Damages and Costs of Stormwater Runoff in the Puget Sound Region

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I. Introduction

The biological health of Puget Sound is declining, and much of that decline is a direct or indirect consequence of stormwater runoff (PSAT 2004). With urban development rapidly growing across the region, greater flooding and property damage is resulting from increased volumes of urban runoff. Both upland and downstream water bodies are experiencing degradation of water quality, destruction of freshwater and estuarine habitat, and harvest restrictions in shellfish-growing areas. This degradation carries a variety of environmental, economic, and social costs resulting from stormwater runoff. This report seeks to document some of these costs, providing quantification in monetary terms where such data exist, and more qualitative (but no less real) costs for other impacts related to stormwater. By documenting costs, we can also begin to quantify some of the benefits of their avoidance through stormwater management.

We recognize four distinct categories of "cost" relating to stormwater. All represent tangible economic losses to individuals, jurisdictions, or entire groups of people or society, although they are not all equally quantifiable. These four categories are:

1. Direct damage caused by stormwater,
2. Cost of government and private actions and programs to mitigate the effects of stormwater,
3. Indirect damage caused by stormwater, and
4. Unquantified (or nonquantifiable) costs caused by stormwater

Some examples of each are shown in Table 1.

Table 1. Categories (and Examples) of Stormwater-Related Costs

1. Direct damage caused by stormwater
    - Property damage due to stormwater-related flooding
    - Habitat degradation due to urban runoff
    - Insurance payouts and legal settlements due to flooding
    - Loss of fisheries and shellfish harvesting due to urban runoff

2. Cost of government and private actions and programs intended to mitigate the effects of stormwater
    - Detention ponds and other BMPs
    - Response to flooding by local governments
    - Clean-up of polluted waters and TMDL programs
    - Staff time to manage stormwater problems

- Government response to shellfish closures
- Additional measures that businesses need to implement in pollution-affected areas
- Salmon restoration projects related to stormwater

3. Indirect damages caused by stormwater
    - Cultural losses to tribes from reduced harvest
    - Tourism and other recreational losses from lost fisheries
    - Other lost business revenues
    - Increased maintenance and management owing to loss of natural stream network

4. Unquantified (or nonquantifiable) costs caused (in whole or in part) by stormwater
    - Reduced fish health; pre-spawning mortality
    - Reduction in aquifer recharge
    - Loss of fish and wildlife habitat
    - Permanent loss of natural resources

Of these categories, the last two include losses and damages that transcend strict monetary valuations, such as loss of aesthetic, ecological, or social values and resources. Consequently, these costs are notoriously difficult to quantify fully in dollar amounts. This difficulty does not negate their importance, but it does require that they be treated differently. Therefore, this report aims to identify examples of economic costs associated with the first two categories, namely direct damage and mitigation efforts, and to acknowledge, rather than attempt to quantify, the broader economic, environmental, and social costs of the last two categories.

Where quantifiable, identified costs are organized by type of stormwater "impact," which here in the Puget Sound region can be grouped under four headings:

- Flooding, landsliding, and property damage
- Degradation of water quality
- Freshwater and estuarine habitat damage
- Closures of shellfish growing areas

To accomplish this, information compiled in this report was obtained from literature reviews; agency and government documents; and interviews of stakeholders, local officials, stormwater managers, and non-profit organizations within the Puget Sound region (Appendix A—Sources of Information). The purpose is to quantify the magnitude of costs, both tangible (i.e. dollars spent) and intangible (i.e. value lost), as well as benefits (e.g., investments that can save money and reduce damage) that result from present levels of stormwater management. While not a comprehensive survey of all costs and benefits, it does demonstrate some of the losses, both financial and resource, that the region currently endures. Ideally, this documentation can provide a framework in which to determine the best and most cost-effective future expenditures to protect and improve Puget Sound.

An overview of stormwater conditions and effects

Stormwater runoff from urban areas is a widely recognized agent of physical, chemical, and biological degradation. At the root of most of these damaging changes is the modification of the land surface that occurs as a result of forestland conversion to urban development. These modifications affect both the magnitude and the type of runoff processes. In the Pacific Northwest, the fundamental hydrologic effect of urbanization is the loss of water storage in the soil column. This occurs because of vegetation clearing, soil compaction, and ditching and draining, with the final land-use condition achieved by covering the land surface with impervious roofs and roads. The infiltration capacity of these covered areas is lowered to zero, and much of the remaining soil-covered area is trampled to a near-impervious state. This compacted, stripped, or paved-over soil also has lower storage volumes, and so even if precipitation can infiltrate below the ground surface, the soil reaches surface saturation more rapidly and more frequently. Once saturated, flow moves rapidly at the ground surface, and thus precipitation falling over a small watershed reaches the stream channel with a typical delay of just a few minutes, instead of what had been a lag of hours, days, or even weeks. Evapotranspiration, which permanently removes a significant fraction of the rainfall from contributing to runoff, is also commonly reduced in urban watersheds.

The result is a dramatically changed pattern of flows in the downstream channel, with the largest flood peaks doubled or more and more frequent storm discharges increased by as much as ten-fold (Figure 1).

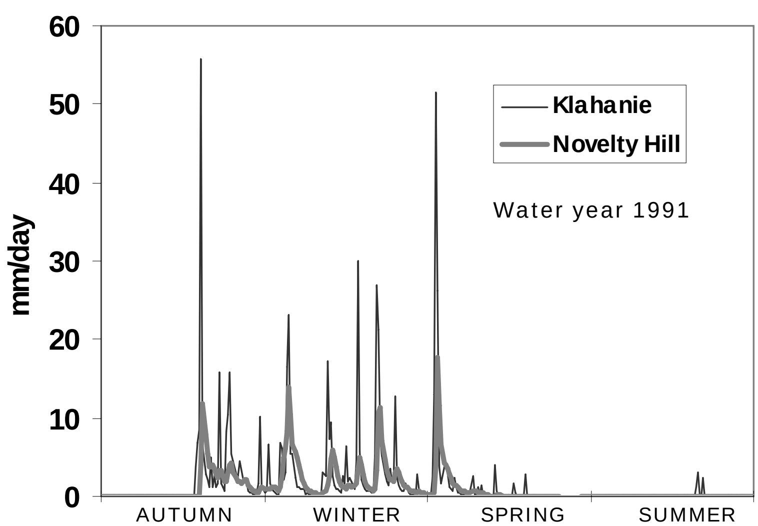

Figure 1. One year’s gauged discharges for two contrasting watersheds in east-central King County, displaying the changes in streamflow that result from forested (“Novelty Hill”) to suburban (“Klahanie”) land conversion. The Novelty Hill catchment was covered in mature second-growth forest when these data were recorded, and it shows the typical low-development pattern of sporadic wintertime peak discharges, moderate intervening base flows, and low (or absent) discharge between mid-spring and early autumn. The Klahanie catchment displays dramatic increases in stormflows year-round (data from Burges et al. 1998).

In addition to directly altering the flow regime, urbanization affects other elements of the drainage system. Gutters, drains, and storm sewers are laid in the urbanized area to convey runoff rapidly to stream channels. Natural channels are often straightened, deepened, or lined with concrete to make them hydraulically smoother. Each of these changes increases the efficiency of the channel, transmitting the flood wave downstream faster and with less retardation by the channel. In total, direct measurements and hydrologic simulation models demonstrate several related consequences: for any given intensity and duration of rainfall the peak discharge is greater (by factors of 2 to 5), the duration of any given flow magnitude is longer (by factors of 5 to 10), and the frequency with which sediment-transporting and habitat-disturbing flows move down the channel network is increased dramatically (by factors of 10 or more) (Booth and Jackson 1997, and references therein).

Changes in upland runoff processes, particularly from conversion of what was originally a predominantly *subsurface* flow regime to a predominantly *surface* flow regime, alter not only the magnitude of discharges but also the delivery of sediment and pollutants to the stream network. With abundant surface runoff, fine sediment is moved into channels throughout the year; when coupled with land-cover changes, the sediment load can increase by many orders of magnitude (Wolman and Schick 1967) and the predominant grain sizes in stream channels can shift to much finer fractions. Such increases in the delivery of fine sediments significantly alters the sediment size distribution of gravel bed streams (e.g., Carling 1984), with attendant changes in stream ecology (recognized as early as Ellis 1936). Surface runoff also efficiently carries dissolved or fine particulate pollutants (e.g. nutrients, petroleum products, heavy metals, and pesticides) into stream channels, typically off of the same upland landscape whose urban land uses introduce significantly greater amounts of those contaminants than did the previously undisturbed forested watersheds.

Urban development not only increases rates of water, sediment, and pollutant delivery into streams but also encroaches on the riparian corridor. Clearing streamside vegetation reduces the wood entering the channel, depriving the stream of stabilizing elements that help dissipate flow energy and usually (although not always) help protect the bed and banks from erosion (Booth and others 1997). Deep-rooted bank vegetation is replaced, if at all, by shallow-rooted grasses or ornamental plants that provide little resistance to channel widening. The overhead canopy of a stream is lost, eliminating the shade that controls temperature and supplies leaf litter, an essential component of the aquatic food chain.

At the end of this causal chain of upland and riparian changes lies the degradation of in-stream biological health that so often motivates rehabilitation efforts (Karr 1996). In the Pacific Northwest, many of these efforts are focused on enhancing populations of anadromous salmon in lowland streams. These fish depend on a particular combination of water and sediment fluxes to maintain favorable channel conditions. Because land-use change in a watershed alters those fluxes, the resulting flow regime and channel configuration no longer tend to favor salmonids, and thus most rehabilitation efforts that address only the in-stream symptoms of these watershed changes are unlikely to succeed (Roper and others 1997).

