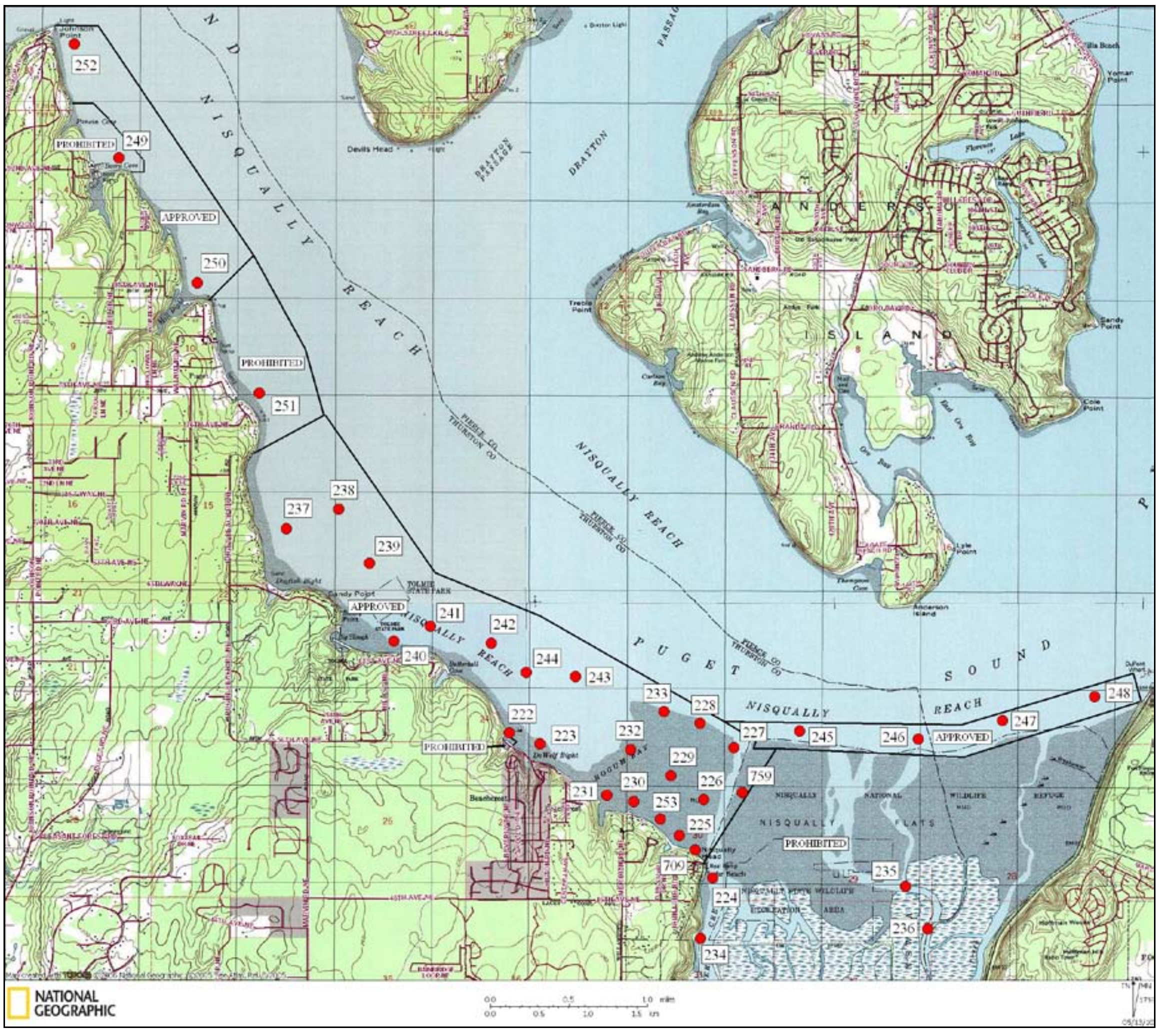
Status and Trends Summary

Fecal Coliform Pollution in Nisqually Reach through 2010



February 2011

Washington State Department of Health

PSAMP
Puget Sound Assessment and Monitoring Program

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Office of Shellfish and Water Protection

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Potential Fecal Pollution Sources and Remedial Action in Nisqually Reach

Major potential sources include onsite sewage systems along marine shorelines, streams and upland drainages; agricultural activities along McAllister Creek drainages; storm water from residential developments; and wild life in upland areas and at the Nisqually Wildlife Refuge. Thurston County Health has conducted dye tests of onsite sewage systems along the Reach and has found that at a minimum 1 in 3 shoreline systems tested are failing. In 2011, an advisory committee of Nisqually residents and stakeholders is proposing adoption of a septic system operation and maintenance program for the Nisqually Reach Shellfish Protection District. Thurston Conservation District has overseen installation of agricultural best management practices. Dikes have been removed from the Wildlife Refuge. Former pastureland is being converted into salt marsh.

Summary of 2010 Analysis

- Thirty-one of 34 stations showed negligible fecal pollution.
- One station near the mouth of McAlister Creek (station 234) showed low fecal pollution impact in 2010. Stations 235 and 236 near the Nisqually River delta carried very high fecal pollution.
- Fecal pollution overall in Nisqually Reach decreased steadily between 2006 and 2010.
- In 2010, Nisqually Reach achieved the lowest impact from fecal pollution since 1998. The fecal pollution impact in 2010 (as measured by the fecal pollution index) was about half that in 1998.

Monitoring Fecal Pollution in Shellfish Growing Areas

DOH protects consumers from eating shellfish contaminated by pollution. The Department continually monitors marine water for fecal pollution in shellfish growing areas and searches for pollution sources on shorelines and adjacent uplands.

