
4. Title and Subtitle
YEAR 3 - RUNOFF WATER QUALITY, AUGUST 1979 - AUGUST 1980

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15. Supplementary Notes
The study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration, under the title Runoff Water Quality.

16. Abstract
This report summarizes findings detailed in Report Nos. 4 and 5 plus the work of Zawlocki on trace organics in highway runoff. Several hundred compounds tentatively, identified by GC-MS were grouped into nine categories, which were not mutually exclusive. Major components of these categories were petroleum products used by vehicles and incompletely combusted hydrocarbons. The concentrations of these trace organics groups were low compared to criteria proposed for protection of aquatic life.

17. Key Words
Highways, Runoff, Water Pollutants, Washington State, Monitoring, Models, Construction, Woodwaste Fills, Leachate, Organics

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.
Introduction

This report is a departure from past annual reports which focused on the single major research development each year. Since three major research tasks were completed, each report was summarized in a separate report and this report is an executive summary of these reports. The major reports exclusive of dissertations prepared by this project are listed in Table 1.

Table 1

Highway Runoff Water Quality Reports


Velocity and nutrient studies at twelve sites in Western Washington streams indicated that 50 cm/sec is the critical average current velocity where the productive base of the food web is impacted. Swift flowing streams rich in nutrients should not be slowed to this value and slow flowing streams should not be altered to have velocities greater than this value.


The initial 15 months of effort to review the literature, select a prototype site, and compare the performance of several automatic sampling devices, and install a prototype sampling site on I-5 north of Seattle.


A composite sampling device was developed that can be installed at less than ten percent of the cost of automatic sampling systems currently used in Federal highway runoff studies. This device was operated for one year, side-by-side the I-5 site, to demonstrate that the composite system provides identical results to the automated system.


Laboratory and field studies of a woodchip fill on SR 302 demonstrated that the ultimate amount of COD, TOC and BOD per ton of woodchips can be defined and that this material is leached exponentially by water. After a year the majority of the pollutant has been removed suggesting that pre-treating the woodchips prior to use in the fill can reduce the pollutant release from a fill. This chips should be protected from rainfall and groundwater intrusion to avoid the release of leachate. Release of leachate onto tidal lands can cause beach discoloration and an underground deep outfall may be required.


Criteria for selecting statewide monitoring sites for highway runoff are established to provide representative combinations of climate, traffic, highway, land use, geographic and topographic characteristics. Using these criteria, a minimum of six sites are recommended for use in this research.


A total of 241 storm events were sampled at ten sites during the first full year of statewide monitoring of highway runoff. Analyses of these data indicate that more than half of the observed solids in this runoff is traced to seeding operations. The total solids loading at each site was correlated with traffic during the storm. The ratio of other pollutants to solids was linear when there was sufficient traffic generated pollutants to saturate the available solids.
This report summarizes the efforts reported in Reports 4 and 6 and a yet-to-be-documented effort on trace organics present in highway runoff.

History

This project was initiated in May 1977 as a five-year field study to establish the impacts of highway operation and maintenance on receiving water quality and on aquatic ecosystems in the State of Washington. During the first year of effort (May 1977 - August 1978) a literature survey (Horner, et al., 1977) was made of existing knowledge and the need for field studies justified. The maritime climate of Western Washington with low intensity long-term rainfall creates a unique set of conditions. Most existing highway runoff data are for high intensity, short duration types of events, and such results are not applicable in the State of Washington. The major thrust of the first year's field activity was to reactivate the site on SR 520 employed by Sylvester and DeWalle (1972) in their cursory examination of this problem and to develop a prototype sampling station to test and improve sampling equipment (Horner et al., 1979). A study was made of the impact of nutrient additions and velocity changes in rivers of Western Washington (Horner and Welch, 1978) and critical thresholds defined for these parameters.

During the second year, criteria and requirements for selection of statewide highway runoff monitoring sites were developed (Aye, 1979), and a new inexpensive runoff sampling device was developed and tested. This device reduced the cost of sampling by a factor of ten and permitted the installation of 10 high performance sampling sites statewide at the cost of installing two conventional sites (Clark and Mar, 1980). Data collected from the
Sylvester site, and the prototype site were used to establish the sampling protocol for all sites.

This report summarizes the results of the third year of research where, for the first time, all ten sites were in operation. A special study of leachate from a woodwaste fill section of highway was also conducted. The samples were routinely examined for solids, metals, COD and nutrients. Special studies were made to identify trace organics in the runoff samples.

