APPRAISAL OF STORM-WATER QUALITY NEAR SALEM, OREGON

By Timothy L. Miller

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 87-4064

Prepared in cooperation with
THE CITY OF SALEM, OREGON and
THE MID-WILLAMETTE VALLEY COUNCIL OF GOVERNMENTS

Portland, Oregon
1987

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary
U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information write to:

Oregon Office Chief
U.S. Geological Survey
847 N.E. 19th Avenue, Suite 300
Portland, Oregon 97232

Copies of this report can be purchased from:

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CONVERSION FACTORS, INCH-POUND TO METRIC

For the use of readers who prefer to use metric (International System) units rather than the inch-pound terms used in this report, the following conversion factors may be used:

Multiply inch-pound units	By	To obtain metric units
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233.	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
pound per day (lb/d)	0.4536	kilogram per day (kg/d)
ton per day (ton/d)	907.2	kilogram per day (kg/d)
	Specific Conductance	
micromhos per centimeter at 25° Celsius (μm/cm at 25° C)	1.000	microsiemens per centimeter, at 25° Celsius (μS/cm at 25° C)

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ABSTRACT

Storm-water runoff for the period December 1979 to May 1981, at 13 sites (12 basins) in the vicinity of Salem, Oregon, was sampled and analyzed for water quality. Constituent concentrations for urban storm water were relatively small when compared to samples from Portland and Medford, Oregon and to samples from Denver, Colorado. The data indicated that levels of suspended sediment, ultimate CBOD (carbonaceous biochemical oxygen demand), and total lead increased with increased urbanization. Much of the suspended sediment and related turbidity result from transport of basin soils rather than from the wash-off of dry fallout solids from impervious areas. Because of small chemical concentrations and winter high-flow and low-temperature conditions in the Willamette River, Salem storm water probably has little effect on biological or on most chemical conditions in the Willamette River.

An analysis of data from a storm-water detention pond (originally designed to reduce peak flows) indicated that the facility was about 47 percent efficient in reducing suspended-sediment loads. The facility also reduced such sediment-related constituent loads as total lead and total phosphorus. Total Kjeldahl nitrogen and ultimate CBOD loads that are transported mostly in the dissolved phase were not measurably affected by the detention pond.

Precipitation samples collected at one site for a year were found to be acidic, with a median pH of 4.6 units. Median total lead concentration was 8 micrograms per liter in precipitation, whereas the median total lead concentration in runoff from the 12 basins ranged from 8 to 110 micrograms per liter. The median dissolved ammonia concentration in precipitation was larger than the median dissolved ammonia concentration at all 13 sites. In contrast, the median total Kjeldahl nitrogen concentration in precipitation samples was about half the median for stream-water concentrations. Median ratios of sulfate to chloride and nitrate to chloride in precipitation were much higher than ratios expected for sea water, suggesting anthropogenic sources for sulfate and nitrate.

INTRODUCTION

Studies in many parts of the United States have shown that urban storm-water runoff can be a significant source of contamination of receiving streams (Lager and Smith, 1974) and that urbanization can increase storm runoff volumes by a factor of two, comparing unurbanized to fully urbanized land use (Laenen, 1980). One example is the sedimentation problem caused by the rapid conversion of land to urban uses. Yorke and Davis (1971), for instance, found sediment concentrations during urbanization of a Maryland basin to be 12 times higher than concentrations prior to construction.

In recent years the City of Salem, Oregon, and the surrounding suburban areas have experienced rapid development. The 1980 population of the area was estimated to be 105,000, a substantial increase above the 1978 estimate of 90,000. In order to manage urbanization, the City of Salem established an Urban Growth Boundary Area (UGBA, see Glossary), where development is encouraged (fig. 1). Fast population growth, along with recognition that urbanization could affect storm-water runoff quality, led to a cooperative study to investigate runoff quality in and near Salem, Oregon. Of particular interest were the range of concentrations for water-quality constituents during storm events and the possible effects on receiving-water quality. Also of interest was the possible enhancement of storm-water runoff quality by storm-water detention structures. In 1979 personnel from the City of Salem, the Mid-Willamette Valley Council of Governments, and the U.S. Geological Survey began to collect storm-runoff samples in different land-use areas on a reconnaissance basis. This final project report identifies sites and presents analyses of data collected at all reconnaissance sites in the Salem area.

Study Setting

Salem is in the middle of the Willamette Valley, which is bordered by the Cascade Range on the east and the Coast Range on the west. The UGBA encompasses both the relatively flat Willamette River flood plain northeast of Salem and the rolling uplands known as Salem Heights in the southwestern part of the UGBA. Within the UGBA, the predominant land uses are single family residential, rural, agricultural, and vacant (undeveloped). Altitudes range from about 200 ft at the city of Salem to about 1,000 ft in the Salem Heights area. (See Glossary for discussion of "Sea Level.")

The climate of Salem is influenced by the proximity of the Pacific Ocean; winters are cool and moist as the result of the influx of marine air. The average annual precipitation at the Salem weather station is 41 inches; most of the precipitation is in the form of gentle rain which occurs between November and May.

Objectives and Scope

The objectives of this reconnaissance study were to (1) describe the quality of storm-water runoff in the Salem area; (2) determine the transferability of data between Salem and Portland, cities which have similar climatic regimes and land uses; (3) study the effects of detention storage on water quality; and (4) compare the quality of precipitation to the stream-water quality. This report addresses the four study objectives, using reconnaissance data collected in 12 basins with varying land uses and intensities of urbanization. The focus of this report is storm-water runoff quality. A companion study (Laenen, 1983) focused on storm-water runoff quantity.

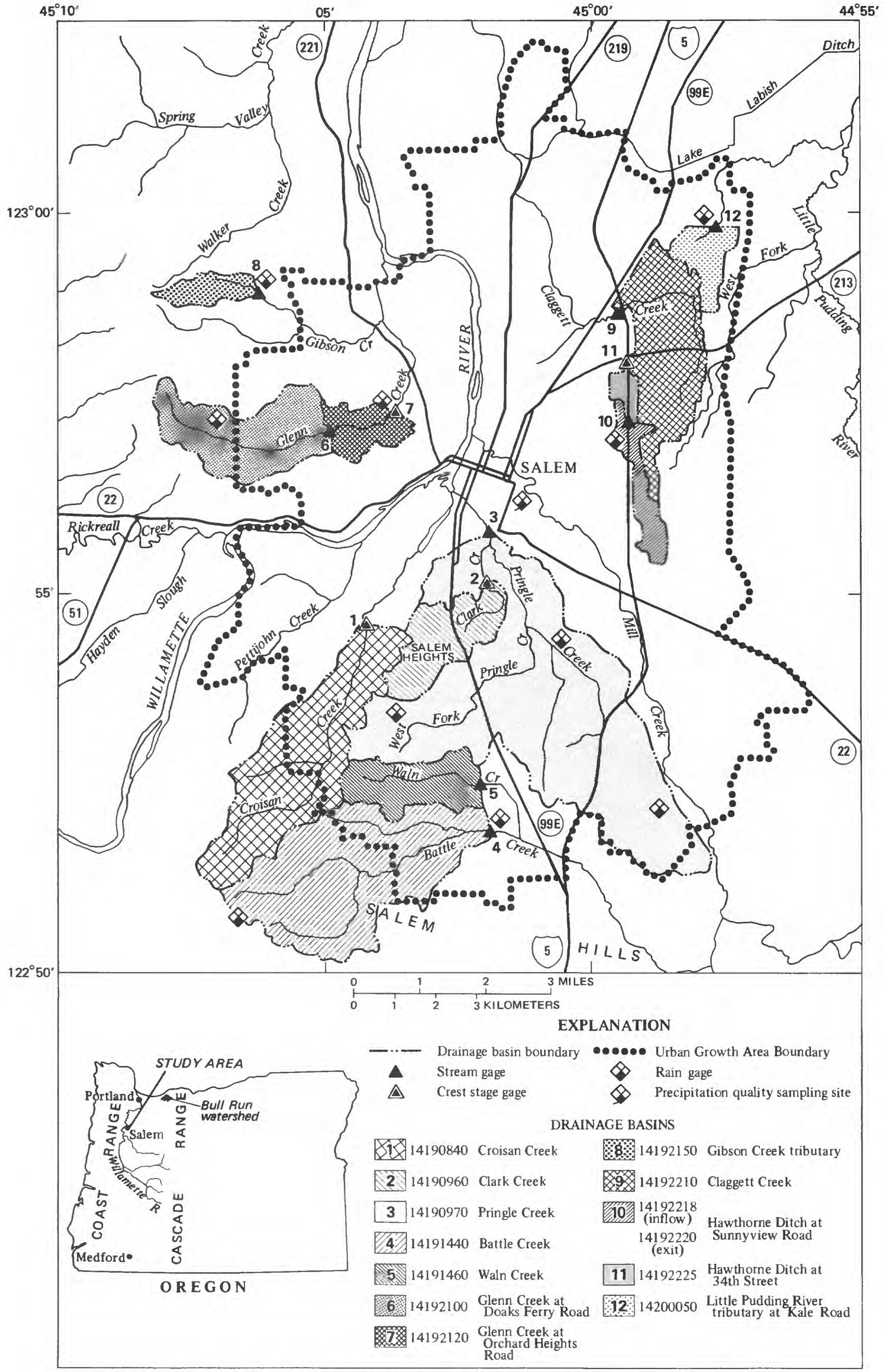

FIGURE 1.--Map showing basin locations and gage sites.

