July 1, 2010

David Dicks, Director
Puget Sound Partnership
P.O. Box 40900
Olympia, WA 98504-4900

Ted Sturdevant, Director
Washington Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

Dear David and Ted,

The Puget Sound Stormwater Work Group (SWG) has developed a stormwater monitoring and assessment strategy for the broader community of Puget Sound. On behalf of the members of the SWG I am pleased to deliver the *2010 Stormwater Monitoring and Assessment Strategy for the Puget Sound Region* (the strategy). We have been working since October 2008 to achieve this milestone at the request of the Puget Sound Partnership (Partnership) and the Washington Department of Ecology (Ecology).

The strategy includes 55 Key Recommendations for establishing the Stormwater Assessment and Monitoring Program for Puget Sound (SWAMPPS). These Key Recommendations have been agreed to by consensus of the broad group of stakeholders that have participated in our meetings during the past six months. SWAMPPS is envisioned to be a founding component of the larger regional ecosystem monitoring program for Puget Sound. We believe that implementing SWAMPSS is critical to the success of the *Puget Sound Action Agenda.*

This is the third version of the strategy the SWG has released. A draft scientific framework released in November 2009 was peer-reviewed by five nationally recognized experts in stormwater and monitoring and the SWG received more than 800 stakeholder comments. The SWG addressed these comments in a revised draft scientific framework and an implementation plan that was released in April 2010 for a second public comment period.

This document represents a major milestone we have reached. However, the SWG has more work to do. More detail is needed to adopt and implement the proposed strategy. Due to time constraints, we have not addressed all of the comments received on the April 2010 version of the strategy. Issues that are yet to be addressed are highlighted in the final strategy. The SWG is committed to continuing to work on key issues over the next four months and to deliver further recommendations at the end of October 2010 to address:

- Ecology's specific requests for information to inform the 2012-2017 NPDES Phase I and Phase II municipal stormwater permits. In particular we plan to:
    - Develop an administrative entity to facilitate cost-sharing to implement regional monitoring and assessment (a "pay-in option").
    - Provide further detail on costs and experimental designs and approaches for the proposed categories of monitoring and assessment activities.
- The Partnership's need to provide the Office of Financial Management with prioritized costs estimates for implementing SWAMPPS as part of the *Action Agenda.*
- Other participants' and stakeholders' needs to better understand their roles and responsibilities in implementing the strategy.
- The overarching need to ensure funding for this effort.

The SWG will continue to address remaining issues in future work. We ask both the Partnership and Ecology to procure and advocate for future state and federal funding to implement the strategy. This includes continuation of key monitoring and assessment efforts already under way and launching the new efforts proposed in the strategy. We understand that the state and federal budget requests will depend upon final allocation of costs among local, state, federal entities.

The strategy indicates a placeholder, planning-level cost estimate of at least $14.9 million annually to implement SWAMPPS. This includes ongoing monitoring activities that might already be included in the *Action Agenda*. For comparison: we estimate that current annual monitoring expenditures in Puget Sound by Phase I jurisdictions (the largest 3 counties, 2 cities, and 2 ports) exceed $6 million; and at least $1.7 million is being spent annually on existing status and trends monitoring that is included in the proposed strategy. We anticipate that another 80 smaller Phase II jurisdictions will participate in SWAMPPS.

In October 2010 we will provide you with recommendations for establishing the "pay-in option" along with updated, prioritized cost estimates and proposed allocations of those costs among local, state, and federal government agencies. During this time frame we will also provide additional detail on designs and approaches for status and trends, source identification, and effectiveness studies. We will continue to work after October on other issues that were raised during the May 2010 public comment period on the strategy.

Please feel free to contact me at 206.296.1986 or Jim.Simmonds@kingcounty.gov, or Karen Dinicola, our Project Manager, at 360.407.6550 or karen.dinicola@ecy.wa.gov for further information.

Sincerely,

Jim Simmonds, Chair
Stormwater Work Group

Enclosures

Stormwater Work Group Members
(January-June 2010 participants)

Local Governments:

Representatives: Dana de Leon, City of Tacoma; Mindy Fohn, Kitsap County; Jonathan Frodge, City of Seattle; Heather Kibbey, City of Everett; Kit Paulsen, City of Bellevue; Jim Simmonds, King County.

Alternates: Neil Aaland, WA Assn. of Counties; Alison Chamberlin, Mason County; Rick Haley, Skagit County; Andy Meyer, Assn. of WA Cities; Jerallyn Roetemeyer, City of Redmond.

State Agencies:

Representatives: Shayne Cothern, Dept. of Natural Resources; Tim Determan, Dept. of Health; Dick Gersib, Dept. of Transportation; Bill Moore, Ecology; Bruce Wulkan, Partnership.

Alternates: Fred Bergdolt, Dept. of Transportation; Nathalie Hamel, Partnership; Julie Lowe, Ecology.

Federal Agencies:

Representatives: Jay Davis, U.S. Fish and Wildlife Service; DeeAnn Kirkpatrick, NOAA Fisheries; Tony Paulson, U.S. Geological Survey.

Environmental Groups:

Representatives: Tom Putnam, Puget Soundkeeper Alliance; Heather Trim, People For Puget Sound.

Business Groups:

Representatives: Allison Butcher, Master Builders Assn. of King and Snohomish Counties; Mel Oleson, The Boeing Company.

Alternates: Kris Holm, Assn. of Washington Business.

Agriculture:

Representative: Carol Smith, WA Conservation Commission.

2010 Stormwater Monitoring and Assessment Strategy for the Puget Sound Region

Created and overseen by:

The Puget Sound Stormwater Work Group

(members listed on the following page)

June 30, 2010

Stormwater Work Group

NAME	AFFILIATION	Caucus
MEMBERS		
Allison Butcher	Master Builders Assn of King & Snohomish Co.	Business Groups
Shayne Cothern	WA Dept. of Natural Resources	State Agencies
Jay Davis	U.S. Fish and Wildlife Service	Federal Agencies
Bill Dewey	Taylor Shellfish	Business Groups
Dana de Leon	City of Tacoma	Local Governments
Tim Determan	WA Dept. of Health	State Agencies
Mindy Fohn	Kitsap County	Local Governments
Jonathan Frodge	City of Seattle	Local Governments
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Heather Kibbey	City of Everett	Local Governments
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Bill Moore, ***Vice Chair***	WA Dept. of Ecology	State Agencies
Char Naylor	Puyallup Tribe	Tribes
Mel Oleson	The Boeing Company	Business Groups
Kit Paulsen	City of Bellevue	Local Governments
Tom Putnam	Puget Soundkeeper Alliance	Environmental Groups
Jim Simmonds, ***Chair***	King County	Local Governments
Carol Smith	WA State Conservation Commission	Agriculture
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Tony Paulson	U.S. Geological Survey	Federal Agencies
Bruce Wulkan	Puget Sound Partnership	State Agencies
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Alison Chamberlin	Mason County	Local Governments
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Andrea LaTier	U.S. Fish and Wildlife Service	Federal Agencies
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Margaret McCauley	U.S. Environmental Protection Agency	Federal Agencies
Andy Meyer	Association of WA Cities	Local Governments
David Price	WA Dept. of Fish & Wildlife	State Agencies
Scott Redman	Puget Sound Partnership	State Agencies
Jerralyn Roetemeyer	City of Redmond	Local Governments
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Tiffany Speir	Master Builders Association of Pierce County	Business Groups
Ken Stone	WA Dept. of Transportation	State Agencies
STAFF		
Karen Dinicola	WA Dept. of Ecology	Project Manager
Leska Fore	Statistical Design	Facilitator

Acknowledgements

The Stormwater Work Group would like to express our appreciation to the many people who have provided us input and ideas for creating this strategy. Dozens of local technical experts and interested parties have attended our meetings and workshops, conducted research, sent emails, and made phone calls to help us achieve our goals. This strategy is stronger because of their contributions.

We wish to specifically acknowledge the contributions of the following non-work group members:

- Derek Booth, Stillwater Sciences, and John Lenth, Herrera Environmental Consultants, each authored many sections of this report and its appendices.
- Pam Bennett-Cumming, retired from Mason County, and Gary Turney, retired from the U.S. Geological Survey, were founding work group members. Gary's active participation was particularly helpful in developing the November 2009 draft scientific framework.
- Others who participated on subcommittees and contributed in other ways to develop the recommendations included in this report include: Steve Britsch, Snohomish County; Chad Brown, WA Dept. of Ecology; John Clemens, U.S. Geological Survey; Scott Collyard, WA Dept. of Ecology; Damon Diessner, Environmental Strategies in Action; Emmett Dobey, Mason County; Ken Dzinbal, WA Recreation and Conservation Office; George Fowler, Independent Consultant; Dennis Helsel, Practical Stats; Joan Lee, Parametrix Consultants; Julie Lowe, WA Dept. of Ecology; Joy Michaud, Herrera Environmental Consultants; Mike Milne, Brown and Caldwell; Joyce Nichols, City of Bellevue; Dale Norton, WA Dept. of Ecology; Stephen Ralph, Stillwater Sciences; Phyllis Varner, City of Bellevue; and Jim West, WA Dept. of Fish and Wildlife.

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Dear Reader:

This document represents the effort we have completed as of June 30, 2010. The Stormwater Work Group will continue to work to address these remaining key issues:

- Costs, and allocation of funding among participating entities.
- Establishing an administrative entity to support collective regional stormwater-related monitoring and assessment efforts.
- Linking the types of monitoring.
- Detailed experimental designs.
- How the monitoring proposed in this strategy fits into NPDES municipal stormwater permits.
- A process to select regional effectiveness studies.
- How to address other land uses, other water bodies, and other NPDES permits.

We will submit our next set of recommendations to Ecology, the Partnership, and others at the end of October 2010 in a series of separate reports.

1. INTRODUCTION

Stormwater is a significant stressor affecting the health of the Puget Sound ecosystem. Efficiently and effectively managing stormwater flows and pollutant loads to prevent, reduce, and mitigate harm to the ecosystem is a common goal of the governments and agencies, environmental groups, business community and citizens of Puget Sound. A considerable amount of stormwater-related monitoring is currently being conducted but it is not being coordinated or compiled to answer regional questions. A collaborative, comprehensive regional strategy is needed for the Puget Sound basin to provide an unbiased assessment of whether stormwater management actions are resulting in genuine progress towards regional conservation targets.

This strategy describes the *scientific framework* for regional stormwater-related monitoring and assessment:

- What decisions were needed and were made about priorities for data collection.
- What information needs to be collected and what analyses need to be conducted.

This strategy also proposes an *implementation plan* for establishing a regional stormwater monitoring program and conducting the monitoring and assessment activities:

- Who will collect what data when, where, and how.
- What methods, protocols, and data reporting standards will be used.

This project was initiated in response to requests for a regional stormwater monitoring program by the Puget Sound Partnership (Partnership) and the Washington State Department of Ecology (Ecology) in 2008. The Partnership is the state agency charged with overseeing ecosystem recovery efforts for Puget Sound. Ecology is the state agency delegated with federal Clean Water Act implementation; one goal of this effort is to inform the monitoring requirements in the 2012-2017 National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits.

The Partnership is leading a concurrent effort to create a broader ecosystem monitoring program. The proposed Stormwater Assessment and Monitoring Program for Puget Sound (SWAMPPS) is intended to be a functioning cornerstone of that broader ecosystem monitoring program. The Puget Sound Stormwater Work Group (SWG) assembles a group of technically and politically savvy representatives from cities, counties, tribes, and state and federal agencies responsible for monitoring and managing stormwater and water quality and other stakeholders that understand stormwater. The SWG's goal is to identify priorities, a starting point, and next steps primarily to support stormwater management efforts; but also to inform the Partnership's broader purposes.

The *Stormwater Monitoring and Assessment Strategy for the Puget Sound Region* provides critical science support for implementation of the *Puget Sound 2020 Action Agenda* (Partnership 2008). Implementation of the SWG's recommendations presented in this strategy will begin to fulfill *Near Term Action C.2.N1* in the *Action Agenda*: Create a regional stormwater monitoring program. SWAMPPS will provide key information about ecosystem status and trends (threats, drivers, state) and important effectiveness research within an adaptive management framework that is connected to policy makers. Future work will more fully address stormwater-related monitoring for other land uses, water bodies, and NPDES permits.

2. KEY RECOMMENDATIONS

These are our 55 key recommendations to the Puget Sound Partnership (Partnership), the Washington State Department of Ecology (Ecology), and others for establishing a Stormwater Assessment and Monitoring Program for Puget Sound (SWAMPPS).

The recommendations are organized into five categories: Strategic priorities and overall framework, status and trends monitoring, source identification and diagnostic monitoring, effectiveness studies, and regional program implementation.

2.1 Strategic Priorities and Overall Framework

The Stormwater Work Group (SWG) recommends:

1. The initial starting point for the Stormwater Assessment and Monitoring Program for Puget Sound (SWAMPPS) is focused on stormwater-related impacts from urban and urbanizing land uses. Robust, fully-scoped monitoring and assessment programs for other land uses need to be cooperatively developed in the future.
2. The initial starting point for SWAMPPS is focused on stormwater-related impacts to small streams and marine nearshore areas. Robust, fully-scoped monitoring and assessment programs for other water bodies should be cooperatively developed as specific priority questions are identified.
3. The initial priorities identified for SWAMPPS are rooted in an adaptive management framework and will inform important policy decisions.
4. The initial categories of experimental designs to be included in SWAMPPS include status and trends, source identification and diagnostic monitoring, and effectiveness studies. Research activities may be added later as specific priority questions are identified.

2.2 Status and Trends Monitoring

The SWG recommends:

5. The proposed number and allocation of samples, specific locations, and temporal aspects of the experimental design need to be further defined relative to the specific parameters of concern. A technical committee will refine these aspects of the experimental design and submit recommendations to the SWG.

2.2.1 Scientific Framework for Small Stream Status and Trends Monitoring

The SWG recommends:

6. Stormwater-related indicators for small streams:
    a. Water quality.
    b. Benthic macroinvertebrates.

   c. Physical features.
   d. Fish diversity and abundance.
   e. Flow.
   f. Temperature.
   g. Streambed sediment chemistry (metals and toxics).

7. Experimental design for small streams:
   a. Probabilistic sampling of randomly selected sites to assess chemical, physical, and biological status and trends over time.
   b. Approach is compatible with Ecology's statewide status-and-trend monitoring program (State EMAP) methodology for wadeable streams.
   c. At the Puget Sound scale: use the existing 30 State EMAP sites located in Puget Sound and/or historical water quality monitoring sites that meet statistical considerations, collect samples for the current State EMAP parameters, and also collect samples for sediment toxic chemicals and water quality.
   d. At a minimum of thirteen stations across Puget Sound (one in each Water Resource Inventory Area (WRIA)), also monitor continuous flow and temperature at existing (non-random) stream gauging stations identified in the final study design.
   e. Within the first year, identify relevant existing data that could further refine the final sampling frequency and design.

8. Identification of small stream sites:
   a. Target second- and third-order "wadeable" streams that are more directly (but not exclusively) affected by stormwater,
   b. Identify 30 sites at the Puget Sound scale for trend assessment:
      i. Use sites selected for State EMAP.
      ii. To the extent possible without compromising the probabilistic design, existing long-term monitoring sites should be included and used.
   c. Focus on the watershed scale using a probabilistic site-selection approach that can be more densely focused within urban growth areas if appropriate.
   d. Add sites to total 30 within each of the thirteen local salmon recovery areas in Puget Sound (WRIAs, and combinations of WRIAs), for a total of 390 sites.
   e. Island-based watersheds would not be included in this component of the monitoring program due to the limited number of wadeable streams.

9. Small stream monitoring frequency:
   a. At the regional scale: Follow State EMAP protocols, and conduct:
      i. Annual sediment chemistry sampling at the 30 State EMAP sites,
      ii. Monthly water quality sampling at the 30 State EMAP sites, and

iii. Continuous measurements at the 13 flow and temperature stations.

b. At the WRIA scale: Consider, as a target: Ramp-up and conduct two rounds of wadeable stream status and trends sampling within a five year cycle from 2012 to 2017 to match the NPDES municipal stormwater permit cycle (begins in 2012), and allow sufficient time for analyses to refine the monitoring program design and inform the following five-year cycle of permits and other efforts.

2.2.2 Implementation Plan for Small Stream Status and Trends Monitoring

The SWG recommends:

10. Local governments and others will use protocols compatible with Ecology's statewide status and trend monitoring (State EMAP) protocols, coordinate with WRIA groups, and partner with others as needed to standardize data collection methods.
11. Local governments will help coordinate sampling among the WRIA groups and other entities involved in conducting monitoring of stream benthos, fish, habitat, water quality, and other parameters to avoid duplication of field efforts and achieve cost savings. Sampling is conducted by NPDES municipal stormwater permittees, Ecology, and others. Within the first year, identify other opportunities for collaboration.
12. Salmon recovery entities, Ecology, the Partnership, and others will coordinate with local governments to fund and conduct two rounds in a five-year period of fish diversity and abundance monitoring and physical feature monitoring.
13. Ecology will fund and oversee the State EMAP program within the Puget Sound basin. Local Governments will coordinate with these efforts.
14. The SWG will compile information within the next year on current streamflow gauging stations in Puget Sound, analyze current regional streamflow monitoring capacity, and develop a regional network of stream gauges associated to the greatest extent possible with the water quality and habitat monitoring sites.
15. Local governments in Puget Sound covered under NPDES municipal stormwater permits will, collectively, fund and conduct the remaining elements of the regional small stream status and trends monitoring program (most of the watershed-scale sampling) as part of their overall mandate. The financial contribution and/or level of effort required of each permittee will be based on equitable factors, and permittees will be allowed flexibility to either pay into a collective fund or conduct the monitoring themselves.
16. The SWG will coordinate with the Partnership, Puget Sound Salmon Recovery Council, and others to seek additional funding and in-kind contributions for this proposed monitoring and assessment.

2.2.3 Scientific Framework for Nearshore Area Status and Trends Monitoring

The SWG recommends:

17. Stormwater-related indicators for nearshore areas:

   a. Fecal coliform,
   b. Bioaccumulation toxicity, and
   c. Sediment chemistry (metals and toxics).

18. Experimental design for nearshore areas:
    a. Probabilistic sampling of randomly selected stratified sites to assess biological and chemical status and trends over time.
    b. Approach is compatible with Washington Department of Health (WDOH) protocols for fecal coliform monitoring.
    c. Approach is compatible with NOAA's national Mussel Watch protocols for bioaccumulation toxicity.
    d. Approach is compatible with PSAMP protocols for sediment chemistry and other nearshore monitoring.
19. Identification of nearshore sites:
    a. Continue bioaccumulation toxicity monitoring at existing ambient Mussel Watch sites.
    b. Randomly select 30 new sites for conducting annual bioaccumulation toxicity monitoring near stormwater outfalls to Puget Sound.
    c. Continue to conduct PSAMP sediment chemistry and other monitoring at nearshore sites.
    d. Conduct sediment chemistry monitoring at 30 randomly selected depositional locations in Puget Sound. Evaluate, statistically and logistically, whether these can be aligned with the Mussel Watch sites.
    e. Focus on areas of the marine nearshore environment that meet Mussel Watch and PSAMP sediment monitoring criteria but are more directly (but not exclusively) affected by stormwater.
    f. Randomly select 50 sites for fecal coliform monitoring at the Puget Sound regional scale, utilizing WDOH, tribal, or other shellfish monitoring data in areas of overlap.
20. Nearshore monitoring frequency:
    a. Monthly fecal coliform sampling,
    b. Annual bioaccumulation toxicity monitoring, and
    c. Annual sediment chemistry monitoring.

2.2.4 Implementation Plan for Nearshore Area Status and Trends Monitoring

The SWG recommends:

21. Local governments with stormwater outfalls to Puget Sound will partner with the Mussel Watch program to develop a probabilistic survey approach to select new sites for conducting bioaccumulation toxicity and sediment chemistry sampling.
22. Local governments with stormwater outfalls to Puget Sound will use protocols compatible with WDOH, Mussel Watch, and PSAMP, and partner with others as needed to standardize data collection methods.
23. Mussel Watch, WDOH, and PSAMP will help coordinate sampling among the entities involved in conducting monitoring of fecal coliform, bioaccumulation toxicity, and sediment chemistry to avoid duplication of field efforts and achieve cost savings. Sampling is conducted by local governments, WDOH, Washington Dept. of Fish and Wildlife, volunteers, Ecology, and others. Within the first year, identify other opportunities for collaboration.
24. Local governments in Puget Sound covered under NPDES municipal stormwater permits will, collectively, conduct the following elements of the regional program as part of their overall mandate. The financial contribution and/or level of effort required of each permittee is based on equitable factors and permittees are allowed flexibility to either pay into a collective fund or conduct the monitoring themselves.
    a. Monthly fecal coliform monitoring at 50 sites,
    b. Annual bioaccumulation toxicity (Mussel Watch) monitoring at 30 sites, and
    c. Annual nearshore sediment chemistry monitoring at 30 sites.
25. Local governments will coordinate with salmon recovery efforts, Puget Sound clean-up efforts, local Departments of Health, the Puget Sound Nearshore Restoration Partnership (PSNRP), and other existing nearshore monitoring efforts.
26. The SWG will coordinate with the Partnership and others to seek additional funding and in-kind resources for this proposed monitoring and assessment.

2.3 Source Identification and Diagnostic Monitoring

2.3.1 Scientific Framework for Source Identification and Diagnostic Monitoring

The SWG recommends:

27. A comprehensive regional stormwater-related source identification framework is needed to help inform and prioritize both local and regional source control activities.
28. Source identification is conducted to address long-term receiving-water problems, as part of a broader effort to identify and eliminate pollution sources. Watershed-specific priorities should be set to target initial source identification efforts on the problems of greatest local concern. Regional and local monitoring data and assessment findings need to be reviewed at least once every five years to identify and prioritize problems to address.
29. Key components of source identification include:

a. Determine the existing problem sources/impairments to beneficial uses.
b. Prioritize sources/impairments.
c. Set a target for source reduction.
d. Locate sources/impairments.
e. Plan the regulatory framework and actions to remove the source(s).
f. Implement source removal actions/programs.
g. Monitor to provide feedback on status of the source.
h. Sustain or implement monitoring to diagnose emerging sources.

These activities occur in an iterative process to track improvements in the receiving waters and to identify needs for additional controls. Multiple entities need to cooperate in situations where the impairment is not confined within the boundaries of a single jurisdiction.

2.3.2 Implementation Plan for Source Identification and Diagnostic Monitoring

The SWG recommends:

30. NPDES municipal stormwater permittees will coordinate with WRIA groups or watershed lead entities to initiate and oversee a process to prioritize problems in each watershed. After prioritization, lead entities will coordinate the development of a plan to address the top priority problem and proceed to implement early management actions and begin appropriate monitoring.
31. In the next six months, Ecology will lead a process, through the SWG, to recommend an approach to source identification monitoring for the NPDES municipal stormwater permits, including appropriate roles and responsibilities.
32. Source identification and diagnostic monitoring, TMDLs, toxic waste clean-ups, and other activities should be coordinated to share resources, reduce costs, and focus on the most important problems.
33. Review source identification and diagnostic monitoring data on a Sound-wide basis at least once every five years to inform and target regional source control initiatives.

2.4 Effectiveness Studies

2.4.1 Scientific Framework for Effectiveness Studies

The SWG recommends:

34. Initial studies to assess effectiveness of stormwater best management practices (BMPs) and other urban/urbanizing stormwater management activities will be conducted to address the following three priority areas of investigation:

   a. Testing the effectiveness of low-impact development (LID) techniques to minimize impacts from future new development and in areas of redevelopment.
   b. Testing the effectiveness of retrofitting urban areas with various flow management and water quality treatment approaches to decrease impacts from the built environment.
   c. Testing the effectiveness of non-structural (i.e., operational, behavior-change, planning) and programmatic approaches used in stormwater management programs, and in particular, of various provisions of the NPDES municipal stormwater permits.

   Future studies should:

   d. Evaluate new technologies.
   e. Fill key knowledge gaps about existing technologies to provide better tools for managing stormwater in the future.

   In general, studies will be directed to evaluating stormwater management programs as well as specific practices and activities. The SWG will reevaluate the focus of regional, prioritized effectiveness studies on a periodic basis.

35. Studies to assess effectiveness of stormwater BMPs will occur at the site scale, basin scale, and regional scale.
36. Studies to assess effectiveness of stormwater BMPs will be designed to answer specific questions with clearly articulated hypotheses for testing.
37. Studies to assess effectiveness of stormwater BMPs will include quantification of the cost of implementing the stormwater management activities being studied, so that cost-effectiveness can be judged by stormwater managers and policy makers.
38. Stormwater impacts from other land use management approaches and other stormwater permits also need to be addressed.
    a. An initial effort for agricultural land use will test the effects of agricultural BMPs.
39. In the area of evaluating new technologies, emerging techniques are a recommended focus. Examples include reducing fecal coliform and metals.

2.4.2 Implementation Plan for Effectiveness Studies

The SWG recommends:

40. A literature review needs to be conducted as soon as possible to focus data collection efforts on studies that are needed and to avoid addressing questions that have already been answered and to build on existing work.
41. Requests for proposals will be issued for effectiveness studies, based on the guidance and priorities identified by the SWG. The SWG will develop and propose an open and transparent process to evaluate the submitted proposals and select studies for initial implementation.

   a. The first round of this process needs to be expedited in fall 2010 in order to meet Ecology's needs to identify effectiveness studies that will be included for implementation in the coming NPDES municipal stormwater permit cycle.

42. A transparent public process will identify and prioritize future and more specific topics, questions, and hypotheses for effectiveness studies, applying the following criteria for evaluating and selecting effectiveness studies:
    a. Meets the criteria for a sufficiently defined working hypothesis.
    b. Important stressors are addressed.
    c. Selected studies address a range of the prioritized topics and categories.
    d. The practices to be evaluated are likely to result in improvements to beneficial uses.
    e. The study is likely to contribute to our collectively ability to implement more cost-effective stormwater management actions.
    f. The study is strongly linked to the Puget Sound Action Agenda and results chains.
43. The Technology Assessment Program - Ecology (TAP-E), which evaluates the effectiveness of new technologies, should continue with funding from new technology proponents and other long-term, reliable funding sources.
44. The Washington State Conservation Commission, Ecology, and other key entities and stakeholders will define a broader effort to assess stormwater impacts from agricultural areas and effectiveness of agricultural BMPs.

2.5 Regional Program Implementation

The SWG recommends:

45. Ecology and the Partnership should evaluate and decide upon a permanent Stormwater Work Group (SWG) charter, composition, host agency, long-term funding, and support of participation. In doing so they should make modifications as needed to improve the SWG's ability to perform our essential functions.
    a. Formalize the SWG as an ongoing part of the broader ecosystem monitoring program being created by the Partnership.
    b. Approve future SWG work plans.
    c. Continue to use the SWG to prioritize SWAMPPS activities.
    d. Maintain SWG roles of decision making and leadership, coordination, and informing the regional stormwater control strategy.
46. The Partnership should include a preliminary annual cost estimate of $14.9 million to implement this strategy for SWAMPPS as part of the Action Agenda. The SWG will provide a more detailed and prioritized cost estimate and recommend the means to meet and sustain the overall funding needs of this strategy for SWAMPPS via contributions from local, state, and federal governments, private sources, and others. The SWG will also estimate start-up costs to establish SWAMPPS.

   a. The new monitoring program should be conducted using efficiently coordinated existing capacities to the extent possible and strategically adding new capacities to fill the remaining need.
   b. Monitoring costs should be reasonably shared between participating entities. The proportions may be different for each category of monitoring. The SWG will propose recommendations to allocate costs.
   c. The SWAMPPS components should be supported and maintained through funding contributions and/or in-kind services from all entities participating in the program.

47. The SWG will identify and recommend to Ecology the means to create an independent entity to administer a fund dedicated to stormwater-related monitoring and assessment activities. The SWG will task a subgroup to address the following topics and present a proposal to the SWG in September 2010. The SWG will make a final recommendation to Ecology in October 2010.
   a. The fund overseen by this independent entity will provide a "pay-in option" for entities covered under NPDES municipal stormwater permits that:
      i. Allows permittees flexibility to meet requirements by either paying into the fund, or conducting monitoring activities themselves.
      ii. Ensures that permittees' contributions are spent exclusively on stormwater-related monitoring and assessment activities.
      iii. Is managed by an independent entity whose budget is permanently dedicated to monitoring and cannot be re-appropriated to other purposes by any legislative body.
   b. The independent entity will allow and encourage all entities in the region to contribute to and participate in coordinated regional monitoring and assessment activities.
   c. The independent entity will provide businesses and other NPDES permittees with a future pay-in option.

48. Entities conducting the regional monitoring and assessment activities should partner to share resources and reduce costs.

49. An ongoing inventory of monitoring and assessment activities in Puget Sound, which includes stormwater-related programs, should be created and maintained.

50. Recent and ongoing stormwater-related studies and findings in Puget Sound should be analyzed. A gap analysis and targeted literature reviews are needed to help refine and direct future priorities and experimental designs.

51. Credible data must be collected in a quality manner.
   a. Ensure that:
      i. Data quality objectives are identified.
      ii. Project plans are approved and shared.
      iii. Standard field collection and data reporting protocols are followed.

iv. Appropriate analytical accuracy, precision, detection, and reporting limits are used at accredited laboratories.

v. Geographic information system (GIS) data follow state guidelines.

b. Formulate and support a process to develop and approve standard methods.

c. Populate an on-line library with approved methods.

d. Maintain a prioritized list of methods that need to be developed.

e. Require NPDES permittees to select from a web-accessible list of approved analytical methods.

52. Data management systems for the regional monitoring and assessment program data and findings should be created and maintained:

    a. Include data repository, storage, and management structures.

    b. Use appropriate meta-data, data descriptors, and qualifiers.

    c. Provide easy public access to all data and findings.

    d. Assign responsibility for providing quality assurance information and for correcting, editing, and updating data to the generators of data or findings.

    e. Build upon existing regional data management systems.

53. Monitoring conducted for all categories of SWAMPPS should be required to follow all applicable regional protocols; and all data and findings should be submitted to the data management system (Key Recommendation #51) and readily available to the public.

54. A collective analysis and synthesis of the data and findings of SWAMPPS and other relevant regional and national science activities should be conducted at least once every five years.

55. Regional stormwater-related modeling needs should be identified and prioritized.

3. BACKGROUND AND CONTEXT

The Puget Sound region has been the focus of numerous widely-cited scientific studies designed to understand and reduce the effects of stormwater. Although many types of human activities threaten the health of the Puget Sound ecosystem, there is considerable agreement among regional scientists and community leaders that the alteration and loss of habitat and the ongoing input of pollution are the most immediate and pervasive threats to the ecosystem (Beyerlein *et al*. 2006 and 2008; Partnership 2008). Surface water and stormwater runoff in urban and rural areas are now recognized as the primary, unaddressed transporters of toxic, nutrient, and pathogen pollutants to surface and groundwater resources throughout the Puget Sound basin (Ecology 2007), and are also now recognized a one of the primary causes of habitat degradation in small streams due to alterations in flow volumes, timing, and duration.

The types and magnitude of threats vary in different places, but the entire region faces challenges from a growing human population and a changing climate that will exacerbate the many existing pressures to Puget Sound. Water quality and stormwater management practices in the region need to be anchored within an ecosystem approach and better coordinated so they can effectively address the ubiquitous nature and diffuse sources of pollutants in our freshwater and marine systems. Current stormwater management programs in the Puget Sound region evolved from local programs focused on drainage and flooding problems; the pollution carried by stormwater was not a driving factor in creating these programs (or infrastructure) until relatively recently. Measures that address the site or project scale collectively fall short of protecting the ecosystem.

Three approaches have been comingled in the creation of this strategy:

1. Scientific understanding and inquiry serve as the foundation for the development of specific, testable hypotheses related to reducing the impact of stormwater throughout the Puget Sound basin.
2. Tenets of adaptive management are adopted to ensure that the results of monitoring are relevant and used to inform management and policy decisions
3. Development of the strategy is an inclusive, transparent process.

A comprehensive, regional <u>S</u>torm<u>w</u>ater <u>A</u>ssessment and <u>M</u>onitoring <u>P</u>rogram for <u>P</u>uget <u>S</u>ound (SWAMPPS) will be developed over time, in an iterative approach. This strategy represents our first steps, those of defining the initial scientific framework, setting priorities, and describing an implementation plan for launching the program. We must prioritize because, given limited resources and the need to efficiently uncover vital information to improve our stormwater management efforts, we cannot afford to undertake every potential stormwater monitoring and assessment activity. Our recommendations must be delivered in time to inform state agency budgets and the monitoring requirements in future National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits.

This overall effort is intended to constitute one portion of an overall ecosystem monitoring program for Puget Sound by satisfying the need to learn more about the effects of stormwater on beneficial uses and the most effective stormwater management and mitigation measures to control those effects. In a separate but connected effort, an overall monitoring and assessment program for the Puget Sound ecosystem is being established so that the region can clearly see if the health of Puget Sound is improving, and whether the legislative goal of restoring the Puget Sound ecosystem by 2020 is being met.

3.1 Purpose and Scope

The overall purpose of this strategy is to bring together the collective capacity and resources of the region to provide a regional understanding of stormwater impacts and enable managers to know whether or not stormwater management actions are reducing harm caused to Puget Sound and the waters that feed it. Both the Partnership and Ecology requested a stormwater monitoring program that provides meaningful management data and supports a larger, integrated effort to protect and restore the Puget Sound ecosystem.

The scope of our effort is limited to stormwater-related monitoring and assessment. Because the stormwater problem in Puget Sound is so extensive and complex this strategy has an even narrower scope: to describe the extent of the problem and define a scientific framework and initial steps for moving forward with implementation beginning in July 2010. The monitoring and assessment results must be closely linked to potential management and regulatory actions to ensure that a cycle of adaptive management is created and maintained.

This strategy emphasizes a hydrologically-oriented definition of "stormwater," which is broader rather than a regulatory perspective (under the Clean Water Act, "stormwater" must pass through some sort of engineered conveyance, be it a gutter, pipe, ditch, or even a roadside curb). Our attention is focused on stormwater that emanates from those parts of the landscape that have been affected in some fashion by human activities.

We also include in our overall framework non-stormwater runoff that is generated by human activities taking place between precipitation events such as car-washing, lawn-watering, *etc.* These discharges can contribute to receiving-water impairments and are managed within the same infrastructure and programs as precipitation-generated runoff.

3.2 An Overarching Strategy

The many groups interested in and responsible for collecting information about stormwater impacts in Puget Sound all agree that an overarching stormwater monitoring and assessment strategy is needed to ensure that the information is meaningful and useful for decision makers, to continue to prioritize the types of data to be collected, and to coordinate the efforts of the multiple parties involved.

The SWG intends to develop and carry out a strategy that improves how we manage stormwater and provides decision makers with critical information to help them make more informed, more successful decisions. In particular, we expect that:

- The Partnership will use information gained from this strategy to inform and improve future revisions to the *Action Agenda* and regional stormwater management policy,
- Ecology will use information gained from this strategy to refine the best management practices recommended in stormwater guidance manuals and required in permits, determine monitoring components of future NPDES stormwater permits, and improve regional stormwater management efforts, and

- Other entities will use information to inform relevant management programs associated with the improving health of Puget Sound basin.

Some of the actions needed to reduce the impacts of stormwater are currently addressed under the *Puget Sound Action Agenda* (Partnership 2008). The Partnership is using an Open Standards model (Conservation Measures Partnership 2007) approach to adaptive management to frame and support implementation of the *Action Agenda,* and the approach presented here is compatible with that model. Results from SWAMPPS will be linked to specific objectives related to the reduction of stormwater runoff through permits, modification of land use practices, retrofits, incentives, and other mechanisms.

The *Stormwater Monitoring and Assessment Strategy for the Puget Sound Region* is intended to be comprehensive, or at least sufficiently broad-based that:

- Local, state, federal, and tribal governments; industries; agriculture; and others throughout the region are interested in joining and contributing to the effort;
- The diverse geography, biology, geology, climate, social/political ranges, and variations in land use combinations within the region are covered; and
- The results of the monitoring and assessment are meaningful and robust.

This strategy defines "the universe" of the stormwater problem and then narrows that universe to what we judge to be an achievable starting point, using a caucus-based stakeholder committee and broader public process (see Appendix A). This narrowing was challenging, and some conditions that are of great regional and local significance are not included as priorities. There are many land-use based management programs in place that are intended to improve water quality.

While focusing on NPDES municipal stormwater permit-mandated programs is not a fully satisfying means of addressing the stormwater problems facing the region, it is the charge to the SWG and therefore our agreed-upon starting point. We also acknowledge the continuing need to focus on local and other watershed based problems while contributing to better understanding and solving regional stormwater-related problems.

3.3 This Strategy is an Adaptive Management Tool

***"Adaptive implementation is, in fact, the application of the scientific method to decision making"* (NRC 2001).**

This strategy invokes the principals of Adaptive Management. Fundamental to this approach is the integration of management and monitoring, recognizing that any management action in the context of a complex ecological system is ultimately experimental, requiring feedback to make progress (see Figure 1; with this strategy, the SWG is addressing Step 1 and Step 2 of this cycle for stormwater-related monitoring and assessment.).

This principle has been articulated in a variety of past ecosystem monitoring and assessment efforts, both regionally and nationally. Some consistent themes emerge that show consistent success or, conversely, increase the likelihood of failing to meet program goals:

1. Clear and well-defined program goals must be articulated. Without this critical step, it is impossible to adequately frame the initial scope of investigations and the overall feasibility of the monitoring or restoration program.

Figure 1. The Adaptive Management Cycle (Open Standards Conservation 2007).

2. Management or program goals must be translated into scientific and technical objectives that are measurable, and that define the means and mechanisms by which the ultimate goal will be realized. Once defined, the technical or scientific objectives are addressed through the application of scientific principals, including testable hypotheses.
3. Hypotheses can only be tested through the application of a robust scientific design. In examining 30 failed monitoring programs, Reid (2001) noted that 70% of the programs had problems in their fundamental scientific design that limited or precluded ultimate success.
4. Program goals must be phrased in ways that are meaningful to the public and directly address things that can be directly affected by management strategies (both current and alternative).
5. The application of science to a given set of resource objectives needs to be well integrated; that is, research, monitoring (in all of its forms), and modeling all need to work in harmony to address information needs and uncertainties.
6. Embrace uncertainty—defining what is not known is as important as what is known.

7. In a true adaptive management framework, the relationship between the policy sector and the science sector must be explicitly and formally defined. Science should inform policy, and vice versa, but neither should regulate the role of the other. Policy-makers must clearly define the program goals, their practical objectives and the nature of the decisions they have some control over; and the scientists in turn must define the application of scientific tools to address achievement of those objectives.
8. Both "bottom-up" science (*i.e.*, arising from the initiative of individual researchers) and "top-down" science (*i.e.*, directed by an oversight panel) need to be integrated into large-scale ecosystem protection and restoration programs. Large-scale ecosystem restoration cannot be strategic if left to bottom-up science alone, but top-down direction is stifling and may reflect only the limited views and interests of the oversight group.
9. Approach the issue from multiple scales—Systematically evaluating alternative strategies for protection and restoration across the landscape must be appropriately scaled to protect and restore ecosystem processes. This is difficult if not impossible with ad hoc deployment of opportunistic, small-scale protection and restoration activities.
10. Multiple layers of independent scientific review are needed to ensure rigor and accountability.
11. Both scientists and policy makers need to understand constraints and opportunities in terms of considering management alternatives. We must analyze the range of possible management strategies (for both protection and restoration) and promote scientific assessment of emerging alternatives.

These worthwhile lessons guide us in crafting a robust conceptual scientific framework in which to identify significant ecosystem threats from stormwater runoff; to stratify the landscape into major categories of land use and receiving water; and to articulate credible, testable hypotheses that can guide future monitoring and assessment efforts.

A robust scientific framework must ensure that the work fills gaps (*i.e.*, gathers information about outcomes that are not yet well understood), and targets issues of primary importance and of known (or at least strongly suspected) major influence. Science can provide defensible and replicable insights regarding the ecological outcomes of management prescriptions, but it cannot offer absolute certainty. Policy can be and should be informed by science but is ultimately based on a variety of considerations that are not always amenable to the limitations of the scientific process (Van Cleave *et al*. 2004). The time frame needed to generate robust information may not be responsive to the much shorter timeline of social and political policy- and decision-making.

These are uncomfortable truths for agency managers and elected officials to acknowledge, and they commonly result in funding decisions and public pronouncements using the "language" of science but not its substance. This overarching strategy seeks to avoid such a bifurcated outcome.

4. PRIORITIES FOR REGIONAL MONITORING

The current, collective regional approach to monitoring stormwater in Puget Sound is a combination of outfall monitoring, site-scale evaluations of Best Management Practices (BMPs), and locally-driven priorities. This approach does not provide the region with the information needed to improve stormwater management actions to protect and restore the ecosystem. The solution is not to do more monitoring; but rather to recommend that our resources be redirected to answer questions of the greatest regional significance for improving stormwater management.

In order to achieve our objectives we must set priorities. This chapter presents the monitoring priorities to be addressed by the proposed SWAMPPS. A fully comprehensive SWAMPPS would:

- Address all receiving waters: small streams, rivers, lakes, groundwater, nearshore areas, and the open marine system.
- Inform all management strategies for all land uses.
- Be regional in scale.
- Address local priorities.

As noted in *The Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery*, Vol. 2, p.8:

"'Comprehensive' is not defined by the measurement of all things, at all times, but rather is aimed at determining the most important things that need to be done to address key questions or objectives."

This strategy recommends the initial regional program (SWAMPPS) focus on small streams, nearshore areas, and the full spectrum of urbanizing lands. All water bodies and land uses need to tie into this regional strategy, eventually, and we recognize that local monitoring priorities may continue to be driven by other issues.

4.1 Identifying the Scientific Information Needs of Stormwater Managers

The development of the strategy depends on the ability to articulate the type of information that would be useful to help stormwater and resource managers make better decisions. These decisions may be related to small- or large-scale issues, and they may require small or large expenditures to implement. In the first half of 2009, the SWG in a series of meetings and workshops articulated a set of Assessment Questions (Appendix C) that captured the collective judgment of the most important types of information needed to help decision-makers.

These key assessment questions were the basis for developing this scientific framework. It is important to acknowledge that various monitoring efforts are already under way or completed that may partially answer some of the assessment questions. To date, however, no coordinated, integrated program has been developed to ensure these questions are answered in a rational, prioritized, and comparable fashion.

The key assessment questions can be summarized as follows:

1. Are management actions making progress in protecting or improving beneficial uses and biological resources from the impacts of stormwater runoff?
2. What is the effectiveness of specific stormwater management techniques, either individually or in combination, with regards to preventing harm: from new development, by retrofitting existing development, and by controlling sources?
3. Where in the landscape are the sources of pollutants in stormwater and volumes of stormwater that impair beneficial uses?

