

6PPD-Quinone in Urban Streams of Humboldt Bay, Lower Eel River, and Mad River Watersheds Humboldt County, California

April 14, 2026



Alex Juan sampling Jolly Giant Creek for 6PPD-quinone.
Photo by Audrey Jackson, Wiyot Tribe Shawir Darrudaluduk.

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Funding provided by:

U.S. Environmental Protection Agency
The Rose Foundation for Communities and the Environment

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Acronyms, Abbreviations, Soulatluk

6PPD-q	6PPD-quinone
Ba'm	Soulatluk. Now known as green sturgeon in English.
Baduwa't	Soulatluk. Now known as Mad River in English.
BMP	Best Management Practice
CDFW	California Department of Fish and Wildlife
DTSC	California Department of Toxic Substances Control
ESU	Evolutionary Significant Unit
Goudi'ni	Soulatluk. Now known as the City of Arcata in English
Gou'daw	Soulatluk. Now known as Pacific lamprey in English
MRL	Method Reporting Limit
NOAA	National Oceanic and Atmospheric Administration
SONCC	Southern Oregon-Northern California Coho
USEPA	U.S. Environmental Protection Agency
Valhuk	Soulatluk. Now known as salmon in English
Wigi	Soulatluk. Now known as Humboldt Bay in English.
Wiya't	Soulatluk. Now known as Eel River in English.
WNRD	Wiyot Tribe Shawir Darrudaluduk, "We belong to the wilderness" / Natural Resources Department

1.0 Abstract

In 2020, 6PPD-quinone, the breakdown product of the tire preservative 6PPD, was identified as a major contributor to Urban Runoff Mortality Syndrome in the Puget Sound watershed, where adult Coho Salmon often die before spawning in areas with high concentrations of road runoff. Since then, studies have been done in San Francisco Bay, but little information is available beyond major metropolitan areas.

Juvenile Coho, which are extremely sensitive to this toxic chemical, rely on small tributaries to Wigi (now known as Humboldt Bay in English) for overwintering habitat. Some of these small streams – particularly the reaches closest to Humboldt Bay – are within urban areas dominated by impervious surfaces, including parking lots and roads.

This study is the first to examine concentrations of 6PPD-q in Humboldt County. The goal of the project was to determine whether 6PPD-q is present in the region in concentrations that could be harmful to Coho Salmon and other aquatic species. Between October 2024 and May 2025, the Wiyot Tribe Shawir Darrudaluduk (Natural Resources Department) and Humboldt Waterkeeper sampled seven small urban streams and four large parking lots that discharge stormwater runoff into Humboldt Bay, the Wiya't (now known as the Eel River) near Fortuna, or the Baduwa't (now known as the Mad River) near Blue Lake. Sixty-three percent of samples (12 out of 19) exceeded the U.S. EPA aquatic screening level for 6PPD-q of 11 nanograms per liter (ng/L). Eight of the nine samples collected in Jolly Giant Creek in Goudi'ni (now known as Arcata) exceeded the screening level. The highest concentrations were found in parking lot runoff. All four parking lot samples contained 6PPD-q concentrations well above the LC₅₀ for juvenile Coho Salmon.

Potential solutions include developing 6PPD substitutes, infrastructure improvements like enhanced street sweeping, capture and treatment of stormwater (e.g., bioswales), consistent road maintenance to reduce wear and tear on tires, and individual actions to reduce tire wear (e.g., proper inflation, careful driving, alternative transportation). Addressing local sampling gaps and implementing effective solutions will require coordinated funding and multi-agency efforts across the region.

2.0 Introduction

6PPD-quinone¹ (“6PPD-q”) is an oxidation product of a tire additive intended to reduce wear and damage to tire rubber. In 2020, it was discovered to be a toxic pollutant in road-related stormwater runoff that was contributing to pre-spawning mortality in Coho Salmon.²

Researchers in the San Francisco Bay Area have since discovered 6PPD-q at concentrations exceeding Coho Salmon acute toxicity thresholds in urban stormwater runoff.³

In 2023, the California Department of Toxic Substances Control (DTSC) listed motor vehicle tires containing 6PPD as “priority products” under the Safer Consumer Products Act.⁴ A Priority Product is a consumer product that (1) contains one or more Candidate Chemicals that have the potential to harm people or the environment, and (2) has been formally listed in the California Code of Regulations through rulemaking.

In 2023, Earthjustice filed a petition on behalf of the Yurok Tribe, the Port Gamble S’Klallam Tribe, and the Puyallup Tribe of Indians urging the U.S. EPA to prohibit 6PPD in tires.⁵ In November 2023, the U.S. EPA granted the petition, agreeing to initiate rulemaking and “data gathering activities to understand and characterize risk associated with 6PPD-quinone and potential risks associated with 6PPD.”⁶

In January 2024, the U.S. EPA approved a draft standard method for laboratory analysis for 6PPD-q in water,⁷ and in June of that year, the U.S. EPA established the acute screening value for 6PPD-q in freshwater at 11 ng/L (0.011 µg/L)(Table 1).⁸ According to the report, “the assessment of the available data for fish and invertebrates indicates this screening value is expected to protect the freshwater aquatic community, including sensitive salmonid species, from acute exposures to 6PPD-q.” The EPA expects to update this screening value in the future as additional aquatic toxicity data become available.

In August 2024, the State of Washington finalized its 6PPD-q Water Quality Objective at 12 ng/L (Table 1).⁹ The State of California has not yet adopted water quality objectives for 6PPD-q, but in 2023, the California Department of Toxic Substance Control designated it a Priority Product under the Safer Consumer Products Act¹⁰ and subsequently ordered an Alternatives Analysis for 6PPD in tires.¹¹ The Alternatives Analysis requires tire manufacturers to explore potential substitutes for 6PPD, the chemical added to tires that breaks down into 6PPD-q. However, it could be many years before a less toxic substitute is found.

Table 1. State and national standards for 6PPD-q.