Systematic Random Sampling (SRS). The Department uses a systematic random sampling (SRS) method mandated by the National Shellfish Sanitation Program (NSSP) to monitor shellfish growing areas. DOH measures levels of fecal bacteria in water samples collected at sampling stations in each area. Under SRS, samples are collected at relatively even intervals over time. SRS purposely avoids targeting specific environmental factors, such as season, weather, tide, etc. SRS also requires substantial data (30 results) to calculate statistics used to classify growing areas. Thus, DOH data represents a wide range of environmental conditions encountered in the growing area. SRS ensures that unbiased, high-quality data are available for DOH tasks.

NSSP Growing Area Criteria. DOH uses the data gathered under SRS to classify shellfish beds according to level of fecal pollution. DOH applies the following NSSP criteria exclusively to areas potentially affected by nonpoint fecal pollution sources:

- The concentration of fecal coliform bacteria cannot exceed a geometric mean of 14 organisms per 100 milliliters (ml) in water (applied in all cases).
- The estimated 90^{th} percentile cannot exceed 43 organisms per 100 ml of water

The Department uses a minimum of 30 results to calculate the criteria. Appendix A (page 10) explains how DOH uses NSSP criteria to classify shellfish growing areas.

DOH has reported status and trends for the Puget Sound Assessment and Monitoring Program (PSAMP) since 1998. The Department also uses the information to report progress on local remedial action programs.

Status and Trends Analysis for Nisqually Reach

To analyze status and trends in Nisqually Reach, DOH selected stations with the longest, most complete record of fecal coliform data. DOH calculated NSSP statistics (geometric means and 90^{th} percentiles) for these stations from the earliest date possible (i.e., those stations with the minimum required 30 results: see paragraph above) and for all subsequent sampling dates through the end of calendar year 2010.

DOH takes the same initial analytical step for status and trends analysis as it takes to classify a growing area. However, analysis for classification may require additional sorting and editing of the data to evaluate the effect of short-term pollution factors. For example, it is sometimes necessary to evaluate the impact of environmental effects, such as rainfall, on the classification of a growing area (see Appendix A, “Classifying Shellfish Growing Areas”, page 10).

DOH uses 90th percentiles to make inferences about status and trends because 90th percentiles are more sensitive to changes in pollution conditions than geometric means. Note that the time-series graphs in Figure 2 (pages 5-8) show both geometric means and 90th percentiles.

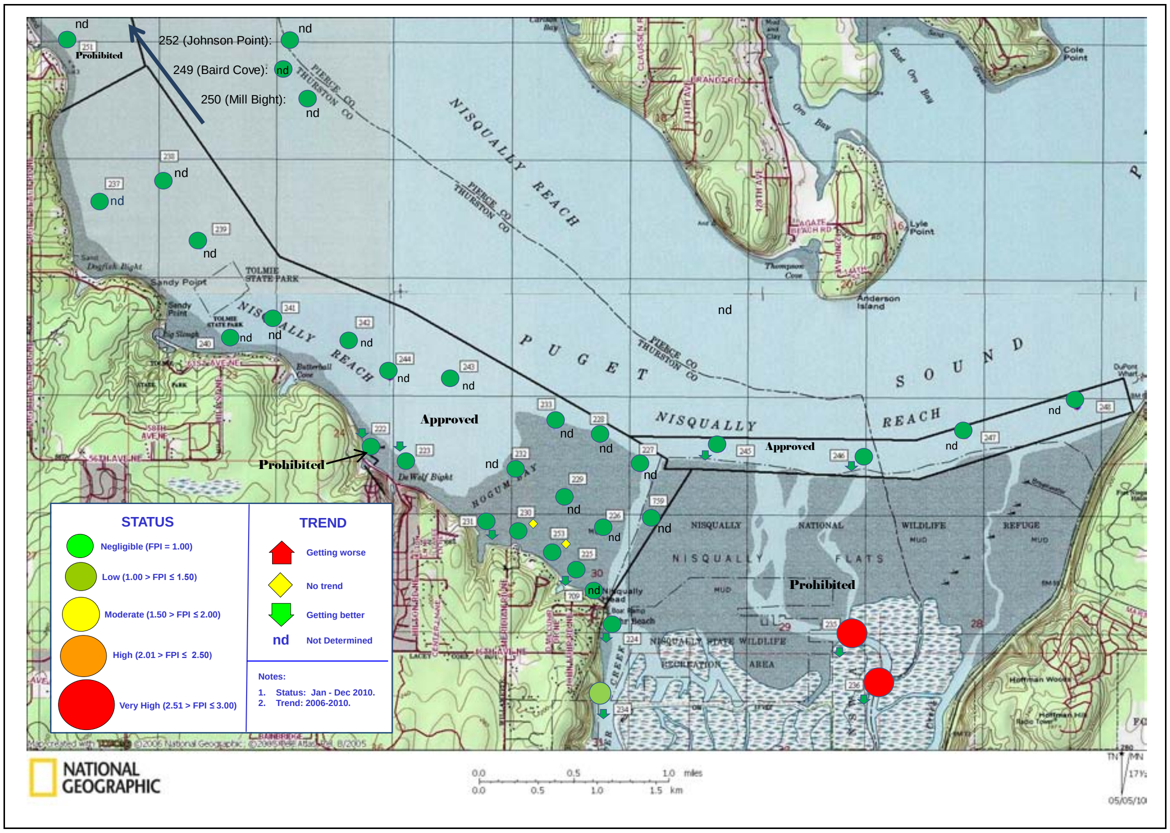
Status of fecal pollution at each station in Nisqually Reach in 2010.