**Third Year Results**

During the first year of full-time operation (1979-80) of ten highway runoff monitoring sites in the State of Washington, a total of 241 storm events were sampled. The locations of the sites are shown in Figure 1, and Table 2 describes each site. Details of the experimental procedures, data and results are reported by Asplund (1980) in his dissertation. A summary of these findings is published by Asplund, et al. (1980).

The characteristics of the storms observed at each site are summarized in Tables 3 and 4. Problems encountered in this collection of data are summarized in Table 5. The data collected at these sites are summarized in Tables 6 and 7 using methods summarized in Table 8. The experimental data included concentration of pollutants for a composite flow weighted runoff sample, rainfall volume and duration, runoff coefficient, and traffic between and during the storm. Details of these measurements are described by Clark (1980) and Asplund (1980). These data suggest that total suspended solids loadings (lbs/curb-mile) were a function of either rainfall duration or traffic during the storm, but not a function of traffic preceding storms, rainfall, or dry periods, as suggested by the literature. Asplund (1980)
Figure 1. Sampling Site Locations in Washington State
Table 2. Physical Characteristics of the Highway Runoff Sampling Sites.

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Climate</th>
<th>Average Rainfall</th>
<th>Site Description</th>
<th>Physical Characteristics</th>
<th>Highway Description</th>
<th>Traffic Volume</th>
<th>Surrounding Land Use</th>
<th>Sampler</th>
<th>Floam splitter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1-5</td>
<td>Puget Sound</td>
<td>32-63</td>
<td>A side road bridge over a 1.16 ft grade on a limited access highway, sample intakes from drop-box</td>
<td>53,160 ft²</td>
<td>734 m³</td>
<td>6-12' concrete lanes</td>
<td>10-12' asphalt-curb</td>
<td>10-12' asphalt-md</td>
<td>Urban</td>
</tr>
<tr>
<td>1-5 &amp; 19th Pl E</td>
<td>Northwest</td>
<td>32-63</td>
<td>Elevated bridge section with 2% grade, sample intakes from drop-box</td>
<td>4,510 ft²</td>
<td>150 m³</td>
<td>12-18' concrete lane</td>
<td>12-18' asphalt-md</td>
<td>12-18' concrete-md</td>
<td>Urban</td>
</tr>
<tr>
<td>Southbound</td>
<td>Leondale</td>
<td></td>
<td></td>
<td>12-18' concrete lane</td>
<td>12-18' asphalt-md</td>
<td>12-18' concrete-md</td>
<td>Urban</td>
<td>6,200</td>
<td>Seattle</td>
</tr>
<tr>
<td>Northbound</td>
<td>Leondale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. NB-520</td>
<td>Seattle</td>
<td>32-63</td>
<td>Bridge over a 1.3% grade on a limited access highway, sample intakes from drop-box</td>
<td>53,160 ft²</td>
<td>734 m³</td>
<td>6-12' concrete lanes</td>
<td>10-12' asphalt-curb</td>
<td>10-12' asphalt-md</td>
<td>Urban</td>
</tr>
<tr>
<td>WA-520 at Montana</td>
<td>Maine</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Southbound</td>
<td>Leondale</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>3. Vancouver</td>
<td>Cascade</td>
<td>45-90</td>
<td>A side road horizontal curve on a limited access highway, sample intakes from existing drop-box</td>
<td>11,970 ft²</td>
<td>120 m³</td>
<td>12-18' concrete lane</td>
<td>12-18' asphalt-curb</td>
<td>12-18' asphalt-md</td>
<td>Urban</td>
</tr>
<tr>
<td>1-95 at St Johns St</td>
<td>Footlog</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Snoqualmie Pass</td>
<td>West Slope</td>
<td>60-100</td>
<td>A side road with 1.25% grade on a limited access highway, sample intakes off curb</td>
<td>7,700 ft²</td>
<td>50 m³</td>
