



Storm Runoff As Related To Urbanization in the Portland, Oregon— Vancouver, Washington Area

U.S. GEOLOGICAL SURVEY
Water Resources Investigations
Open-File Report 80-689

Prepared in cooperation with the
City of Portland, Multnomah County, Oregon,
Clark County, Washington and U.S. Army Corps of Engineers



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From "Souvenir Views of Portland's Great Flood-June 1894"
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By Antonius Laenen

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UNITED STATES DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS

[For use of those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:]

Multiply	By	To obtain
Length		
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi ²)	2.590	square kilometer (km ²)
acre	4,047	square meter (m ²)
Specific combinations		
cubic foot per second (ft ³ /s)	0.0283	cubic meter per second (m ³ /s)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

GLOSSARY

Exceedance probability.--Probability that a random event will exceed a specific magnitude in a given time period. For example, a flood with a 0.01 exceedance probability is a flood that has one chance in a hundred of being exceeded in any one year. This is a 100-year flood under the "recurrence-interval" terminology. In this report, the term "exceedance probability" is used in preference to the term "recurrence interval." Both terms, however, are used in most of the tables, graphs, and illustrative problems.

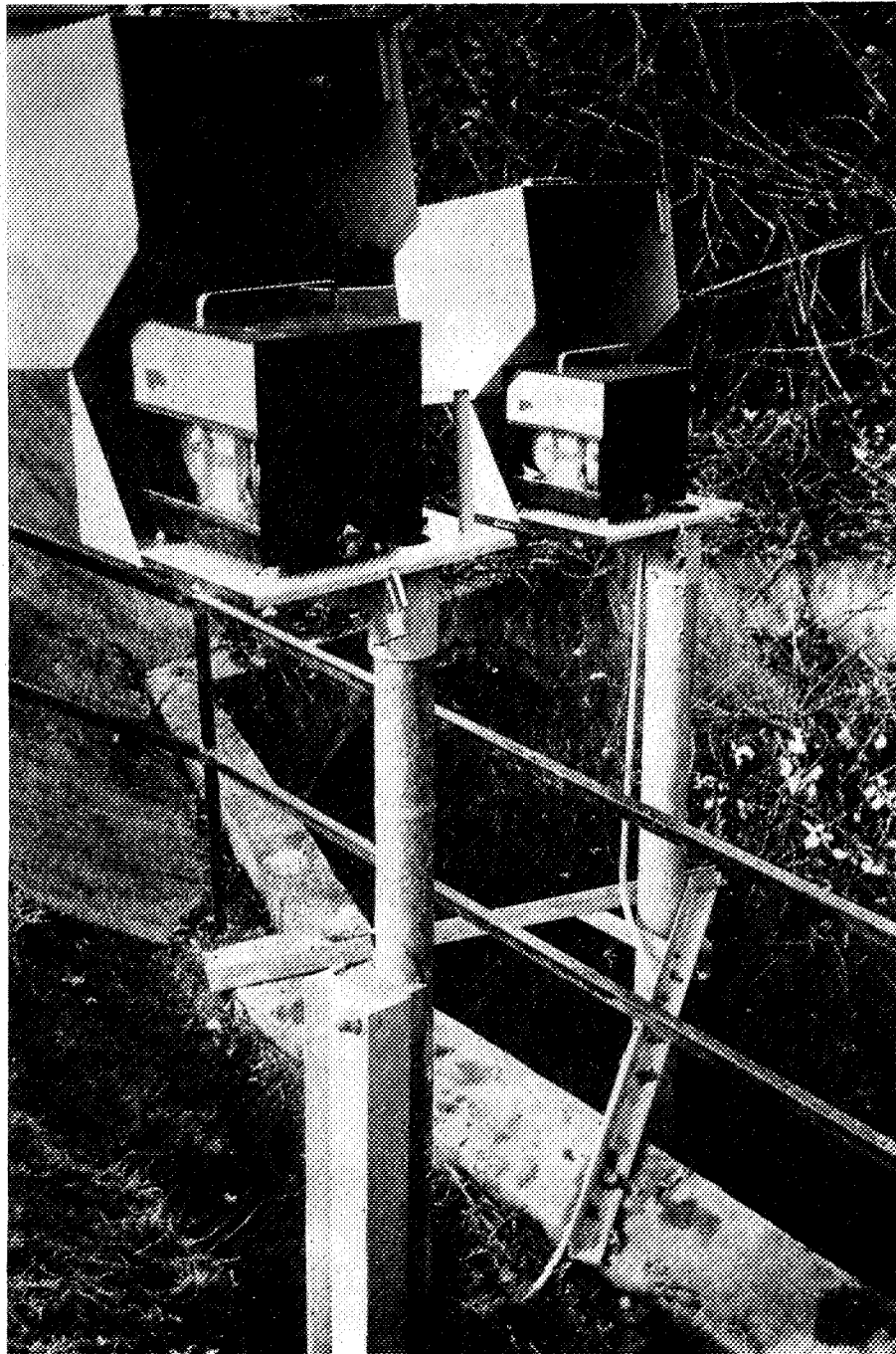
R-square.--The coefficient of determination. It is a measure of the variation explained by the regression equation. $R\text{-square} \times 100$ yields the percent of variation explained. If $R\text{-square} = 1$, then 100 percent of the variation is explained by the equation; if $R\text{-square} = 0.75$, then 75 percent of the variation is explained by the equation. It is a "best-fit" test for the population scatter about a curve.

"F" statistic.--A test that defines the significance of the independent variables. The larger the "F" value, the more significance it has in the equation. Unless otherwise shown, all "F" statistics fall within the 95-percent confidence limit.

Standard error of estimate (SEE).--A statistical measure of accuracy based on population scatter about the curve only. It is the square root of the variance and is graphically defined as having two-thirds of the data points falling within its limits.

Detention storage.--Storage of storm runoff from roofs, parking lots, and other impervious surfaces especially designed to reduce peak flows. Detention-storage areas normally have constricted outlets so that water will flood designated areas and flow out slowly, thereby reducing the effective flood peak.

Effective impervious area (EIA).--The area, as a percentage of total drainage area, having a direct hydraulic link to the stream and impervious to the infiltration of rain.



Typical rainfall-runoff gage installation

STORM RUNOFF AS RELATED TO URBANIZATION IN THE PORTLAND,
OREGON-VANCOUVER, WASHINGTON AREA

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By Antonius Laenen

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ABSTRACT

A series of equations was developed to provide a better method of determining flood frequencies in the Portland-Vancouver urban area than is now available. The resulting regression equations can be used to compute peak discharge and storm runoff with a standard error of estimate of approximately 30 percent. Basins used to define the regression equations ranged in size from 0.2 to 26 square miles. Those physical basin parameters that proved to be significant are: drainage area, effective impervious area, storage, rainfall intensity, basin slope, and soil infiltration. The equations indicate that total urbanization of an undeveloped basin can increase peak discharge as much as $3\frac{1}{2}$ times and almost double the volume of storm runoff.

Impervious area, as delineated by mapping techniques, proved to be an inadequate physical parameter for use in the regression equations because builders and planners have devised many methods of routing storm runoff from impervious areas to the main channel (in effect, speeding up or slowing down the response to the storm). In some parts of the study area, storm runoff was diverted into dry wells and never entered the main channel. To define the effect of this rerouting, the digital model was used to find an effective impervious area that would "best fit" the rainfall-runoff data. Field estimates to verify the effectiveness of the impervious area for two of the basins showed that optimizations were within 20 percent of those shown by the digital model.

Users of these data who may find the effective impervious area a difficult, expensive, and time-consuming parameter to obtain have an alternative. The combination of land-use type I (parks, forests, and vacant lots) and Type II (agriculture) proved to be an excellent inverse indicator of impervious area. Land-use types I and II, coupled with the street-gutter density, an indication of effective routing, provide the user with alternative indices of urbanization.

Storage, as defined by the surface area of lakes, ponds, marshes, flood plains, depressions, and detention facilities, proved to be a highly significant parameter in determining peak flow. Sensitivity analysis shows that peak flows may be decreased as much as 40 percent in a basin with 1 percent of its area utilized for storage, whereas peak flows may be decreased as much as 70 percent in a basin with 10 percent of its area in storage. These gross approximations are highly dependent on the location of the storage in the basin.

INTRODUCTION

The Portland metropolitan area is in a period of rapid growth. This rainfall-runoff study was done in response to a need by local designers and planners to evaluate the effect of urbanization on runoff and to determine the magnitude and frequency of floods. The project provided an opportunity to obtain rainfall-runoff information in the urban environment of the Portland metropolitan area. The purpose of this report is to present an interpretation of the data collected and summarize a series of regression equations that define the magnitude and frequency of floods in the Portland urban area.

Rainfall-Runoff Processes

Rain falling on the land surface fills depressions, infiltrates into the soil, and runs off to drainage channels. Most natural and rural land has some topographic relief and is covered by vegetation. The land is considered to be pervious, or capable of infiltrating some portion of the rainfall. Overland runoff is controlled by the magnitude and intensity of the rainfall event, soil infiltration, vegetation, land slope, topography, drainage geometry, surface geology, and urbanization.

Almost all land has some impervious cover which prevents infiltration and is dependent predominantly on soil type, surface geology, and urbanization. Rain falling on the impervious cover runs off almost immediately, and surface depressions fill quickly. If the impervious area is not directly connected to a drainage channel, the adjoining pervious area will attenuate the almost complete and rapid runoff which will both infiltrate partially into nearby soil and lose some of its velocity. However, much of the runoff from the impervious cover eventually appears as flow in the channel.

Problem

Urbanization brings with it impervious cover and modifications to drainage systems that generally result in increased discharge-carrying capacity. The increase in impervious area reduces the area available for infiltration, thus increasing the amount of runoff for any rainfall event. The response of a rainfall-runoff event is also changed; it is faster and more intense, primarily because of the increased hydraulic efficiency of the overland- and channel-flow conditions. Urbanization, however, can be a paradox. The paving over of the land, the creation of concrete channels, the stripping of natural vegetation and forest litter, and the compaction of soils should increase runoff in all respects. Runoff volumes almost always increase as a result of

urbanization. Peak discharges, on the other hand, are affected by man's structures and channel modifications. Peak discharges can and sometimes do decrease because of, or in spite of, urbanization.

In the Portland metropolitan area, the effects of urbanization on flood peaks were not accurately known. This study was made to define magnitude and frequency of floods more accurately for the area, thereby providing more adequate tools for design and planning than are presently available.

Present Solution

Various methods are presently available to estimate floods in urban areas, and most of these use rainfall-intensity statistics. One of the most common methods for computation is a rational formula ($Q = CiA$) that involves the selection of three values--the coefficient of runoff (C), indicating a dependency on various watershed characteristics; the rainfall-intensity duration (i) related to the time of concentration; and the area (A) of the basin. As can be inferred from the explanation of the rainfall-runoff processes, both the coefficient of runoff and the time of concentration are complex, difficult to express in a single value, and nearly impossible to obtain to any degree of accuracy in the absence of actual data.

Solution Used in This Study

An analysis was made of rainfall-runoff data to improve the accuracy of assessing and estimating the effect of urbanization on the magnitude and frequency of floods. Data from 24 streamflow sites and their associated rain gages, operated by the U.S. Geological Survey (USGS) and the city of Portland, were used to calibrate a digital rainfall-runoff model for each basin. The calibrated digital model was used to generate a synthetic set of flood peaks based on 70 years of storm data from National Weather Service records for Portland. The resulting annual peak-flow and storm-runoff information was used to define individual flood-frequency relations for each gage site. The relations, in turn, were regressed to physical basin parameters resulting in regression equations for peak discharges and volumes for selected exceedance probabilities. In addition, a plot of length-slope ratio to lag time was used to evaluate the effect of urbanization on the lag time of a basin.

Acknowledgments

This study was done in cooperation with the city of Portland, Clark and Multnomah Counties, and the U.S. Army Corps of Engineers. The author acknowledges the direct cooperation of the city of Portland Department of Public Works, Bureau of Sanitary Engineering, and especially Messrs. Gregory Kurahashi, George Myra, and William Boyd, who gave their time and supplied data to meet the Survey's schedule and criteria.

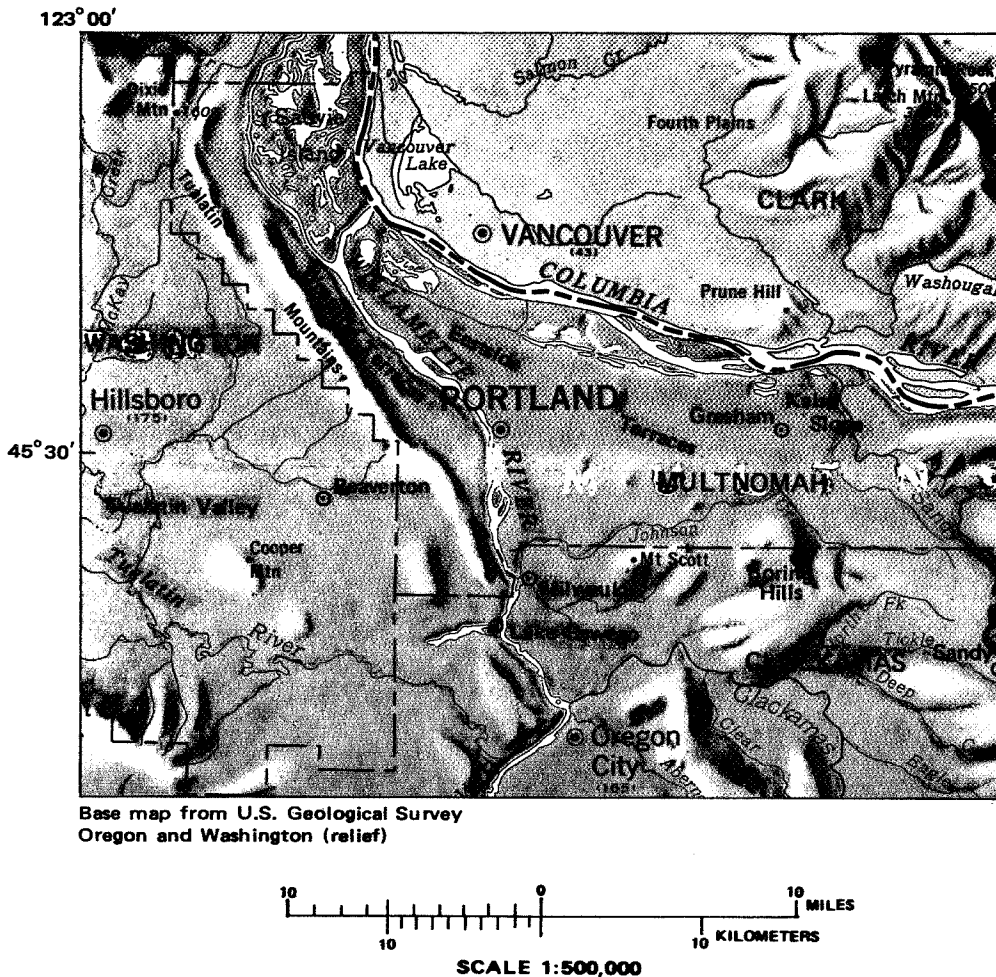


Figure 1.—Geography of the Portland-Vancouver Area.

PHYSICAL SETTING

Geography

The Portland-Vancouver metropolitan area lies at the confluence of the Columbia and Willamette Rivers (see fig. 1 and pl. 1). Geographically, the area can be divided into three subareas--east Portland (east of the Willamette River), west Portland (west of the Willamette River), and Vancouver (north of the Columbia River).

East Portland

The east Portland area is roughly bounded by four large rivers--the Columbia River on the north, the Willamette River on the west, the Clackamas River on the south, and the Sandy River on the east. The area includes the

following distinct topographic features: the Boring Hills, the Kelso slope, the east-side terraces and associated small hills and buttes, and the Columbia River flood plain.

The Boring Hills is an area of rolling hills of volcanic and erosional origin. Several of the hills reach an altitude of about 1,000 ft. The highest is Mount Scott (alt 1,083 ft), which is about 800 ft higher than the terraces to the west and north. The Boring Hills are divided into three main parts by broad and gently rolling valleys.

The Kelso slope is a dissected northwestward-sloping surface west of the canyon of the Sandy River. It slopes from an altitude of about 1,000 ft near Sandy to about 400 ft east of Gresham. A thick clayey soil underlies most of the Kelso slope and valleys in the Boring Hills. The relatively impermeable soil and the sloping land surface cause a rather rapid runoff of surface water.

The east-side terraces were formed by the ancestral Columbia and Willamette Rivers during a time when the rivers were flowing at higher levels than at present. Three isolated hills--Rocky Butte, Mount Tabor, and Kelly Butte--rise about 200 to 400 ft above the surrounding terraces. These hills are composed of the Pliocene and Pleistocene Boring Lava and associated remnants of the Pliocene Troutdale Formation and stood as "islands" when the streams were forming the terraces. The terraces do not have a well-developed stream system in all places and are underlain mostly by permeable sand and gravel. Although the precipitation is fairly abundant, most of it percolates down to the ground-water body and leaves the area by underflow.

A major feature of the terraces is a broad abandoned stream channel that extends in a northwestward arc for about 12 mi from the Clackamas River through the Sellwood district to the Hawthorne Bridge. This channel probably once carried the flow of the Clackamas River and perhaps, at times, all or part of the flow of the Willamette River. This feature is now drained in part by Crystal Springs, Kellogg, lower Johnson, and Mount Scott Creeks.

The flood plain south of the Columbia River contains several marshes, shallow lakes, and sloughs. Most of the flood plain is protected by artificial dikes and is only partly flooded during years of exceptionally heavy rainfall or of very high water in the Columbia River. Under natural conditions, however, the flood plain is partly or completely flooded during normal high-water periods and is naturally drained through a system of sloughs and minor streams.

West Portland

The west Portland area can be roughly divided into the following areas: the Tualatin Mountains (West Hills), the west-side terraces (downtown Portland), and the lower Tualatin Valley (see fig. 1).

The northwest-trending Tualatin Mountains rise to an altitude of 1,100 ft in this area and extend as far south as Lake Oswego. These mountains are better known locally as the West Hills. The flanks sloping northeastward to the flood plains of the Columbia and Willamette Rivers and southwestward into the Tualatin Valley are deeply dissected by streams. The mountains are underlain by the Miocene Columbia River Basalt Group, which is overlain by upland silt.

The eastern and southeastern parts of the Tualatin Valley are separated from the floor of the Willamette Valley by low ridges and uplands called the West Linn Heights, an extension of the Tualatin Mountains. Oregon City, across the Willamette River, lies on a bluff which is a continuation of the heights.

According to Brown (1963), the downtown Portland area from about 50-foot altitude to the base of the West Hills consists of older alluvium and terrace gravel. The terrace gravel was deposited by the ancestral Willamette and Columbia Rivers. Below the 50-foot altitude, the Willamette River flood plain consists of soils that are finer and less permeable than the terrace gravel.

The Tualatin Valley is a broad elliptical plain surrounded by long terraces that slope toward the center of the valley. Cooper and Bull Mountains are near the middle of relatively flat lowlands. The valley floor consists primarily of silt underlain by a thick layer of impermeable clay and silt with widely separated beds of sand and gravel. The clay is so tight in some areas that it takes several months of winter rains before the soil is wetted several feet below the surface.

Vancouver

According to Mundorff (1964), the Vancouver area consists of a series of nearly flat plains and benches rising steplike from the level of the Columbia River. The terraces here, as in the Portland area, are underlain mostly by permeable sand and gravel, and rain percolates readily into the soil. The area from an altitude of 50 ft to the foothills is locally known as Fourth Plains. It contains both the remnants of the original alluvial fill from the East Fork of the Lewis River and the more recent alluvial and glacial outwash material deposited by the Columbia River. The lowest bench, at an altitude below 50 ft, is the flood plain of the Columbia. Vancouver Lake, an old river meander, is part of this flood plain.

Drainage Systems

The entire study area is approximately 500 mi² and lies within the Columbia River drainage basin, which has a drainage area of 241,000 mi². Other major streams that drain parts of the study area include the Willamette River, with a drainage area of 11,100 mi²; the Tualatin River, with a drainage area of about 700 mi²; the Clackamas River, with a drainage area of about 900 mi²; and the Sandy River, with a drainage area of approximately 500 mi².

In east Portland, the largest of the small streams that drain the area are Johnson, Crystal Springs, Mount Scott, and Kellogg Creeks, draining into the Willamette River; Rock and Deep Creeks, draining into the Clackamas River; and Beaver and Kelly Creeks, draining into the Sandy River. The east-side terrace area has few streams and many undrained depressions. The only streams originating in the terrace area are Crystal Springs Creek, Kellogg Creek, and some minor tributaries in the Oak Grove area.

In the west Portland area, the largest streams are Rock Creek and its tributaries (Beaverton and Cedar Mill Creeks) and Fanno Creek. These streams drain into the Tualatin River. Numerous canyons drain the east slope of the West Hills into the Willamette River.

In the Vancouver area, the largest creeks include Burnt Bridge Creek, which drains into Vancouver Lake, and Cougar and Salmon Creeks, which drain into the Columbia River. Here, as in the east-side terrace area, elongated depressions trap rainwater.

RAINFALL CHARACTERISTICS

Portland has a winter-rainfall climate, with a normal annual precipitation of 37.6 in.^{1/} recorded at the Portland International Airport. Approximately 88 percent of the total annual precipitation occurs from October through May as the result of frontal storm systems spawned in the Pacific Ocean. Heavy downpours are infrequent, but gentle rains occur almost continually during the winter. The remaining 12 percent of the annual rainfall occurs from June through September, generally from convection storms occurring on the average of once a month. These storms are generally not very intense compared to storms in other parts of the United States, but are more intense for shorter durations than are the winter storms. Snow seldom falls, and generally lasts for only a few days.

Annual precipitation ranges from 38 to 66 in. over the project area. At the two long-term, first-order precipitation gages (see fig. 2) at the U.S. Customs House (1872-1973) and the Portland International Airport (1946-79), the annual average precipitation is 38 and 45 in., respectively, for the 1946-73 period. The isopluvial map (fig. 2) shows a 1.8- to 3.0-inch difference in rainfall over the project area for the 6-hour precipitation with 0.02 exceedance probability. The pattern of areal distribution of rainfall intensity is similar to that of annual precipitation. Data for both daily rainfall and unit rainfall (5-minute duration) have been adjusted for individual watershed models to compensate for this areal distribution (see table 3).

^{1/} The 1941-70 normal rainfall is determined from records collected primarily at the Portland International Airport and from other nearby locations (from Annual Summary published by the National Oceanic and Atmospheric Administration).

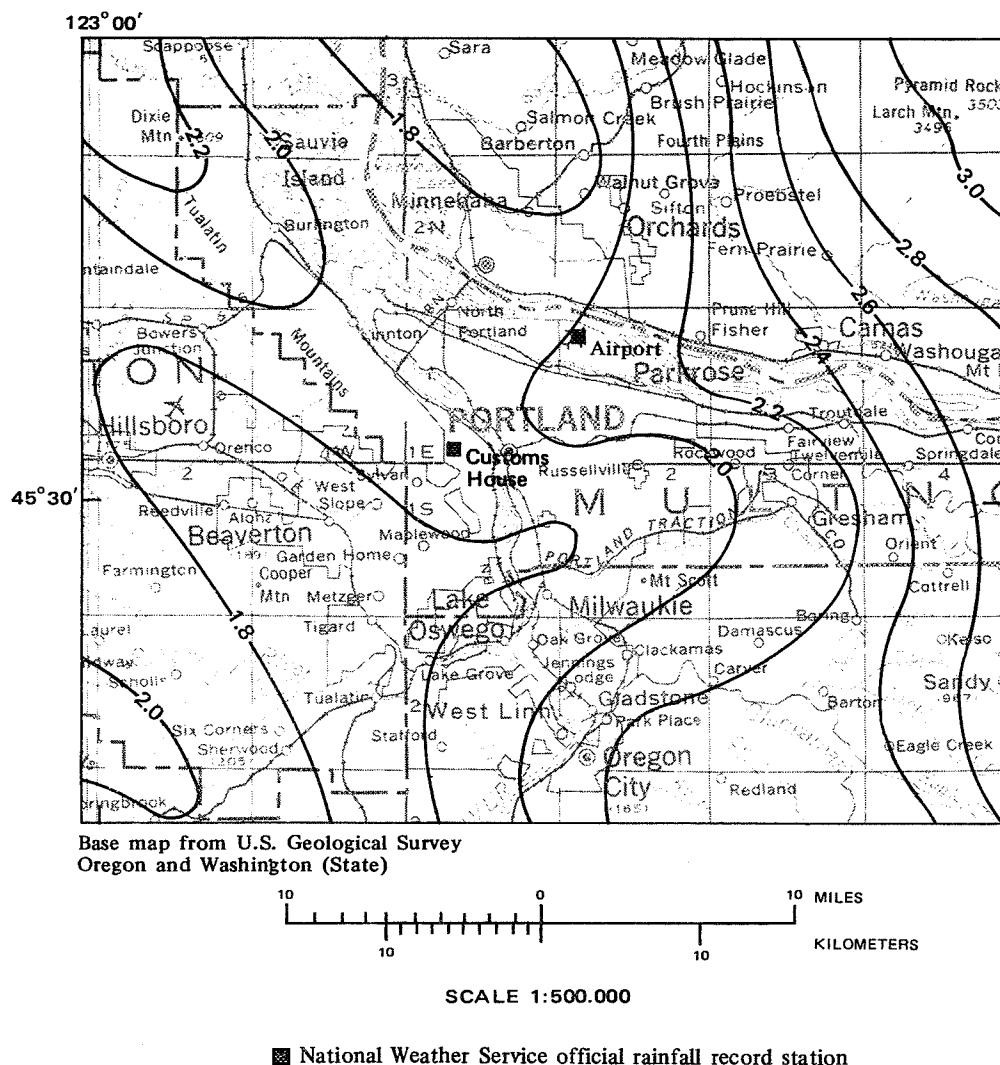


Figure 2.—Map of 0.02 exceedance probability, (50-year), 6-hour precipitation, in inches, for the Portland-Vancouver area. (Adapted from National Oceanic and Atmospheric Administration, 1973a and 1973b).

Data used for all storm analyses in this report were collected between 1902 and 1973 at the U.S. Customs House between NW. Everett and Davis Streets at Park Avenue. On December 12-13, 1882, and on January 5-6, 1883, daily totals of 7.66 in. and 5.55 in., respectively, were recorded. Both these events exceeded the 24-hour, 0.01 exceedance probability intensity (fig. 3) for the rainfall-intensity curves developed from station data for the period 1903-49 (U.S. Weather Bureau, 1955).

During the data-collection period, extremes of note occurred on (1) December 11-12, 1977, when a storm with a 24-hour extreme of 3.3 in. occurred (which was the maximum-yield storm event for many of the basins); and (2) May 1, 1976, when a hailstorm in Vancouver with 5-, 15-, and 30-minute

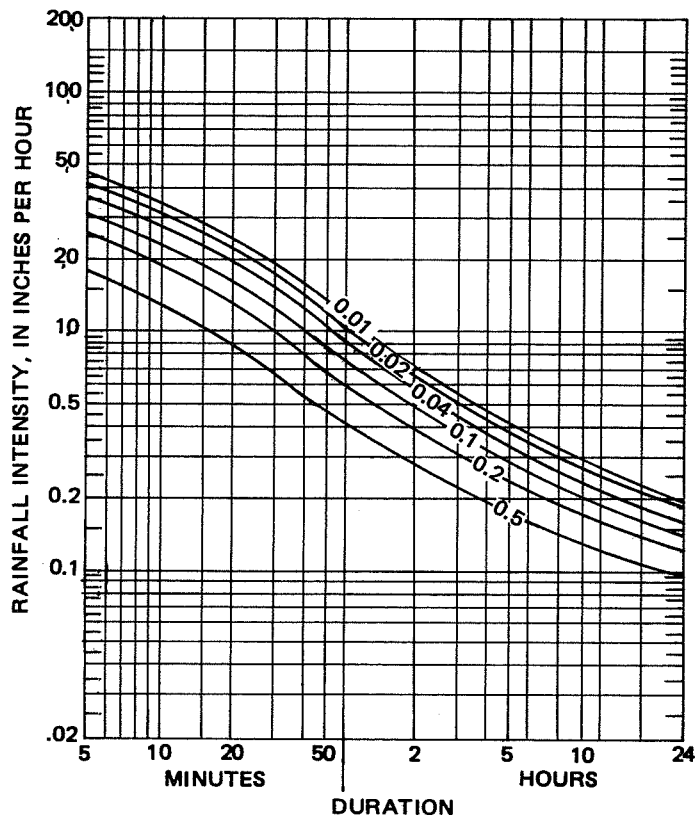


Figure 3.—Rainfall-intensity curves for given exceedance probabilities for U.S. Customs House, Portland, Oreg. (1903-44). (Adapted from intensity curves in U.S. Weather Bureau Technical Paper 25, 1955).

rainfall amounts of 0.34, 0.54, and 0.63 in.^{2/}, respectively, occurred. The intensity curves (fig. 3) show the December 1977 storm to be about a 0.2 exceedance-probability storm. Rainfall intensity has been greater than 2.5 in. in 24 hours only 25 times during the period 1872-1973. Because of the magnitude of the December 1977 storm, it provided more credibility to the rainfall-runoff calibrations described in this report. The May 1, 1976, storm in Vancouver plots near the 0.01 exceedance probability for the 5-minute time durations.

The rainfall record used in synthesis for this report does not include the historical extremes mentioned. However, a sufficient length of historical record indicates that any bias due to this exclusion should be slight. This report includes a brief assessment of hypothetical peaks caused by the historic extreme events in comparison with other peaks of record.

^{2/} For this storm, accumulations of 1 to 2 in. of hail were reported in the vicinity of the Vancouver rain gage. Most of the hail was not measured. The intensities shown reflect very little of the water content associated with the hail.

DATA-COLLECTION METHODS

Rainfall-Runoff Data Collection Network

Rainfall and runoff data were collected at 17 streamflow and 18 rain-gage sites maintained by the USGS and at seven sewer-gage and six rain-gage sites maintained by the city of Portland (see pl. 1 for locations of gage sites). (The city sewer-gage and rain-gage network is considerably larger than shown; however, not all sites could be used in this rainfall-runoff analysis.) A description of the instrumentation and methods used for data collection and the bulk of the data collected are included in a report by Laenen and Solin (1978). The remainder of the data is summarized in tables 13 and 14 of this report (raw data were collected at 5-minute intervals).

