Marine Sediment Quality

Much of the "floor" of Puget Sound is covered with sediment—the gravel, sand, silt, and clay that has accumulated over years, decades, centuries, and even millennia. The accumulation of sediment is a natural estuarine process that occurs as beaches and bluffs erode, as streams and rivers carve their way through watersheds and carry sediments from the land into the water, as glaciers grind down the rocks of mountains, and even as the teeming algae and microscopic animals die and settle slowly to the bottom.

These sediments form a unique habitat that is home to clams, marine worms, burrowing shrimp, bottom-dwelling fish, and thousands of other unique species that live in, or on, the bottom sediments. In turn, these animals form a critical part of the marine food web, help filter the overlying water, and even process and help breakdown the sediments themselves—much as earthworms and other soil organisms process and enrich the soils of our farms, gardens, and forests.

In a well-functioning estuary, marine sediments support a healthy biological community. But in Puget Sound sediments have become contaminated and adversely affect aquatic life that rely upon them.

Photo Credit: Sean Sheldrake, EPA Region 10 diver

Marine Sediment Quality

INDICATOR:

Sediment Chemistry Index

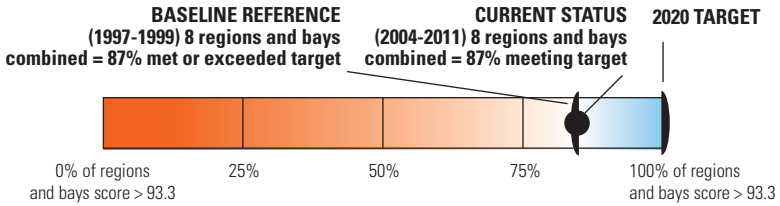
Indicator lead: Maggie Dutch, Department of Ecology

TARGET:

By 2020, all Puget Sound regions and bays achieve chemistry measures reflecting "minimum exposure" with Sediment Chemistry Index (SCI) scores >93.3.

PROGRESS:

IS THE TARGET MET?	NO	IS THERE PROGRESS?	NO



Five Puget Sound regions and three urban bays were sampled from 1997-1999, and re-sampled from 2004-2011. Results show no significant change between sampling periods, with seven of eight areas (87%) meeting (or not statistically different from) the target during both periods.

INDICATOR:

Sediment Quality Standards

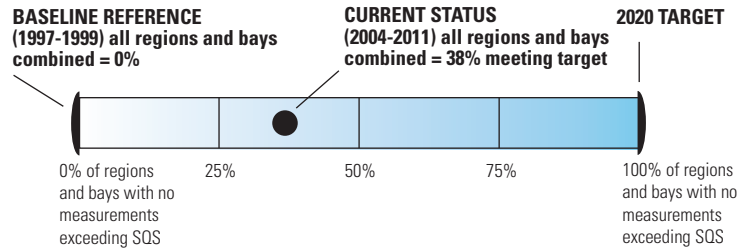
Indicator lead: Maggie Dutch, Department of Ecology

TARGET:

Have no sediment chemistry measurements exceeding the Sediment Quality Standards (SQS) set for Washington State

PROGRESS:

IS THE TARGET MET?	NO	IS THERE PROGRESS?	Yes



For five regions and three urban bays evaluated from 1997-1999, no area met the target that 0% of sediment chemistry measurements exceed Washington State Sediment Quality Standards. However, three of the eight areas re-sampled from 2004-2011 did meet this target.

Progress Towards 2020 Target

Sediment chemistry index values have met or exceeded the 2020 target in all areas sampled so far except Elliott Bay (Figure 1). In all areas that have been sampled twice, none showed any statistically significant change from their original results, including Elliott Bay. Even though the SCI score in Elliott Bay has improved, the change was not statistically different, hence our conclusion that we are not yet seeing progress in this target. Therefore, we remain slightly short of the 2020 goal that all regions and bays show an SCI score >93.3.

