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16. Abstract

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

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SUMMARY

Existing literature and current research on the impacts of highway runoff on receiving water quality are inadequate to develop a predictive model for use in environmental impact analyses. In order to better characterize the quality of highway runoff, the University of Washington is conducting a five-year study of this problem for the State of Washington Department of Transportation. This report presents a rationale for the selection of monitoring sites for this project.

During the initial years of this project a composite sampler was developed that can be installed and operated at much lower costs than traditional discrete sampling systems (Clark and Mar, 1979). Use of such a system would permit the operation of nine or ten stations rather than two or three traditional sampling systems given the level of research funds available. Support data and equipment required to insure that composite sampling data are compatible with other research efforts being conducted under the Federal Highway Administration's Federally Coordinated Program are described. The composite sampling sites should be equipped with a composite sampler, a traffic counter, a continuous recording rain gauge and some method of determining the period of runoff into the sampler. Some sites may also require dustfall buckets depending on climatic conditions and surrounding land uses.

Criteria for selecting statewide monitoring sites for highway runoff have been described. Tentative sites identified by the University of Washington were reviewed in relationship to the criteria and additional sites recommended that should allow characterization of the highway runoff in the State of Washington. Based on the criteria, particularly weather, six (6) locations

are recommended to represent the State. Two (2) sites are suggested in Vancouver to allow comparison between a high and low volume freeway under generally the same geographic and climatic conditions. Table I presents a list of proposed sites and their characteristics.

Table I: Characteristics of Selected Sites

Location [1]	Type	ADT [2]	% Trucks	Surface Type	No. Lanes [3]	Precipitation inches/yr Total	Snowfall
SR-12, Pasco (MP 290.4)	Rural	6,400	14	Asphalt	2 (E. bound)	6.25	10-11
I-5, Seattle (MP 175)	Urban	60,000±	5	Concrete	4 (N. bound)	35-40	10±
I-5, Vancouver (MP 0.9-3.4)	Urban	53,600 - 68,900	8	Concrete	4	35-40	10±
I-205, Vancouver (MP 27.6-30.1)	Urban	11,200 - 12,600	10	Concrete	4	35-40	10±
SR-2 (Division St), Spokane (MP 289.8)	Urban	29,000	4	Asphalt	4	17-18	40±
I-90, Snoqualmie Pass (MP 38.5-82.8)	Rural	14,000 - 15,300	21	Concrete	4	60-100	200-400+
SR-101, Aberdeen-Hoquiam (MP 85.0-87.0)	Urban	13,700 - 14,600	10	Asphalt	2 (One-Way)	80-85	10-15
I-5, North of Longview [4] (MP 49.5-57.1)	Rural	22,000 - 26,000	19	Concrete or Asphalt	6	50-55	10-15
SR-12, East of I-5 [4] (MP 46.5-78.4)	Rural	4,000±	15	Asphalt	2	50+	10-15
SR-14, East of Washougal [4] (MP 18.1-36-4)	Rural	2,700±	8-16	Asphalt	2	70-80	10-15

Notes:

1. Locations whown are general, mileposts (MP) given indicate possible areas to examine.
2. ADT dependent upon exact location of site and number of lanes on drainage area.
3. Number of lanes may change depending on drainage characteristics at specific site selected.
4. Potential sites in addition to Vancouver in East Olympic-Cascade Foothills region.

INTRODUCTION

The National Environmental Policy Act of 1969 (PL 91-190) and the State Environmental Policy Act of 1971 (RCW 43.21C) require that all governmental agencies utilize a systematic, interdisciplinary approach which insures the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making for projects which have an impact on the environment. Environmental impact statements (EIS) prepared to satisfy these requirements must inventory the existing features and address the impacts in a qualitative and quantitative manner. The lack of published definitive data on highway runoff and the absence of a predictive procedure for determining the water quality impacts from highway runoff resulted in the initiation of this research project.

The overall concentrations in highway runoff for selected parameters found by Envirex (Gupta et al., 1978) for all monitored events (159) at six sites were:

	Pollutant Concentration mg/1	
	Average	Range
Total Solids	1147	145-21640
Total Volatile Solids	242	26-1522
Suspended Solids	261	4-1656
Volatile Suspended Solids	77	1-837
Total Phosphate	0.84	0.05-3.55
Total Kjeldahl Nitrogen	3.0	0.1-14
Lead	0.96	0.02-13.1
Zinc	0.41	0.01-3.4
Cadmium	0.04	0.01-0.40

Earlier studies, Sylvester and DeWalle (1972) and Metro (1973), sponsored by the Washington State Highway Commission,were site or condition specific and the results may not be applicable to other areas of the State.