Data were collected to encompass as much of the urban spectrum as possible, within the limits of certain physical constraints. In the planning phase of the project, hydraulically acceptable sites (those sites where little time would have to be spent defining a stage-discharge relation) were canvassed first. Two sets of scatter diagrams were then developed--drainage area versus impervious area (fig. 4) and drainage area versus basin slope (fig. 5), thereby creating envelopes of experience for the study area. The next step was to define a network with an even scatter of physical characteristics within the envelopes. Voids were filled, where possible, by relaxing original-site acceptability specifications and using less favorable locations for the network. Figures 4 and 5 show the characteristics for the final network plotted with the original relations. In final analysis, both basin slope and impervious area proved to be significant characteristics and remained in the resulting regression equations.

Discharge measurements were made at all sites (including city gages) to verify the stage-discharge relations.

Basin Characteristics

Table 1 is a compilation of drainage-basin characteristics. Many characteristics were evaluated in the regression-analysis phase of this study and are included in this report. Not all characteristics proved to be significant; however, because they may be valuable for some future statistical analysis, they are presented in this report in their entirety. Table 1 supersedes the basin-characteristics table in the report by Laenen and Solin (1978, p. 4) and includes city of Portland sewered basins. Definitions are as follows (acronyms are shown in parentheses):

Drainage area (DA).--Area of the basin, in square miles, planimetered from USGS 7½-minute topographic series maps. Basin boundaries were delineated by outlining drainage divides and then adjusting the natural drainage areas, where necessary, on the basis of current storm-sewer information obtained from city and county agencies. A field determination was made at boundaries where drainage area divides could not be determined from the maps.



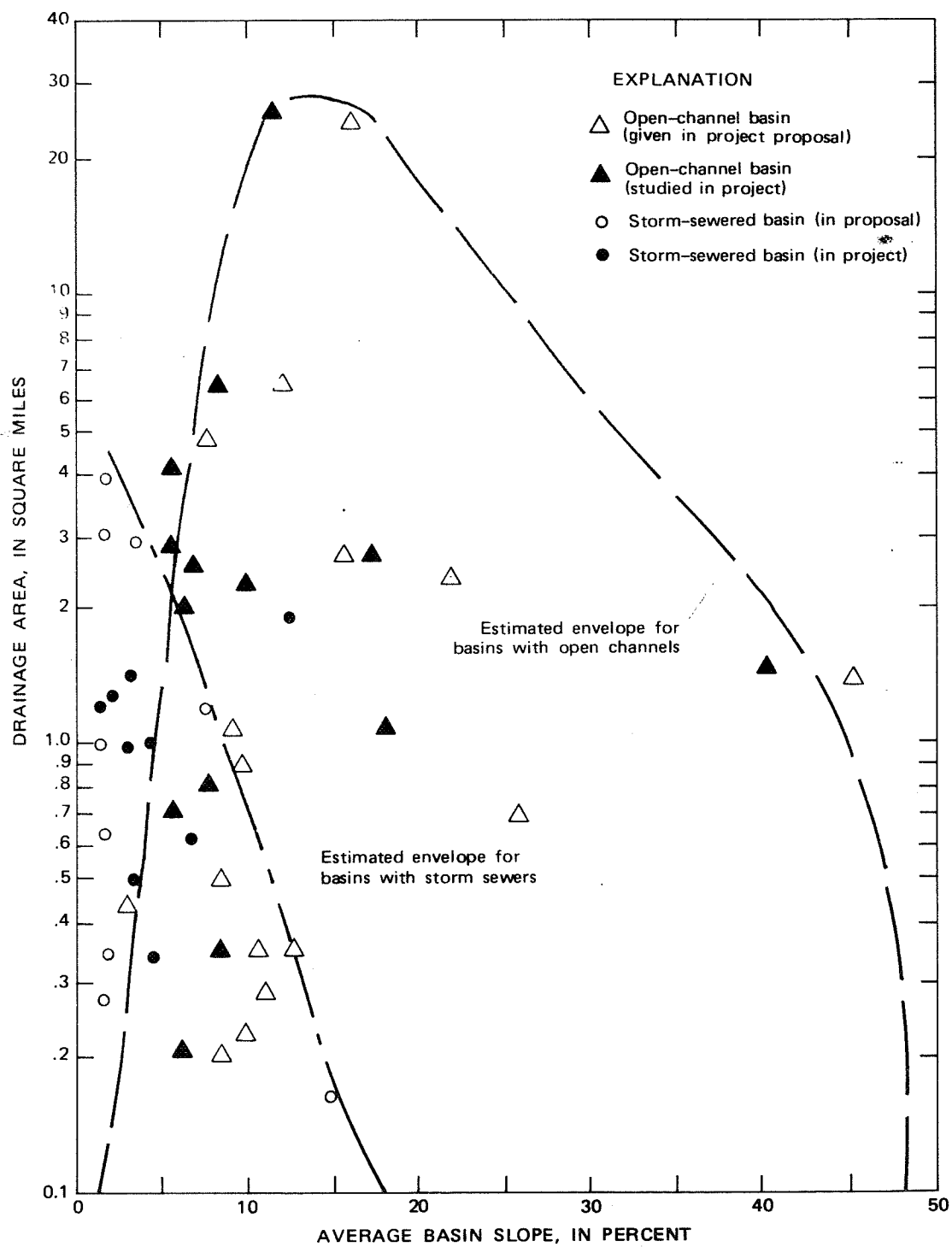


Figure 5.—Distribution of drainage area in relation to average basin slope for project data-collection network.

Table 1.--Drainage-basin characteristics

Item no.	Station number	Station name	Drainage area (mi ²)	Mapped impervious area (percent)	Storage ¹ (cent)	Avg ann. precipi- tation (in.)	Rainfall intensity (in./2)	Land-use types (percent)						BSL (ft/mi)	BSP Basin shape	CSL Channel slope (ft/mi)	CL Channel length (mi)	SA Sewered area (percent)	GUTR Gutter length (mi/mi ²)	Hydrologic soil group (percent)				Soil infiltration rate (in./h)
								I	II	III	IV	V	VI							A	B	C	D	
1	14142580	Kelly Creek	4.16	9	0.1	52	2.2	LU1	LU2	LU3	LU4	LU5	LU6	260	3.69	48	4.7	25	7.0	0	3	87	10	0.09
2	14144690	Vancouver sewer outfall	1.00	49	0	37	1.9	25	0	13	36	21	5	270	3.06	108	2.2	86	44	0	100	0	0	.22
3	14206320	Beaverton Creek	6.63	23	2.0	40	1.9	25	3	51	4	13	4	400	2.66	150	5.7	54	20	0	0	85	15	.09
4	14206330	Beaverton Creek tributary	.21	19	1.1	36	1.8	42	0	53	5	0	0	380	1.77	180	.62	75	37	0	0	90	10	.09
5	14206470	Butternut Creek	.82	8	.3	36	1.8	35	43	20	0	2	0	510	4.13	240	2.4	15	5.6	0	0	80	20	.08
6	14206900	Fanno Creek	2.37	32	0	44	1.8	13	0	75	6	6	0	860	1.75	200	2.5	57	26	0	0	97	3	.10
7	14207800	Singer Creek	.28	28	3.7	50	2.1	18	0	77	4	1	0	580	1.70	310	.77	20	7.3	0	0	100	0	.10
8	14210400	Noyer Creek	2.04	6	0	48	2.2	25	68	6	0	1	0	320	.94	175	1.9	1.3	1.7	0	1	59	40	.07
9	14211110	Willamette River tributary (Robinwood)	1.03	10	0	48	1.9	69	0	29	0	2	0	890	2.71	400	2.1	0	0	0	0	100	0	.10
10	14211120	Willamette River tributary (Oak Grove)	.74	36	.3	44	1.9	14	0	74	4	8	0	280	3.04	160	1.8	.4	0	0	5	85	10	.10
11	14211130	Kellogg Creek	2.42	22	7.0	43	1.9	31	4	62	1	2	0	320	2.18	16	2.7	5.0	2.9	0	47	47	6	.15
12	14211301	Tryon Creek tributary	.36	32	.6	44	1.8	12	0	72	11	5	0	440	1.65	210	.88	29	9.9	0	0	100	0	.10
13	14211450	Johnson Creek tributary	.21	16	0	51	2.1	57	2	33	3	5	0	300	5.15	95	1.1	14	4.9	0	0	100	0	.10
14	14211500	Johnson Creek	26.5	7	.3	53	2.2	35	51	12	1	1	0	580	4.73	32	13.8	3.4	1.1	0	7	85	8	.10
15	14211604	NW. 11th-Everett sewer	1.98	36	0	46	1.9	31	0	12	32	13	12	608	3.65	230	3.4	73	27	0	0	100	0	.10
16	14211610	SE. 9th-Madison sewer	1.53	39	0	45	1.9	4	0	6	60	11	19	136	2.61	66	2.3	89	55	0	100	0	0	.22
17	14211614	NE. Hancock-Flint sewer	1.36	43	0	42	1.9	2	0	0	91	5	2	89	2.49	58	2.8	90	54	0	100	0	0	.22
18	14211617	N. Albina-Kilpatrick sewer	.95	44	0	46	1.9	6	0	1	75	18	0	120	2.24	92	1.6	88	54	0	100	0	0	.22
19	14211618	N. Vancouver-OWR&N ² /sewer	.34	46	0	46	1.9	2	0	0	81	17	0	223	6.62	107	1.5	85	55	0	100	0	0	.22
20	14211625	SE. 27th-Bybee sewer	.77	26	0	46	1.9	7	0	56	37	0	0	317	1.72	166	1.2	91	60	0	100	0	0	.22
21	14211630	SE. 27th-Belmont sewer	.54	35	0	45	1.9	1	0	56	30	13	0	146	1.85	42	1.2	94	48	0	100	0	0	.22
22	14211800	Saltzman Creek	1.48	1	.2	46	1.9	99	0	.5	0	.5	0	1980	2.19	580	2.1	0	0	0	0	100	0	.10
23	14211950	Vancouver Lake tributary	.44	30	2.2	38	1.8	30	0	60	10	0	0	140	1.76	40	1.1	43	17	0	100	0	0	.22
24	14213040	Cougar Creek	2.88	25	3.8	40	1.8	45	5	40	2	8	0	270	4.01	50	4.0	41	16	0	86	0	14	.19

¹/ Surface area in lakes, ponds, depressions, flood plains, and detention storage.²/ Fifty-year (0.02 exceedance probability), 6-hour precipitation intensity.³/ OWR&N, Oregon-Washington Railroad & Navigation Co.

Mapped impervious area (MIA).--Drainage area, in percent of total drainage area, impervious to the infiltration of rain, including such areas as paved roads, paved parking lots, roofs, driveways, and sidewalks. Impervious area was determined from maps made by both the Metropolitan Service District (MSD) and the USGS. MSD mapping was on 1 in. = 600 ft black-and-white 1974 aerial photography. USGS mapping was at a scale of 1:24,000.

Storage (ST).--The surface area, in percent of the total drainage basin, where water can be stored during a storm event. This consists of lakes, ponds, marshes, flood plains, depressions, and detention-storage facilities. Add 0.1 percent to this value to make it valid in regression equations.

Average annual precipitation (AAP).--The average annual precipitation, in inches, for the drainage area for the period 1941-70, estimated from National Oceanic and Atmospheric Administration isohyetal maps (scale 1:2,000,000).

Rainfall intensity (RI).--The 50-year, 6-hour precipitation, in inches, for the drainage area, determined from isopluvial maps (scale 1:2,000,000) published by the National Oceanic and Atmospheric Administration (1973). In this report, it is commonly referred to as intensity. Subtract 1.7 in. from this value to make it valid in the regression equations.

Land-use types.--Land uses in types I through VI, as mapped by MSD and the USGS, and as defined as follows:

- I (LU1). Parks, forests, and vacant lots.
- II (LU2). Agriculture.
- III (LU3). Light-to-normal residential.
- IV (LU4). Dense residential.
- V (LU5). Apartments, commercial areas with some lawns, and industrial areas with gravel lots.
- VI (LU6). Downtown business, shopping centers, and industrial areas with paved lots.

Note: LU12 is the sum of land-use types I and II.

Land Use Inventory maps at a 1-in. = 200-ft scale, which show similar land-use types but in greater detail, are currently in use by MSD.

Basin slope (BSL).--The average slope for the basin, in feet per mile, computed from USGS topographic maps, using the formula described by Wisler and Brater (1959):

$$BSL = CL/DA$$

where

- C = contour interval, in feet,
- L = total length of contours, in miles, and
- DA = drainage area, in square miles.

The relation of basin slope to main channel slope differs considerably between basins in the project area, probably reflecting basin-terrain characteristics. For instance, the Willamette River tributary at Oak Grove has a channel that closely follows the general level of the basin terrain; therefore, the basin slope is not much greater than the main channel slope. The two slope characteristics for Saltzman Creek also are comparable, because both the basin terrain and the channel are quite steep. Characteristics are quite different, however, for Kellogg Creek where the stream lies in a low-gradient valley with steep side slopes. Johnson Creek has similar characteristics and thus has a considerably greater basin slope than channel slope.

Basin shape (BSP).--The ratio of the length to average basin width calculated by the formula:

$$BSP = Lc^2/DA$$

where

Lc = straight-line distance from basin outlet to the point on the basin divide used to measure the main channel, and
DA = drainage area.

Channel slope (CSL).--The channel slope, in feet per mile, for the basin as determined from topographic maps. It is defined as the difference in elevation, in feet, at points 10 percent and 85 percent of the distance upstream from the gaged site along the main channel (see channel length) divided by the distance, in miles, along the channel between the two points.

Channel length (CL).--The channel length, in miles, for the basin as determined from USGS maps. It is defined as the distance from the gaged site upstream to the watershed divide along the most well-defined and longest channel.

Sewered area (SA).--Area, in percent of total drainage area, serviced by storm sewers as taken from drainage maps supplied by various city and county agencies. To define the boundary of the sewered area, the distance of one city block was added to the outermost catch basins on the assumption that the outer catch basins, on the average, would drain approximately a one-block area. Add 0.1 percent to this value to make it valid in regression equations.

Gutters (GUTR).--Length of street gutters, in miles per square mile, defined by drainage maps showing curbs and catch basins, and by field delineation. Add 0.1 mile to this value to make it valid in regression equations. Multiply by 2 if both sides of the street have gutters.

Hydrologic soil group.--Soil group types A through D, as mapped by the U.S. Soil Conservation Service in their county soil surveys (1975) and unpublished soil maps. The range of infiltration rates, in inches per hour, is bracketed following each definition:

- A. (Low runoff potential). Soils having a high infiltration rate, even when thoroughly wetted, and consisting chiefly of deep, well-drained to excessively drained sand or gravel [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 soils with moderately fine to fine texture [0.15 - 0.05].
- D. (High runoff potential). 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 [<0.05].

Soil infiltration rate (INFL).--Average soil infiltration, in inches per hour, as determined by averaging ranges given for each soil group, types A-D, then weighting them by percent of total basin covered.

DESCRIPTION OF THE HYDROLOGIC ANALYSES USED

Digital Model Calibration

The USGS rural and urban rainfall-runoff models developed by Dawdy, Lichty, and Bergmann (1972) were used for modeling and simulation. The intent of this report is not to fully describe the models used, but to describe them adequately enough to give some insight into the models and regression results presented.

Data collected were entered into USGS models as daily rainfall and evaporation (to define antecedent moisture conditions) and as unit rainfall (the individual storm events). During the model-calibration phase for each basin, the various parameters were optimized to yield the best statistical results. Following is a brief description of the model. (See table 2 for a list of model acronyms and definitions.)

Saturated and unsaturated soil-moisture levels for the pervious area are accounted for by using the parameters EVC, RR, BMSM, and DRN. The model simulates hydrographs for pervious and impervious basin segments and adds them together. The model is divided into three phases of optimization--runoff volume, timing, and peak. In both the volume and peak phases, soil-moisture accounting parameters (EVC, RR, BMSM, DRN) and soil-infiltration parameters (PSP, KSAT, RGF) are optimized. For the pervious area, the computation of rainfall excess is accomplished using a modified infiltration equation developed by Phillip (1954). In the timing phase, routing parameters (TC, KSW) are optimized. The surface-routing component is based on unit hydrograph concepts (Sherman, 1932) and assumes a model composed of linear

Table 2.--Identification and definition of parameters used in the digital model^{1/}

Component	Parameter identifier	Units	Definition
Antecedent-moisture accounting	EVC	--	Pan coefficient that converts pan evaporation to potential evapotranspiration.
	RR	--	Coefficient that proportions daily rainfall into infiltration and surface runoff.
	BMSM	Inches	Maximum effective soil-moisture storage volume at field capacity.
	DRN	Inches per hour	Constant coefficient that controls drainage rate of infiltrated soil moisture.
Infiltration	PSP	Inches	Capillary potential, or soil suction, at wetted front for field-capacity conditions.
	RGF	--	Ratio that varies PSP over the soil-moisture range from wilting point to field capacity.
	KSAT	Inches per hour	Minimum saturated value of hydraulic conductivity to determine infiltration rates.
Routing	TC	Minutes	Time characteristic for translation of rainfall excess by distance-area histograms.
	KSW	Hours	Time characteristic for linear reservoir routing.

^{1/} Taken from Dempster (1974).

reservoirs and channels. Optimization is obtained by "hill-climbing" techniques, using bounded parameters (as described by Dawdy, Lichty, and Bergmann, 1972) and the objective function (sum of the squared deviations of logarithms) as the statistical indicator of "best fit."

The model was used to optimize four soil parameters (PSP, KSAT, RGF, and BMSM). All other parameters were set to values computed from either regional data or graphical analysis (table 3).

The urban model allows for the input of multiple rain-gage data for soil-moisture accounting. Subbasin boundaries are defined based on rain-gage location. Sets of distance-area values for both pervious and impervious areas were required for each subbasin. The combination of distributed moisture accounting (multiple input) and distributed routing made it possible to simulate the effects of both rainfall variability and urban development.

The model was used to evaluate the effective impervious area (EIA). This evaluation was based on the premise that runoff volume of a storm in urban areas is highly dependent on the impervious area. This premise has been found to be valid in most urban studies. Verification of this method of estimating effective impervious area was accomplished by a field survey of the effective impervious area in two of the smaller basins.

In many areas in and around Portland and Vancouver, runoff from roofs and any impervious surface either partially or totally drains into dry wells, discharges directly onto lawns, or is routed by unimproved minor channels. In some basins, entire sewered areas are dry-welled. The impervious areas contributing runoff to dry wells or pervious areas in a drainage basin are difficult to determine. One way of estimating an effective impervious area was by using the optimal fitting technique with the Geological Survey's digital rainfall-runoff calibration model. Although this technique lumps many soil and topographic characteristics together, including the impervious area, it still yields a reasonable estimate of the effectiveness of the hydraulic linkage in the system. Effective impervious area can be considerably different from that which may be mapped. To define impervious areas in ungaged basins, the hydraulic connections between the impervious areas and the stream would have to be cataloged, and then evaluated for their effectiveness. This is time consuming and may be impractical for most studies.

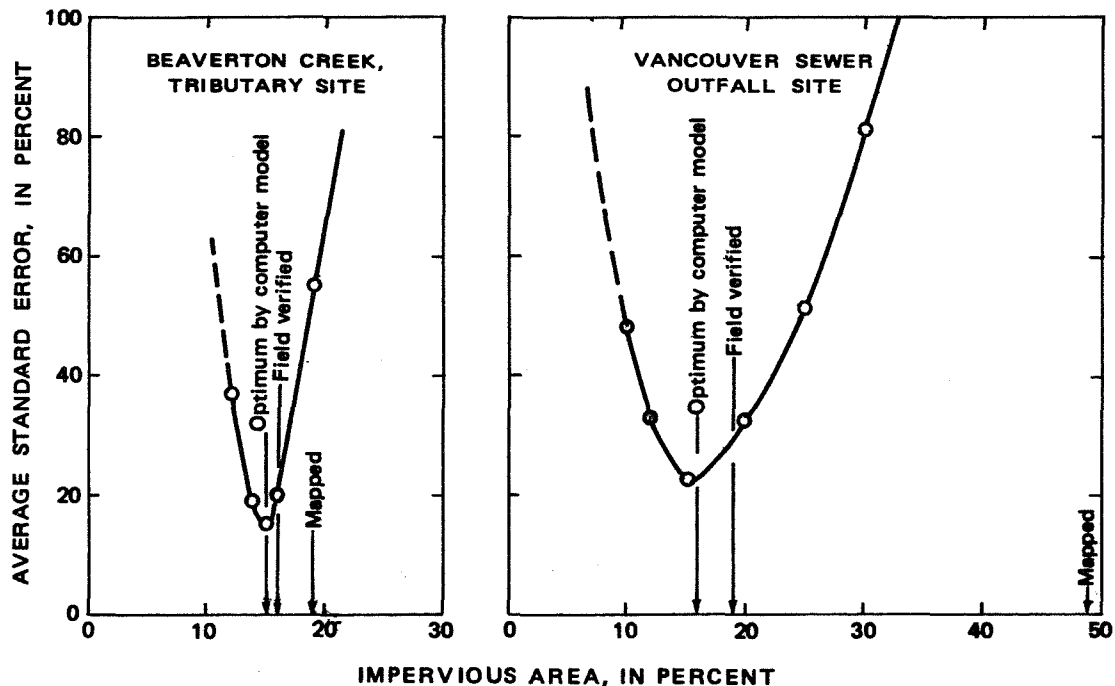
The first phase of the model (volume fitting) was used to compute the standard error for several different values of impervious area. Figure 6 shows how the model "fit" varied with the change in impervious area for two basins. It shows the plot of impervious area, in percent, versus the resulting standard error, with the low point (the best standard error) on the resultant curve yielding the optimal impervious area. The computer-modeled optimal impervious area is, for all practical purposes, the effective impervious area.

Table 3.--Calibrated model parameters used for synthesis of discharge peaks and storm runoff

Station number	Optimized im-pervious area (percent) 1/	Soil parameters 2/					Timing			Avg base flow (ft ³ /s)	Annual rainfall adjust-ment		Slope of re-gression line	Correlation coefficient	Statistics				
		PSP (in.)	KSAT (in./h)	RGF (ratio)	BMSM (in.)	TC (min)	KSW (h)	Lag time (h)	Rainfall intensity adjust-ment		Ratio	Greatest error							
												Average SEE Volume			Peak Volume	Peak Percent	Sample size Avail-able	Used	
14142580	12	2.10	0.080	15.0	2.00	200	3.30	4.96	30	1.20	1.10	1.03	0.852	38	51	180	123	17	14
14144690	16	1.68	.117	21.5	8.00	12	.25	.35	0	.85	.95	.996	.943	22	22	75	49	30	28
14206320	22	1.40	.029	14.9	12.1	240	12	14	15	.98	.98	.970	.988	30	17	47	41	17	13
14206330	15	7.05	.109	20.3	21.2	16	.30	.43	1.5	.85	.95	1.00	.943	15	22	25	50	20	20
14206470	10	.99	.085	16.6	3.83	60	2.50	3.00	7.0	.85	.95	.963	.982	56	20	100	31	28	17
14206900	17	2.05	.070	15.8	7.57	80	1.20	1.87	30	1.00	1.00	.961	.969	23	19	125	46	40	32
14207800	15	4.99	.040	15.4	10.1	20	4.00	4.20	2.5	1.15	1.05	.812	.917	68	35	217	49	23	11
14210400	6	7.85	.027	29.1	1.62	90	4.00	4.75	60	1.13	1.10	1.06	.995	46	14	155	38	17	12
14211110	4	5.44	.039	17.1	7.05	90	3.80	4.55	15	1.10	1.05	1.05	.987	19	16	100	37	24	17
14211120	12	3.51	.101	20.1	8.15	62	1.60	2.12	5.0	1.02	1.02	.811	.894	36	59	60	68	31	28
14211130	15	2.53	.057	12.7	6.64	80	10	10.7	25	.90	.90	.898	.959	65	22	167	73	26	19
14211301	25	5.68	.095	20.0	7.80	40	.60	.93	5.0	1.02	1.02	.958	.950	40	20	175	85	35	35
14211450	7	1.07	.042	21.0	4.86	22	1.70	1.88	3.0	1.16	1.10	1.08	.992	45	19	200	29	20	14
14211500	7	.81	.066	7.15	9.10	600	20	25	300	1.16	1.10	.904	.980	19	20	36	62	17	14
14211604	32	3.78	.117	23.9	6.30	30	.50	.75	20	1.00	1.00	.867	.850	32	36	120	58	39	36
14211610	41	3.54	.272	27.8	7.74	25	.30	.51	7.0	1.00	1.00	1.02	.864	42	34	230	88	29	24
14211614	43	2.14	.137	17.5	14.0	25	.35	.56	5.0	1.00	1.00	.742	.859	30	29	50	46	34	29
14211617	22	6.08	.476	17.7	2.63	15	.20	.32	0	1.00	1.00	.979	.929	37	33	200	46	36	31
14211618	18	2.19	.121	8.69	13.3	10	.20	.28	0	1.00	1.00	.900	.927	30	26	100	49	44	38
14211625	28	2.51	.059	6.98	3.17	10	.20	.28	3.5	1.00	1.00	.876	.909	35	30	75	83	34	32
14211630	35	7.69	.106	7.89	2.47	10	.20	.28	2.5	1.00	1.00	.651	.777	30	42	100	118	40	39
14211800	4	1.22	.035	12.2	6.70	108	3.80	4.70	25	1.10	1.06	1.07	.987	34	22	61	39	8	6
14211950	12	8.87	.811	22.3	3.81	10	.20	.28	0	.90	.90	.768	.869	25	28	75	76	26	25
14213040	11	2.07	.093	22.6	11.4	100	3.00	3.83	12	.90	.90	.646	.872	44	40	92	61	34	28

1/ Optimized impervious area was used as effective impervious area (EIA).

2/ Refer to table 2 for acronym definitions.



Note: Curve delineated by model results of average standard error for various imposed impervious areas with all other model parameters held constant.

Figure 6.—Determination of effective impervious area by digital model.

Field verification was undertaken in two basins--Beaverton Creek tributary (14206330) and Vancouver sewer outfall (14144690). Figure 6 shows the plot of impervious area versus SEE for Beaverton Creek tributary, with the field estimate of the percentage of effective impervious area and the mapped percentage of impervious area indicated. The field estimate showed almost all impervious areas to be effective except for some parking lots that allowed runoff to spill over onto adjacent fields. The Vancouver sewer-outfall basin (see fig. 6) showed the largest difference between mapped impervious area and the computer optimum or effective impervious area for all the basins studied. A field survey showed that only the streets, the freeway, and some downtown buildings were directly connected to the storm-sewer system. In some parts of the basin, paved areas drained into unimproved ditches and swales. In most of the basin, residential dwellings and some downtown buildings had roof drains that were connected directly to dry wells. This basin and adjacent basins have the most extensive use of dry wells as a building practice in the entire study area. There was no way to define the effectiveness of these dry wells during any one storm. For field estimation purposes, all roofs and paved areas were subtracted from the total impervious area where overflow drained onto lawns. No attempt was made to modify the size of the drainage area, which, in reality, has a reduced area contributing to runoff.

The optimization used to define an effective impervious area as described above provides insight into processes that occur between runoff from the actual impervious areas and the ultimate flow in the main channel. This optimization provides a crude way to define interactions that are too complicated to define for a large basin. To some degree, it modifies the apparent influence of soil and topographic parameters of the basin. This optimization technique also masks any error in total drainage area and could reflect some slight bias in the final regression results.

Figures 7, 8, and 9 are graphs of Fanno Creek data. Similar data are available for other basins. Figure 7 is a plot of simulated versus observed runoff volumes, figure 8 is a plot of simulated versus observed peak flows, and figure 9 is a typical storm hydrograph. Table 3 shows a summary of the model calibration results. The average SEE was 36 percent for volumes and 28 percent for peaks. Generally, the model did not simulate thunderstorms well because of the nonuniform areal distribution of the rain. For drainages more than approximately 1 mi², only winter storms were modeled because summer thunderstorms generally simulated lower discharges than observed. In these drainage areas, winter storms produced much larger peaks than did thunderstorms. For basins less than approximately 1 mi², all storms were modeled.

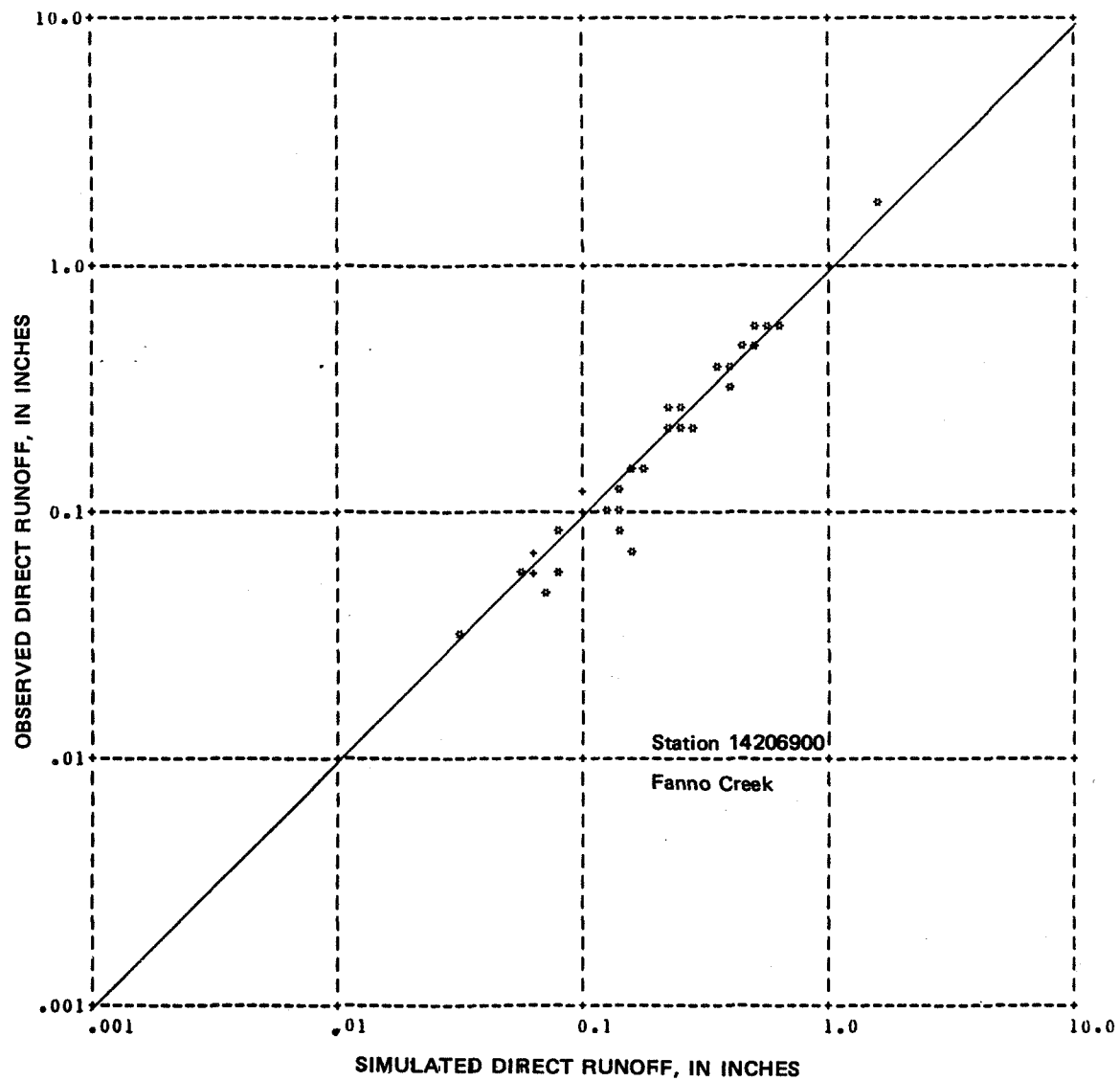
Digital Model Simulation

Five-minute rainfall data for approximately five storms per year for 70 years were obtained from the National Oceanic and Atmospheric Administration. These data were used to drive the calibrated digital model to simulate a set of peaks for each basin studied; these peaks were then used in a flood-frequency analysis.

