PugetSoundPartnership

our sound, our community, our chance

INITIAL DISCUSSION DRAFT

WATER QUALITY TOPIC FORUM

APRIL 14, 2008

PugetSoundPartnership
our sound, our community, our chance

Puget Sound Partnership

Introduction to the Topic Forum Discussion Draft

The attached topic forum discussion draft is one of five papers designed to provoke and inspire a long-term, community conversation and critical thinking about the specific problems facing Puget Sound, and the strategies and actions needed to address the threats we face. These papers and your comments will be used to help create the 2020 Action Agenda. Background on the topic forum process and how this information will be used can be found on our website at www.psp.wa.gov in the Action Agenda Center.

These initial draft papers are the first effort in our region to synthesize and document what we know about the problems, solutions that work, our current approach to solving problems, and what approaches we need to continue, add, or change. This is hard work that has not been done before. It means 1) looking at Puget Sound ecosystem from the crest of the Cascades to the Strait of Juan de Fuca, 2) providing sources to back up our statements and conclusions, and 3) establishing links between science and policy.

The Partnership asked a small group of science and policy experts to prepare these draft discussion papers as a starting place for the discussion. The discussion papers are DRAFT. They do not yet represent an opinion or position of the Partnership. Nor do they entirely represent a consensus opinion or position of the science and policy experts who prepared or commented on the work. The topic is immense and many of you will find gaps in the work that you may be able to fill.

That is why your involvement is crucial. We very much appreciate your interest and expertise in reviewing this initial work. As you read this paper and prepare to participate in one of the five upcoming workshops, participate in an online discussion, or submit specific comments, the Partnership requests that reviewers keep this context in mind.

- The Partnership will be identifying priority actions that are based on science. There is currently a wide range of opinion about the problems and literally hundreds ideas for solutions. Our hope is that if we can agree on the documented threats to Puget Sound in terms of magnitude and impact, we will have a better chance of creating priority and durable solutions.

- The papers mainly focus on the Sound as a whole. We know that there are variations in problems and solutions in different parts of our region. The action area profiles that we are also preparing will highlight local issues.

- The papers are organized to logically step through three initial questions (two are science and one is policy) that build to a rational conclusion (the fourth question) about the strategies and actions that we will need continue, add, or change as a region. The design is intentional so that 1) our policies are based on science and 2) scientists and policy experts talk to one another.

- These initial papers will contribute to a synthesis paper that will describe links between each of the topic areas. Reviewers may want to read more than one paper to begin to see the links across our individual interests and concerns. The papers reach different types of conclusions for where to focus efforts, and in some cases the suggested solutions are far-reaching. Before we get to a synthesis paper (and workshop), we want the initial papers to be as accurate as we can in the time that we have available.

- The intent of papers is to focus on WHAT the problem is and WHAT solutions are needed, rather than HOW to implement specific solutions. For example, we know that we will need to do more to protect habitat and concentrate growth into urban areas. There are many ways to accomplish this task and different methods will be needed around Puget Sound. We will create the "how" with those who have to implement the solutions.

- The papers intentionally do not focus on the need for more education/outreach, new funding strategies including creative incentives, and a coordinated monitoring and adaptive management program. The Partnership knows that these three aspects are critical to long-term success and is using other processes to address them. That work is linked to the development of the action agenda. By addressing the system-wide needs, we will be able to more effectively focus the education/outreach and funding.

- The Quality of Life "topic", or Partnership goal, is not yet represented in these papers, but will be part of our subsequent work to synthesize across the topics.

You may comment on the draft papers by attending in the topic forum workshop, participating in the online discussion at www.psp.wa.gov, or submitting a comment via email or in writing. When reviewing the papers, please consider the following questions:

- Current knowledge: Have we accurately described what we know and don't know about the status of and threats to this topic in the Puget Sound region and the certainty of our knowledge? Have we missed any major documented findings?

- Effectiveness of tools: Have we accurately characterized what is certain and uncertain about the effectiveness of the tools available to address threats to this topic? Have we missed any major documented findings?

- Current strategies: From a topic perspective, have we accurately characterized what we are now doing to address threats? Have we missed any major programs or projects?

- Strategies to continue, add, or change: Given the status of and threats to the topic, effectiveness of the tools available, and current strategies to address threats, have we accurately captured the strategies we should continue, add or change? Have we missed any strategies and actions we should continue, add or change to address the threats (not just good ideas)? What sources have informed your thinking?

- Establishing criteria: Are the proposed criteria for prioritizing topic-specific actions appropriate and sufficient? Are there other criteria to consider?

- Measuring progress: Have we identified appropriate measures to assess progress toward goals for this topic? Have we missed any key measures of progress?

INITIAL DISCUSSION DRAFT PAPER

WATER QUALITY IN PUGET SOUND

This initial discussion draft paper includes several areas where the authors have noted that their preliminary information synthesis and findings are in need of additional information. Topic Forum participants with relevant information are requested to bring this information into the discussion, either by attending the Topic Forum or by providing the publication or relevant citation to the Topic Forum team.

Science Question 1 (S1): Status of Water Quality in Puget Sound

The waters of Puget Sound and its basins range from relatively pristine to degraded. Water quality is affected by pollutants, including toxic compounds, nutrients, and pathogens, and sediment quality is affected by persistent organics, inorganics, and carcinogens from past human activities. Pollutants enter the Puget Sound ecosystem via stormwater runoff, industrial discharge, wastewater discharge, septic leakage, deposition of airborne particulates, and marine discharge and spills. This mix washes down from the rivers and streams to the marine waters, and deposits contaminants in the sediments within the Puget Sound basin.

Regulatory entities such as the Washington State Department of Ecology (Ecology) measure many of the substances deposited in Puget Sound waters, but tracing these pollutants to their sources or determining their risk to humans and other species is extremely difficult. Additionally, the measurement of some pollutants is difficult, since they cannot be detected until they have accumulated in tissue samples of shellfish, fish, marine mammals, and other species.

The available scientific evidence, combined with the regulatory assessments conducted by Ecology under their Clean Water Act responsibilities, does not generally support a conclusion that the freshwater streams and lakes of Puget Sound or the marine waters are universally contaminated from pollutants for which there are established standards. However, we lack standards for many toxics and it is unclear that established standards adequately protect aquatic and human health. In addition, many of the organic compounds of concern are of very low solubility in water, and would not be detected in water samples even though they are seen in sediments and in the flesh of fish and high levels of the food chain.

Serious impairment to water quality and sediment does occur in localized sites in Puget Sound under existing standards and sampling methods. Over 1,000 freshwater bodies around Puget Sound are listed as Category 5 impaired water bodies on the 303(d) list, and over 30,000 acres of shellfish beds are closed to harvest. Low dissolved oxygen events are observed in the marine waters of the south Sound and Hood Canal, and appear to be increasing in frequency and duration. Contamination of marine sediments varies widely throughout the Sound, with high levels of toxics such as polychlorinated biphenyls (PCBs) present in areas such as Elliott Bay. Although “legacy toxics” such as PCBs and DDT are decreasing in some areas, other toxic contaminants such as polynuclear aromatic hydrocarbons (PAHs) appear to be increasing.

Waters of the Sound basin (both fresh and marine) may also be affected by climate change in the future. Climate change scenarios project increasing marine water temperatures and changes to water circulation patterns. Coupled with increasing population, water quality protection and restoration will continue to be severely challenging in Puget Sound.

DRAFT

A. Documented threats to fresh water and marine water quality in Puget Sound

Three general categories of pollutants affect water quality and sediment quality in Puget Sound:

- Nutrients are natural and synthetic substances that stimulate plant growth. Although nutrients occur naturally, excessive loading of nutrients can have significant effects on the condition of marine and freshwater systems, stimulating algal blooms, depressing oxygen levels, and leading to losses of aquatic vegetation and fish kills. Of particular concern for Puget Sound are phosphorus levels in fresh water and nitrogen in marine waters.
- Pathogens are disease-causing microorganisms that include a variety of protozoa, bacteria, and viruses. Some pathogens occur naturally in the marine environment, but most are associated with human and animal wastes and can contaminate shellfish beds, water supplies, and recreational waters and beaches.
- Toxics refer to the array of chemicals that have been released into Puget Sound that can be toxic to humans, animals, and plants depending on the concentration and the length of exposure. Many toxic chemicals create additional risks because they are *persistent* (resist breaking down) and are *bioaccumulative* (increase within organisms) over time.

The fjord-like structure and underwater sills of Puget Sound restrict the circulation of marine water in several locations, and reduce the flushing exchange with the ocean water entering from the Pacific. This hydrologic isolation puts Puget Sound at greater risk from all three categories of pollutants than other estuaries in North America (Puget Sound Action Team, 2007).

Water Quality in Puget Sound Freshwater Systems

Threats to freshwater resources are increasing as a result of urban development. Urbanization typically expands areas of impervious surfaces and reduces forested cover. These changes result in greater volumes and flow rates of stormwater entering freshwater ecosystems, degrading habitats and reducing species diversity (Booth and Reinelt, 1993, Booth et al., 2002, May et al., 1997, Center for Watershed Protection, 2003). Additional, but unquantified, threats from increasing amounts of chemicals entering aquatic ecosystems from these same landscape changes are also likely increasing. Overall trends in water quality for freshwater systems in Puget Sound are difficult to determine due to the lack of consistent data at the same sampling locations over long enough periods of time. There have been an increasing number of impaired water body listings on the State's 303(d) lists for temperature, fecal coliform bacteria, and dissolved oxygen in freshwater streams over the last 10 years. Key findings include:

- Impaired lakes, rivers and streams: Although lakes, streams, and rivers in the Puget Sound basin met most federal and state water quality guidelines (Ebbert et al., 2000), a variety of impairments have been documented representing concerns for both humans and fish. Ecology's 2004 listing of impaired surface waters in the Puget Sound drainages (Water Resource Inventory Areas [WRIAs] 1-19) included 1,135 Category 5 water quality listings (primarily for temperature, dissolved oxygen, and fecal coliforms) and 48 listings for sediments. Documented impairments from the *Washington State Water Quality Assessment: Year 2002 Section 305(b) Report* (Ecology, 2002) included (as a percent of Puget lowlands freshwater stream miles): metals: 50% ± 24%[1]; fecal coliform: 57% ± 8%; dissolved oxygen: 16% ± 6%; ammonia-nitrogen: 1% ± 2%; pH: 1% ± 2%; temperature: 16% ± 6%. As an example of one area of Puget Sound, of the 563 assessed water bodies (stream, river segments, and lakes) included in the 2004 303(d) database for the Green/Duwamish (WRIA 9), 151 (27%) were identified as being impaired (Category 5).

[1] There may be some dispute over the actual level of metals impairment following findings by Johnson and Golding in 2002 that water-column contamination had occurred in the sampling process (Johnson and Golding, 2002).

Additional discussion of this issue on a Sound-wide basis will be included in the Status and Threats Analysis being conducted by NOAA.

- Mixed Findings on Sediment Contamination in Fresh Water: Freshwater sediments show variable conditions throughout the region. The majority of sediment concentrations measured in 27 freshwater streams in King County did not exceed freshwater sediment guidelines (King County, 2005). Historic sediment patterns measured in urban lakes such as Lake Ballinger show decreasing trends for DDT and PCBs, but an increasing trend for PAHs (Van Metre and Mahler, 2005). Several freshwater areas in Puget Sound lakes and rivers are recorded as contaminated and require cleanup under CERCLA regulations (U.S. EPA, 2008, Long et al., 2005).

- Lake Fish Consumption Advisories: The Washington State Department of Health (DOH) has completed an assessment of contaminants in numerous lakes in the Puget Sound basin, and issued health advisories for the amounts of fish that are safe to consume per month. The main contaminants of concern are PCBs and mercury which, once released into the environment, move up through the food chain into fish, marine mammals, and humans. Mercury and PCBs have been shown to cause behavioral and learning deficits in children exposed in the womb, so meal limits of certain fish are especially important for women of childbearing age and young children (National Research Council, 2000, Environmental Protection Agency, 2001, Food and Drug Administration, 2001).

- Emerging Contaminants (Endocrine Disruptors, Pharmaceuticals and Personal Care Products): In a 2007 King County study, four endocrine disrupting chemicals (EDCs) including Bisphenol-A (a plasticizer), total 4-nonylphenol (a surfactant breakdown product), 17-ß estradiol (a natural hormone), and 17-α ethylnylestradiol (a synthetic human hormone) were detected frequently, and seven other EDCs detected less frequently in a survey of major lakes, rivers, and small streams in King County. Other pharmaceuticals and personal care products have not been extensively sampled in Puget Sound fresh waters.

- Groundwater: Shallow groundwater in urban residential areas has been reported to contain chemicals related to transportation and household activities. In addition, shallow groundwater in these areas can contain elevated levels of nitrate from use of fertilizers on lawns, gardens, and septic system drainage (Ebbert et al., 2000). Shallow aquifers used for domestic supply in agricultural areas were commonly reported to have nitrate exceedances of the drinking water quality standard. For example, cropland applications in the Nooksack River basin caused nitrate exceedances above the drinking water quality standard in about 60% of groundwater sampled (Ebbert et al., 2000). Historically, surface water has been the main drinking water source for the region. However, as urban development continues, reliance on groundwater as a drinking water source has increased.

Water Quality in Marine Waters and Nearshore Areas

- 303(d) Listings: Most impairments of existing water quality standards for marine waters in the main Puget Sound basin are for fecal coliform bacteria and low dissolved oxygen. There are additional listings and advisories including organic compounds such as PCBs in fish tissue. Of 704 listings for pathogens in 2004, 79 were for marine sites. For dissolved oxygen, 56 of the 237 listings for dissolved oxygen were for marine areas, and 96 of the 144 total listings for toxics were for marine areas. (Puget Sound Action Team, 2007).
- Pathogens: As of 2005, over 30,000 acres of commercial shellfish beds remained closed to harvesting due to water pollution, including fecal contamination (Newton et al., 2007). Sources include failing septic systems and other nonpoint sources (including stormwater and in some cases, agriculture) (Newton et al., 2007). Fecal coliform bacteria levels above state standards are typically used as an indicator of contamination.

