
## Puget Sound Toxics Control

# Toxics Projects in Puget Sound, 2011-2018, Funded by the NEP Toxics and Nutrients Prevention, Reduction, and Control Cooperative Agreement

September 2017

Publication No. 17-03-003

DEPARTMENT OF
ECOLOGY
State of Washington

## Publication and contact information

This report is available on the Department of Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1703003.html

The Activity Tracker Code for this study is 16-065.

For more information contact:

Debby Sargeant, Supervisor
Toxics Studies Unit
Environmental Assessment Program
P.O. Box 47600
Olympia, WA 98504-7600

Communications Consultant: Phone: (360) 407-6764

Washington State Department of Ecology - www.ecy.wa.gov

- Headquarters, Olympia (360) 407-6000
- Northwest Regional Office, Bellevue (425) 649-7000
- Southwest Regional Office, Olympia (360) 407-6300
- Central Regional Office, Union Gap (509) 575-2490
- Eastern Regional Office, Spokane (509) 329-3400

## Funding

This project has been funded wholly or in part by the U.S. Environmental Protection Agency (EPA) under Puget Sound Ecosystem Restoration and Protection Cooperative Agreement Grant PC-00J20101 and PC-00J889901 with the Washington State Department of Ecology. The contents of this document do not necessarily reflect the views and policies of EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

**Cover photos**

*Eagle:* Washington State Department of Ecology.
*Woodstove*: Washington State Department of Ecology.
*Piling removal and sign:* Southpoint Ferry Terminal, Washington State Department of Natural

Resources from "FY 2012 NEP Toxics and Nutrients Preventing PAH Pollution Grant, Jefferson County Derelict Creosote-Treated Piling Removal Project Final Report, Grant No. G1200469."

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by

Tanya Roberts

Toxics Studies Unit
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Water Resource Inventory Areas (WRIAs) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

WRIAs

- 1-19

HUC numbers

- 1711: 17110001 - 17110021

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# Abstract

During 2011-2018, the Washington State Department of Ecology is serving as the lead organization for a National Estuary Program (NEP) cooperative agreement entitled *Toxics and Nutrients Prevention, Reduction, and Control*. Roughly $10.6 million for Puget Sound was spent on toxics control efforts. A total of 59% of the toxics funds continued or improved management of existing pollutant sources, 27% funded research, and 14% supported innovative prevention efforts.

Accomplishments within the Puget Sound region include:

- Prevention tools and programs for Green Chemistry and sustainable land care were created.
- Partnerships were formed with both roofing and auto industries.
- A total of 1,006 creosote pilings, containing an estimated 7,500 pounds of PAHs, were removed.
- Effectiveness monitoring at a piling removal site showed elevated PAHs post-removal, leading to improved removal protocols.
- Over 800 uncertified woodstoves were scrapped, preventing an estimated 600 pounds of PAH release to the region annually.
- Prototypes of lower-cost retrofit devices for woodstoves were developed.
- A campaign targeting auto leaks that now operates throughout the region was formed.
- Local Source Control specialists were funded in five local jurisdictions. These specialists provided small businesses with technical support on over 1,000 waste management issues.
- In support of the first copper boat paint phase-out in the U.S, an alternatives assessment and a baseline study of metals concentrations at marinas are being conducted.
- Roofing panel studies revealed that toxics concentrations in roof runoff were lower than previously estimated. Additional building components are now being studied as sources of copper and zinc.
- Investigations into the presence of pharmaceuticals, personal care products, and perfluorinated substances filled a regional data gap on these compounds. Findings garnered national media attention.

This report summarizes the toxics projects, comparing them to recommendations made in the 2011 *Assessment of Selected Toxic Chemicals in the Puget Sound Basin* report.

Acknowledgements

The author of this report thanks the following people for their contributions to this study:

- Toxics and Nutrients Core Team (Committee)
  - Ron McBride, Karol Erickson, Christiana Figueroa-Kaminsky, Andrew Kolosseus, Blake Nelson, Dale Norton, Mindy Roberts, Debby Sargeant, Megan Warfield, and Ken Zarker of the Washington State Department of Ecology.
  - Gina Bonifacio of the U.S. Environmental Protection Agency.
  - Mary Knackstedt of the Washington State Department of Health.
  - Scott Redman of the Puget Sound Partnership.
- The numerous project leads, listed in the Appendix, who took the time to discuss their work with me.
- Many of those implementing the programs described in this report who allowed me to observe and ask questions. These included:
  - Anne Alfred, Angela Peterson, and Travis Zuehl of Snohomish County Local Source Control.
  - Tony Benson of City of Bothell Local Source Control.
  - Jennifer Johnson of Thurston County Public Health.
  - Steve Kamieniecki of Pierce County Planning and Public Works.
  - Les Krestel of City of Edmonds Treatment Plant.
  - Lisa Rozmyn of Washington State University's Stormwater Center.
  - Monica Shoemaker of Washington Department of Fish and Wildlife.
  - Amy Warren and Phil Swartzendruber of Puget Sound Clean Air Agency.
- External reviewer: Aimee Kinney of the Puget Sound Institute.
- Members of the Puget Sound Ecosystem Monitoring Program (PSEMP) Toxics Workgroup and other researchers whose work focuses on toxics in the Puget Sound region.
- My co-workers at the Washington State Department of Ecology:
  - Celina Abercrombie, Jessica Archer, Chance Asher, Justine Asohmbom, Saskia van Bergen, Andy Bookter, Becca Conklin, Marv Coleman, Cindy Cook, Randy Coots, Derek Day, Jodi England, Brandee Era-Miller, Hugo Froyland, Will Hobbs, Joan LeTourneau, Brandi Lubliner, Jean Maust, Melissa McCall, Peggy Morgan, Gary Myers, Cheryl Niemi, Diana Olegre, Allison Kingfisher, Carol Smith, Alex Stone, Sandy Weakland, and Ian Wesley.
- The many people who work to protect Puget Sound for all life forms.

# Executive Summary

During 2011-2018, the Washington State Department of Ecology (Ecology) is serving as the lead organization for administering the *Toxic and Nutrients Prevention, Reduction, and Control* cooperative agreement for Puget Sound under the National Estuary Program (NEP). Ecology chairs the NEP Toxics and Nutrients Committee of partner agencies distributing the NEP grant money.

The grant provided $21 million in federal funding for Puget Sound projects over six rounds. Funds are split evenly between toxic chemicals (toxics) and nutrients work. Roughly $10.6 million was spent on toxics projects; these are reviewed in this report. A separate nutrients review is anticipated in 2018.

## What Was Funded?

The NEP Toxics and Nutrients Committee, guided by the (1) Puget Sound Action Agenda, building on planning work done in Washington State Chemical Action Plans (CAPs), (2) Reducing Toxics Threats initiative (RTT), and (3) *Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011* (Norton et al. 2011), formed a strategy that identified three areas in which it would invest:

- Research to fill data gaps on pollutant concentrations or source investigations.
- Prevention to support development of non-toxic alternatives.
- Management of existing toxics.

A total of 59% of the toxics funds were invested in management, 27% in research, and 14% in prevention of toxics production and use, as shown in Figure 1.

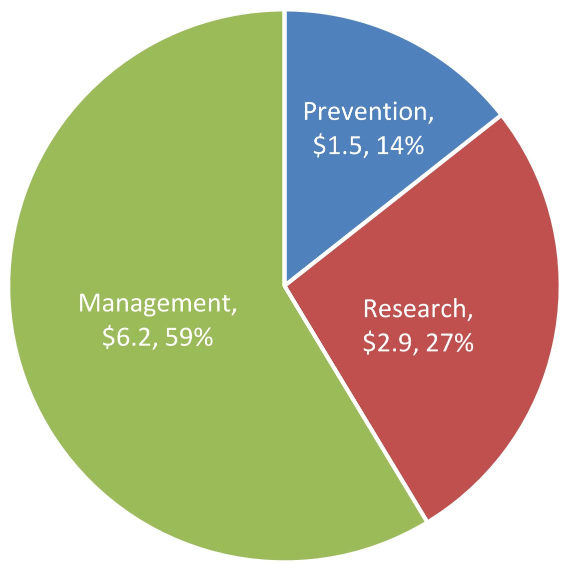
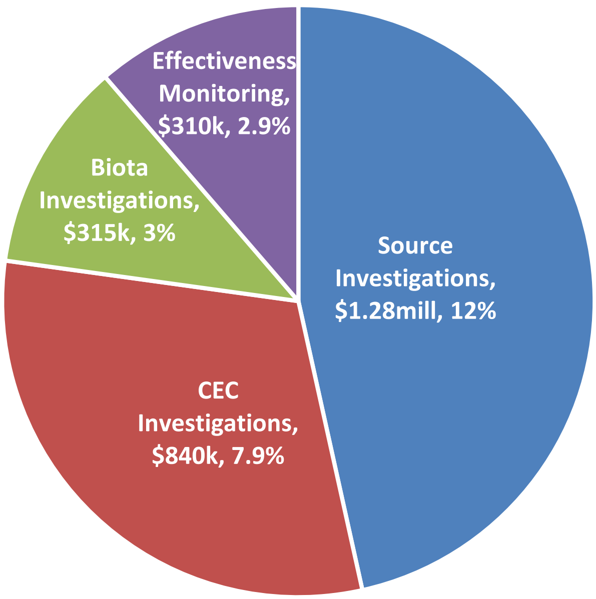



Figure 1. Toxics investments by category, with millions of dollars rounded and percent of the total $10.6 million toxics investment.

### Research

Pollution source investigations were the largest research investment (Figure 2). They totaled nearly 12% of the total $10.6 million in toxics funding. Monitoring is key to identifying the most important sources for control actions. In addition, effectiveness monitoring should be incorporated upfront in projects to gauge how well control actions work.




The investigations revealed that the control of some metals, such as arsenic and zinc from roofing, may require more study. A source investigation for copper and zinc, now underway, may shed additional insight into the contributions of roofing components and other suspected sources.

Analysis for contaminants of emerging concern (CECs) helped to fill a crucial data gap. It revealed that several CECs, including pharmaceuticals, endocrine disruptors, and perfluorinated substances, are present in Puget Sound. Not only were CECs found throughout Puget Sound, they were found to be accumulating in juvenile Chinook.

Figure 2. Research projects, with funding amounts and percent of the total $10.6 million toxics investment.

## Prevention

Prevention efforts received 14% of the total toxics funding. Toxics prevention means not allowing a chemical to be released into the environment or waste stream. This requires identifying and using non-toxic alternatives where possible. If there are products where a safer alternative has not been identified, it means eliminating or reducing the quantities of the potentially harmful materials.

The projects funded promoted Green Chemistry, provided Washington State's only sustainable landscaper's certification, and helped to identify safer products including boat paints and redesigned automobiles.

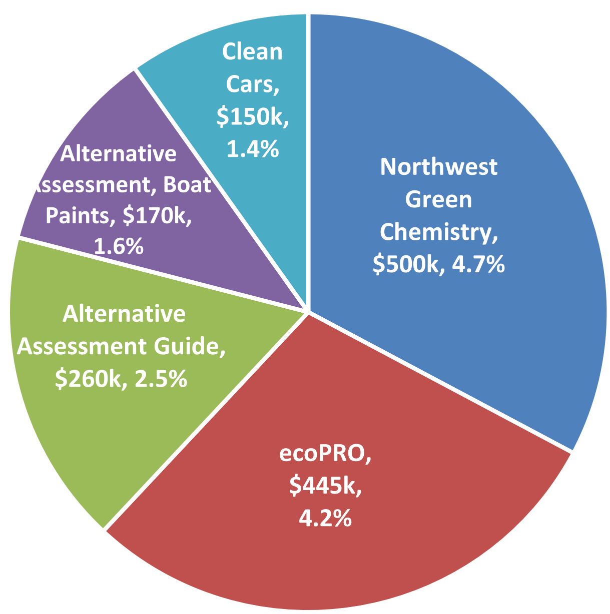



Figure 3. Prevention projects, with funding amounts and percent of the total $10.6 million toxics investment.

## Management

Over half of the funding (54%) supported existing source-control programs. The two largest investments were in the Local Source Control Partnership (29.5%) and two PAH-reduction programs (14.6%), as shown in Figure 4.

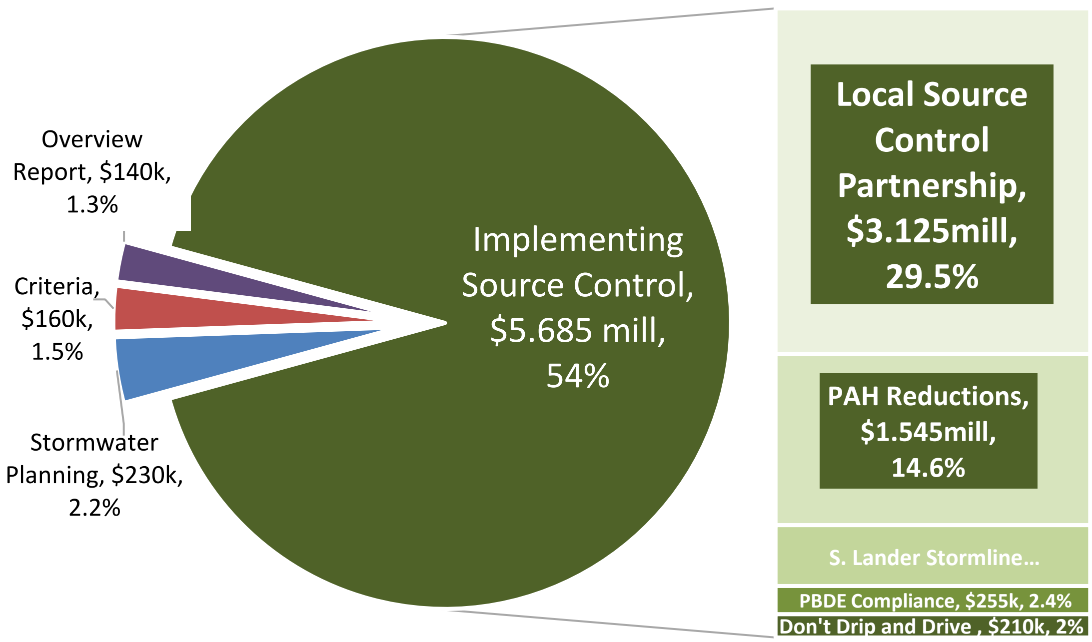



Figure 4. Management projects, with funding amounts and percent of the total $10.6 million toxics investment.

# Successes

The NEP Toxics and Nutrients Committee relied on toxics-reduction planning, including the CAPs, the RTT, and the *Assessment*[1], along with the larger Action Agenda, to determine which projects should be funded. These plans had no attached funding for implementation, but they provided a road map for distribution of NEP funds.