Originally, a fifth objective was considered, that of modeling storm-water quality from four basins to be selected on the basis of the reconnaissance data. However, when the preliminary data were examined, the few constituents (lead, suspended sediment, fecal coliform bacteria) exhibiting high concentrations indicated that modeling success for the other constituents would be marginal. Because of high costs likely to be incurred for instrumentation and analyses needed to provide sufficient data, water-quality modeling was not considered cost-effective and was eliminated as an objective.

Acknowledgments

This study was done in cooperation with the City of Salem and the Mid-Willamette Valley Council of Governments. The author thanks the personnel from both the City and the Council who helped collect samples and who supplied land-use data.

HYDROLOGIC DATA COLLECTION

Site Selection

Site (station) selection involved choosing basins that would provide data on the wide range of basin sizes, land uses, and topographic features in the Salem area. Specific sampling sites within each basin were chosen for collection of accurate streamflow data. In all, 13 sites in the 12 basins were selected for sampling. In the Hawthorne Ditch basin, two of the sampling sites (stations 14192218 and 14192220) were located at the inlet and outlet pipes of a detention-storage facility in order to determine the effects of detention storage on water quality. The precipitation-quality sampling site was located near the center of the UGBA (fig. 1).

Basin Characteristics

The basin characteristics determined for this study are listed in table 1; a definition, or method of determination, for each characteristic is provided in the Glossary. Though many land uses change over time, the percentage change in the 18-month period of this study generally would be within the measurement accuracy.

Runoff Data

Runoff data at continuous recording sites (fig. 1) were collected at 5-minute intervals to the nearest 0.01 foot of stage and converted to discharge with a theoretical stage-discharge relation. At those crest-stage gage sites where water-quality samples were obtained, stage was observed and recorded as the samples were collected. Stage for these sites was then converted to discharge using a theoretical rating. Periodic discharge measurements were made at all sites to verify the stage-discharge relation. A description of the instruments and methods used for runoff data collection can be found in a report of a similar study for Portland, Oregon (Laenen and Solin, 1978).

Table 1.--Characteristics of drainage basins monitored near Salem, Oregon

Characteristics: D.A = drainage area; B.S. = basin slope; C.L. = channel length; C.S. = channel slope; and I.A. = impervious area

Land use: SFR = single family residential; MFR = multifamily residential RUL = rural (parks); AG = agricultural; COM = commercial; IND = industrial; AUC = area under construction; VAC = vacant land (undeveloped)

Measurements: mi^2 = square miles; mi = miles; pct = percent

Station number	Station name	D.A. (mi^2)	B.S. (pct)	C.L. (mi)	C.S. (pct)	I.A. (pct)	Land use, in percent SFR	MFR	RUL	AG	COM	IND	AUC	VAC	Hydrologic soil group[1/], in percent A	B	C	D
14190840	Croisan Cr	4.54	15	5.2	2.2	4	6	0	19	27	0	0	1	47	0	0	98	2
14190960	Clark Cr	1.69	7.5	2.8	2.2	34	66	6	2	0	7	0	0	19	0	0	98	2
14190970	Pringle Cr	12.6	2.9	6.4	.6	22	28	2	10	20	7	4	1	28	0	3	90	7
14191440	Battle Cr	5.56	13	4.7	1.6	2	0	0	21	40	0	0	0	39	0	0	100	0
14191460	Waln Cr	1.47	9.5	2.3	1.3	12	14	0	47	10	0	0	8	21	0	0	100	0
14192100	Glenn Cr at Doaks Ferry Rd	2.51	13	3.2	4.4	6	10	0	1	69	0	0	2	18	0	1	97	2
14192120	Glenn Cr at Orchard Hts Rd	3.31	18	4.4	3.4	8	16	1	0	61	1	0	2	19	1	2	93	4
14192150	Gibson Cr Trib	.54	12	1.8	6.8	2	0	0	0	74	0	0	0	26	0	0	100	0
14192210	Claggett Cr	3.08	1.3	4.8	.2	27	45	5	14	2	10	1	0	23	0	1	78	21
14192218	Hawthorne Ditch at Sunnyview Rd (inflow)	.80	1.0	2.4	.2	53	29	10	2	0	38	1	1	19	0	0	87	13
14192220	Hawthorne Ditch at Sunnyview Rd (exit)[2/]																	
14192225	Hawthorne Ditch at 34th St	1.40	1.0	3.4	.2	45	34	7	2	0	29	2	1	25	0	0	91	9
14200050	Little Pudding River Trib. at Kale Rd.	.75	.5	1.6	.1	20	53	0	2	35	0	0	5	5	0	0	85	15

1/ See descriptions in glossary.

2/ Basin characteristics for the drainage upstream from the exit site are the same as for the inflow site.

Water-quality Sampling

Storm-water Samples

Depth- and width-integrated water-quality samples were collected between December 1979 and May 1981 at each of 13 sites, using a suspended-sediment sampler (US DH-48TM). Cross-sectional water samples were composited into a 2-liter bottle and aliquots were sent to the Geological Survey Central Laboratory in Arvada, Colorado for analysis of the constituents shown in table 2. Separate samples were collected for determinations of suspended sediment and ultimate CBOD (carbonaceous biochemical oxygen demand). Water for bacteria analysis was collected from near the center of flow by dipping a sterile bottle just below the water surface. At each site, an attempt was made to collect at least one water-quality sample from each stage (rising, peak, and falling) of the sampled storm. Generally, one to three samples were collected for each storm at a particular site. The overall primary emphasis at each site, however, was to collect samples near the peak discharge; the maximum concentration was expected to occur near peak flows (Miller and McKenzie, 1978).

Detention Facility Samples

The detention facility selected for sampling is an on-line detention pond located on Hawthorne Ditch at Sunnyview Road (between sites 14192220 and 14192218 on map figure 1). This particular detention facility was selected because it activates frequently, is relatively easy to sample, and the drainage basin upstream is extensively urbanized. The detention-storage facility is triangular in shape, with an 8-ft diameter inflow pipe (fig. 2) and a 4.5-ft diameter outflow pipe. The storage capacity of the detention pond is about 2.3 acre-ft when the outflow pipe is fully submerged. No residual water storage is maintained in the facility during low flow because the outflow pipe fully drains the storage area. The storage area has a soil bottom that is mostly covered with vegetation (fig. 3).

Water-quality samples were collected simultaneously at the inflow and outflow pipes during four storm events. Outflow at the time of sampling was obtained directly from the stage-discharge relation developed for the outflow culvert. Inflow at the time of sampling was computed by combining the average outflow discharge with the change in detention storage volume.

Precipitation Samples

Precipitation samples were collected at one site (see fig. 1) for 1 year to measure precipitation quality. The samples were composites of weekly precipitation collected using an Aerochem Metrics standard model 301 automatic wet-dry deposition collector[1]. The precipitation collection vessel remained covered during dry periods so that evaporation was minimized and dry fallout did not accumulate with the precipitation.

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[1] The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 2.--Maximum, minimum, and median values of selected constituents for storm-water sites in Salem, Oregon

[N = number of samples. CBOD = carbonaceous biochemical oxygen demand. COD = chemical oxygen demand. "K" indicates non-ideal bacteria count. Constituents are given in units of mg/L, except for the following: fecal coliform in colonies per 100 milliliters; specific conductance in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25 °C); total lead in micrograms per liter (μg/L); and turbidity in Jackson Turbidity Units]

Station name and number	Turbidity				Suspended sediment				Specific conductance				Ultimate CBOD				COD			
	N	med	min	max	N	med	min	max	N	med	min	max	N	med	min	max	N	med	min	max
Croisan Cr 1/ 14190840	2	--	190	260	2	--	516	631	2	--	56	60	1	--	--	8.5	1	--	--	72
Clark Cr 14190960	6	50	3	160	7	181	8	738	6	58	42	129	5	3.6	1.5	5.3	3	29	9	44
Pringle Cr 14190970	9	75	5	130	9	112	13	410	8	60	39	133	9	3.2	2.0	4.4	6	22	6	39
Battle Cr 14191440	9	75	7	160	9	163	6	269	8	32	21	53	9	2.6	1.1	4.2	5	26	7	41
Waln Cr 14191460	8	105	3	420	8	88	7	757	7	34	21	55	8	1.6	1.1	2.6	5	18	6	46
Glenn Cr at Doaks Ferry Rd 14192100	7	70	15	490	7	90	8	794	6	52	35	97	7	3.0	1.4	3.6	5	21	6	98
Glenn Cr at Orchard Hts Rd 14192120	8	92	30	450	8	76	21	572	7	51	37	114	8	3.6	0.9	5.2	5	19	8	26
Gibson Cr 14192150	3	250	14	410	3	474	9	1670	3	38	34	65	3	1.7	.8	2.6	2	--	6	20
Claggett Cr 14192210	7	95	4	140	7	161	9	315	7	27	24	281	7	6.2	4.4	8.1	5	44	23	97
Hawthorn Ditch at Sunnyview Rd (inflow) 1/ 14192218	19	45	1	75	24	68	5	256	18	54	17	267	19	5.6	1.8	45	14	38	11	150
Hawthorn Ditch at Sunnyview Rd (exit) 2/ 14192220	10	35	20	65	15	38	30	93	10	66	44	109	9	9.9	5.1	32	9	43	13	93
Hawthorn Ditch at 34th St 1/ 14192225	5	40	30	50	5	53	21	89	5	24	19	30	5	5.1	4.2	8.1	3	34	21	45
Little Pudding River Trib at Kale Rd 1/ 14200050	8	28	20	240	8	22	12	294	8	25	21	52	6	3.6	2.8	6.6	4	32	12	47

1/ Site for which no base-flow sample was collected.

