
- More research is needed on chemical alternatives to meet performance and toxicity requirements

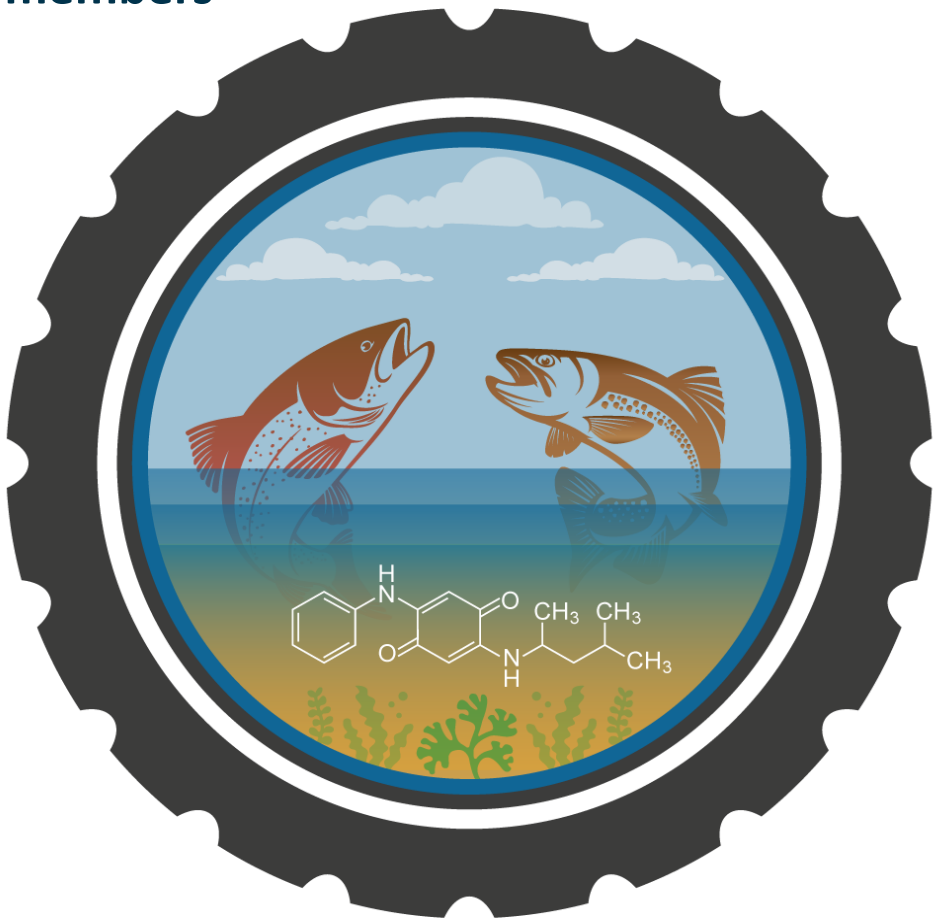
Acknowledgments

U.S. EPA 6PPD team members

- Richard Baldauf
- Allen Brookes
- Susan Cormier
- Kathie Dionisio
- Heather Goss
- Michael Hays
- Mark Jankowski
- Tao Li
- Joseph Martin
- Georges-Marie Momplaisir
- Paul Randall
- Katrina Varner
- Laura Webb
- José Zambrana

Other active, federal team members

- Denis da Silva
- Justin Greer
- Jacob Klaybor
- Rachael Lane
- Christopher Zevitas



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https://6ppd.itrcweb.org/