To estimate the relative importance of sources, the *Assessment* relied on a mix of regional monitoring data and literature values. In some cases, the data were more robust and allowed for the move directly to source-control actions, such as piling removal. In other cases, there was a high degree of uncertainly, such as with roofing material, copper from pesticide use, and PAHs from railroad ties. Follow-up studies were needed before moving to control actions, so we could have more certainty about toxics releases.

[1] *Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-11* (Norton et al. 2011)

## Research

Several of the follow-up monitoring projects examined the sources of metals. The *Assessment* identified runoff and leaching from roofing materials as a major source of several metals. A study was funded to look at runoff from one component of roofing. Experimental panels of various roofing types indicated much lower release rates than seen in the literature used to determine previous release estimates. Findings did show copper and arsenic release from treated wood shakes: copper from the copper roofing panel and zinc from the Zincalume® roofing (Winters et al. 2014). Because of this study, a broader study to determine loading from urban copper and zinc sources (including roofing components) is underway.

The *Assessment* suggested non-agricultural pesticide use (residential users and licensed applicators) was a potentially significant source of copper to the Puget Sound basin. The Washington State Department of Agriculture (WSDA) investigated copper use in pesticides. They found few copper products in a market-shelf survey or reported to be in use by residential users or licensed applicators. Currently, other NEP projects to further assess sources of metals are underway.

## Pollutant Source Control

NEP Toxics funds supported many toxics control and prevention activities. Funds were used to develop and launch the Northwest Green Chemistry center. The center promotes the growth of Green Chemistry and green entrepreneurs through trainings, technical services, and product reviews. Funds were used to develop an alternative-assessment guide that allows users to identify the least toxic chemical or solution for a specific use. The ecoPRO Landscaper Certification Program was funded to promote sustainable landscaping.

NEP Toxics funded many source-control projects that resulted in less toxic chemicals being released to Puget Sound. Projects to remove creosote pilings allowed for removal of an estimated 7,500 pounds of PAHs. Effectiveness monitoring conducted in conjunction with one of the piling removal projects led to improvements in procedures for conducting future piling removal.

Two projects funded programs to reduce wood smoke and PAHs. Both projects funded to reduce wood smoke showed potential for effective reductions in PAHs.

NEP Toxics funded an outreach program to address auto leaks. The program has grown into a regional collaboration and is becoming a model for jurisdictions elsewhere.

Funds also helped support the Seattle Public Utilities cleaning of stormlines that are the largest input to the East Waterway Superfund Site. The lines, which date back to the 1920-30s, had never been fully cleaned. Nearly 300 tons of debris, containing an estimated 432 pounds of toxics including 240 pounds of zinc and 96 pounds of copper, were removed.

The largest single investment made by the NEP Toxics and Nutrients Committee was in the Local Source Control (LSC) Partnership. This program funds LSC specialists (LSCs) who provide technical support to small businesses to assist them with hazardous chemicals management.  A key lesson learned from the LSCs is that enforcement capacity is needed. Jurisdictions that do not have their own regulations to enforce must rely on county or state rules and enforcement capacity.

# Challenges

The NEP Toxics and Nutrients Committee faced several challenges.  Some were administrative, and some were due to the difficulty in pioneering new approaches.

- Meeting the conditions for processes and timelines.  Working through the various layers of requirements and reporting, particularly at the onset of agreements, took time.  Combining these processes with a need to spend funds quickly made thoughtful project selection difficult.  This likely led the committee to select existing programs for funding versus creating new projects.
- Working within the larger network of the Action Agenda.  As the Action Agenda evolves, the processes within it change.  This imposes a constant learning curve and also adds processes and reporting requirements that take time.
- Funding for existing prevention initiatives.  Since the committee identified prevention as the smartest and cheapest approach to toxics control, they spent the majority of their funds to further existing source-control work.  Inadequate funding for source control means that managers may need to make tough choices about which approach is most effective in the long run.

# Conclusions and Recommendations

Results of this 2017 review support the following conclusions.

## Prevention is a priority

The cheapest and most effective approach to reducing toxic threats is to prevent the use of toxic chemicals (toxics) in our products and to keep toxics from being released to our environment. Also, developing protocols that identify safer alternatives to toxics is key.  This ensures when chemicals are phased out, they will be replaced with non-toxic or less toxic substitutes.  The prevention approach relies on alternative assessments, sustainable design, and Green Chemistry.

## Stormwater conveys pollutants, including toxics, to Puget Sound

Impervious surfaces carry stormwater to storm drains instead of allowing stormwater to percolate through soils.

The more intensely developed areas in the Puget Sound region receive the greatest concentrations of toxic inputs.  Impervious surfaces are directly correlated to poorer stream health.

Control mechanisms, such as low impact development, bioinfiltration, and stormwater treatment, can provide treatment of toxics to better protect Puget Sound aquatic life.  Several methods and treatments for stormwater pollution are being implemented around the Puget Sound region. Monitoring results should be periodically reviewed to assess source-control effectiveness.

## Toxics reduction to our waters is essential in restoring healthy salmon populations in Puget Sound

Adult salmon, primarily Coho, returning to spawn in urban streams of the Puget Sound region have been prematurely dying at high rates (up to 90% of the total runs). Toxics from land-based runoff have been identified as the cause (Feist et al. 2011). In addition, juvenile salmon that travel through urban streams to Puget Sound accumulate contaminants at levels of concern. Reductions in toxics to streams is an essential component in restoring salmon populations.

Assessing the efficacy of bioretention treatments in reducing stormwater toxicity is needed. This would prevent pre-spawn mortality in urban streams and reduce accumulation of CECs in juvenile salmon traveling to Puget Sound via urban streams.

## Contaminants of emerging concern (CECs) are present in Puget Sound, and data are needed to assess the impact of CECs

More research is needed on CECs, including spatial distribution, impacts to aquatic life, and sources. While there has been some research, more information is needed on the wide range of potential CECs (e.g., pharmaceuticals, personal care products, brominated flame retardants, and nanomaterials).

Develop methods or actions to control CEC discharge to Puget Sound (e.g., increase take-back programs and education campaigns to promote responsible disposal of pharmaceutical products).

## Groundwater sources of toxics should be investigated

The work done in *Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-11* (Norton et al. 2011) for groundwater loading was preliminary. Pollutant volume estimates are uncertain, and data on many contaminants were lacking.

Surface waters underwent three phases of investigation, including sampling, in the *Assessment*. Groundwater received only a review of existing data.

## Source control and management actions must include a monitoring component to determine effectiveness

Both the creosote-piling-removal effectiveness monitoring and the PCB source-tracing review revealed ongoing contamination from remediated sites. Source-control actions were modified due to monitoring findings. This led to more effective source-control work.

## Continued implementation of source-control actions and recommendations from the *Assessment are needed*

# Introduction

## Restoring Puget Sound

Puget Sound provides great benefits to Washington State. Famous for its aesthetic beauty and recreational opportunities, its estuarine waters also provide millions of dollars of seafood annually. Washington has the largest hatchery and farmed shellfish industry in the U.S. (PSI 2013). Puget Sound and its tributaries support tribal, non-tribal commercial, and recreational fisheries that are important to the local economy and culture.

Many of the Puget Sound animal species are in jeopardy. There are 21 Puget Sound species listed as threatened or endangered and also 107 species of concern (PSP 2009). Puget Sound is designated as critical habitat for many of these threatened or endangered species including Hood Canal summer chum, Puget Sound Chinook, steelhead, and southern resident orcas. Also, while coho have yet to be listed, their populations continue to decline.

In 2007, the Washington State Legislature created the Puget Sound Partnership (Partnership) to organize Puget Sound recovery efforts. The Partnership developed and routinely updates an Action Agenda that guides the recovery efforts for Puget Sound. The Partnership tracks recovery efforts through a matrix of 21 vital signs. The vital signs are linked to key ecosystem functions that represent the Sound’s health. Two of these vital signs, toxic chemicals (toxics) in fish and the sediment quality index, directly track the levels of toxics in Puget Sound.

## Puget Sound Toxics Loading Studies, 2007-2011

To better prioritize toxics management efforts, the Washington State Department of Ecology (Ecology) conducted a series of Puget Sound Toxics Loading Studies. These studies aimed to quantify toxics loadings from various sources and conveyance pathways. A series of reports entitled *Control of Toxic Chemicals in Puget Sound* was produced from 2007-2011; these looked at toxics loading from the following pathways:

- Surface runoff
- Wastewater treatment plants
- Atmospheric deposition
- Ocean exchange
- Direct groundwater discharge

A total of 17 chemical groups were selected for review in the loading studies. These studies included an evaluation of the sources of toxics to Puget Sound. Release of toxics from the 17 chemicals of concern was estimated from a number of products and activities (Roberts et al. 2011).

## The 2011 Assessment

The results of the loading studies were presented in *Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-11* (*The Assessment*) (Norton et al. 2011). For the chemicals investigated, surface runoff was typically the primary pathway for most toxics, with commercial/industrial areas releasing the highest toxics concentrations of any of the four land uses (commercial/industrial, residential, agriculture, and forest). Polybrominated diphenyl ethers (PBDEs) were an exception to this, with atmospheric deposition delivering the largest estimated load and wastewater treatment plants the second largest.

The *Assessment* also included other projects and studies that supplemented the loading studies, including:

- Screening of CECs including pharmaceuticals and personal care products (PPCPs) at wastewater treatment plants (influent, effluent, and sludge).
- Evaluating persistent organic pollutants (POPs) in three marine guilds (plankton, pelagic fish, and harbor seals).
- Numerical modeling of PCBs in Puget Sound's water, sediments, and food web.
- Development of a biota-based monitoring regime for toxics.
- A hazard evaluation.

Results of the hazard evaluation suggest that the following chemicals are most likely to be found at concentrations of concern:

- copper
- mercury
- polychlorinated biphenyls (PCBs)
- polychlorinated dioxins and furans (PCDD/Fs)
- the pesticide DDT and its metabolites DDD and DDE
- polycyclic aromatic hydrocarbons (PAHs)
- bis(2-ethylhexyl) phthalate (DEHP), a plastic additive

The *Assessment* suggested that copper, PAHs, DEHP, and petroleum have the most potential for pollutant reduction. While information to support an assessment for PBDEs was lacking, PBDE effects are demonstrated (Ecology and WDOH, 2006; Ross 2006; Fernie et al. 2009; Norton et al. 2011). In addition, PBDE concentrations in fish tissue serve as an indicator for the Toxics in Fish Vital Sign (Puget Sound Partnership, Leadership Council 2011).

The *Assessment* included recommendations for implementing reduction efforts where a clear path was present, and for further investigations where uncertainty remained high. Information from the *Assessment* helped Ecology determine how toxics were entering Puget Sound and how to better prioritize ongoing work.

## NEP Toxics and Nutrients Cooperative Agreements

In 2010-2011, the U.S. Environmental Protection Agency (EPA) announced National Estuary Program (NEP) funding awards to support the 2009 Puget Sound Action Agenda. Select Washington State agencies were identified as lead organizations to implement Puget Sound recovery in four areas:

- Toxics and nutrients prevention, reduction, and control (Ecology)
- Watershed protection and restoration (Ecology and Commerce)
- Pathogen prevention, reduction, and control (Health and Ecology)
- Marine and nearshore protection and restoration (Fish & Wildlife and Natural Resources)

As the *Assessment* was wrapping up, Ecology was identified as the lead organization for administering the *NEP Toxics and Nutrients Prevention, Reduction, and Control* cooperative agreement. Ecology chairs the NEP Toxics and Nutrients Committee of partner agencies distributing the Toxics and Nutrients grant funds. Partner agencies on this committee include representatives from Ecology, EPA, the Puget Sound Partnership, and the Washington State Department of Health (DOH). For the first six rounds of funding, the committee administered $21 million in NEP Toxics funds (Table 1).

Table 1. NEP Toxics and Nutrients cooperative agreements.

| Agreement # | Funding Round | Award Date | Amount |
|---|---|---|---|
| PC-00J20101 | 1 | 1/19/2011 | $3,089,252 |
| PC-00J20101 | 2 | 7/21/2011 | $5,630,000 |
| PC-00J20101 | 3 | 7/16/2012 | $3,545,000 |
| PC-00J20101 | 4 | 8/8/2013* | $3,402,491 |
| | | **Rounds 1-6 Total:** | **$15,666,743** |
| PC-00J89901 | 5 | 9/25/2014** | $2,740,000 |
| PC-00J89901 | 6 | 9/9/2015 | $2,655,000 |
| | | **Round 5-6 Total:** | **$5,395,000** |
| | | **Rounds 1-6 Total:** | **$21,061,743** |

* Round 4 original total was $3,320,582, awarded on 8/8/2013, with an additional $81,909 for Ocean Acidification Modeling on 9/26/2014.
** Round 5 original total was $2,490,000, awarded on 9/25/2014, with an additional $250,000 for Climate Change Modeling on 5/20/2015.
Source: Nelson, Blake. 2017, email to author, January 5.

## Toxics and Nutrients Multi-Year Implementation Strategy

Ecology's NEP Toxics and Nutrients Committee developed a process for selecting projects, reviewing project proposals, and awarding funds. This process is detailed in a Multi-Year Implementation Plan presented to EPA in Amendment Three of the NEP Toxics and Nutrients cooperative agreement (Ecology 2012). The committee split the NEP funds evenly between toxics and nutrients work. Implementation projects had a higher priority for funding than research projects.

## Existing Toxics Planning Projects

Ecology had already developed comprehensive plans to address toxics issues, documented in part in the Chemical Action Plans (CAPs) and the Reducing Toxic Threats (RTT) initiatives. The CAPs provide an overview of use and management recommendations for specific persistent, bioaccumulative toxins (PBTs) or a class of chemicals, such as lead (Davies et al. 2009), PAHs (Davies et al. 2012), and PCBs (Davies 2015). The RTT initiative focused on *prevention of all toxics*, offering a six-step framework:

1. Identify chemicals of concern.
2. Gather and manage data on chemicals of concern.
3. Phase out PBTs.
4. Spur the use of safer alternatives.
5. Promote Green Chemistry and design.
6. Improve prevention tools and authorities.

The *Assessment* addressed items 1 and 2 above, and the CAPs and Ecology's RTT initiative addressed item 3. NEP provided funds to work on the remaining steps.

The Partnership's Action Agenda and Science Work Plans provided additional guidance for the toxics control efforts. The Agenda offers a general mandate to reduce toxics in fish in support of the Action Agenda's Toxics in Fish Vital Sign. Toxics in fish is one of 21 key indicators being used to evaluate recovery of Puget Sound.

## Approaches for Toxics Control

The strategy was outlined in the 2012 Six-Year Strategy or the Multi-Year Implementation Plan (Ecology 2012).

Five categories of approach were given, in order of funding priority:

- Prevention: least expensive and most effective option.
- Management of existing releases.
- Research (scientific investigations) that informs and evaluates decisions.
- Tracking performance and adapting approaches accordingly (adaptive management).
- Cleanup of existing pollution.

