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THE WILLAMETTE BASIN COMPREHENSIVE STUDY OF WATER AND RELATED L--ETC(U)
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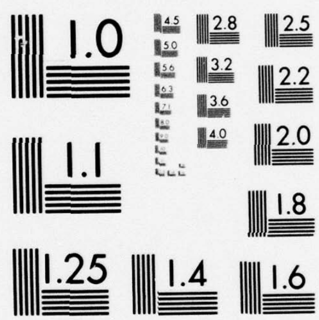

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WILLAMETTE BASIN

COMPREHENSIVE STUDY

Water and Related Land Resources

APPENDIX B

HYDROLOGY

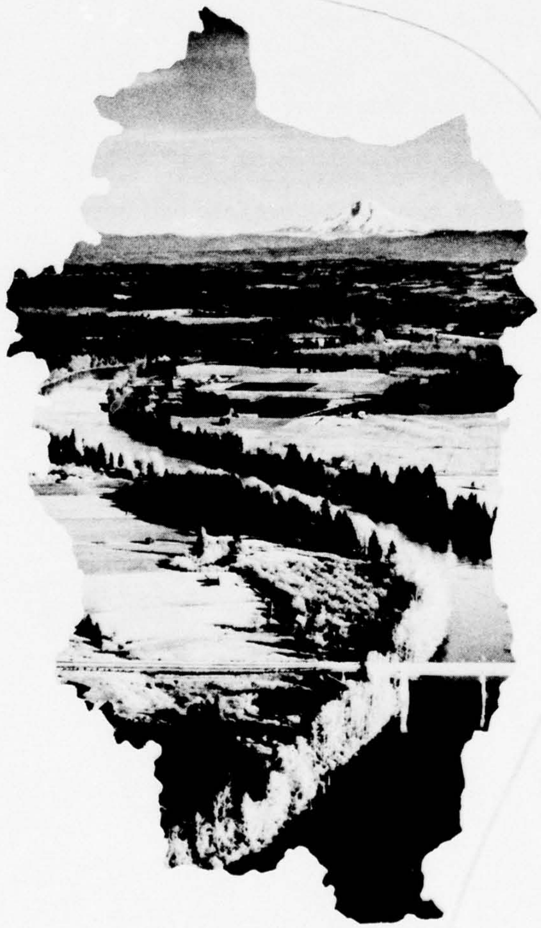
WILLAMETTE BASIN TASK FORCE - PACIFIC NORTHWEST RIVER BASINS COMMISSION

1969

The WILLAMETTE BASIN

COMPREHENSIVE STUDY of

Water and Related Land Resources



APPENDIX B

HYDROLOGY

WILLAMETTE BASIN TASK FORCE - PACIFIC NORTHWEST RIVER BASINS COMMISSION

1969

CREDITS

This is one of a series of appendices to the Willamette Basin Comprehensive Study main report. Each appendix deals with a particular aspect of the study. The main report is a summary of information contained in the appendices plus the findings, conclusion, and recommendations of the investigation.

This appendix was prepared under the general supervision of the Willamette Basin Task Force and by the Hydrology Committee. The committee was chaired by the U. S. Geological Survey and included representatives of the following agencies:

Bureau of Reclamation

Soil Conservation Service

Corps of Engineers

Federal Water Pollution Control Administration

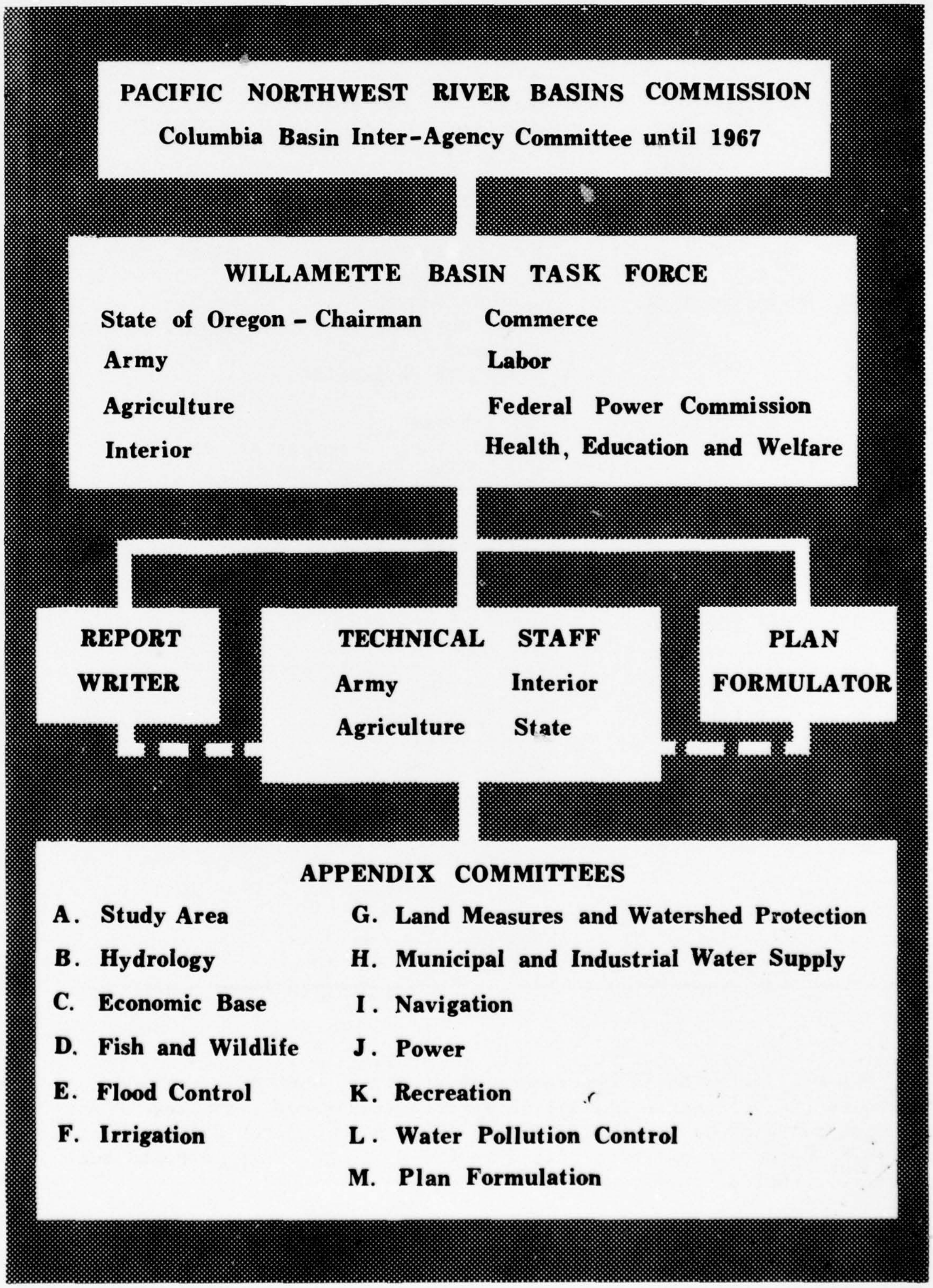
Oregon State Water Resources Board

Oregon State Engineer's Office

Bonneville Power Administration

Environmental Science Services Administration
Weather Bureau

ORGANIZATION



WILLAMETTE BASIN TASK FORCE

State of Oregon	Donel J. Lane, Chairman Director, Oregon State Water Resources Board
Department of Army	Henry Stewart Chief, Planning Branch U. S. Army Engineers, Portland District
Department of Interior	John F. Mangan Area Engineer, Lower Columbia Development Office Bureau of Reclamation
Department of Agriculture	Oke Eckholm Assistant State Conservationist Soil Conservation Service
Department of Commerce	David J. Bauman Hydrologist, Westher Bureau Forecast Center
Federal Power Commission	Allan J. Meadowcroft Engineer-in-Charge, River Basins Federal Power Commission
Department of Labor	Horace Harding Regional Economist Bureau of Employment Security
Department of Health, Education & Welfare	Francis L. Nelson Consultant, Bureau of Water Hygiene Public Health Service

The Willamette Basin Comprehensive Study has been directed and coordinated by the Willamette Basin Task Force listed above. The Task Force has been assisted by a technical staff, a plan formulator and a report writer. Appendix committees listed on the following page, carried out specific technical investigations.

APPENDIX COMMITTEES

Appendix-Subject	Chairman	Members
A - Study Area	OSWRB - Chairman:	FWPCA, USBPA, USBLM, USBM, USBOR, USBR, USBSF&WL, USCE, USERS, USFS, USGS, USNPS, USSCS, OSDC, OSDF, OSDG&MI, OSS&WCC, OSU
B - Hydrology	USGS - Chairman:	FWPCA, USBPA, USBR, USCE, USSCS, USWB, OSE, OSWRB
C - Economic Base	USCE - Chairman:	FWPCA, USBPA, USBCF, USBM, USBOR, USBR, USSF&WL, USDL, USERS, USFS, OSDC, OSU, UOBGRS
D - Fish & Wildlife	USBSF&WL - Chairman:	FWPCA, USBCF, USBLM, USBOR, USCE, USDA, USFS, USGS, USSCS, OSFC, OSGC, OSWRB
E - Flood Control	USCE - Chairman:	FWPCA, USBR, USDA, USGS, USSCS, USWB, OSDC, OSE, OSWRB, UOBGRS
F - Irrigation	USBR - Chairman:	USSCS, OSDC, OSWRB, OSU
G - Land Measures and Watershed Protection	USSCS - Chairman:	FWPCA, USBCF, USBLM, USBOR, USBR, USSF&WL, USFS, OSU
H - M&I Water Supply	FWPCA - Chairman:	USBR, USBSF&WL, USGS, USSCS, OSBH, OSDC, OSWRB,
I - Navigation	USCE - Chairman:	OSDC, OSMB, POP, OSU
J - Power	USBPA - Chairman:	FPC, FWPCA, USBCF, USBR, USCE, USFS, USGS, OSE, OSWRB
K - Recreation	USBOR - Chairman:	FPC, FWPCA, USBLM, USBSF&WL, USCE, USFS, USNPS, USSCS, OSBH, OSDC, OSFC, OSGC, OSHD-PD, OSMB, OSWRB, LCPD, OCPA
L - Water Pollution Control	FWPCA - Chairman:	USBCF, USBLM, USBOR, USBR, USBSF&WL, USGS, USSCS, OSBH, OSE, OSFC, OSGC, OSWRB, OSU
M - Plan Formulation	Plan Formulator - Chairman:	USCE, USDA, USDI, OSWRB

FPC - Federal Power Commission
FWPCA - Federal Water Pollution Control Administration
USBPA - Bonneville Power Administration
USBCF - Bureau of Commercial Fisheries
USBLM - Bureau of Land Management
USBM - Bureau of Mines
USBOR - Bureau of Outdoor Recreation
USBR - Bureau of Reclamation
USBSF&WL - Bureau of Sport Fisheries and Wildlife
USCE - Corps of Engineers
USDA - Department of Agriculture
USHEW - Department of Health, Education and Welfare
USDI - Department of Interior
USDL - Department of Labor
USERS - Economic Research Service
USFS - Forest Service
USGS - Geological Survey
USNPS - National Park Service
USSCS - Soil Conservation Service
USWB - Weather Bureau

OSBH - Oregon State Board of Health
OSDC - Oregon State Department of Commerce
OSDF - Oregon State Department of Forestry
OSDG&MI - Oregon State Department of Geology and Mineral Industries
OSE - Oregon State Engineer
OSFC - Fish Commission of Oregon
OSGC - Oregon State Game Commission
OSHD - Oregon State Highway Department
OSHD-PD - Oregon State Highway Department Parks Division
OSMB - Oregon State Marine Board
OSS&WCC - Oregon State Soil and Water Conservation Committee
OSWRB - Oregon State Water Resources Board
OSU - Oregon State University
PSC-PR&C - Portland State College - Center for Population Research and Census Service
UO - University of Oregon
UO-BGRS - University of Oregon - Bureau of Governmental Research and Service
LCPD - Lane County Parks Department
OCPA - Oregon County Parks Association
POP - Port of Portland

BASIN DESCRIPTION

Between the crests of the Cascade and Coast Ranges in northwestern Oregon lies an area of 12,045 square miles drained by the Willamette and Sandy Rivers--the Willamette Basin. Both the Willamette and Sandy Rivers are part of the Columbia River system, each lying south and at right angles to the lower Columbia River.

With a 1965 population of 1.34 million, the basin accounted for 68 percent of the population of the State of Oregon. The State's 3 largest cities, Portland, Salem and Eugene, are within the basin boundaries. Forty-one percent of Oregon's population is concentrated in the lower basin subarea, which includes the Portland metropolitan area.

The basin is roughly rectangular, with a north-south dimension of about 150 miles and an average width of 75 miles. It is bounded on the east by the Cascade Range, on the south by the Calapooya Mountains, and on the west by the Coast Range. The Columbia River, from Bonneville Dam to St. Helens, forms its northern boundary. Elevations range from less than 10 feet (mean sea level) along the Columbia, to 450 feet on the valley floor at Eugene, and over 10,000 feet in the Cascade Mountains. The Coast Range attains elevations of slightly over 4,000 feet.

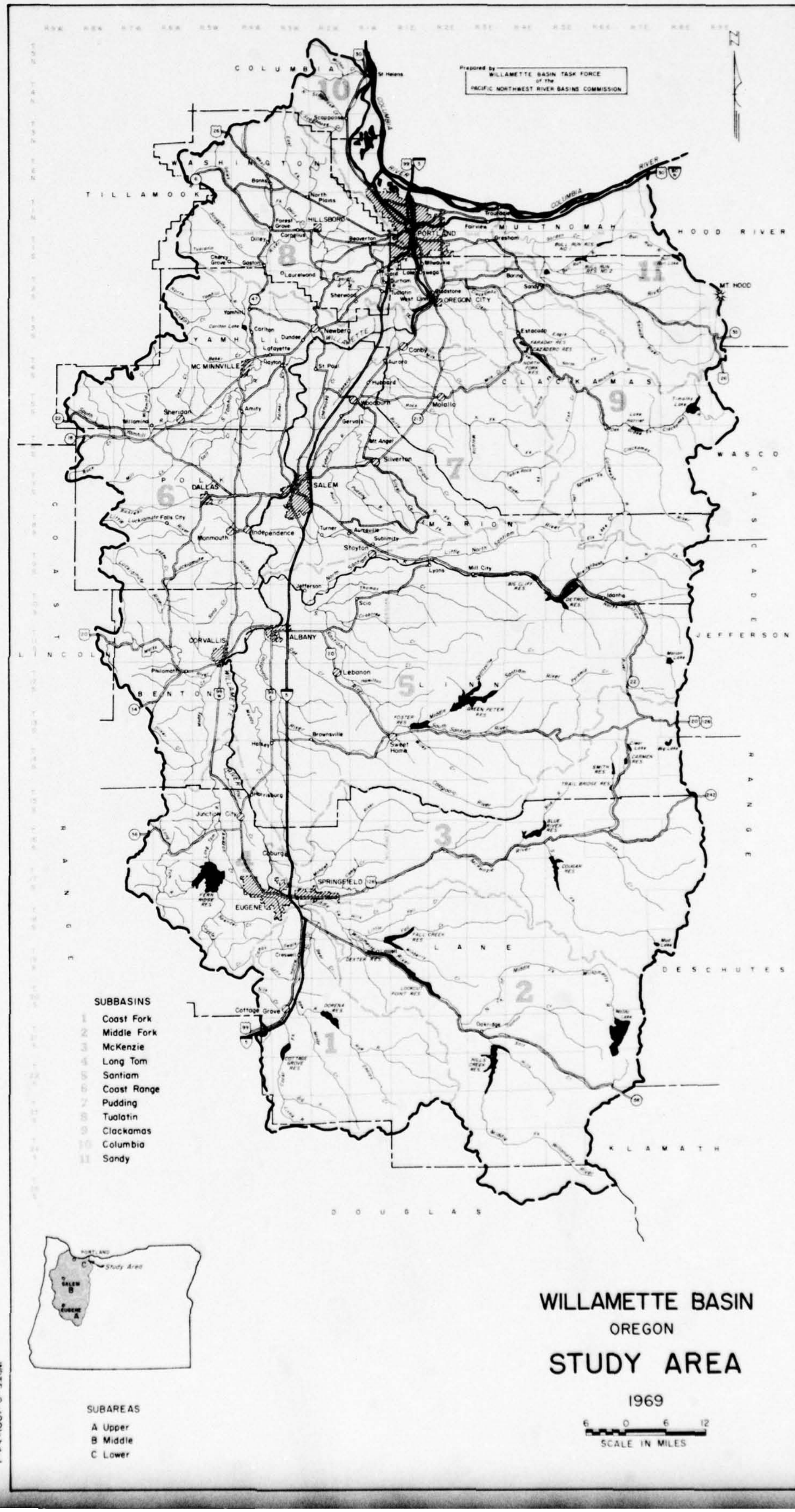
The Willamette Valley floor, about 30 miles wide, is approximately 3,500 square miles in extent and lies below an elevation of 500 feet. It is nearly level in many places, gently rolling in others, and broken by several groups of hills and scattered buttes.

The main stem Willamette River forms at the confluence of its Coast and Middle Forks near Springfield. It has a total length of approximately 187 miles, and in its upper 133 miles flows northward in a braided, meandering channel. Through most of the remaining 54 miles, it flows between higher and more well defined banks unhindered by falls or rapids, except for the basaltic intrusion which blocks the valley at Oregon City and creates Willamette Falls. The stretch below the falls is subject to ocean tidal effects which are transmitted through the Columbia River.

Most of the major tributaries of the Willamette River rise in the Cascade Range at elevations of 6,000 feet or higher and enter the main stream from the east. The Coast Fork Willamette River rises in the Calapooya Mountains, and numerous smaller tributaries rising in the Coast Range enter the main stream from the west.

In this study, the basin is divided into three major sections, referred to as the Upper, Middle, and Lower Subareas (see map opposite). The Upper Subarea is bounded on the south by the Calapooya Mountains and on the north by the divide between the McKenzie River drainage and the Calapooia and Santiam drainages east of the valley floor and by the Long Tom-Marys River divide west of it. The Middle Subarea includes all lands which drain into the Willamette River between the mouth of the Long Tom River and Fish Eddy, a point three miles below the mouth of the Molalla River. The Lower Subarea includes all lands which drain either into the Willamette River from Fish Eddy to its mouth or directly into the Columbia River between Bonneville and St. Helens; the Sandy River is the only major basin stream which does not drain directly into the Willamette River.

For detailed study, the three subareas are further divided into eleven subbasins as shown on the map.



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INTRODUCTION

PURPOSE AND SCOPE

The Willamette Basin is one of the better watered regions of the United States. The average annual precipitation of 63 inches results in a volume of more than 40 million acre-feet of water falling on the basin annually. Of this amount, about 26 million acre-feet runs off in the principal streams that drain the area. Most of the precipitation and runoff occurs during a few months in the winter, and natural water supplies are deficient during the late summer and early fall. Because of the diverse terrain, both precipitation and runoff are distributed unevenly. For this reason, it has been necessary to construct facilities to store the surface water and to drill wells to tap the ground water.

As the population and economy of the basin grow, many additional water developments will be needed. The purpose of the Willamette Basin Comprehensive Study is to develop information on future water and related resource needs and to prepare a plan for meeting those needs.

This appendix contains a description of the water resources, their distribution, and their variation at different periods of time throughout the Willamette Basin. These resources are described in terms of the climatic, geologic, and other environmental factors that influence and control the occurrence of water. The appendix provides statistical and interpretive hydrologic data necessary for broad-scale water-resources planning. These data are essential to the development of plans for meeting the basin's water needs and solving its water problems.

RELATIONSHIP TO OTHER PARTS OF THE REPORT

Hydrologic information is fundamental to the preparation of plans to meet water needs as presented in the functional appendices, D-L. Statistical data and descriptive and comprehensive reports on the various aspects of the water resources were used for the development of those plans. Hence, this appendix provides background data for preparation of the separate and coordinated plans presented in the comprehensive study.

The resource appendices--A, B, and C--describe the physical and cultural features of Willamette Basin. Appendix A - Study Area describes the physical setting and cultural features of the basin. Appendix B - Hydrology supplements the physical description by elaborating on the climatic and hydrologic features. Appendix C - Economic Base supplements the cultural description by elaborating on the economic features. For example, the hydrologic information presented in this appendix is used in Appendix E - Flood Control, and is the basis for studies of biological-biochemical water quality in Appendix L - Pollution Control.

D E S C R I P T I O N O F T H E B A S I N

The Willamette Basin Study Area is a 12,045 square-mile area in northwestern Oregon. It is bounded on the north by the Columbia River from Bonneville to St. Helens, and on the east, south, and west by the summits of the Cascade Range, the Calapooya Mountains, and the Coast Range, respectively. The study area includes the drainages of Willamette and Sandy Rivers, plus areas drained by small streams flowing into Multnomah Channel and into the Columbia River between Bonneville and the mouth of Sandy River. The north-south length of the basin is about 150 miles and its average east-west width about 75 miles. About 3,500 square miles is in the valley floor, about 1,900 in the eastern slope of the Coast Range, and the remainder in the foothills and mountains on the western slope of the Cascades.

The principal streams of the basin head in the bordering mountain ranges. Forests cover about three-fourths of the basin, and most of the vital streamflows originate in mountainous forest lands. In the 1,000- to 4,000-foot elevation range, where the principal forests are located, average annual precipitation ranges from 60 to about 200 inches in the Coast Range. In the higher parts of the Cascade Range, where the upper-slope forests are found, precipitation ranges from 90 to 140 inches and snowfall is heavy with considerable snowpack accumulation. In the 5,500- to 6,000-foot zone, forest cover is largely subalpine; this zone contains about 200 named lakes and many unnamed lakes.

The basin is divided into Upper, Middle, and Lower Subareas (see Frontispiece):

The Upper Subarea is bounded on the south by the Calapooya Mountains, on the north by the divide between the McKenzie River drainage and the Calapooia and Santiam drainages east of Willamette River, and by the Long Tom-Marys River divide west of the Willamette.

The Middle Subarea includes all lands that drain into the Willamette between the mouth of Long Tom River and Fish Eddy, a point 3 miles below the mouth of Molalla River.

The Lower Subarea includes all lands that drain into Willamette River from Fish Eddy to the mouth of the Willamette, and direct drainage into Columbia River between Bonneville and St. Helens.

For detailed study, the three subareas are further divided into 11 subbasins, as tabulated below.

Subunit	Percentage of Total		Area (sq. mi.)	
Coast Fork Subbasin	5		665	
Middle Fork Subbasin	11		1,354	
McKenzie Subbasin	11		1,342	
Long Tom Subbasin	4		526	
Upper Subarea total		31		3,887
Santiam Subbasin	20		2,440	
Coast Range Subbasin	15		1,794	
Pudding Subbasin	10		1,186	
Middle Subarea total		45		5,420
Tualatin Subbasin	6		711	
Clackamas Subbasin	9		1,014	
Columbia Subbasin	4		431	
Sandy Subbasin	5		582	
Lower Subarea total		24		2,738
BASIN TOTAL		100		12,045

Willamette River, formed by the confluence of the Coast and Middle Forks near Springfield, has a length of approximately 187 river miles. Below Oregon City, the Willamette is affected by ocean tides transmitted through Columbia River. Most of the major tributaries of the Willamette rise in the Cascade Range at an elevation of 6,000 feet or higher and enter the main stream from the east. Coast Fork Willamette River rises in the Calapooya Mountains at the south end of the basin, and numerous smaller tributaries rise in the Coast Range and enter the main stream from the west.

MAJOR WATER-RESOURCE DEVELOPMENTS

Water has been developed for a variety of uses throughout Willamette Basin. Reservoirs and major diversions significantly alter the hydrology of the basin.

RESERVOIRS

Table I-1 lists the 39 reservoirs in the basin with usable storage capacities of 300 acre-feet or more. These reservoirs range in usable capacity from the Carmen and Willamette National Lumber Co. reservoirs with 300 acre-feet to Lookout Point Reservoir with more than 349,000 acre-feet. They impound a total usable volume of about 2 million acre-feet of water. Many of these reservoirs were constructed by the Corps of Engineers, and others by municipalities and private companies. Locations of the larger impoundments are shown on the frontispiece.

Photo I-1. Fern Ridge Reservoir, constructed in 1941, on the Long Tom River. Its benefits include use for irrigation, flood control, and recreation.

Table I-1

Willamette Basin reservoirs with more than 300 acre-feet of usable storage capacity

Reservoir	Stream	Drainage area (square miles)	Usable capacity (acre-feet)	Use
Coast Fork Subbasin:				
Cottage Grove	Coast Fk. Willamette	104	30,060	Multipurpose
Dorena	Row River	265	70,500	Do.
Middle Fork Subbasin:				
Lookout Point	Middle Fk. Willamette	991	349,400	Do.
Oak Ridge Millpond	--	--	380	Industrial
Hills Creek	Middle Fk. Willamette	389	249,000	Multipurpose
Dexter	do.	996	4,800	Reregulation
Fall Creek	Fall Creek	184	115,000	Multipurpose
McKenzie Subbasin:				
Weyerhaeuser	Off-channel	--	420	Industrial
Walterville	McKenzie River	1,050	345	Power
Trail Bridge	do.	172	2,750	Do.
Carmen	do.	146	300	Do.
Smith	Smith River	18	9,900	Do.
Cougar	S. Fk. McKenzie River	210	165,100	Multipurpose
Blue River	Blue River	88	85,000	Do.
Long Tom Subbasin:				
Fern Ridge	Long Tom River	273	110,000	Do.
Carrol	Noti Creek	--	355	Irrigation
Santiam Subbasin:				
Detroit	North Santiam River	438	340,000	Multipurpose
Willamette National Lumber Co.	Wiley Creek	54	375	Industrial
Willamette National Lumber Co.	Off-channel	--	300	Do.
Green Peter	Middle Santiam	277	333,000	Multipurpose
Foster	South Santiam	494	33,600	Do.
Big Cliff	North Santiam	452	2,430	Reregulation
Coast Range Subbasin:				
Haskins	Haskins Creek	--	410	Municipal
North Fork	North Fk., Rock Creek	--	307	Do.
Thompson	Bark Creek	--	362	Recreation
Clemens	Off-channel	--	800	Industrial
Dallas	Rickreall Creek	--	1,200	Municipal
Clackamas Subbasin:				
Timothy Lake	Oak Grove Fk., Clackamas River	53	61,650	Power
Oak Grove	do.	131	546	Do.
North Fork	Clackamas River	665	6,000	Do.
Faraday	do.	666	550	Do.
Lake Oswego	Off-channel	--	5,100	Multipurpose
River Mill	--	--	770	Power
Sandy Subbasin:				
Trillium Lake	Mud Creek	--	353	Recreation
Bull Run No. 1	Bull Run River	74	30,100	Municipal
Bull Run Lake	do.	--	12,300	Do.
Bull Run No. 2	do.	102	21,000	Do.
Roslyn Lake	do.	285	970	Power
North Fork	North Fk., Bull Run River	2.4	1,030	Municipal

DIVERSIONS

The principal uses of diverted water are for power generation, irrigation, municipal, and industrial supplies. Table I-2 lists the 22 major diversions by subbasin and gives pertinent data on each.

Table I-2
Diversions, Willamette Basin

Subbasin	Diversion	Owner	Stream	Use 1/	Location Twp	Location Rng	Location Sec
McKenzie	Carmen Tunnel	City of Eugene	McKenzie River	PW	14S	7E	20
	Smith Tunnel	City of Eugene	McKenzie River	PW	14S	6E	36
	Leaburg Canal	City of Eugene	McKenzie River	PW	16S	2E	31
	Walterville Canal	City of Eugene	McKenzie River	PW	17S	1W	23
	McKenzie Ditch	McKenzie Irrigation Association	McKenzie River	IR	17S	3W	22
Long Tom	Amazon Diversion Channel	Private	Amazon Creek	FC	17S	4W	29
Santiam	Brownsville Ditch	Private	Calapooia River	IR	14S	2W	4
	Sodom Ditch	Private	Calapooia River	IR-DR	13S	3W	27
	Lebanon Ditch	Pacific Power and Light	South Santiam River	PW-MU	12S	1W	19
	Santiam Canal (Albany Ditch)	Pacific Power and Light	South Santiam River	PW-MU	12S	2W	11
	Peters Ditch	Private	Thomas Creek	IR	10S	1W	18
	Salem Canal	Columbia Pulp and Paper and Kay Woolen Mill	North Santiam River	PW-IN	9S	1W	13
	West Stayton Ditch	Santiam Water Control District	North Santiam River	IR	9S	1W	15
	Sidney Canal	Marion Water Control District	North Santiam River	IR	9S	2W	34
	Lacomb Canal	Lacomb Irrigation District	Crabtree Creek	IR	11S	1E	25
Coast Range	Seeley Ditch	Private	Coffee L. Creek	IR	3S	1W	10
Pudding	Lake Labish Ditch	Lake Labish Water Control District	Pudding River	IR-DR	6S	2W	14
	Shelton Ditch		Mill Creek	FC	7S	3W	36
Tualatin	Oswego Canal	Lake Oswego Corp.	Tualatin River	PW	2S	1E	2
	Cummings Ditch	Private	Rock Creek	IR	2S	1W	2
Clackamas	Faraday Lake Flume	Portland General Electric	Clackamas River	PW	4S	4E	3
Sandy	Roslyn Lake Flume	Portland General Electric	Sandy River	PW	2S	5E	1

1/ PW = Power; IR = Irrigation; MU = Municipal; IN = Industrial; DR = Drainage; FC = Flood Control.

CLIMATE

CLIMATE

CLIMATIC SIGNIFICANCE OF GEOGRAPHICAL FEATURES

Willamette Basin has a modified marine climate of relatively wet winters and clear dry summers with moderate temperatures in both seasons. However, there are significant climatic variations within the basin. To a large extent this climate is the result of four major geographical features: (1) the Pacific Ocean, (2) the Coast Range, (3) the Cascade Range, and (4) the Columbia Gorge. The Pacific Ocean largely determines the general characteristics of the incoming airmasses, the Coast Range is responsible for most of their modification before reaching the basin, and the Cascade Range and Columbia Gorge are responsible for the variation in climate that takes place within the basin. The role played by each is discussed briefly below.

PACIFIC OCEAN

The valley floor of Willamette Basin closely parallels the coastline of the Pacific Ocean 40 to 50 miles to the west. As airmasses generally move from west to east, air reaches the basin soon after completing several days of ocean travel. Over the ocean, the air becomes nearly saturated and temperatures in the lower several thousand feet closely approach that of the ocean. From mid-October to early April, the ocean is a vast spawning ground for the winter storms that move, often violently, onto the Oregon coast.

COAST RANGE

The Coast Range extends the north-south length of the basin on the west side. This range is both a buffer protecting the basin from the more violent aspects of most ocean storms, and a modifier of the incoming airmasses. The crest of the Coast Range is largely between 1,200 and 2,000 feet above sea level with the highest point, Marys Peak, rising to 4,097 feet.

In the winter, air is cooled as it moves onto the land, both by its passage over the cooler land surface and by its increase in elevation as it moves up the slopes of the Coast Range. This lifting process cools the air three to five degrees Fahrenheit for each 1,000 feet. Because cooling materially reduces the amount of moisture that the air can hold, precipitation is greatly augmented by the Coast Range. Even though much of this additional precipitation falls on the west slopes of the range outside Willamette Basin, a considerable amount is carried over the crest. Because of this moisture release, the air that descends into the basin is much drier than the marine air from which it came. Thus high relative humidity and formation of fog are materially less in Willamette Valley than in the coastal area.

In summer, the Coast Range blocks the marine air offshore, producing a strong contrast between the cool moist air along the immediate coast and the warm dry air in Willamette Valley. Rainfall in summer is not influenced significantly by the Coast Range because the normal storm track shifts north into British Columbia.

CASCADE RANGE

The Cascade crest forms the eastern boundary of the basin with an average elevation of slightly more than 5,000 feet and a number of peaks that tower several thousand feet higher. Just as the air is cooled in moving up the Coast Range, it is again cooled as it ascends the west slopes of the Cascades. On the Cascade slopes, year-round temperatures decrease with elevation and precipitation increases. Due to the higher elevation of the Cascades, temperatures are considerably lower on the upper slopes than in the Coast Range. Precipitation at these higher elevations is mostly in the form of snow.

The Cascades block out great masses of continental air. As a result, extreme winter and summer temperatures that characterize areas 100 to 200 miles to the east rarely occur in the basin.

COLUMBIA GORGE

The Columbia Gorge significantly affects the climate of Willamette Basin, as it affords a nearly sea level route through the mountains for passage of marine air from the west and occasional strong pushes of continental air from the east. The gorge exerts its greatest influence on the lower areas adjacent to the Columbia.

During summer afternoons, sea breezes move up the Columbia Gorge to replace rising hot air. This reduces afternoon heating and lowers by several degrees the maximum temperatures that would otherwise occur in the northern Willamette Basin. Occasionally, in the summer, hot, dry continental air from east of the Cascades will push westward through the gorge causing very low humidities and high temperatures in the northern basin.

In winter, air may move in from the east in the same way, except it then is very cold and dry. The meeting of cold air from the east with the warm, moist marine air from the Pacific results in some of the most severe winter weather in the immediate gorge area. Heavy drifting snow and severe icing conditions create hazardous driving conditions and sometimes disrupts power and telephone service.

C L I M A T I C   E L E M E N T S

Most of the areal variations of temperature and precipitation in the basin are a result of differences in elevation. However, minor differences in temperature and precipitation, and sometimes very significant differences in windspeeds, result from the proximity of areas to the Columbia Gorge or from local peculiarities of the terrain not related to elevation. During cold mornings, low-lying areas may

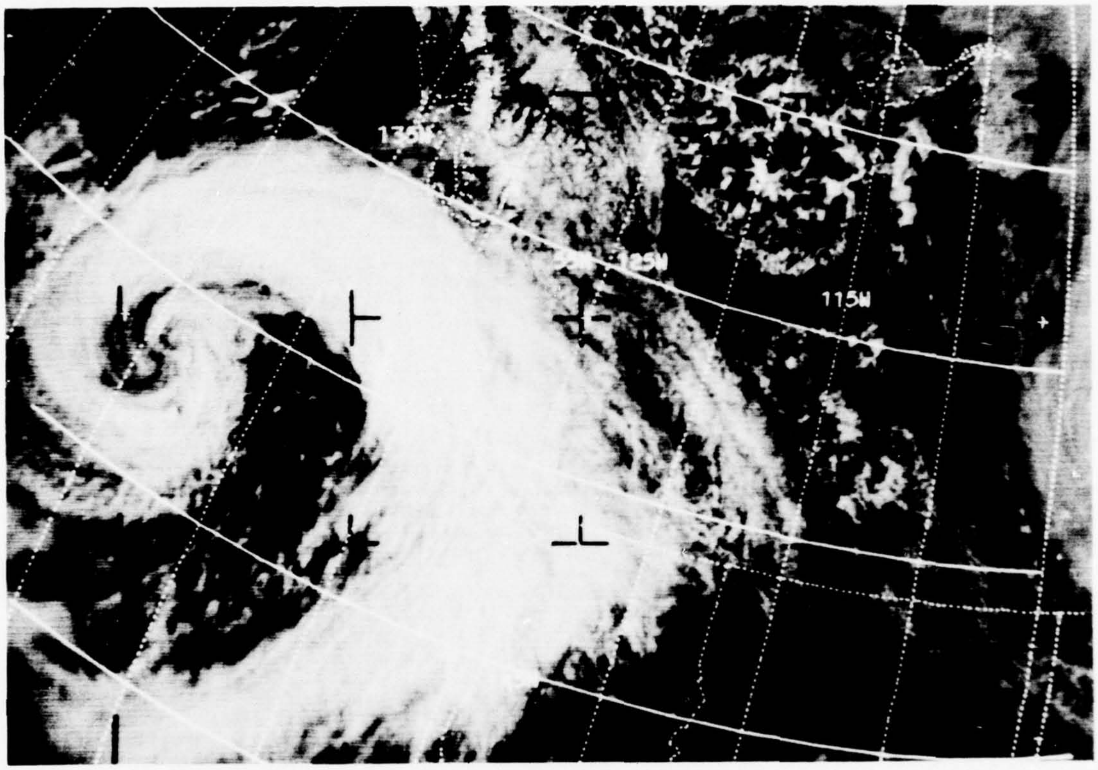


Photo II-1. Clouds spiral around a low-pressure center in the Pacific and drift over western Oregon. ESSA satellite photograph.

have temperatures several degrees lower than nearby higher locations where air movement is better. Isolated knolls, peaks, or ridges usually have much stronger winds than less exposed areas. Local areas on the lee sides (with respect to normal storm movements) of small chains of hills or ridges may have significantly less rainfall than more open areas nearby. These peculiarities partly account for climatic differences that are not consistent with elevation differences.

TEMPERATURE

Officially recorded temperatures in Willamette Basin have ranged from -24 degrees Fahrenheit to 112 degrees Faherenheit (Table II-1). Oddly enough, the lowest of record was observed at McMinnville, on the valley floor, and the highest at Oakridge, relatively high in the foothills of the Cascades. This is contrary to the general statement made earlier that temperatures decrease at higher elevations. The low temperature at McMinnville probably resulted from the flow of colder, heavier air to the lowest point in the terrain--the site of the weather station. The high temperature at Oakridge was likely associated with a foehn effect of a pronounced east wind in which hot continental air moved directly over the Cascades. As this air passed over the mountains and then dropped down to elevations of 500 to 1,500 feet in the western foothills of the Cascades, the temperature progressively increased.

Table II-1

Normal temperatures and the highest and lowest temperatures of record for selected stations

/Based on records of U.S. Weather Bureau, through 1964/

Station	No. of years		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Cherry Grove	27	Max	60	64	77	86	93	99	107	100	100	90	74	62	107
Elev. 780		Min	0	2	19	27	30	36	37	41	35	29	11	5	0
Cottage Grove 1 S	53	Max	68	76	87	87	93	100	105	102	105	93	74	73	105
Elev. 650		Normal	40	43	46	50	55	60	65	65	61	54	46	42	52
		Min	-2	0	14	23	23	32	34	31	26	19	11	-7	-7
Detroit	26	Max	66	69	79	89	95	107	105	101	103	94	75	60	105
Elev. 1,586		Min	-10	-10	10	18	25	26	32	31	28	21	0	2	-10
Eugene WB AP	22	Max	64	69	74	86	91	100	105	100	101	87	71	67	105
Elev. 359		Normal	39	43	46	51	56	61	67	66	61	53	46	42	52
		Min	-4	-3	20	27	28	35	39	38	32	24	14	10	-4
Forest Grove	67	Max	62	77	82	93	98	101	109	103	104	91	77	64	109
Elev. 180		Normal	38	45	45	51	57	62	67	66	62	53	44	40	54
		Min	-18	-15	16	21	28	34	34	35	27	22	7	-15	-18
Headworks	58	Max	61	67	84	93	97	104	110	107	103	90	79	61	110
Elev. 748		Normal	37	40	44	50	55	60	65	64	60	53	44	40	51
		Min	1	7	20	28	28	33	35	31	29	22	11	-2	-2
McMinnville	69	Max	69	69	87	99	100	110	110	108	106	90	80	72	110
Elev. 148		Min	-15	-2	15	24	24	33	34	30	25	26	9	-24	-24
Oakridge Hatchery	34	Max	71	78	86	97	102	110	112	110	108	99	78	66	112
Elev. 1,275		Min	-1	10	19	25	21	32	33	34	29	24	17	1	-1
Odell Lake 1/	33	Max	52	55	63	78	80	94	98	107	89	93	67	58	107
Elev. 4,792		Min	-17	-16	-6	6	10	21	27	27	21	14	-8	-5	-17
Portland WB City	90	Max	65	68	83	93	99	102	107	102	102	90	73	63	107
Elev. 30		Normal	40	44	48	54	59	63	69	68	64	56	47	43	55
		Min	-2	7	20	28	32	39	43	43	35	29	11	3	-2
Salem WB AS	36	Max	64	67	80	88	95	102	108	104	103	92	69	72	108
Elev. 196		Normal	39	42	45	51	56	61	66	66	62	54	45	42	52
		Min	-10	-4	19	24	25	34	35	35	26	26	9	5	-10
Three Lynx	40	Max	60	68	83	93	97	106	107	104	101	90	73	62	107
Elev. 1,120		Normal	36	39	43	49	55	60	65	64	61	52	43	38	50
		Min	-2	-2	19	24	28	33	38	38	32	22	11	1	-2
Valsetz 1/	25	Max	66	71	80	93	98	102	102	97	99	94	76	64	102
Elev. 1,135		Min	-4	0	9	21	20	27	30	28	27	23	4	8	-4

1/ Outside Willamette Basin.

The annual range of average monthly temperatures is approximately 25 to 30 degrees Fahrenheit. Extreme daily temperatures range from an average January minimum of about 35 degrees Fahrenheit on the valley floor to about 20 degrees Fahrenheit at the crest of the Cascades, with average July maximums of 80 to 83 degrees Fahrenheit on the valley floor and 75 degrees Fahrenheit on the mountain crest (Figure II-1). Based upon statistical estimates, the annual extreme temperature recurrence intervals that may be expected at Willamette Basin stations are shown in Table II-2. Table II-3 presents the percentage frequency of daily temperatures at Salem by weeks, for a 30-year period. Latest dates of freezing temperatures in the spring and earliest dates in the fall are given in Table II-4. Actual temperatures for a particular area may deviate from these data because the slope of the terrain is often an important factor influencing morning temperatures. Local terrain also affects dates on which the last lower temperatures occur in the spring and the fall.