Inputs to the simulation program were daily rainfall and evaporation (to determine antecedent moisture conditions), unit rainfall, and the calibrated model parameters. Only one rainfall and one evaporation record can be used. Any areal variation in rainfall volume and intensity must be accounted for by direct multipliers to the data input. An annual rainfall adjustment was applied to daily rainfall values, and a rainfall-intensity adjustment was applied to unit rainfall values. Adjustments used for this project are listed in table 3 and were determined from National Oceanic and Atmospheric Administration isohyetal and isopluvial maps. Because the evaporation record was not as long as the rainfall record, it was synthesized using the existing data patterns.

Model Verification

Peak-flow data available from Johnson and Saltzman Creeks (14211500 and 14211800) were compared with computer-synthesized peaks to evaluate the statistical reliability of the methods used in this report and to detect any bias. The comparisons were made for periods outside the model calibration period and provided an independent verification of the model results.



NUMBER OF POINTS PLOTTED (*) = 32
 NUMBER OF MULTIPLE POINTS (+) = 3
 NUMBER OF POINTS OFF GRID (x) = 0
 NUMBER OF POINTS OMITTED = 8

*** NOTE ***
 PLOT ROUTINE EXCLUDES
 POINTS NOT INCLUDED
 IN CALIBRATION

Figure 7.—Example of scatter diagram of model results for storm runoff.

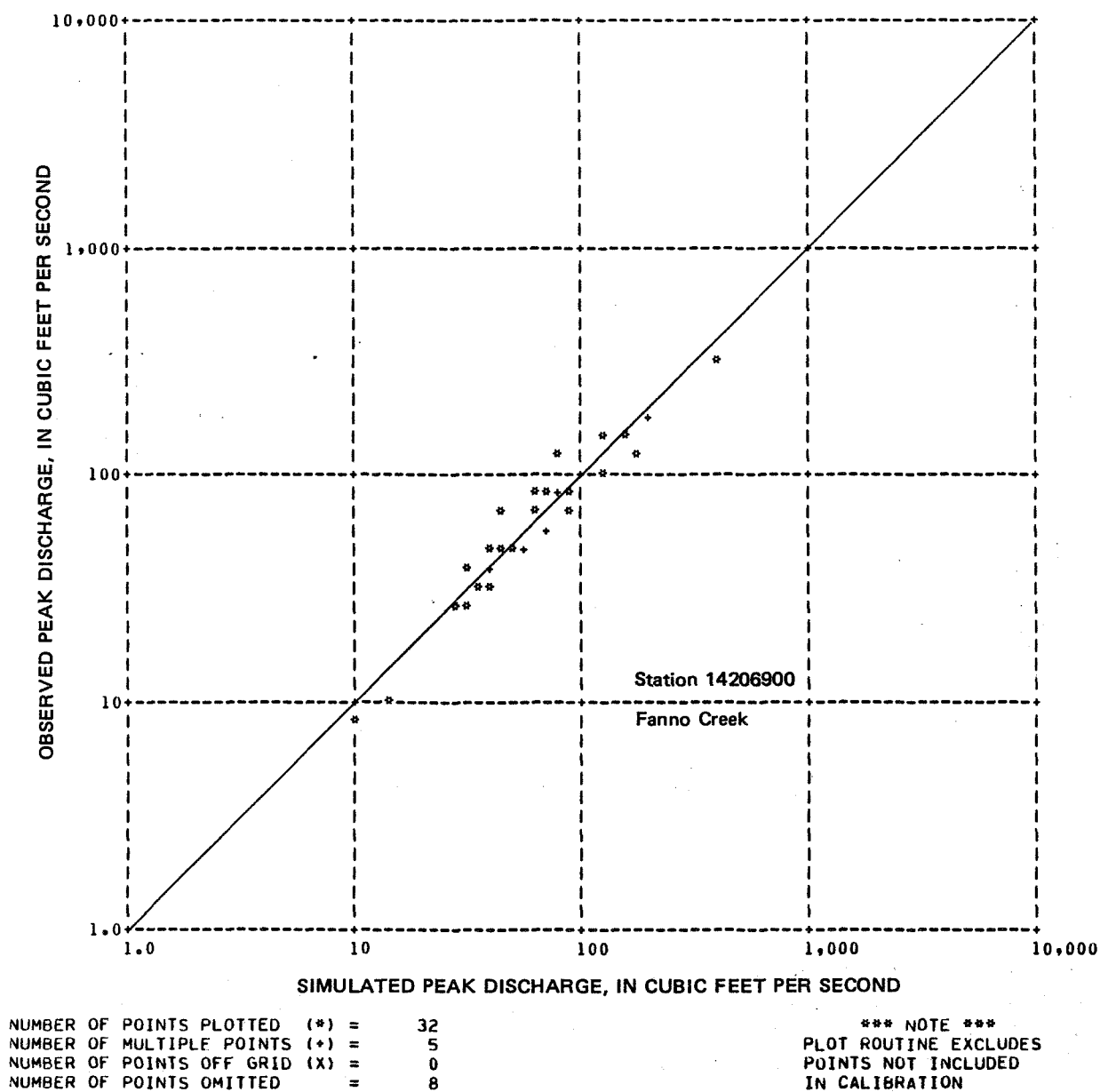


Figure 8.—Example of scatter diagram of model results for peak discharge.

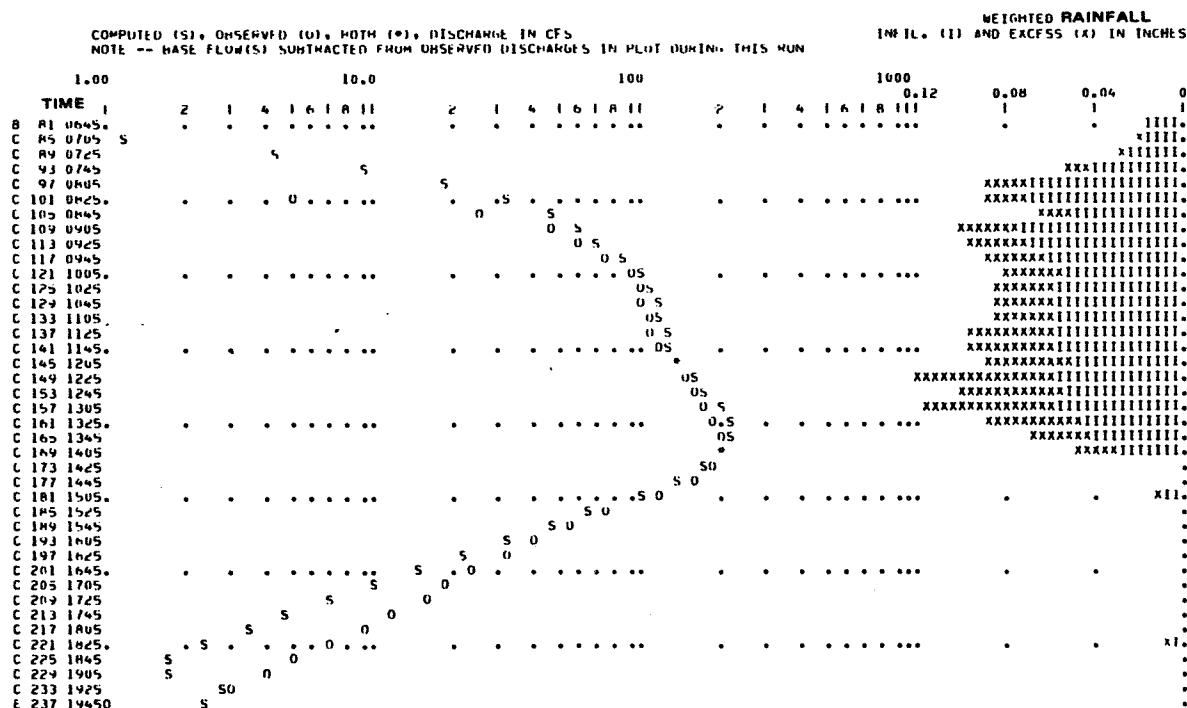


Figure 9.—Storm rainfall and discharge hydrograph.

Johnson Creek, which showed an excellent model calibration, has a large drainage basin. National Weather Service maps indicate that precipitation is 16 percent higher in the Johnson Creek basin than at the location of the rain gage used in synthesis, with at least this much variability for each individual storm. Factors from table 3 were used to adjust historical records in the synthesis. The relation between observed peaks and simulated peaks for Johnson Creek for the period 1949-73 (fig. 10) shows the associated scatter and verifies methods used in this report. The scatter is random, which indicates little, if any, bias. The standard deviation is 30 percent for this relation. Peak-flow data for Saltzman Creek for the period 1952-73 were used in a similar verification. The scatter was random, and the standard deviation was 40 percent. The model calibration for Saltzman Creek is considered to be poor, even with the small SEE shown, because of the small sample size available for calibration.

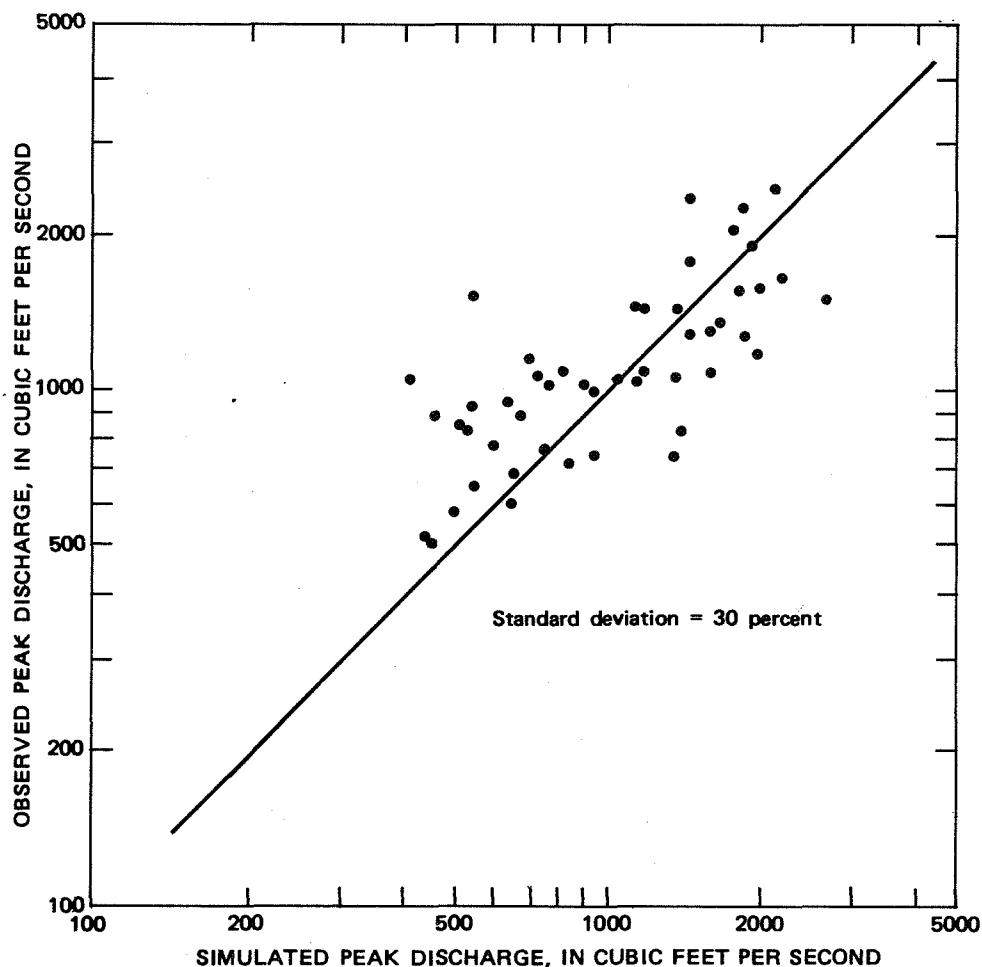


Figure 10.—Johnson Creek (14211500) verification model (1949-73 data plotted).

Peak- and Storm-Runoff Frequency Analyses

Results of the log-Pearson type-III analyses of peak discharges are presented in table 4. Three sets of computations were made using zero skew, a weighted skew using Water Resources Council (WRC) guidelines, and the station skew to show the variability caused by the use of different skews. The average of all station skews for peak-discharge frequency relations in this area is +0.03, which is approximately equal to the regional skew of +0.1 and closely approximates zero skew. The weighted skew was based on annual peak flows synthesized from 71 years of rainfall data. This approach is acceptable since the average of the weighted skews, +0.08, is nearly the same as the averages of the other skews used. Regression analyses covered all skew-discharge data included in table 4, and the final regression analysis used the weighted skew. The various regression results were not statistically different, less than 10 percent change in any one coefficient or exponent, and did not decrease the SEE significantly; therefore, these results were not included in this report.

Table 4.--Peak discharges for selected flood frequencies and skews at gaged sites, derived by synthesizing discharge from historical rainfall data (Portland, Oreg., Customs House, 1903-73)

Station number	Peak discharge, in ft ³ /s, for exceedance probabilities (recurrence interval) at zero skew						WRC weight-skewed skew ^{1/}	Peak discharge, in ft ³ /s, for exceedance probabilities (recurrence interval)						Station skew	Peak discharge, in ft ³ /s, for exceedance probabilities (recurrence interval)						Storm base flow ^{2/} (ft ³ /s)
	0.5 (2 yr)	0.2 (5 yr)	0.10 (10 yr)	0.04 (25 yr)	0.02 (50 yr)	0.01 (100 yr)		0.5 (2 yr)	0.2 (5 yr)	0.10 (10 yr)	0.04 (25 yr)	0.02 (50 yr)	0.01 (100 yr)		0.5 (2 yr)	0.2 (5 yr)	0.10 (10 yr)	0.04 (25 yr)	0.02 (50 yr)	0.01 (100 yr)	
14142580	276	432	546	702	824	953	0.127	273	430	550	718	855	1,000	0.145	272	430	551	720	859	1,010	30
14144690	122	204	268	358	431	510	-.184	124	205	263	341	400	460	-.364	126	206	260	330	381	432	0
14206320	317	474	586	733	848	966	-.157	321	476	581	715	814	914	-.320	325	477	575	694	779	862	15
14206330	13	19	24	30	35	39	.512	12	19	24	32	39	47	.772	12	19	24	33	42	51	1.5
14206470	51	76	93	117	135	153	-.073	52	76	93	115	132	150	-.182	52	76	93	113	128	144	7.0
14206900	212	308	375	461	527	594	.034	211	308	376	464	532	601	-.008	213	308	374	460	526	592	30
14207800	14	22	27	34	39	45	.140	14	22	27	35	41	47	.166	14	22	27	35	41	48	2.5
14210400	167	222	258	303	336	369	.161	165	221	260	310	347	386	.199	165	221	260	310	348	388	60
14211110	59	85	102	124	142	159	.066	59	84	102	125	143	162	.044	59	84	102	125	143	161	15
14211120	38	58	73	91	106	120	.220	37	58	74	95	112	131	.296	36	58	75	100	121	145	5.0
14211130	92	130	155	187	212	236	.239	91	129	156	192	222	252	.327	90	129	157	195	227	260	25
14211301	36	50	60	71	80	89	.386	35	50	60	75	87	100	.567	35	49	61	77	90	105	5.0
14211450	25	35	42	50	56	63	-.563	26	35	40	46	50	53	-.892	27	35	39	44	46	48	3.0
14211500	1,310	1,830	2,180	2,620	2,960	3,300	.164	1,290	1,820	2,190	2,680	3,060	3,450	.205	1,290	1,820	2,190	2,700	3,090	3,500	300
3/ 14211500	1,150	1,830	2,320	3,000	3,530	4,100	-.097	1,160	1,830	2,320	2,970	3,480	4,000	-.796	1,230	1,840	2,190	2,560	2,800	3,000	--
14211604	249	357	431	527	600	675	.205	245	355	435	543	629	720	.272	244	354	436	548	638	735	20
14211610	237	345	419	516	591	667	.211	233	343	423	532	620	712	.281	232	342	424	538	631	730	7.0
14211614	228	344	427	536	621	710	.295	226	341	430	551	648	750	.418	221	340	434	573	691	822	5.0
14211617	95	141	174	218	252	286	.077	94	141	175	220	255	292	.063	94	141	175	220	256	293	0
14211618	51	88	118	162	198	237	-.020	51	89	118	160	195	233	-.096	51	89	118	158	191	277	0
14211625	155	245	311	400	472	547	-.091	158	246	306	385	445	504	-.212	158	246	306	384	443	502	3.5
14211630	102	167	216	285	341	400	.016	102	167	216	284	340	402	-.037	102	167	216	283	337	394	2.5
14211800	133	180	211	250	279	308	-.181	134	180	210	245	272	297	-.359	136	181	208	238	260	279	25
4/ 14211800	104	168	217	286	343	404	.100	104	168	217	287	344	406	-.036	105	169	216	280	330	384	--
14211950	16	25	31	40	47	54	.055	16	25	31	40	48	56	.027	16	25	31	40	47	55	0
14213040	86	143	186	246	295	348	.333	82	143	190	269	334	413	.480	82	140	190	270	343	428	12

- 1/ Time-weighted skew based on guidelines in WRC report (1977).
2/ Average base flow used in calibration and added to simulated peaks.
3/ Actual discharge data for Johnson Creek (1941-78).
4/ Actual discharge data for Saltzman Creek (1952-78).

Included in table 4 are peak discharges based on actual field data for Johnson and Saltzman Creeks. These data have been included so that comparisons can be made with modeled data. The modeled frequency curves have 0.01 exceedance-probability peak discharges that deviate by -14 and -27 percent from station discharge values for Johnson Creek and Saltzman Creek, respectively. A better indicator of bias, however, might be obtained by comparing data derived from actual station skews, where the 0.01 exceedance-probability peaks deviate by +17 and -27 percent for Johnson and Saltzman Creeks, respectively. The maximum deviations are generally the same magnitude as the model calibration errors of 20 and 22 percent for Johnson and Saltzman Creeks, respectively. Statistically, areal variability of rainfall is assumed to be eliminated because of the large sample size of the synthetic data used.

Storm runoffs derived using station skew (table 5) were used in the final regression analysis. Skews based on WRC guidelines do not apply to runoff data.

Storm Base Flow

In this report, base flow during a storm is defined as that component of runoff not attributed to overland flow and is highly variable from storm to storm and from basin to basin. Base flow is influenced by antecedent conditions and can be attributed to the inflow of ground water, interflow between the stream and the unsaturated zone, and return flow from diversions. For combined sewers, the base flow is the flow of sewage.

For the individual model calibrations, base flows were defined by the observed discharge hydrograph. Flows prior to and after the storm event were averaged to define storm base flow for individual peaks. In synthesis, base flow had to be estimated for the individual basins. Because only the larger peaks defined the segment of the log-Pearson type-III frequency curve used in the analysis, the average base flow of the higher peaks was used as the estimate. This estimate was applied uniformly, regardless of peak size, in model synthesis for the individual basin. For peak data in most basins, base flows were normally less than 10 percent of the total flow.

For a few streams at exceedance probabilities between 0.5 and 0.1, the base-flow component could be higher than the runoff component from overland flow (see table 5).

Storm base-flow variability was analyzed, but no well-defined relation between basin parameters or antecedent conditions could be developed. To accommodate the separation of base flow for storms, two sets of regression equations are provided with and without storm base flow. Subtraction of discharges derived by the two equations is not considered a reliable means for deriving base flow.

Table 5.--Peak-discharge yields and storm runoff for selected flood frequencies at gaged sites, derived by synthesizing from historical rainfall data (Portland, Oreg., Customs House, 1903-73)

Station number	Station skew	Peak yield, in (ft ³ /s)/mi ² , for exceedance probabilities (recurrence interval)						Station skew	Runoff with base flow, in inches, for exceedance probabilities (recurrence interval)						Station skew	Runoff less base flow, in inches, for exceedance probabilities (recurrence interval)					
		0.5 (2 yr)	0.2 (5 yr)	0.10 (10 yr)	0.04 (25 yr)	0.02 (50 yr)	0.01 (100 yr)		0.5 (2 yr)	0.2 (5 yr)	0.10 (10 yr)	0.04 (25 yr)	0.02 (50 yr)	0.01 (100 yr)		0.5 (2 yr)	0.2 (5 yr)	0.10 (10 yr)	0.04 (25 yr)	0.02 (50 yr)	0.01 (100 yr)
14142580	0.145	65	103	132	173	206	242	0.131	1.58	2.39	2.99	3.81	4.47	5.18	0.001	0.98	1.67	2.22	2.99	3.63	4.32
14144690	-.364	126	206	260	330	381	432	-.140	.45	.87	1.20	1.70	2.11	2.56	-.140	.45	.87	1.20	1.70	2.11	2.56
14206320	-.320	49	72	87	105	118	130	-.121	1.37	2.18	2.77	3.55	4.16	4.79	-.334	1.26	2.05	2.60	3.29	3.82	4.33
14206330	.772	57	90	114	157	200	243	-.301	.80	1.17	1.42	1.72	1.94	2.16	-.160	.25	.45	.60	.82	.99	1.18
14206470	-.182	63	93	113	138	156	176	-.078	1.48	2.26	2.80	3.52	4.07	4.63	-.215	.75	1.35	1.80	2.42	2.92	3.45
14206900	-.008	90	130	158	194	222	250	-.235	1.80	2.65	3.21	3.90	4.41	4.92	-.313	.78	1.36	1.77	2.32	2.74	3.17
14207800	.166	50	79	96	125	146	171	.329	1.61	2.54	3.28	4.37	5.30	6.32	.106	.81	1.53	2.14	3.08	3.91	4.86
14210400	.199	81	108	127	152	171	190	-.092	3.42	4.79	5.70	6.83	7.67	8.50	-.472	1.00	1.80	2.37	3.11	3.66	4.20
14211110	.044	57	82	99	121	139	156	.141	2.04	3.12	3.93	5.05	5.95	6.92	-.153	.78	1.48	2.06	2.90	3.60	4.36
14211120	.296	49	78	101	135	164	196	.054	1.00	1.60	2.06	2.70	3.21	3.76	-.062	.45	.88	1.24	1.78	2.24	2.76
14211130	.327	37	53	65	81	94	107	.245	1.78	2.60	3.21	4.04	4.72	5.44	-.027	.91	1.56	2.05	2.76	3.33	3.95
14211301	.567	97	136	169	214	250	292	-.290	1.80	2.68	3.26	3.98	4.50	5.01	-.294	.64	1.13	1.50	2.00	2.38	2.78
14211450	-.892	129	167	186	210	219	229	-.182	2.38	3.52	4.28	5.24	5.96	6.67	-.536	1.27	2.11	2.67	3.35	3.83	4.29
14211500	.205	49	69	83	102	117	132	.114	2.30	3.38	4.16	5.20	6.03	6.89	-.292	1.36	2.26	2.90	3.73	4.36	4.99
14211604	.272	123	179	220	277	322	371	-.302	1.56	2.39	2.95	3.65	4.17	4.67	-.319	.75	1.34	1.77	2.35	2.80	3.26
14211610	.281	152	224	277	352	412	477	-.069	1.34	2.12	2.69	3.45	4.05	4.68	-.063	.91	1.56	2.06	2.76	3.34	3.95
14211614	.418	162	250	319	421	508	604	-.101	1.10	1.83	2.37	3.11	3.70	4.32	-.092	.82	1.47	1.97	2.70	3.29	3.94
14211617	.063	99	148	184	232	270	308	.006	.38	.66	.90	1.23	1.50	1.81	.006	.38	.66	.90	1.23	1.50	1.81
14211618	-.096	150	262	347	465	562	668	-.219	.50	.92	1.25	1.71	2.08	2.48	-.219	.50	.92	1.25	1.71	2.08	2.48
14211625	-.212	259	403	502	630	726	823	-.263	1.34	2.15	2.71	3.44	4.00	4.55	-.276	.88	1.56	2.08	2.78	3.22	3.88
14211630	-.037	189	309	400	524	624	730	-.143	1.06	1.73	2.21	2.85	3.36	3.88	-.148	.71	1.27	1.71	2.32	2.82	3.35
14211800	-.359	92	122	141	161	176	189	.021	2.99	4.31	5.23	6.43	7.35	8.29	-.535	1.36	2.31	2.95	3.74	4.30	4.84
14211950	.027	36	57	70	91	106	125	.008	.21	.38	.50	.69	.84	1.00	.008	.21	.38	.50	.69	.84	1.00
14213040	.480	29	49	66	94	119	149	-.132	.75	1.16	1.44	1.81	2.09	2.37	-.334	.41	.72	.95	1.26	1.49	1.73

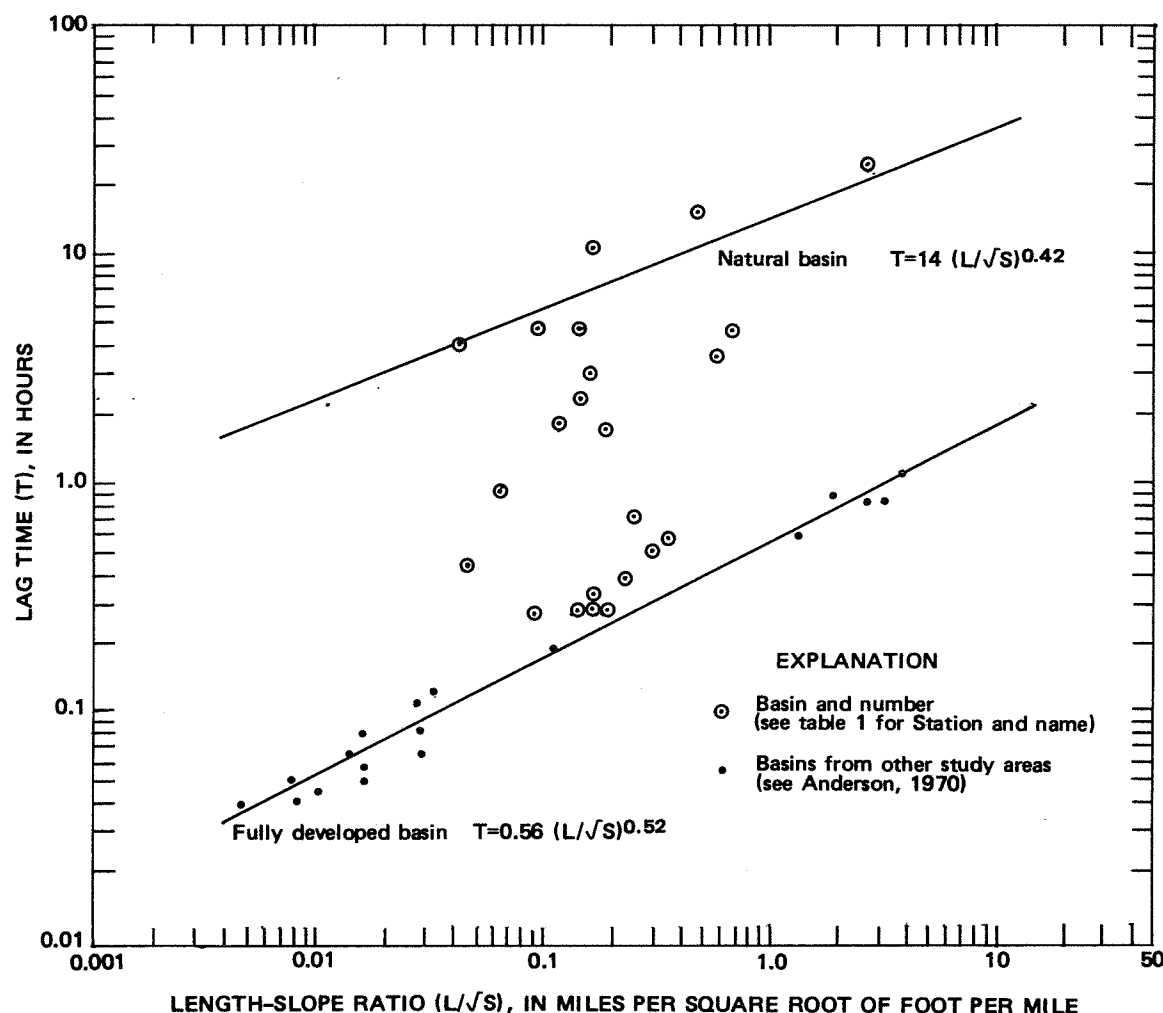


Figure 11.—Relation of lag time to length-slope ratio

Lag-Time Relations

One of the early analyses made in this study was to define the relation of lag time to the length-slope ratio (channel length divided by the square root of the slope). Relations for basins in this area plotted in a random pattern; some highly developed urban basins showed the same relation as did natural basins. The causes of this random pattern are apparently (1) large differences between the mapped impervious area and its effectiveness, (2) differences in topography associated with the pervious terrace areas which create and modify the response, and (3) man's alterations which do not always improve channel conditions. The relations shown in figure 11, however, define boundary conditions and are helpful in determining what may be occurring in a basin. The lag-time relation for natural basins in this area is higher than for other basins (Anderson, 1970). Saltzman and Johnson Creeks were used to define the natural relation shown in figure 11, whereas the slope of the line is from relations shown by Anderson (1970).

UNIQUENESS OF SELECTED INDIVIDUAL BASINS

Natural and manmade conditions in a basin make it unique in its response to any rainfall event. Each basin studied had to be scrutinized to define its hydraulic conditions so that the analysis used would be valid.

