STORMWATER ACTION MONITORING

Effectiveness Study

Source Identification

Receiving Waters

Studies Completed During the 2013-2019 Municipal Stormwater Permit Term

SAM

Stormwater Action Monitoring

July 2019

Dear fellow stormwater professionals and interested stakeholders,

I invite you to learn about the Stormwater Action Monitoring (SAM) study findings from the 2013-2019 municipal stormwater permit term. SAM began in 2014 and funded 22 studies to date. This booklet compiles fact sheets from 12 completed studies, and an interim report on a ten-year study, to provide you a single source of the scientists' collective findings and how the Washington State Department of Ecology (Ecology) has applied this new information.

SAM provides a framework for partnership and collaboration for monitoring stormwater management effectiveness and impacts at a regional scale. Ninety four Western Washington permittees chose to meet permit monitoring requirements by funding SAM directly. State and federal agencies, businesses, and volunteers have provided funds or services to collaborate with SAM and leverage our work. By learning together we can achieve far more than by funding studies individually, and we all benefit by answering regionally relevant questions. Our understanding, and our responses to improve and manage stormwater, are coming faster and more efficiently than before SAM.

I've arranged this booklet according to the three SAM focus areas:

Effectiveness Study — Studies to measure the effectiveness of stormwater management approaches

Source Identification — Projects to identify and address the most common sources of stormwater pollution

Receiving Waters — Studies to measure stormwater impacts and trends over time in small streams and nearshore areas

SAM's early successes are due to sustained commitment by jurisdictions' stormwater staff to committee work that keeps SAM focused on topics most relevant to stormwater management actions and activities. Along with Karen Dinicola and Keunyea Song, the other SAM staff at Ecology, I want to extend my gratitude to the Stormwater Work Group (SWG) for coming up with the novel idea for SAM, continuing to shape it, and creating the Pooled Resources Oversight Committee (PRO-C) to supervise Ecology's administration of this new collaborative monitoring program. We look forward to completing the studies currently underway and launching projects to address new topics during the 2019-2024 permit term.

Enjoy!

Brandi Lubliner, PE
SAM Coordinator
Water Quality Program | Washington State Department of Ecology
Ecology.wa.gov/SAM

ABOUT SAM

Stormwater Action Monitoring

Stormwater Action Monitoring (SAM) is a collaborative, regional stormwater monitoring program that is funded by more than 90 Western Washington cities and counties, the ports of Seattle and Tacoma, and the Washington State Department of Transportation. SAM's goal is to improve stormwater management to reduce pollution, improve water quality, and reduce flooding. We do this by measuring stormwater impacts on the environment and evaluating the effectiveness of stormwater management actions.

Note: the Regional Stormwater Monitoring Program (RSMP) changed its name to Stormwater Action Monitoring (SAM) in 2017 in recognition of SAM's broader role – using the results of monitoring and studies to inform policy decisions and identify the most effective management actions.

Why SAM is Important

Stormwater pollution is one of the biggest threats to western Washington streams, lakes, and Puget Sound. Stormwater runoff from developed areas drains to local water bodies, where it releases pollutants, causes flooding, erodes streams, harms salmon, and closes shellfish beds.

SAM identifies effective actions and tracks regional progress reducing pollution and flooding associated with stormwater. SAM projects are developed in an open and coordinated way. The goal is to capture a regional understanding of how management actions can lead to results. Stormwater managers, field practitioners, and policy makers can use SAM findings to improve management practices and to set project and funding priorities.

The pooling of funds allows jurisdictions – large and small – throughout the region to benefit from SAM projects that are designed to produce transferable findings. Any jurisdiction with science staff, expertise, and interest can participate in SAM studies. Those without science staff, particularly smaller jurisdictions with limited capacity and resources to conduct monitoring, can benefit from these collective efforts. Jurisdictions may also leverage SAM funds to answer relevant local questions. All permittees implement SAM findings to protect lakes, rivers, local streams, and Puget Sound.

How SAM Works

Collectively, municipal stormwater permittees in western Washington spend an estimated $250 million per year to manage stormwater and they invest about one percent of these expenditures into a pooled fund.

SAM efforts produce actionable findings in three focus areas.

Effectiveness Study

How well are required or innovative stormwater management practices working? Our **effectiveness studies** answer why or why not, and under what conditions, various management approaches work or fail.

Source Identification

What are the most common types of pollution in stormwater? Our **source identification** projects identify the most common problems and propose regional actions.

Receiving Waters

How do we know if water quality is getting better or worse? Our **receiving waters** projects evaluate conditions in the water bodies that we are trying to protect. This approach is unique since no other monitoring in the state is designed to give feedback on permitted areas.

The Long View

SAM's unique design provides flexibility to accomplish long-term results. Our projects are not limited by grant program timelines or permit expiration dates. SAM projects deliver concrete interim and final products, and provide useful information throughout the duration of each individual project.

Our Partners

The Stormwater Work Group (SWG), a formal stakeholder group, defines SAM activities. The Pooled Resources Oversight Committee (PRO-Committee), a subgroup of the SWG, oversees transparency, efficiency, and accountability of SAM expenditures. The Washington State Department of Ecology serves as the administrative entity that manages SAM funds and executes SAM contracts. State and federal agencies provide in-kind leadership and support on projects.

What is NPDES?

NPDES stands for National Pollutant Discharge Elimination System. It is the federal Clean Water Act's permitting approach to reduce the impacts of stormwater by requiring local governments, ports, the state department of transportation, and other large public landowners to implement specific practices. In Washington, the State Department of Ecology writes and issues these permits as the U.S. Environmental Protection Agency's delegated authority.

The permits require:

- Public education, involvement, and participation;
- Active management of stormwater runoff from construction projects and developed areas;
- Operation and maintenance (like sweeping and other cleaning) of roads, ponds, parking lots, catch basins, and other parts of the storm sewer system; and
- Efforts to prevent spills and remove illegal sources of pollution in stormwater.

Effectiveness Study

Bioretention reduction of stormwater toxicity to Coho salmon

Bioretention hydrologic performance evaluation

Rain garden and bioretention assessment protocol

Business inspection source control

Catch basin inspection and maintenance

Stormwater retrofits along Highway 99 near Echo Lake

Regional stormwater facility retrofit in Federal Way

Redmond paired watershed retrofits

Testing the effectiveness of bioretention at reducing the toxicity of urban stormwater to Coho salmon

Effectiveness Study

Lead Entity:
Puget Sound Stormwater Science Team

Partners:
U.S. Fish and Wildlife Service, NOAA-Fisheries, Washington State University, and Suquamish Tribe

For more information: See the project website at wastormwatercenter.org/jenifermcintyrespublications.
Visit Ecology.wa.gov/SAM and search for Coho toxicity reduction by bioretention.

Study questions

Bioretention is a common choice for stormwater treatment (filtration through an engineered soil mix) and infiltration in Washington State.

- Is the standard 60% sand 40% compost (60:40 mix) bioretention soil media (BSM) specified by Ecology's stormwater management manual effective enough to prevent toxic impacts of urban runoff from multiple storms to Coho salmon adult spawners and embryos?
- Do contaminants leached from the BSM contribute to water quality problems?

Stormwater management problem

Bioretention is shown to be a highly effective means of reducing many pollutants in stormwater runoff, especially contaminants associated with particulate matter. Bioretention treatment prevented toxicity from road runoff in a single test with juvenile Coho, mayfly nymphs, and daphnia. Pilot work filtering stormwater runoff through bioretention soil media columns showed reductions in metals and PAHs. Recent work has shown that toxicity of road runoff to developing fish is associated with dissolved contaminants rather than particulates.

The 60:40 mix commonly used contains bacteria, nutrients, and metals that are sometimes leached out during stormwater treatment. There is concern that bioretention may be exacerbating water quality problems in some settings, particularly in salmon spawning streams and in lakes and other phosphorus-sensitive water bodies.

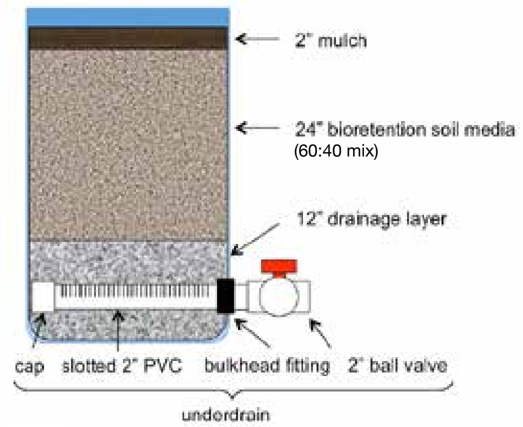


Diagram of bioretention unit using 55-gallon drum.

Project findings

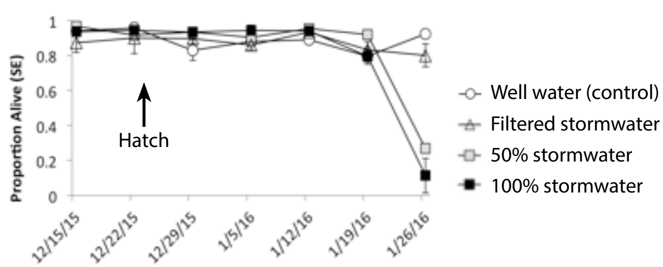
Installing green infrastructure with bioretention treatment cleans urban stormwater runoff sufficiently to help protect sensitive life history stages of salmon species. Results showed the standard BSM provides adequate treatment across numerous storms. Bacteria, nutrients, metals, and polycyclic aromatic hydrocarbons (PAHs) were measured before and after filtration. Concentrations of all of these contaminants except arsenic, nickel, and nutrients were lower in filtered stormwater than in untreated stormwater for the same storm event.

Filtering stormwater through BSM prevents lethal stormwater impacts to adult Coho spawners. Unfiltered stormwater killed 100% of Coho exposed in these experiments, while 100% of Coho exposed to filtered stormwater survived. Bioretention filtration also prevented mortality in Coho embryos episodically exposed to urban stormwater runoff. However, some sublethal effects were observed. Untreated stormwater induced a gene responsible for PAH detoxification (*cyp1a*) on all sampling dates, with the highest induction during exposure and somewhat lower levels on days with clean water. Filtered stormwater rarely induced *cyp1a*. Evidence of cardiac stress (induction of the gene *nppb*) was only present during exposure to runoff, not days with clean water; however filtration through bioretention did not prevent *nppb* induction. The same chemicals may not be triggering the PAH detox and the cardiac stress.

There was a net export of arsenic, nickel, nitrogen, and phosphorus from the BSM, with low concentrations that were higher in the effluent than influent water across the ten treatment events. Although the BSM also contained measurable amounts of other metals, there was a net removal of zinc, copper, chromium, lead, and cadmium from runoff. Most importantly, the study found that sufficient dissolved organic carbon is released from BSM to bind dissolved copper and make it biologically unavailable. More than half of the untreated stormwater samples were predicted to be neurotoxic, whereas none of the BSM filtered stormwater samples were predicted to be neurotoxic. BSM filtration also reduced bacteria. PAHs were always reduced by bioretention treatment, showing an overall 91% reduction. There was no apparent loss of chemical performance after repeated treatment of highway runoff through bioretention.

Recommendations

Bioretention filtration of urban stormwater runoff can prevent pre-spawn mortality in adult Coho salmon during 24 hour exposures and eliminate toxic impacts to Coho embryos developing in episodic exposure to runoff. Assessing the biological benefits of bioretention to receiving waters is mentioned only at the basin scale in the recent review. In contrast, biological impacts should be incorporated at smaller scales in order to increase the likelihood of ecological success as we move towards larger and more comprehensive installations.



Survival of Coho embryos in unfiltered stormwater runoff was high from fertilization until after hatching, when most coho died. Mortality in hatched coho was high in both diluted and undiluted unfiltered stormwater. By contrast, there was very little mortality among embryos in well water (the control) and in the filtered stormwater.

Why does this study matter?