<td>12-18' concrete lane</td>
<td>12-18' asphalt-curb</td>
<td>12-18' asphalt-md</td>
<td>Urban</td>
</tr>
<tr>
<td>East Slope</td>
<td>Mountaine</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>9. Montana</td>
<td>Western</td>
<td>70-100</td>
<td>Curved approach to bridge section and a portion of the ramp, sample intakes off curb</td>
<td>12,210 ft²</td>
<td>210 m³</td>
<td>12-18' asphalt lane</td>
<td>12-18' asphalt-md</td>
<td>12-18' asphalt-md</td>
<td>Agricultural</td>
</tr>
<tr>
<td>9N-12 24 miles West of 50-12</td>
<td>Olympia</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Pescos</td>
<td>Central Soils</td>
<td>7-15</td>
<td>Side road horizontal curve on a 0.5% grade, sample intakes off existing turnout</td>
<td>56,200 ft²</td>
<td>4,000 m³</td>
<td>12-18' concrete lane</td>
<td>12-18' asphalt-curb</td>
<td>12-18' asphalt-md</td>
<td>Semi-arid desert</td>
</tr>
<tr>
<td>East Cascade</td>
<td>Footlog</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>7. Spokane</td>
<td>Northeast</td>
<td>17-28</td>
<td>Horizontal bridge section on a limited access highway, sample intakes from 5 bridge drains at base of middle pier</td>
<td>9,240 ft²</td>
<td>300 m³</td>
<td>12-18' concrete lane</td>
<td>12-18' concrete-md</td>
<td>12-18' concrete-md</td>
<td>Urban</td>
</tr>
<tr>
<td>1-95 at Laton Dr</td>
<td>Bridge</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Eastbound</td>
<td>Leondale</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9. Palouse-9</td>
<td>Palouse</td>
<td>50-19</td>
<td>A side road horizontal grade on 0.30% grade, sample intakes off curb</td>
<td>5,700 ft²</td>
<td>300 m³</td>
<td>12-18' asphalt lane</td>
<td>12-18' asphalt-curb</td>
<td>12-18' asphalt-curb</td>
<td>Agriculture</td>
</tr>
<tr>
<td>SH-57 2.5 mi West</td>
<td>Palouse</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>10. Palouse-Central</td>
<td>Palouse</td>
<td>50-19</td>
<td>A side road horizontal grade on 0.30% grade, sample intakes off curb</td>
<td>10,630 ft²</td>
<td>500 m³</td>
<td>12-18' asphalt lane</td>
<td>12-18' asphalt-curb</td>
<td>12-18' asphalt-curb</td>
<td>Agriculture</td>
</tr>
<tr>
<td>SH-57 2.5 mi West</td>
<td>Palouse</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Palouse</td>
<td>12-18' asphalt lane</td>
<td>12-18' asphalt-curb</td>
<td>12-18' asphalt-curb</td>
<td>Agriculture</td>
<td>2,000</td>
<td>Palouse</td>
<td>0.070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site</td>
<td>no. of events</td>
<td>Monitoring Period</td>
<td></td>
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<tr>
<td>1-5</td>
<td>54</td>
<td>9-79 to 6-80</td>
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</tr>
<tr>
<td>SR-520</td>
<td>43</td>
<td>9-79 to 6-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vancouver</td>
<td>61</td>
<td>8-79 to 6-80</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snoqualmie Pass</td>
<td>12</td>
<td>9-79 to 1-80, 4-80 to 6-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montesano</td>
<td>27</td>
<td>10-79 to 6-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasco</td>
<td>17</td>
<td>9-79 to 3-80, 5/80 to 6-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Spokane</td>
<td>6</td>
<td>9-79 to 6-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pullman - 8</td>
<td>9</td>
<td>9-79 to 6-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pullman - 9</td>
<td>6</td>
<td>9-79 to 3-80</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pullman - control</td>
<td>6</td>
<td>4-80 to 6-80</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Table 4. Seasonal Rainfall, Runoff and Traffic Data.

