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National Water-Quality Assessment Program

Nutrient Transport in the Major Rivers and Streams of the Puget Sound Basin, Washington

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Highlights

- Each year, approximately 11,000 tons of inorganic nitrogen and 2,100 tons of total phosphorus are transported by rivers and streams to Puget Sound and its adjacent waters
- Rivers that have the largest streamflows carry the largest nutrient **loads**
- Nutrient **yields** are largest from basins with higher percentages of urban and agricultural areas and that receive the highest inputs of nutrients

Why are nutrients important in the Puget Sound Basin?

The nutrients phosphorus and nitrogen are essential for the life of plants and animals. However, an overabundance of nutrients in surface water can cause overgrowth of aquatic plants such as algae. This overgrowth can lead to a variety of water-quality problems, including daily, wide swings in concentrations of dissolved oxygen. Fish and other aquatic life can be adversely affected by these swings if the concentrations become too low.

High nutrient concentrations and associated water-quality degradation are of concern in some Puget Sound Basin rivers and lakes near intensive agriculture and population centers (Butkus and Lynch, 1996). A recent study by the Washington State Department of Ecology (Newton and others, 1997) also identified several marine embayments of Puget Sound as sensitive to developing low dissolved oxygen levels as a result of high nutrient inputs. This fact sheet evaluates sources and transport of nutrients in the major rivers to help determine factors that affect the quantity of nutrients reaching Puget Sound and its adjacent waters.

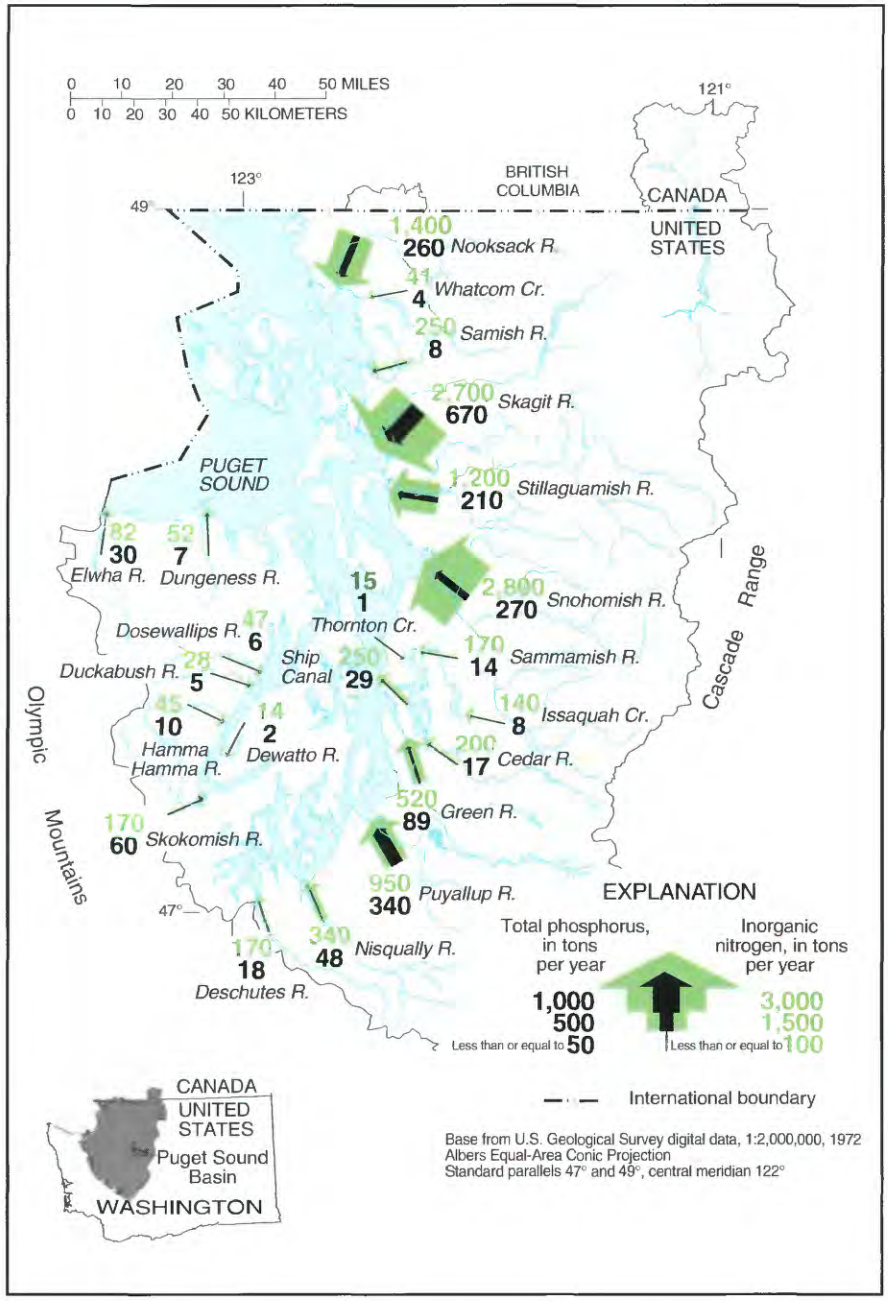

Figure 1. Annual nutrient loads transported by Puget Sound Basin rivers and streams.