This research is part of the Federal Highway Administration's (FHWA) federally coordinated program (FCP) on environmental issues. The direct FHWA research (Gupta et al., 1978 and Meinholz et al., 1978) used study sites in Harrisburg, Pennsylvania; Nashville, Tennesee; Milwaukee, Wisconsin; and Denver, Colorado. Howell et al., (1978) looked at three sites in California and Moe et al., (1977) examined a site in Texas. There have been no study sites located in the northwestern United States. The Northwest represents a distinct geographical regime and, while this research project is quite similar to the above referenced studies, it will complement rather than duplicate existing research. The major objectives of this research program are to better characterize the quality of runoff from highway facilities, determine the significance of the runoff and to develop a predictive method for determining the pollutant loadings from highway runoff. The research will also examine the impacts of highway runoff and investigate mitigation measures if the need is demonstrated. Horner et al., (1979) describe the literature review and exploratory investigations used to define this research and Clark and Mar (1980) describe the development of a composite sampler that can be employed at much lower costs than traditional discrete sampling systems.

This particular report is concerned with establishing criteria for selection of statewide monitoring sites. Traffic characteristics, precipitation and other weather characteristics, pavement condition and type, adjacent land uses, highway maintenance practices, highway geometrics, etc. may affect the quality of highway runoff. Highway geometries must be considered in determining pollutant accumulation rates and washoff coefficients. The slope along the length of the highway and the cross slope, for instance, will have a bearing on the velocity and depth of flow and, consequently, on the amount of pollutants removed from the highway surface. These factors must be taken into account in selecting sites to characterize the conditions that might exist in this State. Economic and manpower limitations of the research program, while not reflecting the quality of runoff have an important bearing on the number of sites possible. The primary objective of this study is to select the minimum number of sites that will allow characterization of the highway runoff in the State.

SELECTION OF SAMPLING METHOD

Discrete sampling with automatic samplers or grab samples has generally been utilized by other researchers on highway runoff (Gupta et al., 1978; Meinholz et al., 1978; Metro, 1973; Sylvester and DeWalle, 1972; Moe et al., 1977; Howell, 1978). This method has allowed the researchers to observe the "first flush" phenomenon associated with highway runoff and study the pollutant concentration and loading variation with time. The major use of these data, however, has been to integrate the concentrations determined by discrete sampling with flow monitoring or hydrograph data to arrive at total pollutant loadings for a particular storm.

According to the Envirex study (Gupta et al., 1978 and Meinholz et al., 1978) the rate of flow and pollutant concentrations must both be considered because the major item of concern is the pounds of pollutant being discharged to a receiving water. This supposes that concentration by itself has little effect on the receiving water and that total loading is the critical measure of impact. Envirex further suggests that perhaps the most meaningful representation of the impact potential is to express the loads on an annual basis.

However, it cannot always be assumed that concentration is unimportant, in the event of a small receiving body the discharge may make up a significant or major portion of the flow or volume. The position or requirements of the regulatory agency must also be considered. Highway runoff is classified as a non-point source of water pollution and generally effluent standards have not been applied. However, the State of California, for instance, has in some cases placed effluent restrictions on highway runoff similar to permits issues under the National Pollution Discharge Elimination System (NPDES) (Howell, 1979). The California Department of Transportation (Caltrans) could be assessed a fine or penalty for the loading discharged to a receiving body above a specific concentration. This would require some knowledge of the concentrations of specific pollutants and how the concentration varied with time.

All of the studies referenced in the first paragraph of this section have found the "first flush" phenomenon. The first flush generally is the initial portion of runoff and contains the highest concentration of pollutants. "First flush" phenomenon may be directly related to the length of piping connecting the highway and the sampling point, since residual pollutants can build up. Some studies have generally concluded that accumulation of pollutants occurs during dry periods. Howell (1978), for instance, found on California highways that concentrations were higher during the first significant rains following the dry summer-early fall period. Whipple et al. (1977) questions this conclusion. The University of Washington has found concentrations to vary seasonally (Horner et al., 1979).

Bioassay studies presently being finalized by Caltrans show some inhibition to growth even though nutrients were added (Howell, 1979). This may be an indication of toxicity by heavy metals contained in the runoff.

These conclusions are in agreement with data supported by Sylvester and DeWalle (1972). Until the potential acute and chronic effects of highway runoff are determined it would seem unwise to ignore the peak concentration or short term loadings which might occur.

COMPOSITE SAMPLING

The University of Washington has developed a composite sampler which will collect a portion of the total flow from the storm. The composite sampler presently in use on Interstate Highway (I-5),north of Seattle, samples 1/100 of the total flow (Clark and Mar, 1980). This sampler allows the researcher to determine a composite or average concentration for the entire period of runoff and the total flow from the storm. The resulting pollutant loading can also be calculated from the concentration and flow. The advantages of this system are that it minimizes the number of samples that have to be collected and it avoids the integration of concentrations and flows for specific periods as required with the discrete sampling method. However, it does not allow the prediction of peak concentrations or the observation of the variation of loading with time during a single storm.

Because of Washington's weather and other variables, the model or type of model developed by Envirex may not be applicable to this area. Peak concentrations may not be highly significant in this State. With collection of proper support data the composite sample data is comparable to data collected by discrete methods that produce a composite sample.