<table>
<thead>
<tr>
<th>Site</th>
<th>Rainfall (in)</th>
<th>Runoff (ft³)</th>
<th>Total (Traffic)</th>
<th>Traffic During</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall - Spring Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-5</td>
<td>9.60</td>
<td>33,600</td>
<td>6,000,000</td>
<td>444,000</td>
</tr>
<tr>
<td>I-5 w/qrit</td>
<td>4.70</td>
<td>26,100</td>
<td>2,990,000</td>
<td>233,000</td>
</tr>
<tr>
<td>SR-520</td>
<td>9.66</td>
<td>2,530</td>
<td>4,420,000</td>
<td>374,000</td>
</tr>
<tr>
<td>Vancouver</td>
<td>16.0</td>
<td>5,310</td>
<td>1,370,000</td>
<td>106,000</td>
</tr>
<tr>
<td>Snoqualmie Pass</td>
<td>11.5</td>
<td>4,430</td>
<td>985,000</td>
<td>154,000</td>
</tr>
<tr>
<td>Montesano</td>
<td>17.4</td>
<td>18,600</td>
<td>881,000</td>
<td>168,000</td>
</tr>
<tr>
<td>Pasco</td>
<td>2.56</td>
<td>7,040</td>
<td>150,000</td>
<td>2,900</td>
</tr>
<tr>
<td>Spokane</td>
<td>3.02</td>
<td>1,250</td>
<td>2,080,000</td>
<td>144,000</td>
</tr>
<tr>
<td>Pullman-9</td>
<td>3.88</td>
<td>2,120</td>
<td>--</td>
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</tr>
<tr>
<td>Winter Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainfall (in)</td>
<td>26.3</td>
<td>74,400</td>
<td>8,460,000</td>
<td>1,960,000</td>
</tr>
<tr>
<td>Runoff (ft³)</td>
<td>7.27</td>
<td>16,400</td>
<td>2,030,000</td>
<td>547,000</td>
</tr>
<tr>
<td>Total (Traffic)</td>
<td>24.2</td>
<td>7,210</td>
<td>4,570,000</td>
<td>872,000</td>
</tr>
<tr>
<td>Traffic During</td>
<td>29.2</td>
<td>5,980</td>
<td>1,210,000</td>
<td>107,000</td>
</tr>
<tr>
<td></td>
<td>30.4</td>
<td>15,200</td>
<td>417,000</td>
<td>202,000</td>
</tr>
</tbody>
</table>
Table 5. Summary of Site Problems and Sources of Errors
(Solutions to Problems Encountered at the Runoff Sites).

<table>
<thead>
<tr>
<th>Location</th>
<th>Specific Site Problems</th>
<th>Runoff Flow Problems</th>
<th>Traffic Management</th>
<th>Sample Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-9</td>
<td>Loss of solids in highs</td>
<td>100Q flow measurement over</td>
<td>Excellent daily and</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>Collection &amp; addition</td>
<td>estimated times (installation of</td>
<td>VOS counts</td>
<td>(Seperate grit analysis for solids)</td>
</tr>
<tr>
<td></td>
<td>to composite samples</td>
<td>flow transmittor) Only</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recurring rain gauge</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2N-520</td>
<td>Leakage of site thru</td>
<td>No problems</td>
<td>Excellent daily and</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>expansion joints</td>
<td>infrequent clogging</td>
<td>VOS counts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Site abandoned 6/79)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vancouver</td>
<td>Possible flow barrier</td>
<td>No problems</td>
<td>Excellent daily and</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>between concrete-asphalt</td>
<td>infrequent clogging</td>
<td>VOS counts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>surfaces</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seattle</td>
<td>No problems</td>
<td>No problems</td>
<td>Multiple composings of</td>
<td>No problems</td>
</tr>
<tr>
<td>Pass</td>
<td>Infrequent clogging</td>
<td></td>
<td>VOS counts</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montrose</td>
<td>Questionable drainage</td>
<td>No problems</td>
<td>Poor daily counts,</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>areas</td>
<td></td>
<td>counter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>from bridge sections</td>
<td></td>
<td>35 ft to 5 ft VOS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Proposed dye tests)</td>
<td></td>
<td>counts, accord to</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>35 ft to 5 ft</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>VOS counts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pease</td>
<td>Site below grade, Sand</td>
<td>Frequent clogging</td>
<td>Poor daily counts,</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>in sampling area</td>
<td></td>
<td>VOS counts, accord to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35 ft to 5 ft</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>VOS counts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spokane</td>
<td>Initial vandalism</td>
<td>No problems</td>
<td>Poor daily counts,</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>(Installation of coke</td>
<td></td>
<td>VOS counts, accord to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>around site)</td>
<td></td>
<td>35 ft to 5 ft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Winter freeze-up</td>
<td></td>
<td>VOS counts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palouse-6</td>
<td>Reported vandalism</td>
<td>Frequent clogging</td>
<td>Poor daily counts,</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>(Anions reported in</td>
<td></td>
<td>VOS counts, accord to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>transmittor) (Site</td>
<td></td>
<td>35 ft to 5 ft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>abandoned 5/90)</td>
<td></td>
<td>VOS counts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palouse-6</td>
<td>Same at site 6</td>
<td>Same as site 6</td>
<td>Poor daily counts,</td>
<td>No problems</td>
</tr>
<tr>
<td></td>
<td>(Coke built around</td>
<td></td>
<td>VOS counts, accord to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>site)</td>
<td></td>
<td>35 ft to 5 ft</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>VOS counts</td>
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<td></td>
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</tr>
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</table>
Table 6. Seasonal Summaries for Total Suspended Solids.