The Puget Sound Basin National Water-Quality Assessment team compiled historical data on nutrient concentrations and streamflows for 22 rivers and streams in the Puget Sound Basin. The data were used to estimate loads and yields of inorganic nitrogen (nitrate, nitrite, and ammonia), organic nitrogen, and total phosphorus for the period 1980-1993 (Embrey and Inkpen, in press). Total nitrogen (inorganic plus organic nitrogen) and total phosphorus inputs to basins from agricultural, urban, and atmospheric sources were also estimated.

What factors affect nutrient loads and yields?

Each year, the major rivers and streams of the Puget Sound Basin transport loads of approximately 11,000 tons of inorganic nitrogen, and 2,100 tons of total phosphorus to Puget Sound and its adjacent waters (fig 1). About 9,900 tons of organic nitrogen are transported by 8 of the largest Puget Sound Basin rivers. Data were not available to compute organic nitrogen loads for all rivers and streams.

As expected, the **largest nutrient loads are carried by the rivers having the largest basins** and consequently the largest streamflows. The Skagit and Snohomish River Basins together comprise 47 percent of the drainage area of the Puget Sound Basin, and transport about 49 percent of the inorganic nitrogen and 45 percent of the phosphorus loads carried by rivers to Puget Sound and its adjacent waters.

Inorganic nitrogen yields in tons per square mile vary with concentrations of inorganic nitrogen in water (fig. 2). The Samish River and Issaquah Creek have the highest concentrations and yields, whereas the Dungeness and Elwha Rivers have some of the lowest. **Nutrient yields also vary with land use.** Yields from basins in the eastern part of the Puget Sound Basin that are dominantly influenced* by urban or agricultural land use, or a mix of both, are on average **three times larger** than yields from the forested basins in the Olympic Mountains (figs. 3 and 4).

* Although most basins in the Puget Sound Basin have large forested areas, the types of land use in the lower parts of the basin where water- quality samples are taken are considered the dominant land use.

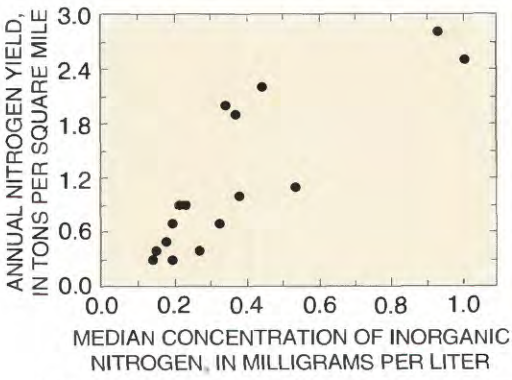

Figure 2. Nitrogen yield varies with concentrations of inorganic nitrogen in water.