The number of individual chemicals exceeding state sediment quality standards (SQS) over the past decade is typically small (mostly less than 1%) except for Central Sound, Elliott Bay, and Commencement Bay, where the number still never exceeded 5%. Even fewer chemicals exceeded state SQS in the most recent round of sampling, with three areas dropping to zero and now meeting the target in those areas. Although the target is not fully met across all of Puget Sound, recent improvements suggest progress toward the target.

What are These Indicators?

The Sediment Chemistry Index (SCI) is one component of the Sediment Quality Triad Index. It combines data on the concentrations of a variety of chemicals into an overall index of chemical exposure (Table 1). Contaminants measured as part of the SCI include metals, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs – flame retardants), chlorinated pesticides, phthalates, some solvents, and various other pollutants. Note that analyses for newer chemicals of concern, such as dioxins, furans, endocrine disrupting chemicals, pharmaceuticals, personal care products, and perfluorinated chemicals, are not conducted as part of the PSEMP sediment component, and therefore not included in these Sediment Quality Dashboard Indicators.

Sediment Chemistry Category	Sediment Chemistry Index
Minimum Exposure	>93.0-100.0
Low Exposure	>80.0 - 93.0
Moderate Exposure	>66.0 - 80.0
Maximum Exposure	>0- 66.0

Table 1. Categories of exposure to chemicals and associated index values

Higher index values indicate less exposure to chemicals and thus healthier sediments (Table 1). Tracking the SCI gives an indication of how concentrations of those chemicals in marine sediments change over time, primarily in response to anthropogenic input, such as stormwater runoff and direct discharge, as well as cleanup activities and passive burial as cleaner sediments settle over older, and sometimes more contaminated, sediments.

The second (related) indicator reports the percent of individual chemical measurements that exceed the Washington Sediment Quality Standards (SQS). SQS values have been determined for a total of 47 chemicals in Puget Sound. Of those, 39 are included in the SCI and evaluated for this indicator.

Interpretation of Data

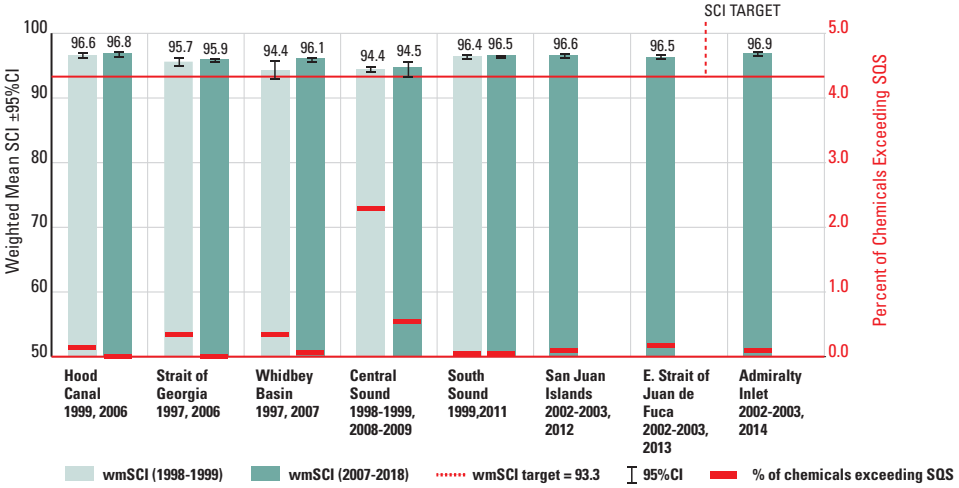
Overall, sediments in Puget Sound appear to be in generally good condition with regard to the measured suite of chemicals. Since 1997, all of the eight sampled regions and four of five urban bays met the SCI target, and values in most areas have changed little since the late 1990s.

In general, levels of toxic chemicals have been, and continue to be, highest in urban bays, but only Elliott Bay was clearly not meeting the SCI target in the low exposure category. The target has not been met in Elliott Bay since SCI scores were first calculated for data collected there in 1998, and only barely met in Commencement Bay, although scores in both bays appear to have improved over the years.