<table>
<thead>
<tr>
<th>Site</th>
<th>Fall - Spring Period</th>
<th>Winter Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concentration (mg/l)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>I-5</td>
<td>115</td>
<td>32-452</td>
</tr>
<tr>
<td>I-5 w/ grit</td>
<td>203</td>
<td>50-741</td>
</tr>
<tr>
<td>SR-520</td>
<td>272</td>
<td>76-894</td>
</tr>
<tr>
<td>Vancouver</td>
<td>48</td>
<td>13-140</td>
</tr>
<tr>
<td>Montesano</td>
<td>155</td>
<td>95-335</td>
</tr>
<tr>
<td>Pasco</td>
<td>199</td>
<td>38-587</td>
</tr>
<tr>
<td>Spokane</td>
<td>1278</td>
<td>67-2490</td>
</tr>
<tr>
<td>Pullman-9</td>
<td>64</td>
<td>14-522</td>
</tr>
<tr>
<td>Snoqualmie Pass</td>
<td>49</td>
<td>23-117</td>
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</table>
### Table 7. Comparison of the Seasonal Runoff Rates from Washington State and Envirex Runoff Sites.

#### Fall-Spring Runoff Rates

<table>
<thead>
<tr>
<th></th>
<th>Snoqualmie</th>
<th>Skagit</th>
<th>Puyallup</th>
<th>Olympia-Puyallup</th>
<th>Mt.</th>
<th>Mt.</th>
<th>Envirex 1</th>
<th>Envirex 2</th>
<th>Range</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lb/curb at-day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS</td>
<td>36.0</td>
<td>17.4</td>
<td>2.36</td>
<td>20.0</td>
<td>6.13</td>
<td>11.3</td>
<td>12.6</td>
<td>0.00</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>0.71</td>
<td>0.34</td>
<td>0.28</td>
<td>2.05</td>
<td>0.54</td>
<td>0.72</td>
<td>-</td>
<td>0.72</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td>0.17</td>
<td>0.36</td>
<td>0.95</td>
<td>1.24</td>
<td>0.61</td>
<td>-</td>
<td>0.14</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>0.40</td>
<td>BDL</td>
<td>0.03</td>
<td>BDL</td>
<td>0.02</td>
<td>BDL</td>
<td>1.64</td>
<td>8.13</td>
</tr>
<tr>
<td></td>
<td>0.001</td>
<td>0.002</td>
<td>BDL</td>
<td>0.003</td>
<td>BDL</td>
<td>0.001</td>
<td>-</td>
<td>0.04</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>PB</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

#### Winter Runoff Rates

<p>| | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lb/curb at-day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS</td>
<td>10.1</td>
<td>46.3</td>
<td>7.4</td>
<td>20.0</td>
<td>256</td>
<td>2.55</td>
<td>31.1</td>
<td>-</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>1.30</td>
<td>1.57</td>
<td>0.87</td>
<td>13.6</td>
<td>35.3</td>
<td>0.61</td>
<td>1.07</td>
<td>-</td>
<td>1.57</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
<td>0.17</td>
<td>0.30</td>
<td>0.54</td>
<td>7.70</td>
<td>0.30</td>
<td>1.07</td>
<td>-</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>0.43</td>
<td>0.17</td>
<td>BDL</td>
<td>0.12</td>
<td>0.11</td>
<td>0.003</td>
<td>0.005</td>
<td>-</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>0.005</td>
<td>0.005</td>
<td>BDL</td>
<td>0.02</td>
<td>0.02</td>
<td>0.001</td>
<td>0.005</td>
<td>-</td>
<td>0.005</td>
</tr>
</tbody>
</table>

1 Yearly TS Runoff Rate
2 Does not include grit fraction
Table 8. Methods Used in the Analysis of Highway Stormwater Runoff.