2/ Because of the effects of detention storage on concentrations, data for this site were not used for comparison to other basins or to test relations with basin characteristics.

Table 2.--Maximum, minimum, and median values of selected constituents for storm-water sites in Salem, Oregon--Continued

Station name and number	Dissolved NH_4 as N				Total Kjeldahl nitrogen as N				Dissolved $NO_2 + NO_3$ as N				Total phosphate as P				Dissolved phosphase as P			
	N	med	min	max	N	med	min	max	N	med	min	max	N	med	min	max	N	med	min	max
Croisan Cr[1/] 14190840	2	--	0.05	0.13	2	--	0.82	3.1	2	--	0.72	1.7	2	--	0.14	0.18	2	--	0.05	0.06
Clark Cr 14190960	3	0.03	.00	.05	3	1.5	.69	1.8	3	0.81	.66	1.4	2	--	.04	.44	3	0.04	.01	.06
Pringle Cr 14190970	5	.03	.00	.38	6	1.2	.46	2.6	5	1.3	.46	1.9	6	0.20	.04	.37	5	.02	.00	.15
Battle Cr 14191440	5	.00	.00	.07	6	0.93	.51	2.0	5	.93	.34	1.4	6	.19	.02	.32	5	.02	.00	.03
Waln Cr 14191460	4	.04	.00	.09	5	.95	.54	1.9	4	.70	.33	.81	5	.13	.03	.45	4	.02	.00	.03
Glenn Cr at Doaks Ferry Rd 14192100	4	.04	.00	.07	6	.83	.51	2.6	4	.54	.42	1.8	6	.05	.03	.57	4	.03	.02	.05
Glenn Cr at Orchard Hts Rd 14192120	5	.05	.00	.06	6	.67	.49	2.4	5	.62	.28	1.9	6	.09	.04	.65	5	.03	.00	.07
Gibson Cr 14192150	2	--	.00	.06	3	1.9	1.0	2.4	2	--	.99	2.3	3	.41	.05	.55	2	--	.01	.01
Claggett Cr 14192210	4	.02	.00	.05	5	.64	.45	1.6	5	.15	.00	.73	5	.15	.13	.45	4	.09	.04	.10
Hawthorn Ditch at Sunnyview Rd (inflow)[1/] 14192218	13	.10	.00	.42	16	.91	.57	2.4	13	.29	.16	.90	16	.21	.05	.51	13	.08	.07	.21
Hawthorn Ditch at Sunnyview Rd (exit)[2/] 14192220	8	.10	.06	.39	10	1.0	.83	1.7	8	.27	.15	.35	10	.18	.05	.45	8	.11	.02	.18
Hawthorn Ditch at 34th St[1/] 14192225	2	--	.03	.06	2	--	.74	.97	2	--	.14	.26	2	--	.10	.11	2	--	.08	.09
Little Pudding River Trib at Kale Rd[1/] 14200050	3	.04	.03	.05	4	.68	.40	1.9	3	.11	.10	.90	4	.13	.10	.72	3	.08	.07	.09

1/ Site for which no base-flow sample was collected.

2/ Because of the effects of detention storage on concentrations, data for this site were not used for comparison to other basins or to test relations with basin characteristics.

Table 2.--Maximum, minimum, and median values of selected constituents for storm-water sites in Salem, Oregon--Continued

Station name and number	Dissolved organic carbon				Suspended organic carbon				Total lead				Fecal coliform bacteria				Dissolved solids			
	N	med	min	max	N	med	min	max	N	med	min	max	N	med	min	max	N	med	min	max
Croisan Cr 14190840 [1/]	2	--	4.1	6.5	2	--	3.2	3.5	2	--	35	44	1	--	--	2200	1	--	--	44
Clark Cr 14190960	3	1.9	1.1	2.6	3	1.6	0.1	2.3	2	--	10	150	1	--	130	--	3	68	39	74
Pringle Cr 14190970	4	2.5	1.7	2.8	4	1.3	.2	3.1	4	16	8	130	2	--	K200	K4500	3	64	45	78
Battle Cr 14191440	3	1.1	1.1	1.5	2	--	.1	1.9	4	8	4	50	2	--	120	K800	3	26	18	36
Waln Cr 14191460	4	0.7	0.5	0.9	2	--	1.0	2.4	4	18	7	60	1	--	160	--	3	24	15	30
Glenn Cr at Doaks Ferry Rd 14192100	2	--	1.2	1.3	1	--	.3	--	5	14	3	60	3	K3200	770	K3600	1	--	--	34
Glenn Cr at Orchard Hts Rd 14192120	2	--	1.2	1.9	1	--	--	2.5	5	15	7	60	3	K1700	K840	K5400	3	47	40	50
Gibson Cr 14192150	2	--	1.2	4.8	2	--	.1	1.2	2	--	14	50	2	--	52	1200	2	--	39	39
Claggett Cr 14192210	4	6.6	3.8	9.4	3	0.8	.4	2.7	5	90	16	130	2	--	K38	K1700	2	--	17	28
Hawthorn Ditch at Sunnyview Rd (inflow) 14192218 [1/]	6	4.9	.8	8.3	6	1.5	.1	2.5	15	110	12	370	6	1050	76	5700	7	60	13	78
Hawthorn Ditch at Sunnyview Rd (exit) 14192220 [2/]	3	4.7	4.5	7.0	3	.7	.2	3.5	8	86	66	370	2	--	K1000	K1200	6	64	40	75
Hawthorn Ditch at 34th St 14192225 [1/]	1	--	--	5.9	1	--	--	1.5	3	110	60	170	1	--	--	630	1	--	18	--
Little Pudding River Trib at Kale Rd 14200050 [1/]	2	--	4.0	6.0	2	--	1.0	1.1	4	26	12	60	3	1600	K50	K6300	5	28	14	62

1/ Site for which no base-flow sample was collected.

2/ Because of the effects of detention storage on concentrations, data for this site were not used for comparison to other basins or to test relations with basin characteristics.

FIGURE 2.--Inflow to Hawthorne Ditch detention basin.

FIGURE 3.--Hawthorne Ditch detention basin with outflow culvert at far end of pond.

Precipitation and stream-water samples were analyzed chemically for many of the same constituents. Analyses were made on a priority basis, depending on available sample volume. The order of priority was pH, specific conductance, total lead, nitrogen and phosphorus, major anions and cations, organic carbon, and COD (chemical oxygen demand).

QUALITY OF STORM-WATER RUNOFF

Storm-water quality data were examined in relation to each of the four following considerations: (1) comparison of basins in the Salem area; (2) relation of storm-water quality to basin characteristics; (3) comparison of geographic areas, including Portland and Medford, Oregon, and Denver, Colorado; and (4) possible effects of runoff on the major receiving stream in the Salem area.

Because many of the data sets from most sites consisted of fewer than 10 observations per constituent, median values rather than averages (means) were used for making comparisons of sites, and medians were calculated only when there were three or more data points. No base-flow samples were collected at three of the sites; therefore, maximum and minimum values at these sites may compare poorly with sites where base-flow samples were collected. For example, the relatively high minimum suspended-sediment concentrations shown for Croisan Creek in table 2 resulted because no base-flow sample was collected at that site. When only one sample was obtained at a site, the resulting value was entered in either the maximum or minimum row, depending on how it compared with values from other sites.

Comparison of Basins

Basin comparisons were made for maximum constituent-concentration values for 13 of the 15 constituents listed in table 2. Maximum values of specific conductance and dissolved solids were not compared because these constituents had maximum values at base flow, reflecting the influences of ground-water inflow and not of storm-water runoff. All other constituent values tended to be higher during periods of rising or peak flow.