Given that sediment contamination generally changes very slowly, we expect most areas currently meeting the target to continue to do so through 2020 unless contaminant inputs to the areas increase. It is possible that the target may eventually be reached in Elliott Bay if conditions there continue to improve.

The second target, chemicals exceeding state sediment quality standards, was not met over the past decade in most regions and bays, again with urban bays—particularly Commencement and Elliott bays—showing the highest numbers. But the percent of chemicals exceeding the SQS value has

Weighted Mean Sediment Chemistry Index (SCI) Scores for 8 Puget Sound Regions and Percent of Chemicals Exceeding Sediment Quality Standards (SQS)



declined in most areas that have been re-sampled, with three regions—Hood Canal, Strait of Georgia, and South Puget Sound—now showing no sediment chemical values exceeding SQS, and both Commencement and Elliott bays dropping to below 3%. The value for Bainbridge Basin remained the same, below 1% for 1998 and 2009. Given the direction of the data, it is possible that values will continue to improve and may reach, or come very close to, the target by 2020.

Weighted Mean Sediment Chemistry Index (SCI) Scores for 6 Puget Sound Urban Bays and Percent of Chemicals Exceeding Sediment Quality Standards (SQS)

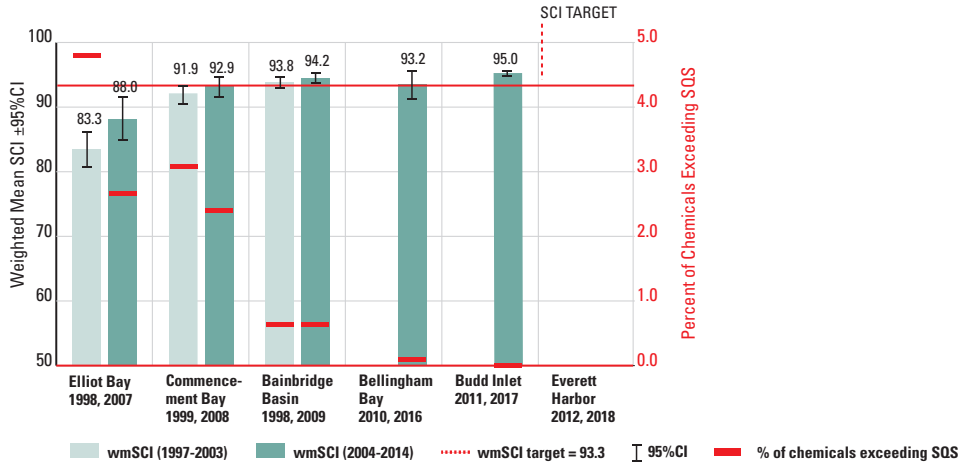


Figure1. The Sediment Chemistry Index (SCI) is shown for eight regions (left panel) and six urban bays (right panel). Light bars show results for first-round sampling efforts. Dark bars show results for second-round re-sampling. Higher values indicate healthier sediments. Also shown (red bars) are the percent of chemicals exceeding Sediment Quality Standards (SQS) for each sampling event.

Source: *Washington Department of Ecology, Marine Sediment Monitoring Team*

Marine Sediment Quality

INDICATOR:

Sediment Quality Triad Index

Indicator lead: Maggie Dutch, Department of Ecology

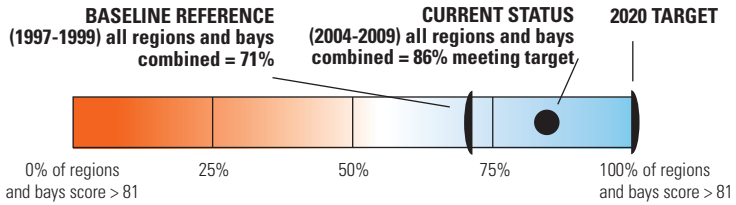
TARGET:

All Puget Sound regions and bays, as characterized by ambient monitoring, achieve the following: Sediment Quality Triad Index (SQTI) scores reflect "unimpacted" conditions (i.e., SQTI values >81)

The threshold criteria for "unimpacted" sediments has been revised from 83 (when the Leadership council adopted the target in 2011) to 81, based on quality control checks indicating the original calculation was incorrect.