DRAFT

- Hypoxia: South Puget Sound has historically shown signs of periodic low oxygen and susceptibility to nutrient enrichment (Ecology, 2002a). Although low concentrations of dissolved oxygen in Hood Canal have been observed during late summer and early fall as far back as the 1950s, available data suggest that concentrations of dissolved oxygen vary from year to year but have been trending lower over time, with longer durations of low concentrations (USGS, 2008).
- Nutrients: Embayments in Puget Sound tend to show higher sensitivity for hypoxia and other problems related to excess nutrients. Inorganic nutrients contribute to algal blooms which in turn contribute to oxygen depletion in the Sound. Fish, shellfish, and eelgrass mortality has been linked to hypoxia related to these blooms. Surface primary production in the open waters of the Puget Sound main basin is nutrient-limited at times during June and October, and therefore sensitive to the addition of nutrients (Newton and Van Voorhis, 2002) The ongoing cycles of increased blooms can also lead to accelerated eutrophication of embayments and other areas of the Sound (Newton et al., 2007). This is a result of the combination of the oceanographic conditions resulting from the shape of these bays and the proximity and importance of terrestrial nutrient and sediment sources transported by stormwater and streams. The low flushing inherent to these shallow and enclosed embayments, the shallow waters that bring much of the bottom into the lighted or euphotic zone, and the relatively high proportion of the bay volume contributed by enriched fresh water increase the prevalence of low oxygen and nuisance blooms of microalgal and macroalgal species.

- Metals: Widespread impairment from metals is uncertain. In 2000, Michelson found that measured metals were significantly below the relevant marine water quality criteria in samples collected at 5 and 50 meters below the surface in several cross transects of the middle Puget Sound basin (Michelson, 2000).

- Endocrine Disrupting Chemicals: A survey of marine waters in King County (King County, 2007) obtained results similar to those for freshwater lakes, rivers, and streams.

Sediment Quality

The available scientific evidence, combined with the regulatory assessments conducted by Ecology under their Clean Water Act responsibilities, generally supports a conclusion that marine sediments in localized areas of Puget Sound are contaminated. However, there is greater variability in the data for freshwater sediments, making it difficult to conclude the status. A large-scale survey undertaken by NOAA and Ecology in 2005 showed widespread contamination but at levels less than regulatory criteria (Long et al., 2005). Key findings include:

- PCB Contamination: Marine sediment PCB contamination varies among Puget Sound basins, with the Seattle area showing the highest concentrations (O'Neill, 2004).
- Biota: Other Topic Forums are covering biota and potential effects from contamination, therefore they are not included here.

[Authors/Reviewers request more information on the contribution of existing contaminated sites to the overall loading.]

B. Sources and pathways for nutrients, pathogens, and toxics entering Puget Sound water bodies

Stormwater Runoff

A large part of the toxic chemicals that enter Puget Sound marine waters is carried through runoff from the land surface. Developed lands contributed the majority of several toxic chemicals to Puget Sound (i.e., cadmium, lead, zinc, nonylphenol, and oil and petroleum products). Studies have suggested that runoff from

DRAFT

the land surface and deposition from the air (directly to marine waters) have imposed considerable loads of contaminants to Puget Sound (Hart Crowser et al., 2007). Roads, farms, highways, parking lots, residential homes, lawns, and golf courses all leave a chemical signature on the landscape. These chemicals are mobilized by rainfall and transported via stormwater runoff to receiving waters and sediments in the marine environment (Ruckelshaus and McClure, 2007).

Stormwater impacts on stream hydrology and habitat have been documented for decades, and it is well established that stormwater is a significant transport mechanism for pollutants to receiving streams and marine waters. These pollutants are both dissolved into water and attached to sediments and other particles mobilized by stormwater and transported to freshwater and marine aquatic habitats (Gobel et al., 2007). Stormwater from urbanized watersheds exhibits higher average concentrations, fluctuations, and loadings of pollutants than undeveloped open space areas (Stein et al., 2007). Increasing extent of impervious surface is associated with decreases in aquatic habitat quality (Booth and Reinelt, 1993, Booth et al., 2002, May et al., 1997, Center for Watershed Protection, 2003).

At the same time, tracking individual pollutant sources to specific land uses has been problematic, based on the high levels of variability observed from differing land use classes (Pitt et al., 2005a, Pitt et al., 2005b). Source identification has been used in some Puget Sound watersheds to identify land use-based causes of fecal coliform loading (Sargent, 1999).

Range and Variability of Pollutants

Pollutants found in stormwater include:

- *Metals* (Woodward and Clyde Consultants, 1994, UNECE, 2003, Stein et al., 2007) from many sources, including transportation-related byproducts such as metals from brake linings (Westerlund, 2001, Woodward Clyde Consultants, 1994, UNECE, 2003, and Brewer, 1997);
- *Airborne pollutants* from more indefinable sources such as remote industrial, heat, and power generating plants (Brinkman, 2004);
- *Polynuclear aromatic hydrocarbons* (PAHs) (Van Metre et al., 2000, Stein et al., 2007) from asphalt surfaces and paving resealants (Kriech, 2002, Mahler et al., 2005) and incomplete combustion of petroleum products from vehicles, homes, and other sources;
- *Organophosphate pesticides* (Schiff and Sutula, 2004) from landscaping byproducts;
- *Nutrients* (Pitt et al., 2005a, Pitt et al., 2005b);
- *Total suspended solids* (Stein et al., 2007, Barco et al., 2008), and
- *Other pollutants* related to industrial, agricultural, recreational, or other activities (Minton, 2005).

The concentrations of pollutants are highly variable from storm to storm event, and by land use (Pitt et al., 2005a, Pitt et al., 2005b, Washbusch et al., 1999, Barr Engineering Company, 2005, Woodward Clyde Consultants, 1994, Westerlund, 2001, Van Metre et al., 2000, Schiff and Sutula, 2004, Stein et al., 2007, UNECE, 2003, Brewer, 1997, Brinkman, 2004, Kayhanian et al., 2002). Different classes of pollutants wash off surfaces at different times during a storm (Egodawatta et al., 2007, Gobel et al., 2007, Kayhanian et al., 2002, Legret and Pagotto, 1999). Specific adverse effects associated with the different pollutants washing off and being transported in stormwater cannot easily be identified based on the differences in their

DRAFT

environmental fates (degradation and compartmentalization) and differences in exposure concentrations as these compounds move through the environment.

Hydrology, Connectivity, and Imperviousness

Research in Puget Sound streams clearly demonstrated the negative effects of increasing extents of impervious surface (e.g., roads, rooftops, parking lots) on aquatic habitat quality (Booth and Jackson, 1997, Booth et al. 2002, May et al., 1997, Center for Watershed Protection, 2003).

Research in Wisconsin in streams with similar characteristics to Puget Sound also demonstrated a strong correlation between impervious connectivity (for example, defined pathways for stormwater to flow via ditches or pipes to an outfall) and habitat quality. The number of fish species, index of biotic integrity (IBI, a measure of the presence and type of macroinvertebrate communities), and base flow were invariably low (Wang et al., 2001) at connected imperviousness levels greater than 12% of a basin.

Puget Sound drainages range from 2% urbanized in the Hood Canal basin to 23% urbanized in the main basin (Ruckelshaus and McClure, 2007). Although aquatic habitat quality has been shown to be impaired at lower levels of imperviousness, water quality impairment from pollutants has been measured at higher levels of imperviousness (greater than 40%) (Brabec et al., 2002) in three studies reviewed. Hydrologic variability in wetlands resulting from urbanization and increased stormwater runoff has also been shown to impact wetland quality more than increased concentrations of pollutants (Azous and Horner, 2000).

Urbanization

Between 1991 and 1999, an additional 1% of the total area in the central Puget Sound region was newly developed and, during the same period, the designated forest land decreased to a total of 55%. In the Puget Sound region, most development has occurred within Urban Growth Boundaries (designated under the State Growth Management Act) and forest cover within those boundaries has decreased by 11.1%. Almost half of the conversion to urban uses has occurred in the Seattle metro area (Alberti in Sound Science, 2007).

Effects of Stormwater Pollutants on Species

Determining the actual effects of stormwater pollutants directly on aquatic organisms in freshwater ecosystems has been difficult. We know that at greater than 10% imperviousness and less than 65% forested land cover, reductions in stream quality, as measured by species diversity, occur (Booth and Jackson, 1997, Booth et al., 2002). However, it is difficult to state with certainty that species diversity will be universally high at less than 10% imperviousness and greater than 65% forested land cover. Receiving water conditions (ions and dissolved organic carbon) strongly influence the toxicity of metals (Santore et al., 2001, Paquin et al., 2005). It is very difficult to create the types of naturally occurring exposures and their episodic nature in laboratory environments (Zhao and Newman, 2006) to evaluate effects. It has also been documented that organisms can potentially recover from short duration exposures to toxicants if they are given a sufficient recovery time before a subsequent exposure (Zhao and Newman, 2006).

Studies on the impacts of stormwater on salmonids have indicated that metals concentrations below those commonly observed in stormwater can adversely affect the salmon's sense of smell (Sandahl et al., 2004). Coho prespawn mortality rates in Longfellow Creek demonstrate the concern for stormwater effects on salmon (McCarthy et al., 2008). No causative agent was identified for pre-spawning mortality of Chinook salmon in King County streams (Berge et al., 2006). What is lacking are standards that capture these ideas of frequency (how often effects occur), magnitude (how much of the toxic substance is present at any one time), and duration (how long the exposure lasts each time a compound is present).

DRAFT

Runoff from Agriculture, Forest Practices, and Landscaping

Puget Sound has plentiful rain, fertile soils, and excellent growing conditions for agriculture and forest practices. Also, many residents in the area participate in small-scale farming activities, and urban and suburban residents landscape their yards. Agricultural, forestry, and landscaping activities can all be sources of pollutants that are transported to Puget Sound water bodies.

- Nutrients: In a 1998 USGS study, animal manures, agricultural fertilizers, and atmospheric deposition were among the top three identified sources of nutrients (inorganic nitrogen and phosphorus) to the rivers and streams of the Puget Sound Basin (Inkpen and Embrey, 1998).

- Pesticides: Pesticides were detected at elevated concentrations in King County streams during wet weather events (King County, 2002).

- Pathogens: Animal waste is a significant source of fecal coliforms as well as *Cryptosporidium* and *Giardia* (Hutchinson et al., 2005, Bradford and Schijven, 2002) which can be transported through stormwater overland flow to streams (Miller et al., 2007, Lewis et al., 2005). This is a frequent concern with livestock operations such as dairies, but pathogenic pollution can also occur as a result of land application of animal manure as fertilizer (Mishra et al., 2008, Soupir et al., 2006, Reilly, 2001).

- Emerging Contaminants: Animal waste has also been pinpointed in recent years as being a source of both natural and synthetic hormones that can act as endocrine disruptors (Lucasa and Jones, 2006, Hanselman et al., 2003). As with pathogens, these contaminants can be conveyed through overland flow to fresh and marine water bodies or as a consequence of purposeful land application.

[Authors request material about the linkage between agricultural and forestry practices and fecal coliform bacteria.]

Algal Blooms

There is an increasing concern over the spread and impacts of toxins generated by harmful algal blooms (HAB) (Jewett et al., 2007). With an increase in the population near coastal areas, along with the apparent spread of harmful algal blooms, it is reasonable to expect an increase in the incidence of poisoning by natural phytoplankton-related toxins. These toxins can cause both short- and long-term health impacts, including death, to humans, marine mammals, and other organisms, including fish species, both wild and farmed (Ruckelshaus and McClure, 2007, Trainer et al., 2007). A network of monitoring sites and research on rapid detection systems are developing. The relationship between anthropogenic causes such as nutrient loading and outbreaks of HABs are areas where additional research has been called for.

Wastewater and Septic Systems

Many municipal wastewater treatment plants discharge treated wastewater directly into Puget Sound, mostly at great depths and distances from shore. Additionally, combined sewer overflow outfalls sometimes discharge mixed stormwater and untreated wastewater to Puget Sound during wet weather when conveyance or plant capacities are exceeded. Wastewater is a source of a broad spectrum of pollutants, nutrients, and pathogens (King County, 1991).

[Authors and reviewers note the need for more information regarding the relative importance of wastewater and septic for marine and fresh waters.]

DRAFT

- Geographic effects of wastewater: South Puget Sound has low dissolved oxygen and is particularly sensitive to increased nutrient inputs, due to restricted circulation, shallow water, and increasing inputs from residential development (Ecology, 2002b). Nutrient contributions to marine areas have been documented to contribute to low dissolved oxygen in shallow embayments throughout Puget Sound (Newton et al., 2007a).

- Wastewater pollutants: Treated municipal sewage contains a complex mixture of personal care products (e.g., shampoo), caffeine, endocrine-modulating chemicals (e.g., birth control pills), antidepressants, and other pharmaceuticals (USGS, 2002, 2008). Many studies have correlated the presence of estrogenic compounds to impaired reproduction in fish, amphibians, and other animals which has raised significant concern in the scientific community about the impacts of these chemicals (Ketata et al., 2008, Stoker et al., 2008, Anway and Skinner, 2006, Anway et al., 2005). A more recent study focused on the bioaccumulation of these compounds in worms, which had impacts on the worms' predators higher in the food chain (Markman et al., 2008). Other studies are starting to document the presence and transfer of these chemicals in human placenta (Tsutsumi, 2005) and what this might imply for human fetal development and reproduction (Takeuchi et al., 2004, Ikezuki et al., 2002, Pauwels et al., 2001).

- Pathogens: Pathogens are indicated in water quality measurements by the use of indicator organisms, common bacteria from the guts of warm-blooded organisms, that while mostly harmless to humans, indicate by their presence the possible risk of fecal contamination. The use of these indicators to manage both shellfish harvest and swimming contact has been largely successful in minimizing water-borne disease transmission. In Puget Sound basins, the principal sources of these indicators are older septic systems that were sited near water bodies, poorly maintained septic systems, some types of livestock practices, cross connections between sanitary and stormwater systems, pet waste, wild animals (including marine mammals), and vessels. Although it is presumed in some locations that the presence of pathogens in water bodies is due to failing septic systems, this is not always the case and extensive testing is needed to identify sources.

  One additional pathogen issue apart from those associated with specifically fecal contamination has been the presence of naturally occurring pathogens such as *Vibrio* sp., which have been implicated in disease outbreaks (Fuenzalida et al., 2007, Su and Liu, 2007, Fuenzalida et al., 2006, Gonzalez-Escalona et al., 2005, DePaola et al., 2000). The sources, extent, and control of pathogens are discussed in the Human Health Topic Forum.

- Wastewater discharges: Loadings of toxics that were attributable to permitted point-source discharges, specifically industrial and municipal wastewater plants, incompletely accounted for total loadings being detected (Hart Crowser et al., 2007). Other potential sources such as stormwater runoff must therefore be contributing to the total load of toxic substances.