Untreated stormwater has been found responsible for Coho salmon pre-spawn mortality in streams in our region; stormwater also causes numerous sublethal effects. Bioretention is a promising solution to this problem. Knowing that the required treatment practices are protective of embryos and adult spawners provides confidence in widespread application of bioretention. These results confirm that treating stormwater using bioretention with the standard 60:40 mix prevents toxic and lethal effects to Coho salmon.

What should we do with this information?

Stormwater managers should continue to install bioretention systems as opportunities arise. Permittees should implement Ecology's guidance for applying bioretention to projects in Western Washington. Bioretention treatment with BSM can be incorporated at any scale, even very small scales, when planning stormwater retrofit projects. Permittees should encourage developers to include bioretention in all site plans for new development, redevelopment, and retrofit projects where bioretention is feasible.

What will Ecology do with this information?

Ecology's stormwater management manual will continue to specify the 60:40 mix as the standard BSM for bioretention. Ecology will continue to discourage underdrains below bioretention facilities due to the lack of flow control and likelihood of transporting nutrients to receiving waters. Meanwhile, stormwater management continues to evolve and Ecology will continue to support studies to improve BSM to reduce nutrient export and not increase toxicity.

Bioretention Hydrologic Performance Study, Phase 1

Effectiveness Study

Lead Entity:
City of Bellingham Public Works Natural Resources

Partners:
Cities of Bellingham, Bellevue, Issaquah, Mill Creek, and Poulsbo Thurston and Pierce Counties, Clear Creek Solutions, Taylor Aquatic Science Associated Earth Sciences, Aspect Consulting, Raedeke Associates.

For more information: Go to Ecology.wa.gov/SAM and search for bioretention hydrologic performance.

Study goals

The Bioretention Hydrologic Performance Study, Phase 1 is the first field-scale regional verification of the performance of early (pre-2012 design) bioretention facilities in Western Washington. The goal of the study was to evaluate how well the modeled expectations for stormwater flow control actually match observed and measured real-world performance. From this assessment, we identified elements of the site designs and performance constraints that should inform the design, model, and review processes to ensure more efficient and predictably performing facilities.

Stormwater management problem

While the use of bioretention facilities in new and re-development is increasing rapidly, there has been little formal scientific assessment of the hydrologic performance of locally-constructed facilities. As population grows and developable area is increasingly scarce, and as natural stream channels remain vulnerable to stormwater runoff, local governments need evidence that these facilities are efficient and effective for protecting water quality in receiving waters. The first step is to confirm that the models, design guidance, and baseline assumptions result in functional facilities during seasonal variations and throughout their expected life cycles.

Project findings

Ten existing bioretention facilities were selected for hydrologic evaluation. We evaluated their performance using a multi-disciplinary approach. Findings include:

Geotechnical and Soil Conditions

Site-specific geotechnical or hydrogeologic data was lacking for early bioretention facilities. Most of the native soil infiltration results were from adjacent geotechnical work. Infiltration rates for subsurface soils, typically outwash soils, were significantly greater than expected in about half the cases. Bioretention soil texture was coarse, resulting in greater infiltration rates than would be expected under the current specifications.

Site Design and Hydrologic Performance

Early bioretention performed better than expected and beyond safety factors during the study. It is plausible that some of the design mis-steps (not getting geotechnical information or getting coarser than modeled soil media) masked design errors or incorrect assumptions. The Western Washington Hydrology Model (WWHM 2012) provided accurate representation of observed hydrology at the sites including the ponding and groundwater response. Early bioretention designs used a variety models that adequately represented these bioretention facilities. Modeling problems, when found, were due to misrepresentation of the bioretention facility using a stormwater pond or gravel trench in the original model set-up.

Vegetation Survival and Establishment

Bioretention soils, and often native soils, drain rapidly. Plants should be drought tolerant, limiting the applicability of wetland species. Shrub species were surviving well. Herbaceous species are less adaptable and some species depended on irrigation. Multiple herbaceous species in a site design tend to transition to a less diverse plant community, due to conditions that are often drier than anticipated during the summer. Recurring problems include plant die-off, invasive species, having to replant cells, and greater maintenance needs than resources allow.

Recommendations

Key recommendations to improve bioretention performance include:

For jurisdictional designers/engineers/landscape architects

- Conduct observations during facility construction to confirm subsurface geologic and groundwater conditions.
- Have inspectors confirm contributing areas and overflow elevations on site.
- Improve plan review to adequately incorporate geotechnical recommendations.
- Select plant species that are consistent with each other for growing success (e.g., ensure that shrubs will not excessively shade herbaceous plants).
- Simplify the planting plan and match institutional or residential owners' needs and commitment to maintenance.
- Include a maintenance schedule and contingency plans in the bioretention design specifications.

For scientific agencies/Department of Ecology:

- Consider updating WWHM 2012 to include multiple soil layer depths, a leaf litter layer, and to set default evapotranspiration rates based on vegetation types.
- Conduct sensitivity analyses using WWHM 2012 to determine the magnitude of effect of infiltration rate variability, contributing drainage area, and use of regional rainfall records on facility performance.

Why does this study matter?

This study verifies that older bioretention facilities perform to modeled expectations for stormwater flow control. Over time, this performance appears to persist despite localized changes in vegetation, soil structure, and/or contributing area. The few facilities that were not performing entirely as expected also provided valuable lessons to include in the study recommendations.

Using the data collected from this study and the professional assessments and recommendations based on those data, we can make improvements to technical guidance, design methodologies, and review processes that govern the use of bioretention. As a result of this study, these changes can be implemented to ensure that future bioretention systems are designed, installed, and maintained to maximize water quality protection.

What should we do with this information?

Stormwater managers now have the evidence that early generation bioretention facilities generally perform as expected via WWHM 2012 to control stormwater runoff. Permittees should inspect sites for short circuited flow paths. When designing and building new bioretention facilities, designers should obtain site-specific information on infiltration rates and develop more drought tolerant planting plans.

What will Ecology do with this information?

Ecology will update the manual and encourage regional partners not to use wetland-obligate species when designing bioretention facilities. Ecology will consider updates to the evaporation rates in WWHM 2012. However, creating a leaf litter layer in the model is not likely at this time. Ecology looks forward to the results of Phase 2 of this study, which will evaluate hydrologic performance of current (post-2012) bioretention facilities.

Rain Garden and Bioretention Assessment Protocol

Effectiveness Study

Lead Entity: City of Puyallup

Partners : Stewardship Partners and Washington State University Extension

For more information: Go to Ecology.wa.gov/SAM and search for raingarden and bioretention assessment protocol.

Study goals

The purpose of the project was to create an easy-to-use field protocol for anyone to use to assess the condition and maintenance needs of a bioretention facility or rain garden in the Puget Sound region. The goals of the project were to:

- Develop data collection methods that are volunteer- and staff-friendly and do not need extensive equipment or access to lab facilities,
- Collect defensible data,
- Better understand landowner values about rain gardens and bioretention purpose, maintenance and acceptance.
- Determine what maintenance incentives landowners might need,
- Provide an initial assessment of rain garden and bioretention function, and
- Create a consistent protocol to assess functionality and help prioritize facilities that need maintenance.

Stormwater management problem

Rain gardens and bioretention facilities are cost-effective tools in the Low Impact Development (LID) toolbox that are being implemented at an accelerating rate in Washington State. In most jurisdictions these facilities have not been assessed for function. In jurisdictions where facilities have been assessed, data are not collected in the same or comparable manner. A tool is needed to uniformly evaluate local and region-wide effectiveness, and to identify common issues that might be more effectively addressed at the regional scale.

Project findings

The Rain Garden and Bioretention Assessment Protocol was developed in two iterations of methodology development and field testing using both trained and untrained volunteers. For field testing of the second version, 77 volunteers in four counties (Pierce, Snohomish, Thurston and Jefferson) received eight hours of training. Six additional volunteers conducted assessments without any formal training; these "untrained" volunteers received the identical instructions developed with the assessment protocol and used by the trained volunteers. Working in teams of 2-3, volunteers assessed 41 sites. At most sites, a different team of volunteers conducted repeat assessments. This field testing with all these different people demonstrated:

- The assessment protocol provides replicable results,
- The assessment provides an overall indication of the current state of a rain garden or bioretention facility,
- The assessment appropriately identifies if maintenance actions are needed,
- Extensive training is not necessary, but some training is suggested (even if self-directed),
- The assessment provides sufficient detail to indicate if a site needs further actions, and
- The assessment can provide direction for future maintenance and some design considerations.

The assessment protocol yields information that can:

- Flag important functional issues related to hydrology, vegetation, and public perception,
- Identify facilities that are prone to issues,
- Indicate issues of concern and guide remediation, and
- Identify common issues that might be addressed at a regionally coordinated scale.

The assessment protocol cannot:

- Precisely quantify hydrologic performance,
- Precisely quantify overall effectiveness of one facility, or of bioretention in general, nor
- Quantify treatment performance.

Recommendations

New rain gardens and bioretention facilities should be assessed at least twice in the first year following construction to assure success of plantings and facility function. Less frequent assessments are recommended for established facilities. Assessments should be conducted periodically and coordinated so that maintenance and issues that are identified may be corrected immediately. Instructions for maintenance activities could be integrated into the assessment protocol.

Municipalities should use the assessment protocol so that information collected can be easily compared to data from other municipalities across the region. Standardized data is critical for regionally coordinated analysis of the ongoing and long-term effectiveness of rain gardens and bioretention facilities.

A combined data form/data entry system should be developed as an app or webform for mobile devices, integrated with a data management system and database that is georeferenced and shareable. The mobile system could link to instructions for each part of the assessment protocol and indicate maintenance activities that should be performed.

The study leads recommend a regional entity oversee, manage, and own the assessment data. Oversight of the assessment database could be minimal, but with more effort, more value could be derived from the data, such that with adequate quality assurance, data analysis at the regional scale could be used to ask and answer questions about effectiveness of design, installation and maintenance, and inform best practice recommendations in the future.

Why does this study matter?

Many jurisdictions and individuals have invested in rain gardens and bioretention facilities as green stormwater management strategies. A consistent methodology to assess the functionality and ongoing management needs of these facilities will improve jurisdictions' ability to manage and utilize these facilities, as well as their confidence in requiring their use. The Rain Garden and Bioretention Assessment Protocol provides consistent methodology that will allow jurisdictions to compare their information at the regional level and potentially collaborate on solutions to common issues.

What should we do with this information?

Stormwater managers should have staff and/or volunteers implement the assessment protocol and use the outcomes to identify maintenance needs. Permittees can use the outcomes to inform, refine, and improve their rain garden and bioretention efforts. The assessment can help permittees determine their staffing needs and prioritize maintenance activities.

What will Ecology do with this information?

Ecology will encourage permittees to use the assessment protocol to help them prioritize maintenance needs. Ecology will support efforts to develop a mobile app on an appropriate platform and to subsequently analyze data from jurisdictions across the region.

Business Inspection Stormwater Source Control Effectiveness Study

Effectiveness Study

Lead Entity: City of Lakewood

Partner: Aspect Consulting LLC, Cardno Inc.

For more information: Go to Ecology.wa.gov/SAM and search for SAM Business Source Control Survey.

Study goals

This study's goals were to compile and analyze data from permittees' business inspections to identify:

- Which types of businesses are inspected;
- What best management practices (BMPs) are implemented well;
- What BMPs need improvement;
- Which business types need follow-up inspections to achieve proper and consistent BMP use; and
- Other factors that make stormwater source control inspections effective.

Stormwater management problem

Businesses with activities that can potentially cause stormwater pollution need to understand the value and effective use of stormwater source control and treatment BMPs. Some business sectors with high potential to pollute also have substantial employee turnover and untrained staff. This can lead to a lapse in implementation and maintenance of BMPs, resulting in polluted runoff entering the stormwater system. Stormwater managers can more effectively use staff time for these pollution prevention efforts if they know types of businesses to inspect, inspection frequency, which BMPs are most likely to be issues, and the most needed technical assistance.

Project findings

The study gathered survey responses from municipal stormwater permittees in western Washington. More than 47,300 inspection records were analyzed from 40 jurisdictions, Ecology's Local Source Control Partnership (LSCP), and the Urban Waters Initiative. The 27 types of businesses in the records were grouped into six business categories. The three most frequently inspected categories where:

- **Auto/boat**: vehicle sales, repair, maintenance, transportation, and fueling;
- **Food/retail**: food stores, restaurants, food production, and hotels; and
- **Land usage**: construction, recreation, and landscaping.