A comparison was made to determine which sites had the maximum constituent concentrations for the greatest number of constituents. Sites most affected by urbanization would normally be expected to have the greatest number of maximum values, but the results of the comparison were mixed. To represent urbanization, SFR and COM (see Glossary) land-use percentages were summed and listed following each site. Of the 13 sites, Hawthorne Ditch at Sunnyview Road (67 percent) had maximum values for 5 of the 13 constituents; Croisan Creek (6 percent), Gibson Creek (0 percent), and Little Pudding River at Kale Road (53 percent) had two maximum values each; and Claggett Creek (55 percent) and Glenn Creek at Doaks Ferry Road (10 percent) each had one maximum value. The Hawthorne Ditch Sunnyview Road site was the most urbanized among the sites listed above and had almost half the maximum values, which may be considered an indication of urbanization effects. Much of the urbanization could be due to the concentrated (38 percent COM) commercial land use, because other basins with considerable residential development (Clark Creek, 66 percent SFR) did not have similarly large concentrations. Additionally, the next downstream station on Hawthorne Ditch (34th Street) has an intervening drainage area that is less developed commercially (17 percent COM), and concentrations at that site are notably smaller than concentrations at Sunnyview Road.

Comparison also was made using the top two ranking maximum values for each constituent. Again, Hawthorne Ditch at Sunnyview Road was at the top of the list, with seven constituents that had either the highest or second highest maximum values. The Pringle Creek site had five consituents (four nutrient values), and all other sites had three or fewer constituents ranking among the top two maximum values.

Samples from the Hawthorne Ditch at Sunnyview Road basin yielded large concentrations of the following constituents: dissolved ammonia, dissolved phosphorus, CBOD, COD, dissolved organic carbon, total lead, and fecal coliform bacteria. The large concentrations were probably due to the extensive urbanization of the basin, especially commercial development adjacent to the drainage ditch. Generally, CBOD, COD, total lead, and fecal coliform bacteria are constituents or properties that increase in concentration as urbanization progresses. The water-quality data of table 2 suggest that Hawthorne Ditch at Sunnyview Road is the basin most significantly and consistently affected by urbanization.

Samples from the Pringle Creek basin yielded large concentrations of dissolved ammonia, total Kjeldahl nitrogen, dissolved nitrite and nitrate, dissolved phosphorus, and suspended organic carbon. These constituents are generally associated with the fertilization of agricultural and urban areas with organic and inorganic chemicals. Thus, the source of the nutrients could be either urban or non-urban.

Relation to Basin Characteristics

Because constituents exhibited a wide variation of values between sites, comparisons of basin characteristics to median storm-water quality values were made for selected constituents or properties. Results of these comparisons, which indicate whether individual comparisons show a relation and whether the relation is positive or negative, are listed in table 3. The relations were determined using Spearman's rank correlation coefficient (Conover, 1980, p. 252); correlations significant at the 95-percent level and the 90-percent level are shown. Because the number of observations was generally less than 10, correlations with the higher level of confidence are of particular interest. Basin characteristic values and median storm-water values are shown in tables 1 and 2. A minimum of three observations per constituent or property per site were required for calculation of a median value and inclusion in the correlation analysis.

The land uses that most frequently related to constituent concentrations were multifamily residential land use, commercial land use, agricultural land use, and single-family residential land use. The impervious area category also exhibited several significant correlations. In addition, two hydrologic soils groups (C and D; see Glossary) showed correlations with several constituents. Comparisons of median constituent concentrations with physical basin characteristics resulted in correlations with basin slope and channel slope, two characteristics that are highly correlated.

Of the correlations significant at the 95-percent confidence level, the urban land uses (SFR, MFR, and COM) exhibited positive correlations in each case (table 3), except for the comparison of SFR with median turbidity, which showed a negative correlation and will be discussed later. Urbanization appears to contribute to increases in concentrations of COD, total lead, and ultimate CBOD. Agricultural land use correlates negatively with CBOD and total lead and also with COD, but at a lower confidence level.

TABLE 3.--Comparisons of median constituent concentrations and basin characteristics

Physical characteristics:
- D.A. = drainage area
- B.S. = basin slope
- C.L. = channel length
- C.S. = channel slope
- I.A. = impervious area

Land uses:
- SFR = single family residential land use
- MFR = multifamily residential land use
- RUL = rural land use (parks)
- AG = agricultural land use
- COM = commercial land use
- IND = industrial land use
- VAC = vacant land (undeveloped)

Correlations:
- \+ = positive correlation, 95-percent confidence
- (+) = positive correlation, 90-percent confidence
- \- = negative correlation, 95-percent confidence
- (-) = negative correlation, 90-percent confidence

Blank implies no trend determined

Median constituent concentrations	Number of samples	Physical characteristics D.A.	B.S.	C.L.	C.S.	I.A.	Land use SFR	MFR	RUL	AG	COM	IND	AUC	VAC	Hydrologic soil group A	B	C	D
COD	10		-		-	+	+	+		(-)	+		(-)				-	+
Total nitrogen	9																	
Turbidity	11		(+)		(+)	(-)	(-)											
Fecal coliform bacteria	4					-				+								
Total lead	9	(-)	-		-	+	+	+		-	+						(-)	+
Ultimate CBOD	11		(-)		-	+	+	+		-	+	(+)					-	+
Suspended sediment	11				+								-				(+)	(-)
Dissolved NH_4	9								(-)				(+)	(-)				
Total phosphorus	9												(-)	(+)				
Total Kjeldahl nitrogen	10																+	-
Suspended sediment yield	10												(-)	+				

In addition to the urban land uses, impervious area (a reflection of urbanization) was found to have positive correlations with COD, total lead, and ultimate CBOD. As would be expected, increased impervious area accompanies increases in SFR, MFR, and commercial land uses, and decreases in agricultural land use. In general, the highest values of ultimate CBOD, total lead, and suspended sediment were measured in basins with more than 20 percent of impervious areas. As urbanization of a basin progresses, automobile traffic and the amount of impervious area increase, leading to additional sources of lead in the basin and accounting for the evident relation between impervious area and total lead. Negative correlations were computed for impervious area with both fecal coliform and turbidity. The relation with fecal coliform is the reverse of the one with agricultural land use, which might be expected if agriculture is the source for the fecal coliform values in this study. Turbidity is discussed below.

By contrast, comparisons of agricultural land use with COD, total lead, and suspended-sediment yield produced negative correlations. These results seem reasonable because much of the agricultural land in the Salem area is not tilled but is used for pasture; thus the agricultural areas do not contribute much to the suspended-sediment and associated loads. The positive correlation between agricultural land use and fecal coliform is based on few samples but probably reflects the presence of livestock and the use of individual septic systems in the agricultural area.

The physical basin characteristics that correlated with median constituent concentrations were basin slope and channel slope. Basin slope correlated negatively with COD and total lead, while channel slope correlated negatively with COD, total lead, and CBOD, and correlated positively with suspended sediment at the 95-percent confidence level. These correlations reflect the fact that the two physical characteristics also correlate well with urban land uses. Specifically, land development tends to take place more readily in basins of relatively gentle slope and relief. Thus, basin and channel slope correlate strongly and negatively with COD, total lead, and CBOD--a reverse of the correlations noted between these constituents and urban land use.

Two hydrologic soil groups (C and D) also correlated well with several constituents, but with consistently opposite trends, because these soil groups are strongly and negatively correlated. Definitions of the various soil groups are provided in the Glossary. Groups C and D represent most of the soils in the 12 study basins (table 1), although soil group C accounts for considerably more basin area than group D. In general, soils of group C are more permeable than soils in group D. Note that group D exhibits the same general trends with COD, total lead, and ultimate CBOD as was found with the urban land uses (SFR and MFR) and impervious areas. Because group D includes clays and claypans, the soils respond somewhat like impervious areas in relation to the constituent concentrations, and group D correlates strongly with urban land uses.

Turbidity correlations were between the 90- and 95-percent levels of confidence. Basin and channel slope correlated positively with turbidity, while impervious area and SFR correlated negatively. Thus, the larger observed median turbidities were from steeper basins with less urbanization. Turbidity was observed to be soil related, with the transported soils possibly related to channel scour in the steeper basins. All basins in this study, except for Hawthorne Ditch, have natural channels; samples collected in the basins with natural channels contain transported soil. The Hawthorne Ditch channel upstream of Sunnyview Road is lined with concrete, which minimizes channel scour and soil-related turbidity.

Suspended sediment also correlated positively with channel slope and, surprisingly, correlated negatively with AUC (area under construction). The negative correlation to AUC resulted from several basins having zero AUC and large sediment concentrations; thus the correlation does not reflect the possible effects of construction on sediment transport. The dynamics of sediment transport on a basin over time have been documented by Leopold (1968).

Leopold indicated that increased flows in developing basins may significantly increase sediment yield, due to channel scour, and that the average annual sediment yield may increase on the order of five times between pre- and post-development conditions. The dynamics described by Leopold are probably active in the Salem basins, but the sampling was not structured to detect these trends.

The relations between total lead concentration and automobile traffic volume for each of the 12 study basins are shown in figure 4. Because a significant source of lead in an urban environment is tetraethyl-lead in gasoline, the relation between lead concentration and traffic volume is expected (Lagerwerff and Specht, 1970). The relation noted in figure 4 reflects the proximity of several sites to the heavily-traveled I-5 Freeway and other nearby commercial developments where traffic volume is high. The range of total lead concentration increases as the amount of impervious area (an indirect measurement of urbanization) increases (fig. 5). As the Federally-mandated reduction of lead in gasoline is implemented, the amount of lead in the stream environment probably will decrease.