- Combined sewer overflows: Episodic discharge of a mixture of untreated wastewaters and stormwater from combined sewer overflow outfalls contributed relatively little to the total loading of toxic chemicals to Puget Sound (Hart Crowser et al., 2007)

- Septic systems: There are approximately 472,000 septic systems in the Puget Sound basin, according to previous estimates by the Puget Sound Action Team. Septic systems are not generally designed for nitrogen removal, and leachate contains high levels of nutrients. If systems are not designed well, which may mean poorly draining soils or excessive hydraulic loading, leachate is not properly treated in the soil column. When systems are located near streams and marine waters, the leachate may be a significant source of nitrogen, and if they are improperly

DRAFT

designed or maintained, they are a major source of pathogens. *[Authors and reviewers note more specific description with data on geographic concentrations and magnitude is needed.]*

- Wastewater discharges to streams: Generally, bioassessment measurements of stream health have not been directly correlated with wastewater treatment plant discharges (Dyer and Wang, 2002, Diamond and Daley, 2000). Endocrine disruptors, generally associated with wastewater discharges (USGS, 2008), have been observed both upstream and downstream of freshwater outfalls in King County, implying additional sources of these substances, such as on-site wastewater system discharges, wastewater cross connections, or agricultural wastes (King County, 2007).

- Effects on lakes: Many lakes are also in decline (Rector and Hallock, 1994) and evidencing signs of accelerated aging (eutrophication). Nonpoint sources and failed or poorly sited septic systems are suspected as the primary inputs of nutrients. In larger basins, like the Lake Washington watershed, nonpoint sources from urban and forestry land uses are generally more significant sources of nutrients than contributions of lakeside resident activities (Ecology, 1997). Lake Washington itself has been the focus of significant cleanup efforts (Edmondson, 1991), and has recovered from the eutrophic, over-enriched state that existed in the 1950s to 1960s (Tetra Tech and Parametrix, 2003). The key to rapid recovery was the lake's depth, which contained large stores of dissolved oxygen; and the reduction in phosphorus loading that occurred with sewage diversion. The lake is sensitive to phosphorus loading, and the maintenance of present-day water quality is dependent on keeping phosphorus loading at or below current levels. Minimal development of the Cedar River basin has been a key factor in recovery and maintenance of lake water quality.

Industrial and Commercial Practices

The effects of industrial discharges, which are normally classified as point sources, are generally localized. Industrial pollutants have been reduced over the last few decades with the advent of source substitution, improved waste management practices, and greater regulatory oversight. Still, past practices continue to have an effect on freshwater and marine resources in Puget Sound, primarily through the remobilization of contaminated sediments that were impacted years ago. There are a few geographic regions in Puget Sound where industrial practices are still the dominant land use; these include the Lower Duwamish Waterway in Elliott Bay, Commencement Bay in Tacoma, and Sinclair Inlet in Bremerton.

Contaminated Sediments

Stormwater provides a primary transport mechanism for pollutants from industrial, transportation, and commercial activities. Concentrations of metals (copper, lead, mercury, and zinc), PAHs, polychlorinated biphenyls (PCBs), and Bis(2-ethylhexyl) phthalate (BEHP) were detected in on-site industrial catch basin sediment samples near the Lower Duwamish Waterway. Many concentrations were above the sediment cleanup screening level (CSL) (King County and Seattle Public Utilities, 2005). Different pollutants attach to different sediment particle sizes. For example, metals are typically associated with finer grained sediments, while PAHs are associated with fine to coarse sediments (Robertson and Taylor, 2007). Several freshwater areas in Puget Sound lakes and rivers are recorded as contaminated and require cleanup under CERCLA regulations (U.S. EPA, 2008)

Contaminated sediments are also an avenue of toxic exposure for marine aquatic organisms. Some toxics are known to bioaccumulate in these organisms and are transported through the food web. The toxicity of metals in sediments depends on their bioavailability (DiToro et al., 1990). Marine sediment PCB contamination varies among Puget Sound basins and is localized to urban and industrial deposition areas, with the Seattle area showing the highest concentrations (O'Neill, 2004, Long et al., 2005).

DRAFT

- Effects of sediment contamination: PCB accumulation in benthic and demersal fishes is correlated with sediment concentrations. The highest correlation is for fish with small home range, and accumulations increase with trophic level (biomagnification) (O'Neill, 2004).

- Biomagnification: Researchers found that sediment-associated flatfish from polluted sites had high incidences of liver disease and cancer. As they move through the food web, concentrations of persistent, bioaccumulative chemicals may become much greater, a process known as "biomagnification," and pose an important health risk for top-level feeders such as salmon, raptors, marine mammals, and humans (Ruckelshaus and McClure, 2007).

- Sediment cleanup: Numerous water and lands recorded as contaminated are requiring cleanup under CERCLA regulations (USEPA, 2008a).

Metals

The level of severity of metals contamination in water samples collected in 2006 by Washington State Department of Ecology at freshwater locations around the state was variable. Only 8 sites out of 639 where dissolved metals and mercury results were reported exceeded 2006 Washington State water quality standards chronic criteria, and none were in the Puget Sound basins (Ecology, 2007d). However, there is an ongoing debate on whether the existing metal standards are protective, particularly for copper. Research by scientists at the Northwest Fisheries Science Center has shown that olfactory response to copper in coho salmon occurs at levels of 2 parts per billion (ppb) over background concentrations (Baldwin et al., 2003). The comparable marine standards are currently 4.8 ppb acute and 3.1 ppb chronic.

Groundwater

[Authors and reviewers note the need for more information regarding the relative importance of groundwater relating to the health of Puget Sound.]

Air Deposition

Atmospheric deposition directly to Puget Sound appears to be an important source of loading for some chemicals of concern (Hart Crowser et al., 2007). Deposition of contaminants from air pollution is increasingly being noted as a significant pollutant source. Growing evidence suggests that toxic contaminants are not confined to a few specific "hot spots" associated with industrial uses. Airborne particulates from the fuel emissions of cars, trucks, and stationary sources wash into rivers, streams, and marine waters and upload back into the food web. In 2001, an estimated 7.7 million pounds of toxic chemicals were released into the air in the Puget Sound basin from stationary sources alone (not including mobile sources such as cars or trucks).

Recent efforts to compare the importance of atmospheric deposition among other sources (Hart Crowser et al., 2007) determined that the atmospheric loading represented a fraction of the surface runoff loading. However, that study also indicated that atmospheric deposition of both metals and organics has a greater degree of uncertainty than the surface runoff loading rates based on the limited number of measurements in the Puget Sound area. *[Authors requesting more material on this topic.]*

Recreational Water Activities

Freshwater lakes and rivers and the marine waters in Puget Sound provide popular recreational opportunities for boaters, anglers, and outdoor enthusiasts. Many of these water bodies have recreation-associated facilities including boat ramps, docks, and dockside fueling facilities. In addition to pollutants from motorized boats (fuel leaks, emissions, waste discharges), docks and fueling facilities can be a source of pollutants to water bodies in Puget Sound. *[Authors requesting more material on this topic.]*

DRAFT

Creosote-Treated Timber Piles

High levels of PAHs and dioxins/furans found in creosote are toxic to fish and sediment organisms (Pastorok et al., 1994). The concentrations of metals and PAHs are higher near treated docks (Wendt et al., 1996). However, studies have shown that there are no measurable short-term effects on estuarine organisms on or near dock pilings (Wendt et al., 1996). The long-term risks associated with docks are unknown, although the PAHs and dioxins/furans associated with creosote are very persistent in the environment.

Marine Traffic

There is little documentation about the importance of marine traffic on water quality conditions in Puget Sound, either through direct discharges of ballast water and wastewater or through deposition from exhaust particulates. *[Authors requesting more material on this topic.]*

Oil Spills

The total amount of reported oil and petroleum products from reported spills directly into the surface waters of the Puget Sound basin was about 4% of the amount estimated to enter via surface runoff. When the relatively rare large spill occurs, it often has a large local impact, including acute toxicity to organisms and plants. Shellfish and other types of marine commercial and recreational harvest are usually curtailed.

C. Gaps in knowledge

Gaps in knowledge exist with respect to pathogens (Newton et al., 2007). Because of requisite disinfection practices at point-source wastewater treatment facilities, nonpoint sources have been identified as a substantial contributor to environmental pathogen loads. Depending on land usage, we may be able to approximate relative contributions of these sources at specific geographic locations around the Sound, but we do not know the precise percent contribution of point versus nonpoint sources to Puget Sound as a whole. In addition, while some work has been done on the survival, fate, and transport of different pathogens in waters and sediments, we still cannot accurately predict the breadth of impacts on water quality.

Emerging contaminants and their environmental consequences are also questions for which the scientific community is developing answers. Although most research points to detrimental effects these constituents may have on freshwater and marine ecological communities, there are still significant facets of this topic that require further research. Our understanding of the impacts of marine traffic is also limited, as is our comprehension of the related pollutant contributions due to recreational water use. The contribution of air pollutant loading to waters is also recently being identified as a potentially significant source of contaminants to Puget Sound waters.

The aforementioned gaps in our current knowledge, however, are exacerbated by perhaps the largest gap in our knowledge surrounding Puget Sound water quality: our understanding of the impacts of climate change. Current predictions incorporate our best estimates of future changes in the Northwest weather regime, based on global-scale models, combined with our understanding of the impacts of these changes on ecosystems. Early indications are that snowfall will decrease, snowmelt will occur earlier, and streamflow will be higher in some winter months and much lower in some late summer months. While new empirical data on climate change impacts continue to inform these projections, uncertainties in the data and model assumptions make it difficult to forecast effects precisely (Lawler and Mathias, 2007). Marine water temperatures are expected to increase in Puget Sound due to increases in air temperature and changes to freshwater inflows. Additionally, Puget Sound circulation patterns are likely to change, with associated impacts to dissolved oxygen (Mantua et al., 2007).

DRAFT

What these predictions mean to water quality in Puget Sound is unknown. However, it is likely that current infrastructure that supports our water, stormwater, and wastewater systems will be affected and could impact the transport, frequency, and duration of pollutants reaching Puget Sound water bodies. It is also likely that current accepted "knowns" about Puget Sound pollutants will be rendered obsolete in the face of these changes.

DRAFT

Science Question 2 (S2): Management Approaches Addressing Water Quality

A. What are the main scientific findings relating to management approaches and their documented effectiveness in Puget Sound?

Management approaches to water quality in Puget Sound include preventive and remediation measures for point discharges (such as wastewater treatment, industrial treatment, and confined animal feeding operations) and for non-point source pollutants from stormwater runoff. Preventive measures include land conservation, structural and non-structural source controls, design standards, best management practices for a variety of land use activities, public education, chemical bans, regulation, and enforcement. Remediation approaches include treatment, retrofits, operations and maintenance, and cleanup of more difficult nonpoint source or legacy pollutants in sediment.

Stormwater

Modern stormwater drainage standards did not begin to come into effect in the Puget Sound region until 1995. Most of the developed land in Puget Sound remains untreated for stormwater quantity and quality (see attached map reflecting an analysis of pre-1995 development in King County). Preventive and remedial measures for stormwater include structural and non-structural Best Management Practices (BMPs) which have varying degrees of effectiveness. Identifying and removing illegal connections of non-stormwater discharges to stormwater systems is considered to be effective in reducing contaminants entering the Sound. Stormwater prevention and remediation problems are compounded by the lack of interjurisdictional mapping of stormwater systems, which can hamper efforts to clean up accidental spills. Most current stormwater management methods utilize site-specific source controls, rather than landscape-scale methods to analyze stormwater management and impervious surface area.

Source control measures

Source control measures include programs that prevent pollutants from being available for transport by stormwater, and programs that reduce the use and availability of pollutants in the environment. National Pollutant Discharge Elimination System (NPDES) permits for construction, industrial, and municipal operations require source control elements such as surface water pollution prevention plans, spill control plans, and educational programs for proper handling and disposal of waste products. Non-structural source controls are difficult to verify or enforce under current regulations. Measures have historically been unevenly implemented and have had varying effectiveness at controlling stormwater pollutants (Duke and Chung, 1995). Some examples of specific source control measures include *[Authors request more information here]*:

- Vacuum-assisted street sweeping reduces pollutant washoff and may remove up to 80% TSS (Sutherland and Jelen, 1996, Breault et al., 2005). Street sweeping methodologies have improved.
- Local conservation districts typically work with agricultural operators to reduce water quality impacts from farming practices.
- Land based (ag BMPs, pesticide reduction, pharmaceutical take-back programs), creosote log removal.
- Airborne.
- Oil spill prevention and cleanup.

DRAFT

Treatment measures

A variety of stormwater treatment techniques are implemented by jurisdictions in the Puget Sound region. As discussed in above, stormwater treatment techniques started being implemented around 1995, with the first *Stormwater Management Manual for Western Washington* (Ecology Manual) (Ecology, 2005). Techniques listed in the Ecology Manual are most often used today; however, many jurisdictions use equivalent manuals specific to their areas or have not yet adopted the Ecology Manual.

Generally, stormwater treatment is now required for new development and redevelopment that meets certain minimum thresholds. Treatment techniques and requirements have evolved over the last decade along with technical understanding of stormwater impacts. Still, most of the Puget Sound basin remains untreated because stormwater treatment requirements were not in place when the bulk of the region's development occurred. In these areas, stormwater treatment retrofits are sometimes incorporated with redevelopment of individual properties. Stormwater retrofit techniques are similar to traditional structural stormwater BMPs installed when properties are newly developed.

Traditional structural stormwater BMPs. The level of treatment provided by structural stormwater BMPs is highly variable and depends on many factors including design, maintenance, and influent conditions (Geosyntec and Wright Engineers, Inc., 2007). A recent study analyzed BMP treatment system performance for six BMP categories: detention basins, biofilters, hydrodynamic devices, media filters, retention ponds, and wetland basins (Geosyntec and Wright Engineers, Inc., 2007). The study observed that:

- BMPs appear to be most consistently effective in the removal of Total Suspended Solids (TSS).
- Total phosphorus appears relatively difficult to remove with existing methodologies, with the exception of media filters and retention ponds.
- Structural BMPs are widely variable in the differences between influent and effluent for total nitrogen. In three BMP categories, the effluent had significantly higher total nitrogen concentrations than the influent.
- There is a significant difference between influent and effluent event mean concentrations (EMCs) for dissolved zinc. However, three categories of BMPs indicated the effluent was significantly greater than the influent.
- There was not a significant difference between influent and effluent EMCs for dissolved copper, with the exception of biofilters and retention ponds where effluent concentrations were less than influent.

Current design and application of BMPs for stormwater are not demonstrated to consistently achieve water quality standards in receiving waters, nor are water quality standards for BMP design explicitly stated in most watersheds. Where Total Maximum Daily Loads (TMDLs) exist, treatment and source reduction requirements have been established that are typically presumptive and not linked to achieving specific numeric standards. Coupled with the limited or absent water quality monitoring conducted in many of these basins, this presumptive approach prevents the possibility of drawing scientific conclusions on TMDL/water quality plan effectiveness. (Washington State Department of Ecology, http://www.ecy.wa.gov/programs/eap/models.html.)