If the composite sampling method will give as accurate a measurement of total loads as the discrete sampling method, substantial savings are realized in less cost to equip a sampling site and a substantial reduction in laboratory cost as a result of far fewer samples to analyze. Correlation of the discrete sampler with the composite sampler has been demonstrated with the data collected from the University's prototype and long term highway runoff monitoring site located on the northbound lanes of I-5 north of Seattle at approximately N.E. 158th Street (Clark and Mar, 1980). One requirement of this research effort is that the results are comparable to other research being conducted under the program. The other major efforts, Envirex, Caltrans and Texas, have used discrete sampling for monitoring highway runoff, flow and precipitation. Phase I of the Envirex study has resulted in a model for predicting pollutant loadings from a highway. The reader is referred to Volume III of the Envirex study for details (Meinholz et al., 1978) of this model.

The following data are required to validate the Envirex model:

- Average daily traffic volume
- Rainfall data including time between events (dry days), date of event, duration of each event, peak intensity, and total volume of rainfall for the event
- Runoff data including duration and total volume per precipitation event
- Site characteristics, particularly the length of the drainage area

Considering the above required data for the Envirex model, the composite sampler sites should be equipped with a traffic counter, a continuous recording rain gage, and some method of determining the period of runoff into the composite sampler.

The period of runoff could be determined by using a flow recorder, however, since a specific portion of the total flow is being collected, the recorder would provide data not actually required. A simple relay switch would suffice if keyed to a clock and some method devised to activate the switch when flow begins and deactivate it when flow ceases. The flow switch should be synchronized with the recording rain gage to determine the lag time from rainfall to runoff. This information will be required if an effort is made to correlate peak concentrations with rainfall intensity given the total loading of the storm.

The continuous recording rain gage should be located at the site. Accurate data on time between storms, total rainfall on the drainage area and intensities are required to validate the model, develop a different model, etc. Weather will vary considerably in short distances. Farris et al., (1974) found wide variances in rainfall patterns even for rainfall gaging stations within a radius of two to three miles. This requirement is even more critical in eastern Washington where storms may be very short and localized. It is also suggested that, because of rainfall variances, it is desirable to minimize the size of the drainage areas.

At some sites it may also be desirable to determine the average dustfall or particulate fallout rate because of weather or atmospheric conditions. These data could be used to further examine the relationship of dustfall to the pollutant accumulation rate. In these cases dustfall buckets would be required equipment.

CLIMATE CONSIDERATIONS

Climate is one of the most important variables in selecting a site. The amount of rainfall per year, frequency of events and intensity all play a part in the amount of pollutant accumulated on and washed from the pavement. The form of precipitation, i.e., rainfall or snow, will also influence the amount and type of pollutants washed from the highway.

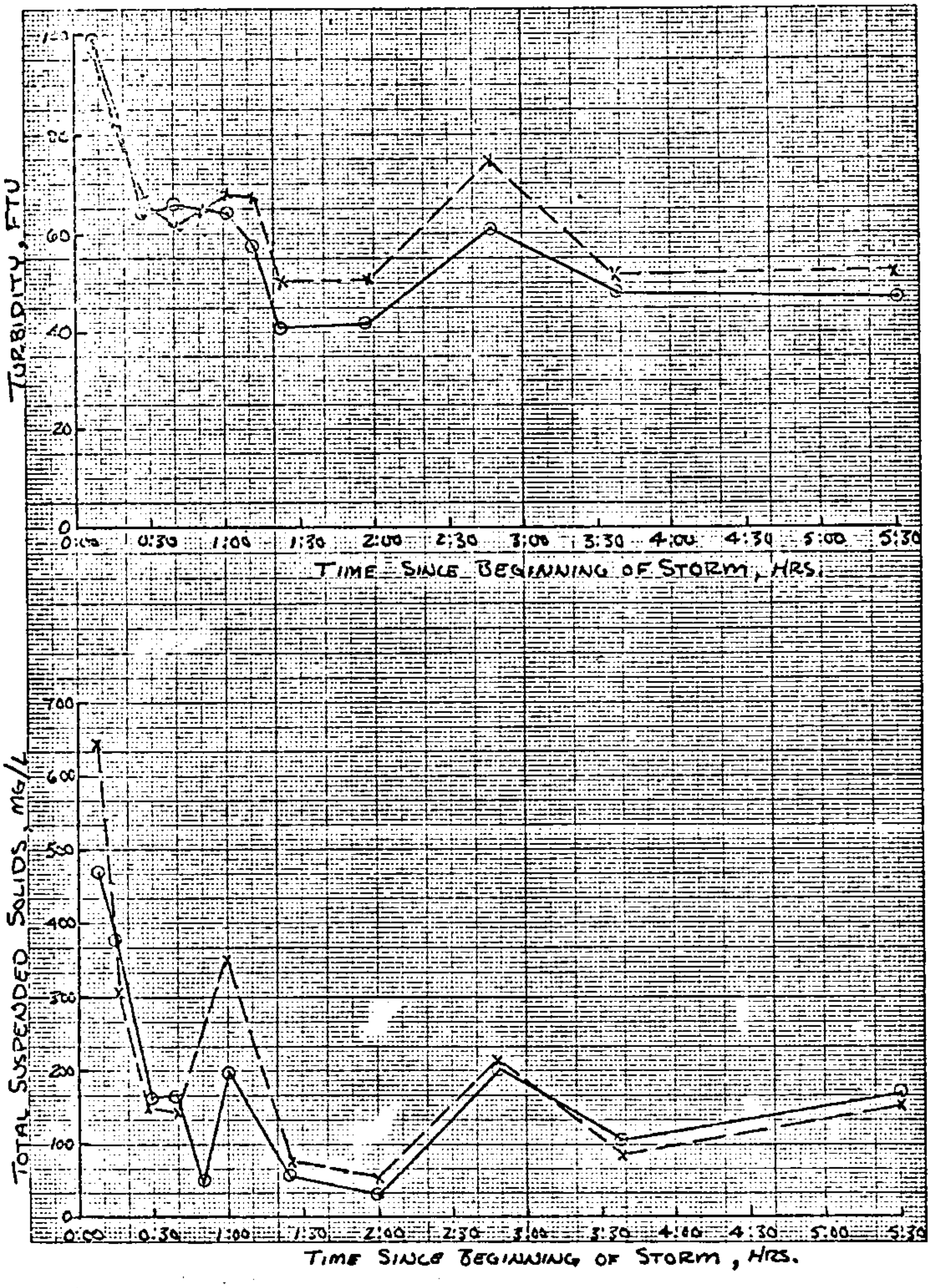
Envirex defined a significant storm as having a minimum rainfall intensity of 0.5 inches per hour (Gupta et al., 1978). To estimate pollutant accumulation rates, Envirex grouped storms into three categories: 0.05 to 0.10 inches (0.13 to 0.25 cm), 0.11 to 1.00 inches (0.28 to 2.54 cm) and greater than 1.00 inches (2.54 cm) of total rainfall. Washington, even in the western portion, generally experiences smaller (less total rainfall) and less intense storms than those monitored by Envirex.