Inspection frequencies ranged from eight to 16 months. The auto/boat category had the most frequent inspections and it also had the most follow-up inspections focused on BMPs for cleaning and washing and for storing and covering materials to prevent leakage, spills, or contact with precipitation.

Other issues repeatedly identified across many business types included BMPs for housekeeping, spill planning, and transfer of materials. Regular attention to proper BMP use and BMP maintenance during inspections will likely help reduce the potential for lapses in proper BMP implementation and increase overall environmental compliance.

Recordkeeping by the permittees doing inspections is inconsistent due to the non-prescriptive approach in the municipal stormwater permits. The data from the LSCP were of consistent quality and completeness per the program requirements and easily evaluated.

Recommendations

Inspect businesses with outdoor activities and all those in the auto/boat, food/retail, industrial, and land usage categories. Assess the risk of pollution potential at each business and inspect high-risk businesses annually or every other year. Where issues are identified, revisit those businesses more often (monthly or quarterly) until the problem is resolved.

Standardize record-keeping. Collect these basic data during business source control inspections:

- Date and type of inspection (full inspection, screening, or follow-up);
- Specific types of operational, structural, and treatment BMPs in use;
- BMP maintenance records;
- Type of technical assistance provided during the inspection; and
- Reasons for lack of BMP implementation, *e.g.*, financial burden, need technical assistance, or maintenance issues.

Consider developing a system for inspectors to evaluate businesses' overall compliance. This could be done by scoring each specific BMP type as to its effective and proper use at the site on a numeric scale from 1 to 5.

Evaluate data collected under source control programs to learn from past efforts and advance stormwater source control efforts.

Do a follow-up study to determine the most optimum inspection frequencies for specific business types. This will also answer questions about barriers to BMP compliance, the most effective technical assistance in the LSCP program, and the optimum inspection frequencies for existing business inspection programs.

Why does this study matter?

Many types of businesses have the potential for illicit discharges and spills into municipal stormwater systems. This study informs stormwater managers about past inspection efforts and makes recommendations for ways to create or improve permittees' business inspection programs. The results help permittees and permit writers focus their efforts for the greatest potential impact: preventing stormwater pollution at its source.

What should we do with this information?

Stormwater managers should use the outcomes of this study to inform, refine, and improve the effectiveness of their source control efforts. This study can help permittees determine their staffing needs and priorities for where to inspect, how often to conduct inspections, and what to look for. Being prepared for possible spills is important, but so is proper materials storage and BMP maintenance. Municipal stormwater permittees who do not already have business inspection programs should consider prioritizing screening level inspections of the auto/boat, food/retail, industrial, and land usage types of businesses that exist in their jurisdictions. Permittees with existing inspection programs should consider optimizing inspection frequencies based on the findings of this study and their own records. The information can also be used to develop tailored education and outreach materials.

What will Ecology do with this information?

Based on the success of the Phase I permittees' business inspection programs and the LSCP technical assistance program, Ecology has proposed adding business source control inspections to Phase II permits. The recommendations from this study will help inform both a source control program requirement for the Phase II permit and future SAM studies to continue to improve the programs. Ecology encourages standardization of recordkeeping protocols for inspections. Future analyses will support data-driven adaptive management of permittees' Stormwater Management Programs. Ecology will continue to support the LSCP statewide and encourage coordination of LSCP technical assistance and any necessary follow-up or enforcement actions.

Using Western Washington Catch Basin Inspection and Maintenance Data to Predict Maintenance Schedules and Identify Cost-Efficiencies

Effectiveness Study

Lead Entity:
King County

Partner:
Osborn Consulting, Inc., Kitsap County, City of Kent, City of Everett, City of Seattle

For more information: Go to Ecology.wa.gov/SAM and search for Catch Basin Cleaning Study.

Study goals

The primary goal of this study was to identify factors that could be used to predict municipal stormwater catch basin (CB) maintenance needs by evaluating existing CB inspection and maintenance records from across Western Washington. A secondary goal was to identify cost efficiencies in CB program implementation by reviewing CB inspection and maintenance program designs and interviewing stormwater managers.

Stormwater management problem

This study helps inform efficient predictions of CB maintenance needs and management of inspection and cleaning costs. The current default CB inspection frequency requirement is annual for Phase I permittees, and generally every 2 years for Phase II permittees. Additionally, both of the permits allow alternative schedules or approaches to meet the maintenance standards.

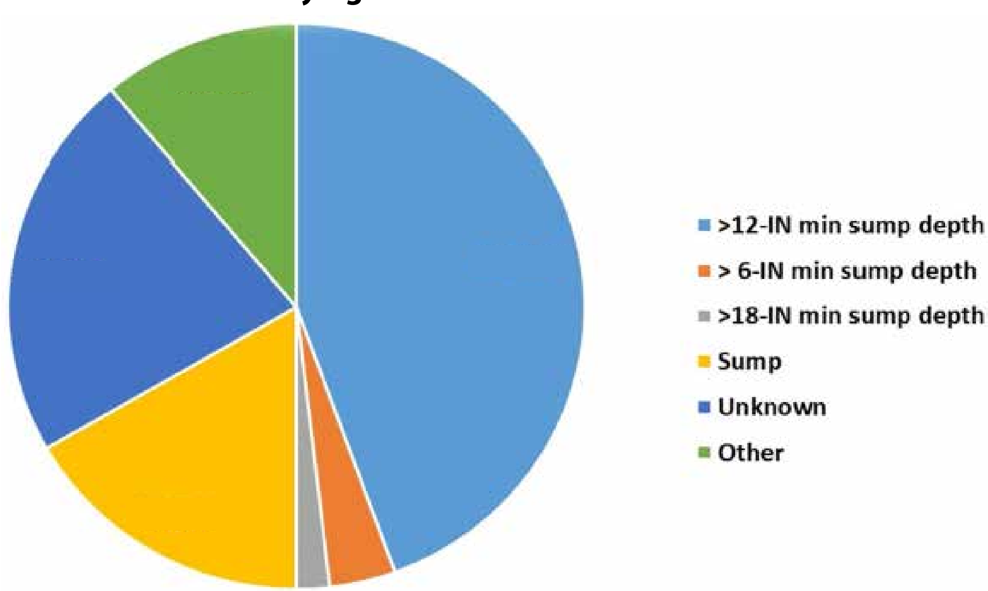
Project findings

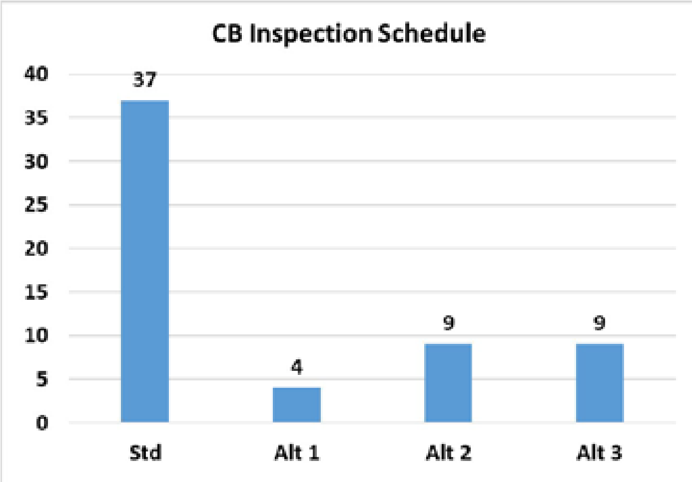
The study could not completely meet the original goals. Significant data quality issues exist across jurisdictions. Approximately half of the 54 survey respondents use paper, at least in part, to record inspection and/or maintenance activities. Record errors were common. For example, sometimes CB cleaning records were missing or showed different sump depths for the same CB. Variable definitions of a CB are in use, mostly relating to sump depth (see Figure 1). Some jurisdictions included inspections of CBs without any sump; these features are not designed to collect suspended solids.

These data quality issues along with an overall lack of existing drainage basin delineations precluded the intended correlation analysis. Instead, the study evaluated records with the highest certainty and then focused on making recommendations in three areas: improving records quality, increasing program cost efficiency, and designing a tool for predicting inspection needs. From the best records compiled for this project (from seven permittees) it appears that, usually, over 80% of CBs do not require more frequent cleaning than the standard inspection schedules.

Due to variable accounting approaches, a quantitative program cost comparison among these permittees was infeasible. However, approximate median annual costs are around $21 per CB, regardless of jurisdiction size and CB count. Permittees have realized substantial cost reductions by transitioning from paper records to integrated digital data management, such as asset management software.

Varying definitions of Catch Basins





Few permittees are utilizing alternative CB inspection schedules allowed by the permits and published guidance (Ecology Publication 13-10-019). This may be due to permittees' confusion as to how to propose a different schedule using an individual jurisdiction's records. Examples are provided in the report that can guide others. The circuit-based alternative schedule was disregarded by some jurisdictions because of confusion about the definition. A circuit can be defined as a land area with similar rates of solids accumulation and maintenance needs; it does not need to discharge to a single point. These alternative schedule clarifications may support future adjustments to permittees' inspection schedules.

Recommendations

Permittees should consider:

- Implementing improved protocols for data measurement and data entry, and conducting periodic quality control checks of their databases to improve data quality and consistency.
- Migrating data collection and management to an integrated digital system to improve cost-efficiency.
- Using available examples of alternative schedules (e.g., Marysville and Federal Way), to propose a less frequent inspection schedule, once enough jurisdiction-specific inspection data are available.
- Revisiting the definition of a circuit to consider if this alternative will work alone or in combination with other approaches.

Ecology should clarify the CB definition by highlighting its purpose, which is to remove solids from stormwater runoff, and excluding inlets or other structures without sumps. This would improve future understanding and use of inspection data and ensure that maintenance standards are being applied appropriately.

Finally, a modest field study of CB dynamics would provide a foundation for long-term, science-based prediction of CB accumulation.

Why does this study matter?

Although permittees may believe that certain factors such as land use, construction site activity, sanding, etc. may drive accumulation more than other factors, no data analyses have been conducted to date that identify which factors are most important. Analysis from the limited data in this study indicates that, usually, over 80% of CBs do not require more frequent cleaning than the standard permit requirements.

The study identified tips for stormwater managers to both improve efficiency and quality of CB inspection and maintenance programs, and to reduce program costs.

What should we do with this information?

Stormwater managers should evaluate software, alternative schedules, and circuit options to direct limited inspection and maintenance resources to provide the greatest environmental benefit. Permittees should work to improve internal approaches to data collection and management and consider utilizing asset management software for CB inspection and maintenance if they have not already done so. Permittees should continue to inspect inlets, but focus maintenance on addressing solids accumulation in CB sumps.

What will Ecology do with this information?

Ecology's definition of CB in the *Stormwater Management Manual* includes only features with a sump, but it does not specify a required sump depth. Ecology's permit managers will work with permittees to answer questions about alternative CB inspection and maintenance schedules. Ecology does not approve individual programs, so Ecology's focus will be on helping permittees ensure that they have adequate data to support their proposed schedules.

Stormwater Retrofit Monitoring in the Echo Lake Drainage Basin

Effectiveness Study

Lead Entity: King County | **Partner:** City of Shoreline

For more information: Go to Ecology.wa.gov/SAM and search for SAM Echo Lake.

Study question

This study evaluated effectiveness of stormwater treatment facilities installed along the Aurora Corridor of State Route 99 where highway, commercial, and residential stormwater runoff discharges to Echo Lake, a small lake that eventually drains to Lake Washington. The study measured how stormwater quality is improved by individual treatment features – bioretention planter boxes (BPBs) and a Filterra planter box (FLT) – as well as system-wide detention tanks. The investigators observed (but did not measure) reduction of peak flows, and intended to compare the quality of stormwater runoff at outfall before and after the retrofit project. The study also assessed changes in water quality in Echo Lake over time, and how these changes correspond to changes in stormwater infrastructure in the contributing basin.