Many other aquatic organisms are also ill-suited to thrive under the altered conditions imposed by urban development. Pollutants consumed by aquatic organisms and biomagnified up the food chain can lead to neurological disorders, decreases in reproduction, and suppressed immune systems. They can also pose a threat to human health through the consumption of fish and shellfish that are contaminated by fecal coliform and heavy metals. By contributing to the reduction of salmon populations, this suite of watershed impacts also decrease food supplies for other endangered species such as Orca whales.

Although the causes and consequences of stormwater damage have been long-recognized, solutions have proven elusive. In response to urban-induced runoff changes, jurisdictions have long required some degree of stormwater mitigation. The most common approach has been to reduce flows through the use of detention ponds, which are intended to capture and detain stormwater runoff from developed areas. The first efforts at runoff mitigation were intended to reduce peak flows, reflecting a traditional focus on flood reduction. Well over one hundred years ago, the fundamental predicting equation of runoff used in these early mitigation efforts was developed (Mulvany 1851). This formula was used by King County in the Pacific Northwest region's first surface-water design manual (King County 1979), but its inherent shortcomings led to the construction of grossly undersized detention ponds having little or no benefit in preventing downstream flooding or habitat damage. Subsequent design iterations of detention facilities are substantial improvements over the 1851 approach, but these methods still contained fundamental flaws such that detention ponds are unlikely to ever provide full mitigation for urban runoff (Booth et al. 2002). These flaws include the conversion of subsurface runoff over the predevelopment landscape into a few point discharges (i.e. detention pond outlets), the loss of subsurface runoff filtration and deep groundwater recharge, and the brief delay of runoff in surface ponds (hours to days) relative to the natural lag imposed by soil storage and subsurface flow (days to weeks, or more).

Pollution reduction has also not kept pace with the increased generation and transport of contaminants from ever-expanding urban development. Stormwater sources of pollution are becoming more closely regulated through assignment of Total Maximum Daily Loads (TMDL) for selected water bodies, which seek to place limits on the amount of pollutants entering downstream water bodies. National Pollutant Discharge Elimination System (NPDES) permits issued by the state Department of Ecology have required the largest jurisdictions in the Puget Sound region to implement stormwater treatment programs for several years. The most recent NPDES permits now require most cities and counties to implement similar treatment programs. However, less populous and more rural jurisdictions often have less developed stormwater management programs. Even with greater resources, older municipalities also struggle with the treatment of stormwater discharge, with conveyance systems commonly buried deeply with limited access or with little documentation of their exact whereabouts. These jurisdictions are also densely settled, with few natural areas remaining to buffer some of the consequences of urban land conversion and very little space for additional treatment facilities. The challenges to improved stormwater management are thus substantial, and the consequences of neglect are ultimately even more costly.

II. Economic Costs of Stormwater

The consequences of stormwater runoff are as diverse as the watersheds that are affected. Available information on costs, however, can be grouped more simply under four general headings: flooding and property damage, degradation of water quality, destruction of freshwater and estuarine habitat, and closure of shellfish growing areas. Within each of these groups, we have presented costs under the categories of direct damage and mitigation efforts. Indirect and more broad, non-quantifiable costs transcend these headings and do not lend themselves to a dollar-based assessment, at least given existing information. Their impacts are no less real, however, and so they are acknowledged separately at the end of this document

A. Flooding, landsliding, and property damage

The direct impact of stormwater on property is perhaps the most prominent, overt expression of the "cost" of urban runoff. Damage and financial losses, the expense of stormwater facilities, and the cost of complying and administering regulatory programs designed to reduce these problems are all apparent. Although large rivers integrate the land-use effects across their entire watershed, flooding from these sources is not necessarily the sole product of urban runoff, but examples of urban flooding can still indicate the likely magnitude of this cost category.

Direct damage to property

Large amounts of property damage occur during periods of heavy rain that result in flooding and landslides (e.g., Figure 2). Flooding and landslides are natural occurrences, but they are particularly common in areas of urban development and are exacerbated by insufficient or poorly maintained stormwater and drainage facilities.

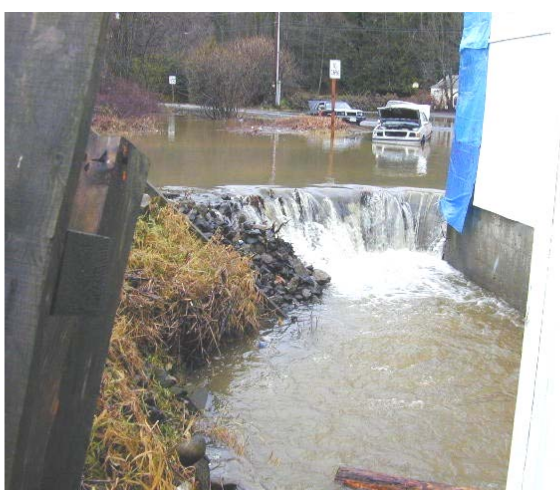

Figure 2. Flooding at Old Belfair Highway near Gorst in Kitsap County. Photo courtesy of Dave Dickson, Public Works assistant director of Kitsap County, WA.

Most city and county officials that were interviewed report that flooding and drainage problems are the most common concerns from citizens, because they result in direct damage to their property and surrounding community. Although anecdotal information clearly demonstrates the general magnitude of damage from urban flooding, precise costs are difficult to assign to stormwater runoff alone. For example, Washington State reported $433 million in property damage due to floods from 1994 to 2003 (U.S.ACE 2003). Insurance claims and payments are also significant. The total amount of flood insurance claim payments paid to the Puget Sound region by the National Flood Insurance Program has totaled $56 million since 1978 (Table 2). Although a significant amount by itself, it does not include all the flood losses borne by the property owners.

Table 2. Flood Insurance Claim Payments Due to Flooding Since 1978

County	Total Claims	Total Payments
King	1448.5	$ 15,521,005
Snohomish	957	$ 11,570,844
Skagit	958	$ 10,413,604
Pierce	498.5	$ 8,349,537
Whatcom	376	$ 4,200,232
Thurston	200	$ 2,503,002
Mason	141	$ 1,299,130
Clallam	83	$ 1,034,446
Kitsap	65	$ 630,033
Island	128	$ 512,419
Jefferson	25	$ 233,503
San Juan	2	$ 20,579
Total	4882	$ 56,288,335

(Source: BureauNet 2006)

Similarly large, but incomplete, cost estimates are available from compiled data on federally declared flood disasters. From 1990 to 2006 in King County, for example, property damage in such declared floods resulted in $21.5 million worth of damages (King County 2005), and this is only for damage to public property. Clearly the total damages caused by floods in the Puget Sound region over this period are significantly greater. Conversely, part of this damage was a result of flooding on the County's large rivers, and so not all was a direct result of stormwater runoff from urban development.

Property damage also results from landslides. Although landslides are "natural" events, they commonly result from human influences. Stormwater runoff, in particular, can be a contributing factor in landslides. A study of landslides within the Seattle area showed that 84% of landslides were influenced by some type of human activity, including insufficient drainage, broken pipes, increases in upslope impervious area, slope alterations, and poor drainage-facility maintenance (Shannon & Wilson 2001). Thus, much of the property damage due to landslides could be avoided or minimized by proper stormwater and drainage management. The City of Seattle is projected to spend an average annual amount of $3.78 million (in 2006 dollars) from 2005–2010 on landslide mitigation (SPU and others 2004).

Cost of stormwater facilities and stormwater management programs

In addition to the direct property damage caused by flooding, agencies endeavor to respond to these problems both by constructing damage-reducing capital facilities and by implementing broader stormwater-management programs. The Flood Control Assistance Program at the Department of Ecology (DOE), for example, provides funding to various counties in Washington State for flood-control issues. For 2005–2007, a flood-control need of $13,352,083 was identified but with program funding available to meet only 14% of the needs (DOE 2005). Despite the magnitude of both project needs and funding deficiencies, this program addresses only one component of such programs, namely one-time funding of capital projects. Even as such projects are funded for construction, the increase in stormwater infrastructure increases the need to fund the maintenance of these facilities, a category of costs that represent one of the largest and fastest-growing segments of agency budgets.

In the Puget Sound basin, the annual expenditures of individual stormwater and flood management programs can be on the order of hundreds of thousands to millions of dollars, depending on size and population of the area. Typical management costs are on the order of $100/person/year, exclusive of the episodic damage that is also incurred.

Table 3. 2006 Stormwater Expenditures of Various Jurisdictions

Jurisdiction	2006 Stormwater Expenditures [a]	2006 Expenditures/Capita [g]
Small (Population < 10,000)		
Town of Friday Harbor[b]	$284,000	$143
Medium (10,000 < Population < 100,000)		
Bellingham[c]	$4.8 million	$71
Bremerton[d]	$ 2.5 million	$67
Olympia[e]	$3.6 million	$84
Large (Population > 100,000)		
Seattle[f]	$42 million	$75

[a] Values in 2006 dollars (converted into 2006 dollar values using the Bureau of Labor Statistics Calculator if necessary; BLS 2006)
[b] (Town of Friday Harbor 2005)
[c] (City of Bellingham 2005)
[d] (City of Bremerton 2005)
[e] (City of Olympia 2006)
[f] (SPU and others 2004), estimated from average expenditures from 2005-2010
[g] Budget per capita = 2006 stormwater budget divided by the area population obtained from the 2000 U.S. Census (OFM 2002).