Table II-2
Expected annual extreme temperatures for various recurrence intervals 1/

Station		2 Yrs.	5 Yrs.	10 Yrs.	20 Yrs.	25 Yrs.	50 Yrs.	75 Yrs.	100 Yrs.
Albany No. 2	Max	96	101	104	106	107	110	111	113
	Min	17	11	7	3	1	-3	-5	-7
Cascadia R.S.	Max	99	102	104	106	106	108	109	110
	Min	14	7	3	-2	-3	-8	-11	-12
Cherry Grove	Max	97	102	105	109	110	113	115	116
	Min	17	9	4	-1	-2	-7	-10	-11
Clatskanie 2/	Max	93	98	102	105	106	109	111	112
	Min	18	11	7	2	1	-3	-5	-7
Corvallis	Max	98	103	106	109	110	113	114	115
	Min	18	11	7	3	2	-2	-5	-6
Cottage Grove 1 S	Max	98	101	104	106	107	109	111	112
	Min	15	6	1	-4	-6	-11	-14	-16
Dallas	Max	99	104	106	109	110	112	114	115
	Min	15	7	2	-3	-4	-9	-12	-14
Detroit	Max	99	103	106	108	109	111	113	114
	Min	10	1	-5	-11	-12	-18	-21	-23
Estacada 2 SE	Max	98	104	108	111	113	116	118	120
	Min	16	8	4	-1	-2	-7	-10	-11
Eugene WB AP	Max	98	102	104	107	107	110	111	112
	Min	16	9	4	-1	-2	-7	-10	-12
Falls City	Max	98	102	105	108	108	111	113	114
	Min	16	9	5	0	-1	-5	-7	-9
Forest Grove	Max	99	104	107	110	111	114	116	117
	Min	13	4	-2	-8	-10	-16	-19	-22
Headworks	Max	99	103	107	110	111	114	115	117
	Min	16	9	5	0	-1	-5	-8	-10
Hood River 2/	Max	99	102	104	107	107	110	111	112
	Min	7	-5	-13	-20	-23	-30	-34	-37
Leaburg 1 SW	Max	98	102	105	107	108	110	112	113
	Min	19	12	7	3	1	-3	-6	-8
McKenzie Bridge	Max	103	106	107	111	112	114	116	117
	Min	10	2	-3	-8	-10	-15	-18	-20
McMinnville	Max	99	104	107	110	111	114	116	117
	Min	16	8	3	-3	-4	-9	-12	-14
Oakridge Hatchery	Max	103	107	110	112	113	115	117	118
	Min	15	7	2	-2	-4	-8	-11	-13
Odell Lake 2/	Max	87	89	91	93	93	95	96	96
	Min	-5	-12	-16	-21	-22	-27	-29	-31
Parkdale 2/	Max	96	99	102	104	105	107	108	109
	Min	-0	-12	-20	-28	-30	-37	-42	-45
Portland WB AS	Max	98	102	105	108	109	112	114	115
	Min	21	14	9	5	4	-1	-3	-5
Salem WB AS	Max	99	104	107	110	111	113	115	116
	Min	15	8	3	-2	-4	-8	-11	-13
Three Lynx	Max	99	104	107	110	111	114	116	117
	Min	15	7	1	-4	-5	-10	-13	-15
Valsetz 2/	Max	96	100	103	106	106	109	111	112
	Min	13	6	2	-3	-4	-8	-11	-13

1/ Prepared at BPA using computer methods of applying the Fisher-Tippet Type I distribution to 30 years of annual extremes.
2/ Denoted stations outside Willamette Basin.

Table II-3

Percentage frequency distribution of daily maximum and minimum temperatures at Salem

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY MAXIMUM TEMPERATURES BY WEEKS

		Temperatures--°F																		
Week No.	Beginning Date	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 to 49	50 to 54	55 to 59	60 to 64	65 to 69	70 to 74	75 to 79	80 to 84	85 to 89	90 to 94	95 to 99	100 to 104	105 to 109
1	Mar. 1				1	2	7	11	32	27	18	2								
2	Mar. 8					1	3	19	31	26	11	4	4	1						
3	Mar. 15						1	16	25	27	16	10	4	1	1					
4	Mar. 22						1	14	31	27	13	8	4	1						
5	Mar. 29						1	8	24	30	19	15	4	1						
6	Apr. 5							5	17	26	22	15	11	3	1					
7	Apr. 12							1	10	27	21	17	10	5	8	1				
8	Apr. 19							2	7	23	21	21	15	8	2	1				
9	Apr. 26							1	5	29	21	20	13	5	3	2				
10	May 3							1	5	15	21	20	19	11	6	2				
11	May 10								3	9	20	22	18	13	9	5	1			
12	May 17								1	6	22	23	13	15	11	7	1	1		
13	May 24								1	3	19	26	23	14	10	5	1			
14	May 31									2	18	25	21	15	9	5	5			
15	June 7								1	4	10	19	23	19	15	4	4	2		
16	June 14									3	11	22	27	19	9	5	4			
17	June 21									1	5	17	27	20	20	8	3	1		
18	June 28									1	5	12	16	26	16	16	5	2	1	
19	July 5											8	12	24	28	18	6	3	1	
20	July 12											1	10	27	22	20	10	5	3	2
21	July 19										1	1	10	16	26	21	16	4	4	1
22	July 26											3	11	23	27	23	10	4	1	
23	Aug. 2										1	3	11	24	28	15	11	5	2	
24	Aug. 9											2	9	25	28	16	15	4	1	
25	Aug. 16										1	1	10	22	24	24	9	9	1	
26	Aug. 23										2	9	15	22	23	15	10	2	2	
27	Aug. 30										3	5	17	25	20	18	8	3	1	
28	Sep. 6									1	3	11	21	23	15	15	7	4		
29	Sep. 13									1	4	15	21	23	19	10	5	1		
30	Sep. 20								2	1	7	20	19	17	16	11	6	2		
31	Sep. 27							1	1	2	17	25	26	18	5	4	2			
32	Oct. 4								2	11	22	22	19	10	11	2	1			
33	Oct. 11								4	12	32	21	19	11	1					
34	Oct. 18							1	9	21	31	22	10	4	2					
35	Oct. 25						1	6	12	31	29	14	5	1						
36	Nov. 1					1	1	6	27	32	24	8								
37	Nov. 8			1	1	1	4	18	32	34	10	1								
38	Nov. 15			1		3	11	27	33	18	6									
39	Nov. 22			1		3	8	20	31	27	8	3								
40	Nov. 29				1	3	19	29	23	22	3									
41	Dec. 6			1	2	6	16	30	27	14	2	1	1							
42	Dec. 13				2	14	21	29	23	12										
43	Dec. 20				4	10	22	25	28	9	1									
44	Dec. 27			1	6	11	16	30	26	1										
45	Jan. 3		1	1	5	16	24	26	21	7	1									
46	Jan. 10		1	1	11	16	16	29	21	7	1									
47	Jan. 17		1	3	7	12	20	24	23	9	1									
48	Jan. 24		1	2	9	13	19	28	18	10	2									
49	Jan. 31	1	1	1	5	9	20	24	24	15	2									
50	Feb. 7			1	1	7	14	30	29	17	2	1								
51	Feb. 14		1		1	4	8	31	30	17	9	1								
52	Feb. 21				1	1	6	21	40	19	12	1								
53	Feb. 28						3	8	37	42	8	3								

Values were carried to whole percent. Not all rows may add up to 100 percent.

MEANS, STANDARD DEVIATIONS AND EXTREMES OF DAILY MAXIMUM TEMPERATURES

Week No.	Beginning Date	Mean Maximum (°F)	Standard Deviation (°F)	Highest Maximum of Record
1	Mar. 1	53.8	6.3	68
2	Mar. 8	54.6	7.1	76
3	Mar. 15	56.6	7.3	80
4	Mar. 22	56.4	7.0	78
5	Mar. 29	58.1	6.6	78
6	Apr. 5	60.6	7.7	83
7	Apr. 12	63.8	8.6	85
8	Apr. 19	64.0	7.6	85
9	Apr. 26	64.0	8.2	88
10	May 3	66.8	8.4	87
11	May 10	69.5	8.8	94
12	May 17	70.5	9.0	95
13	May 24	71.1	7.9	93
14	May 31	71.9	8.6	94
15	June 7	73.7	9.1	98
16	June 14	72.7	7.7	93
17	June 21	75.4	7.3	97
18	June 28	78.0	8.6	104
19	July 5	80.6	7.5	102
20	July 12	83.1	8.2	108
21	July 19	84.3	8.1	106
22	July 26	82.2	7.0	103
23	Aug. 2	82.2	7.7	102
24	Aug. 9	82.9	7.1	102
25	Aug. 16	83.2	7.3	102
26	Aug. 23	80.0	8.1	101

Week No.	Beginning Date	Mean Maximum (°F)	Standard Deviation (°F)	Highest Maximum of Record
27	Aug. 30	80.2	8.2	103
28	Sep. 6	78.6	8.6	99
29	Sep. 13	76.3	8.1	98
30	Sep. 20	75.6	9.4	97
31	Sep. 27	70.8	7.7	92
32	Oct. 4	68.9	8.2	91
33	Oct. 11	65.8	6.7	84
34	Oct. 18	63.0	6.9	84
35	Oct. 25	59.2	6.3	75
36	Nov. 1	56.6	6.1	69
37	Nov. 8	53.2	5.7	68
38	Nov. 15	50.1	6.1	64
39	Nov. 22	51.9	6.3	67
40	Nov. 29	49.3	5.9	63
41	Dec. 6	48.8	7.2	72
42	Dec. 13	46.6	6.3	58
43	Dec. 20	46.9	6.6	64
44	Dec. 27	46.2	6.7	59
45	Jan. 3	44.8	7.1	60
46	Jan. 10	44.5	7.5	60
47	Jan. 17	44.8	8.1	64
48	Jan. 24	44.9	7.9	64
49	Jan. 31	46.9	7.9	63
50	Feb. 7	48.9	6.3	66
51	Feb. 14	50.4	6.7	65
52	Feb. 21	52.3	5.7	68
53	Feb. 28	54.3	4.9	67

Table II-3--Continued

Percentage frequency distribution of daily maximum and minimum temperatures at Salem

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY MINIMUM TEMPERATURES BY WEEKS

Week No.	Beginning Date	Temperatures--°F -10 to -5	-5 to -1	+0 to +4	+5 to +9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 to 49	50 to 54	55 to 59	60 to 64	65 to 69	70 to 74
1	Mar. 1							2	16	26	25	24	6	1				
2	Mar. 8							2	12	24	35	21	6					
3	Mar. 15							1	11	24	32	24	7	1				
4	Mar. 22								7	22	33	29	7	1				
5	Mar. 29							1	9	20	31	28	11	1				
6	Apr. 5								3	21	37	28	10	1				
7	Apr. 12								1	13	33	33	18	3	1			
8	Apr. 19								1	12	36	28	22	1	1			
9	Apr. 26								2	8	28	36	22	4				
10	May 3								1	7	23	39	25	5				
11	May 10									3	17	32	35	12	1			
12	May 17									3	12	36	34	13	1			
13	May 24									1	15	22	36	22	3			
14	May 31									1	9	25	36	27	1	1		
15	June 7										3	18	37	31	10	2	1	
16	June 14									1	4	17	31	38	11			
17	June 21										3	19	32	39	6	1		
18	June 28										1	17	31	35	13	2		
19	July 5										2	11	28	41	17	1		
20	July 12											10	25	37	23	3	1	1
21	July 19										1	8	30	33	24	5		
22	July 26										1	12	33	34	19	2		
23	Aug. 2										1	7	30	42	19	2		
24	Aug. 9											11	28	42	16	3		
25	Aug. 16										1	15	29	33	21	1		
26	Aug. 23										1	1	34	35	14	3		
27	Aug. 30										1	11	38	34	16			
28	Sep. 6										4	15	39	36	6	1		
29	Sep. 13									1	6	24	34	27	8	1		
30	Sep. 20								1	1	17	20	39	18	4	1		
31	Sep. 27									4	17	26	24	20	10			
32	Oct. 4									3	14	29	34	13	6	1		
33	Oct. 11								1	9	19	26	24	19	1			
34	Oct. 18								4	11	21	30	23	9	1			
35	Oct. 25								7	12	21	28	24	7	1			
36	Nov. 1					1	1	2	9	15	23	21	21	5	1	1		
37	Nov. 8					1	1	3	12	16	19	29	16	3				
38	Nov. 15				1		1	3	15	23	23	25	8	1				
39	Nov. 22						3	7	15	18	20	20	14	3	1			
40	Nov. 29						1	6	11	21	24	26	10	1				
41	Dec. 6				1	1	1	2	17	18	34	17	8	1				
42	Dec. 13					1	3	13	10	23	22	19	8					
43	Dec. 20						1	5	13	24	26	22	8	1				
44	Dec. 27					1	4	7	12	24	25	20	6	1				
45	Jan. 3				1	1	2	11	16	29	24	13	3					
46	Jan. 10				1	3	3	5	20	30	17	16	4					
47	Jan. 17		1	1	1	1	9	9	18	22	22	11	6	1				
48	Jan. 24		1	1	1	6	3	11	10	34	21	7	4	1				
49	Jan. 31	1	1	1		1	3	6	15	28	24	16	6					
50	Feb. 7					2	3	4	21	29	21	12	6	1				
51	Feb. 14						3	5	16	35	23	12	6	1				
52	Feb. 21							2	13	36	28	15	5	1				
53	Feb. 28								18	29	21	24	8					

Values were carried to whole percent. Not all rows may add up to 100 percent.

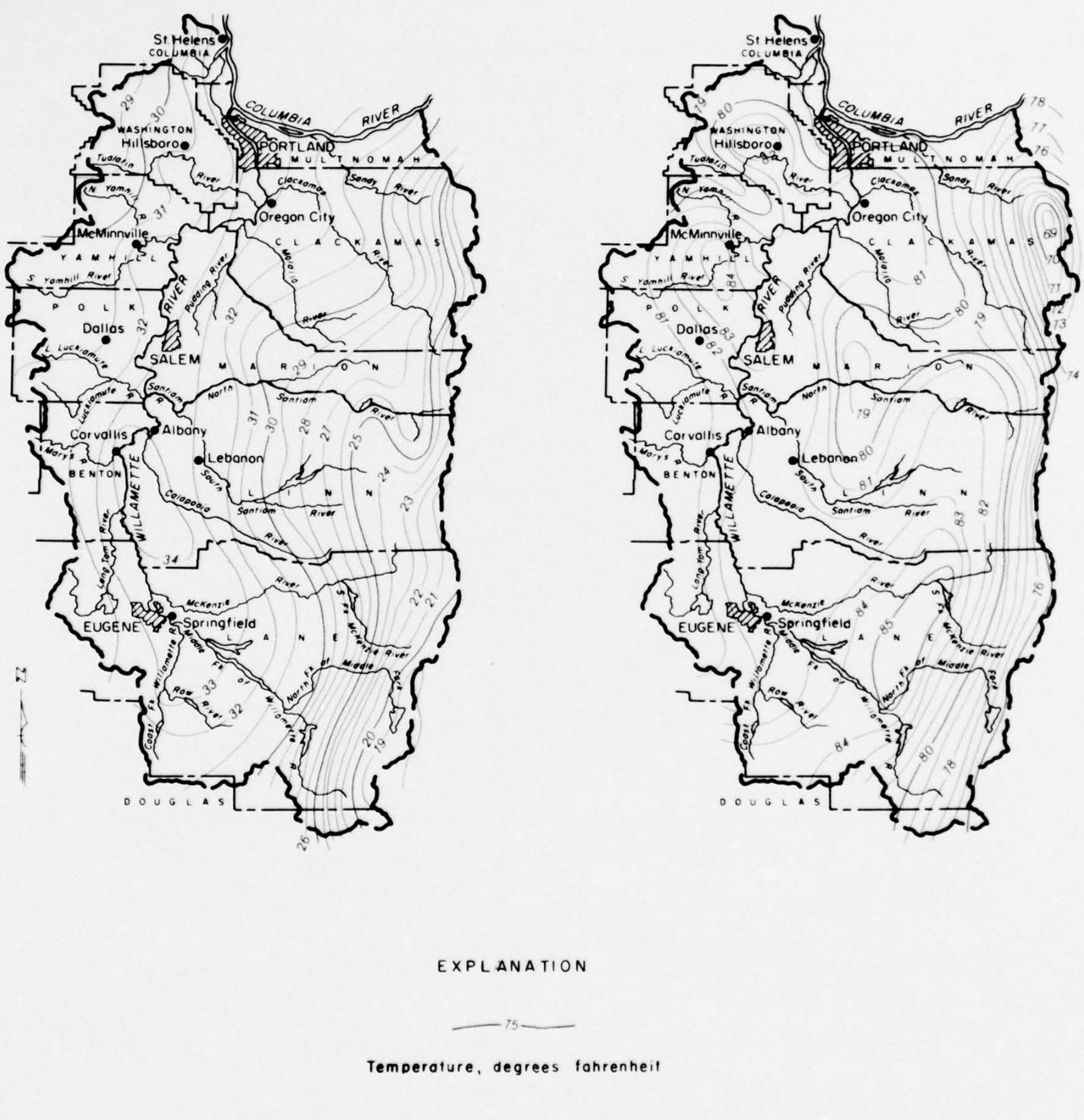
MEANS, STANDARD DEVIATIONS AND EXTREMES OF DAILY MINIMUM TEMPERATURES

Week No.	Beginning Date	Mean Minimum (°F)	Standard Deviation (°F)	Lowest Minimum of Record
1	Mar. 1	35.4	6.0	22
2	Mar. 8	36.0	5.6	23
3	Mar. 15	36.7	5.7	22
4	Mar. 22	37.5	5.2	25
5	Mar. 29	37.6	5.8	24
6	Apr. 5	38.1	4.8	27
7	Apr. 12	40.3	5.0	27
8	Apr. 19	40.1	5.1	26
9	Apr. 26	41.0	5.4	25
10	May 3	41.9	4.8	29
11	May 10	44.0	5.1	32
12	May 17	44.4	4.8	32
13	May 24	45.6	5.4	34
14	May 31	46.4	4.8	34
15	June 7	48.7	4.9	35
16	June 14	48.5	5.0	34
17	June 21	48.4	4.6	36
18	June 28	49.5	5.1	37
19	July 5	50.0	4.5	35
20	July 12	51.4	5.4	40
21	July 19	51.3	5.1	39
22	July 26	50.3	4.9	39
23	Aug. 2	50.8	4.5	39
24	Aug. 9	50.6	4.7	40
25	Aug. 16	50.1	5.1	35
26	Aug. 23	50.0	4.7	39

Week No.	Beginning Date	Mean Minimum (°F)	Standard Deviation (°F)	Lowest Minimum of Record
27	Aug. 30	49.6	4.8	36
28	Sep. 6	48.2	4.6	35
29	Sep. 13	47.4	5.3	34
30	Sep. 20	45.3	5.7	26
31	Sep. 27	45.2	6.4	31
32	Oct. 4	44.9	5.6	32
33	Oct. 11	43.3	6.7	27
34	Oct. 18	41.5	6.5	28
35	Oct. 25	40.7	6.6	26
36	Nov. 1	38.8	8.1	12
37	Nov. 8	37.6	7.6	12
38	Nov. 15	35.8	6.7	9
39	Nov. 22	36.1	8.3	15
40	Nov. 29	36.0	7.2	19
41	Dec. 6	35.0	7.7	5
42	Dec. 13	33.7	8.1	10
43	Dec. 20	35.6	6.9	19
44	Dec. 27	34.5	7.5	12
45	Jan. 3	32.4	7.5	7
46	Jan. 10	31.8	8.3	6
47	Jan. 17	31.3	9.5	-5
48	Jan. 24	30.5	9.3	-3
49	Jan. 31	33.1	8.8	-10
50	Feb. 7	32.7	7.4	12
51	Feb. 14	33.6	6.6	17
52	Feb. 21	34.9	5.7	23
53	Feb. 28	35.5	6.2	25

JANUARY MINIMUM

JULY MAXIMUM



EXPLANATION

—— 75 ——

Temperature, degrees fahrenheit

WBTF-X-1092-L

Figure II-1. Isotherms of average January minimum temperature and average July maximum temperature.

Table II-4

Last occurrence in spring and first in fall of temperatures of 32°, 28°, and 24° F for selected stations

Station	Threshold Temperature	Median date of last Spring occurrence	Median date of first Fall occurrence	Mean No. of Days between dates	Years of record Spring	Years of record Fall
Albany No. 2	32	04-03	11-02	213	30	30
	28	02-27	11-14	260	30	30
	24	01-23	12-14	325	30	30
Bonneville Dam	32	03-27	11-18	188	27	26
	28	02-14	12-15	304	27	26
	24	01-22	#	343	27	26
Cascadia St. Park	32	05-10	10-15	158	29	27
	28	04-03	11-03	214	29	27
	24	02-21	12-06	288	29	27
Cherry Grove	32	04-14	11-13	213	27	27
	28	03-12	11-28	261	27	27
	24	01-31	12-26	328	27	27
Corvallis	32	04-11	11-01	204	30	30
	28	03-04	11-13	263	30	30
	24	01-31	12-14	316	30	30
Cottage Grove 1S	32	05-06	10-25	172	30	30
	28	03-31	11-17	231	30	30
	24	02-18	12-11	296	30	30
Dallas	32	05-10	10-23	166	29	29
	28	03-28	11-09	226	29	29
	24	02-19	12-01	285	29	29
Detroit	32	05-14	09-28	137	29	30
	28	04-14	10-30	199	29	30
	24	03-10	11-16	251	29	30
Estacada 2SE	32	04-23	11-02	193	30	30
	28	03-05	11-18	258	30	30
	24	01-30	12-18	322	30	30
Eugene W.B.A.P.	32	04-18	10-21	186	30	30
	28	03-13	11-14	246	30	30
	24	01-28	12-12	318	30	30
Falls City	32	04-26	10-30	187	29	30
	28	03-12	11-16	245	29	30
	24	02-10	12-14	307	29	30
Forest Grove	32	04-27	10-20	176	30	30
	28	03-22	11-10	233	30	30
	24	02-11	12-05	297	30	30
Government Camp	32	*	*	-	18	21
	28	05-23	10-13	143	18	21
	24	05-02	11-04	186	18	21
Headworks	32	04-17	11-06	203	30	30
	28	03-06	11-20	259	30	30
	24	01-31	#	334	30	30

Station	Threshold Temperature	Median date of last Spring occurrence	Median date of first Fall occurrence	Mean No. of Days between dates	Years of record Spring	Years of record Fall
Lacomb 1WNW	32	04-21	10-30	192	23	21
	28	03-11	11-16	250	23	21
	24	02-12	12-08	299	23	21
Leaburg 1SW	32	04-07	11-08	215	30	30
	28	02-13	12-03	293	30	30
	24	01-22	12-27	339	30	30
Marion Forks	32	05-25	09-23	121	16	16
	28	04-29	10-26	180	16	16
	24	03-25	11-15	235	16	16
McKenzie Bridge	32	05-21	09-19	121	30	30
	28	04-10	10-24	197	30	30
	24	03-12	11-17	250	30	30
McMinnville	32	05-03	10-16	166	27	28
	28	03-26	11-05	224	27	28
	24	02-12	12-13	304	27	28
Molalla	32	04-18	10-17	182	16	16
	28	03-27	11-08	226	16	16
	24	02-22	11-28	279	16	16
Oakridge Salmon Hatchery	32	05-03	10-23	173	30	30
	28	03-26	11-14	233	30	30
	24	02-11	12-06	298	30	30
Odell Lake 1/	32	*	*	-	30	29
	28	05-30	09-26	119	30	29
	24	05-08	10-19	164	30	29
Portland W.B.A.S.	32	03-28	11-08	225	27	27
	28	02-27	11-21	267	27	27
	24	01-27	#	-	27	27
Portland W.B. City	32	02-27	11-27	273	30	30
	28	01-25	12-30	339	30	30
	24	01-18	#	-	30	30
Salem W.B.A.S.	32	04-26	10-30	187	30	30
	28	03-14	11-12	243	30	30
	24	02-13	12-12	302	30	30
Silver Creek Falls	32	05-25	09-22	120	24	26
	28	05-03	10-20	170	24	26
	24	03-15	11-12	242	24	26
Three Lynx	32	04-08	11-04	210	30	30
	28	02-28	11-26	271	30	30
	24	02-01	12-28	330	30	30
Valsetz 1/	32	05-12	10-17	158	25	25
	28	04-17	11-12	209	25	25
	24	02-26	12-11	288	25	25

1/ *Outside Willamette Basin.*
* *May occur any date.*
\# *Does not occur that often.*

PRECIPITATION

Willamette Basin has a winter rainfall climate. Approximately 70 percent of the annual precipitation falls from November through March, and only five percent from June through August. On the average, more than 15 percent of the annual precipitation falls in each of the winter months of December, January, and February. This compares with only about 1 percent of the annual average during either July or August. In some years, no precipitation falls for periods of from 30 to 60 or more days during late summer. During the summer of 1967, 79 days with no measurable precipitation were recorded at Salem.

Most of the precipitation that falls at low elevations occurs as rain. The average annual snowfall at Portland (about 40 feet above sea level) is about nine inches, with a water equivalent of only two percent of the mean annual precipitation at that location. At Portland and at other places on the valley floor, snow seldom accumulates to depths of more than an inch or two and usually melts in a few hours; on rare occasions, 8 to 12 inches of snow may accumulate, but even the heaviest falls seldom remain longer than 3 to 4 days. At the 2,000-foot elevation, approximately 10 percent of the average annual precipitation occurs as snowfall. From that elevation to the crest of the mountains, the percentage of the annual precipitation falling as snow increases roughly at the rate of 10 percent for each 1,000-foot increase in elevation. At progressively higher elevations the depth of snow becomes greater, and it begins to accumulate earlier in the fall and lasts later in the spring. Extreme and average snowfall and snow depths are presented in Table II-5.

Snow data are obtained annually at 36 special snow courses and at regular weather stations in and near the basin (Map II-1). Snow measurements are made at all courses about April 1 to forecast spring runoff from the snowpack. Many courses are measured monthly from January 1 through May 1, and courses that form "profiles" along transmountain highways are measured twice a month during that period. These profiles provide snow data at about 1,000-foot intervals along North Santiam, McKenzie, Middle Fork Willamette, and Coast Fork Willamette Rivers. Figure II-2 shows the average (1948-62) accumulation and depletion of the snowpack along the McKenzie River profile.

Mean annual precipitation for Willamette Basin as a whole is about 63 inches, based on the isohyets on Map II-2. This map shows the striking effect of elevation and topography on annual precipitation. In some small areas along the slopes of the Coast Range, mean annual precipitation exceeds 200 inches. Moving eastward, annual precipitation decreases rapidly to an average of less than 40 inches in the alluvial plain of the valley and again increases to more than 130 inches at isolated locations along the west slopes of the Cascade Range.

The network of precipitation stations (shown on Map II-2) is not sufficiently dense to define the precipitation pattern positively in the mountainous regions of Willamette Basin, particularly parts of the

Table II-5
Selected snow statistics for Willamette Basin stations

Station	Elev.	Max. Depth of Record	Seasonal Ave. Total Snowfall	Average No. Days with 1" or more Snow Cover	Average Depth on Days with Snow Cover
Albany No. 2	220	15	6.6	4	3
Cascadia St. Park	850	26	13.7	14	6
Cherry Grove 2S	780	38	33.2	19	7
Cottage Grove 1S	650	12	8.3	4	3
Dallas	325	29	12.5	8	5
Detroit	1586	56	66.8	47	10
Estacada 2 SE	410	18	9.2	7	2
Eugene WB AP	359	10	7.6	2	3
Forest Grove	180	17	14.4	8	5
Government Camp	3980	183	298.4	177	41
Headworks	748	30	22.5	18	7
Lacomb 1WNW	665	10	5.5	3	3
Leaburg 1SW	675	19	14.6	8	4
McKenzie Br. R. S.	1478	48	38.3	28	10
McMinnville	148	15	10.1	4	4
Oakridge Hatchery	1275	15	20.4	12	4
Odell Lake 1/	4792	140	313.6	190	42
Portland WB AS	21	16	8.4	4	3
Salem WB AS	196	16	7.4	3	2
Scotts Mills 9SE	2315	61	94.8	47	10
Silver Creek Falls	1350	35	17.3	13	6
Three Lynx	1120	51	33.5	25	8
Timberline Lodge	5935	246	490.8	257	104
Valsetz 1/	1135	36	20.4	15	7

1/ *Outside Willamette Basin.*

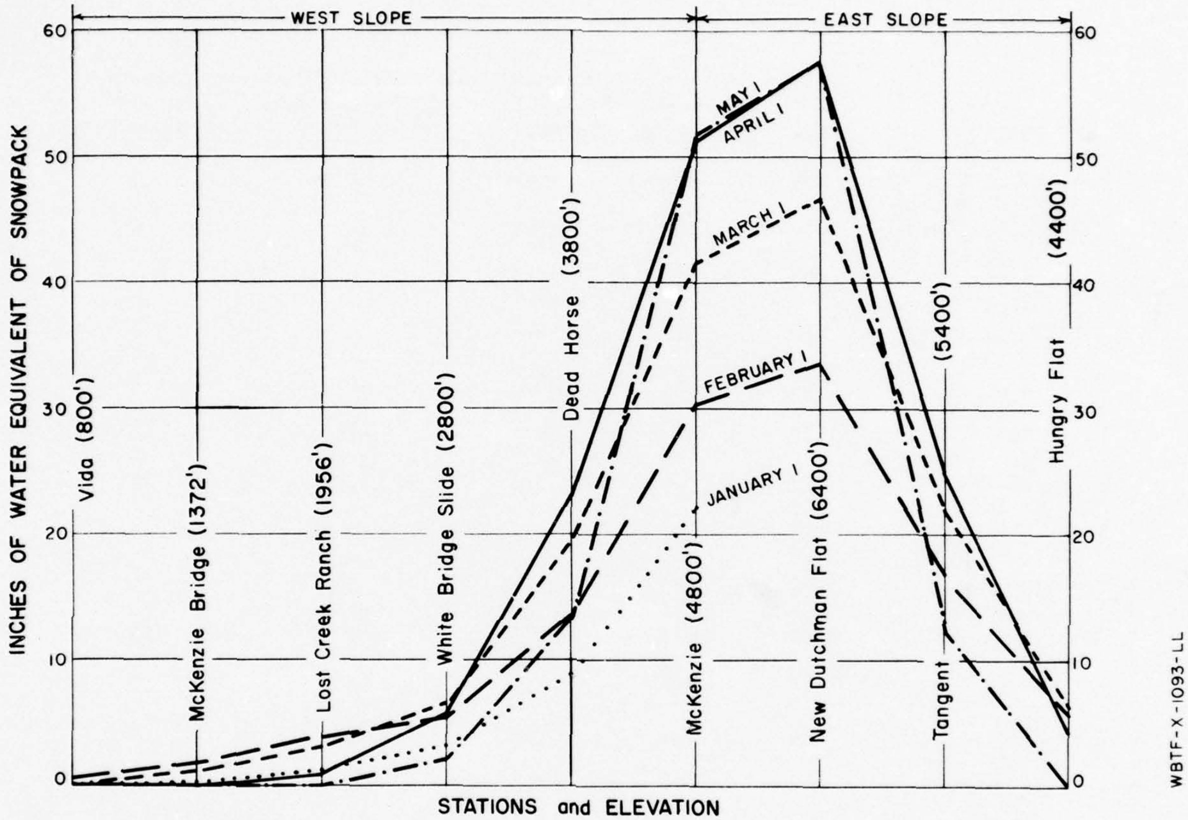
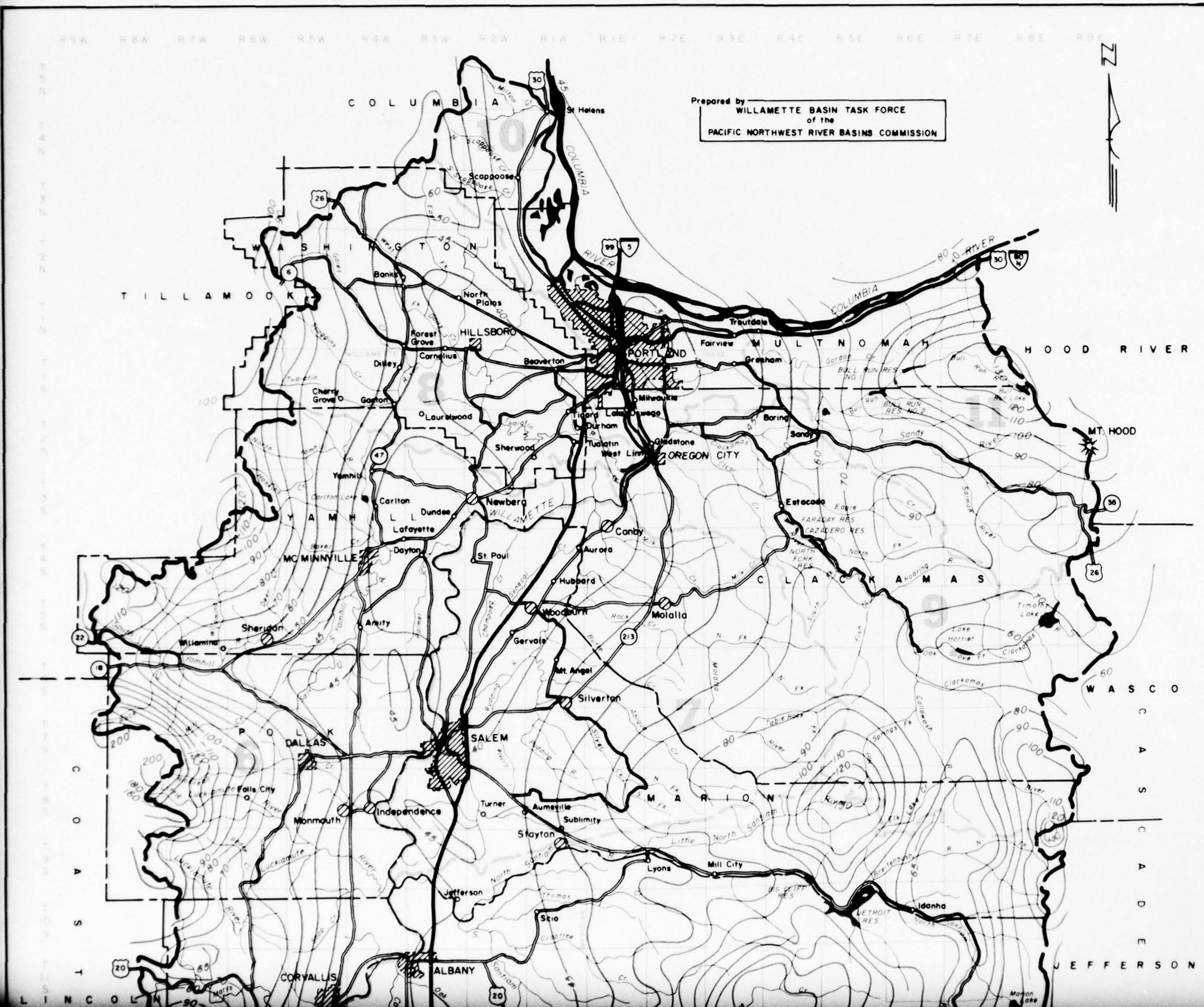


Figure II-2. Profile of snowpack accumulation in Oregon Cascade Range.

Cascade Range. Data from the existing stations, however, when considered in relation to topography and supported by streamflow data, are sufficient to delineate the isohyetal pattern with reasonable accuracy. All data used in developing the isohyets in Map II-1 are adjusted to a common period 1930-57 using the double-mass-curve method. Data from this period and the standard 1931-60 normal period are nearly identical.

Measurable precipitation (0.01 in. or more) falls 150 to 180 days a year, depending on elevation. The average number of days each month on which precipitation occurs at Albany, Detroit, and Valsetz are shown on Table II-6. In winter, precipitation results from frequent storms that move in from the Pacific Ocean. Even as late as June, there is still about one chance in three of rain during any one day caused by these storms. In summer, precipitation usually results from occasional shower and thunderstorm activity.


Prepared by
WILLAMETTE BASIN TASK FORCE
of the
PACIFIC NORTHWEST RIVER BASINS COMMISSION
COLUMBIA
WASHINGTON
TILLAMOOK
YAMHILL
POLK
MULTNOMAH
CLACKAMAS
MARION
HOOD RIVER
WASCO
JEFFERSON
LINCOLN
COAST
CASCADE
St Helens
Scappoose
Banks
North Plains
HILLSBORO
Forest Grove
Cornelius
Dilley
Gaston
Cherry Grove
Laurelwood
Beaverton
PORTLAND
Troutdale
Fairview
Gresham
Milwaukie
Lake Oswego
Tigard
Durham
Tualatin
West Linn
Gladstone
OREGON CITY
Sherwood
Boring
Sandy
Estacada
Newberg
Dundee
Carlton
Yamhill
Lafayette
Dayton
MCMINNVILLE
St Paul
Canby
Aurora
Hubbard
Woodburn
Molalla
Gervais
Mt. Angel
Silverton
Sheridan
Willamina
Amity
SALEM
DALLAS
Falls City
Monmouth
Independence
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Idanha
Jefferson
Scio
ALBANY
CORVALLIS
MT HOOD
COLUMBIA RIVER
WILLAMETTE
BULL RUN RES NO 1
BULL RUN RES NO 2
FARADAY RES
CAZADERO RES
NORTH FORK RES
BIG CLIFF RES
DETROIT RES
Timothy Lake
Lake Harriet
Marion Lake

SUBBASINS
1 Coast Fork
2 Middle Fork
3 McKenzie
4 Long Tom
5 Santiam
6 Coast Range
7 Pudding
8 Tualatin
WASCO
CASCADE RANGE
JEFFERSON
DESCHUTES
COAST RANGE
LINCOLN
POLK
MARION
LINN
BENTON
LANE
SALEM
ALBANY
CORVALLIS
EUGENE
SPRINGFIELD
Sheridan
Willamina
Amity
Woodburn
Molalla
Gervais
Mt. Angel
Silverton
Dallas
Falls City
Monmouth
Independence
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Idanha
Jefferson
Scio
Lebanon
Philomath
Brownsville
Halsey
Sweet Home
Harrisburg
Junction City
Coburg
Creswell
Lowell
Oakridge
Cottage Grove
Timothy Lake
Detroit Res
Big Cliff Res
Green Peter Res
Foster Res
Clear Lake
Carmen Res
Smith Res
Trail Bridge Res
Big Lake
Marion Lake
Blue River Res
Cougar Res
Fern Ridge Res
Fall Creek Res
Dexter Res
Lookout Point Res
Dorena Res
Cottage Grove Res
Hills Creek Res
Waldo Lake
Mud Lake
WILLAMETTE RIVER

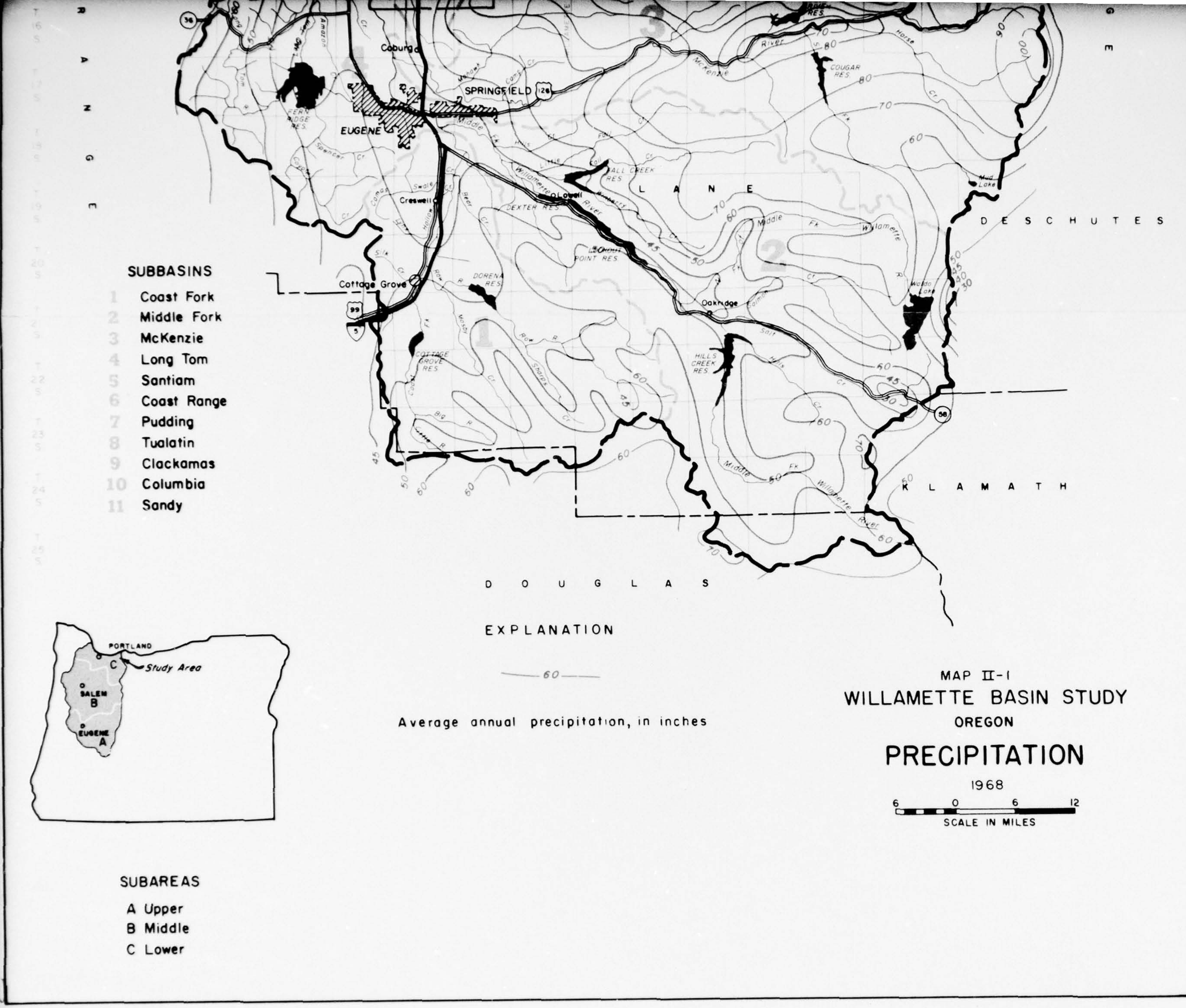

MAP II-1
WILLAMETTE BASIN STUDY
OREGON
PRECIPITATION
1968
6 0 6 12
SCALE IN MILES
EXPLANATION
60
Average annual precipitation, in inches
SUBBASINS
1 Coast Fork
2 Middle Fork
3 McKenzie
4 Long Tom
5 Santiam
6 Coast Range
7 Pudding
8 Tualatin
9 Clackamas
10 Columbia
11 Sandy
SUBAREAS
A Upper
B Middle
C Lower
PORTLAND
Study Area
SALEM
EUGENE
LANE
DOUGLAS
DESCHUTES
KLAMATH
RANGE
EUGENE
SPRINGFIELD
Coburg
Creswell
Cottage Grove
Oakridge
Lowell
COUGAR RES
DEXTER RES
DORENA RES
COTTAGE GROVE RES
HILLS CREEK RES
FERN RIDGE RES
Waldo Lake
Mud Lake
McKenzie
Willamette
Middle
Fk
River

Table II-6

Number of days each month with precipitation more than 0.01, 0.10, 0.50, and 1.00 inch at Albany, Detroit, and Valsetz

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
ALBANY - Elev. 220					0.01 Inch								
Ave. Days/Month	19.7	17.8	18.6	14.3	12.4	9.2	3.0	4.3	6.7	13.6	18.2	20.3	158.1
Max. Days/Month	29	26	26	25	25	21	8	12	15	23	27	28	
Yr. Occurrence	1950	1961	1961	1948	1953	1954	1955+	1953	1941	1950	1953	1964	
Min. Days/Month	9	8	1	3	4	0	0	0	1	3	6	11	
Yr. Occurrence	1936	1941	1965	1951	1947	1951	1962+	1959+	1965	1936	1936	1943	
					0.10 Inch								
Ave. Days/Month	12.8	11.2	11.8	7.8	6.8	4.2	1.2	1.6	3.5	8.1	11.7	13.2	93.9
Max. Days/Month	25	20	20	17	13	10	4	5	10	19	19	21	
Yr. Occurrence	1950	1940	1961	1963	1960+	1937	1954+	1953	1941	1950	1937	1964	
Min. Days/Month	3	4	1	1	1	0	0	0	0	0	1	5	
Yr. Occurrence	1962+	1964	1965	1939	1952	1951+	1962+	1959+	1965+	1936	1936	1943	
					0.50 Inch								
Ave. Days/Month	4.2	3.3	2.6	0.7	0.8	0.6	0.1	0.1	0.9	2.2	4.3	4.2	24.0
Max. Days/Month	9	9	8	4	3	3	1	1	3	9	11	10	
Yr. Occurrence	1964	1940	1938	1937	1963+	1937	1947+	1943+	1948+	1950	1942	1955	
Min. Days/Month	0	0	0	0	0	0	0	0	0	0	0	0	
Yr. Occurrence	1962	1964+	1965+	1964+	1965+	1965+	1965+	1965+	1965+	1964+	1959+	1963+	
					1.00 Inch or more								
Ave. Days/Month	1.2	1.1	0.5	0	0.2	0.1	0	0	0.1	0.7	1.4	1.2	6.5
Max. Days/Month	5	6	3	1	2	2	1	1	1	4	5	4	
Yr. Occurrence	1959	1949	1938	1955	1963	1952	1947	1943	1941	1950	1942	1955	
Min. Days/Month	0	0	0	0	0	0	0	0	0	0	0	0	
Yr. Occurrence	1963+	1965+	1965+	1965+	1965+	1965+	1965+	1965+	1965+	1964+	1964	1963	
DETROIT - Elev. 1896					0.01 Inch								
Ave. Days/Month	19.5	18.4	19.2	16.0	14.0	10.4	3.7	4.5	7.5	13.2	17.5	19.9	163.8
Max. Days/Month	29	25	27	23	22	21	8	11	19	24	26	26	