Comparison of Geographic Areas

The values shown for the Salem area in table 2 appear to be relatively small when compared with maximum concentrations found by Ellis and Alley (1979) at three urban sites in the Denver, Colorado area. Maximum lead concentrations in the Denver area were 2.5 to 3 times larger than those in the Salem area; suspended sediment maximums ranged from 0.6 to 3 times larger, total Kjeldahl nitrogen 3 to 5 times larger, dissolved organic carbon 3.5 to 8 times larger, and dissolved phosphorus 4 to 55 times larger. The smaller lead concentrations observed in Salem may be attributed in part to lower traffic densities, and not to a decreased use of lead in gasoline between the time of the Denver (1976-77) and Salem (1980-81) studies, because comparison of Salem values to 1980-81 Denver concentrations (Ellis and others, 1984) still produced ratios from 1 to 4.

Selected maximum and median constituent values for the Salem sites and similar values for sites near Portland, Oregon (McKenzie and Miller, 1976; and Miller, 1978) and for sites near Medford, Oregon (Wittenberg and McKenzie, 1978; and Wittenberg, 1979) are shown in table 4. A comparison of maximum values reveals that values for both Portland and Medford data are considerably larger than maximum values for Salem. Differences in maximum carbonaceous biochemical oxygen demand, fecal coliform, total Kjeldahl nitrogen, and dissolved nitrite plus nitrate are especially notable; generally similarities between Salem and Portland concentrations are greater than between those for Salem and Medford. Salem and Portland are much closer geographically than Salem and Medford, and Salem and Portland have similar climatic conditions, soil types, and basin characteristics; such similarities are not the case with Salem and Medford.

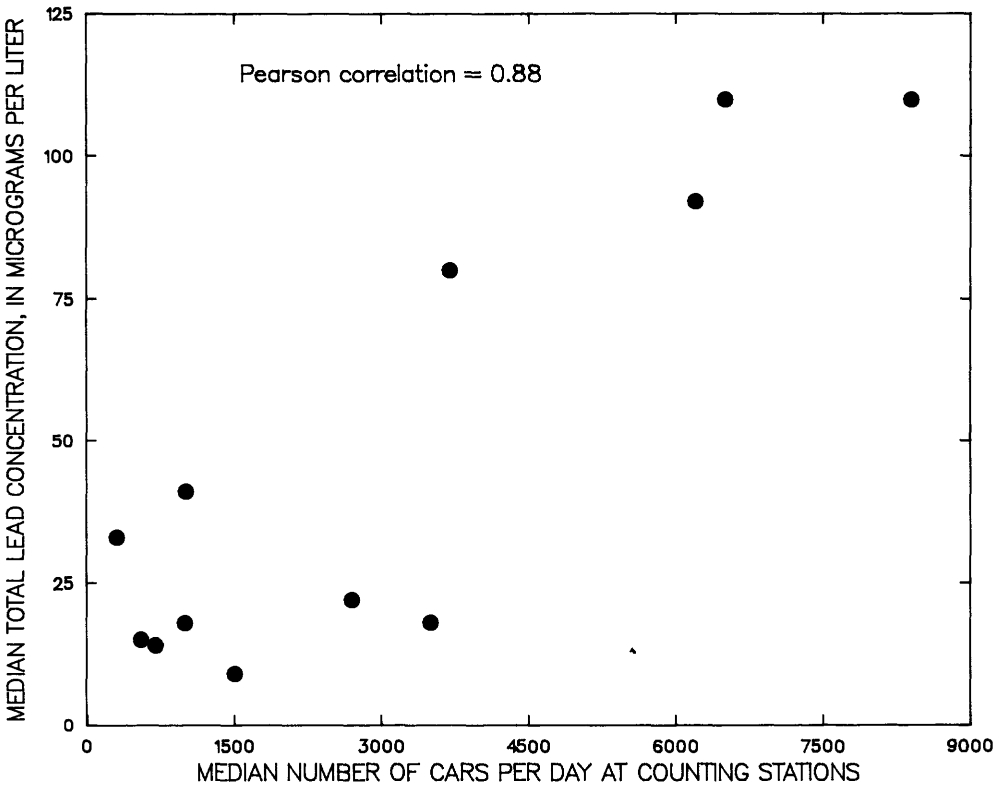

FIGURE 4.--Relation between median number of cars at counting stations and median total lead concentration for each basin.

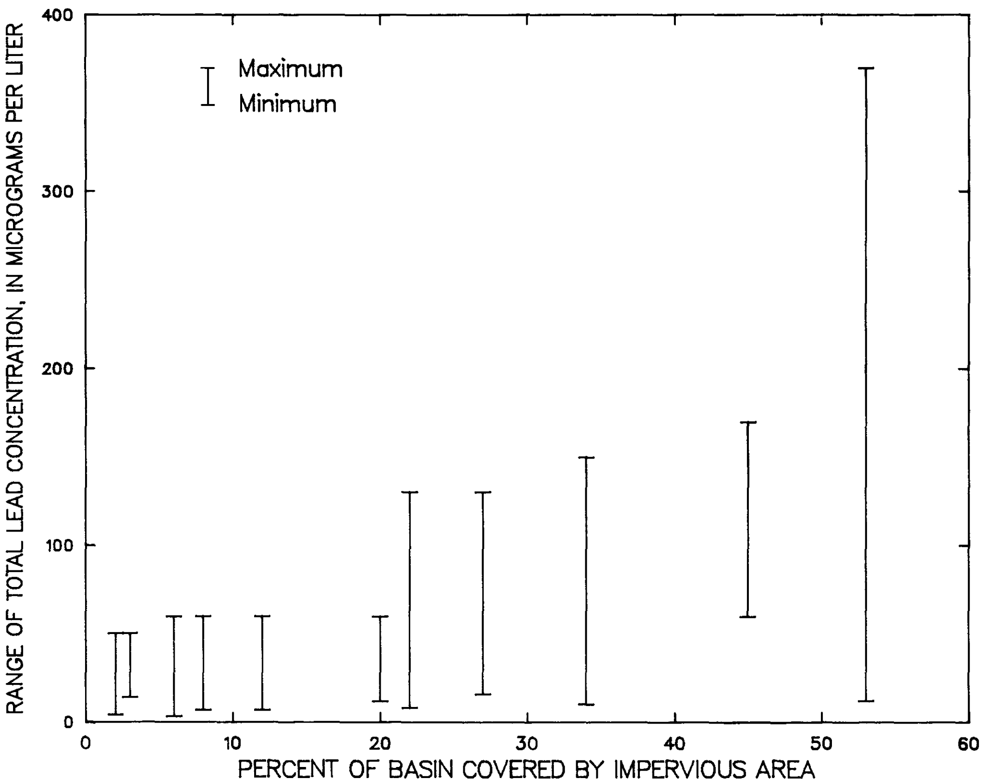

FIGURE 5.--Relation between percent impervious area and range of total lead concentrations for each basin.

Table 4.--Maximum and median constituent values from three Oregon urban studies

[CBOD = carbonaceous biochemical oxygen demand; > = greater than; µS/cm at 25 °C = microsiemens per centimeter at 25 degrees Celsius; mg/L = milligrams per liter; Org/100 ml = organisms per 100 milliliters; JTU = Jackson Turbidity Units.]

Study location		Specific conductance (µS/cm at 25 °C)	Turbidity (JTU)	Suspended sediment (mg/L)	Ultimate CBOD (mg/l)	Fecal coliform bacteria (Org/100 ml)	Chemical oxygen demand (mg/L)	Total phos-phorus (mg/L)	Total Kjeldahl nitrogen (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)
Salem	maximum	281	490	1,670	45	6,300	150	0.72	3.1	2.3
	median	42	60	81	3.6	1,000	26	.15	.94	.49
Portland 1/	maximum	284	900	2,220	120	27,000	210	1.1	6.4	7.0
	median	81	55	119	11	1,400	44	.32	1.2	1.6
Medford 2/	maximum	650	1,200	2,320	>300	1,200,000	950	17.0	9.0	3.1
	median	210	85	200	27	5,700	125	.79	1.7	1.4

1/ From McKenzie and Miller (1976) and Miller (1978)

2/ From Wittenberg and McKenzie (1978) and Wittenberg (1979)

Differences in median values for the three cities are similar to the differences in maximum values, although not as definite. Generally, Salem median concentrations are smaller than either the Portland or Medford median values--one-third for BOD and dissolved nitrite plus nitrate and one-half for COD and total phosphorus. Some differences between Salem and the other two cities that may influence water-quality results are (1) differing air quality, with Portland and especially Medford having poorer air quality; (2) higher population density in Portland; and (3) differing conditions of sewage treatment systems and sewage treatment methods (Medford had combined sewers discharging directly to some receiving streams).

Comparison of median and maximum values for the four cities provides some insight into the transferability of storm-water quality data. Although differences between sites in different cities may be large, those differences tend to be reduced for cities located in similar climatic and geologic areas. More similarities and thus more transferability were found in comparisons of Salem and Portland data than were found in comparisons of Salem with either Medford or Denver. This result is thought to reflect the climatologic and geologic similarities between Salem and Portland. Even though Salem and Portland data in the intracity comparison were most similar, Salem samples were generally lower than Portland samples in ultimate CBOD, COD, total phosphorus, and dissolved nitrite plus nitrate. Therefore, transferability of data between urban areas should not be assumed arbitrarily or without caviats.