PROGRESS:

IS THE TARGET MET?	NO	IS THERE PROGRESS?	Yes*



Four Puget Sound regions and three urban bays were first sampled in 1997-1999 and then re-sampled from 2004-2009. The most recent results showed an increase in the number of regions and bays meeting the target.

*Caution must be used in this interpretation as the weighted mean SQTI values suggest a decline in six of the seven re-sampled areas (see text).

Progress Towards 2020 Target

Sediment Quality Triad Index results suggest that much of Puget Sound has relatively healthy sediments. In the initial round of baseline sampling conducted between 1997 and 2003, four of eight regional areas and all three urban bays (64% of all areas combined) exceeded or were statistically no different from the target value of 81, indicating "unimpacted" sediments (Table 1, Figure 1). The remaining four regions (36% of all areas combined) had somewhat lower scores, but still fell within the range normally characterized as "likely unimpacted" (SQTI >57-81).

While the SQTI scores for the regions and bays fell in the two highest quality categories, values measured in resampled regions and bays still raise a concern. Among four regions and three bays that were re-sampled from 2004-2009, SQTI scores improved in only one area—Whidbey Basin—and declined in the other six areas (Figure 1). The improved score for Whidbey Basin increased the number of regions and bays meeting, or not statistically different from, the 2020 target (now six of seven areas = 86%), despite declining scores at all six other sampled locations . While the results indicate progress towards the target, there is also a somewhat concerning pattern of declining condition evident in sediments across the majority of regions and bays.

What is This Indicator?

Sediment quality is a key indicator of a healthy ecosystem, and high quality sediments support a diverse and important biological community. We monitor sediment quality in Puget Sound by measuring the levels of chemical contamination, assessing the toxicity of the sediments to marine life, and examining the diversity and health of the biological community.

Classification of sediment quality based on SQTI scores

Category	SQTI score	Interpretation
Unimpacted	>81-100	Confident that contamination and/or other stressors are not causing significantly adverse impacts to aquatic life in the sediment.
Likely Unimpacted	>57-81	Contamination and/or other stressors are not expected to cause adverse impacts to aquatic life in the sediment, but some disagreement among lines of evidence reduces certainty that the site is unimpacted.
Possibly Impacted	>36-57	Contamination and/or other stressors may be causing adverse impacts to aquatic life in the sediment, but the level of impact is either small or is uncertain because of disagreement among lines of evidence.
Likely Impacted	>5-36	Evidence of contaminant and/or other stressor-related impacts to aquatic life in the sediment is persuasive, in spite of some disagreement among lines of evidence.
Clearly Impacted	0-5	Sediment contamination and/or other stressors are causing clear and severe adverse impacts to aquatic life in the sediment.
Inconclusive	No SQTI score	Disagreement among or within lines of evidence suggests that either the data are suspect or additional information is needed for classification.

Table 1. Classification of sediment quality based on SQTI scores
Source: Washington Department of Ecology, Marine Sediment Monitoring Team

Citations Dutch, M.E., E.R. Long, S. Weakland, V. Partridge, and K. Welch. 2012. Sediment Quality Indicators for Puget Sound. Indicator definitions, derivations, and graphic displays. Washington State Department of Ecology. Unpublished document. 8 pp.