Source	Standard	Screening Level	Date Published
U.S. EPA ⁸	6PPD-q Freshwater acute exposure, 1-hour average, not to be exceeded more than once in 3 years on average.	11 ng/L (parts per trillion)	May 2024
Washington State Department of Ecology ⁹	6PPD-q Clean Water Act Water Quality Objective, freshwater acute exposure, 1- hour average, not to be exceeded more than once in 3 years on average.	12 ng/L (parts per trillion)	August 2024

The LC₅₀ is defined as the lethal concentration of a substance expected to cause the death of 50% of test animals after 24 hours of exposure. The LC₅₀ for juvenile Coho Salmon is 96 ng/L for 1+ year old fish, and 41 ng/L for approximately 3-week old fish (Table 2).

Table 2. LC₅₀ of 6PPD-quinone for juvenile Coho Salmon.

Source	Life Stage	LC ₅₀
Tian et al. 2022 ¹²	Juvenile Coho Salmon 1+ year old	95 ng/L
Lo et al 2023 ¹³	Juvenile Coho Salmon (age ~3 weeks)	41 ng/L

At a State workshop on 6PPD-q in December 2024, State Water Board Research Scientist Dr. Manoela Romanó de Orte said, “It’s important to highlight here that this is a very low LC₅₀. In fact, it is one of the lowest LC₅₀s ever reported for any chemical. We have just a few chemicals with numbers lower than that, so this is a really toxic chemical, specifically for Coho Salmon.”¹⁴ Studies have also examined the effects of 6PPD-q on other culturally and commercially important fishes, including Rainbow Trout, White Sturgeon,¹⁵ and gou’daw-(now known as Pacific Lamprey) (J. D. Hansen, Western Fisheries Research Center, U.S. Geological Survey, Seattle, WA, July 2, 2025).

During the 2024-25 water year (Oct. 1, 2024 to September 30, 2025), the Wiyot Tribe Shawir Darrudaluduk (Natural Resources Department) and Humboldt Waterkeeper developed sampling plans to examine 6PPD-q contamination in the Humboldt Bay area, Lower Eel River tributaries, and Lower Mad River tributaries, with a focus on areas in or adjacent to salmon spawning habitat.

The goal of this study was to answer the following questions:

- Is 6PPD-q present in surface waters within the Humboldt Bay and Lower Eel River watersheds?
- If so, is it present in receiving waters in concentrations that are known to be harmful to Coho Salmon?
- What types of sites are significant sources of stormwater runoff containing 6PPD-q?

To address these questions, the sampling efforts focused on the following:

- 1) Coho-bearing Humboldt Bay tributaries, particularly downstream from stormwater discharge points that drain areas with impervious surfaces, including parking lots and roads;
- 2) Coho-bearing tributaries to the Eel River (Strong's Creek) and Mad River (Powers Creek); and
- 3) Commercial properties and other facilities with large, high-use parking lots that drain to Humboldt Bay or Coho-bearing streams. These sites are also likely sources of polluted runoff containing toxic metals, oil, grease, and trash.

3.0 Study Area

The Humboldt Bay, Eel River, and Mad River watersheds support Coho Salmon (*Oncorhynchus kisutch*), which were listed under the Federal Endangered Species Act in 1997¹⁶ and the California Endangered Species Act in 2002.¹⁷ The Coho populations in these watersheds belong to the Southern Oregon-Northern California Coho (SONCC) Evolutionarily Significant Unit (ESU), which is listed as Threatened under both state and federal law. These watersheds also support many other species of commercial, sport, and tribal cultural significance, including Chinook Salmon, Steelhead, Pacific Lamprey, and ba'm (now known as Green Sturgeon).

3.1 Humboldt Bay

Humboldt Bay, known as Wigi in the Soulatluk language, is the largest estuary between San Francisco Bay and Coos Bay. Its four major watersheds drain approximately 250 square miles. Land uses include urban and rural residential areas in and around the two largest cities in Humboldt County (Eureka and Arcata), agricultural lands mostly used for raising dairy and beef cattle, and privately-owned industrial timberlands. Public lands include tidal and freshwater wetlands, dunes, and the ancient Headwaters Forest. The watershed also encompasses valhuk

or salmon-bearing streams, huge expanses of tidal mudflats, eelgrass beds, and the only substantial remaining salt marshes between San Francisco Bay and Coos Bay, Oregon.

All of its main tributaries support wild salmon, Steelhead, and Cutthroat Trout populations, and several also support Pacific Lamprey. Impairments to salmon habitat in the Humboldt Bay watershed include high sediment levels, channel aggradation and widening, high temperatures, loss of functioning estuarine habitat, and lack of stream habitat structure such as deep pools.¹⁸

Low-gradient streams and tidally-influenced sloughs in the Humboldt Bay area are critical overwintering habitat for juvenile Coho.¹⁹ Recent surveys have found juvenile Coho and other protected fish species in two urban creeks in Arcata, Janes and Jolly Giant Creeks.²⁰

Many of these streams and sloughs carry stormwater runoff from urbanized areas within the cities of Arcata, Eureka, and Fortuna, the three largest cities in Humboldt County. Roadways and parking lots have the potential to carry stormwater runoff into Coho habitat, where both juvenile and adult Coho can be exposed to potentially toxic concentrations of 6PPD-q.

3.2 Eel River

The Eel River, known as Wiya't in the Soulatluk language, is the third largest river system in California. Coho Salmon are believed to have been extirpated from the North and Middle Forks of the Eel, and fish passage to the upper 31 miles of the mainstem is blocked by two hydroelectric dams built over a century ago that divert water to the East Branch Russian River. Major threats to Coho Salmon in the Eel River include sedimentation from over 10,000 miles of roads, water diversions, high water temperatures, instream mining operations, predation by the invasive Sacramento Pikeminnow, and low stream habitat complexity, including lack of large woody debris.²¹

Strongs Creek is in the lower Eel River and flows directly through Fortuna, the largest city in the Eel River basin. The Strongs Creek watershed is 14.7 square miles and is primarily under private ownership. It is managed for urban development and timber production. Most of the stream is incised, lacks complex habitat and suitable spawning substrate, contains poor fish passage in some reaches due to culvert designs that do not meet state and federal fish passage criteria, and experiences impacts from livestock grazing and sedimentation.²² Coho Salmon, Steelhead Trout, Cutthroat Trout, and lamprey species (Brook Lamprey and Pacific Lamprey) utilize Strongs Creek for spawning and rearing. The invasive Sacramento Pikeminnow also utilizes Strongs Creek.