Max. Days/Month	9	9	8	4	3	3	1	1	3	9	11	10	
Yr. Occurrence	1964	1940	1938	1937	1963+	1937	1947+	1943+	1948+	1950	1942	1955	
Min. Days/Month	0	0	0	0	0	0	0	0	0	0	0	0	
Yr. Occurrence	1962	1964+	1965+	1964+	1965+	1965+	1965+	1965+	1965+	1964+	1959+	1963+	
1.00 Inch or more													
Ave. Days/Month	1.2	1.1	0.5	0	0.2	0.1	0	0	0.1	0.7	1.4	1.2	6.5
Max. Days/Month	5	6	3	1	2	2	1	1	1	4	5	4	
Yr. Occurrence	1959	1949	1938	1955	1963	1952	1947	1943	1941	1950	1942	1955	
Min. Days/Month	0	0	0	0	0	0	0	0	0	0	0	0	
Yr. Occurrence	1963+	1965+	1965+	1965+	1965+	1965+	1965+	1965+	1965+	1964+	1964	1963	
DETROIT - Elev. 1896													
0.01 Inch													
Ave. Days/Month	19.5	18.4	19.2	16.0	14.0	10.4	3.7	4.5	7.5	13.2	17.5	19.9	163.8
Max. Days/Month	29	25	27	23	22	21	8	11	19	24	26	26	
Yr. Occurrence	1959	1961	1961	1955+	1941	1954	1963	1954	1959	1943	1945	1964+	
Min. Days/Month	10	9	4	3	4	2	0	0	1	3	3	15	
Yr. Occurrence	1949	1964	1965	1951	1947	1965+	1952	1955+	1942	1936	1936	1960	
0.10 Inch													
Ave. Days/Month	16.4	15.2	15.5	12.0	9.5	6.8	1.9	2.8	5.0	10.3	14.9	16.5	126.8
Max. Days/Month	27	25	24	19	19	16	6	7	13	20	25	25	
Yr. Occurrence	1953	1961	1961	1955	1960	1947	1963	1965	1959	1950	1945	1964	
Min. Days/Month	8	6	2	3	0	0	0	0	0	2	2	7	
Yr. Occurrence	1949	1947	1965	1951	1952	1965+	1962+	1963	1942	1952+	1936	1943	
0.50 Inch													
Ave. Days/Month	8.0	7.2	6.4	3.4	2.3	1.7	0.2	0.6	1.8	5.0	8.4	9.1	54.1
Max. Days/Month	18	17	12	8	8	6	2	2	6	14	15	17	
Yr. Occurrence	1950	1961	1961+	1960	1960	1947	1947	1960+	1959	1950	1945	1964	
Min. Days/Month	1	1	0	1	0	0	0	0	0	0	0	2	
Yr. Occurrence	1949	1941	1958	1964	1950+	1965+	1965+	1965+	1965+	1952+	1939+	1944	
1.00 Inch or more													
Ave. Days/Month	3.2	3.0	2.0	0.9	0.4	0.3	0	0.1	0.5	1.9	3.8	4.5	20.6
Max. Days/Month	10	8	5	4	2	3	0	1	2	6	8	11	
Yr. Occurrence	1953	1949	1962	1962	1960	1947	All	1953+	1961+	1951	1945+	1964	
Min. Days/Month	0	0	0	0	0	0	0	0	0	0	0	0	
Yr. Occurrence	1963+	1964+	1958+	1964+	1965+	1965+	All	1965+	1965+	1964+	1952+	1947	
VALSETZ 1/ - *Elev. 1135*													
0.01 Inch													
Ave. Days/Month	21.0	19.3	19.9	16.0	12.2	9.5	3.8	5.3	7.9	15.0	19.6	21.0	170.5
Max. Days/Month	31	27	26	26	23	17	12	11	19	25	27	28	
Yr. Occurrence	1950	1961	1961+	1948	1960	1947+	1947	1964	1959	1950	1963	1964	
Min. Days/Month	12	11	5	4	5	1	0	0	1	6	6	14	
Yr. Occurrence	1949+	1954+	1965	1951	1955	1955	1960+	1955	1943	1952	1952	1960	
0.10 Inch													

					1.00 Inch or more								
Ave. Days/Month	3.2	3.0	2.0	0.9	0.4	0.3	0	0.1	0.5	1.9	3.8	4.5	20.6
Max. Days/Month	10	8	5	4	2	3	0	1	2	6	8	11	
Yr. Occurrence	1953	1949	1962	1962	1960	1947	All	1953+	1961+	1951	1945+	1964	
Min. Days/Month	0	0	0	0	0	0	0	0	0	0	0	0	
Yr. Occurrence	1963+	1964+	1958+	1964+	1965+	1965+	All	1965+	1965+	1964+	1952+	1947	
VALSETZ 1/ - Elev. 1135						0.01 Inch							
Ave. Days/Month	21.0	19.3	19.9	16.0	12.2	9.5	3.8	5.3	7.9	15.0	19.6	21.0	170.5
Max. Days/Month	31	27	26	26	23	17	12	11	19	25	27	28	
Yr. Occurrence	1950	1961	1961+	1948	1960	1947+	1947	1964	1959	1950	1963	1964	
Min. Days/Month	12	11	5	4	5	1	0	0	1	6	6	14	
Yr. Occurrence	1949+	1954+	1965	1951	1955	1955	1960+	1955	1943	1952	1952	1960	
						0.10 Inch							
Ave. Days/Month	17.5	16.1	15.8	12.6	7.8	6.0	2.5	3.3	5.8	12.3	16.3	18.2	134.2
Max. Days/Month	27	24	23	20	17	12	8	7	14	21	24	27	
Yr. Occurrence	1964+	1961	1950	1948	1960	1947+	1947	1962+	1941	1947	1963+	1964	
Min. Days/Month	8	8	2	4	2	0	0	0	0	3	3	9	
Yr. Occurrence	1949	1947	1965	1956	1952+	1945	1960+	1955	1965	1952	1936	1943	
						0.50 Inch							
Ave. Days/Month	11.9	10.2	9.3	5.9	3.0	1.8	0.6	1.2	2.5	7.5	10.9	12.1	76.9
Max. Days/Month	21	20	17	12	9	8	3	5	7	16	20	19	
Yr. Occurrence	1964	1961	1956	1948	1945	1947	1955	1953	1959	1950+	1942	1964	
Min. Days/Month	2	4	0	1	0	0	0	0	0	1	0	6	
Yr. Occurrence	1949	1964	1953	1956	1955+	1965+	1965+	1965+	1965+	1952	1952	1944	
						1.00 Inch or more							
Ave. Days/Month	5.9	5.9	3.9	2.2	1.0	0.5	0.3	0.4	1.1	3.5	6.6	7.0	38.3
Max. Days/Month	18	14	9	5	5	4	2	2	7	13	12	11	
Yr. Occurrence	1948	1961	1961	1960+	1945	1937	1955	1943+	1959	1947	1945	1964+	
Min. Days/Month	0	0	0	0	0	0	0	0	0	0	0	0	
Yr. Occurrence	1958+	1941	1953	1964+	1964+	1965+	1965+	1965+	1965+	1964+	1936	1952	

1/ *Outside Willamette Basin.*

EXPLANATION

● Precipitation only

○ Precipitation and temperature

◑ Precipitation, temperature and evaporation

▲ *Snow courses*

MAP II - 2

WILLAMETTE BASIN STUDY

OREGON

HYDROCLIMATIC STATIONS

1968

SCALE IN MILES

Table II-7

Short duration maximum rainfall intensities (in inches) for selected recurrence intervals 1/

(a) Valley Floor

Recurrence interval	Duration of Precipitation 20 Mins.	30 Mins.	1 Hr.	2 Hrs.	3 Hrs.	6 Hrs.	12 Hrs.	24 Hrs.
2 Years	0.2	0.4	0.5	0.8	1.1	1.5	2.0	2.5
5 Years	0.2	0.5	0.8	1.0	1.3	1.7	2.5	3.1
10 Years	0.3	0.6	0.9	1.2	1.5	2.1	2.8	3.5
25 Years	0.3	0.7	1.0	1.4	1.7	2.4	3.2	4.0
50 Years	0.4	0.8	1.1	1.6	1.9	2.7	3.5	4.4
75 Years	0.5	0.9	1.2	1.7	2.1	2.9	3.7	4.7
100 Years	0.5	0.9	1.3	1.8	2.2	3.0	3.9	5.0

(b) Coastal Range

Recurrence interval	Duration of Precipitation 20 Mins.	30 Mins.	1 Hr.	2 Hrs.	3 Hrs.	6 Hrs.	12 Hrs.	24 Hrs.
2 Years	0.2	0.4	0.6	1.3	1.7	2.6	3.8	4.5
5 Years	0.3	0.5	0.8	1.6	2.1	3.2	4.7	5.6
10 Years	0.3	0.6	0.9	1.8	2.4	3.6	5.3	6.3
25 Years	0.4	0.7	1.1	2.1	2.7	4.2	6.2	7.2
50 Years	0.5	0.8	1.3	2.4	3.1	4.6	6.8	8.0
75 Years	0.6	0.9	1.4	2.6	3.4	4.9	7.2	8.5
100 Years	0.6	0.9	1.5	2.7	3.5	5.2	7.6	9.0

(c) Upper Slopes of the Cascades

Recurrence interval	Duration of Precipitation 20 Mins.	30 Mins.	1 Hr.	2 Hrs.	3 Hrs.	6 Hrs.	12 Hrs.	24 Hrs.
2 Years	0.2	0.4	0.6	1.0	1.4	2.0	2.9	3.5
5 Years	0.2	0.5	0.8	1.3	1.7	2.4	3.6	4.3
10 Years	0.3	0.6	0.9	1.5	1.9	2.9	4.1	4.9
25 Years	0.4	0.7	1.1	1.8	2.2	3.4	4.9	5.8
50 Years	0.5	0.8	1.2	2.0	2.5	3.7	5.3	6.3
75 Years	0.6	0.9	1.3	2.2	2.8	4.0	5.8	6.7
100 Years	0.6	0.9	1.4	2.3	3.0	4.2	6.2	7.2

1/ *Computed from U. S. Weather Bureau Technical Paper 28, "Rainfall Intensities for Local Drainage Design in Western United States".*

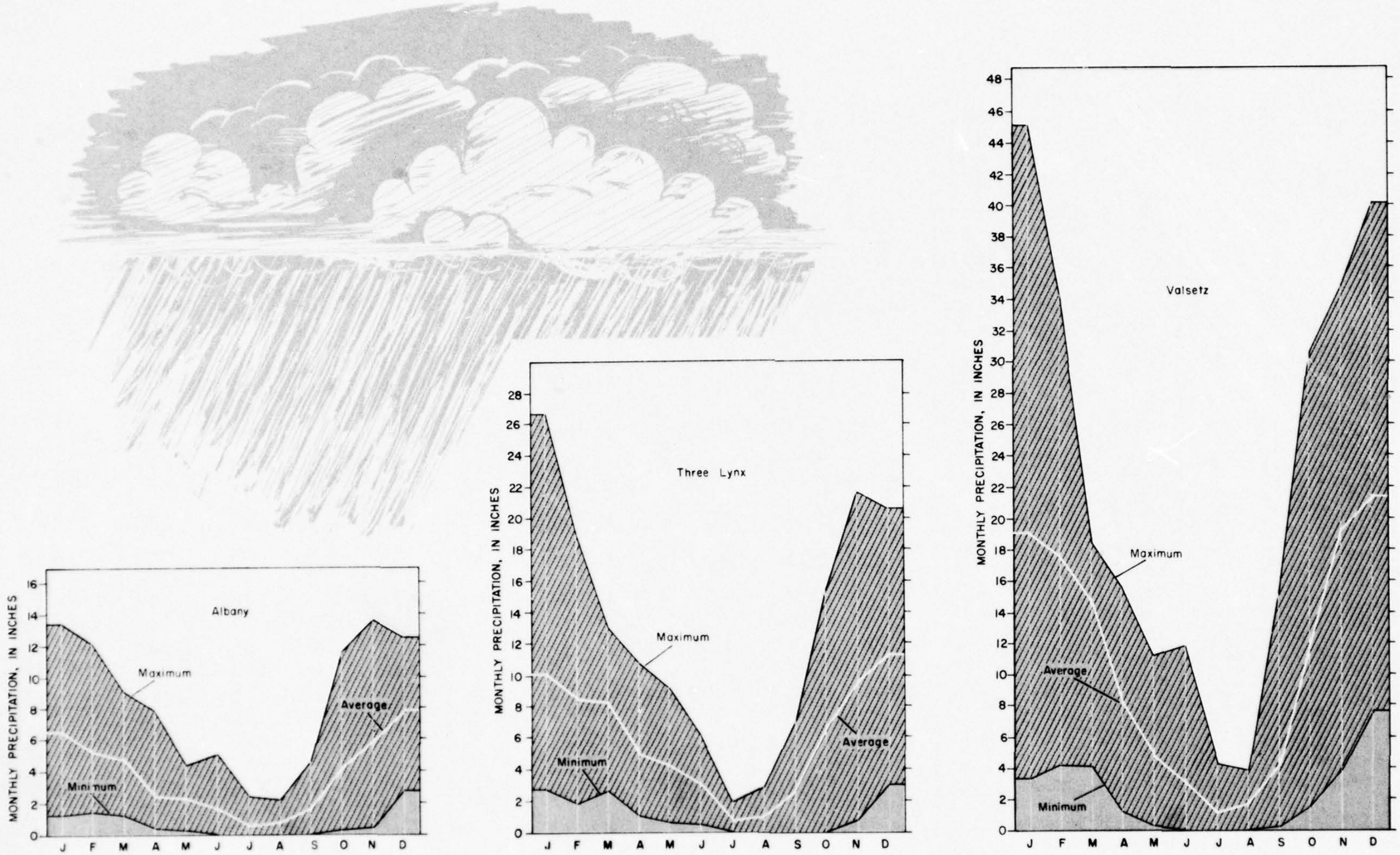


Figure II-3. Average, minimum, and maximum monthly precipitation at Albany, Three Lynx, and Valsetz.

Table II-8

Mean, maximum, and minimum monthly precipitation

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
ALBANY No. 2	Elev. 220												
Mean	6.25	5.06	4.55	2.28	2.13	1.50	0.38	0.48	1.42	4.00	5.87	6.75	40.67
Maximum	13.34	12.06	8.97	7.85	4.35	5.05	2.32	2.13	4.61	11.64	13.72	12.57	57.44
Minimum	1.16	1.33	1.23	0.30	0.25	T	0.00	T	0.07	0.14	0.26	2.68	24.27
CASCADIA ST.PARK	Elev. 850												
Mean	8.31	6.97	7.32	4.83	3.93	3.05	0.57	0.82	2.23	5.84	8.05	9.34	61.26
Max	14.44	13.18	12.75	10.38	8.69	7.09	2.54	2.73	4.91	15.58	20.91	20.65	82.02
Min	3.44	2.34	2.24	1.28	0.84	0.02	0.00	T	0.02	0.66	0.67	3.22	39.36
COTTAGE GROVE 1S	Elev. 650												
Mean	7.03	5.63	5.45	3.10	2.62	1.85	0.30	0.49	1.52	4.35	6.47	7.50	46.31
Max	13.59	13.67	10.34	8.78	6.02	6.42	3.16	1.73	4.32	15.35	13.02	18.38	63.46
Min	1.90	1.60	1.78	0.64	0.43	0.00	0.00	0.00	0.12	0.19	0.53	2.21	29.02
DALLAS	Elev. 325												
Mean	8.34	7.48	5.84	2.95	2.20	1.24	0.40	0.68	1.33	3.87	7.36	8.12	49.79
Max	18.71	15.02	11.42	7.91	4.47	4.38	1.36	1.99	4.05	11.39	15.78	16.07	69.62
Min	1.84	1.82	1.79	0.23	0.03	0.02	0.00	0.00	T	0.51	0.32	3.41	30.11
DETROIT	Elev. 1986												
Mean	11.17	9.80	9.01	5.49	3.89	2.68	0.64	1.00	2.58	7.64	12.51	12.86	79.27
Max	27.09	21.63	13.55	12.28	8.87	8.13	2.08	3.16	9.89	19.80	27.76	30.86	109.13
Min	2.98	2.57	2.60	0.98	0.92	0.06	0.00	0.01	0.04	1.68	1.50	3.50	50.71
ESTACADA 2 SE	Elev. 410												
Mean	7.62	6.58	6.90	4.35	3.64	2.76	0.73	1.13	2.36	5.52	7.86	8.56	58.01
Max	16.69	16.04	11.78	8.93	8.58	6.20	2.02	3.98	5.75	15.71	18.90	17.50	76.82
Min	1.67	1.88	2.20	1.40	0.37	0.16	0.00	T	0.11	0.66	1.24	2.96	35.67
EUGENE WB AP	Elev. 359												
Mean	6.33	4.97	4.32	2.38	2.14	1.42	0.27	0.40	1.27	3.83	5.62	6.61	39.56
Max	14.83	11.58	9.81	7.17	4.44	5.57	2.63	1.70	2.98	12.66	12.02	20.99	57.95
Min	1.39	0.86	1.39	0.55	0.29	T	T	T	0.06	0.14	0.35	2.69	23.26
HEADWORKS	Elev. 748												
Mean	11.76	9.03	9.79	5.87	5.37	4.67	1.09	1.56	3.85	8.04	11.85	12.83	85.71
Max	22.34	19.89	14.85	12.52	9.97	10.05	3.28	5.21	9.16	17.25	30.77	21.00	110.30
Min	3.73	2.91	3.21	1.40	1.73	0.44	0.00	T	0.58	1.52	0.77	4.12	53.59
McKENZIE BRIDGE R.S.	Elev. 1375												
Mean	10.48	8.42	8.39	4.75	3.91	2.93	0.52	0.72	2.25	6.61	9.62	11.84	70.44
Max	23.62	19.07	14.33	10.97	9.39	7.59	2.31	2.73	6.74	18.28	22.54	26.94	93.29
Min	3.10	2.55	1.41	1.36	0.50	0.00	0.00	0.00	0.25	0.12	0.22	3.16	44.75
OAKRIDGE SALMON HATCHERY	*Elev. 1275*												
Mean	6.73	5.24	5.09	3.10	2.74	2.12	0.44	0.50	1.32	3.92	5.96	6.81	43.97
Max	14.29	9.89	10.77	6.41	6.90	4.85	2.56	2.14	5.65	13.22	12.56	21.47	60.32
Min	1.84	1.76	1.57	0.67	0.80	0.00	0.00	0.00	0.11	0.03	0.25	2.26	28.58
ODELL LAKE 1/	Elev. 4792												
Mean	8.83	6.40	6.59	3.67	2.74	2.19	0.43	0.57	1.62	4.69	7.52	9.46	54.71
Max	17.73	11.72	11.87	8.73	6.62	5.01	1.62	3.18	6.91	15.58	17.62	29.83	80.13
Min	2.69	1.54	1.10	0.75	0.32	0.22	T	0.00	T	T	T	1.68	29.99
PORTLAND WB CITY	Elev. 30												
Mean	6.34	4.90	4.78	2.45	2.05	1.68	0.39	0.69	1.74	3.89	6.04	7.42	42.37
Max	14.67	11.43	8.37	6.22	4.97	3.88	1.43	2.84	3.99	9.70	14.40	13.86	57.38
Min	0.90	1.33	1.81	0.50	0.61	0.03	T	T	0.09	0.44	0.36	2.18	27.12
SALEM WB AS	Elev. 195												
Mean	6.70	5.31	4.68	2.33	2.11	1.45	0.35	0.45	1.38	3.91	5.71	7.37	41.75
Max	11.70	12.31	8.19	7.68	4.58	4.61	1.41	2.14	3.22	11.17	13.38	13.60	63.50
Min	0.57	1.43	1.27	0.39	0.18	0.01	0.00	T	0.01	0.21	0.48	2.67	25.20
THREE LYNX	Elev. 1120												
Mean	9.84	8.41	8.11	4.79	4.06	2.94	0.59	0.90	2.45	6.49	9.22	11.10	68.89
Max	26.17	18.91	13.09	10.66	9.12	6.15	1.80	2.82	7.07	15.48	21.53	20.60	93.59
Min	2.74	1.75	2.66	1.01	0.60	0.51	0.00	0.00	0.04	0.38	0.80	2.87	40.38
VALSETZ 1/	Elev. 1135												
Mean	18.96	17.50	15.36	8.20	4.68	2.87	1.14	1.60	4.10	11.84	19.14	21.31	126.70
Max	47.23	34.19	25.47	18.54	11.18	11.89	4.30	3.94	15.35	30.62	34.99	40.25	168.88
Min	3.39	4.19	4.16	1.23	0.30	0.09	0.00	0.00	0.31	1.63	4.00	7.71	80.16

1/ Outside Willamette Basin.

Late spring and summer thunderstorms are usually of brief duration but have produced the heaviest short-period (2 hr or less) rainfall that has occurred in the basin. Recurrence intervals of short-duration maximum rainfall intensities that may be expected at locations on the valley floor, Coast Range, and upper slopes of the Cascade Range are shown in Table II-7.

Table II-8 gives the average monthly precipitation and extremes for selected stations. These data are presented in graphic form for Albany, Three Lynx, and Valsetz in Figure II-3.

EVAPORATION

Records of evaporation in Willamette Basin have been obtained by the U. S. Weather Bureau in cooperation with the Corps of Engineers, Oregon State University Experiment Station, and others. Most of the observations of evaporation are made during April through October. Heavy rainfall and frequent freezing weather normally result in little or no evaporation from October until April. Table II-9 summarized evaporation data.

Table II-9

Monthly evaporation data (inches) for Willamette Basin Stations [1/]

	Apr.	May	June	July	Aug.	Sept.	Oct.
Corvallis (O.S.U.).....Elev. 205							
Mean	3.26	4.18	5.28	7.05	6.23	4.16	
Maximum	4.19	5.20	7.46	9.87	8.33	6.50	
Minimum	1.65	2.48	2.98	4.94	3.76	2.74	
No. Years Record	29	36	42	39	42	37	
Cottage Grove Dam......Elev. 831							
Mean		4.64	5.56	7.88	6.67	4.47	1.91
Maximum		5.95	8.48	9.46	8.21	5.50	2.46
Minimum		2.60	3.83	5.64	5.07	3.30	1.61
No. Years Record		20	22	22	23	19	12
Dorena Dam.............Elev. 757							
Mean		5.07	5.88	8.15	7.10	4.77	
Maximum		6.41	9.24	9.56	8.58	5.35	
Minimum		3.52	4.51	5.84	5.10	3.62	
No. Years Record		16	16	16	16	16	
Fern Ridge Dam.........Elev. 380							
Mean	2.86	4.84	5.81	8.13	6.79	4.60	1.81
Maximum	3.46	7.05	8.42	9.90	8.39	6.16	2.58
Minimum	1.76	2.86	4.05	5.46	4.75	3.13	1.20
No. Years Record	15	22	22	22	23	23	11
Odell Lake (Land Pan) [2/] Elev. 4792							
Mean		3.35	3.94	5.48	3.75	1.98	0.75
Maximum		4.19	5.33	6.36	5.26	3.88	2.17
Minimum		2.62	2.45	4.33	3.02	1.42	0.27
No. Years Record		8	20	20	20	20	19

1/ Records through 1965. 2/ Outside Willamette Basin.

WIND

Figure II-4 shows the January, July, and annual wind roses for stations in the basin. Wind roses show the frequencies that the wind blows from each of the eight principal directions.

Several times each year, October to early April, very strong winds strike the Oregon coast. Occasionally, despite the protection afforded by the Coast Range, they move inland with considerable strength. Sustained speeds of 40 to 50 miles per hour can be expected to occur during most winters. A study by the Bonneville Power Administration (BPA Scheduling Section, 1964) shows that a sustained speed of at least 60 miles per hour can be expected, on the average, every 10 years, 70 miles per hour every 25 years, and 80 miles per hour every 50 years. During the Columbus Day storm in 1962, winds in excess of 70 miles per hour occurred throughout the Willamette Basin; on a number of unofficial instruments speeds of more than 100 miles per hour were noted.

From September through May, windspeeds of 40 to 50 miles per hour are recorded several times each month on top of Mount Hebo in the Coast Range. During these periods, it is not unusual for winds to reach 70 to 90 miles per hour and occasionally they are higher. Mount Hebo, elevation 3,153 ft, is an exposed point considerably highertthan the surrounding terrain.

RELATIVE HUMIDITY

Because of the prevalence of marine air, morning humidities are relatively high throughout the year. Daytime heating in the summer reduces the humidity to between 40 to 45 percent during midafternoon. During an east wind condition in summer, it usually drops to 15 to 20 percent, causing a high fire hazard in the forests. Table II-10 presents the general monthly average humidities for four selected times during the day at Portland, Salem, and Eugene. Figure II-5 shows this information graphically for Salem.

Table II-10

Average relative humidities in Willamette Basin for four 6-hour intervals

Time (P.s.t.)	Jan.	Feb.	Mar.	Apr.	May	June
4 a.m.	86	88	88	88	87	86
10 a.m.	82	81	72	67	64	63
4 p.m.	77	70	62	55	53	49
10 p.m.	84	85	83	78	78	75

Time (P.s.t.)	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
4 a.m.	86	86	88	91	90	89	88
10 a.m.	59	62	65	79	79	84	72
4 p.m.	43	44	48	65	65	80	60
10 p.m.	71	74	77	86	87	87	80

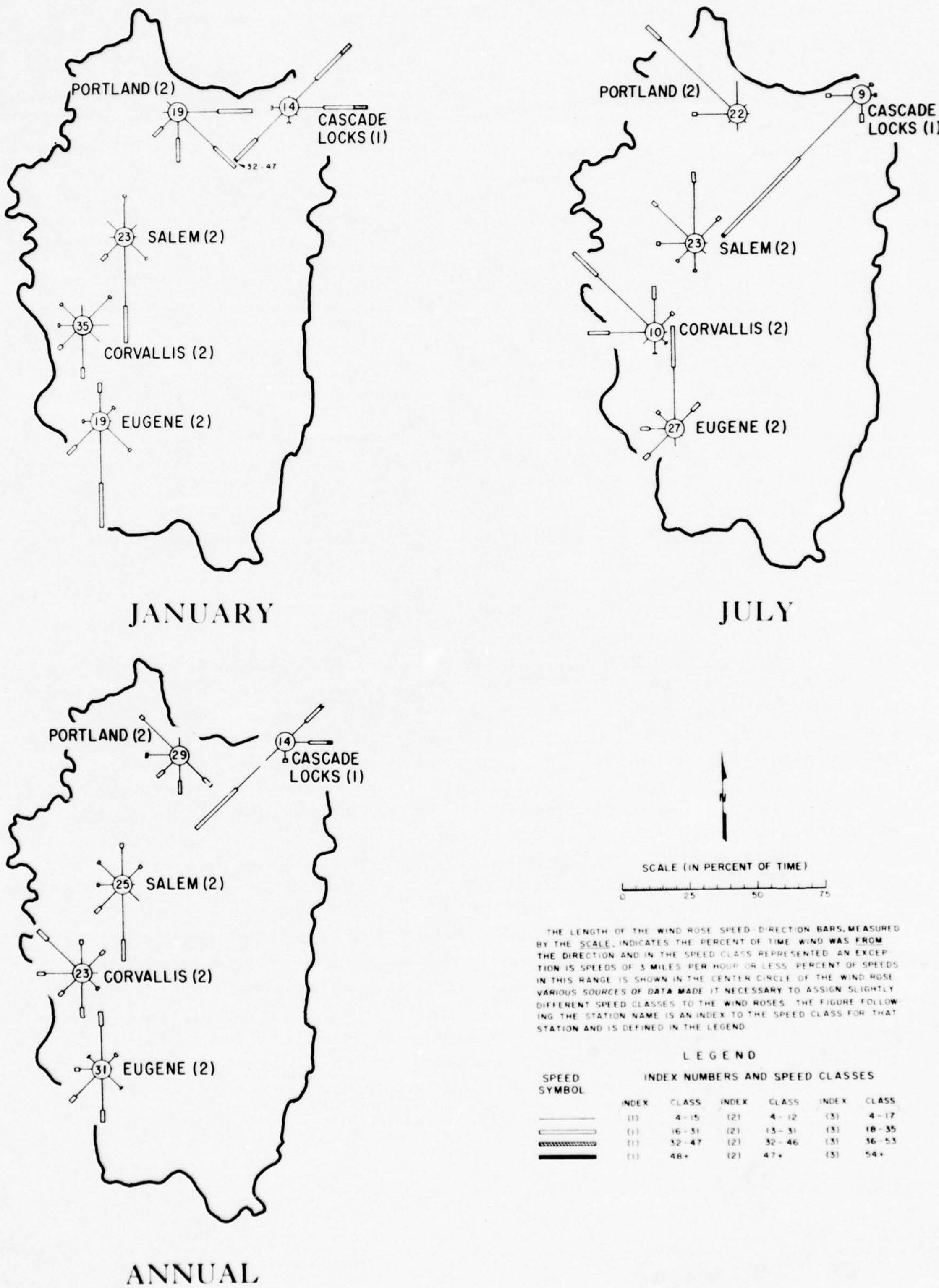


Figure II-4. Surface wind roses, Willamette Basin.

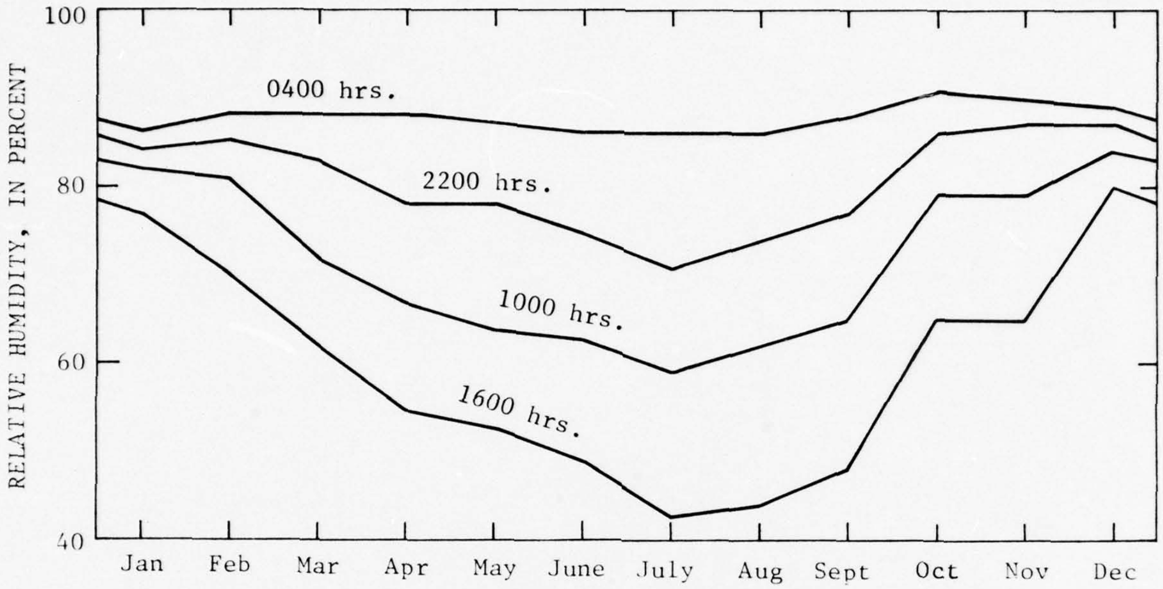


Figure II-5. Relative humidity for four 6-hour intervals at Salem.

SUNSHINE AND CLOUDINESS

Frequent storms moving in from the Pacific Ocean and the cooling of the marine air as it is lifted over the Coast Range combine to produce considerable cloudiness from mid-October to mid-March. Even during this time, however, bright sunny periods of several days' duration can be expected.

Three different measurements are used to estimate sunshine and solar energy: (1) average cloudiness of the sky, in tenths, from sunrise to sunset; (2) average percentage of the time possible that the sun shines; and (3) total solar radiation each day measured in langleys (a langley equals 1 gram calorie of energy per square centimeter per minute). Observed data are few for each of these measurements. Data on average cloudiness are available for stations at Portland International and Eugene Airports for a number of years and are the basis for the estimate for Willamette Basin. Statistical estimates have been made of the percentage of possible sunshine and solar radiation (Sternes, 1959). Table II-11 summarizes these three components on a monthly and an annual basis for the basin.

HAIL

During late winter and early spring, small hail is likely to occur. Hailstones large enough to cause serious damage to property or crops, however, are rare and probably occur on an average of less than once a year in the entire basin. Hail damage generally is confined to small areas, seldom covering as much as 100 acres.

TORNADOES

There have been less than half a dozen tornadoes and funnel clouds officially noted during the entire history of weather observations in Willamette Valley and surrounding mountain slopes. Only three or four actually touched the ground, and none for a distance wider than a few yards or longer than a few hundred feet. No loss of life resulted and property damage was negligible.

Table II-11

Estimates of cloudiness, percentage of possible sunshine, and solar radiation in Willamette Basin

	Jan.	Feb.	Mar.	Apr.	May	June
Cloudiness (percent of sky covered by clouds)	84	82	82	74	71	65
Percent of possible sunshine	25	35	40	50	50	50
Solar radiation (in langleys)	110	185	275	410	500	500

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Cloudiness (percent of sky covered by clouds)	43	48	52	71	81	88	70
Percent of possible sunshine	65	65	60	45	30	20	45
Solar radiation (in langleys)	575	500	400	220	150	90	3,915

METOROLOGICAL ASPECTS OF MAJOR STORMS

Several times each winter, severe storms cause heavy rain, strong winds, or considerable snowfall in the basin. Associated with each of these weather events are several significant meteorological events.

HEAVY RAINS

A long fetch (run) of southwesterly winds aloft is a typical feature of the storms that produce the extremely heavy rains in western Oregon. These winds originate near Hawaii, cross the Pacific Ocean and stream inland, carrying warm, moist air over Oregon and Washington. This warm air meets cold, northerly air pushing south from the Aleutian Islands to form a storm front. Warm waves that form along the front move eastward for periods of several days. As the airmasses move over the Coast Range and up the west slopes of the Cascade Range, precipitation associated with the front increases. A typical storm of this nature was that of December 20-25, 1964, when very heavy precipitation occurred not only in western Oregon but extended over the Cascades into the central-plateau area of the state.

Photo II-2. Storm of December 1964 caused heavy flooding of Santiam River near Jefferson.

STRONG WINDS

A storm center that deepens and intensifies about 500 miles off the southern Oregon-northern California coast is the usual prelude to strong winds at lower altitudes. As the storm center intensifies, warm air that is pumped northward around the low-pressure center steers the "low" northward along the coast.

At about the time the center of low pressure reaches the mouth of the Columbia River, a strong pressure difference develops from north to south through Willamette Valley. With lowest pressure to the north, south winds accelerate down the valley toward the Columbia. Usually the increase in windspeed begins in the southern end of the valley and moves northward so that these winds reach Portland about 2 to 3 hours later than they reach Eugene. During the Columbus Day windstorm in October 1962--one of the most intense ever recorded for Willamette Valley--the extreme pressure difference between Eugene and Portland was about 10 millibars per 100 miles, creating hurricane-force winds. A number of papers and manuscripts have been prepared describing this storm (Harper, 1962; Capell, 1962; Sternes, 1962; Lynott, 1964; Decker and others, 1962).

SNOW

Heavy snows fall each winter on the upper slopes of the Cascades and frequently atop the Coast Range. Substantial snow depths accumulate much less frequently on the valley floor and are typically preceded by movement of cold air into the Willamette Valley, often from the east through the Columbia Gorge and lower passes in the Cascades. The ideal condition for snow exists along a front between very cold air moving out of the north and relatively warm air moving out of the southwest.

Major frontal storms usually bring vast quantities of marine air from the Pacific Ocean, with temperatures well above freezing in the 1,000- to 2,000-foot levels. Consequently, snow turns to rain as it falls through this layer. However, when a blanket of cold air covers the valleys, the falling snow reaches the ground.

When the storm's low-pressure center is well to the southwest, the flow of cold air from the east through the Columbia Gorge is prolonged, and the incoming marine air may continue to ride up over the colder surface layer for many hours. This frontal condition can produce rather heavy snow at all elevations, particularly in the Columbia Gorge and middle and lower Willamette Valley. Eventually, the cold surface layer is displaced by the incoming warmer marine air. These heavy snows are frequently terminated by freezing rain before the cold surface air is completely replaced.

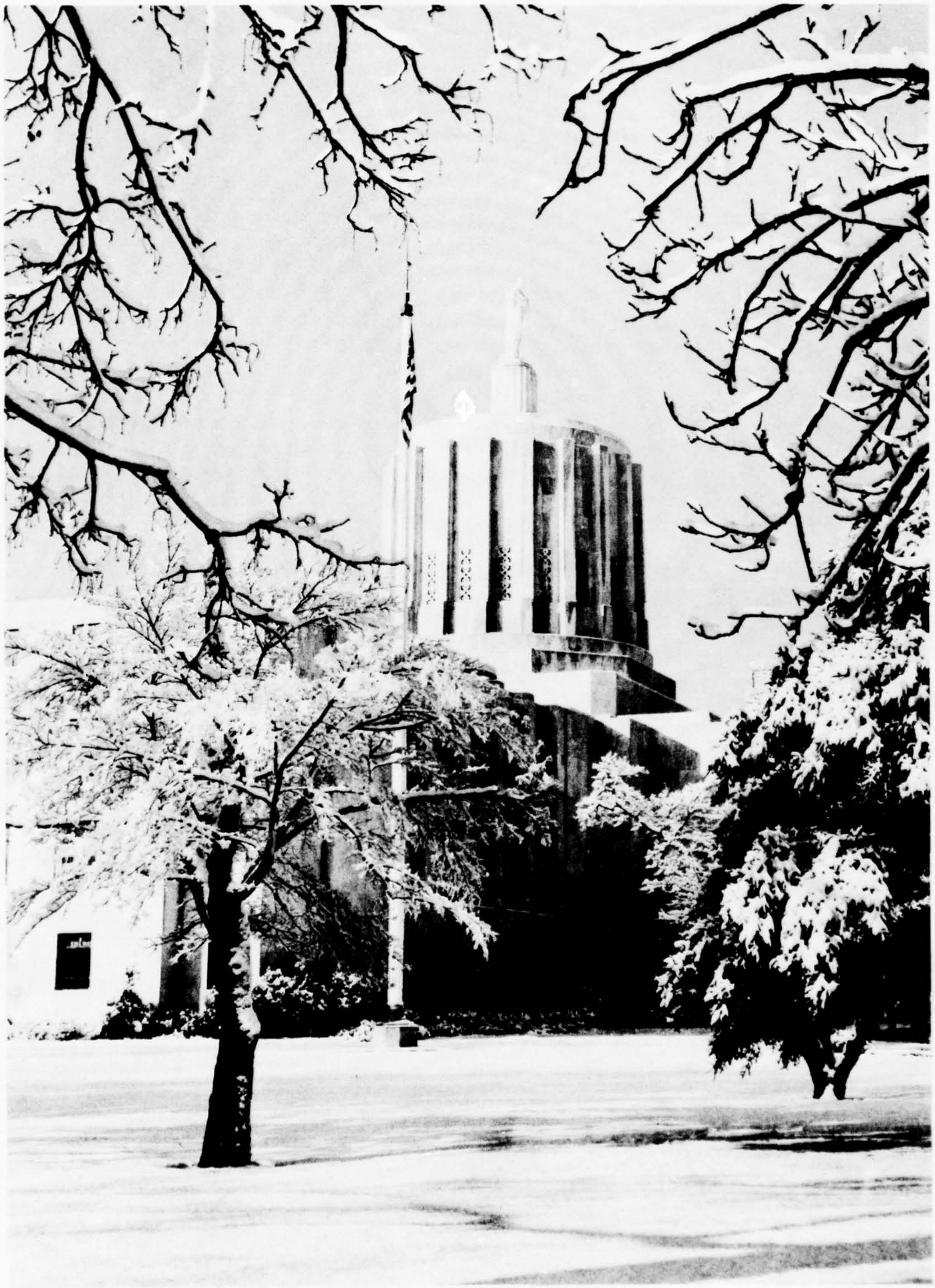


Photo II-3. Snow from a rare winter storm mantles the State Capitol grounds at Salem.

GEOLOGY AND RELATED FACTORS

GEOLOGY AND RELATED FACTORS

Several factors other than climate affect the occurrence, distribution, and availability of water in Willamette Basin. The most important are topography, geology, soils, and vegetation. Elevation has a considerable influence on the amount and form of precipitation. Both precipitation and the proportion that falls as snow generally increase with elevation. Evaporation is also less at high elevations because of lower temperatures. Greater local relief and steeper slopes generally promote greater runoff. The combination of greater precipitation, greater relief, steeper slopes, and lower evaporation rates commonly result in greater runoff for the mountain areas than for the foothills and valley plains.

Rocks, and the soils developed from them, form the framework for the hydrologic system of the basin and knowledge of their characteristics is necessary for understanding and explaining the hydrology of the basin. Permeable soils allow sizable quantities of water to infiltrate, and if the rocks beneath are porous and permeable, a large part of the precipitation may percolate through the ground. Part of this water remains in the ground only a short time, but it may be many years before some of it moves to points of discharge. Certain areas of the basin are underlain by permeable rocks forming ground-water reservoirs capable of receiving and storing large volumes of water. In parts of the basin, these aquifers furnish a large part of the water used for irrigation, municipal, industrial, and domestic purposes.

The vegetative cover may intercept part of the precipitation and prevent it from reaching the ground. Water transpired into the atmosphere from growing vegetation cannot be developed for other purposes. It has been estimated that in forested areas of the basin direct evaporation together with transpiration by trees uses more than 30 inches of precipitation annually (Rothacher, 1965).

Maps and descriptions of the physiography and geology are presented in Appendix A, the Study Area. Pertinent factors of topography, geology, soils and vegetation related to water in Willamette Basin are discussed in the following sections.