In addition to these management costs, DOE has established a budget of $2.5 million to provide jurisdictions with funds to install new, innovative technologies to mitigate effects of stormwater runoff on the Puget Sound and Hood Canal for 2006 (DOE 2006). These technologies include low-impact development and use of natural drainages.

Cost information on stormwater management programs is also compiled through the NPDES program, which requires "Phase 1 jurisdictions" to report the expenditures required to meet their 1995 municipal stormwater permit. Based on 2000 U.S. census data, 24% of Western Washington's population is covered under the NPDES Phase 1 permit (while 63% is covered under the now-active Phase 2; Hashim and Bresler 2005). The total expenditure of Phase 1 permittees in Washington State was $179.7 million (Table 4), of which 75% of the costs were exclusively Puget Sound jurisdictions (since jurisdictions are only required to report expenditures needed to meet the 1995 permit, the tabulated costs, although substantial, may be underestimated).

Table 4. 2003 Phase I Municipal Stormwater Expenditures

Jurisdiction	Total Expenditures (2006 value)[a]
Clark County	$13.2 million
King County	$57.3 million
Pierce County	$25.86 million
City of Seattle*	$11.36 million
Snohomish County	$5.6 million
City of Tacoma	$34.3 million
WSDOT*	$32.1 million
Total	$179.7 million

* Fiscal Years were reported from July 1, 2003 to June 30, 2004.

[a] Based on Annual reports submitted to Department of Ecology in compliance with Municipal Stormwater NPDES permit requirements collated by the Department of Ecology (A. Wessel, pers. commun. June 13, 2006).

A survey of Washington state jurisdictions and utilities (Washington Public Works Board 1999), reported that 324 of the 487 jurisdictions within Washington State needed $570 million to fund their stormwater projects from 1998 to 2003. This statewide "stormwater need" per capita for years 1998–2003 (in 2006 dollars based on 2000 U.S. census) thus equates to $19/year for a total of 6 years. When compared to the per capita needs of individual jurisdiction for a single year (Table 3), however, it clearly underestimates the stormwater need in Washington State due to unreported costs by jurisdictions or for the specified time period. In Puget Sound alone, responding jurisdictions were responsible for $350 million of this total, accounting for 61% of state need. These jurisdictions statewide also reported that 52 percent of those stormwater funding needs were unmet, and they already are spending 2 to 7 times this amount.

Specific examples demonstrate the degree to which individual jurisdictions are already experiencing substantial management costs, and the magnitude of their estimated shortfalls. The City of Bellingham has estimated $300,000–500,000/year in additional funds would be required to keep up with current technologies and population growth beyond the $4.8 million currently budgeted (W. Reilly, pers. commun. February 6, 2006).

Since 1994, the City of Kirkland's surface water utility has reduced major flooding, documented surface water systems, and implemented a program prioritizing responses to flooding "hot spots" (City of Kirkland 2005). It emphasizes problem reduction through routine maintenance, but this attention requires an annual budget of $1.5 million.

At the county level, Pierce County has spent about $40 million in the past 15 years just to implement flood-control measures (excluding the cost of maintenance; H. Hunger, pers. commun. February 13, 2006). In Kitsap County, 65–75% of the Public Works Stormwater Management budget ($4.5 million) is allocated to inspection and maintenance of stormwater management infrastructure (D. Dickson, pers. commun. February 7, 2006; FCS Group, Inc. 2005). As part of this expenditure, emergency teams for Kitsap County must respond to as many as 400 or more drainage problems per year, reflecting the large amount of time and effort demanded by such issues during periods of heavy rains.

In 2001, Snohomish County started the $12 million Drainage Needs Report Project that assessed the condition of about 60 square miles of unincorporated urban growth areas within the county, inventoried the drainage system, and identified present and potential drainage and surface water issues (Snohomish County 2005). In addition to the inventory, the identification of present and future problems helped to develop a list of 220 recommended projects with a total project cost of $85 million (representing a per capita expense of about $130). As of 2005, the county has completed $9.6 million worth of drainage projects identified by the Drainage Needs Report, with 163 projects remaining at an estimated cost of $69 million.

In some areas, investments made as early as the 1970's and through the 1990's have successfully reduced the impact and cost of flooding. Larger stormwater programs, such as Pierce County and King County, have successfully reduced property damage due to flooding by restricting new development in flood-prone areas or requiring stricter regulations when building in floodplains. These programs help reduce, but do not eliminate, the costs associated with stormwater management. For example, most jurisdictions in western Washington require new developments to be constructed to experience a 100-year flood event without suffering major damages. New developments are required to build their finished floor 1 foot above the 100-year flood elevation and all structures within the 100-year floodplain must have sufficient anchoring "to prevent floatation, lateral movement, or collapse" (King County 2006). Although these measures can restrict new development from areas prone to flooding, they only reduce the further growth of such problems; frequent complaints are still received from areas of older development.

B. Degradation of water quality

Representatives from most jurisdictions interviewed identified water quality as the main problem resulting from stormwater runoff in their area. However, many interviewees felt that water quality issues are often ignored because local officials and citizens are more immediately concerned about flooding and drainage issues. Residents express interest in water quality only when flooding and drainage issues are not an immediate problem, and so community perspective may not reflect the actual harm being caused to Puget Sound.

The costs identified in this study that are directly associated with degraded water bodies are primarily those associated with cleaning polluted surface water bodies and protecting such resources from future or additional contamination. Degradation of water quality is also a factor in a host of ecological problems, notably the restrictions on harvest at shellfish growing areas, which are addressed in a later section. Finally, poor water quality has been implicated in a number of environmental studies of diseased aquatic organisms where the causal linkage is suggestive but not yet proven. Some examples are discussed in the final section of this document, in acknowledgement of their likely significance tempered by the difficulty of assigning a dollar cost to the specific contribution made by urban stormwater.

Degradation of drinking-water supplies

Although Puget Sound is the ultimate recipient of polluted water, the consequences of degraded water quality begin in upstream water bodies and drinking-water supplies. Threats to their quality can create an immediate public health risk and necessitate significant financial outlays. Lake Whatcom is an important drinking-water supply for the City of Bellingham but is being contaminated by stormwater runoff from urban development. The Washington State Department of Ecology (DOE) estimates that Lake Whatcom provides water supplies for approximately 86,000 residents (Cusimano 2002). The lake is on DOE's 303(d) list for impaired waters due to problems with Dieldrin, dissolved oxygen, mercury, PCBs, and phosphorus (DOE 2005a). By previously permitting new urban development in the Lake Whatcom catchment, the city now must take measures to reduce the impact of stormwater runoff on their water quality by retrofitting stormwater outfalls to treat stormwater before discharge to the lake. It has cost the City of Bellingham $400,000 per year to construct and maintain these retrofits; their overall capital expenditure is nearly $900,000 to date (W. Reilly, pers. commun. February 6, 2006). Whatcom County is also spending about $800,000 in constructing water quality treatment retrofits in 2006 alone, such as swales and vaults, to mitigate stormwater effects on Lake Whatcom (K. Christensen, pers. commun. June 12, 2006).

Whatcom County is also experiencing more widespread threats to their groundwater supplies (Cox et al. 2005). The County has experienced pollutant loading from construction runoff, contaminated sediments, lawn fertilizers and pesticides, and agricultural runoff. Groundwater supplies within this county are impacted by both urban and agricultural runoff; the latter in particular are causing nitrogen levels to exceed U.S. EPA drinking-water standards. Shallow water tables and highly permeable soils also put Whatcom County groundwater supplies at greater risk, with as-yet undetermined costs for protection or replacement of this resource.

Elsewhere in the Puget Sound region, groundwater supplies currently enjoy generally high quality, with monitoring by the U.S. Geological Survey (USGS) showing the majority complying with EPA standards. The most common shortfall is locally elevated nitrate concentrations and some pesticides in shallow groundwater supplies (Ebbert and others 2000). One or more pesticide compounds were detected in 30% of 157 sampled wells but almost exclusively in those that were less than 100 feet deep (Bortleson and Ebbert 2000). Pesticide compounds were found in 40% and 25% of the wells that were less than 50 feet deep and 50 to 100 feet deep, respectively. Pesticides were only detected in 1 well out of a total of 51 wells greater than 100 feet deep.

The Vashon Groundwater Protection Committee is taking measures to protect groundwater supplies of Vashon-Maury Island, located in King County and subject to a range of both rural and urban contaminants. The committee has been successful in educating the public and identifying critical aquifer recharge areas to prevent contamination. King County has spent about $661,000 (2006 value) from 2000 to 2004 to identify potential problems, and to monitor and protect groundwater supplies (King County 2005a).

A lesson in deferred costs can be found in history of the water-supply system for the 9 million people in New York City. Although a system of natural watersheds provided high-quality drinking water, increased development within these watersheds threatened this water supply with contamination from onsite septic systems and runoff from roads and agriculture. In 1996, the US EPA required New York City to ensure that the water supply would meet federal standards by either building a water filtration system or by protecting its watersheds from sources of contamination (NRC 2005).

The estimated cost of building and maintaining a new filtration system necessary to meet water quality standards was $6 billion to $8 billion. This was compared to a projected cost of $1 billion to $1.5 billion to protect and restore natural ecosystem processes in the watershed. New York City opted for protection of the watersheds to maintain water quality. To accomplish this, the City passed legislation protecting these critical areas by increasing riparian buffer zones, minimizing impervious surfaces, and restricting certain types of development along rivers and around reservoirs. They also acquired land, held environmental education workshops, and provided programs for dairy and livestock farms to minimize nutrient input from agricultural runoff.