DOH developed a "Fecal Pollution Index" (FPI) to provide a single value to describe the annual status of fecal pollution. Appendix B (page 12) shows the how the FPI is derived. The FPI can be applied at several geographic levels (sampling station, growing areas, regions within Puget Sound, or Puget-Sound wide). Figure 1 shows the status of fecal pollution at each station in Nisqually Reach for calendar year 2010 according to its annual FPI.

Trend of fecal pollution at each station in Nisqually Reach 2006-2010.

Figure 1 also shows the trend in fecal pollution at each station for the most recent 5-year period (2006-2010). A green arrow pointing down means fecal pollution decreased. A red arrow pointing up means fecal pollution increased. A yellow diamond means no significant change occurred. The abbreviation "nd" means that trend was not determined because either the 90th percentiles were too low (less than 10 MPN per 100ml), or the record of 90th percentiles was too short (less than 3 years long). "Spearman's Rho", a "nonparametric" test based on ranked data (Sokal and Rohlf, 1969) statistically tested the significance of the 5-year trends (significant at $p<0.05$).

Figure 1. Status and trends in fecal pollution at Nisqually Reach through 2010.



General Observations from Figure 1:

- Thirty-one of 34 stations showed negligible fecal pollution during 2010.
- Station 234 (near McAlister Creek) showed low fecal pollution. Stations 235 and 236 (near Nisqually River delta) showed very high fecal pollution.
- These most heavily affected stations showed significant decreased pollution since 2006.
- Thirty-one of 34 stations in Nisqually Reach showed negligible fecal pollution. Twenty stations were so low in fecal pollution impact that they were not analyzed for temporal trends.

Trends Analysis for Selected Individual Stations in Nisqually Reach

Figure 2 shows graphs of NSSP statistics (geometric means and 90th percentiles) for six stations in Nisqually Reach for the 12-year period from 1998 through 2010. These stations were chosen because they represent stations that showed the greatest effect of fecal pollution over the years.

Note that the 90th percentiles show a greater response to changing pollution conditions than the geometric means. Thus, DOH used 90th percentiles for statistical analysis of trends.

Figure 2. Trend in geometric means and ninetieth percentiles (NSSP statistics) from 2000 through 2010 at selected DOH stations in Nisqually Reach.