G E O H Y D R O L O G I C   S E T T I N G

On the basis of physiography and geology, Willamette Basin can be divided into three north-south bands: the Coast Range, Willamette Valley, and the Cascade Range. Differences in the occurrence and availability of water in these three areas are caused by differences in their topography, climate and geology.

In general, rocks in the basin are of two types--volcanic and sedimentary. The foothills and mountains are formed by the volcanic rocks and older indurated sediments, whereas the lowlands are largely floored by younger consolidated and unconsolidated deposits overlying the bedrock. The geohydrologic characteristics of the geologic units are listed in Table III-1.

COAST RANGE

In northwestern Oregon, the Coast Range extends laterally from Willamette Valley to the Pacific Coast and the crest forms the western boundary of the basin. About 1,900 square miles of foothill and mountain terrain make up the Willamette Basin portion of the Coast Range. This band is about five to eight miles wide at the south, near Fern Ridge Reservoir, increasing to about 20 miles near Salem and McMinnville. At the northern end of the basin, mountainous terrain completely surrounds Tualatin Valley except for three narrow gaps, each less than a mile wide.

Coast Range elevations generally range from about 250 to 400 feet along the edge of the valley and from about 2,000 to 3,000 feet along the crest. Several peaks rise to more than 3,000 feet, and the highest, Marys Peak, reaches 4,097 feet. In contrast, in the headwaters of the South Yamhill River a few miles west of Grand Ronde, the lowest point on the Coast Range crest is only about 700 feet above sea level. In that area, the Willamette Basin extends to within 12 miles of the Pacific Ocean.

The Coast Range is deeply dissected and is characterized by steep to precipitous slopes. Slopes greater than 800 feet per mile (15 percent) are common, even in the foothills. In the more mountainous areas, many slopes are greater than 1,500 feet per mile and, near some of the higher peaks and sharper ridges, slopes are as much as 2,500 to 3,000 feet per mile (47 to 57 percent). Stream valleys are narrow and deep, and in their upper reaches, many streams have gradients of 100 to 200 feet per mile (2 to 4 percent) with numerous rapids. A large part of the Coast Range is forested, although parts of the foothills are used for pasture, orchards, and other cultivated crops.

The mountains and foothills of the Coast Range are underlain largely by older volcanic rocks and by marine sedimentary rocks derived from them. The older volcanic rocks consist of numerous lava units interbedded with breccia, pumice, tuff, and marine sedimentary rocks. The marine sedimentary rocks consist of layered sandstone, shale, and

Table III-1

Geologic units in the Willamette Basin and their hydrogeologic characteristics

Unit	Area of exposure	Lithology	Thickness (feet)	Hydrologic characteristics	Water-supply potential
Alluvium	400 sq mi along Willamette, Columbia, and other major streams	Clay, silt, sand, and gravel	0-200	High in permeability and porosity. Generally directly connected to a stream so that water is exchanged readily between the deposits and streams. Most precipitation on the unit infiltrates	Supplies large quantities of good-quality water to wells. Capable of substantial additional development in most areas of occurrence.
Terrace deposits	About 1,950 sq mi, mostly in Willamette and Tualatin Valleys and Portland Basin	Clay, silt, sand, and gravel. Includes cobble gravel in Portland Basin; much gravel on eastern side of Willamette Valley	Generally 30-100; locally 200	Highly porous; permeability low to high. A large part of the precipitation infiltrates the unit and recharges underlying beds, even where surface materials are fine grained. Unit contributes large quantities of seepage which sustains the base flow of Pudding River and other streams draining area of occurrence	Yields small to large quantities of water to wells. Readily transmits recharge to underlying aquifers such as the Troutdale Formation.
Piedmont deposits	About 150 sq mi in lower slope of Western Cascades, northern part of basin	Gravel and sand of alluvial fans interbedded with volcanic mudflow debris	0-200; average 100	Clay soil developed from weathering impedes infiltration and promotes rapid runoff. Permeability of deposits and base flow are both generally low. Unweathered gravels form local aquifers	Most wells have low yields, but supply adequate quantities of water for stock and domestic supplies.
Young volcanic rocks	2,000 sq mi, mostly in High Cascades but also in Portland area	Basaltic and andesitic lava; include pyroclastic debris and volcanic cones	0-3,000	High permeability and porosity. Most of the precipitation infiltrates, and a high percentage of runoff in High Cascades is through this unit. Highest base-flow contributions in basin (more than 1 cfs per sq mi)	Not generally developed for supply because of lack of need in area of occurrence and because of great depth to saturated zone. Large potential for supply in High Cascades if needed.
Troutdale Formation	100 sq mi in foothills of northern Cascade Range	Conglomerate, sandstone, siltstone, and mudstone	0-1,500	Receives large quantities of infiltration where exposed or through overlying silt beds. Stores and transmits large volumes of water. Contributes large quantities of water to base flow and to wells	Supplies water to about 900 irrigation, public-supply, and industrial wells in northern part of Willamette Valley, Tualatin Valley, and East Portland area. Wells yield 200 to 1,000 gpm.
Sardine Formation	2,000 sq mi in northern and central parts of Western Cascades	Andesitic lava, breccia, agglomerate, and tuff	Averages about 3,000	Interstitial voids and joints provide moderate permeability. Unit receives infiltration readily and yields small to moderate quantities of water to wells and to base flow of streams	Adequate for domestic and stock supplies.
Columbia River Group	600 sq mi in northern part of Cascades, in hills in Willamette Valley, and in Portland area	Dark basaltic lava flows; columnar jointed; tops of some flows scoriaceous, brecciated	0-800	Overall porosity and permeability low, but considerable water moves through permeable interflow zones. Precipitation infiltrates where flows are upturned; mostly runs off of other areas. Many springs of moderate yield contribute to base flow of streams	Excellent source for domestic and stock supplies from wells deep enough to reach saturated permeable zone. Wells at favorable sites yield 100 to 1,000 gpm. Susceptible to local overdevelopment with falling water levels and saline-water encroachment. Wells in perched-water zones have small yields.
Intrusive rocks	100 sq mi, mostly small areas in Coast Range	Igneous dikes, sills, plugs, and stocks	More than 100	Dense with only fracture permeability. No significance as a hydrologic unit	None.
Little Butte Volcanic Series	2,100 sq mi in southern part and central foothills of Cascade Range	Basaltic and andesitic lava, tuff, breccia, and agglomerate	Average 5,000 to 10,000	Overall permeability and porosity low but concentrated in breccias and fractured lava. Contribute small but dependable base flows to streams and usable quantities of water to wells	Generally adequate for dependable stock and domestic supplies. Yield up to 100 gpm to wells locally.
Marine rocks (of Tertiary age)	1,150 sq mi, mostly in Coast Range; small areas in Cascade foothills	Volcanic-derived, marine-deposited sandstone, shale, and mudstone	10,000±	Volcanic materials alter readily to clay, therefore have low permeability and porosity. Store and transmit only meager quantities of water to wells and streams	Generally suitable only for domestic and stock supplies, which are difficult to obtain in places. Locally, water is too saline for most uses.
Lava and interbedded pyroclastic and sedimentary rocks	750 sq mi of Coast Range	Basalt, pumice, tuff, and interbedded sandstone and shale	10,000±	Low in permeability and porosity except for some sandstone, tuff, and breccia beds locally. Store and transmit only meager quantities of water to wells and streams	Generally suitable only for domestic and stock supplies. Locally (south of Eugene) contain water with excessive arsenic.

mudstone. Both the volcanic and marine rocks are severely folded and faulted and have been intruded at many places by dikes, plugs, and sills of younger igneous rocks.

The rocks are characteristically dense and therefore permit little infiltration, movement, or storage of water. Consequently, precipitation runs off rapidly and Coast Range streams have small base flows. Wells drilled into these rocks generally have low yields. In some areas, "dry holes" are common, and wells adequate for domestic or stock supplies can be obtained only with difficulty. In other places, sedimentary rocks contain water that is too mineralized for most uses.

CASCADE RANGE

The Cascade Range separates eastern and western Oregon, and its crest forms the eastern boundary of Willamette Basin. The Willamette Basin part of the range is 50 to 60 miles wide toward the south and 35 to 40 miles wide north of Salem. The average crest of the Cascades is at an elevation of slightly above 5,000 feet; however, numerous volcanic cones along it rise to elevations of more than 6,000 feet and several to more than 10,000 feet.

A 5- to 10-mile-wide gently sloping area just west of the crest is designated as the High Cascades. In that area, the ground slopes at only about 400 to 500 feet per mile, in marked contrast to 2,000 to 3,000 feet per mile on lower slopes a short distance to the west. Marsh areas and natural lakes--such as Waldo, Marion, and Bull Run Lakes--are common. Small valley glaciers extend down the slopes of the highest peaks--Mount Hood, Mount Jefferson, and the Three Sisters. Much of the High Cascade area is forested, but large areas have only sparse alpine vegetation, and some of the youngest lava flows as well as the highest mountain areas are nearly devoid of vegetation.

The principal area of the Cascades lies below elevations of about 3,000 to 4,000 feet and is called the Western Cascades. That part is deeply dissected, has the steepest slopes in the basin, and is drained by streams entrenched in deep, steep-walled canyons. Slopes commonly are 2,000 to 3,000 feet per mile in the higher parts of the area. To the west, however, they become progressively less--about 1,000 feet per mile below elevations of 2,000 feet and only 400 to 500 feet per mile in the foothills just east of the Willamette Valley.

The major tributaries of the Willamette--Coast Fork, Middle Fork, McKenzie, North Santiam, South Santiam, Molalla, Pudding, and Clackamas Rivers--all rise in the Cascades. The Sandy River and its principal tributaries, Bull Run and Salmon Rivers, also rise in the Cascades. Stream gradients are steep and rapids and waterfalls are common. Generally, gradients are steepest in the eastern part of the Western Cascades where many streams have gradients of more than 100 feet per mile and some have gradients of more than 200 feet per mile. As streams reach lower elevations, gradients flatten appreciably--they are only about 60 feet per mile below elevations of 1,500 feet and become progressively lower where streams reach the foothills.

The Willamette Basin portion of the Cascade Range is formed largely of volcanic rocks. Minor amounts of sedimentary rocks, of both marine and continental origin, also occur in the area. The oldest rocks exposed are older volcanic rocks and marine sandstone and shale similar to rocks in the Coast Range. These rocks occur in the Coast Fork Subbasin and in the foothills between Springfield and Molalla. Younger sedimentary deposits which occur in the northern one-third of the basin, mainly beneath Willamette Valley, also extend into the foothills of the Cascades.

The volcanic rocks that form the Cascades are of two major sequences and are mostly younger than those in the Coast Range. The older sequence consists of lava and pyroclastic debris, such as agglomerate, breccia, and tuff, that are of Eocene to Miocene age. Most rocks have been warped or folded to some degree; the oldest generally have been folded, faulted, and altered mineralogically. The younger sequence includes late Tertiary to Recent lava and pyroclastic rocks, among which occur the rocks that form the volcanic cones of the High Cascades. Some of the lava flows are so young that their surfaces are relatively unaltered, and some of the volcanoes along and near the crest of the range are little eroded except by Recent glaciers.

Photo III-1. Volcanic cones and young lava flows characterize the High Cascades.

In the Western Cascades, the older volcanic rocks generally have moderate to low permeability and are less dense than the rocks in the Coast Range. In most places the older volcanic rocks supply small quantities of water to streams and to wells. These wells have yields that are low, but generally adequate for local domestic and stock needs. Along the lower slopes of the Western Cascades between Columbia and Santiam Rivers, lava of the Columbia River Group is an important aquifer.

A small area in the foothills from Molalla northward is underlain by beds of conglomerate, sandstone, and siltstone (the Troutdale Formation). These beds also extend into the alluvial areas of northern Willamette Valley, Tualatin Valley, and Portland Basin, where they are an important aquifer. Precipitation readily infiltrates these beds where they are exposed, and the small springs and seeps that issue from the formation add substantial amounts of water to streams draining the outcrop area in the northern foothills of the Western Cascades.

The younger sequence of volcanic rocks that forms the High Cascades is very permeable and precipitation is readily absorbed through the surfaces of the rough and porous lava flows. Consequently, a large part of the precipitation drains from the area through the ground, and springs are common. As a result of the large transmissibility and storage capacity of the rocks and infiltration of the heavy precipitation, streams in the area have high base flows. Because the area is mostly National forest and occupied by few people, only a few wells have been drilled into these volcanic rocks. Yields of water from those wells generally are high.

WILLAMETTE VALLEY

Willamette Valley is the predominantly flat alluvial area along and adjacent to Willamette River and its tributaries. It occupies about 3,500 square miles and extends about 125 miles from near Eugene northward to Columbia River. It is bounded on the west by the foothills of the Coast Range, on the south by the Calapooya Mountains, and on the east by the foothills of the Cascades.

Near Corvallis, the maximum width of the valley is about 20 miles. North of Salem, between McMinnville and Mount Angel, the valley is about 25 miles wide. Tualatin Valley is an elliptical area about 10 miles wide and about 30 miles long. Portland Basin is a triangular area that extends along Willamette River for about 15 miles and along Columbia River for about 20 miles.

Most of Willamette Valley is flat to gently rolling, but isolated bedrock hills protrude above the valley plain in many places. The valley plain is a broad, irregular alluvial terrace, relatively undissected by modern drainage courses. Its surface is modified locally by alluvial fans that have formed where major streams emerge from the adjacent mountains. The valley plain slopes from elevations of about 400 feet near Eugene to about 150 feet near Canby and less than 50 feet at Portland.

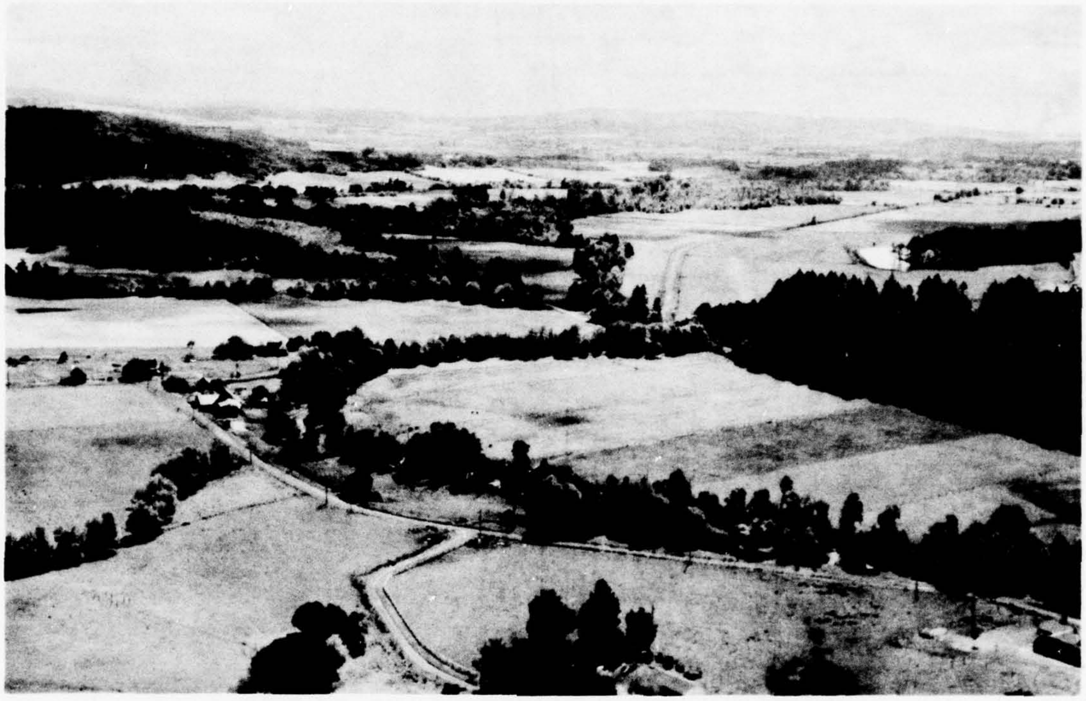


Photo III-2. The flat alluvial valley of North Yamhill River contrasts with rolling hills and distant ridges of the Chehalem Mountains.

Most tributaries have narrow meandering channels that are entrenched 10 to 50 feet below the level of the valley plain. In contrast, Willamette River flows through a poorly defined flood plain about 2 to 3 miles wide between Eugene and Newberg. The plain broadens at the confluences of major tributaries and between Albany and Salem is restricted by resistant bedrock bluffs. In the south, the flood plain is entrenched only a few feet below the terrace surface, but north of Salem it is entrenched 50 to 100 feet. The Willamette meanders widely within its flood plain, which is marked by cutoff meanders, oxbow lakes, braided and distributary channels, and sloughs.

The gradient of Willamette River flattens from about 6 feet per mile near Eugene to 4.5 feet per mile near Harrisburg and 1.6 feet per mile near Newberg. Because of the impounding effect of a rock barrier at Willamette Falls, the gradient in a 30-mile reach just upstream from the falls is less than 0.4 foot per mile. At the falls, the river drops about 45 feet, and in the tidal reach below, the gradient is only about 0.2 foot per mile.

Geologically, Willamette Valley is part of a long, narrow lowland--the Puget-Willamette Trough--which extends from Eugene northward through Puget Sound. Willamette Valley is a syncline, or structural downwarp, partly filled with consolidated and unconsolidated alluvial deposits. Although the geologic structure is complex, the concept of a broad, elongated lowland framed by resistant volcanic and sedimentary rocks is adequate for an understanding of the hydrogeology. The rocks that frame the valley are primarily the marine rocks of the Coast Range and the volcanic rocks of the Cascade foothills. These rocks extend beneath the alluvial deposits and, in places, protrude as hills above the valley floor.

The alluvial deposits that underlie the lowland areas were derived largely from the surrounding mountains and reflect the diversity of their rock sources. These deposits consist of layers of clay, silt, sand, and gravel, in a rather heterogeneous arrangement. They generally are stratified, but many of the beds are lenticular and some consist of tongue- or fan-shaped masses that were laid down along old stream courses. In much of the valley, the surface material is a sandy to clayey silt (Willamette Silt) that settled from water ponded in a great, but short-lived lake. This fine-grained deposit is permeable and allows considerable infiltration of precipitation, which is transmitted to underlying gravel beds or to the streams draining the area. The thickness of the alluvial deposits varies greatly from place to place because the bedrock floor is an irregular erosional surface.

The ridges of volcanic rock that extend across the valley just south of Salem and near Oregon City cut the valley into four segments--the southern Willamette Valley, northern Willamette Valley, Tualatin Valley, and Portland Basin.

Southern Willamette Valley is underlain by terrace deposits and alluvium that lie on poorly permeable marine and volcanic bedrock. The valley fill generally contains better water-yielding beds east of the river, where the thickness is 30-130 feet, than west of the river, where the thickness commonly is 50-100 feet.

Much of the surface in northern Willamette Valley is formed by sandy silt, which in places is 100 feet thick. The principal water-bearing units are sand and gravel along the flood plain, and the Troutdale Formation, which consists of up to 600 feet of stratified mudstone, sandstone, and conglomerate. Bedrock beneath the valley consists of marine and volcanic rocks, including Columbia River Group, which locally is a good aquifer.

Portland Basin was formed by downwarping of the Troutdale Formation, basalt of the Columbia River Group, and older rocks. The surface in the eastern part consists of clayey piedmont deposits and in other areas of bouldery gravel (terrace deposits). The valley fill, which includes these deposits and the underlying Troutdale Formation, ranges from 200 to 1,000 feet in thickness. Principal water-yielding rocks are the alluvium along Columbia River, terrace deposits, Troutdale Formation, and basalt of the Columbia River Group.

Tualatin Valley also is a structural basin formed by downwarping of the Columbia River Group and underlying rocks. The valley fill generally consists of clay to fine sand ranging in thickness from a few feet to 1,500 feet. Principal aquifers are gravel lenses in the valley fill and basalt of the Columbia River Group.

SOILS

Soil properties influence the generation of runoff from rainfall and must be considered, at least indirectly, in methods of runoff estimation. Where runoff from individual storms is the major concern, as for flood prevention, the properties can be represented by a hydrologic parameter: the minimum rate of infiltration obtained for a bare soil after prolonged wetting. The influences of both the surface and the horizon of a soil are thereby included.

Soil properties also play an important part in the recharge of ground water. A sandy soil is particularly favorable to recharge because its high infiltration and transmission rates allow the water to enter and move through the soil. A soil with a high clay content has low infiltration and transmission rates and, therefore, does not allow rapid recharge of ground water.

Soil cover is important to the rainfall-runoff relationship because it determines the relative quantities of water that will run off or will be available for plant use and for ground-water recharge. Soil cover also determines the rate at which runoff will occur.

Photo III-3. *The valley fill in this vertical bank of Willamette River ranges from silt at the top to cemented gravel at the base. Bank, exposed near river mile 55, is about 100 ft high.*

In Willamette Basin, hydrologic soil groups are classified according to their runoff potential. Some of the classification is based on rainfall-runoff data from small watersheds or infiltrometer plots, while other parts of the classification are based on a comparison of soil profiles between classified and unclassified areas. It is assumed that soil surfaces are bare, that maximum swelling has taken place, and that rainfall rates exceed surface-intake rates. Thus, most of the classifications are based on the premise that soils with similar physical properties will respond similarly during a rainstorm of excessive intensity (U.S. Soil Conserv. Service, 1964).

The hydrologic soil groups are defined as follows:

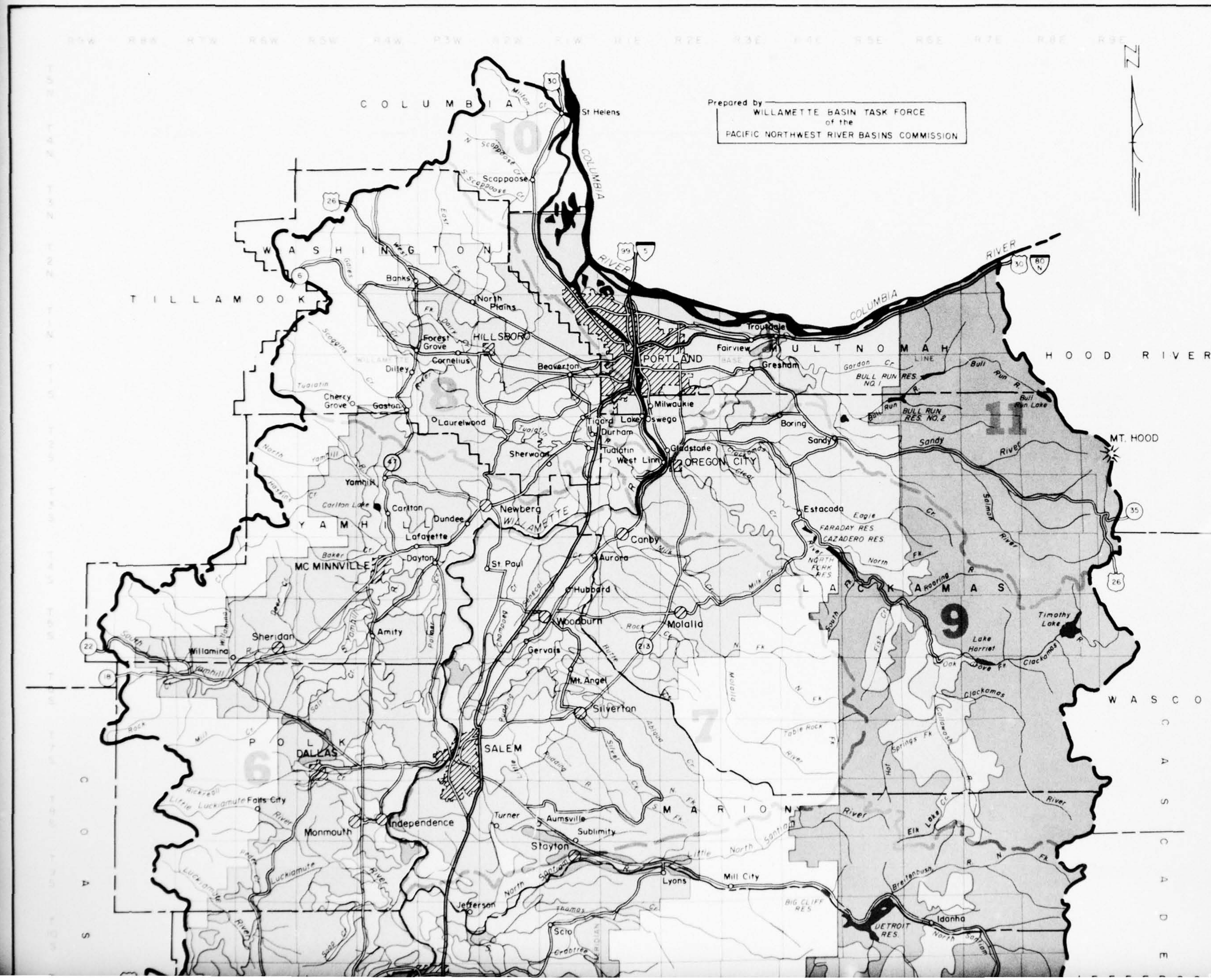
A - Soils with low runoff potential have high infiltration rates even when thoroughly wetted and consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

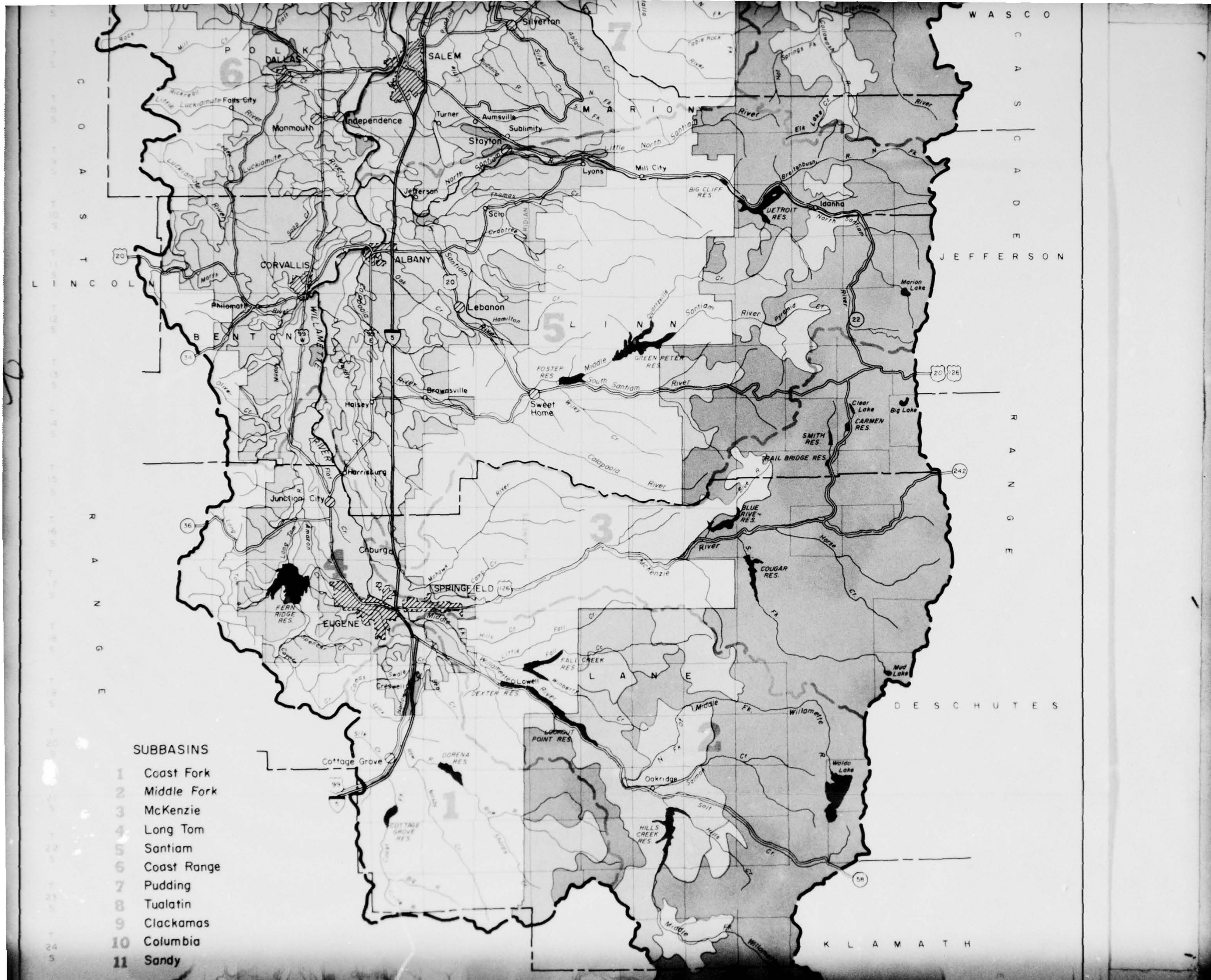
B - Soils having medium infiltration and transmission rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to coarse textures.

C - Soils having slow infiltration and transmission rates 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.

D - Soils with high runoff potential have very slow infiltration and transmission rates when thoroughly wetted and consist chiefly of clay soils with 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.

Map III-1 shows hydrologic soil groups in the basin. Some soils are in the D class because a high water table inhibits drainage. However, if these soils are effectively drained, many can be reclassified locally and placed in the C group.

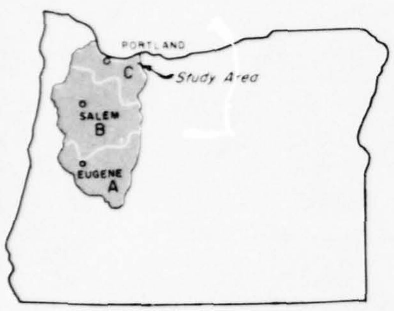

Prepared by
WILLAMETTE BASIN TASK FORCE
of the
PACIFIC NORTHWEST RIVER BASINS COMMISSION
COLUMBIA
WASHINGTON
TILLAMOOK
MULTNOMAH
HOOD RIVER
CLACKAMAS
YAMHILL
POLK
MARION
WASCO
CASCADE
COAST
COLUMBIA RIVER
St Helens
Scappoose
Banks
North Plains
HILLSBORO
Forest Grove
Cornelius
Dilley
Gaston
Cherry Grove
Laurelwood
Beaverton
PORTLAND
Troutdale
Fairview
Gresham
Milwaukie
Lake Oswego
Tigard
Durham
Tualatin
West Linn
Gladstone
OREGON CITY
Sherwood
Boring
Sandy
Estacada
FARADAY RES
CAZADERO RES
NORTH FORK RES
BULL RUN RES. NO. 1
BULL RUN RES. NO. 2
Bull Run Lake
MT. HOOD
Timothy Lake
Lake Harriet
Yamhill
Carlton
Dundee
Newberg
Lafayette
Dayton
MC MINNVILLE
St Paul
Canby
Aurora
Hubbard
Woodburn
Molalla
Gervais
Mt. Angel
Silverton
Amity
Sheridan
Willamina
DALLAS
SALEM
Falls City
Monmouth
Independence
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Jefferson
Scio
BIG CLIFF RES
DETROIT RES.
Idanha
WILLAMETTE
Sandy River
Salmon River
Clackamas
Molalla
North Santiam
Little North Santiam
Breitenbush
Luckiamute
Yamhill
Tualatin
Pudding
10
11
9
8
7
6



SUBBASINS
1 Coast Fork
2 Middle Fork
3 McKenzie
4 Long Tom
5 Santiam
6 Coast Range
7 Pudding
8 Tualatin
9 Clackamas
10 Columbia
11 Sandy
COAST RANGE
CASCADE RANGE
LINCOLN
POLK
MARION
LINN
BENTON
LANE
WASCO
JEFFERSON
DESCHUTES
KLAMATH
SALEM
Silverton
DALLAS
Independence
Monmouth
Falls City
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Idanha
Jefferson
Scio
ALBANY
CORVALLIS
Lebanon
Philomath
Brownsville
Halsey
Sweet Home
Harrisburg
Junction City
Coburg
SPRINGFIELD
EUGENE
Lowell
Creswell
Cottage Grove
Oakridge
WILLAMETTE RIVER
DETROIT RES.
BIG CLIFF RES
GREEN PETER RES
FOSTER RES
SMITH RES.
CARMEN RES.
TRAIL BRIDGE RES.
BLUE RIVER RES.
COUGAR RES.
FERN RIDGE RES.
FALL CREEK RES
DEXTER RES
LOOKOUT POINT RES.
DORENA RES
COTTAGE GROVE RES
HILLS CREEK RES
Marion Lake
Clear Lake
Big Lake
Mud Lake
Waldo Lake

SUBBASINS

1 Coast Fork
2 Middle Fork
3 McKenzie
4 Long Tom
5 Santiam
6 Coast Range
7 Pudding
8 Tualatin
9 Clackamas
10 Columbia
11 Sandy



SUBAREAS

A Upper
B Middle
C Lower

EXPLANATION

Soils having moderate infiltration and transmission rates when thoroughly wetted. They consist chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to coarse textures.

Soils having high runoff potential and very slow infiltration and transmission rates when thoroughly wetted. They consist chiefly of clay soils with 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 overlying nearly impervious material.

Soils having low runoff potential. They have high infiltration rates even when thoroughly wetted and have a high rate of water transmission. They consist chiefly of deep, well to excessively drained sands or gravels.

Soils having slow infiltration and transmission rates when thoroughly wetted. They consist chiefly of soils with a layer that impedes downward movement of water, or of soils with moderately fine to fine texture.

Unknown soil groups

MAP III-1

WILLAMETTE BASIN STUDY

OREGON

HYDROLOGIC SOIL GROUPS

1968

6 0 6 12
SCALE IN MILES

WBTF-0-1073abc-LL

THE WATER RESOURCE

THE WATER RESOURCE

Water on the earth circulates continually--from the sea to the air to the land and back to the sea (Figure IV-1). This system, called the hydrologic cycle, is kept in motion by energy from the sun and by the earth's gravity. Water evaporates from the oceans, lakes, rivers, and wet ground surface and is also transpired by plants. Within the atmosphere, it is carried along as vapor in airmasses and currents until cooling causes the vapor to condense into droplets and fall as rain or snow. As it falls through the air, some of the moisture evaporates and some is intercepted by vegetation. Water that reaches the surface evaporates, infiltrates the ground, or runs off to enter streams. Water that infiltrates the ground evaporates, is absorbed by plant roots and transpired, or percolates downward to ground-water reservoirs. Part of the water that enters the ground may move laterally to be discharged at the land surface as springs or seeps, or may flow directly into streams or oceans. Some of the water that runs off the surface may accumulate in lakes and surface reservoirs, some may be lost by evaporation or transpiration by marsh or riparian vegetation, some may seep downward into ground-water reservoirs, and some may continue to the oceans.

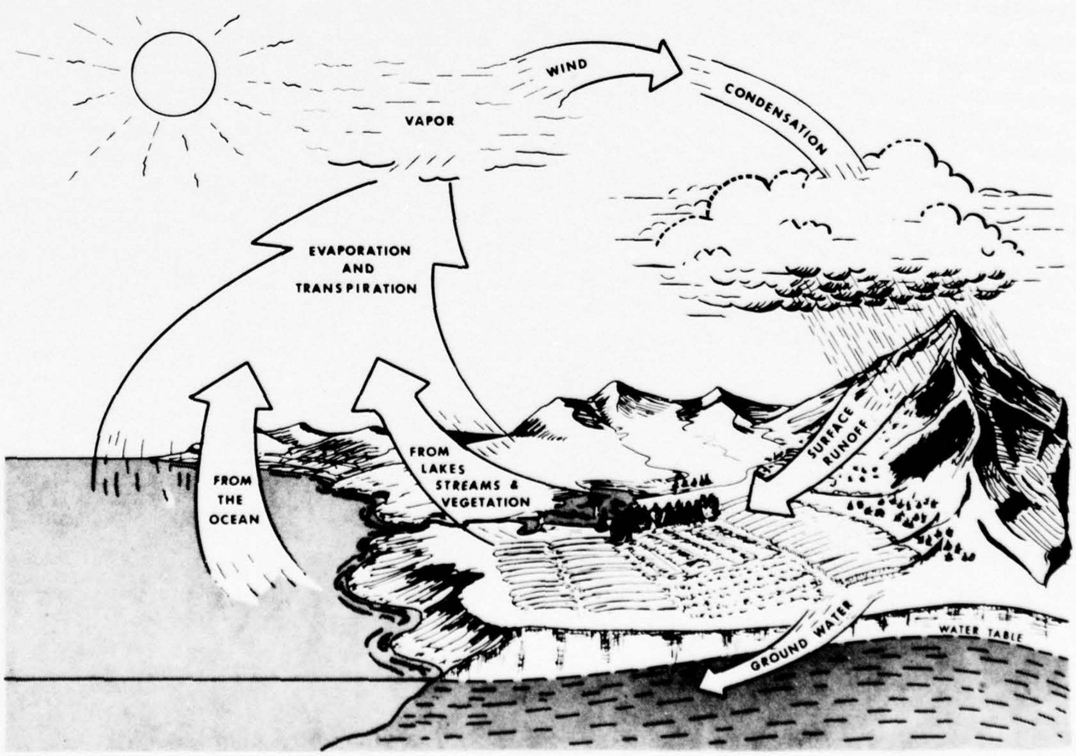


Figure IV-1. The hydrologic cycle.

Within the hydrologic cycle, the sea functions as the ultimate reservoir. Solar energy, air movement, and gravity are the forces that cause movement; the soils and the rocks are the regulators; and the stream systems are the overflow conduits. The cycle is governed by a series of priorities, of which evaporation is first, infiltration next, and overland runoff last. There is no overland runoff where and when precipitation falls slowly enough to be absorbed into the ground. When precipitation is at a faster rate, part of it runs off the land surface; and when the rate is great enough, floods may occur.

Moisture-laden airmasses drift into Willamette Basin from the Pacific Ocean. As these airmasses rise over the Coast and Cascade Ranges, the moisture is precipitated as rain or snow. Much of the mountain area is forested, and the trees intercept sizable amounts of precipitation. Because the permeability of the soil and rocks varies considerably within the basin, precipitation infiltrates much more rapidly at some places than others. Consequently, runoff will occur from lower rates of precipitation at some places than at others.

The following description of the water resources of the basin is based on the available data. Because data-collection points are not evenly distributed over the basin, much more information is available for some areas than others. Also, because certain data-collection programs have been in operation longer and are more comprehensive than others, it is possible to describe some facets of the water resources in more detail than others. Streamflow data are reasonably adequate for major streams but additional data, particularly low-flow data, are needed on the small streams. The time of travel of water has been measured for several of the principal tributaries of the Willamette at low, medium, and high flows. Time-of-travel data are not available for Sandy, Clackamas, and Molalla Rivers, for most Coast Range streams, nor for small streams. Stream-temperature data are adequate for only a part of the basin. Detailed ground-water studies have been made for about 15 percent of the basin, principally in valley areas. Few data have been obtained on the sediment yield of streams. Data on the chemical quality of water are adequate for only a general description of the quality of the surface and ground water.

S U R F A C E   W A T E R

QUANTITY OF STREAMFLOW

This section depicts the quantity of runoff (streamflow that is unaffected by regulation or diversion) in Willamette Basin. It is in two parts, "Patterns of Runoff" describing the basinwide distribution of average annual runoff, and "Concordant Flows for River Channels" describing selected flows along the courses of the major rivers and tributaries in the basin. Separate descriptions are needed because of the difficulty in depicting basinwide and local variation simultaneously.

Streamflow data are available from more than 230 sites in the basin. Map IV-1 shows the locations of 110 stations for which five years or more of daily discharge records are available, and the period of record at each station is shown graphically in Figure IV-2.

Patterns of Runoff

Runoff is defined as the part of the precipitation that appears in surface streams that are not regulated. Quantitatively, runoff can be expressed for a given basin for a given time period by the equation:

$$\text{Runoff} = \text{Precipitation} - (\text{losses} \pm \text{change in storage}),$$

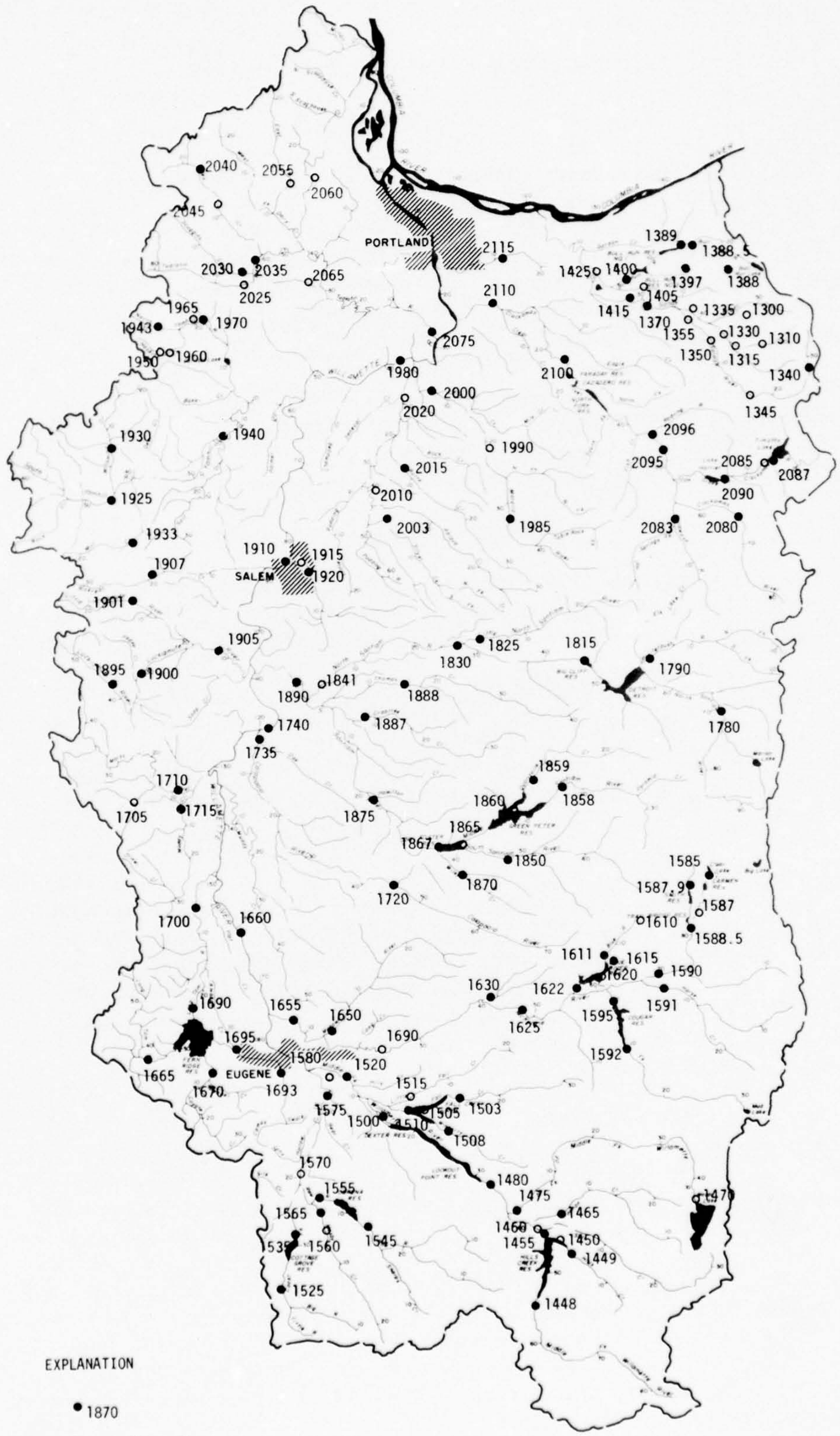
where:

> losses include the sum of all natural losses, and change in storage is the total change in storage within the basin during the period.