Cleanups were not prioritized for funding because substantial programs already target cleanup. To date, the majority of funding for toxics has been to support cleanup work. Despite this, funding continues to lag behind what is needed to meet existing cleanup demands (Ecology 2012).

## Approaches for Priority Chemicals

Toxics projects focused on a reduced list of chemicals that (1) were present in Puget Sound at harmful levels (Norton et al. 2011) and (2) reduction of these chemicals was feasible (Table 2).

Table 2. Priority chemicals in the NEP Toxics and Nutrients Strategy.

| Parameter | Reason for Selection |
|---|---|
| PAHs | Identified in the Puget Sound Toxics Assessment;<br>Toxics in Fish threshold for liver disease and PAH metabolites in bile of English sole. |
| Phthalates | Identified in the Puget Sound Toxics Assessment;<br>Toxics in Fish threshold for reproductive impairment in English sole. |
| Copper | Identified in the Puget Sound Toxics Assessment;<br>Reports indicating impairment on juvenile salmonids. |
| Petroleum | Identified in the Puget Sound Toxics Assessment;<br>Source of PAH release. |

Source: Ecology 2012b

Additionally, contaminants of emerging concern (CECs) were noted as important to investigate because little data were available on CECs in Puget Sound. The Strategy aimed to "identify problematic chemicals as soon as possible and address these problems before they become a widespread concern" (Ecology 2012).

## Priority Source Control Investigations

Several source investigation projects were identified in the Strategy. These projects addressed gaps identified in the *Assessment* (such as the roofing materials studies), where an appropriate management action remained uncertain. Other research projects included filling identified data gaps in the Puget Sound Ecosystem Monitoring Program (PSEMP) regime, such as monitoring for CECs. Other projects helped to assess the effectiveness of current toxics control legislation (such as testing for PBDEs in consumer products).

## Implementation Focus

Implementation projects under NEP Toxics and Nutrients took several approaches:

- Specific remediation activities – funding local source control specialists, creosote-piling removal, and uncertified woodstove replacements.
- Creation of new programs – ecoPRO Landscaper Certification, Don't Drip and Drive, and Northwest Green Chemistry Center.
- Tools to better support toxics reduction work – Alternative Assessment Guide and a PCB source control program review.
- Supporting revised water quality criteria – development of a fish consumption rate and associated human health criteria revisions to Washington State Water Quality Standards.

## Cross-Cutting Projects

Several cross-cutting projects were funded. These span the four Puget Sound recovery efforts. The mussel survey conducted by Washington Department of Fish and Wildlife (WDFW) measured toxics in the nearshore environment throughout Puget Sound. This study drew on three of the recovery priorities: Toxics and Nutrients, Marine and Nearshore Protection and Restoration, and Watershed Protection and Restoration. This project was funded through the Marine and Nearshore Protection and Restoration group.

## Project Selection

A total of 32 toxics projects were funded (Table 3), some with multiple phases and funding agreements. A total of 20 projects focused on implementation, and 12 focused on research.

Table 3. Toxics projects by greatest to least funds invested.

| Rank | Projects | Funds | Percent |
|---|---|---|---|
| 1 | Local Source Control | $3,050,000 | 28.8% |
| 2 | Hood Canal Piling Removal | $600,000 | 5.7% |
| 3 | Roofing Materials | $570,000 | 5.4% |
| 4 | Woodstove Replacements | $560,000 | 5.3% |
| 5 | South Lander Street Storm Drain Cleaning | $550,000 | 5.2% |
| 6 | Biomonitoring for Emerging Contaminants | $500,000 | 4.7% |
| 7 | Northwest Green Chemistry | $500,000 | 4.7% |
| 8 | ecoPRO | $445,000 | 4.2% |
| 9 | Copper and Zinc in an Industrial Watershed | $430,000 | 4.1% |
| 10 | Alternative Assessment Guide | $260,000 | 2.5% |
| 11 | Compliance with PBDE Ban | $255,000 | 2.4% |
| 12 | Woodstove Retrofits | $250,000 | 2.4% |
| 13 | CECs in Sole | $240,000 | 2.3% |
| 14 | Don't Drip and Drive | $210,000 | 2.0% |
| 15 | PAHs near Railroads | $200,000 | 1.9% |
| 16 | Crab and Shrimp | $185,000 | 1.7% |
| 17 | Marinas | $180,000 | 1.7% |
| 18 | Copper Boat Paint Alternatives | $170,000 | 1.6% |
| 19 | Puget Sound Clean Cars | $150,000 | 1.4% |
| 20 | Overview Report | $140,000 | 1.3% |
| 21 | PCBs Guide Project | $140,000 | 1.3% |
| 22 | Chambers Bay Piling Removal | $135,000 | 1.3% |
| 23 | Effectiveness Monitoring (Piling Removal) | $130,000 | 1.2% |
| 24 | Juvenile Chinook Monitoring | $130,000 | 1.2% |
| 25 | Modeling | $115,000 | 1.1% |
| 26 | CECs in Elliott Bay Sediments | $100,000 | 0.9% |
| 27 | Fish Consumption Rate | $100,000 | 0.9% |
| 28 | Pesticide Use Surveys | $75,000 | 0.7% |
| 29 | Sectors Go Green | $75,000 | 0.7% |
| 30 | Phase I Stormwater Data Review | $60,000 | 0.6% |
| 31 | Water Quality Criterion Revisions | $60,000 | 0.6% |
| 32 | Stormwater Information Repository Guidance Paper | $30,000 | 0.3% |
| | **Total** | **$10,595,000** | **100%** |

This report evaluates projects funded, comparing the toxics work completed to the recommendations made in the *Assessment*. A separate Nutrients review will be done in 2018.

# Project Review

## Process

Project documents are stored on a *NEP Toxics and Nutrients* SharePoint site at Ecology. In compiling this report, the following were reviewed for each project: grant agreement, amendments, quality assurance project plans (QAPPs), final reports, affiliated websites, and any outreach materials. In addition, most project managers and some additional staff or participants were interviewed by phone or in person.

## Organization

Projects are presented according to the three funding priorities: prevention, management, and research. Some projects spanned categories.

Prevention projects are those that work toward reducing the creation of toxic chemicals. Management projects include those designed to prevent releases of current-use toxics. Research projects are those seeking to answer questions about toxics.

## Investment by Categories

Though the priority for funding was prevention, management was funded more than the other categories (Table 4).

Following is a summary of each project. It is divided into three sections: Prevention, Management, and Research.

The Appendix contains a 1-page summary for each project that include timelines, funds, project contacts, publications, and outcomes.

Table 4. Projects funded, by category.

| Projects | Funds | No. of Projects | Percent of Funding |
|---|---|---|---|
| **Prevention** | **$1,525,000** | **5** | **14.4%** |
| Northwest Green Chemistry | $500,000 | 1 | 4.7% |
| ecoPRO | $445,000 | 1 | 4.2% |
| Alternative Assessment, Guide | $260,000 | 1 | 2.5% |
| Alternative Assessment, Boat Paints | $170,000 | 1 | 1.6% |
| Clean Cars | $150,000 | 1 | 1.4% |
| **Management** | **$6,215,000** | **15** | **58.7%** |
| Source Control | $5,825,000 | 10 | 55.0% |
| Improving Water Quality Criterion | $160,000 | 2 | 1.5% |
| Overview Report | $140,000 | 1 | 1.3% |
| Stormwater | $90,000 | 2 | 0.8% |
| **Research** | **$2,855,000** | **12** | **26.9%** |
| Source Investigations | $1,275,000 | 4 | 12.0% |
| CEC Investigation | $840,000 | 3 | 7.9% |
| Biota Investigations | $315,000 | 2 | 3.0% |
| Effectiveness Monitoring | $310,000 | 2 | 2.9% |
| Modelling | $115,000 | 1 | 1.1% |
| **Grand Total** | **$10,595,000** | **32** | **100.0%** |

CEC: Contaminant of emerging concern

# Prevention

Historically, toxics management began as an effort to control discrete (point) source pollution. Currently, focus has increasingly shifted from targeting point sources to include more diffuse (nonpoint) sources. The pollutant loading studies demonstrated that diffuse sources were the largest contributors of many of the contaminants studied (Norton et al. 2011).

These diffuse sources include current-use products ranging from brake pads (copper); compact fluorescent lightbulbs (mercury); and foam furnishings and electronic housings (PBDEs and other flame retardants). Toxics can be released from products designed to be sealed, such as mercury-containing lightbulbs, and PCB transformers. Once toxics are released into the environment, it can be difficult if not next to impossible to reduce levels of some of these toxics. Thus prevention has emerged as the best and cheapest solution (Ecology 2017).

Toxics prevention means not allowing toxics to enter the environment or waste stream. This requires identifying and using non-toxic alternatives where possible. If there are products where a safer alternative has not been identified, it means eliminating or reducing the quantities of potentially harmful materials.

Chemical bans have controlled discharge of proven hazardous toxic compounds. However, there continues to be a wide assortment of toxics entering the marketplace. Some larger companies across America are initiating sustainability programs and chemical policies. For example, Walmart and Target have implemented chemical disclosure policies. Walmart also has asked for a 95% reduction of 16 high priority chemicals from its manufacturers (Safer Chemicals, Healthy Families 2017).

Consumers are becoming more educated about potential threats from toxics. As green, non-toxic alternatives become more mainstream, it is easier for consumers to identify safer product alternatives.

Five of the NEP Toxics projects provided tools to advance the market capacity for non-toxic, or less toxic, alternatives (Figure 3). These prevention projects are reviewed below.

### Alternative Assessment Guide

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Alternative Assessment, Guide | $260k | 2.5% | 10 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

This alternative assessment tool allows users to identify the least toxic chemical or solution for a specific application. An alternative assessment is a process for ranking chemicals against specific criteria in order to select the most preferred, least toxic option.

The Interstate Chemicals Clearinghouse (IC2) is a multi-state collaboration that shares data on chemicals, such as hazard assessments, to support regulation of chemicals. Ecology and IC2 created an alternative assessment guide (IC2, 2013). Washington State then developed an abbreviated, hazard-based guide to serve small-to-medium-size businesses. The Washington Guide establishes minimum requirements for an alternatives assessment and recommends methods for implementation (Stone and Zarker 2015).

### Northwest Green Chemistry

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Northwest Green Chemistry | $500k | 4.7% | 7 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Green Chemistry is a safer alternative to the traditional, more toxic chemistry that is typically practiced. Green Chemistry is the design of chemical products and processes that reduce or eliminate the generation of hazardous substances (EPA 2016). Northwest Green Chemistry (NGC) grew from a recommendation within Washington State's five-year plan for implementing Green Chemistry, called the Green Chemistry Roadmap (Ecology and Commerce 2013).

Ecology's Reducing Toxics Threats (RTT) team used NEP funds to develop and launch NGC. The NGC center now operates independently under the umbrella of Social and Environmental Entrepreneurs. The center promotes the growth of Green Chemistry and green entrepreneurs, offers trainings, and provides technical services and product reviews.

Recently NGC helped support a local business test of ethylene propylene diene monomer (EPDM) boat fenders. EPDM is a synthetic rubber with a wide range of applications. Old tires are commonly used as boat fenders; however, the tires are toxic to aquatic organisms. NGC and Washington State University's Stormwater Center performed toxicity screening of both the EPDM fender and an old tire fender. The old fender proved toxic, killing the study organisms, but organisms from the new fender group survived, indicating a less-toxic solution.

NGC is revising the 5-year Green Chemistry Roadmap for Washington; the current Roadmap expires in 2017. NGC will extend the Roadmap to cover the area from Vancouver B.C. to Portland, OR. NGC is also leading Washington's copper boat paint alternative assessment, described below.

### Copper Boat Paint Alternatives Assessment

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Alternative Assessment, Boat Paints | $170k | 1.6% | 18 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

In 2011, Washington became the first state in the U.S. to limit copper in boat paint. Chapter 70.300 RCW requires (1) the phase-out of copper-containing paint for recreational vessels under 65' in length and (2) the identification of safer alternatives. NGC was contracted to develop the alternative assessment.

NGC formed an Industry Roundtable of representatives from the boat paint industry, boat paint users, environmental groups, and other interested parties to evaluate alternatives. NGC is collecting data on potential alternatives, including chemical hazard, performance, cost and availability, and exposure.

The contract requires the completion of at least 15 chemical hazard assessments. The assessment will also consider things that are not 1:1 replacements, such as alternative technologies including nano and sonar. There will not be a full evaluation of all products on the market, but a representative of each category will be reviewed (A. Stone 2016, personal communication, Sept 3).

If no safer alternative is identified and funding is available, NGC will establish an Innovations Roundtable to explore the possibility of developing safer alternatives to copper antifouling paint using the 12 principles of Green Chemistry.

Stakeholder involvement has been high, with several meetings held during late 2014 (Ecology 2016c). The assessment is ongoing, with a final result anticipated in the fall of 2017 (A. Stone 2017, email to author, Jan 4).

### ecoPRO Landscaper Certification Program

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| ecoPRO | $445k | 4.2% | 8 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

While there are many certification programs promoting sustainability, ecoPRO is the only landscapers' certification in Washington State.  EcoPRO provides a list of sustainable best practices its practitioners can choose from, that align as much as possible with existing business and site specification.  The best practices have the following guiding principles at their core:

- Protect and Conserve Soils
- Conserve Water
- Protect Water and Air Quality
- Protect and Create Wildlife Habitat
- Conserve Energy
- Sustain Healthy Plants
- Use Sustainable Methods and Materials
- Protect and Enhance Human Health and Well-being

There are now nearly 100 certified ecoPROs.  Of those, approximately 15 are Oregon Tilth Organic Landscape Certified (OLC) Professionals that were grandfathered into the program when Oregon Tilth ceased to offer their own certification.

ecoPRO continues to grow.  The first recertification period in 2016 saw 100% renewal (B. Chavez 2016, personal communication, Sept 7).  Partners continue to co-host trainings to reduce cost and increase visibility and relevance.  As the certification program grows more established, the program will shift its focus from training to promoting the guiding principles throughout the industry and also increasing consumer demand for certified ecoPROs.

ecoPRO faces several challenges as it moves to independence.  A large number of recent trainees have failed to pass the certification exam, even after supplemental training was provided (B. Chavez 2016, personal communication, Sept 7; B. Chapman 2016, personal communication, July 28; J. Johnson 2016, personal communication, Oct 14).  The program also seeks funding sources to maintain itself past the initial NEP grant (B. Chavez 2016, personal communication, Sept 7).

### Puget Sound Clean Cars Partnership

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Clean Cars | $150k | 1.4% | 19 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

As discussed in the Management section below, the primary intent of the Clean Cars Partnership is to reduce auto leaks.  In addition, the Puget Sound Partnership includes automotive fluid ingredient review and possible screening for toxics of particular concern.