Effects of Runoff on a Receiving Stream

The Willamette River is the ultimate receiving stream for runoff from the study area. Several constituents and characteristics of water that warrant discussion regarding their possible effects on the Willamette are discharge quantity, turbidity, suspended sediment, fecal coliform bacteria, ultimate CBOD, nutrients, and total lead. Turbidity, suspended sediment, fecal coliform bacteria, and ultimate CBOD are of interest because concentrations of these variables increase substantially during a storm. Ultimate CBOD and nutrients are of additional interest because of their association with sediment and their possible accumulation in the river bottom sediments.

Although volumetric contribution of storm-water from the Salem urban area to the Willamette River at Salem was not measured directly, a perception of the volumetric relation can be derived from the following information. First, the Willamette drainage basin upstream from Salem encompasses about 7,280 square miles. Second, the UGBA encompasses about 65 square miles of drainage area and represents less than 1 percent of the Willamette drainage area at Salem. Third, the UGBA is located in the area (valley floor) of lowest annual precipitation for the Willamette Valley (Laenen, 1983, p. 10). Even accepting Laenen's (1980) findings that fully urbanized areas may discharge twice the storm volume of unurbanized areas, the Salem UGBA may at most account for less than 2 percent of the Willamette River discharge at Salem on an annual basis. The percent of runoff would be higher during storm events because discharge from the UGBA would (due to travel time) reach the Willamette at Salem before much of the runoff from the upper Willamette basin reaches Salem. Thus, constituents from the Salem urban area that have concentrations within a factor of 3 or less of Willamette River concentrations will probably not significantly contribute to Willamette River loads at Salem. However, constituents from the urban area that are more than an order of magnitude larger than Willamette River concentrations should have a measurable influence on river loads during storm events. Some constituents that might be included in this category are turbidity, sediment, fecal coliform, and total lead.

Turbidity and suspended-sediment values ranged widely at most stations in the Salem area and were correlated ($r = 0.80$). This association is readily explained by the fact that most samples contained sediments in the silt-clay size fraction, which usually contribute to turbidity. Because of the small size of the sediment, much of the turbidity in smaller streams of the Salem area could be expected to reach the Willamette River during storm events. Turbidity and sediment-concentration values from the UGBA during storm events are expected to be much larger than baseline Willamette River values during low-flow runoff. However, these larger turbidity and sediment-concentration values probably are not significant, because these constituents are associated with steeper agricultural areas in the UGBA, and many similar basins discharge to the Willamette upstream of Salem.

Fecal coliform bacteria are commonly used as indicators of pollution of water by fecal wastes. If fecal contamination of the water can be shown to have occurred, pathogenic organisms (bacteria and viruses) may also be present, even though the indicators are not themselves pathogenic.

Fecal coliform bacteria counts in the study area were frequently above the recommended maximum levels set by the U.S. Environmental Protection Agency (1976) for contact recreation, but the streams in the Salem area and the Willamette River are used only to a limited extent for recreation during times when storm runoff occurs. No maximum levels have been set for storm-water runoff. Possible sources of the fecal coliform bacteria include domestic animals (Mattraw and Miller, 1981) and septic tanks, which often fail to operate properly under high ground-water conditions.

Concentrations of ultimate CBOD were small (<10 mg/L) for most samples collected in the study area. It is doubtful that CBOD generated in the study basins would have a significant impact on the dissolved oxygen of the Willamette River. The highest ultimate CBOD concentrations measured in the study were comparable to concentrations introduced by secondary sewage treatment plant wastes. As pointed out by McKenzie and others (1979), the Willamette River under critical steady-state conditions is relatively insensitive to CBOD loading. Also, during winter-storm conditions, the river conditions are not critical.

The nutrient concentrations observed in the Salem basins were small, but not small enough to impede algal growth. Although nutrient concentrations in the Willamette River are similar, nuisance algal growths are not present in the Willamette due to relatively low water temperature, shallow light penetration, presence of phytoplankton (mostly diatoms) and short residence time for the water in each subreach, even during summer low-flow conditions. Nutrients introduced to the Willamette River during storm events enter the river when temperatures and residence times are even lower than in summer. Therefore, because algal growth in the Willamette River system seems to be substantially controlled by physical factors (Rickert and others, 1977, Circular 715-F), nutrients from the Salem area at the level observed should have no noticeable effect on Willamette River algal growth.

The total-recoverable lead concentrations in Salem streams ranged from 29 to 3,800 μg/g (Rickert, Kennedy, McKenzie, and Hines, 1977). In that study of the Willamette River, Rickert examined bottom sediments less than 20 μm in diameter and concluded that concentrations of total lead greater than 25 μg/g represented contaminated samples. Rickert also concluded that Willamette River bottom sediments did indicate increased lead levels near urban areas; however, in that study, results of sampling the Willamette River near Salem were inconclusive concerning possible urban impacts from the Salem area because no samples were obtained directly downstream from Salem. Although lead does reach the Willamette River from urban areas, an ecologically detrimental accumulation of lead and other metals was not evident in the Willamette at the time of Rickert's study (Rickert, Peterson, McKenzie, Hines, and Wells, and others, 1977, Circular 715-G).

EFFECTS OF DETENTION STORAGE ON RUNOFF WATER QUALITY

Detention storage of streamflow has been used for years to mitigate storm-water runoff damage by decreasing peak discharges originating in urban areas. The design and construction of detention storage facilities in Salem was directed toward this primary purpose. However, secondary benefits in the form of water-quality enhancement were realized after the detention basins were constructed.

Data for water collected from the inflow and outflow pipes of a detention storage facility on Hawthorne Ditch were used to develop transport curves for suspended sediment, ultimate CBOD, total Kjeldahl nitrogen, total phosphorus, and total lead. The suspended-sediment transport curves for the Hawthorne Ditch detention facility are shown in figure 6 and illustrate the effectiveness of the facility in reducing suspended-sediment loads. Detention facility reductions in loads of five other constituents at various discharges are shown in table 5. No measurable load reduction was apparent for ultimate CBOD or total Kjeldahl nitrogen over the range of sampled flows. Reductions of suspended-sediment loads ranged from 15 to 53 percent, with the greatest percentage reduction occurring at the higher flows. Load reductions of about 20 percent were evident for total phosphorus and 12 to 43 percent for total lead. Total lead and total phosphorus are associated for the most part with fine suspended particles (with only slight amounts of these elements associated with the dissolved phase); therefore, reductions in loads of total lead and total phosphorus were anticipated because of the observed reduction in the suspended-sediment load. The fact that both ultimate CBOD and total Kjeldahl nitrogen were not significantly affected by detention storage suggests that these variables are either associated with the very fine particles (which are relatively unaffected by detention) or are primarily in the dissolved state.

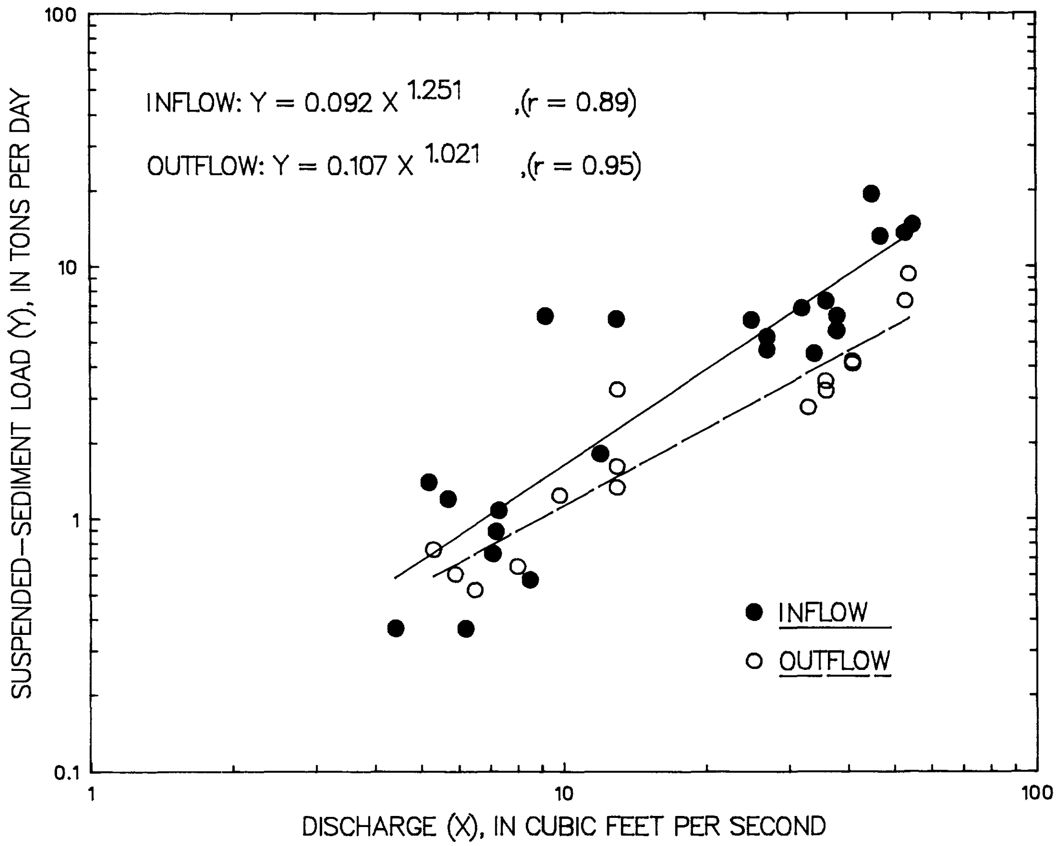

FIGURE 6.--Suspended-sediment transport curves for Hawthorne Ditch detention facility.