The fourteen storms monitored at the SR 520 site during the initial year of this study ranged from 0.03 to 0.61 inches (0.08 to 1.55 cm) of total rainfall. The average total rainfall was 0.16 inches (0.41 cm) and eight of the storms were less than 0.10 inches (0.25 cm) (Horner et al., 1979).

The variability of Washington's climate may make characterization of the climate difficult at best. The effects of climatic controls such as the terrain, the Pacific Ocean and the semi-permanent high and low pressure regions located over the North Pacific Ocean all combine to produce entirely different conditions within short distances (U.S. Department of Commerce, 1972). The following description of Washington climate is summarized from a report by officials of the National Oceanic and Atmospheric Administration, NOAA (U.S. Department of Commerce, 1972). Detailed discussion will be limited to precipitation and snowfall since these parameters are of most importance to this study.

Washington's climate is mixed with a predominantly marine-type characteristics east of the Cascades. There are two ranges of mountains parallel to the east coast of Washington and which cross the State in a north-south direction, perpendicular to the prevailing westerly winds from the Pacific Ocean. The major amount of precipitation occurs on the western slope of

Figure 1: Plots of Contaminant Level vs Time (Horner et al., 1979)



the Coastal Range. A second major area of precipitation is the westerly slope of the Cascades which range in elevation from 4,000 to 10,000 feet and are located approximately 90-130 miles inland. This major range of mountains separates eastern and western Washington, the two major climatic regions of the State.

Total precipitation within the State ranges from in excess of 150 inches on the Olympic Peninsula to about 7 to 9 inches in the near desert area in the lower Columbia Basin. Figure 1 gives a contour mapping of the mean annual precipitation in inches for the State of Washington and approximate boundaries for the regions to be discussed below are indicated.

According to NOAA, there are several distinct climatic areas within each of the two major climatic regions. A brief description of each follows beginning with the five regions in western Washington.

The West Olympic-Coastal area includes the coastal plains and the western slope of the coastal range from the Columbia River to the Strait of Juan de Fuca. The "rainforest" area of the Olympic Peninsula receives the heaviest precipitation in the continental United States. Annual precipitation of the Coastal Plains ranges from 70 - 100 inches with 150 inches plus along windward slopes of the mountains. Snowfall ranges from 10-30 inches at the lower elevations but melts rather quickly.

The Northeast Olympic-San Juan area includes the lower elevations along the northeastern slope of the Olympic Mountains extending eastward along the Strait of Juan de Fuca from near Port Angeles to Whidbey Island then northward into the San Juan Islands. The Olympic Mountains shield this area from winter storms off the coast. This is the driest area in western Washington with average annual rainfall of about 18 inches near Sequim and 25-30 inches in the vicinity of Everett and Port Angeles.

The Puget Sound-Lowlands region generally includes the land surrounding Puget Sound from Centralia to the Canadian Border. Annual precipitation ranges from 32 to 35 inches from the Canadian Border to Seattle and increasing to about 45 inches in the vicinity of Centralia. Snowfall ranges from 10 to 20 inches and generally melts very quickly with depths seldom exceeding 6 to 15 inches.

The East Olympic-Cascade Foothills include foothills along the eastern slope of the coastal range, foothills along the western slope of the Cascade Mountains and the valley separating these ridges from the vicinity of Chehalis to the Columbia River. The average annual precipitation ranges from 40 inches in the valleys near the Columbia River to 90 inches at areas 800-1,000 feet above sea level.