Stormwater management problem

Untreated stormwater is a major contributor of contaminants and habitat degradation in urban water bodies. Highway corridor projects aim to improve traffic safety, traffic flow, and stormwater quality. These projects have limited space for stormwater treatment and therefore tend to use technologies that have small footprints and provide streetscape amenities. Project requirements are based on the amount of roadway added and replaced, not the expected results in the receiving water body. To select the best technologies, stormwater managers want information about the effectiveness of these treatment facilities in the field and their collective potential to improve water quality in receiving water bodies.

Project findings

Individual BPBs significantly reduced stormwater concentrations of total suspended solids (TSS), ammonia, total metals, polycyclic aromatic hydrocarbons (PAHs), and total lube oil-/diesel-range petroleum hydrocarbons (TPH-Dx). The average percent reduction in stormwater concentration was greater than 80% for total polychlorinated biphenyls (PCBs). Toxicity was also assessed at one BPB and was always reduced in effluent when initially observed in the influent. Total copper was reduced, and while dissolved copper sometimes increased, effluent concentrations were low (≤6 µg/L). Dissolved cadmium and lead were infrequently detected in both influent and effluent samples. Flow was not measured, but a substantial reduction in stormwater volume was visually observed at each BPB.

The FLT also significantly reduced concentrations of TSS, total nitrogen, ammonia, total metals, total PAHs, TPH-Dx, and total phosphorus. The average concentrations of dissolved copper and zinc increased in the FLT effluent compared to the influent concentrations. The FLT was very effective at removing ammonia and organic contaminants and performed better than the BPBs for removal of total phosphorus and total nitrogen. However, it was generally less effective than the BPBs at reducing concentrations of metals and TSS.

The system-wide detention tanks provided some additional water quality treatment, reducing TSS and total zinc by <20% on average. Overall, concentrations of other contaminants were comparable between influent and effluent for most events.

This study looked for a pattern in Echo Lake water quality concentrations by using existing monitoring data and found no substantial changes in the lake that correspond to the retrofit installations. The retrofits treat only 2.9 acres of impervious surface out of the 207-acre basin. To achieve measurable water quality improvement, a higher density of stormwater treatment retrofits throughout the watershed may be needed.

The quality of stormwater runoff at the outfall before and after the retrofits could not be quantified because substantial physical changes in the drainage system made the data incomparable.

	BPB	FLT
Suspended Solids	↓	↓
Dissolved Zinc	↓	↑
Dissolved Copper	mixed	↑
Total Phosphorus	↑	↓
Petroleum Hydrocarbons	↓	↓
PCBs	↓	↓

Though not directly related to the study objectives, the study discovered important facility maintenance needs resulting from improperly designed curb cuts. The BPBs required frequent maintenance visits and cleaning because debris often blocked the inlets and prevented stormwater from entering. The FLT inlet was much larger and remained clear of debris; however, facility media replacement has been needed every two-to-three years since installation to address clogging by fine sediments.

Recommendations

The retrofits targeted the arterial road in the basin and reduced concentrations of most pollutants in the stormwater runoff, but further study is needed to identify what density of treatment facilities throughout the basin is required to result in detectable water quality improvements in the lake.

Routine site inspections are needed to ensure treatment installations remain functional. Each BMP site is unique, and it is important for stormwater managers and city-wide programs to plan for inspections to ensure that the anticipated maintenance schedule truly meets the needs of the individual site.

Inlet designs should be larger for BPBs to keep roadway debris from blocking curb cuts and allow facilities to receive the volume of stormwater that matches their capacity. The presence of trash does not appear to affect facility performance.

Why does this study matter?

Highway corridors have limited land area and opportunities for retrofits to improve stormwater treatment. This study provides insight into how to maximize the benefits of retrofit projects in these space-constrained areas. The study area has typical commercial and residential land use along a busy roadway. Some of the treatment facilities were installed more than three years before the study began, allowing for assessment of performance of a more mature installation. The study evaluated the BMPs for their effectiveness to reduce many pollutants common in stormwater, including some like PAHs and PCBs that are rarely included in stormwater treatment studies.

What should we do with this information?

Stormwater managers should use information from this study in deciding what treatment technologies will be most effective and appropriate for their local conditions and evaluate maintenance needs of their existing and future roadside treatment facilities.

What will Ecology do with this information?

This study underscores that downstream water quality improvements cannot be provided by a single retrofit project. Ecology will continue to encourage, support, and fund opportunistic and strategic retrofitting of road corridors using these and other types of treatment facilities to improve the quality of stormwater discharges and reduce flows. Ecology may establish funding priorities for projects that are part of thorough planning processes. Curb cut inlets must be large enough to not be easily clogged by road debris; Ecology added emphasis in technical guidance (BMPT7.30 Bioretention) that the designer should calculate the size and choose the style of curb cut that is appropriate for the site conditions and runoff expectation.

Regional Stormwater Facility Retrofit Study in Federal Way, Washington

Effectiveness Study

Lead Entity: King County

Partner: Federal Way

For more information: Go to Ecology.wa.gov/SAM and search for SAM Federal Way.

Study goals

This study evaluated effectiveness of stormwater treatment facilities built as part of an expansion and retrofit of a regional stormwater detention facility in Federal Way. The overall goal was to evaluate two new bioretention facilities, an expanded and new combined detention stormwater treatment wetlands (wetland complex), and the regional facility as a whole, for their ability to improve water quality and to reduce peak flows of stormwater runoff.

Stormwater management problem

Stormwater managers across the region are updating old stormwater detention facilities and other outdated infrastructure. Effectiveness monitoring is needed to evaluate whether new technologies are achieving the intended water quality and flow control goals. This study was designed to address data gaps regarding the effectiveness of stormwater treatment technologies when built as retrofits. Stormwater managers want to know how much they can expect to reduce the impacts of stormwater on aquatic ecosystems with similar retrofit projects.

Project findings

Eighteen storms between March 2016 and April 2017 were sampled using compositors. Flows were measured continuously. Both bioretention facilities, the expanded wetland complex, and the system as a whole reliably attenuated stormwater flows by reducing and delaying the timing of peak flows. The bioretention facilities and the wetland complex had mixed water quality treatment results, they were able to treat some targeted pollutants but not others. The system as a whole reduced total suspended solids (TSS), polycyclic aromatic hydrocarbons (PAHs), polychlorinated bi-phenyls (PCBs), and total metals (zinc, lead, copper and cadmium). However, the system increased concentrations of nutrients and dissolved lead. The bioretention facilities were a source of nutrients.

The bioretention facilities were newly constructed with 30 inches of the default bioretention soil media (BSM), based on old guidance in the 2012 SWMMWW that more soil mix would provide better nutrient treatment. Instead, they contributed nearly 80% of the total phosphorus leaving the system, despite receiving less than 10% of the runoff to the system.

Water quality and benthic community data from the North Fork of West Hylebos Creek were collected downstream of the retrofit and expansion before and after the project to assess overall performance of the system. Turbidity improved, though the data are not yet significant. Changes in the benthic community were not observed, though it is likely too early to detect a change. More time is needed to determine any long term recovery of the benthic communities in the creek.

Recommendations

The nutrient export observed from bioretention is consistent with prior studies on the default BSM. Designers and stormwater managers should carefully consider designs and siting arrangements that will reduce the impacts of nutrient export. Managers should avoid designs that may facilitate or exacerbate nutrient export, such as more compost or delayed drainage of the bioretention – both conditions in this project.

Siting, designing, and monitoring stormwater treatment facilities is complex and should consider the potential for groundwater to affect flows of water and pollutants into and out of the facilities. To measure effectiveness, all inlets and outlets need to be accessible and easy to instrument with necessary monitoring equipment.

Why does this study matter?

Standard design criteria bioretention contains flexibility for site considerations. BMPs in retrofit situations are given further flexibility to accommodate space constraints and other limitations. Studies like this help us understand how modified BMPs perform in retrofit projects. This study identified some benefits and limitations of large bioretention facilities and a treatment wetland complex in one particular situation. The wetland complex successfully reduced nutrients, and in a different scenario could follow the bioretention. We are still learning whether and to what extent individual projects result in improvements in biological communities in the receiving water.

What should we do with this information?

Yet-to-be-built bioretention facilities designed according to the 2012 recommendation for 24" or more soil depth should be constructed with 18" soil depth instead, to help control nutrient export. Stormwater engineers and managers can use the findings from this study to help inform their decisions and expectations regarding site selection, design and monitoring of regional stormwater treatment facilities and retrofits, particularly in space-constrained situations. At a site where nutrients are a concern and a wetland complex is feasible, that approach may be preferable to and provide better overall treatment than a large bioretention facility. Bioretention facilities attenuate flows, but the reduction in pollutants is mixed: toxics such as PAHs and total metals are effectively removed, but if nutrient export is a concern for the receiving water, treatment trains or polishing should be added to the site design.

What will Ecology do with this information?

Ecology will continue to fund retrofits to improve stormwater quality opportunistically. Bioretention soil media mixes that release fewer nutrients and metals are being pursued. Ecology changed language in the SWMMWW to recommend against additional soil media depths due to the export of nutrients (plant growth and survival appears to depend more on hardiness and suitability of the dry climate of a bioretention cell in summer). Ecology continues to support the bioretention guidance within the 2014 and upcoming 2019 SWMMWW that advises against use of bioretention within one-quarter mile of a phosphorus-sensitive waterbody without further treatment, suitable soils, or when an underdrain would be routed to the receiving water.

Redmond Paired Watershed Study – Status Update

Effectiveness Study

Lead Entity:
City of Redmond

Partner:
City of Seattle, King County, Kitsap County, U.S. Environmental Protection Agency, U.S. Geological Survey, Washington State Department of Ecology, and Herrera Environmental Consulting

For more information: Go to Ecology.wa.gov and search for SAM paired watershed.

Study question

This ten-year study sets out to answer: how effective are combined stormwater retrofits and other watershed-scale rehabilitation efforts at improving habitat and water quality conditions in receiving waters?

Many individual stormwater management techniques have been tested and proven to improve stormwater quality and reduce environmental impacts. But it is not currently known whether our collective stormwater management practices are effective at recovering the health of urban streams. The City of Redmond is accelerating the installation of stormwater facilities in selected areas ahead of the rate of development to provide an early example of targeting stormwater controls.

Stormwater management problem

Healthy streams in western Washington have only moderately altered hydrology. For over a century the region has transformed from forest to urban areas. Small stream aquatic biota and habitats are impacted by changes to hydrology and pollutants from runoff.

Until very recently, most of western Washington was developed without what is now considered necessary infrastructure and construction practices to protect aquatic habitat in urban watersheds from stormwater impacts. Local, state, and federal government agencies are implementing various programs and regulations intended to create healthy aquatic habitat in urban areas.

Since 2014, new stormwater management approaches are required to control runoff volumes and reduce pollutants in areas of new development and re-development. Additional retrofitting of older stormwater infrastructure above and beyond current requirements is probably needed to increase the pace and certainty at which urban waterbodies can be recovered to healthy conditions.

Project status and expected findings

This is a long-term effectiveness monitoring project to measure the health of streams as Redmond implements an aggressive retrofitting and restoration program designed to improve in-stream conditions. The project began in 2015 and the first two years of data collection have established baseline conditions in watersheds to be retrofitted and in control watersheds

where retrofits are not planned or funded. In 2017, Redmond began constructing the first retrofit projects and restoration programs. The goal is to get ahead of development and to see measurable improvements in the streams, with the ultimate goal to recover these urban water bodies to healthy conditions within a decade.

Redmond conducted a statistical simulation to choose meaningful metrics and design monitoring to measure trends and assess the health of the study streams. In years 4, 6, 8, and 10 of this project, Redmond will report on trends by summarizing the results of statistical analyses performed on data from all previous years of monitoring. In these reports, Redmond will evaluate potential relationships between the rehabilitation efforts and observed improvements in the receiving water conditions.

Recommendations

This project will continue to gather data that informs the region within the next decade if Redmond's long-term stormwater management strategy in these watersheds is effective at recovering the urban streams.