DRAFT

Additionally, as stated in GeoSyntec et al., 2002:

> *Direct comparisons between stormwater quality and the water quality criteria should be interpreted with caution because the effects of receiving water hardness levels do not account for mixing and dilution in the receiving waters or for such comparisons on heavy metals. This is especially true when the stormwater discharge is very small relative to the receiving waterbody. The variable nature of stormwater quality further complicates comparison to water quality standards.*

Low Impact Development methods: Low impact development techniques for stormwater management include the installation of features that attempt to mimic natural hydrological conditions, such as porous pavement, infiltration facilities, rain gardens, and other techniques (Puget Sound Action Team, 2005). Limited research has been conducted on the effectiveness of low impact development techniques to improve water quality.

Other measures

Following are examples of additional measures to reduce the negative effects of stormwater, along with some of the successes and limitations of these measures:

- Interjurisdictional Coordination and Mapping: Potential for acute impacts exists due to lack of explicit mapping of interjurisdictional drainageways. For example, in the Urban Growth Areas of Snohomish County, over 800 miles of pipes, culverts, and ditches comprise the drainage system. It is possible for a diesel spill on Interstate 5 to flow through Snohomish County, then through the City of Marysville prior to discharge to the Snohomish River without clarity on the points of connection between each jurisdiction's drainage systems. This situation may limit the ability to quickly respond to landside hazardous substance spills.

- Illicit Connection Removal Programs. Wastewater, industrial, or other non-stormwater connections to stormwater systems have the potential for acute impacts to receiving waters. Since 1995 when the first Phase 1 NPDES municipal stormwater permits were issued, removal of illicit connections has been a requirement. While the cumulative number of illicit connections is unknown, professional judgment indicates that the potential for acute impacts was reduced by removing such connections. Most Phase 1 jurisdictions have evidence of significant reductions in fecal coliform bacteria and other constituents as a result of focused tracking and removal of illicit connections.

- Inspection and Enforcement: The effectiveness of regulatory programs in protecting water quality is not well known due to challenges in enforcement. State agencies and local governments lack staff to ensure that permitted facilities are constructed and operated as designed. For example, Ecology inspected 434 of more than 2,000 industrial permitted sites in the Commencement Bay and Lower Duwamish areas during 2006. There is not enough staff to annually visit or inspect facilities with industrial permits (Ecology, 2007).

[Reviewers/authors have stated the need for more findings in the following topics]

- Stormwater management at a landscape scale: *[findings about reduction of impervious surface, avoiding compaction, and the need to manage at a landscape scale, rather than site-by-site, could be inserted here.]*

- Limitation on impervious surface, and protection of ecologically functional areas:

DRAFT

- Interface with small agricultural and landscape operators:

- Spill prevention:

Wastewater

Secondary treatment of wastewater at municipal wastewater treatment facilities is effective in reducing loads of biodegradable organics, suspended solids, and fecal coliform bacteria (Metcalf and Eddy, 2005). Most larger facilities are operated to remove some nutrients, primarily nitrogen, but these facilities are not generally designed to remove other constituents such as toxics and endocrine disrupting compounds (EDCs). There is growing evidence, however, that traditional biological wastewater treatment can partially and/or completely remove some EDCs (Jiang et al., 2005, Nasu et al., 2001).

Well sited, well designed and constructed on-site wastewater systems are effective in removing pathogens from human wastewater. However, on-site wastewater system siting standards, while accounting well for human health, do not generally account for the condition of receiving waters, such as nutrient limitations. Technologies for nitrogen removal from on-site systems are not routinely utilized at this time, increasing the challenges of adequate treatment in areas subject to hypoxia and other side effects of excess nutrient discharges.

Technologies are available to effectively reduce the discharge of nutrients and toxics:

- Membrane bioreactor (MBR) technology reduces toxic compounds and EDCs more effectively than conventional secondary treatment (Lesage et al., 2005).

- Ozonation, ultraviolet radiation, and advanced oxidation processes can effectively reduce many trace compounds (Jasim et al., 2006, Ried et al., 2005).

- Tertiary wastewater treatment and wastewater facilities that produce Class A reclaimed water can achieve greater levels of both nutrient and contaminant removal because of their frequent use of membrane filtration and other advanced processes (Ngheim et al. 2004, Wintgens, et al. 2002).

Industrial wastewater treatment systems are designed specifically to deal with the industry's unique waste stream. Increasingly, industrial discharges are being diverted into municipal systems following pretreatment to make the waste compatible with municipal domestic waste.

[Authors/Reviewers note that a discussion of findings on mixing zones and their effectiveness or limitations could be added here.]

Contaminated Sediments

[Authors suggest an analysis of the effectiveness of cleaning up contaminated sediments relative to cost, and under what conditions. Issues include historic liabilities and the potential for Puget Sound-wide regulatory agency alignments on strategies, limitations of liabilities and prioritized mitigations.]

B. How is the effectiveness of management techniques measured and documented?

Effectiveness of management programs is generally measured and documented with water quality monitoring, numbers of water quality complaints received, and operation and maintenance tasks completed.

The degree to which monitoring occurs depends on the funding, staffing, and often regulatory requirements. Current monitoring programs include comprehensive ambient monitoring programs such as the Puget Sound Ambient Monitoring Program, a variety of state monitoring programs, Phase 1 jurisdictional efforts, and monitoring required under the variety of NPDES permits or CERCLA/RCRA compliance conditions at the jurisdictional and industry level. A variety of compilations are available on the state and local jurisdiction web sites. There has also been important work done by the Water Environment Research Foundation (WERF).

In general, wastewater treatment plant operators routinely monitor water quality to document NPDES compliance. Annual reports submitted to the Washington State Department of Ecology summarize water quality monitoring results for compliance. The Washington State Department of Transportation also submits annual monitoring reports to Ecology in accordance with their NPDES stormwater permit.

C. Gaps in our understanding

The largest current gap is the absence of an overarching ecosystem monitoring program that links measurable pollutants to intended outcomes to expenditures so that more accurate estimates of effectiveness and cost-benefit can be obtained. The following represents a very partial list of gaps in understanding related to management approaches to water quality improvement in Puget Sound:

- Connection between a suite of BMPs and numeric water quality standards and then to protection of the designated uses for a specific water body.
- Effectiveness of standards for achieving water quality health.
- Clarity and standardization of effective nitrogen removal technologies for on-site wastewater systems.
- Measured effectiveness of stormwater retrofit approaches that ensure contaminants are effectively removed or contained and not inadvertently transferred to groundwater.
- Extent of non-commercial agricultural livestock wastes and nursery discharge in rural and urbanizing areas.

DRAFT

Policy Question 1 (P1): Policy Approaches to Address Water Quality in Puget Sound

A. Existing regulatory or management programs

The Federal Clean Water Act (CWA) (1972) is the legal driver for the regulations and management programs that are in place to protect and restore water quality in Puget Sound. The CWA establishes the framework and minimum requirements for setting effluent limitations and water quality and sediment quality standards that address dissolved oxygen, nutrients, pathogens, and a limited array of toxic compounds. Washington State has used its authority to establish water quality and marine sediment standards unique to the state.

The Washington State Department of Ecology implements the CWA National Pollutant Discharge Elimination System (NPDES) permit program. For the most part, NPDES is the program that covers water quality issues for stormwater, wastewater, and industrial discharges in the state.

In addition to the CWA, the Federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); the Federal Resource Conservation and Recovery Act (RCRA); and the state Model Toxics Control Act (MTCA) drive the cleanup of contaminated sediment and groundwater, which are known to be sources of water quality pollutants in Puget Sound. CERCLA and RCRA are carried out by the U.S. Environmental Protection Agency. Federal and state programs have made progress in addressing a number of contaminated sites, but the requirements are extensive, expensive, and time consuming. The programs are facing new challenges associated with recontamination of remediated sites, for example the Thea Foss waterway in Commencement Bay.

Other regulations that manage water quality indirectly include the federal Endangered Species Act (ESA) (1973); the National and State Environmental Policy Acts (NEPA/SEPA); and the Washington State Shoreline Management Act.

Specific regulatory and management programs operating in Puget Sound are described as follows: *[Reviewers note that more information on CWA 319 programs for non-point source control could be included.]*

DRAFT

Stormwater

- Most urban areas around Puget Sound have established stormwater drainage utilities of some type to fund maintenance and operation of municipal stormwater systems and capital projects. These utilities develop Comprehensive Stormwater Management Plans that are updated every 10 years.

- Most counties and cities must comply with NPDES municipal separated sewer (MS4) permits. Phase I (population over 100,000), and Phase II (population between 1,000 and 100,000) NPDES MS4 permits address water quality threats from stormwater through public education and outreach requirements; illicit discharge detection and elimination programs; reduction of pollutants from new development, redevelopment and construction sites; and pollution prevention and operation and maintenance programs for municipal operations.

- The NPDES permit program covers many other activities besides municipal stormwater, including highway runoff (WSDOT NPDES permit), general construction (construction sites over 1 acre), general

industrial activities, general boatyards, sand and gravel mining operations, and others.

- The Washington State Department of Ecology 2005 Stormwater Manual for Western Washington (Ecology, 2005) is used by many, but not all NPDES communities. Adoption of the manual or equivalency must be completed by August 2009 for Phase II communities.

- The federal Endangered Species Act allows incidental take of listed species. Federal agencies are required to consult with the U.S. Fish and Wildlife Service and National Oceanographic and Atmospheric Administration (NOAA) Fisheries (collectively known as "the Services") about their activities, including activities that could affect water quality, including stormwater runoff.

- Local conservation districts and water quality field agents with University Extension Services provide technical assistance to landowners in the management of runoff from agricultural and other rural activities.

[Authors/reviewers note the need for more description on advances that have been made in this arena, such as LID.]

Wastewater

- Most urban communities in Puget Sound have local or regional wastewater utilities to fund operation and maintenance of municipal wastewater treatment plants. These utilities develop Comprehensive Wastewater Management Plans coincident with Growth Management Act Comprehensive Plan updates or as required by their authorizing legislation.
- Rural communities in Puget Sound do not have regional wastewater facilities, and residents typically use on-site wastewater treatment techniques for sewage treatment. Local and state health departments regulate on-site wastewater systems.

- Municipal wastewater treatment plants and industrial treatment plants must comply with NPDES permits for wastewater discharges. These permits outline requirements for discharge limits (frequency, concentration of key constituents, and volume), as well as water quality monitoring to document compliance.

- Municipal wastewater treatment plants are treating waste streams from industrial facilities, following pretreatment to reduce constituents that are not easily treated in the municipal waste stream, including metals and other toxic compounds (Metcalf and Eddy, 2005). Municipal operators are required under their NPDES permits to ensure waste from industrial facilities does not adversely impact the receiving water bodies where treated municipal sewage is discharged.

[Authors/reviewers note the need for more description on advances that have been made in this area.]

Sediments

- Federal and state cleanup programs administered by the EPA or Ecology under CERCLA, RCRA, and MTCA address contaminated freshwater and marine sediments through voluntary and mandated cleanup programs. These programs address the threat of sediments containing a number of legacy contaminants that impact water quality and can bioaccumulate in aquatic organisms.

DRAFT

B. Limitations of existing programs

Despite the number of regulations and programs designed to address water quality in Puget Sound, there are still receiving waters that are not achieving the existing standards (see discussion in Memoranda S1 and S2). Limitations of existing stormwater, wastewater, and other specific water quality programs are discussed below, but a number of general themes emerge from the review of these programs:

- The lack of integrated planning between stormwater, wastewater, non-point source control, and water supply has led to geographic gaps in coverage and functional gaps in how well programs perform.
- The pursuit of separate goals (and segmented programs and standards) to address human health and ecosystem constraints has led to the design and operation of facilities that do not address both objectives effectively.
- Historically, land use planning has not been strongly influenced by the provision for water supply, wastewater treatment, or stormwater management from an ecological perspective. More typically, land use decisions determined how water supply, wastewater disposal, and stormwater management would occur.
- Many jurisdictions lack funding for adequate enforcement and outreach programs. The training of staff for preparing or reviewing designs, monitoring, and conducting enforcement is highly variable.
- Additionally, it is not known whether the existing standards are sufficient to be protective of aquatic communities, particularly for nutrients and toxic compounds.

Stormwater

The focus of stormwater treatment until the last two decades has largely been quantity-based for flood control, and secondarily for water quality. In the freshwater system, the historic focus on controlling quantity has had some positive ecological benefits through reduced flooding, erosion, and sediment transport. For the most part, there has been very little water quality monitoring to address the effectiveness of stormwater treatment on receiving water conditions. To date, Phase I and Phase II NPDES permits have not required monitoring (Ecology, 2007a, 2007b). Key findings include:

- The CWA NPDES regulations treat stormwater as a point source although stormwater behaves more like a non-point source.
    - The application of BMPs is presumed to achieve water quality standards, which may be true in some situations, but not in others.
    - There is no requirement for analysis of the effectiveness of BMPs to meet the water quality standards in the specific water body which will be receiving the BMP-treated stormwater, although current Phase I permits attempt to make progress in the linkage of select BMPs and loading reductions.
- With the uncertainty surrounding BMP effectiveness, a currently contentious aspect of the NPDES MS4 permits pertains to the exposure of municipal stormwater dischargers to third-party lawsuits for failure to meet water quality standards that are unachievable with current programs, policies, projects, or funding levels. *[Authors/ reviewers note the need for more information on this issue.]*
- Stormwater quality and quantity are tied to land use and transportation, yet they are not currently planned together.
- Existing stormwater BMPs prescribed in Ecology's Stormwater Management Manual for Western Washington (Ecology, 2005) are not effective at removing all of the constituents associated with stormwater runoff from new development. In general, most are fairly effective at removing total suspended solids (TSS).

DRAFT

- Water quality threats from urban stormwater constituents such as polynuclear aromatic hydrocarbons (PAHs), dissolved metals, phthalates, and other compounds are not being addressed by existing regulations.
- Stormwater treatment and flow control requirements have focused almost exclusively on new development and construction activities, and have not dealt in any meaningful way with existing (pre-1995) urban development in most areas.
    - Most of the urban development in the Puget Sound region occurred prior to 1995 (prior to current stormwater manuals). Unless retrofitted with controls, this development provides no or minimal management of stormwater (see representative map provided in the response to Question S2.
    - Retrofitting has been attempted in some portions of Puget Sound, but these "fixes" are frequently costly and implemented in a fragmented way with limited effectiveness.
- NPDES Phase I and Phase II stormwater permits are issued to individual government entities, leaving gaps in geographic coverage.
    - Urban areas below the Phase II threshold (less than 1,000 people and a minimum density) are not covered under NPDES. The vast amount of land area of Puget Sound counties is not covered by permits.
    - Federally recognized Indian Tribes are not required to obtain NPDES MS4 permits, and they operate under different water quality guidelines.
    - Federally owned lands (U.S. military, Bureau of Land Management, National Park Service, and other federal agencies) are not required to obtain NPDES MS4 permits but do need to comply with federal water quality standards.
- NPDES application of requirements is inconsistent in the same watershed.
    - Phase I and Phase II requirements are different (reflects the phased implementation of requirements).
    - Washington State Department of Transportation operates under a different NPDES MS4 permit.
- There is no area-wide application of CWA NPDES for stormwater in watersheds or areas with known water quality problems.