4.2 Conceptual Model of Stormwater Impacts and Information Needs

The direct and indirect effects of stormwater on the ecosystem of Puget Sound, and the various pathways by which those effects are transmitted, are well studied (*e.g.*, Horner and May 1997, Booth *et al*. 2004, and NRC 2009). Figure 2 shows the types of stressors that should be considered, the pathways by which those stressors are transmitted, and how the outcomes of our management efforts should be assessed, using a Driver-Pressure-State-Impact-Response (DPSIR) conceptual model approach. The DPSIR approach, combined with a process to select

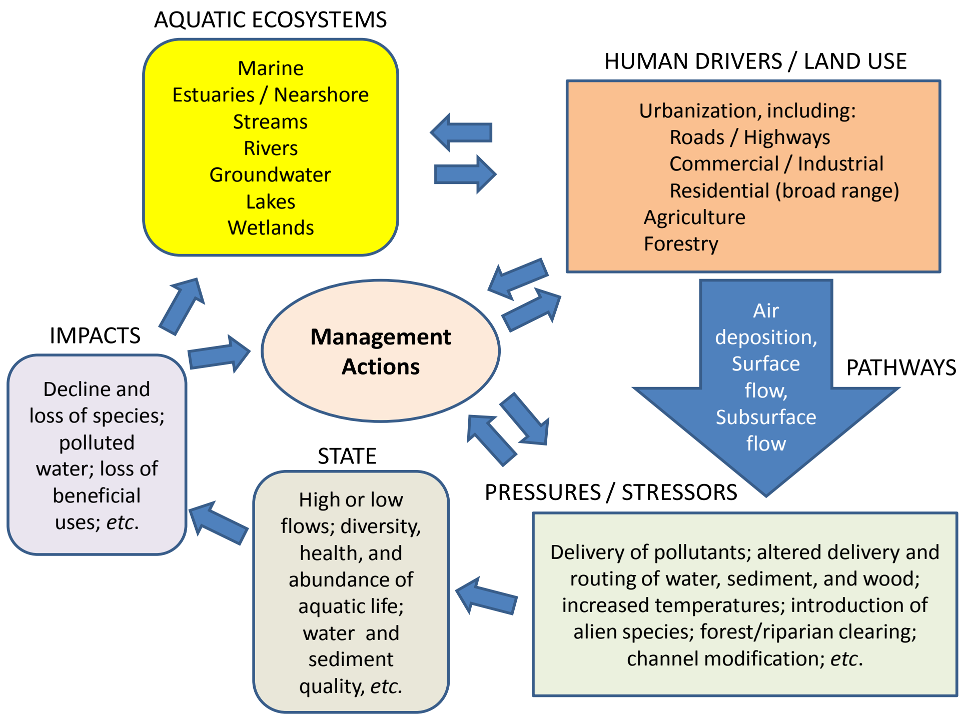

Figure 2. Conceptual Driver-Pressure-State-Impact-Response (DPSIR) model showing the complex interactions of land use and management actions on stressors impacting biological endpoints and beneficial uses in receiving waters and aquatic ecosystems.

appropriate indicators, is being applied by the Partnership to organize ecosystem recovery efforts and use monitoring information for adaptive management.

Within this broad conceptual approach, each element can be further deconstructed. Management actions intended to minimize or eliminate the effects of stormwater on downstream systems are addressing (whether knowingly or implicitly) linkages between human drivers (particularly land alteration) and one or more of the "States" in the diagram. To be effective, those actions need to be applied in the right places in the landscape, and they need to "work." Whether stated explicitly or not, *what to do* and *where to do it* are both hypotheses, and so their accuracy should be tested and their guidance modified, if and as needed.

Land conversion, or more specifically "urbanization" itself is multidimensional, and it has been defined in many different ways (McIntyre *et al.* 2000). It may constitute industrial, retail, housing developments, or farms; an urbanized watershed may contain polluting or nonpolluting industries, many roads or only a sparse road network. The topography, soils, vegetation, and channel networks in an urban basin may be altered in ways that vary within the same category of urban development. Across a single region, however, attributes of urbanization generally correlate with broad land-use categories. For purposes of outlining the overall scope of this adaptive management program we structured our discussion using common land-use categories:

- Urban/urbanizing, including:
    - Roads and highways.
    - The broad range of low- to high-density residential.
    - Commercial.
    - Industrial uses.
- Agriculture.
- Forestry.

Substantial differences exist even within each land-use category, however, that must be incorporated into the specifics of any stormwater-management approach (and the monitoring necessary to evaluate its effects). Most prominent of these differences is between disturbed land, structures, and roads: each of these landscape elements contribute to stormwater but in very different ways, suggesting an alternative organizational structure to that of land use.

However, runoff from one such element (*e.g.*, a rooftop) may be conveyed by the road network even as it comingles with additional wash-off from the road surface itself, suggesting no simple method (or rationale) for discrimination. Roads therefore are considered primarily within the land uses that contain them, while also recognizing that they generate a particular set of stressors, may require targeted management alternatives, and pose specific monitoring needs. We differentiate between roads and major highways as well, because highways might act uniquely rather than within the land uses that contain them.

Just as land alteration has multiple facets, so "water features" comprise a variety of aquatic environments in the Puget Sound region. Not all of them are equally affected by urban stressors or stormwater runoff, and the pathways by which those stressors are expressed will vary with the nature of the receiving water (as well as with the nature of the stressor itself). The potential impacts, and sensitivity of the receiving water to those impacts, will vary across the landscape.

Table 1 and Figure 3 inform our discussion of the relative impacts of stormwater-related stressors on receiving waters in the Puget Sound Basin. Washington State is required under the federal Clean Water Act to evaluate the health of all water bodies every two years. In a report called the *Water Quality Assessment*, beneficial uses in water body segments are evaluated using available water and sediment quality data, habitat assessments, and/or best professional judgment.

Most of the stressors are related to stormwater flow or to contaminants carried in stormwater. Table 1 shows that, of nearly 15,000 segments of creeks and rivers that Ecology has assessed in the Puget Sound basin, about 28% of the assessed creeks and rivers are impaired; and about 14% of the more than 3,000 assessed lake segments are impaired. Relatively fewer marine and nearshore waters have been assessed. The maps in Figure 3 showing locations and results of marine and nearshore assessments help us to better understand the extent of known impaired conditions in marine and nearshore areas.

A truly comprehensive SWAMPPS would address every water body in every land use in Puget Sound. Our region lacks the resources and the time required to complete such a long list, and the ecosystem cannot wait for so many studies to be completed before stormwater management policy and implementation improves. The above review of existing *Water Quality Assessments* supports a focus on small streams and the nearshore as a starting point for our strategy. It also demonstrates that there are significant data gaps that need to be addressed by improved coordinated regional monitoring and assessment.

Starting with a smaller list of questions is also practical considering that launching the regional monitoring and assessment strategy is itself an experiment. No single set of measured parameters or indicators should be expected to capture every potential combination of conditions expressed by even this (nominally) simple conceptual model. As we gain experience with implementing this strategy, we can refine and add additional questions. We anticipate that the strategy will be refined, expanded, and updated in an iterative process over a long period of time.

4.3 Identifying Categories of Monitoring to Include

We decided to focus on major categories of monitoring that are somewhat interrelated but that use a division commonly expressed by other ecosystem monitoring programs, including the interests of both the Partnership and Ecology:

1. **Status and trends monitoring**: provides an integrative assessment of whether (biological or other) endpoint indicators are showing any consistent, statistically significant change over time. It provides the basis for assessing our overall progress in protecting and restoring water bodies impacted by stormwater. Even if the goals for each monitored water body are not the same, a measured observed improvement or decline in a key indicator will help target management actions across the region as well as locally. We recommend tying status and trends monitoring to ongoing efforts in a way that fills gaps in knowledge and provides a more comprehensive regional understanding of the impacts of stormwater.
2. **Source identification and diagnostic monitoring**: assist in determination of what specific physical, chemical, or biological stressors (see Figure 2), emanating from which locations or from which elements of what specific land use, in what quantities, and

Table 1. Results of Washington Water Quality Assessment 2008 for segments of Lakes, Streams/Rivers and Marine Waters/Estuaries in the Puget Sound Basin, for specific stressors. (www.ecy.wa.gov/programs/wq/links/wq_assessments.html). The numbers in each column are *segments* (not miles) of water bodies. These assessments are based on existing data and so do not cover every mile/acre of every water body type. In addition, the data are limited by factors such as the level of sampling effort within a particular area and the willingness of entities to provide data to Ecology. Category 1 - Meets tested standards for clean waters; Category 2 - Waters of concern; Category 3 - Insufficient data; Category 4a - has a TMDL; Category 4b - has a pollution control program; Category 4c - is impaired by a non-pollutant; and Category 5 - Polluted waters that require a TMDL.

Stressor	Cat 5	Cat 4A	Cat 4B	Cat 4C	Cat 3	Cat 2	Cat 1	Total assessed	Total Impaired (4A & 5)	% Impaired of Segments Assessed
LAKES										
Bacteria	33				56	31	9	129	33	25.6%
Dissolved Oxygen	7				13	6		26	7	26.9%
Temperature	25				7	12	1	45	25	55.6%
Turbidity								0	0	
Tot. Dissolved Gas		24			5	2		31	24	77.4%
pH	4				13	11	9	37	4	10.8%
Fine Sediment								0	0	
Bioassessment								0	0	
Phosphorus	41	10			88	52	98	289	51	17.6%
Invasive Species				129		2		131	129	98.5%
Instream Flow								0	0	
Coarse Sediment								0	0	
Nitrogen	1							1	1	100.0%
Fish Habitat				1				1	1	100.0%
Bioassay	1				1			2	1	50.0%
Toxics	149	28			753	105	1557	2592	177	6.8%
Totals	**261**	**62**	**0**	**130**	**936**	**221**	**1674**	**3284**	**453**	**13.8%**
STREAMS / RIVERS										
Bacteria	595	617	44		509	364	325	2454	1256	51.2%
Dissolved Oxygen	574	106	11		1009	631	14	2345	691	29.5%
Temperature	924	367	21		927	556	409	3204	1312	40.9%
Turbidity	15	5			2	15		37	20	54.1%
Tot. Dissolved Gas	6	22			3	2		33	28	84.8%
pH	272	33	7		957	624	494	2387	312	13.1%
Fine Sediment	9	1						10	10	100.0%
Bioassessment	13			1	28	76	43	161	14	8.7%
Phosphorus	1	2						3	3	100.0%
Invasive Species				18				18	18	100.0%
Instream Flow				55		3	2	60	55	91.7%
Coarse Sediment		9						9	9	100.0%
Nitrogen								0	0	
Fish Habitat				53				53	53	100.0%
Bioassay	1				4	1		6	1	16.7%
Toxics	241	131			2183	333	1070	3958	372	9.4%
Totals	**2651**	**1293**	**83**	**127**	**5622**	**2605**	**2357**	**14738**	**4154**	**28.2%**
MARINE WATERS / ESTUARIES										
Bacteria	155	41			661	151	216	1224	196	16.0%
Dissolved Oxygen	138	12			101	93	42	386	150	38.9%
Temperature	5	1			38	114	83	241	6	2.5%
Turbidity								0	0	
Tot. Dissolved Gas								0	0	
pH	19	1			211	28	3	262	20	7.6%
Fine Sediment								0	0	
Bioassessment								0	0	
Phosphorus					1			1	0	0.0%
Invasive Species				93				93	93	100.0%
Instream Flow								0	0	
Coarse Sediment								0	0	
Nitrogen								0	0	
Fish Habitat				24				24	24	100.0%
Bioassay						2		2	0	0.0%
Toxics	53	4	1		179	49	846	1132	58	5.1%
Totals	**370**	**59**	**1**	**117**	**1191**	**437**	**1190**	**3365**	**547**	**16.3%**
Grand Totals	**3282**	**1414**	**84**	**374**	**7749**	**3263**	**5221**	**21387**		

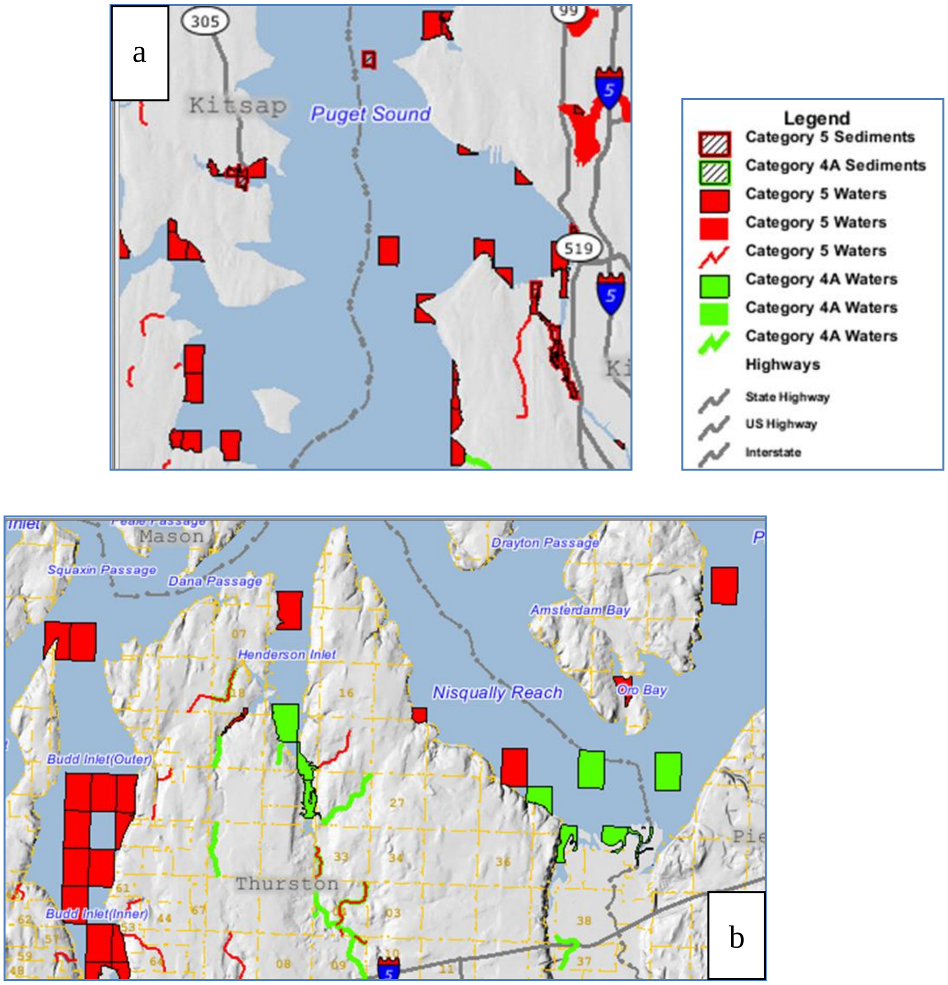

Figure 3. Impaired waters with focus on nearshore areas. Views of (a) the Central Basin and (b) the South Sound. (http://www.ecy.wa.gov/programs/wq/303d/2008/index.html). For category definitions, see Table 1.

affecting what specific types of receiving waters, are causing significant impacts to beneficial uses. Source identification and diagnostic monitoring provides local governments with the necessary information to formulate active adaptive management strategies. We recommend that the collective information gained from local source identification activities be routinely assessed to inform a regional perspective.

3. **Effectiveness studies:** provide an assessment of how well specific management actions or suites of actions reduce or eliminate the direct impacts of stormwater to receiving waters. We should be able to apply findings from each of these studies to management activities across the region. We propose an initial set of studies to be undertaken to evaluate key practices associated with major land-use categories.

4. **Research**: targeted investigation into cause and effect relationships to provide improved understanding of basic ecosystem functions, and impacts of stressors on those functions. We propose that research activities be tracked and periodically synthesized to identify emerging issues and use this information to refine our other categories of monitoring. In the future, SWAMPPs might establish priorities and target funds for conducting basic research.

To the extent practicable, a watershed approach will tie together the above categories of monitoring. However, monitoring will be conducted at various scales from local to regional to suit different purposes, and not always addressing the same stressors.

Another category that we considered was **characterization monitoring**. Characterization monitoring is typically conducted to understand the range of existing conditions. This information may be used for a variety of purposes, including identifying and quantifying sources of pollution in stormwater so that we can target and assess actions intended to reduce pollutant concentrations and loadings. Although once anticipated to be a category of this scientific framework, characterization monitoring is not further considered as a separate activity. We decided that characterizing the condition of a water body or an outflow discharge at a particular time and place can be the product of the other kinds of monitoring.

Future "characterization" monitoring efforts should be clearly articulated in either hypothesis-testing or systematic trend evaluation. As noted by NRC (2009, p. 508), "…monitoring under all three [NPDES municipal, industrial, and construction] stormwater permits is according to minimum requirements not founded in any particular objective or question. It therefore produces data that cannot be applied to any question that may be of importance to guide management programs, and it is entirely unrelated to the effects being produced in the receiving waters." We seek to proactively avoid this problem.

Still another category to be addressed is **compliance monitoring**. The value of this activity extends beyond "bean counting" and, in an approach similar to that proposed for characterization monitoring, we believe the most valuable compliance monitoring information will be that which provides environmentally meaningful metrics that are directly tied to improving our interpretation of monitoring results. Compliance monitoring recommendations will be made most obviously in developing effectiveness studies, but should also be made in future refinements of status and trends monitoring and source identification and diagnostic monitoring designs.

Our purpose is to understand what is causing negative impact to beneficial use and the extent to which management actions are reducing or preventing the impact. There are many cases in which indicators such as chemical pollutants apply across the categories of monitoring. However, in proposing initial activities for each category of monitoring we have not restricted ourselves to a single list of indicators.

Instead, we recommend indicators that are most suitably and practicably applied to improving our understanding of stormwater impacts in various receiving waters, biota, or other conditions. We started with a long list of problems and stressors that have been identified in the region, prioritized them based on known impact and practicability of regional application. The rationale is given for selecting each indicator, whether the monitoring is biota-based or stressor-based.

Research can include any number of various types of studies and monitoring programs. Under most types of scientific frameworks, research is encouraged to highlight new and emerging issues and to explore essential unknown relationships between various environmental factors necessary to improve management actions. Research efforts have clearly been of use locally (for example, research to characterize Lake Washington's degraded water quality in the 1950s led to the formation of Metro to divert and treat sewage flowing into the lake). This type of monitoring is best described as essential basic research, where the results might indeed be used to improve management efforts or policy. But at the outset it is unknown how, or if, the results will be used, and no recommendations for this category are included in this strategy.

4.4 Monitoring Indicators

Stormwater conveyance systems in the built environment, and in particular in urbanized centers and agricultural areas located near shorelines, provide a rapid conveyance of pollutants where water quality treatment and flow reduction were not considered during the development of these areas. To assess stormwater impacts, many monitoring programs focus on water quality metrics or physical metrics, which are receiving water exposure indicators. However, indicators at the "biological response" level are closer to the designated uses of the water bodies (NRC, 2001; Karr and Yoder, 2004; EPA, 2005) and reflect the combined influence of all of the receiving water body exposures, landscape exposures, and sources throughout the watershed.

Monitoring indicators will be used differently for each category of monitoring. For status and trends, indicators measure the state of the system and track improvement or decline in a biological endpoint, or increase or reduction in a stressor. For source identification and diagnostic monitoring, indicators are used to locate and track sources of problems. For effectiveness studies, indicators are used to determine whether stormwater management actions are protective of, or restoring, resources. Indicators from any category of monitoring may be useful to identify impaired water bodies; to provide data for modeling; or to provide data for mass loadings of pollutants to Puget Sound.

Stormwater indicators apply to a subset of environmental indicators that specifically address urban stormwater runoff impacts and the evaluation of stormwater programs and practices. Individual indicators can be used to assess different aspects of practices and programs. Some indicators are suited to problem identification, some are suited to assess particular techniques and best management practices (BMPs), while others are more appropriate for judging stormwater program management success.

"Indicators are a useful tool for evaluating stormwater pollution prevention programs if they are applied in the context of continuous improvement and are framed by a conceptual model that illustrates causal relationships between stormwater pollution, the prevention program, and other factors affecting beneficial uses of water." (Cloak undated.)

It is difficult to write this strategy for SWAMPPS in the absence of an overall ecosystem monitoring and assessment plan for Puget Sound. The complexity of an ecosystem monitoring plan is compounded by:

- The need to scale up from the sub-basin or catchment level to the regional level.
- The necessity of having both short-term, spatially limited indicators as a measure of local effectiveness along with long-term biological indicators that can track changes to the health of the regional ecosystem over longer time periods.

A meaningful program will have nested indicators for multiple purposes at multiple levels; the challenge is to identify the appropriate indicators to answer specific questions.

Effectiveness indicators must operate in the context of two principles:

- A dedication to continually improving the program, whether by finding more effective structural, non-structural, and treatment Best Management Practices (BMPs) or by improving management and behavioral BMPs.
- A clear understanding of the causes and effects the stormwater management program is expected to address.

Prioritization is necessary. Status and trends monitoring will provide dynamic data about trends over time, but it is also possible to apply analytical methods to previously collected data to establish baselines and to identify areas of critical importance where damage has already occurred and that need priority treatment.

Stormwater indicators apply to a subset of environmental indicators that specifically address urban stormwater runoff impacts and the evaluation of stormwater programs and practices. Individual indicators can be used to assess different aspects of practices and programs. Some indicators are suited to problem identification, some are suited to assess particular techniques and BMPs, while others are more appropriate for judging stormwater program management success.

According to guidance from the Environmental Protection agency, evaluation of Stormwater Management Programs can proceed at three levels:

- Monitoring water quality.
- Assessing program operations.
- Evaluating social indicators.

The Center for Watershed Protection has published a thorough review of watershed and stormwater management, including a recommended suite of indicators for tracking progress towards goals. These indicators are listed in Table 2.

4.5 Scales at Which to Conduct Monitoring

As with most other programs, an optimal approach will encompass multiple, nested scales of monitoring, and thus scales for any particular hypothesis that will guide their implementation.

The broadest scale of monitoring is that of the integrated effect of stormwater impacts and stormwater management on receiving waters. *Status and trends monitoring* addresses these questions, and it also allows stormwater and resource managers to measure the broad benefits obtained from management investments. This follows the recognition that impacts will differ by water body and will reflect multiple stressors and the effect of multiple management actions. Individual conditions normally cannot be traced back to specific generators of pollution (NRC 2009), and so identifying conditions at this scale requires a larger spatial scale over longer time frames, the essence of status and trends monitoring. We propose complementary status and trends designs at both the watershed resource inventory area (WRIA) scale and the Puget Sound regional scale.

Table 2. Center for Watershed Protection Stormwater Indicators (CWP 2008).

- Water Quality Indicators
  - Water quality pollutant constituent monitoring
  - Toxicity testing
  - Non-point source loadings
  - Exceedance frequencies of water quality standards
  - Sediment contamination
  - Human health criteria
- Physical and Hydrological Indicators
  - Stream widening/downcutting
  - Physical habitat monitoring
  - Impacted dry weather flows
  - Increased flooding frequency
  - Stream temperature monitoring
- Biological Indicators Fish assemblage
  - Macro-invertebrate assemblage
  - Single species indicator
  - Composite indicators (*e.g.*, Index of Biotic Integrity (IBI))
  - Other biological indicators (*e.g.*, mussels)
- Social Indicators
  - Public attitude surveys
  - Industrial/commercial pollution prevention
  - Public involvement and monitoring
  - User perception
- Programmatic Indicators
  - Number of illicit connections identified/corrected
  - Number of practices installed, inspected, and maintained
  - Permitting and compliance
  - Growth and development metrics
- Site Indicators
  - BMP performance monitoring
  - Industrial site compliance monitoring

If status and trends monitoring (or other knowledge) indicates that there are impacts on beneficial uses in a specific water body, a second scale is invoked, that of *source identification and diagnostic monitoring*: "what are the specific stressors and sources causing these impacts, and how can we best plan for their removal?" These efforts are conducted at a local scale but they provide information that is applicable at a regional scale for ubiquitous stressors and sources of pollutants: "what regional source removal actions are necessary where local source removal actions are not sufficient to correct problems?"

This category of monitoring also seeks to answer: "what specific locations and which parts of the landscape generate stormwater of sufficiently deleterious quantity and quality to cause impacts to beneficial uses, be they direct or indirect?" This question is widely posed in stormwater management programs, and a number of existing monitoring programs seek to provide answers. The science of stormwater suggests where the greatest attention is probably warranted, namely a particular focus in all land uses on areas of well-connected (or "effective") impervious area (NRC 2009, p. 120, 231, 232), high vehicular traffic (NRC 2009, p. 232), and exposure to toxic chemicals (NRC 2009, p. 330).

We are attempting to broaden the finest scale at which our third category of monitoring, *effectiveness studies*, is typically conducted: we seek to move from, "are pollutant concentrations lower in the effluent" to, "which of our many stormwater-management actions achieve the greatest reduction in downstream impacts?

On the whole, these stormwater control measures, both structural and nonstructural, vary by land use; the measures suitable for a residential neighborhood will likely be impractical or ineffective (or both) in an industrial setting. Most effectiveness studies will be stratified by land use, acknowledging that truly homogenous land uses are rare.

Nonetheless, this organizational approach is used successfully by the Nationwide Stormwater Quality Database, which contains water-quality data from more than 8600 events and 100 municipalities throughout the country, of which 5800 events are associated with "homogeneous land uses." We see no basis to eschew the approach of this nationally recognized and funded effort in Puget Sound, and embrace the conceptual approach of land-use stratification for evaluating the effectiveness of stormwater control measures.

4.6 Attributes of Hypotheses for an Adaptive Management Program

A key element of any adaptive management approach is the set of hypotheses that guide both the management actions and their associated monitoring. Because these management actions are recognized as "experimental" (because in a complex system most outcome(s) cannot be predicted with absolute certainty), their selection must be guided by assumptions about what *might happen*, or what is *expected* to happen.

This defines the first attribute of a useful hypothesis: it is **credible**, typically because it is based on prior knowledge or scientific understanding of the system. Indeed, some hypotheses may already be so well evaluated and understood (*e.g.*, "Stormwater runoff from freeways carries measurably elevated concentrations of toxic pollutants") that there is little point in going into detail about them in this scientific framework or to recommend that scarce monitoring resources be allocated to test hypotheses that are unlikely to result in new information or knowledge that would change management practices.

The second attribute of a useful hypothesis stems from the scientific reality that any experiment, whether conducted in the laboratory or across the landscape, provides value only insofar as its outcomes are measured and the effects are distinguishable from the influence of other, unrelated factors. Thus, the hypothesis that guides the experiment should not only be credible but also **testable**. Otherwise, why bother making measurements at all?

Lastly, these actions and measurements and analyses do not occur in a vacuum. In the present context, their purpose is to improve the management of stormwater and to reduce the associated impacts on the ecosystem of Puget Sound. Thus, the final guiding principle for any hypothesis in an adaptive management approach is that it be **actionable**, or that different outcomes, as revealed by monitoring, can (and will) result in different management responses. If no difference occurs, then clearly there is no reason to have made the effort in the first place.

4.7 Translating our Assessment Questions into Hypotheses for Each Category of Monitoring

The information generated by SWAMPPS is designed explicitly to inform the ongoing implementation of the institutional framework for the full adaptive management cycle.

We propose an initial set of questions to be answered for each of three monitoring categories and scales to provide different types of information useful for decision making:

- Long-term regional status and trends monitoring.
- Mid-scale targeted effectiveness studies.
- Local source identification and diagnostic monitoring efforts.

A subset of these questions has been has been translated into hypotheses to be tested by specific experimental designs. These are not meant to define a comprehensive suite of stormwater monitoring actions, but rather to establish an overarching scientific framework for stormwater monitoring that will allow otherwise independent efforts or whole programs to contribute to our greater understanding and evaluation of progress. Concrete experimental designs must meet the necessary criteria for sensitivity, statistical power, and feasibility.

Existing data need to inform SWAMPPS efforts. In particular, existing outfall information, including data from Phase I monitoring and other NPDES permit-related monitoring (industrial, construction, boatyard, *etc.*) should be integrated. Targeted literature reviews and ongoing analyses of monitoring data are necessary for refining our approach, and useful for early identification of problems and information gaps.

As described above, hypotheses used to guide the adaptive management approach must be credible, testable, and actionable. These criteria were applied to develop an initial set of priority hypotheses for more rigorous development. About 50 preliminary hypotheses were initially developed, used as the starting point, and narrowed to a list of priority hypotheses.

As hypotheses have been developed, we have aligned them with the three categories of monitoring listed above because these categories best reflect the underlying structure of the assessment questions and thus the broadly articulated stormwater-monitoring needs of the region. We also considered which land uses, which receiving waters, and which impact(s) to beneficial uses are most likely to be most problematic; and where is it most important to improve our understanding of the effectiveness of our management actions?

4.7.1 The Role, Utility, and Application of "Hypotheses" to Guide Monitoring

In order to meaningfully inform adaptive management, monitoring should be designed to test goals that can be measured and evaluated. We begin with a set of broadly vetted, overarching assessment questions (Appendix C) and drill them down to various levels – only some of which satisfy the criteria of testable hypotheses. For practical purposes, different types of hypotheses will guide the types of monitoring that will be conducted by SWAMPPS.

In this strategy we have not offered technically traditional statistical hypotheses with statements of a 'null' and one or more 'alternative' hypotheses associated with each. The practical application of hypotheses recognizes a distinction between "working hypotheses" and "experimental hypotheses" (Taylor 2009):

> "Working hypotheses are affirmative conjectures that propose a condition, affect, or outcome in the system being evaluated. Experimental hypotheses are the 'null' hypotheses posed in experimental studies that attempt to falsify the working hypothesis. Working hypotheses cannot be 'proved' *per se* by the collection of experimental data. Rather, working hypotheses are increasingly supported by the accumulation of observational or experimental tests of the working hypothesis. If these tests fail to show evidence contrary to the working hypothesis, the working hypothesis continues to be supported. This is the traditional use of working and experimental hypotheses in the scientific method."

We do favor hypotheses that indicate a measurable outcome, and there will be cases for some of our monitoring studies in which statistical tests can be performed on the data to determine if there is evidence to reject the 'null' and accept an 'alternative' (with various levels of confidence). But we are not convinced that policy makers require the experimental and statistical rigor involved in such scientific precision: they simply have questions that do not conform well to this approach. Taylor's definition of "working hypotheses" seems to best suit the desired management goals.

Each of our "hypotheses" should be sufficiently testable that an outcome can be measured and compared to some (preferably specified) alternative. This approach should meet the collective expectations of scientists, policy makers, and the public, provided we select indicators that help us separate out stormwater impacts. Therefore each "hypothesis" will need to include (either in this strategy or at some point in the near future) a clear statement of:

- What specific pollutant, stressor, or impairment is targeted for evaluation.
- What specific management action (or collection thereof) is expected to cause a change in the pollutant, stressor, or impairment.
- How to measure the change in the pollutant, stressor, or impairment.
- How to confirm and quantify implementation of the management action(s).
- The level of confidence with which a change can be reported, over what time period.

The example "hypotheses" and hypothesis-driving questions presented in this strategy are provided as a starting point. More specific, detailed hypotheses will be decided after further discussions of issues among stakeholders.

4.7.2 "Hypotheses" for Each Category of Regional Monitoring

We recommend the following "hypotheses" and hypothesis-driving questions for prioritizing the initial efforts of SWAMPPS:

For status and trends monitoring:

1. Salmon (focusing on appropriate life stages) in small streams show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.
2. Instream biological metrics (*e.g.*, B-IBI) show statistically significant improving trends in Puget Sound lowland streams in concert with increased and improved stormwater management efforts.
3. Bacteria levels limiting primary human contact show decreasing trends over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.
4. Bacteria levels in water and bacteria and/or toxics in shellfish along the nearshore limiting primary contact and harvest show decreasing trends over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.
5. Resident fish in nearshore areas show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts. – *Future Work*
6. Forage fish in nearshore areas show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts. – *Future Work*

For source identification and diagnostic monitoring:

7. Identification, prioritization, and removal of stormwater sources and stressors result in the improved targeted beneficial use.
8. Receiving-water status and trends monitoring in targeted watersheds results in early detection and prioritization for source removal.

For effectiveness studies:

We have identified the following "guiding questions" or focus areas for organizing future discussion, development, and selection of hypotheses to be tested by effectiveness studies:

9. What is the effectiveness of various low-impact development (LID) techniques in areas of new development and redevelopment?
10. What is the effectiveness of retrofitting existing development with various flow management and water quality treatment approaches?
11. What is the effectiveness of programmatic and non-structural best management practices, such as:
    a. Various provisions of the NPDES municipal stormwater permits, and
    b. Various agricultural best management practices.

12. What emerging technologies and treatment techniques show the most promise? *– Future Work*
    a. Examples include reducing fecal coliform and metals concentrations in stormwater runoff.

4.8 Priorities for Each Category of Regional Monitoring

The need to include and undertake sufficient monitoring and assessment actions in multiple locations around the Sound so variations are considered is balanced with the need to efficiently employ limited resources. Our intent is to create a comprehensive monitoring and assessment strategy by:

- Monitoring and assessing the most critical elements of stormwater.
- Conducting monitoring that helps answer the most important questions for decision makers.
- Collecting sufficient data to account for regional variations.
- Conducting a sufficient number of assessments to produce robust information.
- Ensuring data collection and assessments follow standardized protocols.
- Compiling and sharing the results so that all interested parties can learn from the effort and regional decision makers can revise and improve stormwater management policy.

In describing this scientific framework and in our approach to creating the overall study designs, we have intended to be specific about how much effort is required, how often, and what information we expect to get given the indicated level of effort. To the extent that we had the capacity to do so for this strategy, we have tried to ensure that level of confidence provided has been clearly articulated and appropriate for decision makers.

To address the range of uncertainty the concept of "power" of statistical tests should be applied and considered before studies are implemented, but it is too early in the development of our experimental designs, described below, to provide this level of detail. When experimental designs are more fully developed, the complete data needs for each hypothesis will be articulated, including the appropriate level of confidence and uncertainty of the outputs. Assumptions will be explicitly stated along with references to prevailing theories.

The following chapters describe how the different types of monitoring designs would be used within an adaptive management structure. Information gathered under each category of monitoring can and should inform work under each of the other categories.

To successfully implement this strategy and support this new, integrated monitoring system, local jurisdictions, state and federal government agencies, and others will need to work together to develop and adopt new methods and infrastructure such as regional standardized operating protocols, data repositories, and regional conferences.

5. STATUS AND TRENDS MONITORING

In this chapter we propose a scientific framework and implementation plan for our first priority within the three categories for regional stormwater monitoring in Puget Sound:

- Status and trends: Long-term regional monitoring focused on biological communities in small streams and nearshore areas to improve understanding of whether stormwater management programs are helping to achieve the larger goal of restoring the Puget Sound ecosystem.

Details and examples of the proposed experimental approach are given in Appendix D.

5.1 Scientific Framework for Status and Trends Monitoring

Status and trends monitoring for SWAMPPS will not measure all things, at all times. We have aimed to determine the most important monitoring to be done to address key questions.

Historically, the impacts of urbanization on receiving waters have been tested by comparing water quality to various sets of standards or guidelines. However, to truly assess cumulative impacts, "[b]iological monitoring of waterbodies is critical to better understanding the cumulative impacts of urbanization on stream condition" (NRC 2009, p. 233). To this end, hypotheses that address the integrated effects of stormwater-management actions on the biota of receiving waters are the recommended emphasis for status and trends monitoring.

Biological communities and water quality are affected by more than just stormwater management activities. The information collected will integrate influences from various land uses, geologic and geomorphic conditions, and other factors outside the control of stormwater managers.

As discussed in section 4.7, specific hypotheses should reflect the current understanding of stressors and the parameters being affected, and how those influences are likely to be expressed in the biota. Clearly, there are a vast number of unique combinations around which hypotheses could be constructed, and for which conditions could be monitored. The challenge at this level of hypothesis-generation is to identify a more limited, tractable number of such combinations. They must also each meet the test of being credible, testable, and actionable.

The priority hypotheses in section 4.7.2 address those receiving-waters that are currently understood to be more directly associated with stormwater, as discussed in section 4.2. Small streams (or "creeks") are an obvious choice, given the decades of research on them in the region, their recognized sensitivity to adjacent land-use activities, their critical role (both direct and indirect) in the life history of anadromous salmon and our corresponding lack of information about the effectiveness of proposed management actions to prevent these harms. We also focus on the nearshore, because of the importance and sensitivity of this interface between land-based activities and Puget Sound, and its importance to both natural and human (especially food- and recreation-based) resources.

This strategy is a starting point and recognizes there remains a need for monitoring stormwater impacts on other aquatic resources. Efforts are underway to develop marine nearshore monitoring protocols for aquatic habitat, various fish population health indicators, and other monitoring that could be effective measures of stormwater impacts on ecosystem and biological health. As these efforts and potentially others become more established and found to be reliable, they should be reviewed for inclusion in the strategy.

Small streams, while having the benefit of much more monitoring focus over the last few decades, also have a number of monitoring programs that look promising but do not yet have accepted reliability or clear response for stormwater-related impacts. These efforts, including caged or natural mussel/shellfish monitoring, biological or chemical parameters for salmonid pre-spawn mortality, or others, should also be reviewed for potential inclusion in the strategy in the future.

5.1.1 Sound-wide and Watershed Probabilistic Designs

The first three priority hypotheses for status and trends monitoring are designed to evaluate the status of water resources, *e.g.*, the percentage of stream miles supporting their beneficial uses, and to detect trends over time in water resources affected by stormwater and other land uses. The ultimate goal of this monitoring is to determine whether stormwater management is helping to protect the resource.

The Washington State Department of Ecology is charged with designing and implementing a statewide monitoring program to assess stream habitat and watershed health (Ecology 2006). We propose utilizing and building upon Ecology's probabilistic survey design for small streams in the Puget Sound region to assess status and measure trends over time. This probabilistic design allows for a quantitative understanding of the extent and magnitude of the impacts on beneficial uses across the multiple jurisdictions and watersheds of the Puget Sound region.

A probabilistic survey design starts with a complete master list of all possible sampling sites and selects a random subset for site visits to evaluate access and suitability prior to selection for monitoring. Figure 4 shows an example of the sampling locations for probabilistic stream monitoring in the Puget Sound region. Similar probabilistic survey designs will be developed for nearshore monitoring of bacteria and toxic chemical accumulation in sediment and mussels.

The U.S. Environmental Protection Agency encourages states to adopt a probabilistic sampling design for the following reasons:

- A probabilistic survey design is, by definition, integrated [across land uses] because it includes all possible sites in the sampling frame (Larsen *et al*. 2001; Stevens and Olsen 1999).
- The design is flexible because the same design can be expanded to increase sampling densities based on geographic area, land use or some other factor (Ode and Rehn 2005).
- The magnitude of the problem can be evaluated, *e.g.*, "50% of stream miles are failing to support their designated uses" (Urquhart 1998; Stevens and Olsen 2003).
- The random nature of the design supports risk analysis to determine the most important drivers of degradation associated with stormwater (EPA 2006).

The potential exists for agencies to support each other's program by sharing the burden of data collection across projects (for example, all jurisdictions in one watershed may choose to pool resources to have one jurisdiction, consultant, university or other entity collect all the samples to reduce training, equipment, data management and other costs).

The intent of the status and trends monitoring is not to identify every variable or establish the loading or variability of each parameter. The intent of the monitoring effort is to produce sufficient information to inform stormwater management actions and to determine over time whether these actions are improving the beneficial uses of receiving waters. As noted above, we have initially focused stormwater status and trends monitoring in small streams and nearshore

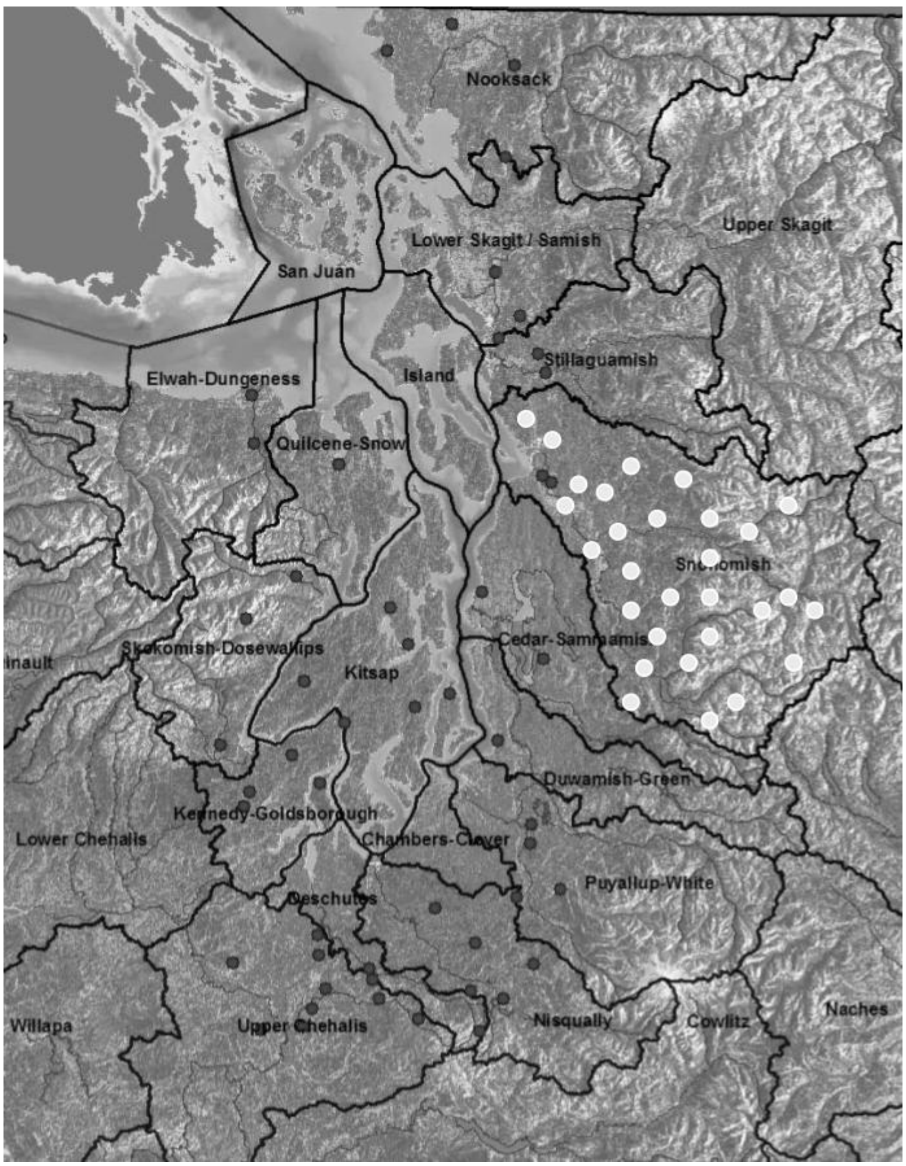

Figure 4. Probabilistic survey design for stream sampling in the Puget Sound watershed (gray dots) and an example of high density stream sampling in the Snohomish watershed (white dots). Both sets of points are derived from the same master set of sampling sites.

areas. Stormwater status and trends monitoring for other water bodies may be tied into programs designed by other work groups included in the overall ecosystem monitoring program for Puget Sound (see chapter 3 and section 8.1).

The proposed stream monitoring includes sub-basin sampling at the WRIA-level for the water quality index, aquatic macroinvertebrates, fish diversity and abundance, stream physical features, and sediment chemistry for metals and petroleum. Additional sampling proposed at the Puget Sound scale includes sediment chemistry (phthalates, poly-aromatic hydrocarbons, and other toxics of concern), flow, temperature, and a pilot study for periphyton.

The Puget Sound-scale sites (with the exception of the periphyton pilot study) will be a sub-set of the watershed-level sites that have the additional sampling. Figure 5 shows the watersheds (WRIAs and combinations of WRIAs) we propose for this focus. The approach will use current randomly selected sites, where available, to build upon historical data.

Marine nearshore sampling would focus at the Puget Sound scale on probabilistic sampling for fecal coliform, sediment chemistry, and caged mussel toxic accumulation. Because chemical data are not always reliable indicators of biological effects, direct biological testing (sediment toxicity tests) is often used in conjunction with sediment chemistry and infaunal community structure analysis (diversity and abundance of organisms living in the bottom substrate) to determine the biological significance of the chemicals measured in the sediments.

This series of monitoring is known as the Sediment Quality Triad. However, as a tool for monitoring status and trends, using two (invertebrates sampling and sediment chemistry) of the three parts of the triad are recommended in this initial phase of the regional monitoring and assessment strategy.

The benefits of a WRIA-based Puget Sound-wide probabilistic survey design are that it:

- Summarizes the current condition of streams and nearshore with an estimated level of statistical precision at a watershed and Puget Sound levels;
- Makes regional comparisons of stream condition within and across WRIAs
- Prioritizes areas for protection and restoration in terms of physical, chemical and biological condition at the Puget Sound scale;
- Recognizes temporal and geographical variability and environmental response time to management practices.
- Provides regional estimates of water quality and flow conditions that support salmon recovery endpoints and other water resource issues,
- Answers at a spatial scale that often better matches the scale of decisions needed for stormwater management issues,
- Identifies common problems due to land use impacts or sources of pollutants that may need common solutions.