Map IV-2 portrays the areal distribution of average annual runoff, in inches, in the study area (Willamette River and Sandy River Basins). On the map, runoff is expressed by isograms (lines that connect points of equal runoff). The value of the isogram which crosses a stream does not represent the runoff of the stream at that point. Rather, the runoff at any point on a stream is the cumulative total runoff from all the drainage area above that point. The runoff from a basin is the average, weighted by area, of the runoffs from the incremental areas of that basin.

The pattern of average annual runoff follows closely the pattern of average annual precipitation. Runoff is large along the Coast Range, uniformly small along the floor of Willamette Valley, and large with local variations along the western slope of the Cascade Range.

Runoff varies considerably from season to season and from year to year. The term "average annual runoff" means the average of many years of runoff. The data used in the preparation of Map IV-2 were based on the period 1928-1963. A brief study of several long-term streamflow records shows that during the period 1928-1963 the periods of excessive streamflow nearly balanced the periods of deficient streamflow (Table IV-1).



EXPLANATION

• 1870

Active gaging-station site and station number

○ 1776

Discontinued gaging-station site and station number

MAP IV-1

WILLAMETTE BASIN STUDY

OREGON

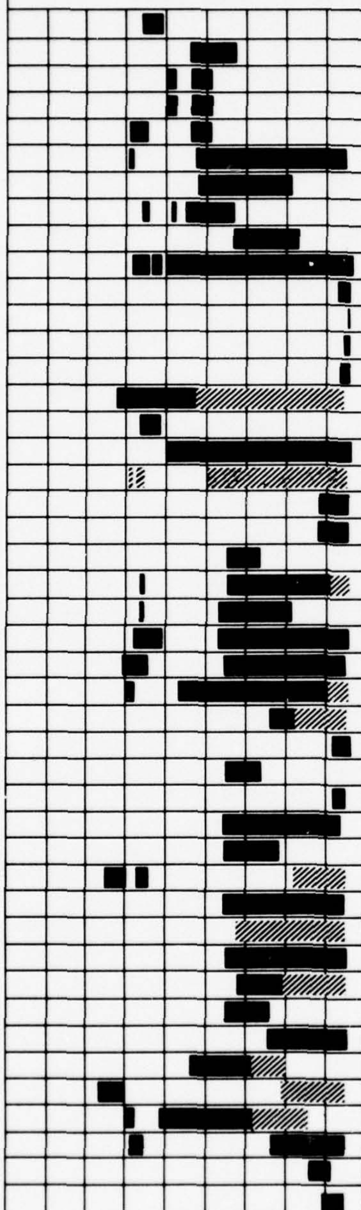
STREAM-GAGING STATIONS

1968

SCALE IN MILES

Complete water and/or climatic years of record

1890 1900 1910 1920 1930 1940 1950 1960



Part 14 Station number	Gaging-station name	Drainage area Sq. Mi.
1300	Lost Creek near Brightwood	11.2
1310	Little Zigzag River at Twin Bridges near Rhododendron	3.7
1315	Zigzag River at Rhododendron	31
1330	Still Creek at Rhododendron	23
1335	Sandy River above Salmon River, at Brightwood	117
1340	Salmon River near Government Camp	8.7
1345	Salmon River below Linney Creek	54
1350	Salmon River at Welches	100
1355	Salmon River above Boulder Creek, near Brightwood	106
1370	Sandy River near Marmot	262
1388	Blazed Alder Creek near Rhododendron	8.17
1388.5	Bull Run River near Multnomah Falls	47.9
1389	North Fork Bull Run River near Multnomah Falls	8.32
1397	Cedar Creek near Brightwood	7.93
1400	Bull Run River near Bull Run	107
1405	Little Sandy River near Marmot	17.9
1415	Little Sandy River near Bull Run	22.3
1425	Sandy River below Bull Run River, near Bull Run	440
1448	Middle Fork Willamette River near Oakridge	258
1449	Hills Creek above Hills Creek Reservoir, near Oakridge	52.7
1450	Hills Creek near Oakridge	59
1455	Middle Fork Willamette River above Salt Creek, nr. Oakridge	392
1460	Salt Creek near Oakridge	113
1465	Salmon Creek near Oakridge	117
1475	North Fork of Middle Fork Willamette River near Oakridge	246
1480	Middle Fork Willamette River below North Fork nr. Oakridge	924
1500	Middle Fork Willamette River near Dexter	1,001
1503	Fall Creek near Lowell	118
1505	Fall Creek above Winberry Creek, near Lowell	127
1508	Winberry Creek near Lowell	439
1510	Fall Creek below Winberry Creek, near Fall Creek	186
1515	Little Fall Creek near Fall Creek	52.5
1520	Middle Fork Willamette River at Jasper	1,340
1525	Coast Fork Willamette River at London	72.1
1535	Coast Fork Willamette River below Cottage Grove Dam	104
1545	Row River above Pitcher Creek near Dorena	211
1555	Row River near Cottage Grove	270
1560	Mosby Creek near Cottage Grove	85
1565	Mosby Creek at mouth, near Cottage Grove	95.3
1570	Coast Fork Willamette River at Saginaw	529
1575	Coast Fork Willamette River near Goshen	642
1580	Willamette River at Springfield	2,030
1585	McKenzie River at outlet of Clear Lake	92.4
1587	McKenzie River near Belknap Springs	146
1587.9	Smith River above Smith River Reservoir, nr. Belknap Springs	16.2

Legend:
- Black bar: (Natural) Flow not appreciably affected by regulation or diversion
- Hatched bar: Appreciable flow regulation or diversion

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	Drainage area Sq. Mi.
	11.2
r Rhododendron	3.7
	31
	23
ghtwood	117
	8.7
	54
	100
Brightwood	106
	262
	8.17
	47.9
h Falls	8.32
	7.93
	107
	17.9
	22.3
Bull Run	440
idge	258
r, near Oakridge	52.7
	59
t Creek, nr. Oakridge	392
	113
	117
iver near Oakridge	246
th Fork nr. Oakridge	924
er	1,001
	118
Lowell	127
	439
Fall Creek	186
	52.5
	1,340
	72.1
ge Grove Dam	104
ena	211
	270
	85
ve	95.3
	529
n	642
	2,030
	92.4
	146
r, nr. Belknap Springs	16.2

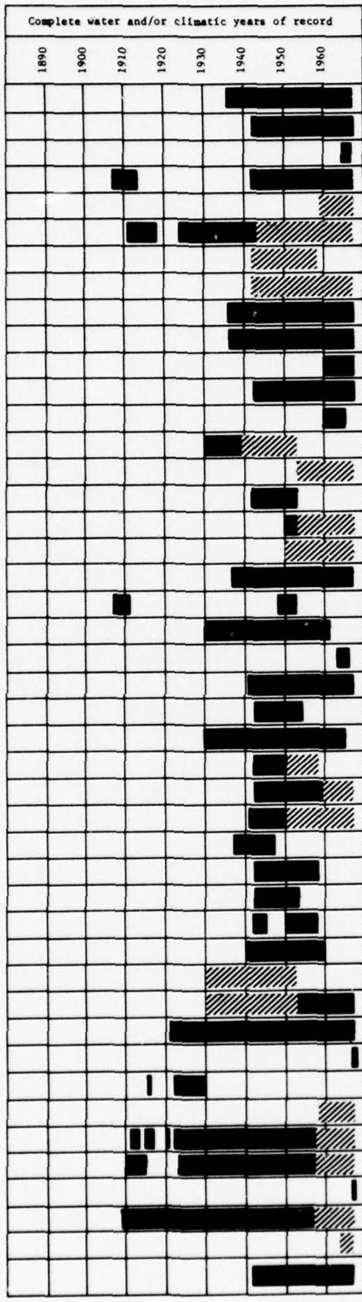
tion or diversion

Complete water and/or climatic years of record (1890, 1900, 1910, 1920, 1930, 1940, 1950, 1960)	Part 14 Station number	Gaging-station name	Drainage area Sq. Mi.
	1588.5	McKenzie River below Trail Bridge Dam, nr. Belknap Springs	184
	1590	McKenzie River at McKenzie Bridge	348
	1591	Horse Creek near McKenzie Bridge	149
	1592	South Fork McKenzie River above Cougar Reservoir, nr. Rainbow	160
	1595	South Fork McKenzie River near Rainbow	208
	1610	Blue River above Quentin Creek	11.5
	1611	Blue River below Tidbits Creek, near Blue River	45.8
	1615	Lookout Creek near Blue River	24.1
	1620	Blue River near Blue River	75.0
	1622	Blue River at Blue River	87.7
	1625	McKenzie River near Vida	930
	1630	Gate Creek at Vida	47.6
	1640	McKenzie River near Springfield	1,095
	1650	Mohawk River near Springfield	177
	1655	McKenzie River near Coburg	1,337
	1660	Willamette River at Harrisburg	3,420
	1665	Long Tom River near Noti	89.3
	1670	Coyote Creek near Crow	95.1
	1690	Long Tom River near Alvadore	252
	1693	Amazon Creek at Eugene	3.35
	1695	Amazon Creek near Eugene	21.3
	1700	Long Tom River at Monroe	391
	1705	Rock Creek near Philomath	14.6
	1710	Marys River near Philomath	159
	1715	Muddy Creek near Corvallis	107
	1720	Calapooia River at Holley	105
	1735	Calapooia River at Albany	372
	1740	Willamette River at Albany	4,840
	1780	North Santiam River below Boulder Creek, near Detroit	216
	1790	Breitenbush River above Canyon Creek near Detroit	106
	1815	North Santiam River at Niagara	453
	1825	Little North Santiam River near Mehama	110
	1830	North Santiam River at Mehama	665
	1841	North Santiam River near Jefferson	736
	1850	South Santiam River below Cascadia	174
	1858	Middle Santiam River near Cascadia	104
	1859	Quartzville Creek near Cascadia	99.2
	1860	Middle Santiam River near Foster	271
	1865	Middle Santiam River at mouth, near Foster	287
	1867	South Santiam River at Foster	493
	1870	Wiley Creek near Foster	52.3
	1875	South Santiam River at Waterloo	640
	1887	Crabtree Creek near Crabtree	111
	1888	Thomas Creek near Scio	109
	1890	Santiam River at Jefferson	1,790

Complete water and/or climatic years of rec							
1890	1900	1910	1920	1930	1940	1950	

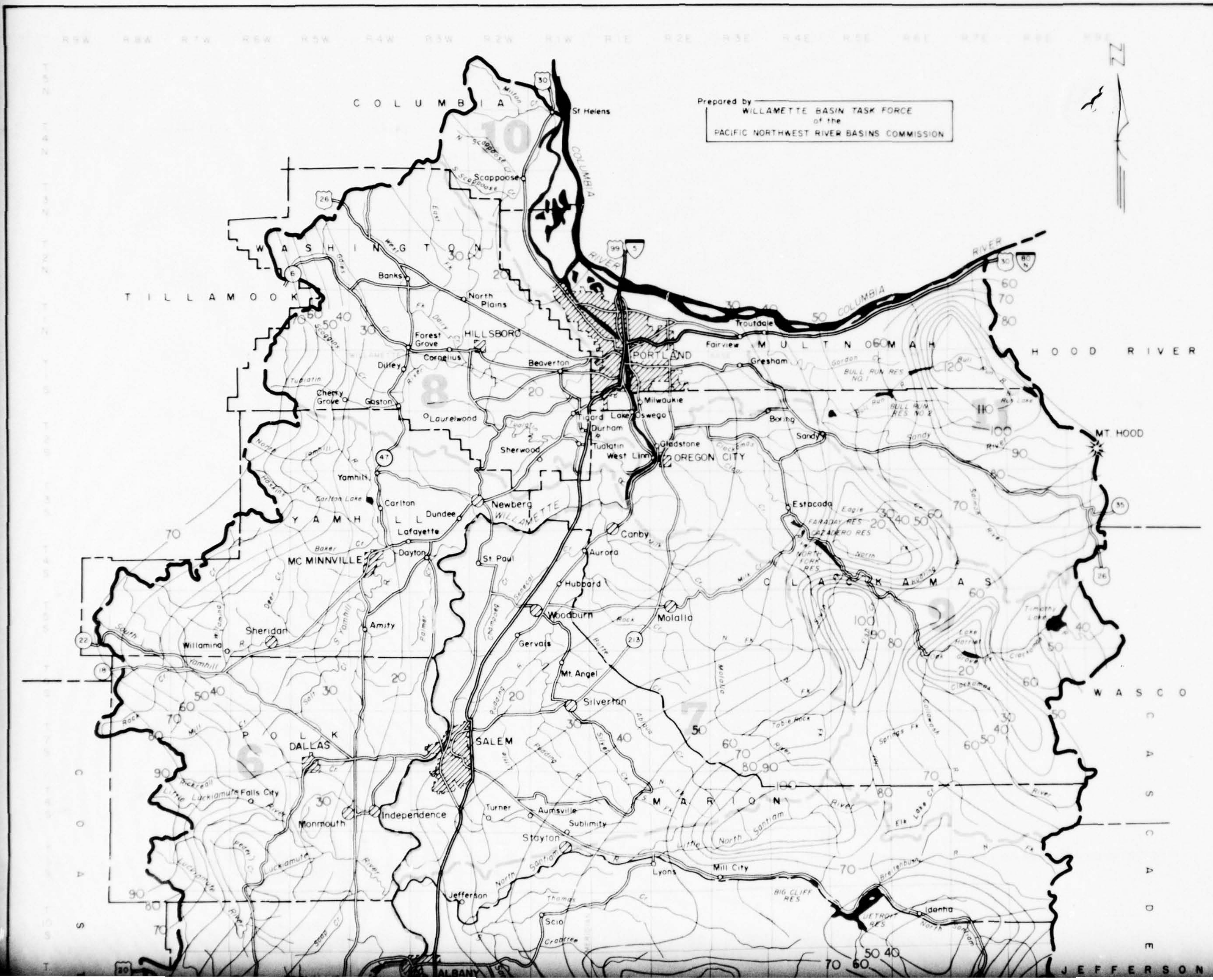
Figure

g-station name	Drainage area Sq. Mi.
Trail Bridge Dam, nr. Belknap Springs	184
Kenzie Bridge	348
enzie Bridge	149
River above Cougar Reservoir, nr. Rainbow	160
River near Rainbow	208
ntin Creek	11.5
bits Creek, near Blue River	45.8
lue River	24.1
River	75.0
iver	87.7
Vida	930
	47.6
Springfield	1,095
pringfield	177
Coburg	1,337
Harrisburg	3,420
Noti	89.3
row	95.1
Alvadore	252
ene	3.35
ugene	21.3
onroe	391
lomath	14.6
ilomath	159
rvallis	107
Holley	105
Albany	372
Albany	4,840
r below Boulder Creek, near Detroit	216
above Canyon Creek near Detroit	106
r at Niagara	453
River near Mehama	110
r at Mehama	665
r near Jefferson	736
r below Cascadia	174
r near Cascadia	104
near Cascadia	99.2
r near Foster	271
r at mouth, near Foster	287
r at Foster	493
ster	52.3
r at Waterloo	640
r Crabtree	111
cio	109
fferson	1,790

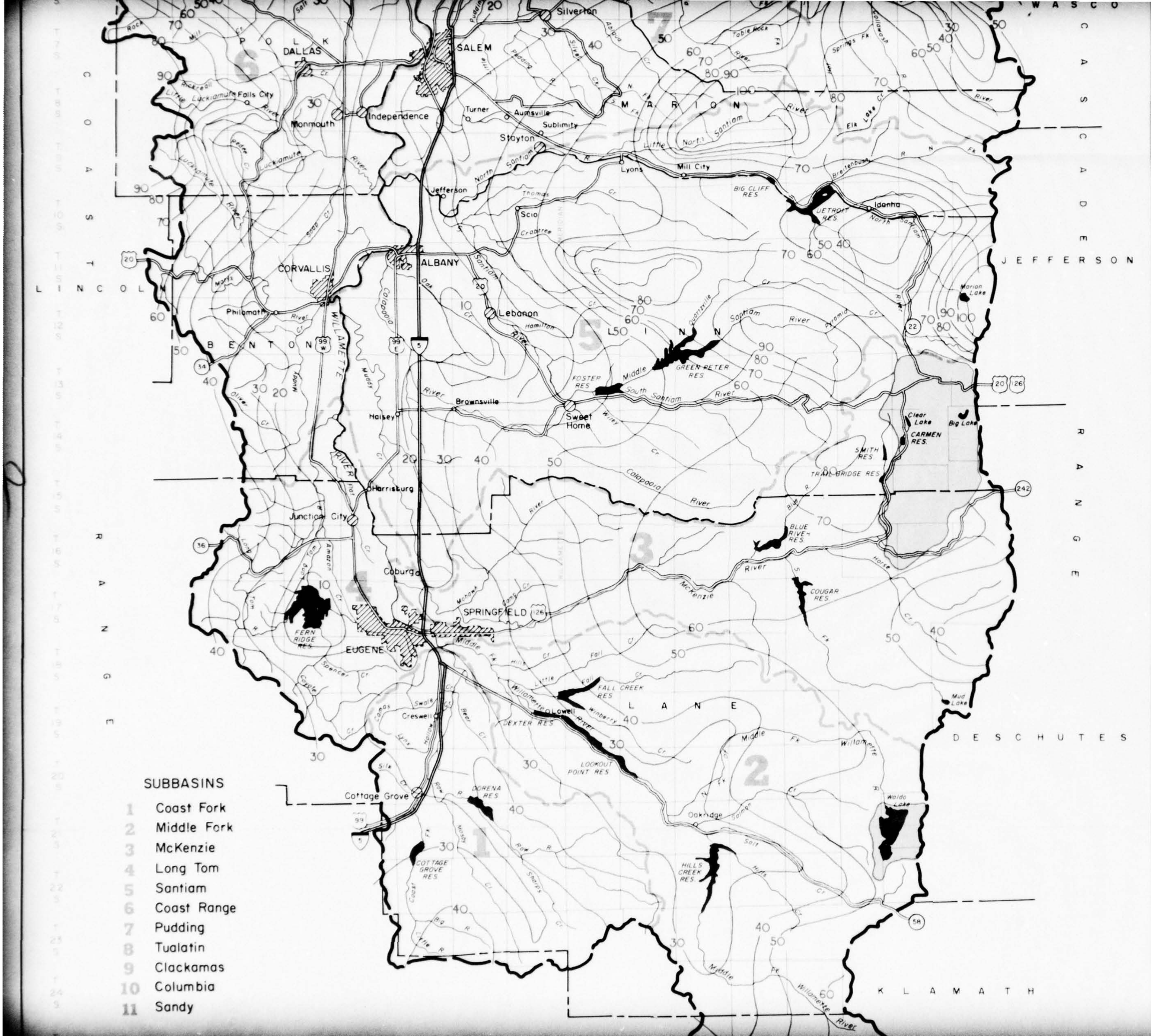


Part 14 Station number	Gaging-station name	Drainage area Sq. Mi.
1895	Luckiamute River near Hoskins	34.3
1900	Luckiamute River at Pedee	115
1901	Little Luckiamute River at Fall City	22.7
1905	Luckiamute River near Suver	240
1907	Rickreall Creek near Dallas	27.4
1910	Willamette River at Salem	7,280
1915	Mill Creek at penitentiary annex, near Salem	104
1920	Mill Creek at Salem	110
1925	South Yamhill River near Willamina	133
1930	Willamina Creek near Willamina	64.7
1933	Mill Creek near Willamina	27.4
1940	South Yamhill River near Whiteson	502
1943	North Yamhill River near Fairdale	9.03
1950	Haskins Creek near McMinnville	6.7
1960	Haskins Creek below reservoir, near McMinnville	6.9
1965	North Yamhill River near Pike	47.8
1970	North Yamhill River at Pike	66.8
1980	Willamette River at Wilsonville	8,400
1985	Molalla River above Pine Creek, near Wilhoit	97.0
1990	Molalla River near Molalla	201
2000	Molalla River near Canby	323
2003	Silver Creek at Silverton	47.9
2010	Pudding River near Mount Angel	204
2015	Butte Creek at Monitor	58.7
2020	Pudding River at Aurora	479
2025	*Tualatin River at Gaston*	51.0
2030	Scoggin Creek near Gaston	43.3
2035	Tualatin River near Dilley	133
2040	Gales Creek near Gales Creek	33.9
2045	Gales Creek near Forest Grove	67.2
2055	East Fork Dairy Creek at Mountaindale	43.0
2060	McKay Creek near North Plains	27.6
2065	Tualatin River at Farmington	568
2070	Oswego Canal near Lake Oswego	-
2075	Tualatin River at West Linn	710
2080	Clackamas River at Big Bottom	136
2083	Collawash River near Breitenbush	142
2085	Oak Grove Fork at Timothy Meadows	52
2087	Oak Grove Fork near Government Camp	53
2090	Oak Grove Fork above powerplant intake	126
2095	Clackamas River above Three Lynx Creek	479
2096	Roaring River near Estacada	42.4
2100	Clackamas River at Estacada	671
2110	Clackamas River near Clackamas	936
2115	Johnson Creek at Sycamore	28.2

Figure IV-2. Gaging stations and years of records.

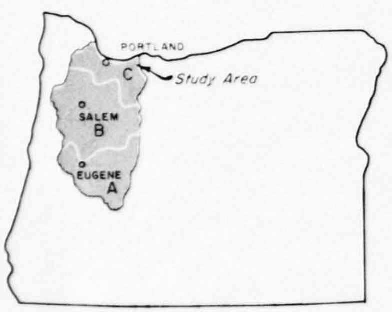


Prepared by
WILLAMETTE BASIN TASK FORCE
of the
PACIFIC NORTHWEST RIVER BASINS COMMISSION
COLUMBIA
WASHINGTON
TILLAMOOK
YAMHILL
POLK
MARION
CLACKAMAS
MULTNOMAH
HOOD RIVER
WASCO
CASCADE
COAST
JEFFERSON
PORTLAND
SALEM
OREGON CITY
HILLSBORO
MC MINNVILLE
DALLAS
MT. HOOD
St Helens
Scappoose
Banks
North Plains
Forest Grove
Cornelius
Beaverton
Dufey
Gaston
Cherry Grove
Laurelwood
Tigard
Lake Oswego
Milwaukie
Durham
Tualatin
Sherwood
West Linn
Gladstone
Troutdale
Fairview
Gresham
Boring
Sandy
Estacada
Yamhill
Carlton
Dundee
Newberg
Lafayette
Dayton
St Paul
Canby
Aurora
Hubbard
Woodburn
Molalla
Gervais
Mt. Angel
Silverton
Amity
Sheridan
Willamina
Falls City
Monmouth
Independence
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Jefferson
Scio
Idanha
ALBANY
COLUMBIA RIVER
WILLAMETTE
BULL RUN RES NO.1
BULL RUN RES. NO. 2
FARADAY RES
ESTACADA RES
NORTH FORK RES
BIG CLIFF RES
DETROIT RES
Timothy Lake


SUBBASINS
1 Coast Fork
2 Middle Fork
3 McKenzie
4 Long Tom
5 Santiam
6 Coast Range
7 Pudding
8 Tualatin
9 Clackamas
10 Columbia
11 Sandy
CASCADE RANGE
COAST RANGE
JEFFERSON
DESCHUTES
KLAMATH
WASCO
LINCOLN
POLK
MARION
LINN
BENTON
LANE
SALEM
DALLAS
Silverton
Independence
Monmouth
Falls City
Turner
Aumsville
Sublimity
Stayton
Lyons
Mill City
Idanha
Jefferson
Scio
ALBANY
CORVALLIS
Philomath
Lebanon
Brownsville
Halsey
Sweet Home
Harrisburg
Junction City
Coburg
SPRINGFIELD
EUGENE
Creswell
Lowell
Oakridge
Cottage Grove
BIG CLIFF RES
DETROIT RES
GREEN PETER RES
FOSTER RES
SMITH RES
TRAIL BRIDGE RES
CARMEN RES.
Clear Lake
Big Lake
Marion Lake
BLUE RIVER RES
COUGAR RES
FALL CREEK RES
DEXTER RES
LOOKOUT POINT RES
HILLS CREEK RES
DORENA RES
COTTAGE GROVE RES
FERN RIDGE RES
Waldo Lake
Mud Lake
WILLAMETTE RIVER

SUBBASINS

1 Coast Fork
2 Middle Fork
3 McKenzie
4 Long Tom
5 Santiam
6 Coast Range
7 Pudding
8 Tualatin
9 Clackamas
10 Columbia
11 Sandy



SUBAREAS

A Upper
B Middle
C Lower

EXPLANATION

—30— Line of equal average annual runoff, Interval, 10 inches

Areas where annual runoff is not defined because hydrologic and topographic boundaries do not correspond

MAP IV-2

WILLAMETTE BASIN STUDY

OREGON

PATTERNS OF RUNOFF

1968

6 0 6 12
SCALE IN MILES

WBTF-O-1075abc-LL

Table IV-1

Average annual runoff of selected streams, 1928-63

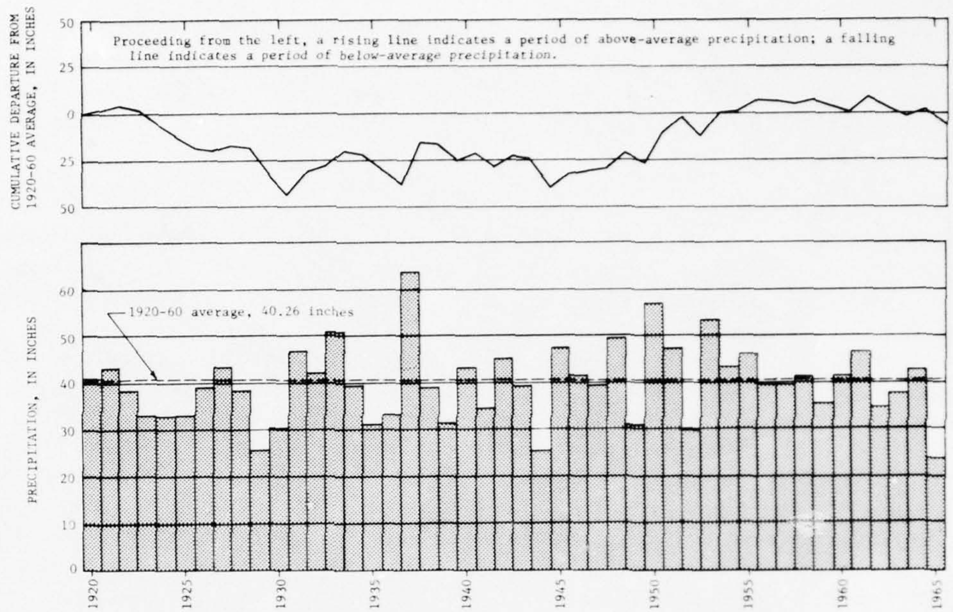
Streams	Drainage area (sq mi)	Average annual runoff (Cfs)	Average annual runoff (Acre-ft)	Average annual runoff (Inches)
Sandy River below Bull Run River	440	2,480	1,800,000	77
Middle Fork Willamette River at Jasper	1,340	3,970	2,870,000	40
Coast Fork Willamette River near Goshen	642	1,680	1,220,000	35
Willamette River at Springfield	2,030	5,780	4,180,000	39
McKenzie River near Coburg	1,337	5,400	3,910,000	55
Willamette River at Harrisburg	3,420	1/11,600	8,400,000	46
Long Tom River at Monroe	391	780	565,000	27
Marys River near Philomath	159	460	333,000	39
Calapooia River at Albany	372	910	659,000	33
Willamette River at Albany	4,840	14,400	10,400,000	40
Santiam River at Jefferson	1,790	1/8,200	5,940,000	62
Luckiamute River near Suver	240	880	637,000	50
Rickreall Creek near Dallas	27.4	130	94,000	64
Willamette River at Salem	7,280	23,500	17,000,000	44
Yamhill River at Lafayette	735	1/2,250	1,630,000	42
Willamette River at Wilsonville	8,400	26,100	18,900,000	42
Molalla River near Canby	323	1,130	818,000	48
Pudding River at Aurora	479	1,220	883,000	34
Tualatin River at West Linn	710	1,490	1,080,000	28
Clackamas River near Clackamas	936	3,700	2,680,000	54
Willamette River at Portland	11,100	1/33,000	23,900,000	40

1/ *Approximate.*

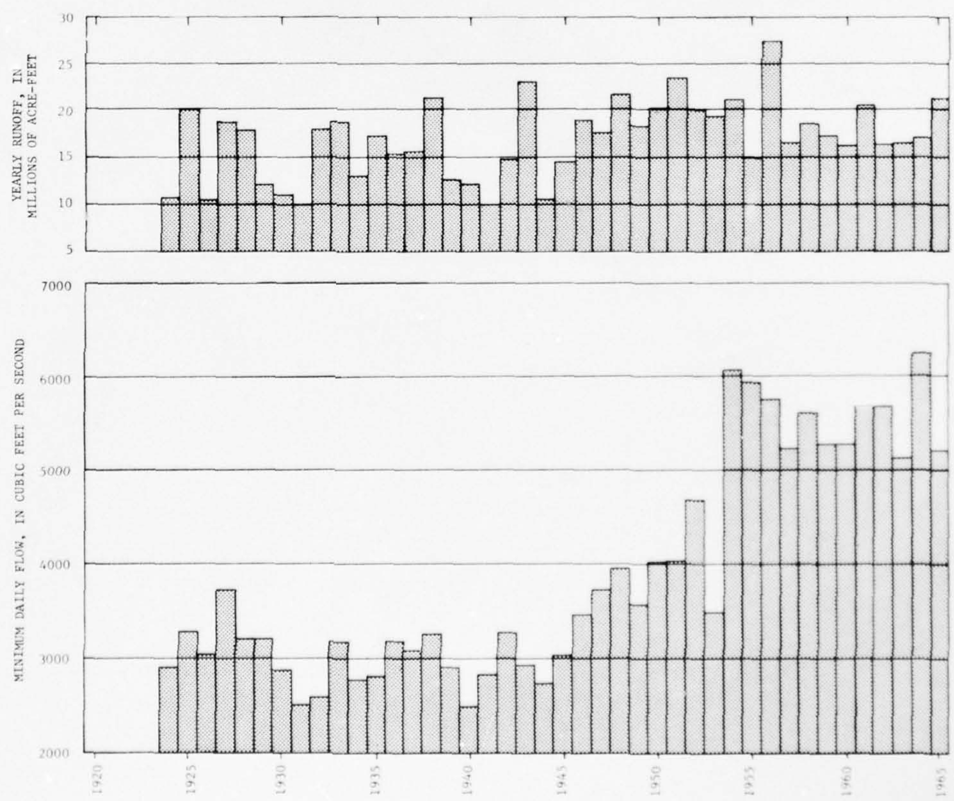
Photo IV-1. Measuring streamflow from a cableway, Long Tom River at Monroe, Oregon.

Streamflow in the Pacific Northwest has historically followed trends with long periods of abundance or deficiency. Records of streams indicate a trend in the past 20 years (1946-1965) toward above-average yearly runoff and higher-than-average minimum flows; precipitation during the last 20 years has also been above the long-term average (Figure IV-3). Figure IV-3 also shows the range of lowest daily discharge for Willamette River at Salem for each water year from 1925 to 1965 and the yearly runoff for the same period. For the period 1925-1945, the yearly runoff averaged 15 million acre-feet and the average minimum flow was in the range of 3,000-3,500 cfs (cubic feet per second). For the period 1946-1965, the average yearly runoff was more than 19 million acre-feet and the average minimum flow range was 4,000-4,500 cfs.

The higher low flows over the past 20 years are not entirely the result of larger yearly runoff. Most of the large reservoirs in the basin were constructed during that period, and the resultant regulation of flow has affected the low-flow regimen of the streams. Figure IV-4 is a plot of the mean monthly discharge during September (a low-flow period) of Middle Fork Willamette River both above and below Lookout Point Reservoir. Prior to construction of the reservoir, the flow at the two points was nearly the same, but since the regulation began in 1954, the mean September discharge at the lower point has averaged more than twice that above the reservoir.



A.--Average annual precipitation and cumulative departure at Salem, 1920-1965.



B.--Yearly runoff and minimum daily flow of Willamette River at Salem, 1925-1965.

Figure IV-3. Precipitation and Willamette River runoff at Salem.

Because of the regulation of streamflow by reservoir operation, future annual low flows probably will be higher than the long-term average. Yearly runoff, however, will follow the precipitation pattern, and the 1946-1965 period of high runoff undoubtedly will be balanced by later years of low runoff.

At places, recorded values of runoff between adjacent areas are not consistent with expected values because geologic conditions permit an interchange between surface water and ground water. In the young lava formations of the High Cascades, the hydrologic drainage boundaries may be considerably different from the topographic basin boundaries. Values of runoff based on the topographic drainage area alone are not applicable in such areas. For example, Anderson Creek near Belknap Springs has an average annual runoff of 51 inches from 7.13 square miles of drainage area. Adjacent to Anderson Creek is Olallie Creek, which has an average runoff of 261 inches from 8.14 square miles. A contrasting pattern prevails where a reach of stream is losing water to the ground-water body. Examples are Coyote Creek and Long Tom River in the vicinity of Fern Ridge Reservoir. For that area, expected runoff is greater than actual runoff measured in the stream channel.

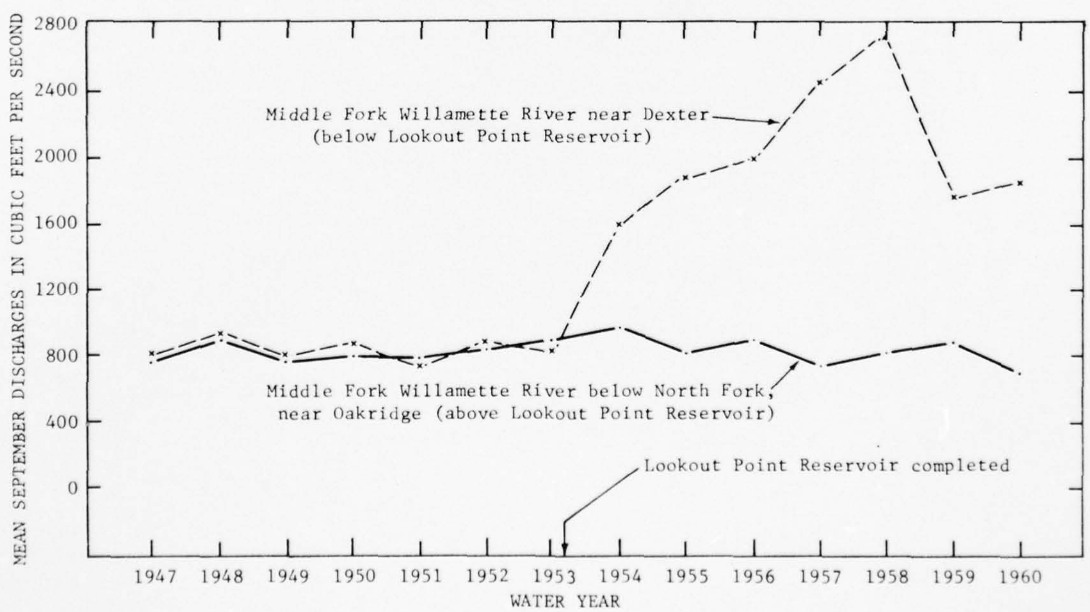


Figure IV-4. Mean September discharge of Middle Fork Willamette River above and below Lookout Point Reservoir.

Concordant Flows for River Channels

The objective of this section is to show the amount and variability of unregulated and undiverted streamflow in the basin by depicting selected discharges along the courses of the major streams. In this presentation, the selected discharges are referred to as concordant flows. Concordant flows are flows that have the same recurrence interval, or the same average frequency of occurrence, at different points in a river system.

A concordant flow may be portrayed by means of a graph that shows discharge, by river miles, for a selected recurrence interval. The number of graphs that can be presented and the number of streams for which they are presented are limited by the amount of data available and by the methods used to analyze those data.

Data for Concordant Flows

Streamflow data are collected at stream-gaging stations for which continuous records of daily mean, monthly mean, and yearly mean and peak discharges are computed. Tables of these data are published by the U. S. Geological Survey in water-supply papers. A hydrograph is a chronological plot of mean daily discharge taken from these records. The hydrograph illustrated in Figure IV-5(A) for South Santiam River is very similar in shape to hydrographs of other streams in Willamette Basin for the period shown. It is also typical, except in magnitude, of the general seasonal distribution of flows for most years. Variation in the magnitude of annual flows may be shown by chronological arrays, such as those shown for South Santiam River in Figure IV-5(B), which are typical of the time pattern of annual flows for Willamette Basin streams. A plot of annual discharges, arranged in order of magnitude, against computed recurrence intervals is a frequency graph as in Figure IV-5(C). It is from frequency graphs that concurrent flows are derived.

A common period of years provides an equivalent basis for comparing and analyzing data for concordant flows. The period 1928-1963 was chosen for average flows on the basis of a study of the length of gaging-station records in the basin. The 1928-1963 period was also chosen for low flows, determined for gaging stations from annual low-flow summaries (Swift, 1966). Floodflows were determined for the period 1912-1957 because data for that period were already available (Hulsing and Kallio, 1964). Differences between discharges for selected recurrence intervals due to differences between data for the two periods 1912-1957 and 1928-1963 are considered to be small.

Concordant-Flow Graphs

Graphs of concordant flow are shown for the major streams and for some smaller streams in Figures IV-6 through IV-21. Graphs for the Willamette River are shown in Figures IV-6 and IV-7. Those for the principal tributaries of Willamette River and for Sandy River follow in numerical sequence of the subbasins as indicated on Map IV-2.

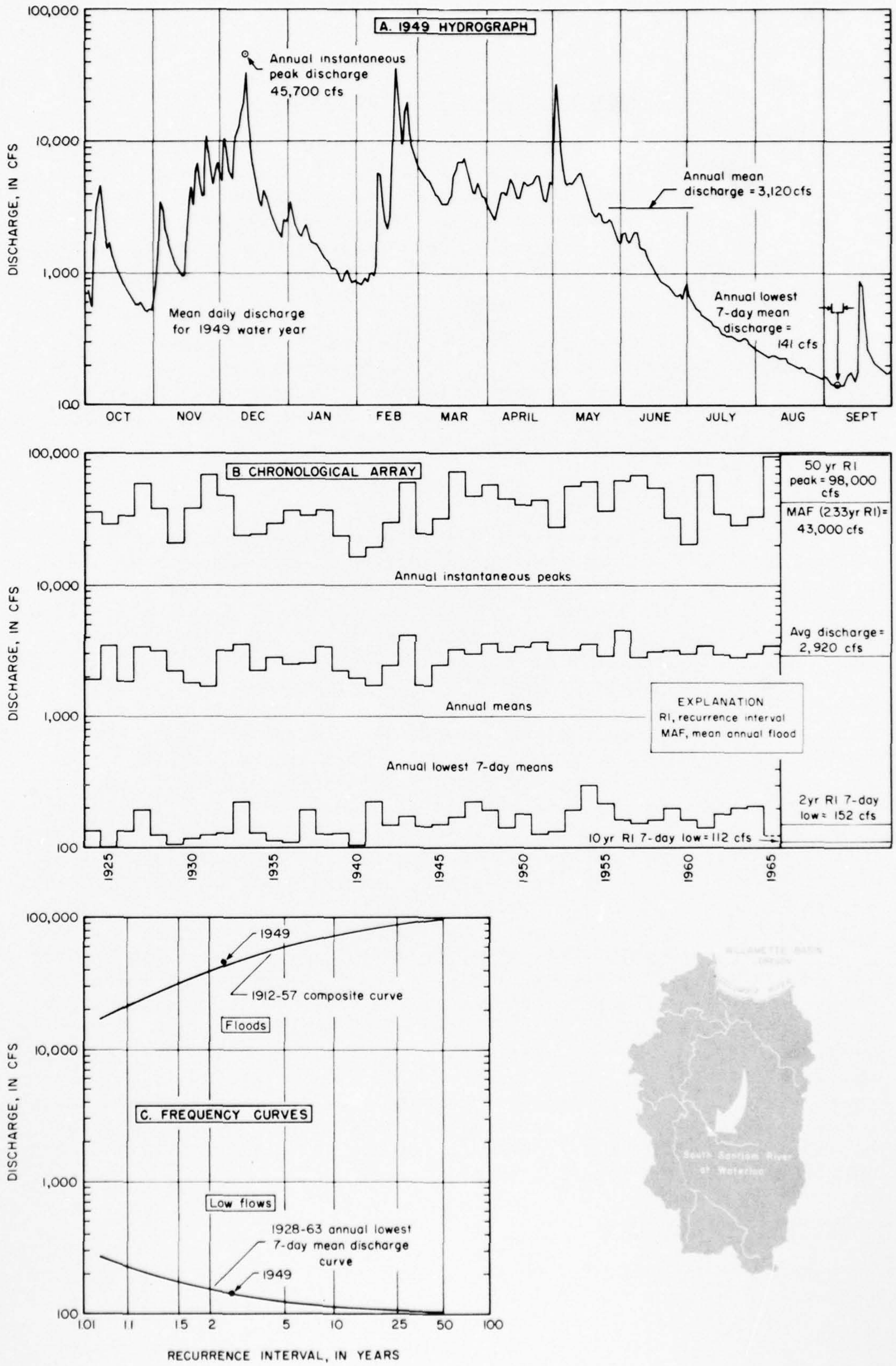


Figure IV-5. Discharge graphs for South Santiam River at Waterloo.

Range of flow at a particular site is indicated by graphs (curves) of concordant flow that show both floods and low flows. Unusual extremes of flow are indicated by graphs that show infrequent floods and low flows. Usual extremes of flow are indicated by graphs that show commonly occurring floods and low flows. A graph for average flow separates high flows from low flows.

Five graphs are shown for each stream in the following order from top to bottom:

1. Peak discharge for the 50-year recurrence-interval flood.

2. Peak discharge for the mean-annual flood (MAF--2.33-year recurrence interval).

3. The average discharge (recurrence interval uncertain, but concordant in the general sense that frequency of occurrence is equivalent throughout the basins).

4. Lowest mean discharge for seven consecutive days and two-year recurrence interval.

5. Lowest mean discharge for seven consecutive days and ten-year recurrence interval.

The graphs were constructed by interpolating between points on the streams where concordant flows could be computed or estimated and by adding concordant inflow from tributaries. Concordant-flow graphs were extrapolated to the mouths of streams, but not upstream. The steplike appearance of the graphs shows that tributary inflow is the principal source of flow for most streams.

These graphs reflect discharges derived from records unaffected by regulation or diversion, or from records corrected for the amount of diversion where the amount was known. Graphs of unmodified flow provide a consistent base for planning or for appraising regulation or diversion of streamflow.

The five graphs are not the only ones that can be presented--others could be constructed to show additional concordant flows. Those shown are representative of the amount and variability of flows and should be useful for water-resources planning.