In 1997 alone, the Catskills Watershed Protection and Partnership Programs cost an estimated $292 million (NRC 2000). Stormwater funds and retrofit programs were an estimated 13% of the total program. Other programs included the “Croton Plan” (23% of the budget) and the “Catskills Fund for the Future” (20% of the budget). The Croton Plan helped identify sources of pollution in the Croton Watershed and provided recommendations for improvement, while the Catskill Fund for the Future provided support for “environmentally sensitive economic development projects in the watershed” (NRC 2000). The division of funds indicate the importance of collaboration among different entities to accomplish watershed protection goals.

Although not inexpensive, this strategy ultimately saved the region many billions of dollars and also avoided most maintenance and operational costs. It is a strategy largely being pursued by the largest water purveyors in the region (the cities of Seattle, Tacoma, and Everett), but the benefits and potential cost savings of source protection are not limited to high-mountain surface-water supplies.

Degradation of surface water quality

Even where drinking-water supplies are not directly affected, degradation of the water quality of streams and rivers is a primary concern of stormwater managers and public works directors. The Puget Sound lowlands account for approximately 60% of impaired streams within Washington State, second only to the Columbia Basin (Butkus 2002). According to the Department of Ecology, stormwater runoff directly accounts for 6%, 4%, and 4% of possible sources accountable for impaired streams, estuaries, and lakes, respectively, within Washington State (Beckett 2002). Stormwater runoff in this context is classified as "runoff from urbanized areas" by the U.S. EPA, but its influence is probably understated because it is closely associated with other sources such as combined sewer overflows, agriculture, construction, and hydromodification (Table 5).

Table 5. Source Definitions and of Impairment for Assessed Waters (from Beckett 2002)

Source	Definition	Source of Impairment for Assessed Waters %		
		Streams	Estuaries	Lakes
Stormwater Runoff	Urban Runoff	6	4	4
Agriculture	Crop production; pasture land, feedlots, aquaculture, animal holding and management areas, manure lagoons, etc.	30	13	6
Combined Sewer Overflows	Sanitary sewer overflows due to excessive stormwater infiltrating the system.	1	4	0
Hydromodification	Channelization, dredging, dam construction, flow regulation or modification, removal of riparian vegetation, streambank modification or destabilization, drainage or filling of wetlands.	18	0	1
Other Sources	Industrial point sources, municipal point sources, septic tanks, silviculture, construction, resource extraction, land disposal, natural, and unknown.	45	70	89

According to Ed O'Brien, DOE, "Ecology's observations are that water quality standards are frequently exceeded in urban stormwater runoff. Where that runoff makes up the bulk of the flow in a lowland stream, violations are highly likely" (E. O'Brien, pers. commun. May 31, 2006). In such areas, contamination from vehicles is probably the most widespread water-quality concern. For example, stormwater runoff from the Highway 520 bridge across Lake Washington, with 100,000–150,000 vehicle trips daily, drains directly into the lake. An analysis of the bridge stormwater runoff detected significantly elevated concentrations of zinc, barium, copper, lead, nitrogen, ammonia and organic compounds (King County 2005b).

Other water-quality problems are shared by both rural and urban areas. Elevated temperature and fecal coliform bacteria are the two most common water quality problems reflected in 303(d)-listed impaired water bodies across Washington State (Erickson 2004). DOE notes that "Increased temperatures can primarily be attributed to the loss of vegetation along streams, and to lower flows of water remaining in streams after withdrawals," changes that are common in both rural and urban landscapes. Pitt et al. (2004) reported average fecal coliform concentrations of 8,345 organisms/100 ml for residential areas, 4,300 for commercial areas, and 2,500 for industrial areas. This reflects local experience as well—runoff from urbanized areas always causes fecal coliform standards violations (and subsequent shellfish bed closures), according to DOE. An analysis of microbial pollution in Sinclair–Dyes Inlet found that fecal coliform levels were elevated in more urbanized areas. The study also showed heightened fecal coliform levels shortly after major storm events (May 2005).

At the state government level, DOE's 2005–2007 water quality budget is $54.1 million, of which 17% ($9.0 million) is dedicated to controlling stormwater and 7% ($3.9 million) for addressing non-point pollution (DOE 2005b). The Environmental Assessment Program is budgeted for $25 million to implement water quality monitoring, watershed cleanup studies, compliance monitoring, groundwater investigations, and sediment monitoring.

Local examples of direct water-quality costs are also abundant. Thornton Creek, located in the City of Seattle, is on DOE's 303(d) list for impaired waters due to fecal coliform, temperature, and dissolved oxygen (DOE 2005c). It is Seattle's largest creek and home to chinook, coho, and sockeye salmon, as well as cutthroat and rainbow trout (Seattle Public Utilities and others 2004). In order to improve water quality, Seattle Public Utilities (SPU) is installing water-quality swales and sediment basins to treat stormwater from a 670-acre urban subbasin that enter Thornton Creek. The Washington state DOE's Centennial Clean Water Program has offered the City of Seattle $6,819,995 for 2006 for this project (DOE 2005d). The program also offered SPU $1,034,000 in funding to implement disinfection by ultra-violet light in three Seattle creeks (Thornton, Pipers, and Longfellow creeks) to reduce fecal coliform levels.

Even in areas where much of the fecal contamination from stormwater is due agriculture, farming, or failing septic systems, urban runoff still contributes a large percentage of fecal contamination. In Kitsap County, the Public Works Department estimates that between 35-50% of fecal contamination is a direct result of stormwater runoff from impervious surfaces in urbanizing areas (D. Dickson, pers. commun. February 7, 2006).

Although examples of surface-water degradation are widespread, direct expenditures to correct these problems are much less common and undoubtedly fall well short of what would be needed. Since 2000, for example, Washington State has provided about $1.5 million to rectify the fecal contamination in Dungeness Bay (U.S. EPA 2005). In 2001, additional efforts were made by the Clallam Conservation District and Clallam County Environmental Health to address the problems of agricultural runoff and management and failing septic systems. Clallam County Conservation District is projected to spend $172,000 and $203,000 (2006 dollars) on an annual basis to address stormwater and agriculture-caused water quality issues, respectively, from 2005–2010 (Clallam Conservation District 2005). A portion of the budget required for water quality issues caused by agriculture directly targets agricultural conservation practices that will contribute to reducing the impact of fecal coliform contamination on shellfish harvest areas in Dungeness Bay.

C. Freshwater and estuarine habitat damage

Direct costs of habitat damage are difficult to assign, because the "value" of habitat is rarely measured in strictly monetary terms. More commonly, the damage is reflected in the response of the organisms that depend on that habitat (e.g., "loss of fish"), but the specific contribution of habitat loss to that change has engendered more than two decades of debate and is unlikely to be resolved any time soon. Economic costs can more readily be assigned on the basis of remedial programs; as with those programs targeting degraded water quality, however, they are surely reversing only a scant fraction of the actual damage that is occurring. Despite this limitation, the amounts being spent are quite substantial.

Loss of fish and wildlife habitat

In general, the habitat values of urban streams and creeks in the Puget Sound region are significantly degraded. Problems identified by various jurisdictions around Puget Sound include channel incision, sediment contamination, bank erosion, sediment loading, and resulting loss of salmon runs and overall degradation of aquatic health. Although some jurisdictions do not have the funds or staff to document habitat degradation, such damage is ubiquitous with urban development and is almost certainly occurring throughout western Washington, whether quantified or not. By one estimate (Bernhardt et al. 2005), $1 billion per year is currently being spent nationwide in the name of stream restoration, and a significant fraction of that outlay is contributed by the Pacific Northwest in general and the Puget Sound region in particular. An even greater cost is the intangible and likely irrevocable loss of biological resources, a cost that is compounded by expenditures on ineffectual projects (Frissell and Nawa 1992; Booth 2005).

Despite such challenges, a number of jurisdictions have implemented ambitious habitat-restoration programs to improve fish and wildlife habitat. Within Pierce County, for example, $3 million to $4 million has already been spent on restoration projects (excluding the cost of maintenance; H. Hunger, pers. commun. February 13, 2006). This value may be an underestimate, since other stream projects commonly have a habitat-improvement component but generally are not labeled as "habitat restoration projects."

In the Puget Sound region, examples of restoring damaged salmon habitat are commonplace. Padden Creek flows through a ½-mile-long culvert in the City of Bellingham that salmon cannot pass. Large numbers of chum salmon arrive at the inlet to the culvert and must be trucked to the other side of the creek by volunteers. Plans are progressing to allow the salmon to travel up the creek through the now culvert-covered area, but just the preliminary work for this project has cost the city $4 million (W. Reilly, pers. commun. February 6, 2006). In King County, an estimated cost of $556,000 (2006 value) was spent on habitat restoration efforts for three creeks (Maplewood, Patterson, and Taylor creeks) to enhance fish habitat (SRF Board 2006). Some of the restoration activities include bank stabilization, planting vegetation, and incorporating large woody debris.

In Pierce County, the Lake Tapps Parkway Wetland Mitigation project was intended to mitigate some of the wetland impacts incurred during road construction and to provide water treatment for the discharges entering the wetland from Government Canal (Hashim 2002). Government Canal receives stormwater runoff from roughly 600 acres of paved surfaces and eventually drains into the Stuck River. Travel through urbanized areas also allows for further pollutant loading into the channel. Wetland construction reduced pollutant concentrations in the discharges entering the Stuck River from the wetland site; the Washington State Department of Fish and Wildlife also found wild coho salmon within the wetland. In addition to salmon, Great Blue herons, kingfishers, foxes, deer, waterfowl, and bald eagles have inhabited the wetland since completion of the construction, which cost $323,000 in 2006 dollars (M. Van Haren, pers. commun. June 6, 2006).