## Management

Management projects include those designed to (1) prevent releases of current-use toxics and (2) cleanup of existing sources, including permitting, mitigating, and cleaning up contamination. Several NEP Toxics and Nutrients projects bolstered existing management efforts.  These management projects, broken out by funding amount (Figure 4), are reviewed below.

## Reducing PAHs

Polycyclic aromatic hydrocarbons (PAHs) in Puget Sound are elevated. The *Assessment* identified PAHs as one of the target chemicals for source control. The *Assessment*, using findings from the PAH Chemical Action Plan (CAP), identified wood smoke and creosote-treated pilings as the largest sources of PAHs to the Sound (Norton et al. 2011; Davies et al. 2012).

Several existing programs were identified that supported the PAH reduction recommendations made in the CAP and the *Assessment* (Figure 5). These included the creosote-piling removal work by the Washington State Department of Natural Resources (DNR) and replacement of non-certified woodstoves by the Puget Sound Clean Air Agency (PSCAA). These program were given NEP funds to increase the scope of their work. Also, a competition for the design of a wood smoke pollution-reducing retrofit device was funded.

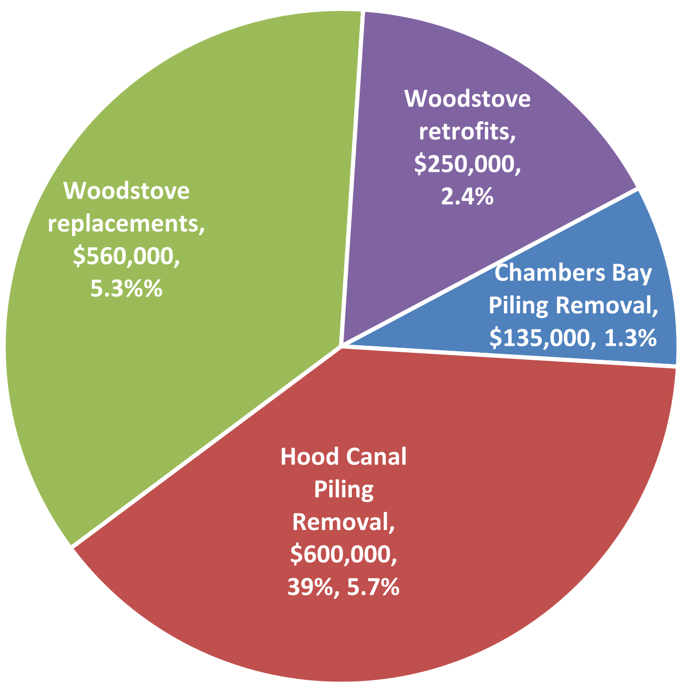



Figure 5. PAH reduction projects, with funding amounts and percent of the total $10.6 million toxics investment.

### Creosote Pilings

Two creosote-piling removal projects were funded, receiving a total of $735,000 (Table 5). One project was in the Hood Canal region, the other at Chamber's Bay in Pierce County. An additional 600 creosote pilings were removed from Woodard Bay with support from the Nearshore NEP Committee as part of a larger habitat acquisition and restoration project. The total cost was $1,214,746, of which the committee contributed $161,735.

Table 5. Creosote-piling removal projects funded by the Nearshore NEP Committee.

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Hood Canal Piling Removal | $600,000 | 5.7% | 2 |
| Chambers Bay Piling Removal | $135,000 | 1.3% | 22 |
| **Total** | **$735,000** | **6.9%** | |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Over 1,000 creosote pilings were removed, with PAH reductions estimated as shown in Table 6.

Table 6. Reported removal metrics from two creosote-piling removal projects.

| Factors reported | Hood Canal Region | Chambers Bay |
|---|---|---|
| Pilings Removed | 894 | 225 total, 112 creosote |
| *Creosote Reduced* | *429 kg/yr.* | *2156 kg total* |
| Weight Disposed | 1,335 tons | 26.5 tons |
| Total Dimensions | 4,600 $ft^2$ | 1770 $ft^3$ |
| Average Diameter | -- | 1.25 ft. |
| Average Length | -- | 12 ft. |
| Release Rate (total) | 0.54 kg/PAH/piling/yr. | 1.2 kg PAH/$ft^3$ |
| Portion Released to Water | 0.48 kg PAH/piling/yr. | -- |
| Assumed Average Weight | -- | 32 lbs./ft. |

If an estimate is made for Hood Canal by applying a 19.25 kg per piling creosote estimate obtained using Chambers Bay values, 17,000 kilograms of creosote were removed in Hood Canal, for a total of just under 20,000 kilograms, or 9,000 pounds, from both areas combined as shown in Table 7.

Table 7. Creosote removal estimates.

| Region | Pilings removed | Creosote removed (kg) |
|---|---|---|
| Chambers Bay | 112 | 2156 |
| Hood Canal | 894 | 17,209 |
| **Total** | 1006 | **19,365** |

*Calculated using 19.25 kg/piling obtained from the Chambers Bay numbers.

Creosote mixtures contain 85% PAHs (Padma et al. 1998). Thus, approximately 7,500 pounds of PAHs were taken directly out of Puget Sound's nearshore environments through these efforts.

Additional state funds contributed to the removal of all remaining legacy nearshore structures at Chambers Bay in 2015. Disposal records provided by Steve Kamieniecki of Pierce County state that an additional 213.7 tons of creosote-treated wood was removed (email to author, May 3, 2017).

An estimated 100,000 creosote pilings remain in Puget Sound (DNR, 2014; Roberts et al. 2011).

### *Removal Practices*

Effectiveness monitoring of the Hood Canal piling removal, described in the Research section, was also funded. Results showed PAHs were elevated even a year after the piling removal. This led Ecology's Toxics Cleanup Program (TCP) and DNR to more closely consider their removal methods.

DNR now adds a stipulation that removals must be inspected with underwater cameras upon completion. Their most recent hydraulic permit (HPA), issued in December 2016, also requires any cut-off pilings to be cut at least 2 feet below the mud line. The previous HPA required only 1 foot.

Ecology's TCP is in the process of writing a removal protocol for their own projects that will be included in their Sediment Cleanup User's Manual, version II (SCUM II) updates. Presently, TCP follows best management practices from EPA. At the Port Gamble cleanup site, TCP protocol included sifting for loose debris at the surface and sea floor during the removal process (C. Abercrombie 2017, personal communication, Mar 17).

## Wood Smoke

The *Assessment* estimated 48,500 pounds of PAHs per year are released from woodstoves and fireplaces in the Puget Sound basin, implicating wood burning as the single largest source of PAHs to the region, nearly double that of creosote pilings (Norton et al. 2011).

To reduce PAHs, two wood-smoke-reduction projects were funded: an uncertified woodstove replacement program and a woodstove retrofit challenge.

### *Uncertified Woodstove Replacement*

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Woodstove replacements | $560,000 | 5.3% | 4 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The Puget Sound Clean Air Agency (PSCAA), responsible for air quality in King, Pierce, Kitsap, and Snohomish Counties (the most populous counties in the region), estimated that, as of 2011, there were 82,000 uncertified fireplace inserts and 98,000 uncertified wood-burning stoves in its operation area (Table 8).

In 2007, the PSCAA began replacing uncertified woodstoves within an area of Pierce County as a means to control particulates (A. Warren 2016, personal communication, Oct 18). Because wood smoke is also a large source of PAHs (Norton et al. 2011; Davies et al. 2012), the PSCAA woodstove replacement program also helped control these target compounds.

In 2011, a portion of Pierce County was designated as the only Clean Air Act nonattainment zone in Washington State, because the 2006 daily standard for particulate matter was not met (PSCAA 2011). The PSCAA identified wood smoke reduction as the primary method of meeting Clean Air Act requirements in Pierce County.

Table 8. Estimate of wood-burning devices within the Puget Sound Clean Air Agency counties, 2011.

| County Area | Open Hearth Fireplaces | Uncertified Fireplace Inserts | Certified Fireplace Inserts | Pellet Stoves | Uncertified Wood Stoves | Certified Wood Stoves | Total |
|---|---|---|---|---|---|---|---|
| King UGA | 236,000 | 33,000 | 31,000 | 15,000 | 31,000 | 22,000 | 368,000 |
| King Non-UGA | 35,000 | 5,000 | 5,000 | 2,000 | 5,000 | 3,000 | 55,000 |
| **King Total** | **272,000** | **38,000** | **35,000** | **17,000** | **36,000** | **25,000** | **423,000** |
| Kitsap UGA | 7,000 | 3,000 | 3,000 | 2,000 | 4,000 | 3,000 | 22,000 |
| Kitsap Non-UGA | 14,000 | 5,000 | 5,000 | 3,000 | 8,000 | 6,000 | 42,000 |
| **Kitsap Total** | **21,000** | **8,000** | **7,000** | **5,000** | **13,000** | **9,000** | **63,000** |
| Pierce UGA | 32,000 | 9,000 | 8,000 | 4,000 | 15,000 | 10,000 | 78,000 |
| Pierce Non-UGA | 24,000 | 7,000 | 6,000 | 3,000 | 11,000 | 8,000 | 59,000 |
| **Pierce Total** | **56,000** | **16,000** | **14,000** | **7,000** | **26,000** | **18,000** | **137,000** |
| Snohomish UGA | 31,000 | 12,000 | 11,000 | 7,000 | 13,000 | 9,000 | 84,000 |
| Snohomish Non-UGA | 22,000 | 8,000 | 8,000 | 5,000 | 9,000 | 7,000 | 59,000 |
| **Snohomish Total** | **53,000** | **20,000** | **18,000** | **12,000** | **23,000** | **16,000** | **142,000** |
| **PSCAA Total** | **402,000** | **82,000** | **74,000** | **41,000** | **98,000** | **68,000** | **765,000** |

From PSCAA, Amy Warren, Nov 10, 2016.
UGA: Urban Growth Area.

Approximately 800 uncertified woodstoves were replaced with non-wood-burning devices. This removed an estimated 600 pounds of PAHs and 18 tons of particulate matter 2.5 microns or smaller ($PM_{2.5}$) annually (A. Warren 2016, personal communication, Oct 18).

In 2015, after a targeted campaign to improve the area's air quality, the Pierce County non-attainment zone was brought back into compliance with the Clean Air Act requirements for particulate matter. EPA required a maintenance plan in order to lift the nonattainment status. Uncertified woodstove replacement was the second highest priority action in the plan (Carson, 2015).

The woodstove replacement program has removed over 24,000 uncertified stoves from the former Pierce County nonattainment area since its inception in 2007 (A. Warren 2016, personal communication, Oct 18) and is now expanding to serve the entire PSCAA region.

### *Woodstove Retrofit Challenge*

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Woodstove retrofits | $250,000 | 2.4% | 12 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The woodstove takeback program has been very successful but requires ongoing funding. One recommendation of the PAH Chemical Action Plan (CAP) was to identify a woodstove retrofit device that would reduce emissions without a full stove replacement (Davies et al. 2012).

Replacing older stoves with new ones reduces PAHs by as much as 10-25 grams per hour (A. Warren 2016, personal communication, Oct 18) but costs several thousand dollars per stove.

A worldwide woodstove retrofit challenge produced four successful designs. One of the four is currently available for purchase for around $600. All of the retrofit challenge winners reduced emissions from stoves in laboratory tests. Two lowered particulate emissions to below the present standards (Swartzendruber 2016). The lower cost and significant improvements in emissions suggest that retrofit devices can be a viable solution for controlling air pollution originating from woodstoves.

Manufacturers are working on producing and selling these devices in the retail market. PSCAA is supporting them, in the hopes of being able to apply the technologies to their wood smoke reduction efforts (Swartzendruber 2016).

## Reducing Petroleum Leaks

The *Assessment* identified petroleum leaks from vehicles as the largest source of pollution to Puget Sound by volume, estimating 6,100 tons per year (Norton et al. 2011). Two projects addressed leaks and drips from cars, one through public education and outreach, the other through design advances.

### Don’t Drip and Drive

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Don't Drip and Drive | $210,000 | 2.0% | 14 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Don’t Drip and Drive (DD&D) is an education and outreach campaign that offers leak detection workshops, hands-on training in vehicle maintenance, and monetary vouchers for participants who repair leaks. The program continues to expand throughout the region. DD&D has reached thousands of auto owners with leak detection support, maintenance tips, and repair vouchers.

Recent municipal stormwater permits have indirectly fostered the DD&D program. DD&D began as the Automotive Maintenance Program (AMP) under Seattle Public Utilities (SPU) in response to education and outreach requirements in the Phase I NPDES municipal permit (Malatinsky 2016, personal communication, Aug 16). Further expanding the requirements for outreach, the Phase II permit places the same requirements on smaller municipalities throughout western Washington (Ecology 2013).

NEP Toxics and Nutrients funds supported Phase I and II of DD&D, in which 95 workshops hosting 1,120 attendees were conducted. The program continues to expand and now offers workshops, leak detection events, and other activities throughout the Puget Sound region.

### Puget Sound Clean Cars Partnership

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Clean Cars | $150k | 1.4% | 19 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The primary objective of the Puget Sound Clean Cars Partnership is to reduce stormwater pollution associated with automotive vehicle fluid leaks in Washington. The Clean Cars Partnership is a collaboration between Gradient Toxicological Services, a GreenScreen certified company, the Society of Automotive Engineers, and Ecology. The Clean Cars Partnership aims to form a stakeholder group of experts from government, academia, non-governmental organizations, and industry.

This group of stakeholders will work together to research and identify the following:

- Environmental and human health impacts of automobile fluid leaks.
- Vehicle leak data (for example: sources, frequency, and volume of leaks) to identify potential management options.
- Current automotive design and maintenance.
- Vehicle design efforts related to preventing vehicle leaks.
- Innovative technologies and onboard diagnostics.
- Policy options and incentives to accelerate efforts to reduce vehicle leaks using automotive technologies.
- Drivers and barriers to preventing vehicle leaks using automotive technologies.
- Safer chemical alternatives.

A final review of the above items will be delivered to Ecology in June 2018 (Gradient and SAE 2017).

## Reducing Pollution from Small Businesses

### Local Source Control (LSC) Partnership

| Projects | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Local Source Control | $3,050,000 | 28.8% | 1 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The Local Source Control (LSC) Partnership is a small business technical assistance program. The Partnership aims to reduce toxics and improve water quality by funding local pollution prevention specialists. Starting in 2007, Ecology awarded 14 contracts to local jurisdictions, 13 of which were in the Puget Sound region. The Partnership now works with 22 jurisdictions (Ecology 2016a), 19 in the Puget Sound region. Of these, five are currently NEP funded.