3.3 Mad River

The Mad River, known as Baduwa't in the Soulatluk language, opens to the ocean just north of Humboldt Bay. The watershed covers 497 square miles and the river flows 113 miles from Trinity County to Humboldt County. Many of its major tributaries are important for Coho spawning and juvenile rearing.

One of the lower tributaries on the Mad River, Powers Creek, runs through the city of Blue Lake. The watershed is a 3.5-square-mile drainage area with 3.2 miles of stream. Stream inventories show that Coho Salmon and trout species populate Power Creek.²³ With several roads crossing the creek, the Mad River and Powers Creek flood portions of the town in most years.

4.0 Methods

4.1 Humboldt Waterkeeper

Sampling sites²⁴ were identified via spatial analysis based on the following factors: proximity to Coho-bearing streams, proximity to stormwater inlets draining to Coho-bearing streams, perceived adjacent high traffic volume, and the extent of paved areas.

Sampling events were planned around rain events, aiming for at least 0.25 inch of rain within a 24-hour period prior to sampling, preceded by at least 48 hours of dry weather (defined as less than 0.25 inch of rainfall). NOAA's California Nevada River Forecast North Coast Observed Precipitation Map²⁵ was used to determine inches of rain within a 24-hour period.

Wearing nitrile gloves, samples were collected using a hand-held, new Ziploc bag or a clean glass jar attached to a sampling pole and rinsed three times. Each sample was then poured into two 40-mL VOA amber glass vials (no preservative) that were provided by the laboratory. The samples were labeled, stored in a cooler with ice, and shipped as soon as possible to Weck Laboratories,²⁶ where they were analyzed using EPA Method 1694M. The holding time for 6PPD-q samples is 21 days at <6 C. (<42.8 F.), and the samples were received within the holding time and at the proper temperature.

4.2 Wiyot Tribe Shawir Darrudaluduk

Sampling sites were selected based on whether Coho Salmon utilize streams for juvenile rearing and the proximity to busy roads that also had reduced riparian buffer zones between the road and the stream. In addition to these criteria, some of the sampling sites were selected if they

were also located on Wiyot-owned parcels. Sampling was also timed within the first 8 hours of a precipitation event after a 72-hour dry period. The initial sampling event was spatially distributed to cover multiple sub watersheds and watersheds in the Humboldt Bay area. The second sampling event focused on sampling throughout Jolly Giant Creek, with the addition of choosing a site at the Wiyot-owned parcel along Elk River. Samples were collected chronologically during the first sampling round and collected simultaneously along Jolly Giant Creek during the second round to see if 6PPD-q concentrations were cumulative from multiple sources along the creek or if the chemical was moving downstream from one specific source.

Prior to sampling, field data was collected: date, time, location, site photo, fish observations, and any additional comments. Samples were collected via two 40 mL amber glass VOA vials. A cooler was brought on-site to place full vials for transport. Collectors wore nitrile gloves, ensuring the inside of the bottle and cap were not touched, then used the water source on-site to rinse the bottle and lid three times. With the cap removed, the bottle was submerged with the vial opening facing upstream until the bottle was full. Each bottle was properly labeled with the respective location data.

Samples were immediately placed into a cooler with ice which was then prepared for shipping the same day to Weck laboratories where they were analyzed using EPA Method 1694M.

5.0 Results

Sixty-three percent of samples (12 out of 19) exceeded the U.S. EPA aquatic screening value for 6PPD-q of 11 ng/L (Table 3). Of the nine samples collected in Jolly Giant Creek, eight exceeded the screening value. Samples in which 6PPD-q was not detected above the Method Reporting Limit (six of 19) were bounded on at least one side by riparian vegetation. Sixty-four percent of receiving water (i.e., in-stream) samples were above the lab's Minimum Reporting Limit for 6PPD-q.

The highest concentrations were found in parking lot runoff (Table 3). The highest level detected was nearly 40 times the screening value. All four parking lot runoff samples contained more than 100 ng/L, exceeding the 11 ng/L screening value by 119-419 ng/L (Table 3). All four samples contained 6PPD-q above the LC₅₀ for juvenile Coho (Figure 1). Maps of sampling locations with results are provided in Figures 2-4.

Weck Laboratories used three different Method Reporting Limits (MRLs) due to sample matrix interference. The Method Reporting Limit (MRL) is the minimum concentration of a target analyte that can be reported with a specified degree of confidence. The MRLs are important to

consider when interpreting non-detections; if the MRL is 10 ng/L, a non-detection is most accurately interpreted as <10 ng/L. In a study examining passive soil filtration media for removing 6PPD-q from tire-derived aggregate, Finney and Cashman (2025) noted similar inconsistencies in laboratory reporting limits related to matrix interference.²⁷

6.0 Discussion

The ubiquitous nature of tire wear particles that are the source of 6PPD-q, combined with the high frequency of rain events on the North Coast, suggests that concentrations similar to those found in this study may be common throughout the region during the rainy season. Our study found concentrations of 6PPD-q ranging from 1 to 35 times the US EPA's freshwater acute exposure screening value (11 ng/L). These results point to 6PPD-q being a potentially significant contributor to the decline of Coho Salmon populations in the Humboldt Bay watershed.

The high concentrations of 6PPD-q found in this study occurred during relatively small rain events. These findings are concerning, and further studies are warranted to determine whether even higher concentrations of this toxic chemical is present in receiving waters during larger precipitation events.

Of particular concern are the first major storms in autumn that flush tire particles that build up over the dry summer months into small urban creeks. Known as First Flush, these rain events typically occur in autumn, and usually coincide with the return of the Coho from the ocean to the freshwater streams where they spawn. First Flush is defined as the 85th-percentile, 24-hour storm event, which in the Humboldt Bay area is 0.65 inches in 24 hours.²⁸

In small coastal streams, Coho spawning typically begins between mid-November and mid-January.²⁹ The eggs hatch between March and July, after which the juvenile Coho spend up to one year in small coastal streams and sloughs, off-channel ponds, and other slow-moving waters. This winter rearing habitat is critical to fish health, and in coastal urban streams, is likely to receive stormwater polluted with 6PPD-q throughout the rainy season.