Long, E.R., S. Aasen, M. Dutch, K. Welch, and V. Partridge and D. Shull. 2007. Relationships between the Composition of the Benthos and Sediment and Water Quality Parameters in Hood Canal, WA: Task IV – Hood Canal Dissolved Oxygen Program. Washington State Department of Ecology Publication No. 07-03-40, Olympia, WA and Western Washington University, Bellingham, Wa. 197 pp. + appendices

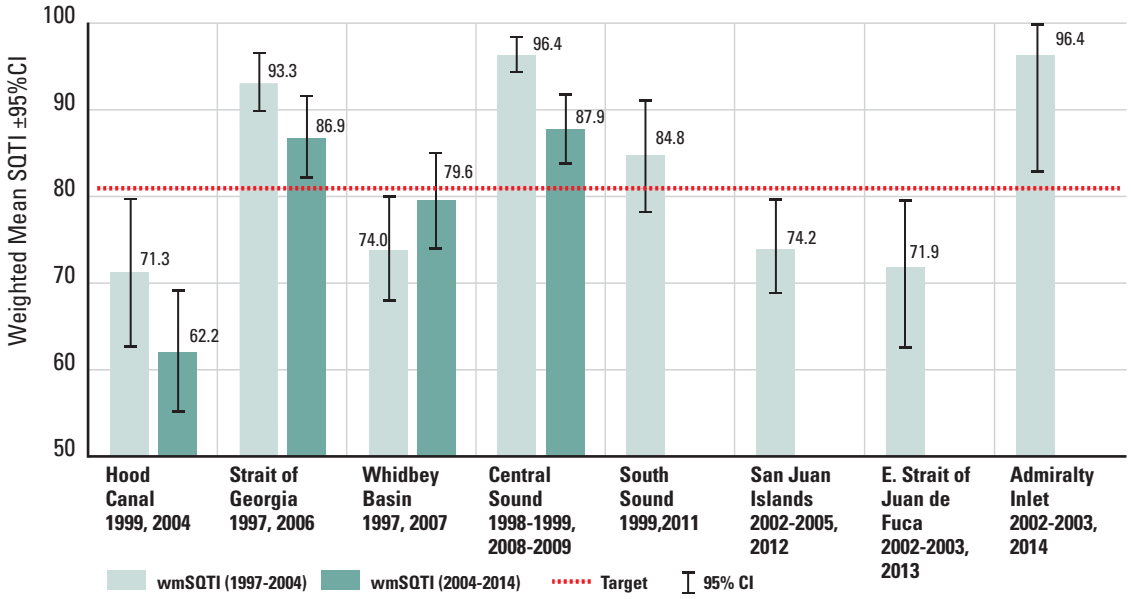
Marine Sediment Quality

In Puget Sound and many estuaries around the world, sediments have become contaminated with toxic chemicals from industrial discharges, contaminated run-off from urban streets and roads, discharges from wastewater treatment plants, agricultural and forest chemicals carried down rivers and streams, oil spills, and even chemicals carried long distances through the atmosphere that eventually fall out of the sky with our rain. As the forests around Puget Sound have been logged, our streams and rivers channelized, and towns and cities built up, the amount, rate, and quality of sediment deposited into Puget Sound has changed dramatically.

The Sediment Quality Triad Index (SQTI) provides a weight-of-evidence approach that combines three different types of data into a single index measured from 1 – 100, with higher index values indicating higher quality sediments (Table 1).

The SQTI combines the Sediment Chemistry Index (SCI), sediment toxicity data, and benthic invertebrate community (small animals in sediment) data into a single, broad measure of sediment quality[1]. The SCI measures the concentrations of chemical contaminants. Laboratory toxicity tests measure the combined (synergistic) effects of those chemicals and other sediment characteristics on laboratory test animals. And the benthic invertebrate data reflects the actual biological condition of the sediments as a response to all possible human-caused and natural stressors, whether measured or not.

Weighted Mean Sediment Quality Triad Index Scores in eight Puget Sound Regions



[1]Dutch, et al., 2012

Together, the SCI and SQTI Indicators describe the overall "health" of the sediments, including their ability to sustain the sediment-dwelling invertebrates that form an important component of the Puget Sound food web.