The LSC Partnership was the single largest NEP grant investment made by the NEP Toxics and Nutrients Committee. It was awarded at least $3.2 million, or 30% of the toxics funds, over the six rounds of the grant. This amount includes funds for the Sectors Go Green. These funds paid for LSC specialists in Bothell, Snohomish County, Port Angeles, Puyallup, and Kirkland. In the 2013-2015 reporting period, NEP-funded specialists made 973 visits to local businesses, during which they uncovered 1,012 issues (Ecology 2016a) (Table 9).

Table 9. NEP-funded Local Source Control Partnership results, 2013-2015

| 2013-2015 Reporting Period | Bothell | Snohomish County | Port Angeles | Puyallup | Kirkland | Total |
|---|---|---|---|---|---|---|
| Number of visits | 122 | 435 | 187 | 105 | 124 | 973 |
| Issues found | 212 | 80 | 151 | 186 | 383 | 1012 |
| Businesses with no issues | 39% | 86% | 77% | 57% | 9% | |

From: Ecology 2016: “Local Source Control Partnership 2013-15 Biennium Report.” Washington State Department of Ecology.

Pollution issues that LSC specialists might address include illegal discharges to storm drains and sewers. A recent LSC visit to an auto shop revealed floor drains in each of three bays that led directly to sewers. Shop practices included using a degreasing solvent and discharging it directly to the drains.

Other problems specialists have found are outdoor areas being cleaned with disinfectant that is then washed into storm drains. In many cases, the businesses do not realize they are doing something potentially harmful. Specialists can provide them with better ways to operate and reduce pollution.

The LSC Partnership specifies that the following nine high-priority issues justify a follow-up visit:

Hazardous Waste

1. Improper waste designations
2. Improper waste disposals
3. Improper storage of both products and wastes
4. Degraded or open chemical containers

Stormwater

5. Illegal plumbing connections
6. Improper discharges of process wastewaters to storm drains
7. Improper storage of containerized materials
8. Improper storage of non-containerized materials
9. Need to clean and eliminate leaks and spills from storage areas

Of the problems found by LSC specialists statewide in 2013-2015, 21% were high priority issues (Ecology 2016a). The most commonly reported problems included inadequate spill response procedures or materials (27% of all issues reported in 2013-2015; Ecology 2016a).

### *Lessons for Success*

LSC specialists interviewed emphasized that a multi-tier approach that combines the helpful educational intent of the specialist with a layer of enforcement was the most effective way to create behavior change within the business community.

Understanding how to establish trust is fundamental to an LSC specialist's work. Approaching the businesses with educational tools and resources is important. Explaining why something matters and the potential consequences is far more effective than simply telling a business they must do something. Also, selling source control as a good business practice can increase their desire to learn more. Once a business agrees to participate in the program, specialists need to provide something of value to the business to establish credibility (T. Benson 2016, personal communication, July 28).

Often businesses do not have training in hazardous waste management. These businesses benefit from LSC technical assistance because LSC specialists can help them understand what is required and support them in following best practices.

Agreeing to a visit is voluntary. Because LSC specialists stress the educational focus of their visits as opposed to regulatory enforcement, businesses rarely refuse LSC visits.

### *Challenges*

While LSC specialists are doing educational outreach business by business, they find in some cases a business has no issues at all, while others have many. Having a larger educational campaign with a region or sector-wide reach would help to increase the program's effectiveness (A. Alfred, A. Peterson, and T. Zuehl, 2016, personal communication, July 28).

Some of the most common problems seen are lack of secondary containment and improper storage. Sometimes these can be readily fixed; however, cost can be a barrier. Alternative designs should be explored. For example, a local auto shop owner designed and built a containment system for far less using common building materials. Effective designs could be shared throughout the LSC program as a model for other businesses. This makes a case for information sharing throughout the LSC network.

Challenges cited by both Snohomish and Bothell specialists include identifying which businesses to visit and locating problems. Often businesses do not realize there may be a problem and thus might not seek assistance without the specialist pinpointing a problem. Recently Ecology developed a methodology using spatial analysis to help identify businesses where problems may be found (Medlen 2017). Local jurisdictions can use this method to identify areas for targeting outreach.

Another challenge lies in enforcement, particularly for those LSC specialists without a regulatory component to their program. LSC specialists within stormwater and waste programs may have an internal enforcement capacity. While others may not have mechanisms to apply enforcement when needed.

### *Local Source Control Effectiveness Monitoring*

A state-funded monitoring study to determine effectiveness of the LSC program is being conducted, beginning in Clark County in 2017 (Medlen 2017). While not NEP-funded, the study findings could apply to the Puget Sound region as well.

### Sectors Go Green

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Sectors Go Green | $75,000 | 0.7% | 29 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Sectors Go Green provided tools to support LSC work. Sectors Go Green funds purchased spill kits and provided vouchers to support secondary containment installation for small businesses. These are delivered through LSC specialists. Spill kits are given to businesses as incentives to draft Spill Response Plans.

As secondary containment was a frequent problem, some of the funds were available for vouchers to assist with the installation. However, the amount of the vouchers was only a small portion of the average total cost, and few vouchers were used (P. Morgan 2016, personal communication, July 19). The cost of installing a secondary containment system continues to be a barrier for many businesses.

## Stormwater Management

The *Assessment* identified stormwater as the primary conveyance pathway for most of the toxic chemicals (toxics) studied (Norton et al. 2011). Recent municipal stormwater permits have increased the level of stormwater management and control efforts. Several toxics projects supported these efforts.

### South Lander Stormline Cleaning

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| South Lander Street Storm Drain Cleaning | $550,000 | 5.2% | 5 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Seattle Public Utilities (SPU) undertook a massive stormline cleaning in 2014. The line (South Lander Street) is the largest input to the East Waterway Superfund Site. Line cleaning is SPU's primary source control activity for both the East Waterway and the Lower Duwamish Superfund Sites.

The project was about 60% funded by a Toxics NEP grant. Leveraging the opportunity provided by the grant, SPU added internal funds which enabled cleaning of the entire line in one season. It would have taken multiple stages over an estimated six years with their existing budget (B. Schmoyer 2016, personal communication, Oct 26). Not only did this grant increase the pace, it provided cost savings. The dewatering set-up and breakdown costs were roughly $40,000. They are typically anywhere from 5-10% of the project total.

The lines, which date back to the 1920-30s, had never been fully cleaned. Nearly 300 tons of debris containing an estimated 432 pounds of toxics, including 240 pounds of zinc and 96 pounds of copper, were removed (Table 10).

Table 10. Toxics removed from South Lander during line cleaning.

| Metals | lbs[1] | | Chemicals | lbs[1] |
|---|---|---|---|---|
| Arsenic | 5.3 | | Bis(2-ethylhexyl)phthalate* | 2.4 |
| Copper | 96 | | Butylbenzylphthalate | ND |
| Lead | 85 | | Diethylphthalate | ND |
| Mercury | 0.12 | | Dimethylphthalate* | 0.05 |
| Zinc | 240 | | Di-n-butylphthalate* | 0.11 |
| **Metals (total)** | **426.42** | | Di-n-octylphthalate* | 0.1 |
| LPAH | 0.4 | | **Phthalates** (*sum of detects) | **2.66** |
| HPAH | 2.7 | | PCBs | 0.11 |
| **PAH (total)** | **3.1** | | **Total Toxics Removed** | **432.29** |

[1] Average sample concentration (n = 9) times total pounds removed.
* Sum of detects included in total.

## PCB Source Investigation Review

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| PCBs Source Investigation Review | $140,000 | 1.3% | 21 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

A review and summary of several PCB source-tracing programs was conducted, and a report summarizing the programs was written (Colton et al. 2016). This report will guide ongoing source control work in the Puget Sound region and elsewhere.

Programs report that finding pollutant sources becomes more difficult over time. Ongoing sources discovered by the source control programs reviewed included cleanup sites, even those already deemed NFA (No Further Action). Where source control efforts have been more extensive (Lower Duwamish and the City of Tacoma), sources such as PCB paint or caulking in buildings or road sealants were uncovered.

PCBs can also be produced as a by-product, or contaminant, in the chemical processes used in the making of dyes, paints, and other goods. The Toxic Substances Control Act (TSCA) allows PCB contamination up to 50 ppm in products. These inadvertently-produced PCBs are another source of PCBs in the environment. The total amount of inadvertently-produced PCBs is unknown.

Key findings of the review were:

- Each location is unique; there is no one-size-fits-all approach.
- PCB source tracing works, although it is expensive.
- PCB congener patterns help to identify sources.
- Highest PCB concentrations do not necessarily mean the biggest PCB load; complementary water flow data are needed.

### Stormwater Information Repository Guidance Paper

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Stormwater Information Repository Guidance Paper | $30,000 | 0.3% | 32 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

A guidance document supporting creation of a Stormwater Source Identification and Diagnostic Monitoring Information Repository (SIDIR) was developed. The document provided guidance on the content and structure of the repository proposing two repositories:

- To support smaller programs getting started by providing lessons and methods from larger, more established programs.
- To share information on illicit discharge detections (Monsey et al. 2012).

The document includes findings from interviews with local stormwater professionals regarding information needs, and provides a list of existing materials. The SIDIR is still being created under the guidance of the Stormwater Work Group members.

### Phase I Municipal Stormwater Permit, Stormwater Data Analysis

Because the *Assessment* found stormwater to be the largest conveyance pathway for toxics, a wide-scale characterization of stormwater quality was recommended (Norton et al. 2011). At the same time, the first regional stormwater monitoring under the Phase I permit was underway, providing data to support such a characterization. A review of these data confirmed that runoff from urban developed areas contains the highest concentrations of toxics, with commercial/ industrial areas having the highest levels overall (Hobbs et al. 2015).

Monitoring continues under the Stormwater Action Monitoring (SAM) Program. Phase II permittees were included in the most recent permit. Along with SAM, several regional stormwater management collaborations have emerged, including the Stormwater Work Group (Ecology 2017a), the Washington Stormwater Center (Washington Stormwater Center 2017), and the Stormwater Outreach for Regional Municipalities (STORM) (STORM 2012).

## Compliance Testing

### Enforcement of PBDE Ban with Product Testing

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Compliance with PBDE Ban | $255,000 | 2.4% | 11 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

A total of 169 products were tested for compliance with the PBDE ban and the Washington State Children's Safe Products Act (CSPA). Several new flame retardant mixtures were identified at levels exceeding the CSPA (van Bergen and Stone 2014). Additional brominated flame retardants, other than PBDEs, were also indicated by the X-ray fluorescence screening for bromine coupled with low PBDE results upon analysis (van Bergen and Stone 2014).

## Water Quality Criteria Revisions

Two projects supported revised water quality criteria for toxics. The existing criteria were based on the National Toxics Rule (NTR). Ecology's Water Quality Program wanted to develop Washington-specific criteria based on Washington's fish consumption rates.

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| **Improving Water Quality Criterion** | **$160,000** | **1.5%** | -- |
| Fish Consumption Rate | $100,000 | 0.9% | 27 |
| Water Quality Criterion Revision | $60,000 | 0.6% | 31 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

### Fish Consumption Rate

The fish consumption rate was based on the NTR rate of 6 grams per day. Many Washington residents and first-generation Pacific Islanders are documented to consume seafood at much higher rates. Funds were awarded to the Northwest Indian Fisheries Commission (NWIFC) to conduct outreach with local tribes on their fish consumption rate. A revised consumption rate of 167 grams per day was selected.

### Water Quality Rule Revision

Ecology's Water Quality Program went through the rule revision process to add human health criteria for priority toxic pollutants. The criteria proposed by Washington was partially approved by EPA. Ultimately, EPA finalized 144 new and revised Washington-specific human health criteria for priority toxic pollutants. This rule was effective on December 28, 2016.

# Research

Most projects focused on actions to prevent or reduce toxics. Scientific investigations received 27% of the total toxics funding as shown in Table 11 and Figure 6. Research projects funded filled crucial data gaps. The projects provided:

- Data on environmental concentrations of contaminants of emerging concern (CECs).
- Investigations of toxics sources in order to inform management strategies.
- Effectiveness monitoring for creosote-piling removals. This provided information to those overseeing removal projects. The information helped them to craft more effective piling removal protocols which will reduce PAH releases during removal operations.

Table 11. Research project types, with funding and percent of total $10.6 million toxics investment.

| Project Type | Total Funds | Percent |
|---|---|---|
| **All Research Projects** | **$2.86 million** | **26.9%** |
| CEC Investigations | $840k | 7.9% |
| Biota Investigations | $315k | 3.0% |
| Effectiveness Monitoring | $310k | 2.9% |
| Source Investigations | $1.28 million | 12.0% |

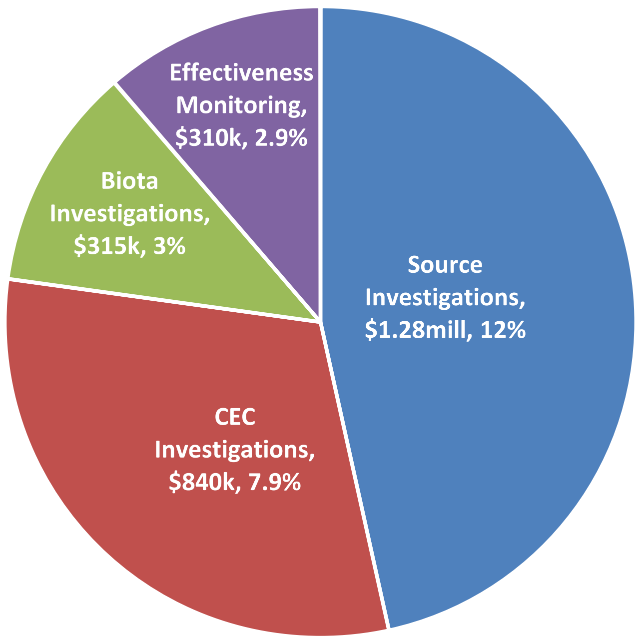



Figure 6. Research project types, with funding amounts and percent of the total $10.6 million toxics investment.

The research projects are presented below. More detailed information on each project can be found in the Appendix.

## Contaminants of Emerging Concern Investigations

Contaminants of emerging concern (CECs), including pharmaceuticals and personal care products, are increasingly being detected at low levels in surface water. It is important to determine the impact of these chemicals on aquatic life in Puget Sound. However, little research into CECs in Puget Sound had occurred. To address this gap, three CEC investigations were conducted (Figure 7). A review of each project follows.