The paired watershed study design allows for other local governments in western Washington to use the data to measure their effectiveness at recovering urban streams. Local governments could do similar monitoring of streams where they are trying to improve conditions. Data from this study for both control and reference streams can be used in other studies to evaluate in-stream responses. We can differentiate between natural variations and responses to recovery actions.

Other local governments should follow this project. The findings can be used to refine stormwater management programs and will help federal and state agencies assess whether current regulations and program requirements are effectively improving stream conditions in urban areas.

Why does this study matter?

Planning and construction of stormwater retrofitting projects is expensive. Stormwater managers and policy makers want more certainty of success before widespread implementation of these projects. The public wants to know that their tax dollars are being spent to improve conditions in their local water bodies. This study will tell us whether going "all-in" on combined retrofit and restoration projects delivers a return on these investments that is measurable within a decade.

What should we do with this information?

Stormwater managers should continue to gather the information necessary to understand the current conditions in their local receiving waters. Permittees should consider the hydrology and water quality impacts of their municipal separate storm sewer discharges to these water bodies in relation to other problems in their watersheds and, if appropriate, develop programs to target aspects of stormwater management in key areas of these watersheds where receiving water conditions are likely to measurably improve as a result.

What will Ecology do with this information?

Ecology will continue to fund stormwater infrastructure retrofits and other restoration and recovery efforts – particularly those identified and prioritized through science-based planning efforts. Ecology may determine that changes to municipal stormwater permit requirements are needed to meet Clean Water Act goals of protecting and restoring beneficial uses in receiving waters.

Source Identification

IDDE data evaluation

Illicit discharge detection and elimination (IDDE) regional data evaluation for Western Washington

Source Identification

Lead Entity:
City of Lakewood

Partner:
Aspect Consulting, Cardno, Inc. and WA Dept. of Ecology Water Quality Program

For more information: Download the report at Ecology.wa.gov; search for SAM IDDE data analysis report.

Study goals

The goals of the project were to:

1. Compile a regional dataset of illicit discharge detection and elimination (IDDE) activities by municipal stormwater permittees; and
2. Analyze the data to: provide information about the most common problems; compile the source identification and elimination methods in use; and find opportunities for regional solutions to common problems and support permittees' IDDE programs.

Stormwater management problem

Municipal stormwater staff invest a substantial amount of time investigating and addressing potential illicit discharges to their storm sewer systems. They encounter many different types of problems that require unique approaches. Over the past decade of implementing IDDE programs, stormwater staff have gained a general sense of the most common problems in their jurisdictions. A collective summary of permittees' IDDE activities helps the region to set overall priorities and secure funding to enhance efforts to address sources of stormwater pollution.

Project findings

Permittees throughout Western Washington reported 2,913 illicit discharge detection and elimination (IDDE) incidents for the 2014 calendar year. Fifteen permittees reported zero illicit discharges or illicit connections during this time period. The evaluation compared counts of record types and incident characteristics. About two-thirds of the Phase I records and about one-fifth of the Phase II records came from just two cities. Much of the data summary and analysis was weighted toward these cities' programs. Statistical analysis was done to quantitatively compare all permittees' records.

The most common stormwater pollution problems were petroleum hydrocarbons and other vehicle fluids from spills and accidents, sediment from construction sites and flooding, chemicals from industrial activities, and sewage from illicit connections.

Most of the incidents were reported directly by the public via pollution hotline calls and other citizen complaints. Municipal staff observations during inspections resulted in the second highest number of reports. A significant number of the incidents permittees responded to were not illicit discharges to the stormwater system; these included allowable discharges, solid waste dumping, and unconfirmed complaints. Permittees will continue to spend time and effort responding to such calls.

Photo credit: Diana Halar, City of Lakewood

Permittees most commonly traced sources using visual indicators and empirical methods, which included visual reconnaissance, field observations, and mapping analysis. Problems were most commonly corrected and eliminated using best management practices (BMPs) such as adding or improving source control, cleaning up spills, education, technical assistance, and behavior or operational modification.

Enforcement was used in relatively higher proportion for Phase I jurisdictions than for Phase IIs. Incident response times were mostly within one to three days on average and resolution times were mostly under eight days for Phase I permittees and up to 53 days for Phase II permittees. Almost all of the 59 illicit connections reported were resolved within six months.

Recommendations

A regional dataset provides objectivity to understand and therefore address the most common IDDE problems encountered by municipal stormwater permittees. The entry of data for this evaluation from permittee submittals was a time-consuming process that would be more efficient with standardization of information that permittees report. An expanded and improved list of standard data fields and entry options was developed through this project to provide consistent and richer data while not increasing the time needed for data entry by permittees.

Knowing the relatively large number of incidents related to vehicle spills and accidents, we should consider enhanced efforts to educate transportation accident responders such as tow truck drivers and police on the use of spill kits and the importance of timely reporting. We should place more spill kits in emergency response vehicles and in businesses. Ecology and local jurisdictions should consider more frequent and proactive construction inspections to reduce the incidents of sediment leaving those sites.

Why does this study matter?

The goal of stormwater management is to protect receiving waters and biota. These results confirm that collectively, the large number of small spills from vehicles and incidents of sediment runoff from construction sites are likely posing a threat to these public resources. Local jurisdictions may need assistance from a regional effort to make meaningful headway to reduce these types of pollution. This type of objective data – rather than a collection of anecdotes – is needed to set priorities for regional activities. Standardized data from permittees will provide even more basis for regional action.

What should we do with this information?

Stormwater managers should consider prioritizing education and outreach campaigns and staff training programs around the most common stormwater pollution problems in their jurisdictions. Permittees should keep good records to support enforcement actions and to explain the value of their IDDE programs to their councils and commissions.

What will Ecology do with this information?

Ecology will use these findings to drive priorities for funding requests that support permittees' IDDE programs and address common IDDE problems. Ecology will continue to invest in developing tools and technologies to identify, prevent, and reduce illicit discharges from various sources and support permittees' efforts to keep pollution from entering stormwater systems. Ecology has already assisted many permittees in making needed improvements to their record keeping and reporting, and has proposed a detailed municipal stormwater permit requirement to improve and standardize future reporting. Ecology is committed to supporting the regional effort to collect and maintain a consistent dataset to inform regional funding priorities.

Receiving Waters

Receiving water studies synthesis

Puget Sound mussel monitoring

Puget Sound nearshore sediment monitoring

Puget Sound nearshore bacteria data compilation

Puget lowland ecoregion streams

SAM Receiving Water Studies Synthesis

Receiving Waters

Lead Entity:
SAM Staff

Partner:
U.S. Geological Survey, King County, Washington Department of Fish and Wildlife, Washington Department of Natural Resources, Puget Sound Partnership, and Washington State Department of Ecology

For more information: See the SAM Status and Trends website at Ecology.wa.gov/SAM.

Study goals

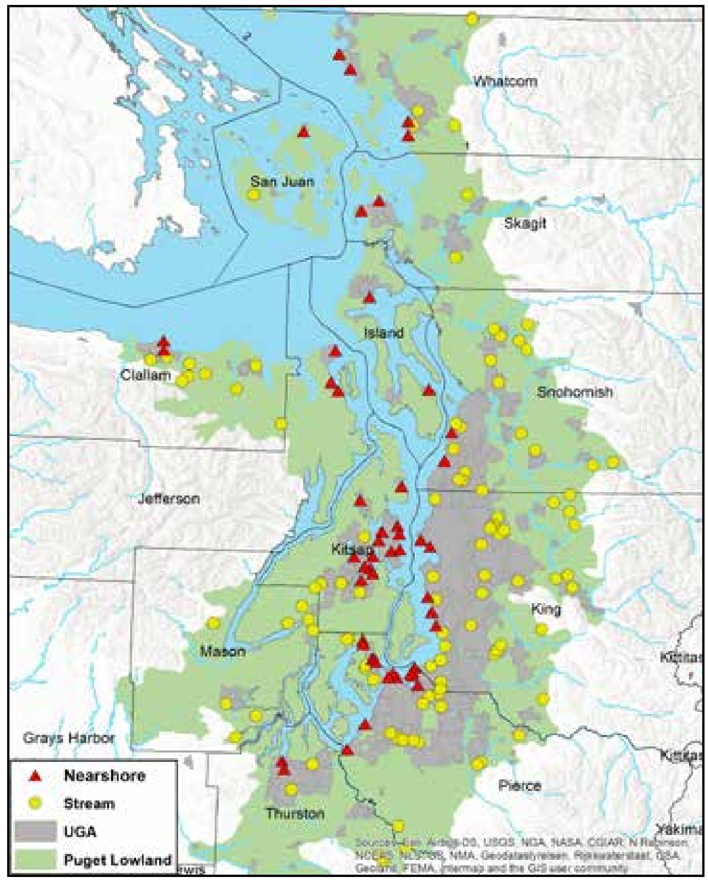
The overarching goals of SAM receiving water studies are to:

- Help us better understand the impacts of stormwater on water quality and biota, and
- Tell us whether receiving water conditions across the region are getting better or worse.

The purposes of synthesizing the first round SAM receiving water studies are to share key findings with stormwater managers and guide the design of future trends monitoring and other SAM studies.

Stormwater management problem

The stormwater problem has been well understood for decades, but before SAM we did not have a monitoring program to objectively measure at the regional scale whether or not our collective management approaches are reversing past damage to receiving waters and preventing new impairments. Local governments are investing increasing amounts of funding and staff time in municipal stormwater permit-required management activities. Many areas of the permit provide flexibility for implementation of stormwater management programs. The region needs sound science to help set priorities and establish reasonable recovery goals.



Project findings

Three regional receiving water studies were conducted in 2015-2016 at randomly selected sites. The largest study, Puget Lowland Ecoregion Streams, sampled both within and outside of Urban Growth Areas (UGAs) for water quality monthly at 60 sites and one summertime sampling of fine sediments, algae (periphyton), and benthic invertebrates at 105 sites. The two urban Puget Sound nearshore studies evaluated sediment quality and mussel tissue bioaccumulation at 40 sites along UGA shorelines. Clean aquaculture-sourced mussels were deployed in cages as sampling devices for 3 months. Nearshore sediment samples were collected from a boat at about one fathom depth at most of the same locations as the mussel sampling.

The streams and mussel studies identified key environmental health indicators that correlate strongly with urban development. Overall, conditions were predictably worst in the most urbanized settings. In streams, watershed canopy cover explained most of the health of benthic invertebrate communities, even more so than riparian canopy, the urban development coverage in the watershed, or pollutant concentrations in the sediment.

In the nearshore, concentrations of organic contaminants (PAHs, PCBs, PBDEs, and DDTs) in mussels along city shorelines were consistently higher than in the unincorporated areas of the UGA shoreline and highly correlated with impervious surface at the watershed scale. Most of the variation in chemical concentrations in sediment along the shoreline is explained by the natural variable of drift governing sediment transport and deposition.

A fourth regional study of fecal indicator bacteria in the Puget Sound nearshore was initially planned but deemed too expensive. Instead, bacteria data were compiled from 27 existing programs. The SAM study observed that differences among the programs' monitoring goals, study designs, and approaches to bacteria sampling drove the differences in their findings.

Recommendations

Future SAM receiving water monitoring should improve our understanding of key development- and stormwater-related stressors. Studies should also give insight into long-term trends, guiding stormwater management program activities and priorities across the entire spectrum of urban conditions. Least-impacted sites are needed for the nearshore framework for comparison of the results when established criteria are unavailable. The next rounds of SAM studies should focus on continued use of mussels and conducting stream sampling frequently. Nearshore sediment sampling should be less frequent, every ten years. A stormwater focused bacteria effort would be better scaled as an effectiveness or source control study. Results and lessons learned from the first round studies should be used to update the sampling design to efficiently detect trends sooner, and better match the SAM funding source.

photo by David Toth

Why does this study matter?