A comparison of total and dissolved Kjeldahl nitrogen revealed that about 70 percent of the nitrogen was in the dissolved phase. The results of studies in the Portland area indicate that a considerable portion of the ultimate CBOD in storm-water runoff also is in the dissolved phase (J. F. Rinella, U.S. Geological Survey, oral commun., 1982).

The data in table 5 indicate that, as flows increased, the percentage load reduction increased for lead but remained almost constant for phosphorus. Most of the lead entering the detention pond was not in the dissolved phase but was transported with the particulates. The greater reduction of lead associated with increasing flow may result from longer detention time; as the basin fills, more of the particulates and associated lead settle out. Retention times nearly double as the basin becomes full. The relatively constant percentage reduction of phosphorus with flow may result because most of the phosphorus is dissolved; thus the length of detention may have little effect on the phosphorus leaving the detention structure.

As expected with this type of detention facility, those constituents usually found associated with suspended sediments are most affected by the detention process. Additionally, the vegetation-covered soil bottom of this facility tends to have an effect on some constituents at low flows, because the vegetation may act as a mechanical filter and the soil may sorb some constituents.

Table 5.--Comparison of inflow and outflow transport data for Hawthorne Ditch detention facility in Salem, Oregon

[NMR = no measurable reduction; -- = not applicable; ft^3/s = cubic feet per second; T/d = tons per day; pct = percent; lb/d = pounds per day]

	Suspended sediment			Ultimate CBOD			Total Lead			Total Kjeldahl Nitrogen			Total Phosphorus		
Flow (ft^3/s)	In-flow (T/d)	Out-flow (T/d)	Reduc-tion (pct)	In-flow (lb/d)	Out-flow (lb/d)	Reduc-tion (pct)	In-flow (lb/d)	Out-flow (lb/d)	Reduc-tion (pct)	In-flow (lb/d)	Out-flow (lb/d)	Reduc-tion (pct)	In-flow (lb/d)	Out-flow (lb/d)	Reduc-tion (pct)
4	0.52	0.44	15	92	90	NMR	1.5	1.6	NMR	17	18	NMR	2.9	2.3	21
6	.86	.67	22	220	230	NMR	3.4	3.0	12	31	33	NMR	6.2	4.8	23
10	1.6	1.1	31	680	720	NMR	9.4	6.4	32	66	71	NMR	16	13	19
15	2.7	1.7	37	1,600	1,800	NMR	21	12	43	120	130	NMR	34	27	21
30	6.4	3.4	47	--	--	--	--	--	--	--	--	--	--	--	--
60	15	7.0	53	--	--	--	--	--	--	--	--	--	--	--	--
Reductions at midrange of sampled flows	7.0	3.7	47	610	640	NMR	8.5	6.0	29	61	66	NMR	14	11	21

QUALITY OF PRECIPITATION

Results of precipitation-quality samples collected at the single site are given in table 6. Precipitation samples collected in the Salem area were acidic. The median pH value of 4.6 units reflects a hydrogen-ion concentration that is 10 times larger than the pH value that can be expected for "pure" precipitation in equilibrium with carbon dioxide (5.6 units). The pH values of precipitation in the Salem area are comparable to those reported for most of the industrialized northeastern United States (U.S. Environmental Protection Agency, 1980).

The median total lead concentration for precipitation was 8 μg/L, which was smaller than concentrations in streams for all study basins. Basins such as Claggett Creek and Hawthorne Ditch at Sunnyview Road and at 34th Street had median lead concentrations of 11 to 14 times larger than the precipitation median concentration. All three of these basins have high volumes of auto traffic, and the larger concentrations in storm water from these basins suggest that the chief source of lead is automobile exhaust emissions.

Table 6.--Chemical characteristics of precipitation in Salem area, February 1981 to February 1982

[μS/cm = microsiemens per centimeter; μg/L = micrograms per liter; mg/L = milligrams per liter]

Constituent	Concentration	
	Range	Median
pH (units)	4.0 - 5.8	4.6
Specific conductance (μS/cm)	7 - 59	12
Total lead (μg/L)	0 - 40	8
Total Kjeldahl nitrogen (mg/L)	.18 - .89	.52
Dissolved ammonia (mg/L)	.00 - .41	.12
Total phosphorus (mg/L)	.00 - .02	.01

The median concentrations of total Kjeldahl nitrogen and of dissolved ammonia in precipitation were 0.52 and 0.12 mg/L, respectively. Nitrogen concentration was about half the median concentration found in stream samples; ammonia concentration was larger than the median values in all the streams. Total phosphorus concentrations in precipitation were usually less than 10 percent of those measured in storm-water samples.

A computations of the ratios of selected ions to chloride for Salem precipitation are given in table 7. Comparisons are made with chloride because the predominant source of chloride is the ocean and because chloride concentrations in this area remain relatively unaffected by man's activities. Concentrations of sodium, calcium, magnesium, nitrate and sulfate ions were divided by chloride concentrations and the median ratio determined for each ion pair. For comparison purposes, the table also contains similar ratios for precipitation in the Bull Run watershed near Portland, Oregon, and for sea water.

Both the Salem and the Bull Run precipitation sites exhibited ratios considerably higher than those of sea water; ratios for Salem were generally higher than those for Bull Run. Of particular interest are the ratios for nitrate and sulfate. Large concentrations of nitrogen are usually associated with the combustion of fossil fuel, and large concentrations of sulfur are usually associated with industrial processes. The ratio for nitrate in the Salem area was half of that in Bull Run, but the ratio for sulfate in Salem was about 2.5 times that in Bull Run. This difference may indicate that auto traffic and home heating have more of an impact on air quality near Portland than in Salem and may also indicate that industry has more of an impact on the quality of precipitation at Salem than it does at Bull Run. The low pH values observed at Salem, mentioned previously, may be the result of upwind sulfur dioxide sources. These apparent differences in precipitation quality in the Portland and Salem areas may partly explain differences in storm-water quality.

Table 7.--Median ratios of selected ions to chloride for precipitation samples, Salem and Bull Run watershed, Oregon

Source of water	Na/Cl	Ca/Cl	Mg/Cl	NO_3/Cl	SO_4/Cl
Salem precipitation (samples from 2/80 to 2/81)	1.4	0.63	0.18	0.53	2.8
Bull Run precipitation[1] (samples from 6/80 to 9/81)	0.77	.19	.10	.92	1.1
Sea water[2]	0.56	.02	.07	.00002	0.14

[1]Unpublished data, Frank Rinella, U.S. Geological Survey, written communication, 1983.
[2]Data from Chemical Rubber Company Handbook of Chemistry and Physics, 1977.

SUMMARY AND CONCLUSIONS

The objectives of this reconnaissance study were to (1) describe the quality of storm-water runoff in the Salem area, (2) determine the transferability of data between Salem and Portland, (3) study the effects of detention storage on water quality, and (4) compare the quality of precipitation to the stream-water quality.

This reconnaissance study indicated that constituent concentrations in storm-water runoff varied considerably from site to site and from storm to storm. Several land uses and other variables, such as traffic volume, were closely related to certain water-quality constituents. Specifically, increased SFR, MFR, COM, and impervious-area land use was accompanied by increased lead, COD, and ultimate CBOD concentrations, whereas decreased agricultural land use was inversely correlated to total lead, COD, and ultimate CBOD concentrations. Basins with increased traffic volume also exhibited increased lead concentrations.

For most of the basins sampled, sediment yield seemed to originate from basin soils and not from the washing of dry fallout from impervious surfaces in the basin. The exception to this generalization is the Hawthorne Ditch basin, which has a concrete-lined channel and an impervious area of more than 50 percent. For the Hawthorne Ditch basin, sediment does seem to result from the washoff of impervious surfaces, but, by comparison, this basin had the lowest median sediment concentrations.

Maximum and median constituent values in the Portland and Medford urban areas generally were several times larger than those in Salem. Constituents generally lower in the Salem samples were ultimate CBOD, COD, total phosphorus, and dissolved nitrite plus nitrate. The transferability of data between these urban areas, therefore, should not be assumed arbitrarily.

Because most storm-water runoff from the Salem area occurs in winter, when water temperatures and chemical concentrations for many constituents are low, the runoff has little effect on biological or chemical conditions in the Willamette River. Constituents that may have an effect on the Willamette River are fecal coliform and total lead.