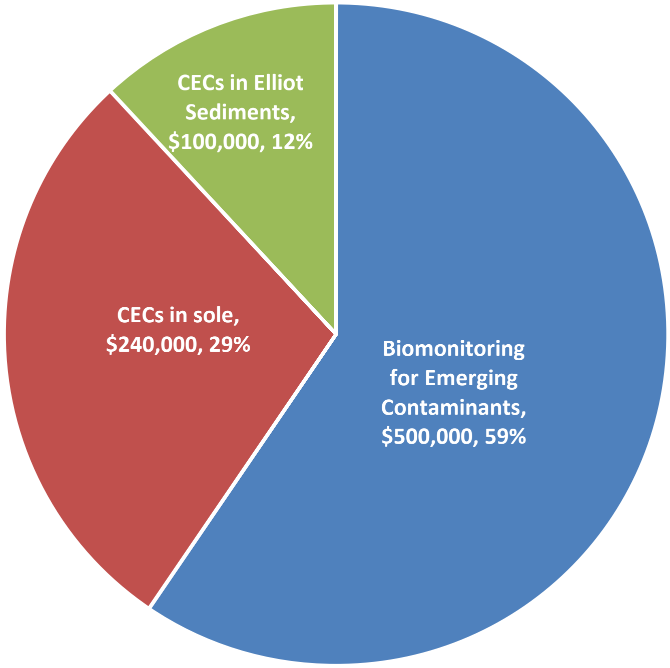



Figure 7. Contaminants of emerging concern (CEC) investigations, with funding amounts and percent of the total $10.6 million toxics investment.

### CECs in Elliott Bay Sediments

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| CECs in Elliott Sediments | $100,000 | 4.7% | 26 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The Puget Sound Ecosystem Monitoring Program (PSEMP) collected and analyzed sediment for CECs in four Puget Sound urban bays: Bellingham (2010), Elliott (2013), Commencement (2014), and Bainbridge (2015). In addition, sediment samples were analyzed at 10 long-term stations throughout Puget Sound (2010). To date, only results from the long-term stations, Bellingham and Elliott Bays, have been published (Long et al. 2013; Dutch et al. 2014). Though the NEP Toxics grant funded the Elliott Bay analysis, general results from both Elliott and Bellingham Bays will be presented here.

The same CECs were analyzed at all 4 urban bays. The list includes 119 pharmaceuticals and personal care products (PPCPs), as well as 13 perfluoroalkyl substances (PFAS). The compounds included for analysis were selected based on discussions with Ecology's Toxics Cleanup Program and other researchers (M. Dutch 2016, personal communication, July 21).

In 2010 in Bellingham Bay, only 14 of the 119 PPCPs analyzed were quantifiable, and only 3 of the PFAS compounds were detected: perfluorobutanoate (at 7 stations), perfluorooctane sulfonate (PFOS; at 5 stations), and perfluorooctane sulfonamide (at 1 station) (Long et al. 2013).

In 2013 in Elliott Bay, 13 of the PPCPs were detected, and 3 PFAS compounds were detected: PFOS (at 7 stations), perfluoro decanoate (PFDA; at 1 station), and perfluoroundecanoate (PFUnA; at 1 station each) (Dutch et al. 2014).

The presence of PPCPs varied across bays with 3 compounds consistently detected with higher frequency: triclocarban (a disinfectant), diphenhydramine (an antihistamine), and triamterene (a diuretic).

The only pattern observed in Elliott Bay was a correlation between higher percent fines and higher CEC concentrations (Dutch et al. 2014).

### CECs in English Sole

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| CECs in sole | $240,000 | 2.3% | 13 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

English sole (*Parophrys vetulus*) were sampled from multiple Puget Sound locations. Liver composites were analyzed for 3 selective serotonin reuptake inhibitors (SSRIs): sertraline, fluoxetine, and citalopram. Liver bile was analyzed for 8 estrogenic compounds (ECs).

No SSRIs were detected, indicating less direct exposure to wastewater treatment plant (WWTP) effluent where SSRIs are thought to be found in the highest concentrations. Of the 8 ECs, 5 were detected: 3 natural estrogens (17β-estradiol (E2), estrone (E1) and estriol (E3)), the synthetic hormone 17α-ethynylestradiol (EE2), and 4 xenoestrogenic compounds (bisphenol A, nonylphenol, and octylphenol as tert-OP and n-OP). The 3 natural estrogens had the highest concentrations, followed by bisphenol A and then octylphenol as tert-OP.

Urban areas had the highest levels of ECs, but individual fish at a sample site were highly variable. Several mitigating factors were proposed, including the potential presence for opposing hormones. Reproductive cycles in female fish from Elliot Bay were disrupted. Vitellogenin (VTG), an egg yolk protein produced in female fish, has been observed in male fish exposed to ECs. VTG induction is now used to document exposure to endocrine disrupting compounds (EDCs) in fish. English sole throughout Puget Sound were reviewed for VTG induction using an assay developed by the study authors. 100% of the fish expressed VTG induction.

### CECs in Sculpin, Chinook, Estuarine Waters, and Wastewater

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Biomonitoring for Emerging Contaminants | $500,000 | 4.7% | 6 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Effluent from both the Tacoma (Commencement Bay) and the Bremerton (Sinclair Inlet) WWTPs, water, and whole-body juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and Pacific staghorn sculpin (*Leptocottus armatus*) were sampled for 150 CECs. The CECs analyzed included pharmaceuticals, personal care products, and industrial compounds. A total of 81 of these compounds were detected in effluent, 25 in estuary water, and 42 in fish tissue.

## Additional Biota Sampling Investigations

Several more studies filling gaps in biota sampling were funded. A study to conduct contaminant monitoring of juvenile Chinook salmon was conducted. This study complemented the existing PSEMP analyses of English sole and herring. A crab and prawn assessment was also conducted to inform a Washington State Department of Health (DOH) consumption advisory. DOH presently has several health advisories for Puget Sound salmon.

### Juvenile Chinook

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Juvenile Chinook Monitoring | $130,000 | 1.2% | 24 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

This study collected juvenile Chinook from estuaries, nearshore areas, and surrounding bays to compare contaminant exposure along the migration route.

The study found that fish from the most developed rivers were the most highly contaminated. The uptake of contaminants continued throughout their life-cycle. Fish in remote embayments continued to have increases in contaminant concentrations (O'Neill et al. 2015). Fish from the more heavily developed central Puget Sound basin were more contaminated that fish from the southern and northern basins.

These findings highlight the need for more focus on toxics in salmon recovery efforts. Since 1997, the Salmon Recovery Funding Board has invested over $1 billion in recovery projects throughout Washington. Over half of this went toward Puget Sound. Despite these investments, the salmon population continues to decline for most species (Washington State Recreation Office, 2016).

### Crabs and Prawns

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Crabs and Prawns | $185,000 | 1.7% | 16 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Dungeness crab (*Metacarcinus magister*) and spot prawn (*Pandalus platyceros*) from throughout Puget Sound were assessed for organic compounds and metals. This information was needed to determine if a health advisory was warranted (Carey et al. 2014).

Results showed preferential accumulation of organics in the hepatopancreas of crabs (crab butter) and the head (carapace) tissue of prawns. PBDEs were detected in the crabs but rarely in prawns. PCBs were present in the most locations, followed by PAHs and DDT. Urban locations had higher levels of these organic compounds. Cadmium was higher in prawns than crab. Generally metals were more uniformly distributed than organic compounds, with the exception of mercury which was higher in urban areas.

DOH used these data to issue a health consumption advisory limiting the intake of crab butter and prawn heads, particularly in developed areas. Recommendations included avoiding crab butter from around Seattle (Marine Unit 10) and Port Angeles Harbor (DOH 2016). The most restricted marine areas for crab (meat) are Elliott and Sinclair Bays (2 servings per month). The most restricted area for prawns is Commencement Bay (4 servings per month). The San Juan Islands Marine Area is the only unrestricted area for whole prawn (head and body). All areas were restricted for crab butter (DOH 2016).

## Effectiveness Monitoring

Two projects provided data to evaluate the effectiveness of toxics source control actions.

### Creosote-Piling Removals

| Project | Funds | Percent | Funding Rank* |
| --- | --- | --- | --- |
| Effectiveness Monitoring (Piling Removal) | $130,000 | 1.2% | 23 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

Post-removal effectiveness monitoring of a piling removal project in Quilcene was conducted by the Washington Department of Fish and Wildlife (WDFW). Monitoring showed average PAH concentrations in herring embryos were 17 times higher after piling removal than before (West et al. 2016).

DNR contractors performing the removal found it difficult to remove deteriorating pilings. They did not follow best management practices (BMPs) outlined by DNR (M. Shoemaker 2017, personal communication, May 4). Pilings were cut in place, and a large amount of loose debris was left behind after the removal operations.

While this was considered an exceptional site due to age of the pilings, it raises concerns about other removal operations. It also highlights the need for monitoring to determine if source control actions achieve the desired results.

As a result of WDFW's findings, DNR revised its piling removal protocols. They are adding an underwater camera inspection element, and they are investigating alternative means to remove difficult pilings. DNR, or their contractor, is expected to conduct further cleanup of the Quilcene site.

### Metals in Marinas

| Project | Funds | Percent | Funding Rank* |
| --- | --- | --- | --- |
| Metals in Marinas | $180,000 | 1.7% | 17 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

In 2011, the Washington State Legislature passed a bill phasing out copper in marine antifouling paints. This legislation states that new recreational vessels with copper-containing bottom paint may not be sold in the state after January 1, 2018.

The study provides a baseline to determine effectiveness of the regulation.  Baseline data for copper, zinc, and lead will be established for five marinas on Puget Sound.  Both copper and zinc are components in antifouling paint, while lead is associated with upland boatyard activities.

All three metals are monitored in stormwater and wastewater under the Boatyard General Permit. Sample media will consist of water (dissolved and total recoverable concentrations), sediments (suspended and bottom), and transplanted mussel tissue.

Initial sampling showed higher levels of copper and zinc (dissolved) in water and suspended sediment at sites in the marinas as compared to sites outside the marinas.

Complete results are anticipated in summer 2017.

## Source Investigations

The largest research investment, $1.3 million, or 12% of the total toxics investments, was for pollutant source investigations.  Four source investigation projects were funded (Figure 8).

In the *Assessment*, these sources were determined to have the potential to contribute large loads of contaminants of emerging concern (CECs).  Data supporting these determinations were highly uncertain, and further investigation was recommended.

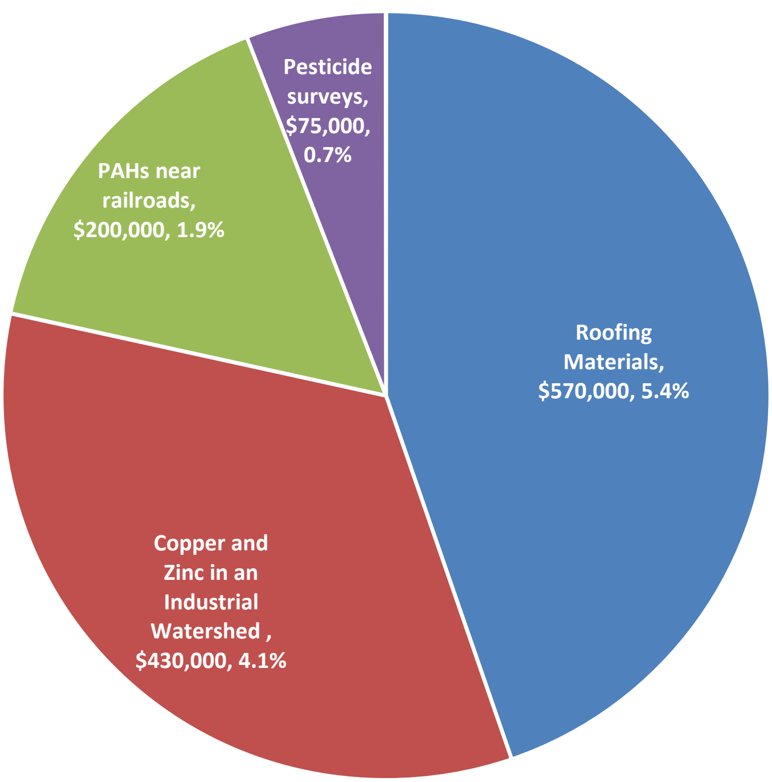



Figure 8.  Source investigation projects, with funding amounts and percent of the total $10.6 million toxics investment.

### Roofing Materials

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Roofing Materials | $570,000 | 5.4% | 3 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The *Assessment* tentatively identified roofing as a large source of metals to the Puget Sound basin (Norton et al. 2011). Covering a large expanse of area, roofing has high runoff volumes, and published literature release rates suggested a cumulative concern (Roberts et al. 2011).

To determine if roofing was a large contributor of metals, experimental panels of various roofing types were constructed, from which runoff was sampled over two wet seasons. The results of these studies indicated much lower release rates than seen in the literature used to determine the 2011 estimate (Roberts et al. 2011). The exception was the release of copper from the copper panel (Winters et al. 2014).

The number of variables involved, including the variety of in-use roofing materials and ages, makes a Puget Sound basin-wide application of release values obtained from this study difficult.

Despite the overall lower release values obtained, the following show potential for concern:

- Zinc from zinc roofing
- Arsenic from treated wood shingles and PVC roofing
- Copper from copper roofing

(Winters et al. 2014).

### Pesticide Use Surveys

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Pesticide use surveys | $75,000 | 0.7% | 28 |

*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The *Assessment* suggested non-agricultural pesticide use was a potentially significant source of copper to the Puget Sound basin (Norton et al. 2011). To investigate this, Ecology partnered with the Washington State Department of Agriculture (WSDA) to investigate copper use in non-agricultural pesticides. WSDA suggested broadening the scope to cover all pesticides. WSDA applied both an anonymous survey (to residential users) and direct inquiry methods (to public and commercial users). In addition to the survey of residential users, WSDA conducted a retail shelf assessment to ground-truth the types of products available to the average person (McLain 2014).

Usage rates and purposes were reported by county, with a special sub-section for the community around Thornton Creek in King County. This community has been the target of much outreach and education on water stewardship and integrated pest management.

The surveys provided the following conclusions:

- The higher response rates and lower pesticide use around Thornton Creek indicated that outreach efforts may be successful in fostering environmentally conscious behavior.
- Few copper products were reported either on the market shelf survey or in use by residential users or licensed applicators.
  - Copper-based products represented only 0.4% of all residential pesticides used.
  - Licensed public and commercial applicators showed little use of copper pesticides.
  - Golf courses, thought to be high users of copper (Norton et al. 2011), reported that the industry had moved away from copper formulations.

While WSDA did not find high rates of copper usage, they did highlight the need for education. They found that licensed applicators use minimal pesticides and strictly follow label requirements, while homeowners often have only a vague understanding of the proper application of the product in use. Homeowners need more education to make informed and sound choices (K. McLain 2016, personal communication, July 14). Because different methods were used with commercial applicators, comparisons of usage between commercial applicators and residential users could not be made from the data obtained.

### Ongoing Investigations

Two pollutant source investigations are underway (Table 12).