Stormwater runoff continues to produce destructive flows and deliver bacteria, nutrients, soil particles, and toxic contaminants to receiving waters. These studies provide the means for tracking our region's progress reducing stormwater impacts on environmental health. SAM's status and trends monitoring in receiving waters was undertaken due to the strong desire of elected officials to know whether combined state and local investments of hundreds of millions of dollars each year to fund stormwater management programs, activities, and capital projects are working to protect and recover conditions in streams and nearshore environments. In 2015-2018, SAM receiving water assessments established regional baseline conditions for assessing future trends and answering this question.

What should we do with this information?

Stormwater managers should review the key findings of each first round status and trends study, determine what combinations of the key stressors are present in their jurisdictions, and then consider adjusting their management programs to address these stressors. Permittees should use the SAM findings to understand their own receiving waters in a regional perspective. In the absence of local monitoring, SAM's results for streams and shorelines with similar watershed characteristics can provide useful information for targeting local stormwater management actions.

What will Ecology do with this information?

Ecology will use this objective regional information to evaluate the efficacy of the overall permitting program over time in slowing or reversing the decline in receiving water conditions caused by stormwater from existing and new development. Ecology can use SAM's assessments of receiving water conditions in areas covered by the municipal stormwater permits to prioritize stormwater grant funding. Ecology will relay these findings to the new urban stream monitoring program beginning soon in the Lower Columbia region of western Washington.

2015/16 Mussel Monitoring Survey

Receiving Waters

Lead Entity:
Washington Department of Fish and Wildlife

Partner:
Bainbridge Beach Naturalists, Bainbridge Island High School, Bainbridge Water Resource Council, Cherry Point Citizen Stewardship Committee, City of Bellingham, Coastal Volunteer Partnership at Padilla Bay, Evergreen State College, Feiro Marine Life Center, Harbor Wildwatch, King County, Kitsap County Public Works, Lighthouse Environmental Programs, Nisqually Reach Nature Center, NOAA's Northwest Fisheries Science Center, Pacific Lutheran University, Pacific Shellfish Institute, Penn Cove Shellfish, Port Gamble S'Klallam Tribe, Port Townsend Marine Science Center, Puget Sound Partnership, Puget Sound Corps, Puget Sound Ecosystem Monitoring Program, Puget Soundkeeper Alliance, San Juan County Marine Resources Committee (MRC), Seattle Aquarium - Beach Naturalist Program, Snohomish County MRC, Sound Water Stewards of Island County, South Puget Sound Salmon Enhancement, Stillaguamish Tribe, Suquamish Tribe, Toxics-focused Biological Observation System, University of Puget Sound, University of Washington-Tacoma, Vashon Nature Center, Washington Conservation Corps, Washington Department of Ecology, Washington Department of Natural Resources Aquatic Reserves Program, Western Washington University, Whatcom County MRC

For more information: Download the report at http://wdfw.wa.gov/publications/01925/

Study goals

Contaminant levels in mussels and tissues of other filter feeders are a good indicator of water contamination and whether the health of biota in the urban nearshore is improving, deteriorating, or remaining the same in the urban growth areas (UGAs) where stormwater management activities are currently focused. This project's study questions were designed to tell us:

- Do mussel tissue contaminant levels correlate with urbanization indicators such as land use and impervious surface in the adjacent shorelines and contributing watersheds?
- How do mussel tissue contaminant levels change over time in response to stormwater management and urban population growth in Puget Sound?

This long-term project will gather data every two years. The 2015-16 round of sampling and analysis answered the first question above. It also gathered information to refine the design for future trends monitoring to answer the second question. The project leverages previous and ongoing state and federal programs that assess the health of Puget Sound. It engages dozens of volunteers in learning more about stormwater pollution and its impacts on biota.

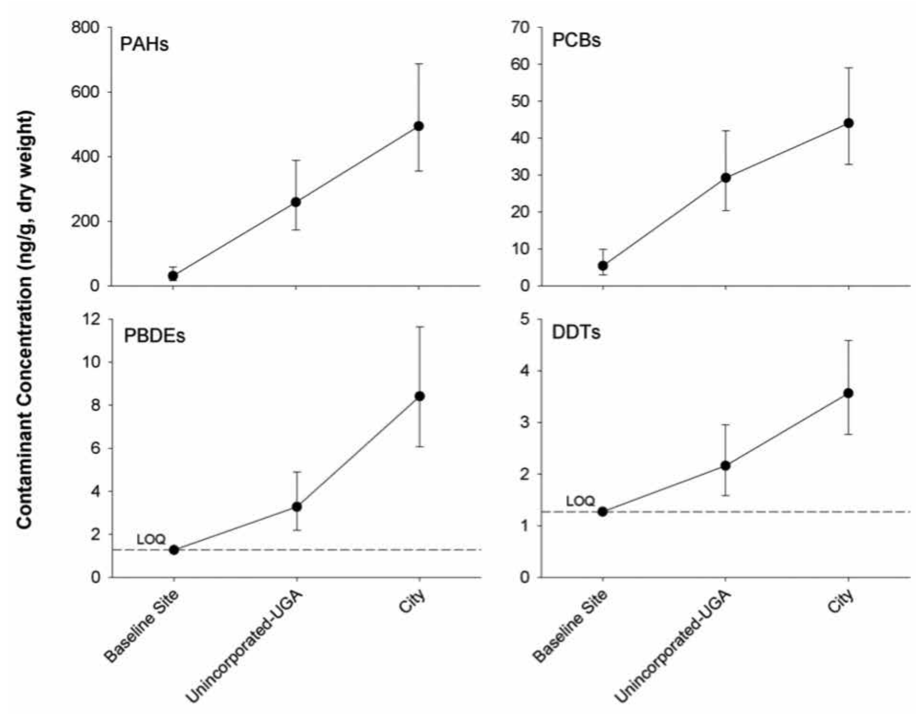


Figure 1: Municipal land use designations adjacent to sampling sites show differences in concentrations of PAHs, PCBs, PBDEs, and DDTs in mussel tissue. Dots are geometric means and bars are 95% confidence intervals. LOQ is level of quantitation.

Stormwater management problem

Stormwater delivers diverse toxic metals, organic contaminants, and other chemical pollutants into Puget Sound. These pollutants accumulate in biota. This study is specifically designed to assess Puget Sound nearshore biota health along urban growth area shorelines – the areas presumed to be most affected by stormwater runoff. Mussels and other filter feeders are a good tool to measure the extent of impacts from stormwater pollution.

Project findings

Mussels were used to assess bioaccumulation of common stormwater pollutants over three winter months in the urban nearshore of Puget Sound. Native mussels (*Mytilus trossulus*) from Penn Cove were transplanted to 43 randomly selected sampling locations along shorelines of incorporated and unincorporated urban growth areas. The transplanted mussels were successfully retrieved from 90% of the sites with an overall 78% survival rate.

Polycylic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) were the most abundant organic contaminants. They were detected in mussel tissues from every site. Polybrominated diphenyl ethers (PBDEs) and dichloro-diphenyl-trichloroethanes (DDTs) were detected in samples from about 85% of the sites. PAHs from 21% of the sites, PCBs from 5% of the sites, and DDTs from 5% of the sites exceeded Washington Department of Health threshold values for consumption. PBDEs were lower than the threshold value at every site. Concentrations of all of these organic contaminants correlated with the urbanization characteristics of municipal land use classification and percent impervious surface. The other organic contaminants, including additional pesticides, were detected at only a few sites and at low levels.

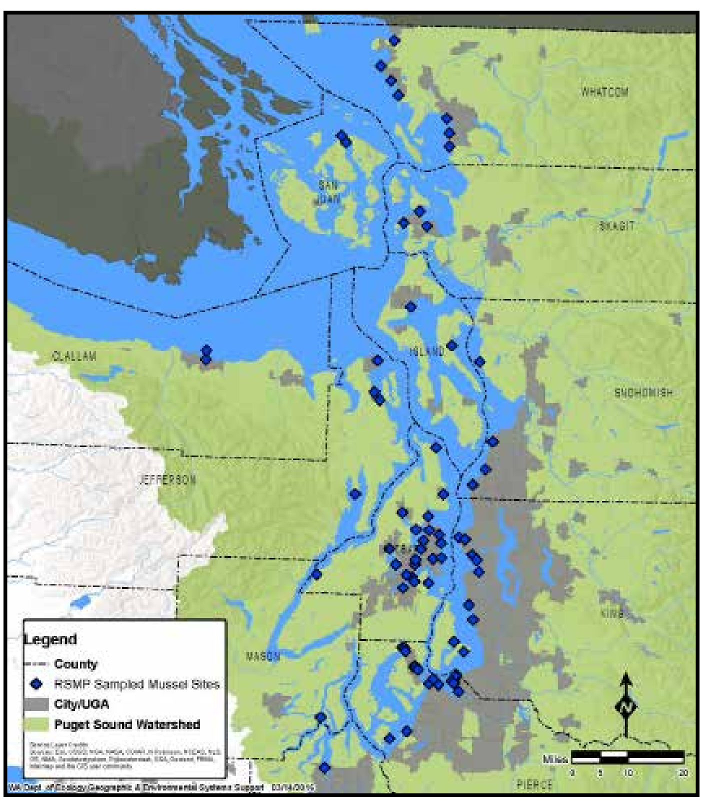
Zinc, copper, cadmium, arsenic, and mercury were detected in mussels from every study site. Lead was detected at 86% of the sites. Metal contaminant levels in the mussel tissues were lower than toxic levels as defined by U.S. Environmental Protection Agency, Washington Department of Health, or otherwise available in scientific literature. Zinc was weakly related to urbanization characteristics and the other metals concentrations did not show a clear spatial pattern.

Recommendations

This first round of data was collected for a new regional long-term study designed to assess stormwater impacts in Puget Sound. Improving the study design by adding substrata of land-use type may help identify the spatial patterns and track changes in contamination related to stormwater impacts. Additional sites sponsored by partner groups provided data outside the UGAs for comparison. Least-disturbed reference sites are needed to establish regional scale thresholds and natural variability.

This project is just one part of the SAM assessment of nearshore conditions relative to urban stormwater management. A similar suite of contaminants was measured in sediments at most of the same sites. The findings of both projects will be used to compile a regional assessment of conditions in Puget Sound and considered in making adjustments to future monitoring.

Nearshore mussel sampling locations



Why does this study matter?

Local governments in Puget Sound spend hundreds of millions of dollars each year managing stormwater. The purpose of stormwater management is to minimize pollutants in stormwater runoff and protect designated uses of receiving waters. This project tells us how much bio-available contamination is in the food web during the winter months – a direct link to the health of Puget Sound biota – and will help us focus and support efforts to prevent contamination from entering Puget Sound via stormwater. We are improving our understanding of the effects of stormwater from a wide variety of landscape conditions. We will learn how conditions are changing over time and whether stormwater management is working to reduce and prevent these impacts to nearshore biota.

What should we do with this information?

Stormwater managers should be aware that toxic contaminants are entering the nearshore food web of the greater Puget Sound, especially along shorelines adjacent to highly urbanized areas. Mussel tissue contamination levels in their areas, or in areas with similar land use patterns, can help permittees understand what problem areas likely exist along their shorelines. Permittees should use this information to help explain the importance of stormwater management in minimizing discharges of pollution and to inform local project priorities in catchments that drain to nearshore marine areas.

What will Ecology do with this information?

This study provides Ecology and other agencies the means to measure and track progress in reducing impacts to the urban nearshore areas of Puget Sound. Ecology looks forward to the long-term results. Meanwhile this knowledge will be useful to support funding initiatives and to inform all of Ecology's programs that regulate discharges to nearshore marine environments and remediate polluted sites.

Nearshore Sediment Monitoring for the Stormwater Action Monitoring (SAM) Program, Puget Sound

Receiving Waters

Lead Entity:
U.S. Geological Survey

Partner:
Washington State Dept. of Natural Resources, King County Environmental Lab, and Washington State Dept. of Fish and Wildlife

For more information: Download the report at https://pubs.er.usgs.gov/publication/sir20185076

Study questions

The goals of this study are to assess environmental health in the Puget Sound nearshore adjacent to Urban Growth Areas (UGAs) and, in the long term, to monitor how nearshore health changes over time.

- What is the health of the Puget Sound nearshore as indicated by sediment quality?
- What are the existing sediment quality problems?
- What are the major natural and human stressors on nearshore sediment quality?