In planning this study, (1) problem basins were excluded, especially those with variable backwater at the proposed gaging site and with upstream storage problems thought to be untypical of the study area; and (2) urban development had to be minimal. Even with this screening of the network, many basin characteristics were less than ideal. Following is a discussion concerning basins that were not ideal, but from which usable data were obtained.

Kelly Creek (14142580)

Urban development in Kelly Creek was extensive during the period of data collection. Mapped impervious area increased from 9 to about 16 percent of the total area. Because not enough data were collected to provide a large statistical sample to define different periods, the calibrated model used all peaks collected and a "median" relation was developed. It appears, however, that the magnitude for the lower peaks modeled increased about 60 percent from 1975 to 1978. The SEE for model calibration for this basin was greater than for other basins, probably because of the increase in urban development.

Vancouver Sewer (14144690)

Early calibrations of the Vancouver sewer basin showed that something was amiss with the impervious value determined by mapping techniques. A field survey revealed that many of the roofs in this basin, as well as in much of the Vancouver area, drained directly into dry wells. However, field assessment to determine the volume of water drained into dry wells for any one storm event is difficult. Dry wells in this area have been in use for at least 30 to 75 years, collecting organic material and clogging the gravel. Many downspout tiles have overflow holes, and all tiles can overflow if they are plugged or if their infiltration rates are exceeded. For field-estimating purposes, all roofs and paved areas were subtracted from the total impervious area where overflow drained onto lawns. No attempt was made to modify the size of the drainage area that is effectively smaller because of the use of dry wells. In other parts of the basin, paved areas drained into unimproved ditches and swales and were subtracted from the total impervious area. The remaining impervious areas of streets, sidewalks, some downtown buildings, and the freeway are directly connected by a storm-sewer system.

Beaverton Creek (14206320)

Peak discharges for this site are modified significantly because of upstream storage caused by several undersized culverts in the main channel. Volume data are not affected. The magnitude of this anomaly was not realized until the basin was modeled. An excellent simulation was defined, as shown by the high correlation coefficient (table 3); however, the extremely long lag time (fig. 11) and low peak yields (table 4) were inconsistent considering

basin size. This inconsistency might be considered to be an example of the urban paradox where channel modifications reduce peak flows and back up water. In addition to the storage created by channel modifications, Beaverton Creek has substantial storage in lakes and reservoirs, and some storage in detention facilities. The effect of new county codes requiring detention-storage facilities for new construction cannot be assessed at this time.

The log-Pearson type-III frequency analysis for peak discharges for this basin is probably valid to at least the 0.04 exceedance probability. For less than 0.04 exceedance probability, it can be postulated that the stored water will likely either back up or overflow. At what probability this will occur or to what magnitude is unknown unless a detailed backwater analysis is made. When flood-plain storage (0.9 percent) is excluded from the equation computation, regression equations developed later in this report show a 20-percent increase in peak magnitude for the 0.01 exceedance-probability peak.

Beaverton Creek Tributary (14206330)

Peak discharges for the Beaverton Creek tributary site are slightly modified because of detention-storage facilities in the basin. Only about 1 acre is in detention storage within the basin; however, because of the small total drainage involved, it has a significant impact on peak flows. Additional storage area is created by natural depressions and low areas.

Butternut Creek (14206470)

Urban development in the Butternut Creek basin increased extensively during the period of data collection. The mapped impervious area increased from 8 to about 12 percent of the total area. All peak discharges were used to define the median relation. In contrast to Kelly Creek for the same data-collection period, no difference in flood magnitudes was detected from 1975 to 1978. Differences in soil and natural vegetation between the two areas may have lessened the impact of urbanization in this area.

Singer Creek (14207800)

As in the Beaverton Creek basin, the Singer Creek basin has reduced peak flows and increased lag times compared to most urban basins. Much of the storage in Singer Creek basin is variable, however, and is primarily caused by debris continually clogging upstream culverts and sewers. This stream is typical of urban streams with deep canyons and "high-fill" culvert crossings. Also typical is the fact that considerable urban refuse finds its way into the stream channels, thereby impeding flow through the culverts. A significant number of peaks at the stream-gage location at Singer Creek had to be deleted from the record because of debris jams caused by refuse. Because of these storage problems, the SEE for the model calibration of Singer Creek was greater than that for most other sites. Debris jams also caused considerable loss of data at other stream-gage locations.

Kellogg Creek, Vancouver Lake Tributary, and Cougar Creek (14211130),
14211950, 14213040)

The Kellogg Creek, Vancouver Lake tributary, and Cougar Creek basins are all on terraces. Topographic depressions in the terrace surfaces restrict drainage and store water in each basin. In Vancouver Lake tributary and Cougar Creek, this stored water is lost to the streamflow system so that peak storm volumes are decreased (see table 4). City sewer gages for areas on the terrace also record decreased runoff volumes. Kellogg Creek, however, eventually receives most of the water stored in depressions back through inter-flow, as indicated by the large storage component (KSW) of its hydrograph. Kellogg Creek basin also has additional storage in the form of manmade ponds and natural marshes along its channel. Cougar Creek has a minor amount of storage caused by backwater at small culverts in the upper basin.

Tryon Creek Tributary (14211301)

A significant segment of the Tryon Creek tributary basin loses rainwater through improper connections of roof drains to the sanitary-sewer system. Although this condition occurs frequently in many basins, it is more extensive in this basin than in most others. Six percent of the basin, or 17 percent of the impervious area, is affected, according to a study by the city of Portland Department of Public Works, Bureau of Sanitary Engineering.

Saltzman Creek (14211800)

Saltzman Creek basin was the only totally forested basin and also the steepest basin in the study area (table 1). Because vegetation and forest litter provided significant water retardation and storage, only the longest duration rainstorms had sufficient runoff to model. Rain from thunderstorms was absorbed in the basin with virtually no runoff, and light winter rains tended only to increase base flow. When the basin was saturated, however, peak flows were high in magnitude because of fast runoff from the steep terrain. The runoff hydrograph is complicated by the presence of a storage reservoir (generally full in winter) and an undersized culvert in the upper basin.

REGIONALIZATION OF FLOOD-PEAK AND STORM-RUNOFF CHARACTERISTICS

Peak discharges and runoff volumes, determined by log-Pearson type-III analyses, were regressed against basin parameters. Effective impervious area proved to be a better indicator of urbanization than mapped impervious area, decreasing the SEE by approximately 10 percent. The combination of land-uses I and II and street-gutter density had a good correlation with effective impervious area ($R^2 = 0.804$ and $SEE = 32$ percent). The equation is as follows: $EIA = 25 LU12^{-0.29} (GUTR + 0.1)^{0.16}$. The land-use and gutter parameters, regressed in separate analyses to define peak discharge and storm runoff, showed sensitivities and SEE's similar to those using the effective impervious area parameter. All basin parameters defined in this report were included in the regression analyses; however, only those that were statistically significant and that improved results are included in the regression

results shown in tables 7 through 12. The following equations are extracted from tables 7 through 12 because they have acceptable SEE's and utilize the most practical basin characteristics available:

Equation 8, table 8.--Peak discharge, in cubic feet per second, for exceedance probabilities shown (recurrence intervals are shown in parentheses):

$$\begin{aligned} Q_{0.5} (2 \text{ yr}) &= 79 \text{ DA}^{0.93} \text{ LU12}^{-0.12} (\text{GUTR}+0.1)^{0.05} (\text{ST}+0.1)^{-0.27} \\ Q_{0.2} (5 \text{ yr}) &= 127 \text{ DA}^{0.93} \text{ LU12}^{-0.14} (\text{GUTR}+0.1)^{0.06} (\text{ST}+0.1)^{-0.26} \\ Q_{0.1} (10 \text{ yr}) &= 162 \text{ DA}^{0.94} \text{ LU12}^{-0.16} (\text{GUTR}+0.1)^{0.06} (\text{ST}+0.1)^{-0.25} \\ Q_{0.04} (25 \text{ yr}) &= 214 \text{ DA}^{0.94} \text{ LU12}^{-0.17} (\text{GUTR}+0.1)^{0.07} (\text{ST}+0.1)^{-0.24} \\ Q_{0.02} (50 \text{ yr}) &= 256 \text{ DA}^{0.93} \text{ LU12}^{-0.18} (\text{GUTR}+0.1)^{0.07} (\text{ST}+0.1)^{-0.23} \\ Q_{0.01} (100 \text{ yr}) &= 303 \text{ DA}^{0.94} \text{ LU12}^{-0.19} (\text{GUTR}+0.1)^{0.08} (\text{ST}+0.1)^{-0.22} \end{aligned}$$

The above equations yield an average R-square of 0.97 and have an average SEE of 23 percent. Figure 12 is the residual plot for the individual basins at the 0.5 exceedance-probability level.

Equation 5, table 10.--Storm runoff, less base flow, in inches, for exceedance probabilities shown:

$$\begin{aligned} R_{0.5} (2 \text{ yr}) &= 0.39 (\text{RI}-1.7)^{0.70} \text{BSL}^{0.34} \text{LU12}^{-0.07} \\ R_{0.2} (5 \text{ yr}) &= 0.48 (\text{RI}-1.7)^{0.60} \text{BSL}^{0.39} \text{LU12}^{-0.11} \\ R_{0.1} (10 \text{ yr}) &= 0.66 (\text{RI}-1.7)^{0.60} \text{BSL}^{0.39} \text{LU12}^{-0.12} \\ R_{0.04} (25 \text{ yr}) &= 0.96 (\text{RI}-1.7)^{0.60} \text{BSL}^{0.38} \text{LU12}^{-0.13} \\ R_{0.02} (50 \text{ yr}) &= 1.22 (\text{RI}-1.7)^{0.60} \text{BSL}^{0.37} \text{LU12}^{-0.13} \\ R_{0.01} (100 \text{ yr}) &= 1.52 (\text{RI}-1.7)^{0.59} \text{BSL}^{0.36} \text{LU12}^{-0.14} \end{aligned}$$

The above equations yield an average R-square of 0.62 and have an average SEE of 32 percent. Figure 13 is the residual plot for the individual basins at the 0.5 exceedance-probability level.

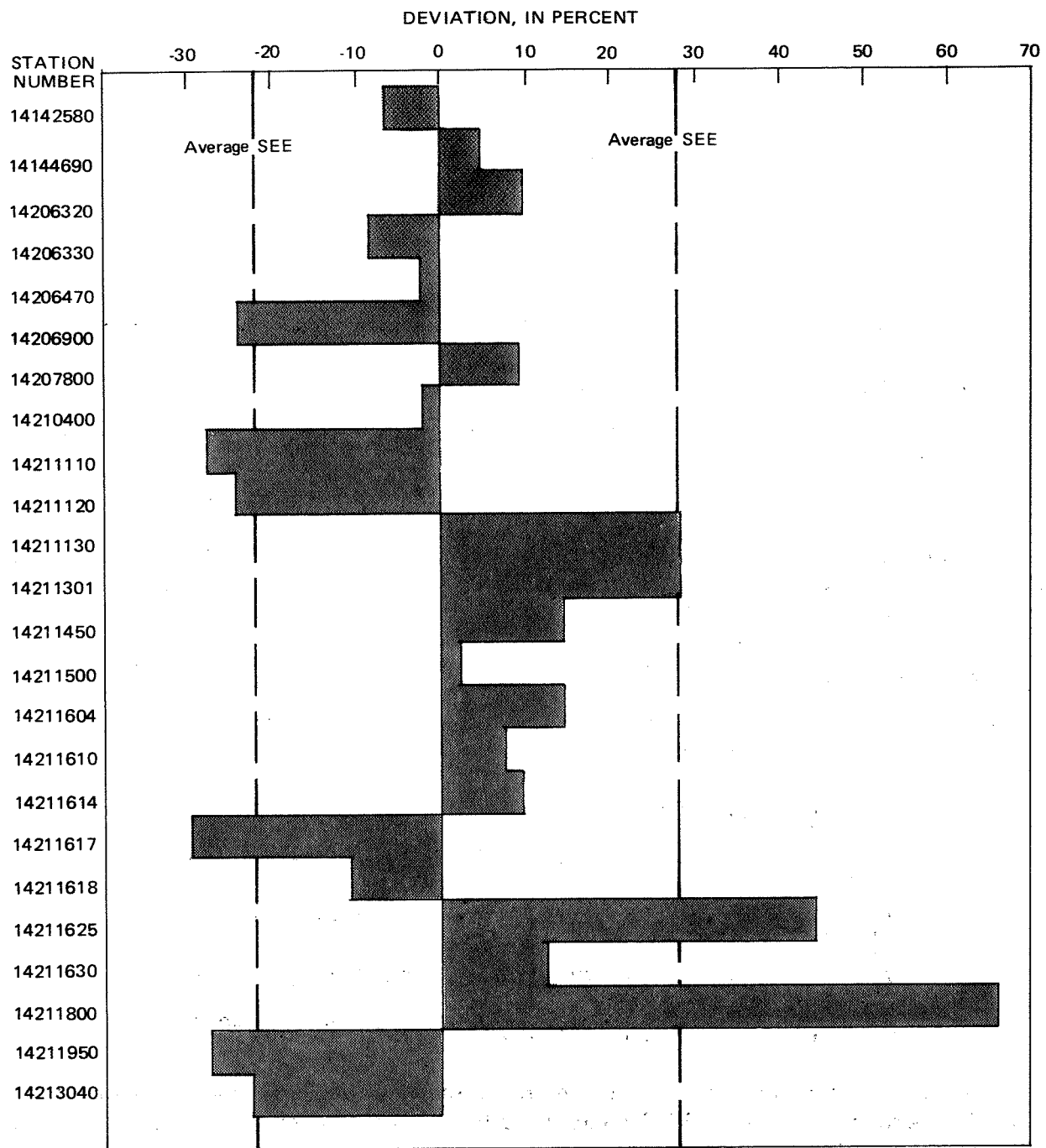


Figure 12.—Residuals of peak discharge for 0.5 exceedance probability for individual basins

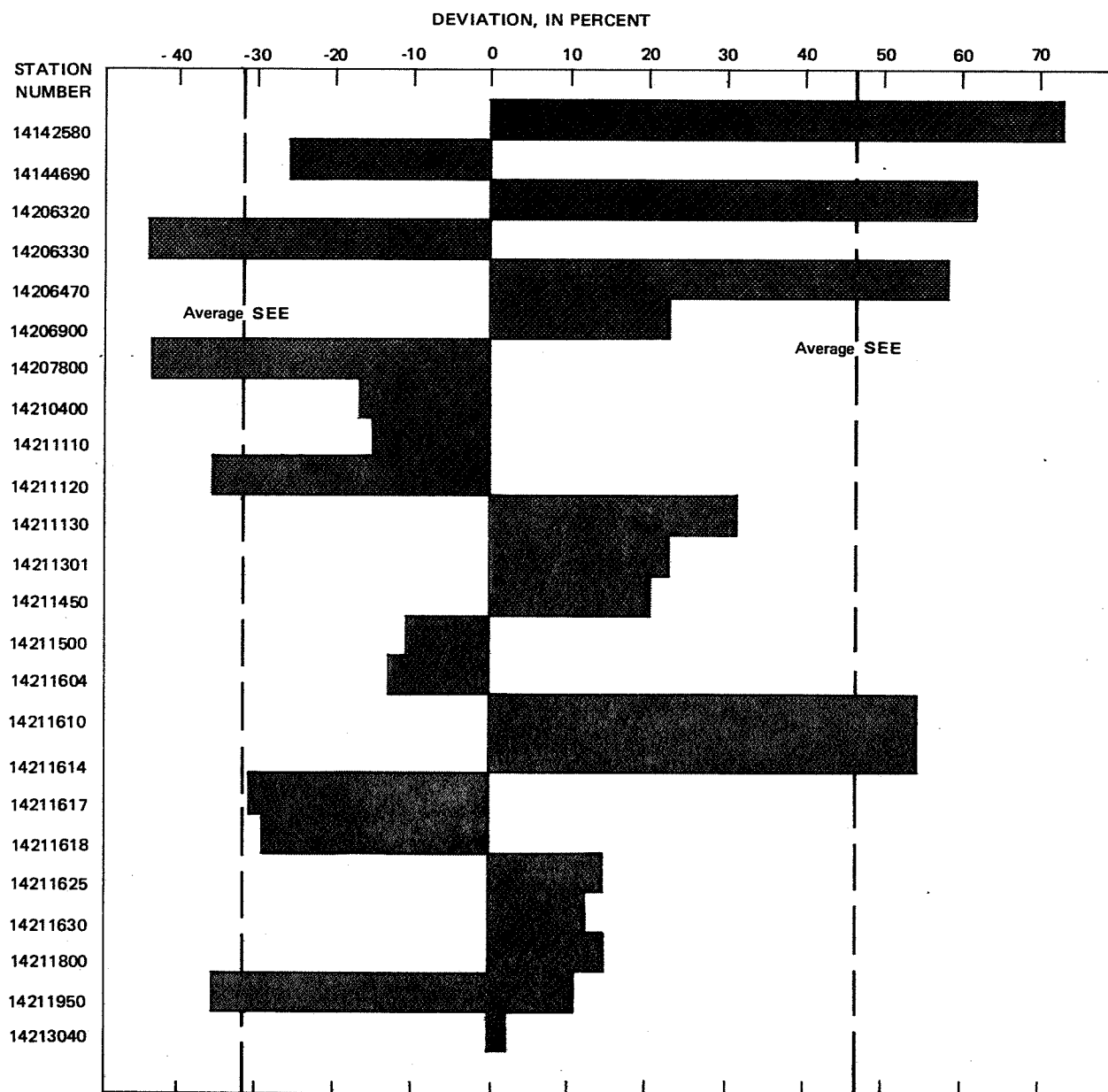


Figure 13.—Residuals of storm runoff for 0.5 exceedance probability for individual basins.

Equation 7, table 12.--Storm runoff, with base flow, in inches, for the exceedance probabilities shown:

$$\begin{aligned}
 R_{0.5} \text{ (2 yr)} &= 0.078 (\text{RI}-1.7)^{0.49} \text{BSL}^{0.44} \text{LU12}^{-0.15} \text{INFL}^{-0.72} \\
 R_{0.2} \text{ (5 yr)} &= 0.17 (\text{RI}-1.7)^{0.49} \text{BSL}^{0.42} \text{LU12}^{-0.15} \text{INFL}^{-0.61} \\
 R_{0.1} \text{ (10 yr)} &= 0.26 (\text{RI}-1.7)^{0.50} \text{BSL}^{0.41} \text{LU12}^{-0.16} \text{INFL}^{-0.55} \\
 R_{0.04} \text{ (25 yr)} &= 0.41 (\text{RI}-1.7)^{0.51} \text{BSL}^{0.40} \text{LU12}^{-0.15} \text{INFL}^{-0.49} \\
 R_{0.02} \text{ (50 yr)} &= 0.54 (\text{RI}-1.7)^{0.52} \text{BSL}^{0.40} \text{LU12}^{-0.15} \text{INFL}^{-0.44} \\
 R_{0.01} \text{ (100 yr)} &= 0.69 (\text{RI}-1.7)^{0.53} \text{BSL}^{0.40} \text{LU12}^{-0.15} \text{INFL}^{-0.40}
 \end{aligned}$$

The above equations yield an average R-square of 0.68 and have an average SEE of 37 percent.

Equation 3 from both tables 8 and 10 can be used instead of the foregoing equations if the user feels he has enough data to accurately define the effective impervious area. Adequate field surveys can be made, but this requires considerable time and expense.

All regression equations shown in this report have associated standard errors of estimate and should be used only within the range of values shown in table 1 (p.13) to be within this standard error.

Example

The foregoing equations can be used to determine the peak discharge and the runoff volume of an event having a 0.04 exceedance probability (25 yr) for a basin in the Portland area, and the following is an example to illustrate the use of the equations: From a topographic map, the drainage boundary is defined and the drainage area determined to be 2.85 mi². The map shows no definable area in lakes, ponds, depressions, nor detention-storage facilities, and none is known to be in the basin. Forests, parks, agriculture, and vacant lots can be determined from MSD land-use maps or from aerial photography. The LU12 is found to be 53 percent. From city or county drainage maps or aerial photography, streets with gutters and catch basins can be determined. Measure their total length, multiply by 2 if both sides of the street have gutters, and divide by the total drainage area. The gutter density is found to be 12 mi/mi². Add 0.1 to this value. Now these values can be substituted into the discharge equation:

$$\begin{aligned}
 Q_{0.04} \text{ (25 yr)} &= 214 (2.85)^{0.94} (53)^{-0.17} (12.1)^{0.07} (0.1)^{-0.24} \\
 &= 603 \text{ ft}^3/\text{s}
 \end{aligned}$$

Therefore, a discharge of 600 ft³/s has one chance in 25 of being exceeded in any one year in this basin.

Storm runoff (less base flow) can now be calculated for this same basin. Basin slope is computed from a topographic map and is determined to be 290 ft/mi. The 50-year, 6-hour rainfall intensity obtained from the isopluvial map (National Weather Service, 1973) or figure 2 of this report averaged 1.9 in. for this basin. Subtract 1.7 in. from this value. Now these values can be substituted into the volume equation:

$$R_{0.04} (25 \text{ yr}) = 0.96 (0.2)^{0.60} (290)^{0.38} (53)^{-0.13} \\ = 1.88 \text{ in.}$$

Therefore, 1.9 in. of runoff will have one chance in 25 of being exceeded in any one year in this basin. This value, however, does not include the base flow of the stream.

Storm runoff with base flow for the example above, including the infiltration rate of 0.10 in./h, can be calculated as follows:

$$R_{0.04} (25 \text{ yr}) = 0.41 (0.2)^{0.51} (290)^{0.40} (53)^{-0.15} (0.10)^{-0.49} \\ = 2.97 \text{ in.}$$

Therefore, 3.0 in. of runoff, including base flow, will have one chance in 25 of being exceeded in any one year in this basin.

As noted on page 27, subtraction of discharges computed from the last two equations above is not a reliable means of deriving base flow.

Sensitivity

Regression equations were used to determine the sensitivity of physical basin parameters in the study area. Specific parameters were varied while all other parameters were held constant. Equations utilizing both the land-use and street-gutter parameters (recommended equations) and the effective impervious area (alternative equations) were used in this analysis. To examine the effect of each parameter, realistic maximum and minimum parameter values were substituted in the equations and the results compared. Table 6 shows these results.

Table 6 can be roughly interpreted (by evaluating the EIA parameter and the LU12 and GUTR parameters) to show that the change, caused by urbanization, from a natural basin (minimum parameter value) to a fully developed basin (maximum parameter value) will increase peak discharge more than threefold, whereas storm runoff will increase twofold. In addition to the sensitivity of storage shown in table 6, figure 14 shows graphically how storage will affect peak discharge in a 1-square-mile basin. For example, figure 14 shows that when 1 percent of the basin area is used for storage, the peak discharge for 0.09 exceedance probability is decreased approximately 40 percent and that when 10 percent of the basin is used for storage, peak discharge is decreased approximately 70 percent. Similar decreases apply to larger and smaller basins in the study area for other exceedance probabilities.

Table 6.--Sensitivity analysis of parameters in regression equations

$$\begin{aligned} \text{Peak discharge equations: } Q_{ep} &= a DA^b EIA^c (ST + 0.1)^d \\ Q_{ep} &= e DA^f LU12^g (GUTR + 0.1)^h (ST + 0.1)^k \end{aligned}$$

Parameter name	Acro- nym	Range of parameter values expected in study area		Percent range in discharge (Q) for selected exceedance probabilities (ep) resulting from range in parameter values						Average percent range of discharge
		Maximum	Minimum	0.5	0.2	0.1	0.04	0.02	0.01	
Effective impervious area	EIA	50 percent	2 percent	280	320	340	390	410	440	360
Land uses I and II (forests, parks, agriculture, vacant lots)	LU12	1/1 percent	1/99 percent	240	280	310	340	360	400	320
Street-gutter density	GUTR	60 mi/mi ²	0 mi/mi ²							
Storage	ST	10 percent	0.1 percent	-71	-70	-68	-67	-65	-64	-68
Drainage area	DA	30 mi ²	0.2 mi ²	1,100	1,100	1,100	1,100	1,100	1,100	1,100

$$\begin{aligned} \text{Storm runoff equations: } R_{ep} &= a RI^b BSL^c EIA^d \\ R_{ep} &= e RI^f BSL^g LU12^h \end{aligned}$$

Parameter name	Acro- nym	Range of parameter values expected in study area		Percent range in runoff (R) for selected exceedance probabilities (ep) resulting from range in parameter values						Average percent range of runoff
		Maximum	Minimum	0.5	0.2	0.1	0.04	0.02	0.01	
Effective impervious area	EIA	50 percent	2 percent	250	240	240	230	230	230	240
Land uses I and II (forests, parks, agriculture, vacant lots)	LU12	1/1 percent	1/99 percent	140	170	170	180	180	190	170
Rainfall intensity	RI	3.0 in./6 h	1.8 in./6 h	600	470	470	470	470	450	490
Basin slope	BSL	2,000 ft/mi	80 ft/mi	300	350	350	340	330	320	330

1/ LU12 is used as an inverse indication of urbanization; therefore, maximum urbanization is a minimum percentage of land uses I and II.

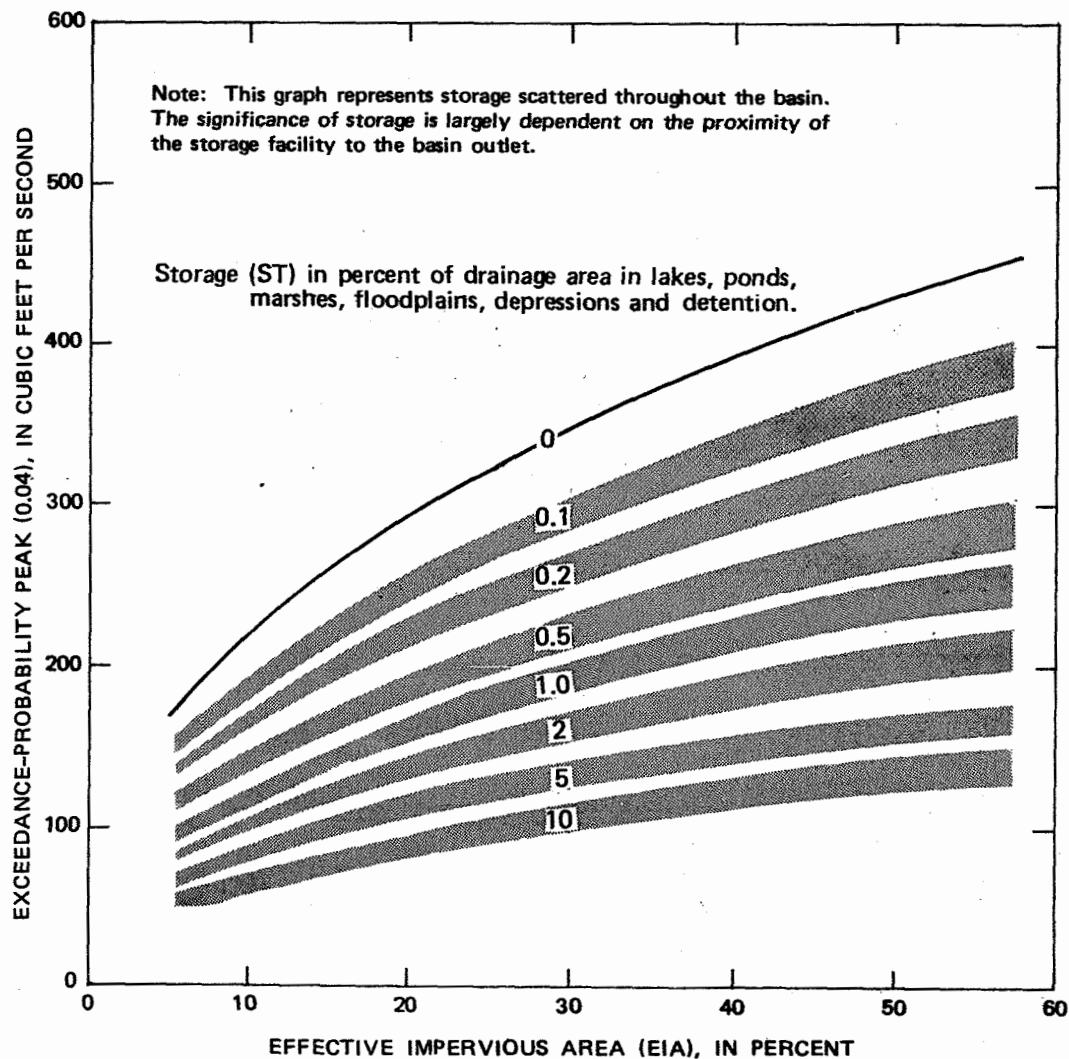
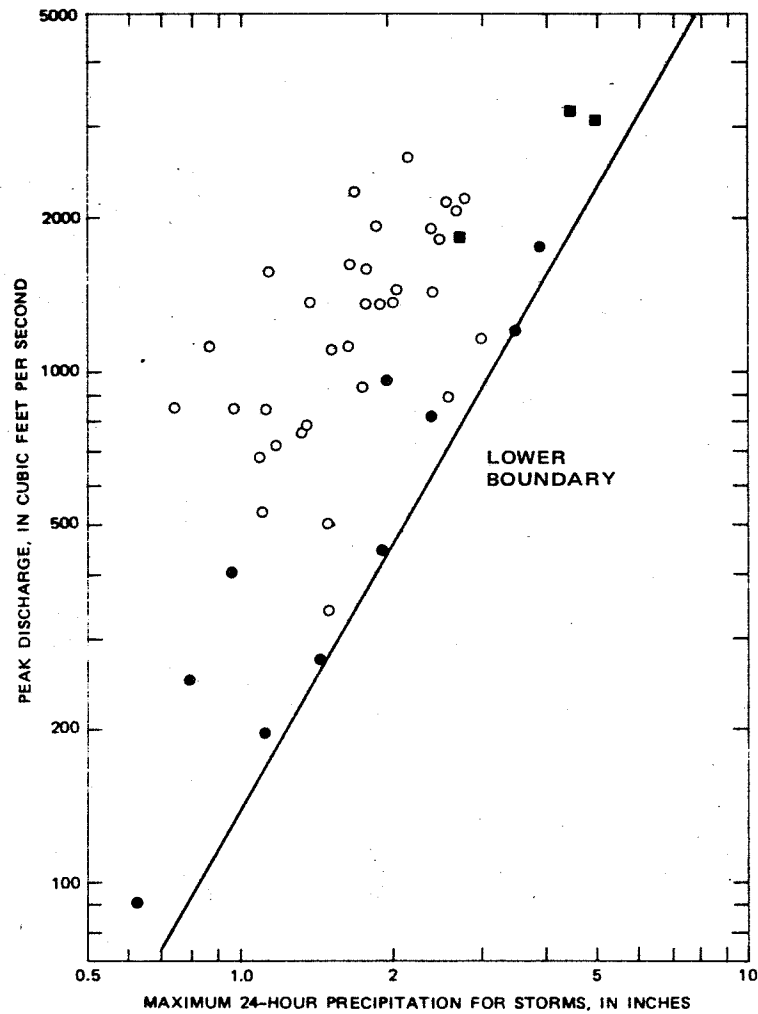


Figure 14.—Sensitivity of storage for basins of one square mile.