The clean-up of Commencement Bay provides another, particularly challenging and costly example. This Superfund site contains highly contaminated sediments; extreme habitat destruction, water pollution, and ecological losses have occurred here. Eel grass beds within the bay are long gone and none of the marine organisms in Commencement Bay are edible except for migratory salmon. Many of the shellfish species that were native to Commencement Bay are no longer present, except for a few pollutant-tolerant species.

In the Thea Foss Waterway, an inlet of Commencement Bay adjacent to downtown Tacoma, sediment dredging is anticipated to be completed by the end of 2006 at an estimated final cost of over $100 million and stormwater has been identified as one of several sources of the contamination (City of Tacoma 2006; S. Hansen, pers. commun. July 28, 2006). This 23-year effort to restore the Thea Foss Waterway has been successful in removing historic contamination. Ongoing urban stormwater discharges into the Waterway and other sources such as marinas and private outfalls continue to cause accumulation of pollutants in the waterway sediment (Figure 3). From 1997 to the present, sediment samples have been collected in the public storm mains upstream of the stormwater outfalls that discharge to Thea Foss Waterway. Contaminants of Concern (COCs) found through stormwater outfall sediment trap and discharge monitoring include mercury, polycylic aromatic hydrocarbons (PAHs), phthalates, heavy oil, and diesel (City of Tacoma, 2006b). Stormwater was responsible for 12%, 21%, 16%, and 56% of Phenanthrene, Dibenz(ah)anthracene, Pyrene, and Bis(2-ethylhexyl)phthalate loadings to the waterway, respectively (City of Tacoma, 2006a).

Current steps are being taken by the city to reduce the effects of stormwater contamination in the Thea Foss Watershed Basin. In 2005 alone, these efforts to clean up waterway sediments and perform stormwater source control to reduce pollutant accumulation in the Thea Foss Waterway cost the City of Tacoma’s Surface Water Management Division $26 million, which accounts for 52% of its total budget for stormwater (City of Tacoma 2006). Actions included stormwater outfall water and sediment quality monitoring, business inspections spill response, and studies of new stormwater treatment technologies. The City is currently using a $500,000 grant from the Federal Highway Administration to evaluate treatment technologies that may potentially reduce recontamination of the waterway. Based on 2001–2005 stormwater monitoring completed by the City of Tacoma, various stormwater contaminant loads were reduced by 40–80 percent since the late 1990s (City of Tacoma 2006a).

Figure 3. Twin eight-foot diameter outfalls that discharge stormwater into the Thea Foss Water Way (Source: City of Tacoma 2006).

Contaminated sediments are not restricted to one site, however. Overall, municipal stormwater is estimated by the DOE to be responsible for 10% of sediment contamination at Washington state sediment clean-up sites (DOE 2005e). Stormwater runoff is also a common secondary source of sediment contamination that contributes to primary sources such as industrial runoff and combined sewer overflows. An estimated 2,940 to 3,340 acres of Puget Sound area are sediment cleanup sites with 5,750 acres exceeding sediment quality standards.

D. Closure of shellfish growing areas

Determining the cost of shellfish-area closures and assigning a reasonable contribution to urban runoff are challenging because the shellfish industry has significant and multifaceted value, both economic and social, and because Puget Sound is a waterbody that integrates contributions from urban and non-urban areas alike. The role of urban runoff can be determined only by inference, recognizing that the juxtaposition of shellfish beds with urban areas provides a reasonable linkage between them. Where costs can be quantified, they fall into the categories of protective measures and the direct loss of revenue. The following sections discuss the costs associated with shellfish harvest-area closures; however it is important to acknowledge that there are also costs associated with shellfish harvest restrictions. Shellfish harvest restrictions (i.e., following heavy rains) delay the production and sales of shellfish with shellfish growers incurring additional costs to ensure that the shellfish are safe to eat following the restriction.

Extent of the problem

According to the Washington State Department of Health (DOH), 25 out of the state's 95 shellfish harvesting areas were threatened by pollution in 2004. DOH classifies "threatened" areas as those that are subject to classification downgrades. There are four categories that shellfish harvest areas can be classified under which are approved, conditionally approved, restricted, and prohibited. Approved areas must have average concentrations less than 14 units/100 ml of fecal coliform bacteria in their water samples and must not exceed concentrations of 43 organisms/100 ml in the 90th percentile of their samples (DOH 2005). "Conditionally approved" areas are those that meet the approved classification during the majority of the year except during times of predictable violations, i.e. after heavy storms. "Restricted" areas do not meet the approved category requirements but contain concentrations of contaminants that are low enough to be expunged by shellfish when placed in clean water for a given period. "Prohibited" areas contain shellfish that contain contaminant levels that are too dangerous for consumption. Twenty of these threatened areas are located in the Puget Sound region (DOH 2005a). Table 6 shows the history of threatened shellfish harvest areas, with a steadily worsening trend over this 4-year period.

Table 6. Threatened Shellfish Harvest Areas from 2001 to 2004

Year	Threatened areas in Puget Sound	% of Washington State total
2001	14	88%
2002	17	85%
2003	18	82%
2004	20	80%

(Sources: DOH 2002, 2003, 2004, 2005a).

Tabulated values do not tell a complete story, however. According to Bob Woolrich, who classifies shellfish areas for the Washington State Department of Health, many counties and jurisdictions have been successful in minimizing the effects of pollution on their shellfish harvest areas. Yet many of these same areas are now being pressured by rapid growth along their shorelines and development of the contributing watersheds. Since 1981, 34 of a total of 41 shellfish classification-area downgrades (>80%) were caused by nonpoint sources (DOH 2005), which include river discharges, agricultural runoff, and failing septic systems. Although many of these sources are rural non-point sources, at least four of the closures are in urban areas and are almost certainly a result of urban stormwater runoff (Henderson Inlet, North Dyes Inlet, North Bay, and Lynch Cove). Furthermore, shellfish harvesting remains closed along the highly urbanized east coast of Puget Sound, from Tacoma to Everett (B. Woolrich, pers. commun. June 12, 2006).

Outside of these urban areas, some shellfish harvest areas have been reopened but others have not been as successful. One example of the latter is Burley Lagoon, whose management is shared by Pierce County and Kitsap County. This lagoon has been closed and reopened several times during a 25-year effort to keep this shellfish harvest area open. Grants and local and state money have been used to mitigate the effects of on-site septic systems and agricultural runoff on the shellfish beds; however, the large amounts of development within the watershed, coupled with limited flushing of the bay, is proving to be difficult to overcome.

Protective Measures

Cities and counties where shellfish beds are degraded to a lower classification must develop closure response plans and designate shellfish protection districts, actions that cost local governments money to develop and implement. For example, the efforts to protect Burley Lagoon have included contaminant source identification and correction and public education at fairs and special events. The cost of this program was $184,055 (2006 dollars) in 2003, with funding provided by Pierce County Public Works and Utilities and grants (Pierce County 2004). In addition, the Pierce County Conservation District has requested a $5/parcel annual fee in unincorporated and some incorporated areas of Pierce County for enhanced protection. This fee would raise $576,476 annually in additional funds for the Pierce County Conservation District (Pierce County 2004).

In Thurston County, a shellfish protection district was formed for Henderson Inlet due to a downgrade of shellfish harvesting area by the DOH in 2000 and 2001. While the county is still in the process of implementing stormwater mitigation plans, the City of Lacey has taken steps to minimize their stormwater impacts on Henderson Inlet. Currently, the city is spending $1.6 million on the College Ditch Stormwater Facility to treat storm and sewer discharges entering Woodland Creek, which is a tributary to Henderson Inlet (D. Christenson, pers. commun. June 8, 2006). Other stormwater retrofits are also being installed throughout Lacey.

In some areas, local funds are being invested specifically for stormwater management techniques to protect shellfish harvest areas. Within Kitsap County, for example, 14% of the total surface and stormwater management program funds the local health district that helps minimize stormwater impacts (FCS Group, Inc. 2005). In contrast, many other areas are not properly funded or staffed to fix many of the stormwater problems, or even to identify the pollution source.

Lost revenues and lost jobs

Shellfish production within the state of Washington accounts for 83% of the total shellfish production by weight on the West Coast of the United States (Pacific Coast Shellfish Growers Association 2004), and many of the harvest areas within the state are located in the Puget Sound basin. When a shellfish harvest area is closed, the losses suffered by shellfish growers can be dramatic. With more than 80% of current area downgrades resulting from nonpoint sources, septic systems and stormwater from rural areas are the most likely sources of recent shellfish harvest-area contamination (DOH 2005). In part, however, this reflects the long-standing pattern of urbanization across Puget Sound. Shellfish harvesting along the eastern shoreline of the Sound, including valuable geoduck resources, remain closed due to wastewater treatment plant discharges and urban stormwater discharges.

Figure 4 displays the total gross revenue reported annually by the shellfish industry for the state of Washington, reflecting the important role of the industry in local coastal economies. Although the decline in revenue seen in Figure 4 may be a result of a variety of factors, shellfish harvest area closures certainly have a major impact on the shellfish industry.