Table 12. Ongoing source investigation projects with timelines.

| Project Title | Timeline |
|---|---|
| Copper and Zinc Sources in a Commercial-Industrial Watershed | QAPP: July 2017<br>Final Report: June 2018 |
| Screening for PAHs and Metals in the Puget Sound Basin at Aquatic Habitats Adjacent to Mainline Railroad Tracks | QAPP: October 2016<br>Final Report: June 2018 |

QAPP: Quality Assurance Project Plan

Both of the above projects are a result of recommendations and findings from the *Assessment.*

## Puget Sound Regional Toxics Model

### The Puget Sound Regional Toxics Model Update

| Project | Funds | Percent | Funding Rank* |
|---|---|---|---|
| Modeling | $115,000 | 1.1% | 25 |

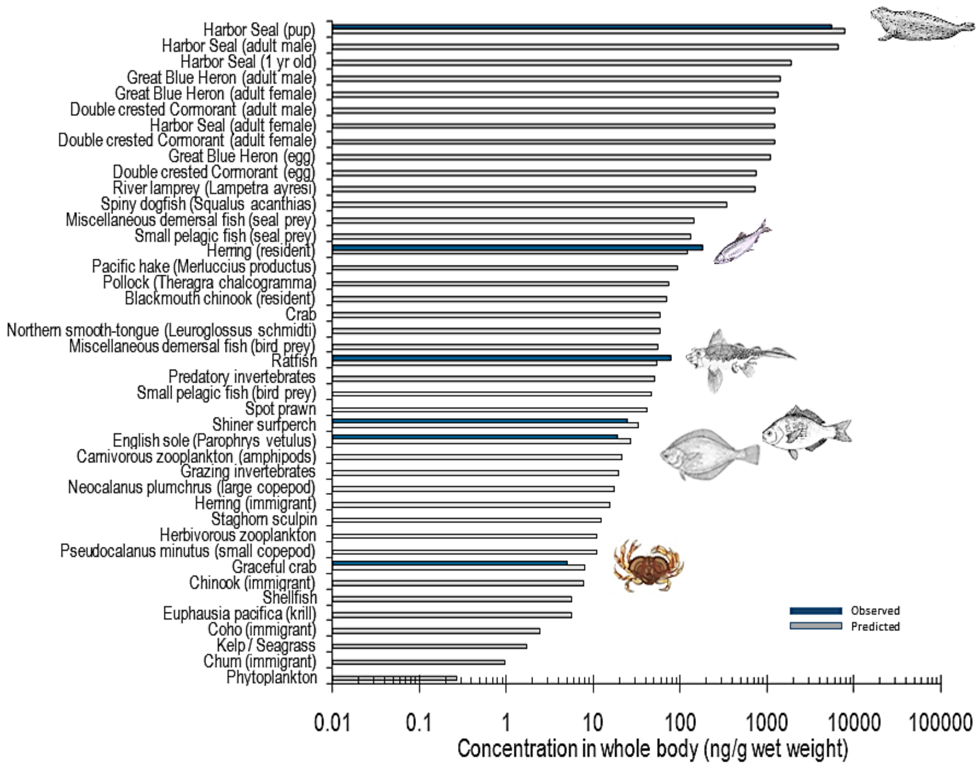
*From Table 3. Rank represents the relative expenditures of all 32 Toxics projects, from greatest to least invested.

The Puget Sound Regional Toxics Model (PSRTM) was developed by Ecology. The model estimates fate and transport as well as bioaccumulation of toxic chemicals (toxics). Initially, only PCBs were included in the model (Pelletier and Mohamedali 2009). Data collected during the *Assessment* supported the inclusion of other contaminants such as PBDEs, PAHs, copper, lead, and zinc (Osterberg and Pelletier 2015).

The fate and transport model underestimated the concentration of contaminants in water and sediments by five to 10 times. This is likely due to significantly lower watershed contaminant source loadings estimated in previously published studies. The model was successful at predicting food web bioaccumulation as compared to observed concentrations. Figure 9 compares PCB predictions from the 2009 modeling to available measured concentrations.

The bioaccumulation portion of the model can be used to estimate the maximum water and sediment PCB concentrations that keep biotic levels below a certain threshold. Thus, the model could generate concentration thresholds for water and sediment that correspond to a desired biota concentration.

Applying present PCB concentrations to the model shows that concentrations in water will continue to drive PCB levels with the 25$^{th}$ percentile concentration observed in sediments.




From Pelletier 2010, Figure 15

Figure 9. Puget Sound Regional Toxics Model predicted and observed PCBs.

# Discussion

## Comparison to the *Assessment* Recommendations

This Discussion section reviews recommendations made in *Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-11* (*The Assessment*) (Norton et al. 2011) compared to the work funded under the NEP Toxics and Nutrients cooperative agreement.

The *Assessment* made recommendations for controlling toxic chemicals (toxics) in Puget Sound. Many of the NEP Toxics projects addressed recommendations from the *Assessment*.

The *Assessment* recommended control of diffuse (nonpoint) sources of pollution by preventing their initial release, or reducing or treating stormwater inputs. NEP-funded projects such as the Local Source Control Partnership, ecoPRO, and Don't Drip & Drive; all work to prevent initial toxic releases, targeting nonpoint sources.

Several projects address toxics from vehicles: copper, zinc, PAHs, and petroleum. Legislation will limit the amount of copper in brake pads to less than 0.5 percent by 2025. PAH releases via petroleum leaks are being addressed by Don't Drip & Drive as well as the Clean Cars Partnership. No NEP Toxics projects addressed the recommendation for reducing PAHs from fuel combustion.

NEP Toxics projects, including the woodstove replacement program and the removal of creosote-treated pilings, contributed to PAH reductions recommended in the *Assessment*. Puget Sound-wide expansion of the woodstove replacement program is recommended. While removal of creosote-treated pilings can reduce PAHs, stringent protocols must be applied to ensure PAHs are not released during piling removal.

The Local Source Control (LSC) Partnership works with small businesses to reduce pollution. Other programs work with large-quantity waste generators.

Several NEP Toxics projects investigated roofing materials. Release rates from the studied roofing materials were lower than those found in the literature. Roofing components also merit investigation. Some components, such as gutters, will be assessed as a source of metals pollution in the ongoing copper and zinc study.

The *Assessment* recommended investigating pollutant sources and control methods in urban areas. A current project is investigating sources of copper and zinc in a commercial/industrial watershed. Pollution control mechanisms, additional contaminants, and land use types need to be investigated.

While NEP Toxics projects studied contaminants of emerging concern (CECs) in sediments, water, and several Puget Sound fish species, a pollutant loading study incorporating more contaminants has not been attempted.

Copper-based pesticide use by both residential and commercial applicators was evaluated in the pesticide-use survey, with little copper use reported.

The *Assessment* recommended a spatial review of available data to determine data coverage and robustness in order to identify locations and/or contaminants lacking coverage. This has not yet been completed.

Reductions in copper from brake pads should be occurring based on recent reformulations. A 2017 retail survey assessed compliance with the law. Ongoing monitoring required to meet municipal stormwater permits should show ongoing copper-reduction trends.

Copper-based antifouling paint has yet to be phased out. A baseline assessment of metals levels in marinas, funded through NEP Toxics and Nutrients, is presently underway.

Work is still needed to differentiate between legacy, natural, and current toxics sources in order to determine the feasibility for control. Legacy toxics include PCBs and DDTs. PCBs were discussed in the PCB Source Control Survey (Colton et al. 2016). However, control options are unclear. Natural sources of metals have not been partitioned from the overall loadings.

# NEP Toxics Projects

Most of the NEP Toxics funds continued or improved management of existing pollutant sources (59%); just under a third funded research (27%); and 14% supported innovative prevention efforts.

## Prevention

Preventing the use of toxic chemicals (toxics) is the cheapest and most effective approach to reducing toxic threats to humans and the environment. Several prevention projects were funded by NEP Toxics, such as the Green Chemistry Roadmap (Ecology and Commerce 2013) and the Reducing Toxic Threats initiative (Ecology 2015). The flexible funds allowed for innovative ideas and created proof-of-concept demonstrations for non-traditional approaches.

Redesigning products and processes can prevent or limit toxics release into the environment. Legislative attempts to limit toxics have resulted in several laws that either ban a class of chemicals (such as PBDEs) or limit the amount of certain chemicals in certain products (such as under the Children's Safe Products Act and the Better Brakes Bill).

## Management

Several NEP Toxics projects manage or reduce toxics from existing sources. The *Assessment* and the Chemical Action Plan for PAHs identified wood smoke and creosote-treated pilings as the largest sources of PAHs to Puget Sound (Norton et al. 2011; Davies et al. 2012). Two projects funded to reduce wood smoke showed potential for effective reductions in PAHs. Stove retrofit devices offer potential for wide-scale implementation due to their lower cost and easier installation. This work should be expanded throughout the Puget Sound region.

While removing creosote pilings is an important source control measure for PAHs, during removal significant amounts of creosote can be released. Both Ecology's Toxics Cleanup Program and the Washington State Department of Natural Resources (DNR) are sharing lessons and improving piling removal methods in order to reduce leaching during removals. An estimated 100,000 creosote pilings remain in Puget Sound (DNR 2014).

Vehicles and vehicle-related activities are sources of contaminants such as copper, zinc, PAHs, and petroleum. Projects funded included Don't Drip & Drive (DD&D). This program works to reduce petroleum leaks and is expanding throughout the region. The Clean Cars Partnership also can benefit the auto industry, consumers, and the environment. The two programs have the potential to reach the entire market of vehicles, old and new.

Surface water from storms was identified as the major pathway for most contaminants to Puget Sound. Recent municipal stormwater permits have expanded the breadth of management required from local jurisdictions (Ecology 2013, 2016b). Additionally, low impact development (LID) techniques are being required throughout Washington State to provide better stormwater management.

Recent studies have shown that bioinfiltration of runoff through compost and sand mixtures prevents coho pre-spawn mortality, documented as a consequence of stormwater run-off as early as 1988 (Kendra 1988; Feist et al. 2011; Scholz et al. 2011a; McIntyre et al. 2014; Spromberg et al. 2016).

Ongoing monitoring through the Stormwater Action Monitoring Program, as required in municipal Phase I and II NPDES permits, has the potential to provide valuable data to support management efforts.

Brake reformulations are expected to result in reduced copper on a Puget Sound watershed scale within the next decade (I. Wesley 2017, personal communication, Feb 9).

## Research

A comprehensive, coordinated monitoring program for Puget Sound is needed, one that assesses change over time and contaminants of emerging concern (CECs). It is also important to monitor source control and management actions to determine if they are effective at reducing toxics. Monitoring conducted after creosote-piling removal showed that significant amounts of creosote were released after removal. Therefore, more stringent protocols for piling removal were put into place.

The CEC investigations highlighted the difficulties and short-comings in toxics monitoring. Many of the CECs monitored have been on the market and in the environment for many years. For example, 3M voluntarily withdrew perfluorooctane sulfonate (PFOS) from its product line in 2002 amidst concerns of persistence and toxicity. Despite this, perfluorinated compounds continue to be used in many everyday products, including food packaging (Stone 2017a).

Monitoring programs usually target a limited number of contaminants and may miss others. This problem is due to current technological limitations and budget restrictions. Fortunately, new technologies, such as time-of-flight analysis (a broad spectrum, non-targeted analysis tool), are being developed. Such tools offer the potential for a much broader network of screening capabilities in the future. This includes the potential to detect new contaminants as they emerge.

Additionally, high-through-put toxicology screenings promise to provide better risk assessments at a more rapid pace than traditional whole-body toxicology tests have done (Villeneuve 2016). Applying such tools to a methodical monitoring regime could allow for more responsive reporting.

Research projects examined the sources of metals. The *Assessment* identified runoff and leaching from roofing materials as a major source of several metals. A study looking at runoff from experimental panels of various roofing types indicated much lower release rates than had been seen in the literature. The exception was the release of copper from copper-panel roofing (Winters et al. 2014).

The *Assessment* suggested non-agricultural pesticide use was a potentially significant source of copper to the Puget Sound basin. WSDA investigated copper use in pesticides. They found that few copper products were reported in the market-shelf survey or in use by residential users or licensed applicators.

The current study to assess sources of copper and zinc in a commercial/industrial watershed should help to determine contributions from other building materials, including additional roofing components.

# Lessons Learned

## Grant Administration

During the *Toxics and Nutrients Prevention, Reduction, and Control* cooperative agreement's operation period (2011-2018), changes in staffing created some variability in administrative approaches. This highlighted the benefit of having defined processes for some of the administrative elements. Key lessons include:

- Employ a streamlined tracking system, available to all staff involved. The tracking system should list all projects funded and key details for each, such as contacts, deliverables with timelines, funding amounts, agreement numbers, and associated publications and datasets.
- Establish a naming convention and filing system to be maintained throughout the grant administration process for all key documents.
- Include a copy of all finished documents in an electronic folder for each project funded.

Additionally, data management and quality assurance (QA) review for research projects is critical from the outset. The need for QA review was identified early on by the NEP Toxics and Nutrients Committee, resulting in joint funding of an Ecology-based QA Coordinator to ensure all NEP projects met a minimum QA standard (D. Norton, personal communication, 2017).

Data management should be budgeted into projects, including long-term data storage in a specified repository. Ecology's Environmental Information Management database (EIM) stores environmental data from monitoring projects statewide and is used to inform many management efforts. Data in EIM are publically accessible. EPA also requires water quality data in STORET; a project to transfer key NEP data from EIM to STORET is underway. Because the public is funding the collection of these data, making them publically available is a priority.

## Fostering Change

The prevention and management projects demonstrated that a multi-pronged approach is most effective in supporting the establishment of new paradigms. Three key elements emerged:

- Regulatory pressures—Legislative or permit requirements impose the impetus for change.
- Financial support—promotes the desired change.
- Regional collaboration networks—foster communication and create lasting and far-reaching impacts.

The importance of these three elements in concert can be seen when reviewing the successes and challenges faced by individual projects.

Regulatory requirements in permits and through legislation provide an impetus to change where none may otherwise exist.

Flexible funding provided the opportunity to advance toxics-reduction efforts on numerous fronts. This highlights the need for further flexible funding pools for managers to respond to existing needs.

The regional collaborative management arising in response to stormwater permits demonstrates the potential for successful coordination on a regional scale.

Regional collaborations enhance consistency and promote best practices among entities throughout the region. Higher-level organizations, such as state agencies, particularly the Puget Sound Partnership, could assist local jurisdictions by offering facilitation, developing tools, and providing networking and training opportunities.

## Persistent Organic Pollutants

PCBs and PBDEs are among the class of chemicals termed persistent bioaccumulative toxins (PBTs) or persistent organic pollutants (POPs). While many of these contaminants have been restricted for many years, we continue to expend resources to mitigate their presence in the environment. In the Puget Sound basin, the resident Orca are some of the most highly POP-contaminated species in the world (Ross et al. 2000).

Though the bulk of PCB sources have been controlled, and concentrations are declining, PCBs remain above levels of concern. PBDEs, while banned from further production, are still present in our products. Researchers report rising PBDE levels in sediment cores taken near the outfall of the Iona Island WWTP in Vancouver B.C. (Johannessen 2017), as shown in Figure 10.