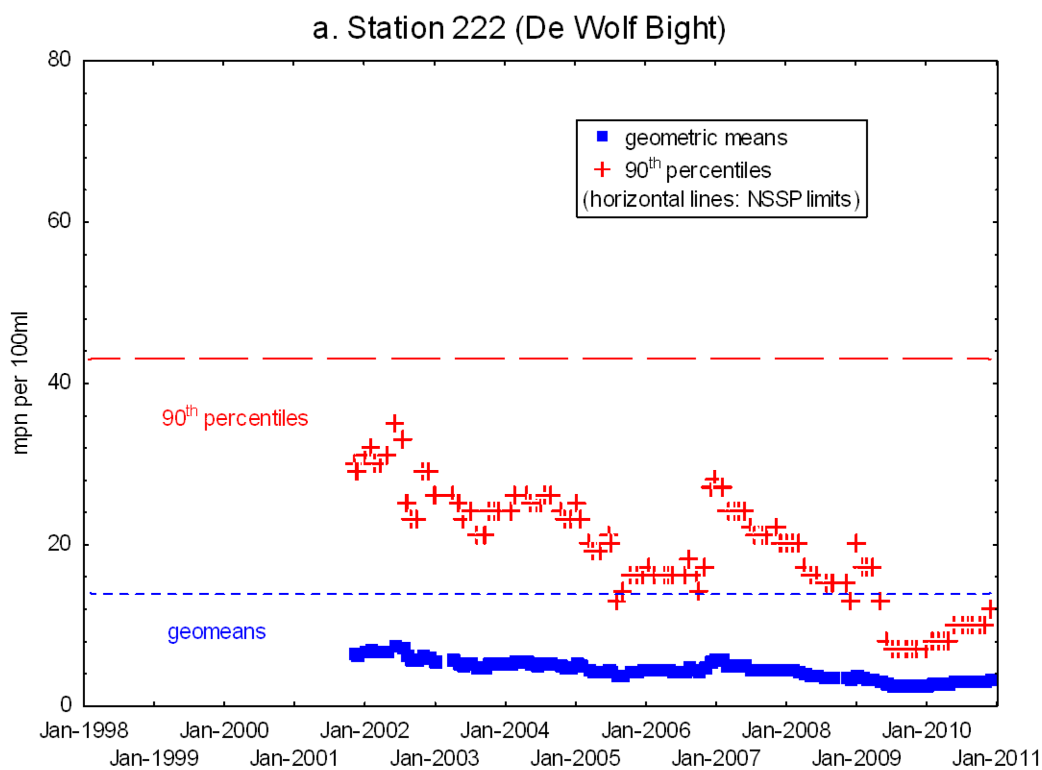


Figure 2. Trend in geometric means and ninetieth percentiles, continued

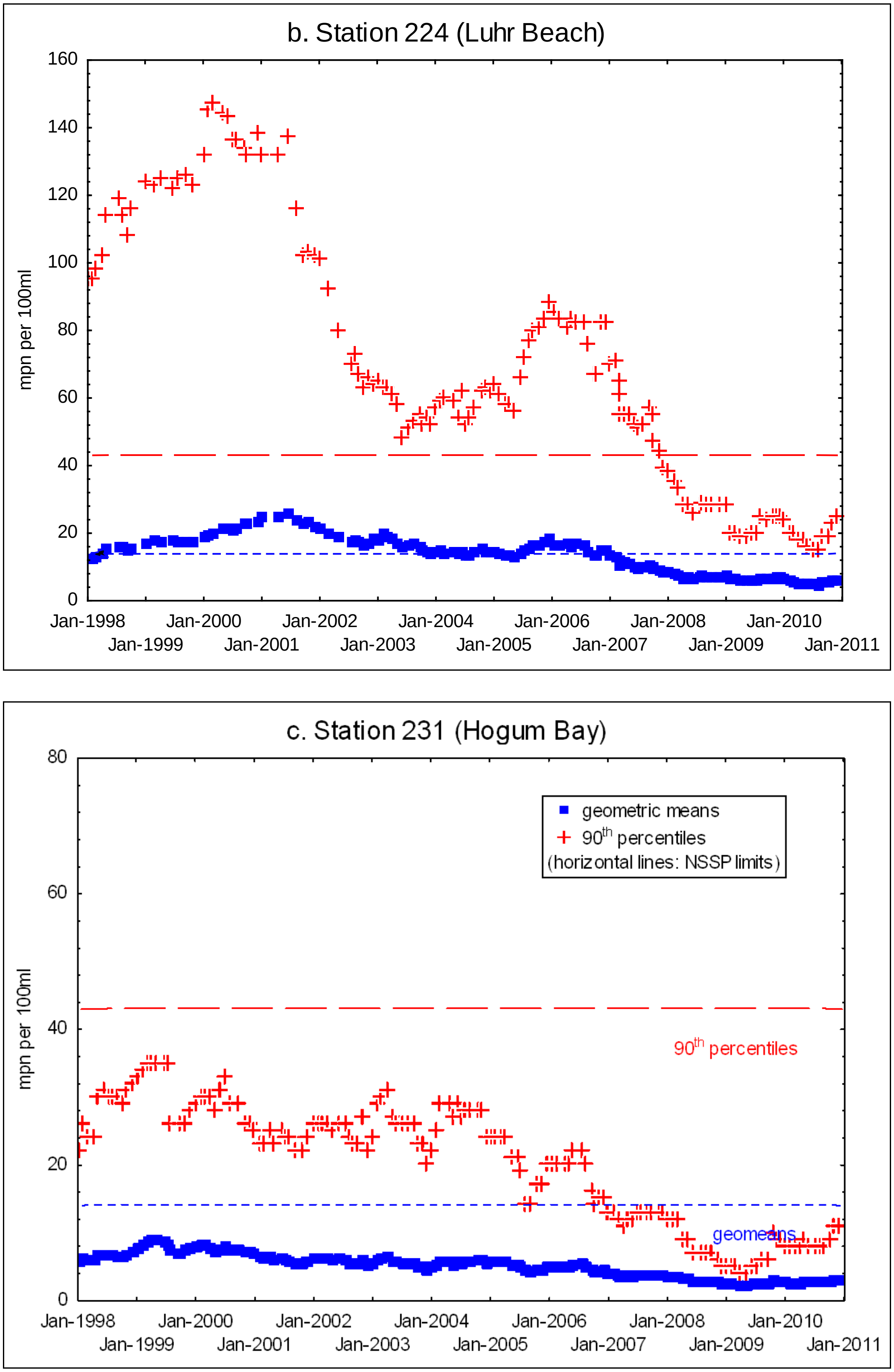
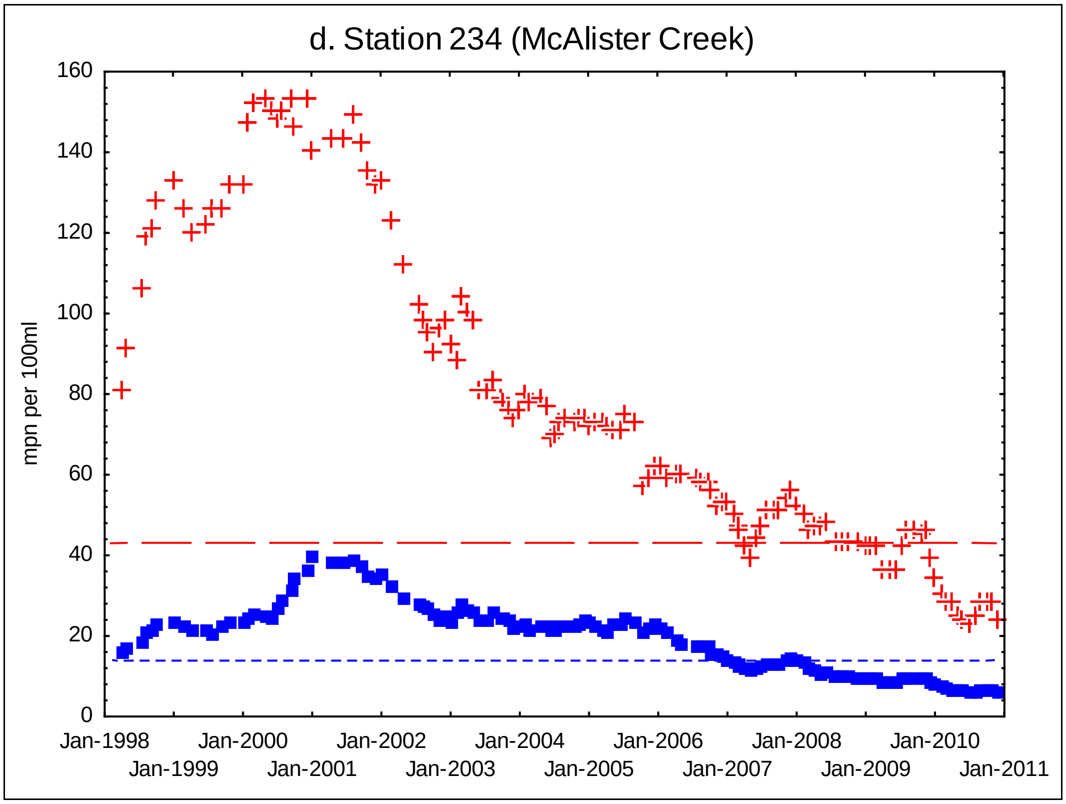