The Cascade Mountains - West area includes the western slope of the Cascade Mountains above an elevation of approximately 1,000 feet to the summit and extending from the Columbia River to the Canadian Border. Heavy precipitation occurs in this area and ranges from 60 to 100 inches or more annually. Snowfall ranges from 50 to 75 inches at the lower elevations to 400 to 600 inches above 4,000 feet. Snowfall at the higher elevations begins in September and continues until late spring.

East of the Cascades, summers are warmer, winters colder and precipitation is less than in western Washington. Eastern Washington like Western is divided into five rather distinct climatic regions.

The East Slope - Cascades includes the area from the summit easterly for 25 to 75 miles and extends from the Columbia River to the Canadian border. Precipitation decreases with distance from the summit and decrease in elevation, from about 90 inches at the summit to 20 inches near Cle Elum. Snowfall decreases from 400 inches near the summit to about 75 inches at 2,000 feet above sea level. Snow accumulation begins in October or November and remains until late spring.

The Okanogan-Big Bend region includes the valley areas along the Okanogan, Methow and Columbia Rivers, Okanogan Highlands Waterville Plateau and part of the channeled scablands. Annual precipitation ranges from 11 inches in the valleys to 16 inches over the Plateau. Snowfall varies from 30 to 70 inches.

The Central Basin includes the Ellensburg valley, the central plains area in the Columbia basin south from the Waterville Plateau to the Oregon border and east to near the Palouse River. This is the lowest and driest area in eastern Washington. Precipitation ranges from 7 inches in the vicinity of the Tri-Cities to 15 inches in the Blue Mountains area. Summer precipitation is frequently associated with thunderstorms. Winter snowfall ranges from 10 to 35 inches and seldom exceeds depths of 8 to 15 inches.

The northeastern area includes the higher elevations of the Okanogan highland, the Selkirk Mountains and the lower elevations southward to the vicinity of the Spokane River. The average annual precipitation is 17 inches in the Spokane area increasing to 28 inches in the northeastern corner of the State. Winter snowfall varies from 40 to 80 inches.

The Palouse - Blue Mountains area includes the counties along the eastern border of the State south from Spokane to the Oregon border and west to Walla Walla. Annual precipitation is between 10 to 20 inches increasing to 40 inches in the Blue Mountains. Snowfall ranges from 20 to 40 inches.

Table II presents a summary of the precipitation data discussed above. The table also gives a range of rainfall intensities as extracted from National Weather Service (1973). The one-hour intensities were estimated by using equations relating 6-hour and 24-hour intensities to the one-hour intensity. The 6-hour and 24-hour intensity values are obtained from isopluvials included in the above-cited reference.

An examination of the annual precipitation and intensity values shown in Table II reveals similarities and overlap between the areas described. The regions were rearranged grouping like areas to arrive at the list shown below.

Central Basin, Okanogan-Big Bend region and Palouse-Blue Mountains area

Northeast Olympic - San Juan area and Northeastern area

Puget Sound - Lowlands region

East Olympic - Cascade Foothills region

West Olympic - Coastal area

Cascade Mountains - West and East Slope - Cascade areas

It is suggested that selection of one monitoring site within each of the regions or group of regions shown above will permit characterization of the State's climate.

The initial site selection effort (Mar, 1977 and Horner et al., 1979) included sites in five of the groups shown above.

Central Basin, etc. - Tri-Cities Area

Northeastern, etc. - North Division St., Spokane

Puget Sound Lowlands - I-5 at N.E. 158th St., Seattle

East Olympic - Cascade Foothills - I-5 and I-205, Vancouver

Cascade Mountains West, etc., - I-90 at Snoqualmie Pass

Examination of weather data at the tentative sites indicates that the sites are fairly representative of the regions with the exception of Vancouver. Vancouver has an annual precipitation of about 35 to 40 inches which is at the extreme low end of the range for the East Olympic - Cascade Foothills region and is quite similar to the Puget Sound - Lowlands region. However, this should not detract from the study since both the Snoqualmie Pass site and the site

Table II: Annual precipitation and 1 and 6 hour intensities for climatic regions of Washington.