DRAFT

Wastewater

Municipal wastewater treatment (WWTPs), combined sewer overflows (CSOs), reclaimed water, and septic systems are focused mostly on removing pathogens, biochemical oxygen demand, and suspended solids for the primary objective of protecting human health. Although treatment for ecological purposes (removal of nutrients) has become fairly standard practice, most systems will face costly upgrades to meet increasingly stringent effluent criteria. *[Authors/reviewers note the need for more description of how this is changing.]* Municipal waste operators conduct regular water quality monitoring to document compliance with NPDES discharge permits and water quality standards. Key findings include:

- There is good geographic coverage of WWTPs around Puget Sound at secondary treatment levels. *[Authors/reviewers request clarification on whether this is widespread in Puget Sound or confined to highly populated areas.]*
    - Funding for WWTPs has been generous at the federal and state levels in the past, with 75% federal and 15% state grant funding in the early days of implementation of the CWA to take the nation to secondary treatment.
    - Current WWTP upgrades face funding shortages in non-urban areas because most of the funding is through local sewer utility fees.

- The discharge of toxic compounds, such as pharmaceuticals, presents an emerging challenge for treatment in municipal systems, because some of it is discharged in human waste, is present in very low levels, and is ever-changing in composition and increasing in number and complexity. Sampling protocols are largely undeveloped and testing is expensive, treatment options are expensive, and existing regulatory and testing procedures do not address these pollutants.
- The reuse of treated wastewater has been developed as an alternative to marine and freshwater discharge. Reclaimed water can reduce pollutant discharges and may serve as a water conservation option. Reclaimed effluent is being utilized for wastewater treatment plans of various sites such as Lacey, Olympia, Tumwater, Thurston County (LOTT), King County, and Sequim; however, there are a number of barriers that hinder its widespread:
    - Water supply planning is not required to include reuse as a significant component. Non-potable demand is not adequately accounted for as a separate demand in water supply planning.
    - Exclusivity of service area may give water utilities veto over water reuse in their areas; water reuse is viewed by some water utilities as competition for their customers.
    - Pricing policies are widely varied from free to equal to potable rates; cost recovery policies are not uniform; some areas of the country charge reclaimed water at 80% of potable regardless of the cost of production; equity for cost allocation between wastewater and water supply customers is unresolved.
    - Liability for the use of reclaimed water is an unresolved issue for the producer, for the water utility if they become a purveyor of reclaimed water, and for the user.
    - If the WWTP operator is required to reduce discharge through production of reclaimed water, the only real cost for supply is the distribution system (purple pipe), but due to location of reclaimed sources this can be high.
    - The benefit cost (triple bottom line) analysis of reclaimed wastewater reuse versus tertiary treatment to reduce treatment plant discharges is unknown.
    - The Washington State Department of Revenue has denied sales tax credit to facilities built to reclaim and reuse wastewater. This represents a significant barrier because the offset of taxes has the potential to be sufficient to fund the facilities.
- Methods for treating wastewater to Class A reclaimed water standards, and tertiary treatment for nutrient removal are known. The cost of providing this level of treatment may be modest. However, the challenge with reclaimed water is the cost of the distribution system for the use of the reclaimed water and the economic impact to existing water purveyors of introducing an additional source of water into the current water supply system (King County 2006- King County 2006. Regional Wastewater Services Plan Comprehensive Review and Annual Report, Chapter 7, Water Reuse Policies).
    - A paradox exists that to fund higher levels of treatment with local financial resources, greater population densities are needed to keep utility rates affordable, which drives the need for higher levels of treatment. This is especially problematic in areas that already present risks to Puget Sound water quality health but cannot support the densities necessary to make high levels of wastewater treatment affordable.
    - GMA helps steer growth into already urbanized areas, which goes some way toward helping reconcile population density and affordable WWTP facilities (King County, LOTT). Conversely, where GMA has allowed density in ecologically sensitive areas, wastewater treatment costs are high.

DRAFT

- While secondary treatment has been the standard for years, higher levels of treatment and reduced discharges are now being driven by the Washington State Department of Natural Resources (WDNR), manager of the state's tidelands and shorelines. An inconsistency exists between WDNR and Shoreline Management Act interpretations regarding the designation of wastewater outfalls as water-dependent uses or non-water-dependent uses. Designation as a non-water-dependent use opens the door to additional options for wastewater discharge, such as land application of biosolids or reuse of wastewater.

- "Flow blending" while maintaining basic secondary or more restrictive treatment requirements makes affordable higher levels of treatment of base flows, and overall reduced loads. Flow blending involves treating baseflows to a higher standard and then blending them with storm flows, which are treated at a lower standard. The aggregate result is overall lower loadings over the traditional secondary treatment approach.

Wastewater: Combined Sewer Overflows

- The current state standard is one uncontrolled overflow per year per CSO outfall, compared to the current federal standard of approximately four uncontrolled overflows per outfall per year.
    - We know how to design, operate, and maintain CSO facilities to meet current uncontrolled overflow standards.
    - CSO treatment is very costly.
    - CSO programs are very expensive and not generally driven by the overall achievement of water quality standards, but to achieve a standard based on the number of untreated overflows allowed per year.
- CSO separation programs were generated under the theory (prevalent at the time) that rainfall runoff was clean relative to wastewater and could be used for dilution. However, numerous studies of non-point source pollution (Response to Question S1) have shown that this is not always the case.
    - In most areas, adding stormwater to the combined sewer system is not now allowed, except in special cases.
- State treatment standards for CSOs are inconsistent with stormwater requirements for new development as determined by solids removal efficiencies.
- Sediment contamination resulting from previous discharges at CSOs is being addressed through CERCLA remediation in some geographic areas of Puget Sound.

Wastewater: On-site Sewage Systems

- The standards for septic system design do not typically address removal of nutrients and toxic compounds.
- Septic system siting standards do not address specific receiving water conditions, including nutrient limitations.
- Regulations for septic system performance are clear and achievable. However, inspection and enforcement do not typically occur unless problems with septic leach field failures can be observed.
    - There is no consistent system for maintenance and operation of septic systems.
    - There is a lack of funding and alternatives for failing septic systems (state laws enacted in 2007 now provide for the formation of septic system utilities).
- Regulatory oversight by the Washington State Department of Health (DOH) and local public health departments is affected by the limitations of permit-fee based funding. Also, human health has generally been the primary goal of on-site systems although critical areas setbacks have been included in state

DRAFT

design standards for on-site systems. Legislation adopted in 2006 established new laws requiring the 12 counties surrounding Puget Sound to: (1) identify "marine recovery areas" where failing septic systems threaten water quality; (2) locate and track those systems that threaten public health; and (3) work with system owners to make necessary repairs. (http://www.martenlaw.com/news/?20060329-failing-septic-systems) *[Authors and reviewers note the need for more information on the status of implementation of this law.]*

Airborne Pollution

- There is growing evidence that air deposition of some pollutants, mainly in the form of fine particulates, can be significant (phthalates, mercury, arsenic, cadmium, etc.). There is no mechanism to deal with this type of source and the link to air quality standards. Air pollution is monitored by the Puget Sound Air Pollution Control Authority. *[Authors/reviewers note the need for more information for this subject.]*

Direct Marine Pollution

- The cruise ship industry is growing in Puget Sound, with six cruise lines using Seattle as a port-of-call. The Northwest Cruise Ship Association has a signed Memorandum of Understanding with Washington State Department of Ecology and Port of Seattle, outlining procedures to be followed for waste management, including discharges to marine waters.
- The US Coast Guard has a primary role in the enforcement of federal regulations pertaining to marine traffic.
- The Shoreline Management Act has been used to protect shorelines but also allows for water-dependent uses (e.g., docks, marine commerce) which have known or strongly suspected sources of environmental degradation (e.g., use of creosote, bilge water disposal).
- Much effort has been spent on the need for a tugboat at Neah Bay to provide support and prevent catastrophic spills. Funding for this program has been difficult to maintain.

Land Use Planning

[Authors note that this issue is not addressed in detail as it is the focus of the land use/habitat paper.]

- The Growth Management Act (GMA) advanced the integration of land use planning with water resources to the extent that critical areas are specifically addressed.
- GMA contains a balancing provision which results in some cases of environmental degradation to accommodate growth.
- The objectives of GMA to reduce urban sprawl overlap with findings that expansion of impervious surfaces impairs stream hydrology and habitat, and may impair water quality.
- Water supply, wastewater treatment, stormwater management, and land use planning have not been well integrated within localities in Puget Sound.
- Land use planning has been a strongly held purview of local governments, which makes large-scale land use planning for the protection of large geographies such as Puget Sound difficult. GMA and shoreline management have made some progress in guiding local land use planning

DRAFT

C. Other types of plans or programs used in other locations to address water quality; documented effectiveness

Source Control

REACH is a new European community regulation of chemicals and their safe use (EC 1907/2006). It deals with the "Registration, Evaluation, Authorization and Restriction of Chemical Substances." The new law came into effect on June 1, 2007, to improve the protection of human health and the environment through the better and earlier identification of the presumed hazard of chemical substances. In the ideal, those substances with high hazard would be phased out in favor of alternatives with lower potential to cause harm to people or the environment.

[Authors/reviewers note the need for more information relating to source control programs, including the Oil Spill Prevention Program.]

Comprehensive Watershed Planning

A few communities in the United States, most notably the Madison, Wisconsin area, are coordinating water resources planning through collaborative watershed initiatives. These initiatives take a holistic ecosystem approach to watershed management and share decision-making, collaboration, and engagement with a wide array of stakeholders. The EPA also expressed its support for issuing NPDES permits on a watershed basis to meet overall watershed goals in a January 7, 2003 Policy Statement. Because these programs are so new, it is not known whether they have been effective.

DRAFT

Policy Question 2 (P2): Strategies to Improve Water Quality in Puget Sound

Water quality threats associated with our approach to urban living are ubiquitous. Our region is faced with a seemingly incompatible combination of (1) development approaches that do not incorporate multiple goals for human health and ecosystem protection, (2) increasing population levels, and (3) a desire to minimize or eliminate water quality threats resulting from additional growth. Current interventions and efforts, in total, do not appear to be effective in restoring all beneficial uses for water quality. Since 1995 when the first Phase I NPDES municipal stormwater permits came online, only a handful of urban streams or lakes have been removed from a 303(d) listing and more have been added. This does not imply failure of the permits, but rather underscores the difficulty of the charge for widespread pollution management.

A. Principles for water quality improvement in Puget Sound

The goal of improving water quality in Puget Sound by the year 2020 will require thoughtful consideration of the projects and programs most likely to move us toward that goal without losing ground on the stressors that continue to act on the ecosystem, including population growth and land conversions. The following preliminary principles and criteria are recommended to guide consideration in the development of strategies:

- Recognize that water quality improvement opportunities need to be closely orchestrated with land use/habitat and water quantity strategies and with the decisions of individual land owners. Water quality strategies alone, without consideration for the interrelated issues associated with land use and water quantity, cannot be expected to be successful. Success is unlikely without common intent across jurisdictions and cooperation and collaboration with property owners.
- Focus on ecosystem function improvement. Strategies that work with the natural ecosystem function (including human health) will have a better chance of being sustainable in the long term, and should be considered high priority. This includes strategies that reduce risks to human health, preserve natural ecosystem function, increase habitat complexity, and accomplish multiple objectives. For instance, low impact development techniques attempt to mimic the natural hydrology of a particular site and reduce the pollutants available for transport to receiving waters.
- Strategies for moving forward will need to embrace uncertainty; adaptive management will continue to be an essential element of moving toward water quality health. Memoranda S1, S2 and P1 provided overviews of some of the gaps in what we know and the effectiveness of what we are doing. Climate change, economic crises, and shifts in modes of transportation may all dramatically affect strategies for water quality improvement.
- Control sources of known pollutants without introducing new and ultimately more problematic constituents (reduce, reuse, recycle).
- Certainty: Accelerate the implementation of known solutions that have already proven to be effective. Water quality strategies that are certain to make a positive difference in water quality and for which science clearly supports the strategy should be our highest priority. Those strategies with a high degree of certainty will likely have the most measurable results. Strategies with flexibility in implementation afford greater agility in responding to the uncertainties of climate change or economic disruptions.
- Increase feasibility for new and emerging strategies by resolving regulatory and technical barriers. Many of the water quality strategies identified in this discussion draft have regulatory or technical barriers that need to be resolved. Projects that have no barriers to implementation should be

DRAFT

given highest priority. Greater feasibility, however, does not imply lower importance. However, less feasibility may suggest the need for greater study.

- Wherever possible, turn stormwater and wastewater into water resources.

B. Preliminary recommended near-term strategies

The strategies listed below are endeavors that the team agreed could be enacted immediately because they are highly certain to have a positive effect on water quality in Puget Sound.

Stormwater

- Begin or accelerate retrofits of impervious surfaces in untreated urban areas. The majority of urban development occurred in the years prior to current stormwater management standards. This action would require jurisdictions to develop and implement a plan for the prioritized installation of water quality and water quantity treatment (retrofit) for existing impervious surfaces for which no or inadequate treatment exists. This would address the threat of pollutant transport from urban landscapes to streams, lakes, and marine waters of Puget Sound. It would reduce pollutant and hydrologic loadings from existing urban land developed without stormwater controls. A high priority of the retrofit effort would be to reduce system connectivity (e.g., removing areas from the larger drainage system) without concurrently increasing potential flood damages.

  The certainty of effectiveness and feasibility, not including funding considerations, are both high if the effort remains in the public sector. Coordination with private properties would introduce additional challenges both for near-term agreements and long-term maintenance, but could provide additional finances and is necessary to be successful. Financial resources required to meet this goal are expected to be at least on the order of the funds it took to move primary wastewater treatment to secondary treatment in the 1970s.