<table>
<thead>
<tr>
<th>Pollutant Test</th>
<th>Procedure</th>
<th>Analysis</th>
<th>Averaged Estimated Laboratory Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard Methods</td>
<td>EPA Math-Chem. Analysis</td>
<td>Atomic Absorption Method</td>
</tr>
<tr>
<td>TSS</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VSS</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOC</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease &amp; Oil</td>
<td>Freon-extraction &amp; distillation, then run as TOC</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₃-NO₂-N</td>
<td>X</td>
<td>Micro</td>
<td></td>
</tr>
<tr>
<td>TKN</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Phos.</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>Specific Electrode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Conductance</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
presents detailed examination of data for each site. Based on literature values, a mass balance is developed for sources of solids observed in highway runoff. These data suggest adjacent land use in Western Washington contributes less than 10% of these solids and the major sources appear to be vehicle related and, in winter, related to sanding application in icy conditions. Ash from the eruption of Mt. St. Helens was detected immediately after the major eruptions, but traffic-generated winds removed these solids from the Western Washington sites prior to the storms that were monitored.

Two major conclusions were drawn from these results: The first conclusion was that solids present in highway runoff are strongly correlated with traffic during the storm and not traffic during the period preceding a storm as reported in the literature. This may be unique to Western Washington where the pavement remains wet for many hours and vehicles act as scrubbing agents to remove solids. During short, intensive storms the impact of the precipitation may be the major source of solids removal, but during the low intensity, long duration storms in Western Washington the vehicles can be the major removal mechanism. The data also indicated that sand added during icy periods contributed more than fifty percent of the annual solids loading observed in highway runoff. The second major conclusion from the third year of study was that, excluding the sand applications for de-icing, the highway runoff solids loadings (lb/curb-mile/1000 vehicles during storm) are higher than natural values and appear to be constant among Western Washington sites when corrected for variability in runoff coefficients (Figure 2). These two conclusions permit the formulation of a simple model to predict solids loading from highway runoff of the form:

\[ \text{TSS (lbs/curb-mile)} = K \cdot VDS \cdot RC \]
Figure 2. Total Suspended Solids Runoff Rate Versus Runoff Coefficient for the Fall-Spring Period at the Western Sites.*

* Derived from the cumulative TSS to cumulative VDS plots and based on actual runoff loads at the SR-520 site.
TABLE 9. Rainfall, runoff and traffic data for storms sampled for trace organics.

<table>
<thead>
<tr>
<th>Storm Event</th>
<th>Date</th>
<th>Rainfall (in)</th>
<th>Duration (Hr)</th>
<th>Average Intensity (In/Hr)</th>
<th>Vehicles During Storm</th>
<th>Vehicles Preceding Storm</th>
<th>Runoff Volume (ft³)</th>
<th>Runoff Coefficient</th>
<th>Dry Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-78¹</td>
<td>10-14-79</td>
<td>0.25</td>
<td>7</td>
<td>.036</td>
<td>5,980</td>
<td>2,022,980</td>
<td>903</td>
<td>0.82</td>
<td>36</td>
</tr>
<tr>
<td>15-79¹</td>
<td>10-20-79</td>
<td>0.74</td>
<td>18</td>
<td>.041</td>
<td>38,540</td>
<td>142,690</td>
<td>1287</td>
<td>0.39</td>
<td>6</td>
</tr>
<tr>
<td>15-93¹</td>
<td>12-18-79</td>
<td>1.34</td>
<td>22</td>
<td>.061</td>
<td>46,300</td>
<td>46,300</td>
<td>4301</td>
<td>0.93</td>
<td>1</td>
</tr>
<tr>
<td>520-11¹</td>
<td>12-02-79</td>
<td>1.39</td>
<td>17</td>
<td>.082</td>
<td>26,610</td>
<td>224,200</td>
<td>350³</td>
<td>0.75⁴</td>
<td>5</td>
</tr>
<tr>
<td>520-16¹</td>
<td>12-19-80</td>
<td>0.7</td>
<td>19</td>
<td>.037</td>
<td>35,800</td>
<td>62,650</td>
<td>176³</td>
<td>0.75⁴</td>
<td>1</td>
</tr>
<tr>
<td>520-43²</td>
<td>05-28-80</td>
<td>0.80</td>
<td>18</td>
<td>.044</td>
<td>23,400</td>
<td>187,200</td>
<td>201³</td>
<td>0.75⁴</td>
<td>6</td>
</tr>
<tr>
<td>15-131²</td>
<td>05-28-80</td>
<td>0.86</td>
<td>20</td>
<td>.043</td>
<td>46,980</td>
<td>298,120</td>
<td>3059</td>
<td>0.80</td>
<td>6</td>
</tr>
<tr>
<td>15-87¹,²</td>
<td>12-2-79</td>
<td>1.20</td>
<td>18</td>
<td>.067</td>
<td>58,830</td>
<td>294,570</td>
<td>2862</td>
<td>0.71</td>
<td>5</td>
</tr>
</tbody>
</table>

1. Extraction for aliphatic and aromatic fractions.
2. Extraction for GC/MS analysis.
3. Measured values are low due to leakage through expansion joints.
where: \( K \) is obtained from the slope of the curve in Figure 2;

\( \text{VDS} \) is the number of vehicles crossing the highway section of interest during the storm;

\( \text{RC} \) is the runoff coefficient of a particular storm, and may vary depending on storm characteristics and traffic.