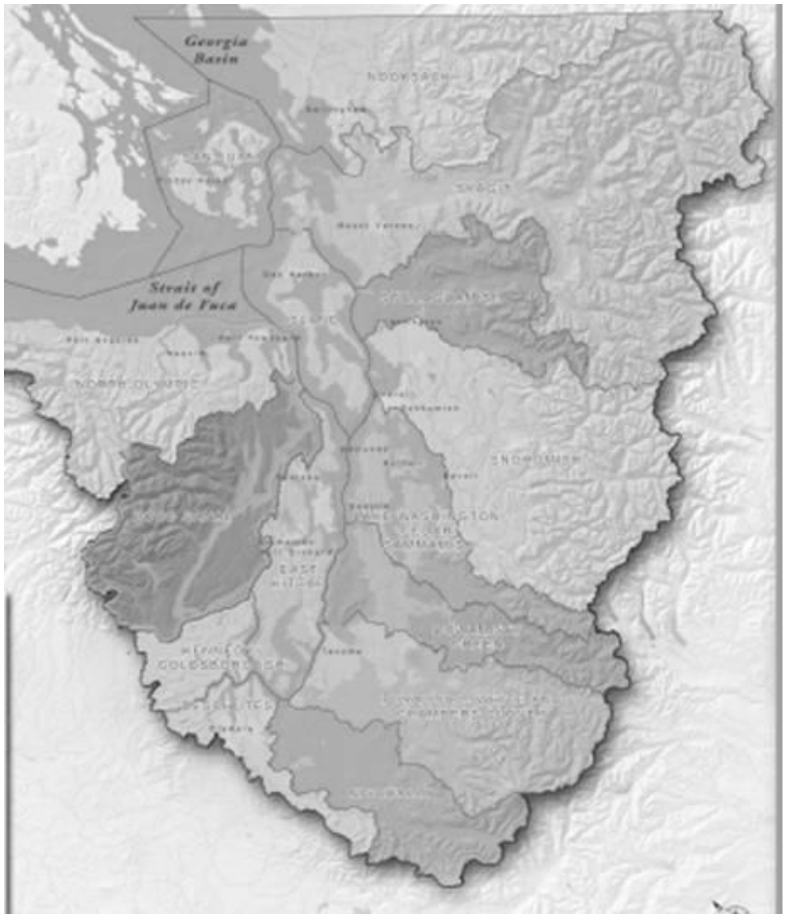

Figure 5. Map showing the local salmon recovery areas in Puget Sound (Water Resource Inventory Areas (WRIAs) and combinations of WRIAs) proposed for probabilistic densified sampling. Island-based watersheds have few wadeable streams and therefore are not included in the proposed design.

- Provides consistency over time and is not subject to changing jurisdictional boundaries.
- Considers entire watersheds without the constraints of jurisdictional boundaries.
- Provides a baseline for documenting longer-term and larger scale impacts, such as climate change.
- Recognizes that change of ownership may prohibit continued access for a site or reduction of flow may also preclude the ability to sample at a site. Sampling design will be robust enough to account for losing sites during the process.

The types of information <u>not</u> provided by a WRIA-based Puget Sound-wide probabilistic survey design include:

- Specific information about sites of interest, *e.g.*, sites with BMPs, cannot be addressed due to the random nature of the design. Some sites from specific locations would be needed to make comparisons and test for differences.
- Specific management practices or jurisdictional programs cannot be evaluated by this approach, though the information can be useful to support more localized monitoring efforts to evaluate individual programs.
- Trend information will not be available in the typical planning horizon for individual projects or permits. Trends require sufficient sampling to determine significant changes from natural variability, but also require the system has sufficient time to respond to actions or lack of action. More sampling does not necessarily mean a quicker detection of trends.
- Cause and effect relationships cannot be identified.

The probabilistic design allows for the nesting of monitoring programs of different densities in a comparable manner. Using the small streams example described above, the probabilistic survey design can be scaled to smaller watersheds, basins, and subbasins by increasing the density of sampling sites. The density can also be increased according to other factors, *e.g.*, stream size, land use, *etc*. Results from these areas of greater sampling effort should be rolled up in the regional reporting. In short, one probabilistic survey can be nested within another. (For an example, see the white dots in Figure 4 showing additional sites for the Snohomish watershed.) The watersheds (WRIAs and combinations of WRIAs) we propose for this focus are shown in Figure 5.

The types of information provided by a watershed probabilistic survey design include:

- The change in percentage of the watershed supporting its beneficial uses after 5 years of sampling.
- How areas with different land uses, *e.g.*, urbanizing areas with LID construction vs. areas with predominantly existing residential, compare regarding their relationship to the supporting of beneficial uses.
- Identification of the greatest threats to water resources in the watershed and their relative risks.

The types of information <u>not</u> provided by a watershed probabilistic survey design include:

- Effectiveness of specific BMP treatments.
- Identification of sources of pollutants and diagnosis of stressors.

5.1.2 Non-probabilistic Sampling

In addition to the probabilistic sampling identified above, stream flow and temperature will be collected continuously at a series of sites across Puget Sound. These sites will be selected from existing U.S. Geological Survey and local government-operated stream gauge locations that represent a variety of stream sizes, geographic distribution and land uses. If necessary, additional gauges will be established to fill specific gaps in unrepresented areas. While flow and temperature vary substantially by location, they are responsive to land use impacts and stormwater management. The design of this effort will be determined after compilation of existing federal, state and local gauge information, anticipated in the second half of 2010.

5.2 Implementation Plan for Status and Trends Monitoring

Establishing SWAMPPS status and trends monitoring with a watershed focus will be a fundamental change from current NPDES permit-required and other current stormwater monitoring efforts. More work is needed to refine and finalize the experimental design for status and trends monitoring in both small streams and nearshore areas. Status and trends monitoring has two parts: 1) "status" is the assessment of current conditions and 2) "trends" is the ability to see changes over time. Status can be analyzed after each sampling period, whereas trends will require time for results of management actions to emerge and a level of monitoring rigor to accurately detect changes. As with any new venture, we strongly recommend that this program be flexible enough to respond to lessons learned during implementation.

In future work, the SWG will address major issues raised during the May 2010 public comment period that we were unable to address prior to our June 30, 2010 deadline (see Appendix I). Next steps and longer term implementation components for status and trends monitoring are recommended and discussed in the following sections.

5.2.1 Steps to Implement Status and Trends Monitoring

Many necessary tasks related to organizational structure, database development and management, and other aspects of SWAMPPS are not explicitly included in this section, but are detailed in Chapter 8: Regional Program Implementation. The following specific tasks are necessary to implement SWAMPPS status and trends monitoring.

Task 1. Refine Hypotheses re. Stormwater Impacts on Aquatic Biota

- Revisit initial hypotheses and draft more specific questions to be answered through status and trends monitoring (*e.g.*, benthic scores remain stable or improve over time despite new development in catchment area; biological conditions at sites under new stormwater standards are closer to biological potential than sites developed under older standards).
- Discuss basin characterization data needed to interpret results (*e.g.*, key stressors in area draining to site).
- Statistical considerations.

Task 2. Review Existing Programs for Potential Coordination Opportunities

- Review monitoring program inventory currently under development (see section 8.8).
- Compare salient data (*e.g.*, monitoring objectives, parameters, sites, frequency, duration, QA/QC level, reporting) to proposed SWG monitoring program.
- Identify potential coordination opportunities. Discuss with contacts. Develop appropriate formal agreements. Refine agreements if needed after final site selection (Task 6).

- Consult with PSAMP regarding coordination and opportunities for refining the study design for sediment sampling in the Puget Sound nearshore.

Task 3. Refine Sampling Design

- Develop initial statistical goal.
- Estimate number of observations needed to attain goal based on expected variability of key indicator parameters (*i.e.*, do not try to assess variability of each pesticide or endocrine disrupter).
- For random monitoring:
    - Define weighting criteria (different criteria for urban and rural WRIAs).
    - Identify marine outfalls to establish sampling frame for mussel watch and fecal coliform sites.
    - Apply EMAP procedures to develop candidate site list.
    - Evaluate randomly selected sites to identify any that are already being monitored.
    - Use GIS data to screen out sites that are likely to be unsuitable based on physical access or lack of desired channel conditions (*e.g.*, too steep). Sort sites into physical access categories (*e.g.*, easy, medium, hard) to allow estimation of level of effort (see Task 5). Identify sites that will require legal access requirements.
    - Continue until targeted number of sites is attained (or scale back on statistical goal).
- Freshwater flow and temperature sites:
    - Evaluate existing gages with respect to :
        - Proximity downstream of S&T sites.
        - Length of record.
        - Estimated accuracy.
        - Other considerations (*e.g.*, high flow access, power, vandalism).

Task 4. Document Monitoring Protocols

- Describe monitoring locations, frequency, field methods, health and safety, analytical methods, data quality objectives, QA/QC sample needs, data review and reporting.
- Incorporate EMAP and other existing protocols by reference.
- Identify responsibilities (*e.g.*, monitoring activities to be performed by volunteers or added to other on-going programs identified in Task 2, in-kind contributions).

Task 5. Refine Monitoring Cost Estimates

- Develop a more detailed cost estimate for each monitoring component (*i.e.*, WQI, physical channel, sediment). Consider the following line items:
    - Site visits to finalize monitoring locations.
    - Legal access negotiations.
    - Site recon.
    - Mobilization (acquisition of equipment and materials, monitoring team training).
    - Equipment installation.

- Monitoring procedures.
- Lab procedures.
- QA/QC.
- Data review and reporting.
- Data management.

Task 6: Develop Implementation Agreements

- Develop formal interagency agreements as needed for NPDES municipal stormwater permit-required monitoring at the watershed scale.
- Identify cost-sharing arrangements that are equitable for NPDES municipal stormwater permittees for both pay-in and in-kind contributions.
- Identify monitoring team members and specific assignments. Encourage volunteers where appropriate. Provide them with relevant monitoring documents from Task 4.

Task 7. Finalize Sites

- Obtain permission to inspect candidate sites on private property. If permission is not granted, remove site from pool of candidate sites.
- Visit candidate sites to evaluate suitability for monitoring (*e.g.*, riffles for BIBI, low velocity areas for sediment sampling, physical access). Prepare maps showing exact locations for monitoring, site access route, etc.
- Negotiate legal access for monitoring of suitable sites on private property. Coordinate with local jurisdictions if appropriate to facilitate negotiations.
- Coordinate with other jurisdictions (*e.g.*, tribes, federal agencies) where necessary to access sites.
- Eliminate sites with physical or long-term legal access problems.
- Prepare final site list.
- Update Task 4 monitoring documents and Task 5 cost estimates to reflect final site list.

Task 8. Mobilize (training, equipment, materials)

- Identify monitoring team members and specific assignments. Encourage volunteers where appropriate. Provide them with relevant monitoring documents from Task 4.
- Acquire equipment and materials if needed (*e.g.*, stage and/or velocity sensors and data loggers for new flow gages). Get permits for electro-fishing.
- Install equipment.
- Train field crews to ensure they are familiar with monitoring procedures, site locations, *etc*.

Task 9. Implement Monitoring

- Freshwater
  - Water Quality Index, rotating – sample 390 sites twice per 5-year term.
  - Water Quality Index, permanent – sample 30 sites monthly.

  - Benthic macroinvertebrates – sample 390 sites twice per 5-year permit term.
  - Periphyton – two pilot studies during 5-year permit term.
  - Fish surveys – two surveys at 390 sites per 5-year permit term.
  - Stream physical features – two surveys at 390 sites per 5-year permit term
  - Flow – continuous at 13 gages.
  - Temperature – continuous at flow gages.
  - Bottom sediment metals – annual grabs at 390 sites.
  - Bottom sediment toxics – annual grabs at 30 sites.
- Marine Nearshore
  - Fecal coliform – sample 50 sites monthly.
  - Mussel watch bioaccumulation toxicity – annual at 30 sites.
  - Bottom sediment metals and toxics – annual grabs at 30 sites.

Task 10. Analyze Results

- Perform lab data quality review after each sampling round. Flag any results that did not meet data quality criteria. Work with lab and/or field crews to correct any problems.
- Screen qualified results to identify sites where rapid follow-up (*e.g.*, source identification) may be warranted.
- At end of each year, evaluate monitoring results to summarize current status and variability of each parameter. Evaluate sites with pre-existing data to discern potential trends.
- At end of year two, revisit monitoring results and identify monitoring components that may need to be adjusted (*e.g.*, remove parameters that consistently met criteria). Discuss adjustments with SWG and Ecology. Refine monitoring protocols as needed. Train monitoring team members in new procedures.
- At end of year four, review the periphyton and mussel watch pilot study results. Identify potential improvements to monitoring procedures. Discuss potential changes with SWG and Ecology. Recommend revisions for next NPDES municipal stormwater permit term.

Task 11. Prepare Reports

- In year five, prepare reports summarizing the status and trends monitoring results, tailored to the target audiences listed below.
  - SWG report: Summarize results and recommend changes in monitoring strategy as appropriate.
  - WRIA report: Summarize results to facilitate use by WRIA-based salmon restoration and shoreline management programs; identify areas where source identification appears warranted.
  - Puget Sound report: Summarize key findings with respect to Puget Sound clean-up actions and priorities.
  - Other reports as identified.

5.2.2 Placeholder Cost Estimates

Planning-level cost estimates to implement the status and trends monitoring and assessment were developed using direct input from experts in the field, knowledge of existing costs, and extrapolation to possible new costs. Cost estimates for the entire recommended status and trend monitoring programs average about $5 million per year. Actual annual costs will likely vary based on the level of monitoring conducted each year.

We estimate that at least $1.7 million of the status and trends monitoring is already ongoing, and does not represent new costs.

See section 8.13 and Appendix D for more information.

6. SOURCE IDENTIFICATION AND DIAGNOSTIC MONITORING

In this chapter we propose a scientific framework and implementation plan for our second priority within the three categories for regional stormwater monitoring in Puget Sound:

- Source identification and diagnostic monitoring: prioritized based on local water body impairments, and collective assessments to identify regional issues.

Details and examples of the proposed experimental approach are given in Appendix E.

6.1 Scientific Framework for Source Identification and Diagnostic Monitoring

A comprehensive regional stormwater source identification and diagnostic monitoring framework is needed to help inform and prioritize both local and regional source control activities. This section outlines a diagnostic process to find causes of problems and fix them rapidly, with a feedback loop to measure and assess progress toward restoring failed receiving water biological endpoints or other problems or impairments caused all or in part by stormwater. Implementation of source identification and diagnostic monitoring should be preceded by prioritization of the known problems that need to be addressed. Source identification and diagnostic monitoring is a tool to:

- Determine the locations and sources of stressors for the highest priority problems. Sources include toxic chemicals, nutrients, pathogens, flows and other stormwater indicators or parameters identified to be a stressor.
- Identify the corrective action(s) to remove the stressors. Stormwater adaptive management strategies are integrated into the source identification and diagnostic monitoring framework.
- Assess progress towards correcting the problem and achieving the targeted goal.

Source identification and diagnostic monitoring use the existing framework of regulatory programs for Total Maximum Daily Loads (TMDLs), Clean Water Act 303(d) listings, Superfund sites, and more. The framework incorporates data from other sources including NPDES municipal stormwater permit-required Illicit Discharge Detection and Elimination (IDDE) programs, state watershed assessments, and stormwater outfall characterization monitoring. Ambient monitoring provides an "early" warning system for stormwater impacts. The regional status and trends monitoring will serve as another tool to identify problem areas for focused source removal projects.

The general "causal sequence" by which human activities can impair receiving-water health is shown in Figure 6. The potential impacts resulting from human activities can be assessed at each level in this causal sequence. Source identification and diagnostic monitoring seek to interrupt this "causal sequence" in a targeted, planned series of actions that sufficiently reduce sources exposures to result in improved biological endpoints.

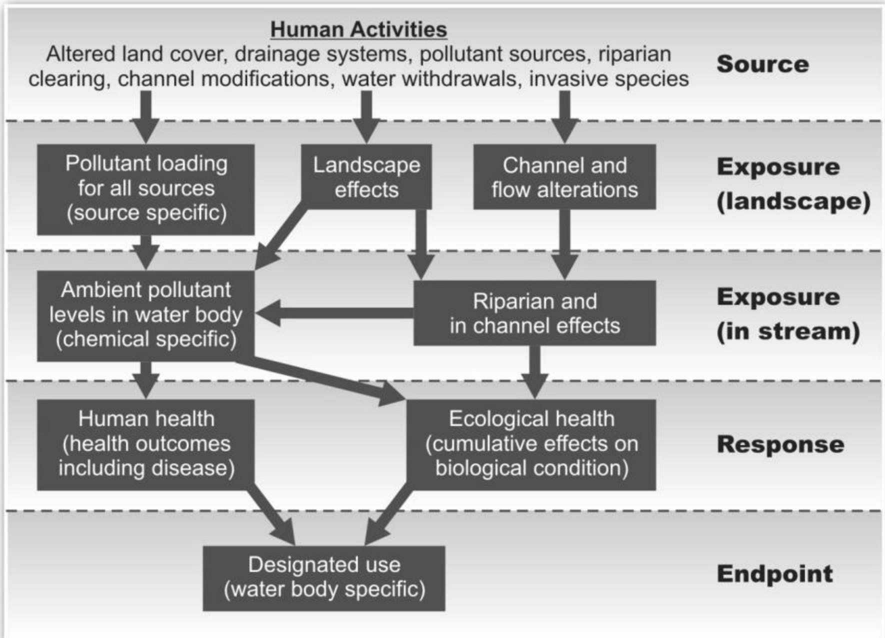

Figure 6. Causal sequence by which human activities affect receiving waters (EPA 2005, modified from Karr and Yoder, 2004)

The control, removal and prevention of sources can be accomplished through activities including behavior change, infrastructure repair, product substitution, regulatory prohibition, or retrofit with improved structural best management practices. The framework for source control efforts is to prioritize impairments at the WRIA level and subsequently implement monitoring and management actions at a scale that is sensible for the scope of the problem.

Additional monitoring may better refine source locations and provide for a more efficient and effective plan that addresses the highest priority areas and sources contributing to the impairment. Some sources are so ubiquitous that removal or prevention is only cost-effective and practical by enacting legislation or other regional policy actions where the source is prevented from presence in the product (*e.g.*, phasing out copper from vehicle brake pads). However, other sources are most effectively controlled at the sub-watershed scale. Collective analyses of source identification and diagnostic monitoring efforts across Puget Sound will help target future regional source control initiatives.

Key components of source identification include:

- Determine the existing problem sources/impairments to beneficial uses.
- Prioritize sources/impairments.
- Set a target for source reduction.
- Locate sources/impairments.
- Plan the regulatory framework and actions to remove the source(s).

- Implement source removal actions/programs.
- Monitor to provide feedback on status of the source.
- Sustain or implement monitoring to diagnose emerging sources.

A more detailed description of each of these key components is provided in Appendix E. These activities occur in an iterative process to track improvements in the receiving waters and to identify needs for additional controls. Multiple entities need to cooperate in situations where the impairment is not confined within the boundaries of a single jurisdiction.

The approach is connected to watershed-scale prioritization of specific impairments that have been identified, and provides tools and support for communities to participate in identifying and correcting their biggest pollution problems.

Source identification and diagnostic monitoring is distinct from response to emergency water quality problems such as illicit connections, spills, and transient illicit discharges. Source identification and diagnostic monitoring can include:

- Detailed monitoring to trace sources of pollutants or altered flow volumes upstream from the observed impacts on beneficial uses to their sources on the landscape.
- Business inspections; on-site septic system inspections.
- Illicit connection detection.
- Other programs.

This approach is not focused on clean-up activities; but rather on removal of current stormwater sources.

Two examples of successful source control programs initiated based upon high priority receiving water problem and controlled at the local jurisdictional level are the City of Tacoma Thea Foss Source Control Program to control PAHs and DEHP in sediments, and the Kitsap County Health District Pollution Identification and Correction (PIC) Program to reduce fecal coliform in marine and fresh waters (see Appendix E for more information). The common denominator of these programs is that they are:

- Performed on a site-by site basis by local entities.
- Address an identified stormwater pollution impact or degraded beneficial use.
- Result in improved environmental quality.

All source identification and diagnostic monitoring projects should be required to follow all applicable regional protocols; and all data and findings should be submitted to a central monitoring data management system and readily available to the public.

6.1.1 Possible Role of Outfall Characterization in Source Identification and Diagnostic Monitoring

Source identification and diagnostic monitoring will include stormwater outfall characterization when such data are required to further identify the location, frequency and possibly the quantities of sources. The need for characterization data is different for various types of studies, and to inform different diagnoses of impairments. Credible information is available in existing literature that can meet the needs of a particular study or problem. Where characterization is required, it should relate back to an identified problem and assist in determining the sources of problems and quantifying how much is coming from each source.

Calculation of loads is not of particular interest to source identification and diagnostic monitoring unless it directly informs corrective actions or policy changes. A characterization study design (not currently included in this strategy) would be required to calculate loads.

Outfall data are collected from sites covered under various NPDES stormwater permits including the general permits for boatyards, construction sites, industrial activities, municipal separate storm sewer systems, sand and gravel operations, and shipyards, and sites with individual permits. With the exception of the current NPDES Phase I municipal stormwater permit, the monitoring is currently conducted only for compliance purposes. However, these monitoring programs could focus on providing information on specific activities to identify sources, contaminants or impairments.

6.2 Implementation Plan for Source Identification and Diagnostic Monitoring

Most source identification activities are appropriately undertaken by local jurisdictions because they have detailed knowledge of their respective land uses, receiving waters, and potential pollutant sources. Unfortunately, while some local jurisdictions have in-house expertise and capacity to undertake these types of source identification and diagnostic monitoring efforts, many do not. In addition, many source identification efforts require working across departments (*e.g.*, the local health department and surface water management utility) within each jurisdiction and across multiple jurisdictions since the receiving water cross jurisdictional boundaries.

Conversely, more specific contaminants associated with particular land uses (or specific high-risk activities within particular land uses) identified through local source identification activities may be recognized as problems that should be addressed regionally. We need an established process for elevating those issues. The collective information gained from local source identification activities should be routinely assessed to identify such regional issues. Standard operating protocols (SOPs) and data reporting requirements need to be established to enable a collective regional assessment of the source identification and diagnostic monitoring information gathered locally.

In future work, the SWG will address major issues raised during the May 2010 public comment period that we were unable to address prior to our June 30, 2010 deadline (see Appendix I). Next steps and longer term implementation components are recommended and discussed in the following sections.

6.2.1 Prioritization of Problems/Impairments for Source Identification and Diagnostic Monitoring

A long-term, iterative process is needed whereby limited resources in each watershed are targeted on restoring the highest priority problems or impairments (failed receiving water biological endpoints) related to stormwater impacts of greatest local concern. Regional and local monitoring data should be reviewed at least every five years to help identify and prioritize which problems to address. For example, if monitoring of small streams identifies stream segments that are more directly degraded by stormwater relative to others, this information will be used to implement more intensive investigations within associated upstream tributaries and stormwater conveyance systems to identify and remove the specific source of the degradation.

More problems may be identified in a particular watershed than can be investigated and corrected at any one time. Therefore, it will be necessary to prioritize the identified problems/impairments so that source identification and diagnostic monitoring is focused on the most important problems. This process should also be informed by a determination of water bodies where Total Maximum Daily Loads (TMDLs) might be avoided by implementation of early action plans.

The 5-year NPDES municipal stormwater permit term could provide a helpful and predictable framework for scheduling and implementing prioritization. Prioritization should consider local concerns as well as priorities for the Puget Sound region. For example, problems could be ranked based on:

- Potential to cause or contribute to shellfish closures.
- Potential source of constituent(s) of concern for a TMDL or Category 5 water body.
- Potential impact on existing or planned salmon habitat restoration project(s).
- Potential importance of municipal stormwater discharges.
- Poor benthic macroinvertebrate health compared to other sites with similar levels of urban development (*e.g.*, based on Water Environment Research Foundation (WERF) bioassessment method). For example, sites with good biological potential but relatively poor current conditions could be classified as high priority for source identification.

6.2.2 Regional Database, Support Structure, and Other Tools for Source Identification and Diagnostic Monitoring

The following processes/activities/tools need to be established, conducted, and developed in coordination with other processes described in this chapter.

- Develop a regional data management structure to organize the information collected throughout the region, inform the prioritization effort, assist in developing plans to address local and regional problems, and share knowledge across watersheds and the region.
- Develop standard data collection and reporting methods for source identification and diagnostic monitoring.
- Establish common definitions for source control actions including enforcement, inspections, etc.
- Develop a regional approach to evaluate source control and removal program effectiveness. Include a feedback loop system for data to be used by local entities to adaptively manage source control and removal activities.
- Create regional tools and methods to remove sources including failing onsite sewage systems, agricultural manure practices, illicit connections, and enforcement.

6.2.3 Roles and Responsibilities for Source Identification and Diagnostic Monitoring

NPDES municipal stormwater permittees should work with Ecology and others on source identification activities for stormwater-related problems that have been identified based on water quality constituent concentrations in their jurisdictions. Particularly where problems affect multiple jurisdictions, the permittees should coordinate and involve other entities as needed.

Jurisdictions should be responsible for fixing identified sources. An appropriate level of effort for permittees needs to be determined, and responsibility for diagnosing and solving problems needs to be distributed equitably. However, funding sources, roles, and responsibilities are not limited to NPDES permittees.

Biological impairments can be more difficult to diagnose than water quality impairments because they could be related to a wide array of chemical, physical, and/or biological stressors. Some jurisdictions may not have the staff resources to evaluate the full range of potential stressors. Therefore, some diagnostic monitoring for biological impairments might be led by the regional status and trends monitoring effort, with support from the affected local jurisdiction(s).

6.2.4 Proposed Schedule and Sequencing for Implementation of Source Identification and Diagnostic Monitoring

This timeline assumes that the prioritization cycle will be integrated with the five-year NPDES municipal stormwater permit cycle beginning in February 2012.

Activity	Timeframe
Review existing data to identify & prioritize problems	2012
Perform source identification on top priority problems	2013-14
Implement early action plans	2013
Prepare scope & budgets for source control planning and CIP	2014-2015
Review S&T or other new data to identify & prioritize problems	2016

6.2.5 Placeholder Cost Estimates

Planning-level cost estimates to implement source identification and diagnostic monitoring were developed assuming that, at a minimum, efforts would occur in each of three categories: (1) bacteria in streams, (2) toxic chemicals in urban bays, and (3) bacteria along the nearshore. To develop planning-level cost estimates, it was assumed that one stream bacteria study and one nearshore bacteria study would occur in each WRIA each year. Similarly, it was assumed that one toxic chemical source identification study would occur in each of five urban bays each year.

Based on these assumptions, annual average costs for source identification and diagnostic monitoring would be about $2.8 million. See section 8.13 and Appendix E for more information.

7. EFFECTIVENESS STUDIES

In this chapter we propose a scientific framework and implementation plan for our third priority within the three categories for regional stormwater monitoring in Puget Sound:

- Effectiveness studies: evaluating whether best management practices in major land-use categories achieve intended outcomes of water quality improvements or stormwater volume reductions (or other protective or corrective measures).

Details and examples of the proposed experimental approach are given in Appendix F.

7.1 Scientific Framework for Effectiveness Studies

Stormwater management effectiveness studies are intended to test our assumptions about whether or not stormwater management approaches are functioning as anticipated and result in improvements in beneficial uses. Some effectiveness studies of public domain structural BMP designs is already being performed through current NPDES municipal stormwater permit requirements and other efforts, and effectiveness studies of proprietary technologies are done through Ecology's program to evaluate emerging stormwater treatment technologies (the TAP-E protocol, see http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html).

All effectiveness studies should be designed to answer specific questions with clearly articulated hypotheses for testing (see section 4.7). Effectiveness studies will likely occur at different spatial and temporal scales, depending on the intent of the study. (For example, studies may investigate the effectiveness of specific, parcel-scale approaches in individual storms, or the effectiveness of region-wide programs over the course of two to five years.) Typical methodologies to be used for evaluating stormwater management effectiveness include comparison of conditions:

- Upstream and downstream from management actions.
- In paired watersheds.
- Before and after management actions.
- In runoff influent and effluent.

As part of each effectiveness study, the costs of various techniques and approaches should be quantified. Only with quality data on the cost of various management actions and approaches can a cost/benefit evaluation be conducted. We recognize that in this age of limited resources, smart investments in stormwater management are a priority, to ensure that maximum benefit is obtained. Use of this information would occur though an adaptive management approach for stormwater management.

All effectiveness studies should be required to follow all applicable and agreed upon regional protocols; and all data and findings should be submitted to a central monitoring data management system and readily available to the public.

A robust literature review is essential to effectively and efficiently address monitoring needs related to the effectiveness of stormwater management practices and programs. As appropriate within each of the five focus areas for effectiveness studies, the effectiveness of both individual practices and overall programs should be evaluated.

Table 3 shows a proposed outline for the literature review.

7.1.1 Focus Areas for Effectiveness Studies and Initial Prioritization of Topics

Information collected through effectiveness studies will help quantify the costs and benefits of stormwater management approaches and target our efforts to better protect and restore beneficial uses. Effectiveness studies are needed in the following five focus areas. The beginning focus of SWAMPPS effectiveness studies will be on the below-listed "initial topics" for each of the five focus areas.

1. New development and redevelopment:
   Testing the effectiveness of low-impact development (LID) and other techniques to minimize impacts from future new development and in areas of redevelopment.
   Initial topic: Effectiveness of various LID techniques in new development.

2. Retrofit of existing development:
   Testing the effectiveness of retrofitting urban areas with various flow management and water quality treatment approaches to decrease impacts from the built environment.
   Initial topic: Effectiveness and cost of retrofitting existing development with various flow management and water quality treatment approaches.

3. Non-structural, operational, programmatic approaches used in stormwater programs such as educational, source control and maintenance programs:
   Testing the effectiveness of non-structural (*i.e.*, operational, behavior-change, planning) and programmatic approaches used in stormwater management programs, and in particular, of various provisions of NPDES stormwater permits and other regulatory programs.
   Initial topics: Effectiveness and cost of various provisions of the NPDES municipal stormwater permit and effectiveness of various agricultural best management practices.

4. New and emerging techniques:
   Evaluating and assisting in the development of new technologies targeted at reducing specific stressors.
   Initial topics: Fecal coliform and metals treatment techniques.

5. Key knowledge gaps for existing technologies:
   Fill key gaps in our current tools and practices to provide better tools for managing stormwater in the future.
   Initial topic: No topics prioritized at this time.

These five focus areas are believed to encompass the complete range of types of information necessary for evaluating and improving stormwater management approaches. The first three focus areas are of approximate equal priority, relative to one another. We recommend that (apart from privately-funded TAP-E studies to gain regulatory approval for new proprietary

Table 3. Proposed Outline for Effectiveness Study Literature Review

I. New Development and Redevelopment

A. Effectiveness of various BMPs in managing peak flows and flows above forested conditions, using continuous runoff modeling
B. Effectiveness of various BMPs in removing various pollutants
C. Effectiveness of LID approach and techniques
D. Applications: Residential, Commercial, Municipal roads, State highways, Industrial, Agriculture
E. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions
F. Identification of what's known and well documented, and data gaps

II. Retrofitting existing development

A. Effectiveness of various BMPs in reducing surface runoff volumes and peaks
B. Effectiveness of LID techniques vs. more conventional BMPs
C. Applications: Residential, Commercial, Municipal roads, State highways, Industrial, Agriculture
D. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions
E. Identification of what's known and well documented, and data gaps

III. Non-structural, operational, programmatic approaches used in stormwater programs

A. Non-structural (Operational/Programmatic) BMPs

1. Effectiveness of various BMPs in reducing surface runoff volumes and peaks
2. Effectiveness of various BMPs in treating targeted pollutants
3. Applications: Municipal, Commercial, Agriculture, Industrial
4. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions
5. Identification of what's known and well documented, and data gaps

B. Effectiveness of Overall Municipal and Other Stormwater Management Programs

1. Effectiveness in not increasing, or in reducing, flow volumes and peaks to flow sensitive water bodies
2. Effectiveness in not increasing, or reducing, pollutant loadings and concentrations, and protecting beneficial uses
3. Applications: Municipalities (MS4's), Agriculture, Industrial, and other
4. Experimental designs used: parameters, locations, protocols, land use densities, type of development, soil types, meteorological conditions, indicators
5. Areas/locations targeted for this type of monitoring

IV. New and emerging techniques and technologies

V. Identification of what is known and well documented, and data gaps

technologies) studies related to the fourth and fifth effectiveness focus areas be delayed until satisfying information is being provided for the first three effectiveness focus areas.

More work is needed to articulate working hypotheses that are suitable for designing studies (see section 4.7). This focus of effectiveness studies should be re-evaluated on a routine basis, and after the initial focus, future investigation can consider the effectiveness studies for other stormwater permits and land-uses.

The initial studies to address priority topics, questions, and/or hypotheses within each focus area should be selected based on the results of the literature reviews, existing monitoring programs, and other information. Before studies are designed, each hypothesis must be subjected to evaluation of whether it is in fact credible, testable, and actionable.

7.1.2 Summary of Scientific Framework for Effectiveness Studies

Effectiveness studies will test our assumptions about whether or not selected stormwater management approaches are functioning as anticipated and result in improvements in beneficial uses and help quantify the benefits of stormwater management approaches. These studies will provide unbiased information about whether specific management actions are preventing, reducing, or mitigating known stormwater impacts to beneficial uses in receiving waters.

To be successful, effectiveness studies must be performed at sites selected within relatively small spatial scales (*e.g.*, site or catchment) to reduce influences from other actions or natural phenomena. Reducing influences not related to the management action itself is necessary for a robust experimental design. A final component of this monitoring is the linkage to specific "outcomes" as described in section 4.2 and elsewhere in chapter 4.

Many effectiveness studies require a relatively small-scale focus and treatment locations where stormwater management actions are applied and their implementation is well documented. For each treatment location, the monitoring design may include upstream/downstream monitoring, before/after monitoring, or treatment/control monitoring. The selection of the appropriate approach is dependent on the specific hypotheses to be tested.

The types of information provided by effectiveness studies include:

- The amount of change in flow parameters or water quality parameters downstream relative to upstream of the stormwater management location.

  OR

- The amount of change in flow parameters or water quality parameters from before and after installation of the stormwater management action.

  OR

- The amount of difference in flow parameters or water quality parameters between a site receiving stormwater management action and a control site not receiving stormwater management action.

The types of information <u>not</u> provided by effectiveness studies include:

- Identification of sources of pollutants and stressor diagnosis.

- Cumulative impact of multiple stormwater management actions at the watershed or regional scale.

7.2 Implementation Plan for Effectiveness Studies

To implement stormwater management effectiveness studies, we recommend that a public and transparent process be developed and initiated to identify and prioritize effectiveness hypotheses (see below). Effectiveness studies should be conducted, as appropriate, at the site, watershed, and regional scales. Studies should include programmatic approaches as well as specific practices and activities, and should include the analysis of costs of the technique studied.

In future work, the SWG will address major issues raised during the May 2010 public comment period that we were unable to address prior to our June 30, 2010 deadline (see Appendix I). Next steps and longer term implementation components are recommended and discussed in the following sections.

7.2.1 Design and Implementation of Effectiveness Studies

Additional specific questions to guide initial development of effectiveness studies are provided in Appendix F. For each hypotheses-driving question, the following information must inform refinement of the questions into working hypotheses:

- Who will be responsible for implementation;
- When is implementation recommended;
- What are the recommended methodologies for implementation;
- Where is the geographic scope for implementation; and
- How will this be funded?

And finally, each hypothesis must be subjected to evaluation of whether it is in fact credible, testable, and actionable.

The information derived from effectiveness studies should be used as part of an adaptive management approach. For example, when status and trends monitoring detects stormwater impacts, the source is identified and action is undertaken to minimize that impact. Effectiveness studies assure that the actions taken are sufficient and the results are used to direct the choices and development of future actions, and the techniques are used to address impacts elsewhere.

We recommend that effectiveness studies be implemented by all interested entities, potentially including:

- Local municipalities
- WSU research/evaluations
- Academic institutions
- Conservation Districts
- Tribes
- Federal and state agencies
- Ecology, EPA, and other grantors*

- National & international effectiveness studies (accessed through literature searches and other methods)
- Non-profits
- Consultants
- Others

*Current sources for Ecology's stormwater grants are limited and dwindling. We recommend that the funding of these grant programs be stabilized and the funding pool increased.

7.2.2 Process for Selecting Topics for Effectiveness Studies

We recommend a public, transparent process to identify and prioritize future and more specific topics, questions, and hypotheses for effectiveness studies, applying the following criteria for evaluating and selecting effectiveness studies:

- Meets the criteria for a sufficiently defined working hypothesis (see sections 4.6 and 4.7).
- Addresses one of the most important stormwater-related threats or impacts in Puget Sound, based on prior assessments.
- Diversity of studies across all of the prioritized topics within the new development / redevelopment, retrofit, and programmatic / non-structural BMP effectiveness study focus areas.
- Likelihood of the practice to result in improvements to beneficial uses.
- Likelihood of the study to result in increased cost-effectiveness of stormwater management actions mandated by the NPDES municipal stormwater permits with special focus on the costliest of the programs.
- Likelihood to generate results within a given time frame.
- Strength of link to the Partnership's Action Agenda and results chains.

We recommend that requests for proposals be issued for effectiveness studies, based on the guidance and priorities identified by the SWG, and that an open and transparent process be developed to evaluate the submitted proposals and select those for initial implementation. For effectiveness studies to be targeted for implementation through the NPDES municipal stormwater permits, this process needs to be expedited in fall 2010 in order to meet the timeline to inform the requirements for the coming permit cycle.

The SWG should re-evaluate the focus of effectiveness studies on a periodic basis.

For the new technologies evaluations, there are multiple possible technologies to test and evaluate. Possible methods for prioritization include the availability of private funding from technology proponents, interest among various stormwater managers in the new technologies, and whether the new technology addresses a high-priority stormwater management problem.

7.2.3 Recommendations for NPDES Municipal Stormwater Permit-Required Effectiveness Studies

The cities and counties covered under NPDES Phase I and Phase II municipal stormwater permits want to know whether their stormwater management programs are effective. There is also a need to have more "tools in the toolbox" when it comes to additional techniques for flow control, preventing pollution, and treating stormwater discharges. With that in mind, and in anticipation of the next permit issuance in 2012, the permittees are willing to develop designs for five effectiveness studies to be started in the next permit term. The reasons these studies should be started at the beginning of the regional efforts are:

- Permit compliance: permittees need monitoring to fulfill permit requirements.
- Rigorous, directed monitoring that answers well-defined questions is extremely expensive, and beyond the ability (monetary and technical) of most Phase II jurisdictions. Phase I and II communities are poised to contribute to a pool of money to accomplish the monitoring proposed here.
- Results from the initial proposed monitoring have a direct impact on future permits and requirements. For instance, a particular technique required in the Stormwater Manual may work marginally well, but by monitoring effectiveness under differing modifications, we may find simple retrofits that increase its efficiency significantly. These improved techniques could then become part of the subsequent updated Manual.

We do not recommend that these effectiveness studies all be undertaken simultaneously, but rather that an implementation cycle be set up whereby the initial set of priority hypotheses are identified and all are tested in the next decade. The SWG has a caucus-based, transparent decision-making process in place, and could act as the evaluation body to prioritize which studies will be done first. This prioritization should mesh with permit requirements and with regional needs. Local governments, Ecology, the Partnership, and others could weigh in on the priorities through their participation in this group.

As part of the next cycle of NPDES municipal stormwater permits, we recommend that the permits include requirements to conduct or contribute to effectiveness studies, and allow jurisdictions the flexibility to meet their requirements by either paying into a fund for effectiveness study activities (a "pay-in option" described in section 8.3.1); or conducting effectiveness studies themselves (a "self-conducted study option"). Funds generated by the "pay-in option" should be managed as described in section 8.3.1. The cost to each NPDES municipal stormwater permittee should be developed based on equitable factors.

7.2.4 Recommendations for Other Effectiveness Studies

The technology assessment program (TAP-E) should continue with funding from new technology proponents and other long-term, reliable funding sources.

Other entities beyond NPDES municipal stormwater permittees should be encouraged to self-fund and/or conduct effectiveness studies following SWG priorities and guidance and regional protocols. Other entities beyond NPDES permittees should also be encouraged to contribute to the "dedicated stormwater monitoring and assessment fund" to increase funding available for coordinated effectiveness studies.

Entities conducting effectiveness studies should partner to share resources.

7.2.5 Recommended Roles

- NPDES municipal stormwater permittees: Add a new permit requirement that provides flexibility for permittees to either pay into a fund to conduct effectiveness studies or do an approved study themselves.
- Non-permitted municipalities and others: As part of future grants from Ecology for retrofits and non-structural BMPs, establish a new policy of setting aside small amount for effectiveness studies.
- WSU Puyallup: Continue ongoing testing and evaluation of LID techniques as part of grants from Ecology and match from Puyallup. Establish Stormwater Technical Resource Center (SRTC) with UW Tacoma and the City of Puyallup.
- State and Federal Agencies: Assist in the implementation of this strategy.
- Conservation Districts: Assist in the development and implementation of a robust monitoring strategy for evaluating effectiveness of various BMPs to reduce stormwater impacts from agricultural practices. Coordinate that effort with this strategy.
- Dedicated stormwater monitoring entity: Provide administrative mechanism for collective pay-in, support structure, and tools to implement selected effectiveness studies.

7.2.6 Schedule and Sequencing

2010 and forward: Ongoing studies conducted by state and federal agencies and at WSU Puyallup and by others.

2011 to 2012: Studies conducted as part of revisions to Ecology's grant programs.

2012-2017: Stormwater effectiveness studies required as part of reissued NPDES municipal stormwater permits.

7.2.7 Placeholder Cost Estimates

Planning-level cost estimates were developed for effectiveness studies based on the costs to manage a "Request for Proposals" program, and costs to fund effectiveness studies. Based on this breakdown, annual average costs were estimated to be about $7 million. See section 8.13 and Appendix F for more information. Costs to manage and implement the TAP-E program will be developed by the Stormwater Technical Resources Center (STRC), whose recommendations are due in December 2010.

8. REGIONAL PROGRAM IMPLEMENTATION

Many support structures, resources, tools, and additional data will be included in establishing SWAMPPS. The following sections describe steps toward providing the governance, administration, financial arrangements, and standardized methods and procedures for stormwater monitoring without presupposing or posing obstacles to making the necessary arrangements for ecosystem monitoring. The following sections focus on the issues of greatest importance to our initial efforts to establish SWAMPPS.

In future work, the SWG will address major issues raised during the May 2010 public comment period that we were unable to address prior to our June 30, 2010 deadline (see Appendix I). Next steps and longer term implementation components are recommended and discussed in the following sections.

8.1 Puget Sound Coordinated Ecosystem Monitoring and Assessment Program

The activities recommended in the previous chapters should ideally be conducted as part of the larger regional effort to monitor stressors, biota, and management activities, and other key aspects of the ecosystem critical to understanding its function and assessing progress toward its recovery. The Partnership, in advance of its efforts to create such a system, and in the absence of such a program, tasked the SWG with developing a component of the program to address stormwater and link to other program components. The effort underway by the Partnership will elaborate on how the full adaptive management framework will function to get corrective feedback to managers, make this monitoring program more useful, and help us communicate the information.

The essential functions and characteristics of a successful regional monitoring program, as described in the December 2008 report of the Puget Sound Monitoring Consortium (Consortium) (http://www.ecy.wa.gov/programs/wq/psmonitoring/swworkgroup.html) to the Washington State Legislature, continue to guide our recommendations. The SWG must fit into a broader ecosystem monitoring program when it is formally established. In establishing our process, deciding upon a framework for SWAMPPS, and making the recommendations, the SWG has relied heavily on the consensus recommendations of the Consortium, a time-limited broad stakeholder group funded by the state Legislature to "facilitate the development of an ongoing monitoring consortium similar to Chesapeake Bay or San Francisco Bay to institute coordination between local, state, and regional monitoring agencies. The goal is to integrate ongoing monitoring efforts for stormwater, water quality, watershed health, and other state indicators and enhance monitoring efforts in Puget Sound." See Appendix A for more information.