Figure 2, continued



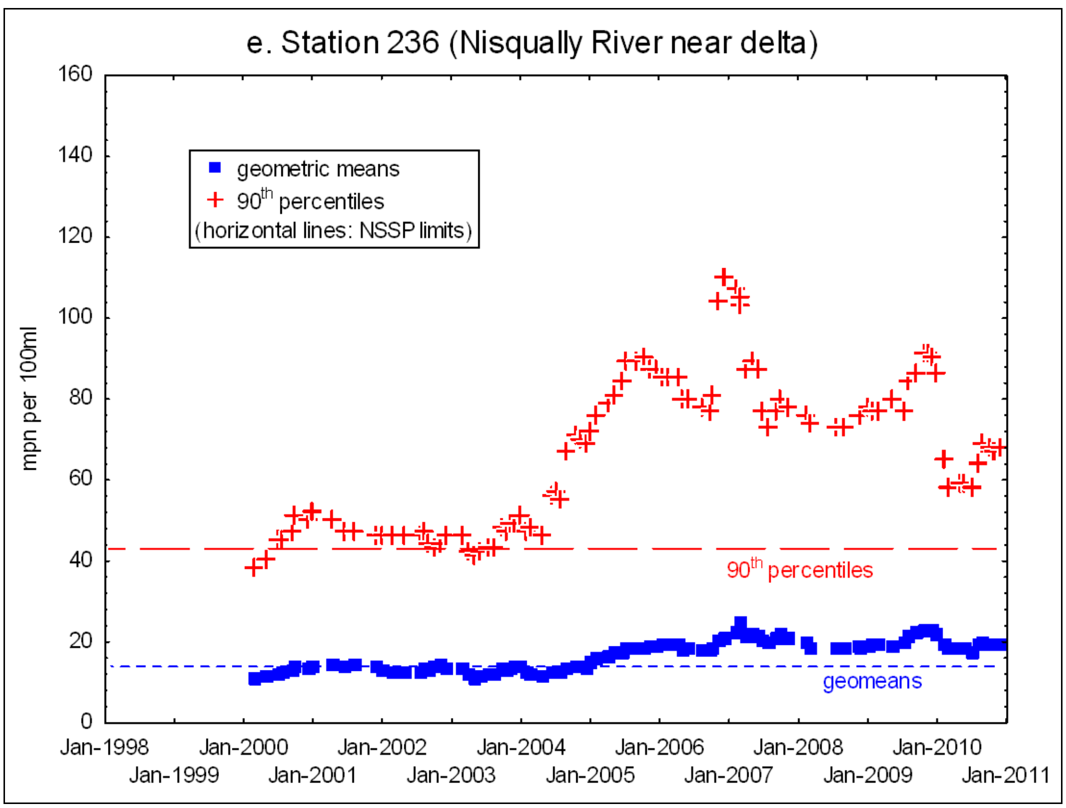
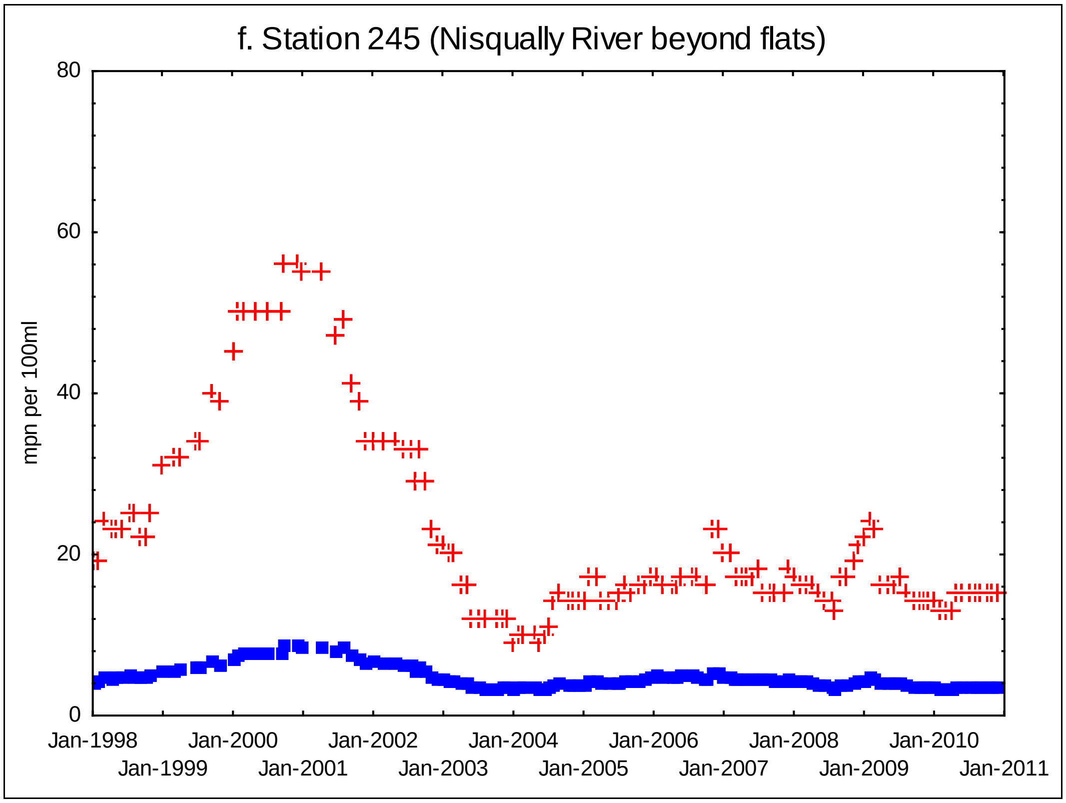