There are insufficient data from Eastern Washington sites to develop a statistically sound conclusion on pollutant loading causality at this time, and year four studies are designed to increase this data base.

A weaker conclusion from the third year's data is that the ratio of any pollutant loading to the total suspended solids loading is a constant. This observation is being explored during year four of the project to develop definitive values for these ratios applicable to highways in the State of Washington.

During year three an intensive effort was made to establish the presence of trace organics in highway runoff. The analyses required many weeks of sample preparation to separate the trace organics from runoff water and into fractions containing different types of organic compounds. Analytical costs of several thousand dollars per sample were necessary to conduct this study, and these costs limited the scope of effort. A total of six samples obtained from the Interstate-5 and State Route 520 sites plus controls were processed (filtration, extraction, clean up and concentration) to measure the weights of trace organics in the particulate and soluble extract fractions of highway runoff. Three samples were analyzed by gas chromatography (GC) coupled to mass spectroscopy (MS) using computer data systems (CDS). Characteristics of the storms sampled are shown in Table 9. Table 10 presents the summary of the data for gross parameters used in
TABLE 10. Concentration of suspended solids, composite organic parameters and extract weights in storm samples.

<table>
<thead>
<tr>
<th>Storm</th>
<th>TSS</th>
<th>VSS</th>
<th>COD</th>
<th>TOC</th>
<th>Oil/Grease</th>
<th>Soluble Extract</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/l</td>
<td>mg/l</td>
<td>mg/l</td>
<td>mg/l</td>
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<tr>
<td>15-78</td>
<td>97</td>
<td>26</td>
<td>61</td>
<td>21.8</td>
<td>38.7</td>
<td>15.6</td>
</tr>
<tr>
<td>15-79</td>
<td>32</td>
<td>12</td>
<td>61</td>
<td>18.4</td>
<td>28.7</td>
<td>7.3</td>
</tr>
<tr>
<td>15-93</td>
<td>118</td>
<td>26</td>
<td>52</td>
<td>28.3</td>
<td>30.7</td>
<td>9.5</td>
</tr>
<tr>
<td>520-11</td>
<td>335</td>
<td>115</td>
<td>271</td>
<td>36.8</td>
<td>40.8</td>
<td>19.4</td>
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<tr>
<td>520-16</td>
<td>144</td>
<td>53</td>
<td>130</td>
<td>25.8</td>
<td>48.0</td>
<td>17.6</td>
</tr>
<tr>
<td>520-43</td>
<td>408</td>
<td>74</td>
<td>280</td>
<td>97.5</td>
<td>93.5</td>
<td>13.4</td>
</tr>
<tr>
<td>15-131</td>
<td>57</td>
<td>19</td>
<td>166</td>
<td>97.6</td>
<td>93.5</td>
<td>13.4</td>
</tr>
<tr>
<td>15-87</td>
<td>72</td>
<td>10</td>
<td>59</td>
<td>12.5</td>
<td>14.6</td>
<td>13.5</td>
</tr>
</tbody>
</table>

1. Samples from storms 15-78 and 15-79 were obtained for Oil/Grease analysis.
**TABLE 11.** Identified organic compounds grouped into nine categories.

<table>
<thead>
<tr>
<th>Class of Compounds</th>
<th>STORM I5-87</th>
<th>STORM I5-131</th>
<th>STORM 520-43</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Particulate (µg/l)</td>
<td>Soluble (µg/l)</td>
<td>Total (µg/l)</td>
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<tr>
<td>Aliphatic Alcohols</td>
<td>T</td>
<td>160</td>
<td>160</td>
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<tr>
<td>Aliphatic Hydrocarbons</td>
<td>3710</td>
<td>3220</td>
<td>6930$^1$</td>
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<tr>
<td>Aromatic Compounds Including</td>
<td>2050</td>
<td>148</td>
<td>2200</td>
</tr>
<tr>
<td>Heterocyclics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halogenated Organics</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>Ketones and Aldehydes</td>
<td>1130</td>
<td>T</td>
<td>1130</td>
</tr>
<tr>
<td>Organosulfur Compounds</td>
<td>1200</td>
<td>62</td>
<td>1260</td>
</tr>
<tr>
<td>Oxygenates excluding Alcohols,</td>
<td>3170</td>
<td>410</td>
<td>3580</td>
</tr>
<tr>
<td>phenolics, ketones, aldehydes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen Containing Compounds</td>
<td>1420</td>
<td>62</td>
<td>1480</td>
</tr>
<tr>
<td>Phenolics</td>
<td>2830</td>
<td>80</td>
<td>2910</td>
</tr>
<tr>
<td>Total Chromatographed</td>
<td>13800</td>
<td>9520</td>
<td>23300</td>
</tr>
</tbody>
</table>