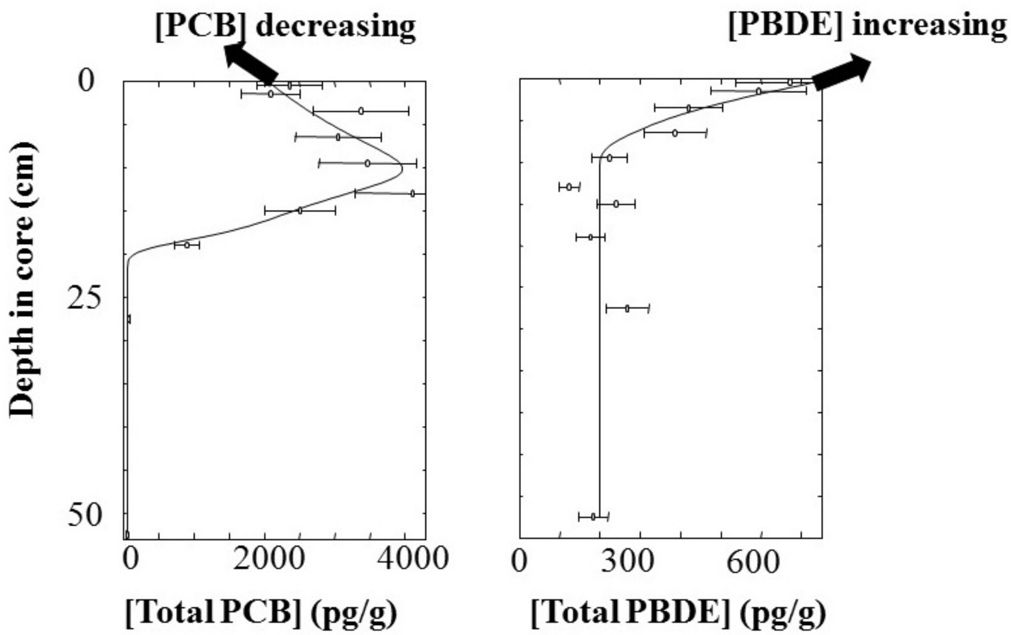



Figure 10. Trends in persistent organic pollutants (POPs) concentrations in sediments near a WWTP outfall.

Figure 1 from Johannessen 2017. Depth profiles of Total PCB and Total PBDE in a sediment core collected near Vancouver, B.C., just north of the Iona Island wastewater treatment plant (WWTP) outfall.

In Washington State, lake sediment cores obtained through the PBT monitoring program also show rising PBDE concentrations (Mathieu and McCall 2016), as shown in Figure 11. Changes in sediment-core concentrations lag behind changes in fish tissues; human-tissue and fish-tissue levels have been falling since the PBDE phase-out (C. Mathieu 2017, email to author, March 21).

In the *Assessment*, an estimated 44-56% of PBDEs to Puget Sound were from atmospheric deposition directly to the Sound, and 25-38% were from WWTPs (Norton et al. 2011).

PBTs continue to affect the biota and habitat of Puget Sound. PBTs are consistently found in samples at levels of concern, with the highest concentrations in developed areas. Once PBTs become a part of the environment, they are difficult to get rid of.

Efforts to mitigate toxics are only marginally successful and are very expensive. Source tracing at low levels is extremely expensive. Even when a pollutant source can be identified, it may not be addressed due to expense of remediation. For example, the City of Tacoma traced PCBs to large, caulk-laden buildings in its downtown corridor at a high cost to the city. However, the cost of removing and replacing the caulk is high, and a solution has yet to be achieved.

The best approach is to prevent toxics, particularly POPs, from entering the marketplace and our environment in the first place.

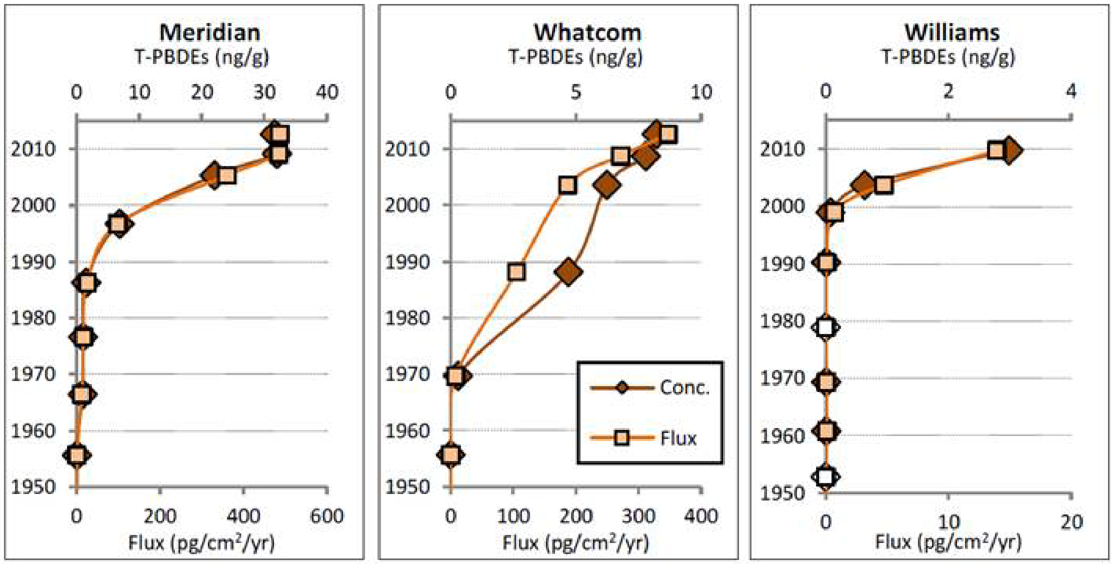



Figure 11. Sediment cores from two Puget Sound lakes (Meridian and Whatcom) and one eastern Washington lake (Williams) show rising PBDE levels.

# Conclusions and Recommendations

Results of this 2017 review support the following conclusions.

## Prevention is a priority

The cheapest and most effective approach to reducing toxic threats is to prevent the use of toxic chemicals (toxics) in our products and to keep them from being released to our environment. It is important to develop protocols that identify safer alternatives to toxics. This ensures that when toxics are phased out, they are replaced with non-toxic or less toxic substitutes. The prevention approach relies on alternative assessments, sustainable design, and Green Chemistry.

## Stormwater conveys pollutants, including toxics, to Puget Sound

Impervious surfaces such as asphalt carry stormwater to storm drains instead of allowing stormwater to percolate through soils.

The more intensely developed areas of the Puget Sound region receive the highest concentrations of toxic inputs. Impervious surfaces are directly correlated to poorer stream health. Projects funded did not directly investigate the relationship between development and toxics.

Control mechanisms, such as low-impact development, bioinfiltration, and stormwater treatment, can help protect Puget Sound aquatic life from toxics. Several methods of treatment for stormwater pollution are being implemented around the Puget Sound region. Monitoring results should be periodically reviewed to assess the effectiveness of pollutant source control.

## Toxics reduction is essential in restoring healthy salmon populations in Puget Sound

Adult salmon, primarily Coho, returning to spawn in urban streams of the Puget Sound region have been prematurely dying at high rates (up to 90% of the total runs). Toxics from land-based runoff have been identified as the cause (Feist et al. 2011). In addition, juvenile salmon that travel through urban areas to Puget Sound accumulate toxics at levels of concern. Reductions in toxics to streams are essential for restoring salmon populations.

It is important to assess the efficacy of bioretention treatments to reduce stormwater toxicity. This would prevent pre-spawn mortality in urban environments and reduce accumulation of toxics in juvenile salmon traveling to Puget Sound via urban streams.

## Data are needed to assess the impact of CECs in Puget Sound

More research is needed on contaminants of emerging concern (CECs), including their spatial distribution, impacts to aquatic life, and sources. While some research has occurred, more information is needed on the wide range of CECs (e.g., pharmaceuticals, personal care products, brominated flame retardants, nanomaterials).

Development of actions to control CEC discharge to Puget Sound (e.g., increase take-back programs and education campaigns to promote responsible disposal of pharmaceutical products).

## Groundwater sources of toxics should be investigated

The work done in *Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-11* (The *Assessment*; Norton et al. 2011) for pollutant loading from groundwater was preliminary. Pollutant volume estimates are uncertain, and data on many contaminants were lacking.

## Pollutant source control and management actions must include a monitoring component to determine effectiveness

Both the creosote-piling-removal effectiveness monitoring and the PCB source-tracing review revealed ongoing contamination from remediated sites. Source control actions were modified due to these findings. This led to more effective source-control work.

## Continued implementation of source control actions and recommendations from the *Assessment* is needed

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Asohmbom, Justine. Washington State Department of Ecology, Don't Drip and Drive.

Benson, Tony. Bothell Local Source Control.

Chapman, Brad. Washington State Horticulturist.

Chavez, Breanne. Executive Director, ecoPRO.

Colton, Jenée. King County.

Dutch, Margaret.  Washington State Department of Ecology, PSEMP.

Heine, Lauren.  Executive Director of Northwest Green Chemistry.

Johnson, Jennifer.  Thurston County Health Department.

Kamieniecki, Steve.  Pierce County Planning and Public Works.

Malatinsky, Bill.  Seattle Public Utilities, Automotive Maintenance Program.

Mathieu, Callie.  Washington State Department of Ecology, PBT Monitoring Lead.

McLain, Kelly. Washington State Department of Agriculture.

Morgan, Peggy.  Washington State Department of Ecology, Statewide Coordinator for the Local Source Control Program.

Norton, Dale. Washington State Department of Ecology.

Schmoyer, Beth.  Seattle Public Utilities.

Shoemaker, Monica.  Washington State Department of Natural Resources, Restoration Coordinator.

Stone, Alex.  Formerly of Washington State Department of Ecology.

Warfield, Meg.  Washington State Department of Ecology.

Warren, Amy.  Project Manager for PSCAA's Woodstove Buy-Back Program.

Wesley, Ian.  Washington State Department of Ecology.

Zarker, Ken.  Washington State Department of Ecology.

# Glossary, Acronyms, and Abbreviations

## Glossary

**Anthropogenic:** Human-caused.

**Assessment, The:** Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-11 (Norton et al. 2011).

**Effluent:** An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

**National Pollutant Discharge Elimination System (NPDES):** National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

**NEP Toxics and Nutrients Committee:** The Department of Ecology and partner agencies that distribute Toxics and Nutrients grant funds. Partner agencies include the U.S. Environmental Protection Agency, Puget Sound Partnership, and Washington State Department of Health.

**Nonpoint source:** Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

**Parameter:** Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

**Point source:** Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

**Phase I and II:** Under the State general NPDES Municipal Stormwater Permit, refers to Permittee status, based on the size of the jurisdiction permitted, Phase I Permittees are larger jurisdictions.

**Pollution:** Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

**Stormwater:** The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

**Toxics:** Toxic chemicals.

**Watershed:** A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

## Acronyms and Abbreviations

| | |
|---|---|
| AMP | Auto Maintenance Program |
| BMP | Best management practice |
| CAP | Chemical Action Plan, Washington State Department of Ecology's |
| CDR | Chemical Data Reporting database |
| CEC | Contaminant of emerging concern |
| CPE | chlorinated phosphate ester |
| CSPA | Children's Safe Products Act, Washington State's |
| CPE FR | chlorinated phosphate ester flame retardants |
| DD&D | Don't Drip & Drive program |
| DDT | dichloro-diphenyl-trichloroethane |
| DEHP | bis(2-ethylhexyl) phthalate |
| DNR | Washington State Department of Natural Resources |
| DOH | Washington State Department of Health |
| Ecology | Washington State Department of Ecology |
| EC | estrogenic compound |
| EDC | endocrine disrupting compound |
| EIM | Environmental Information Management database |
| EPDM | ethylene propylene diene monomer |
| EPA | U.S. Environmental Protection Agency |
| FPUF | flexible polyurethane foam |
| IC2 | Interstate Chemicals Clearinghouse |
| IDDE | Illicit [Stormwater] Discharge Detection and Elimination |
| LSC | Local Source Control |
| NEP | National Estuary Program |
| NFA | No Further Action, Designation for Cleanup Site |
| NPDES | (See Glossary above) |
| NTR | National Toxics Rule |
| NWGCC | Northwest Green Chemistry Center |
| OLC | Oregon Tilth Organic Landscaper Certification |
| PAH | polycyclic aromatic hydrocarbon |

| | |
|---|---|
| PBDE | polybrominated diphenyl ether |
| PBT | persistent, bioaccumulative, and toxic substance |
| PCB | polychlorinated-biphenyl |
| PCDD/F | polychlorinated dioxin and furan |
| PFAS | perfluoroalkyl substances |
| PM | particulate matter |
| POP | persistent organic pollutants |
| PPCPs | pharmaceuticals and personal care products |
| PSAMP | Puget Sound Ambient Monitoring Program, now PSEMP |
| PSCAA | Puget Sound Clean Air Agency |
| PSEMP | Puget Sound Ecosystem Monitoring Program, formerly PSAMP |
| QAPP | quality assurance project plan |
| RSMP | Regional Stormwater Monitoring Program |
| RTT | Reducing Toxic Threats Initiative, Washington State Department of Ecology's |
| SAM | Stormwater Action Monitoring |
| SIDIR | [Stormwater] Source Identification and Diagnostic Monitoring Information Repository |
| SIL | Strategic Implementation Lead (Under the Puget Sound Action Agenda) |
| SPU | Seattle Public Utilities |
| STORM | Stormwater Outreach for Regional Municipalities |
| SSRI/s | selective serotonin reuptake inhibitors |
| SWG | Stormwater Work Group |
| TCEP | tris(2-chloroethyl) phosphate |
| TCPP | 2-propanol, 1-chloro-, phosphate |
| TDCPP | 2-propanol, 1,3-dichloro-, phosphate |
| VTG | vitellogenin |
| WAC | Washington Administrative Code |
| WDFW | Washington Department of Fish and Wildlife |
| WRIA | Water Resource Inventory Area |
| WSDA | Washington State Department of Agriculture |
| WWTP | Wastewater treatment plant |

*Units of Measurement*

| | |
|---|---|
| ft | feet |
| g | gram, a unit of mass |
| gpd | grams per day |
| kg | kilograms, a unit of mass equal to 1,000 grams |
| kg/d | kilograms per day |
| ng/g | nanograms per gram (parts per billion) |
| ng/Kg | nanograms per kilogram (parts per trillion) |
| ng/L | nanograms per liter (parts per trillion) |
| ug/L | micrograms per liter (parts per billion) |
| yr | year |

# Appendix. Project Summaries

The Appendix is posted to the web as a separate pdf file at:
https://fortress.wa.gov/ecy/publications/SummaryPages/1703003.html