Figure 2, continued



General Observations from graphs in Figure 2:

- From 1998 through 2003, the fecal pollution patterns at Station 224 (Luhr Beach) and Station 234 (near the mouth of McAllister Creek) were similar. (Both stations may have shown the effects of McAllister Creek.) Station 234 showed steady improvement since that time, whereas fecal pollution at Station 224 spiked from mid-2005 through late 2006. Since 2006, fecal pollution at Station 224 steadily dropped.

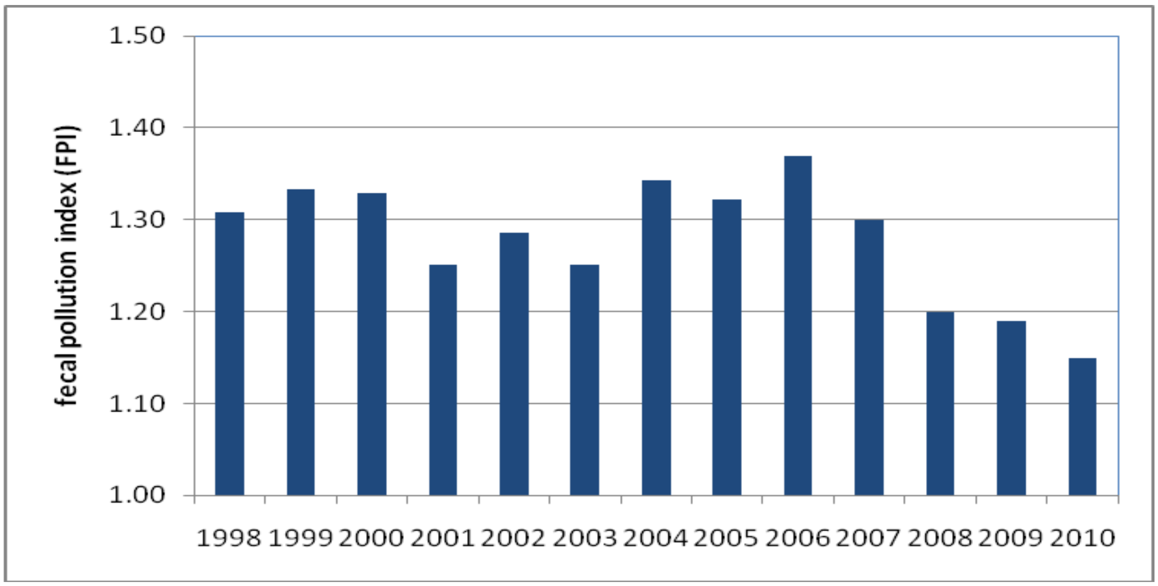
- Fecal pollution at Station 236 (near the Nisqually River delta) increased substantially from 2004 through 2006. Since then, fecal pollution appears to have dropped slightly.

- The dramatic increase in 90^{th} percentiles in late 2006 at stations 224 (Luhr Beach) and stations 235 and 236 (Nisqually River area) may have been related to lengthy and intense regional rainfall late in the year. The anomalous rainfall affected many growing areas in Puget Sound. In contrast, the 5-year trend in fecal pollution at Station 245 (located directly north of the Nisqually River mouth, and presumably affected by the Nisqually river plume) remained low during the past 5 years.

Fecal Pollution Trend in Nisqually Reach 1998-2010

Figure 3 extends the concept of the Fecal Pollution Index (FPI) to all of Nisqually Reach. An annual FPI was calculated from 90th percentiles pooled from all dates and stations in Nisqually Reach for each year from 1998 through 2010 (see Appendix B, page 12). All 90th percentiles from Nisqually Reach were included in the calculations regardless of the DOH classification (Prohibited, Conditionally Approved, or Approved) of the sub area in which it is located.

Figure 3. Trend in fecal coliform pollution in Nisqually Reach 1998-2010.



General Observations from Figure 3:

- The year 2010 had the lowest fecal pollution impact of any year since 1998. The annual "historical" fecal pollution index in 2010 was about half that of 1998.
- The reduction in fecal pollution appears to have been steady since 2006.
- A runs test (Sokal and Rohlf, 1969) indicates no clear evidence of a significant trend in fecal pollution over the period 1998-2010 (t_r = 0.248, p = .05).

REFERENCES

Sokal and Rohlf, 1969. Biometry. Freeman and Co., San Francisco. 776 pp.

Appendix A. Classifying Shellfish Growing Areas

DOH applies guidelines set by the National Shellfish Sanitation Program (NSSP). Each harvest area is classified into one or more of four categories:

- An area is classified **Approved** for unlimited harvest if water quality criteria are met and significant pollutant sources are absent.
- An area is classified **Conditionally Approved** if water quality criteria are met, except during pollution events that are e*pisodic* and *predictable*, such as rain-related runoff. Harvests from Conditionally Approved areas require a “Conditionally Approved Area Management Plan” (or CAAMP).
- An area is classified **Restricted** if it is subject to limited pollution. Shellfish from Restricted areas cannot be harvested directly. They may be “relayed” under strict supervision to clean waters for natural cleansing.
- If an area receives pollution that is *chronically excessive* and/or *unpredictable*, it is classified **Prohibited** (P).