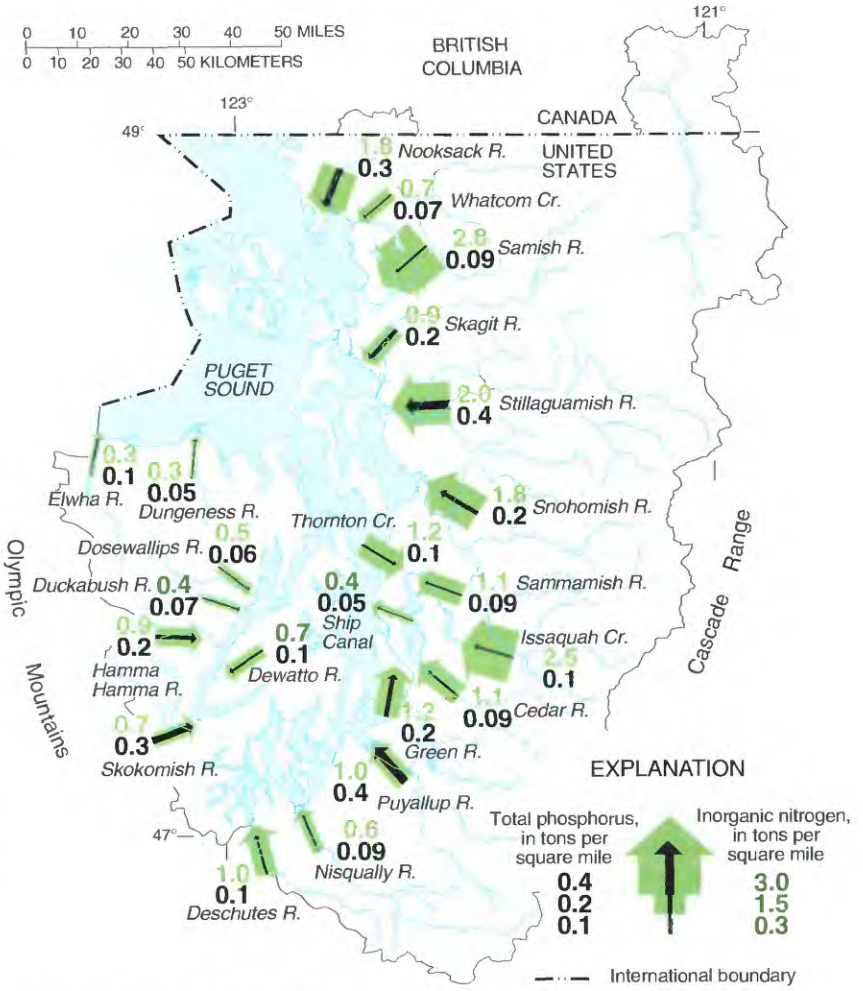

Figure 3. Annual nutrient yields from river basins in the Puget Sound Basin

Comparing loads and yields

- **Loads** are estimated using water discharge and nutrient concentration data and represent the total amount of nutrients transported by each river in tons per year (tons/yr).
- **Yields** are calculated by dividing load estimates by basin areas and are expressed as tons per square mile per year [(tons/mi^2)/yr]. Because yield estimates are not influenced by basin area, they are useful for comparing nutrient transport in basins of different sizes.

Loads carried by the Skagit and Samish Rivers are indicative of their basin sizes. Yields are indicative of these basins' land use. The Skagit River yield is more influenced by the large percentage of its basin that is forest, and the Samish River Basin yield is more influenced by the agricultural areas (fig. 4).

Basin (area)	Inorganic nitrogen load [tons/yr]	Inorganic nitrogen yield [(tons/mi^2)/yr]	Dominant land use*
Skagit R. (3,090 mi^2)	2,800	0.9	forest
Samish R. (87.8 mi^2)	250	2.8	agriculture