Graphs of concordant flow are unique in the amount of information they convey. The size of the steps on any graph is a measure of the increase in main-stem streamflow contributed by tributaries. Thus, the larger step increases are caused by the entrance of tributaries that exert the most influence on the flow of the main stream. For instance, a major addition to the floodflow of Clackamas River is produced by Collawash River, and a major addition to the low flow is produced by Oak Grove Fork of Clackamas River. The largest steps on the respective graphs of concordant flow for the Clackamas (Figure IV-20) occur at the confluences with those tributaries. Small tributaries, such as North

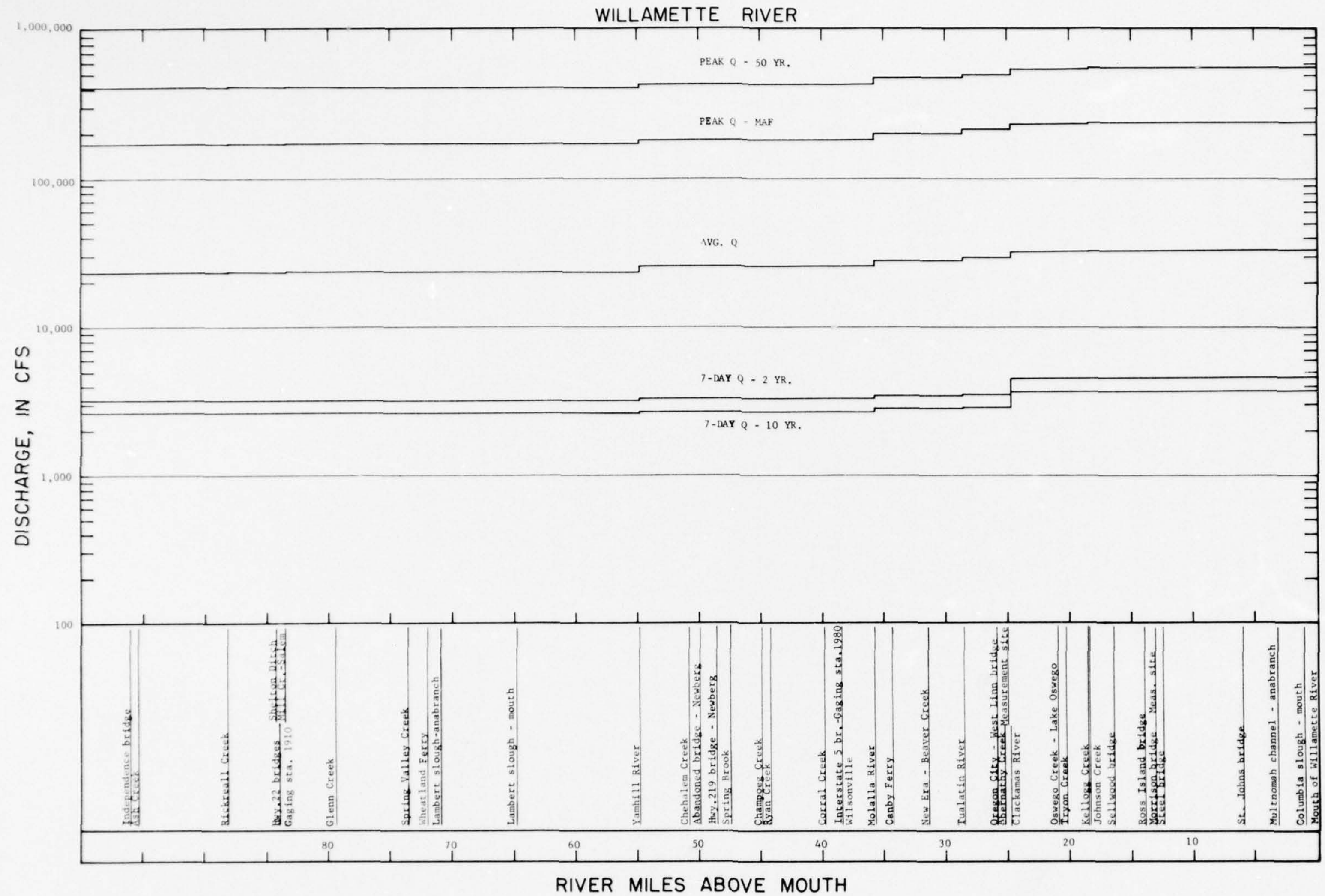


Figure IV-6. Concordant flows for Willamette River (mouth to river mile 100).

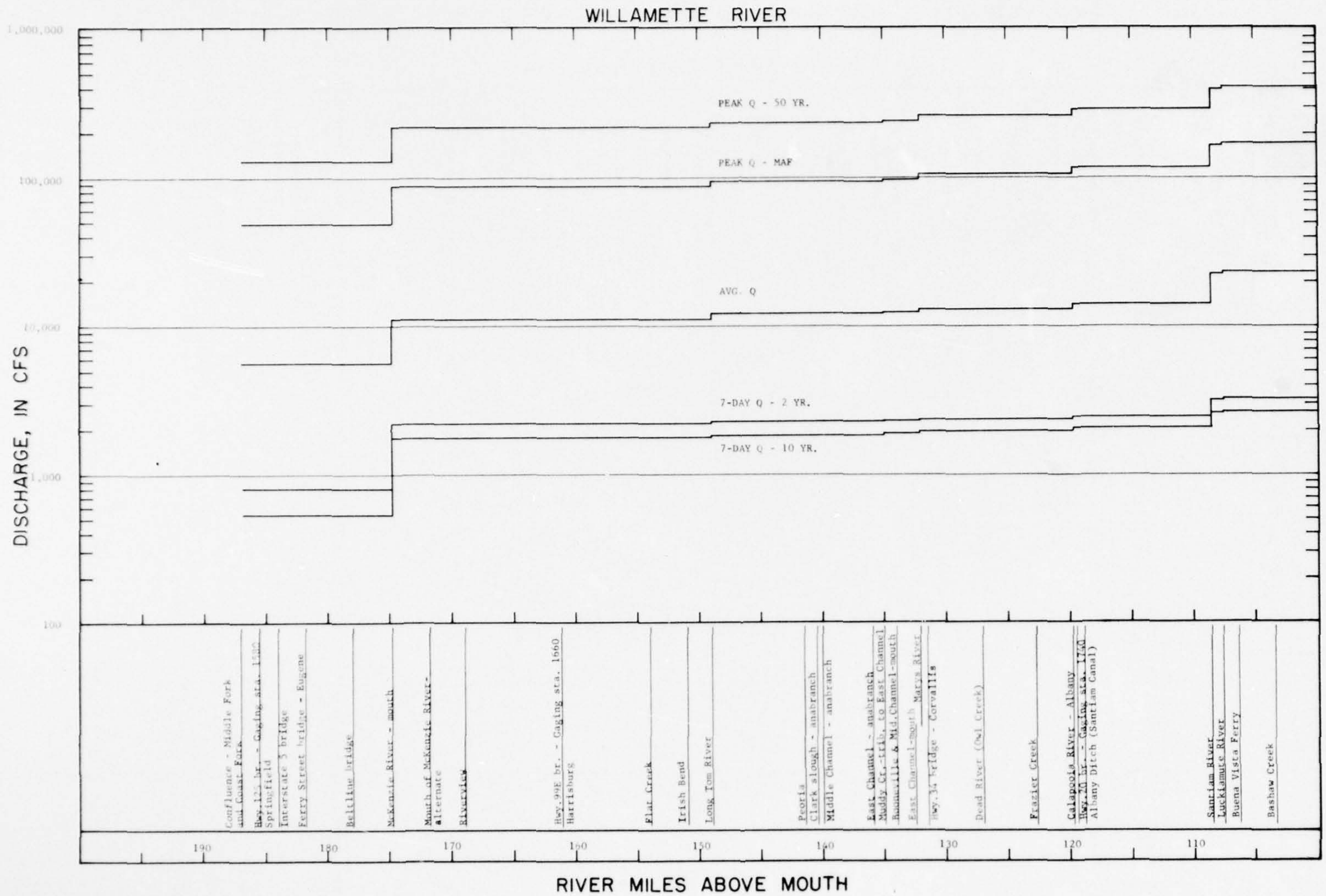


Figure IV-7. Concordant flows for Willamette River (river miles 100-187).

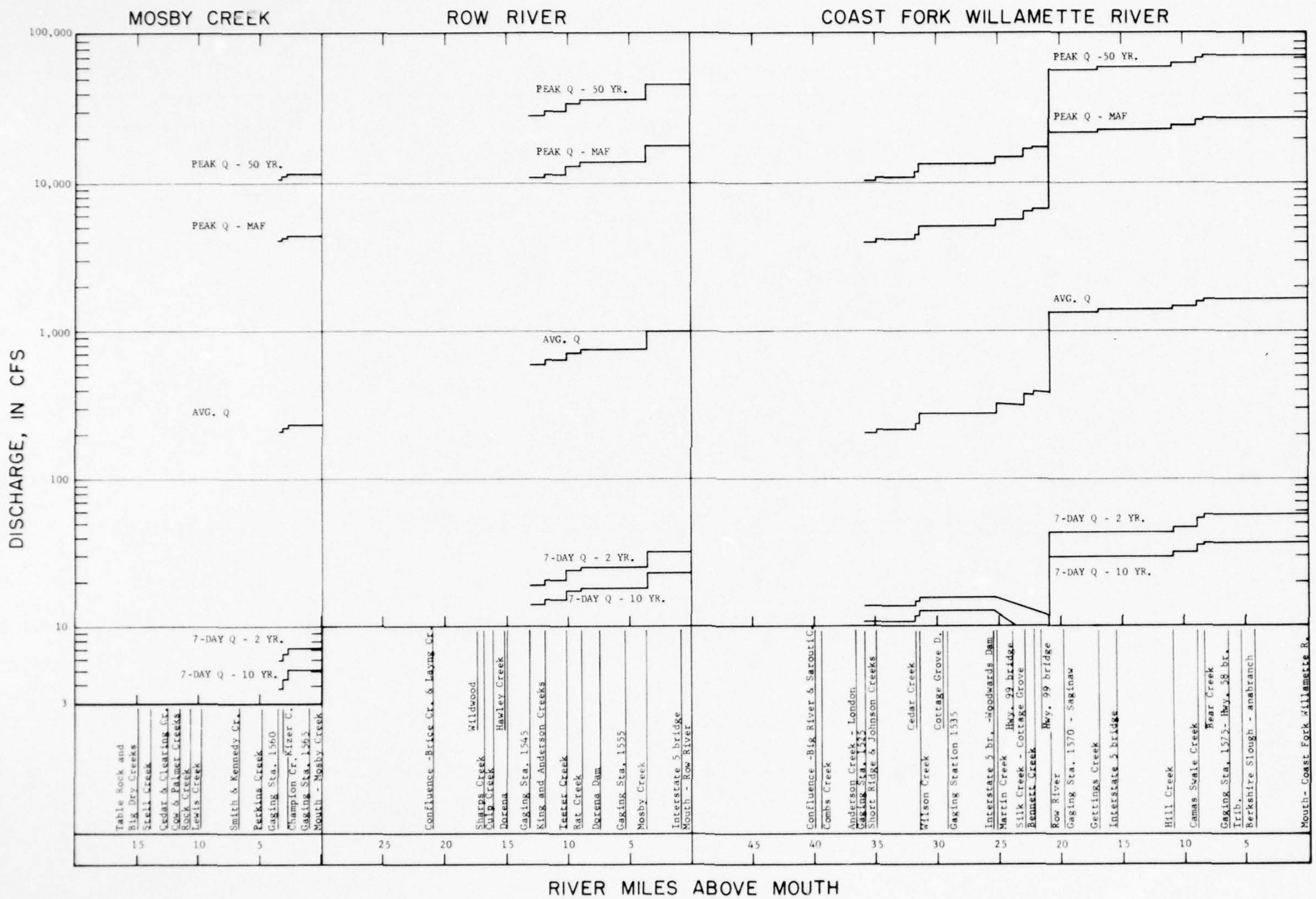


Figure IV-8. Concordant flows for Coast Fork Willamette River.

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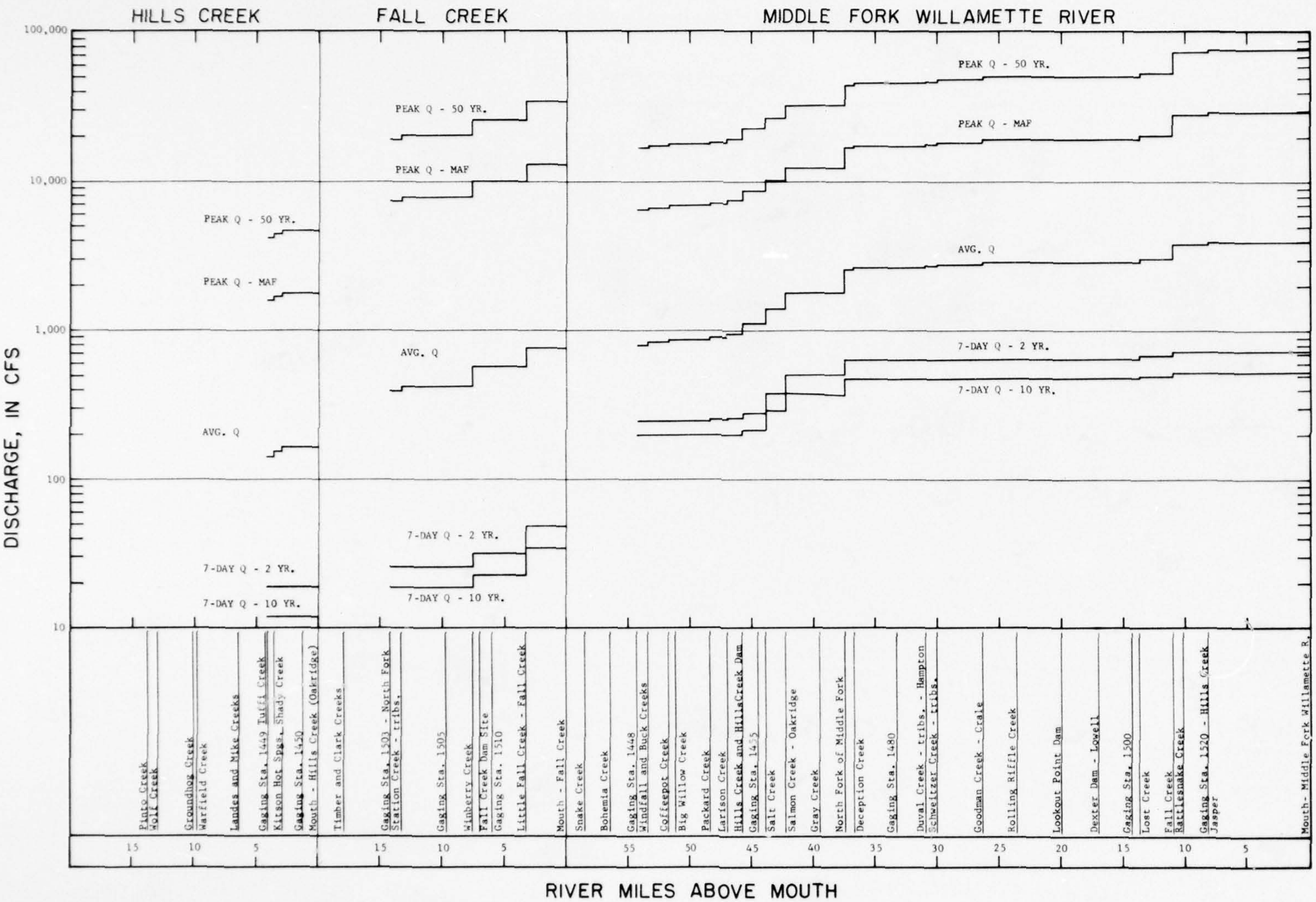

Figure IV-9. Concordant flows for Middle Fork Willamette River.

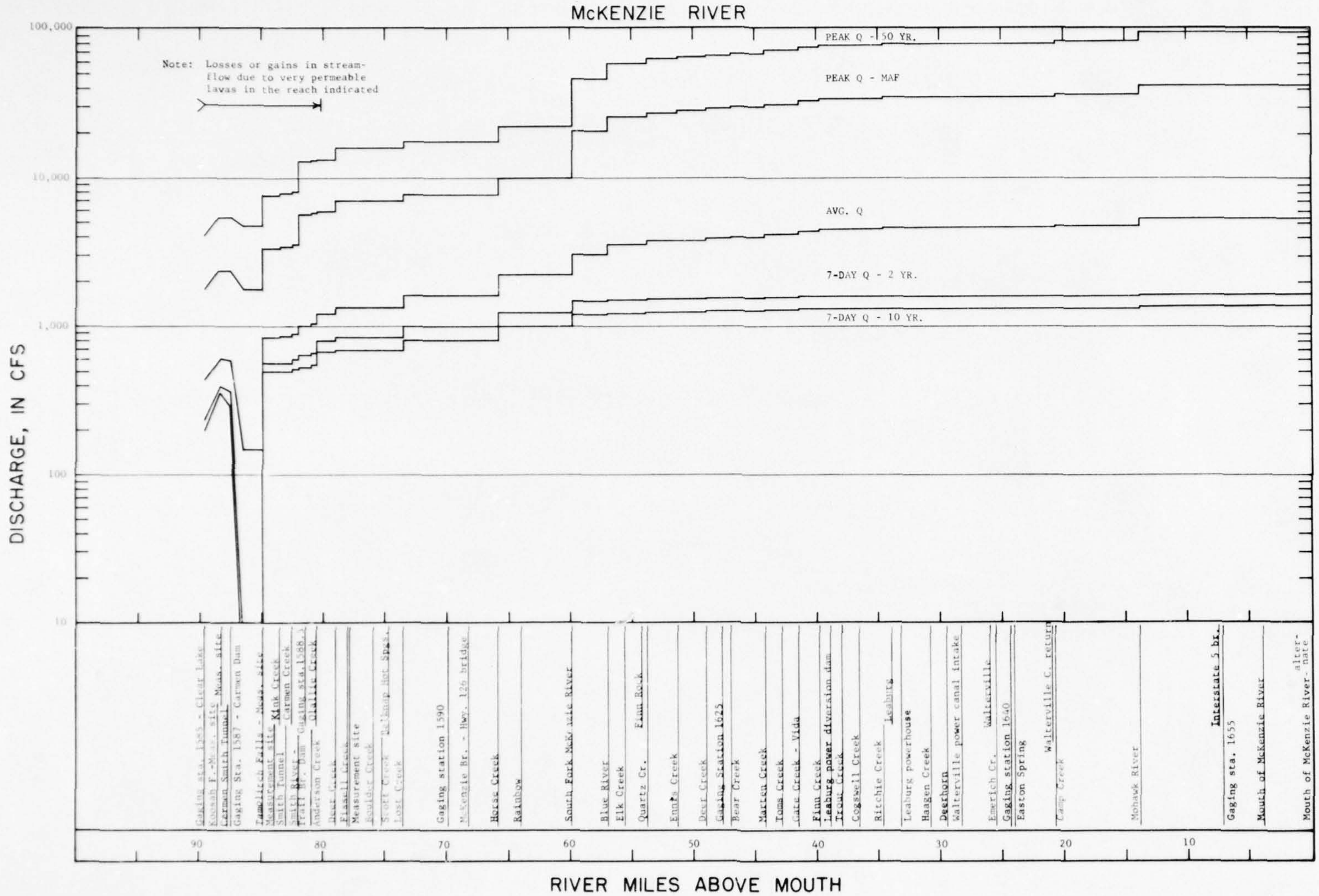

Figure IV-10. Concordant flows for McKenzie River.

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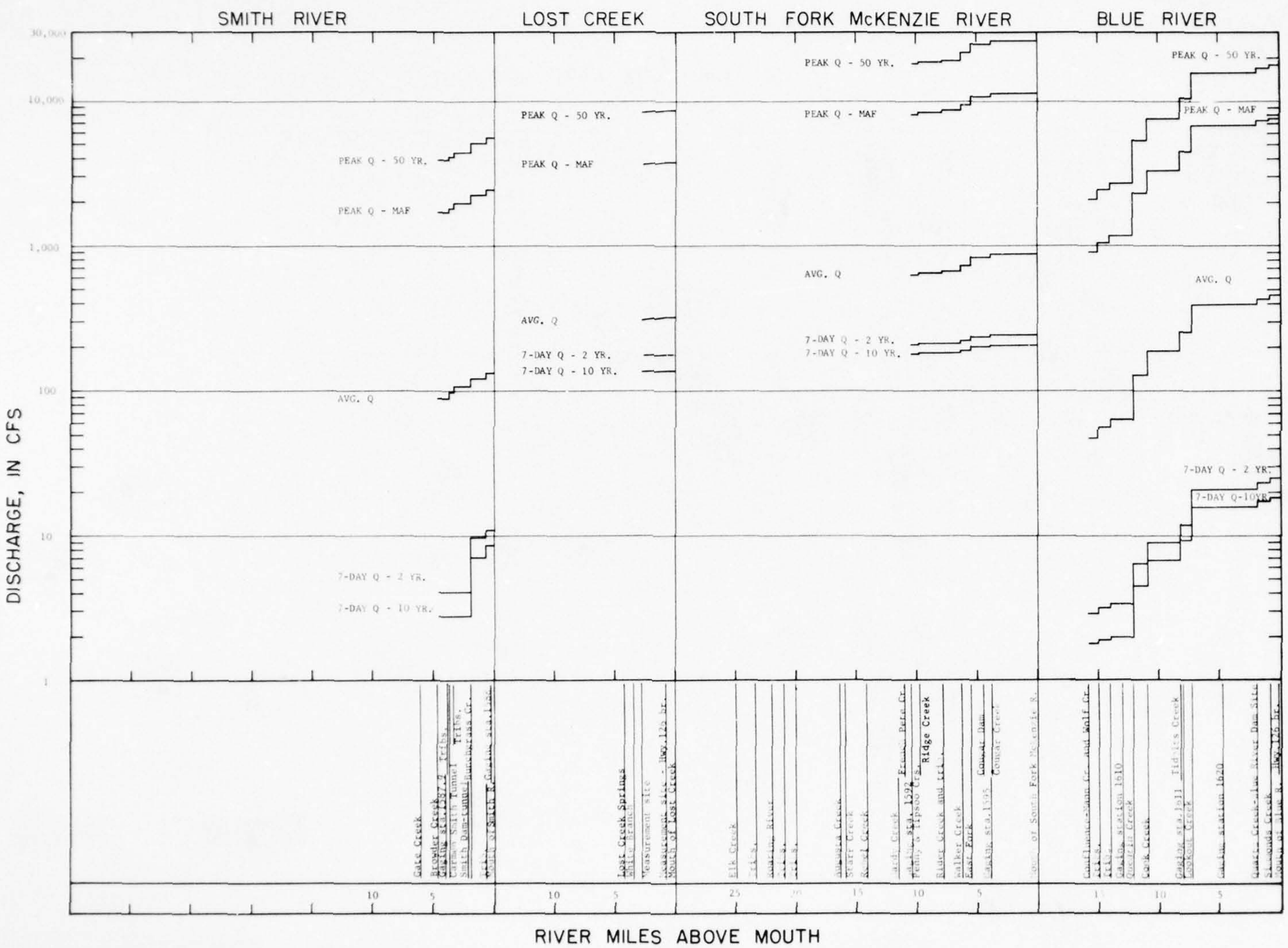

Figure IV-11. Concordant flows for McKenzie River tributaries.

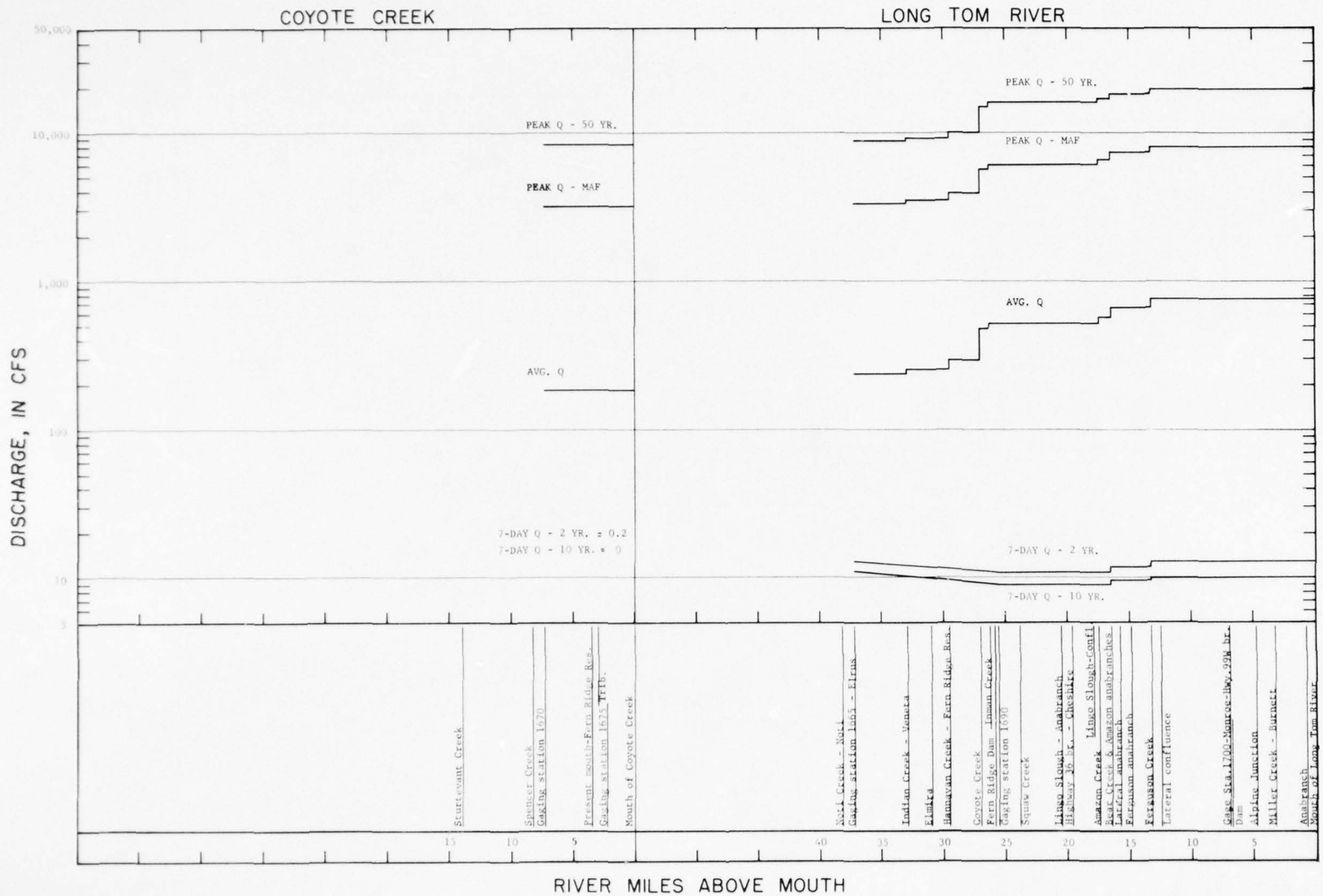

Figure IV-12. Concordant flows for Long Tom River.

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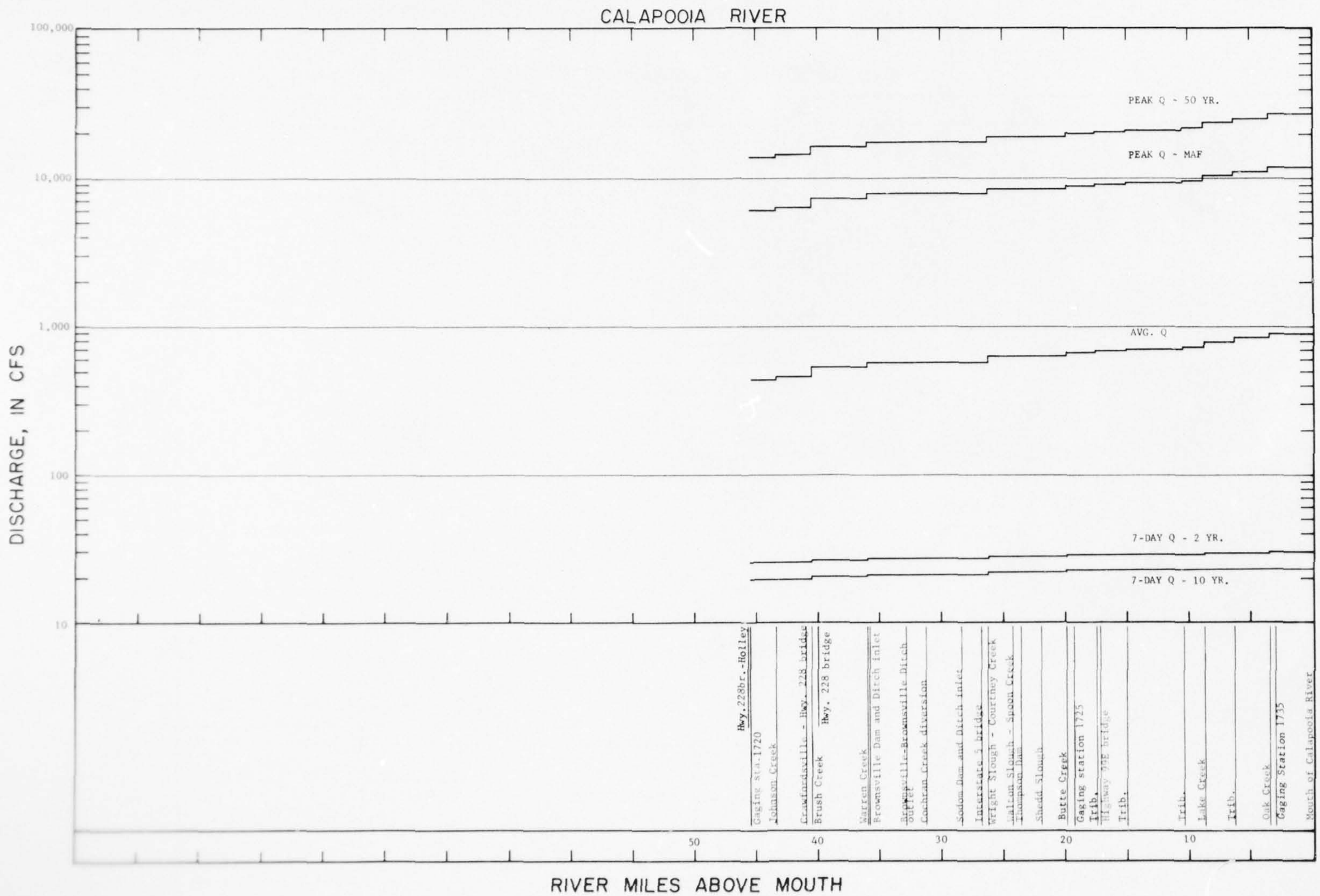

Figure IV-13. Concordant flows for Calapooia River.

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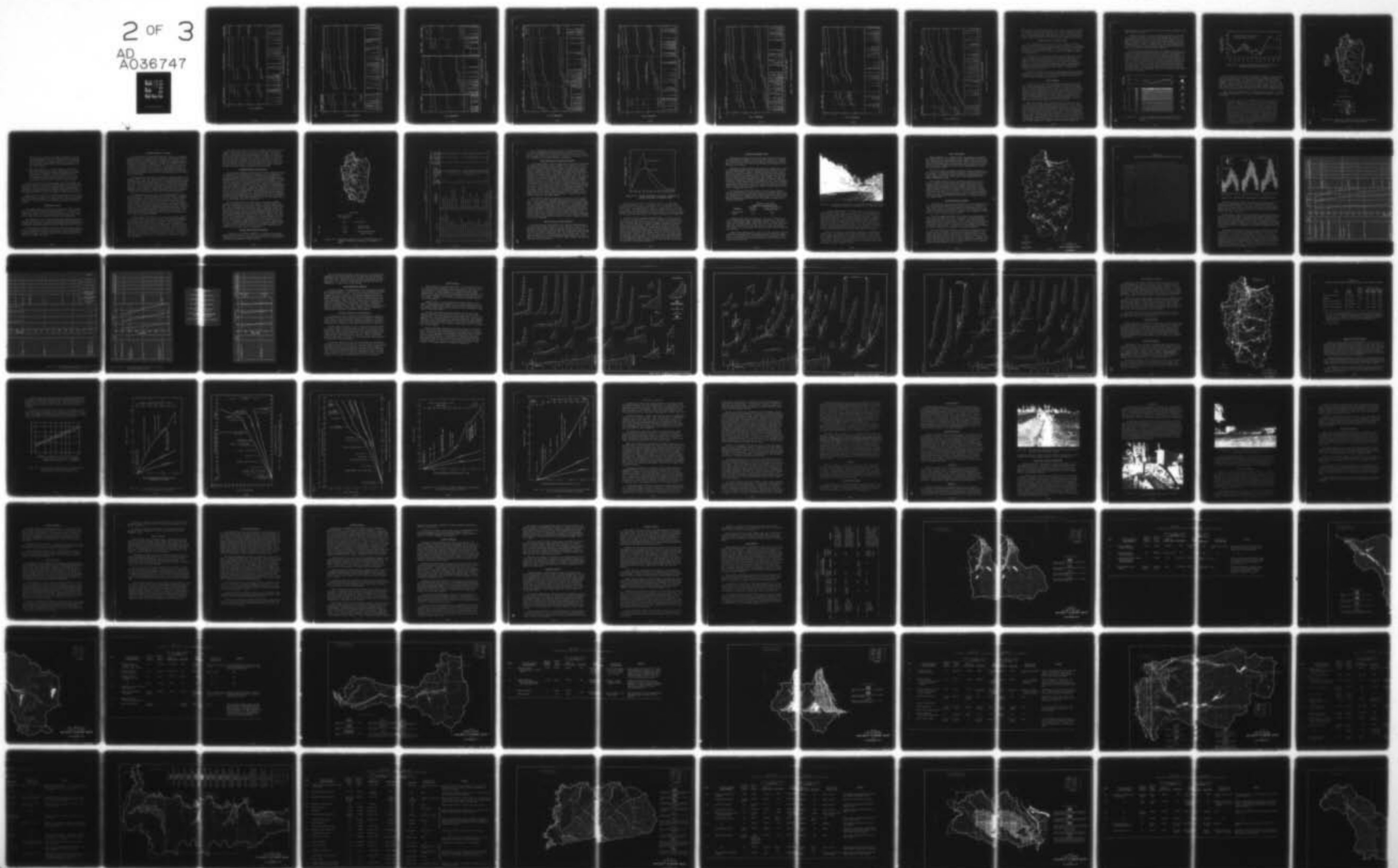

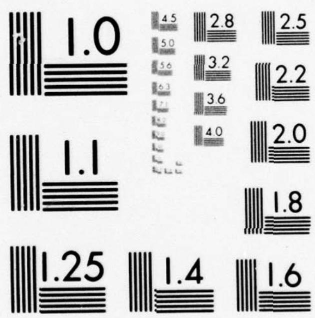

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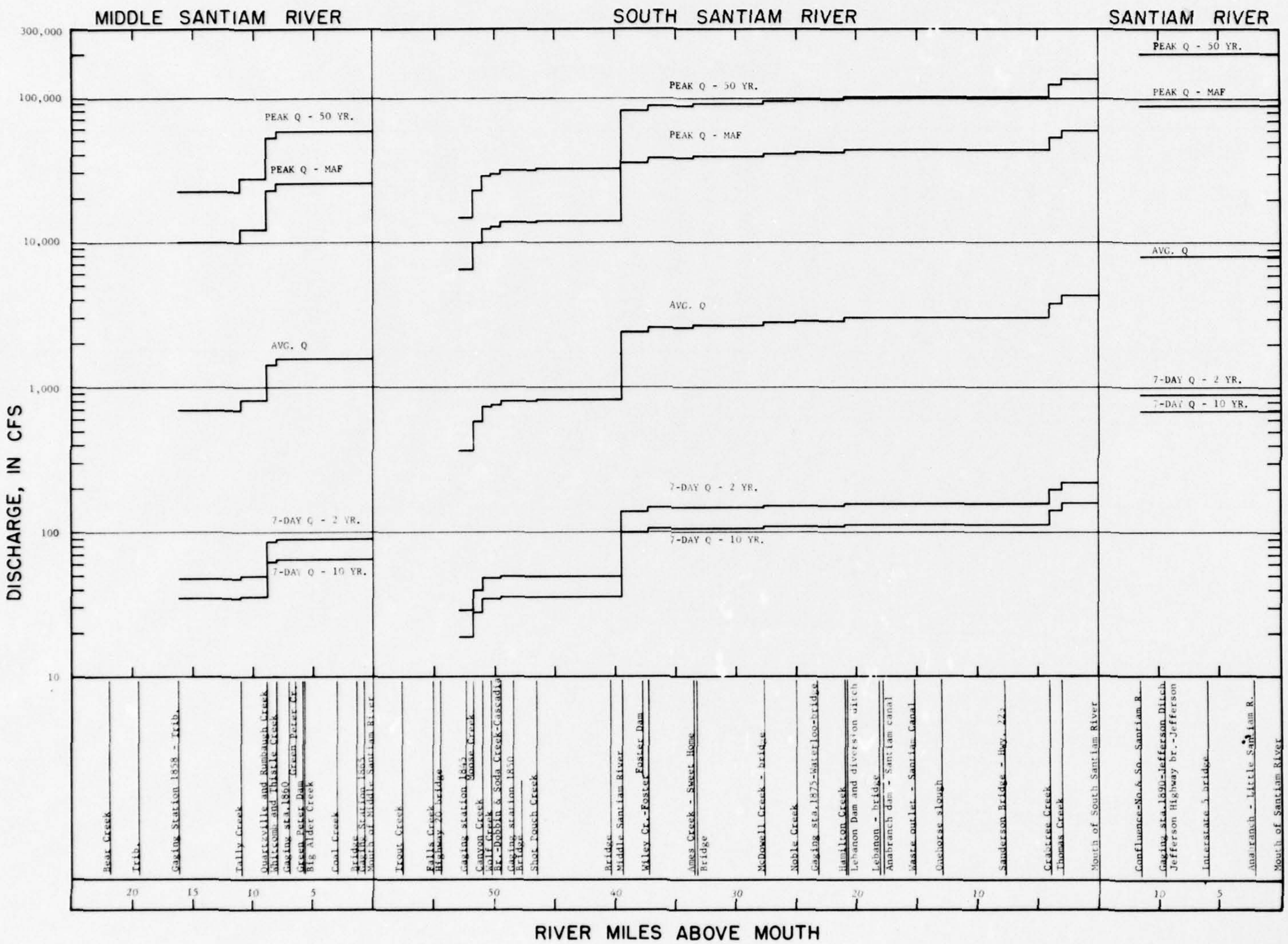

Figure IV-14. Concordant flows for Santiam River.

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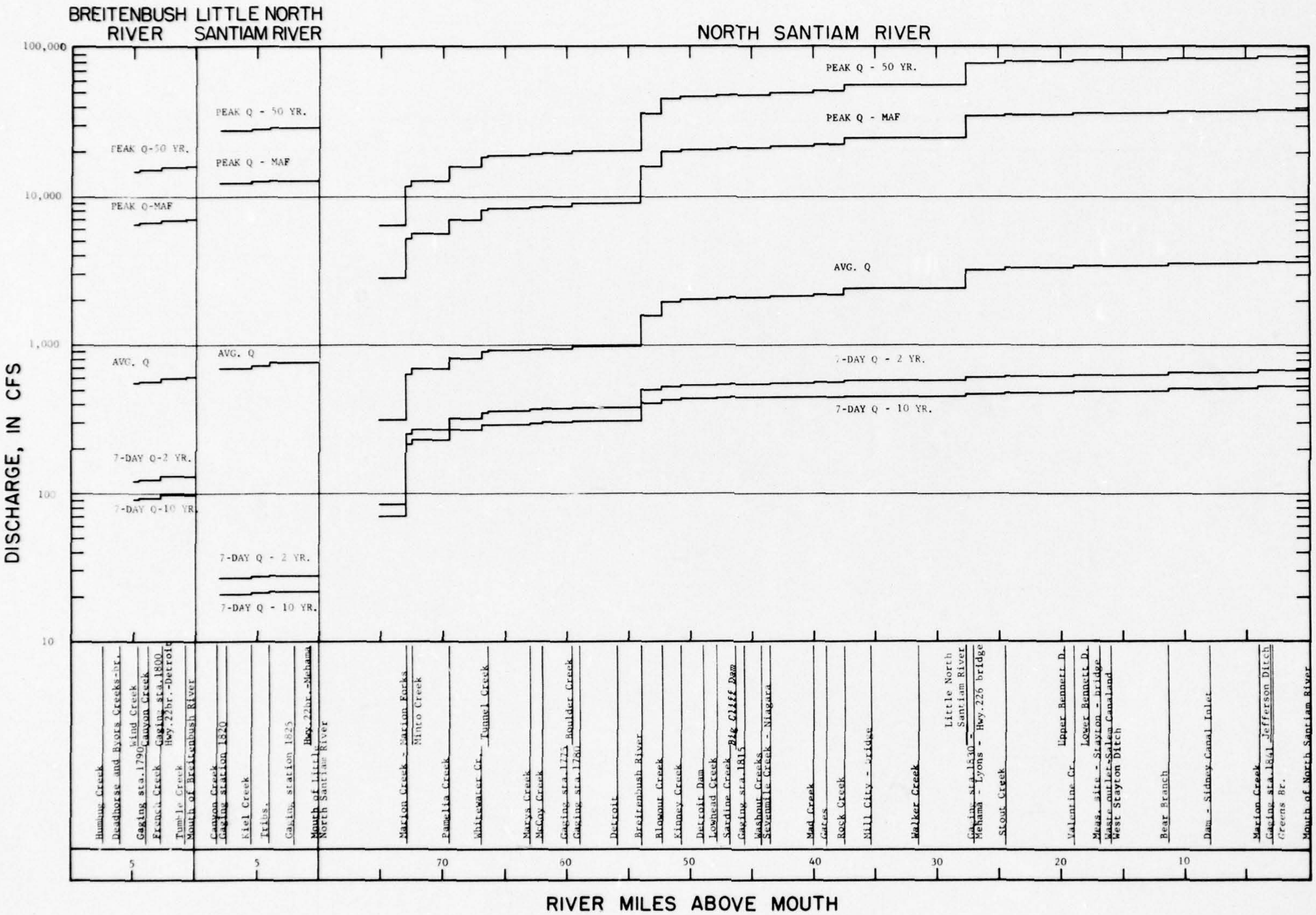

Figure IV-15. Concordant flows for Santiam River.