Region	Annual precipitation inches (cm)	1-hour intensity 2-yr. return period inches/hr. (cm/hr.)	6-hour intensity[1] 2-yr. return period inches/6 hr. (cm/6 hr.)
Central Basin	7-15 (17.8 - 38.1)	0.25-0.30 (0.64 - 0.76)	0.60⁻ - 0.80 (1.52⁻-2.03)
Okanogan-Big Bend	11-16 (27.9 - 40.6)	0.26-0.35 (0.66 - 0.89)	0.60 - 0.80 (1.52 -2.03)
Palouse-Blue Mtns.	10-20 (25.4 - 50.8)	0.30-0.55 (0.76 - 1.40)	0.60 - 1.30 (1.52 -3.30)
N. E. Olympic-San Juan	18-30 (45.7 - 76.2)	0.35-0.48⁺ (0.89 - 1.22⁺)	0.70⁻ - 0.95 (1.78⁻-2.41)
Northeastern	17-28 (43.2 - 71.1)	0.35-0.40 (0.89 - 1.02)	0.70 - 1.20 (1.78 -3.05)
Puget Sound Lowlands	32-45 (82.3 - 114)	0.35-0.40 (0.89 - 1.02)	0.80 - 1.10 (2.03 -2.79)
E. Olympic-Cascade Foothills	40-90 (101 - 228)	0.45-0.55⁺ (1.14 - 1.40⁺)	1.00 - 2.00⁺(2.54 -5.08⁺)
W. Olympic-Coastal	70-100⁺ (178 - 254⁺)	0.50-0.82⁺ (1.27 - 2.08⁺)	1.60 - 3.20 (4.06 -8.13)
Cascade Mtns.-West	60-100 (152 - 254)	0.55-0.61⁺ (1.40 - 1.55⁺)	1.10 - 2.20 (2.79 -5.59)
East Slope Cascades	20-90 (51 - 229)	0.30-0.60 (0.76 - 1.52)	0.80 - 2.20 (2.03 -5.59)

Notes:
1. Taken from isopluvials of 2-yr., 6-hr. precipitation map (National Weather Service, 1973).
2. Estimated from equations and values from 6-hr. and 24 hr. isopluvial precipitation maps (National Weather Service, 1973)

selected in the West Olympic - Coastal region will provide data on areas of heavier rainfall. The Vancouver area also presents a unique opportunity to compare a high and low volume freeway, I-5 and I-205, under generally the same geographic and climatic conditions.

Other potential locations in the East Olympic-Cascade Foothills region which would experience greater annual precipitation than Vancouver include: SR-14 east of Washougal, SR-12 east of I-5, or I-5 north of the Longview-Kelso area. One of these sites could be selected if there appears to be a void in the data.

To complete the site selection a site should be selected in the West Olympic-Coastal region to represent an area with high annual precipitation and little snowfall. A tentative site in the Aberdeen-Hoquiam area is recommended.

Other climatic factors which may affect the quality of highway runoff include wind, temperature and humidity. The sites described above give a fairly representative sampling of these factors. The western Washington sites will have fair temperatures, high humidity, generally low winds and most of the precipitation in the form of rainfall. The I-90, Snoqualmie Pass, site should have a broad range in temperatures and a significant amount of precipitation in the form of both rain and snow. The eastern Washington sites will exhibit high temperatures in the summer and low temperatures in the winter, low humidity and in some locations significant wind activity, e.g., Tri-Cities.

HIGHWAY AND TRAFFIC CHARACTERISTICS

The major highways of the State are surfaced with Portland cement concrete (PCC) or asphalt concrete (AC). A significant number of secondary highways, primarily in eastern Washington, are surfaced with bituminous surface treatment (BST). A small number of State Highways are surfaced with gravel or only soil. PCC is used primarily on interstate highways and highways in the urban environment. These highways tend to have higher traffic volumes and more elaborate drainage systems. In urban areas the highways generally have closed sewer drainage systems.

The sites selected will include both PCC and AC pavements. No attempt will be made to locate a site with BST, gravel or soil because of low traffic volumes. Ideally sites will be chosen which will allow comparison between PCC and AC pavements on the east and west portions of the State. This situation would also allow some evaluation as to whether climate has an effect on the loading from each pavement type. One site on each side of the State should be chosen which will give a mix of impervious and pervious areas. Care should be taken to obtain sites with typical surface conditions avoiding new pavements or pavements exhibiting substantial wear. Each district should verify that no construction or resurfacing is to take place within the time frame of the scheduled monitoring program.

Existing Washington State highways have average daily traffic volumes ranging from a very few vehicles, 50 on State Route (SR) 140, to approximately 182,600 vehicles on I-5, between Mercer Street and the junction with SR 520 (Washington State Transportation Commission, 1977). The section of I-5 between Mercer Street and SR 520 has a total of 16 traffic lanes, the maximum number of lanes for an existing highway in the State. The percentage of vehicles represented by trucks ranges from zero on some highways to about 36 percent on portions of SR 101.

With the range in traffic volumes and number of lanes on Washington highways, sites can be chosen to represent a broad range of conditions.

The ranges of average daily traffic values used in the Envirex study (Gupta et al., 1978) are shown below:

Less than 20,000 ADT

20,001 to 35,000 ADT

35,001 to 50,000 ADT

50,001 to 80,000 ADT

Greater than 80,001 ADT

The tentative sites and corresponding traffic volumes for this study are:

SR-12 as Pasco; 6,400 ADT

I-205 at Vancouver; 11,200 - 12,600 ADT

SR-101 at Aberdeen-Hoquiam; 13,700 - 14,600 ADT

I-90 at Snoqualmie Pass; 14,000 - 15,200 ADT

SR-2 (North Division St.) at Spokane; 29,000 ADT

I-5 at N.E. 158th St. at Seattle; 60,000 ± ADT

Other potential sites are:

SR-14 east of Washougal; 2,700± ADT

SR 12 east of I-5; 4,000 ± ADT

I-5 north of Longview-Kelso area; 22,000 - 26,000 ADT

Review of the above traffic volumes reveals all ranges are represented with the exception of 35,001 to 50,000 and greater than 80,001 ADT. Since specific sites are not known at this time no attempt will be made to select additional tentative sites to fill these gaps. The traffic volumes should be reviewed after all sites are located and a determination made as to whether additional sites are necessary.