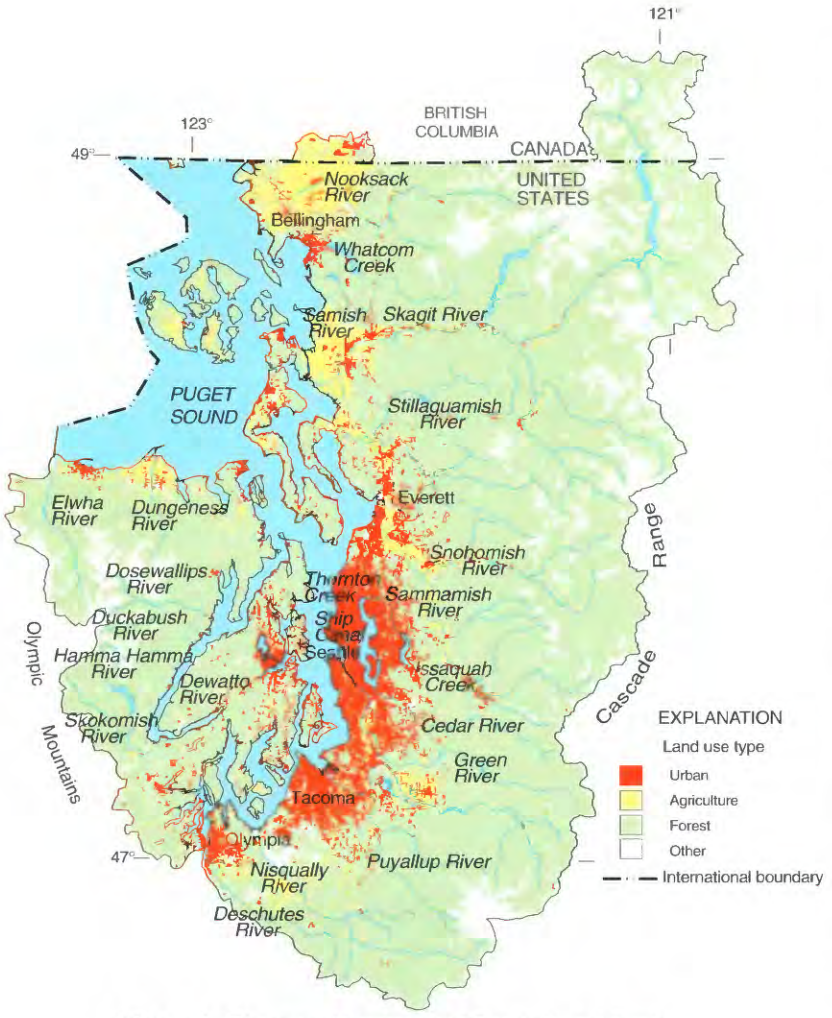

Figure 4. Rivers and land uses of Puget Sound Basin.

What are major sources of nutrients?

The top three sources of nutrients and their annual inputs, in tons, to the Puget Sound Basin are:

	Nitrogen	Phosphorus
Animal manures	15,000	3,000
Agricultural fertilizers	9,300	1,100
Atmospheric deposition	7,800	900

Table 1 shows the inputs from animal manures, agricultural fertilizers, and atmospheric deposition to each basin. These sources are considered **non-point sources** of nutrients because they are distributed over the basin landscape, and the nutrients are transported to rivers in surface runoff and ground-water discharge. Some portion of the nutrients are retained on soil particles or taken up by plants and so are prevented from entering surface waters and becoming part of the river load. For this reason, the non-point sources are considered as potential sources of nutrients to the rivers. Other non-point sources that might be important in urban areas but for which data were not available include domestic fertilizer applications and septic systems.

In urban areas, wastewater treatment plants (WWTPs) are typically an important source of nutrients. WWTPs are known to be **point sources** of nutrients because the nutrients are discharged directly to a river and become part of the transported load. In the Puget Sound Basin, however, most WWTPs discharge directly to Puget Sound or its adjacent waters and so are generally not a major source of nutrients to the rivers. Two exceptions are the Puyallup River, where WWTPs account for 22

Table 1.--Annual nutrient inputs, yields, and land use of rivers draining to Puget Sound and adjacent marine waters

[Values are in tons per square mile per year; differences in totals due to rounding; N = total nitrogen, P = total phosphorus, IN = inorganic nitrogen, WWTP = wastewater treatment plant, -- = no WWTP or no data, F = forest, A = agriculture, U = urban, M = mixed (urban and agriculture)]

Basin (area in square miles)	Dominant land use[a]	Non-point sources: Animal manures N	Animal manures P	Agricultural fertilizers N	Agricultural fertilizers P	Atmospheric deposition N	Atmospheric deposition P	Total N	Total P	Point sources WWTP IN	Point sources WWTP P	Nutrient yields IN	Nutrient yields P
Nooksack (786)	A	5.3	0.9	3.0	0.33	0.77	0.09	9.1	1.3	0.06	0.02	1.8	0.3
Samish (87.8)	A	3.4	0.65	5.6	0.73	0.96	0.11	10.0	1.5	--	--	2.8	0.09
Skagit (3,090)	F	0.48	0.09	0.79	0.10	0.70	0.08	2.0	0.27	0.05	0.01	0.9	0.2
Stillaguamish (704)	A	2.2	0.45	0.85	0.11	0.86	0.09	3.9	0.65	0.04	0.01	2.0	0.4
Snohomish (1,730)	M	1.6	0.32	0.69	0.09	1.2	0.10	3.6	0.51	0.10	0.03	1.8	0.2
Ship Canal (619)	U	0.43	0.08	0.15	0.02	1.8	0.15	2.4	0.25	--	--	0.4	0.05
Green (440)	U	2.5	0.45	0.88	0.12	1.1	0.12	4.5	0.69	--	--	1.2	0.2
Puyallup (996)	M	0.98	0.22	0.35	0.05	0.44	0.09	1.8	0.36	0.22	0.05	1.0	0.4
Nisqually (726)	M	2.5	0.57	0.79	0.10	0.48	0.10	3.8	0.77	0.006	0.002	0.6	0.09
Deschutes (168)	M	1.5	0.38	0.18	0.02	0.43	0.09	2.1	0.49	--	--	1.0	0.1
Skokomish (248)	F	0.11	0.03	0.04	0.08	0.27	0.08	0.42	0.19	--	--	0.7	0.3
Hamma Hamma (51.3)	F	0	0	0	0	0.37	0.08	0.37	0.08	--	--	0.9	0.2
Duckabush (67)	F	0	0	0	0	0.17	0.09	0.17	0.09	--	--	0.4	0.07
Dosewallips (93.5)	F	0	0	0	0	0.39	0.09	0.39	0.09	--	--	0.5	0.06
Dungeness (156)	A	1.4	0.33	0.67	0.09	0.39	0.09	2.5	0.51	--	--	0.3	0.05
Elwha (269)	F	0.18	0.04	0.09	0.01	0.38	0.08	0.64	0.13	--	--	0.3	0.1