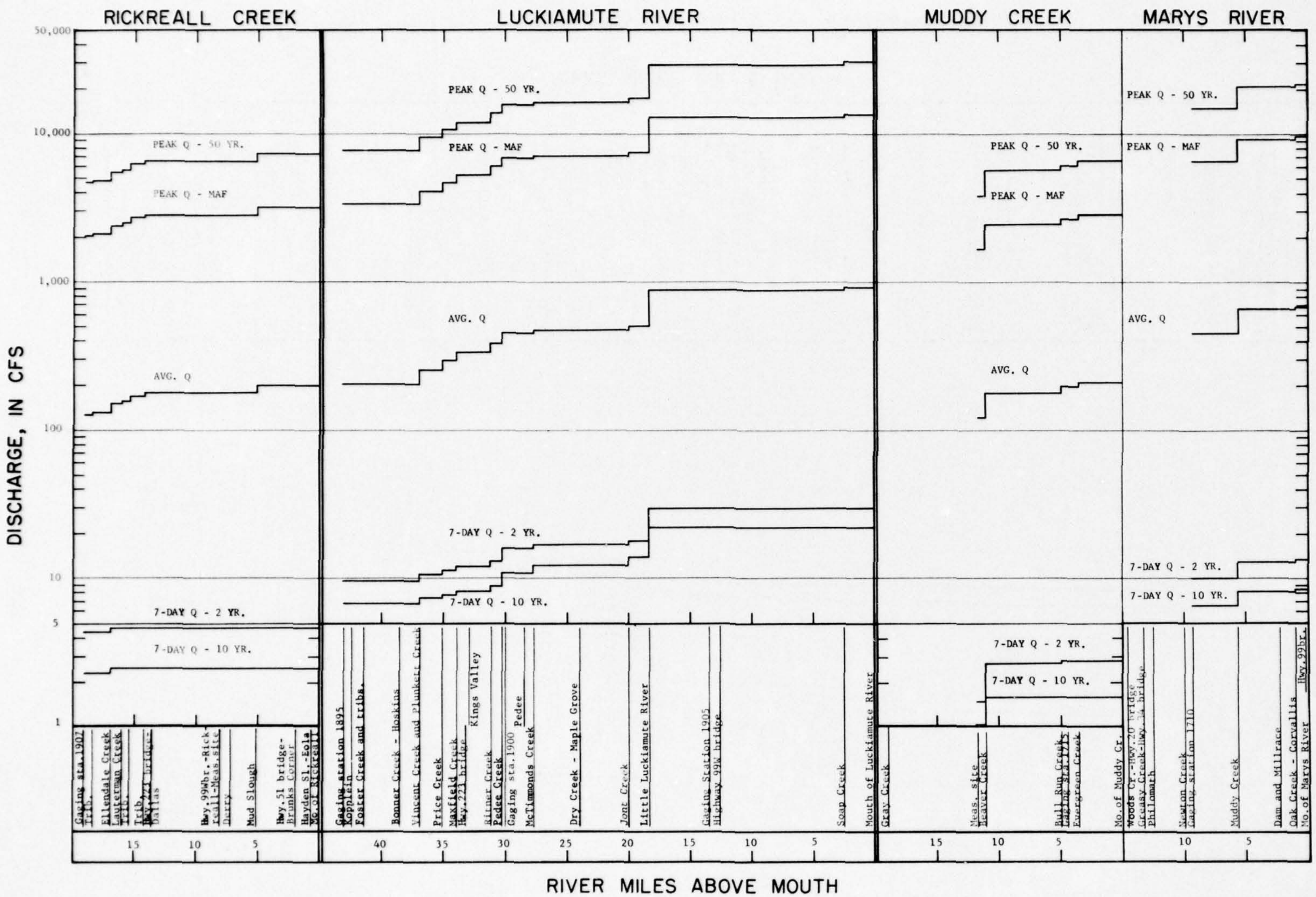

Figure IV-16. Concordant flows for Rickreall Creek and Luckiamute and Marys Rivers.

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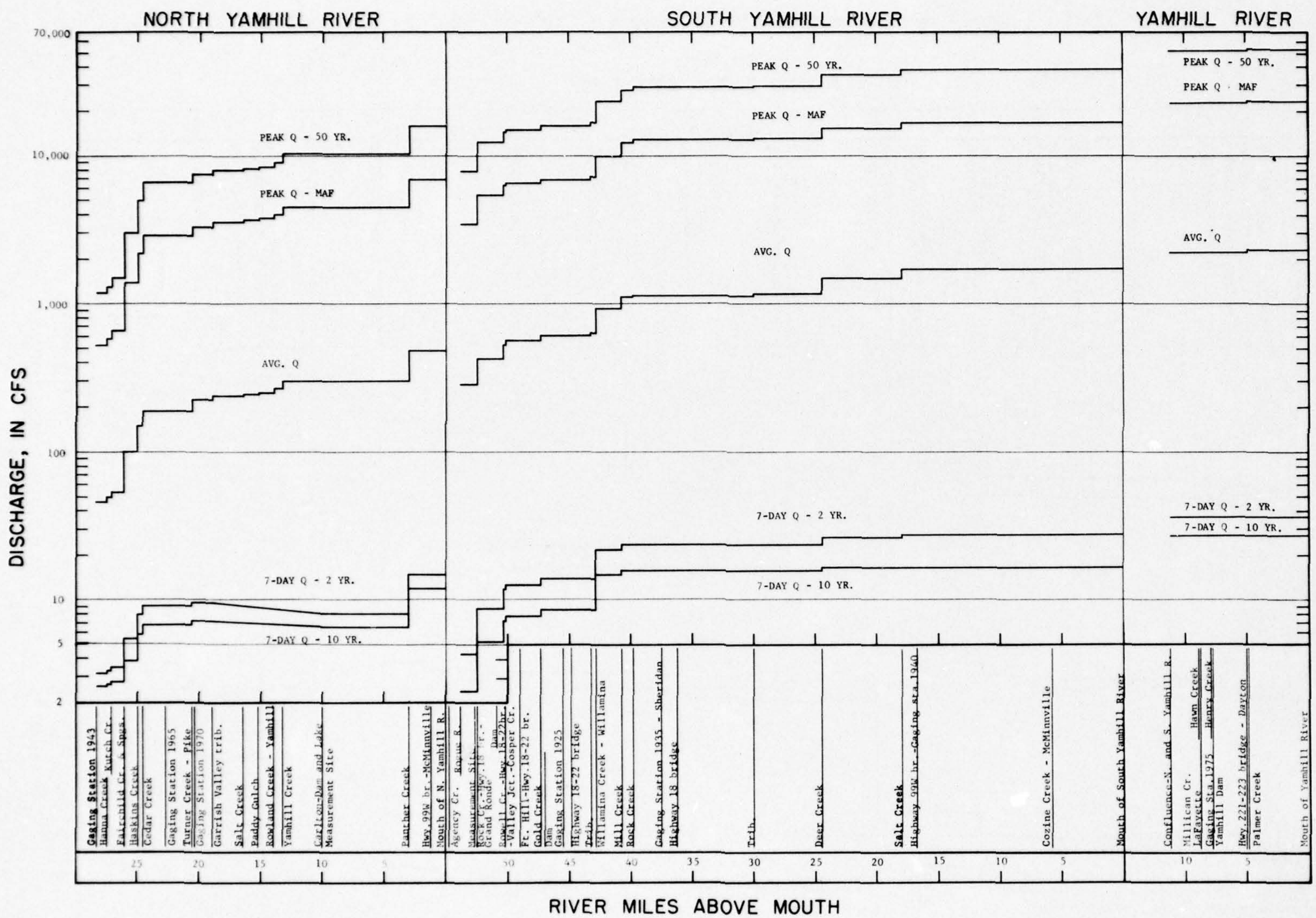

Figure IV-17. Concordant flows for Yamhill River.

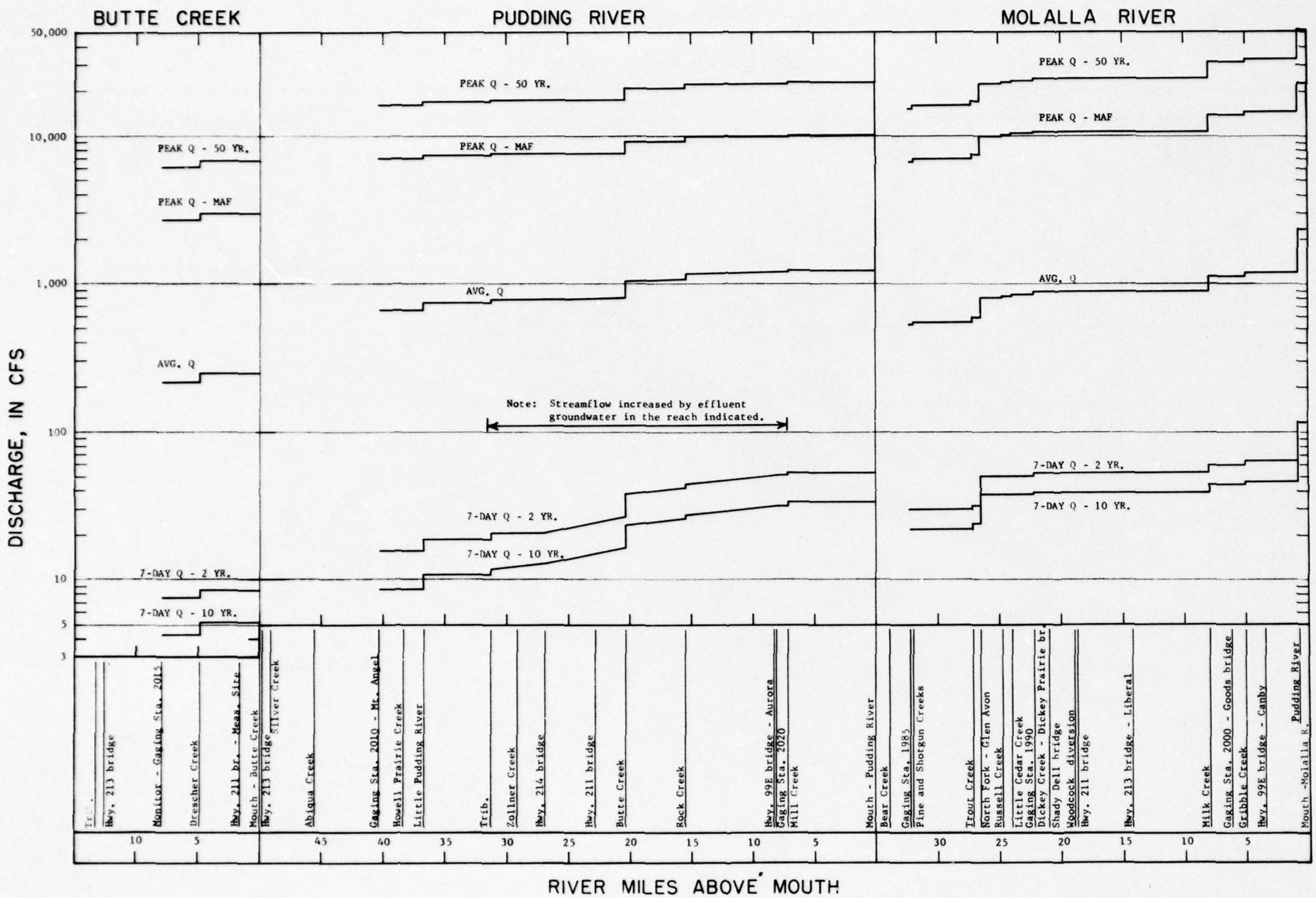

Figure IV-18. Concordant flows for Molalla River.

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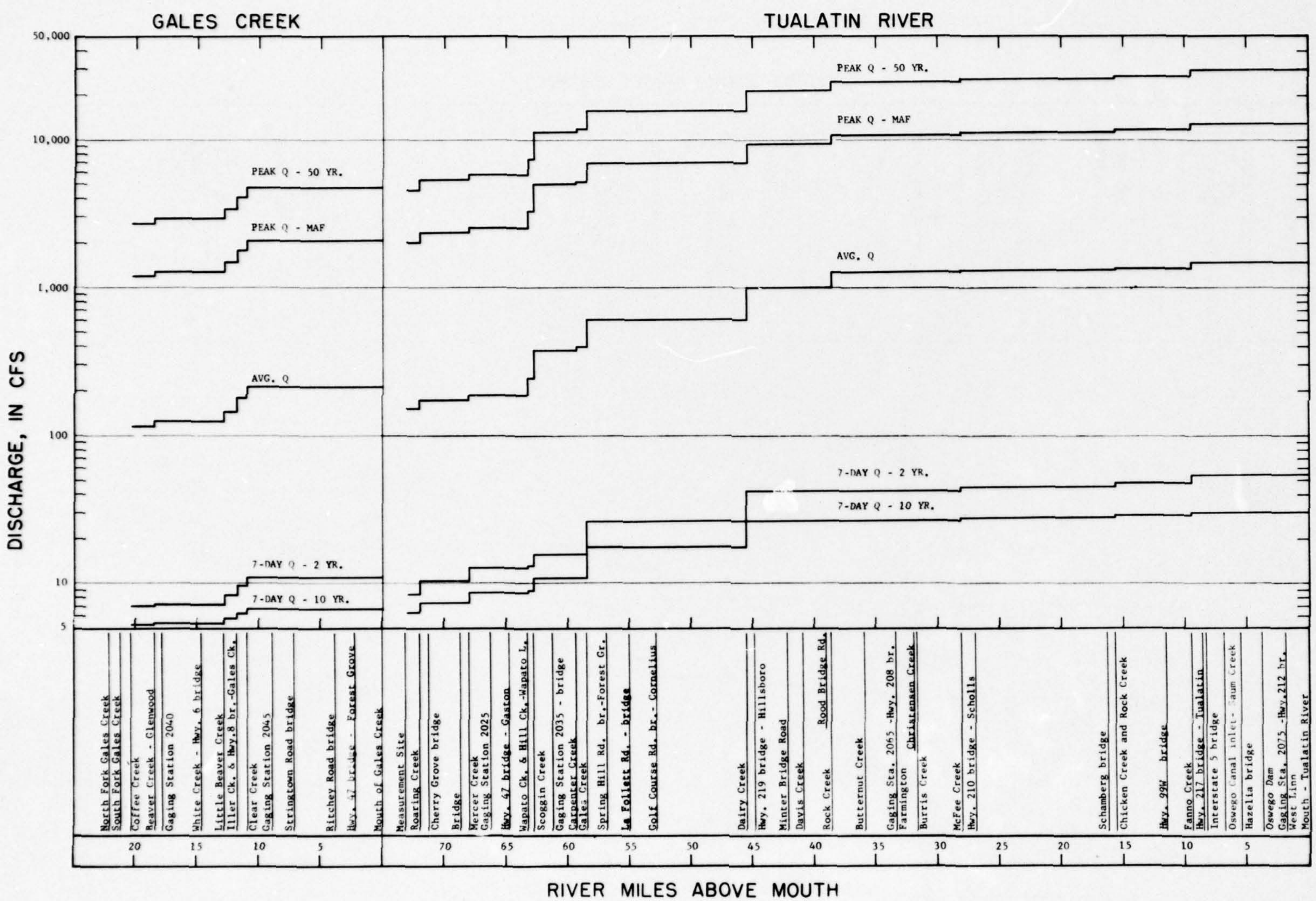

Figure IV-19. Concordant flows for Tualatin River.

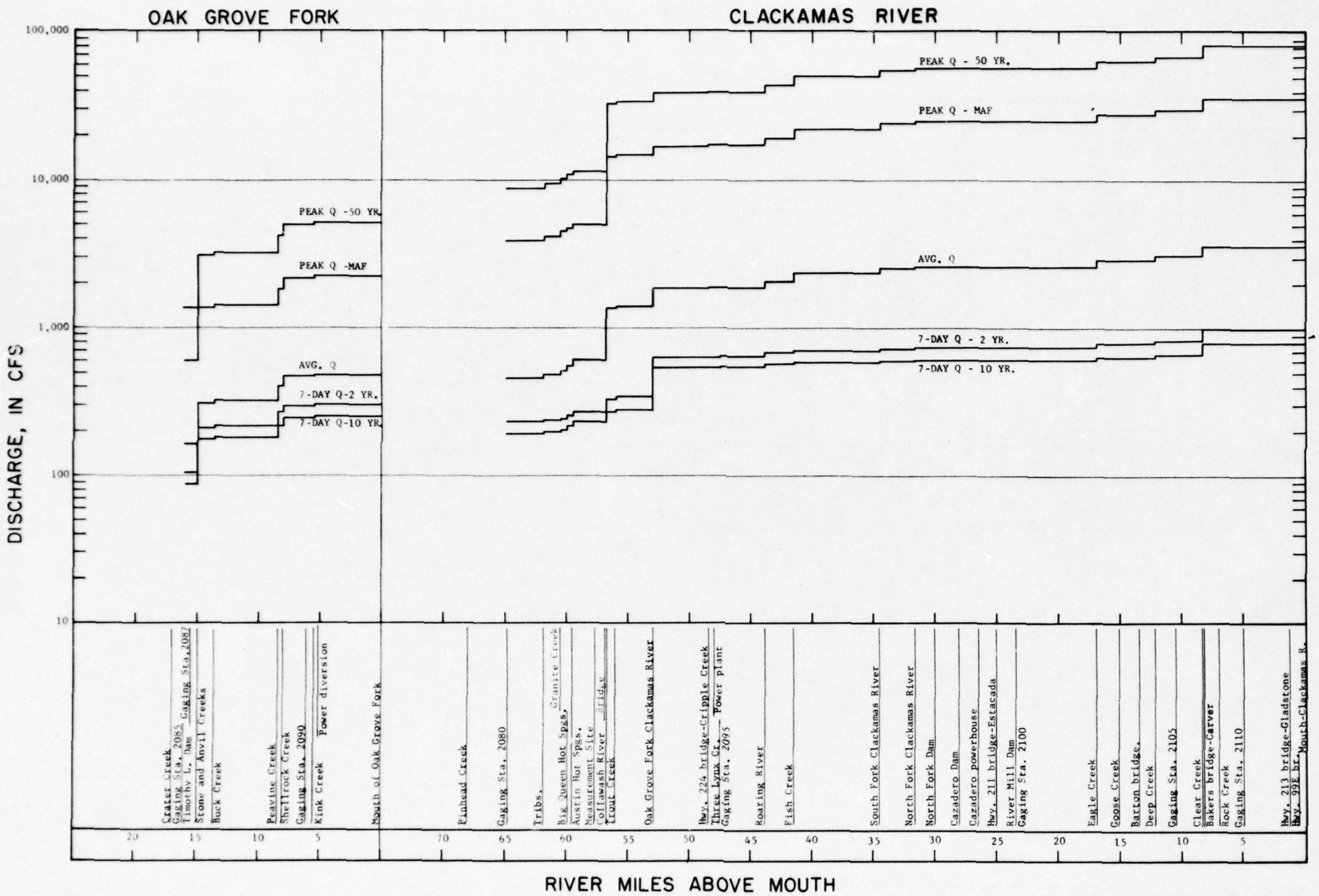

Figure IV-20. Concordant flows for Clackamas River.

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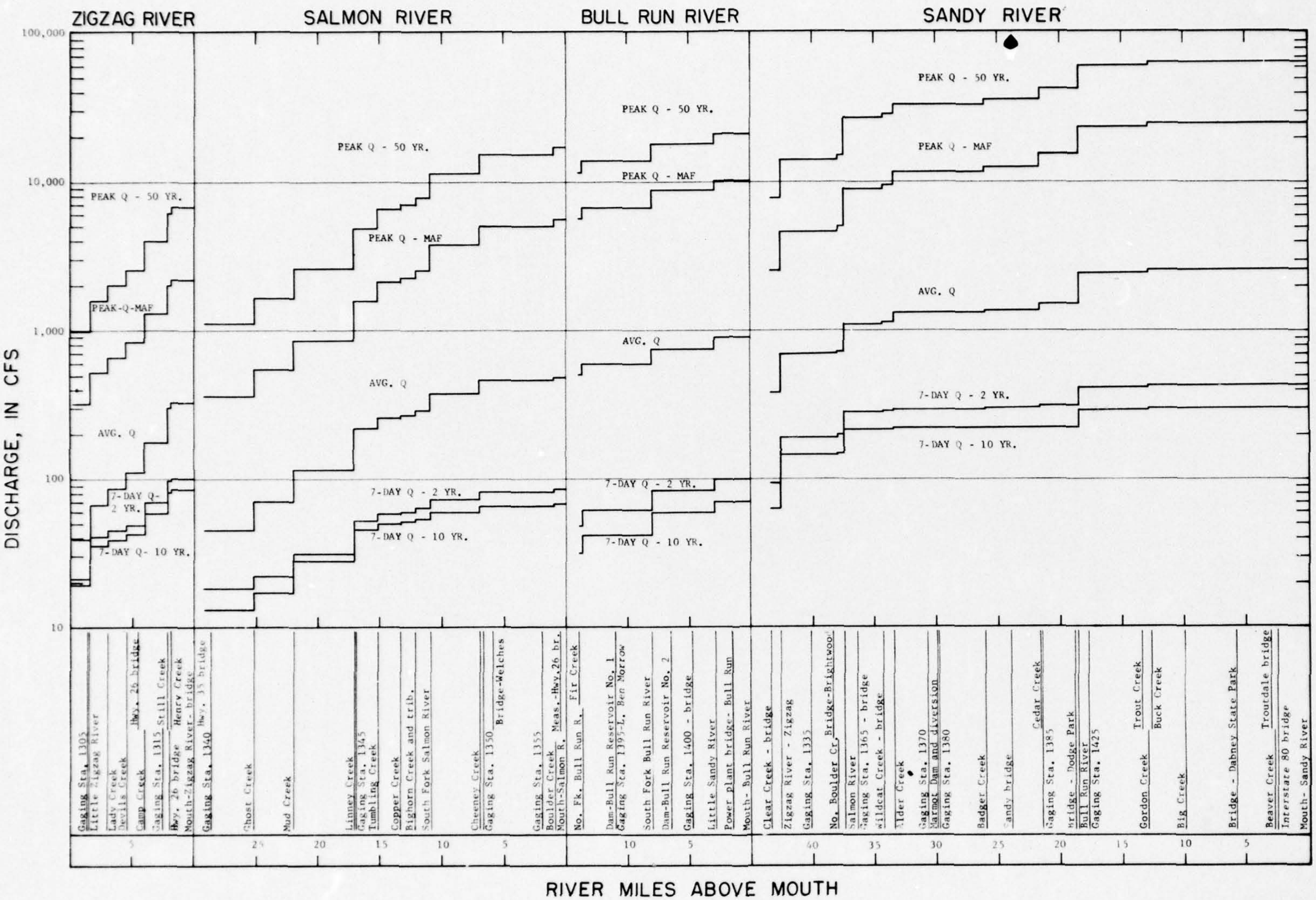

Figure IV-21. Concordant flows for Sandy River.

Fork and South Fork Clackamas Rivers, cause smaller steps on the graphs. The relative range of tributary inflow may also be determined from the relative size of the steps. For example, Collawash River has a wider range of discharge than does Oak Grove Fork because the Collawash contributes smaller amounts of low flow and greater amounts of floodflow.

MINERAL QUALITY OF SURFACE WATERS

This section presents the general chemical quality of surface waters in Willamette Basin. The basic data are available in a separate compilation of all the chemical-quality data collected by the Geological Survey in the basin (Madison, 1966). The bacterial quality of waters and organic pollution in the basin are discussed in Appendix L--Water Pollution Control.

In 1910, the U. S. Geological Survey began collecting daily samples of surface water at four locations for chemical analysis. The analytical data, based on two years of record (Van Winkle, 1914), showed the waters of Willamette Basin to be of excellent chemical quality. In the years since that pioneering study, a great number of samples have been collected for mineral analysis at many locations throughout the basin, including 13 years of daily sampling from Willamette River at Salem.

The more recent data show little variation from those collected by Van Winkle 55 years ago. In 1912 and also in 1965, the surface waters throughout the basin were soft, low in dissolved-solids content, and notably uniform in chemical composition.

Mineral Content

The waters are of the calcium-magnesium bicarbonate type, with these constituents making up about 70 percent of the total dissolved ions. The dissolved-solids content of waters of most streams ranges from less than 40 ppm (parts per million) to a maximum of about 85 ppm. Hardness of water (equivalent to calcium carbonate concentration) generally is less than 30 ppm and in many areas less than 20 ppm. The maximum hardness reported from a major tributary is 46 ppm for South Yamhill River near Whiteson. The major streams draining the Coast Range are slightly more mineralized than those draining the Cascade Range, but the chemical composition is almost the same.

Some small streams on the valley plain that receive their base flow from terrace deposits (particularly Willamette Silt) may contain dissolved solids in excess of 100 ppm during low flow. In one small area northeast of Salem, dissolved-solids values exceed 100 ppm. During a low-flow period in November 1961, a sample from Little Pudding River at Hazel Green had a specific conductance of 281 micromhos and a sample from Lake Labish Ditch near Brooks had a specific conductance of 256 micromhos. The dissolved-solids contents were not determined, but based on specific-conductance relationships, would be in the range of 175-200 ppm. Values for hardness of water for the two samples were 103 and 114 ppm, respectively. Samples of water from wells that tap terrace deposits in the same area have similar chemical composition and dissolved-solids content.

Population and water use have increased substantially since 1910, but the mineral character of the water has changed very little. Although man's activities have caused a considerable change in the organic and bacterial character of the water, there appears to be little change in mineral content. A comparison of the data collected from Willamette River at Salem in 1910-1912 with data collected during the period 1952-1965 shows no discernible change in dissolved-solids content nor in chemical composition (Figure IV-22).

The dissolved-solids content increases slightly in the lower part of the basin between Salem and Portland. The maximum dissolved-solids content of samples collected at monthly intervals at the Spokane, Portland, and Seattle Railway bridge (near Portland) was 65 ppm. The maximum observed value at Salem for the same water year (1960) was 57 ppm. The chemical composition was virtually the same at the two locations. Figure IV-23 shows a plot of specific-conductance values for the samples collected at Portland and for samples collected one day earlier at Salem. Because travel time between Salem and Portland is not known exactly, the differences shown are not absolute. However, the data indicates the approximate increase in dissolved-solids content between the two points.

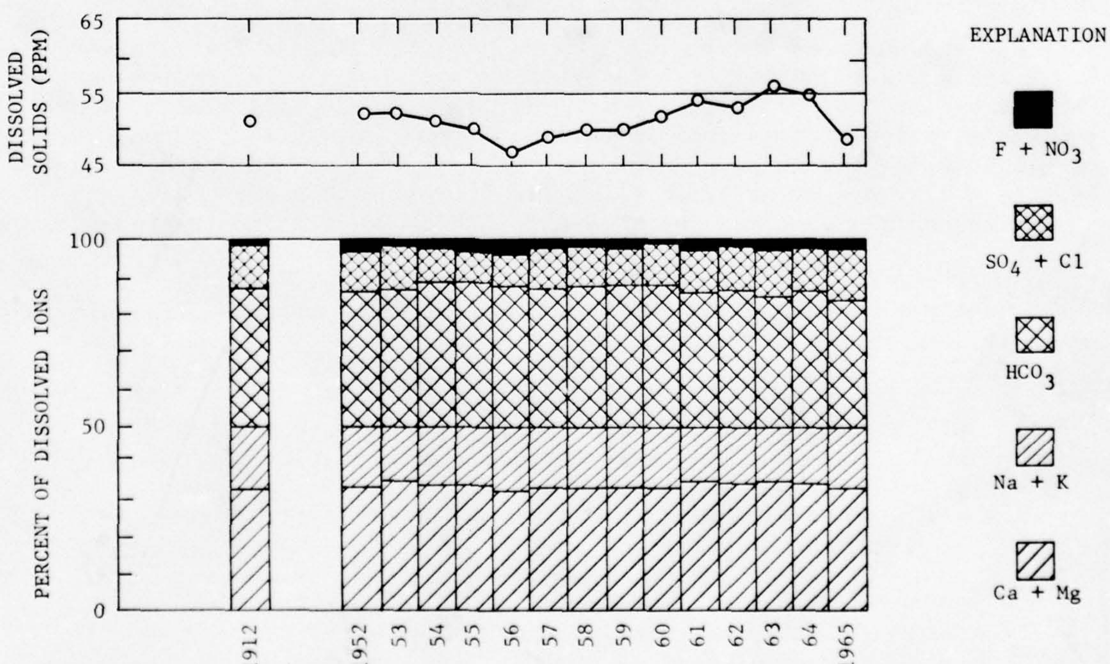

Figure IV-22. Chemical composition and average dissolved solids content of Willamette River at Salem, 1912 and 1952-65.

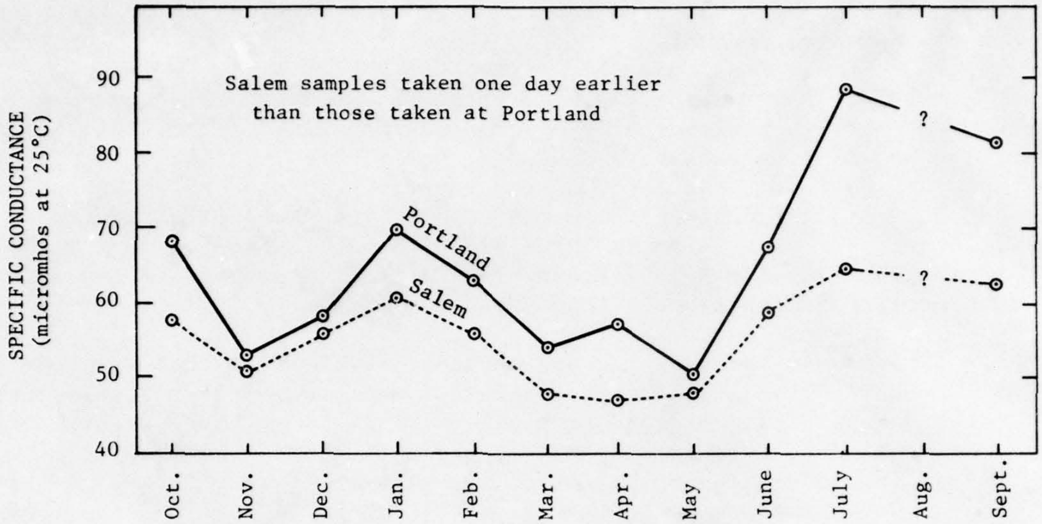

Figure IV-23. Specific conductance of monthly samples for Willamette River, 1960 water year.

Figure IV-24 shows the chemical composition, ranges of dissolved-solids content, and hardness of water for representative streams that drain the Coast and Cascade Ranges. The locations of sampling sites for streams sampled by the U.S. Geological Survey are also shown. The amount of data available varies greatly from site to site. For instance, for many sites, only spot samples have been collected for analysis, whereas data are available from 17 years of daily sampling for Willamette River at Salem and from 1 year of monthly sampling for Willamette River at Portland (Madison, 1966).

There are several reasons for the uniform mineral character of waters throughout the basin and for the lack of significant increases in salt load since 1912:

1. Willamette Valley lies in a humid zone and the streams drain soils that have been well leached by the infiltrating precipitation. Consequently, only small quantities of soluble salts are available for removal by applied irrigation water. Although use of water for irrigation has increased continuously in the Willamette Basin over the last 50 years, the increase in salt load from irrigation return flows has not been comparable to that in other parts of the State, particularly in areas east of the Cascades. Bodhaine and others (1965) estimated the salt contribution from irrigated land in Willamette Basin to be 0.02 ton (40 pounds) per acre per year. The total solute load from the basin has been estimated to be 0.28 tons (560 pounds) per acre per year (Van Denburgh and Feth, 1965).

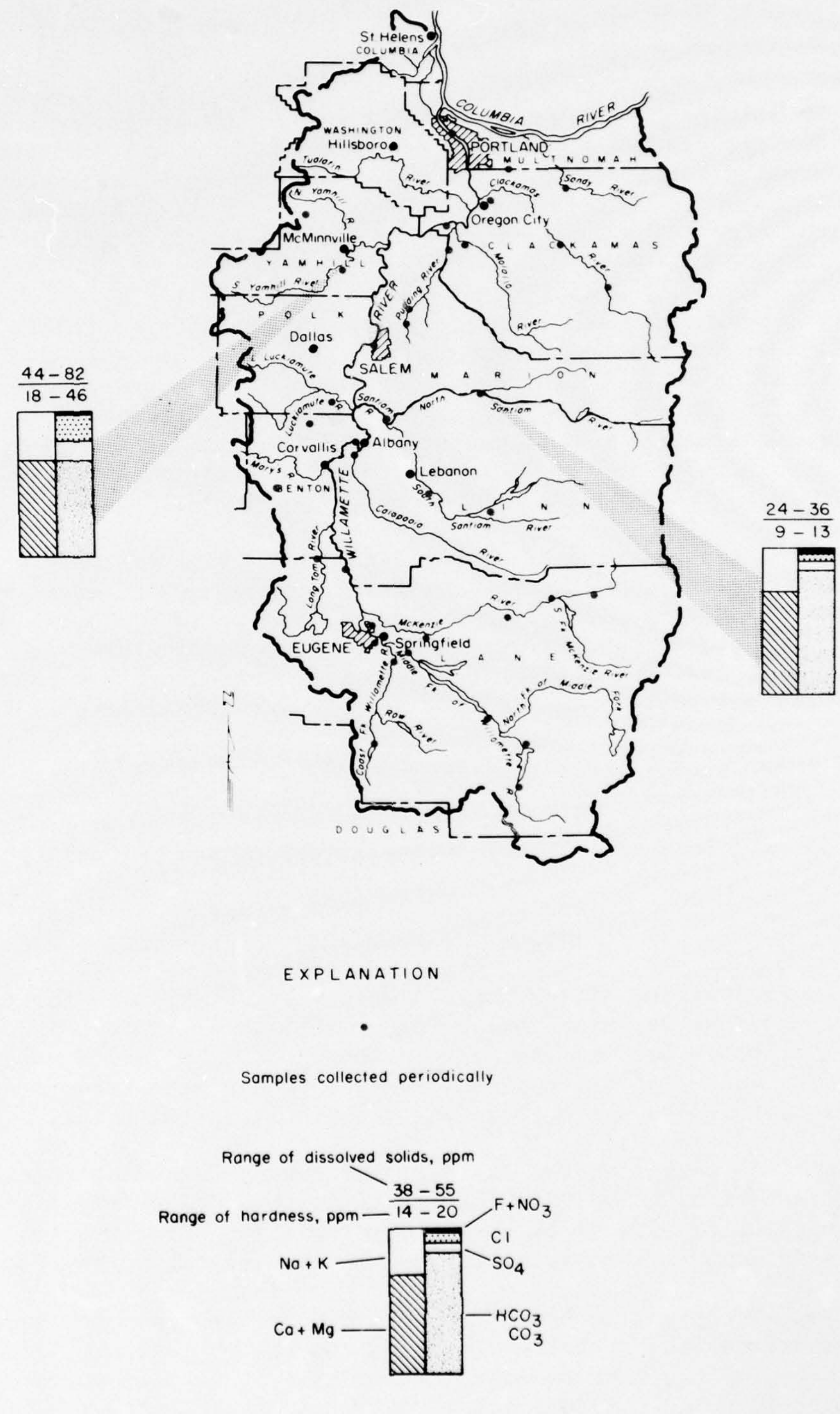

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Figure IV-24. Locations of quality sampling points and representative composition of selected streams.

2. Industrial use of water in the basin is primarily for cooling and waste disposal by the timber-resource and food-processing industries. The wastes contributed to the streams by these industries are mostly organic or insoluble and do not contribute substantially to the dissolved-mineral content of the water.

3. The recent samples were collected during a period (1952-1965) when average yearly runoff, minimum flows, and precipitation were all above the long-term average (see section on "Patterns of Runoff"). Because maximum dissolved-solids content usually occurs during periods of low flow, any increase in salt load due to man's activity may have been somewhat masked by the increases in yearly runoff.

The most recent period of above-average runoff (1945-1965) coincided with a period of accelerated economic growth and increased water use, during which time most of the major reservoirs in the basin were constructed. Because the periods of higher runoff coincided with periods of increased regulation, the degree to which each has affected water-quality patterns in the basin cannot be accurately identified.

Regulation of low flows will continue to be beneficial in controlling water quality. However, the effect of man's activity in the basin may be more significant than it now appears to be, and an appreciable increase in salt load could occur during future periods of deficient runoff.

Suitability for Use

The surface waters of the basin are chemically suitable for most uses. All the streams in the basin for which data are available are chemically suitable for domestic and municipal use. In certain parts of the lower reaches of some tributaries and in the main stem, treatment is required to remove organic and bacterial contamination.

The surface water has low salinity and sodium hazards according to the rating method of the U. S. Salinity Laboratory Staff (1954) and is suitable for irrigation. Problems of water-quality deterioration due to irrigation return flow probably will not be significant in the future.

Surface waters in the basin are suitable for use by most industries. Industries that require waters of low silica content would have to use treated water, because most streams have silica concentrations in excess of 10 ppm. For some industrial uses, treatment would be required for turbidity and color.

SEDIMENT TRANSPORT BY STREAMS

This presentation of sediment transport by streams in Willamette Basin is based on an analysis of data available from previous studies. It provides only a preliminary guide from which to estimate rates of sediment accumulation in reservoirs, ascertain the treatment needed for municipal and industrial supplies, and judge the suitability of the streams for fish habitat and recreation. It also might be used for preliminary evaluation of the effects of land treatment measures and for determining changes in water quality. Many additional data are needed on erosion and on the transport and deposition of sediment before accurate appraisals can be made of these phenomena and the factors that control them.

An investigation by the Corps of Engineers (1954), conducted from December 1948 to July 1951, produced most of the available data on concentration, discharge, and particle sizes of suspended and bed sediment. Suspended sediment was sampled about once a week during the investigation at 21 sites located on Willamette River and its main tributaries. These data, of course, may not represent the present status of sediment transport in basin streams. Other studies were made by the Corps of Engineers (1949a, 1949b, and 1958) to determine the rates of sediment accumulation in Cottage Grove, Fern Ridge, and Dorena Reservoirs.

Suspended-sediment data collected during 1948-1951 were used by Anderson (1954) to relate sediment yield to precipitation, streamflow, soils, topography, vegetative cover, and land use. Flaxman and High (1955) developed similar relations and also reported results of an erosion-damage survey conducted in April 1949. In 1959, the Forest Service began an investigation of the effects of land use on sediment loads of streams in forested watersheds (Fredricksen, 1963). The U. S. Geological Survey determined sediment discharge of Willamette River at Portland from July 1962 to September 1964 (Haushild and others, 1966) and measured sediment discharge at Portland and other sites in the basin during the floods of December 1964 and January 1965 (Rantz and Moore, 1964, and unpublished data).

Sediment yield in the basin is low because of favorable combination of physiographic and climatic factors. The geologic formations that underlie much of the basin, particularly the west flank of the Cascade Range where land slopes are steepest, consist of erosion-resistant basalt, andesite, and pyroclastic rocks. Although the soil layer is generally thin, except on the alluvium of the valley bottoms and on semiconsolidated formations in other areas, the trees, brush, and grass that grow abundantly because of the moist, mild climate tend to protect the surface of the basin from rapid erosion. Erosion has been severe locally when rains of high intensity fell on soils that had been stripped of vegetation by timber harvest, construction, agriculture, or mining.

Willamette River and its tributaries transport small quantities of sediment compared to quantities carried by other major rivers of the country, particularly those in the semiarid Southwest. For example, before the construction of Glen Canyon Dam, the sediment discharge of the Colorado River at Grand Canyon, Arizona, averaged about 96 million tons per year--about 42 times that for Willamette River at Portland--with the mean water discharge at Grand Canyon only about one-half of that at Portland. However, the average sediment yield per square mile at Grand Canyon was only 3.3 times as great as the yield at Portland because of the much larger area drained by the Colorado.

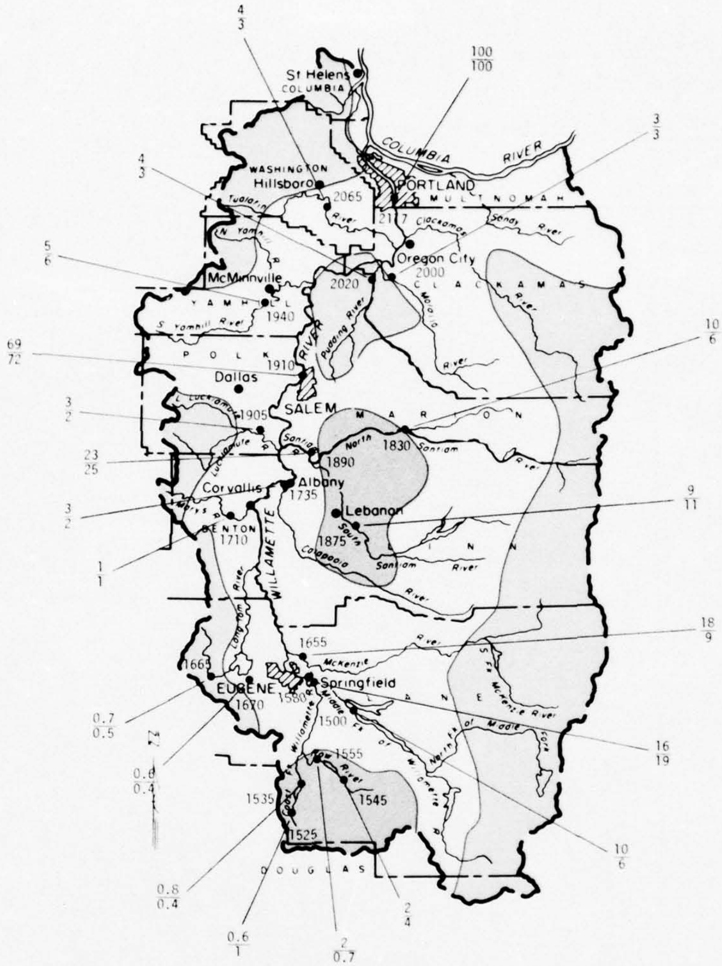
Suspended-Sediment Concentration

The suspended-sediment concentration of streams in Willamette Basin is important in the development and management of water supplies, recreation facilities, and fish habitat. The discharge-weighted mean suspended-sediment concentration is the theoretical suspended-sediment concentration if all the water and suspended sediment passing a section during a time interval were mixed and is useful in determining the effects of development on sediment discharge. Changes in the drainage-basin environment are reflected by the relationship of suspended-sediment discharge to water discharge. Long-term trends cannot be identified at any site in the basin from available data; however, the areal variation within the basin is suggested from the weighted-mean concentrations for the 21 sites listed in Table IV-2. These concentrations were computed from mean water discharge (for the period of record) and average annual sediment discharge determined from approximately 2½ years of sediment data at each site. The concentrations range from 21 to 90 ppm, which is a very narrow range for such a large area.

On an average of about once each year, the maximum suspended-sediment concentration in the large streams in the basin exceeds 400 ppm. The concentration in some major streams exceeded 2,000 ppm during the floods of December 1964 and January 1965. Landslides in the Blue River drainage basin east of Eugene caused the suspended-sediment concentration of a small stream to exceed 13,000 ppm during the January 1965 flood (Columbia Basin Inter-Agency Committee, 1965, p. 42). Minimum concentration for most streams in the basin is generally less than 10 ppm. The concentration extremes may be changed by man's activities or by some unusual natural phenomenon such as the landslides cited above. These changes in concentration can be of either short or long duration. Fredricksen (1963) found that construction of logging roads in a small forested watershed increased the suspended-sediment concentration of the stream; for more than two years the concentration remained about twice that prior to construction.

Average Annual Sediment Discharge

A measure of the sediment transport of a stream is its average annual sediment discharge. For this study, the average annual sediment discharge at each of the sites given in Table IV-2 is the combination of bedload and suspended-sediment discharge.