Sampling Design

The Washington Department of Ecology monitors sediments in eight regional areas across Puget Sound and, separately, in six urban bays (see map). Multiple replicate samples are collected during each sampling effort, and weighted according to the size of the area each sample represents. Because sediment condition is not generally expected to change quickly over time, regions and urban bays are sampled on a rotating basis over a ten- and six-year period, respectively, thus it takes ten years to complete one full round of regional sampling, and six years to complete one full round of urban bay sampling in Puget Sound.

In order to evaluate progress toward the targets, results are discussed here primarily for areas that have been sampled twice: generally first sampled in the late 1990s, and then re-sampled in the mid to late 2000s. Results are evaluated separately for regions (Figure 1, left panel) and urban bays (Figure 1, right panel). This allows comparison of sediment quality in areas more closely associated with urban and industrial discharges and runoff to areas with less intensively developed landscapes, keeping in mind that some

Weighted Mean Sediment Quality Triad Index Scores in six Puget Sound Urban Bays

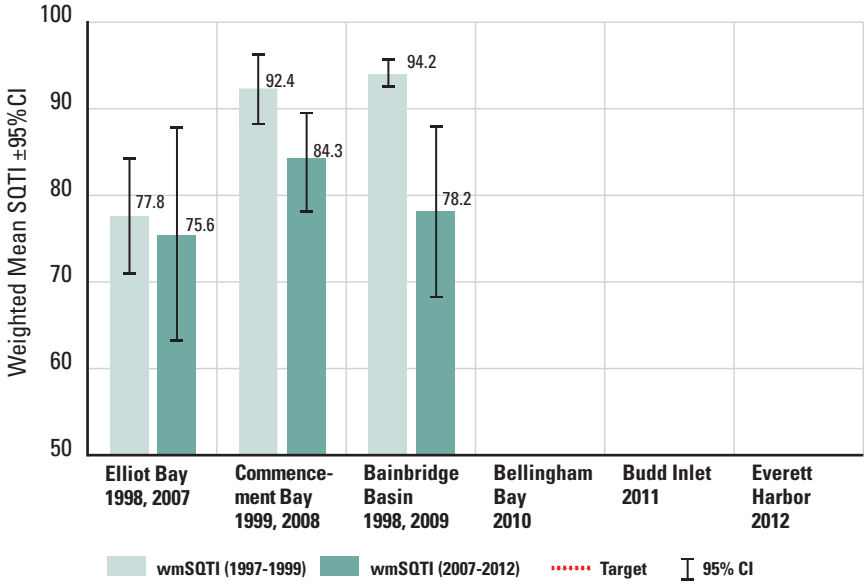


Figure1. Sediment Quality Triad Index, reported for eight regions (left panel) and six urban bays in Puget Sound (right panel). The light bars show the overall SQTI scores for samples collected in 1997-2003. The dark bars show the overall SQTI scores for samples collected in 2007-2009. The higher the index value, the higher the sediment quality. *Source: Washington Department of Ecology, Marine Sediment Monitoring Team*

Marine Sediment Quality

pesticides and certain other contaminants and natural impacts may in fact be more closely associated with agriculture and rural land uses.

Finally, it is important to note that results presented here are representative of only those regions and urban bays that have been sampled, and not necessarily all of Puget Sound since we do not have data for areas not sampled.

Interpretation of Data

Sediment quality monitoring in Puget Sound shows that about two-thirds of the areas monitored have sediments classified as "unimpacted", as indicated by low chemical concentrations, absence of toxicity, and the presence of abundant and diverse benthic invertebrate communities. The remaining one-third of the monitoring areas generally have sediments of "likely unimpacted" quality (Figure 1, Table 1).