Stormwater management problem

Major cities and areas targeted for urban growth are located along the Puget Sound shoreline. Stormwater generated in these urban and urbanizing areas carries pollutants into Puget Sound. These pollutants, including metals and organics, can degrade the quality of Puget Sound marine nearshore habitats and impact the biota in these environments.

Local jurisdictions are increasing their efforts to manage stormwater to reduce these discharges of pollutants to Puget Sound. This is the first regional evaluation of nearshore health with a focus on areas covered by the municipal stormwater permits. Stormwater managers and policy makers need a better understanding of the most influential stressors on environmental health to help focus on the most promising solutions. Over time we anticipate detecting improvements in nearshore indicators in response to permittees' collective stormwater management efforts.

Project findings

Nearshore sediment samples were collected in 2016 from 41 spatially balanced nearshore sites (see Figure 1) along the Puget Sound UGA shorelines. The 41 sites represent 1,344 km (835 mi) of UGA shoreline. Because metals and organics tend to bind strongly to fine particles, only fine sediment was used for chemical analysis of ten metals, polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), and phthalates.

The concentrations of metals and organics in nearshore sediment were relatively low with the exception of site-specific, point-source problems. Most (95 to 99%) of the Puget Sound UGA nearshore had concentrations below Washington State marine sediment standards. Pollutant concentrations were highly variable across the region despite that we found some evidence of urban origination.

Natural variables appear to explain the variation in UGA nearshore sediment concentrations better than human factors. Except for a few metals, common indicators of urban growth and stormwater impacts explain very little of the variation. Lead, copper, and zinc concentrations were only weakly related to percent of urban cover, impervious surface, and road density.

Instead, sediment movement by strong ocean currents seems to govern spatial distribution of chemicals in the nearshore (see Figure 2). The sites with drift cells identified as depositional areas contained more chemicals than high-energy areas with strong water movement. This suggests that ocean currents likely disperse potentially contaminated sediment particles around Puget Sound and dilute urban

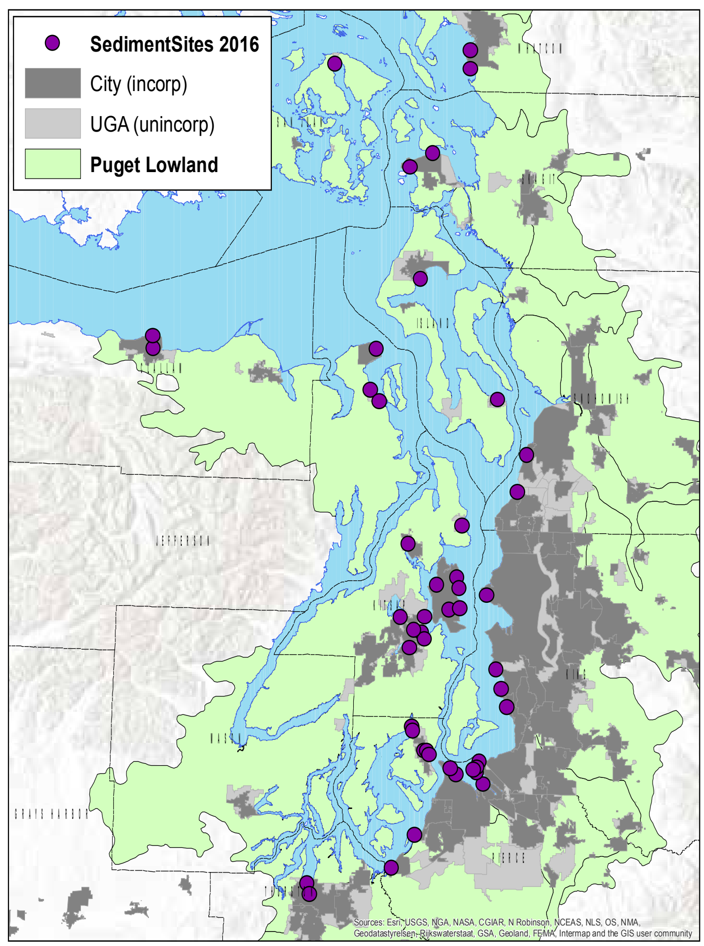


Figure 1. Puget Sound Urban Growth Area (UGA) nearshore sampling locations.

signals on nearshore sediment chemistry. These findings help us understand why nearshore sediment concentrations, especially the low solubility organic pollutants, were not, or were only weakly, correlated to urban land use indicators.

Recommendations

Adjustments to the study design are needed to better sample where urban sediments are likely to be deposited in the nearshore where strong and complex currents drive the spatial pattern of sediment chemistry and stormwater impacts. Regional changes in these relatively low sediment concentrations will probably take a long time to occur and detect, so less-frequent monitoring is recommended.

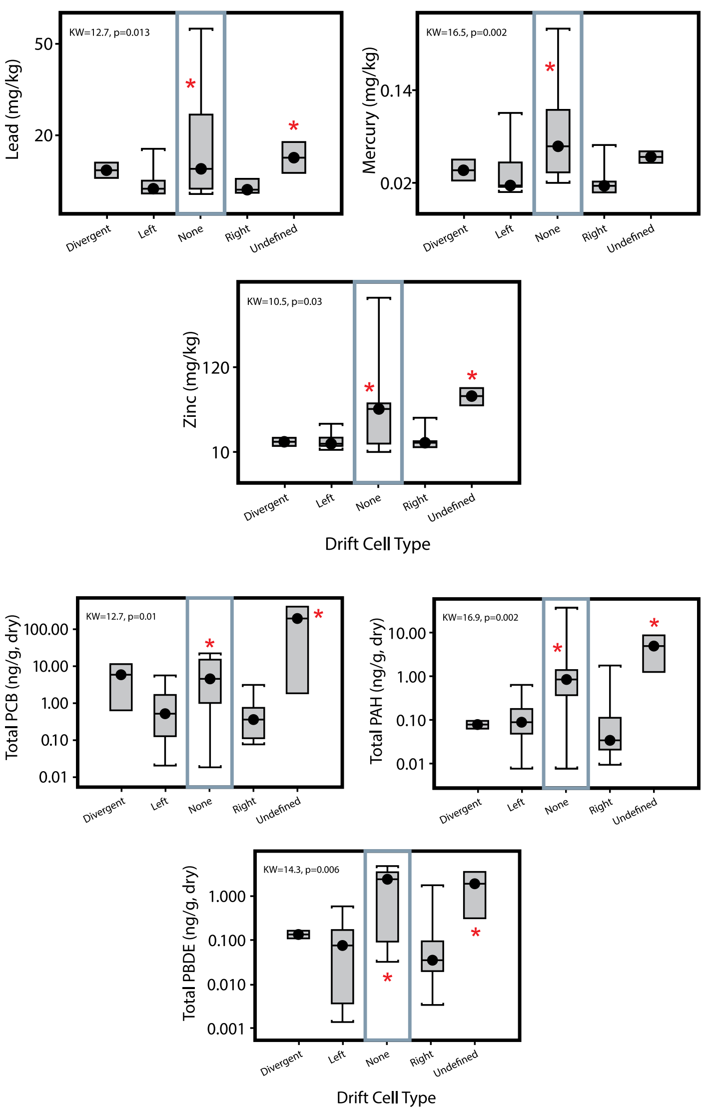


Figure 2. Pollutant concentrations compared to drift cell types indicative of water and sediment movement directions. None (blue box in center) indicates depositional areas with very low wave energy whereas divergent, left and right cell types are erosional areas. Undefined means no drift cell information was available. Red asterisks indicate significantly higher values for these drift cell types.

Why does this study matter?

This project is one component of the SAM nearshore monitoring to evaluate impacts of stormwater in the Puget Sound nearshore. Regional-scale monitoring with a probabilistic sampling design is a cost-effective, unbiased way to assess status and trends to tell us how these impacts change over time with continuing stormwater management efforts. In contrast to the weak urban signal found in nearshore sediment chemistry, the SAM mussel monitoring study (see SAM FS #004) found significant bioaccumulation of contamination related to urban growth across the same study area.

What should we do with this information?

Stormwater managers in jurisdictions with direct discharges to Puget Sound should consider the complex mobility of contaminants in the urban and urbanizing nearshore in prioritizing stormwater management actions. Low-energy shorelines or embayments may benefit more quickly from stormwater retrofits and enhanced operation and management practices in pollutant-generating catchment areas.

What will Ecology do with this information?

Ecology will use this objective regional information to evaluate the efficacy of the overall permitting program over time in slowing or reversing the decline in receiving water conditions caused by stormwater from existing and new development. Ecology can use SAM’s assessments of receiving water conditions in areas covered by the municipal stormwater permits to prioritize stormwater grant funding. This study will also help Ecology and other agencies to develop and adapt nearshore and marine monitoring and restoration programs.

2010-2015 Bacteria Data Compilation from Nearshore Marine Areas in Puget Sound

Receiving Waters

Lead Entity:
Washington Department of Ecology Environmental Assessment Program

Partner:
Washington Departments of Health, and Ecology Beach Environmental Assessment, Communication, and Health (BEACH) Program

For more information: Download the report at https://fortress.wa.gov/ecy/publications/SummaryPages/1703004.html.

Study goals

Bacteria is a vexing stormwater problem. The sources are varied and ubiquitous. When SAM was launched in 2014, stakeholders agreed that before initiating a new nearshore marine status and trends monitoring program for bacteria we should first conduct a data and gaps assessment based on existing marine bacteria monitoring programs. The goals of this project were:

- Assess current collective understanding of bacteria levels in Puget Sound nearshore areas along the urban shoreline.
- Make recommendations for future monitoring to assess changes as a result of stormwater management.

Stormwater management problem

Bacteria is the most common cause of stormwater-related water quality impairment listings. Total maximum daily load (TMDL) pollution reduction strategies for this parameter are mostly focused on public education. While TMDLs also require monitoring to assess progress, they are focused at an individual watershed scale.

Project findings

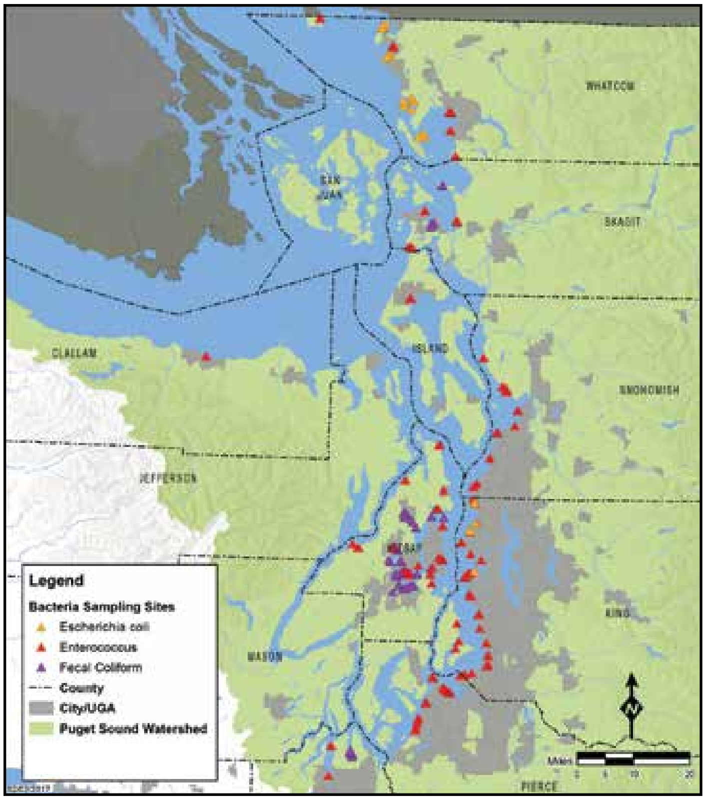
Throughout Puget Sound, bacteria is sampled for many reasons, including ambient monitoring to protect public health and targeted monitoring to identify and solve specific problems. The most consistent ambient monitoring programs are the Washington Department of Health (DOH) Shellfish Program and Washington Departments of Health and Ecology Beach Environmental Assessment, Communication, and Health (BEACH) Program. Several counties collect nearshore marine bacteria data, particularly Kitsap and King. Few cities collect nearshore bacteria data. The Lummi Nation and Nooksack Indian Nation also conduct some ambient monitoring.