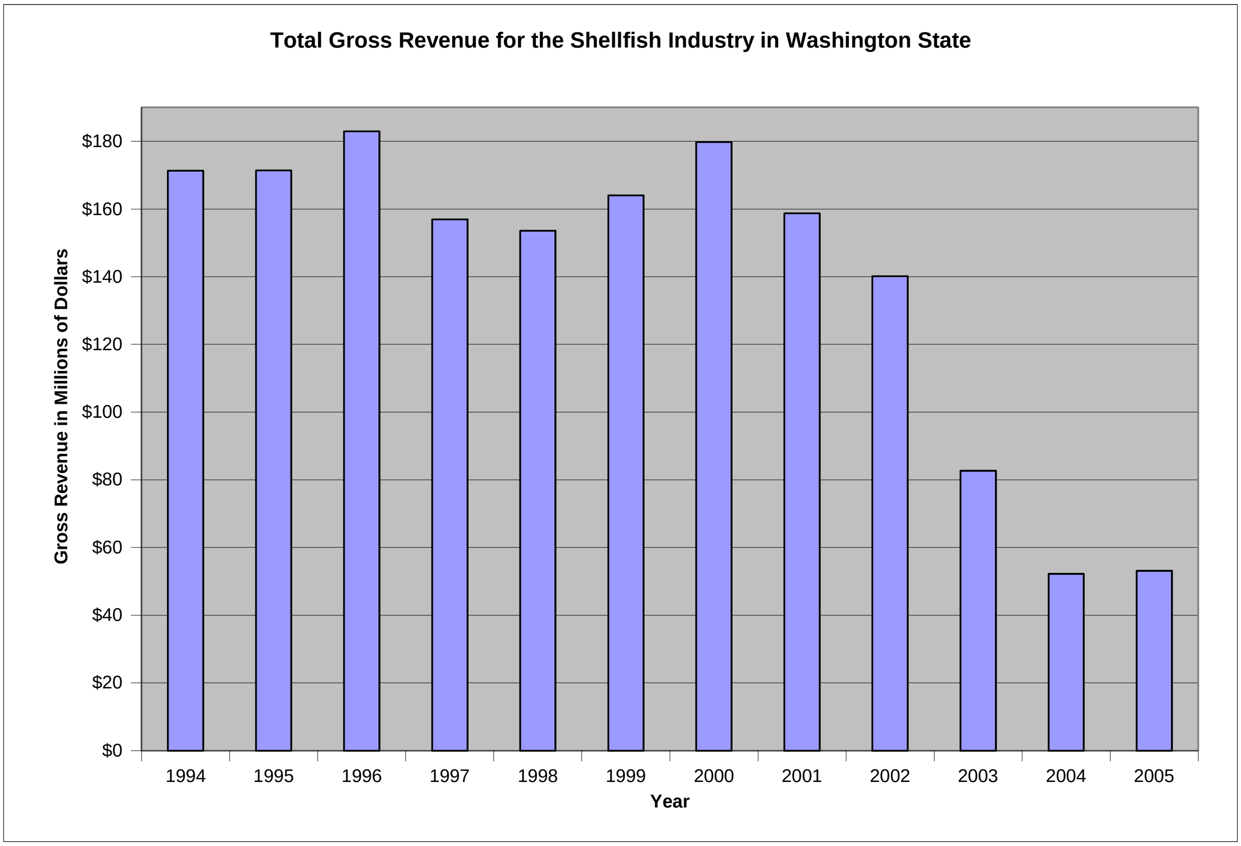

Figure 4. Total Gross Revenue for the Shellfish Industry in Washington State (Washington State Department of Revenue 2006)

Perhaps the best-documented example of economic losses from a shellfish closure is provided by the 2003 emergency closure of shellfish growing areas in Samish Bay, Skagit County. An outbreak of the norovirus pathogen, which causes vomiting and diarrhea and can spread quickly with very little contamination, was the cause of this closure. The outbreak was caused by raw sewage suspected to be from fishermen along the Samish River that was absent of restroom facilities, live-a-board boaters, and failing on-site septic systems (DOH Shellfish Programs 2004). According to the Center for Disease Control, “Food can also be contaminated at its source, and oysters from contaminated waters have been associated with widespread outbreaks of gastroenteritis…Waterborne outbreaks of norovirus disease in community settings have often been caused by sewage contamination of wells and recreational water” (CDC 2005).

Although this incidence probably was not stormwater-related, it provides a clear example of the costs incurred when a shellfish area is closed (for whatever reason). Bill Dewey, senior manager at one of the biggest shellfish companies in the Puget Sound area (Taylor Shellfish Company), analyzed the impact of the closure on production and loss costs due to the norovirus outbreak in 2003 (Table 7).

Table 7. 2003 Samish Bay Overall Production and Closure Losses

Type of Cost	Value*
Payroll	$ 1,224,760
Gross Sales	$ 3,516,660
Production Value	
Live Oysters	$ 907,474
Shucked Oysters	$ 674,077
Manila Clams	$ 921,615
Losses	
Impact of Closure Due to Lost Sales	$ 140,390
Product Recall	$ 21,598
Lost Product (Mortality and Predation)	$ 4,320
Total Losses	**$ 166,307**

*Value shown is in 2006 dollars. Information from Bill Dewey, Taylor Shellfish Co.

The closure resulted in a total loss of $166,307 and caused 11 employees to be laid off; at the time, Samish Bay shellfish industries had a total of 36 full-time equivalent employees. Six of those employees are still unemployed today, and consumer confidence in Samish Bay products has been damaged. The Hong Kong shellfish market is completely closed to Samish Bay industries, because they continue to refuse all products from Samish Bay regardless of the bay's present condition. Although costs of shellfish harvest areas vary with shellfish species, level of pollution, and area, the Samish Bay closure of 2003 suggests the magnitude of costs incurred when a closure does occur.

Similarly, the commercial shellfish industry in Drayton Harbor (Whatcom County) has suffered extreme losses due to urban development. It once was a well-known area for commercial oyster and recreational shellfish harvesting, but rapid development of the watershed and shorelines that began in the 1980's resulted in a total ban on shellfish harvesting in the entire harbor starting in 1999 (Callahan and Menzies 2004).

Wastewater treatment plants, marinas, onsite sewage systems, agriculture, and stormwater are just some of the pollution sources that now affect Drayton Harbor due to urbanization. Geoff Menzies, chairman of the Drayton Harbor Shellfish Protection Advisory Committee and manager of the Drayton Harbor Community Oyster Farm, has been working for 10 years to upgrade Drayton Harbor shellfish harvesting areas. Drayton

Harbor was downgraded to "prohibited" status by the Washington State DOH in 1995 and was upgraded to "conditionally approved" in 2004 (DOH 2005). A shellfish protection district has been implemented since 1995. While there are a number of contaminant sources linked to the pollution of Drayton Harbor (i.e., septic systems, sewer systems, marinas, and agriculture), Menzies identifies stormwater runoff as one of the top three significant sources. Substantial efforts have been made by non-profit organizations and local governments to clean up the harbor at an estimated cost of $160,000–200,000 annually (G. Menzies, pers. commun. June 15, 2006).

The closure of shellfish harvesting area has also impacted the Drayton Harbor community and the Lummi Nation. Prior to the 1995 closure, the Lummi Nation harvested about 30,000 pounds of clams per year, which is estimated to generate $87,000/year. This represents a value of $870,000 in lost revenue over the past 10 years of closures. Closures also mean lost commercial oyster revenue that is estimated at $2.5 million over the past decade. It is important to note that these costs are significantly underestimated because they fail to account for lost recreational, tourism, and business revenues resulting from closures.

Recreation

The value of recreational fisheries is substantial, and so the cost of their closures can also be significant. The Washington state Department of Fish and Wildlife (WDFW) licensing department reported $16.9 million in state sales for fishing licenses, which includes shellfishing, for a total of 763,109 customers (WDFW 2006). In 2001, the U.S. Fish and Wildlife Service surveyed 34 million anglers and found that their recreation expenses totaled $35.6 billion, which corresponds to a $1,046 per angler (U.S. FWS 2002), which include licensing, food, lodging, and equipment. Based on the number of 2005 fishing license customers in Washington and converting the estimated expenses per angler into current value, an estimated sales revenue of $917 million could have been generated by Washington State from recreational fishing and shellfishing in 2005 alone.

Belfair State Park located in Lynch Cove is one example of the lost recreational shellfishing opportunities affected by shellfish harvest closures due to stormwater runoff. According to Bob Woolrich of the Washington State Department of Health, Belfair State Park has been closed to commercial and recreational shellfishing for the past 18 years due to contamination, although one third of the park was reopened to commercial and recreational shellfishing in 2005. Camille Speck of the Department of Fish and Wildlife estimates that there are 1.5 million oysters of legal, harvestable size in this opened area of park alone. Clamming may also be available to harvest once the Department of Fish and Wildlife assesses the stock.

The annual amounts of shellfish harvesters for beaches within Washington are estimated by the Department of Fish and Wildlife (Figure 5). Data provided for North Bay shows a dramatic increase in shellfish harvesting in 2002, which corresponds to an upgrade of shellfish harvest areas by the Department of Health in 2002 from “restricted” to “approved” status (DOH 2005). On the other hand, Belfair State Park efforts were extremely low from 1990 to 2001 due to area closures (effort was not observed from

2002–2005); however, surveys made during closure show that people will still harvest despite DOH advisories.