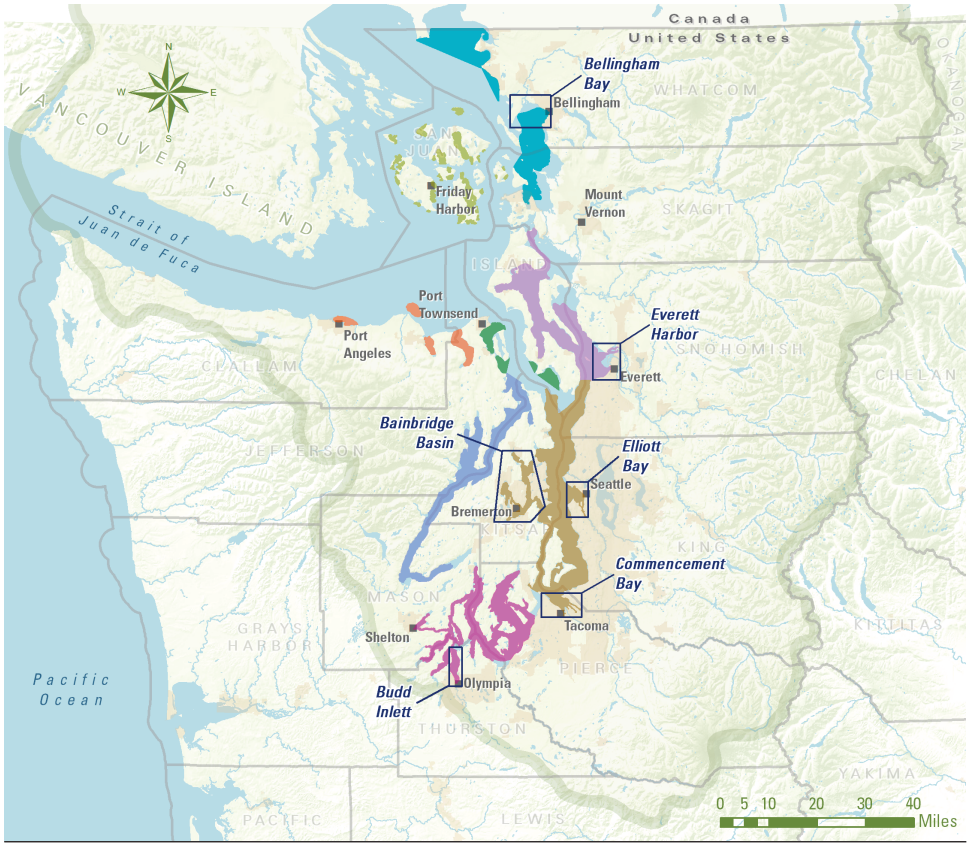
Only a small percentage (~3.2%) of the sediment monitoring area in Puget Sound has sediments classified as "possibly, likely, or clearly impacted" (Table 1) with impairment in one, two, or all three components of the SQTI.[1] These impacted sediments are located in and around both the urban and industrial bays with measurable levels of chemical contaminants in the sediments, and in more rural bays which are likely experiencing pressure from other stressors, such as low dissolved oxygen in bottom waters. Although small in total area, the proximity of these impaired sediments to important river mouths and nearshore habitats may disproportionately affect fish, shellfish, and other aquatic life.

Trends

Despite the small improvement shown in this indicator relative to the target, the most striking feature of the data is the apparent widespread decline in overall SQTI scores. This decline was statistically significant in two areas: Central Sound and Bainbridge Basin.

The lower SQTI values were driven primarily by reductions in the benthic invertebrate community measures. There appear to be large increases in the incidence and spatial extent of adversely affected benthos between the first (baseline) samples collected in the late 1990s and more recent samples. Invertebrate abundance and species richness has decreased significantly in some areas. The reasons for the decline in benthic health are not known. Decline in benthic invertebrate communities is evident in both urban and

[1] unpublished data, Washington State Dept of Ecology; data not displayed.
[2] Long et al., 2007



Marine sediment monitoring regions and urban bays

- Admiralty Inlet
- Central Sound
- E Strait of Juan de Fuca
- Hood Canal
- San Juan Archipelago
- Strait of Georgia
- South Sound
- Whidbey Basin
- Cities and urban growth areas
- County border
- Salish Sea Basin boundary

Marine Sediment Quality

nonurban areas, with only limited correlation with changes in sediment chemistry or toxicity.