Some pollutants in stormwater runoff are more concentrated during First Flush, although a study in Puget Sound found no significant seasonal variation in peak 6PPD-q concentrations, suggesting year-round risks to Coho Salmon across multiple life stages.³⁰ However, this finding may not be applicable to the dry summers that are typical in the Humboldt Bay area and across most of California.

7.0 Recommendations

7.1 Additional Sampling

This study was the first to sample for 6PPD-q in the region, but there are many more Coho-bearing streams that have not yet been studied. Further sampling should be conducted in Coho-bearing streams across the region, with a focus on reaches that provide rearing and overwintering habitat for juveniles. Additional sampling should be conducted throughout the rainy season in Janes Creek and Jolly Giant Creek, where 6PPD-q concentrations were found to be above the U.S. EPA freshwater acute screening level of 11 ng/L. Sampling should also be conducted in other Humboldt Bay tributaries that provide Coho spawning and rearing habitat, including Freshwater Creek, Jacoby Creek, and Elk River.

In addition, sampling should be conducted in streams and sloughs downstream of large parking lots, including the four that were sampled during the 2024-25 rainy season. Sampling throughout the rainy season should be conducted to quantify peak concentrations of 6PPD-q that aquatic species are exposed to. If funding allows, auto-samplers should be used to determine how the concentration of 6PPD-q in receiving waters changes throughout a storm event. Identifying the timing of peak 6PPD-q concentrations would help inform the timing of future grab sampling efforts. Development of a Quality Assurance Program Plan (QAPP) to standardize sampling methods across the region would be helpful to ensure consistency and scientific validity of sampling efforts conducted by various organizations and tribes.

Currently, there are many data gaps that agencies are working to address. Such gaps include: how 6PPD-q concentrations are transported across larger bodies of water like Humboldt Bay; 6PPD-q concentration gradients from freshwater to saline water during major storm events; impacts of 6PPD-q on other species and on human health; and how to best capture peak 6PPD-q concentration after storm events. To address these data gaps and additional sampling needs, regional collaboration among government agencies and nonprofit organizations throughout the range of the Coho is necessary.

In the short-term, there are actions that local governments can take to reduce stormwater runoff polluted with 6PPD-q. There are also individual actions that can help, although these are unlikely to be effective enough to protect fish health.

Potential Solutions to Reduce 6PPD-q Levels in Streams and other Waterways

Government Actions:

- Require non-toxic substitute for 6PPD in tires
- Proper road maintenance
- Street sweeping, particularly before major rain storms
- Stormwater capture & treatment (stormwater detention basins, bioswales, permeable pavement, etc.)

Individual Actions:

- Drive less by carpooling, walking, cycling, and using public transit
- Check tire inflation levels monthly
- Avoid abrupt turns and stops to reduce wear

7.2 Better Road Maintenance

Better road maintenance can reduce bumps and potholes that may increase tire wear, while also reducing vehicle maintenance costs. A study of 6PPD-q on various types of roadways in Norway found the highest concentrations in water from a country road pothole.³¹ However, no studies have been conducted to examine whether improving road conditions can reduce 6PPD-q in streams.

Funding for road maintenance is a challenge for many city and county governments. Due to the lack of grant funding for road maintenance, voters in the cities of Arcata and Eureka, as well as unincorporated areas of Humboldt County, have approved sales tax increases dedicated to road maintenance. Prioritizing road maintenance near Coho-bearing streams could be one way for local governments to reduce 6PPD-q concentrations within their jurisdictions.

7.3 Street Sweeping

Regular street sweeping can reduce pollutants that accumulate on roads and in parking lots. Without street sweeping, these pollutants are carried by stormwater into storm drains which carry them into streams, rivers, Humboldt Bay, and coastal waters. Increasing the frequency of street sweeping on roads near streams, especially just before rain storms, could help reduce the amount of tire particles that make their way into the streams during rain events. The type of street sweeping equipment used may result in different levels of effectiveness.

In 2022, a team of consulting, academic and agency scientists prepared a report for Washington's Department of Ecology assessing the effectiveness of various Best Management

Practices (BMPs) in reducing 6PPD-q.³² An effective BMP described in the report is the removal of soil and organic matter from roads and parking lots, which 6PPD and 6PPD-q are likely to adhere to.

In a study that will be done through 2028, Seattle Public Utilities is studying the potential for street sweeping to reduce the amount of tire wear pollutants, including 6PPD-q, on roads.³³ Types of equipment used, frequency, and timing street sweeping before major storms could be factors in its effectiveness in reducing 6PPD-q levels in urban streams.

7.4 Stormwater Capture & Treatment

There are various ways to capture stormwater from pavement and other impervious surfaces before it makes its way into streams. One common example is the stormwater detention basin or bioswale, which is a temporary holding pond that allows stormwater to slowly seep into the soil where microbes can break down some of the pollutants commonly found in runoff. Also known as green infrastructure or “low impact development,” these types of stormwater capture-and-treatment structures must be properly designed, with well-drained substrates like gravel to prevent oversaturation and plants chosen for their ability to tolerate saturated soils. They must be sized appropriately depending on regional rainfall patterns and the area from which runoff will be captured. One recent study found that bioswales provided a 10-fold reduction in 6PPD-q mass loadings to receiving waters.³⁴

The State Water Resources Control Board’s Small Municipal Separate Storm Sewer System (MS4) permit³⁵ adopted in 2015 requires projects creating and/or replacing 2,500 square feet or more of impervious surface to incorporate stormwater capture features.³⁶ Owners and operators of parking lots that were built prior to 2015 are not currently required to upgrade them to protect water quality and aquatic habitat. However, existing parking lots can be retrofitted to add stormwater capture features as well as permeable pavement. Funding through various grant programs is available to retrofit existing parking lots. Local examples of stormwater retrofit projects include some parking lots at Cal Poly Humboldt in Arcata and the City of Arcata’s parking lot at 7th and H Streets (Figures 5 and 6).