[a] Although most basins in the Puget Sound Basin have large forested areas, the types of land use in the lower parts of the basin where water-quality samples are taken are considered the dominant land use.

percent of the transported nitrogen load, and the Snohomish River, where WWTPs account for 15 percent of the transported phosphorus load (table 1). Other point sources that might be important but for which data were not available include nutrients from commercial and industrial discharges.

How does land use affect nutrient inputs?

In the Puget Sound Basin, land use is a major factor that influences what sources will contribute nutrients to a river's basin, and, in part, the quantity of inputs. The Samish and Nooksack Rivers drain basins dominantly influenced by agriculture. These two basins receive the largest nutrient inputs (up to 10 (tons/mi^2)/yr of nitrogen and up to 1.5 (tons/mi^2)/yr phosphorus), 90 percent of which comes from animal manures and agricultural fertilizers (table 1). In contrast, the Green River Basin, which has more urban areas and less agricultural areas, receives from manures and atmospheric deposition less than half the nutrient input to the Samish and Nooksack Basins. Forested basins receive the smallest inputs of nutrients, and atmospheric deposition is the only major nutrient source identified (table 1). Other nutrient sources to forested watersheds could include recreation, logging, and other forest practices, but the lack of data on human activity and natural processes in those areas prevented a more comprehensive estimate.

Yields of inorganic nitrogen from river basins are related to total nitrogen inputs from the major non-point sources (fig. 5). The Samish and Nooksack Rivers in the eastern part of Puget Sound Basin, where there are greater areas of urban and agricultural land use, have some of the highest yields, and these basins also receive the largest nutrient inputs (table 1). In contrast, the forested watersheds, such as the Elwha and the Duckabush in the Olympic Mountains, yield considerably smaller amounts of nutrients and have much smaller nutrient inputs. However, **phosphorus yields are not related to inputs of phosphorus,** most likely because of its tendency to adsorb to soil particles.

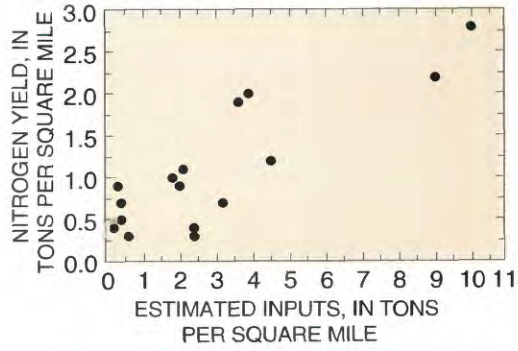

Figure 5. Estimated nitrogen yields vary with nitrogen inputs.

Nutrient inputs to a basin are generally greater than the yield from that basin. This is to be expected because some nutrients will be removed by natural processes before they reach a river. In the Hamma Hamma, Skokomish, Dosewallips, and Duckabush River Basins, however, yields are greater than inputs. Because so little information regarding nutrient inputs and sample concentration data were available for these basins, estimates of inputs and yields for these basins were made with less confidence than for other basins.

Future plans and nutrients in the Puget Sound Basin

The Puget Sound Basin National Water-Quality Assessment team plans to refine estimates of nutrient loads for the Nooksack River, Skokomish River, and Green River Basins using data collected monthly and also during storms and floods. To estimate total nitrogen loads, organic nitrogen will also be included. New data on nutrient concentrations and loads will help to further the understanding of the relation between land use and water quality.

References Cited

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Newton, J.A., Albertson, S.L., and Thompson, A.L., 1997, Washington State marine water quality in 1994 and 1995: Olympia, Wash., Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, No. 97-316, 71 p.

This fact sheet is based on the report:

Embrey, S.S., Inkpen, E.L., in press, Nutrient transport in rivers of the Puget Sound Basin, Washington 1980-1993: U.S. Geological Survey Water-Resources Investigation Report 97-4270, [about 38 p.]

National Water-Quality Assessment (NAWQA) Program

The Puget Sound Basin is part of a national program consisting of more than 50 NAWQA study areas nation-wide. Teams in each study area will assess the water quality of surface- and ground-water resources, how the water quality changes over time, and determine what natural and human factors affect the water quality.

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