T - trace
characterizing organic pollutants. Details of the experimental procedures and data analysis are found in Zawlocki (1981). Table II presents the results of the GC/MS/CDS analysis. To simplify the interpretations the several hundred compounds tentatively identified by this analysis were grouped into nine categories, which are not mutually exclusive. Comparing sums of the detected trace organics with the amount introduced indicates that not all trace organics were identified. These data suggest that the major categories present are aliphatics that can be traced to petroleum products such as fuels, oils, rubber or plastics, aromatics which may be added to fuels for octane improvement, and oxygenated compounds that suggest incomplete combustion of hydrocarbons. Halogenated compounds were observed in two of the three samples and probably originate from bromine compounds found in leaded gasolines. The compounds detected by GC/MS/CDS were not consistent in each sample and additional sample analyses are necessary to resolve these differences. Since the concentrations observed in these samples are quite low compared to criteria proposed for the protection of aquatic life, the extent of the analyses do not seem to justify further analysis at this time. On the other hand, the criteria for potential carcinogenic compounds are very stringent; and if highway runoff can enter drinking water supplies, additional study of these trace organics may be necessary.

This project has elected to focus on bioassay studies to determine if highway runoff waters can be demonstrated to be harmful to aquatic life. If no problem can be demonstrated, the need for the analysis of trace organics will be eliminated.
An extensive literature review, laboratory column studies and field observations on SR 302 woodwaste fill project near Victor, Washington, were completed to establish the water quality impacts of woodwaste fills. Vause (1980) reports the details of these efforts and Vause, Ferguson and Mar (1980) have summarized these findings for the Washington State Department of Transportation. Six columns (6" dia. x 5' high) were filled with woodchips from the SR 302 project and subjected to a range of flow rates anticipated in the actual site. The columns and the site were monitored for almost one year to determine the concentration and loadings of COD, BOD and TOC. The data indicated that the pollutants were caused by physical leaching of wood extracts and that microbial fermentation was of secondary importance. Passage of low pH leachate through soils can increase concentrations of metals, but these were not high enough to cause toxicity problems. Based on laboratory and field studies the ultimate release of pollutants appears to be:

80 ± 20 lb COD/ton solids
20 ± 5 lb TOC/ton solids
30 ± 8 lb BOD/ton solids

The pollutants are released at an exponentially decreasing rate, and concentrations low after one year of soaking. The environmental impacts of these pollutants depends on the dilution and assimilation provided prior to discharge. Since pre-soaking of woodwaste prior to placement would remove much of these pollutants, the use of old weathered chips rather than fresh waste would reduce the pollution problem. Proper placement and installation may prevent water from entering the fill and subsequent leaching. Finally, proper drainage and discharge of the leachates to high volumes of dilution waters would reduce environmental impact.
Future Work

The fourth year of this project will obtain one more year of field data for all sites except the SR 520 site. The SR 520 site was discontinued because of low runoff coefficients caused by leaking between bridge sections. These field data will be used to validate the solids loading model and to establish the ratio of pollutants to solids at each site. Two years of field data from Eastern Washington will hopefully be adequate to describe the pollutant loading for these arid sites.

Three special studies will be intensified this year. Metal analysis will focus on the transport and assimilation of trace metals between the highway and receiving waters. Bioassays will attempt to establish if highway runoff are toxic to aquatic life and what are the natures of the toxicants. Material balances for pollutants generated on the highway will be conducted to identify the fraction of pollutants released during dry periods that enter the receiving waters. These three results will be used to estimate the effectiveness of practices to mitigate highway runoff impacts.

A prototype environmental impact statement will be prepared to provide a framework and procedures for future EIS describing the impact of highway runoff.
LITERATURE CITED