7.5 Individual actions

Changes at the individual level can reduce tire wear, which reduces the amount of tire particles and 6PPD-q that end up in streams. Checking tire inflation levels monthly, avoiding abrupt turns and stops to reduce wear, and driving less by carpooling, walking, cycling, and using public transit where possible all have potential to help reduce the amount of tire particles polluting

our roads and waterways. However, these individual actions are unlikely to significantly reduce 6PPD-q concentrations in urban waterways.

7.6 Tire Particle Capture Devices

Studies are under way using devices installed on buses to capture tire particles as they are shed, although such devices are not commercially available.³⁷ It remains to be seen whether these devices can effectively reduce the amount of tire wear particles that are deposited on roads and parking lots.

8.0 Glossary

Acute toxicity: Acute toxicity involves adverse effects that occur in a relatively short timeframe after exposure to toxic substances.

First Flush: The first major rain event of the Water Year (Oct. 1-Sept. 30), defined as the 85th-percentile, 24-hour storm event (0.65 inches in 24 hours in the Humboldt Bay area).

Impervious surface: Any surface that prevents water from seeping into the ground, including pavement, asphalt, concrete, brick, stone, and rooftops. Impervious surfaces carry polluted runoff into storm drains, which discharge it into nearby creeks and streams. Impervious surfaces result in erosion, flooding, and water pollution, including 6PPD-quinone, fecal bacteria, metals, petroleum products, pesticides, and fertilizers.

Low-gradient stream: These streams or segments of streams are on relatively flat areas, typically near the stream's mouth. They are characterized by slower-moving water than high-gradient streams, which flow through steep slopes. In the Humboldt Bay area, they are tidally-influenced brackish areas where saltwater mixes with freshwater.

Overwintering habitat (also known as rearing habitat): Coho salmon in Northern California tend to overwinter in fresh or brackish water in the lower reaches of tributaries which are characterized by slow-moving water. Overwintering habitat often overlaps with urbanized areas featuring impervious surfaces that direct polluted runoff into small, shallow streams, concentrating 6PPD-quinone and other harmful contaminants.

Tributary: A tributary is a stream that flows into a larger stream, river, lake, or an enclosed estuary like Humboldt Bay, as opposed to flowing directly into the ocean. Tributaries and main stem rivers drain the surrounding watershed of its surface water and groundwater into an ocean or another river.

Urban Runoff Mortality Syndrome: This term was coined by scientists in the Puget Sound area, where adult Coho often die before spawning in areas with high concentrations of road runoff.

9.0 Appendix

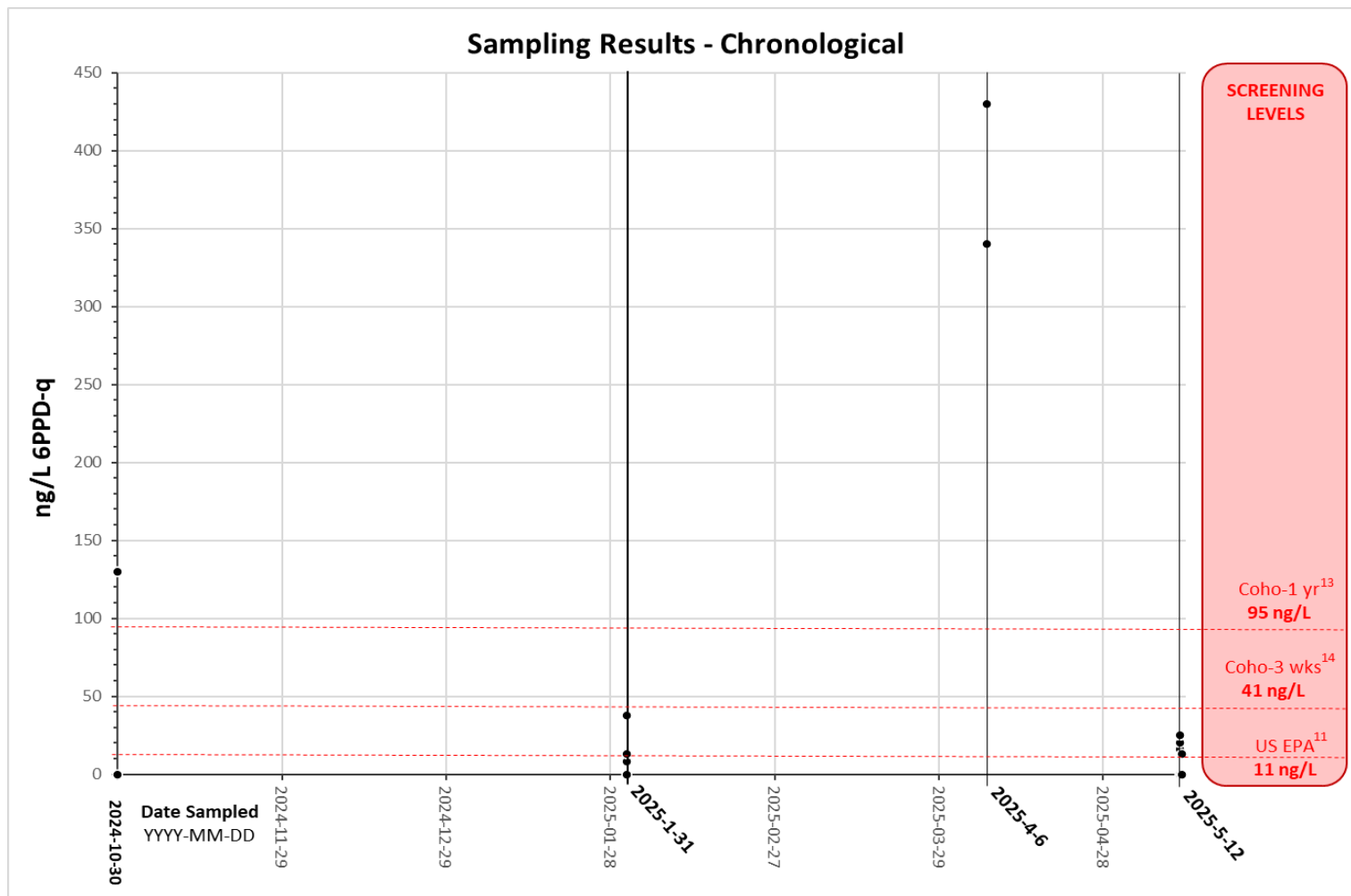


Figure 1. Sample results in chronological order, with the various screening levels and LC₅₀s for reference. Sample results of 'non-detect' are represented as zero on this graph.