Although the detention storage facility on Hawthorne Ditch was designed to control peak discharge, data show that it also enchanced water-quality conditions. The most significant water-quality effect of the detention pond was to reduce suspended-sediment concentrations at midrange flows by about 47 percent. Some sediment-related constituents, such as total phosphorus and total lead, also showed midrange load reductions of 21 and 29 percent, respectively. Reductions for these constituents were less because they are generally associated with fine suspended particles that are less affected by detention. The effects of detention storage became more pronounced for sediment and total lead as discharge increased, whereas the effects on total phosphorus remained about the same over the entire range of discharge sampled. The detention storage facility had no measureable effect on constituents such as ultimate CBOD and Kjeldahl nitrogen, which are transported mostly in the dissolved phase.

Median pH value of precipitation in Salem was 4.6 units. Median concentration of dissolved ammonia was larger for precipitation than for streams, whereas median concentration of total Kjeldahl nitrogen in precipitation was about half the median stream concentration. Median total lead concentrations in streams of study basins with high traffic volumes were about 12 times larger than concentrations in precipitation.

Ratios of selected ions to chloride in the precipitation samples generally were much higher than those found in sea water. Elevated ratios for sulfate and nitrate to chloride suggest that those compounds may have anthropogenic sources. Sulfur dioxide also may contribute to the relatively low pH values observed in precipitation in Salem.

It would be desirable to monitor trends in storm-water quality in the Salem area. A discernable trend toward increasing peak storm concentrations with increasing urban land use was evident for several constituents. Based on data in this study, there is no evident effect on the quality of the Willamette River from Salem storm water; available data are not adequate, however, to address the potential impacts on the Portland harbor from specific upstream urban areas.

GLOSSARY

Basin slope.--The average slope of the basin, in percent, as described by Wisler and Brater (1959). Basin slopes were computed as follows:

$$\text{Basin slope} = \frac{DL}{A} \times 100$$

where

D = contour interval, in feet;
L - total length of contours, in feet; and
A - drainage area of the basin, in square feet.

Channel length.--The channel length of the basin, in miles, defined as the distance from the gaged site to the upstream watershed divide along the longest well-defined channel.

Channel slope.--The channel slope for the basin, in percent, computed as follows:

$$\text{Channel slope} = \frac{A_{85} - A_{10}}{d} \times 100$$

where

A_{85} = altitude at 85 percent of channel length from gage, in feet;
A_{10} = altitude at 10 percent of channel length from gage, in feet; and
d = distance between A_{85} and A_{10}, in feet.

Drainage area.--The area of the basin, in square miles, determined by outlining and planimetering drainage divides on 7-1/2 minute quadrangle maps and adjusting for existing storm-sewer diversions.

Hydrologic soil group.--Each group is shown in table 1 as a percentage of the basin. The groups are defined by the U.S. Soil Conservation Service (1975); the infiltration rate, in inches per hour, is in brackets following each definition:

A. Soils having a high infiltration rate, even when thoroughly wetted, and consisting chiefly of deep, well-drained to excessively drained sand or gravel (low runoff potential) [0.45 - 0.30].

B. Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well- to well-drained soils with moderately fine to moderately coarse texture [0.30 - 0.15].

C. Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or of soils with moderately fine to fine texture [0.15 - 0.05].

D. Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material (high runoff potential) [<0.05].

Impervious area.--Drainage area, in percent of total drainage area, impervious to the infiltration of rain. Included are paved roads, paved parking lots, sidewalks, roofs, and driveways.

Land use.--Land-use types are defined as follows:

SFR. Single-family residential -- Single-family detached dwellings and duplexes.

MFR. Multiple-family residential -- Multiple-family housing units and trailer parks.

RUL. Rural -- All undeveloped land, cemeteries, parks, and schools playgrounds.

AG. Agriculture -- All developed pasture, croplands, and orchards.

COM. Commercial -- Wholesale and retail buildings; school, church, and institutional buildings; and airports.

IND. Industrial -- Heavy and light industries.

AUC. Areas under construction -- Areas where construction activities have exposed soils.

VAC. Vacant -- Undeveloped land.

Sea Level.--In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

Urban Grown Boundary Area (UGBA).--Boundary encompassing Salem, Oregon within which urban development is considered desirable and is encouraged. The desirability for development within the boundary results in part because utility and public services are readily available and are less costly than in other areas.

Urbanization.--The conversion of land use from rural, vacant, or agricultural to one of the intensive uses requiring construction and elimination of pervious area.

Wet deposition.--Precipitation and associated solid and dissolved constituents reaching land surfaces during rainfall and snowfall events.

REFERENCES

Conover, W. J., 1980, Practical nonparametric statistics (2nd ed.): New York, John Wiley, 493 p.

Ellis, S. R., and Alley, W. M., 1979, Quantity and quality of urban runoff from three localities in the Denver metropolitan area, Colorado: U.S. Geological Survey Water-Resources Investigations Report 79-64. 60 p.

Ellis, S. R., Doenfer, J. T., Mustard, M. H., Blakely, S. R., and Gibbs, J. W., 1984, Analysis of urban storm-runoff data and the effects on the South Platte River, Denver Metropolitan Area, Colorado, U.S. Geological Survey Water-Resources Investigations Report 84-4159, 66 p.

Laenen, Antonius, 1980, Storm runoff as related to urbanization in the Portland, Oregon-Vancouver, Washington area: U.S. Geological Survey Water-Resources Investigations Report 80-689, 71 p.

Laenen, Antonius, 1983, Storm runoff as related to urbanization based on data collected in Salem and Portland, and generalized for the Willamette Valley, Oregon: U.S. Geological Survey Water-Resources Investigations Report 83-4143, 88 p.

Laenen, Antonius, and Solin, G. L., 1978, Rainfall-runoff data for selected basins, Portland, Oregon, and Vancouver, Washington, 1973-77: U.S. Geological Survey Open-File Report 78-291, 48 P.

Lager, J. A., and Smith, W. G., 1974, Urban storm-water management and technology: An assessment: Metcalf and Eddy, Inc., Report, Environmental Protection Technology Series, EPA 670/2-74-040, 447 p.

Lagerwerff, J. V., and Specht, A. W., 1970, Contamination of roadside soil and vegetation with cadmium, nickel, lead, and zinc: Environmental Science and Technology, v. 4, No. 7, p. 58-586.

Leopold, L. B., 1968, Hydrology for urban land planning--A guidebook on the hydrologic effects of urban land use: U.S. Geological Survey Circular 554, 18 p.

Mattraw, H. S., and Miller, R. A., 1981, Storm-water quality processes for three land-use areas in Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 81-23, 56 p.

McKenzie, S. W., Hines, W. G., Rickert, D. A., and Rinella, F. A., 1979, Steady-state dissolved oxygen model of the Willamette River, Oregon: U.S. Geological Survey Circular 715-J, 28 p.

McKenzie, S. W., and Miller, T. L., 1976, Basic data on urban storm-water quality, Portland, Oregon: U.S. Geological Survey Open-File Report 76-594, 71 p.

Miller, T. L., 1978, Urban storm-water quality data, Portland, Oregon and vicinity: U.S. Geological Survey Open-File Report 78-851, 23 p.

Miller, T. L., and McKenzie, S. W., 1978, Analysis of urban storm-water quality from seven basins near Portland, Oregon: U.S. Geological Survey Open-File Report 78-662, 47 p.

Rickert, D. A., Kennedy, V. C., McKenzie, S. W., and Hines, W. G., 1977, A synoptic survey of trace metals in bottom sediments of the Willamette River, Oregon: U.S. Geological Survey Circular 715-F, 27 p.

Rickert, D. A., Peterson, R. R., McKenzie, S. W., Hines, W. G., and Wille, S. A., 1977, Algal conditions and the potential for future algal problems in the Willamette River, Oregon: U.S. Geological Survey Circular 715-G, 39 p.

U.S. Environmental Protection Agency, 1976 (1977), Quality criteria for water: Washington: U.S. Environmental Protection Agency, 256 p.

______ 1980, Acid rain: EPA 600/9-79-036, Washington, D.C., 36 p.

U.S. Soil Conservation Service, 1975, Urban hydrology for small watersheds: U.S. Department of Agriculture Technical Release 55, 92 p.

Weast, R. C., ed., 1964, Handbook of chemistry and physics: The Chemical Rubber Co., Cleveland, Ohio, p. F82.

Wisler, C. O., and Brater, E. F., 1959, Hydrology (2nd ed.): New York, John Wiley, 408 p.

Wittenberg, L. A., 1979, Storm-water data for Bear Creek basin, Jackson County, Oregon 1977-78: U.S. Geological Survey Open-File Report 79-217, 28 p.

Wittenberg, L. A., and McKenzie, S. W., 1978, Hydrologic data in Bear Creek basin and Western Jackson County, Oregon, 1976-77: U.S. Geological Survey Open-File Report 78-230, 181 p.

Yorke, T. H., and Davis, W. J., 1971, Effects of urbanization on sediment transport in Bel Pre Creek basin, Maryland: U.S. Geological Survey Professional Paper 750-B, p. B218-B223.