To classify a growing area, DOH evaluates two questions:

1. Does the area comply with the NSSP requirements for unlimited harvest of shellfish (Approved)?
2. If unlimited harvesting is not possible, are there conditions under which harvesting can be done (Conditionally Approved)?

Question 1: Does an area comply with Approved classification? DOH collects water samples in the growing area according to SRS (see **Introduction** on page 3). NSSP requires at least 30 samples be collected from each sampling station in a growing area. DOH calculates a geometric mean and a 90th percentile from the 30 results. These are compared to the NSSP criteria. Both the geometric mean and 90th percentile must meet the NSSP criteria.

1. The concentration of fecal coliform bacteria cannot exceed a geometric mean of 14 organisms per 100 milliliters (ml) in water (applied in all cases).
2. The estimated 90th percentile cannot exceed 43 organisms per 100 ml of water (applied to areas potentially affected by only nonpoint sources); OR not more than ten percent of the samples are to exceed 43 organisms per 100 ml of water (applied where point sources are present).

Besides the collection of fecal pollution data, DOH carries out a “shoreline survey” of the upland watershed and the marine shoreline to find and assess pollution sources. DOH cannot approve an area if the shoreline survey reveals pollution that presents a public health hazard, even if the water quality meets the NSSP criteria. If statistics from all stations meet the NSSP criteria and the shoreline survey does not reveal significant pollution that presents a public health hazard, DOH classifies the area Approved.

Question 2. Can a growing area be classified Conditionally Approved? If a shellfish growing area cannot be classified as Approved, DOH looks at the data to see if it can be classified Conditionally Approved. If conditions are found that would allow safe harvest, DOH prepares a "Conditionally Approved Area Management Plan" (CAAMP) for the area.

DOH examines the affect of various pollution factors in a growing area. Pollution factors include rainfall (daily or seasonal), flooding by major rivers, or seasonal boat activity. The most common Conditionally Approved classification is based on 24-hour rainfall. To set the rain-related condition, statistics are recalculated from edited data (i.e., fecal coliform results from the rainiest days are removed) to see if an upper limit on 24-hour rainfall exists below which harvest can be done. DOH puts the rainfall limit into a "Conditionally Approved Area Management Plan" (CAAMP) for the area. DOH removed the rainfall-based CAAMP in 1998 when Nisqually Reach was reclassified from Conditionally Approved to Approved.

DOH reviews the classification of a growing area periodically. An objective review requires updated analysis of the water quality and the shoreline survey. For this reason DOH continues fecal pollution monitoring under SRS in ensure unbiased results are available when needed, even while the area does not meet the conditions specified in the CAAMP.

Appendix B. Derivation of the Annual Fecal Pollution Index (FPI)

The fecal pollution index (FPI) is a single number that describes the annual status of fecal pollution. FPIs can be applied to any level of resolution: sampling station, growing area, region, or all of Puget Sound.

We will use Dungeness Bay in 2008 as an example to show how to derive the FPI, and show how the FPI can be used to show annual impact at an individual sampling station, at the level of the growing area, or trend on the growing area. To begin, we calculate the estimated 90th percentiles for each station and sampling date in 2008.

After the 90th percentiles are calculated, we follow the steps described below (cross-referenced with color-coded text in Table B-1 (next page).

Step 1. NUMBERS. Sort the estimated 90th percentiles from each station into categories:

- "GOOD" (90th percentiles ≤ 30 mpn/100ml)
- "FAIR" (30 mpn/100ml < 90th percentiles ≤ 43 mpn/100ml)
- "BAD" (90th percentiles > 43 mpn/100ml)

Table D-1 shows that Station 113 had **four** GOOD 90th percentiles, **four** FAIR 90th percentiles, and **4** BAD 90th percentiles during 2008 (in columns b-d in Table D-1).

Step 2. FRACTIONS. For each station, divide the number of estimated 90th percentiles in each category by the total 90th percentiles in all categories. For Station 113, **four** GOOD 90th percentiles (column b) ÷ **12** total 90th percentiles (column e) = **0.33** (in column f).

Step 3. WEIGHTED FRACTIONS. Now, "weight" each fraction by multiplying it by a weighting factor:

- "GOOD" fractions × 1.00
- "FAIR" fractions × 2.00
- "BAD fractions" × 3.00

For example, for Station 113: the weighted FAIR fraction (**0.33** in column g) × 2.00 = **0.67** (in column j).

Step 4. FPI. Finally, add the weighted fractions. The sum is the fecal pollution index for each station. The FPI will range from 1.00 (100% of estimated 90th percentiles are GOOD) to 3.00 (100% of 90th percentiles are BAD). For example, the FPI for Station 113 (column l): (**0.33** + **0.67** + **1.00**) = **2.00**.