- Reuse stormwater generated from rooftops for non-potable uses. Rooftops constitute a significant portion of impervious surfaces in developed areas. State water rights law currently presents road blocks to the reuse of rooftop water. While rainwater collection is being promoted at both the state and local level to address urban stormwater issues, work is needed at the state level to amend water rights law to exempt the reuse of rooftop runoff. With the regulatory pathway cleared, significant progress could be made in addressing degradation that results from modified hydrology that occurs during land conversion. Benefits could include: (1) reduced volume of stormwater entering infrastructure, thereby reducing treatment facility sizes (including retrofit treatment sizes), (2) reduced demand on domestic water supplies, and (3) reduced water quality impacts resulting from stream-channel peak flows.

- Coordinate with regional transportation efforts. As noted in the response to question S1, many pollutants in stormwater are associated with the byproducts of vehicle operation. There is a high level of certainty that reducing the total vehicle miles traveled would coincidentally reduce the amount of wear on brakes and the byproducts of that wear (such as copper and zinc), would reduce road wear, and would reduce vehicle emissions with potential for deposition and transport through stormwater. *[Authors note the need to document the links from the threat to the action.]* Clearly there is much work underway in the region to address this issue. Opportunities exist with efforts such as the Puget Sound Regional Council (PSRC) update of the long-range transportation plan with its new regional growth strategy, which will include analysis of climate change and environmental effects of actions. PSRC is only one of five current regional councils around Puget Sound. This effort will require extensive coordination to provide opportunities for water quality (and other Action Agenda) priorities to be considered in the growth and transportation plans.

DRAFT

- **Mapping of interjurisdictional stormwater networks.** Improved coordination and mapping of stormwater networks across jurisdictions is needed to reduce the potential for spills to travel across waterways through stormwater connections. This strategy would provide funding for mapping of stormwater drainage pathways from jurisdiction to jurisdiction throughout a watershed. The mapping would be provided in Geographic Information System (GIS) format and made available to first responders to provide more rapid response during spills of hazardous substances (landside). A number of jurisdictions have now mapped their systems in GIS format (an effort required under Phase I NPDES stormwater permits). NPDES Phase II jurisdictions are now required to map their systems. What is needed is both a requirement and funding to link up maps between jurisdictions whose drainage systems connect, to ensure that first responders can respond with maximum speed to address spills of hazardous substances entering drainage systems and minimizing the downstream impact of those spills. In addition, mapping and analysis of systems will provide essential data for system retrofits.

Wastewater

- **Require tertiary or Class A wastewater treatment and reuse at WWTPs to reduce nutrient loadings.** In nutrient-sensitive areas of Puget Sound, require either tertiary wastewater treatment, or treatment to Class A standards for reuse, to address the potential for hypoxia, algal blooms, and other related threats in nutrient-limited waters such as south Puget Sound. Effective wastewater treatment technologies exist to address nitrogen and other nutrient loadings. Benefits would be a reduction in nutrient loading to nutrient-limited areas of Puget Sound (tertiary treatment) and ability to reuse wastewater (Class A treatment) where uses (synergies) for the treated wastewater can be identified. Reusing treated wastewater has the added benefit of supporting the freshwater ecosystem through the reduction in dewatering.

  The primary barriers would be the availability of funding, identification of access to customers for reclaimed water (Class A treatment), public acceptance, and state water rights law. This nutrient reduction strategy may only need to be used for critical parts of the year when receiving waters are most sensitive; also the increased expense in energy and other operating costs to the wastewater system must be considered in the balance. *[Authors note more discussion needed on size parameters and cost impacts to small systems.]*

- **Expand outreach efforts to reduce emerging pollutants in personal care products such as EDCs and pharmaceuticals.** Efforts to reduce EDCs and other pharmaceuticals may have the potential for significant pollutant reduction prior to more costly investments in enhanced wastewater treatment systems. While additional technology exists to reduce EDCs through wastewater treatment processes, educational efforts are a feasible alternative to reduce EDCs input from human sources into the wastewater stream.

- **Identify and replace failing septic systems, with particular focus in areas with demonstrated water quality problems such as shellfish closures and hypoxia.** Building on the recently adopted state septic system utility law, establish septic system utilities to serve sensitive drainages throughout the Sound to ensure that existing septic systems are well maintained, but particularly in south Sound areas prone to increasing levels of hypoxia. The septic system utilities would provide a means to monitor septic system performance, increase the maintenance (and potentially longevity) of existing systems, and provide a mechanism for funding community systems in areas where densities, soils, or other site conditions preclude appropriate use of on-site wastewater systems. The utilities could also provide an increasing focus on emerging technologies related to nutrient removal. Existing on-site wastewater system design in Washington does not focus on nutrient removal. Benefits include the potential reduction in failed on-site systems and the related potential for untreated wastes to migrate to receiving waters or create human health risks. Coordination with the State Department of Health would be necessary.

DRAFT

- Review wastewater outfalls for potential decommissioning. At least 95 municipal marine outfalls, 166 industrial marine outfalls, and 60 individual marine outfalls discharge into Puget Sound (data provided by Redman, 2008). Because few existing wastewater treatment plants remove nitrogen and endocrine disruptors, and both represents concerns, a plan to explore possibilities for combining and potentially reducing the number of outfalls could yield reduced shellfish bed closures and other potential reductions in exposures, as well as efficiencies of scale in operations and costs.

Land Use

- Focus protection efforts on intact and high-quality lands and watersheds. Continue the support, through grant programs and public-private partnerships, to set aside portions of Puget Sound watersheds that remain in pristine condition. Protect (through direct acquisition, conservation easements, or other mechanisms) high-quality watersheds in Puget Sound that support ecological functions and are largely intact. Preservation of intact ecosystems reduces the potential for pollutant loadings, and preserves existing hydrologic regimes with a high level of certainty. The Cascade Land Conservancy, The Trust for Public Land, The Nature Conservancy, and others are important partners in efforts to secure intact ecosystems. This strategy may have important synergies with both recreational and wildlife protection goals.
- Integrate land use and water resources planning. As covered in Memoranda S1, S2, and P1, land use and stormwater, wastewater, septic systems, and other water uses are inextricable intertwined and yet not planned together. Land use is a determinant in water planning but not the reverse. Yet we know that current methods for mitigating adverse effects from unlimited growthhave not prevented water quality degradation in Puget Sound. Whether Section 208 of the CWA or some other integrated planning method is put into use that gives priority to the protection of water quality, it needs to be done.

C. Regulatory strategies

Stormwater, wastewater, and land use

Increase the clarity of stormwater regulatory programs. A variety of adjustments in existing stormwater regulations could reduce the threat of pollutants contributed by sources that aren't fully captured by existing stormwater regulations:

- Expand municipal separated storm sewer system (MS4) permits geographically to include communities that fall under the population threshold for areas contributory to 303(d) listed water bodies. Phase I and Phase II permits do not include all the area within watersheds. While the permits have progressed, the need remains to synchronize efforts within watersheds to increase efficient use of limited staff and financial resources typical of many jurisdictions, and to adopt area-wide approaches to receiving water improvement.
- Address all surface water discharges in MS4 permits.
- Implement source control for existing developed commercial areas.
- Develop a strategy for treating urban pollutants such as copper, zinc, phthalates, and PAHs.
- Develop and implement creative approaches for agricultural-related discharges that reflect the realities of food production while reducing impacts from more diffuse rural land uses such as non-commercial livestock facilities and nurseries.
- Address the lag in adoption of new stormwater standards with state vesting laws (e.g, many properties may be "grandfathered in" and not subject to current regulations).

DRAFT

- Improve the rate of compliance with existing permits, which may require additional staff trained in both the science of stormwater and the realities of construction.
- Conduct monitoring to determine if permits and programs are effectively implemented and effective in intent (water quality improvement).

Correcting some or all of the above gaps could increase the effectiveness of our stormwater regulatory programs and resource use. *[Reviewers noted the need for more description of the rationale for these recommendations.]*

Establish watershed area-wide permits that focus on the multitude of discharges that occur in logical geographic areas, rather than discharge-specific inputs or jurisdictional boundaries. A legal methodology for doing this is already in place through Section 208 of the Clean Water Act. Improved coordination of the discharges, land uses, and human stressors that impact a watershed will lead to better answers for improving overall watershed health and potentially to a reduction in the number of discharges needed. The threat of unintended cumulative impacts potentially could be reduced by looking at the wastewater and industrial discharges in a larger context. This effort could potentially be used to bring federal, tribal, state, and local agencies into alignment both in coordination of efforts and in the development of flexibility and incentives to ensure that the rule of law is upheld, progress in water quality is achieved, and unintended regulatory burdens or processes on industry and individuals are minimized.

Source control

Implement more comprehensive chemical management in Puget Sound. One of the concerns of addressing or reducing contaminants is that the alternative may produce more unintended consequences than the contaminants. To address the human and environmental concerns associated with chemical manufacturing and use, the European Union has moved forward with a regulatory program that requires cradle-to-grave understanding of chemicals prior to allowing their import or use within the European Union. Implementation of the regulation is in its early stages, but a part of the effort that may be of immediate use to the Partnership is the "REACH" database that is being assembled to assess relative risks and potential for source reduction of commonly used chemicals. The intent of the program is to provide information to industries and the public about potential for chemical substitutions in different industrial, commercial, and residential applications, reducing the potential for more harmful chemicals to enter receiving waters (and other parts of the environment). The Partnership could begin by tracking the REACH database and bringing the available information to bear on decisions in the Puget Sound region.

D. Recommendations for further assessment

There are gaps in our current understanding of the nature and transport of pollutants that cause water quality impairments and ecological harm. To lessen these gaps and move forward in our scientific understanding so that our strategies become more effective, the team has assembled the following preliminary list of recommended actions for discussion by the working group:

- Evaluate the role of sediment in water quality issues to better define the relative contribution of previously contaminated sediment to the overall health of Puget Sound, including the effectiveness of sediment cleanup programs, recontamination issues, and source control program effectiveness. Focus of the analysis would include the mechanisms for contaminated sediments presenting threats to the ecosystem and related risks, and the relative effectiveness of current regulatory programs in effecting cleanups opposite the cost of arriving at cleanup agreements. In addition, this analysis would include an evaluation of sediment cleanup standards for protectiveness of aquatic ecosystems, and development of protective freshwater sediment standards. In particular, there may be opportunities for expediting cleanup efforts that move public funds from contentious to cooperative efforts.

- Evaluate the link between stormwater pollutant loads and ecological effects. While it is clear that changes in stormwater hydrology affect aquatic organisms through damage to habitat, the effects of stormwater pollutants on the organisms themselves is much less understood. This study would be used to increase the understanding of the conditions producing high concentration storms as well as the frequency, duration, and magnitude of stormwater concentrations that harm and do not harm aquatic organisms. This study would be used to evaluate the effectiveness of existing stormwater BMPs, determine if they treat the right constituents or right part of the storm, and increase certainty in the selection of appropriate BMPs.
- Evaluate existing water quality standards. The question of the level of protection provided by our current water quality standards is at the core of any effort to determine the effects of pollutants on aquatic habitats. Existing water quality standards need to be reviewed for protectiveness. Site-specific water quality criteria should be developed for water bodies that may be more sensitive to the input of particular pollutants.

  Washington State's toxic substances criteria, codified in the Washington Administrative Code (WAC) 173-201A-240 Table 240(3), are the basis of all regulatory assessments conducted by Ecology about the status of the state's waters. Two basic concerns have been raised concerning these criteria: (1) the numeric values do not adequately prevent adverse effects to sensitive species; and (2) no standards have been adopted for some common pollutants. Ongoing efforts to establish cleanup goals and standards for Puget Sound will need to resolve each of these concerns. The strategy would include a recommendation that the Washington Department of Ecology: (1) review and modify as necessary existing standards (e.g., copper); and (2) adopt numeric limits for common pollutants (e.g., phthalates) for which there are no current state criteria.
- Improve predictive capability of ecosystem function through the development and refinement of modeling tools.
    - Models that simulate circulation patterns in Puget Sound. *[More description could be contributed to this issue.]*
    - Prioritization and performance assessment tool. Create a modeling tool that links scientific knowledge and management decisions in the recovery of Puget Sound to assess threats such as increasing nutrient loadings, increasing temperatures, toxic loadings, and complex food web interrelationships. The intent of the model (or series of linked models) would be to provide better capabilities for predicting ecological and human health outcomes of specific recovery actions in specific geographical areas. Actions could be prioritized based on their positive impacts. Barriers would include the challenges inherent in representing complex hydrodynamic, chemical, and biological reactions and the related uncertainty of predicted outcomes. The benefits include the deepening of understanding of processes that can occur when modeling is conducted. These tools will also point to the gaps and uncertainties in our knowledge, and the resulting uncertainties in the degree and speed of progress toward recovery as a result of our actions.
- Improve understanding of the dynamics and levels of nutrients in Puget Sound. Nutrients are creating an increasing challenge in Puget Sound, particularly in embayments and areas with low circulation. However, the dynamics and levels of nutrients from natural sources such as the Pacific Ocean and undeveloped landscapes are less well known. Additional questions pertain to:
    - How increased nutrient levels affect the Puget Sound food web. In this case we lack both the basic monitoring information on the phytoplankton and zooplankton constituents of the

DRAFT

food web and an understanding of the dynamics related to nutrient additions.

- How specific forms of nitrogen and phosphorus affect the biological community, or whether harmful algal blooms can be triggered by changes in the availability or form of nitrogen or other nutrients.

- The role of groundwater in nutrient delivery to nearshore areas.

How will we know when we're making progress?

The only way we will know that progress is being made to improve water quality in Puget Sound is to measure it against baseline conditions. There are limited water quality monitoring data available for all of the geographic regions of interest, so a carefully thought out water and sediment quality monitoring program should be established against which to compare future conditions in the fresh and marine water bodies of the Puget Sound basin. It is important to compile all of the existing data available, identify geographic or chemical constituent data gaps, and collect baseline data to fill the gaps. Long-term monitoring programs will need to be developed in the regions where actions will occur. In the near term, reductions in the number of 303(d) listed water bodies, the numbers of closed shellfish beds, the number of sites with highly contaminated sediments, and a reduction in vehicle miles traveled will serve as good indicators of progress toward overall water quality.