ASSESSMENT OF PEAK DISCHARGES FOR HISTORIC EXTREMES PRIOR TO PERIOD OF STUDY

As noted in the "Rainfall Characteristics" section of this report, two 24-hour extremes have been recorded outside the period of record used to synthesize the frequency analysis and generate the regression equations. Do these storms significantly affect the relations developed? This was evaluated by relating historic storm events to discharges from the long-term gaging station on Johnson Creek (14211500).

Realizing that spatial variations in rainfall will exist between the Customs House and Johnson Creek drainage, and recognizing that Johnson Creek has a response (lag time = 25 hr) close to 24 hours, peak discharges versus 24-hour storm extremes for Johnson Creek can be plotted for all winter events. This data plot yields a fair relation (fig. 15). Data that were used to calibrate the model of Johnson Creek are plotted and show less scatter than the previous data mentioned, probably because there is no spatial variation in rainfall (rainfall data are weighted data from three drainages in the Johnson Creek basin). A lower boundary can be estimated for these relations and can



EXPLANATION

Symbol	Precipitation data	Peak-discharge data
■	From U.S. Customs House	Maximum synthesized historic peaks (1903-73)
○	From U.S. Customs House	Observed peaks (1949-73)
●	Weighted average from rain gages in basin	Observed peaks (1974-78) used in model calibration

Figure 15.—Relation of maximum 24-hour precipitation to peak discharge for Johnson Creek.

be extended to the 7.66-inch extreme of 1882, from which a corresponding discharge can be estimated. Thus, it can be stated with some confidence that, under present conditions, a storm with the intensity of the December 1882 storm on Johnson Creek would yield a discharge of at least 5,000 ft³/s. A discharge of this magnitude would be the largest in at least the last 105 years, and larger than the 100-year log-Pearson type-III frequency peak discharge. Papers and periodicals of 1882 substantiate that this was an extreme event to some degree. The Oregonian newspaper of Thursday, December 14, 1882, v. XXII, listed among other flood statistics the fact that there was major flooding on Johnson Creek, with some sewers and sidewalks gone. River rises on the Willamette, Tualatin, and Yamhill Rivers were extreme, reportedly ranging from 4 in. per hour to 1 ft per hour, and stages were high, washing out many railroad bridges along these streams and their tributaries. Tanner Creek, in west Portland, washed out the bridge on Canyon Road (Oregon State Highway 26). Fatalities were reported, along with considerable property damage, among the Chinese community living along the creek. Newspaper articles indicated that the storm probably never exceeded an hourly rate of 0.4 in. (1-hour duration, 2-yr frequency).

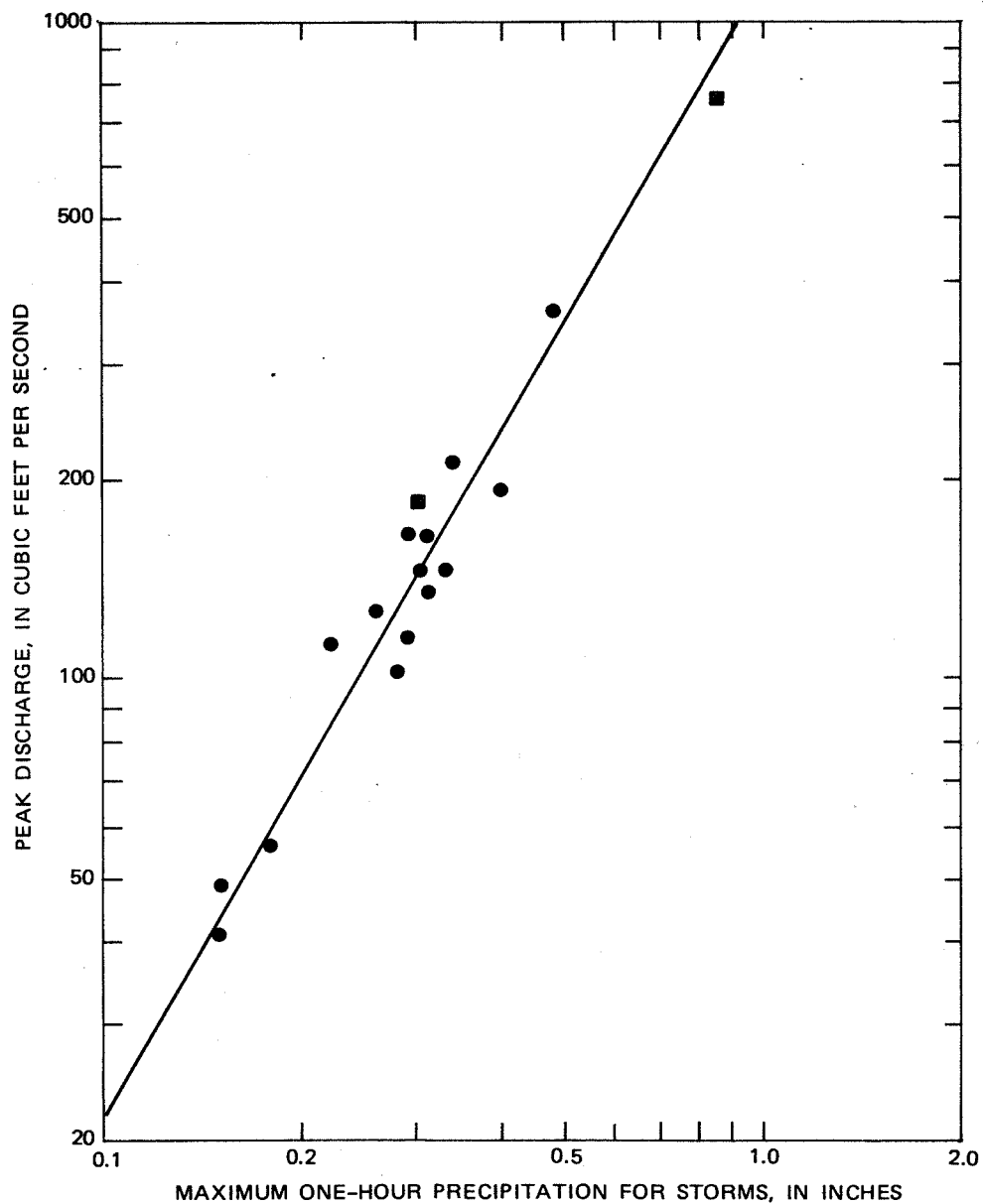
No well-defined relations exist between 24-hour extremes and peak discharges for basins smaller than the Johnson Creek basin, because the small basins respond more quickly. Excellent relations, however, can be established by correlating shorter duration extreme precipitation with peak discharges. For example, figure 16 relates the 1-hour maximum intensity to peak discharge for Fanno Creek (Fanno Creek has a lag time of 1.2 hr).

The inclusion of historic storm events in the storm analysis did not significantly change any of the analyses, except for Johnson Creek. Imposing a historic peak of 5,000 ft³/s, with a known period of at least 105 years of record^{3/}, on the log-Pearson type-III flood-frequency analysis for Johnson Creek, results in a curve that shows slightly higher results than the systematic (station) curve (see fig. 17). This trend is also valid for slightly larger drainage areas. The December 1882 48-hour extreme of 10.75 in. also indicates that larger basins may have experienced a more extreme peak. Log-Pearson results for Johnson Creek, regardless of the skew or the inclusion of an estimated peak of record, show the estimated peak for 1882 may have been at least a 500-year event.

CONCLUSIONS

Urban development brings with it impervious cover and generally improved storm-drainage systems. Man does his best to drain water from his property during storm events. His design for accelerating storm-water drainage is varied and complex and sometimes inadequate.

^{3/} The 105 years is a minimum period of record. The interval between peaks of this magnitude may be much longer.



EXPLANATION

Symbol	Precipitation data	Peak-discharge data
■	From U.S. Customs House gage	Maximum synthesized historic peaks (1903-73)
●	Weighted average from gages in basin	Observed peaks (1974-78) used in model calibration

Figure 16.—Relation of maximum one hour precipitation to peak discharge for Fanno Creek.

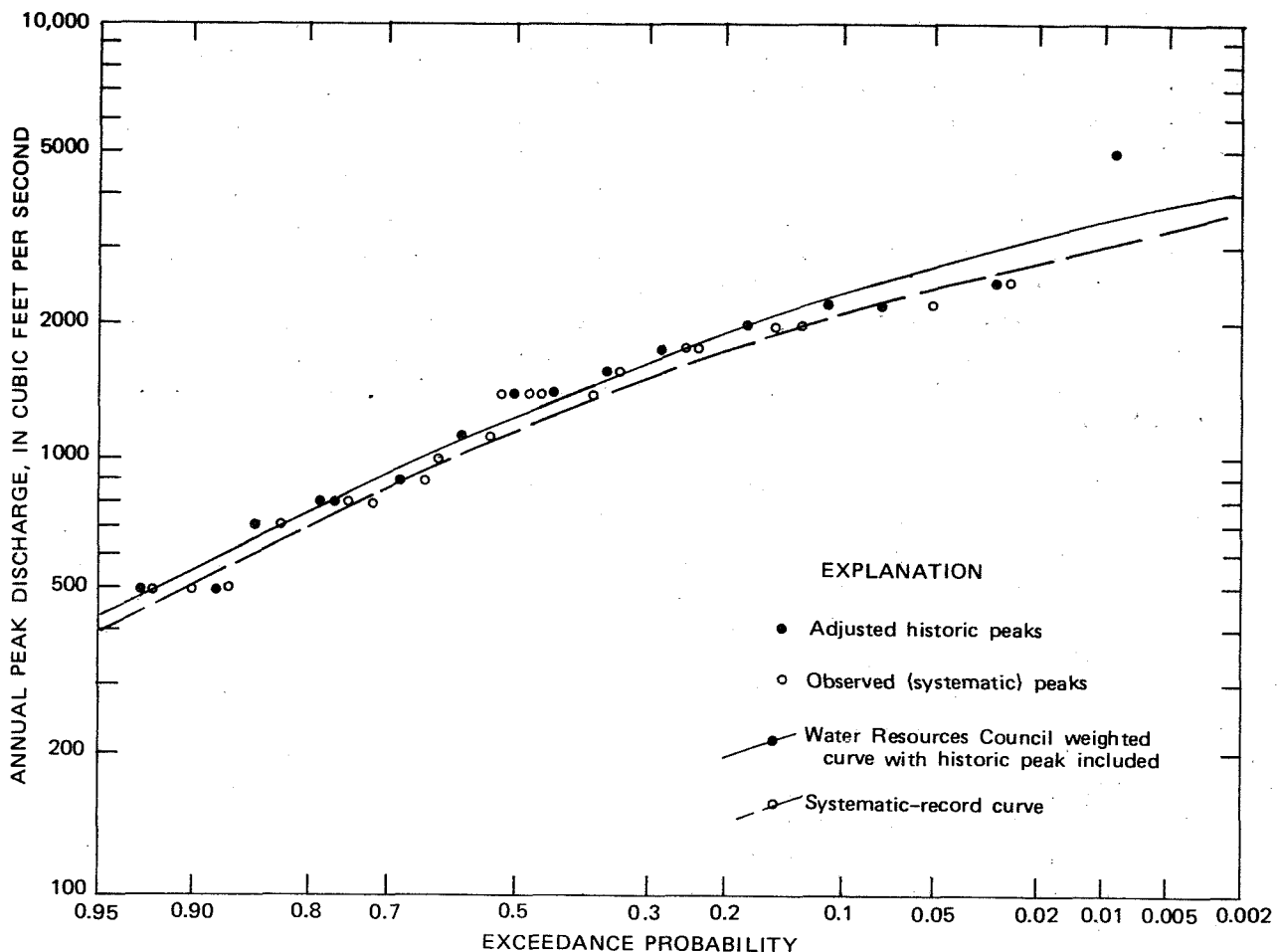


Figure 17.—Log Pearson Type-III frequency curves for Johnson Creek.

In this study, the best index of urbanization in a basin was found to be effective impervious area, which is related to the total impervious cover and its linkage to the main channel (or trunk sewer). Effective impervious area can be costly to determine because of the time involved to measure this basin characteristic in the field. For most basins in this report, a digital model was used to approximate this characteristic.

Effective impervious area, although developed in this report, is not recommended for use by most users in estimating peak flows at ungaged sites. The combination of land uses I and II and the street-gutter density in a basin shows significant correlation to effective impervious area and is recommended as a substitute index of urbanization. Land uses I and II, which categorize all forest, park, agricultural, and vacant-lot land uses, prove to be an inverse indicator of urban development. Street-gutter density, with somewhat less significance than land uses I and II, helps to identify the effects of the increased response of an urban basin. Current maps are available through city and county agencies to define both land-use and street-gutter parameters.

Storage, as defined in this report, proved to be another significant parameter affecting runoff in the Portland-Vancouver area. However, graphs and percentages shown in this report should be used only as estimates. Storage was small compared to the overall drainage, but it influenced discharge considerably. The proximity of the storage to the outlet of the basin was not considered. Several basins with significant area in storage coincidentally had culverts that would restrict high flows. Only six of the basins studied had significant amounts of storage. All these factors combined tend to reduce the accuracy to which this parameter can be predicted from data in this report. Wherever possible, detention storage was included in total storage; however, detention storage proved to be a significant part of the total in only one basin. This study shows that storage will reduce peak flows significantly.

A variety of local conditions were sampled to make the statistical analysis for this study as valid as possible. The average standard error of estimate for all model calibrations was approximately 30 percent. The verification analysis of the simulation and the regression error analysis showed a similar standard error. The verification analysis indicated that little bias was introduced from digital-model calibration and simulation. Regression equations are shown on pages 33 and 36 of this report. Peak-discharge equations have an associated average SEE of 23 percent, storm-runoff (less base flow) equations have an average SEE of 32 percent, and storm-runoff (with base flow) equations have an average SEE of 37 percent. A sensitivity analysis of these equations is given on pages 37 and 38 of this report. This analysis shows that a fully developed urbanized basin in the Portland area will have peak discharge three times greater and storm runoff two times greater than a natural basin.

Table 7.--Summary of statistics for regression analysis of peak discharge for selected exceedance probabilities (recurrence intervals)

Equation no.	Exceedance probability 0.5 (2-year)										Equation no.	Exceedance probability 0.04 (25-year)									
	Parameter "F" value								R-square	Avg SEE		Parameter "F" value								R-square	Avg SEE
	DA	EIA	LU12	GUTR	ST	BSL ^{1/}	RI ^{1/}	INFL ^{1/}				DA	EIA	LU12	GUTR	ST	BSL ^{1/}	RI ^{1/}	INFL ^{1/}		
1	74	--	--	--	--	--	--	--	0.771	57.6	1	68	--	--	--	--	--	--	0.757	58.5	
2	102	7.8	--	--	--	--	--	--	.833	49.8	2	114	13.4	--	--	--	--	--	.851	45.9	
3	433	17.9	--	--	67.2	--	--	--	.962	23.8	3	431	32.1	--	--	57.6	--	--	.962	23.3	
4	432	18.3	--	--	70.2	1.75	--	--	.965	23.3	4	403	22.7	--	--	55.4	0.19	--	.962	23.8	
5	392	20.7	--	--	55.6	--	1.93	--	.965	23.2	5	379	32.7	--	--	46.8	--	1.08	.964	23.3	
6	412	10.8	--	--	64.0	--	--	0.25	.962	24.2	6	485	17.4	--	--	62.7	--	--	.967	22.0	
7	361	--	12.2	--	47.4	--	--	--	.955	25.8	7	383	--	25.6	--	38.5	--	--	.956	25.0	
8	384	--	4.4	2.3	51.8	--	--	--	.960	24.9	8	482	--	10.7	6.2	50.8	--	--	.967	22.2	
Exceedance probability 0.2 (5-year)											Exceedance probability 0.02 (50-year)										
1	72	--	--	--	--	--	--	--	.766	57.6	1	67	--	--	--	--	--	--	.754	58.7	
2	108	10.2	--	--	--	--	--	--	.842	47.7	2	117	14.8	--	--	--	--	--	.855	45.1	
3	456	25.3	--	--	66.9	--	--	--	.964	22.8	3	409	33.7	--	--	51.8	--	--	.960	23.9	
4	437	21.3	--	--	66.7	.87	--	--	.965	22.9	4	380	22.7	--	--	49.5	.07	--	.960	24.5	
5	411	27.8	--	--	55.2	--	1.74	--	.967	22.4	5	356	33.3	--	--	41.8	--	.80	.961	24.0	
6	463	13.8	--	--	66.9	--	--	1.40	.966	22.6	6	477	18.3	--	--	58.1	--	--	.967	22.1	
7	389	--	18.7	--	45.8	--	--	--	.957	24.7	7	368	--	27.2	--	34.1	--	--	.954	25.5	
8	450	--	7.2	4.2	54.9	--	--	--	.965	22.9	8	475	--	11.6	6.9	46.5	--	--	.966	22.4	
Exceedance probability 0.10 (10-year)											Exceedance probability 0.01 (100-year)										
1	70	--	--	--	--	--	--	--	.761	58.3	1	66	--	--	--	--	--	--	.750	59.1	
2	110	11.4	--	--	--	--	--	--	.845	47.2	2	120	16.2	--	--	--	--	--	.859	44.5	
3	456	29.0	--	--	65.5	--	--	--	.964	22.8	3	383	34.7	--	--	45.9	--	--	.957	24.6	
4	431	22.3	--	--	64.0	.48	--	--	.965	23.1	4	357	22.4	--	--	43.6	.01	--	.957	25.2	
5	406	30.7	--	--	53.7	--	1.42	--	.966	22.6	5	331	33.1	--	--	37.0	--	.52	.958	24.9	
6	486	15.6	--	--	68.1	--	--	2.30	.968	22.1	6	459	18.9	--	--	52.5	--	--	.966	22.5	
7	399	--	22.5	--	44.6	--	--	--	.958	24.5	7	350	--	28.4	--	29.8	--	--	.952	26.2	
8	476	--	9.1	5.0	55.5	--	--	--	.967	22.4	8	457	--	12.3	7.2	41.3	--	--	.965	22.8	

^{1/} Outside of 95 percent significance level.

Table 8.--Summary of regression-equation coefficients and exponents for peak discharge for selected exceedance probabilities (recurrence intervals)

$$\left[\begin{array}{l} \text{General form of the equation: } Q_{ep} = a DA^b EIA^c (ST + 0.1)^d \\ \text{or } Q_{ep} = e DA^f LU12^g (GUTR + 0.1)^h (ST + 0.1)^j \end{array} \right]$$

Exceedance probability 0.5 (2-year)											Exceedance probability 0.04 (25-year)										
Equation no.	Constant	Parameter exponent								Avg SEE	Equation no.	Constant	Parameter exponent								Avg SEE
		DA	EIA	LU12	GUTR	ST	BSL	RI	INFL				DA	EIA	LU12	GUTR	ST	BSL	RI	INFL	
1	82	0.86	--	--	--	--	--	--	--	57.6	1	193	0.84	--	--	--	--	--	--	--	58.5
2	27	.89	0.42	--	--	--	--	--	--	49.8	2	50	.87	0.51	--	--	--	--	--	--	45.9
3	26	.90	.32	--	--	-0.28	--	--	--	23.8	3	48	.88	.42	--	--	-0.26	--	--	--	23.3
4	11	.89	.38	--	--	-.28	0.11	--	--	23.3	4	36	.88	.44	--	--	-.26	0.04	--	--	23.8
5	30	.88	.35	--	--	-.26	--	0.14	--	23.2	5	54	.87	.44	--	--	-.24	--	0.11	--	23.3
6	32	.90	.29	--	--	-.28	--	--	0.07	24.2	6	96	.89	.34	--	--	-.25	--	--	0.24	22.0
7	103	.94	--	-0.17	--	-.26	--	--	--	25.8	7	313	.94	--	-0.24	--	-.23	--	--	--	25.0
8	79	.93	--	-.12	0.05	-.27	--	--	--	24.9	8	214	.94	--	-.17	0.07	-.24	--	--	--	22.0
Exceedance probability 0.2 (5-year)											Exceedance probability 0.02 (50-year)										
1	124	.85	--	--	--	--	--	--	--	57.6	1	224	.84	--	--	--	--	--	--	--	58.7
2	36	.88	.46	--	--	--	--	--	--	47.7	2	55	.87	.52	--	--	--	--	--	--	45.1
3	35	.89	.36	--	--	-.27	--	--	--	22.8	3	53	.88	.44	--	--	-.25	--	--	--	23.9
4	20	.88	.41	--	--	-.27	.08	--	--	22.9	4	45	.88	.45	--	--	-.25	.02	--	--	24.5
5	40	.87	.39	--	--	-.26	--	.18	--	22.4	5	59	.87	.46	--	--	-.24	--	.10	--	24.0
6	55	.90	.31	--	--	-.27	--	--	.16	22.6	6	116	.89	.35	--	--	-.24	--	--	.27	22.1
7	174	.93	--	-.21	--	-.25	--	--	--	24.7	7	384	.94	--	-.26	--	-.22	--	--	--	25.5
8	127	.93	--	-.14	.06	-.26	--	--	--	22.9	8	256	.93	--	-.18	.07	-.23	--	--	--	22.4
Exceedance probability 0.10 (10-year)											Exceedance probability 0.01 (100-year)										
1	151	.85	--	--	--	--	--	--	--	58.3	1	257	.83	--	--	--	--	--	--	--	59.1
2	42	.88	.48	--	--	--	--	--	--	47.2	2	61	.87	.54	--	--	--	--	--	--	44.5
3	40	.89	.38	--	--	-.27	--	--	--	22.8	3	58	.88	.46	--	--	-.24	--	--	--	24.6
4	26	.88	.42	--	--	-.27	.06	--	--	23.1	4	54	.88	.46	--	--	-.24	.01	--	--	25.2
5	46	.87	.41	--	--	-.25	--	.12	--	22.6	5	64	.87	.47	--	--	-.23	--	.08	--	24.9
6	72	.90	.32	--	--	-.26	--	--	.20	22.1	6	136	.89	.36	--	--	-.24	--	--	.29	22.5
7	229	.94	--	-.22	--	-.24	--	--	--	24.5	7	462	.94	--	-.27	--	-.21	--	--	--	26.2
8	162	.94	--	-.16	.06	-.25	--	--	--	22.4	8	303	.94	--	-.19	.08	-.22	--	--	--	22.8

Table 9.--Summary of statistics for regression analysis of storm runoff without base flow for selected exceedance probabilities (recurrence intervals)

Exceedance probability 0.5 (2-year)									Exceedance probability 0.04 (25-year)								
Equa- tion no.	Parameter "F" value						R- square	Avg SEE	Equa- tion no.	Parameter "F" value						R- square	Avg SEE
	RI	BSL	EIA	LU12	GUTR ¹ /	ST ¹ /				RI	BSL	EIA	LU12	GUTR ¹ /	ST ¹ /		
1	16.2	--	--	--	--	--	0.424	43.2	1	14.6	--	--	--	--	--	0.399	36.5
2	19.8	6.1	--	--	--	--	.554	38.7	2	19.0	7.9	--	--	--	--	.564	31.7
3	26.2	10.7	3.8	--	--	--	.626	36.2	3	27.2	14.2	4.9	--	--	--	.649	29.0
4	21.7	10.2	3.2	--	--	0.13	.628	37.1	4	21.9	13.6	3.9	--	--	0.46	.657	29.4
5	20.0	5.8	--	0.60	--	--	.568	39.1	5	24.7	12.5	--	3.7	--	--	.632	29.8
6	19.5	5.9	--	.28	0.41	--	.577	39.7	6	21.6	9.5	--	3.3	0.01	--	.632	30.5
Exceedance probability 0.2 (5-year)									Exceedance probability 0.02 (50-year)								
1	12.9	--	--	--	--	--	.370	39.8	1	15.3	--	--	--	--	--	.410	35.4
2	17.0	8.2	--	--	--	--	.547	34.3	2	19.6	7.5	--	--	--	--	.565	31.0
3	23.9	13.8	4.4	--	--	--	.628	31.8	3	28.0	13.8	4.9	--	--	--	.651	28.4
4	19.3	13.2	3.5	--	--	.37	.636	32.3	4	22.6	13.2	3.9	--	--	.41	.658	28.8
5	20.4	10.8	--	2.42	--	--	.596	33.2	5	26.1	12.7	--	4.2	--	--	.640	28.9
6	18.6	9.1	--	1.89	.05	--	.597	34.0	6	22.6	9.3	--	3.9	.06	--	.641	29.6
Exceedance probability 0.10 (10-year)									Exceedance probability 0.01 (100-year)								
1	13.7	--	--	--	--	--	.384	38.4	1	15.7	--	--	--	--	--	.417	34.6
2	18.0	8.2	--	--	--	--	.557	33.1	2	19.7	6.8	--	--	--	--	.560	30.7
3	25.6	14.2	4.6	--	--	--	.641	30.5	3	28.5	13.3	5.2	--	--	--	.650	28.0
4	20.6	13.6	3.7	--	--	.46	.649	30.9	4	23.1	12.7	4.2	--	--	.38	.657	28.4
5	22.4	11.8	--	3.0	--	--	.615	31.6	5	27.2	12.8	--	4.8	--	--	.645	28.2
6	20.1	9.4	--	2.5	.01	--	.615	32.4	6	23.4	9.2	--	4.6	.14	--	.648	28.8

¹/ Outside of 95 percent significance level.

Table 10.--Summary of regression-equation coefficients and exponents for storm runoff without base flow for selected exceedance probabilities (recurrence intervals)

$$\left[\begin{array}{l} \text{General form of the equation: } R_{ep} = a (RI - 1.7)^b BSL^c EIA^d \\ \text{or } R_{ep} = e (RI - 1.7)^f BSL^g LU12^h \end{array} \right]$$

Exceedance probability 0.5 (2-year)									Exceedance probability 0.04 (25-year)								
Equation no.	Constant	Parameter exponent						Avg SEE	Equation no.	Constant	Parameter exponent						Avg SEE
		RI	BSL	EIA	LU12	GUTR	ST				RI	BSL	EIA	LU12	GUTR	ST	
1	2.1	0.67	--	--	--	--	--	43.2	1	5.3	0.54	--	--	--	--	--	36.5
2	.44	.67	0.27	--	--	--	--	38.7	2	1.21	.54	0.25	--	--	--	--	31.7
3	.096	.76	.43	0.28	--	--	--	36.2	3	.30	.63	.40	0.26	--	--	--	29.0
4	.096	.75	.43	.27	--	--	-0.02	37.1	4	.30	.60	.40	.24	--	--	-0.03	29.4
5	.39	.70	.34	--	-0.07	--	--	39.1	5	.96	.60	.38	--	-0.13	--	--	29.8
6	.28	.72	.38	--	-0.05	0.04	--	39.7	6	.99	.59	.37	--	-0.13	-0.004	--	30.5
Exceedance probability 0.2 (5-year)									Exceedance probability 0.02 (50-year)								
1	3.0	.55	--	--	--	--	--	39.8	1	6.4	.54	--	--	--	--	--	35.4
2	.60	.55	.28	--	--	--	--	34.3	2	1.55	.54	.24	--	--	--	--	31.0
3	.14	.64	.43	.27	--	--	--	31.8	3	.40	.62	.38	.26	--	--	--	28.4
4	.14	.62	.43	.25	--	--	-.03	32.3	4	.39	.60	.38	.24	--	--	-.03	28.8
5	.48	.60	.39	--	-.11	--	--	33.2	5	1.22	.60	.37	--	-.13	--	--	28.9
6	.43	.61	.41	--	-.11	.01	--	34.0	6	1.34	.59	.36	--	-.14	-.01	--	29.6
Exceedance probability 0.10 (10-year)									Exceedance probability 0.01 (100-year)								
1	4.0	.55	--	--	--	--	--	38.4	1	7.4	.53	--	--	--	--	--	34.6
2	.83	.55	.27	--	--	--	--	33.1	2	1.97	.53	.23	--	--	--	--	30.7
3	.20	.64	.42	.27	--	--	--	30.5	3	.50	.62	.37	.26	--	--	--	28.0
4	.20	.61	.42	.25	--	--	-.03	30.9	4	.49	.60	.37	.24	--	--	-.03	28.4
5	.66	.60	.39	--	-.12	--	--	31.6	5	1.52	.59	.36	--	-.14	--	--	28.2
6	.64	.61	.40	--	-.12	.004	--	32.4	6	1.75	.58	.35	--	-.14	-.02	--	28.8

Table 11.--Summary of statistics for regression analysis of storm runoff with base flow for selected exceedance probabilities (recurrence intervals)

Exceedance probability 0.5 (2-year)										Exceedance probability 0.04 (25-year)									
Equa- tion no.	Parameter "F" value							R- square	Avg SEE	Equa- tion no.	Parameter "F" value							R- square	Avg SEE
	RI	BSL	EIA	LU12	GUTR ^{1/}	ST ^{1/}	INFL				RI	BSL	EIA	LU12	GUTR ^{1/}	ST ^{1/}	INFL		
1	5.3	--	--	--	--	--	--	0.195	65.8	1	7.9	--	--	--	--	--	--	0.264	49.8
2	9.8	19.4	--	--	--	--	--	.582	46.6	2	14.4	19.1	--	--	--	--	--	.614	36.2
3	11.1	20.1	3.6	--	--	--	3.2	.667	44.1	3	15.6	20.5	2.6	--	--	--	1.6	.680	34.6
4	9.6	19.0	1.4	--	--	0.14	--	.614	44.1	4	14.8	19.7	2.2	--	--	0.46	--	.662	35.6
5	9.4	18.8	--	0.25	--	--	--	.587	48.1	5	14.4	19.2	--	1.1	--	--	--	.635	36.1
6	9.0	17.9	--	.23	0.07	--	--	.589	50.4	6	13.9	18.4	--	1.1	0.20	--	--	.639	36.9
7	11.0	16.3	--	5.9	--	--	4.3	.663	44.3	7	16.0	21.2	--	1.2	--	--	3.1	.686	34.3
Exceedance probability 0.2 (5-year)										Exceedance probability 0.02 (50-year)									
1	6.1	--	--	--	--	--	--	.218	57.6	1	8.7	--	--	--	--	--	--	.284	47.5
2	11.2	19.2	--	--	--	--	--	.591	41.6	2	15.8	19.0	--	--	--	--	--	.624	34.7
3	12.5	20.4	3.0	--	--	--	2.4	.669	39.3	3	17.0	20.3	2.5	--	--	--	1.3	.684	33.4
4	11.3	19.3	1.8	--	--	0.31	--	.633	41.5	4	16.4	19.6	2.3	--	--	.46	--	.671	34.1
5	11.0	18.8	--	.55	--	--	--	.602	42.1	5	16.1	19.3	--	1.4	--	--	--	.648	34.4
6	10.4	17.9	--	.52	.08	--	--	.604	43.2	6	15.6	18.6	--	1.3	.28	--	--	.653	35.0
7	12.4	21.4	--	.62	--	--	3.8	.668	39.4	7	17.6	21.1	--	1.5	--	--	2.8	.693	32.9
Exceedance probability 0.10 (10-year)										Exceedance probability 0.01 (100-year)									
1	6.8	--	--	--	--	--	--	.237	53.8	1	9.6	--	--	--	--	--	--	.304	45.5
2	12.5	19.1	--	--	--	--	--	.600	39.1	2	17.4	18.8	--	--	--	--	--	.633	33.3
3	13.8	20.6	2.8	--	--	--	2.0	.674	37.0	3	18.5	19.9	2.4	--	--	--	.98	.688	32.3
4	12.8	19.5	2.1	--	--	.41	--	.646	38.6	4	18.0	19.5	2.3	--	--	.46	--	.679	32.7
5	12.4	18.9	--	.82	--	--	--	.616	39.2	5	18.0	19.4	--	1.6	--	--	--	.661	32.8
6	11.8	18.1	--	.79	.12	--	--	.618	40.2	6	17.4	18.8	--	1.6	.40	--	--	.663	33.3
7	13.9	21.3	--	.93	--	--	3.5	.676	36.9	7	19.3	20.9	--	1.8	--	--	2.5	.700	31.6

^{1/} Outside of 95 percent significance level.