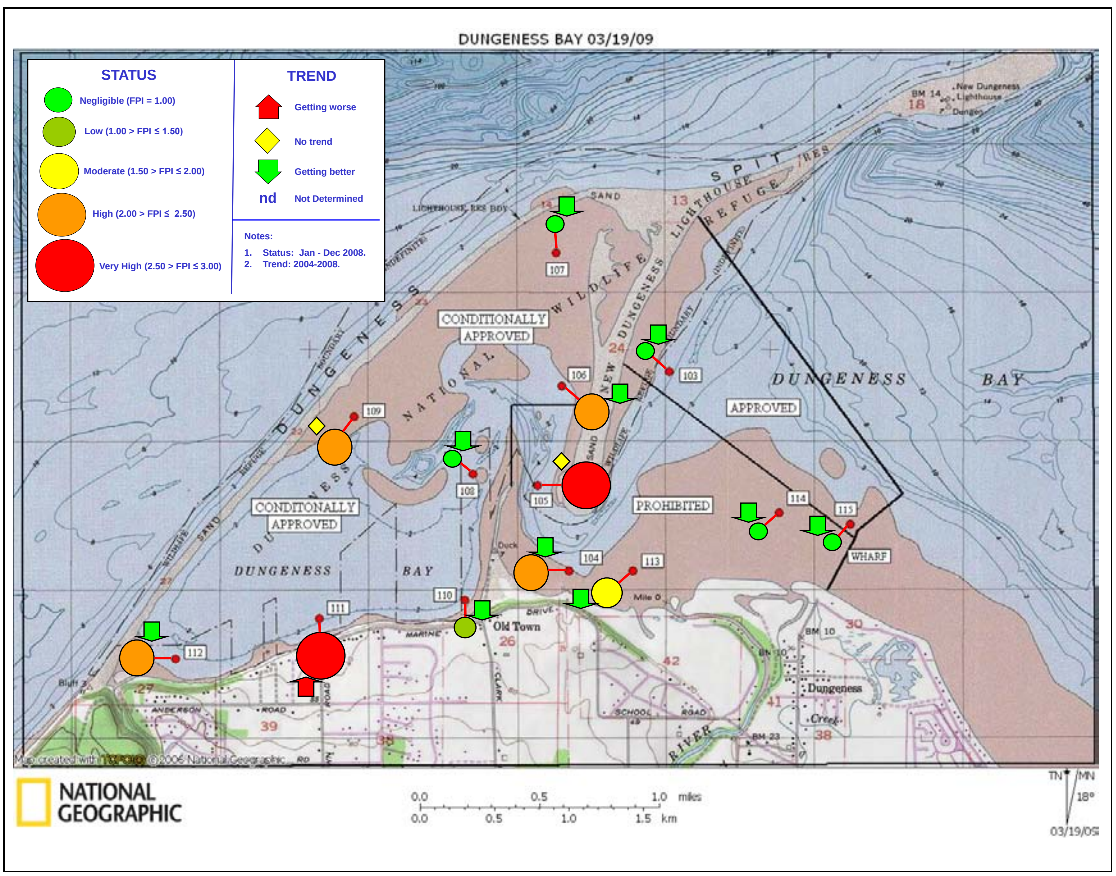
Figure B-1 uses the fecal pollution index at sampling stations in Dungeness Bay to characterize how fecal pollution was distributed in 2008.

Growing Area and Puget Sound FPI. To calculate the annual FPI for Dungeness Bay in 2008, we sum the numbers within each category for *all* stations (TOTAL DB line in Table B-1) and repeat the steps described above. The annual FPI for Dungeness Bay in 2008 was **1.57**. By extending the method to all stations in all Puget growing areas, the annual FPI for Puget Sound in 2008 was **1.16**.

Table B-1 summarizes FPI calculations for Dungeness Bay and Puget Sound in 2008.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	NUMBERS				FRACTIONS			WEIGHTED FRACTIONS			
STATION	GOOD	FAIR	BAD	TOTAL	GOOD	FAIR	BAD	GOOD	FAIR	BAD	FPI
103	11	0	0	11	1.00	0.00	0.00	1.00	0.00	0.00	1.00
104	0	0	12	12	0.00	0.00	1.00	0.00	0.00	3.00	3.00
105	6	6	0	12	0.50	0.50	0.00	0.50	1.00	0.00	1.50
106	0	12	0	12	0.00	1.00	0.00	0.00	2.00	0.00	2.00
107	11	1	0	12	0.92	0.08	0.00	0.92	0.17	0.00	1.08
108	8	4	0	12	0.67	0.33	0.00	0.67	0.67	0.00	1.33
109	11	1	0	12	0.92	0.08	0.00	0.92	0.17	0.00	1.08
110	7	6	0	13	0.54	0.46	0.00	0.54	0.92	0.00	1.46
111	0	8	4	12	0.00	0.67	0.33	0.00	1.33	1.00	2.33
112	11	0	0	11	1.00	0.00	0.00	1.00	0.00	0.00	1.00
113	4	4	4	12	0.33	0.33	0.33	0.33	0.67	1.00	2.00
114	12	0	0	12	1.00	0.00	0.00	1.00	0.00	0.00	1.00
115	12	0	0	12	1.00	0.00	0.00	1.00	0.00	0.00	1.00
TOTAL DB	81	42	20	143	0.57	0.29	0.14	0.57	0.59	0.42	1.57
TOTAL PS	7962	436	506	8897	0.89	0.05	0.06	0.89	0.10	0.17	1.16

Figure B-1 shows fecal pollution impact at each sampling station in Dungeness Bay in 2008.



Temporal Trend Using FPI. The method is modified slightly to calculate annual "historical" FPIs for tracking change over time. "Historical" means that we use only 90th percentiles from stations with a continuous sampling history. We eliminate 90th percentiles from stations that were either dropped or added over time. Following the initial edit, we calculate an annual FPI for each year (1998 through 2008). Figure B-2 (below) shows the trend in "historical" FPIs in Dungeness Bay from 1998 through 2008. Note that the annual FPI calculated for any particular year (used to show current status) may differ slightly from the annual "historical" FPI, which is used to track temporal trend.

Figure B-2. Fecal Pollution impact in Dungeness Bay 1998-2008.