8.2 Stormwater Work Group

The SWG was created by the Consortium in 2008 following requests by both the Partnership and Ecology. The SWG is one of many topical work groups that will be coordinated, connected, and integrated by direct representation on the technical committee of the broader ecosystem monitoring program. The SWG has been formally established as the stakeholder group to oversee collective regional science needs for the topic of stormwater, and has been learning through applying this new process to collective prioritization. Several SWG members and staff also participate on other topical work groups, enhancing coordination and communication.

The SWG represents a substantial investment in time and staff contributions from participating entities. The SWG has reached a level of group process and function that would take a long period of time to recreate. Ecology and the Partnership should evaluate the SWG and decide upon a permanent charter, composition, host agency, stable funding, and means to support long-term participation by stakeholders.

Ecology and the Partnership should also approve future SWG work plans.

We recommend that the approach described in our bylaws and charter (http://www.ecy.wa.gov/programs/wq/psmonitoring/swworkgroup.html) be continued, with modifications as needed to improve our ability to perform and maintain these essential ongoing roles and functions:

- Decision making and leadership:
    - Set priorities within broad scientific framework.
    - Get stakeholder buy-in on recommendations.
    - Encourage broad participation.
- Coordination and communication:
    - Establish and maintain connections to other topical work groups and to other existing efforts
    - Recommend assigned roles and responsibilities.
- Informing and advising the development of a regional stormwater control strategy:
    - Recommend stormwater management actions.
    - Provide a sounding board for ideas.

8.3 Proposed Administrative Entity to Support Local Monitoring Activities and Cost Sharing

A new administrative entity is needed to enable and support cost-sharing, in addition to memoranda of understanding among participants.

8.3.1 Pay-in Option for NPDES Municipal Stormwater Permittees

The SWG recommends that a fund be formally and permanently established and dedicated exclusively to implementing prioritized stormwater-related monitoring and assessment activities in the Puget Sound region. The fund will provide a technically and fiscally credible means of coordinating stormwater-related data collection and analyses, sharing data, and reporting findings. Collective pay-in to the fund will enable the fund to carry out regional stormwater science monitoring and assessment activities as articulated in other SWG recommendations.

The fund will serve as a cash flow tool to facilitate sustained long-term stormwater monitoring by accommodating annual payments by permittees and other participants. Expenditures by the fund cannot exceed the committed contributions; nor can funds be diverted to unapproved projects. Any and all interested parties can pay into the fund.

The fund will be administered by an independent entity and overseen by a board. The entity will not decide how the funds are to be spent; the board will. The entity will enter into contracts for data collection, studies, and analyses to support implementation of:

- Regional status and trends monitoring,
- Source identification investigations,
- Effectiveness studies,
- Data management and accessibility, and
- Analysis and synthesis.

Over time the activities supported by the fund will include:

- Continued development of standard methods and procedures,
- Cross-topic analyses and synthesis, and
- Development of models to support extrapolation and extension of findings.

For NPDES permit-required monitoring activities in Puget Sound, a “pay or play” option needs to be adopted and approved by Ecology for 2012 and beyond. Other regulated entities should be able to meet part of their monitoring requirements through participation in the future, but we recommend beginning this program with a focus on NPDES municipal stormwater permittees. The SWG will make establishment of this fund a priority for fall 2010.

We recommend a “pay-in option” dedicated to stormwater-related monitoring and assessment with the following characteristics:

- It allows permittees flexibility to meet requirements by *either* paying into the fund, *or* conducting monitoring activities themselves.
- It ensures that permittees’ contributions are spent exclusively on monitoring activities that are related to municipal stormwater management, and have quality assurance project plans (QAPPs) that have been reviewed and approved by Ecology.
- It is independently managed by an entity, whose budget is permanently dedicated to monitoring and cannot be re-appropriated to other purposes by any legislative body,
- It allows and encourages all entities in the region to contribute to and participate in coordinated regional monitoring activities.
- It provides businesses and other NPDES permittees with a future pay-in option.

We recommend that annual contributions from permittees be expected at the levels of effort recommended in each of the specific sections outlining the roles and responsibilities for status and trends, source identification, and effectiveness studies, plus a modest amount to support overall assessments and administration of the fund. The funding mechanism should maintain different accounts for specific science activities and for overall assessment.

Adequate flexibility must remain to allow permittees to conduct some or all of their required status and trends, source identification, and effectiveness studies themselves. However, all permittees should be required to pay into the fund at a reasonable level to sustainably maintain the infrastructure of the regional monitoring program and its overarching responsibilities for contract oversight, data management, and synthesis activities.

Ecology and the local government caucus will help the SWG develop fiscal oversight and work planning arrangements that ensure the funds are dedicated to activities and products that meet needs of permitting authorities, permittees, and others who pay in. The structure and an initial, phased work plan should be developed in the coming six to nine months and finalized by March 2011 in time for the pay-in option to be included in the next round of NPDES municipal stormwater permits. The program should begin phased-in implementation in late 2012 or early 2013.

8.4 State and Federal Monitoring Activities

SWAMPPS is built upon the following specific, ongoing monitoring programs that are currently conducted by state and federal agencies. These programs provide key information to answer important stormwater questions. The following monitoring activities that are currently funded and conducted by state and federal agencies should continue:

- Ecology's statewide status-and-trend monitoring program (State EMAP),
- Fish diversity and abundance monitoring for salmon recovery efforts,
- Shellfish bed monitoring by state and local health departments,
- Puget Sound Mussel Watch, and
- Sediment and other nearshore monitoring by the Puget Sound Assessment and Monitoring Program (PSAMP).

Memoranda of understanding may need to be adopted to implement components of these programs with shared responsibilities.

In addition to continuing these important investments in regional monitoring, the SWG's subgroup working on further defining pay-in option and allocation costs among NPDES municipal stormwater permittees (see prior section) will also propose specific ways in which the federal and state shares of funding regional monitoring should be expanded in the coming biennium.

8.5 Targeted Literature Reviews and Gap Analysis

Existing data and programs must be a foundation for all later work done by the regional monitoring and assessment program. This strategy outlines initial steps to tie the monitoring recommended here to other existing short- and long-term monitoring in Puget Sound. We also recognize the need for a thorough analysis that would result in:

- A catalog of watershed land-use metrics.
- Identification of stressors.
- Prioritization of at-risk watersheds.
- Identification of what techniques are most effective in which watersheds.
- Identification of data gaps and needed research.

The literature reviews that are detailed in the scientific framework for each category of monitoring should be conducted in the coming six months to one year to further inform the development and finalization of initial study designs. Each will be targeted differently, but categories include:

- Review of existing data;
- Compilation of programs;
- Review of specific types of effectiveness studies;
- Identification of data gaps and research needs;
- Identification of modeling activities and needs.

These literatures should use other compilations from around the country (CASQWA, CWP). These reviews should cost somewhere between $15,000 and $40,000 depending primarily on the number and timing of reviews to be conducted to assist in selection and design of effectiveness studies.

8.6 Standard Operating Procedures and Data Reporting Requirements

To ensure data comparability across the multiple monitoring efforts, it is essential that a common set of standard operating procedures be developed and used throughout the region. The following necessary steps must be taken to ensure that credible data are collected in a quality manner for all monitoring and assessment conducted by the regional program (see Appendix G):

- Data quality objectives must be identified.
- Project plans must be approved and shared.
- Standard field collection and data reporting protocols must be followed.
- Appropriate analytical accuracy, precision, detection, and reporting limits must be used at accredited laboratories.
- Geographic information system (GIS) data must follow state guidelines.

Among the pilot projects conducted by the Puget Sound Monitoring Consortium in 2008-09 was an effort to brainstorm and prioritize what standard methods needed to be adopted and used in order to be able to collectively analyze and interpret stormwater data collected in the region. We recommend that regional program participants contribute to and participate in ongoing efforts to develop and approve new standard methods.

We further recommend that an online a library be populated with an extensive set of approved standard operating procedures, methods, and protocols for stormwater-related data collection. Accompanying this library should be a prioritized list of methods that need to be standardized to improve our ability to perform regional science assessments with data collected by multiple entities. NPDES permittees doing their own monitoring would be required to follow (select from) these prescribed, web-accessible methods. Detailed recommendations for SOP elements are provided in Appendix G.

8.6.1 Recommended Process for Developing New SOPs

The 2008-09 SOP Pilot project was formed and funded by the Puget Sound Monitoring Consortium (http://www.ecy.wa.gov/programs/wq/psmonitoring/technical_advisory.html). This group developed a process for developing stormwater-related SOPs by partnering with multiple stakeholders to provide maximum information, research and resources and ensure clear interpretation.

This collaborative SOP process is currently in place, but unfunded. Continuation of this group through the SWG can provide a means to develop SOPs for SWAMPPS projects. SOPs identified by the SWG can be developed and maintained to provide a comparable set of reliable data that can be used to confidently identify stormwater concerns and address them with an effective management strategy.

For successful SOPs to be developed, strong leadership and funding are needed. In order to successfully develop SOPs the SWG should do the following:

- Identify specifically what type of SOPs will be needed in order to implement the design.
- Identify funding sources and costs associated with developing the necessary SOPs.
- Identify how SOPs will be managed, updated, and shared with the public.
- Identify the process for development, review and approval process, building upon the current the SOP group's process and lessons learned.
- Identify stakeholders and participants who should be involved with development, review and approval of SOPs.

8.6.2 Costs and Schedule

The SOP group demonstrated that four SOPs can be developed in one year at a cost between approximately $40,000 and $60,000.

8.7 Coordinated Information Management

SWAMPPS needs data repository, storage, and management structures that do not currently exist. Much of the information currently available on the status and health of Puget Sound has been collected by numerous agencies through preexisting monitoring programs; however, this information has generally not been coordinated or shared in a way that helps scientists, managers, and decision-makers answer key questions about the health of the Puget Sound ecosystem.

Information management will likely require the tracking of multiple types of data, collected by multiple organizations and individuals, related to other data in complex ways, and sought after by many interested stakeholders. This complex set of relationships requires a holistic evaluation of data needs and approaches for assembling the data. However, an aim towards early delivery of some data management is likely to be of highest priority, to ensure that the largest and most commonly requested data are managed in a manner that maintains integrity and maximizes data sharing.

Information management is a field of specialized effort, where experts in database design and construction, website design and construction, and user interface design and construction must interact with experts in the various types of monitoring programs described, and policy experts in the use of the information generated by the monitoring programs. This multidisciplinary approach, and the time needed to create the information management systems, suggests that this task is never to be "completed", even as new and improved systems are developed. Instead, information management builds upon completed systems and operates, maintains, and builds new systems to improve the sharing and analysis of information gathered.

Other entities in Puget Sound, including the Washington Forum on Monitoring Watershed Health and Salmon Recovery and the Pacific Northwest Aquatic Monitoring Partnership, are addressing regional data management needs. We will benefit from these efforts. In addition, the coordinated information management system will likely build on existing efforts for managing stormwater-related data. Several examples of existing systems include, but are not limited to:

- Washington Department of Ecology's Environmental Information Management (EIM) system. This system includes water quality, sediment quality, stormwater quality, effluent quality, and tissue quality data collected by Ecology and multiple other organizations.
- Washington Department of Ecology's Hydrology system. This system includes continuous weather, flow, and water quality data collected by Washington State Department of Ecology.
- United States Geologic Survey's National Hydrology System. This system includes hydrology data collected by the USGS from throughout the United States.
- Puget Sound Stream Benthos. This system includes the majority of the stream benthos data collected in the Puget Sound region since 2002.
- King County's Hydrologic Information Center. This system includes continuous weather, flow, and water quality data collected by King County. Copies of this data management system are also used by Pierce County and Kitsap Public Utilities.
- Snohomish County Stormwater NPDES Data Management System. This system houses data collected by Snohomish County under their current NPDES municipal stormwater permit.

None of these examples would serve as a complete information management system for SWAMPPS, but each could be leveraged to manage certain aspects of the program.

All SWAMPPS monitoring results data, QC data, meta data, and reports should be stored in data management system(s) where responsibility for providing QA/QC for data and for correcting, editing, and updating data lies with the data generators, and where all data are easily shared with all interested parties and the public.

Developing such a system will take the coordinated effort from a multidisciplinary team from multiple organizations. We recommend that such a team strive to leverage existing capacities. We also recommend that all entities participating in SWAMPPS contribute funding and/or in-kind services to data management and data analysis activities.

There are multiple possible approaches that could be used to achieve the vision of the coordinated data management system. It is possible that different "modules" could be created to serve the different categories and components of the coordinated monitoring and assessment strategy. These modules would then feed data into a data mart, or be accessible via a single web portal, to allow for analysis across multiple data types. Also of critical importance is the standardization and automation of data analysis to track key indicators, such as the stream water quality index, and making these results available via the web.

The multidisciplinary, multi-entity data management team tasked with developing the data management framework will need to assess all existing systems, understand the requirements of the new system, identify overlaps, and develop a work plan for filling the gaps. This task is likely to be relatively time consuming, and it would be highly advantageous to complete this task, and begin constructing the new system, before additional data gets collected. The SWG should be responsible for reviewing and approving the data management approach. Examples of some key issues that need to be considered when designing a data management system are listed in Appendix I.

8.8 Inventory of Monitoring and Assessment Activities in the Puget Sound Basin

An ongoing inventory of monitoring and assessment efforts in the Puget Sound region will inform the priorities of regional and local monitoring efforts and assist in their coordination and implementation. This early work will also help inform the next round of the NPDES municipal stormwater permits. The inventory will:

- Include all monitoring and assessment efforts, not just those directly associated with stormwater, because we need to conduct stormwater-associated monitoring and assessment within the context of the entire ecosystem.
- Cover a wide range of efforts from volunteer monitoring to wastewater discharge and sediment cleanup site monitoring to fisheries assessments and special studies on specific species, because we need to coordinate and partner with other efforts.
- Be organized by Watershed Resource Inventory (WRIA) so that one can search for relevant projects on a watershed scale, but also searchable by other categories such as stressors.

The inventory is a work in progress and is not complete. It is built upon inventories previously compiled by the Washington Forum on Monitoring Salmon and Watershed Health (Forum), the Partnership, the Environmental Information Management (EIM) system, Washington SeaGrant, and others. The SWG released a draft version, concurrent with the April 30, 2101 draft strategy, in order to solicit help in filling in the gaps. The SWG plans to continue to update and correct the inventory through at least fall 2010.

The inventory should ultimately be housed and maintained by the new ecosystem monitoring program that is presently being created by the Partnership, and will be turned over to them when they are ready for it. The inventory should be ongoing, with regular updates.

8.9 Regional Stormwater Modeling Needs

There must be a strong connection between ongoing modeling activities and SWAMPPS data collection and analysis. The intent of this regional strategy is to collect data that supports modeling activities and can be used to verify past efforts, transfer results to un-monitored parts of the watershed, and better describe the water quality improvements and other benefits expected from various management activities. Data collection must be targeted to modeling efforts that will be useful in providing insight to help answer our questions.

Modeling might use and expand the usefulness of the data obtained by the strategy in one or more of the following ways:

- To extrapolate and credibly transfer information obtained from localized monitoring efforts to larger scales or areas where monitoring does not take place, thereby extending the utility of the data to unmonitored areas.
- To examine different future-oriented and hypothetical scenarios for stormwater management that cannot be directly monitored, and
- To improve estimates of the origin and fate of contaminants in streams, interpretations of water quality patterns based on nonpoint and point pollution sources, and predictions of biota responses to water quality improvements or degradations.

A process whereby the data collected by SWAMPPS feeds into the modeling work that is needed, and vice versa, does not exist. A list of modeling needs should be generated and prioritized for stormwater science and management issues.

SWAMPPS intends to collect data that is needed and relevant for many stormwater-related models, and key relevant data gaps. In the coming year, the SWG will go through/identify the list of most relevant models that are in use or under development and identify their stormwater-related data needs. There are different types of models that:

- Model problems and mechanisms;
- Extrapolate results from small scale studies to regional effects; and
- Infer or estimate the benefits associated with different management actions.

The goal is to connect stormwater-related monitoring to the models that support actions to restore watershed health, but the specifics of all the possible connections is outside the scope of this strategy.

A process is needed to determine what data would support those efforts. What priorities have been identified by the Puget Sound Science Panel, Ecosystem Coordination Board, and Leadership Council? What focus do we need for stormwater management? How can we cross boundaries to see where our efforts inform other activities? Specifically, our objectives are to:

  - Identify relevant regional efforts that are underway to predict the outcomes of various land-use or other stormwater management scenarios,

- Work with modeling experts to identify specific stormwater-related data needs for models, and
- Incorporate a modeling-specific data collection plan into the strategy.

8.10 Ancillary Data

Many additional types of data are useful and necessary to understand stormwater impacts and effectiveness of management activities in Puget Sound. An extensive body of knowledge is available for us to build upon, and this provides another area for literature review. Some examples include:

- Land use and land cover data and other watershed characterization metrics. To allow for the extrapolation of information to unmonitored areas and at different scales, it is necessary to have land use and land cover data for the region, particularly for impervious surfaces. We recommend a standardized means to routinely update and verify this information across the Puget Sound region and utilizing it to provide a screening and guiding mechanism for targeting and refining our monitoring efforts.
- Climate data. Many different state and federal agencies, local jurisdictions, tribes, individuals, and businesses operate climate modeling systems throughout the Puget Sound region. Some of these systems have been in operation continuously for many decades, while others are recently installed. To allow for coordinated analysis of stormwater impacts, an agreed-upon set of climate data is important.
- Stormwater infrastructure mapping: The region's stormwater infrastructure has been built over the past decades with varying understanding and consideration of stormwater impacts, and even more variation in requirements to address these impacts. Current NPDES municipal stormwater permittees are mapping their storm sewer systems, an invaluable tool for source identification and diagnostic monitoring. Widespread cataloging of structural treatment practices could be immensely helpful for effectiveness studies.
- Transportation corridor information. Numerous metrics are available including but not limited to stream crossings, vehicle miles traveled, and average daily trips. We need to continue discussing which of these are most helpful to our understanding of how management actions prevent and reduce impacts.

SWAMPPS will identify what descriptive ancillary data about watershed conditions are required to help explain monitoring results. These details need to be articulated in each experimental design as QAPPs are developed. National GIS standards should be applied throughout the region.

8.11 Other Assessment Activities

In addition to, or to follow up on, analyses described in previous chapters, standardized approaches for analyzing the data collected for this strategy need to be proposed in sufficient detail that sufficient resources are reserved for these analyses to be performed and the results communicated to stormwater managers and other key decision makers in a timely fashion.

8.12 Gaps in this Strategy

Compliance monitoring and tracking actions: Specific needs for compliance and implementation information should be identified in the course of developing more detailed study designs, but this issue was not addressed directly. The SWG sees this as a future work plan item.

Global pollutant levels: Global pollutant loading impacts impacts the goals and activities of the SWAMPPS, and this strategy needs to tie into a bigger picture addressing this issue over the long term. Air deposition may be addressed in source identification and diagnostic monitoring.

Climate change: Climate change is a priority for the overall framework but not included in the initial prioritization and focus. We recognize that climate change impacts the goals and activities of SWAMPPS, and this strategy needs to tie into a bigger picture addressing this issue over the long term.

8.13 Placeholder Cost Estimates

Long-term, sustainable funding sources for SWAMPPS will be identified and secured over time. The SWG is currently working to refine cost estimates and propose realistic funding mechanisms for Ecology and the Partnership to implement and advocate in the couple of years.

Funding and/or in-kind services should be contributed by all of the regional entities participating in SWAMPPS. Entities conducting the regional monitoring and assessment component activities should partner to share resources and reduce costs.

The SWG understands the need for all interested parties to know:

- What the complete proposed SWAMPPS “package” looks like, and how much will it cost.
- What are the funding sources and what is needed to maintain those sources over the long term to make the program sustainable.

Previous chapters included preliminary, planning-level cost estimates for implementing the Status and Trends, Source Identification and Diagnostic Monitoring, and Effectiveness Studies components of SWAMPPS. Planning-level costs for Regional Program Implementation were estimated for science and assessment components, and for administration and management. The annual average science and assessment component costs were estimated to be about $1.7 million. The annual average administration and management costs were estimated to be about $0.55 million.

Our current cost estimates are provided in Table 4. This table is presented as a starting point for discussion and refinement of the total program costs and cost-sharing arrangements. The annual average total SWAMPPS cost, including the implementing all three monitoring categories and the regional program, is estimated to be about $14.9 million.

For comparison: current annual Phase I monitoring expenditures in Puget Sound total more than $6M; and at least $1.7 million is being spent annually on existing status and trends monitoring included in the proposed strategy. A large portion of the current Phase I investment is anticipated to be redirected to SWAMPPS; and another 80 smaller Phase II jurisdictions are expected to participate.

Table 4. Preliminary cost estimates for SWAMPPS. Dollar amounts are rounded so sums may not equal.

Category of Activity	1-Year Cost	# years in 5 years	Annual Average Cost	5-Year Cost
Status and Trends Monitoring	$4,800,000		$2,900,000	$14,400,000
Puget Sound-wide wadeable streams (existing)				
quarterly for two out of five years water quality index monitoring at 30 sites	$100,000	2	$40,000	$200,000
twice-per-five-year sediment chemistry monitoring at 30 sites	$71,000	2	$28,000	$142,000
twice-per-five-year stream benthos monitoring at 30 sites	$46,000	2	$18,000	$92,000
twice-per-five-year stream habitat monitoring at 30 sites	TBD	TBD	TBD	TBD
twice-per-five-year fish community monitoring at 30 sites	TBD	TBD	TBD	TBD
WRIA-scale wadeable streams (new)				
quarterly for two years water quality index monitoring at 390 sites	$1,000,000	2	$400,000	$2,000,000
twice-per-five-year sediment chemistry monitoring at 390 sites	$650,000	2	$260,000	$1,300,000
twice per five year stream benthos monitoring at 390 sites	$370,000	2	$150,000	$740,000
twice per five year stream habitat monitoring at 390 sites	TBD	TBD	TBD	TBD
twice per five years fish community monitoring at 390 sites	TBD	TBD	TBD	TBD
USGS flow gaging network (existing)				
Wadeable stream flow/temperature gaging (assume 13 existing gages)	$210,000	5	$220,000	$1,100,000
Wadeable stream periphyton pilot study (new)	$40,000	1	$8,000	$40,000
Marine nearshore existing Mussel Watch (existing)	$72,000	5	$72,000	$360,000
Marine nearshore stormwater Mussel Watch (new)	$72,000	5	$72,000	$360,000
Marine nearshore ambient sediments (PSAMP) (existing)	$210,000	5	$220,000	$1,100,000
Marine nearshore ambient sediments (Urban Bays) (existing)	$200,000	5	$200,000	$1,000,000
Marine nearshore stormwater outfall sediments (new)	$300,000	5	$300,000	$1,500,000
Marine nearshore recreational beaches water column *Enterococcus* (existing)	$350,000	5	$36,000	$180,000
Marine nearshore shellfish bed water column fecal coliform (existing)	$580,000	5	$580,000	$2,900,000
Marine nearshore stormwater outfall fecal coliform (new)	$470,000	5	$280,000	$1,400,000
Source Identification and Diagnostic Monitoring	$2,800,000		$2,800,000	$14,000,000
Stream bacteria (assume 13 streams per year, 20 sites per stream)	$890,000	5	$900,000	$4,500,000
Urban bay sediment chemical recontamination (assume 5 bays, 20 sites each)	$810,000	5	$820,000	$4,100,000
Nearshore bacteria (assume 13 nearshore reaches, 20 sites per reach)	$1,100,000	5	$1,100,000	$5,500,000
Prespawn mortality source identification study	TBD	TBD	TBD	TBD
Superfund source identification monitoring	TBD	TBD	TBD	TBD
TMDL monitoring	TBD	TBD	TBD	TBD
Effectiveness Studies	$6,900,000		$6,900,000	$33,000,000
Administer TAP-E and test new BMPs*	TBD	TBD	TBD	TBD
Administer Effectiveness Study Grant Program	$200,000	5	$200,000	$1,000,000
Funds for BMP/Programmatic Effectiveness Studies	$6,000,000	5	$6,000,000	$30,000,000
Agriculture BMP Effectiveness Study	$650,000	3	$400,000	$2,000,000
Regional Program Components	$1,700,000		$1,700,000	$8,500,000
Oversight of data collection: SOPs (assume 4 SOPs per year, 1/3 FTE per SOP)	$200,000	5	$200,000	$1,000,000
Oversight of data collection: QA/QC (assume 3 FTE)	$450,000	5	$450,000	$2,250,000
Data management (assume 3 FTEs)	$450,000	5	$450,000	$2,250,000
GIS, mapping, other ancillary data (assume 2 FTEs)	$300,000	5	$300,000	$1,500,000
Roll-up synthesis (assume 1 FTE)	$150,000	5	$150,000	$750,000
Cross-topic analysis (assume 1 FTE)	$150,000	5	$150,000	$750,000
Regional Program Management	$550,000		$550,000	$2,800,000
Overhead	$50,000	5	$50,000	$250,000
Pay-in option project manager (assume 1 FTE)	$150,000	5	$150,000	$750,000
Pay-in option financial and administrative support (assume 4 months)	$50,000	5	$50,000	$250,000
Pay-in option legal support (assume 4 months)	$50,000	5	$50,000	$250,000
SWG support (assume 1 FTE + consultant costs)	$250,000	5	$250,000	$1,300,000
Total Estimated Cost			**$14,900,000**	**$72,700,000**

**Note: STRC business plan due in December 2010*

The SWG will deliver revised and prioritized cost estimates to the Partnership and Ecology in a separate report in fall 2010. That report will include more detail about the context, assumptions, and caveats of those numbers, and a quantification of the proposed additional investment in regional stormwater-related monitoring as compared with continuation and redirection of current expenditures. It will also detail both start-up costs and ongoing program implementation costs.

8.13.1 Allocation of Costs

The total recommended level of effort for SWAMPPS will be more clearly defined in future work. Costs need to be allocated among federal, state, and local governments and among local jurisdictions. State and federal agencies and NPDES municipal stormwater permittees (local governments, ports, and the Washington State Department of Transportation) will play a substantial role in funding and implementing regional stormwater monitoring.

The final cost-share for local jurisdictions will be formally established as part of the process of issuing the revised NPDES municipal stormwater permits. In order to be included in the permits, an administrative means to collect and manage cost-share contributions (the "pay-in option" described in section 8.3.1) needs to be decided upon and established before the end of October 2010. Ecology is expected to issue a draft permit in spring 2011 for a formal public comment period.

The mandated cost to, or level of effort contributed by, each local jurisdiction covered under the NPDES municipal stormwater permits should be based on equitable factors. Other NPDES municipal stormwater permittees should contribute equitably to SWAMPPS. The SWG will recommend an appropriate NPDES municipal stormwater permittee cost-share to Ecology. The SWG has not yet agreed upon a recommended methodology for allocating costs among NPDES municipal stormwater permittees as part of 2012-2017 and future Phase I and Phase II permit monitoring requirements. Annual costs may be estimated using a population-based approach.

A non-population-based approach should be used to develop cost estimates for the Washington State Dept. of Transportation and the Ports of Seattle and Tacoma. The SWG has not yet developed placeholder cost estimates for these NPDES Phase I municipal stormwater permittees.

8.14 Summary of Roles and Responsibilities to Implement SWAMPPS

A number of roles and responsibilities are proposed in previous chapters, sections, and in the Key Recommendations. Below is a summary of the roles and responsibilities currently envisioned by the SWG. These roles and responsibilities are expected to evolve as SWAMPPS is implemented. In particular, we expect the role of the private sector to expand as other NPDES stormwater permit monitoring requirements are evaluated in the future and tied into this strategy.

8.14.1 Government Agencies

Federal Agencies

- Continue key programs and strategically expand federal monitoring and assessment activities.

- Advocate for the federal funding share of funding for SWAMPPS.

State Agencies

- Continue recommended stormwater-related programs and strategic expansions of state monitoring and assessment activities to support SWAMPPS.
- Partnership:
  - Determine how the SWG fits into the larger Puget Sound Ecosystem Monitoring Program.
  - Advocate for both the state and federal shares of funding for SWAMPPS.
  - Coordinate with Ecology, WDFW, WDOH, the Washington Forum on Monitoring, and others on the development of a central data management system (portal)
- Partnership and Ecology: approve future SWG work plans.
- Ecology: issue NPDES permits with monitoring requirements that support establishing and implementing SWAMPPS.

NPDES Municipal Stormwater Permittees

- Participate in SWAMPPS status and trends monitoring and effectiveness studies via pay-in, contracting, and/or conducting monitoring.
- Work with Ecology and others on source identification and diagnostic monitoring efforts.

Tribes

- Participate in regional program via funds, in-kind contributions, or by conducting monitoring.
- Participate in process to identify, develop, and refine study designs.

8.14.2 Private/Non-profit/Academic/Other

- Participate in regional program via funds, in-kind contributions, or by conducting monitoring.
- Participate in process to identify, develop, and refine study designs.

8.14.3 Programs

Proposed Administrative Entity (see section 8.3)

- Establish dedicated fund for stormwater monitoring and assessment activities for entities collectively contributing to cost-share.
- Administer a pay-in option for NPDES permittees.

- Oversee contracts and other administrative means to conduct monitoring (pay-outs from the dedicated fund).

Uncertain or Transitional

These roles and responsibilities may fall to the new independent stormwater assessment and monitoring entity or to the Puget Sound Coordinated Ecosystem Monitoring and Assessment Program, depending on the scopes of work identified in the coming months.

- Develop Standard Operating Procedures and Quality Assurance Project Plans.
- Coordinate/conduct literature reviews.
- Oversee data collection, reporting, and Quality Analysis/Quality Control.
- Oversee synthesis and analysis of regional stormwater data.

Puget Sound Coordinated Ecosystem Monitoring and Assessment Program

- Set priorities for regional ecosystem monitoring and assessment.
- Provide guidance to topical work groups, including the SWG.
- Oversee cross-topic synthesis and analysis.
- House and maintain inventory of monitoring and assessment activities.
- House and maintain data management system.

Stormwater Work Group

- Develop more detailed recommendations for dedicated sustainable funding mechanism, including an independently managed pay-in fund for NPDES municipal permittees.
- Coordinate with Partnership and others to seek funding beyond pay-in program.
- Direct the independent stormwater monitoring and assessment coordination entity.
- Continue to set priorities and make recommendations for SWAMPPS components.
- Coordinate stormwater monitoring and assessment activities.
- Coordinate with other topical work groups under the ecosystem monitoring and assessment program umbrella and participate in the technical committee.
- Identify stormwater-related modeling needs.
- Advise policy makers.

Guide to Appendices

The appendices to this strategy, published separately, provide additional detailed information about: the stakeholder process, our connections to other efforts, adaptive management structure, assessment questions, hypotheses, and experimental designs. Here is a brief description of the contents of each appendix.

Appendix A. The Process to Develop a Regional Stormwater Monitoring and Assessment Strategy

The SWG was launched as a project of the Puget Sound Monitoring Consortium. The SWG includes 26 representatives of 7 caucus groups. We have a charter, bylaws, and work plan. We have sponsored workshops and are developing products to foster an integrated, strategic approach to monitoring and assessing stormwater.

Part of our charge is to act as a pilot model effort for creating the Puget Sound Coordinated Ecosystem Monitoring and Assessment Program. We will recommend to Ecology monitoring components for NPDES municipal stormwater permits that are more relevant to regional needs. This is the most recent effort to develop an integrated approach to surface water management and builds on a long history of efforts.

Appendix B. Applying Lessons Learned from Adaptive Management at a Regional Scale

Many resource managers have recognized the need to integrate resource management and monitoring at a regional scale. A brief description and lessons learned from these efforts provide guidance for creating a regional stormwater monitoring and assessment program in Puget Sound.

Appendix C. Assessment Questions to Guide Regional Stormwater Monitoring

Starting with the request from the Partnership and Ecology, stakeholder workshops were convened to develop specific assessment questions that need to be answered for Puget Sound stormwater management. Under broad headings, we developed specific questions that were vetted by stakeholders, scientists, and managers.

Appendix D. Status and Trends Monitoring Design

This appendix presents example description of probabilistic monitoring designs for small streams and nearshore areas. Included are descriptions of site selection methods, potential indicators, methods, and the sampling schedule.

Appendix E. Source Identification and Diagnostic Monitoring Design

This appendix presents a more complete description of the framework for prioritizing and conducting source identification and diagnostic monitoring. The framework represents a method of linking the status and trend monitoring and source control activities.

Appendix F. Selecting and Developing Designs for Effectiveness Studies

Additional guidance for developing study designs is given. The assessment questions presented in Appendix C related to effectiveness of stormwater management are refined and prioritized into an initial suite of questions to address. Example cost estimates for a range of possible effectiveness studies are presented to allow for estimating level of effort for an effectiveness monitoring program.

Appendix G. Data Collection and Data Management

A more detailed description of the variety of issues that need to be considered to ensure quality and comparable monitoring information.

Appendix H. Response to Formal Peer Review and Public Comments on November 2009 Draft Scientific Framework

We commissioned five formal peer review reports on the November 2009 Draft Scientific Framework, and also received over 800 public comments. We substantively modified our scientific framework in response to this feedback. This appendix presents a summary of the comments and feedback received, with discussion of the approach we used to address the input.

Appendix I. Issues that Remain to be Addressed

This appendix presents a summary of the comments and feedback received on the April 30, 2010 draft strategy. The SWG will address these issues in future work.

Definitions and Acronyms

Adaptive management: an approach to directly and iteratively inform policy-making and decisions about resource management with scientific data. Management activities are treated as experimental components within the larger structure of a monitoring program. Specific management decisions that affect ecological processes and functions are systematically evaluated in ways that affirm or refute expected outcomes. Uncertainty is embraced and serves as a focal point for more specific evaluations. See Appendix B for further discussion.

Beneficial use: means uses of waters of the state, which include but are not limited to: use for domestic, stock watering, industrial, commercial, agricultural, irrigation, mining, fish and wildlife maintenance and enhancement, recreation, generation of electric power and preservation of environmental and aesthetic values, and all other uses compatible with the enjoyment of the public waters of the state.

Characterization: measuring variation in relevant indicators across the landscape and through time.

DQOs: Data Quality Objectives.

EMAP: Environmental Monitoring and Assessment Program.

Homogeneous: denotes basins or sub-basins of the same land use. In reality, nearly all basins and sub-basins in the Puget Sound region are of mixed land use. Previous projects have used a threshold of 60% to 80% of the land area categorized of a single land use type (including the road network serving the developed or converted area) for a sub-basin to serve as an indicator of that land use.

IBI: Index of Biotic Integrity.

Nearshore areas: from the Puget Sound Nearshore Ecosystem Restoration Project website (http://www.pugetsoundnearshore.org/what.htm), "The Puget Sound nearshore is defined as that area of marine and estuarine shoreline extending approximately 2,500 miles from the Canadian border, throughout Puget Sound and out the Strait of Juan de Fuca to Neah Bay. It generally extends from the top of shoreline bluffs to the depth offshore where light penetrating the Sound's water falls below a level supporting plant growth, and upstream in estuaries to the head of tidal influence. It includes bluffs, beaches, mudflats, kelp and eelgrass beds, salt marshes, gravel spits, and estuaries." This strategy envisions sampling sediment and shellfish between sea level and minus 20 feet elevation.

NPDES: National Pollution Discharge Elimination System; the primary permitting system used to implement the Clean Water Act.

Outfall: the discharge point where a stormwater conveyance (pipe, ditch, *etc.*) meets a receiving water body (*i.e.*, stream, river, lake, wetland, or nearshore area).

PSAMP: Puget Sound Assessment and Monitoring Program.

QAPP: Quality Assurance Project Plan.

QA/QC: Quality Assurance/Quality Control.

SOPs: Standard Operating Procedures for field and laboratory methods and protocols for data collection, reporting, and analysis.

Small streams: wadeable, 2-3 order streams; also called "creeks" in this strategy.

Stormwater: from NRC 2009, "That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels, or pipes into a defined surface water channel or a constructed infiltration facility. According to 40 C.F.R. § 122.26(b)(13), this includes stormwater runoff, snow melt runoff, and surface runoff and drainage." Mostly this includes water that flows over the ground surface and is subsequently collected by natural channels or artificial conveyance systems, but it can also include water that has infiltrated into the ground but nonetheless reaches a stream channel relatively rapidly and that contributes to the increased stream discharge that commonly accompanies almost any rainfall event in a human-disturbed watershed.

SWAMPPS: Stormwater Assessment and Monitoring Program for Puget Sound.

SWG: (Puget Sound) Stormwater Work Group. One of 3-5 initial work groups envisioned to prioritize topical science needs and coordinate monitoring and assessment efforts for the broader ecosystem monitoring program. See Appendix A for further discussion.

WRIA: Water Resource Inventory Area.

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2010 Stormwater Monitoring and Assessment Strategy for the Puget Sound Region: Appendices

June 30, 2010

Contents

Appendix A The Process and Steps to Develop a Regional Stormwater Monitoring and Assessment Strategy

Running steadily in the background behind the visible production of documents and the articulation of goals are the meetings and discussions and experiences of the people involved. The ultimate success of a regional monitoring and assessment program depends on cooperation of individuals and the agencies and groups they represent; therefore, we have tried to organize, involve and engage people in a way that is as inclusive and transparent as possible.

The risk associated with creating a regional stormwater monitoring and assessment program is that the complexity of the effort can overwhelm its purpose. Our efforts to date provide an example: because a large number of professionals and stakeholders participated in workshops designed to identify the most important questions that a regional monitoring program should address, the process generated more questions about stormwater than we can answer in a reasonable time. Similarly, the list of actions proposed to reduce stormwater impacts is also long. Prioritizing which hypotheses to test and which actions to take is very difficult in the absence of more complete information; but if we wait until we know everything, or even 'enough', no action will ever be accomplished. In our case, the potential complexity associated with testing for what we don't know threatens to distract us from our purpose, which is to reduce the effects of stormwater.

The remainder of this appendix provides the interested reader a history of the Puget Sound Stormwater Work Group (SWG), an overview of the ways we have worked to engage the tremendous assets of the region in solving our problem, and a description of our relationship and connections to other key efforts to restore Puget Sound.

A.1 Creating the Stormwater Work Group

In 2006, a group of interested parties were brought together by the Washington Department of Ecology (Ecology) to consider development of a coordinated regional monitoring program for the Puget Sound region. This group evolved into the Puget Sound Monitoring Consortium (Consortium), funded by the Washington State Legislature. Information about the Consortium, including its reports, can be found at http://www.ecy.wa.gov/programs/wq/psmonitoring/index.html.

The Consortium developed a set of recommendations for organizing and establishing a coordinated ecosystem recovery monitoring program for Puget Sound. The Consortium proposed a *Puget Sound Coordinated Regional Monitoring and Assessment Program* with authority to assure funding; ensure high-quality science, including adequate study design, QA/QC, and peer review; track projects; develop and maintain databases; conduct cross-topic synthesis and analysis; and more. The Consortium's proposal was taken on by PSP, which is in the early stages of implementing the first recommendations and establishing an ecosystem monitoring program to coordinate and manage this effort and connect it to other topic-driven monitoring coordination and prioritization efforts.

The structure the Consortium recommended provided an umbrella for topical work groups that provide a forum for key stakeholders to determine monitoring and assessment needs by geography or issue and to oversee collection of the data that help improve our understanding of the ecosystem. The Consortium anticipated work groups comprised of members involved in monitoring and assessment activities. Some work groups already existed in other forms but a work group for stormwater was identified as a priority need. At the request of the Puget Sound Science Panel, the executive director of the Puget Sound Partnership, and the director of Ecology, the Consortium oversaw the establishment and launching of the SWG.

In addition to launching the SWG, the Consortium launched pilot projects to meet pressing needs for coordination and improved credibility of the monitoring data that is routinely collected in the Puget Sound region, including: developing standard operating procedures for automated sampling of stormwater and subsequent analysis of the data; standardizing reporting methods and expand a database for stream benthos information that can be populated by all entities in Puget Sound that collect this information; and conducting an inter-laboratory calibration exercise. The SWG is building upon these efforts, and the lessons learned in conducting the pilot projects, in developing a monitoring and assessment strategy for Puget Sound.

The Consortium committees' recommendations (Surface Water and Aquatic Habitat Monitoring Advisory Committee 2007 and Puget Sound Monitoring Consortium 2008) are reflected in SWG mandates: transparency of the process, inclusivity of discussions and decision-making, specific focus on improving stormwater management to protect and restore designated uses, making an explicit connection to Clean Water Act NPDES permit monitoring requirements for municipal stormwater, clear connection to and coordination with other efforts, effective use of resources, meaningful and credible data and analyses produced and used by decision-makers.

The SWG is now a formal effort that has the support of the Partnership, Ecology, and others. A draft charter, bylaws, and caucus-based system of representation on an oversight committee were formally adopted in December 2008. An initial work plan was adopted in January 2009 and formally amended in April 2009; and numerous amendments and adjustments have been agreed upon at SWG meetings since then but not yet reflected in the formal work plan due to competing priorities for staff time. These living, founding documents and all SWG meeting agendas and summaries are available at http://www.ecy.wa.gov/programs/wq/psmonitoring/swworkgroup.html. Interim working documents, supporting information, and agendas for the SWG's working subcommittees are posted at http://sites.google.com/site/pugetsoundstormwaterworkgroup/.

The SWG is working to address the following specific agency needs:

- For Ecology:
    - Define efficient and effective monitoring protocols and priorities to inform permits;
    - Serve as a part of a bigger effort to better articulate and quantify the region's stormwater funding needs, particularly for local governments, including ongoing maintenance and operational practices, new capital facilities, strategic retrofit,

technical assistance, pollution prevention source control and safer alternatives, and education and outreach programs, and other ways; and
    - In the future, continue to develop a water quality monitoring program that leverages the participation of governments and the private sector to inform adaptive management actions.

- For the Partnership:
    - Define efficient and effective monitoring protocols to inform ecosystem monitoring program;
    - Implement Action Agenda NTA C.2.N1 Create a regional stormwater monitoring program;
    - Inform the effort to establish credible benchmarks and threat reduction objectives to inform the Puget Sound Action Agenda; and
    - Provide a resource-based measure of whether the suite of best practices for stormwater management that are intended to address high priority pollutants (*e.g.*, low impact development, treatment systems, pollution prevention and safer alternatives, *etc.*) are successful in reducing loadings.

- For both agencies:
    - Identify steps to implement information technology to support the storage, management, and sharing of this monitoring data and findings.

The SWG is formally comprised of 22 representatives of business, environmental, agriculture, tribal, local, state, and federal government agency caucuses. The members are listed on the reverse side of the cover page of this document. All SWG members accept responsibility for communicating with their caucuses about the progress and upcoming decisions to be made by the SWG. Each meeting agenda provides time for other parties in attendance to comment on decisions that are on the table. The SWG's efforts since October 2008 have been focused on the development of the draft *Stormwater Monitoring and Assessment Strategy for the Puget Sound Region*.