No attempt will be made to control vehicular mix, number of lanes, ramps, etc., or vehicular speed. However, as mentioned in the introduction to this report, highway slopes will influence pollutant buildup and washoff and must be recorded to use in the analysis of the data. Other details, such as braking and acceleration by vehicles, may affect pollutant loadings deposited by the vehicles or wear of the roadway surface and should be considered in evaluating different loadings or coefficients for the model at specific sites.

DRAINAGE CHARACTERISTICS

This study is primarily concerned with analyzing only the runoff from the highway; therefore sites will generally be selected which will preclude runoff from adjacent land. The drainage area should be well-defined in order to determine areal loadings of pollutants; rainfall-runoff relationships and time of concentration.

The proposed composite sampler has a volume of about 48 cubic feet (1.36 cubic meters). The flow splitter, presently being used, withdraws 1/100 of the total flow; therefore, the total volume of runoff from the highway should not exceed 4,800 cubic feet (136 cubic meters). However, it should be noted that the flow splitter can be altered to sample any desired percentage of the total flow. Based on the maximum rainfall anticipated during the monitoring period and the estimated runoff coefficient, the maximum desired drainage area size can be determined.

In environs with high rainfall and small loadings of some pollutants, it may be necessary to collect more than one composite sample or to use a larger sample container to obtain a representative sample.

The drainage area should not be in a depressed section (cut section) because of the undesirability of pumping the sample from the collection device to the container. The preferable situation is for the drainage area to be elevated so that the flow splitter and composite sample tank can be located down grade from the roadway (gravity system). Figure 2 shows the preferred installation.

In eastern Washington, particularly, curbed or guttered sections of highway are scarce. It may be necessary to construct a collection device such as slotted pipe along the shoulder or to collect from a drainage area containing both impervious and pervious surfaces. The latter situation would also allow some evaluation of constituents and concentrations from the entire highway right-of-way versus just from the paved surfaces.

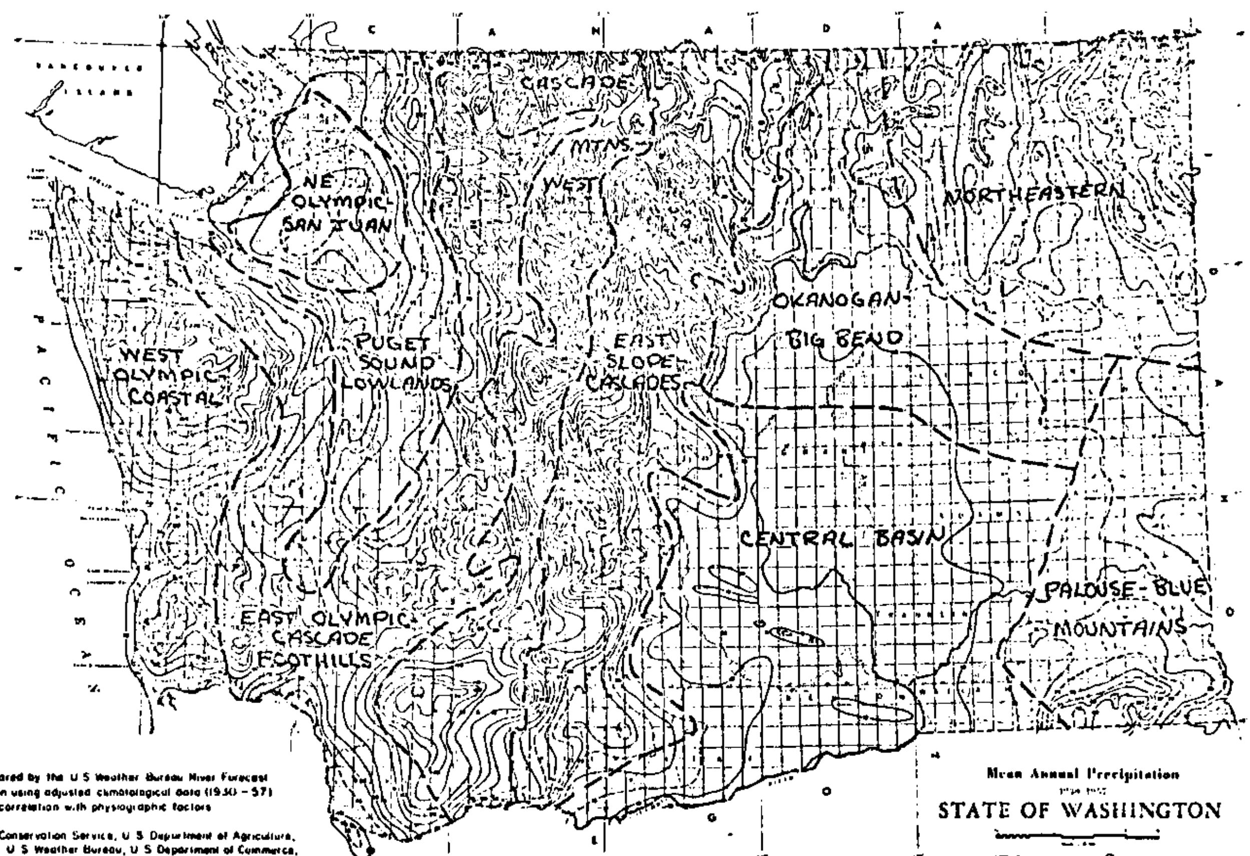
With installations where it is anticipated that special studies will be conducted using the discrete samplers, care should be taken to insure that critical flows in drainage structures will be avoided at the point of sampling.