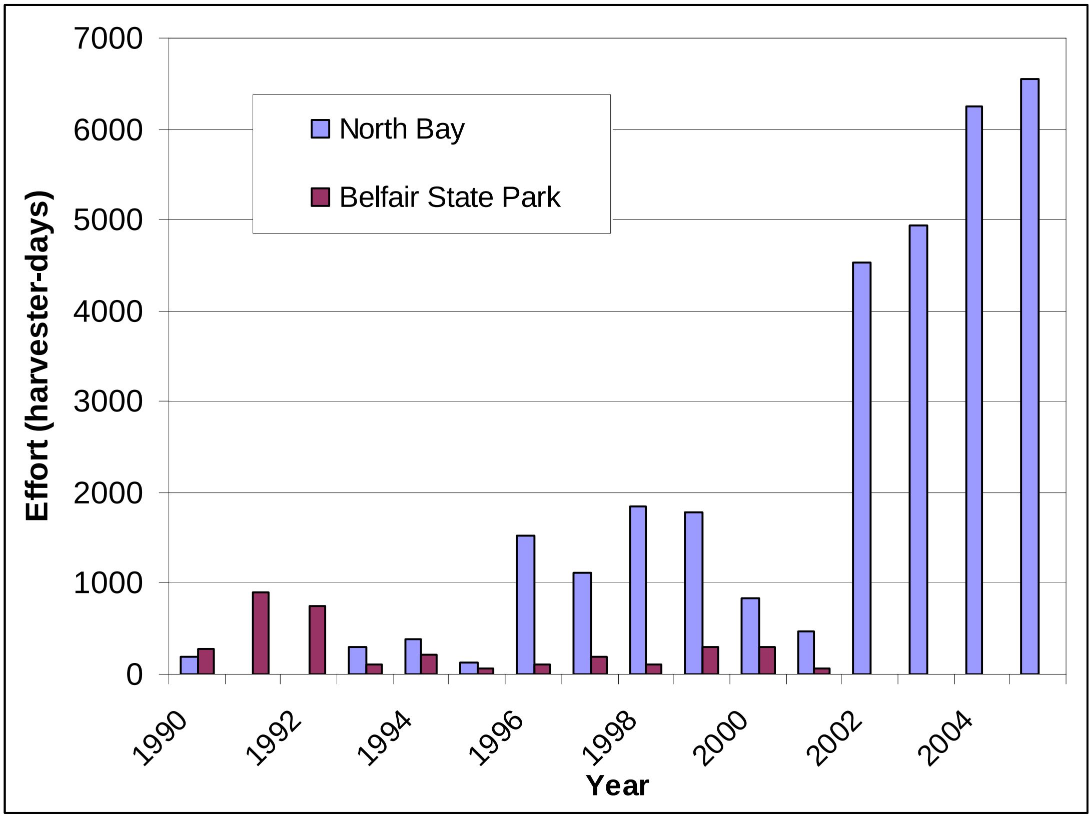

Figure 5. Shellfish Harvesting Effort in North Bay from 1990 to 2004 and Belfair State Park from 1990 to 2001 (C. Speck, pers. commun. June 9, 2006). Shellfish harvesting significantly increased after 2002 following shellfish harvest area upgrades, while shellfish harvesting in Belfair State Park remained low due to shellfish harvest area closures since 1987.

III. A Summary of Quantifiable Costs

The economic costs of stormwater in the Puget Sound region range from thousands to millions of dollars per year within a single jurisdiction; per capita costs are in the tens to hundreds of dollars for each individual element that can be readily quantified. In aggregate, current expenditures and unfulfilled needs almost certainly exceed $1 billion for the region over the next decade. These costs include losses from degraded water quality, habitat and restoration, landslide mitigation, and drainage and flood mitigation. Figure 6 highlights some examples of the division of costs associated with managing stormwater and mitigating stormwater-related problems, based on information from various-sized jurisdictions. Total annual costs, previously presented for selected jurisdictions in Table 3, range from a few hundred thousand to many millions of dollars per year.

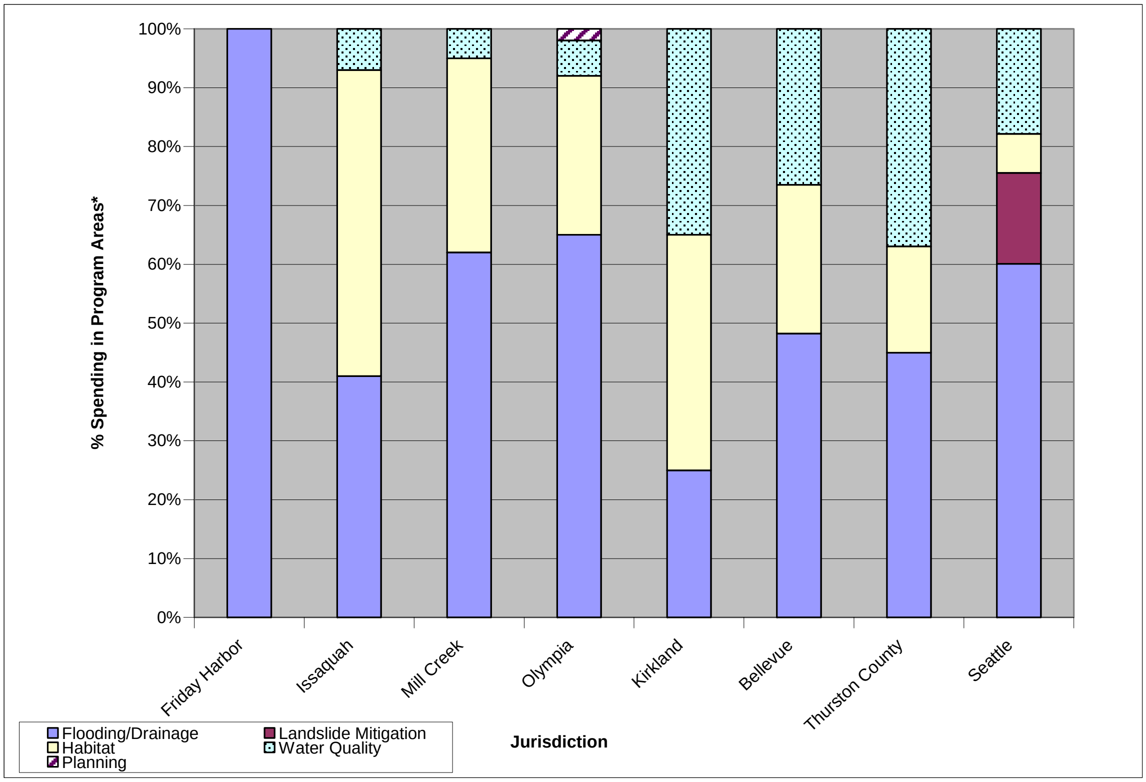

Figure 6. The total capital improvement project costs of jurisdictions in the Puget Sound region, in order of increasing population, are as follows (2006 dollar values): (a) Town of Friday Harbor costs represent a total budget of $2,422,000 for years 2006-2027 (Gray & Osborne 2005), (b) City of Issaquah total budget = $7.3 million for years 2005-2010 (City of Issaquah 2005), (c) City of Mill Creek total budget = $5.3 million for years 2005–2011 (City of Mill Creek 2005), (d) City of Olympia total budget = $12.5 million for the capital improvement program from 2004-2012 (City of Olympia 2003), (e) City of Kirkland total budget = $8.7 million for years 2004–2009 (City of Kirkland 2005), (f) City of Bellevue total budget = $30 million for projects from years 2005–2011 (City of Bellevue 2005), (g) Thurston County total budget = $5.7 million for years 2006–2011 (Thurston County 2005), and (h) City of Seattle total budget = $19.0 million as an average annual cost for years 2005–2010 (Seattle Public Utilities and others 2004). It is important to note that the impacts due to stormwater may not necessarily be reflected in stormwater and surface water program expenditures displayed above, because stormwater costs may also be shared with other departments.

Efforts to reduce flooding and drainage are the largest costs among all jurisdictions, regardless of size. This is not surprising, because many jurisdictions interviewed indicated that the majority of citizens and local officials are primarily concerned with flooding and drainage issues. In contrast, the importance of water quality and habitat issues varied significantly among the jurisdictions interviewed, with funding to address these problems also varying across jurisdictions. Each of these problems, however, has a significant (and in some cases almost exclusive) contribution from stormwater runoff, and so the magnitude of these costs are a good first-order estimate of what the region is spending, and how it is spending it, on measures to reduce stormwater-related damage. It is important to note that the impacts due to stormwater may not necessarily be reflected in stormwater and surface water program budgets displayed above, because stormwater costs may also be shared with parks and recreation and planning and development that are not specifically listed in stormwater budgets.

Although jurisdictions are currently spending thousands to millions of dollars annually on stormwater management, these costs are dwarfed by the damage caused by stormwater runoff and attempts to mitigate these problems. The major impacts of stormwater runoff that could be quantified in economic terms are summarized below.

Table 8. Summary of Stormwater Costs by Impact

Types of Costs	Reported Costs
Flooding, Landsliding, and Property Damage	
Property damage and financial losses	Flood insurance claim payments to the Puget Sound region have totaled $56 million since 1978. Although significant, it still underestimates the total flood losses borne by property owners.
Expense of stormwater facilities	Capital improvement plans of Puget Sound jurisdictions reviewed in this study indicated annual expenditures of $115,333 to $5 million; however, many millions of dollars in shortfalls exist across the Puget Sound region beyond this reported value.
Expense of stormwater programs	Annual stormwater program budgets within the Puget Sound region range from hundreds of thousands to millions of dollars, with typical annual costs of approximately $100/person within a stormwater utility district.
Degradation of Water Quality	
Clean-up of polluted water resources	A review of expenditures within the Puget Sound region revealed that water quality improvement in a single watershed due to a single, stormwater-related contaminant can cost as much as $1.5 million.
Protecting water resources from additional contamination	Various Puget Sound jurisdictions report that treatment costs for stormwater discharges range from $172,000 to $6.8 million.
Loss of Fish and Wildlife Habitat	
Habitat restoration and protection efforts	Individual restoration projects associated with stormwater discharges have cost individual Puget Sound jurisdictions $100,000 to as much as $100 million. Efforts in one jurisdiction to restore and prevent continued degradation of critical fish and wildlife habitat cost $25.8 million in 2005 alone.