A.2 Steps to Achieve our Goals

- **Creation and vetting of Assessment Questions (Appendix C) by experts and stakeholders.**
    - <u>February 17-19, 2009 technical expert workshops</u>. Participants: Allison Butcher (Master Builders Association of King and Snohomish Counties); David Batts (King Co.); Jill Brandenberger (PNNL); Scott Collyard (Wash. Dept. of Ecology); Ken Currens (NWIFC, for Puget Sound Partnership); Tim Determan (Wash. Dept. of Health); Karen Dinicola (Ecology); Jeff Fisher (Environ, for NMFS/NOAA); Mindy Fohn (Kitsap Co.); Jonathan Frodge (Seattle); Thom Hooper (NOAA Fisheries); Doug Hutchinson (Seattle); Bob Johnston (U.S. Navy); Heather Kibbey (Everett); DeeAnn Kirkpatrick (NOAA Fisheries); Andrea LaTier (U.S. Fish and Wildlife Service); Joan Lee (Parametrix); Jim Maroncelli (Wash. Dept. of Ecology); Doug Navetski (King Co.); Char Naylor (Puyallup Tribe); Dale Norton (Wash. Dept. of Ecology); Ed O'Brien (Wash. Dept. of Ecology); Kit Paulsen (Bellevue); Tom Putnam (Puget Soundkeeper Alliance); Randy Shuman (King Co.); Jim Simmonds (King Co.); Carol Smith (Wash. State Conservation

Commission); Tom Sibley (NMFS); Heather Trim (People For Puget Sound); Gary Turney (USGS); Dean Wilson (King Co.); and Bruce Wulkan (Puget Sound Partnership).

- May 19, 2009 public workshop. About 170 people participated; the workshop facilitator produced a summary of the feedback provided. The report is posted at http://www.ecy.wa.gov/programs/wq/psmonitoring/ps_monitoring_docs/SWworkgroupDOCS/SWGWorkshopFinalReport.pdf.

- **June 11 and 16, 2009 "Sprint" workshops of technical experts to translate assessment questions into hypotheses.** (Appendix D, also see link to the document at http://www.ecy.wa.gov/programs/wq/psmonitoring/swworkgroup.html.) Participants: Howard Bailey, Nautilus; Abby Barnes, Kennedy/Jenks; David Batts, King County; Derek Booth, Stillwater Sciences; Jill Brandenberger, PNNL; Scott Collyard, Ecology EAP; Cat Curran, Nautilus; Jay Davis, U.S. Fish & Wildlife Service; Curtis DeGasperi, King County; Dana de Leon, City of Tacoma; Tim Determan, WA Dept of Health; Damon Diessner, ESAction; Karen Dinicola, Ecology; Mark Ewbank, Herrera; Jeff Fisher, Environ; Mindy Fohn, Kitsap County; Leska Fore, Statistical Design; George Fowler, Independent Consultant; Jonathan Frodge, City of Seattle; Dick Gersib, WA Dept of Transportation; Eric Greenwald, The Boeing Company; Julie Hampden, Herrera; Curtis Hinman, WA State University; Heather Kibbey, City of Everett; Joan Lee, Parametrix; John Lenth, Herrera; Julie Lowe, Ecology WQP; Tetyana Lysak, The Boeing Company; Curtis Nickerson, Taylor & Associates; Dale Norton, Ecology EAP; Mel Oleson, The Boeing Company; Kit Paulsen, City of Bellevue; Rob Plotnikoff, TetraTech; Steve Ralph, Stillwater Sciences; Scott Redman, Puget Sound Partnership; Rich Sheibley, U.S. Geological Survey; Jim Simmonds, King County; Glen Sims, Puget Soundkeeper Alliance; Bill Taylor, Taylor & Associates; Scott Tobiason, Brown & Caldwell; Heather Trim, People for Puget Sound; Gary Turney, U.S. Geological Survey; Dean Wilson, King County; and Bruce Wulkan, Puget Sound Partnership.
- **Small team identified to develop draft scientific framework document:** Derek Booth, Stillwater Sciences; Karen Dinicola, Ecology; John Lenth, Herrera; and Jim Simmonds, King County
- **Oversight and direction of writing team by subgroup:** Scott Collyard, WA Dept. of Ecology; Jay Davis, U.S. Fish and Wildlife Service; Dana de Leon, City of Tacoma; Tim Determan, WA Dept. of Health; George Fowler, Independent Consultant; Dick Gersib, WA Dept. of Transportation; Jonathan Frodge, City of Seattle; Heather Kibbey, City of Everett; Julie Lowe, WA Dept. of Ecology; Dale Norton, WA Dept. of Ecology; Kit Paulsen, City of Bellevue; Gary Turney, U.S. Geological Survey; Bruce Wulkan, Puget Sound Partnership
- **Dynamic process of integration:** Oscillation from the small to the large; dynamic tension between structure and initiative; dynamic tension between process and content
    - This document provides the recommended starting point and approach to achieving a comprehensive regional understanding of the impacts of stormwater and the effectiveness of our management actions to prevent, reduce, or mitigate those impacts.
    - We anchor the strategy in adaptive management structure to support and evaluate alternative actions with scientific monitoring and hypothesis testing.
    - We still need to refine indicators, targets, and benchmarks as we better understand the relationships among ecosystem components and the impacts of stormwater on the Sound. Part of this process requires identifying any new indicators and

developing indicator indices. Selection of the final set of indicators will be based on several factors, such as data availability, how well the set captures the full range of ecosystem functions impacted by stormwater, and the costs of monitoring and analysis.

- **Peer review and stakeholder comments on draft scientific framework document:** Five formal peer reviewer reports from Rich Horner, Bob Pitt, Tom Schueler, Jean Spooner, Steve Weisberg) and more than 800 stakeholder comments from 22 agencies and individuals, and more than 100 participants at the November 10, 2009 public workshop.
- **Entire work group discussion of major themes in comments:** December 2009 through April 2010 work group decided how to change the scientific framework in response to the input received. Subgroups were formed to develop new sections and to tie the scientific framework to the implementation plan. Subcommittees of work group work to revise chapters on status and trends, source identification, effectiveness, and regional program implementation.
- **Stakeholder review by outside experts and stakeholders**
    - Review of strategy by stakeholders at public workshop on May 19, 2010.
    - Public comment period continues through May 28, 2010.
- **Final strategy completed June 2010.**
    - Includes broadly approved priority starting point for a regional monitoring program as well as specific next steps to launch the program, including mechanics of monitoring (*i.e.*, SOPs and data management requirements) and effective use of the region's collective capacity and resources to collect and analyze data:
        - Commitment of agencies and individuals to implement the strategy,
        - Better understanding of the roles of individuals and agencies,
        - Better understanding of the relationships between individuals and agencies.

A.3 Example of a Detailed Conceptual Model of Stormwater Impacts

The integrated success of various efforts to avoid impacts to water features can only be determined by evaluating the condition of integrating attributes, best evidenced by biological responses or endpoints. Other such integrators relating to human health and well-being have been suggested in the course of developing the *Action Agenda*, the Partnership's plan for recovering the Puget Sound ecosystem by 2020 (Partnership 2008); they occupy the same conceptual position in this strategy.

Within the broad conceptual model described in section 4.2 in the strategy (see Figure 2), each element can be further deconstructed. Figure A.1 shows an example of a more specific conceptual scientific model for comprehensively evaluating stormwater. We consider this to be a useful approach to inform our thinking and future development and refinement of monitoring

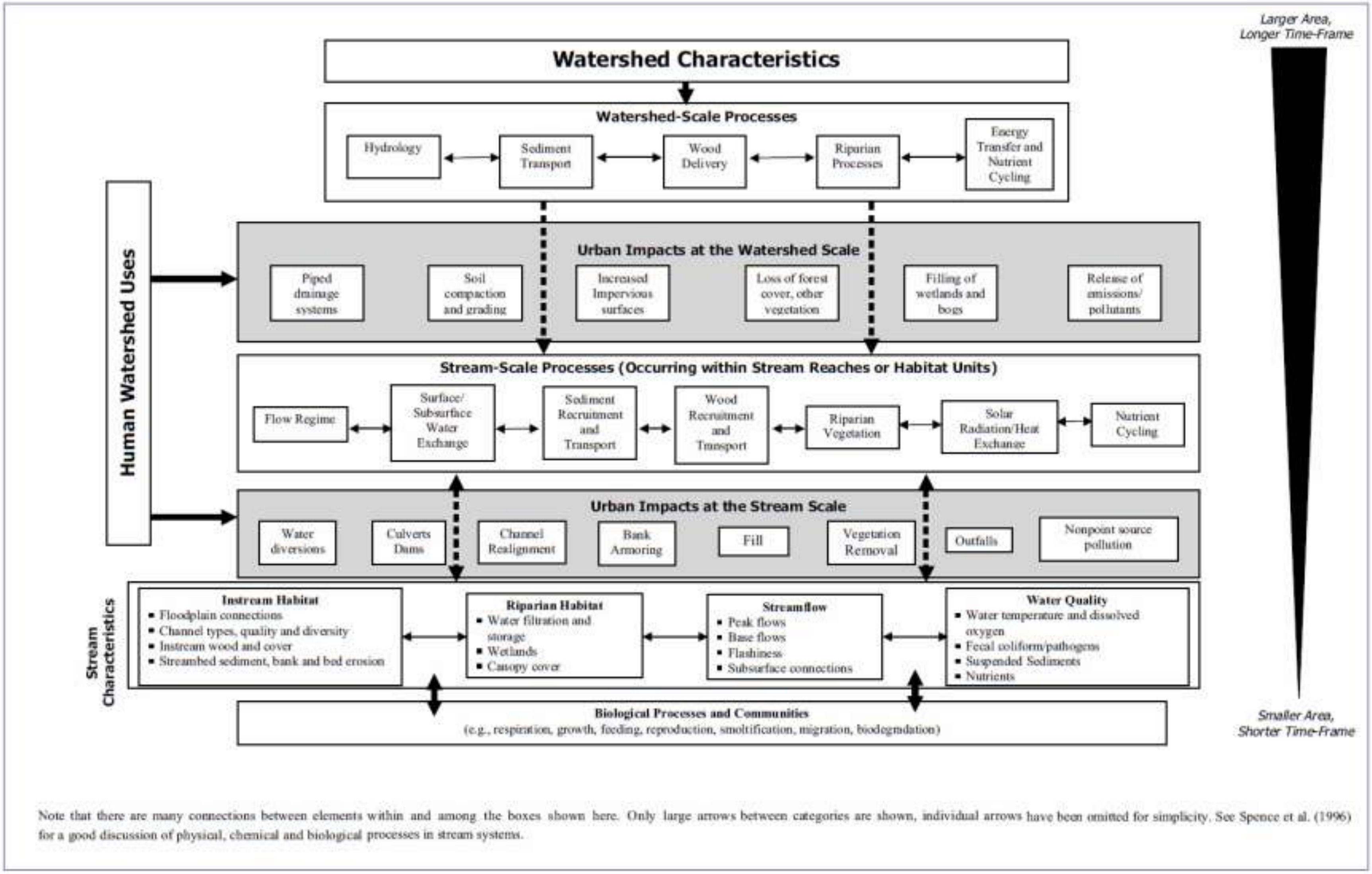

Figure A.1. Conceptual model of a stream ecosystem functioning in an urban environment (Seattle, 2007). The model includes many but not all areas targeted for investigation by the proposed regional stormwater monitoring and assessment strategy.

efforts. It provides a good starting point for guiding monitoring efforts to evaluate progress toward ecosystem recovery. A similar specific conceptual model for nearshore areas should be developed and utilized in guiding the monitoring efforts in that part of the ecosystem, putting the specific habitat and other features supporting the biological endpoints selected as indicators should in broader context.

A.4 Connections to Other Efforts

A.4.1 Puget Sound Partnership

The Puget Sound Partnership (PSP) is charged with overseeing the efforts to restore Puget Sound and is also accountable for measuring the progress made towards ecosystem recovery goals by implementing specific activities articulated in the "Puget Sound Action Agenda: Protecting and Restoring the Puget Sound Ecosystem by 2020" (PSP, 2008). The SWG's development of a regional approach for monitoring stormwater is listed as a Near Term Action in the *Action Agenda* among many other key stormwater management activities.

Continued collaboration with the many governments and interests in Puget Sound will be essential in implementing solutions and sustaining actions that support a healthy ecosystem while moving forward with a vibrant economy. The *Action Agenda* calls for large-scale regional approaches and the creation of consistent protection and restoration standards for the region; reducing pollutant inputs at the source; prioritizing and retrofitting existing stormwater management facilities (particularly in areas that were urbanized long ago); and ramping up low impact develop techniques in urbanizing areas. The *Action Agenda* also calls for the reform of environmental regulatory programs as well as improvements to the capacity of local partners to implement actions and compliance efforts across Puget Sound.

The *Action Agenda* states the need to establish priorities and resource needs for creating a coordinated water quality monitoring program under National Pollutant Discharge Elimination System (NPDES), and the need to coordinate with the overall regional monitoring program identified in the Action Agenda. Utilizing the NPDES permit structure will enable the development of a regional program that works synergistically with the multiple local stormwater monitoring efforts and address both the local stormwater impacts and develops a program to address the cumulative Puget Sound wide stormwater impacts.

A.4.2 Puget Sound Coordinated Ecosystem Monitoring and Assessment Program

As part of its mandate to oversee efforts to recover Puget Sound, PSP is establishing a coordinated ecosystem monitoring program to guide recovery efforts and provide feedback about progress toward recovery (see section A.1). The ecosystem monitoring program is envisioned to provide an umbrella under which multiple, topical monitoring efforts are overseen in three key ways: first, a science-policy interface is created and maintained whereby scientific knowledge can better inform key decisions and policies; second, efficiencies are gained by prioritizing and coordinating the work done by multiple entities operating under multiple mandates; and third, a better understanding of the complex ecosystem is achieved through cross-topic analysis and synthesis of information.

The Stormwater Work Group (SWG) is among the first work groups envisioned to be formally incorporated into this structure. The SWG is a test pilot model for setting priorities and developing a strategy to gather and analyze key data to solve the biggest problems facing the Puget Sound basin. Other Work Groups include but are not limited to:

- Chinook Recovery monitoring;
- the Puget Sound Assessment and Monitoring Program (PSAMP);
- Cooperative Monitoring Evaluation and Research (CMER); and
- the Toxics Loading Steering Committee that is coordinating ongoing efforts to fill gaps in knowledge and understanding of toxic pollutant sources, fate, and transport in the Puget Sound region.

All of these efforts are coordinated under the umbrella of the Puget Sound Action Agenda, populated with "Near Term Actions" to recover the Puget Sound Ecosystem.

A.4.3 The Clean Water Act and National Pollutant Discharge Elimination System Permit Monitoring Requirements

The primary objective of the Clean Water Act (CWA) is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. 1251, sec. 101). Reducing the impact of stormwater on receiving waters has been notoriously difficult because stormwater is produced everywhere that the landscape has been developed; stormwater is episodic and its impact on the natural hydrology is difficult to reduce; and stormwater accumulates and transports the toxins, waste, and sediment associated with developed lands (NRC, 2009). Under the CWA, are required to control urban and industrial stormwater through the National Pollutant Discharge Elimination System (NPDES) permit program (sec. 402) and effective BMPs to control nonpoint source pollution (sec. 208).

The Washington State Department of Ecology (Ecology) is delegated by the U.S. Environmental Protection Agency (EPA) to implement the CWA in Washington. Ecology requires monitoring as a condition of granting NPDES permits. In recent years, disagreements over permit monitoring requirements have motivated the permittees, the regulators, and other interested parties to work together to find a more efficient, meaningful and scientifically-based approach to monitoring. This strategy will include monitoring and assessment that can be used to formulate requirements in future stormwater permits.

Monitoring is a presumptive element of most CWA-permitted stormwater management programs. It can demonstrate compliance with regulations, identify sources and loadings of pollutants and characterize their effects on receiving waters, evaluate the effectiveness of stormwater control measures, and provide feedback to managers and the public about whether ecosystem improvements are occurring. As an example, the types of monitoring typically contained in NPDES Phase I municipal stormwater permits include:

(1) wet weather outfall screening and monitoring ("source identification"),

(2) dry weather outfall screening and monitoring ("illicit discharge detection and elimination" or IDDE),

(3) biological monitoring to determine stormwater impacts ("status and trends"),

(4) ambient water quality monitoring ("characterization"), and

(5) measuring the efficacy of stormwater control measures ("effectiveness") (NRC, 2009).

Industrial and construction stormwater general permits require sampling of discharges from outfalls but not monitoring of the quality of the receiving water. Other types of stormwater monitoring have existing statutory requirements and others are responding to very local or site-specific needs. Ideally, a monitoring and assessment strategy will provide guidance on how all prescribed and local efforts can contribute to an increased, data-supported understanding of how stormwater affects receiving waters and what are the most effective, or most promising, stormwater management approaches.

Recent Pollution Control Hearing Board rulings on the municipal stormwater permits issued in Puget Sound endorsed the SWG's process as a means of informing future permit monitoring requirements. This has provided additional incentive for permittees, environmental groups, regulators, and other interested parties to work collaboratively to create a solution.

Future efforts of the SWG may address specific NPDES stormwater general permits, specifically those for: construction sites, industrial activities, confined animal feeding operations, the WA State Dept. of Transportation, and others.

Appendix B Applying Lessons Learned from Adaptive Management at a Regional Scale

By Derek Booth, Ph.D., Stillwater Sciences

Land and water resource management agencies routinely make decisions that affect natural processes and ecological functions. Developing successful, large-scale management and restoration programs requires not only the identification of knowledge gaps but also a commitment to robust monitoring programs that are modeled on the concept and implementation of what is broadly termed "adaptive management."

It is not within the scope of this strategy to describe the institutional framework for the full adaptive management cycle: that task is assigned to the Partnership. In parallel with our development of this strategy, an adaptive management approach is being pursued by the Partnership to implement the *Action Agenda* to recover the Puget Sound ecosystem by 2020 (Partnership 2008). The Partnership's evolving framework can be informed by our Key Recommendations.

Nor is it within the scope of this strategy to define a comprehensive suite of stormwater monitoring actions. This strategy establishes an overarching scientific framework for stormwater-related monitoring that will allow otherwise independent efforts or whole programs to contribute to a greater understanding and evaluation of progress.

B.1 What is Adaptive Management, and How Does it Apply to our Problem?

Adaptive management, as first outlined by Holling (1978) and later revised, renamed, and recast by others (*e.g.*, Walters 1986; Lee 1999), is an approach for overcoming uncertain ecological outcomes associated with land-use and natural resource management actions by treating management activities as experimental components within the larger structure of a monitoring program (Ralph and Poole 2003). Specific management decisions that affect ecological processes and functions are systematically evaluated in ways that affirm or refute expected outcomes. Uncertainty is embraced and serves as a focal point for more specific evaluations. The process of adaptive implementation is iterative and continuous; new knowledge is actively incorporated into revised experiments, a practice best described as "learning while doing" (Lee 1999). The key difference between this approach and other environmental management strategies that are often implemented is the application of scientific principles, such as hypotheses-testing, to explicitly define the relationships between policy decisions and their measured ecological outcomes. Further, the adaptive implementation approach provides a means to understand and document these cause-and-effect relationships, as well as to evaluate alternative actions that may produce more desirable outcomes.

Scientifically credible and relevant information can only be generated when the monitoring "experiments" are designed with clear hypotheses about the effects of proposed management prescriptions. These hypotheses must be testable at multiple scales using available technology and methods (Conquest and Ralph 1998; Currens *et al*. 2000). Hypotheses that cannot be tested, or only account for site-specific conditions, are not useful in considerations of cumulative effects.

In order to retain clear linkages between key questions, hypotheses, and monitoring protocols, the experimental approach must be designed before determining which goals and targets are appropriate (Ralph and Poole 2003) since appropriate goals should be *outcomes* of the effort, not a precondition; and the approach must explicitly tie stated hypotheses to the key ecological questions. For example, in order to judge the relative capacity of rivers, lakes and marine waters to support "beneficial uses," existing state regulatory programs for water quality typically use a suite of evaluation criteria that provide specific thresholds above (or below) which it is assumed that the water quality is "unacceptable." In this case, there is a water quality indicator, and a target value to judge acceptability. In recent years, comprehensive monitoring programs are beginning to be developed to provide statistically valid designs to characterize water quality across state waters. New programs will be able to provide more clear insights into the ultimate and proximate causes when water-quality criteria are exceeded. Thus when the management objectives are stated, the underlying assumptions and hypotheses can be better articulated and more systematically tested.

Wagner (2006) asserts that [stormwater] regulatory programs in the past often failed because they were designed in ways that ignored technological and scientific limitations. "Science-based" does not simply mean the monitoring of status and trends followed by responding to imposed benchmarks and goals, but rather that scientific principles must be the foundation of regulatory program design, and that these programs must rely on scientific methods to demonstrate results. Wagner suggests that regulations can still be designed despite incomplete or developing knowledge, but that gaps and limitations must be acknowledged and used to inform ongoing investigations. His argument clearly echoes those of scientists who insist that monitoring experiments and testable hypotheses must frame management decisions and land-use objectives.

B.2 What are Some Pitfalls to Avoid?

In natural resource management, the following process traditionally dominates:

(1) a problem is identified, but not translated into a well-defined key question, and a cause is simultaneously assigned (*e.g.*, "increased sediment inputs into a stream are negatively impacting salmonid survival");

(2) a solution or set of solutions is proposed (*e.g.*, timber harvest is restricted and riparian buffer width is increased), but the prescription is not translated into a testable hypothesis associated with the problem or question;

(3) if the problem is not solved within an arbitrarily reasonable period of time (*e.g.*, a few years) then a different solution is proposed (*e.g.*, "augmented upland and riparian restoration must be implemented").

Although simplified, even this outline displays its divergence from adaptive management and from the basic principles of the scientific process, and the resulting process is perpetually reactive.

Recent efforts to build large, collaborative programs are commonly characterized by increasing stakeholder involvement, information sharing, outreach, and voluntary participation. These reflect the movement to extend natural resource management decision-making processes beyond just technical experts in order to reflect evolving social values (Pahl-Wostl *et al*. 2007). This shift implies "an adaptive co-management of social and ecological systems in which combines the dynamic learning of adaptive management with the linkage characteristics of cooperative management" (Berkes *et al*. 1998), but it does not require it. Greater participation does not necessarily mean that true adaptive management is occurring, or that scientific principals are being applied to either the choice of management actions or their evaluation. If successful, however, it also opens a path to achieving the best of both realms, namely scientific rigor with a broad base of community support. This document reflects such an effort.

B.3 Applying Lessons Learned from Previous Efforts

Numerous large-scale ecological monitoring efforts have been implemented around the nation, and they offer recommendations for the key elements of a successful program:

- Identifying clear and relevant goals.
- Setting measureable objectives.
- Using the best available science.
- Establishing an accountable organizational and funding structure that facilitates clear communication of stated objectives, methods, and results at all applicable levels.

Recent summaries of these "lessons learned" include the Puget Sound Nearshore Partnership's Application of the "Best Available Science" in Ecosystem Restoration: Lessons Learned from Large-Scale Restoration Project Efforts in the USA (Van Cleave *et al*. 2004)); the Surface Water and Aquatic Habitat Monitoring Advisory Committee's Report and Recommendations (2007); and PSAMP's Keys to a Successful Monitoring Program: Lessons Learned by the Puget Sound Assessment and Monitoring Program (2008). All of these syntheses echo the need for integrated monitoring programs and adaptive management mechanisms that provide not just a tracking of "success" or "failure," but insight into why objectives are or are not being met. The development of and the implementation of this stormwater monitoring and assessment strategy for the Puget Sound region attempt to apply the lessons articulated from comparable programs to frame a scientifically credible and useful approach based on the tenants of adaptive management and hypothesis-testing.

B.4 Large-scale Ecosystem Programs Around the Nation

Nationally and regionally, many systematic monitoring programs have been implemented over the past 1–2 decades. These programs vary in their adherence to the principals of adaptive management, and both their successes and their shortcomings provide instructive examples for the region. These examples are grouped into those that are broadly construed "ecosystem management/monitoring" programs (both nationwide and local to our regional) and those that focus explicitly on stormwater management programs. These examples were selected based on our perception of their relevancy to the proposed stormwater monitoring and assessment strategy for the Puget Sound region, but they are by no means exhaustive.

Chesapeake Bay Program (CBP)

The Chesapeake Bay Program (CBP) was established in 1983 and has evolved as a voluntary partnership between states, local and inter-state advisory and steering committees, and the EPA with the stated goal of restoring and protecting the Chesapeake Bay and its tidal tributaries. A Science and Technical Advisory Committee was formed shortly after CBP's inception to facilitate scientific communication between academic institutions, engineering and technical professionals, and organizations within the program, as well as to identify research needs and provide overall assessments and recommendations. The Monitoring and Analysis Subcommittee is comprised of five technical working groups that are charged with implementing monitoring and modeling programs, managing data, etc. This organizational structure is commonly cited for its successful "vertical and horizontal coordination and integration" of science (Van Cleave *et al*. 2004) and its effectiveness at maintaining sustainable funding and participation commitments by providing readily accessible and scientifically credible monitoring data (Surface Water and Aquatic Habitat Monitoring Advisory Committee 2007).

Although widely recognized as a potential analog, if not a leader, for efforts in Puget Sound, we note that "No organized monitoring system currently exists in the [Chesapeake] Bay to conduct critical stormwater research and feed it back into the design process" (Schueler 2008, p. 11). Similar to most regions, local and state jurisdictions have been responsible for stormwater management and implementation of municipal and industrial stormwater regulations to meet NPDES permit requirements. Only recently has a new organization, the Chesapeake Stormwater Network, been created to encourage more sustainable stormwater and environmental site design practices and align the efforts of individuals, municipalities, and watershed resource organizations such as the Center for Watershed Protection. As noted in the Bay-Wide Stormwater Action Strategy (Schueler 2008), the Chesapeake Stormwater Network could provide stormwater management guidance beyond permitting assistance, but as yet an overall stormwater monitoring strategy has not been conceived.

San Francisco Estuary Institute (SFEI)

The San Francisco Estuary Institute (SFEI) is a non-profit organization established in 1986 to advance the development of the scientific understanding needed to protect and enhance the San Francisco Estuary by conducting monitoring and research. The Regional Monitoring Program for Water Quality (RMP) is a collaborative effort between scientists, the San Francisco Bay Regional Water Quality Control Board, and discharging industries to "collect data and communicate information about water quality in the San Francisco Estuary to support management decisions" (see SFEI's RMP website). Annual "Pulse of the Estuary" reports present selected monitoring results to a wide audience, and all reports and data are publicly available.

The RMP is subject to independent science review every five years to ensure that it is meeting its objectives and that appropriate adjustments are made in response to past reviews. For example, major elements of the status and trends monitoring program were modified in 2007 to better address pollutant source and distribution monitoring objectives, including the refinement of the episodic toxicity program goal to address the key question "what is causing the sediment toxicity in the Bay?" (SFEI 2009).

The mercury TMDL for the San Francisco Bay demonstrates a clear adherence to the process of adaptive implementation as outlined by the National Research Council's 2001 TMDL program review. The primary challenge for establishing a TMDL is to identify and implement actions that will solve the water quality problem in light of uncertainty about cumulative effects and technological and economical constraints (SFEI 2004). Recognizing that there are inherent shortcomings to a mercury TMDL based solely on management and measures of total mercury, the adaptive implementation plan includes provisions for: (1) immediate actions, (2) monitoring, (3) management questions, associated hypotheses, and a schedule for measuring benchmarks, (4) reviewing and incorporating monitoring and study results into the TMDL. Using urban runoff as one mercury source example, immediate actions include evaluating the benefits of specific management practices in terms of reduced loads and quantifying load reductions as a function of specific practices using interim benchmarks (SFEI 2004). This approach allows for quantitative results to inform practical management decision moving forward while research aimed to better understand methylation and other processes contributing to overall mercury loads continues.

The SFEI has been mentioned as a model for the Puget Sound regional monitoring and assessment effort because of the third party nature of the institute and their focus on "getting everyone to agree on the facts" in an objective manner.

Louisiana Coastal Area Ecosystem Restoration

Ecosystem restoration efforts in the Louisiana coastal area have received increasing attention due in part to annual coastal wetland losses that exceed 60 km^2 per year, as well as large weather events such as Hurricanes Katrina and Rita. The 1989 Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA; or "Breaux Act") served as a catalyst for small projects, and the 1998 federal and state and federal plan "Coast 2050: Toward a Sustainable Coastal Louisiana" proposed integrating restoration and protection measures to restore natural processes that build and maintain the coast (USACE 2009). Since that time the US Army Corps of Engineers (USACE) (in concert with Louisiana State DNR and other agencies) conducted the Louisiana Coastal Area Ecosystem Restoration Study (see USACE website) to identify the most critical human and ecological needs, establish near-term prioritization of restoration and protection projects, and present a strategy for addressing long-term ecological and protection concerns. Following Hurricane Katrina, USACE was directed to reexamine, assess, and present recommendations for a comprehensive approach to coastal restoration, hurricane storm damage reduction, and flood control. The Coastal Protection and Restoration Authority of Louisiana (state) released its Comprehensive Master Plan for a Sustainable Coast in 2007 and is still in the process of soliciting public input on concerns and proposed solutions for implementing outlined actions (letter from Governor Bobby Jindal's office to concerned citizens dated August 17, 2009).

While there have been numerous starts and stops along the way to implementing a large-scale ecological restoration strategy for the Louisiana coastal area, there have been and currently are several monitoring efforts of note. The Coastwide Reference Monitoring System uses a multiple reference approach consisting of hydrogeomorphic functional assessments and probabilistic sampling in order to provide information that can be used for effectiveness monitoring and assessing cumulative effects of management prescriptions (see CRMS website). In 2002, CWPPRA scientists conducted an adaptive management review of constructed projects to improve the linkages among planning, engineering, and monitoring. Constructed projects were studied as they evolved from the concept stage through construction and several years of monitoring.

The CWPPRA review demonstrated the value of comprehensive information at multiple scales, from project-specific, to project-type, to ecosystem-wide. Notable recommendations consisted of asking key questions tied to ecological function and setting quantifiable objectives at the project inception phase. Monitoring programs are certainly recognized as an important component of restoration and protection of the Louisiana coastal area and copious resources are committed to research and monitoring. However, a cursory inspection of current efforts suggests that monitoring has not been the predominant framework of an experimental management design; thus, adaptive implementation is not fully integrated.

National Park Service Vital Signs Monitoring Program

Th National Park Service Vital Signs Monitoring Program has established long-term ecological monitoring for 270 parks in 32 identified ecoregional networks, with status and trends systems-based monitoring for a broad understanding to inform land management decisions. The authors of a recent publication outlining the program conclude that:

> "one of the most critical steps in designing a complex interdisciplinary monitoring program is to clearly define the goals and objectives of the program and get agreement on them from key stakeholders. In our evaluation of "lessons learned" by other monitoring programs, we found that *differences in opinion regarding the purpose of the monitoring* [emphasis added] as the program was being developed often led to significant problems later during the design and implementation phases" (Fancy *et al*. 2009, p. 4).

Monitoring, adaptive management, and the iterative assessment of management actions should be viewed as integrated parts of a long-term restoration program. Education about the scientific process of adaptive implementation and discussion amongst participants is an important component of program and project design (Van Cleve *et al*. 2004).

As a result of education and collaboration at program inception, objectives for vital signs monitoring evolved from general statements such as, "Determine trends in the incidence of disease and infestation in selected plant communities and populations," to objectives that met the test of being realistic, specific, and measurable (*e.g.*, "Estimate trends in the proportion, severity, and survivorship of limber pine trees infected with white pine blister rust at Craters of the Moon National Monument," Garrett *et al*. 2007)." In the context of the Puget Sound effort, we note that information from the local network of parks *(i.e.*, North Coast and Cascades) could provide useful baseline conditions from which to judge the extent of changes in altered landscapes.

B.5 Stormwater-specific Monitoring Programs

California Stormwater Monitoring: a comparison of land-use and industrial programs

Lee and Stenstrom (2005) and Lee *et al*. (2007) evaluated various stormwater monitoring programs within the state of California to determine their usefulness to planners and policy makers charged with abating stormwater pollution. The foci of the monitoring program evaluations were on data collection methods and the utility of data collected to identify discharge sources. General relationships between water quality and land use were confirmed (*e.g.*, highways convey a different suite of pollutants than residential lots); however, distinctions between industrial land uses were not defensible. The authors assert that the data reviewed did not allow for hypothesis-testing and therefore could not be used to indentify high dischargers with any confidence. Furthermore, Lee *et al*. suggest that regulators must recalibrate their expectations about how they use stormwater data if statistical inferences are not well-founded.

The overarching conclusion of these studies is that that design and execution of many monitoring programs may not produce data with sufficient precision for decision-making, because the methods are not explicitly linked to goals and objectives within a scientifically sound monitoring structure. Data-collection methods and sampling strategies that produce statistically meaningful inferences can only succeed when framed by hypotheses.

Tahoe Basin Regional Stormwater Monitoring Program (RSWAMP)

The Tahoe Basin Regional Stormwater Monitoring Program (RSWAMP) is a collaboration between the Tahoe Science Consortium and other Tahoe Basin agencies to design and ultimately implement a science-based program to track progress and guide stormwater management revisions to improve and protect water quality within the Lake Tahoe watershed. A conceptual plan was completed in 2008 and the monitoring design is currently being developed, but no document is yet available for review (September 2009).

The conceptual development plan calls for monitoring and data analysis based on a unified set of key management questions generated within an adaptive management framework that can be applied to multiple projects and at multiple scales (see Heyvaert *et al*. 2008). While the Tahoe Basin RSWAMP acknowledges that it is only one piece of the greater "Tahoe Basin adaptive management system," it asserts that it will facilitate evidence-based management by presenting statistically robust and scientifically credible data and information. The plan states that the monitoring design will incorporate a well-articulated connection between different monitoring "sub-programs"—implementation, effectiveness, targeted, and status and trends monitoring—and overall critical questions identified for TMDL development (*e.g.*, are the expected reductions of each pollutant to Lake Tahoe being achieved?).

City of Seattle, Seattle Public Utilities, Street Edge Alternatives (SEA) Project

The Street Edge Alternatives (SEA) Project was conceived as a neighborhood-scale retrofit using low-impact design techniques, primarily impervious-area reduction and shallow infiltration, to reduce runoff rates and volumes. It was initiated following construction of the Viewlands Cascade Drainage System, which replaced traditional ditches with a series of wide, stepped pools. Pre- and post-construction monitoring indicated a one-third reduction in runoff volume during the wet season, and consequently the City increased its efforts to curtail runoff volume by reconstructing the entire street area of 2nd Avenue NW (adjacent to the Viewlands Cascade). They applied before- and after-treatment water quality and quantity monitoring of total site stormwater runoff following reconstruction of neighborhood stormwater conveyance facilities to evaluate effectiveness, and the overall success shown by these results has provided the basis for additional, expanded efforts in other parts of the city (Horner *et al*. 2002; see the City of Seattle website). This is an example of a clear linkage between an initial management action being an acknowledged experiment, with the measured results (in this case, showing a successful outcome) being reflected in a programmatic change (*i.e.*, expansion of the effort to other parts of the city).

B.6 Ecologically-based Monitoring Programs in the Puget Sound Region

Cooperative Monitoring Evaluation and Research (CMER)

The Cooperative Monitoring Evaluation and Research (CMER) committee is the "science branch" of Washington State Forest Practices Board Adaptive Management Program (which also consists of a Policy group, Independent Science Panel and Program Administrator). The CMER research and monitoring strategy is outlined in the CMER Work Plan, which is revised annually. The goal of the CMER Work Plan is to "present an integrated strategy for conducting research and monitoring to provide credible scientific information to support the Forest Practices Adaptive Management Program" (CMER 2008). Critical questions about forest practice rules and their effectiveness at meeting resource objectives are the cornerstone of CMER's *effectiveness*, *status and trends*, and *intensive* monitoring programs, and rule implementation tool development programs.

While prioritization of research efforts to evaluate whether forest practice rules achieve resource protection objectives and integration of study results continue to challenge CMER, the organization and operation of the Forest Practices Adaptive Management Program is consistent with the goal of science informing policy and generating a timely feedback loop.

In early 2009, the Washington Department of Natural Resources commissioned a comprehensive review of studies completed for the adaptive management program under CMER (Stillwater Sciences 2009) associated with the ten-year-old Forest and Fish Agreement. CMER is charged with evaluating the effectiveness of the forest practices rules in protecting public resources (*e.g.*, fish, wildlife, and water quality), and it has initiated or completed over 80 individual studies to that end. These studies were evaluated in light of their stated objectives, key questions, hypotheses, and interim performance targets.

The overarching finding of the 2009 CMER review was that the monitoring framework approach is well-founded but its implementation over the first ten years of the program has not been uniformly well-executed, primarily because of a preference for site-scale studies over integrative (status-and-trend) evaluations, and from insufficient cross-coordination amongst the various components of the program.

Puget Sound Nearshore Estuary Partnership (PSNRP)

The Puget Sound Nearshore Ecosystem Restoration Project (PSNRP) is a partnership between the U.S. Army Corps of Engineers (Corps), state, local, and federal government organizations, tribes, industries, and environmental organizations. PSNRP's goals are to identify significant ecosystem problems, evaluate potential solutions, and restore and preserve critical nearshore habitat in Puget Sound. While early restoration efforts have been encouraging, these efforts have paled in light of widespread on-going environmental deterioration. The agencies and tribes involved with this effort are determined to define and apply a much broader and systematic approach to reverse and prevent the harm by establishing a sound scientific basis to understand fundamental ecological processes and functions, establish reliable measures of current conditions, define and implement a research agenda to fill in knowledge gaps, and to identify and prioritize specific restoration actions that address the root causes of environmental damage.

While the focus of the project is on restoration, the group has embraced the application of scientific principals as the foundation of their work. Already, PSNRP has accomplished a considerable amount of research, including a comprehensive geomorphic classification of marine shorelines in Puget Sound; a comprehensive evaluations of marine biota including Orca whales and marine forage fish, shoreline and submerged marine vegetative communities, nearshore processes; a comprehensive research strategy for coastal habitats and a conceptual model to better understand restoration efforts of nearshore ecosystems; an historical change analysis of marine shorelines; and a report on best available science and "lessons learned" from large scale restoration efforts throughout the nation. The research agenda they have defined uses a hypotheses-based approach to defining appropriate indicators and laying out the logic of their inquiry.

PSNRP provides an example of an organizational structure with the inherent capacity to address environmental change and restoration needs at multiple spatial scales within Puget Sound. Their program, as of yet, does not appear to have a formal adaptive management component that would ensure that the outcomes of their efforts are well connected to inform policy makers.

To provide scientific direction for PSNRP, a "lessons learned" exercise (Van Cleve *et al.* 2004) characterized the role of science in five large-scale restoration programs beyond the Pacific Northwest: the Chesapeake Bay Program, the Comprehensive Everglades Restoration Plan (CERP), the California Bay-Delta Authority, the Glen Canyon Adaptive Management Program, and the Louisiana Coastal Areas Ecosystem Restoration Program. Many of those findings are already included in the discussions above. Overall, their review strongly suggests that using science as a foundation for making decisions will greatly improve a restoration program's ability to successfully conceptualize, design, and implement large-scale restoration efforts over the long term.

Puget Sound Assessment and Monitoring Program (PSAMP)

The Puget Sound Assessment and Monitoring Program (PSAMP) is a program established to coordinate research and monitoring in the Puget Sound marine waters by state, federal and local agencies. In 2008, the Steering Committee and Management Committee produced a review document of their process: Keys to a Successful Monitoring Program: Lessons Learned by the Puget Sound Assessment and Monitoring Program (PSAMP 2008). This report's purpose is well-aligned with the intention of the SWG's effort, namely to articulate:

> "…what organizational features and what technical elements are most important for a successful regional monitoring program. We believe that a successful monitoring program could be developed under any one of a variety of potential governance structures, so long as that structure supports and provides the necessary organizational features and technical elements…" (PSAMP 2008, p.7)

Their key relevant recommendations are: To be successful, a coordinated, regional monitoring program must have:

- Clear monitoring objectives derived from clear management goals through ecosystem-based assessment.
- Integrated monitoring, research and modeling activities, implemented at appropriate scales, including:
  a. Status and trends monitoring,
  b. Compliance and effectiveness monitoring,
  c. Implementation and validation monitoring,
  d. Cause-and-effect studies,
  e. Process and landscape models to synthesize monitoring and provide feedback, and
  f. An adaptive management framework that targets restoration and conservation activities which improve environmental condition.

PSAMP has been collecting such data for over 20 years, and it has contributed much to our understanding of the decline in certain species and the increasing accumulation of toxicants in the environment and in biota. Unfortunately, this has not catalyzed a significant change in the way shoreline areas are managed nor how pollutants enter the system. The precautionary lesson here is that even a well-orchestrated program that tracks status or trends over time or space in key ecological indicators, if not directly linked to management decisions nor based on testable hypotheses about the underlying causal mechanisms, may not ultimately influence those decisions needed to forestall further decline in those indicators. Also, if the monitoring is conducted at too large a scale, it may also fail to provide much insight into how to reverse the trends of decline.

Appendix C Assessment Questions to Guide Regional Stormwater Monitoring

The following priority assessment questions were officially adopted by the Stormwater Work Group on June 3, 2009. These questions were developed and vetted through a series of committee meetings and technical and public workshops culminating in the spring of 2009 (see Appendix A). Although interest was expressed in having an even larger number of questions, the final assessment questions were narrowed down in order to provide a manageable scope for this near-term strategy development effort.

Overarching questions:

1. Given limited resources, what combination of targeting new development and retrofitting existing development is most effective in minimizing the impact of land use/stormwater to receiving waters?
2. How effective are the Clean Water Act permit-mandated municipal (including highways), industrial, construction, livestock, and dairy stormwater programs?

For efficacy of management actions, the priority questions are:

- Among the most widely used practices and promising new practices that are available, what specific retrofits or restoration practices are most effective in reducing pollutant loads, restoring hydrologic function, and recovering damaged habitat?
    - To what extent can retrofits and application of BMPs at redevelopment sites reverse past impacts? To what extent can the water and sediment quality and hydrologic conditions necessary to support beneficial uses of water bodies be restored in sub-basins that already have some degree of development? At what degree of development, or under what other specific conditions, is a particular retrofit strategy most likely to be successful?
- Are our stormwater management actions preventing and reducing future disruption of natural hydrologic conditions and minimizing pollutant loads in areas of new development in Puget Sound?
    - What is the effectiveness of subbasin-scale to watershed-scale combinations of stormwater management actions (techniques) at reducing impacts?
- How effective are source control and other programmatic stormwater management practices in reducing pollutant loads from existing development and from other specific land use activities such as agriculture?

For impacts to beneficial uses, the priority questions are:

- *Where* does stormwater significantly impact receiving waters, resources, species, or beneficial uses in the lowland streams, lakes, rivers, ground, and marine waters of the Puget Sound basin?

  - What is the current condition of streams, lakes, rivers, and nearshore marine waters, by representative land use?
    - What are the worst spots, when, and why?
    - What are the impacts to biota?
    - What areas should be targeted for protection?
- Over time, how effective are source control, prevention, and retrofit efforts? Are beneficial uses improving in response to our stormwater management actions?

For characterization and pollutant loadings, the priority questions are:

- How does land use influence pollutant concentrations, flow volumes, and loadings? What land uses or land use combinations are of greatest interest for applying and improving our stormwater management actions?
  - What is the variability in stormwater pollutant concentrations and flow volumes by land use and geographic area?
  - What is the variability within and among WRIA level basins for similar land uses?
  - What factors within a land use control pollutant concentrations and flow volumes?
    - How do differences in stormwater infrastructure (*i.e.*, pipes versus ditches, developments built at different times under different standards) affect pollutant loads and flows from similar land uses?
    - What proportion of the pollutant loads reach receiving waters and what are the explanations for the differences (*i.e.*, due to losses)?
  - What proportions of the pollutants in stormwater are from various sources such as air deposition and transport, spills, erosion and resuspension?
- What are the seasonal variations and long term trends in pollutant loads and what variables influence the temporal distributions?

For research, the priority questions are:

- What are the best indicators of stormwater impacts to water or sediment quality, streamflow, habitat, and biota?
  - What are the best indicators of various categories of chemical pollutants? Of solid-phase versus dissolved phase chemical pollutants?
- What are the synergistic effects of pollutants from stormwater?
- What is the toxicity in surface waters impacted by stormwater?
  - What is the seasonal and annual variation and the variation within the hydrograph?
- What are the effects of stormwater up through the food chain/food web?