Table 12.--Summary of regression-equation coefficients and exponents for storm runoff with base flow for selected exceedance probabilities (recurrence intervals)

$$\begin{aligned} \text{General form of the equation: } R_{ep} &= a (RI^{-1.7})^b BSL^c EIA^d INFL^e \\ \text{or } R_{ep} &= f (RI^{-1.7})^g BSL^h LU12^j INFL^k \end{aligned}$$

Exceedance probability 0.5 (2-year)										Exceedance probability 0.04 (25-year)									
Equation no.	Constant	Parameter exponent							Avg SEE	Equation no.	Constant	Parameter exponent							Avg SEE
		RI	BSL	EIA	LU12	GUTR	ST	INFL				RI	BSL	EIA	LU12	GUTR	ST	INFL	
1	3.0	0.56	--	--	--	--	--	--	65.8	1	7.3	0.54	--	--	--	--	--	--	49.8
2	.10	.56	0.58	--	--	--	--	--	46.6	2	.54	.53	0.45	--	--	--	--	--	36.2
3	.025	.55	.50	0.26	--	--	--	-0.56	44.1	3	.16	.55	.45	0.23	--	--	--	-0.31	34.6
4	.030	.61	.70	.21	--	--	-0.03	--	44.1	4	.17	.57	.56	.19	--	--	-0.04	--	35.6
5	.093	.58	.63	--	-0.05	--	--	--	48.1	5	.46	.57	.53	--	-0.08	--	--	--	36.1
6	.11	.57	.61	--	-0.06	-0.02	--	--	50.4	6	.57	.55	.51	--	-0.10	-0.03	--	--	36.9
7	.078	.49	.44	--	-0.15	--	--	-0.72	44.3	7	.41	.51	.40	--	-0.15	--	--	-0.49	34.3
Exceedance probability 0.2 (5-year)										Exceedance probability 0.02 (50-year)									
1	4.6	.54	--	--	--	--	--	--	57.6	1	8.6	.54	--	--	--	--	--	--	47.5
2	.23	.53	.51	--	--	--	--	--	41.6	2	.71	.53	.43	--	--	--	--	--	34.7
3	.060	.54	.48	.25	--	--	--	-0.44	39.3	3	.21	.56	.44	.23	--	--	--	-0.27	33.4
4	.068	.58	.64	.20	--	--	-0.03	--	41.5	4	.23	.57	.54	.18	--	--	-0.03	--	34.1
5	.20	.56	.58	--	-0.07	--	--	--	42.1	5	.60	.57	.52	--	-0.09	--	--	--	34.4
6	.24	.55	.56	--	-0.08	-0.02	--	--	43.2	6	.76	.55	.49	--	-0.10	-0.03	--	--	35.0
7	.17	.49	.42	--	-0.15	--	--	-0.61	39.4	7	.54	.52	.40	--	-0.15	--	--	-0.44	32.9
Exceedance probability 0.10 (10-year)										Exceedance probability 0.01 (100-year)									
1	5.7	.53	--	--	--	--	--	--	53.8	1	10	.54	--	--	--	--	--	--	45.5
2	.35	.53	.48	--	--	--	--	--	39.1	2	.92	.54	.41	--	--	--	--	--	33.3
3	.092	.54	.47	.25	--	--	--	-0.38	37.0	3	.29	.57	.44	.22	--	--	--	-0.23	32.3
4	.10	.57	.60	.20	--	--	-0.04	--	38.6	4	.31	.57	.52	.18	--	--	-0.03	--	32.7
5	.30	.56	.56	--	-0.08	--	--	--	39.2	5	.77	.58	.50	--	-0.09	--	--	--	32.8
6	.36	.55	.54	--	-0.09	-0.02	--	--	40.2	6	1.0	.56	.47	--	-0.11	-0.03	--	--	33.3
7	.26	.50	.41	--	-0.16	--	--	-0.55	36.9	7	.69	.53	.40	--	-0.15	--	--	-0.40	31.6

TABLE 13.-DAILY PRECIPITATION

STATION NUMBER 14142570 RAIN GAGE ON POWELL VALLEY GRADE SCHOOL
 LATITUDE 452926 LONGITUDE 1222254

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.95	.10	.00	.50	.00	.12	.00	.00	.12	.00	.00
2	.02	.03	2.62	.00	.51	.00	.26	.00	.00	.04	.00	.02
3	.05	.01	.47	.00	.03	.03	.04	.03	.00	.03	.00	.25
4	.00	.21	.25	.60	.01	.14	.02	.32	.00	.00	.00	.22
5	.00	.08	.20	.15	.25	.04	.13	.00	.00	.00	.00	.25
6	.35	.07	.75	.00	.25	.04	.00	.01	.00	.00	.00	.08
7	.30	.32	.05	.20	.80	.50	.00	.00	.00	.00	.00	.08
8	.00	.02	.00	.35	.20	.05	.00	.00	.00	.00	.00	.43
9	.00	.00	.20	.20	.10	.00	.00	.12	.30	.00	.00	.28
10	.00	.01	.50	.03	.00	.00	.00	.23	.30	.00	.00	.50
11	.00	.11	1.73	.20	.00	.25	.00	.35	.01	.00	.00	.00
12	.00	.34	.99	.11	.02	.02	.00	.32	.16	.00	.70	.00
13	.06	.59	2.21	.00	.00	.28	.15	1.15	.35	.00	.10	.20
14	.00	.78	1.04	.21	.30	.00	.43	1.16	.85	.00	.00	.10
15	.00	.18	.66	.21	.40	.00	.40	.34	.01	1.00	1.20	.00
16	.00	.02	.35	.40	.03	.00	.20	.00	.00	.50	.55	.20
17	.03	.25	.15	.07	.02	.00	.40	.00	.00	.00	.00	.10
18	.01	.19	.10	.00	.02	.00	.10	.00	.00	.00	.00	.00
19	.00	.22	.01	.93	.00	.00	.40	.00	.00	.00	.07	.05
20	.01	.01	.00	.17	.00	.00	.20	.00	.00	.00	.55	.00
21	.00	.08	.00	.98	.00	.00	.45	.00	.00	.00	.07	.00
22	.00	.80	.02	.02	.00	.00	.40	.08	.00	.00	.10	.05
23	.31	.80	.20	.01	.05	.37	.00	.03	.15	.00	.10	.00
24	.13	.90	.40	.00	.35	.20	.00	.16	.05	.00	.40	.00
25	.31	.90	.00	.00	.80	.00	.25	.03	.01	.00	.08	.00
26	.18	.00	.02	.00	.20	.01	.75	.27	.00	.10	.00	.00
27	.01	.50	.03	.30	.10	.00	.35	.27	.10	.00	.00	.05
28	.37	.10	.10	.12	.00	.01	.03	.00	.00	.00	.00	.00
29	.91	.25	.25	.00	---	.01	.00	.00	.00	.00	.00	.00
30	.26	.00	.00	.00	---	.07	.10	.00	.00	.00	.00	.15
31	.14	---	.00	.21	---	.00	---	.00	---	.00	.00	---
TOTAL	3.45	8.72	13.40	5.74	4.94	2.02	5.18	4.87	2.29	1.79	3.92	3.01
WTR YR 1978 TOTAL	59.33											

STATION NUMBER 14144680 RAIN GAGE ON VANCOUVER CITY HALL
 LATITUDE 453754 LONGITUDE 1224008

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.36	.00	.13	.45	.00	.01	.01	.00	.00	.00	.00
2	.00	.01	1.37	.10	.27	.00	.02	.00	.00	.15	.00	.00
3	.00	.00	.12	.08	.00	.04	.02	.00	.00	.02	.00	.20
4	.00	.09	.09	.35	.00	.06	.15	.14	.00	.00	.00	.05
5	.00	.15	.07	.41	.23	.00	.18	.00	.00	.01	.00	.01
6	.19	.06	.14	.00	.10	.10	.03	.00	.00	.00	.00	.00
7	.43	.11	.03	.19	.51	.48	.00	.00	.00	.00	.00	.02
8	.00	.00	.00	.34	.08	.00	.00	.00	.00	.00	.00	.35
9	.00	.02	.12	.30	.00	.00	.00	.00	.11	.00	.00	.49
10	.00	.07	.51	.00	.00	.00	.00	.06	.16	.00	.00	.12
11	.00	.03	.46	.06	.00	.10	.00	.22	.01	.00	.01	.01
12	.00	.35	.79	.00	.00	.03	.00	.30	.03	.00	.21	.00
13	.00	.15	1.62	.25	.00	.05	.26	1.17	.10	.00	.07	.20
14	.00	.34	.51	.08	.16	.00	.19	.67	.30	.00	.00	.04
15	.00	.11	.85	.12	.04	.00	.33	.07	.01	.81	.66	.00
16	.00	.11	.26	.19	.02	.00	.28	.00	.00	.44	.12	.03
17	.00	.06	.04	.19	.02	.00	.33	.01	.00	.00	.01	.16
18	.00	.03	.00	.32	.00	.00	.30	.00	.00	.00	.00	.01
19	.00	.02	.00	.05	.00	.00	.24	.00	.00	.00	.05	.00
20	.00	.10	.00	.00	.00	.00	.03	.00	.00	.00	.38	.08
21	.00	.14	.00	.27	.00	.00	.18	.00	.00	.00	.08	.01
22	.00	.35	.00	.00	.00	.00	.18	.16	.00	.00	.07	.00
23	.07	.56	.21	.00	.02	.30	.00	.01	.14	.00	.14	.00
24	.27	.35	.11	.00	.25	.10	.00	.18	.00	.00	.16	.00
25	.30	.87	.00	.12	1.07	.02	.10	.01	.00	.00	.00	.00
26	.00	.00	.00	.00	.07	.00	.35	.22	.01	.04	.00	.00
27	.00	.11	.00	.00	.00	.00	.04	.13	.00	.00	.00	.00
28	.22	.13	.14	.05	.00	.00	.05	.00	.00	.00	.00	.00
29	.38	.03	.29	.00	---	.00	.00	.00	.00	.00	.00	.00
30	.21	.00	.11	.00	---	.03	.07	.00	.00	.00	.00	.10
31	.04	---	.00	.51	---	.00	---	.00	---	.00	.00	---
TOTAL	2.12	4.71	7.84	4.11	3.31	1.31	3.34	3.36	0.67	1.47	1.96	2.04
WTR YR 1978 TOTAL	36.48											

TABLE 13.-DAILY PRECIPITATION--Continued

STATION NUMBER
LATITUDE 45375414144640 RAIN GAGE ON VANCOUVER CITY HALL
LONGITUDE 1224008

RAINFALL (IN.), WATER YEAR OCTOBER 1978 TO SEPTEMBER 1979

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.00	.10	.01	.00	.00	.00	.00				
2	.00	.07	.04	.00	.00	.00	.00	.00				
3	.00	.36	.01	.00	.25	.64	.00	.00				
4	.00	.13	.73	.01	.17	.46	.00	.55				
5	.00	.00	.00	.04	.24	.15	.00	.17				
6	.00	.01	.01	.03	.99	.12	.00	.20				
7	.00	.04	.02	.00	.15	.03	.00	.36				
8	.00	.18	.08	.02	.04	.00	.07	.06				
9	.00	.00	.14	.04	.00	.00	.29	.02				
10	.00	.00	.63	1.35	.45	.00	.23	---				
11	.00	.00	.05	.10	.50	.00	.07	---				
12	.00	.01	.00	.01	.29	.00	.10	---				
13	.00	.07	.01	.10	.03	.00	.05	---				
14	.00	.02	.06	.14	.00	.04	.03	---				
15	.00	.02	.00	.00	.10	.29	.18	---				
16	.00	.15	.00	.00	.17	.09	.14	---				
17	.00	.08	.00	.00	.13	.00	.39	---				
18	.00	.90	.00	.00	.01	.00	.04	---				
19	.00	.43	.00	.16	.00	.00	.00	---				
20	.08	.05	.23	.01	.00	.00	.00	---				
21	.00	.11	.07	.16	.00	.00	.01	---				
22	.00	.07	.04	.00	.61	.00	.07	---				
23	.00	.13	.04	.01	.10	.00	.64	---				
24	.02	.01	.07	.03	.26	.00	.01	---				
25	.00	.00	.01	.00	.28	.00	.00	---				
26	.00	.00	.01	.09	.00	.11	.00	---				
27	.00	.28	.00	.20	.12	.23	.21	---				
28	.39	.40	.15	.00	.26	.04	.00	---				
29	.20	.20	.15	.09	---	.01	.00	---				
30	.00	.39	.00	.09	---	.00	.00	---				
31	.00	---	.00	.01	---	---	---	---				
TOTAL	0.69	4.11	2.65	2.70	5.27	2.21	2.53	1.36				

WTR YR 1979 TOTAL

21.52

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

STATION NUMBER
LATITUDE 45293714206310 RAIN GAGE ON RALEIGH PARK SCHOOL
LONGITUDE 1224521

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.37	.05	.10	.63	.00	.06	.01	.00	.00	.00	.00
2	.00	.10	1.44	.02	.24	.00	.20	.00	.00	.05	.00	.00
3	.00	.01	.04	.60	.04	.00	.05	.00	.00	.00	.00	.45
4	.00	.09	.15	.00	.00	.09	.01	.00	.00	.00	.00	.09
5	.00	.15	.02	.70	.26	.00	.03	.00	.00	.00	.00	.10
6	.24	.18	.15	.01	.21	.02	.01	.00	.21	.00	.00	.01
7	.29	.07	.03	.22	.90	.45	.00	.00	.12	.00	.00	.26
8	.00	.01	.01	.34	.14	.07	.00	.00	.01	.00	.00	.23
9	.00	.00	.20	.27	.00	.00	.00	.00	.05	.00	.00	.81
10	.00	.01	.44	.04	.00	.00	.00	.04	.26	.00	.00	.57
11	.00	.18	.93	.10	.00	.15	.00	.20	.30	.00	.00	.06
12	.00	.43	.88	.01	.06	.02	.00	.19	.01	.00	.27	.01
13	.00	.20	1.96	.30	.00	.14	.26	1.25	.08	.00	.07	.18
14	.00	.31	.77	.14	.07	.00	.16	.82	.16	.00	.00	.01
15	.00	.09	1.32	.28	.04	.00	.22	.50	.00	.46	.70	.00
16	.00	.02	.40	.26	.04	.00	.03	.00	.00	.18	.00	.10
17	.00	.25	.02	.24	.01	.00	.26	.00	.00	.00	.01	.37
18	.00	.17	.03	.42	.00	.00	.20	.01	.00	.00	.00	.01
19	.00	.00	.00	.03	.00	.00	.15	.00	.00	.00	.02	.00
20	.00	.06	.00	.04	.00	.00	.06	.00	.00	.00	.59	.05
21	.00	.08	.00	.42	.00	.00	.22	.00	.00	.00	.03	.01
22	.00	.50	.02	.04	.00	.00	.23	.14	.00	.00	.03	.00
23	.11	.35	.15	.00	.00	.41	.00	.10	.08	.00	.07	.01
24	.49	.55	.10	.00	.04	.18	.01	.15	.00	.00	.27	.01
25	.48	1.20	.01	.13	.42	.00	.15	.01	.00	.00	.06	.00
26	.00	.00	.00	.01	.01	.00	.50	.26	.00	.01	.01	.00
27	.00	.10	.00	.01	.00	.00	.12	.18	.00	.00	.00	.00
28	.33	.10	.15	.09	.00	.00	.11	.00	.00	.00	.00	.00
29	.57	.15	.35	.00	---	.00	.03	.00	.00	.00	.00	.00
30	.25	.00	.05	.00	---	.04	.05	.00	.00	.00	.00	.09
31	.07	---	.00	.68	---	.00	---	.00	---	.00	.00	---
TOTAL	2.83	5.73	9.67	5.50	3.18	1.57	3.12	3.86	1.28	0.70	2.13	3.43

WTR YR 1978 TOTAL

43.00

TABLE 13.-DAILY PRECIPITATION--Continued

STATION NUMBER
LATITUDE 45290214206315 RAIN GAGE AT BEAVENTON CITY HALL
LONGITUDE 1224811

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.37	.06	.12	.62	.00	.07	.00	.00	.00	.00	.01
2	.00	.11	1.44	.03	.22	.00	.21	.00	.00	.06	.00	.01
3	.00	.01	.05	.65	.00	.08	.06	.00	.00	.00	.00	.46
4	.00	.13	.15	.00	.00	.10	.17	.05	.00	.00	.00	.10
5	.00	.18	.02	.70	.25	.00	.32	.00	.00	.00	.00	.11
6	.19	.13	.14	.01	.22	.04	.00	.00	.00	.00	.00	.01
7	.33	.06	.03	.30	.75	.50	.00	.00	.00	.00	.00	.71
8	.00	.00	.01	.34	.22	.06	.00	.00	.00	.00	.00	.25
9	.00	.01	.18	.31	.06	.00	.00	.02	.19	.00	.00	.84
10	.00	.01	.44	.01	.00	.00	.00	.10	.11	.00	.00	.49
11	.00	.16	.93	.10	.00	.13	.00	.17	.00	.00	.00	.13
12	.00	.33	.88	.00	.01	.01	.00	.18	.11	.00	.21	.02
13	.02	.23	1.96	.29	.00	.11	.29	1.31	.09	.00	.08	.19
14	.00	.32	.77	.09	.22	.00	.15	.76	.15	.00	.00	.01
15	.00	.07	1.32	.25	.09	.00	.20	.13	.00	.71	.49	.00
16	.00	.05	.37	.24	.07	.00	.01	.02	.00	.23	.04	.00
17	.00	.23	.02	.24	.00	.00	.29	.00	.00	.00	.00	.31
18	.00	.08	.03	.41	.00	.00	.13	.00	.00	.00	.00	.01
19	.00	.00	.00	.00	.00	.00	.13	.00	.00	.00	.03	.01
20	.00	.00	.00	.01	.00	.00	.02	.00	.00	.00	.57	.07
21	.00	.06	.00	.41	.00	.00	.18	.00	.00	.00	.14	.04
22	.00	.50	.02	.02	.00	.00	.27	.19	.00	.00	.03	.00
23	.11	.33	.14	.00	.04	.42	.00	.02	.08	.00	.09	.00
24	.53	.54	.08	.00	.19	.16	.00	.03	.00	.00	.18	.00
25	.33	1.20	.01	.09	.36	.00	.17	.02	.00	.00	.05	.04
26	.01	.00	.00	.00	.04	.00	.34	.30	.00	.12	.01	.08
27	.00	.11	.00	.00	.02	.00	.06	.16	.00	.00	.00	.00
28	.31	.10	.13	.06	.00	.00	.04	.00	.00	.00	.01	.00
29	.65	.14	.36	.00	---	.00	.00	.00	.00	.00	.02	.07
30	.32	.00	.04	.00	---	.02	.05	.00	.00	.00	.00	.05
31	.04	---	.00	.60	---	.00	---	.00	---	.00	.00	---
TOTAL	2.85	5.46	9.58	5.28	3.36	1.63	3.16	3.46	0.73	1.12	1.95	3.52
WTR YR 1978 TOTAL	42.12											

STATION NUMBER
LATITUDE 45280814206330 BEAVENTON CR TRIB ON SW MURRAY BLVD
LONGITUDE 1224928

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.43	.06	.10	.66	.00	.12	.01	.00	.01	.00	.01
2	.00	.09	1.61	.02	.26	.00	.22	.00	.00	.19	.00	.00
3	.00	.01	.04	.60	.05	.10	.09	.01	.00	.00	.00	.43
4	.00	.15	.10	.20	.00	.10	.21	.19	.00	.00	.00	.12
5	.00	.19	.02	.75	.25	.00	.31	.00	.00	.00	.00	.11
6	.20	.11	.16	.01	.25	.07	.00	.00	.00	.00	.00	.01
7	.45	.05	.05	.30	.75	.51	.00	.00	.00	.00	.00	.19
8	.00	.00	.00	.36	.25	.03	.00	.00	.00	.00	.00	.27
9	.00	.00	.20	.36	.09	.00	.00	.04	.12	.00	.00	.86
10	.00	.00	.40	.02	.00	.01	.00	.11	.12	.00	.00	.50
11	.00	.10	.80	.12	.00	.17	.00	.26	.00	.00	.00	.10
12	.01	.30	.85	.02	.05	.04	.00	.18	.08	.00	.19	.00
13	.01	.20	2.00	.35	.00	.14	.32	1.21	.10	.00	.06	.20
14	.00	.35	.80	.11	.27	.01	.14	.75	.20	.00	.00	.00
15	.04	.07	1.30	.31	.13	.00	.20	.12	.01	.83	.56	.00
16	.00	.05	.40	.29	.09	.00	.02	.01	.00	.16	.14	.00
17	.00	.20	.02	.24	.02	.00	.34	.00	.01	.00	.00	.30
18	.00	.05	.02	.44	.01	.00	.15	.00	.00	.00	.00	.00
19	.00	.00	.00	.04	.01	.00	.12	.00	.00	.00	.07	.00
20	.00	.00	.00	.05	.00	.00	.01	.00	.00	.00	.75	.10
21	.00	.05	.00	.40	.00	.00	.21	.00	.00	.00	.07	.05
22	.00	.50	.03	.05	.00	.00	.23	.35	.01	.00	.01	.00
23	.15	.40	.15	.00	.00	.41	.00	.20	.10	.00	.09	.00
24	.53	.60	.10	.00	.10	.22	.00	.02	.01	.00	.19	.00
25	.25	1.10	.00	.13	.40	.01	.22	.04	.00	.00	.07	.05
26	.00	.00	.00	.01	.00	.00	.34	.32	.00	.08	.00	.05
27	.00	.10	.00	.01	.00	.00	.11	.12	.00	.00	.00	.00
28	.34	.10	.10	.09	.00	.00	.04	.00	.00	.00	.01	.00
29	.52	.10	.40	.00	---	.01	.00	.00	.00	.00	.01	.05
30	.32	.00	.05	.02	---	.03	.06	.00	.00	.00	.00	.05
31	.05	---	.00	.62	---	.01	---	.00	---	.00	.00	---
TOTAL	2.87	5.30	9.66	6.02	3.64	1.87	3.46	3.94	0.76	1.27	2.22	3.45
WTR YR 1978 TOTAL	44.46											

TABLE 13.-DAILY PRECIPITATION--Continued

STATION NUMBER 14206470 BUTTERNUT CR IN ALOMA, OREG.
 LATITUDE 452852 LONGITUDE 1225141

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.35	.02	.02	.63	.00	.11	.02	.00	.05	.00	.00
2	.00	.06	1.36	.00	.24	.00	.25	.00	.00	.14	.00	.00
3	.00	.01	.01	.19	.05	.05	.05	.00	.00	.00	.00	.45
4	.00	.17	.10	.62	.00	.06	.17	.03	.00	.00	.00	.10
5	.00	.17	.02	.78	.29	.00	.25	.04	.00	.00	.00	.10
6	.19	.14	.16	.03	.18	.07	.00	.00	.00	.00	.00	.00
7	.28	.08	.02	.30	.65	.49	.00	.00	.00	.00	.00	.20
8	.00	.01	.01	.38	.22	.03	.00	.00	.00	.00	.00	.23
9	.00	.01	.17	.38	.08	.00	.00	.05	.16	.00	.00	.00
10	.00	.00	.41	.02	.01	.00	.00	.08	.13	.00	.00	.37
11	.00	.09	.78	.11	.00	.16	.00	.17	.00	.00	.00	.03
12	.00	.27	.79	.01	.01	.04	.00	.14	.03	.00	.20	.00
13	.02	.14	2.05	.28	.00	.12	.35	1.20	.06	.00	.05	.24
14	.00	.33	.79	.11	.28	.00	.08	.57	.09	.00	.00	.01
15	.00	.07	1.25	.25	.13	.00	.18	.08	.00	.92	.50	.00
16	.00	.02	.39	.26	.07	.00	.03	.01	.00	.18	.05	.00
17	.00	.20	.03	.18	.01	.00	.29	.00	.00	.00	.00	.14
18	.00	.05	.03	.32	.01	.00	.20	.00	.00	.00	.00	.00
19	.00	.00	.00	.03	.01	.00	.11	.00	.00	.00	.05	.00
20	.00	.00	.00	.02	.00	.00	.21	.00	.00	.00	.65	.13
21	.00	.01	.00	.37	.00	.00	.17	.00	.00	.00	.10	.00
22	.00	.45	.04	.05	.00	.00	.31	.09	.01	.00	.00	.00
23	.09	.46	.15	.00	.00	.30	.00	.02	.13	.00	.10	.00
24	.32	.70	.07	.00	.09	.18	.00	.04	.00	.00	.20	.00
25	.31	1.09	.00	.11	.29	.01	.07	.03	.00	.00	.05	.00
26	.01	.00	.01	.00	.07	.00	.42	.24	.00	.03	.00	.00
27	.00	.11	.00	.01	.03	.00	.05	.10	.00	.00	.00	.00
28	.32	.14	.14	.08	.00	.00	.03	.00	.00	.00	.03	.00
29	.57	.06	.41	.00	---	.00	.01	.00	.00	.00	.00	.00
30	.38	.00	.03	.03	---	.01	.04	.00	.00	.00	.00	.04
31	.03	---	.00	.58	---	.01	---	.00	---	.00	.00	---
TOTAL	2.53	5.19	9.24	5.52	3.35	1.53	3.38	2.91	0.61	1.32	1.98	2.94
WTR YR 1978 TOTAL	40.50											

STATION NUMBER 14206850 RAIN GAGE AT KPAM-FM RADIO ON COUNCIL CREST
 LATITUDE 452921 LONGITUDE 1224141

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.43	.05	.00	.71	.00	.04	.00	.00	.00	.00	.00
2	.00	.02	2.13	.00	.29	.02	.20	.00	.00	.08	.00	.00
3	.00	.00	.07	.52	.01	.00	.04	.03	.00	.00	.00	.41
4	.00	.08	.19	.02	.00	.09	.15	.01	.00	.00	.00	.12
5	.00	.15	.05	.91	.27	.00	.36	.00	.00	.00	.00	.09
6	.19	.15	.20	.04	.19	.02	.00	.00	.00	.00	.00	.01
7	.44	.06	.04	.20	.64	.41	.00	.00	.00	.00	.00	.18
8	.00	.00	.00	.31	.20	.04	.00	.00	.00	.00	.00	.18
9	.00	.00	.13	.25	.03	.00	.00	.02	.12	.00	.00	.73
10	.00	.00	.39	.01	.00	.00	.00	.09	.17	.00	.00	.69
11	.00	.13	1.08	.07	.00	.16	.00	.23	.00	.00	.00	.00
12	.00	.52	.95	.02	.00	.03	.00	.11	.10	.00	.56	.00
13	.00	.23	2.56	.24	.00	.17	.23	.91	.09	.00	.05	.18
14	.00	.36	.83	.07	.27	.00	.20	.29	.21	.00	.00	.00
15	.00	.09	1.15	.25	.08	.00	.27	.11	.00	.71	.84	.00
16	.00	.04	.43	.28	.04	.00	.03	.00	.00	.33	.02	.05
17	.00	.08	.03	.25	.01	.00	.29	.00	.00	.00	.00	.28
18	.00	.16	.00	.39	.00	.00	.17	.00	.00	.00	.00	.00
19	.00	.00	.00	.06	.00	.00	.13	.00	.00	.00	.04	.00
20	.00	.00	.00	.05	.00	.00	.07	.00	.00	.00	.52	.05
21	.00	.00	.00	.51	.00	.00	.12	.00	.00	.00	.06	.00
22	.00	.55	.00	.02	.00	.00	.12	.05	.00	.00	.00	.00
23	.13	.90	.02	.00	.05	.39	.00	.00	.12	.00	.09	.00
24	.32	.57	.16	.00	.18	.23	.00	.15	.00	.00	.36	.00
25	.57	1.29	.01	.14	.64	.00	.16	.00	.00	.00	.11	.00
26	.01	.00	.00	.00	.20	.00	.50	.25	.00	.01	.00	.00
27	.00	.13	.00	.00	.00	.00	.09	.16	.00	.00	.00	.00
28	.34	.11	.00	.08	.00	.00	.04	.00	.00	.00	.00	.00
29	.67	.16	.21	.00	---	.00	.00	.00	.00	.00	.00	.00
30	.26	.00	.04	.00	---	.09	.04	.00	.00	.00	.00	.07
31	.09	---	.00	.78	---	.00	---	.00	---	.00	.00	---
TOTAL	3.02	6.21	10.72	5.47	3.81	1.65	3.25	2.41	0.81	1.13	2.65	3.04
WTR YR 1978 TOTAL	44.17											