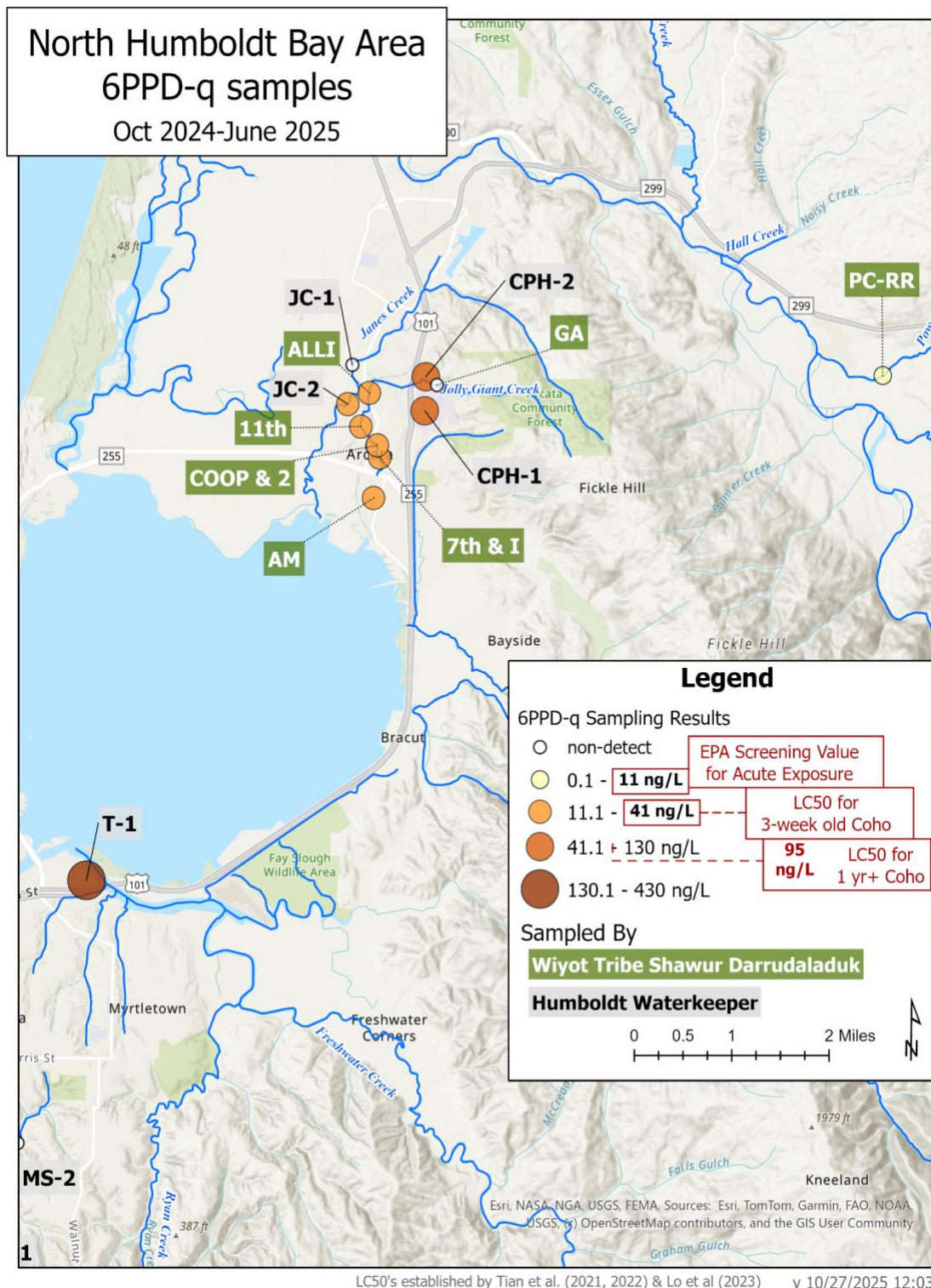
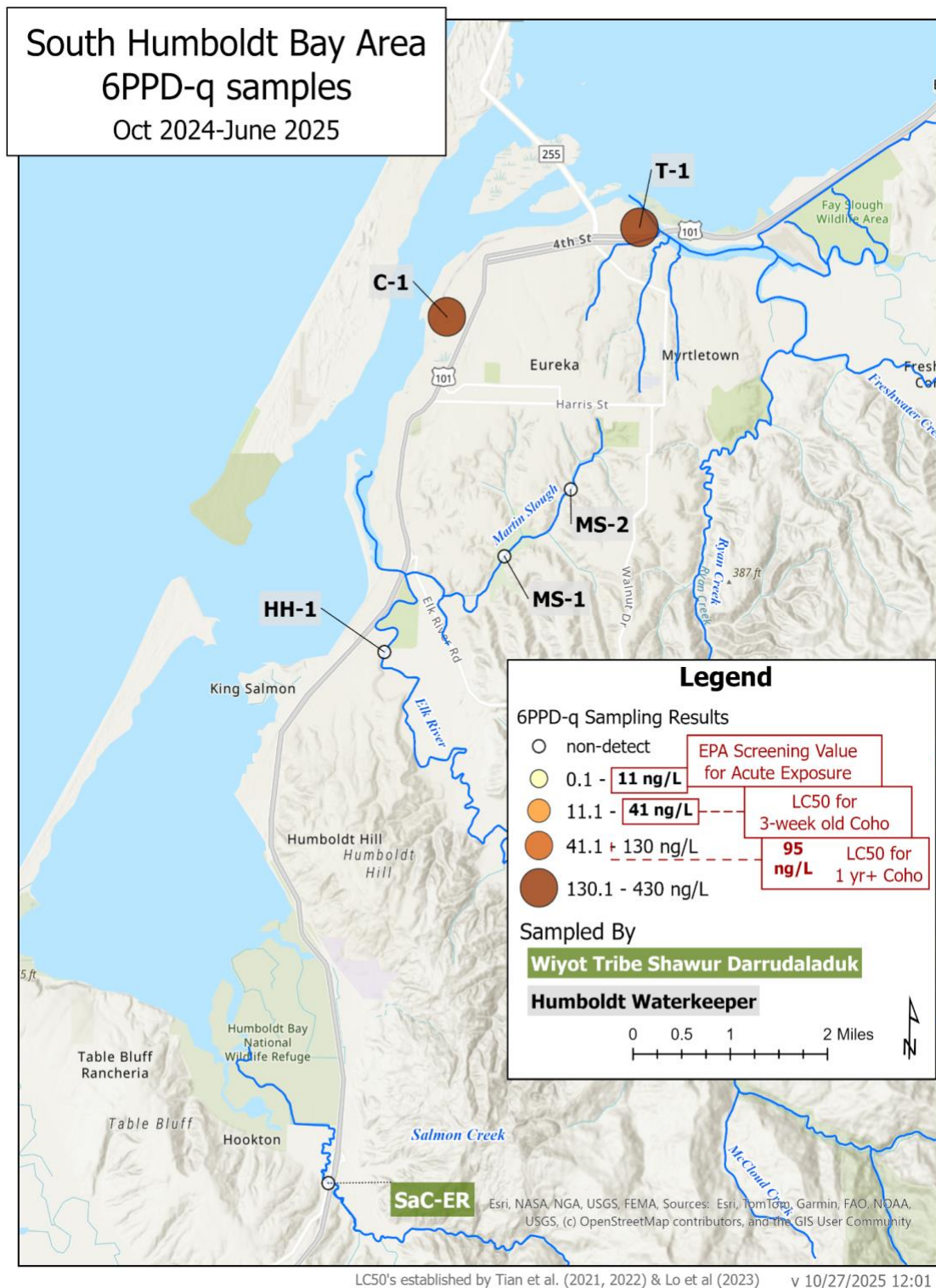