Appendix D: Status and Trends Monitoring Design

Status and trends monitoring is included in this strategy to provide key indicators for stormwater impacts over time. Two water body types were selected for detailed status and trends monitoring plans: small streams and nearshore areas. The monitoring designs that are proposed for each water body are described in the following sub-sections.

D.1 Status and Trends Monitoring in Small Streams

The proposed priority hypotheses for status and trends monitoring in small streams are as follows, from Section 2.6.1:

1. Salmon (focusing on appropriate life stages) in small streams show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.
2. In-stream biological metrics (e.g., benthic index of biotic integrity [B-IBI]) show statistically significant improving trends in Puget Sound lowland streams in concert with increased and improved stormwater management efforts.
3. Bacteria levels limiting primary human contact show decreasing trends over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.

Small streams (here defined as second- and third-order streams) are a critical component of this strategy because the health of the biota can be more directly linked to land use patterns and stormwater management activities. Status and trends monitoring of small streams will involve measuring a targeted suite of biological, chemical, hydrologic, and physical indicators for stormwater impacts at a randomly selected group of sites from a list of sites found in the Washington Master Sample. Selection of stream sites will follow U.S. Environmental Protection Agency (EPA) protocols that have been adopted by the Washington Department of Ecology (Ecology) for the Watershed Health and Salmon Recovery Status and Trends (WHSRST) monitoring program (Ecology 2006). This approach and protocols have been endorsed by the Washington Forum on Monitoring and the Puget Sound Partnership to provide information on salmon recovery and watershed health. Specifically, stream sites will be selected from the list of random sites found in the Washington Master Sample (www.ecy.wa.gov/programs/eap/stsmf/); Ecology also used this list for the WHSRST monitoring program.

Use the same approach that was used for Ecology's WHSRST monitoring program, the experimental design for small stream status and trends monitoring under this strategy includes a fairly large number of randomly selected sites in the Puget Sound lowlands. These sites will be grouped into two categories: permanent and rotating. In general, this design represents an attempt to balance limited monitoring resources between a fewer number of permanent sites that will be sampled intensively over time to detect trends in stormwater pollutant concentrations and loads, and a larger number of rotating sets of sites that will be sampled less intensively but provide broader spatial coverage for assessing impairment from stormwater.

The proposed stream monitoring would include sub-basin sampling at the Water Resource Inventory Area (WRIA) level, except for island-based watershed, for the water quality index, aquatic macroinvertebrates, fish diversity and abundance, stream physical features, and sediment chemistry for metals and petroleum. Additional sampling at the Puget Sound scale would include sediment chemistry (phthalates, PCBs, hormone disrupting chemicals, and other toxics of concern), flow, temperature, and a pilot study for periphyton. As shown in Table D-1 below, the Stormwater Work Group (SWG) recommends that a subset of these monitoring activities be required by future National Pollutant Discharge Elimination System (NPDES) permits for municipal stormwater discharges. However, the SWG believes that the NPDES and non-NPDES monitoring should be coordinated to maximize efficiency and reduce overall monitoring costs.

The status and trends monitoring program will provide an indication of current status in the first monitoring cycle. As noted in Chapter 3, trend information will not be available in this first monitoring cycle or in the typical planning horizon for individual projects or NPDES permits. Trends not only require sufficient sampling to determine significant changes from natural variability, but also require the system has sufficient time to respond to actions or lack of action. Where possible without compromising the statistical design of the approach, historical water quality and biological monitoring sites will be incorporated. This will provide information on site variability and may provide the opportunity to detect trends earlier.

D.1.1 Site Selection

As noted above, all sites for small streams status and trends monitoring will be selected from the list of random sites found in the Washington Master Sample. The first step in this process will define a sampling frame for these sites (i.e., the spatial domain over which the sites are selected). For small streams status and trends monitoring the sampling frame is the set of second- and third-order streams draining to Puget Sound. The site selection can be stratified so that two-thirds of the sites will be located within UGAs in more urban watersheds. This would serve to focus the monitoring at streams within lowland areas where adverse stormwater impacts are known to be more prevalent. In more rural watersheds, development patterns may not warrant this focus on urban areas.

The next step is assignment of probabilities of selection to all stream reaches in the sampling frame. This is done through the generalized random tessellation stratified (GRTS) method, an EPA-approved statistical model for probabilistic survey designs. The GRTS method has an advantage over a uniformly random sample set because selected sites are spatially balanced. Uniform random spatial distributions tend to be more clumped than GRTS samples. After defining the target population, the GRTS model will be used to select approximately 30 permanent sites and 90 rotating sites, which will allow for three rotating sets of 30 sites each. Some of the selected sites may be on private land and accessible only if the property owner grants permission. Therefore, we will evaluate the initial sites and select alternatives for those deemed legally or physically inaccessible. The specific number and location of sites (and frequency of sampling) may be adjusted upward or downward in order to meet the statistical goals for this status and trend monitoring.

Status monitoring and trend monitoring are often described as a single design, particularly in recent years as a result of widespread EPA support for probabilistic sampling as part of EMAP. For regional assessment of condition, *i.e.*, status assessment, probabilistic or some other type of random sampling, is the only design (besides a full census) that will provide an unbiased estimate of resource condition. Trend monitoring is somewhat different because the intention is to capture information about both regional condition and change through time, in other words, to answer the question, How is the resource changing through time at the regional scale?

For the Puget Sound region, many sites have a long record of sampling. Some of these sites were selected randomly, e.g., within King County, while others were not. When designing a trend monitoring program, the question arises, Which is more important, trend information at the regional scale or trend information over a long period of time?

For a trend monitoring design for Puget Sound, three types of trend monitoring sites exist.

1) Randomly selected sites that have never been visited.

Advantages associated with these sites is that will yield unbiased regional estimates of trends through time. The primary disadvantage it may take 5-10 years to obtain information about temporal trends.

2) Randomly selected sites that were sampled in years past.

An example of this would be benthic macroinvertebrate samples collected from random stream locations in King County beginning in 2002. Advantages associated with using these sites to test for trend is that the sites were randomly selected and, therefore, provide trend information about the entire sample area. In addition, these sites were sampled in the past and will yield trend information if revisited within the next few years. One disadvantage is that they were not randomly selected using EPA's EMAP protocol; the random methods are comparable, but not identical. In addition, the sites are only representative of the area that they were selected from (*e.g.*, King Co., not Puget Sound). Jurisdictions from other areas have similar type of sites.

3) Non-randomly selected sites sampled over many years.

These sites are referred to as "legacy" sites or "historic" sites. The advantage of these sites is that they provide long-term data that can be used to assess change through time. They can be used to estimate variability and provide pilot data to determine the best survey designs for detecting future trends. Disadvantages include the data do not represent regional trends, only trends at the sites sampled and measurements collected in the past may not provide the data needed in the present or future.

It is necessary to determine how many long term monitoring sites are active in the Puget Sound basin, the geographic distribution of the sites, what parameters have been and are currently sampled, sampling methodology and data quality of these existing monitoring sites. Once this dataset has been identified it can be evaluated relative to the geographic distribution around the Puget Sound basin. While the distribution of these monitoring sites was not established to conduct trend analysis on a Sound wide basis, these datasets represent the only source of historic data, and comprise the only opportunity to do trend analysis immediately. There would need to be an evaluation of what value and/or bias would be included by using any of these existing monitoring sites for a Puget Sound basin tend monitoring effort.

A sampling design using existing long term monitoring sites is potentially a transitional issue and will likely become less critical as a new monitoring program establishes a sufficient record to detect trends. Based on information from some of these existing sites, it will likely take a minimum of ten years of data collection at the new sites before there will be sufficient data available to do statistically valid trend analysis. In the interim, trend analysis will be continued at a set of monitoring sites with currently existing long term datasets. The randomly selected trend monitoring sites could minimize the bias potentially inherent in a design using existing long term monitoring sites that were not randomly selected from the Puget Sound basin.

It may be prudent to continue monitoring at a set of sites that have current, long term datasets, and is the only dataset that allows for immediate trend analysis while a new set of Puget Sound wide randomly selected becomes established and accumulates the necessary long term dataset for trend analysis.

The inclusion of non-random legacy sites will be identified and reviewed for statistical power within the next 4 months and evaluated based on value and cost for inclusion in the Status and Trends and potential NPDES municipal permit recommendations.

D.1.2 Data Types and Indicators

Table E.1 lists the parameters, frequencies, and site selection procedures for the small streams regional monitoring program, which is WRIA-based. Table D.2 summarizes the rationale for each parameter included in the small streams monitoring program.

D.1.3 Sampling Procedures Will Be Consistent with State Status and Trends Monitoring

Water quality samples will be collected and analyzed for the chemical indicators identified in Table E.1. Sample sets will consist of single grab samples that are collected at the 30 permanent and 390 rotating monitoring sites (30 sites in each of the 13 non-island based WRIAs in the Puget Sound basin). The permanent sites will be sampled monthly and the rotating sites will be sampled twice during the 5-year NPDES permit cycle, if possible. Water samples will be collected in accordance with the procedures described in Ecology's Environmental Assessment Program's standard operating procedures (SOPs). Benthic macroinvertebrate samples will be collected from the rotating monitoring sites twice during the 5-year NPDES permit cycle, if possible. The samples will be collected in the late summer or early fall (August through October) in order to provide adequate time for the in-stream environment to stabilize following natural disturbances (e.g., spring floods). In addition, representation of benthic macroinvertebrate species typically reaches a maximum during this period. Benthic macroinvertebrate collection, processing, and analysis will follow Ecology protocols for in-stream biological assessment (Publication 94-113).

Fish diversity and abundance will be surveyed at the 390 rotating sites. The fish surveys will be conducted twice during the 5-year NPDES permit cycle, if possible. The fish surveys will be conducted in accordance the Environmental Monitoring and Assessment Program (EMAP) wadeable streams protocols.Sediment samples for metals analyses will be collected once per year from the 390 rotating monitoring sites, if possible. Samples from 30 of these sites will be analyzed for a suite of organic contaminants, in addition to metals. Because contaminants are more likely to be concentrated in fine sediments with high organic matter content, sample locations will focus on depositional areas where fines are present. Sediment samples will be

Table D.1. Summary of WRIA-Based Freshwater Status and Trends Monitoring

Parameter	**Frequency***	**Site Selection**	**State Status and Trends Protocols**	**NPDES**
Water Quality Index** **--Rotating Sites**	Two grab samples during 5-year permit term	30 per WRIA (390 total), random stratified UGA/rural 2nd & 3rd order streams.	√	√
Water Quality Index** **--Permanent Sites**	Monthly grab samples during 5-year permit term	30 randomly selected WQI sites. After analyses, may recommend some non-random sites to aid trend assessment.		√
Aquatic Benthic Macroinvertebrates —B-IBI/RivPac, individual metrics	2 samples within 5-year permit	30 sites per WRIA, random, stratified UGA/rural, 2nd & 3rd order streams.	√	√
Periphyton	Pilot in 2 WRIAs	Co-locate with benthic/WQI sites. Select one rural and one urban basin within Puget Sound; follow Ecology study design and protocols.	√	√
Fish Diversity, Abundance	2 samples within 5-year permit	30 sites per WRIA, random, stratified UGA/rural, 2nd & 3rd order streams.	√	
Stream Physical Features -- EMAP wadeable streams parameters	2 samples within 5-year permit	30 sites per WRIA, random, stratified UGA/rural, 2nd & 3rd order streams.	√	
Flow	Continuous	Non-random, GIS analysis of current distribution of next 9–12 months. Minimum of 13 sites associated with permanent sampling locations.	√	√
Temperature	Continuous	Non-random, associated with flow gauges.	√	√
Sediment Metals** --arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc	Annual grab	30 sites per WRIA (390 total), random, stratified UGA/rural, 2nd & 3rd order streams.	√	√
Sediment Toxics** --metals, PAHs, pesticides, PCBs, phthalates, PBDEs, hormone-disrupting chemicals	Annual grab	Randomly select 30 of the 390 Sediment Metals sites across the Puget Sound basin		√
*** actual sampling frequency to be determined in final design based on statistical goals and feasibility**				
****See Table E.2 for parameter descriptions**				
NOTE: Information from historical monitoring information and the first sampling cycle will be used to determine the sampling frequency necessary for trend assessments. Trend assessment is anticipated to be conducted on a regular, but not annual basis.				

Table D.2. Parameters for WRIA Based Status and Trends Monitoring in Freshwater

Parameter	Rationale
Water Quality	
Total phosphorus	Nutrients are a pollutant of concern from residential development (Ecology 2005a). High concentrations can lead to accelerated plant growth, algal blooms, low dissolved oxygen, decreases in aquatic diversity, and eutrophication in freshwater systems. TP is needed to calculate Water Quality Index (WQI) value.
Total nitrogen	Nutrients are a pollutant of concern from residential development (Ecology 2005a). TN is a concern in the Puget Sound, since nitrogen is typically the limiting nutrient in marine systems. TN is needed to calculate Water Quality Index (WQI) value.
Turbidity	Primary indicator of water quality and metric of stormwater management systems. Needed to calculate Water Quality Index (WQI) value.
Total suspended solids	Pollutant of concern from a variety of land uses including residential development (Ecology 2005a). Key indicator used to measure the basic treatment effectiveness of a stormwater treatment technology. Can reduce light penetration and lead to a smothering effect on fish spawning and benthic biota. Associated with other pollutants that adsorb to particles such as nutrients, bacteria, metals, and organic compounds. Inexpensive to monitor, minimal field and QA problems, and a reliable indicator. Needed to calculate Water Quality Index (WQI) value.
Conductivity	Easily measured and correlates to the total dissolved solids. Needed to calculate Water Quality Index (WQI) value.
pH	Principal driver of aqueous chemical reactions including effects on ammonia volatilization, nitrification, and the precipitation of metals. Needed to calculate Water Quality Index (WQI) value.
Chloride	Elevated levels of chloride usually indicate the presence of other chemicals. Road salt application can result in chloride concentrations in stormwater at levels that may harm aquatic life. Needed to calculate Water Quality Index (WQI) value.
Fecal coliform	A common indicator of urban stormwater pollution or failing septic systems. Needed to calculate Water Quality Index (WQI) value.
Temperature	Key parameter affecting the health and survival of biological communities. Needed to calculate Water Quality Index (WQI) value.
Dissolved oxygen	Key parameter affecting the health and survival of biological communities that is affected by biological and chemical oxygen demand. Needed to calculate Water Quality Index (WQI) value.
Aquatic Biology	
Aquatic benthic macroinvertebrates: B-IBI/RivPac, individual metrics	Integrates water quality and habitat impacts from stormwater over time (Karr 1998; Karr and Rossano 2001; Fore et al., 2001).
Periphyton	Valuable indicators of short-term impacts. Directly affected by physical and chemical factors. Sensitive to some pollutants which may not visibly affect other aquatic assemblages, or may only affect other organisms at higher concentrations (e.g., herbicides).
Fish diversity, abundance	Species diversity and abundance directly correlate to the stress of an ecosystem.

Parameter	Rationale
Stream Physical Features	
Channel type and shape, riparian condition, sediment, LWD (EMAP wadeable streams parameters)	Urban development can alter basin hydrology and adversely affect stream channels (e.g., accelerated bank erosion, loss of LWD, reduced baseflow).
Flow	Needed to discern hydrologic trends related to land use and stormwater management measures. Can be used to calculate a variety of metrics (e.g., peak winter flows, summer base flows, storm pulses) that may aid in trend detection, interpretation of biological parameters, and stressor identification.
Temperature	Key parameter affecting the health and survival of aquatic communities.
Stream Bottom Sediment	
Heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc)	A group of ecologically consequential heavy metals with defined sediment management standards in WA. Heavy metals contribute to toxic effects on aquatic life and impact the beneficial use of a water body.
PAHs	Associated with urban runoff and characteristic measure for roadway impacts. Can accumulate in aquatic organisms and are know to be toxic at low concentrations. Can be persistent in sediments for long periods, resulting in adverse impacts on benthic community diversity and abundance.
Pesticides	Common in residential and agricultural runoff.
Phthalates	Pervasive sediment contaminant in the Puget Sound region.
PCBs	Corollary to industrial/urban stormwater impacts. Salmonid fish are highly susceptible to PCB accumulation (fatty tissue deposition/accumulation).
PBDEs	Correlates to urban impacts. Growing evidence of PBDE persistence and accumulation in the environment.
Hormone disrupting chemicals	A broad indicator of pollution from urban development. Commonly detected in Puget Sound sediments, with some monitoring stations observing increases in concentrations over recent years (Ecology 2005b).

collected following the guidelines set forth in Ecology's Environmental Assessment Programs SOPs.

Sampling procedures for physical habitat indicators (percent substrate by size, embeddedness, bed stability, and bank instability) will be adopted from the WHSRST monitoring program (Ecology 2006).

D.1.4 Expected Outcomes

The small stream status and trends monitoring program will:

- Summarize the current condition of streams with an estimated level of statistical precision at watershed and Puget Sound levels.
- Allow regional comparisons of stream conditions within and across WRIAs.

- Support prioritization of areas for protection and restoration in terms of physical, chemical and biological condition at the Puget Sound scale.
- Recognize temporal and geographical variability and environmental response time to management practices.
- Provide regional estimates of water quality and flow conditions that support salmon recovery endpoints and other water resource issues.
- Answer at a spatial scale that often better matches the scale of decisions needed for stormwater management issues.
- Identify common problems due to land use impacts or sources of pollutants that may need common solutions.
- Provide consistency over time even if jurisdictional boundaries change.
- Consider entire watersheds without the constraints of jurisdictional boundaries.
- Provide a baseline for documenting longer-term and larger scale impacts, such as climate change.
- Provide useful results even if some monitoring sites are lost due to changes in land ownership or other factors.
- Provide flow and water quality data that could be used for hydrologic and water quality modeling.

D.2 Status and Trends Monitoring in Nearshore Marine Areas

The proposed priority hypotheses articulated in Section 2.6.1 for status and trends monitoring in the nearshore are:

1. Bacteria levels in water and bacteria and/or toxics in shellfish along the nearshore limiting primary contact and harvest show decreasing trends over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts.
2. Measured constituents related to stormwater are decreased in marine sediments over time.
3. Resident fish in nearshore areas show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts. – (Addressing this hypothesis is reserved as future work)
4. Forage fish in nearshore areas show improving population health over time throughout the Puget Sound region in concert with increased and improved stormwater management efforts. – (Addressing this hypothesis is reserved as future work)

Nearshore areas are the aquatic interface between fresh and marine waters. Nearshore areas are generally considered to include the areas commonly known as shore, beach, intertidal, and subtidal zones to a depth of about 20 meters relative to mean lower low water (average depth limit of photic zone). Due to the variations in physical processes such as wave, wind, and sediment transport, the nearshore zone supports a wide diversity of habitats and is considered the "nursery zone" of Puget Sound. Examining the nearshore marine area is a critical component of status and trends monitoring for ecological health. In addition, the nearshore area is directly associated with human health concerns because many of the fish and shellfish we consume are harvested from this part of the ecosystem and because our recreational activities are also concentrated in the nearshore zone.

Marine nearshore sampling would focus at the Puget Sound scale on probabilistic sampling for fecal coliform, sediment chemistry, and caged mussel toxic accumulation. Because chemical data are not always reliable indicators of biological effects, direct biological testing (sediment toxicity testing) is often used in conjunction with sediment chemistry and infaunal community structure analysis (diversity and abundance of organisms living in the bottom substrate) to determine the biological significance of the chemicals measured in the sediments. This series of monitoring is known as the Sediment Quality Triad. However, as a tool for monitoring status and trends, using two (invertebrates sampling and sediment chemistry) of the three parts of the triad are recommended in this initial plan.

D.2.1 Site Selection

Similar to the small streams strategy, a random approach will be used to select 30 sites sites for monitoring toxic constituents in the bottom sediment and 50 sites for monitoring fecal coliform in the water column. The sediment sites will be randomly selected from protected embayments. The fecal coliform sites will be spatially distributed across Puget Sound. Fecal coliform data from the state and county health departments will be used in areas of overlap. Approximately 10 percent of the bacteria and sediment stations will be identified as permanent sites and the remainder will be rotating sites. The permanent sites will be continually and consistently monitored, while the rotating sites will be monitored twice in every 5 years. This approach provides the benefits of consistent long-term monitoring at some sites, while also allowing for many more sites and more spatial coverage through the system of rotating sites. This frequency of sampling is suggested and will be determined in final study design based on statistical goals and feasibility. Where possible, existing monitoring locations will be incorporated into the design to provide historical continuity and support earlier detection of trends.

Mussel Watch (http://ccma.nos.noaa.gov/about/coast/nsandt/musselwatch.html) is our nation's longest running continuous contaminant monitoring program in coastal waters. It was designed to monitor the status of toxic contaminants in coastal waters and track changes in contamination through time. Mussel Watch efforts are focused on a sentinel group of organisms, the blue mussel (*Mytilus* spp), and it currently tracks 26 stations in Washington State, including Puget Sound, the Straits of Juan de Fuca and Georgia, the Pacific Coast, coastal estuaries, and mouth of the Columba River. Mussel Watch monitoring is recommended to be performed at 30 sites located near randomly selected stormwater outfalls across Puget Sound.

The existing suite of toxics monitored by Mussel Watch include PCBs, organochlorine and other pesticides, polycyclic aromatic hydrocarbons and their alkylated homologs, and a large suite of metals. It is anticipated that polybrominated diphenyl ethers (PBDEs) will be added to the analyte list permanently this year. It is possible that bis-phenol-A, nonylphenol, ethynylestradiol, and pharmaceuticals and personal care products could be added to the list.

D.2.2 Data Types and Indicators

Table D.3 lists the indicators that have been selected for monitoring in the nearshore marine area and a general summary of the monitoring approach that will be applied for each. The indicators focus largely on toxic contaminants. Table D.4 summarizes the rationale for selecting each indicator.

D.2.3 Sampling Procedures

Grab samples for fecal coliform analysis are recommended to be collected monthly from the water column at 30-50 randomly selected sites. Sediment samples will be collected once per year from 30 sites randomly selected from protected embayments. Sediment sampling will follow procedures developed for the Puget Sound Assessment and Monitoring Program (PSAMP, Ecology 2007). "Mussel Watch" sites will be established at 30 sites near stormwater outfalls in order to assess potential toxicity to shellfish. These sites will be monitored once per year. All sampling frequencies are draft recommendations and subject to modification based on statistical goals after reviewing existing data. In addition, sampling frequency requirements under the next NPDES municipal stormwater may have to be adjusted to accommodate new institutional structures, approaches, protocols, site access issues, and other new monitoring program issues that must be addressed.

D.2.4 Expected Outcomes

The nearshore status and trends monitoring program will:

- Help identify the current condition related to swimming and shellfish harvest beneficial uses of the marine nearshore in Puget Sound.
- Help identify nearshore areas that may be affected by toxic constituents from nearby stormwater outfalls.
- Summarize contaminant concentrations in bottom sediments with an estimated level of statistical precision.
- Support prioritization of nearshore areas for protection and restoration in terms of physical, chemical and biological condition at the Puget Sound scale.
- Recognize temporal and geographical variability in sediment chemistry.
- Answer at a spatial scale that often better matches the scale of decisions needed for stormwater management issues.

Table D.3. Summary of Puget Sound Based Status and trends Monitoring of Nearshore Areas

Parameter	**Frequency***	**Site Selection**	**NPDES**
	Water Quality Parameters		
Fecal coliform	Monthly	50 randomly selected sites at Puget Sound scale; use shellfish monitoring data in areas of overlap.	√
Mussel Watch: bioaccumulation toxicity	Annually	Mussel Watch – 30 sites, consisting of existing sites and randomly selected new sites near selected stormwater outfalls (specific design to be determined).	√
	Sediment Quality Parameters		
Sediment Metals & Toxics** --antimony, arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc, PAHs, pesticides, phthalates, PCBs, PBDE, hormone-disrupting chemicals, total organic carbon	Annual grab	30 sites randomly selected from protected embayments; depositional areas with fine sediments.	√
*actual sampling frequency to be determined in final design based on statistical goals and feasibility			
****See Table E.4 for parameter descriptions**			

Table D.4. Parameters for Puget Sound Based Status and Trends Monitoring in Marine Nearshore Areas

Parameter	Rationale
Water Quality	
Fecal coliform	A common indicator of urban stormwater pollution or failing septic systems.
Mussel watch	Indicator of bioaccumulation toxicity. Build on existing data set.
Bottom Sediment	
Heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc)	A group of ecologically consequential heavy metals with defined sediment management standards in WA.
Antimony	Used in brake pads. Can be difficult to analyze. Results should be reviewed at the end of the first monitoring cycle.
PAHs	Associated with urban runoff and characteristic measure for roadway impacts. Can accumulate in aquatic organisms and are know to be toxic at low concentrations. Can be persistent in sediments for long periods, resulting in adverse impacts on benthic community diversity and abundance.
Pesticides	Common in residential and agricultural runoff.
Phthalates	Pervasive sediment contaminant in the Puget Sound region.
PCBs	Corollary to industrial/urban stormwater impacts. Salmonid fish are highly susceptible to PCB accumulation (fatty tissue deposition/accumulation).
PBDEs	Correlates to urban impacts. Growing evidence of PBDE persistence and accumulation in the environment.
Hormone disrupting chemicals	A broad indicator of pollution from urban development. Commonly detected in Puget Sound sediments, with some monitoring stations observing increases in concentrations over recent years (Ecology 2005b).
Total organic carbon	Good indicator of general mercury contamination in Puget Sound.

Appendix E Source Identification and Diagnostic Monitoring Design

Existing monitoring data is available to determine many problem sources/impairments. The following steps outline a process for (1) utilizing this information and setting priorities to address the most important problems first; (2) gathering additional information as needed; and (3) planning the necessary actions to remove stressors and other sources of pollutants and ultimately improve beneficial uses in the receiving waters.

Step 1. Evaluate existing data to determine problem sources/impairments

Determine which problems to work on first. This can be accomplished by evaluating data linked to stormwater from existing programs including, but not exclusively: TMDLs, Category 4 and 5 303(d) impaired listings, Shellfish Protection Districts, Superfund sites, MTCA sites, Industrial permit Discharge Monitoring Reports, CSO discharge data and Phase I stormwater characterization data and regional and local monitoring data. It is understood that most local jurisdictions are aware of not only regional, federal and state monitoring historically or concurrently and this step should be performed at the local level. However, coordination through a regional monitoring entity could provide more efficient and effective coordination of evaluation of the sources of data. It is recommended that this step be performed at the WRIA or watershed level, rather than at the Action Area or larger scale in order to evaluate information at a manageable scale.

Step 2. Prioritize sources/impairments

It is recognized that not all sources/impairments identified in Step 1 can be addressed concurrently. Therefore, prioritization must be performed in order to determine which problems to work on first, *i.e.*, which source control/removal programs are to be continued, which new programs should be planned, funded and implemented, and which programs should be addressed at a later time. Examples of prioritization categories include: human health, salmon health, forage fish health, watershed health, toxics body burden and drinking water. It is recommended that a prioritization method be developed with consideration of local priorities as well as priorities for the Puget Sound region.

Step 3. Set a target for source reduction

It is important to determine to what level the source is to be controlled. For example, is the goal to meet a water quality or sediment criteria or a specific productivity goal for out migration of juvenile salmon? Without a target or goal, source control activities could be performed to a level with little benefit. There needs to be a scientifically valid target for the future source removal actions. Additionally, biological endpoints need careful assessment since an ideal endpoint may not be achievable and that an optimum or interim endpoint for the condition may be set.

Step 4. Locate sources/causes

In some cases further monitoring may be necessary to refine the location of the sources. Examples of additional monitoring upstream or upland of the identified impairment stations such as upstream segment water quality samples or sediment sampling of catch basin material upstream. Location of sources may be not require monitoring but may simply be an assessment of land use practices or activities. An example may be a farm with uncontrolled animal waste entering a stream tributary or an industrial site discharging wastewater into the storm system.

Step 5. Plan actions to remove the source(s)

This step is not monitoring but is a management action necessary for Source Identification Monitoring. It is a key step in the process and must occur in order to continue the monitoring. It is recommended that a communication system be implemented to relay successful source removal programs, actions, strategies and successes be shared across Puget Sound. Removing many sources locally will result in overall improvement of the health of Puget Sound.

Step 6. Implement source removal actions/programs

Source removal actions are implemented. Implementation is not a focus of this Scientific Framework but is a necessary step in the process.

Step 7. Monitor to provide feedback on status of source

Monitoring is to be performed during the implementation phase of source removal to provide a feedback loop on the status of the actions. Are the actions resulting in reduced sources at the upstream locations? Are short-term reductions observed? This step may not be necessary but should be included to provide feedback.

Step 8. Implement a framework to prioritize watersheds where the watershed health is unknown

It is recognized that concurrently with historical data and data from existing programs, an additional Diagnostic Framework must be implemented to determine the priority of watersheds or sub-basins where impairment is expected and no previous monitoring or assessment has been performed. Status and Trend monitoring within each WRIA will generate the information necessary for this assessment.

Step 9. Incorporate results from effectiveness and status and trends monitoring into the prioritization process

- Provide a framework for stormwater monitoring from Effectiveness Monitoring and Status and Trends Monitoring to be available in a timely manner to feedback into the prioritization step of Source Identification Monitoring.

Figure E.1 shows the stepwise process that may be necessary for a source identification and removal plan. The monitoring framework that is specified will be dependent upon the defined impairment, biological endpoint or exceedance: different approaches and steps are needed for approaching different types of impairments (see Appendix E). Not all sources will fit neatly into this recommended framework. However, our goal is to describe a framework that can be used not only locally at the WRIA or watershed level, but at the Puget Sound regional level.

Source identification and diagnostic monitoring provide an organized, step-wise approach to restore receiving-waters that have been identified as impaired by stormwater impacts. This approach provides tools to:

- Set priorities for investigation.

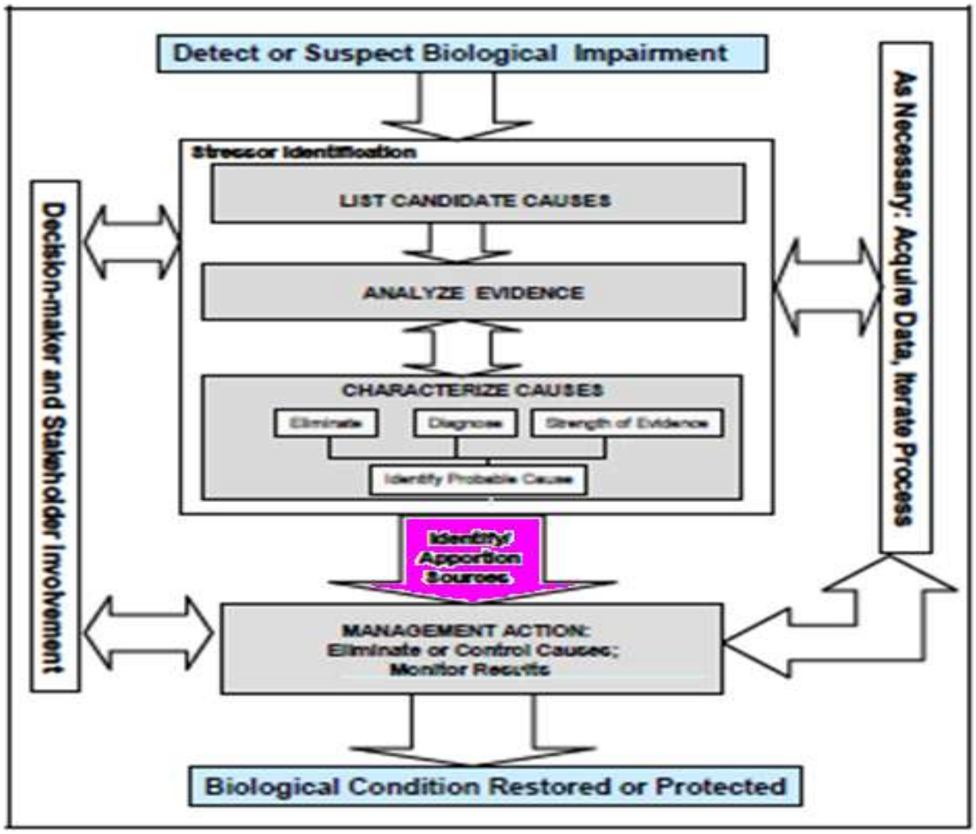

Figure E.1. The stressor identification process (EPA, 2000).

- Determine the locations and sources of stressors causing impairments.
- Identify the corrective action(s).
- Monitor to assess progress.
- Achieve the targeted goal of improved receiving-water conditions.

Stormwater adaptive management strategies are an integral key to the source identification and diagnostic monitoring framework.

Below are two example projects in the Puget Sound area of Source Identification Monitoring: City of Tacoma Thea Foss Source Control Strategy and Kitsap County Surface and Stormwater Management Dyes Inlet Fecal Coliform Reduction Project. The initial monitoring will focus on problems identified based primarily on existing water or sediment quality data that can be compared to water quality criteria or biological data that can be compared to regional reference conditions or other sites with similar development levels. Initially, flow and physical channel data will be used primarily for causal analysis (rather than problem identification). As flow and physical channel data are collected over time, trend analyses may identify additional problems related to stormwater. Basic approaches will be different based on the identified impairment being addressed.

Source Identification Example 1:

The Thea Foss Waterway is a high priority receiving water body in the City of Tacoma. Tacoma developed a stormwater monitoring and source control program for the municipal storm drains entering the waterway to help provide long-term protection of bottom sediment quality. The chemicals of concern were basin specific and included mercury, aromatic petroleum hydrocarbaons (PAHs), and phthalates. The goals of the monitoring programs were to measure the effectiveness of program activities, identify trends in stormwater quality, provide early warning of new sources and trace sources for correction/removal. Monitoring for this program included outfall characterization for both storm and baseflow events and storm system in-line sediment traps. See Figure E.2 for a flowchart of the steps followed.

Source Identification Example 2:

Kitsap County Surface and Stormwater Management responded to a TMDL study performed by the US Navy that indicated stormwater was a contributor of fecal coliform bacteria to the marine waters of northern Dyes Inlet. Kitsap County developed and implemented a fecal coliform source control program which identified the contaminated stream segments, implemented enhanced storm system maintenance in the public areas, and encouraged commercial property owners to improve system maintenance, inspected private septic systems, and performed source control of dumpster and grease storage areas. These efforts resulted in statistically significant bacterial reductions in the streams and nearshore marine estuary.

E.1 Problems Identified Based on Constituent Concentrations

For problems identified based on water or sediment quality constituent concentrations, follow the IDDE-type approach outlined below:

1. Obtain relevant County and/or City GIS data and aerial photos for area that drains to identified problem location. Obtain other potentially relevant information if available (e.g., comp. stormwater plans, CIP plans, TMDL studies, H&H models). Identify key natural and manmade drainage systems. Prepare base maps for source tracking.
2. Screen available data, such as stormwater outfall monitoring data, to see if there's an obvious source/cause for observed problem. Focus on areas close to drainage systems.

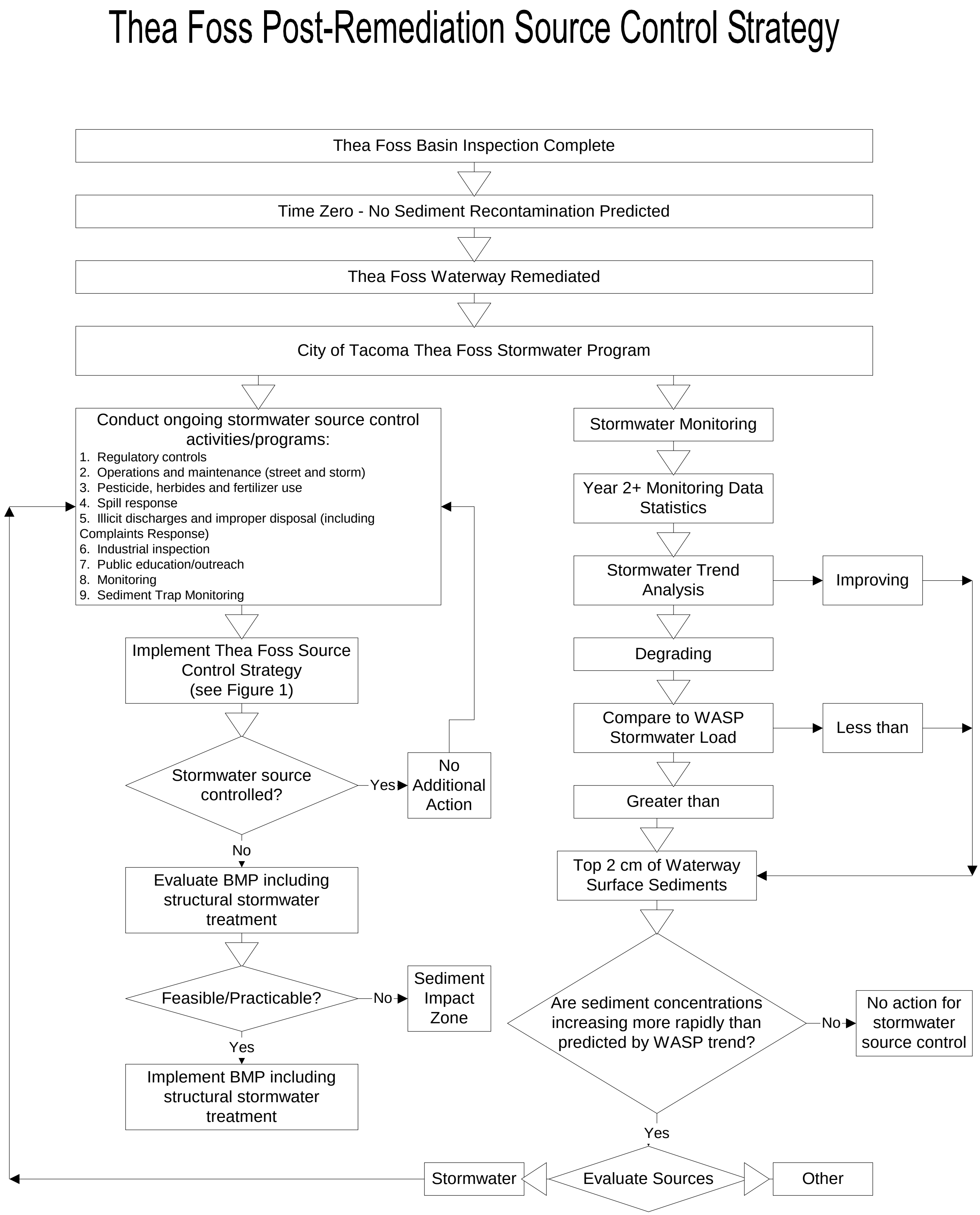

Figure E.1 Example process to develop and implement a source identification and removal plan.

3. Identify potential source indicators for observed problems (e.g., large stormwater outfalls, land use/land cover, soils, road density, road crossings, road miles within stream buffers, eroding areas visible on aerials, planned CIP, baseflow data, etc.). Meet with municipal O&M staff to review preliminary maps and evaluations, identify other known or suspected sources, confirm priorities, and develop a field reconnaissance approach. Delineate areas to be included in field reconnaissance.
4. Conduct field reconnaissance to look for visual evidence of potential sources along key transport pathways. Meet with owners/operators of potential source areas.
5. Evaluate the results of Steps 1-4 to determine the next steps.
   - If the key source or cause of the problem is evident and the entity has the necessary resources, develop and implement an early action source control plan (need a reference here). The control plan should include post-implementation monitoring to confirm that source control objectives have been met.
   - If the key source or cause of the problem is evident but not controllable within the entities' available resources, prepare a capital project scope and budget for development of a source control plan. After the requisite funds have been secured, prepare the source control plan. If the plan calls for capital improvements or additional staff, prepare a capital project scope and budget for implementation of the recommended measures.
   - If more comprehensive monitoring is needed to trace or confirm sources, develop a monitoring plan tailored to local conditions and the constituents of concern. Follow the general procedures outlined in the IDDE manual or similar regional approved protocols. Consider the full range of potentially applicable monitoring approaches (e.g., dry weather sampling of sediments in catch basins and ditches; synoptic water sampling during runoff events; passive samplers; continuous conductivity or turbidity monitoring; microbial source tracking).

E.2 Problems Identified Based on Biological Monitoring

Poor biological conditions can be related to a wide range of stressors. Therefore, a more comprehensive approach is generally needed to identify the likely sources or causes for biological impairment and support development of corrective actions. The general steps are outlined below:

1. Obtain relevant County and/or City GIS data and aerial photos for area that drains to identified problem location. Obtain other potentially relevant spatial information if available (e.g., comp. stormwater plans, CIP plans, TMDL studies, H&H models). Identify key natural and manmade drainage systems. Prepare base maps for source tracking.
2. Review available data to see if there's an obvious source/cause for observed impairment. Focus on areas close to the receiving water body and its natural and man-made tributaries.

3. Perform an initial screening to identify potential stressors as described in EPA's Stressor Identification guidance manual (EPA 2002). Figure E.1 above shows EPA's recommended approach for diagnosing the causes for biological impairments and developing management actions to address them.
4. Evaluate the results of Steps 1-2 to determine the next steps.
   - If the key stressor is apparent and the entity has the necessary resources, develop and implement an early action stressor reduction plan. The plan should include post-implementation monitoring to confirm that plan objectives have been met.
   - If the key stressors are evident but not controllable within the entities' available resources, prepare a capital project scope and budget for development of a stressor reduction plan. After the requisite funds have been secured, prepare the plan. If the plan calls for capital improvements or additional staff, prepare a capital project scope and budget for implementation of the recommended measures.
   - If the key stressors are evident but there are no technolog for effective treatment, then work for source elimination. If the key stressors are evident but are not within the purview of the permittee, coordinate efforts with the responsible party and regulatory agencies.
   - If more additional monitoring is needed to trace or confirm stressors, develop a capital project scope and budget for preparation of a stressor investigation plan tailored to local conditions and the stressors of concern.
   - Entities that do not have sufficient staff time and/or technical expertise will need to engage outside help for stressor identification investigations, development of response plans, etc. Perhaps the entities engaged in the status and trends monitoring program could assist with these activities.

E.3 Estimated Cost to Implement Source Identification and Diagnostic Monitoring

The cost to develop a source identification and removal plan is dependent upon several factors including the size of the sub-basin, the source, the management actions and the extent of the impairment. Two cost estimate examples are provided below:

<u>Example 1</u>: City of Tacoma Thea Foss Basin Source Control Program (De Leon and Thornburgh 2009)

Impairment: Metals, PAHs, DEHP in sediment.

Implementation Activities: Source tracing investigations, business inspections, data analyis/reporting, program management.

Cost: $260,000 annually 2007-2011.

Monitoring: Stormwater outfall and storm system sediment trap 2007-2009 $5 million, 2009-2010 $6 million.

<u>Example 2</u>: Kitsap County Health District North Dyes Inlet Restoration (Bazzell 2009)

Impairment: Fecal coliform bacteria, marine nearshore receiving water body and stream.

Implementation activities: Septic system inspections, commercial property inspections, source control tracing and correction.

Cost: $350 per septic inspection, $160 per commercial property inspection, $1,000 per source control tracing. Total program cost for 250 properties $110,000 2003-2006.

Monitoring: $10,000 annually for fecal coliform trend monitoring and tracing.

Appendix F Selecting and Developing Designs for Effectiveness Studies

This chapter provides additional details needed for selecting and developing study designs to assesss effectiveness of management approaches. This chapter also lists initial example questions that can be used to develop working hypotheses for each of the five effectiveness monitoring focus areas, acknowledging that additional hypotheses could be added over time. It also presents detailed cost information for a range of possible types of effectiveness studies.

F.1 Collecting the Right Information: Data Quality Objectives for Effectiveness Studies

After a specific question has been selected and an appropriate monitoring design developed to answer the question, the next step is to identify the type and amount of data to be collected. Data Quality Objectives (DQOs) refer to the precision and accuracy of the data needed to answer the question. Too much data (oversampling) is unnecessarily expensive, and too little data can doom a project to irrelevance.