TABLE 13.-DAILY PRECIPITATION--Continued

STATION NUMBER
LATITUDE 45291714206900 FANNO CR AT 56TH AVE IN PORTLAND
LONGITUDE 1224401

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.59	.06	.09	.31	.00	.06	.00	.00	.00	.00	.00
2	.01	.17	1.80	.07	.25	.00	.20	.01	.00	.12	.00	.00
3	.00	.00	.07	.25	.02	.11	.04	.02	.00	.00	.00	.45
4	.00	.11	.19	.58	.01	.14	.15	.16	.00	.00	.00	.10
5	.00	.14	.04	.86	.26	.00	.28	.00	.00	.00	.00	.10
6	.25	.11	.19	.02	.21	.05	.00	.00	.00	.00	.00	.00
7	.43	.09	.05	.05	.71	.56	.01	.00	.00	.00	.00	.25
8	.00	.01	.01	.35	.21	.08	.00	.00	.00	.00	.00	.05
9	.00	.00	.23	.31	.02	.00	.00	.03	.15	.00	.00	.81
10	.00	.00	.47	.03	.00	.01	.00	.09	.20	.00	.00	1.00
11	.00	.09	.99	.11	.00	.18	.00	.23	.01	.00	.00	.02
12	.01	.42	.87	.03	.08	.04	.00	.18	.14	.00	.25	.00
13	.01	.46	2.29	.38	.00	.16	.27	1.31	.26	.00	.10	.22
14	.00	.42	.79	.15	.28	.00	.16	.88	.22	.00	.00	.00
15	.00	.14	1.08	.30	.09	.00	.24	.26	.02	.71	.70	.00
16	.00	.02	.37	.27	.07	.00	.02	.01	.00	.30	.00	.08
17	.00	.14	.04	.25	.01	.00	.28	.01	.00	.00	.00	.38
18	.00	.05	.03	.46	.00	.00	.17	.00	.00	.00	.00	.01
19	.00	.01	.01	.04	.01	.00	.11	.00	.00	.00	.00	.06
20	.00	.15	.00	.04	.00	.00	.05	.00	.00	.00	.60	.01
21	.00	.06	.00	.45	.00	.00	.25	.00	.00	.00	.02	.00
22	.00	.50	.04	.03	.00	.00	.19	.15	.00	.00	.05	.00
23	.26	.75	.14	.01	.08	.39	.00	.11	.12	.00	.05	.00
24	.42	.92	.13	.00	.18	.20	.01	.20	.00	.00	.30	.00
25	.16	1.12	.00	.14	.59	.01	.24	.01	.00	.00	.05	.00
26	.01	.00	.00	.00	.11	.00	.48	.24	.00	.00	.00	.01
27	.00	.32	.00	.01	.01	.00	.14	.17	.00	.00	.00	.00
28	.35	.08	.15	.09	.02	.00	.08	.00	.00	.00	.00	.00
29	.60	.19	.38	.00	---	.00	.00	.00	.00	.00	.00	.00
30	.32	.00	.06	.00	---	.08	.09	.00	.00	.00	.00	.11
31	.12	---	.00	.72	---	.01	---	.00	---	.00	.00	---
TOTAL	2.95	7.06	10.48	6.09	3.53	2.02	3.52	4.07	1.12	1.13	2.12	3.66
WTR YR 1978 TOTAL	47.75											

STATION NUMBER
LATITUDE 45205714207800 SINGER CR ON PEARL ST IN OREGON CITY
LONGITUDE 1223558

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.59	.10	.33	.55	.00	.14	.00	.00	.00	.00	.00
2	.00	.17	2.21	.06	.40	.00	.39	.00	.00	.35	.00	.00
3	.01	.00	.27	.42	.06	.09	.04	.02	.00	.09	.00	.30
4	.01	.11	.09	.31	.00	.19	.17	.09	.00	.00	.00	.10
5	.00	.14	.08	.68	.20	.00	.53	.00	.00	.00	.00	.15
6	.39	.11	.64	.06	.25	.05	.01	.01	.00	.00	.00	.29
7	.27	.09	.05	.25	.75	.40	.00	.00	.00	.00	.00	.25
8	.00	.01	.01	.36	.20	.08	.00	.00	.00	.00	.00	.33
9	.00	.00	.20	.20	.05	.00	.00	.10	.31	.00	.00	.41
10	.00	.00	.50	.07	.00	.00	.00	.26	.50	.00	.00	.10
11	.00	.09	1.29	.12	.00	.38	.00	.11	.02	.00	.00	.01
12	.00	.42	.77	.15	.02	.01	.00	.70	.13	.00	.26	.19
13	.05	.46	1.96	.40	.00	.14	.24	1.45	.29	.00	.10	.01
14	.00	.42	.95	.10	.20	.00	.48	1.08	.19	.00	.00	.02
15	.00	.14	.98	.35	.10	.00	.27	.02	.04	.87	.75	.05
16	.00	.02	.35	.40	.03	.00	.14	.00	.00	.26	.30	.26
17	.00	.14	.10	.25	.00	.00	.26	.00	.00	.00	.00	.01
18	.00	.05	.10	.55	.03	.00	.20	.01	.00	.00	.00	.00
19	.00	.01	.02	.05	.00	.00	.31	.00	.00	.00	.05	.04
20	.00	.15	.00	.10	.00	.00	.24	.00	.00	.00	.55	.01
21	.00	.06	.00	.45	.00	.00	.43	.00	.00	.00	.00	.05
22	.00	.50	.03	.02	.00	.00	.50	.03	.00	.00	.05	.00
23	.26	.75	.10	.00	.02	.39	.00	.01	.29	.00	.10	.00
24	.42	.92	.25	.00	.25	.23	.01	.10	.00	.00	.40	.00
25	.16	1.12	.00	.15	.75	.03	.39	.00	.00	.00	.05	.01
26	.01	.00	.00	.00	.23	.00	.75	.30	.00	.06	.00	.00
27	.00	.32	.00	.00	.00	.00	.02	.20	.00	.00	.00	.00
28	.35	.08	.15	.05	.00	.00	.02	.00	.00	.00	.00	.00
29	.60	.19	.50	.00	---	.00	.00	.00	.00	.00	.00	.00
30	.32	.00	.05	.03	---	.16	.05	.00	.00	.00	.00	.05
31	.12	---	.00	.07	---	.01	---	.00	---	.00	.00	---
TOTAL	2.98	7.06	11.75	5.98	4.09	2.16	5.59	4.49	1.77	1.63	2.61	2.84
WTR YR 1978 TOTAL	52.95											

TABLE 13.-DAILY PRECIPITATION--Continued

STATION NUMBER 14210400 NOYER CREEK ON HWY 212 NR DAMASCUS, OREG.
 LATITUDE 452506 LONGITUDE 1222431

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.67	.07	.00	.55	.00	.05	.00	.00	.12	.00	.01
2	.00	.22	1.68	.00	.34	.00	.17	.00	.00	.04	.00	.01
3	.00	.01	.36	.00	.05	.07	.15	.02	.00	.00	.00	.20
4	.00	.16	.08	.50	.00	.19	.29	.35	.00	.00	.00	.15
5	.00	.19	.11	.10	.21	.00	.23	.01	.00	.00	.00	.25
6	.42	.10	.45	.00	.23	.00	.01	.00	.00	.00	.00	.01
7	.34	.16	.02	.20	.57	.00	.01	.00	.00	.00	.00	.24
8	.00	.06	.03	.30	.14	.00	.00	.00	.00	.00	.00	.23
9	.00	.00	.20	.15	.06	.00	.00	.17	.29	.00	.00	.21
10	.00	.00	.46	.07	.01	.00	.00	.17	.35	.00	.00	.44
11	.00	.08	1.67	.18	.00	.00	.00	.23	.01	.00	.00	.01
12	.00	.24	.68	.10	.02	.00	.00	.26	.15	.00	.63	.00
13	.07	.45	1.69	.31	.00	.00	.12	1.14	.34	.00	.11	.19
14	.00	.33	1.11	.19	.25	.00	.45	1.20	.89	.00	.00	.09
15	.00	.13	.42	.23	.10	.00	.34	.12	.01	1.00	1.47	.00
16	.00	.01	.30	.49	.03	.00	.13	.00	.00	.40	.34	.11
17	.00	.22	.15	.23	.04	.00	.37	.00	.00	.00	.00	.15
18	.00	.19	.10	.54	.02	.00	.10	.00	.00	.00	.00	.00
19	.00	.14	.01	.16	.00	.00	.39	.00	.00	.00	.09	.04
20	.00	.12	.00	.09	.01	.00	.16	.00	.00	.00	.57	.00
21	.00	.08	.00	.59	.00	.00	.33	.00	.00	.00	.09	.01
22	.00	.55	.02	.09	.00	.00	.40	.02	.00	.00	.17	.04
23	.19	.80	.20	.00	.03	.25	.00	.01	.16	.00	.11	.01
24	.41	.86	.30	.01	.43	.15	.00	.21	.06	.00	.42	.00
25	.32	.93	.00	.23	.70	.06	.29	.01	.00	.00	.10	.00
26	.00	.00	.02	.01	.28	.00	.95	.20	.00	.01	.01	.00
27	.00	.52	.03	.02	.07	.18	.48	.29	.00	.00	.01	.05
28	.33	.10	.10	.21	.00	.00	.03	.00	.00	.00	.02	.00
29	.47	.25	.20	.00	---	.00	.01	.00	.00	.00	.00	.00
30	.41	.00	.00	.00	---	.13	.11	.00	.00	.00	.00	.12
31	.23	---	.00	.52	---	.00	---	.00	---	.00	.00	---
TOTAL	3.20	7.57	10.46	5.52	4.14	1.03	5.57	4.41	2.26	1.57	4.14	2.57
WTR YR 1978 TOTAL	52.44											

STATION NUMBER 14211105 RAIN GAGE ON VIEW DR IN ROBINWOOD
 LATITUDE 453224 LONGITUDE 1223853

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.64	.15	.08	.63	.00	.08	.00	.00	.00	.00	.01
2	.00	.19	2.43	.00	.43	.00	.41	.00	.00	.20	.00	.02
3	.00	.00	.20	.06	.05	.08	.04	.02	.00	.01	.00	.38
4	.01	.11	.09	.76	.00	.19	.13	.07	.00	.00	.00	.15
5	.00	.17	.06	.68	.27	.00	.33	.00	.00	.00	.00	.17
6	.42	.09	.77	.11	.23	.04	.01	.00	.00	.00	.00	.01
7	.28	.16	.04	.28	.89	.43	.00	.00	.00	.00	.00	.27
8	.01	.01	.02	.37	.20	.07	.00	.00	.00	.00	.00	.27
9	.00	.00	.22	.20	.07	.00	.00	.05	.18	.00	.00	.53
10	.00	.00	.50	.04	.00	.00	.00	.19	.38	.00	.00	.42
11	.00	.10	1.71	.14	.00	.25	.00	.19	.02	.00	.00	.01
12	.00	.43	.85	.09	.03	.02	.00	.31	.16	.00	.44	.00
13	.03	.44	2.01	.36	.00	.20	.19	1.49	.28	.00	.05	.18
14	.00	.50	1.00	.12	.24	.00	.34	1.08	.73	.00	.00	.01
15	.00	.13	1.01	.31	.10	.00	.28	.17	.02	.87	.81	.00
16	.00	.01	.39	.40	.03	.00	.23	.00	.00	.29	.43	.00
17	.00	.22	.10	.24	.02	.00	.33	.00	.00	.00	.00	.26
18	.00	.21	.08	.54	.00	.00	.13	.00	.00	.00	.01	.01
19	.00	.01	.02	.12	.00	.00	.27	.00	.00	.00	.06	.00
20	.00	.15	.00	.02	.00	.00	.19	.00	.00	.00	.56	.06
21	.00	.06	.00	.44	.00	.00	.47	.00	.00	.00	.03	.00
22	.00	.50	.04	.03	.01	.00	.53	.02	.00	.00	.01	.04
23	.31	.85	.17	.00	.04	.53	.01	.01	.19	.00	.16	.00
24	.57	.92	.25	.00	.26	.31	.00	.07	.01	.00	.67	.00
25	.25	1.12	.00	.16	.76	.02	.33	.00	.00	.00	.12	.00
26	.01	.00	.00	.00	.17	.00	.61	.29	.01	.14	.02	.00
27	.00	.32	.00	.01	.00	.00	.02	.21	.00	.00	.01	.00
28	.39	.08	.16	.14	.02	.00	.06	.00	.00	.00	.01	.00
29	1.04	.19	.48	.00	---	.00	.00	.00	.00	.00	.01	.00
30	.30	.00	.08	.03	---	.13	.07	.00	.00	.00	.00	.05
31	.13	---	.00	.61	---	.01	---	.00	---	.00	.00	---
TOTAL	3.75	7.61	12.83	6.34	4.45	2.28	5.06	4.17	1.98	1.51	3.40	2.85
WTR YR 1978 TOTAL	56.23											

TABLE 13.-DAILY PRECIPITATION--Continued

STATION NUMBER 14211115 RAIN GAGE ON OAK LODGE RFPD NO. 4 IN OAK GROVE
 LATITUDE 452457 LONGITUDE 1223753

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.60	.09	.33	.57	.00	.07	.00	.00	.00	.00	.01
2	.00	.14	2.21	.06	.34	.00	.28	.00	.00	.20	.00	.01
3	.00	.01	.20	.42	.02	.05	.05	.00	.00	.02	.00	.40
4	.00	.12	.05	.31	.00	.14	.15	.11	.00	.00	.00	.13
5	.00	.19	.03	.68	.20	.00	.37	.00	.00	.00	.00	.17
6	.35	.11	.81	.06	.19	.03	.01	.00	.00	.00	.00	.02
7	.36	.15	.01	.25	.76	.39	.00	.00	.00	.00	.00	.18
8	.01	.02	.01	.36	.18	.05	.00	.00	.00	.00	.00	.24
9	.00	.00	.21	.09	.03	.00	.00	.02	.15	.00	.00	.53
10	.00	.00	.48	.03	.00	.00	.00	.17	.18	.00	.00	.70
11	.00	.06	1.29	.13	.00	.17	.00	.27	.01	.00	.00	.01
12	.00	.44	.77	.07	.00	.01	.00	.26	.16	.00	.55	.01
13	.00	.34	1.96	.34	.00	.17	.22	1.24	.19	.00	.09	.17
14	.06	.41	.95	.10	.18	.00	.29	.97	.36	.00	.00	.01
15	.00	.11	.98	.26	.06	.00	.27	.10	.02	.74	.74	.01
16	.00	.01	.36	.36	.03	.00	.24	.00	.00	.28	.23	.01
17	.00	.21	.08	.19	.00	.00	.29	.01	.00	.00	.01	.31
18	.00	.15	.10	.53	.15	.00	.06	.01	.00	.00	.00	.02
19	.00	.01	.02	.07	.01	.00	.34	.00	.00	.00	.05	.00
20	.00	.15	.00	.01	.00	.00	.11	.00	.00	.00	.51	.04
21	.00	.05	.00	.44	.00	.00	.56	.00	.00	.00	.02	.01
22	.00	.50	.03	.00	.00	.00	.46	.04	.00	.00	.02	.00
23	.29	.85	.13	.00	.01	.41	.00	.01	.22	.00	.16	.01
24	.70	.92	.23	.00	.25	.25	.00	.14	.00	.00	.48	.00
25	.37	1.12	.00	.12	.40	.05	.27	.00	.00	.00	.09	.00
26	.02	.00	.00	.00	.15	.00	.59	.29	.00	.10	.03	.00
27	.01	.30	.00	.08	.00	.00	.03	.20	.00	.00	.01	.00
28	.47	.10	.13	.00	.00	.00	.15	.00	.00	.00	.03	.00
29	.95	.20	.49	.00	---	.00	.00	.00	.00	.00	.01	.00
30	.17	.00	.07	.00	---	.11	.06	.00	.00	.00	.00	.03
31	.10	---	.00	.59	---	.00	---	.00	---	.00	.00	---
TOTAL	3.81	7.27	11.69	5.88	3.53	1.83	4.87	3.84	1.29	1.34	3.03	3.03
WTR YR 1978 TOTAL	51.41											

STATION NUMBER 14211125 RAIN GAGE ON BILQUEST SCHOOL NR CLACKAMAS
 LATITUDE 452434 LONGITUDE 1223518

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.59	.06	.10	.00	.00	.07	.01	.00	.00	.00	.00
2	.00	.18	2.04	.04	.00	.00	.31	.00	.00	.13	.00	.01
3	.00	.06	.23	.69	.03	.10	.04	.00	.00	.02	.00	.31
4	.00	.14	.31	.09	.00	.15	.13	.11	.00	.00	.00	.10
5	.00	.18	.03	.67	.22	.02	.27	.01	.00	.00	.00	.17
6	.42	.06	1.00	.03	.25	.04	.01	.00	.00	.00	.00	.01
7	.20	.16	.43	.41	.70	.38	.00	.00	.00	.00	.00	.11
8	.00	.02	.06	.22	.17	.08	.00	.00	.00	.00	.00	.25
9	.00	.00	.77	.13	.06	.00	.00	.06	.22	.00	.00	.42
10	.00	.01	.54	.05	.00	.00	.00	.16	.27	.00	.00	.59
11	.00	.05	1.48	.15	.01	.24	.00	.20	.00	.00	.00	.00
12	.00	.35	.72	.09	.05	.01	.00	.26	.12	.00	.28	.02
13	.03	.32	1.74	.36	.00	.15	.18	1.42	.30	.00	.11	.14
14	.00	.35	.44	.13	.19	.00	.34	1.06	.58	.00	.00	.03
15	.00	.15	.61	.21	.09	.00	.33	.11	.00	.85	.77	.01
16	.00	.01	.47	.46	.03	.00	.14	.01	.00	.28	.32	.01
17	.00	.18	.40	.16	.01	.00	.30	.00	.00	.00	.00	.21
18	.00	.14	.10	.56	.16	.00	.14	.01	.00	.00	.00	.02
19	.00	.01	.08	.01	.02	.00	.37	.00	.00	.00	.04	.00
20	.00	.04	.01	.17	.00	.00	.15	.00	.00	.00	.56	.02
21	.00	.04	.00	.45	.00	.00	.34	.00	.00	.00	.02	.00
22	.00	.55	.05	.00	.01	.00	.41	.00	.00	.00	.05	.02
23	.33	.97	.15	.00	.03	.38	.00	.01	.21	.00	.12	.01
24	.74	.89	.28	.00	.28	.24	.01	.08	.00	.00	.45	.00
25	.33	.94	.00	.15	.60	.02	.28	.00	.00	.00	.07	.00
26	.01	.00	.00	.00	.18	.00	.64	.24	.00	.15	.02	.01
27	.01	.25	.07	.00	.00	.00	.09	.23	.00	.00	.00	.00
28	.32	.06	.47	.10	.00	.00	.11	.00	.00	.00	.00	.00
29	.79	.24	.32	.00	---	.00	.01	.00	.00	.00	.00	.00
30	.18	.00	.03	.00	---	.11	.05	.00	.00	.00	.00	.00
31	.09	---	.00	.60	---	.00	---	.00	---	.00	.00	---
TOTAL	3.45	6.94	12.89	6.03	3.09	1.92	4.72	3.98	1.70	1.43	2.81	2.47
WTR YR 1978 TOTAL	51.43											

TABLE 13.-DAILY PRECIPITATION--Continued

STATION NUMBER 14211301 TRYON CREEK TRIB AT DOLPH CT AT PORTLAND, OREG.
 LATITUDE 452743 LONGITUDE 1224218

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.42	.03	.14	.65	.00	.08	.00	.00	.00	.00	.00
2	.00	.10	1.97	.00	.31	.00	.26	.00	.00	.12	.00	.00
3	.00	.01	.03	.00	.03	.11	.06	.00	.00	.04	.00	.40
4	.00	.11	.13	.06	.00	.17	.37	.08	.00	.00	.00	.10
5	.00	.17	.03	.46	.30	.00	.38	.00	.00	.00	.00	.10
6	.28	.16	.24	.04	.12	.09	.00	.00	.00	.00	.00	.00
7	.51	.09	.04	.29	.62	.49	.01	.00	.00	.00	.00	.20
8	.00	.01	.01	.38	.31	.10	.00	.00	.00	.00	.00	.20
9	.00	.00	.29	.33	.13	.00	.00	.05	.21	.00	.00	.70
10	.00	.00	.47	.02	.00	.00	.00	.13	.22	.00	.00	.70
11	.00	.11	1.11	.10	.00	.22	.00	.51	.01	.00	.00	.00
12	.00	.45	.96	.07	.01	.05	.00	.21	.17	.00	.55	.00
13	.00	.21	2.40	.39	.00	.19	.29	1.24	.20	.00	.05	.20
14	.00	.31	.99	.12	.30	.00	.22	.87	.41	.00	.00	.00
15	.00	.08	.98	.18	.07	.02	.28	.31	.02	.70	.85	.00
16	.00	.05	.48	.45	.09	.00	.05	.00	.00	.22	.02	.05
17	.00	.17	.03	.33	.01	.00	.32	.00	.00	.00	.00	.30
18	.00	.29	.05	.27	.00	.00	.23	.01	.00	.00	.00	.00
19	.00	.01	.00	.28	.01	.00	.27	.00	.00	.00	.05	.00
20	.00	.15	.00	.09	.00	.00	.33	.00	.00	.00	.50	.05
21	.00	.04	.00	.40	.00	.00	.47	.00	.00	.00	.05	.00
22	.00	.50	.04	.17	.01	.00	.24	.13	.02	.00	.00	.00
23	.19	.90	.14	.01	.05	.39	.01	.00	.15	.00	.10	.00
24	.53	.68	.16	.00	.25	.27	.01	.40	.03	.00	.35	.00
25	.52	1.04	.00	.18	.61	.02	.29	.02	.02	.00	.10	.00
26	.01	.00	.00	.01	.10	.00	.48	.27	.01	.00	.00	.00
27	.01	.16	.02	.01	.00	.00	.09	.20	.00	.00	.00	.00
28	.36	.20	.35	.11	.00	.00	.11	.00	.00	.00	.00	.00
29	.67	.10	.28	.00	---	.00	.00	.00	.00	.00	.00	.00
30	.18	.00	.06	.00	---	.10	.08	.00	.00	.00	.00	.05
31	.09	---	.00	.57	---	.02	---	.00	---	.00	.00	---
TOTAL	3.35	6.52	11.29	5.46	3.98	2.24	4.93	4.43	1.47	1.08	2.62	3.05
WTR YR 1978 TOTAL	50.42											

STATION NUMBER 14211450 JOHNSON CR TRIB ON ROBERTS IN GRESHAM
 LATITUDE 452926 LONGITUDE 122522

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.59	.10	.01	.62	.00	.05	.00	.00	.12	.00	.00
2	.00	.04	2.62	.00	.36	.00	.17	.00	.00	.04	.00	.01
3	.00	.01	.47	.01	.05	.08	.15	.00	.00	.03	.00	.25
4	.00	.22	.23	.51	.00	.16	.29	.32	.00	.00	.00	.25
5	.00	.15	.22	.11	.33	.00	.23	.00	.00	.00	.00	.25
6	.37	.12	.74	.00	.32	.02	.00	.01	.00	.00	.00	.05
7	.31	.08	.06	.17	.82	.50	.00	.00	.00	.00	.00	.08
8	.00	.02	.00	.33	.19	.07	.00	.00	.00	.00	.00	.22
9	.00	.00	.19	.16	.10	.00	.00	.08	.35	.00	.00	.21
10	.00	.01	.49	.05	.01	.01	.00	.23	.23	.00	.00	.53
11	.00	.08	1.73	.17	.00	.26	.00	.43	.01	.00	.00	.05
12	.00	.30	.99	.08	.03	.01	.00	.32	.17	.00	.77	.00
13	.06	.55	2.21	.29	.00	.30	.16	1.15	.37	.00	.09	.19
14	.00	.80	1.04	.21	.27	.00	.42	1.16	.76	.00	.00	.07
15	.00	.20	.66	.22	.42	.00	.44	.34	.01	.98	.79	.04
16	.00	.02	.36	.44	.03	.00	.26	.01	.01	.47	.72	.21
17	.00	.25	.17	.26	.02	.00	.47	.00	.00	.00	.01	.07
18	.00	.20	.10	.50	.02	.00	.08	.00	.00	.00	.00	.00
19	.00	.20	.01	.07	.01	.00	.45	.00	.00	.00	.05	.00
20	.00	.00	.00	.15	.00	.00	.25	.00	.00	.00	.45	.01
21	.00	.08	.00	.55	.00	.00	.59	.00	.00	.00	.05	.01
22	.00	.80	.02	.03	.00	.00	.42	.11	.00	.00	.06	.06
23	.23	.80	.23	.00	.05	.26	.00	.03	.13	.00	.09	.00
24	.67	.90	.38	.00	.36	.15	.01	.11	.05	.00	.36	.00
25	.46	.90	.01	.25	.82	.09	.22	.03	.01	.00	.07	.00
26	.01	.00	.01	.01	.16	.00	.62	.27	.00	.08	.00	.00
27	.00	.50	.03	.00	.00	.18	.23	.28	.11	.00	.00	.00
28	.30	.10	.12	.11	.00	.00	.03	.00	.01	.00	.01	.00
29	.70	.25	.24	.01	---	.13	.00	.00	.00	.00	.00	.01
30	.18	.00	.00	.00	---	.00	.07	.00	.00	.00	.00	.04
31	.13	---	.00	.88	---	.00	---	.00	---	.00	.00	---
TOTAL	3.43	8.17	13.43	5.58	4.99	2.22	5.61	4.88	2.22	1.72	3.52	2.61
WTR YR 1978 TOTAL	58.38											

TABLE 13.—DAILY PRECIPITATION—Continued

STATION NUMBER 14211800 SALTZMAN CREEK AT PORTLAND, OREG.
 LATITUDE 453354 LONGITUDE 1224438

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.01	.35	.05	.00	.60	.00	.06	.01	.00	.00	.00	.00
2	.00	.08	1.77	.15	.31	.00	.11	.00	.00	.13	.00	.00
3	.01	.00	.06	.26	.04	.11	.11	.00	.00	.02	.00	.44
4	.00	.12	.12	.00	.00	.10	.30	.22	.00	.00	.00	.09
5	.00	.22	.12	.55	.29	.00	.25	.00	.00	.01	.00	.08
6	.28	.15	.28	.03	.23	.07	.00	.00	.00	.00	.00	.01
7	.41	.09	.16	.27	.72	.62	.00	.00	.00	.00	.00	.10
8	.00	.00	.00	.35	.20	.02	.00	.00	.00	.00	.00	.30
9	.00	.03	.26	.45	.04	.00	.00	.03	.26	.00	.02	.91
10	.00	.04	.57	.02	.00	.00	.00	.09	.40	.00	.00	.39
11	.00	.09	.71	.12	.00	.14	.00	.25	.00	.00	.00	.04
12	.00	.40	.92	.01	.00	.03	.00	.32	.08	.00	.04	.01
13	.00	.22	2.22	.35	.00	.13	.30	1.33	.08	.00	.02	.24
14	.00	.44	.64	.20	.33	.00	.25	.89	.23	.00	.00	.01
15	.00	.11	1.15	.25	.13	.00	.35	.12	.02	.95	.36	.00
16	.00	.13	.53	.27	.03	.00	.30	.00	.01	.30	.37	.00
17	.00	.32	.37	.28	.01	.00	.33	.00	.00	.00	.02	.22
18	.00	.05	.10	.40	.00	.00	.28	.01	.00	.00	.01	.01
19	.00	.00	.00	.07	.01	.00	.28	.00	.00	.00	.07	.00
20	.00	.01	.00	.07	.00	.00	.04	.00	.00	.00	.58	.07
21	.00	.00	.00	.47	.00	.00	.24	.00	.00	.00	.02	.00
22	.00	.50	.00	.02	.00	.00	.27	.52	.00	.00	.07	.02
23	.06	.66	.20	.00	.01	.41	.00	.03	.06	.00	.12	.00
24	.38	.71	.10	.00	.24	.21	.01	.00	.00	.00	.21	.00
25	.19	1.14	.00	.18	.70	.07	.11	.00	.00	.00	.13	.00
26	.01	.01	.00	.02	.05	.00	.44	.08	.00	.04	.00	.00
27	.00	.21	.00	.02	.00	.00	.13	.19	.00	.00	.00	.00
28	.31	.29	.15	.16	.00	.03	.04	.00	.00	.00	.00	.00
29	.63	.05	.30	.01	---	.04	.00	.00	.00	.00	.00	.00
30	.39	.00	.07	.01	---	.11	.07	.00	.00	.00	.00	.00
31	.09	---	.00	.72	---	.00	---	.00	---	.00	.00	---
TOTAL	2.77	6.42	10.85	5.71	3.94	2.08	4.27	4.09	1.14	1.45	2.04	2.94
WTR YR 1978 TOTAL	47.70											

STATION NUMBER 14211950 VANCOUVER LAKE TRIB NR VANCOUVER
 LATITUDE 454136 LONGITUDE 1224203

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.46	.03	.04	.48	.00	.03	.01	.00	.00	.00	.00
2	.00	.26	1.50	.07	.58	.00	.06	.00	.00	.15	.00	.00
3	.00	.01	.19	.02	.28	.13	.06	.00	.04	.02	.00	.35
4	.00	.11	.13	.77	.00	.08	.18	.20	.10	.00	.00	.10
5	.00	.14	.12	.67	.00	.00	.26	.00	.00	.00	.00	.01
6	.25	.14	.25	.00	.41	.10	.01	.00	.00	.00	.00	.01
7	.30	.07	.19	.33	.22	.50	.00	.00	.00	.00	.00	.00
8	.00	.00	.00	.42	.52	.00	.00	.00	.00	.00	.00	.32
9	.00	.06	.15	.43	.15	.00	.00	.02	.17	.00	.00	.93
10	.00	.14	.49	.02	.04	.00	.00	.11	.16	.00	.00	.25
11	.00	.03	.47	.11	.00	.24	.00	.23	.00	.00	.00	.02
12	.02	.39	.97	.02	.00	.02	.00	.30	.08	.00	.80	.00
13	.00	.15	1.66	.38	.00	.10	.31	1.28	.15	.00	.05	.25
14	.00	.38	.64	.17	.00	.00	.19	.60	.25	.00	.00	.05
15	.00	.12	.84	.15	.35	.00	.35	.03	.02	.60	.60	.00
16	.00	.11	.25	.29	.08	.00	.25	.00	.00	.40	.20	.10
17	.00	.05	.10	.24	.00	.00	.43	.00	.00	.00	.00	.15
18	.00	.05	.02	.43	.00	.00	.28	.00	.00	.00	.00	.00
19	.00	.04	.00	.02	.00	.00	.28	.00	.00	.00	.20	.00
20	.00	.06	.00	.01	.00	.00	.04	.01	.00	.00	.50	.10
21	.00	.02	.00	.25	.00	.00	.21	.00	.00	.00	.35	.00
22	.00	.50	.00	.00	.00	.00	.17	.31	.00	.00	.20	.00
23	.13	.50	.30	.00	.00	.38	.00	.01	.15	.00	.15	.00
24	.19	.33	.25	.00	.00	.17	.01	.26	.00	.00	.25	.00
25	.32	1.31	.02	.18	.40	.08	.14	.07	.00	.00	.25	.00
26	.01	.00	.00	.00	.67	.00	.40	.39	.00	.04	.02	.00
27	.00	.17	.00	.00	.05	.00	.06	.22	.00	.00	.00	.00
28	.27	.23	.15	.11	.04	.01	.05	.00	.00	.00	.00	.00
29	.45	.03	.35	.00	---	.00	.00	.00	.00	.00	.00	.00
30	.23	.00	.20	.00	---	.05	.08	.00	.00	.00	.03	.10
31	.10	---	.02	.01	---	.01	---	.00	---	.00	.00	---
TOTAL	2.27	5.86	9.29	5.14	4.27	1.87	3.85	4.05	1.12	1.21	3.60	2.74
WTR YR 1978 TOTAL	45.27											