Since changes in the benthos aren't closely correlated to the chemical and toxicity-related environmental parameters currently being measured, other factors must be important. Benthic invertebrate communities are affected by a complex interplay of natural and human-caused variables, and there are many environmental factors that can impact benthic invertebrate populations that aren't measured by the SQTI. These include low dissolved oxygen, pH, sediment flux and loading, natural population cycles, and a variety of species interactions. All of these factors can have important local effects. For example, benthic communities sampled in Hood Canal in 2004 appeared to be adversely affected by very low, near-bottom dissolved oxygen concentrations.[2]

Other possible factors include the introduction of new chemicals of concern not currently monitored, and sub-lethal toxic effects such as reproductive impairment, that are not easily identified by current toxicity testing methods.

Over time, changes in sediment quality reflect the cumulative effects of many factors impacting the chemistry, physical processes, and biological responses of the Puget Sound ecosystem. The Sediment Quality Triad is a useful integrating measure of sediment condition, which can both explain observed effects, and help focus new inquiries on emerging problems.

Clean Sewers, Clean Thea Foss Waterway

Located in the heart of downtown Tacoma, the Thea Foss Waterway was once characterized by dilapidated buildings, oil sheens, coal tar deposits, and contaminated bottom sediments which led the Environmental Protection Agency to declare the waterway a Superfund site in 1983. For more than 100 years, the Thea Foss Waterway had been a sink for waste from industrial dischargers and runoff from the upland drainages.

Today, it's a very different picture. The Thea Foss Waterway is the centerpiece of bustling marinas, internationally renowned museums, restaurants, grass esplanades, luxury apartments, and a variety of business and industry.

Even before the City of Tacoma and its partners finished the $105 million remediation of the Thea Foss Waterway in 2006, they knew it was imperative to find ways to protect the quality of the sediment and receiving water in the waterway.

While significant efforts were made by the City to reduce or eliminate ongoing sources of contamination to the storm drainage system, it was found that elevated levels of PAHs, PCBs , and mercury remained in sediment and debris collected from Tacoma's 100-year-old storm sewer lines. This legacy pollution was being washed into the Thea Foss by stormwater, threatening to degrade the quality of the newly remediated marine sediment.

Photo Credit: mash187@flickr

Clean Sewers, Clean Thea Foss Waterway

LOCAL STORY

In response, Tacoma launched two new enhanced maintenance programs to prevent new and legacy contaminants from reaching the waterway.

- Storm Line Cleaning - completed in four entire drainages and part of a fifth between 2006 and 2011. This program was intended to remove legacy contaminants from storm pipe.

- Street sweeping - expanded to a more aggressive city-wide street sweeping program in 2007. This program was intended to remove more street contaminants preventing them from entering the storm system.

These two maintenance efforts, storm cleaning and street sweeping, were above and beyond Tacoma's NPDES permit requirements. This enhanced maintenance resulted in dramatic reductions in contaminant levels:

- PAH1 [1] concentrations showed 59-92% reductions in four drainages tested.

- DEHP [2] concentrations showed 26-68% reductions in three of the four drainages tested.

- TSS [3] concentrations showed 17- 44% reductions in three of the four drainages tested.

- Lead and zinc concentrations showed 11- 36% reductions in three drainages.

These programs were so successful that they are now part of Tacoma's city-wide operating procedures. The work is not over. The City of Tacoma's team of innovative stormwater professionals will continue to use every tool at its disposal– science, investigation, education, enforcement and even intuition – to do its part to protect the investment in the Thea Foss Waterway. Their mission is to create an asset for future generations by making sure stormwater discharges do not harm the health of the water and sediments in the Foss.

[1] PAH = Polycyclic aromatic hydrocarbons, PCB = polychlorinated biphenyl

[2] DEHP = Di-(2-Ethylhexyl) phthalate

[3] TSS = Total suspended solids