For this data review, 27 entities that conduct Puget Sound nearshore monitoring provided bacteria data. The combined dataset has over 42,000 bacteria data points from 2010-2015 including 27,050 for fecal coliform, 14,750 for enterococci, and 848 for E-coli. The DOH Shellfish Program data made up 74% of the available fecal coliform data from 2010-2015, and the BEACH Program made up 85% of the enterococci data (during the May-August period). MAP

The amount of data varied between entities and sub-regions. Some areas like Kitsap County have comprehensive nearshore bacteria data sets due to their ongoing monitoring program. Most areas had localized data but no comprehensive shoreline coverage. Rural areas with shellfish beds had good nearshore fecal coliform bacteria coverage through the DOH Shellfish Program. While the urban corridor shoreline from Tacoma to Everett did not have DOH Shellfish Program data, it did have some nearshore enterococci bacteria data coverage through Ecology's BEACH Program.

The data sets from entities with different sampling goals showed diverse results, as expected. Ambient monitoring programs tend to have lower bacteria levels. Programs that focus on monitoring storm events or source identification tend to have higher bacteria levels.

Shoreline bacteria sampling locations



Service Layer Credits
Sources: Esri, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyreisen, Rijkwaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

Recommendations

A new monitoring program may not be needed to answer key questions. The BEACH and DOH programs might provide sufficient information to measure whether bacteria levels in Puget Sound are changing over time. If new monitoring is pursued:

- Focus on specific sites to consistently monitor. Because there is such a large area to cover (Phase I and II permittees in the Puget Sound area as well as the Strait of Georgia and Strait of Juan de Fuca), it is not possible to monitor all areas. One approach is to develop a list of core sites that are monitored consistently over time.
- Consider focusing on monitoring nearshore sites adjacent to small stream discharges or large stormwater discharge areas. Sampling for the BEACH Program has shown that these areas have higher bacteria levels during and immediately after storm events, especially in densely populated urban areas.
- Ensure consistent sampling methodology (i.e., wade-in versus from-a-boat) to ensure that the depth of the sample obtained is consistent for all sample events.

Why does this study matter?

The goal of stormwater management is to protect Puget Sound and the rivers and streams that flow into it. Stormwater has been found responsible for shellfish and beach closures in Puget Sound and lakes in our region. Understanding the breadth of the bacteria problem and the sources, help us target management actions. These results tell us where we should focus best management practices (BMPs) and whether those practices are working over time.

What should we do with this information?

Stormwater managers should consider how their local data fits into the regional picture. Have you been collecting ambient bacteria data or targeting sources? Permittees should focus bacteria monitoring on identifying and removing sources, and confirming effectiveness of outreach programs and other source-specific BMPs.

What will Ecology do with this information?

Ecology will continue to invest in efforts to develop tools and technologies and to identify, prevent, and reduce bacteria from various sources in stormwater discharges.

Status and Trends Study of Puget Lowland Ecoregion Streams: Evaluation of the First Year (2015) of Monitoring Data

Receiving Waters

Lead Entity:
King County

Partner:
U.S. Geological Survey, Washington Department of Ecology, Skagit County, San Juan Conservation District, and Puget Sound Partnership

For more information: Go to Ecology.wa.gov/SAM and search for SAM streams.

Study goals

This study will monitor how the health of streams change over time in urban, urbanizing, and rural areas of the Puget Lowlands. The study is looking at the full range of urban development conditions to track how stormwater runoff affects small, wadeable streams. In 2015, the first round of monitoring evaluated the condition of streams both within urban growth areas (UGAs) and outside UGAs. The study questions are:

- What is the status of Puget Lowland ecoregion stream health within and outside UGAs?
- What percent of wadeable streams are in "poor" and "good" condition within and outside UGAs in comparison to least-disturbed reference site conditions in the region?
- What are the major natural and human stressors that impact stream health?

Stormwater management problem

Stormwater runoff from urban and urbanizing areas causes the majority of habitat and water quality degradation in small streams. Local jurisdictions throughout Puget Sound are increasing their stormwater management efforts to reduce flow volumes and pollutants. This is the first regional evaluation of stream health that focuses on areas covered by municipal stormwater permits. Stormwater managers and policymakers need a better understanding of the most influential stressors on biological health in order to identify the most promising solutions. Over time, we believe that permittees' collective stormwater management efforts will result in detectible stream quality improvements.

Project findings

The study randomly selected and monitored 105 sites (Figure 1) to represent the total 1,668 miles or 2,685 kilometers of wadeable streams in the Puget Lowland ecoregion. The study evaluated stream health using biological measures, water and sediment chemistry, and physical habitat conditions in streams and watersheds. A benthic invertebrate index of biotic integrity (B-IBI) is a comprehensive indicator of stream biological health.

Urban development negatively influenced nearly all of the stream health indicators (B-IBI, water and sediment chemistry, habitat and landscape metrics). While 69% of the stream length outside UGAs was in good to fair conditions for B-IBI, 82% of the length within UGAs was in poor condition (Figure 2).

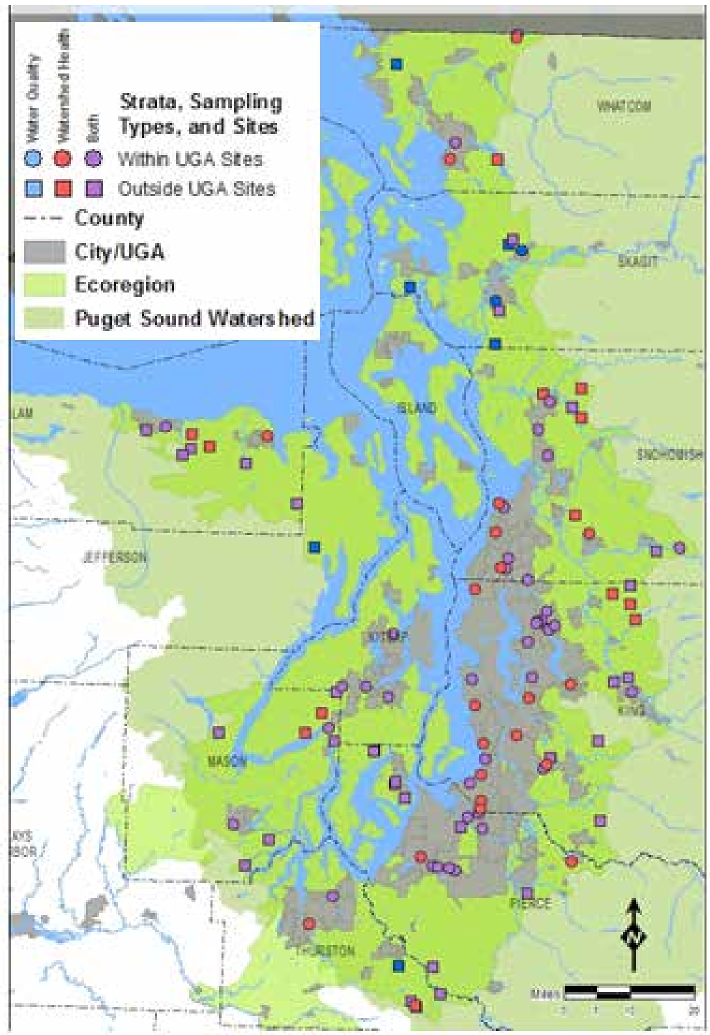


Figure 1. Puget Lowland Ecoregion small streams sampling locations.

Key stressors driving poor B-IBI scores included landscape-scale watershed characteristics, physical habitat, nutrients, sediment zinc, and stream substrate characteristics (Table 1). The study found that low watershed and riparian canopy cover are the most important stressors to B-IBI at the regional scale. This suggests that canopy cover protection and recovery (reducing impervious surface) could lead to substantial improvements in B-IBI scores.

Recommendations

Stormwater managers should review Table 1, determine what combinations of the key stressors are present in their jurisdictions, and then consider adjusting their management programs to address these stressors.

Regional scale monitoring with spatially balanced sampling is a cost-effective way to evaluate unbiased status and trends in the ecoregion. SAM will continue to gather long-term status and trend data in the region. We will modify the monitoring design based on current study findings and scientific recommendations to emphasize understanding of status and trends in stream conditions. Continued monitoring of least-disturbed reference conditions will help establish reasonable expectations for good and poor biological conditions and help identify important stressors.

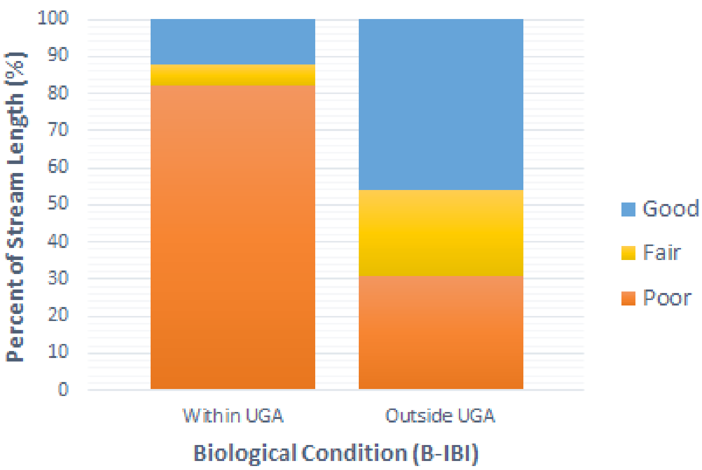


Figure 2. Percentage of total Puget Sound Lowland Ecoregion wadeable stream length in good, fair, and poor condition inside and outside of Urban Growth Areas (UGAs).

Stream Health Category	Significant regional stressors to address to improve B-IBI scores
Watershed scale land cover	• Watershed Canopy Cover • Riparian Canopy Cover • Percent of Urban development
Water	• Total Nitrogen • Total Phosphorus*
Sediment	• Total Zinc* • Substrate Embeddedness* • Substrate Particle Diameter*

Table 1. List of the most important stressors identified for B-IBI for each category of stream health indicators.

** These parameters are important stressors to B-IBI (per the relative risk analysis) but were not found significant at the regional scale.*

Why does this study matter?

With this regional-scale monitoring program, we are improving our understanding of the effects of urbanization and influences of stormwater management efforts on stream health across Puget Sound. Over time, this stream monitoring will tell us whether our overall management strategies, including stormwater management, are improving stream health. More specific studies, in particular, effectiveness studies complementing this monitoring, will help inform how stormwater management contributes to overall improvements in stream health.

What should we do with this information?

Stormwater managers should consider the findings of this study and compare their local monitoring data to the regional data set. In the absence of local monitoring, the results for streams with similar watershed characteristics sampled in this study can provide useful information for targeting stormwater management actions. Permittees can use this knowledge, coupled with findings of effectiveness studies, to help prioritize and implement stormwater runoff management practices in their jurisdictions. Every stormwater manager should consider how to incorporate the protection and restoration of canopy cover in riparian areas and throughout the watershed as part of their efforts to improve B-IBI scores in local streams.

What will Ecology do with this information?

Ecology needs this objective regional information to evaluate whether or not the overall permitting program is slowing or reversing the decline in receiving water conditions caused by stormwater from existing and new development. Ecology can also use the study findings about conditions of streams in areas covered by the municipal stormwater permits to prioritize stormwater grant funding in western Washington.

SAM studies underway in 2019

Effectiveness studies

Redmond paired watershed retrofits

Oyster shell retrofits in catch basins

Bioretention amendment with fungi

Bioretention reduction of PCBs

Longevity of biological protection using bioretention

Mulch choices for bioretention

Water budgets of individual trees

Source identification projects

Regional stormwater spill hotline feasibility study

Illicit Connection/Illicit Discharge field screening manual updates and trainings

Receiving water monitoring

Puget Sound nearshore mussel contaminants

Puget Sound lowland small streams

SAM

Stormwater Action Monitoring