TABLE 13.—DAILY PRECIPITATION—Continued

STATION NUMBER 14211950 VANCOUVER LAKE TRIB NR VANCOUVER
 LATITUDE 454136 LONGITUDE 1224203

RAINFALL (IN.), WATER YEAR OCTOBER 1978 TO SEPTEMBER 1979

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.00	.13	.00	.08	.01	.30	.00				
2	.00	.10	.03	.00	.01	.01	.10	.00				
3	.00	.40	.11	.00	.09	.62	.01	.00				
4	.00	.02	.62	.00	.26	.55	.00	.92				
5	.00	.00	.00	.03	.29	.20	.01	.34				
6	.00	.01	.01	.01	1.02	.12	.00	.24				
7	.00	.15	.00	.04	.23	.01	.00	.24				
8	.00	.20	.03	.00	.10	.00	.19	.00				
9	.00	.01	.16	.10	.05	.00	.21	---				
10	.00	.02	.73	1.20	.59	.00	.34	---				
11	.00	.00	.08	.20	.60	.00	.06	---				
12	.00	.01	.01	.01	.30	.00	.20	---				
13	.00	.04	.04	.00	.12	.00	.02	---				
14	.00	.03	.11	.25	.01	.05	.06	---				
15	.00	.05	.01	.00	.18	.33	.14	---				
16	.00	.20	.01	.01	.34	.25	.18	---				
17	.00	.04	.05	.04	.20	.02	.18	---				
18	.00	.90	.00	.01	.06	.00	.33	---				
19	.00	.30	.00	.25	.05	.01	.01	---				
20	.08	.15	.22	.00	.05	.00	.01	---				
21	.00	.06	.05	.15	.01	.00	.00	---				
22	.00	.02	.02	.01	.71	.00	.07	---				
23	.00	.03	.03	.10	.22	.00	.57	---				
24	.02	.00	.08	.07	.53	.00	.01	---				
25	.00	.01	.00	.00	.33	.00	.00	---				
26	.00	.00	.00	.05	.01	.13	.00	---				
27	.00	.35	.01	.27	.31	.20	.27	---				
28	.30	.38	.19	.01	.65	.06	.03	---				
29	.30	.28	.11	.06	---	.02	.00	---				
30	.01	.69	.00	.08	---	.04	.00	---				
31	.00	---	.00	.10	---	.06	---	---				
TOTAL	0.71	4.45	2.84	3.05	7.40	2.69	3.30	1.74				

WTR YR 1979 TOTAL 26.18 NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

STATION NUMBER 14213030 RAIN GAGE ON COLUMBIA R HIGH SCHOOL
 LATITUDE 454138 LONGITUDE 1224040

RAINFALL (IN.), WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.46	.03	.00	.62	.01	.06	.00	.00	.00	.00	.00
2	.00	.18	1.39	.01	.31	.00	.07	.00	.01	.12	.00	.00
3	.00	.01	.23	.15	.02	.10	.07	.00	.01	.03	.00	.35
4	.00	.10	.14	.71	.00	.06	.17	.20	.00	.00	.00	.10
5	.00	.14	.13	.71	.44	.00	.32	.00	.00	.00	.00	.07
6	.26	.16	.20	.01	.25	.08	.02	.00	.00	.01	.00	.00
7	.32	.06	.19	.30	.63	.48	.00	.00	.00	.00	.00	.01
8	.01	.00	.00	.40	.01	.01	.00	.00	.00	.00	.00	.27
9	.01	.06	.14	.42	.08	.00	.00	.01	.24	.00	.00	.85
10	.00	.13	.54	.04	.01	.00	.00	.13	.20	.00	.00	.19
11	.00	.03	.49	.12	.00	.19	.00	.21	.00	.00	.00	.02
12	.03	.44	.97	.04	.01	.02	.00	.30	.18	.00	.78	.00
13	.01	.18	1.66	.35	.01	.11	.29	1.25	.26	.00	.05	.24
14	.00	.35	.64	.16	.36	.00	.25	.62	.19	.00	.00	.03
15	.00	.11	.84	.17	.11	.00	.39	.06	.03	.54	.63	.00
16	.00	.10	.26	.31	.02	.00	.36	.00	.01	.35	.21	.08
17	.00	.07	.12	.27	.01	.00	.42	.00	.01	.00	.01	.16
18	.00	.09	.02	.43	.01	.00	.42	.00	.00	.00	.00	.01
19	.00	.04	.00	.04	.01	.00	.30	.00	.00	.00	.19	.00
20	.00	.04	.00	.05	.00	.00	.05	.00	.00	.00	.53	.09
21	.00	.00	.00	.36	.00	.00	.23	.00	.00	.00	.34	.01
22	.00	.50	.01	.03	.01	.00	.21	.35	.01	.00	.15	.00
23	.11	.60	.30	.00	.00	.38	.01	.01	.16	.00	.15	.00
24	.21	.44	.26	.00	.39	.16	.00	.26	.00	.00	.25	.01
25	.41	1.32	.02	.22	.73	.09	.12	.06	.00	.00	.24	.00
26	.01	.00	.01	.01	.09	.01	.43	.38	.00	.01	.02	.00
27	.00	.20	.00	.00	.00	.00	.06	.24	.00	.00	.00	.00
28	.24	.20	.17	.25	.02	.00	.08	.00	.00	.00	.00	.00
29	.47	.03	.34	.08	---	.00	.00	.00	.00	.00	.00	.00
30	.23	.01	.20	.00	---	.04	.09	.00	.00	.00	.02	.10
31	.11	---	.02	.49	---	.00	---	.00	.00	.00	.01	---
TOTAL	2.43	6.05	9.32	6.13	4.34	1.74	4.42	4.08	1.31	1.06	3.58	2.59

WTR YR 1978 TOTAL 47.05

TABLE 13.—DAILY PRECIPITATION—Continued

STATION NUMBER
LATITUDE 45413814213030 RAIN GAGE ON COLUMBIA R HIGH SCHOOL
LONGITUDE 1224040

RAINFALL (IN.), WATER YEAR OCTOBER 1978 TO SEPTEMBER 1979

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.00	.00	.16	.01	.08	.01	.31	.00				
2	.00	.09	.05	1.00	.01	.01	.10	.00				
3	.00	.42	.17	.04	.09	.62	.01	.00				
4	.00	.02	.64	.01	.26	.55	.00	.92				
5	.00	.00	.01	.02	.29	.20	.01	.34				
6	.00	.01	.01	.11	1.02	.12	.00	.24				
7	.00	.13	.03	.03	.23	.01	.00	.24				
8	.00	.22	.06	.05	.10	.00	.19	.00				
9	.00	.01	.15	.11	.05	.00	.21	---				
10	.00	.02	.75	1.20	.59	.00	.34	---				
11	.00	.00	.10	.18	.60	.00	.06	---				
12	.00	.01	.00	.01	.30	.00	.20	---				
13	.00	.04	.08	.00	.12	.00	.02	---				
14	.00	.03	.13	.24	.01	.05	.06	---				
15	.00	.05	.01	.00	.18	.33	.14	---				
16	.00	.21	.02	.01	.34	.26	.18	---				
17	.00	.04	.08	.04	.20	.02	.18	---				
18	.00	.89	.00	.01	.06	.00	.33	---				
19	.00	.33	.00	.24	.05	.01	.01	---				
20	.08	.13	.28	.00	.05	.00	.01	---				
21	.00	.06	.08	.17	.01	.00	.00	---				
22	.00	.02	.03	.01	.71	.00	.07	---				
23	.00	.03	.05	.10	.22	.00	.57	---				
24	.02	.00	.08	.07	.53	.00	.01	---				
25	.00	.01	.00	.00	.33	.00	.00	---				
26	.00	.00	.00	.05	.01	.13	.00	---				
27	.00	.36	.01	.27	.31	.22	.27	---				
28	.31	.38	.03	.01	.65	.06	.03	---				
29	.32	.29	.10	.06	---	.02	.00	---				
30	.01	.73	.04	.08	---	.04	.00	---				
31	.00	---	.01	.10	---	.06	---	---				
TOTAL	0.74	4.53	3.16	4.23	7.40	2.72	3.31	1.74				

WTR YR 1979 TOTAL

27.83

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

Table 14.--Selected storm data

Station number and name: 14142580 - Kelly Creek

Location: Lat 45°30'44", long 122°23'56".

Control: At low stages, it is a rock and gravel riffle; at high stages, it is a large 13- by 8½-ft arch culvert (type II flow).

Datum: Zero datum is 0.08 ft below upstream invert.

Rain gage (1) station no. 14142570

Location: Lat 45°29'26", long 122°22'54", at Powell Valley Grade School on Powell Valley Road.

Storm								Rain gage no.	Precipitation (inches)							Number of events	Discharge peak							Remarks
Begin				End					Maximum intensities								Time					Magnitude		
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes			Hours			Total		Year	Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)	
									5	15	30	1	6	24										
1978	05	13	0	1978	05	14	24	1	0.02	0.05	0.09	0.16	0.52	1.41	2.31	1	1978	05	14	20	20	2.66	83.00	

Station number and name: 14144690 - Vancouver sewer outfall

Location: Lat 45°37'21", long 122°40'14".

Control: A 90° sharp-crested weir set on the end of a 5-foot-diameter concrete sewer pipe set 0.15 in. above pipe invert.

Datum: Zero datum is at bottom of weir notch.

Rain gage (1) station no. 14144680

Location: Lat 45°37'54", long 122°40'08", at Vancouver City Hall, Vancouver, Wash.

Storm								Rain gage no.	Precipitation (inches)								Number of events	Discharge peak						Remarks	
Begin				End					Maximum intensities									Time					Magnitude		
																		Year	Month	Day	Hour	Minute	Gage height (ft)		Discharge (ft ³ /s)
Minutes			Hours			Total																			
5	15	30	1	6	24		Total																		
Year	Month	Day	Hour	Year	Month	Day	Hour	5	15	30	1	6	24	Total	Year	Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)	Remarks			
1978	03	06	23	1978	03	07	19	1	0.02	0.05	0.09	0.17	0.30	--	0.53	1	1978	03	07	17	40	3.01	37.0		
1978	05	13	05	1978	05	14	20	1	.10	.12	.16	.22	.54	1.30	1.77	1	1978	05	13	15	50	3.22	43.0		

Table 14.--Selected storm data--Continued

Station number and name: 14206320 - Beaverton Creek near Cedar Hills Boulevard at Beaverton, Oreg.

Location: Lat 45°29'02", long 122°48'11".

Control: At low stages, a grass and silt riffle; at high stages, channel control subject to backwater.

Datum: Zero datum.

Rain gage (1) station no. 14206310

Location: Lat 45°29'37", long 122°45'21", at Raleigh Park Grade School above Raleigh Park in West Slope.

Rain gage (2) station no. 14206315

Location: Lat 45°29'02", long 122°48'11", on Beaverton City Hall on Hall Boulevard in Beaverton.

Storm								Rain gage no.	Precipitation (inches)								Number of events	Discharge peak						Remarks	
Begin				End					Maximum intensities									Time					Magnitude		
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes			Hours			Total	Year		Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)		
									5	15	30	1	6	24											
1978	05	13	04	1978	05	15	19	1	0.17	0.35	0.38	0.42	0.57	1.48	2.55	3	1978	05	13	17	30	4.25	126.0		
								2	.12	.19	.20	.25	.59	1.47	2.24										
1978	09	08	23	1978	09	11	16	1	.13	.24	.29	.34	.57	.83	1.45	3	1978	09	09	08	25	3.79	104.0		
								2	.10	.19	.25	.29	.59	.85	1.55	3									

Station number and name: 14206330 - Beaverton Creek tributary at SW. Murray Boulevard at Beaverton, Oreg.

Location: Lat 45°20'08", long 122°51'41".

Control: A 2-foot-diameter concrete culvert (type I to V control).

Datum: Zero datum is 0.07 ft above upstream culvert invert.

Rain gage (1) at stream-gage site.

Storm								Rain gage no.	Precipitation (inches)								Number of events	Discharge peak						Remarks
Begin				End					Maximum intensities									Time			Magnitude			
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes			Hours			Total	Year		Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)	
									5	15	30	1	6	24										
1978	04	27	17	1978	04	27	18	1	0.07	0.10	0.10	0.10	--	--	0.10	1	1978	04	27	17	35	1.04	5.1	
1978	05	13	04	1978	05	14	20	1	.08	.15	.17	.20	0.55	1.37	1.95	2	1978	05	13	15	25	1.77	12.0	
1978	05	22	11	1978	05	22	20	1	.13	.23	.27	.28	.32	--	.34	1	1978	05	22	17	20	1.83	13.0	
1978	07	15	17	1978	07	15	21	1	.09	.21	.33	.45	.77	--	.77	1	1978	07	15	18	10	1.89	14.0	

Table 14.--Selected storm data--Continued

Station number and name: 14206470 - Butternut Creek at 180th Avenue at Aloha, Oreg.

Location: Lat 45°28'52", long 122°51'41".

Control: A 1.85-foot-high dam with 90° "W"-notch weir set in front of a 4- by 7-ft rectangular concrete culvert.

Datum: Zero datum is 0.77 ft below notch of weir at Invert of culvert.

Rain gage (1) at stream-gage site.

Storm				Precipitation (inches)												Number of events	Discharge peak					Remarks		
Begin				End				Maximum intensities						Total	Time					Magnitude				
								Minutes			Hours				Year	Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)			
Year	Month	Day	Hour	Year	Month	Day	Hour	5	15	30	1	6	24											1
1978	04	13	13	1978	04	13	24	1	0.03	0.07	0.10	0.17	0.29	--	0.35	1	1978	04	13	14	10	1.96	5.0	
1978	05	13	05	1978	05	14	21	1	.04	.11	.14	.23	.51	1.31	1.74	2	1978	05	13	15	35	2.48	19.0	
1978	07	15	08	1978	07	16	08	1	.10	.26	.37	.51	.86	1.07	1.07	2	1978	07	15	18	40	2.67	26.0	
1978	09	08	11	1978	09	10	18	1	.07	.12	.17	.22	.56	.90	1.50	4	1978	09	10	17	00	2.89	34.0	

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Station number and name: 14206900 - Fanno Creek at 56th Avenue at Portland, Oreg.

Location: Lat 45°29'17", long 122°44'01".

Control: A 6-inch-diameter concrete culvert set flush in vertical headwall; type I to V culvert entrance control.

Datum: Zero datum is 0.18 ft above upstream invert of culvert.

Rain gage (1) station no. 14206850

Location: Lat 45°29'21", long 122°41'41", atop KPAM-FM Radio Station on Council Crest Drive.

Rain gage (2) at stream-gage site.

Storm										Precipitation (inches)										Number of events	Discharge peak					Remarks
Begin				End				Rain gage no.	Maximum intensities						Total	Time				Magnitude						
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes			Hours				Year	Month	Day	Hour		Minute					
									5	15	30	1	6	24												
1978	05	13	03	1978	05	15	19	1	0.09	0.11	0.13	0.20	0.40	0.95	1.19	3	1978	05	13	09	40	2.88	66			
1978	05	13	03	1978	05	15	19	2	.12	.17	.18	.26	.61	1.44	2.35	3	1978	07	15	19	20	2.59	54			
1978	07	15	02	1978	07	16	08	1	.05	.12	.23	.35	.62	.97	1.04	1	1978	09	10	17	35	3.12	76			
1978	09	08	11	1978	09	10	20	1	.07	.16	.22	.28	.53	.82	1.57	3										
1978	09	08	16	1978	09	10	20	2	.12	.33	.44	.51	.63	1.11	1.83	3										
Rain gage no. 2 not operating during storm.																										

Table 14.--Selected storm data--Continued

Station number and name: 14207800 - Singer Creek at Pearl Street at Oregon City, Oreg.

Location: Lat 45°20'57", long 122°35'58".

Control: a 3.0-foot-diameter corrugated metal pipe culvert (type I to V control).

Datum: Zero datum is 0.29 ft above upstream culvert invert.

Rain gage (1) at stream-gage site.

Storm				Precipitation (inches)												Number of events	Discharge peak					Remarks	
Begin			End	Rain gage no.	Maximum intensities																		
Year	Month	Day	Hour		Minutes			Hours			Total												
					5	15	30	1	6	24													
1978	04	22	02	1978	04	22	14	1	0.08	0.16	0.19	0.22	0.36	--	0.49	1	1978	04	22	12	05	1.03	8.70
1978	05	13	00	1978	05	14	19	1	.08	.15	.22	.29	.76	1.45	2.52	1	1978	05	14	18	20	1.44	14.00
1978	07	15	02	1978	07	16	11	1	.07	.17	.23	.36	.76	1.04	1.13	2	1978	07	15	18	05	.83	6.20
1978	09	09	00	1978	09	10	16	1	.06	.12	.13	.15	.24	.61	.70	1	1978	09	10	00	35	.58	3.70

Station number and name: 14210400 - Noyer Creek on Highway 212 near Damascus, Oreg.

Location: Lat 45°25'06", long 122°24'31".

Control: A slightly elliptical 7-foot-diameter corrugated metal pipe culvert with mitered entrance (type I to V control).

Datum: Zero datum is 0.31 ft below upstream invert of culvert.

Rain gage (1) at stream-gage site.

Storm								Rain gage no.	Precipitation (inches)												Number of events	Discharge peak						Remarks		
Begin				End					Maximum intensities													Time							Magnitude	
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes			Hours			Total	Year	Month	Day	Hour	Minute		Gage height (ft)	Discharge (ft ³ /s)							
									5	15	30	1	6	24																
1978	05	13	6	1978	05	15	20	1	0.03	0.07	0.11	0.17	0.56	1.20	2.46	1	1978	05	14	21	00	2.49	45							

Table 14.--Selected storm data--Continued

Station number and name: 14211110 - Willamette River tributary at Old River Road at Robinwood, Oreg.

Location: Lat 45°24'01", long 122°38'37".

Control: A 5-foot-diameter corrugated metal pipe culvert (type I to V control).

Datum: Zero datum is 0.10 ft above upstream invert of culvert.

Rain gage (1) station no. 14211105

Location: Lat 45°23'24", long 122°38'53", on View Drive, located near large water tanks at Robinwood, Oreg.

Storm								Rain gage no.	Precipitation (inches)							Number of events	Discharge peak								Remarks
Begin				End					Maximum intensities								Time					Magnitude			
																	Year					Gage height (ft)		Discharge (ft ³ /s)	
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes			Hours					Total	Year	Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)	
									5	15	30	1	6	24											
1978	04	22	0	1978	04	22	24	1	0.09	0.16	0.18	0.22	0.39	0.52	0.53	1	1978	04	22	12	35	1.13	10		
1978	05	13	1	1978	05	15	4	1	.06	.12	.20	.31	.75	1.57	2.74	1	1978	05	14	19	45	1.55	18		

Station number and name: 14211120 - Willamette River tributary at SE. River Road at Oak Grove, Oreg.

Location: Lat 45°24'34", long 122°38'39".

Control: A 4.6-foot-diameter corrugated metal pipe culvert (type I to V control).

Datum: Zero datum is 0.16 ft above upstream invert of culvert.

Rain gage (1) station no. 1411115

Location: Lat 45°24'57", long 122°37'53" on Oak Lodge RFD No. 4 garage at Oak Grove, Oreg.

Storm								Rain gage no.	Precipitation (inches)							Number of events	Discharge peak						Remarks	
Begin				End					Maximum intensities								Time					Magnitude		
																	Year	Month	Day	Hour	Minute	Gage height (ft)		Discharge (ft ³ /s)
Minutes			Hours																					
5	15	30	1	6	24	Total																		
1978	04	19	13	1978	04	19	15	1	0.11	0.17	0.24	0.26	0.30	0.34	0.34	1	1978	04	19	14	15	1.78	24	
1978	04	22	2	1978	04	22	14	1	.05	.08	.10	.13	.31	.46	.46	1	1978	04	22	12	05	2.07	31	
1978	05	13	3	1978	05	14	20	1	.07	.09	.14	.23	.60	1.36	2.21	2	1978	05	13	09	05	1.62	21	
1978	07	15	17	1978	07	15	24	1	.05	.11	.20	.28	.66	.74	.74	1	1978	07	15	18	55	1.40	16	

Table 14.--Selected storm data--Continued

Station number and name: 14211130 - Kellogg Creek at Rusk Road at Milwaukie, Ore.

Location: Lat 45°25'23", long 122°36'09".

Control: Two parallel 2.5-foot-diameter concrete culverts (type I to V control).

Datum: Zero datum is 0.20 ft above upstream invert of right bank culvert.

Rain gage (1) station no. 14211125

Location: Lat 45°24'23", long 122°35'18", on Bilquist Grade School at Webster Road at Milwaukie, Ore.

Storm								Rain gage no.	Precipitation (inches)								Number of events	Discharge peak						Remarks
Begin				End					Maximum intensities									Time			Magnitude			
									Minutes				Hours					Year	Month	Day	Hour	Minute	Gage height (ft)	
Year	Month	Day	Hour	Year	Month	Day	Hour		5	15	30	1	6	24	Total									
1978	02	07	4	1978	02	07	23		1	0.04	0.07	0.10	0.16	0.39	0.70	0.70		2	1978	02	07	22	55	
1978	04	19	13	1978	04	19	15	1	.13	.21	.27	.32	.33	.37	.37	1	1978	04	19	14	40	1.37	22	
1978	04	22	2	1978	04	22	13	1	.05	.11	.13	.17	.31	.41	.41	2	1978	04	22	12	35	1.31	21	
1978	05	13	0	1978	05	15	6	1	.04	.10	.17	.30	.76	1.42	2.59	1	1978	05	13	09	35	1.81	34	

Station number and name: 14211301 - Tryon Creek tributary at Dolph Court at Portland, Ore.

Location: Lat 45°27'43", long 122°42'18".

Control: A 3.0-foot-diameter corrugated metal pipe culvert (type I to V control).

Datum: Zero datum is 0.03 ft above upstream invert of culvert,

Rain gage (1) at stream-gage site.

Storm								Rain gage no.	Precipitation (inches)								Number of events	Discharge peak						Remarks										
Begin				End					Maximum intensities									Time			Magnitude													
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes			Hours			Total	Year		Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)											
									5	15	30	1	6	24																				
1978	04	19	13	1978	04	20	18	1	0.11	0.15	0.17	0.22	0.49	0.60	0.61	2	1978	04	19	19	35	1.31	8.70											
1978	05	13	6	1978	05	13	24	1	.07	.10	.13	.22	.54	1.24	1.24	2	1978	05	13	15	55	1.64	13											
1978	07	15	2	1978	07	15	22	1	.04	.10	.22	.39	.57	.70	.70	1	1978	07	15	18	25	1.45	10											

Table 14.--Selected storm data--Continued

Station number and name: 14211450 - Johnson Creek tributary on Roberts Avenue at Gresham, Oreg.

Location: Lat 45°29'26", long 122°25'22".

Control: A 4-foot-diameter corrugated metal pipe culvert (type I and V control).

Datum: Zero datum is 0.53 ft below upstream culvert invert.

Rain gage (1) at stream-gage site.

Remarks: Point of zero flow is at -0.30 ft from zero datum.

Storm								Rain gage no.	Precipitation (inches)								Number of events	Discharge peak						Remarks
Begin				End					Maximum intensities				Time					Magnitude						
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes		Hours		Day	Month	Year	Hour		Minute	Gage height (ft)	Discharge (ft ³ /s)				
									5	15	30	1									6	24	Total	
1978	04	19	7	1978	04	19	15	1	0.07	0.13	0.25	0.32	0.34	0.45	0.45	1	1.61	4.7						
1978	05	13	1	1978	05	15	17	1	.07	.18	.21	.22	.56	1.16	2.65	3	1.63	5.1						
1978	06	14	11	1978	06	14	19	1	.14	.19	.21	.21	.45	.76	.76	3	1.37	1.8						
1978	08	16	12	1978	08	16	16	1	.17	.36	.39	.39	.68	.72	.72	2	1.57	4.1						

Station number and name: 14211800 - Saltzman Creek at Balboa Avenue at Portland, Oreg.

Location: Lat 45°33'54", long 122°44'38".

Control: An 18.0- by 4.0-ft concrete flume with web and contoured wingwalls.

Datum: Zero datum is 0.76 ft below upstream culvert invert.

Rain gage (1) at stream-gage site.

Remarks: Other data are available from a crest gage located at this site from December 1954 to present.

Storm				Precipitation (inches)												Number of events	Discharge peak						Remarks
																	Time			Magnitude			
																	Year	Month	Day	Hour	Minute	Gage height (ft)	
Year	Month	Day	Hour	Year	Month	Day	Hour	Minutes	5	15	30	1	6	24	Total	1978	05	14	20	20	1.70	35	
1978	05	13	2	1978	05	15	6	0.19	0.24	0.25	0.28	0.53	1.48	2.34	2	1978	05	14	20	20	1.70	35	

Table 14.--Selected storm data--Continued

Station number and name: 14211950 - Vancouver Lake tributary at Lake Shore Drive near Vancouver, Wash.

Location: Lat 45°41'36", long 122°42'03".

Control: A 2.0-foot-diameter concrete culvert (type I and V control).

Datum: Zero datum is 0.25 ft below upstream culvert invert.

Rain gage (1) at stream-gage site.

Remarks: Point of zero flow is at invert.

Storm								Rain gage no.		Precipitation (inches)										Discharge peak						Remarks
Begin				End				no.	Maximum intensities								Time						Magnitude			
Year	Month	Day	Hour	Year	Month	Day	Hour		Minutes				Hours				Day	Month	Year	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)			
									5	15	30	1	6	24	Total											
1978	04	16	13	1978	04	16	15	1	0.08	0.11	0.12	0.14	0.19	0.25	0.25	1	1978	04	16	12	35	2.46	13			
1978	05	13	6	1978	05	14	19	1	.04	.11	.18	.24	.51	1.28	1.88	3	1978	05	13	15	35	3.19	17			

Station number and name: 14213040 - Cougar Creek on NE. 13th Avenue at Vancouver, Wash.

Location: Lat 45°42'35", long 122°40'58".

Control: A 4.5-foot-diameter corrugated metal pipe culvert (type I to V control).

Datum: Zero datum is 0.16 ft above upstream culvert invert.

Rain gage (1) station no. 14213030

Location: Lat 45°41'38", long 122°40'40", on Columbia River High School near Vancouver, Wash.

Storm								Rain gage no.		Precipitation (inches)								Discharge peak						Remarks																	
Begin				End				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		17	18	19	20	21	22	23	24	Total	Number of events	Year	Month	Day	Hour	Minute	Gage height (ft)	Discharge (ft ³ /s)
Year	Month	Day	Hour	Year	Month	Day	Hour																																		

SELECTED REFERENCES

- Allison, I. S., 1978, Late Pleistocene sediments and floods in the Willamette Valley: The Ore Bin, v. 40, nos. 11 and 12.
- Anderson, D. G., 1970, Effects of urban development on floods in northern Virginia: U.S. Geological Survey Water-Supply Paper 2001-C, 22 p.
- Brown, S. G., 1963, Problems of utilizing ground water in the west-side business district of Portland, Oregon: U.S. Geological Survey Water-Supply Paper 1619-0, 42 p.
- Dawdy, D. R., Lichty, R. W., and Bergmann, J. M., 1972, A rainfall-runoff simulation model for estimation of flood peaks for small drainage basins: U.S. Geological Survey Professional Paper 506-B, 28 p.
- Dempster, G. R., Jr., 1974, Effects of urbanization on floods in the Dallas, Texas, metropolitan area: U.S. Geological Survey Water-Resources Investigations 60-73, 51 p.
- Hogenson, G. M., and Foxworthy, B. L., 1973, Ground water in the East Portland area, Oregon: U.S. Geological Survey Water-Supply Paper 1793, 78 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.
- Mundorff, M. J., 1964, Geology and ground-water conditions of Clark County, Washington, with a description of major alluvial aquifers along the Columbia River: U.S. Geological Survey Water-Supply Paper 1600, 268 p.
- National Oceanic and Atmospheric Administration, 1973a, Precipitation-frequency atlas of the Western United States, NOAA Atlas 2, volume IX - Washington: Silver Spring, Md., 43 p.
- _____, 1973b, Precipitation-frequency atlas of the Western United States, NOAA Atlas 2, volume X - Oregon: Silver Spring, Md., 43 p.
- Phillip, J. R., 1954, An infiltration equation with physical significance: Soil Science Society American Proceedings, v. 77, p. 153-157.
- Putnam, A. L., 1972, Effect of urban development on floods in the piedmont province of North Carolina: U.S. Geological Survey Open-File Report, 87 p.
- Sherman, L. K., 1932, streamflow from rainfall by the unit hydrograph method: Engineering News Record, v. 108, p. 501-505.
- U.S. Soil Conservation Service, 1975, Urban hydrology for small watersheds: U.S. Department of Agriculture Technical Release 55, 92 p.

U.S. Weather Bureau, 1955, Rainfall intensity-duration-frequency curves for selected stations in the United States, Alaska, Hawaiian Islands, and Puerto Rico: U.S. Weather Bureau Technical Paper 25.

1963, Maximum recorded United States point rainfall for 5 minutes to 24 hours at 296 first-order stations: U.S. Weather Bureau Technical Paper 2 (revised), 56 p.

U.S. Water Resources Council, rev. 1977, Guidelines for determining floodflow frequency: Bulletin 17A of the Hydrology Committee.

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