Types of Costs	Reported Costs
Closure of Shellfish Growing Areas	
Shellfish harvest area protection and clean-up	Pollution-prevention and clean-up measures cost $160,000 to $200,000 annually for Drayton Harbor, for example, which was once a valuable Puget Sound shellfish harvest area.
Lost revenues and lost jobs	One Puget Sound harvest area alone experienced a loss of over $3 million in shellfish sales due to closed shellfish harvest areas.
Lost recreation opportunities	The state generated $16.9 million in sales for fishing and shellfishing licenses with over 700,000 customers indicating the popularity of fishing and shellfishing. With the majority of shellfish harvest areas located in the Puget Sound, closed beaches in the region result in lost opportunities for recreational revenue and shellfishing.

In addition to the reported costs listed above, there are consequences of stormwater runoff that are not easily quantified but are also important to recognize. These costs are discussed in the successive section and include social, cultural, and quality-of-life changes; lost recreational opportunities due to degraded water quality; reductions in consumer confidence; decreased tourism; and loss of fish and wildlife.

IV. Other "Costs" of Urban Stormwater

The majority of this report presents examples of incurred costs (i.e. dollars spent) and lost economic value that have resulted from our present levels of urban development and its associated stormwater management. The interviewees, however, commonly articulated other "costs" that do not translate readily into monetary terms, or that cannot be assigned unequivocally and solely to urban runoff. The dollar value of a degraded fishery, for example, is only one dimension of what has been lost; the related social, cultural, and quality-of-life losses are far more difficult to quantify. Furthermore, those losses are strongly correlated with urban development but are probably not caused exclusively by urban runoff—other factors may include overharvest, competition from invasive species, and physical alteration of habitat. Thus any attempt to assign a purely monetary, "stormwater-based" cost would not be correct, and it would also overstep the information provided by respondents that form the basis of this report.

That said, a list of some of the unquantified "losses" that have been caused in whole or part by urban runoff make a sobering litany of what the region has given up under the onslaught of urban development. Perhaps the most prominent of these losses is the local collapse of aquatic ecosystems, but degradation is also expressed by the reduced recreational value of polluted waters for swimming, boating, water skiing, and windsurfing; and the lost opportunities from damages that, once imposed, can never be fully reversed no matter how heroic the efforts.

A nationwide survey of states, tribes, local governments, and other agencies that maintain beaches identified that stormwater was the single greatest known source (21%) of beach closures and advisories in the nation (U.S. EPA 2003), particularly from fecal coliform contamination. While there has been some success in the Puget Sound region controlling sources of bacterial pollution (mainly from onsite sewage systems and farm animal wastes) and restoring water quality for shellfish harvesting in areas such as Burley Lagoon, Eld Inlet and North Bay (DOH 2005), stormwater runoff from urbanizing landscapes has proven to be a more intractable pollution problem. As a consequence of the region's large and fast growing population, stormwater contamination of beaches and shellfish growing areas will very likely worsen and result in corresponding reductions in recreational and commercial uses of these waters, consumer confidence, tourism, and the region's quality of life.

Loss of fish

Urban stormwater is a critical element in the decline in urban salmon but it is not the sole cause, because the cumulative effect of the wide variety of human activities in urban basins profoundly influences urban streams and their biota (Booth et al. 2004). Because of this complexity, a simple “cost” is impossible to determine; and, more importantly, successful rehabilitation must be similarly multifaceted. This rarely occurs in most stream-restoration projects, and so a continued loss of ecological health (and, as its best-known expression, a continued loss of salmon) is almost guaranteed under present practices. Changing these practices should lead to a potential increase in the success of stream-restoration efforts. It will probably also result in increasing economic outlays to achieve meaningful results, however.

In some cases, treatment is difficult because the reason(s) for documented fish losses are not well understood. For example, both local and federal agencies in the Seattle area have monitored streams in the Puget Sound lowlands since the late 1990’s and have discovered high death rates of pre-spawning salmon. Prior to death, many of these salmon suffer from loss of equilibrium and orientation. It is estimated that 20%–90% of spawning coho salmon in the fall have been affected, notably in Seattle’s Longfellow Creek, with stormwater runoff from nonpoint sources the as-yet unconfirmed but most probable source (NOAA 2006). Stormwater is the suspected culprit since most of the flow in Longfellow Creek is contributed by stormwater, the fish kills are directly correlated with storm events, and the affected salmon show no signs of disease or pathogens (Scholz 2006). Pre-spawn mortality in coho salmon has also been discovered in Kelsey Creek, Thornton Creek, and Piper's Creek within King County. Ongoing studies by NOAA Fisheries predict that a pre-spawn mortality rate of 0–65% of the population will lead to extinction of Pacific salmon species in next 59 years (Scholz 2006).

Similarly, the effects of individual stormwater pollutants on fish species have been studied in the Puget Sound region, but even the strong causal (and detrimental) linkages that can be documented do not easily translate into discrete “costs.” For example, concentrations of Chlorpyrifos, a common insecticide, exceed the criterion for “aquatic life protection” in surface waters of the Puget Sound basin (Bortleson and Ebbert 2000). A study of streams in King County detected pesticides, including Chlorpyrifos, more frequently and at higher concentrations during storm events than at normal base flow (Frans 2004). Studies have shown increased lethargy and decreased feeding and swimming rates in Coho salmon exposed to Chlorpyrifos (Sandahl et al. 2005). Studies also show that Coho salmon were also affected by copper exposure, a common constituent of stormwater runoff, which inhibits their olfactory system and is vital for recognition of predators and kin and reproduction (Baldwin et al. 2003). Increases in polycyclic aromatic hydrocarbons (PAHs) were found in sediments that were monitored for 12 years during 1989–2000 by the Puget Sound Ambient Monitoring Program (Partridge and others 2005). Stormwater is suspected to be a significant source of PAH contamination at these sites. The risks of English sole developing liver lesions increase with fish age and exposure to PAHs, especially in urban areas where sediment PAH concentrations are the highest (Puget Sound Water Quality Action Team, 2002).

Although damages such as these do not have a direct dollar value attached to them, they must be part of any evaluation of the consequences of urban development in the Puget Sound region because their effects are so widespread. Documented expenditures in the name of urban stormwater management are substantial but the hidden costs of untreated problems may be even greater. Every category of cost discussed in this report—direct damage, stormwater facilities and programmatic responses, indirect damage, and unquantifiable (but very real) losses—must be acknowledged as the region seeks to develop a rational framework for deciding the best and most cost-effective path to protect and improve Puget Sound.

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VI. Appendix A

Sources of Information

Name	Organization
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Kurt Baumgarten	Whatcom County, Planning Division
Steve Bleifuhs	King County, Department of Natural Resources and Parks
Kirk Christensen	Whatcom County, Public Works Stormwater Division
Doug Christenson	City of Lacey, Stormwater Manager
Scott Clark	Thurston County
Sue Davis	Thurston County Health Department
Anne Dettelbach	Washington State Department of Ecology
Bill Dewey	Taylor Shellfish Company
Dave Dickson	Kitsap County, Public Works Department
Margaret Dutch	Washington State Department of Ecology
Irene Fadden	Taylor Shellfish Farms
Steve Foley	King County, Department of Natural Resources and Parks
Melissa Gildersleeve	Washington State Department of Ecology, TMDL Program
Stuart Glasoe	Puget Sound Action Team
Shauna Hansen	City of Tacoma, Public Works Department
William Hashim	Washington State Department of Ecology
Andy Haub	City of Olympia Public Works
Hans Hunger	Pierce County Public Works & Utilities
Sue Joerger	Puget Soundkeeper Alliance
Douglas Kelly	Island County Groundwater Resources Program
Teri King	Washington Sea Grant Program
Katrina Landau	Citizen's for a Health Bay
Arthur Lee	Tulalip Tribe, Community Development
Kathryn Liberman	Muckleshoot Tribe
Brian Lynn	Washington State Department of Ecology, Shorelines & Environmental Assistance Program
Sarah McCarthy	NOAA Northwest Fisheries Science Center
Geoff Menzies	Chairman of the Drayton Harbor Shellfish Protection District Advisory Committee, Manager of the Drayton Harbor Community Oyster Farm

Name	Organization
Mike Milne	Brown and Caldwell Environmental Engineers & Consultants
Bill Moore	Washington State Department of Ecology
Dick Oltman	Shelton Skookum Rotary Club Foundation
Sandra O'Neill	Washington Department of Fish and Wildlife
William Reilly	City of Bellingham, Public Works Department
Kerry Ritland	City of Issaquah
Camille Speck	Washington Department of Fish and Wildlife, Point Whitney Lab
Christy Strand	City of Tacoma Public Works Department
Ralph Svrjcek	Washington State Department of Ecology
Mark Swartout	Thurston County Natural Resources Program
Tracy Tackett	Seattle Public Utilities
Heather Trim	People for Puget Sound
Shaun Ultican	Kitsap County Health District
Misha Vakoc	U.S. EPA Region 10
Mary Van Haren	Pierce County
Ann Wessel	Washington State Department of Ecology, Water Quality Program
Fran Wilshusen	Northwest Fisheries Commission
Bob Woolrich	Washington State Department of Health, Shellfish Program
Craig Young	Snohomish County Watershed Steward