DRAFT

References

Alberti, M., P. Christie, J. Marzluff, J.J. Tewksbury. 2007. Interactions between Natural and Human Systems in Puget Sound. 1. Interactions between ecosystem and human well-being. IN: Ruckelshaus and McClure. 2007. Sound Science: Synthesizing Ecological and Socioeconomic Information about the Puget Sound Ecosystem. Northwest Fisheries Science Center. January 2007

Ando, M., H. Saito and I. Wakisaka, Transfer of polychlorinated biphenyls (PCBs) to newborn infants through the placenta and mothers' milk, Arch. Environ. Contam. Toxicol. 14 (1985), pp. 51–57. Full Text via CrossRef | View Record in Scopus | Cited By in Scopus (9)

Anurag Mishra, Brian L. Benham and Saied Mostaghimi. 2008. Bacterial Transport from Agricultural Lands Fertilized with Animal Manure Journal Water, Air, & Soil Pollution Issue Volume 189, Numbers 1-4 / March, 2008

Anway, D. A.S. Cupp, M. Uzumcu and M.K. Skinner, Epigenetic transgenerational actions of endocrine disruptors and male fertility, Science 308 (2005), pp. 1466–1469. Full Text via CrossRef | View Record in Scopus | Cited By in Scopus (187)

Auckland Regional Council. 2005. Sources and loads of metals in urban stormwater. Technical Publication No. ARC04104; June 2005. AKL2004-070.

Azous, A. and R. Horner. Wetlands and Urbanization: Implications for the Future. CRC Press, 356 p.

Baldwin; D.H.; J.F. Sandahl; J.S. Labenia; and N.L. Scholz. 2003. Sublethal effects of copper on coho salmon: impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry; 22(10): 2266-2274.

Barco, O.J., C. Caiponi, and S. Papiri. 2008. Quantitative and qualitative analysis of storm water runoof in an urban experimental catchment. http://www.unipv.it/webidra/02idraulicaUrbana/index_file/11.pdf

Barr Engineering Company 2005 Detailed Assessment of Phosphorus Sources to the Ramsey-Washington Metro Watershed District. Prepared for the Ramsey-Washington Metro Watershed District

Berge, H.B., M.L. Hammer and S.R. Foley. 2006. Timing, abundance, and population characteristics of spawning Chinook salmon in the Cedar/Sammamish Watershed. Funding provided by the King Conservation District, July 2006

Booth, D.B. and L.E. Reinelt. 1993. Consequences of Urbanization on Aquatic Systems – Measured Effects, Degradation Thresholds, and Corrective Strategies. Watershed '93 Proceedings. Alexandria, Virginia;

Booth, D. B. and C. R. Jackson, 1997, Urbanization of aquatic systems-degradation thresholds, stormwater detention, and limits of mitigation: Journal of American Water Resources Association: v. 33, no. 5, p. 1077-1090.

Booth, D.B., D. Hartley, and R. Jackson. 2002. Forest Cover, Impervious Surface Area, and the Mitigation of Stormwater Impacts. Journal of the American Water Resources Association, 38(3): 835-845;

Brabec, Elizabeth, Stacey Schulte, and Paul L. Richards. 2002. Impervious surfaces and water quality: a review of current literature and its implications for watershed planning. Journal of Planning Literature, 16(4): 499-514/

Bradford, S. A., and J. Schijven. 2002. Release of Cryptosporidium and Giardia from dairy calf manure: impact of solution salinity. Environ. Sci. Technol. 36:3916-3923. [PubMed].

DRAFT

Breault, R.F., Smith, K.P., and Sorenson, J.R., 2005, Residential street-dirt accumulation rates and chemical composition, and removal efficiencies by mechanical- and vacuum-type sweepers, New Bedford, Massachusetts, 2003–04: U.S. Geological Survey Scientific Investigations Report 2005-5184, 27 p.

Brewer 1997; MSc. Thesis: Vehicles as a source of heavy metal contamination in the environment (unpublished). University of Reading, Berkshire, UK

Brinkmann, W.L.F. 2004. Urban stormwater pollutants: sources and loadings. GeoJournal, 11(3): 227-283

Center for Watershed Protection. 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1. Prepared by the Center for Watershed Protection, 8391 Main Street, Ellicott City, MD 21043. March 2003.

Chiou, C.S., Hsu, S.Y., Chiu, S.I., Wang, T.K., Chao, C.S., 2000. Vibrio parahaemolyticus serovar O3:K6 as cause of unusually high incidence of food-borne disease outbreaks in Taiwan from 1996 to 1999. Journal of Clinical Microbiology 38, 4621–4625.

Clean Water Act of 1972, (33 U.S.C. §§ 1251-1387, October 18, 1972) as amended 1973-1983, 1987, 1988, 1990-1992, 1994, 1995 and 1996.

DePaola, A., Kaysner, C.A., Bowers, J., Cook, D.W., 2000. Environmental investigations of Vibrio parahaemolyticus in oysters after outbreaks in Washington, Texas, and New York 1997 and 1998. Applied and Environmental Microbiology 66, 4649–4654.

Diamond, J. and C. Daley. 2000. What is the relationship between whole effluent toxicity and instream biological condition? Environmental Toxicology and Chemistry, 19: 158-168.

DiToro; D. M.; J. D. Mahony; D. J. Hansen; K. J. Scott; M. B. Hicks; S. M. Mayr; and M. S. Redmond. 1990. Toxicity of cadmium in sediments: The role of acid volatile sulfide. Environmental Toxicology and Chemistry 9:1487-1502.

Duke, L.D., and Y. Jae Chung. 1995. Industrial Storm Water Pollution Prevention: Effectiveness and Limitations of Source Controls in the Transportation industry. Waste Management. 1995. Vol 15, No.8 pp(543-558)

Dyer, S.D. and X. Wang. 2002. A comparison of stream biological response to discharge from wastewater treatment plants in high and low population density areas. Environmental Toxicology and Chemistry, 21: 1065-1075;

Ebbert, J.C., Embrey, S.S., Black, R.W., Tesoriero, A.J., and Haggland A.L., 2000, Water Quality in the Puget Sound Basin, Washington and British Columbia, 1996–98: U.S. Geological Survey Circular 1216, 31 p., on-line at http://pubs.water.usgs.gov/circ1216/

Edmondson; W.T. 1991. The Uses of Ecology: Lake Washington and Beyond. University of Washington Press; Seattle; Washington.

Egodawatta, P., E. Thomas, and A. Goonetilleke. 2007. Mathematical interpretation of pollutant wash-off from urban road surfaces using simulated rainfall. Water Research, 41: 3025-3031.;

Endangered Species Act of 1973 (16 U.S.C. 1531-1544, 87 Stat. 884), as amended -- Public Law 93-205, approved December 28, 1973, repealed the Endangered Species Conservation Act of December 5, 1969 (P.L. 91-135, 83 Stat. 275). The 1969 Act had amended the Endangered Species Preservation Act of October 15, 1966 (P.L. 89-669, 80 Stat. 926).

Environmental Protection Agency. National advice on mercury in fish caught by family and friends: For women who are pregnant or may become pregnant, nursing mothers, and young children. Washington: Environmental Protection Agency, 2001. Available at: http://www.epa.gov.offcampus.lib.washington.edu/ost/fishadvice/factsheet.html. Accessed 2002 Aug 1

DRAFT

Food and Drug Administration. Consumer advisory: An important message for pregnant women and women of childbearing age who may become pregnant about the risks of mercury in fish. Washington: FDA, 2001. Available at: http://www.cfsan.fda.gov.offcampus.lib.washington.edu/lrd/tphgfish.html. Accessed 2002 Aug 1

Fuenzalida, L., Hernandez, C., Toro, J., Rioseco, M.L., Romero, J., Espejo, R.T. 2006. Vibrio parahaemolyticus in shellfish and clinical samples during two large epidemics of diarrhoea in southern Chile. Environmental Microbiology 8, 675–683.

GeoSyntec Consultants, the Urban Drainage and Flood Control District and Urban Water Resources Research Council (UWRRC) of ASCE. 2002. Urban Stormwater BMP Performance Monitoring. A Guidance Manual for Meeting the National Stormwater BMP Database Requirements. Prepared In cooperation with Office of Water (4303T), US Environmental Protection Agency, Washington, DC 20460, April 2002, EPA-821-B-02-001.

GeoSyntec and Wright Engineers, Inc. 2007. Geosyntec Consultants and Wright Water Engineers, Inc. 2007. Analysis of Treatment system Performance: International Stormwater Best Management Practices (BMP) Database [1997-2007] prepared for Water Environment Research Foundation, American society of civil engineers (Environmental and Water Resources Institute/Urban Water Resources Research Council), U.S. Environmental Protection Agency, Federal Highway Administration, and American Public Works Association

Gobel; P.; C. Dierkes; and W.G. Coldewey. 2007. Storm water runoff concentration matrix for urban areas. Journal of Contaminant Hydrology; 91: 26-42.

Gonzalez-Escalona, N., Cachicas, V., Acevedo, C., Rioseco, M.L., Vergara, J.A., Cabello, F., Romero, J., Espejo, R.T., 2005. Vibrio parahaemolyticus diarrhea, Chile, 1998 and 2004. Emerging Infectious Diseases 11, 129–131.

Hanselman, Travis A. * Donald A. Graetz, and Ann C. Wilkie. 2003. Manure-Borne Estrogens as Potential Environmental Contaminants: A Review Environ. Sci. Technol., 37 (24), 5471 -5478, 2003.

Hart Crower; Inc.; Washington Department of Ecology; U.S. Environmental Protection Agency; and Puget Sound Partnership. 2007. Phase 1: Initial estimate of toxic chemical loadings to Puget Sound. Ecology Publication Number 07-10-079. October 2007. Olympia; Washington.

http://soundwaves.usgs.gov/2006/07/

http://www.doh.wa.gov/ehp/sf/vibrio2007-icp.ppt#256,1,The Washington Vibrio parahaemolyticus Control Plan for 2007

http://www.epa.gov/r10earth/psgb/indicators/shellfish/what/

http://www.martenlaw.com/news/?20060329-failing-septic-systems

http://www.nmfs.noaa.gov/mb/sk/saltonstallken/algal.htm

Hutchison, M. L., L. Walters, S. M. Avery, F. Munro, and A. Moore. 2005. Analyses of livestock production, waste storage, and pathogen levels and prevalences in farm manures. Appl. Environ. Microbiol. 71:1231-1236. [PubMed].

Ikezuki, Y., O. Tsutsumi, Y. Takai, Y. Kamei and Y. Taketani. 2002. Determination of bisphenol A concentrations in human biological fluids reveals significant early prenatal exposure, Hum. Reprod. 17 (2002), pp. 2839–2841.

Inkpen; E.L. and S.S. Embrey. 1998. Nutrient Transport in the Major Rivers and Streams of Puget Sound Basin; Washington. http://wa.water.usgs.gov/pubs/fs/fs.009-98/

Jasim, Saad Y.; Antonette Irabelli; Paul Yang; Shamima Ahmed; L. Schweitzer. 2006. Presence of Pharmaceuticals and Pesticides in Detroit River Water and the Effect of Ozone on Removal. Ozone: Science & Engineering, Volume 28, Issue 6 December 2006 , pages 415 – 423

DRAFT

Jewett, E.B., Lopez, C.B., Dortch, Q., Etheridge, S.M. 2007. National Assessment of Efforts to Predict and Respond to Harmful Algal Blooms in U.S. Waters. Interim Report. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Jiang, J.Q. , Q. Yina, J.L. Zhoub and P. Pearcec. 2005. Occurrence and treatment trials of endocrine disrupting chemicals (EDCs) in wastewaters Chemosphere Volume 61, Issue 4, October 2005, Pages 544-550

Johnson Art and Steven Golding. 2002. Results of Sampling to Verify 303(d) Metals Listings for Selected Washington State Rivers and Creeks. Washington Department of Ecology Environmental Assessment Program, Olympia, Washington 98504-7710. August 2002. Ecology Publication Number: 02-03-039.

Kayhanian M., L.Hollingsworth, M. Spongberg, L. Regenmorter, and K. Tsay. January 2002. Characteristics of Stormwater Runoff from Caltrans Facilities. Transportation Research Board, Annual Conference, Washington D.C.;

Ketata, Imen Xavier Denier, Amel Hamza-Chaffai and Christophe Minier. 2008. Endocrine-related reproductive effects in mollusks. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, Volume 147, Issue 3, April 2008, Pages 261-270

King County and Seattle Public Utilities. 2005. King County and Seattle Public Utilities Source Control Program for the Lower Duwamish Waterway. January 2005 Progress Report

King County Department of Natural Resources. 1991. Water Quality Effects Assessment. Summary Report. Prepared by Parametrix Inc.

King County. 2002. Small streams toxicity/pesticide study 2000. King County Department of Natural Resources, Water and Land Resources Division. November 2002

King County. 2005. Freshwater stream sediments: review of historical monitoring data 1987-2002. Prepared by Jon Shields, Water and Land Resources Division. Seattle, Washington.

King County. 2007. Survey of Endocrine Disruptors in King County Surface Waters. Prepared by Richard Jack and Deb Lester. Water and Land Resources Division. Seattle; Washington

Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B. and Buxton, H.T., 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000: a national reconnaissance. Environ. Sci. Technol. 36, pp. 1202–1211.

Kriech, A. J. Undated. Evaluation of Hot Mix Asphalt [for] Leachability. Report prepared by Heritage Environmental Services for the Asphalt institute. www.asphaltinstitute.org/environ/leachma.html. Viewed 18 July 2002

Lawler; J.J. and M.Mathias; 2007. Climate Change and the Future of Biodiversity in Washington. Report prepared for the Biodiversity Council

Legret M and Pagotto C (1999). Evaluation of pollutant loadings in the runoff waters from a major rural highway. The Science of the Total Environment, 235, 143-150

Lesage, N., Sperandio, M, and Cabassud, C. 2005. Performances of a hybrid adsorption/submerged membrane biological process for toxic waste removal. Water Science and Technology, 2005. (vol. 51) (No. 6/7) 173-180

Lewis, D. J., E. R. Atwill, M. S. Lennox, L. Hous, B. Karle, and K. W. Tate. 2005. Linking on-farm dairy management practices to storm-flow fecal coliform loading for California coastal watersheds. J. Environ. Monit. Assess. 107:407-425.

DRAFT

Long, E., M. Dutch, S. Aasen, K. Welch, and M.J. Hameed. 2005. Spatial extent of degraded sediment quality in Puget Sound (Washington State, U.S.A.) based upon measures of the sediment quality triad. Environmental Monitoring and Assessment 111: 173-222

Long; E.; M. Dutch; S. Aasen; K. Welch and M.J. Hameed. 2005. Spatial extent of degraded sediment quality in Puget Sound (Washington State; U.S.A.) based upon measure of the sediment quality triad. Environmental Monitoring and Assessment 111:173-222.

Loreto Fuenzalida, Lorena Armijo, Beatriz Zabala, Cristina Hernández, M. Luisa Rioseco, Carlos Riquelme and Romilio T. Espejo. 2007. Vibrio parahaemolyticus strains isolated during investigation of the summer 2006 seafood related diarrhea outbreaks in two regions of Chile International Journal of Food Microbiology, Volume 117, Issue 3, 15 July 2007, Pages 270-275

Lucasa. Sophie D. and David L. Jones. 2006. Biodegradation of estrone and 17 β-estradiol in grassland soils amended with animal wastes Soil Biology and Biochemistry Volume 38, Issue 9, September 2006, Pages 2803-2815

M.D. Anway and M.K. Skinner, Epigenetic transgenerational actions of endocrine disruptors, Endocrinology 147 (2006), pp. S43–S49.