DQOs can be interpreted in a strictly statistical sense, for example, in terms of the acceptable uncertainty associated with estimates (e.g., the error bars around estimates), or in terms of the probability of making a wrong decision (e.g., false positives or false negatives). DQOs may also be interpreted more broadly in the sense of an overall process to collect reliable data that will answer the question in a meaningful and complete way (EPA, 2006).

Law *et al*. (2008) provide a series of questions to guide the development of effectiveness studies. Several of their questions support thinking around what types of data to use and the quality of the expected data.

- *What factors should be considered when selecting study sites?*

  The study sites should be representative of conditions or situations that the study is designed to address. Alternatively the study sites should be representative of the most commonly found conditions; one way to insure this type of representativeness is to sample randomly. Other covariates that could affect the outcome should be considered, e.g., surrounding land use for a street sweeping study, age of structure for a retrofit study, or demographics for an education survey.

- *What minimum data are needed to characterize site conditions?*

  Often the preparatory work is equal to the amount of effort spent collecting the data. Desktop analysis may be extensive to locate appropriate study sites that are representative and safe to sample. This step focuses on the ancillary data needed to describe, select, and later evaluate the data collected from the sites. Only data that will contribute to the final analysis or interpretation of the study question should be collected. At this step the indicator list is carefully pruned.

- *How much sampling effort is needed to get reliable data?*

  The most important outcome of this step is that the data collected are adequate to answer the study question with an acceptable level of precision; in other words, to avoid collecting data that are too imprecise to answer the study question in any definitive way.

  The number of site-visits and samples are easier to define for some studies than for others. To estimate the needed number of data points for a specified level of statistical confidence, the statistical model must be defined (e.g., a paired design to compare toxic concentrations upstream and downstream of the LID development) and an estimate of variance must be available. National databases are available to obtain estimates of variance from similar projects.

  Statistical power analysis can be used to estimate the confidence associated with different outcomes and different sample sizes. Law et al. (2008) provide table values and other sources for calculating sample sizes for standard statistical tests. For projects that have no variance estimates available, the statistical test should still be specified and applied to some good guesses of what the data will be in order to evaluate whether the statistical approach will be appropriate.

  Although statistical texts often specify a p-value < 0.05 and a statistical power of 0.80, the acceptable confidence limits can vary widely depending on the study. Nonetheless, expectations should be specified for the type of difference that would be statistically significant or meaningful to the investigator before collecting the data. An assessment of the study design should be made to determine whether the data collected will meet the expectations.

- *What are the special data management and quality control considerations?*

  This step summarizes any unusual considerations for the type of data being collected. Examples might include chain of custody requirements, limited access to selected sites, or sample handling instructions. Any problems that are likely to occur and can negatively impact the value of the data should be emphasized during the data collection process.

F.2 Indicators to Track Effectiveness of Stormwater Management

Effectiveness studies provide unbiased information about whether specific stormwater management actions and programs are reducing, preventing or mitigating stormwater impacts to beneficial uses in receiving waters. Effectiveness studies' goals are:

- Providing data for adaptive management.

- Demonstrating compliance.

Effectiveness indicators have constraints: They are meant to provide information about the success or failure of specific management actions. As such they must be of appropriate scale to screen out other possible causes of observed effects.

A proper effectiveness study assessment and prioritization scheme will be applied first to existing programs and data in the form of a comprehensive literature review and a review of findings from existing programs.

Indicators for effectiveness studies will be highly dependent on the practice, scale, and scope of the technique, program, or landscape being evaluated. The goals of effectiveness studies are to provide data for adaptive management and to demonstrate compliance with applicable regulations.

In this context several factors can be identified for assessment as hypotheses are defined and study designs are developed, finalized, and approved.

- Reference Conditions
  - Paired watershed approach- the paired watershed monitoring protocol compares the response of two watersheds, with a documented relationship, when subjected to different management strategies and/or development patterns. One watershed usually serves as the control, where no changes occur, while the other watershed receives some kind of treatment. (From Watershed Protection Techniques 2(2): 587-594)
  - Pre- and post-treatment
  - Upstream/downstream treatment
- When to measure: consider intermittent nature of flows
- Spatial approach: to be successful, effectiveness studies must be highly aware of the spatial scale involved, and relatively small spatial scales (e.g., site or catchment) will be most effective in reducing influences from natural conditions or other actions.
- What to measure
  - Water quality (chemical and physical)
  - Biological indicators
  - Behavioral and attitudinal changes
- How to measure: standards and criteria
  - Human health criteria
  - Aquatic species criteria
    - Fish
    - Macroinvertebrates
    - Plankton and algae
  - Habitat criteria
  - Other

F.3 Example Questions to Guide Designs for Initial Effectiveness Studies

For each of the hypotheses-driving questions below, we recommend that the following information be developed in detail to allow refinement of questions into working hypotheses: 1) who will be responsible for implementation; 2) when is implementation recommended; 3) what are the recommended methodologies for implementation; 4) where is the geographic scope for implementation; and 5) how will this be funded?

1) **The proposed initial example questions for testing the effectiveness of LID techniques to minimize impacts from new development and redevelopment are:**
   i. How effective are LID BMPs at flow control and pollutant removal for stormwater, and are they protective of groundwater?
   ii. Flow in small streams over time – Is application of Ecology manual, or local technical equivalents, making a difference?
   iii. Can a full complement of the LID approach and techniques, used throughout a sub-basin, prevent measurable harm to sub-basin (as measured by flow changes and/or pollutants)?
   iv. On a basin basis, what percentage of LID infiltration enters the local aquifers and what percent is interflow that enters the municipal separated storm sewer system.
   v. What is the relative effectiveness, in terms of flow control and/or pollutant control, of certain land use planning practices (e.g., retention of native vegetation, reduction of impervious surfaces, clustering, reduced building footprint, etc.)
   vi. How effective is LID along state highways, for flow control and treatment?
   vii. For LID, what are the costs of construction sequencing and inspections; operations and maintenance inspections and enforcement; source control education; and long term maintenance and replacement when compared to other management approaches?
2) **The proposed initial example questions for testing the effectiveness of retrofit techniques to decrease impacts from the built environment are:**
   i. Flow in small streams over time – Is application of Ecology manual, or local technical equivalents, making a difference?
   ii. Does retrofit of older residential development (no or inadequate flow control, no water quality) produce statistically significant results for flow control and pollutant removal over one with no retrofits?
   iii. Which mix of BMPs (LID and conventional) provide the greatest flow control and pollutant removal benefits in retrofit projects for the best cost?

3) The proposed initial example questions for testing the effectiveness of operational and programmatic approaches used in stormwater programs are:

i. Are current erosion and sediment control programs effective?

When: can be started immediately as it is a predominantly a paper exercise.

ii. Are targeted education programs significantly changing behaviors to reduce stormwater pollutants?

When: already required in current Phase I-II permits, but finding it very difficult and expensive to do individually and makes more sense as a regional approach rather than by individual. Could potentially be done by enhancing the STORM program.

iii. Beyond counting catch basins cleaned, are “pounds- removed” an adequate measure of protection (removed from environment), habitat protection (sand away from fish gills), or is more needed, such as particle size distribution, depth of sump, etc.?

iv. What is the optimum level/regime of ditch maintenance to protect water quality?

v. Is the current set of implemented Natural Resources Conservation Service Best Management Practices (BMPs) at existing agricultural sites achieving long-term reductions in pollutants and meeting water quality standards at points of discharge?

a. **Who:** The Conservation Commission will work with Puget Sound conservation districts, the Washington Department of Agriculture, and members of the Agriculture/Water Quality Workgroup (NRCS, DOE, EPA, WA Dept. Ag) to further refine the methodology and implementation of the effectiveness monitoring of agricultural BMPs. The Conservation Commission will seek funding, lead, and coordinate the project.

b. **When:** This is a high priority need as elevated by the Agriculture/ Water Quality Workgroup, and the results of this study are germane to the Stormwater Work Group. Work should start as soon as funds and a more complete study design are obtained.

c. **Methodology:** Either a paired-watershed or an upstream/ downstream, before/after design would be used (Clausen and Spooner 1993; Plotnikoff *et al.* 2006). Suggested parameters are: water temperature, dissolved oxygen, conductivity, pH, total suspended solids, nitrogen, nitrate/nitrite, phosphorus, turbidity, fecal coliform, ammonia, and pesticides with more refined tailoring after choosing the specific monitoring areas and examining the current land use and type of agriculture production at each site.

d. **Geographic Scope:** It is recommended that monitoring target areas of more intense agricultural activity. The results and methodology used to determine these priority areas can be found in Appendix 1.

e. **Ideas for resources:** Natural Resources Conservation Service, Puget Sound Partnership, Department of Ecology, Conservation Commission.

vi. What is the optimal mix of industrial non-structural/operational BMPs to reduce targeted pollutants at point of compliance?

vii. What are the optimal industrial structural BMPs and/or mix of BMPs for reducing targeted pollutants at point of compliance?

viii. What is the relative effectiveness of street cleaning?

ix. How effective are business inspection programs?

4) New and emerging techniques and technologies:

i. Investigate the effectiveness of new fecal coliform and metals treatment techniques, such as mycological remediation.

5) **Fill Key Data Gaps:**

i. What is the relative effectiveness, in terms of flow control and/or pollutant control, of certain land use planning practices (e.g., retention of native vegetation, reduction of impervious surfaces, clustering, reduced building footprint, etc.).

F.4 Cost Estimates for Effectiveness Studies

Costs for effectiveness studies can vary dramatically depending on the spatial and geographic scale and the type and scope of the study. Definitive hypotheses must be chosen, and therefore site distribution determined, in order for it to be possible to estimate specific costs for the initial effectiveness studies that will be conducted by SWAMPPS.

However, based on the work of others, we can give approximate costs for types of studies that fit into the categories of monitoring that are being proposed. This section includes cost tables from the Center for Watershed Protection report entitled *Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs, August 2008*.

The following five tables provide planning-level cost estimates for conducting various types of effectiveness studies. These tables are offered to provide a range of the possible level of effort that will be required to conduct not only the proposed studies but also the overall regional stormwater monitoring and assessment program. The information in the tables comes from the Center for Watershed Protection 2008. The estimates shown are for studies that range from about $30,000 to $250,000 each. It is anticipated that this range of costs will encompass the majority of the stormwater effectiveness studies conducted in the Puget Sound region.

Table F.1 describes a two-year budget for studies that can provide baseline data prior to an action taken and data after the action taken. Examples of the types of studies could include catchbasin cleaning efficacy, education programs (pesticide use, pet waste pickup, for example), roof pollutant loadings prior to disconnection, etc.

Table F.2 describes a two-year budget for studies that examine the effectiveness of stand-alone structural treatment practices. This would be applicable for constrained LID practices, such as rain gardens or bioretention facilities, or for testing new practices, such as mycological remediation.

Table F.3 describes a discreet project that performs implementation and longevity surveys of STPs. This would be applicable for studies such as implementation of erosion and sediment control practices on construction sites, maintenance of LID techniques, and catchbasin maintenance adequacy, for example.

Table F.4 gives costs for a three-year study that is designed to evaluate the changes in behavior resulting from a stormwater education program. This is a survey exercise.

Table F.5 shows the budget for a traditional paired watershed study conducted over four years to assess the effectiveness of treatments or practices in one basin to a basin in which no treatments or practices were used. It is cautioned that costs can run much higher that the amount given (their example was up to $1.3 million dollars).

Table F.1. Example budget for residential law fertilization source area monitoring study (CWP 2008)			
Source Area Sampling	**Staff Resources**	**Unit Cost**[1]	**Total Cost**
Monitoring 12 sites (10 lawns, 2 control), 20 storms			
PLANNING (25%)			
Background Research (incl. data acquisition)	40 hours		$2,000
Desktop analysis	32 hours		$1,600
Field reconnaissance for final site selection (incl. homeowner interview and permissions)[2]	80-100 hours		$4,000-5,000
Project scope and sample design	40-80 hours		$2,000-4,000
Develop monitoring plan	40 hours		$2,000
Planning Subtotal			**$11,600-14,600**
IMPLEMENTATION (75%)			
Equipment and supply costs[3] (e.g. latex disposable gloves, sample bottles, sample collection device, coolers for sample storage)			$6,250
Training(staff and/or volunteers)	3 day, 2 staff		$1,600
Sample collection, storage and transfer[4]	240 hours		$12,000
Sample analyses 5 (TSS, BOD, TP, TN, TKN, NO2, NO3)		$120	$14,400
Data analysis and interpretation	80 hours		$4,000
Final Report	80 hours		$4,000

IMPLEMENTATION SUBTOTAL			**$36,250**
TOTAL			**$53,850-56,850**

[1]Assume $50/hr

[2]Allows about 1-hour per site to include travel

[3]will vary based on method(e.g. grab bottle to complex sampler design), assume a 25% replacement cost

[4]20 samples, collected per site. Allows 1-hour per site to included travel, site maintenance, rainfall measurements

[5]10 of the 20 sampler are "keeper" samples, see Appendix C for cost estimates

Table F.2. Individual Structural STP Monitoring Budget for Simple and Complex Situations						
	Simple STP Monitoring Situation			**Complex STP Monitoring Situation**		
	Staff Resources	Unit Cost	Total Cost	Staff Resources	Unit Cost	Total Cost
PLANNING	5%			6%		
Background Research (identify potential STPs, determine data needs and monitoring parameters)	40 hours	$50/hour	$2,000	40 hours	$50/ hour	$2,000
Desktop Analysis (major tasks include: preliminary site selection, preliminary site characterization, generate field maps)	32 hours	$50/hour	$1,600	32 hours	$50/hour	$1,600
Field Reconnaissance and Site Selection	32 hours	$50/hour	$1,600	32 hours	$50/hour	$1,600
Project Scope and Sample Design	16 hours	$50/hour	$800	32 hours	$50/hour	$1,600
Develop monitoring plan	8 hours	$50 hour	$400	16 hours	$50/hour	$800
Planning Subtotal			**$6,400**			**$7,600**
IMPLEMENTATION	**95%**			**95%**		
Equipment [1]			$15,000			$17,000
Equipment Installation and Maintenance[2]	256 hours	$50/hour	$12,800	512 hours	$50/hour	$25,600
Training	32 hours	$5/ hour	$1,600	32 hours	$50 /our	$1,600
Sample Collection[3]	512 hours	$5/ hour	$25,600	512 hours	$50/hour	$25,600
Sample Storage and Transport			$10,000			$10,000
Chemical Analysis[4]		$200/ per sample	$8,800			$8,800

Data QA/QC	40 hours	$5/ hour	$2,000	40 hours	$50/hour	$2,000
Data Analysis and Interpretation	80 hours	$5/ hour	$4,000	80 hours	$50/hour	$4,000
Final Report	80 hours	$50/hour	$4,000	80 hours	$50/hour	$4,000
IMPLEMENTATION SUBTOTAL			**$83,800**			**$98,600**
TOTAL			**$90,200**			**$106,200**

[1]Simple = 2 automatic samplers, triggering sensors, pump, lumber, concrete, battery waders, clipboards, field books, first aid kits Complex = 2 automatic samplers, triggering sensors, pump lumber, concrete, battery, pipe for underdrain, flow concentrator at inlet.

[2]Maintenance for simple assumes 1 person, 2 hours per week, for 2 years. Maintenance for complex assumes 1 person, 4 hours per week, for 2 years. Installation for simple assumes 3 people for 2 days. Installation for complex assumes 3 people for 4 days.

[3]Sample collection assumes 2 people for 8 hours for each storm event. A total of 30 storm events will be sampled and 2 base flow events. Out of the 30 sampled events, only 20 are expected to meet QA/QC standards.

[4]Chemical analysis assumes contract lab analysis for standard pollutants/constituents. One composted inflow and one composited outflow sample will be analyzed for a total of 20 storm events and 2 base flow events.

Table F.3. Budget for Monitoring the Performance of Population of STPs (CWP 2008)			
	Staff Resources	**Unit Cost**	**Total Cost**
PLANNING (17%)			
Background Research (compile local STP inventory, secure GIS mapping layers)	40 hours	$50/hour	$2,000
Desktop analysis (major tasks include: preliminary site selection, preliminary site characterization, generate field maps)	32 hours	$50/hour	$1,600
Site visit to verify STP information prior to making the final site selection	32 hours	$50/hour	$1,600
Project Scope	16 hours	$50/hour	$800
Develop Monitoring Plan	8 hours	$50/hour	$400
Develop Field Forms	16 hours	$50/hour	$800
PLANNING SUBTOTAL			**$7,200**
IMPLEMENTATION (83%)			
Travel and Supplies			$2,000
Conducting the Study	4 hours/site investigation	$50/hour	$10,000[1]
Data Management (entering field data)	2 hours /site investigation	$50/hour	$5,000[1]
Data Evaluation	40 hours	$50/hour	$2,000
Final Report	100 hours	$50/hour	$5,000
IMPLEMENTATION SUBTOTAL			**$24,000**
TOTAL			**$31,200**
[1]Assumes 25 sites with 2 investigations per site (wet and dry weather conditions)			

Table F.4. Example monitoring budget for a rooftop disconnection program (CWP 2008)		
Monitoring 12 sites (10 lawns, 2 control, 20 storms	**Staff Resources**[1]	**Total Cost**
PLANNING (16%)		
Background research (data acquisition incl. studies)	3 days	$1,200
Desktop analysis (major tasks include: preliminary site selection, survey sample population, generate field maps)	7 days	$2,800
Project scope and sample design	3 days	$1,200
Develop monitoring plan	5 days	$2,000
Subtotal		**$7,200**
IMPLEMENTATION (over 3-year period 84%)		
(note see Profile Sheet 1 for example source area monitoring budget)		
Supplies (GPS, cameras, street maps, postage* etc)		
Field Survey		
Perform USSR	16 staff days	$6,400
Survey		
Survey development	10 staff days	$4,000
Pilot survey[2,3]	25 hours	$1,250
Revise survey as needed	1 day	$400
Implement survey[2] & follow-up	2 staff, 60 hours each	$6,000
Training (both field and watershed behavior surveys)	2 staff, 24 hours each	$2,400
Data Management		
Data QA/QC	16 hours	$1,300
Data analysis and interpretation	10 days	$4,000

SUBTOTAL YEAR 1		**$26,750**
Repeat survey and source area monitoring Year 2[4]		$3,000
Repeat survey and source area monitoring Year 3[4]		$3,000
Final Report	5 days	$1,000
TOTAL		**$40,950**

[1]Assume $50/hr

[2]Allows 15 minutes per survey plus travel to site, cost will vary on survey method

[3]Administer 50 surveys, in person

[4]Cost of survey implementation

Table F.5. Budget for Monitoring the Cumulative Treatment Effect (CWP 2008)			
	Staff Resources	**Unit Cost**	**Total Cost**
PLANNING (20%)			
Background research (determine the control and treatment catchments)	40 hours	$50/hour	$2,000
Desktop analysis (site characterization, generate field maps, determine cross-section locations)	40 hours	$50/hour	$2,000
Project Scoping	32 hours	$50/hour	$1,600
Develop Monitoring Plan	32 hours	$50/hour	$1,600
Project Management	200 hours/year	$50/hour	$50,000
Planning Subtotal			**$57,200**
IMPLEMENTATION (80%)			
ISCO sampler with flow meter (2)		$10,000	$20,000
YSI6000 Turbidity optical sensor (2)		$5,000	$10,000
Sokkia Total Survey Station (1)		$6,000	$6,000
Digital camera (1)		$200	$200
Equipment Installation	64 hours	$50/hour	$3,200
Calibration Monitoring (2 years)	400 hours/year	$50/hour	$40,000
Treatment Monitoring (2 years)	400 hours/year	$50/hour	$40,000
Laboratory Analysis (for 10 storm events per year)		$1,500/year	$7,500

Data Management	100 hours/year	$50/hour	$25,000
Data Evaluation	200 hours/year	$50/hour	$50,000
Final Report	250 hours	$50/hour	$12,500
IMPLEMENTATION SUBTOTAL			**$201,600**
TOTAL			**$258,800**

Appendix G Data Collection and Data Management

For a functioning coordinated and integrated Puget Sound wide stormwater monitoring program, an initial and essential first step is to develop a coordinated and integrated data management system. A regional data management system is essential for collecting the data necessary at the quality necessary for monitoring stormwater impacts to Puget Sound, and would simultaneously provide a technical resource for data collectors. We strongly recommend that each data collector should not be required to independently to develop a data management system. Instead, monitoring data should be stored regionally in one primary database that is locally accessible. Monitoring data that is collected locally is far more valuable if it can be combined and compared so it can be put into a regional context. The data management should be available on-line to all entities in the region that collect stormwater monitoring data.

Multiple entities, including the Puget Sound Partnership, Department of Ecology, United States EPA, US Geologic Service, Snohomish County, King County, and others, have deployed, and/or are developing data management systems relevant to the stormwater monitoring and assessment strategy. Coordination between efforts is essential for successful implementation of a data management system.

G.1 Steps and Structures Needed to Ensure that Quality, Credible Data are Collected

G.1.1 Data Management

An online data management system initially comprised of locally collected monitoring data will provide an incremental method for the development of a regional database. Data collected for multiple local programs collectively will not provide a comprehensive dataset necessary to carry out the regional analyses necessary, whether effectiveness, status and trends, or source identification. But local data in an organized and accessible location will provide the necessary background data that the regional monitoring programs can be built upon. Additional data collections specifically designed to answer specific hypotheses and fill data gaps for these regional efforts can provide the data density and specificity necessary for hypotheses testing, and will provide additional data useful in evaluating the impact of stormwater on Puget Sound.

For a regional database to be of sufficient quality to be applicable to the hypothesis driven approach outlined in the Strategy report, data needs to be collected using a consistent level of precision and accuracy. The use of a Data Quality Objective (DQO) approach, developing Quality Assurance Project Plans (QAPP) is the appropriate level of organization and documentation to assure collecting data at the necessary level of quality. Acceptance of approved standard operation procedures (SOP) for both the local and regional monitoring is mandatory, and should provide a useful service to all permit holders.

G.1.2 Data Quality Objectives (DQOs)

Data Quality Objectives (DQOs) describe and document the type, quality and quantity of data needed to support the intended use of the data. Data requirements are established after understanding the context for which the data will be used to address a specific hypothesis. It is important to establish data requirements in advance of data collection and analyses to ensure that the right information is collected, using the appropriate methodologies and appropriate levels of accuracy. It is important to document the intended use of the data, quantitative measures and thresholds for decisions. While it may not be possible or necessary in all cases to develop quantitative thresholds, investigators are encouraged to think in these terms when possible and where it adds value to do so. This information also provides the basis for determining if the data is useful for addressing additional future and potentially not yet defined monitoring requirements.

While monitoring data is often collected to provide the quantitative information to answer a local or specific question (e.g. metal concentration in oysters in a particular bay, location of a fecal coliform source in specific creek), the documentation process established in the DQO allows an evaluation to determine if the data may be useful for multiple projects. The requirements for a piece of data to be useful in multiple contexts, the documentation, or metadata attached to the monitoring data needs to be collected and stored along with the quantization.

Planning for data collection that supports decisions involving large investments, high risk or political sensitivity will be more extensive and rigorous than for those studies where there is less at stake. It is important to complete the DQO process before a study is begun and identify the level of effort associated with responses necessary to collect data at the level of significance and nature of the study. For studies where environmental information will be used to make decisions with high risk and/or where a significant investment is made in the collection of environmental data, the DQO process should be followed comprehensively. For situations where environmental information will be used to make decisions that are low to moderate risk or the investment in data collection is limited, the DQO process can be less detailed.

G.1.3 Spatial Data

High quality, accurate spatial data is essential for implementation of a Geographic Information System (GIS), and it is also important to know if the spatial data will meet user needs. Metadata is a summary document providing content, quality, type, creation, and spatial information about a data set. It represents the who, what, when, where, why and how of the source data.

Keeping spatial metadata records is important and has multiple benefits an organization collecting or using spatial data. From a data management perspective, metadata is important for maintaining an organization's investment in the accuracy of spatial data. . Data users need metadata both to assess the quality of the data and to locate appropriate data sets. Metadata provides information about the data available within an organization or from catalog services, clearinghouses, or other external sources. Once data has been located, metadata defines how to interpret and use data. Any regional spatial analysis will require a review of data comparability that can only be carried out if the appropriate level of metadata is associated with the spatial data.

In 2003 the Washington State Information Services Board accepted a new Geographic Information Technology Standard that designated the State's preferred Horizontal Datum and Coordinate Systems. The standard mandates that all significant geographic data sets maintained by executive and judicial branch agencies and educational institutions … must store, or make their data readily available in, the North American Datum 1983 (1991 adjustment)," in addition, the data must be provided in the Washington Coordinate System of 1983 (a.k.a., Washington State Plane) or in a NAD 83 (1991) based Geographic Coordinate System. This should be the standard required for all geographic datasets collected as part of NPDES permit compliance. If any spatial data is not collected as part of a GIS, the data needs to have the same level of spatial accuracy as the Washington State Standards for electronic spatial data.

For a comprehensive integrated monitoring program for Puget Sound, a DQO for monitoring data should be developed to identify the standard protocols and necessary levels of data quality necessary so all monitoring data collected is comparable and has the necessary level of metadata associated with the data to make a data quality determination. Additionally, data collectors implementing each of the three monitoring components (Status and Trends, Effectiveness and Source Identification) should develop monitoring project-specific DQOs for each Quality Assurance Project Plan (QAPP). The project specific DQOs and QAPP should use the approved SOPs or provide documentation demonstrating comparable levels of MDLs, precision, and accuracy.

G.1.4 Quality Analysis Project Plans (QAPPs)

A Quality Assurance Project Plan (QAPP) is a written document that describes the quality assurance procedures, quality control specifications, and other technical activities that must be implemented to ensure that the results of the project or task to be performed will meet project specifications. Primary data collection, data usage, and data processing (such as modeling) project activities can be described and documented in QAPPs. A QAPP should be developed before beginning collecting data so that the desired quality in sample collection, laboratory analysis, data validation and reporting, and documentation and record keeping is achieved and maintained. A QAPP provides a written document that acts as a blueprint for the entire project and each specific task to ensure that the project produces reliable data that can be used to meet the project's overall objectives and goals. The QAPP defines specifically how the DQO will be implemented. Most monitoring programs require QAPP to be developed and approved prior to implementation of a sampling program. QAPPs typically contain the following elements, further description of these elements is found in (USEPA, 2001, EPA Requirements for Quality Assurance Project Plans):

- Title and Approval page
- Table of Contents and Distribution List
- Background of the Project

- A Project Description
- Organization and Project Schedule
- Data Quality Objectives (DQOs)
- Sampling Process Design or Experimental Design
- Sampling Procedures (or SOPs)
- Measurement Procedures
- Quality Control
- Data Management Procedures
- Audits and Reports
- Data Verification and Validation
- Data Quality Assessment/Usability

QAPPs should be designed to answer question related to data quality. The purpose of a QAPP is to provide a design that adequately displays whether or not data of sufficient quality and quantity are collected to meet the use for which they are intended.

G.1.5 Standard Operating Procedures (SOPs)

Data generated from stormwater monitoring is highly variable and often difficult to use to describe long term trends, determine the effectiveness of management actions, or determine source contributions occurring in Puget Sound. A Standard Operating Procedure (SOP) is a set of written instructions that can be used to describe a routine or repetitive data collection activity. SOPs can ensure reliable and representative monitoring data is collected. A series of SOPs often forms the backbone of a QAPP. Using SOPs to collect Puget Sound related monitoring data from various locations can assist with data pooling and data usability. The use of SOPs by all data collectors increasing the comparability of the data set and creates a common, larger dataset which increases the statistical robustness, accuracy, and predictive capabilities of the data analysis results. Additionally, by making a larger dataset directly comparable, smaller dataset benefit financially from the cost savings associated with comparisons with existing comparable data. By creating SOPs, data utility is maximized to ensure clear interpretation and comparability of results. SOPs provide a training tool (a written procedure) for field staff and/or consultants conducting monitoring that can help prevent unnecessary resource deterioration and enable stormwater managers to make management decisions with greater confidence. SOPs developed with this strategy can be made publicly available to assist other similar efforts State for stormwater data collection.

Anticipated outcomes of developing and implementing SOPs include:

- SOPs help ensure work is performed at a consistent and high level of quality in Puget Sound;
- Data are reliable and scientifically defensible;
- Data utility is maximized making it possible to clearly interpret monitoring results and compare data collected from multiple sources;
- Reliable monitoring data can be used to identify concerns early, while cost-effective solutions are still available;

- Common datasets with statistical robustness, accuracy, and predictive capabilities of the data analysis results; and
- Early detection of issues prevents further deterioration of Puget Sound.

For implementing this Monitoring Strategy, development of a list of needed sampling and analytical SOPs is important. This Puget Sound program will provide a robust monitoring design and implementation strategy. As part of the implementation strategy, SOPs should be identified and developed for each monitoring component (Status and Trends, Effectiveness and Source Identification) for use by data collectors.

G.1.6 Quality Control and Assessment

Once SOPs, QAPP and DQOs are developed for a specific monitoring program checks and compliance assurance is needed. While each QAPP has a Quality Control chapter, sometimes it is difficult for data collectors to ensure data is collected properly in accordance with a QAPP, SOPs or DQOs. This insurance is crucial for data comparability and usability. In provide such insurance would require compliance checks or quality control checks. To perform quality control check without bias, this is typically done by a third party or someone with knowledge of the program and data collection skills not tasked with data collection.

To insure data are collected properly, quality control for *field data* checks should be required. Frequency of quality control checks should be at the best professional judgment of the data collecting agency. The checks can help to evaluate if data are collected properly and in accordance with appropriate QAPPs, SOPs and DQOs.

G.2 Key Considerations for Developing a Data Management System

Listed below are some key considerations for developing a data management system to store and provide access to the information generated by the regional stormwater monitoring and assessment program.

1) Who are the data providers?

- What leverage does one have to get them to cooperate? (Making their life easier is a good one.)
- What resources do they have?
- What internal procedures do they have that impact when and how they deliver data?
- What political needs must be met?
- What would make them "happy customers"?

2) Who are the data consumers?

- What tools do they use?
- How do they want to interact with the data?
- What output formats do they prefer?
- Are there requirements to interact with other software systems? (e.g. "web services")

- What would make them "happy customers"?

3) Who is responsible for managing the data management system?
- Is their responsibility mandated or voluntary.
- What resources does this individual/team have?

4) What resources exist that are specifically dedicated to data management?
- Money
- People
- Hardware

5) What kinds of Authentication & Authorization are needed at which levels?
- Who is allowed to enter data?
- Who is allowed to extract data?
- What should be open to the general public?
- What kind of secure technology is mandated/desired?

6) What categories of raw data exist?
- sampling at a site
- time series (e.g. stream flow gauges)
- gridded fields generated from models
- other?

7) What other data needs to be kept track of?
- textual metadata
- GIS layers
- model output
- text documents
- other?

8) Validation
- How is the raw data currently being validated?
- Is it being done with software or by visual inspection?

9) Versioning
- How is raw data being versioned? (e.g. How are changes to the data store being tracked?)
- Can earlier versions be retrieved?
- How is released data ("output data", "summary data") "sous chef" concept being versioned. (Monthly release is one system.)

10) Provenance
- How is the history and origin of each data point being tracked as data goes from individual submissions to larger aggregations?

11) Transactional/Archival

- How frequently does data come in? (need precision at the second/minute/hour/day/month/year scale)
- How up-to-date should the released data. (Everything up to the last minute/hour/day/month/year?)

12) Raw Data Volumes
- How many actual measurements (not ancillary- or meta-data) are made and stored in a year? (thousand, million, billion, trillion?)

13) What sorts of interactive access should be provided?
- subsetting
- querying
- reformatting
- analysis
- visualization

Appendix H Response to Formal Peer Reviews and Public Comments on November 2009 Draft Scientific Framework

The SWG's current proposed scientific framework for regional stormwater monitoring is substantially revised from the November 2009 draft. Changes were based on the formal peer reviews and over 800 stakeholder comments we received, and on other new information. The SWG discussed the reviews and comments as a committee in five all day meetings over the course of December 2009 through March 2010 and continued making decisions about the details of the monitoring framework and the implementation plan through April 2010. Many subgroups of the committee addressed specific topics that were identified as key themes. New work was done to address some of the gaps identified by reviewers, to hone our priorities, and to improve our experimental designs.

H.1 Response to Formal Peer Reviews

The scientific framework is substantially revised from the November 2009 draft. Changes were based on discussions of the five formal peer reviews; consideration of the more than 800 stakeholder comments we received; and new work that was done to address some of the gaps identified by the reviewers, to clarify our purpose and scope, to hone our priorities, and to improve our experimental designs. Here is a summary of the SWG's response to the formal peer reviewers' comments. Appendix H includes the details of our discussions and decisions made to address these issues together with the issues raised in stakeholder comments.

Scientific peer reviews on the *Draft Stormwater Monitoring and Assessment Strategy for the Puget Sound Region Volume 1: Scientific Framework* were conducted by Rich Horner, Bob Pitt, Jean Spooner, Tom Schueler, and Steve Weisberg. Their complete written reports are posted at http://sites.google.com/site/pugetsoundstormwaterworkgroup/home/strategy-document-comments/formal-scientific-peer-reviews. Below are the major themes of their collective reports that the SWG discussed early in the process of revising the scientific framework. As a group, the SWG came to agreement as to whether and how to address each of these issues.

Gaps in the document, and thoughts on our approach and categories of monitoring:

- Need a more descriptive discussion of the problems caused by stormwater, their specific sources, and objectives of categories of management actions (i.e. to improve conditions or to prevent degradation). Do a gap analysis relating to specific sources/stressors/ controls prior to designing effectiveness studies, and focus on filling those gaps. Response*: We do need the gap analysis, and have taken initial steps to do conduct one. However we do not need another white paper on stormwater.*

- Biological focus is good, but be sure to measure indicators that have quicker and more direct responses to stormwater management actions, like pollutant loads, sediment contamination, and hydrology.
  Response: Agreed. We have included both types of indicators.
- Connect all three types of monitoring. Put more focus on status assessment and what specific stressors are being evaluated, and include baseline or reference conditions.
  Response: Agreed. Although the categories of monitoring serve very different purposes it was important that we think about and describe their relationships for our readers.
- Source identification approach is too limited: tie in compliance monitoring, characterization data, and illicit discharge survey information to help diagnose reasons water quality/beneficial use conditions are not met. Connect this to receiving water monitoring and do this prior to designing effectiveness studies to help define goals and get a better idea of how much control may be needed to achieve a biological response. Good idea to inform region-wide source control efforts.
  Response: Agreed. We have developed a new approach to this category of monitoring and described it in the revised scientific framework.
- Describe the analyses that will be performed.
  Response: We agree that all of the data that will be collected needs to serve a particular purpose, but we disagree that the specific analyses need to be described in this document. QAPPs are yet to be developed for all of the monitoring described herein and those documents will describe analyses that will be performed.
- Describe how the adaptive management framework will be used both to inform the monitoring and after reporting monitoring findings.
  Response: Agreed. We have intended to do this to the extent possible during development of the full institutional framework for adaptive management of ecosystem recovery efforts.
- Add a research category to help improve overall mechanistic understanding of stormwater effects and controls.
  Response: Agreed. We added the category but have neither identified priority topics for this category nor articulated a process by which those topics should be identified. This merits future work.
- Identify and include descriptive ancillary data about watershed conditions such as specific development land use/land cover metrics to help explain monitoring results.
  Response: Agreed. These details need to be articulated in each experimental design as QAPPs are developed.
- Explain the important role and application of various types of modeling to help managers use the data collected.

Response: Agreed. We have added a brief section and next steps to address modeling needs.

Conceptual model and priorities for monitoring:

- Fix the mix of beneficial uses and stressors listed in the table summarizing current understanding of the most significant stormwater impacts to beneficial uses (categorized by receiving water and major land-use category). It is confusing to readers and if made more stressor-effect specific can be better used to inform monitoring priorities. A few specific cells in the table were of concern.
  Response: The table served its purpose in helping the SWG articulate its priorities but was not sufficiently backed up by scientific references. We modified our approach to the conceptual model and offer a different table that we believe is less confusing.
- Overall, reviewers support an initial emphasis on small streams and nearshore, and probably would add lakes next.
  Response: Thank you. We have augmented our best professional judgment with a look at existing data that is presented in our revised section on monitoring priorities. We would like to address other water bodies besides small streams and nearshore areas in the future and also emphasize that water bodies of local concern still warrant local attention.
- Need to look at mosaic pattern of land development, including changes in infrastructure and treatment over the past decades.
  Response: We agree with this statement and are primarily addressing this issue within our proposed focus areas for effectiveness studies: retrofitting will take place in areas with older infrastructure and LID will take place in new development. The proposed inventory could be a useful tool and we will look into this further in future development of the source identification category of monitoring.
- Definition of stormwater needs to include human activities.
  Response: Agreed. We added non-precipitation-generated flows to our definition.

Hypotheses:

- Reviewers made numerous specific comments about individual hypotheses. In general, they were concerned that the set of hypotheses in the November 2009 draft document oversimplified the situation and may not provide the best approach for designing a regional monitoring program. Some suggested fixes included rewriting in a way that: not all of the hypotheses should be assumed true unless otherwise proven; consider more neutral statements, and/or more quantitative, stressor-specific statements; and consider a rating or ranking system. Reviewers also suggested that we conduct a literature review and look at findings elsewhere.
  Response: Agreed. We took a more thoughtful approach to translating our assessment questions into hypotheses for this version of the scientific framework. As a result we are at different places in articulating the hypotheses for each category of monitoring. We also include literature reviews as early

implementation steps, most particularly to inform our selection of hypotheses for effectiveness studies.

- Need more definition of "increased or improved stormwater management efforts."
  Response*: Agreed, particularly for effectiveness studies. For status and trends monitoring we are looking at broad, programmatic efforts and therefore can be more general. In selecting testable effectiveness hypotheses, we will describe: the specific type of actions targeted for evaluation, why we are targeting each action (the potential relevance of the actions to correct regional problems), and assumptions about its effectiveness.*
- Effectiveness studies need more focus on specific beneficial use endpoints.
  Response*: Agreed in principle, however in practice we will initially focus on more proximate indicators and perhaps articulate research needs to tie reductions in stressors to improvements in beneficial uses.*
- Address construction phase impacts from which beneficial uses might not recover.
  Response*: We agree that these impacts are important to understand better, but beyond our highlighting impacts of hydrologic alterations these changes were not identified as a priority topic for investigation in the initial phase of the regional monitoring program.*

Experimental designs:

- Difficult to determine cause and effect for the chosen designs.
  Response*: We have substantially revised our experimental designs, and attempted to be more specific about what we can and cannot infer from findings of each type of monitoring.*
- Concerns about probabilistic design, analyses, and about parameters selected need to be addressed in evaluating and rewriting Experimental Design sections and appendices.
  Response*: This section has been revised and the concerns addressed to the extent that we were able. Future work will need to address unresolved issues.*

The reviewers also offered many comments about implementation planning, including the importance of having an overarching strategy to assign roles and responsibilities, establish standard methods, and coordinate/manage the information that is collected. The reviewers' input related to implementation planning was considered in developing the following chapter of this document and will continue to inform later work by the SWG.

H.2 Key Themes in Public Comments

This section provides more detailed information about how we discussed the stakeholder comments and how we decided to revise the scientific framework.

To help manage the large number of public comments received on the November 2009 draft, a subgroup of the SWG members divided up the stakeholders' comments among themselves for compilation and each identified and summarized the key themes in the sets of comments they reviewed. Here is the list we collectively compiled:

1. Table 1 - blanks and potential flaws in linkages, inconsistent entries (beneficial uses vs impacts). Suggest transportation as land use, rivers a main source of mass loading of pollutants to PS (should be filled in for 3 land uses), runoff from commercial and industrial sources impacting marine water quality and contact recreation in small streams, runoff from residential, commercial and industrial land uses cause habitat damage and contribute to flooding. Chronic/sublethal toxicity is not mentioned. Highways should be own category. Concern that homogenous land covers do not exist and that there will be many confounding elements to any stormwater monitoring design. Inclusion of urban embayments/industrial areas as monitoring sites. Expand the list of categories evaluated. Wide agreement on forestry, but also divide residential into subcategories, and also add transportation.
2. Including transportation as a separate monitoring component. "How does this approach fit with the current regulatory (and monitoring framework), wherein the DOT is not permitted with the munis but instead receives its own NPDES Permit? Will excluding highways as a targeted land use for monitoring and assessment limit Ecology's ability to improve the WSDOT permit over time? Or are we missing an opportunity to engage the EO T more fully in this strategy?"
3. Like macroinvertebrates/biological end-points, but question whether stormwater impacts can be teased from other influences (salmon too removed) and need more clarity on statements like “population health.” Support for using beneficial uses as indicators, but also concern about using salmon due to the many influences beyond stormwater. Difficult to tease out stormwater impacts when monitoring fish health for status and trends monitoring. "How will you measure “improving population health over time in Puget Sound” for the fish hypotheses in both streams and nearshore areas? The confounding variables that affect fish are quite numerous. In addition, what does “population health” really mean? The devil is in the details on this one for sure."
4. Need for explicit connection to decision making processes and managers. Coordination and information exchange needs better explanation, especially coordination with public and the link to decision-makers.
5. Not good understanding of linkages (or lack thereof) between types of monitoring (status and trends, effectiveness, source control – and how does Industrial permit monitoring fit?). Need better linkage to actions to be adaptive.
6. Clarify the use of “hypothesis.” Discuss the definition and application of working vs. experimental hypothesis. “To further clarify the use of hypotheses in this document, it should be noted that in developing and using hypotheses there is a distinction between ‘working hypotheses’ and ‘experimental hypotheses.’ Working hypotheses are affirmative conjectures that propose a condition, affect, or outcome in the system being evaluated. Experimental hypotheses are the “null” hypotheses posed in experimental studies that attempt to falsify the working hypothesis. Working hypotheses cannot be ‘proved’ per se by the collection of experimental data. Rather, working hypotheses are increasingly supported by the accumulation of observational or experimental tests of the working hypothesis. If these tests fail to show evidence contrary to the working hypothesis, the working hypothesis continues to be

supported. This is the traditional use of working and experimental hypotheses in the scientific method."

7. Missing link of modeling, and loading and characterization of stormwater. Comments regarding utilizing modeling in place of some status and trends monitoring, because can't do everything everywhere, and also the loading characterization piece came back. Is there a relationship between these two in the desire to know how much is coming from where? and showing improvement over time? Can these be linked with permanent long term land use sites for loading/ characterization/status-trends/ and the desire to measure decline or improvement?
8. Need to summarize and use existing programs/knowledge in establishing the sampling design – feel that some of these hypotheses have already been answered or that we could refine the design better. Compilation/analysis/incorporation of current data. Starting to move forward with what we know now.
9. Technical questions about random approach to status and trends – whether it should be classified/stratified/some non-random/etc. – while they like the focus on small streams/nearshore, some concern that rivers/major river mouths are not specifically addressed (both in design and table 1).
10. Scale-a preference to monitor effectiveness and source control at the sub-basin scale. "We know that LID/Green Stormwater and source control work at the site scale, it is recommended to assess on the sub-basin scale whenever possible and not on the individual techniques."
11. Add operations and maintenance as a hypothesis "...at least some limited assessment of the benefits of inspecting and maintaining permanent BMPs." and "Any testing of BMPs should include an O&M component. A treatment device is useless if it requires constant operational care and/or frequent maintenance."
12. Flow as the primary measure of impacts on streams.
13. Source control hypothesis by contaminant of concern rather than site.
14. Lots of work needs to be done on the experimental designs, including developing QAPPs, agreeing on parameters, sampling sites, methods, data analysis methods, relationship to local monitoring efforts, etc. Lots of comments on specific technical sampling details to be added in Appendices E and F. How do we resolve the problems of automated samplers with regard to particle size.
15. Chemical and physical parameters for status and trends monitoring vs. biological endpoints, when the framework defines success as ecosystem integrity.
16. Commercial land uses in LID effectiveness.
17. Source control at permitted industrial sites or unpermitted parking lots and rooftops from big box stores.
18. Table 2 needs work – mix of outcomes, approaches, activities is confusing.
19. Skeptical about local governments supporting monitoring without changes in penalties (303d lists) and also need to recognize other factors in decision-making besides environmental data.