Figure 2. Map of 6PPD-q sampling locations in the north Humboldt Bay area, with the color and size of point symbols representing the results. Green labels represent Shawur Darrudaladuk samples; gray labels represent Humboldt Waterkeeper samples.



LC50's established by Tian et al. (2021, 2022) & Lo et al (2023) v 10/27/2025 12:01

Figure 2. Map of 6PPD-q sampling locations in the south Humboldt Bay area, with the color and size of point symbols representing the results. Green labels represent Shawur Darrudaladuk samples; gray labels represent Humboldt Waterkeeper samples.

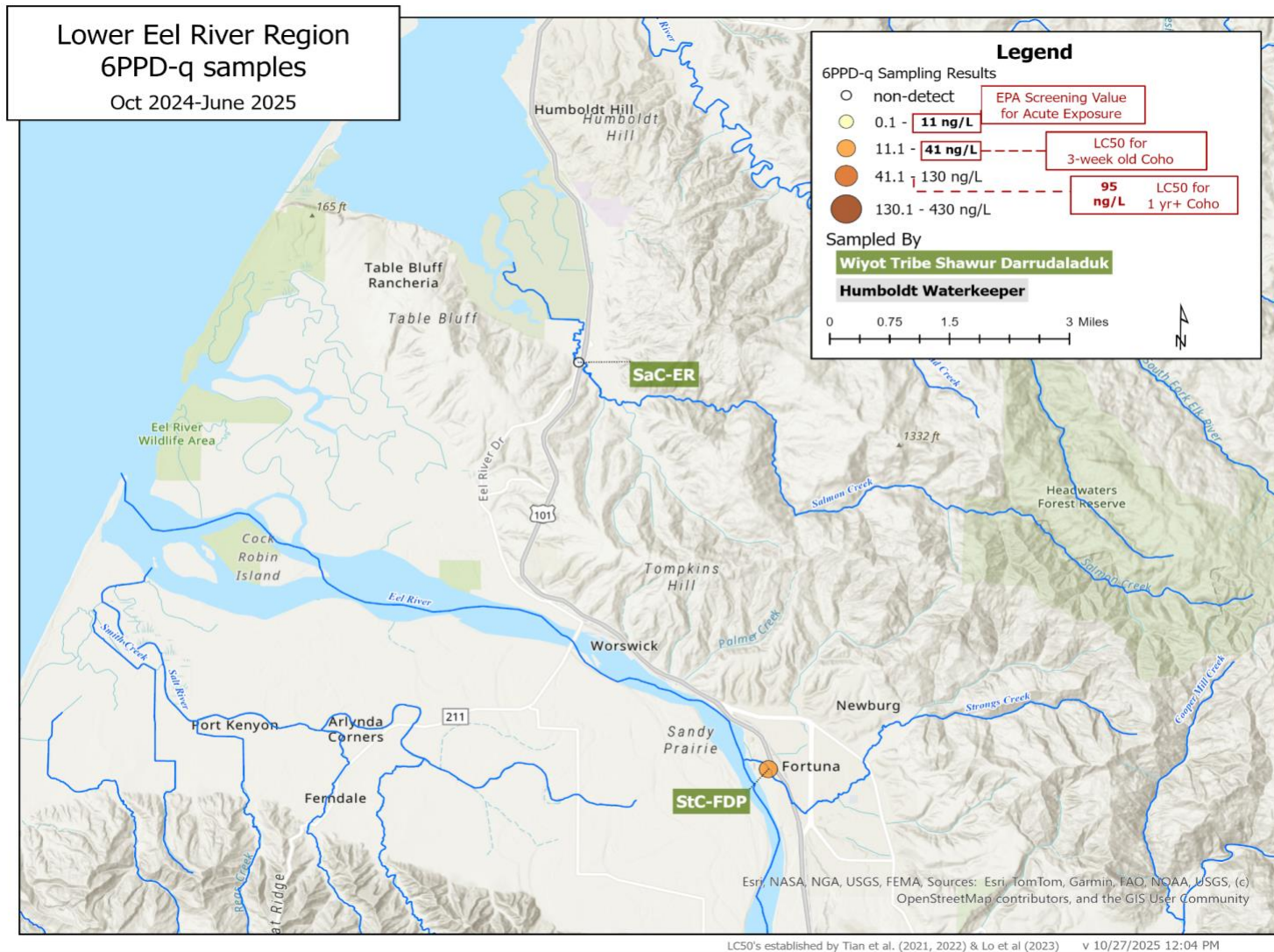


Figure 4. Map of 6PPD-q sampling locations in the lower Eel River region, with the color and size of point symbols representing the results. Green labels represent Wiyot Shawur Darrudaladuk samples, grey labels represent Humboldt Waterkeeper samples.