Mahler, B.J., P.C. Van Metre, T.J. Bashara, J.T. Wilson, and D.A. Johns. 2005. Parking Lot Sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons Environ. Sci. Technol., 39 (15), 5560 -5566, 2005. .

Mantua, N., S. Moore, R. Palmer and W. Palsson, 2007. Climate Change and Puget Sound. In Sound Science.

Markman, S, Leitner S, Catchpole C, Barnsley S, Müller CT, et al. (2008) Pollutants Increase Song Complexity and the Volume of the Brain Area HVC in a Songbird. PLoS ONE 3(2): e1674. doi:10.1371/journal.pone.0001674

May; D.W.; R.R. Horne; J.R. Karr; B.W. Mar; and E.B. Welch. 1997. Effects of Urbanization on Small Streams in the Puget Sound Ecoregion. Watershed Protection Techniques; 2(4): 483-494.

McCarthy; S.G.; J.P. Incardona; and N.L. Scholz. 2008. Coastal storms; toxic runoff; and the sustainable conservation of fish and fisheries. In Mitigating Impacts of Natural Hazards on Fishery Ecosystems. American Fisheries Society Symposium 64: 000-000. In press.

Metcalf and Eddy, Inc. 2005. Wastewater Engineering: Treatment and Reuse. 5th Edition. McGraw Hill. Boston, MA.

Mickelson, S. 2000. Metal Concentrations in Puget Sound, Marine Outfall Siting Study, North Treatment Facility Project. King County Department of Natural Resources and Parks, Water Lands Resource Division. Unpublished Data

Minton; Gary; Stormwater Treatment; Sheridan Books; Inc.; 2005

Nasu, M.*, M. Goto*, H. Kato**, Y. Oshima*** and H. Tanaka****.2001. Study on endocrine disrupting chemicals in wastewater treatment plants Water Science and Technology Vol 43 No2 pp 101–108 © 2001

National Research Council. Toxicological effects of methylmercury, National Academy Press, Washington (2000).

Newton J.A, and K. Van Voorhis. December 2002. Seasonal Patterns and Controlling Factors of Primary Production in Puget Sound's Central Basin and Possession Sound. http://www.ecy.wa.gov/biblio/0203059.html

Newton, J., C. Bassin, A. Devol, M. Kawase, W. Ruef, M. Warner, D. Hannafious, and R. Rose. 2007a. Hypoxia in Hood Canal: An overview of status and contributing factors. Hood Canal Dissolved Oxygen Program. http://www.hoodcanal.washington.edu/documents/document.jsp?id=2123 Accessed April 10, 2008.

DRAFT

Newton, J., S. Glasoe, R. Thom, A. Devol, B. Dewey, B. Nairn, B. Sanderson, C. Bassin, C. DeGasperi, C. McKinnon, D. Fagergren, D. Peeler, D. Woodruff, E. Faustman, J. Elliott, J. Konovsky, L. Keesecker, M. Brett, M. Roberts, M. Warner, P. Kiffney, S. Meschke, S. Whitford, T. Determan, T. Nelson, T. Paulson. 2007. Nutrients and Pathogens in Puget Sound: Recommendations for Scientific Advances. 30 May UW-APL Nutrient and Pathogen Workshop.

Nghiem, L. D. A, A. Manis, b, 1, K. Soldenhoff, b, 1 and A. I. Schäfer. 2004., Estrogenic hormone removal from wastewater using NF/RO membranes. Journal of Membrane Science Volume 242, Issues 1-2, 15 October 2004, Pages 37-45

O'Neill, S. 2004. Factors affecting contaminants in fishes. Habitat, life history and diet. Washington Department of Fish and Wildlife, Puget Sound Ambient Monitoring Program. http://www.epa.gov/waterscience/fish/forum/2004/presentations/tuesday/oneill.pdf

Paquin, Paul, Robert Santore and Rooni Mathew. 2005. The Biotic Ligand Model Windows Interface, Version 2.1.2: User's Guide and Reference Manual, HydroQual, Inc, Mahwah, NJ, April 2005.

Pastorok, Robert A., Daniel C. Peek, Jennifer R. Sampons, and Michael A. Jacobson. 1994. Ecological Risk Assessment for River Sediments contaminated by Creosote. Environmental toxicology and Chemistry 13:1929-1941.

Pauwels, A., P.J. Schepens, T. D'Hooghe, L. Delbeke, M. Dhont, A. Brouwer and J. Weyler. 2001. The risk of endometriosis and exposure to dioxins and polychlorinated biphenyls: a case-control study of infertile women, Hum. Reprod. 16 (2001), pp. 2050–2055.

Pitt, R., R. Bannerman, S. Clark and D. Williamson. 2005a. Chapter 23: Sources of Pollutants in Urban Areas (Part 1) - Older Monitoring Projects. IN: Effective Modeling of Urban Water Systems, Monograph 13. W. James, K.N. Irvine, E.A. McBean and R.E. Pitt, eds. Computational Hydraulics International, Guelph, Ontario. pp. 465-483

Pitt, R., R. Bannerman, S. Clark and D. Williamson. 2005b. Chapter 24: Sources of Pollutants in Urban Areas (Part 2) - Recent Sheet Flow Monitoring. IN: Effective Modeling of Urban Water Systems, Monograph 13. W. James, K.N. Irvine, E.A. McBean and R.E. Pitt, eds. Computational Hydraulics International, Guelph, Ontario. pp 485-506

Puget Sound Action Team. 2005. Low Impact Development Technical Guidance Manual for Puget Sound. January 2005.

Rector, J. and D. Hallock. 1994 Statewide water quality assessment lakes chapter. Companion document to Washington State's 305(b) Report. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Ambient Monitoring Program. Publication number 95-311.

Reilly, Maureen. 2001. The case against land application of sewage sludge pathogens. Can J Infect Dis. 2001 Jul–Aug; 12(4): 205–207.

Ried, A., Mielcke, J., Kampmann, M., Ozone and UV processes for additional wastewater treatment to remove pharmaceuticals and EDCs, 2nd IWA Leading-edge on Water and Wastewater Treatment Technologies, pp 231-239, 2005

Robertson, D.J. and K.G. Taylor. 2007. Temporal Variability of Metal Contamination in Urban Road-Deposited Sediment in Manchester, UK: Implications for Urban Pollutant Monitoring. Water Air Soil Pollution, 186: 209-220.

Ruckelshaus and McClure. 2007. Sound Science: Synthesizing Ecological and Socioeconomic Information about the Puget Sound Ecosystem. Northwest Fisheries Science Center. January 2007

DRAFT

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2004. Odor-evoked field potentials as indicators of sublethal neurotoxicity in juvenile coho salmon (Oncorhynchus kisutch) exposed to copper, chlorpyrifos, or esfenvalerate. Canadian Journal of Aquatic Sciences, 61(3): 404-413

Santore, R.C., D.M. Di Toro, P.R. Paquin, H.E. Allen, and J.S. Meyer, 2001, "A Biotic Ligand Model of the Acute Toxicity of Metals: II. Application to Acute Copper Toxicity in Freshwater Fish and Daphnia", Environmental Toxicology and Chemistry, 20(10):2397- 2402.;

Sargent; D. 1999. Lilliwaup Bay Bacterial Source Identification Monitoring. Waterbody No. WA-PS-0250. Ecology Report #99-329. September 1999.

Schiff, K. and M. Sutula. 2004. Organophosphorus pesticides in storm-water runoff from Southern California (USA). Environmental Toxicology and Chemistry, 23(8): 1815-1821.

Soupir, M.L., S. Mostaghimi , E. R. Yagow, C. Hagedorn and D. H. Vaughan. 2006. Transport Of Fecal Bacteria From Poultry Litter and Cattle Manures Applied to Pastureland Journal Water, Air, & Soil Pollution, Issue Volume 169, Numbers 1-4 / January, 2006

State of Washington Department of Ecology, Western Washington Phase I Municipal Stormwater Permit, January 17, 2007.

State of Washington Department of Ecology, Western Washington Phase II Municipal Stormwater Permit, January 17, 2007.

Stein; E.D.; L.L. Tiefenthaler; and K.C. Schiff. 2007. Sources; patterns; and mechanisms of storm water pollutant loading from watershed and land uses of the greater Los Angeles area; California; USA. Southern California Coastal Water Research Project; Technical Report 510. March 2007.

Stoker, Cora, Pablo M. Beldoménico, Verónica L. Bosquiazzo, Marcelo A. Zayas, Florencia Rey, Horacio Rodríguez, Mónica Muñoz-de-Toro and Enrique H. Luque. 2008. Developmental exposure to endocrine disruptor chemicals alters follicular dynamics and steroid levels in Caiman latirostris. General and Comparative Endocrinology, In Press, Corrected Proof, Available online 29 February 2008

Sutherland, R.C., and S.L. Jelen. 1996. Studies show sweeping has beneficial impact on stormwater quality. APWA Reporter (November): 8-23

Takeuchi, O. Tsutsumi, Y. Ikezuki, Y. Takai and Y. Taketani. 2004. Positive relationship between androgen and the endocrine disruptor, bisphenol A, in normal women and women with ovarian dysfunction, Endocrine J. 51 (2004), pp. 165–169. Full Text via CrossRef | View Record in Scopus | Cited By in Scopus (37)

Taylor, Hugh S.. 2008. Endocrine disruptors affect developmental programming of HOX gene expression. Fertility and Sterility, Volume 89, Issue 2, Supplement 1, February 2008, Pages e57-e58

Tetra Tech ISG; Inc. and Parametrix; Inc. 2003. Sammamish/Washington Analysis and Modeling Program - Lake Washington Existing Conditions Report. Submitted to King County Department of Natural Resources and Parks; Water and Land Resources Division September 2003

Trainer, V.F., R. Loge, F. Paranjoye, F. Cox and R. Duff. 2007. Puget Sound: Marine Ecosystems and Human Health. IN Sound Science (ibid).

UNECE 2003. Automobile Tyre and Brake Wear website supporting the development of chapter B770 (SNAP 0707) of the EMEP/Corinair Emission Inventory Guidebook. http://vergina.eng.auth.gr/mech/lat/PM10/ Accessed December, 2003.

DRAFT

UNECE 2003. Automobile Tyre and Brake Wear website supporting the development of chapter B770 (SNAP 0707) of the EMEP/Corinair Emission Inventory Guidebook. http://vergina.eng.auth.gr/mech/lat/PM10/ Accessed December, 2003.;

United States Environmental Protection Agency. 2008. National Priorities List Sites in Washington. http://www.epa.gov/superfund/sites/npl/wa.htm

USGS. 2008. Emerging Contaminants In the Environment. http://toxics.usgs.gov/regional/emc/. Accessed April 2; 2008.

Van Metre, P. C, and B. J. Mahler. 2004. Contaminant trends in reservoir sediment cores as records of influent stream quality. Environmental Science and Technology, 38: 2978-2986

Van Metre, P. C, B. J. Mahler, and E. T. Furlong. 2000. Urban Sprawl Leaves Its PAH Signature. Environmental Science and Technology 34(19):4064-4070

WACAP. 2008. WACAP Final Report - January 2008 EPA Western Airborne Contaminants Assessment Project

Wang, L. J. Lyons, P. Kanehl, and R. Banerman. 2001. Impacts of Urbanization on Stream Habitat and Fish across Multiple Spatial Scales. Environmental Management, 28(2) 255-266.

Washbusch, R.J., W.R. Selbig, and R.T. Bannerman. 1999. Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin. U.S. Geological Survey. Middleton, Wisconsin

Washington Department of Ecology. 1997. Using invertebrates to assess the quality of Washington streams and to describe biological expectations. September 1997. Publication No. 97-332.

Washington Department of Ecology. 2002a. Washington State Water Quality Assessment: Year 2002 Section 305(b) Report. June 2002, Publication No. 02-03-026

Washington Department of Ecology. 2007. River and Stream Water Quality Monitoring Report for Water Year 2006 May 2007, Publication No. 07-03-022.

Washington State Department of Ecology, http://www.ecy.wa.gov/programs/eap/models.html

Washington State Department of Ecology. 2005. Stormwater Management Manual for Western Washington, Publication Numbers 05-10-029 through 05-10-033, February 2005.

Washington State Department of Ecology. 2002b. South Puget Sound Water Quality Study (Phase 1) by Storrs "Skip" L. Albertson; Karol Erickson; Jan A. Newton; Greg Pelletier; Rick A. Reynolds; and Mindy Roberts. Environmental Assessment Program; Olympia; Washington. October 2002

Washington State Department of Ecology. 2007. http://www.accountability.wa.gov/reports/environment/20070320/Stormwater.pdf

Wendt, P.H., R.F. Van Dolah, M.Y. Bobo, T.D. Mathews, and M.V. Levisen. 1996. Wood preservative leachates from docks in an estuarine environment. Archives of Environmental contamination and Toxicology 31:24-37.

Westerlund K-G. 2001. Metal emissions from Stockholm traffic - wear of brake linings. The Stockholm Environment and Health Protection Administration; 100 64; Stockholm; Sweden

Wintgens, Thomas, Martin Gallenkemper and Thomas Melin. 2002. Endocrine disrupter removal from wastewater using membrane bioreactor and nanofiltration technology. Desalination Volume 146, Issues 1-3, 10 September 2002, Pages 387-391

DRAFT

Woodward-Clyde Consultants; 1994; Contribution of Heavy Metals to Storm Water from Automotive Disc Brake Pad Wear; Westerlund K-G (2001). Metal emissions from Stockholm traffic - wear of brake linings. The Stockholm Environment and Health Protection Administration; 100 64; Stockholm; Sweden;

Woutrina A. Miller,1 David J. Lewis,2 Michael Lennox,2 Maria G. C. Pereira,3 Kenneth W. Tate,4 Patricia A. Conrad,1 and Edward R. Atwill. 2007. Climate and On-Farm Risk Factors Associated with Giardia duodenalis Cysts in Storm Runoff from California Coastal Dairies Appl Environ Microbiol. 2007 November; 73(21): 6972–6979.

Yi-Cheng Su and Chengchu Liu. 2007. Vibrio parahaemolyticus: A concern of seafood safety Food Microbiology, Volume 24, Issue 6, September 2007, Pages 549-558

Zhao Y, Newman MC. 2006. Effects of exposure duration and recovery time during pulsed exposures. Environ Toxicol Chem 25:1298–1304

DRAFT