ACCESSIBILITY, SAFETY AND MAINTENANCE CONSIDERATIONS

Ease of accessibility should be considered in the site selection. The sites must be serviced by monitoring personnel after each storm and some equipment maintenance may be necessary between storms. Safety of access should also be of prime concern. The sampling site preferably should be removed from the immediate proximity of the roadway, i.e., behind a guardrail section.

Present plans provide for WSDOT personnel to collect samples and perform routine maintenance at sites removed considerable distances from the University of Washington. While not critical, sites should be located in close proximity to a Project Engineer's office. District personnel can provide office locations.

Vandalism is a potential problem. Sites should be located within State right-of-ways, preferably in areas where fencing is present. Monitoring instrumentation should be in locked containers. This is a critical consideration in the case of a fully automated site. The I-5 site in Seattle has a metal shed which is ideal for instrument storage.



Isohyetal analysis prepared by the U S Weather Bureau River Forecast Center, Portland, Oregon using adjusted climatological data (1930 - 57) and values derived by correlation with physiographic factors

Published by the Soil Conservation Service, U S Department of Agriculture, in cooperation with the U S Weather Bureau, U S Department of Commerce, March 1965

Mean Annual Precipitation

STATE OF WASHINGTON

Figure 2

The storage capacity required for a composite sample site is much less than that required for an automated site, but provisions for some storage is still desirable for the recording rain gage and maintenance tools, extra sample bottles and other supplies.

The availability of power to composite sampling sites is not crucial to site selection. The minor amount of instrumentation required can be operated by battery or a spring wound mechanism. The availability of electrical power should be given more consideration if it is anticipated that automatic sampling may also be used at the site. Most of the automatic equipment can also be operated with battery power but electrical power reduces the maintenance requirements of charging batteries, etc. The availability of water is an important consideration to facilitate testing of the systems.

Prior to establishing a site, WSDOT district personnel should be contacted to insure that no construction projects are planned within the selected site drainage area during the proposed monitoring period. District maintenance personnel should be contacted regarding routine maintenance activities and frequencies. It would be well to have maintenance personnel report their activities in the proximity of site on some periodic basis. Consideration should be given to curtailing maintenance activities unless it is the intent to study the effects of maintenance operations.

LAND USE, GEOGRAPHIC AND TOPOGRAPHIC FEATURES

Since the major emphasis is on selecting sites which will allow sampling of runoff only from the highway, the mix of land uses is relatively insignificant. Adjacent land uses could include agricultural, residential, industrial, commercial, park, natural or undeveloped, etc. To select sites which would include every possibility is prohibitive.

The primary distrinction in regard to land use will be urban vs. rural. Dustfall and traffic movements, particularly in relation to speed, will be the most significant differences in these sites. A rural site in eastern Washington will also most likely have agriculture as the primary land use.

Land uses at each site will be recorded for possible use in examining variances in pollutant concentrations and/or loadings.

Sites should be selected to represent different geographic regions of the State. The sites as described in the Climate section of this report give a good cross section of the different geographic regions of the State including the four corners of the State, the coastal region and the central basin.

The sites represent level, rolling and mountainous areas and have a broad range in elevations. Aberdeen is very near sea level, elevation approximately 13 feet, Spokane has an elevation of about 1,900 feet and the summit of Snoqualmie Pass is 3,022 feet above sea level.

CONCLUSIONS

This report has concluded that with the collection of proper support data (continuous traffic volumes, continuous precipitation data and period of runoff) composite sampling data is comparable to discrete sampling data for determining total pollutant loadings from highways and to validate the Envirex model in Washington State sites. To document maximum concentrations and their temporal patterns, discrete sampling may be necessary at selected sites.

Based on the site selection criteria, particularly weather, a minimum of six (6) sampling sites at specific locations is necessary to characterize highway runoff in the State of Washington. The recommended locations are:

SR-12 at Pasco

I-5 at Seattle

I-5 and/or I-205 at Vancouver

SR-2 at Spokane

I-90 on Snoqualmie Pass

SR-101 at Aberdeen-Hoquiam

While the site at Pasco has some potential problems, an arid climate site is essential to the study and it is recommended that this site be monitored for a long-term period and that monitoring be conducted on an annual basis.

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