20. Concern about schedule for finishing, and the potential need for additional review or additional revisions to the scientific framework.

H.3 SWG Decisions to Revise Scientific Framework Based on Comments

The SWG grouped the key themes in the public comments with the themes in the peer review comments to ensure that we discussed all of the major issues as a group. Subgroups were assigned to address detailed technical issues raised. This section provides the record of the decisions made by the SWG in considering each of the key themes identified in the peer review and stakeholder comments. The complete 20-page documentation of the discussions and our 84 consensus decisions is available at http://sites.google.com/site/pugetsoundstormwaterworkgroup/home/strategy-document-comments/swg-decisions-on.

H.3.1 Scope and Purpose

Clarify the purpose of the SWG monitoring program and how the strategy document supports the SWG's purpose. Don't accept a task that was never ours to accomplish (nor could be accomplished). Use our charge from ECY and PSP, based on the Monitoring Consortium's recommendations, as our foundation (caucuses have accepted this). Remove contradictory statements in Task 4 of work plan and strategy – make sure documents are fully aligned. Modify based on all of the decisions we've made to this point.

<u>All water bodies and land uses</u> need to tie in. However, this document recommends the initial regional stormwater monitoring program focus on small streams, nearshore areas, and the full spectrum of urbanizing lands. Local priorities driven by other issues remain inherently supported.

<u>Unregulated Stormwater</u>: areas with no permits: These areas are covered by the scientific framework we've proposed. How to support and conduct any monitoring proposed for these areas will be addressed in implementation.

H.3.2 Conceptual Model (formerly Table 1 and Figure 2)

Include the elements in the subgroup's conceptual model: aquatic ecosystems, drivers, pressures, states, etc. – use the DPSIR model (and PSP indicator process) components and use open source language to describe how we'll use the monitoring information for adaptive management. Concern remaining that this doesn't depict stormwater impacts well

Include the arrows illustrating relationship between the elements. Make them all the same size except for the pathways (label added); add arrow from impacts to ecosystems

Include the specific examples included in each of the element boxes. Subgroup will continue to refine the content of the boxes. Figure in general is good enough to meet our purpose.

Include as a separate figure the "Watershed Characteristics" model ***as an example*** of a more specific conceptual scientific model for evaluating stormwater. Highlight areas where our hypotheses are targeted. Describe it as a useful approach and be clear about our intent.

H.3.3 Adaptive management

Restructure the primary document organization around types of monitoring, not adaptive management and retain adaptive management discussion.

- Acknowledge that the document did suffer from confusion and breakout: keep brief discussion of AM up front (it frames the entire strategy, not just the scientific framework). In Section 1 of our document, intro/purpose: Keep 1.4 and Reduce/edit 1.5 and 1.6 to key bullets and include in sidebars. And add transition text (how Adaptive Management applies to each type of monitoring)

Either describe the institutional framework for the full adaptive management cycle (that is, inform monitoring and report findings) **OR** say that the job of this document is not to define that institutional framework and let this go. This is governance, so state the latter in the scientific framework – goes in implementation plan.

H.3.4 Connect Trio of Monitoring Types

Use a watershed approach to tie the three types of monitoring -- this is one of the scales at which we could do monitoring

Tie the different types of monitoring together more closely in terms of stressors where we can, depending on the purpose of the monitoring. Don't restrict ourselves to a single list of indicators for the three types of monitoring. Do a better job of showing the linkages and how it all works together. Status and trends monitoring is biota-based and other types are stressor based. How do we link them (need to know what is causing negative impact to beneficial use)? Acknowledge this is an issue that we need to decide how to address in source identification monitoring. We are addressing this, needs to be in both volumes in parallel. Source id section was too slim in scientific framework.

Add Horner's ideas to our descriptions of our three categories: works for status and trends. We've described how monitoring applies, and need to link things together logically and clearly describe how change is made. Are there goals for all watersheds in PS that suit this approach? Do biotic endpoints suffice for this? Extrapolate based on what learning in certain areas?

Start with the stressors/problem for the region or in a particular watershed (use info from status and trends monitoring to direct source ID efforts and prioritize effectiveness monitoring). Prioritize monitoring across categories, based upon impact. Tie status and trends monitoring and management actions to the impacts in that watershed. See also figure 2/table 1 discussion topic.

Address uncertainty range as an overarching goal of the strategy – articulate credibility and confidence in each of our experimental designs.

- Add a paragraph: we need to address our collective/joint ability to sustain the effort to provide the answers we need with appropriate study designs and prioritized our efforts.
- Also articulate scale, how much, how often, and what we get for the effort. Be honest and transparent in approach to creating the overall study design, ensure that level of confidence is clearly articulated and appropriate for decision makers.

Focus on characterization is in source identification section [Define characterization (variation in relevant indicators/variables across the landscape and through time), the need for it in various studies, and what info we can get out of literature for a particular study. Relate back to an identified problem (status and trends, existing literature, etc). Where are sources of problems and how much is coming from each source, to inform actions.

- Will need a certain characterization study design to calculate loads (not currently in strategy). Different data gap.
- Might be included in a research category – separate discussion

State in text that the example hypotheses in the revised scientific framework (as modified per above decisions) will be a starting point, and that we recognize that they are not necessarily everyone's highest priorities, and likely will change. Acknowledge the prioritization process we went through, ensure we pick indicators that help us separate out stormwater impacts.

Include short discussion/definition/purpose of hypotheses in Strategy. As a base, consider Spooner's <u>Goals and Hypotheses</u> (in her peer review). Also consider Bill Taylor's comment about "working" hypotheses.

Include concept of "power" of statistical tests. Add to the text a discussion of data needs for specific hypotheses with experimental design.

- Power analysis is important and should be done before studies implemented, but too early to provide this level of detail

Include discussion of necessity of a literature review. <u>Stress importance of using existing data (particularly local data) to inform stormwater monitoring efforts</u>.

Do not respond to each detailed critique of a particular hypothesis. Rather, consider a general response that the hypotheses in the draft strategy are starting points. Additional hypotheses will be decided after detailed discussions of issues (appropriate scale, level of confidence, study design, power analysis, QA/QC, etc.) among specific stakeholders.

Describe purpose of Indicator Monitoring? How will data be used?

- To measure the state of the system
  - Not to diagnose problems
- To determine if stormwater management actions are protective of, or restoring, resources.
- To measure improvements or decline in a biological endpoint.
- Useful:
  - To determine which water bodies are to be 303(d) listed.
  - To determine the miles of streams in poor health.
  - To provide data for modeling

- o To provide data for mass loading to PS.

Conduct ongoing Puget-Sound-wide analyses of stormwater-related indicators and syntheses of stormwater-related scientific knowledge

Start a "parking lot" for details and issues that could be helpful at a later phase of implementation.

Analysis of Phase I monitoring info should inform the starting point

Loadings/Characterization. Add text to document that says: We need a literature review before specific studies can be implemented

- We need to evaluate existing monitoring before implement more monitoring. Integrate existing outfall information where possible. As appropriate, evaluate data from Phase 1 monitoring and other NPDES permit-related monitoring (industrial, boatyard, shipyard, etc. for early identification of problem sectors, areas, and information gaps)
- As relates to Experimental Design: At some point in experimental design the assumptions being made should be clarified and explicitly stated. What is the "prevailing knowledge" about the relationship of concentrations, flow rates, volumes, loadings, sediment transport, particle size, etc.? Reference should be made to a prevailing theory, a reference, or perhaps some topics should be the subject of a white paper so that monitoring participants and study designers will be aware of background assumptions.

Do not adopt the structure in Horner's suggestions for a four-tiered approach that incorporates our three approaches and melds them with characterization and research but instead keep our three categories AND use his ideas.

H.3.5 Literature Review

Do initial step of reviewing existing data and programs must be a foundation for all later work. This analysis would include a thorough catalog of watershed land-use metrics, identification of stressors, a prioritization of at-risk watersheds, an identification of what techniques are most effective in which watersheds, and what are the data gaps and needed research. Already discussed and recognized need to do this. Should discuss how and when to do it (sooner than later). Categories include: review of existing data, compilation of programs, review of effectiveness (program approaches and BMPs), identification of data gaps and research needs (studies vs monitoring vs modeling); use other compilations from around the country (CASQWA, CWP). Pure probabilistic design won't get us all the answers in a timely fashion, need to prioritize. Need another discussion of monitoring design.

Investigate tying the monitoring to other existing Puget Sound long-term or short-term monitoring programs.

H.3.6 Status and Trends Monitoring

Distinguish between indicators with a quick and long term response to management actions. Both have value, but the November draft is too sparse on the former.

Include a baseline (status) or reference conditions, and identify stressors being evaluated. Need to address in experimental design, but this is inherent in status and trends.

Decide what hypotheses to address and what experimental design to use. Describe the process by which these decisions will be made. Do not include rigorous study designs. We need monitoring to answer specific questions and retain the hypothesis-based focus on streams and nearshore. Want to ensure that contribute to Adaptive Management framework.

- Start with status and trends hypotheses, best in draft, generally favorable comments, address concerns with indicators. Keep these (with modifications) in the scientific framework.

Describe where (geographic/water bodies) stormwater-related indicators will be evaluated for status and trends, and why?

- Start by establishing a regional stormwater monitoring program which focuses on small streams and nearshore marine environment (state of ecosystem health; pressures/stressors) within the context of the larger Puget Sound ecosystem.

  Explain why – how to measure progress in stormwater mgmt (testable, verifiable, actionable)

- Continue locally-identified and prioritized monitoring of other water bodies/resources to protect, such as lakes, groundwater/aquifers, wetlands, marine areas, or large rivers and integrate these efforts into the context of the larger Puget Sound ecosystem

Address where within the water bodies will indicators/endpoints be evaluated:

- Consider land use stratification and status of implementation of stormwater management programs in selecting status and trends sites.
- How will sites be selected?
  - Use the probabilistic design –OR–
  - Do not use the probabilistic design and position stations near problem areas and resources of interest to protect –OR–
  - Select locations that are representative of reference conditions and can provide paired watershed approach sites

Decide whether to (see John Lenth’s write-up):

- Change text to say S & T is long-term
- Add text to describe nested probability designs within watersheds
- Modify design to balance status and trend monitoring
- Follow QAPP for WHRST monitoring program (Ecology 2006) to sample non-random reference sites

H.3.6.1 Indicators for Status and Trends Monitoring

Monitoring Parameter Selection: Look at stressors not being monitored currently – get recommendations from toxics loading committee (gaps id'd), address in communication and governance? Opportunity for SWG to lead.

Decide whether/how to prioritize development of benthic indicators and biological indices, especially for nearshore and marine environments.

Decide whether/how nutrient loading should be included as a parameter for monitoring and should be correlated to its possible impacts in fresh and marine waters.

Review programs and research currently dealing with the chemicals in Appendix E. Some of the parameters may warrant inclusion in the list for monitoring. We may modify the list in Appendix E in the future. Consider this as a list of examples and review as a group.

- Add sentence "Note not all of the parameters listed below will be monitored at all sites; see Table E.1 for which parameters are monitored at permanent and rotating sites."

<u>Biological Indicators for Status and Trends Monitoring:</u>

Good candidate indicators for stormwater impacts in small streams include:

- Salmon in small streams can be a good biological indicator for assessing stormwater impacts. Use various life stages for specific reasons. Examples:
    - Juvenile salmon
    - Pre-spawn mortality
    - In situ Salmonid Embryo toxicity testing
- Add coho to cutthroat ratio as an indicator in small streams.
- Juvenile salmon prey species
    - Vegetation
    - Terrestrial insects
- Benthic measurement (B-IBI) in small streams is a good biological indicator.
- Other

Good candidate indicators for stormwater impacts in nearshore areas include:

- Resident fish
- Forage fish
- Bacteria levels in water and shellfish
- Other

Determine indicators from among these lists (including "other") in process of writing the QAPPs for these two regional status and trends programs; done in coordination with effectiveness and source identification indicator selection

<u>Sediment quality and WQ parameters/indicators to consider for status and trends monitoring (proximate to stormwater to support biotic monitoring):</u>

- Use the Ecology WQI methodology for WQ parameters (Temp, DO, pH, FC, TN, TP, TSS and turbidity placed into a formula) so conform to this index.
    - Is Ecology's WQI SOP adequate or do we need more?

- Use the list of parameters on pages 63-64 of the strategy document (TSS, TP, TN, T and D Cu, T and D Zn, Hardness, Temp, TPH, SVOCs, FC, OrganoPhos Pesticides)
- Use peer review list of parameters: Toxicity (chronic not acute?), zinc, copper, lead, bacteria (FC, EC, enterococci), ammonia, nitrates, phosphates, pH, cond, turbidity, suspended solids, COD.
- Add organic carbon to small stream list.
- Focus less on WQ parameters and more sediment and energy.
- Eutrophication
- Focused toxics monitoring to fill in and complement toxics loading modeling work
- Other

Add table to text in Volume 1 (scientific strategy) with examples of stormwater-related indicators and parameters needed to assess indicators. Note that not all of these indicators will make it into the QAPPs.

Discussion: tables in draft doc appendix text not reviewed by committee. Strategy document needs to capture the examples we're thinking about for both proximate (stormwater-related, quicker timeframe) and long-term indicators and parameters.

Determine indicators from among this list (including "other") in process of writing the QAPPs for small stream and nearshore regional status and trends programs; do in coordination with effectiveness and source identification indicator selection; get input from toxics loading steering committee.

- Hydrologic Parameters
  - Keep what's there
  - Add energy
  - Use level and flow (continuous) as in the document
- Sediment parameters
  - Is this a priority?
  - Add sediment toxicity test for wet weather
  - Focus on sediment contamination
- Physical Habitat Parameters
  - Use list of parameters
  - Use Ecology Federal Pacific Fish/Interior Fish Biological Opinion stream physical habitat index

Decide whether to (see John Lenth's write-up):

- Identify short term indicators for detecting trends earlier

H.3.7 Source Identification Monitoring

Source identification needs a clearer articulation of purpose, a better framework, an appendix section, and a better explanation of how it interacts with status and trends and effectiveness monitoring. Tie in compliance data, use characterization data (e.g. Phase 1), and use illicit survey data, etc. Include CSOs. Add text to strategy.

Capture this in source id sections of both volumes, will review new proposal in implementation plan recommendations: Determining how much source control is needed to get a biological response is not needed necessarily. Doing this beforehand could impede progress. After source id, next step is source control. Need to continuously tie our work into the bigger picture of AM. Each source control activity needs a metric to measure its success, *i.e.*, roughly quantify load reduction targets to provide science-based recommendation (How clean is clean? What is dirty? Adaptive). Stormwater monitoring feeds into this bigger-picture discussion of targets.

Decide what hypotheses to address and what experimental design to use. Describe the process by which these decisions will be made: when ID a problem (or early warning signal) through status and trends or literature, design an appropriate study with appropriate indicators to address the problem. Short term process of describing the initial study design and long term process to add/connect. Process includes review/evaluation/vetting of new studies. Need a better discussion of what examples are included. Do not include rigorous study designs.

Include characterization in source identification section. Define characterization (variation in relevant indicators/variables across the landscape and through time), the need for it in various studies, and what info we can get out of literature for a particular study. Relate back to an identified problem (status and trends, existing literature, etc). Where are sources of problems and how much is coming from each source, to inform actions.

- Source ID hypotheses need background work and information (lit review). Be more vague about these in the revised scientific framework; include a couple of hypotheses as examples. Drop 4 Hypotheses in scientific framework. Perhaps have subgroup identify hypotheses for what are regionally significant source identification efforts? What collective analyses could be done? Connect to watershed specific efforts. Consider coming up with categories: e.g., copper, phthalates, fecal coliforms, locally-determined sources, specific land-use issues? Have source ID implementation plan section group work on this and develop hypotheses for each category.
- Add a sentence to Section 2.6.3 that “An essential component of the monitoring program will be to identify and characterize sources and loadings of pollutants in stormwater throughout the basin” in the source ID section. Need draft language – hybrid of source id and characterization discussions
- Add a sentence to Section 2.6.3 as follows: “Data from compliance monitoring, characterization data, and illicit discharge survey information will be used to help diagnose reasons water quality/beneficial use conditions are not met.” With modification: change “compliance monitoring” term because it is confusing, it means both sampling data and implementation of actions to different people (both are needed). Also include idea of both source and conveyance of pollutants. Source ID is finding the problem.
    - Data management issues (local-regional) can only be resolved when the structure and relationships in the monitoring agency are clarified. Deal with this in the implementation stage section 6.3 in implementation plan

draft outline. Do a lit review and set up a framework for SOPs and data reporting for collective regional assessments.

- In text: Cite earlier successful studies as examples (for all categories of monitoring). Need to know what SOPs are needed. Look at toxics loading steering committee work to help identify initial areas of concern. Discuss known sources of key stressors in text. Separate sources and conveyances.

Loadings/characterization issues to discuss with indicators:

- Add to the text that we may identify a representative number of specific outfalls and perform monitoring. Weisberg recommended loadings and hydrographs as proximate indicators of management responses.
  - This may be a data gap
  - Study design question? How do you get representative outfalls to sample?

Propose: Stay with original decision and focus on collecting characterization data needed for effectiveness and source identification studies:

"Define characterization (variation in relevant indicators/variables across the landscape and through time), the need for it in various studies, and what info we can get out of literature for a particular study. Relate back to an identified problem (status and trends, existing literature, etc)."

Propose: get clarification from S Weisberg about his recommendation to get a better idea of proximate responses to stormwater management; i.e. is outfall monitoring needed to do this?

Discussion: Perhaps consider outfalls as an indicator to inform a probabilistic model? Phase I characterization data has come in with variability similar to that in the national data base. Do we need some outfall monitoring to support status and trends (with other ancillary data)? Source identification and effectiveness monitoring would likely include outfalls. Probabilistic status and trends monitoring of outfalls might be helpful to answer effectiveness hypotheses? Might have a different perspective with respect to industrial outfalls.

Add a sentence to Section 2.6.3 as follows: "Data from compliance monitoring, characterization data, and illicit discharge survey information will be used to help diagnose reasons water quality/beneficial use conditions are not met."

The document must acknowledge that part of experimental design will be to evaluate known source ID information, screen for stressors, and focus on receiving water monitoring where impacts may be greatest.

All four source ID Hypotheses were roundly trashed; Recommendations should be made by the chapter writing team.

Do a lit review and set up a framework for SOPs and data reporting for collective regional assessments

In the implementation plan we will recommend developing a standardized version of a stormwater infrastructure and BMP inventory tool (see Schueler's comment #5) for use across the region

Discussion: applies to diagnoses and targeting management approaches as well as to effectiveness studies – belongs more in source identification section. A possible approach; tool for a focused study? Would provide methodology for collective regional analyses. Not just public infrastructure.

H.3.8 Effectiveness Monitoring

Decide what hypotheses to address and what experimental design to use. Describe the process by which these decisions will be made. Do not include rigorous study designs.

Discussion: do we need to do a literature review to inform this? Got good feedback from public review and can do targeted searches. Or state that this can be refined as we do a literature review. Can we view hypotheses as questions we'd like to be able to answer, rather than these are the studies we're going to design? Stay with assessment questions, and move to credible, testable, actionable hypotheses later? Concern that examples infer priorities.

Effectiveness hypotheses were too detailed, too quickly, without background work and information (lit review). Be more vague about these in the revised scientific framework; include a hypothesis as an example for each category of effectiveness monitoring; refer back to assessment question process.

Add a 4th bullet/category for studies to test new and emerging techniques as needed (for both new and existing development). (Connect to TAPE)

Add a 5th bullet/category to continue to fill key data gaps for existing techniques. Say in text that it is not a current priority to recommend new studies, but… dependent on Phase I results and other research, we should evaluate needs for this type of information (fits into literature review and data management).

Add this wording/concept to the effectiveness monitoring framework and continue this idea in implementation plan: Identify effective stormwater management techniques (programs, methods, BMPs at a basin-wide level) that we know now, and work to implement them as soon as possible. "Work to implement ASAP" should be more along the lines of communication, AM. Ongoing feedback into management loop in addition to acting on what we already know. "As we learn from our monitoring and assessments, we apply what we've learned as quickly as possible." "Recommendations of what should be in the next permits will be decided in the process of writing the implementation plan."

Remove the phrase "increased/improved management actions" and instead describe the type of actions targeted for evaluation and the potential relevance of the actions to correct regional problems. Be specific enough to have a testable hypothesis.

- Before final hypotheses are collected/agreed upon, articulate why we are targeting each action, consider assumptions about its effectiveness (and perhaps available information about its costs and benefits); tie back to assessment questions.

State that we will do a literature review prior to designing a study.

Add section in scientific framework explaining the need to track municipal and other stormwater management activities and programs and the information will be used as ancillary data to support effectiveness and source ID monitoring and help us answer other questions

- Includes municipal, business, other activities in a basin
- Also need to track other land use planning/land acquisition activities that affect stormwater management
- In the implementation document, describe how these types of compliance/programmatic data are (or will be) cataloged and tracked

Add text saying that we will take advantage of the opportunity to design efficacy studies in basins with stormwater-related TMDLs where actions are targeted at a specific impairment and progress in the receiving water will be tracked.

Public Education and Outreach:

- Education/outreach activities as BMPs?: this is part of the effectiveness component of the strategy which includes programmatic activities as well as traditional facilities
- Education/outreach activities planned as part of our regional coordinated monitoring program for stormwater: this is a chapter proposed for the implementation plan, should address audiences and vehicles for communication – should also be briefly referenced in executive summary for both volumes. Address transfer of science information in AM section.

Include planning hypotheses: Means: approach to manage stormwater through land use/watershed planning. Could also address development/zoning rules; other strategies besides LID for developing lands to address. Sources that require regional approaches. Already covered expanding hypotheses to include evaluation of these tools (say: <u>range is broad and will expand over time</u>). Be specific. Scale question. Say: <u>Prioritization will occur in making effectiveness implementation chapter decisions</u>.

Decide whether/how to incorporate water quality analysis/hypotheses into LID monitoring (Ho in strategy is flow; experimental design in appendix is Q and WQ?)

Decide whether to (see John Lenth's write-up):

- Keep emphasis on receiving water monitoring and aggregate effects of stormwater BMPs rather than a focus on influent and effluent
- Add monitoring before and during construction phase of BMPs

H.3.9 Other Gaps in the Document

<u>Climate</u>: we have not discussed this, should this be part of effectiveness studies? These are different questions. Is this a priority for (1) the overall framework **<u>yes</u>** and (2) our initial prioritization and focus **<u>no</u>**. We should add a high level recognition that climate change impacts what we're doing, and our work needs to tie into a bigger picture over the long term.

Global pollutant levels: We should add a high level recognition that global pollutant loading impacts what we're doing, and our work needs to tie into a bigger picture. Bring in air deposition early for source identification.

H.3.10 Additional Science Needs/Ancillary Data

Do not add detail on land use/land cover metrics. This could be a potential outcome of the monitoring, depending on specific monitoring activities, but should not be a precondition. We don't need the breakdown – we need the overall activity:

Watershed characteristics: Land cover, impervious surface and other land-use characteristics must be surveyed. Extensive body of knowledge to build upon – another area for literature review. Screening and guiding mechanism for what to monitor.

- Need to continue to collect and maintain this data.
  - Meaning of "ancillary" – absolutely required information (find and use a different word?)
  - Might need to collectively integrate
- Land use/land cover (continue Ecology's 5-yr interval analyses)
  - Mapping
- Current Phase I permit requirements with requirement to use national GIS standards help with this and should continue throughout region – how?

Discuss whether to use VMT/ADT/Stream crossing/Street dirt/Urban simulation data and approaches that are available

- From Seattle street sweeping study: VMT could be surrogate for estimating pollutant loads up to a certain level (then traffic seems to dissipate pollutants)

H.3.11 Modeling

Make a better connection from our data to modeling. Modify the current section on models to say:

- There are different types of model that 1) model problems and mechanisms, 2) extrapolate results from small scale studies to regional (urban and rural) effects, and 3) extrapolate the benefits associated with different management actions.
- Our goal is to connect our monitoring to the models that support actions to restore watershed health, but the specifics of all the possible connections is outside the scope of this document.

In the meantime, author might describe an appropriate, relevant example of how we would connect to a program (for example, HSPF/WHM or others).

Process to determine what we need to collect. Go through/identify the list of most relevant models that are out there and identify their data needs. (What priorities have been identified by PS Science Panel? What suits focus of what we need for stormwater management?) State intention that we'll collect data under this monitoring plan that we know is needed for many stormwater-related models, and key relevant data gaps. Cross boundaries to see where our efforts inform other activities.

Discussion: work we're doing needs to feed into the modeling work that is needed (and vice versa). For example, Toxics Loading committee has a list of modeling needs. Need to identify this step and create this list for stormwater.

We will work with modeling experts to identify specific data needs for models. Incorporate a modeling-specific data collection plan into the strategy.

Add text to Modeling Activities – expansion of recommendations above

- Examples: need watershed runoff and loading, empirical models relating upstream land use and cover to stream and outfall quality, etc.
- Intent of strategy is to collect data that supports modeling activities and can be used to verify past efforts. This data collection must be targeted to modeling efforts that will be useful in providing insight to help answer our questions.

H.3.12 Research

Add a short section to the document that says: Research is important, agency support is needed to manage research projects, and list the projects above as examples. Add new category but don't necessarily prioritize it. Also, it is outside the scope of this document (scientific framework and implementation plan) to define the structure needed to make this happen. Our current goal is to implement best available science now, that is, connect management to results of earlier research; and address emerging issues and distribution of research dollars at a later time.

Discussion: we are adding a 4th category of monitoring. Do we endorse an activity of tracking research activities and emerging issues and recommending new studies relating to the other three categories? Does a comprehensive strategy necessitate this category under the big tent? Not necessarily prioritized in our starting point. Horner's comment was that problem diagnosis and research are confused in our document. Basic research that is not directly applied to what we're doing needs to be conducted. We had a research category of assessment questions in our initial document (decided not to prioritize those questions as part of initial starting point).

H.3.13 Experimental Designs

Appendices E and F: Remove the appendices and details from the scientific framework. Leave only high-level discussion and respond to higher-level comments (i.e., scale, paired watershed, etc.). Post all of the examples provided by the consulting team in an online library, separate out by category of monitoring, and summarize relevant comments on the ones that were included in draft vol 1. The status and trends, effectiveness, and source identification writing teams will address the relevant examples and decides explicitly to: use/modify/replace each example and dive down in the implementation plan where each chapter will propose whatever level of detail is appropriate for their category of monitoring):

- Propose/outline experimental designs for small stream and nearshore status and trends and how we would move forward to approve monitoring plans (recognize commitment to build on state/PS indicators and ECY small stream monitoring). If examples are used, address the detailed technical comments, contact specific commenters to help.

- Build specific tools/approach for source id (there was no Appendix in draft vol 1).
- For effectiveness, articulate a vision rather than study designs, and concentrate on who can do what.

ONLY the examples that are determined to be useful for the regional monitoring program will be retained in the strategy document.

Decline reviewers' request to specifically describe the analyses that will be performed. Include the monitoring designs as examples, but this is a "scientific framework" document, not the implementation document. We will include a broader set of designs as examples, over time. We will discuss which specific examples below with experimental design.

H.3.14 Yet to be Done/Discussed:

Not deciding whether/how to address compliance monitoring yet

Focus on the strict definition of stormwater (conveyance) and not non-point (other sources such as failing septic systems, historical sediment toxics, etc.). – different topic, doesn't belong here, hold for later discussion

Include new version of Table 1.

Economics and costs. Address in implementation (scientific framework is setting priorities acknowledging the need to prioritize); add big picture statement that monitoring needs to be sustainable – governance/implementation issue; recognize that it is expensive and we need to know what we can afford to do, also include benefits (what the investment saves us down the line). Vol 1 doesn't talk about cost, Vol 2 will executive summary for paired set should have this concept (keep management audience in mind).

Include in implementation strategy:

- SOPs and data management; data sharing
- Use monitoring data to define research needs

H.3.15 Governance Issues:

Include in Strategy the concept of a "monitoring consortium" (Horner/Schueler) with authority to assure funding, rule on adequacy of science, study design, QA/QC, peer review completed work, track projects, maintain databases, etc. Develop full proposal to include in implementation document.

A "lead entity" has to coordinate and manage this effort.

Public education/outreach; Including community in decision making

Strengthen diagnostic approach and elaborate on how adaptive management will work to get corrective feedback to managers. Do this primarily in the implementation plan. Add some text and perhaps a diagram to scientific framework: how do we make this useful? How do we apply the information? How do we communicate the information? We really need to work on this issue. Needs to dovetail with governance being developed by PSP.

Appendix I Issues that Remain to be Addressed

This is a summary of the unresolved issues raised in the public comment period on the April 30, 2010 revised scientific framework and draft implementation plan for the strategy. The SWG has struggled with most of these issues in the process of developing this strategy, and we realize that more work is needed to resolve these outstanding issues.

The SWG proposes to address as many of these issues as possible and deliver further recommendations to Ecology and the Partnership by the end of October. We will continue to work on other issues as we move forward.

The topics are:

- Costs and pay-in option.
- NPDES stormwater permit-related questions.
- Roles and responsibilities for implementing the strategy.
- Shortcomings/concerns about overall framework.
- Status and trends monitoring design and implementation.
- Source identification and diagnostic monitoring roles and implementation.
- Focus and process for selecting and implementing effectiveness studies.

Topic 1: Costs and Pay-In Option

1. COSTS: How will this be paid for? How funding responsibility be allocated among levels of government, among regions, and among monitoring types? Why should locals pay for ambient status and trends? What is the state/federal share?
    a. Overall cost is too high, and it is unclear how municipalities will pay for this, especially given existing economy. What *is* the total monitoring package cost, especially for permittees?
    b. Concern about increased cost in addition to existing monitoring costs – will layoffs occur? Will existing monitoring programs be cut?
    c. Instead of raising funds for monitoring, money is better spent providing services and implementing fixes/controls.
2. FUNDING ALLOCATION:
    a. Lack of specificity allocating costs between feds/state/municipalities – some activities should be funded by each.
    b. Need reasonable cost-sharing approach between municipalities.
3. PAY-IN OPTION: General (but not universal) support for pay-in option. Many issues remain. Include these ideas for consideration:

a. Possible conflict of interest. One concern is having the same entity operate as the coordinator/clearing house for the studies and funding and also conducting/competing for the funding to conduct the studies.

b. Increased overhead for independent entity is unnecessary.

c. Whether to require permittees to pay-in to the regional program.

d. Who provides oversight?

e. Funding of monitoring outside of jurisdiction (it is unclear whether funds from municipalities can be used for activities outside jurisdictional boundaries). Also, need for actual benefits to be received by every municipality contributing funds to the pay-in option, with a focus on actual monitoring within each municipality's boundaries.

f. More accounting and legal are detail needed for pay-in option: SCCWRP as model?

g. Use Interlocal Agreements if possible. MS4 Permittees should be able to use interlocal agreements to achieve economies of scale, to share resources and expertise, and to address watershed interests in performing their stormwater monitoring tasks. Through interlocal agreements, smaller Phase II Permittees and secondary Permittees could take advantage of the efforts and expertise of larger, more established stormwater management programs.

h. Consider Ecology having the responsibility for contracting with the Entity for the required services.

Topic 2: NPDES Stormwater Permit Related Questions

1. How does this fit with NPDES municipal stormwater permits?
    a. Is this beyond the legal purview of the Clean Water Act?
        i. Can permittees legally be required to use MS4 ratepayer funds for science not directly related to managing stormwater, or that benefits other jurisdictions?
    b. How do non-municipal-stormwater-permitted geographic areas fit in?
    c. Are watershed-based permits necessary to implement this program?
    d. How does this proposal affect MY permit? Will the regional program be 100% compliant or will municipal permittees have to monitor further?
    e. If problems are identified, will municipalities be required to fix them?
    f. This is a great idea, but why are you putting it in the permit? How is this stormwater? Aren't you stretching the definition of stormwater? How does sampling reference sites for status and trends relate to stormwater?
    g. How does this fit in a 5-year permit cycle? How does program inform adaptive management of stormwater?

    i. Requires more than five years to generate significant trends and lead to related follow-up actions.
    ii. Long term monitoring better conducted outside of the permits under longer term planning and budget cycles.

2. How will other types of NPDES permittees participate in this program?
3. What is the regional scope? How do the agencies fit together? Who does what? How will the regional plan incorporate existing programs? Will people lose their jobs?
4. What are the next steps? Who are the next people to involve? How does this work fit into Ecology's timeline for permits?
5. What are the full package costs for permittees?
6. Scope and costs are too ambitious, significant burden to municipalities.

Topic 3: Roles and Responsibilities for Implementing the Strategy

1. Key recommendations #10 – 16 lack a responsible party. Who is charged with these tasks?

   a. Key Recommendations 12 and 14 describe the need to formulate and support a process to develop and approve standard methods for regional monitoring efforts to follow. The current Standard Operating Procedures and Quality Assurance Project Plan Standardization Project (SOP work group) has developed four standard operating procedures (SOPs). Many more are needed, but funding to continue SOP development is in doubt. Is there another source of funding to support this effort in the near term? Articulate a clear strategy to fund and support SOP development.

   b. Key Recommendation 13, Consider the Partnership or Ecology as the lead entity for creating the IT infrastructure needed to compile and provide access to the data. Discuss issues related to and options for data management (where to house, who would analyze, etc). Data management, standards etc: Ecology or some other technical resource needs to provide a consulting service to help in this respect or it will not happen.

   c. Key Recommendation 14: Requiring "all data and findings to be submitted to a central data management system" may be problematic… The SWG should consider creating a much simpler portal… Building a portal could occur much more quickly and would allow individual data users to hook into the region-wide system at their own pace. The "independent entity" should be designed so that it is well suited as a repository for Municipal Stormwater Permit and other stormwater data. However, it should be recognized that there are some types of Permit-related data that are best collected and analyzed by local permittees.

2. OVERSIGHT ROLES:

a. Roles of SWG, Independent Entity, Ecosystem Monitoring Program, PSP, Ecology need to be specified and/or clarified.

b. It will be very important for stakeholders to have a role in oversight of the Entity, particularly with respect to lending practical stormwater management experience to potentially academic endeavors. SWG may not be the right organization, structure, or group to continue on with regional program *implementation*. It seems more appropriate that an independent monitoring and analysis entity (i.e. the SCCWRP model) be created to coordinate stormwater monitoring and broader efforts. Perhaps a "board of directors" or "advisory group" made up of jurisdictional, private, and regulatory representative is a better role for the current SWG representation? Other comments encourage an ongoing role of the SWG related to defining, implementing, and directing stormwater monitoring and assessment; that the SWG (or a similar representative body) serve as the oversight body for the monitoring program implemented by the independent entity.

3. Roles of state and federal agencies: The role of the ongoing state and federal monitoring programs needs to be better described relative to the level of effort intended, and the relationship to stormwater monitoring and assessment. Ecology believes that state and federal agencies will play a larger role in implementing this new regional stormwater monitoring and assessment program than is shown in the Key Recommendations.

a. Ecology is committed to looking at existing funding sources and supporting new initiatives to the extent we are able under our statutory authority and as a cabinet agency.

Topic 4: Shortcomings/Concerns About Overall Framework

1. Underdevelopment of source identification and effectiveness components compared to status and trends: The strategy appears to place a majority of emphasis on Status and Trends relative to Source Identification and Diagnostic and Program Effectiveness efforts. This seems disproportionate given that the latter two have a stronger tie to the stormwater management adaptive management framework.

a. Consider different sequencing of implementation.

b. Need more detail on processes for both source identification and effectiveness and how each relates to current work done by permittees and others.

c. Hypothesis testing is important and a robust scientific design is a must.

d. Consider scaling back status and trends.

e. Assess the larger scale condition status, perform large scale trend analyses and undertake research efforts necessary to forward the state of the art.

   f. Data needs in managing stormwater for rural, agricultural and forest lands may be different from data needs for managing urban stormwater.

2. How do the parts of the monitoring program (effectiveness, status and trends, and source ID) interact with each other? How do the parts feed back into the adaptive management framework?

3. How to balance probabilistic sampling and targeted sampling? At what point along the continuum of monitoring does it make sense to switch from looking for problems vs. taking care of problems that have already been identified?

4. Should the strategy include agriculture and forestry? Opinion seems to be running about 50/50.

5. Modeling: More details on how modeling can and will be utilized needs to be included in this proposal. Modeling can save resources in many cases, but only if it is integrated into the monitoring program up front.

6. Connection to ecosystem monitoring: SWG should continue to work closely with Puget Sound science staff and the Science Panel to design this program in a way that will inform their efforts to conduct regional ecosystem monitoring.

Topic 5: Status and Trends Monitoring Design and Implementation

Overall summary of comments and issues raised on this component of monitoring:

1. A majority of the comments are in agreement with the proposed design, at least in part.

2. Responsibility and means to implement: Status and trends monitoring is a good idea and should be part of the monitoring program, but the assumption that the random EMAP design is appropriately linked to stormwater and confounding effects are accounted for needs to be more strongly defined. A minority did not think status and trends monitoring should be part of NPDES sampling and was beyond the purview of the NPDES permit. There is a minority theme of ‘unfunded mandate’ and local jurisdictions should not be required to do regional monitoring (spending money on large-scale ambient monitoring programs is a poor use of time and money if the stated objective is to clean up local stormwater). Several of these commenters also were in favor of the pay-in option to fund someone else doing the regional monitoring.

3. Biological end points are appropriate to use for status and trends. Should the program include fish? To what extent are fish abundance and diversity sufficiently linked to direct impacts of stormwater to include this in permits? Biological indicators respond to a number of different environmental stressors. Separating effects from stormwater will be difficult, especially in the nearshore environment. The extent of the challenge posed by confounding factors in the interpretation and analysis of monitoring results is not described in the status and trends implementation plan.

4. There were a large number of comments on the specifics of the sampling design, primarily related to location, allocation and timing of the proposed sampling. There was some skepticism that the probabilistic design presented will be able to tease out stormwater related influences from the many other confounding impacts that are present in Puget Sound, and that random sampling is not appropriate for monitoring the impacts of stormwater and far too expensive. Several suggestions were made for targeted sampling as opposed to random.

   a. Equal allocation of sampling by WRIA, non 'stormwater' sites

   b. Random vs. targeted sampling needs to be discussed and addressed.

      i. Choose sample sites based on targeting stormwater problems and determining the level of impact and changes based on implementation of corrective actions.

      ii. There is a serious disconnect between the desire to have a probabilistic design and the use of existing programs such as EMAP and existing Ecology sites based upon a judgment sample design.

   c. How do the regional random sites provide useful information to local jurisdictions?

   d. Timing: assess the value of adding additional sample collection during storm events to ensure that the impacts of storm events can be assessed.

   e. Where did the proposed number of samples come from?

5. The choice of bacterial monitoring and sediment chemistry in nearshore areas is good, but the choice of a random scheme is not appropriate.

   a. Use *E. coli* and *Enterococcus* as the indicator of choice.

6. Use of existing monitoring sites needs to be incorporated into the design. The availability of continuous flow data from existing non-random locations that are also located near water quality and benthic invertebrate monitoring sites should be weighted appropriately when considering the value of including existing non-random monitoring stations in the proposed status and trends monitoring framework. Currently maintain 20 long-term stream water quality sampling sites with over 20 years of monthly data. Value of these long-term data sets would warrant their inclusion in the new monitoring and assessment strategy.

7. Existing data collection efforts should be used for trend analysis.

8. Mussel Watch is a good program, but (again) the direct link to stormwater is hard to prove.

9. Add nutrients and benthic infauna to marine nearshore monitoring. Include a hypothesis for nutrient reduction to the nearshore along the lines of 'reducing nutrient enrichment to nearshore areas and decreasing macroalgae blooms through improved stormwater management efforts.'

10. Annual sediment sampling is too frequent – maybe every 5-10 years.

11. Expand program to lakes and large rivers.

12. Implementation: Who should do this work? Where are the Feds, where is the State? (Ecology's response was positive in that regard). Partnership staff commented that 'If the status and trends section retains elements of a more ecosystem-based monitoring program, those elements could be coordinated and administered by the Ecosystem Monitoring Program as it develops. This would allow the SWG to focus on the Source ID and Effectiveness monitoring elements. Make sure all three are directly linked.'

13. SWG should identify what a prioritized, scaled-back option for status and trends monitoring in case funding is problematic. (Is it too late, or is this feasible?)

14. Sequencing: Due to the extensive need for coordination and synthesis of data at a regional level associated with the status and trends monitoring, the formation/identification of an independent monitoring institution is essential for successful implementation and to achieve meaningful results. Until institution identified and supported, status and trends monitoring should not be undertaken.

Topic 6: Source Identification and Diagnostic Monitoring Roles and Implementation

1. Prioritization of problems by WRIA: Prioritization by WRIA is not compatible with the NPDES municipal permits, which are not watershed based. The current recommendation is problematic because not all jurisdictions may participate at the same level of commitment. Each jurisdiction should prioritize problems.
2. Linking source identification and diagnostic monitoring to status and trends ambient monitoring: The link with status and trends to source identification is problematic because status and trends uses a probabilistic design. Status and trends will miss water bodies in many smaller jurisdictions and not provide information for source identification. There may be better ways to link receiving water problems with source identification, such as in-line sediment monitoring, to find source problem areas.
3. Source ID on the regional scale and the local scale: Replicating successful programs is a good idea and there needs to be more clarity on what's local and what's regional.
4. Monitoring should include counting management activities: Assessment of source control activities and results can inform the benefits of stormwater management actions locally and regionally.
5. Source identification relationship to Illicit Discharge Detection and Elimination (IDDE) and Total Maximum Daily Loads (TMDLs); how to link with the permit: There is confusion regarding the roles of IDDE and TMDLs.
6. Funding: Jurisdiction funding vs. pay-in option for source identification: there should be more emphasis on source identification either in the permit or the pay-in option. Jurisdictions should be responsible for fixing identified sources, and

funding and implementing the source identification and diagnostic monitoring program.

Topic 7: Focus and Process for Selecting and Implementing Effectiveness Studies

1. Process to identify and prioritize effectiveness studies is not well defined. Beef up implementation section -this is where initial efforts should go, not status and trends- stakeholders are disappointed in progress to date. Consider what can get accomplished by October. Process for submitted proposals, guidance and criteria needed.
   a. Consider the current program effectiveness monitoring requirements in the Phase I permit. This program is acceptable; there is no need to replace it with a proposal from the SWG.
   b. Criteria for selecting effectiveness studies— specific comments:
      i. Item c. is confusing-should state that all prioritized topics for effectiveness studies are covered.
      ii. Item d. should expanded to include protecting beneficial uses, not just restoration.
      iii. Item e. is narrow, only for NPDES, will need to rewrite whole section when agricultural and industrial issues addressed, so broaden this out.
      iv. Eliminate reference to preference for projects that generate results within X years. It is impossible to evaluate impact of practices in one permit term, so do not tie to permit term.
      v. Add criteria of transferability.
      vi. Who defines important threats or impacts? Let permittees do it?
   c. Concern with caucus-based process determining direction of permit program.
   d. Comments on Topics: Retrofit good focus area, done at all scales. Non-structural BMPS (education and outreach, maintenance optimization, business inspection effectiveness) should be emphasized, and prioritized on a regional scale. Non-structural should be priority for effectiveness research. Low benefit of testing BMPs by SWG—already done by Ecology. Agriculture and forestry impacts important, but should not be addressed here.
   e. Provide examples of programmatic approaches and NPDES provisions that might be monitored
2. Identify feedback loops for management decisions. Agree with effectiveness as part of adaptive management, but if status and trends is random and not tied to problems, how is a connection possible?

3. The proposed cost estimates for effectiveness studies are too low; double them.
4. A timeline for all proposed actions should be included.
5. Need a national program for BMP effectiveness.