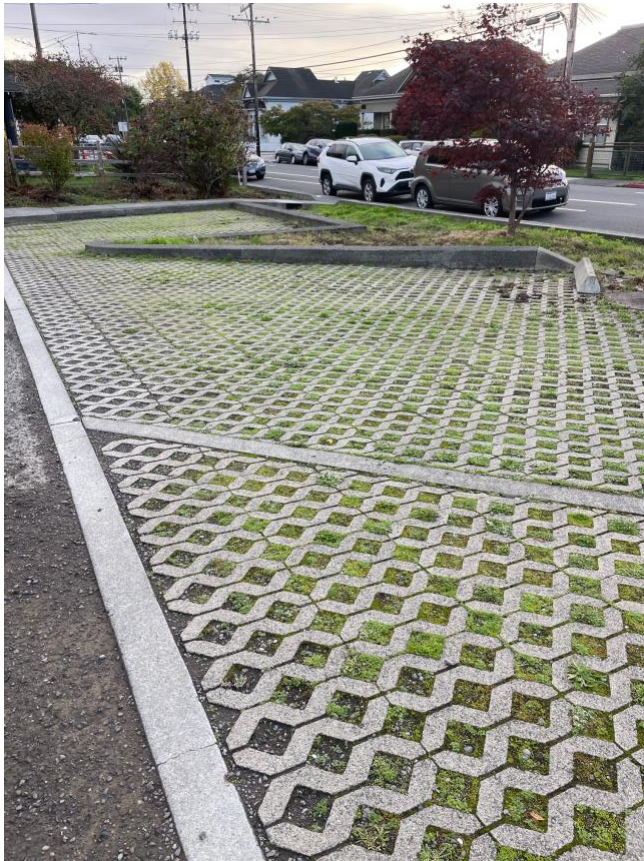


Figure 5. The City of Arcata’s parking lot on 7th and H Streets features permeable pavement and open pavers that prevent stormwater runoff from leaving the site.



Figure 6. A bioswale at Cal Poly Humboldt allows parking lot runoff to percolate through vegetation and infiltrate into the soil rather than entering streams.

Table 3. Results of 6PPD-q sampling from Wiyot Tribe Shawir Darrudaluduk and Humboldt Waterkeeper. The highlighted rows are exceedances of the U.S. EPA aquatic screening value for juvenile Coho Salmon listed in Table 1.

Map Site ID	Longitude (X)	Latitude (Y)	Collected By	Date	Results (ng/L)	Sample Type	Watershed	Previous 24 hours rain (inches)	Antecedent Dry Days
CPH-1	-124.0798	40.8745	Humboldt Waterkeeper	10/30/2024	130	parking lot runoff	Jolly Giant Creek	0.55	1
CPH-2	-124.0797	40.8795	Humboldt Waterkeeper	10/30/2024	130	parking lot runoff	Jolly Giant Creek	0.55	1
HH-1	-124.1940	40.7442	Humboldt Waterkeeper	10/30/2024	0	outfall pipe	Elk River	0.55	1
COOP-1	-124.0891	40.8694	Wiyot Tribe	1/31/2025	38	in stream	Jolly Giant Creek	0.5	24
PC-RR	-123.9901	40.8804	Wiyot Tribe	1/31/2025	8.5	in stream	Powers Creek	0.72	24
SaC-ER	-124.2036	40.6673	Wiyot Tribe	1/31/2025	0	in stream	Salmon Creek	0.4	24
StC-FDP	-124.1569	40.5879	Wiyot Tribe	1/31/2025	13	in stream	Strongs Creek	0.57	24
T-1	-124.1450	40.8061	Humboldt Waterkeeper	4/6/2025	430	parking lot runoff	Humboldt Bay slough	0.28	3
C-1	-124.1825	40.7928	Humboldt Waterkeeper	4/6/2025	340	parking lot runoff	Wigi	0.28	3

Map Site ID	Longitude (X)	Latitude (Y)	Collected By	Date	Results (ng/L)	Sample Type	Watershed	Previous 24 hours rain (inches)	Antecedent Dry Days
ALLI	-124.0907	40.8770	Wiyot Tribe	5/12/2025	18	in stream	Jolly Giant Creek	0.66	14
11th	-124.0923	40.8721	Wiyot Tribe	5/12/2025	16	in stream	Jolly Giant Creek	0.66	14
COOP-2	-124.0890	40.8695	Wiyot Tribe	5/12/2025	20	in stream	Jolly Giant Creek	0.66	14
7th & I	-124.0886	40.8677	Wiyot Tribe	5/12/2025	25	in stream	Jolly Giant Creek	0.66	14
AM	-124.0896	40.8618	Wiyot Tribe	5/12/2025	25	in stream	Jolly Giant Creek	0.66	14
GA	-124.0775	40.8783	Wiyot Tribe	5/12/2025	0	in stream	Jolly Giant Creek	0.66	14
JC-1	-124.0941	40.8810	Humboldt Waterkeeper	5/12/2025	0	in stream	Janes Creek	0.75	14
JC-2	-124.0949	40.8753	Humboldt Waterkeeper	5/12/2025	13	in stream	Janes Creek	0.75	14
MS-1	-124.1707	40.7583	Humboldt Waterkeeper	5/12/2025	0	in stream	Martin Slough	0.75	14
MS-2	-124.1578	40.7681	Humboldt Waterkeeper	5/12/2025	0	in stream	Martin Slough	0.75	14

*ND = Non-detect with a Method Reporting Limit of 2.0 ng/L

**ND = Non-detect with a Method Reporting Limit of 10 ng/L due to matrix interference

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