EXPLANATION

ANNUAL YIELD IN TONS PER SQUARE MILE

50-150

150-300

300-500

• 1967 Sediment-data station

23/25 — Average percentage of streamflow at Portland / Average percentage of sediment discharge at Portland

Figure IV-25. Generalized sediment yield of Willamette Basin, and sediment discharge as percentage of discharge at Salem

Table IV-2
Sediment-transport characteristics at sites on selected streams

Station number	Sampling site	Flow regulation during period of data collection	Median particle diameter of streambed sediment (mm)	Water discharge at which transport of significant amounts of streambed sediment begins (cfs)	Sediment: Discharge-weighted mean concentration (ppm)	Sediment: Mean annual discharge (1,000 tons)	Sediment: Mean annual yield (tons per sq mi)
1500	Middle Fork Willamette River at Lowell	None	55	1/20,000	47	150	150
1525	Coast Fork Willamette River at London	Slightly, by millponds	0.2	210	53	34	470
1535	Coast Fork Willamette River below Cottage Grove	By Cottage Grove Reservoir	1.4	1,200	33	10	100
1545	Row River above Pitcher Creek near Dorena	Slightly, by log ponds	0.3	1,300	21	97	460
1555	Row River near Cottage Grove	By Dorena Reservoir	70	1/13,000	22	16	60
1580	Willamette River at Springfield	Slightly, by Cottage Grove Reservoir	37	54,000	79	447	220
1655	McKenzie River near Coburg	Slightly, by log ponds and powerplants	55	1/80,000	34	201	150
1665	Long Tom River near Noti	Slightly, by log pond	0.2	2/100	32	12	140
1670	Coyote Creek near Crow	None	0.6	1/5,000	46	9	90
1690	Long Tom River below Fern Ridge Dam	By Fern Ridge Reservoir	0.2	-	-	-	-
1710	Marys River near Philomath	Slightly, by small reservoir on Rock Creek	0.2	1/7,000	69	32	200
1735	Calapooia River at Albany	Slightly, by ponds	4.7	1/30,000	61	56	150
1830	North Santiam River at Nehama	Slightly, by milldam	120	1/20,000	45	150	220
1875	South Santiam River at Waterloo	Slightly, by numerous log ponds	70	1/70,000	90	260	400
1890	Santiam River at Jefferson	None	47	1/150,000	77	590	330
1905	Luckiamute River near Suver	Slightly, by millpond	0.4	1/20,000	55	50	210
1910	Willamette River at Salem	At times by upstream reservoirs	16	70,000	70	1,700	230
1940	South Yamhill River near Whiteson	Slightly, by log pond	0.02	2/1,500	67	130	260
2000	Molalla River near Canby	None	35	14,500	64	71	220
2020	Pudding River at Aurora	Slightly, by mills	0.2	2/500	44	67	140
2065	Tualatin River at Farmington	Slightly, by dams below Gaston	0.04	2/400	47	68	120
2117	Willamette River at Portland	At times by upstream reservoirs	0.6	50,000	71	2,300	210

1/ *Bedload movement not indicated at water discharge shown, the highest discharge tested.*
2/ *Bedload movement still indicated at water discharge shown, the lowest discharge tested.*

The average annual sediment discharge for Willamette River at Portland is compared with sediment discharge for other sites in the basin. These comparisons are illustrated on Figure IV-25, which gives the discharge of water and sediment for each site in percentages of the water discharge and sediment discharge at Portland.

Time Distribution of Sediment Discharge

In Willamette Basin, both the amount and the seasonal distribution of sediment discharge are closely related to the amount and seasonal distribution of precipitation and runoff. As in most large river systems, the seasonal distribution of sediment discharge varies among streams--depending on size, elevation of the stream basin, geographic location, and other factors. The graphs in Figure IV-26 show the distribution of average monthly streamflow and sediment discharge for streams in the basin as percentages of the annual totals. The curve of streamflow is an average developed from streamflow data for selected stations in the basin. Because of the scarcity of monthly sediment-discharge records in the basin, data for adjacent areas west of the Cascade Range were used to help define the sediment-discharge distribution curve. The distribution of monthly sediment discharge for Willamette Basin streams should be similar to the distribution shown in Figure IV-26. Sediment discharge is much less uniformly distributed throughout the year than streamflow. The sediment-discharge curve shows that, on the average, about 82 percent of the sediment is discharged during the four-month period November to February and the remainder during the other eight months.

The sediment discharge of streams in the basin can vary greatly from one year to another, depending principally on how many freshets occur. More sediment is sometimes transported during one large flood than is transported during several average years. For example, during the 10-day flood period December 21-30, 1964, the 6.4 million tons of sediment discharged by Willamette River at Portland (Rantz and Moore, 1965, p. 199-201) was almost three times the average annual discharge (2.3 million tons). The unusually high sediment discharge of the December 1964 flood, combined with the discharge during a second major flood in January 1965, probably resulted in a total sediment discharge for the 1965 water year of more than four times the average for Willamette River at Portland.

Particle Size of Stream Sediments

The particle-size distribution of the sediment transported by a stream often determines the extent to which the water can be utilized. At present, only a small amount of data is available to define the particle-size gradation of stream sediments in the basin. Analyses for 16 sites on the major streams show that the suspended sediment averages about 45 percent clay, 38 percent silt, and 17 percent sand. This agrees closely with a discharge-weighted average gradation of 51 percent clay, 36 percent silt, and 13 percent sand, computed from data for Willamette River at Portland.

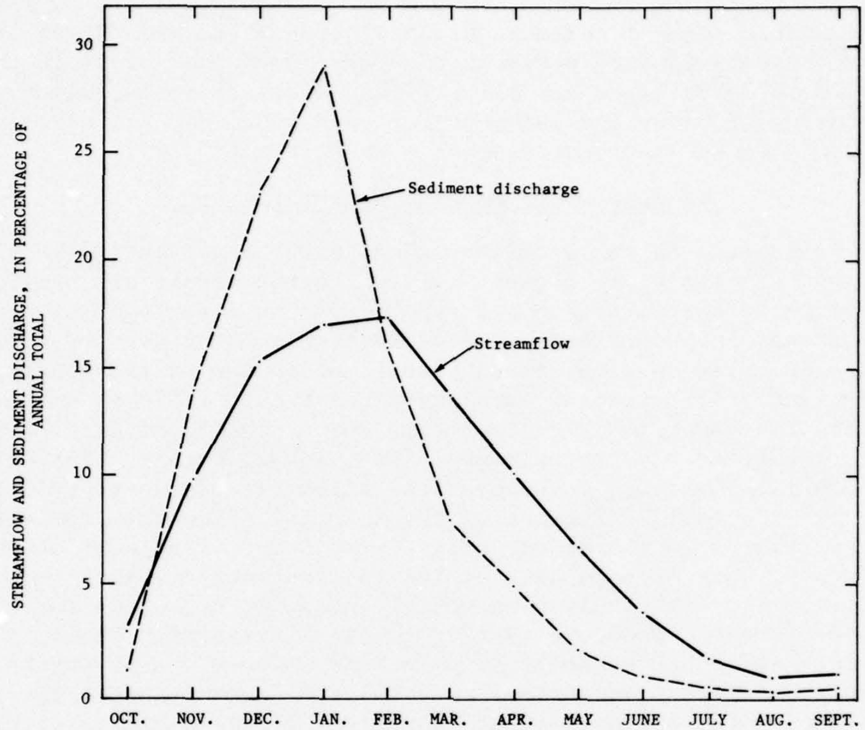


Figure IV-26. Average distribution of monthly streamflow and sediment discharge in Willamette basin.

Bed material from rivers in different parts of the basin has a wide range in particle size. For example, sizes in the sample from Tualatin River at Farmington ranged from less than 0.004 mm to 0.6 mm, whereas sizes from Santiam River at Waterloo ranged from less than 0.004 mm to 200 mm. The median particle diameter (defined as the particle diameter at which half the material is larger and half is smaller by weight) is often used as an indication of how readily sediments are transported.

Table IV-2 gives the median particle diameter of the bed material for 22 sites on major rivers in the basin. Except for Willamette River at Portland, the data for each site are based on one sample obtained in 1950. The data show that the smaller streambed sediments are found in streams with low gradients. Smaller particles are more abundant in streams draining the pyroclastic formations and alluvium on the north slope of the Calapooya Mountains and the marine formations and alluvium on the east slope of the Coast Range. The larger particles were generally found in streams on the steeper slopes of the west slope of the Cascade Range, where the underlying rocks are lavas. The median particle diameter of bed sediments in the Willamette decreases progressively from Springfield to Portland. This decrease results from the decrease in the sediment-transport competence of the river and from the mechanical abrasion of the sediment particles.

Generalized Sediment Yield

Available data indicate that average annual sediment yields over the basin ranged from about 60 to 470 tons per square mile. Compared to the variation in sediment yield for areas of similar size in other parts of the country, the eight-fold difference for different parts of the basin is not large.

Estimates of annual sediment yield are given in Table IV-2. Long-term sediment-discharge data are insufficient for verification of the sediment yields shown. However, sediment-accumulation rates, determined from sediment discharge at sites above and below two reservoirs, may be compared with accumulation rates determined from field surveys of these reservoirs (Corps of Engineers, 1949a, 1958). For that comparison, the following assumptions are made: (1) Sediment yield per square mile between the upstream and downstream sites at each reservoir is the same as the yield at the upstream site; (2) little or no channel aggradation or degradation occurs that is not accounted for in the reservoir surveys; and (3) dry weight of sediment in the reservoir deposits is 70 pounds per cubic foot.

The accumulation rates determined by the two methods compared closely for Cottage Grove Reservoir (Coast Fork Willamette River), but the accumulation rate computed from sediment discharge is almost twice the surveyed rate for Dorena Reservoir (Row River). The rates of sediment accumulation as determined by the two methods are shown in the following tabulation:

Reservoir	Sediment accumulation (Acre-feet per sq mi per yr)	
	Reservoir survey	Difference above and below reservoir
Cottage Grove	0.25	0.24
Dorena	.15	.26

Sediment-yield values from Table IV-2 are used with data on geology, precipitation, runoff, topography, and land use to delineate zones of approximately equal yield (Figure IV-25). Because these zones are based on a small amount of data from a few sites, areas within a particular zone may have yields much greater or much less than the value shown. The data shown on this map are suitable only for preliminary planning.

Figure IV-25 generally agrees closely with the sediment-yield maps developed by Anderson (1954) and Flaxman and High (1955) for broader areas. Some differences occur partly because of differences in the data available when the maps were developed and partly because of the method of interpretation.

Photo IV-2. Landslides, such as this one during the December 1964 flood, are major contributors to sediment load in Willamette Basin.

A detailed investigation of sediment sources in the basin is beyond the scope of this study. In a study of the sediment discharge at Salem, Anderson (1954) estimated that 24 percent of the sediment came from forest land, 22 percent from agricultural land, and 54 percent from eroding channels. Accelerated erosion from logging, construction, farming, and other activities has a considerable effect on sediment yield. The effect of land exploitation can be particularly severe where the vegetation is removed and the soil is left disturbed during periods of heavy precipitation and runoff. The importance of the effects of exploitation and natural short-term phenomenon such as slides on long-term sediment yields is unpredictable from existing data.

Except in a few places, the erosion, transport, and deposition of sediment have not created serious long-range problems. Hence, treatment of water supplies has been economical and industries requiring large amounts of high-quality sediment-free water have been attracted to the basin. The use of good conservation practices and timely consideration of effects of development on stream environment should limit the number of future sediment problems.

STREAM TEMPERATURES

Water temperature in a stream affects fish resources, industrial use, quality control, and recreation. Water-temperature data from 125 sites (Map IV-3) have been compiled (Moore, 1964). Data for some sites are from thermograph records and for other sites are from daily observations of water temperature or observations spaced several days to several weeks apart. Summaries of data from 20 representative stations are given in Table IV-3.

Figure IV-27 shows the monthly temperature ranges in Willamette River at Salem, North Santiam River at Niagara, and South Yamhill River at Willamina. In general, streams draining the Cascade Range have cooler temperatures in all seasons than streams draining the Coast Range or Willamette Valley.

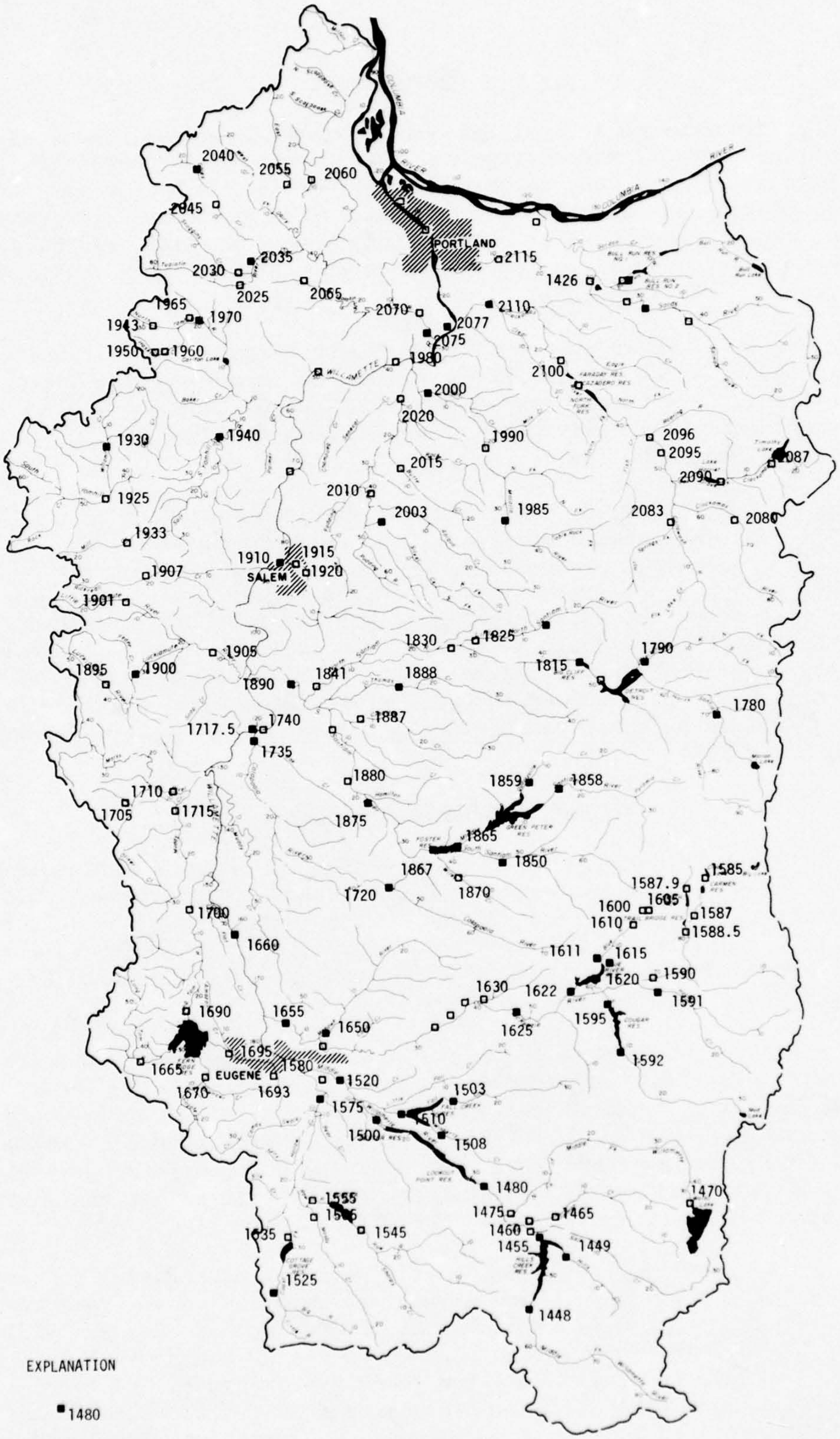
The maximum, minimum, and average monthly temperatures do not provide a complete picture because water temperatures may fluctuate widely during the day, particularly in summer. Fluctuations are generally only a few degrees in small spring-fed streams, in streams largely protected from direct sunlight, and in large, deep streams where the volume of water to be warmed is relatively great. Minimum temperatures generally occur about 8 a.m. or 9 a.m. and maximums about 4 p.m. or 5 p.m. The maximum recorded diurnal fluctuation for 39 stations in Willamette Basin ranged from 3 degrees to 13 degrees Fahrenheit (Moore, 1967).

Stream-Temperature Profiles

In Willamette Basin, the critical months for water temperature are July and August when temperature is highest and natural streamflow is low. Figures IV-28, -29, and -30 show water temperatures for July by a series of profiles for Willamette River and two representative tributaries. The profiles can be used to estimate water temperature between the sites where records have been obtained.

The water temperatures shown on the profiles are representative of water years 1954-1962, inclusive. In general, minimum July-August water temperatures for that period occurred in July 1955 and maximum temperatures occurred in July 1958. Earlier studies by Moore (1967) indicated that those extremes were events having a probable recurrence interval of about 25 years. In general, the divergence between minimum and maximum temperatures is greater in July than in August.

The mean monthly flows shown on the profiles are generally those for water years 1951-1960. This period was selected because (1) records of flow were readily available (U. S. Geological Survey, 1963) and (2) the average flow in that period was nearly the same as in the period 1954-1962, generally used for water temperatures. However, this 10-year period could not be used for gaging stations established after 1951 or discontinued before 1960, or where construction of a reservoir during 1951-1960 changed the flow pattern.



EXPLANATION

■ 1480

Temperature station, thermograph record

□ 1460

Temperature station, spot observations

MAP IV-3

WILLAMETTE BASIN STUDY

OREGON

STREAM TEMPERATURE STATIONS

1968

6 0 6 12

SCALE IN MILES

WBTF-O-1076-L

Table IV-3

Water-temperature data for selected stations and streams

[Data from U.S.G.S. open-file report, Moore, 1964. Adjusted temperatures based on correlation with thermograph record for Middle Santiam River at mouth, near Foster, except as noted]

Stream station and number		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Row River above Pitcher Creek, near Dorena (1545)	Mean	41	43	43	46	50	58	68	68	63	51	45	43
	Max.-Min.	47 33	49 35	48 35	55 39	66 42	75 45	81 50	78 59	74 51	61 42	52 38	48 38
Coast Fork Willamette River near Goshen (1575)	Mean	43	45	45	48	55	61	66	63	63	55	47	44
	Max.-Min.	49 35	51 36	50 36	56 41	68 46	74 44	76 50	75 53	72 54	65 47	54 40	52 39
Mid. Fk. Willamette R. above Salt Cr., near Oakridge (1455)	Mean	40	41	42	46	51	59	61	60	57	51	45	41
	Max.-Min.	48 32	49 32	48 32	56 39	65 40	70 46	70 47	68 53	65 48	60 44	55 34	49 36
Mid. Fk. Willamette R. below N. Fk., nr. Oakridge (1480)1/	Mean	40	41	42	45	49	54	62	62	58	50	44	42
	Max.-Min.	46 35	46 35	49 35	55 39	61 41	66 43	73 48	74 54	66 48	59 42	51 35	48 36
McKenzie River at McKenzie Bridge (1590)2/	Mean	40	40	41	43	44	47	48	48	47	44	43	41
	Max.-Min.	46 35	44 34	43 35	46 39	50 40	53 42	55 41	52 45	51 40	49 39	50 37	46 34
McKenzie River near Coburg (1655)	Mean	43	43	45	48	52	55	61	61	56	50	46	43
	Max.-Min.	49 36	48 35	49 38	54 43	65 44	66 44	68 47	68 47	63 48	57 43	51 40	48 39
Long Tom River near Noti (1665)	Mean	44	45	47	48	55	59	64	63	57	53	47	45
	Max.-Min.	50 33	50 35	51 38	55 40	66 46	71 50	72 51	70 56	67 48	61 45	53 38	51 39
Long Tom River at Monroe (1700)	Mean	43	45	48	53	62	67	70	71	64	57	48	45
	Max.-Min.	53 32	54 32	55 33	63 45	75 53	81 55	81 53	80 63	74 53	68 46	57 35	54 37
North Santiam River at Niagara (1815)2/	Mean	39	39	41	43	46	51	56	57	55	49	44	41
	Max.-Min.	48 32	46 32	44 32	49 38	56 39	61 42	66 44	64 51	62 47	58 42	56 34	50 33
Santiam River at Jefferson (1890)2/ (1947-52)	Mean	43	43	45	48	52	58	65	67	64	57	50	45
	Max.-Min.	55 35	52 33	50 33	63 41	65 43	72 47	79 50	76 59	74 53	69 47	65 36	57 35
(1953-62)	Mean	44	43	44	47	50	55	61	62	59	55	49	45
	Max.-Min.	53 37	50 33	49 33	55 41	63 42	66 44	74 48	70 55	68 51	64 47	61 39	55 37
Willamette River at Salem (1910)1/	Mean	43	44	46	51	56	61	68	68	63	55	48	44
	Max.-Min.	49 34	50 32	53 38	61 40	67 48	75 53	78 56	75 55	75 52	67 43	57 35	51 35
South Yamhill River near Willamina (1925)	Mean	42	44	44	48	52	61	68	68	61	51	45	44
	Max.-Min.	48 32	51 35	50 36	58 42	69 43	79 47	81 48	79 58	73 49	63 41	53 37	50 39
South Yamhill River nr. Whiteson (1940)	Mean	43	45	46	50	54	61	69	70	63	53	47	44
	Max.-Min.	50 33	52 34	52 35	59 42	69 44	77 47	81 51	80 58	74 52	64 42	55 37	52 38
Pudding River at Aurora (2020)	Mean	43	44	45	50	55	63	69	69	61	53	46	45
	Max.-Min.	51 32	51 32	52 32	60 43	70 45	80 50	81 51	79 60	72 50	65 43	54 37	52 38
Tualatin River near Dilley (2035)	Mean	41	44	44	51	55	59	67	64	60	52	47	43
	Max.-Min.	48 32	51 34	50 34	60 43	70 46	75 46	79 49	74 55	71 48	63 42	54 38	50 37
Tualatin River at West Linn (2075)	Mean	42	46	46	52	56	64	70	69	65	55	47	44
	Max.-Min.	50 32	53 34	52 35	61 46	72 47	81 50	83 51	80 60	76 53	67 45	55 38	51 38
Clackamas River at Big Bottom (2080)	Mean	38	40	40	43	44	48	52	51	48	44	41	39
	Max.-Min.	42 33	43 35	43 35	47 39	51 39	55 41	57 43	55 45	53 42	50 40	44 36	43 36
Clackamas River at Estacada (2100)	Mean	39	41	41	44	48	54	61	60	55	48	42	40
	Max.-Min.	44 34	46 35	46 35	51 40	60 41	67 45	70 46	69 53	65 45	57 41	48 37	45 37
Sandy River near Marmot (1370)	Mean	39	41	41	44	47	53	57	58	53	49	43	40
	Max.-Min.	44 32	46 33	46 34	50 39	57 40	64 44	66 46	65 52	60 46	56 43	48 32	45 35
Sandy River below Bull Run River, near Bull Run (1425)	Mean	39	41	43	44	49	56	60	61	55	52	44	41
	Max.-Min.	46 32	47 32	49 33	53 38	60 41	66 46	68 48	67 54	63 47	59 43	51 35	47 34

1/ Average of thermograph record for 1951-61 or 1951-62.
2/ Adjusted temperatures based on correlation with thermograph record for Breitenbush River above Canyon Creek, near Detroit.

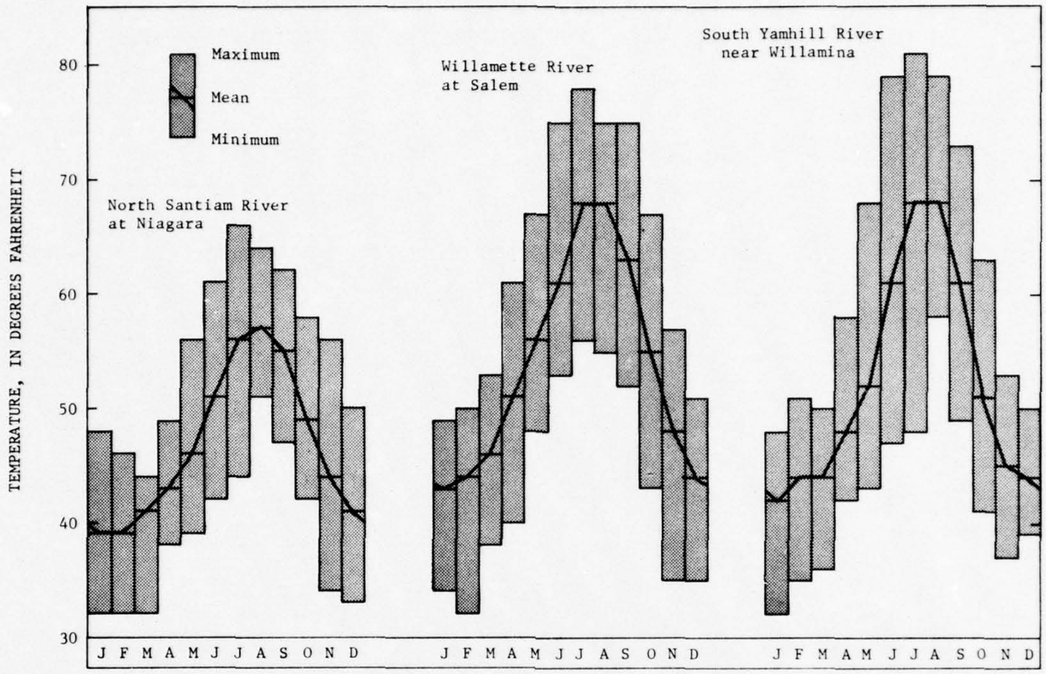


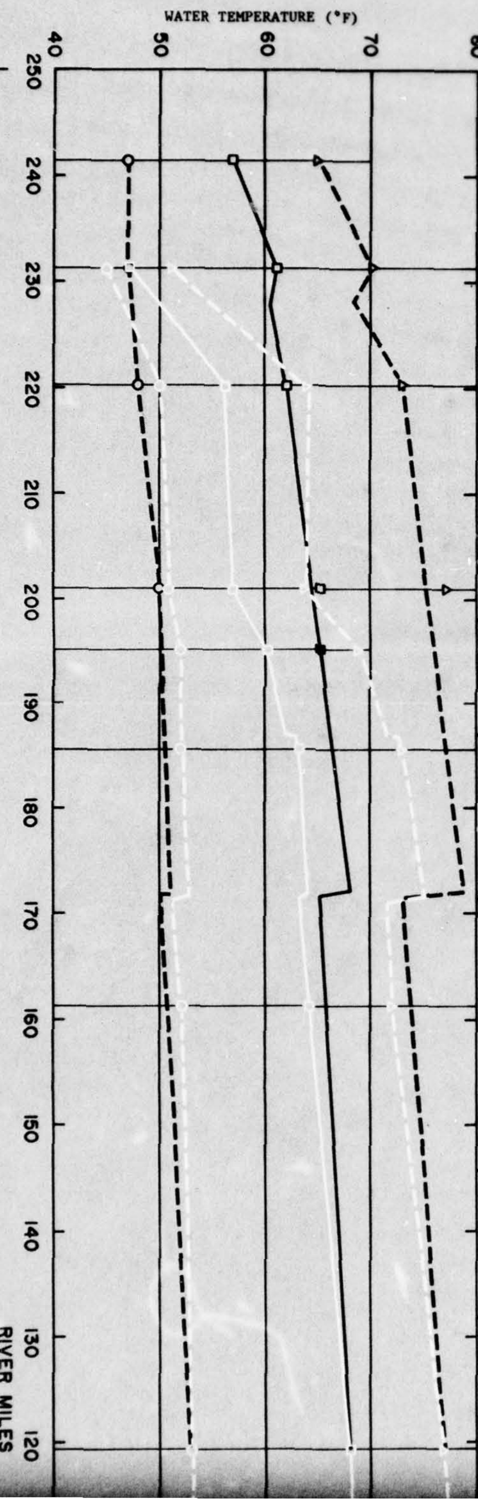
Figure IV-27. Monthly water temperatures for selected stations.

The profiles (Figures IV-28, -29, and -30) show minimum, mean, and maximum water temperatures for each data-collection site plotted against river-mile location of the sites. Points where various tributaries enter the main stream are indicated by arrows above the profile. Temperature data for the tributaries are not plotted, but are shown in tabular form above the arrows.

On each profile, mean flow for the month for each main-stream site and each tributary is shown. The main-stream temperature below the confluence of each tributary is computed by weighting the temperatures of the two streams in proportion to their flows. Thus, a stream at temperature of 72 degrees Fahrenheit with a flow of 1,000 cfs, when joined by a tributary having a temperature of 66 degrees Fahrenheit and a flow of 200 cfs, would have a temperature of 71 degrees Fahrenheit below the confluence.

River-mile location of the site to which the tributary data apply is shown because it is needed to estimate temperature of the tributary at its mouth. If the site is within about five miles of the mouth, temperatures at the mouth are considered to be the same as those measured at the site. If the site is more than five miles from the mouth, maximum and mean water temperatures are assumed to increase two degrees Fahrenheit per 10 miles and minimum water temperatures to increase one degree Fahrenheit per 10 miles. However, if the temperature of the tributary was nearly equivalent to the air temperature when the observation was made, flatter gradients are used.

Station and number	Mean flow (cfs)
Middle Fork Willamette River near Oakridge (1448)	309
Middle Fk. Willamette R. above Salt Cr. nr. Oakridge (1455)	576
Middle Fk. Willamette R. below North Fk. nr. Oakridge (1480)	1,400
Middle Fork Willamette River near Dexter (1500)	1,580
Middle Fork Willamette River at Jasper (1520)	
Willamette River at Springfield (1580)	
Willamette River at Harrisburg (1660)	
Willamette River at Albany (1740)	



Tributary	Water temperature (°F) Min.	Mean	Max.	Mean flow (cfs)	Trib. river mile
Hills Creek	49	60	69	43	4.1
Salt Creek	45	55	61	174	0.7
Salmon Creek	46	56	63	255	5.0
North Fork	47	62	71	312	1.0
Fall Creek	50	67	79	104	6.1
Coast Fork Willamette R.					
McKenzie River	48	63	69	2,940	0
Long Tom River					
Marys River	46	66	80	35	9.4
Calapooia R.	47	68	82	92	0

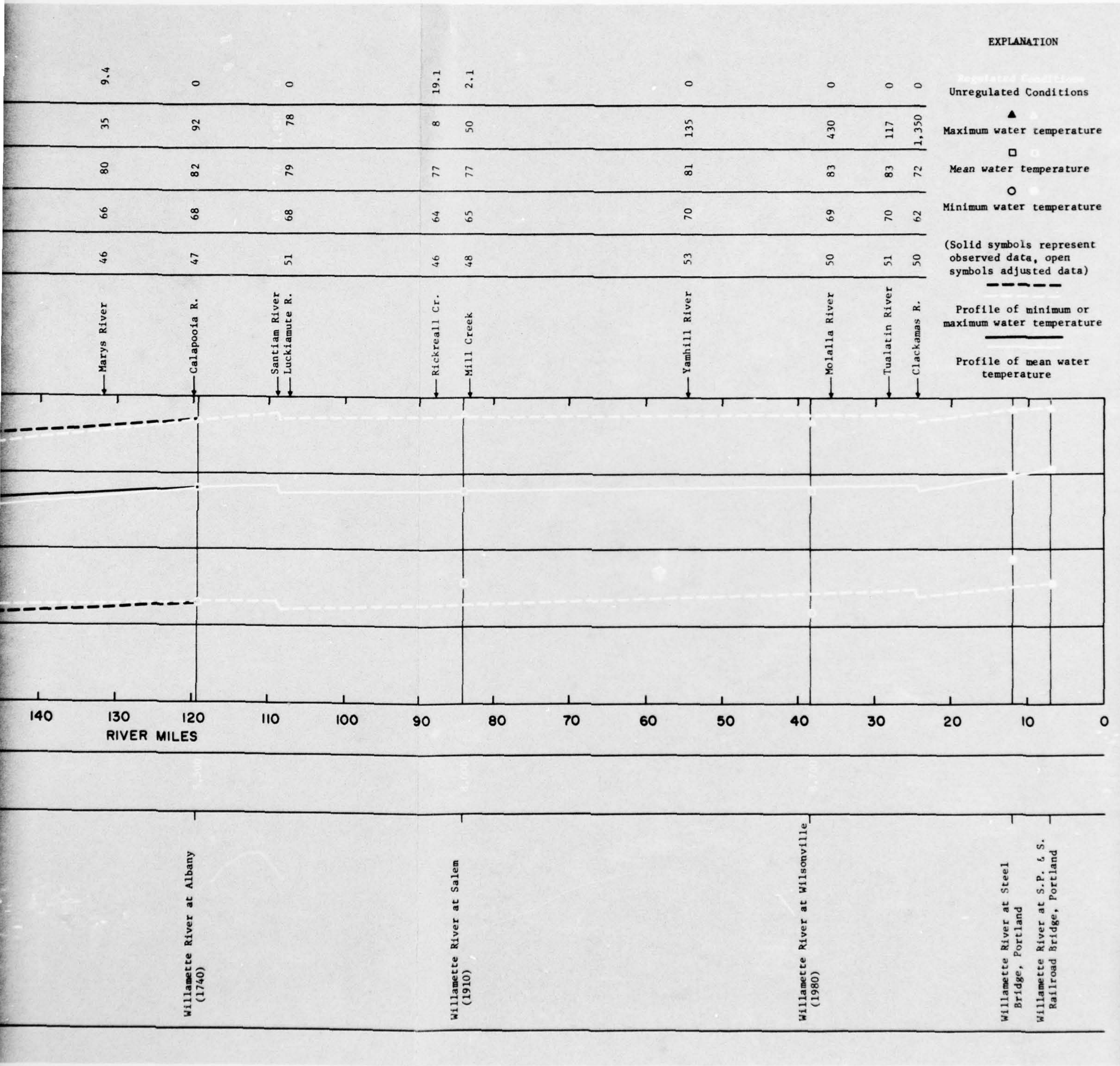


Figure IV-28. Water-temperature profiles for July, main stem and Middle Fork Willamette Rivers.

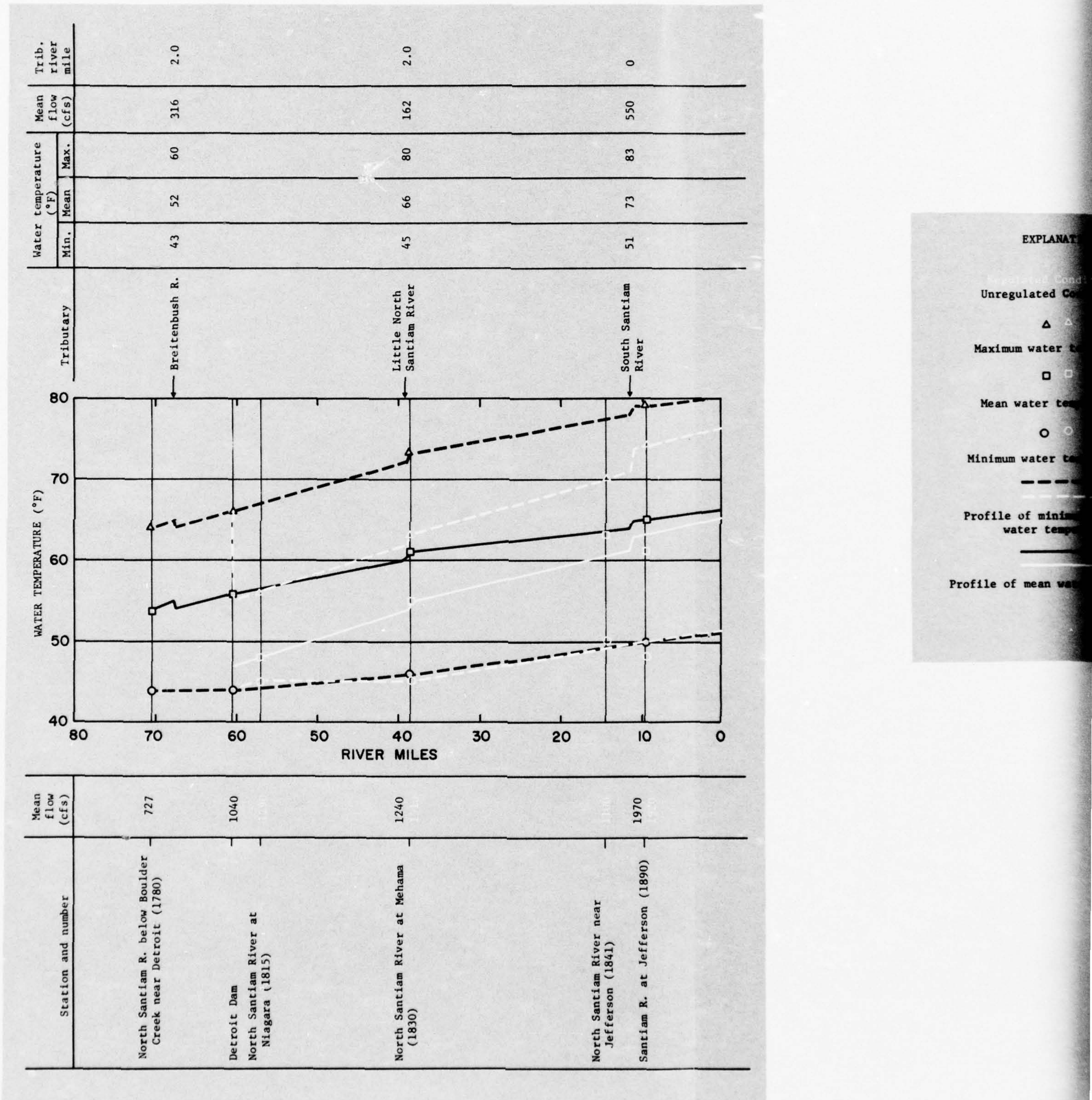


Figure IV-29, 30. Water-temperature profiles for July, North Santiam and Yamhill Rivers.

EXPLANATION

gulated Conditions

gulated Conditions

△

m water temperature

□

water temperature

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water temperature

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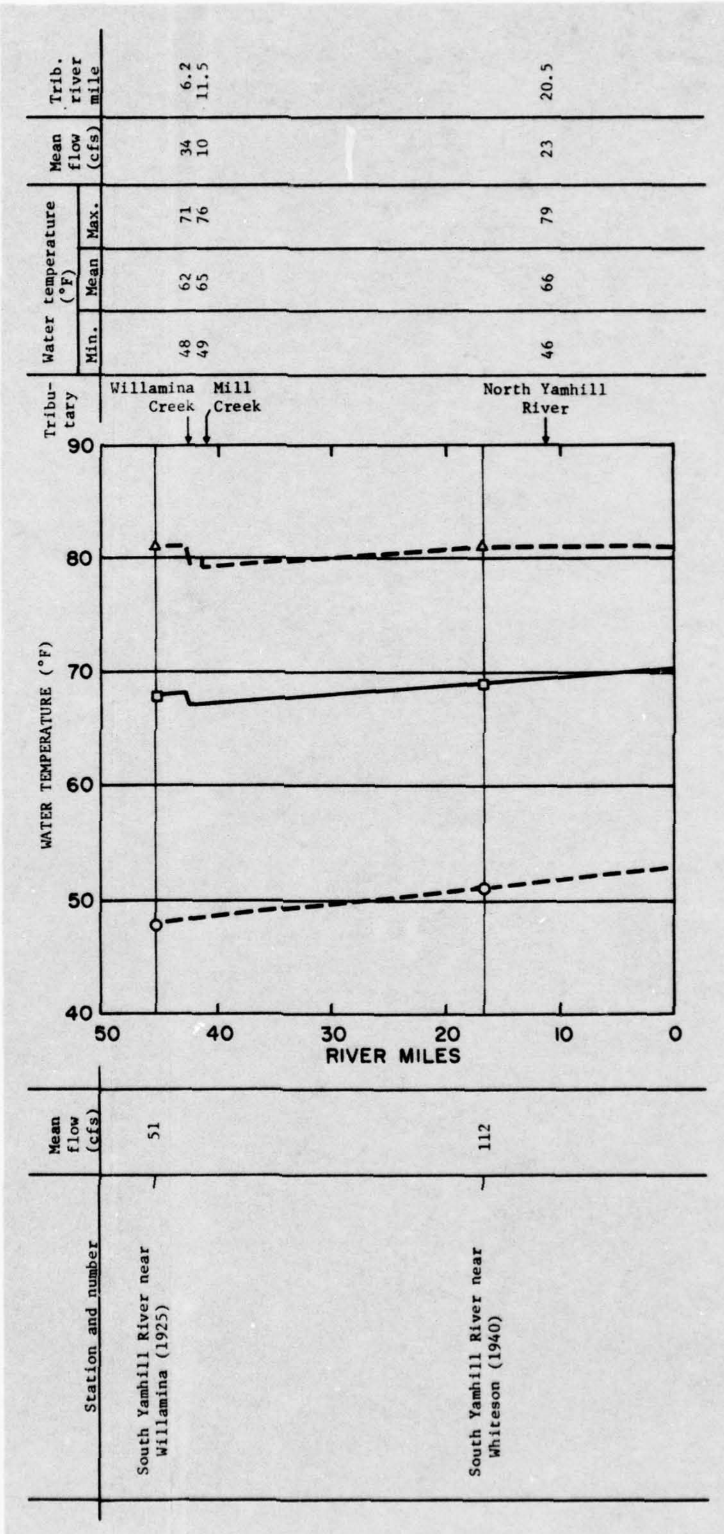
of minimum or maximum
ter temperature

———————

f mean water temperature



The water-temperature profiles show not only the long-term mean temperatures that can be expected for July but also the extremes of temperature that probably will not be exceeded more than an average of once in 25 years. The profiles show the means and extremes of water temperature at the points of observation and represent estimates of temperatures at other points on the streams.

Water-Temperature Gradients

During the summer, the temperatures of the streams become progressively warmer downstream. Several streams, such as McKenzie, Santiam, and Clackamas Rivers, are cool in their upper reaches because they originate at high elevations in the Cascade Range where springs and snowmelt contribute to the flow and where air temperatures are cool. Water temperatures remain relatively cool until lower elevations are reached downstream. There, the water temperatures rise sharply, but temperature gradients flatten gradually as the water temperature approaches air temperature. Streams such as Calapooia, Luckiamute, Yamhill, and Tualatin Rivers, which originate at lower elevations, have such warm temperatures in their upper reaches that the temperatures increase only a few degrees throughout their lengths.

Effect of Tributaries and Reservoirs

As the profiles show, tributaries with significantly different temperatures from the main stream cause abrupt changes in temperature of the stream. Even more dramatic changes are caused by reservoirs, where the entire flow of the river downstream consists of releases of stored water at temperatures much different from natural streamflow.

During summer, the entire flow of a stream in places may consist of releases of water from deep reservoirs that have stratification of temperature. Water released from the bottom of a deep reservoir may have a temperature as low as 39 degrees or 40 degrees Fahrenheit (the temperature at which maximum density occurs). Water released from slightly higher levels may also be cooler than natural streamflow. Water released from the surface of a reservoir during summer generally is warmer than natural streamflow.

Periods of temperature record for some streams are sufficiently long to show two sets of profiles--one set including and the other set excluding the effect of the reservoir. For Hills Creek, Lookout Point, and Detroit Reservoirs, black profiles represent natural conditions and white profiles represent regulated conditions (figures IV-28 and -29). Because reservoir operation can significantly affect the flow regimen, separate sets of discharge figures (also in black and white) are given for the reaches downstream from the three reservoirs.

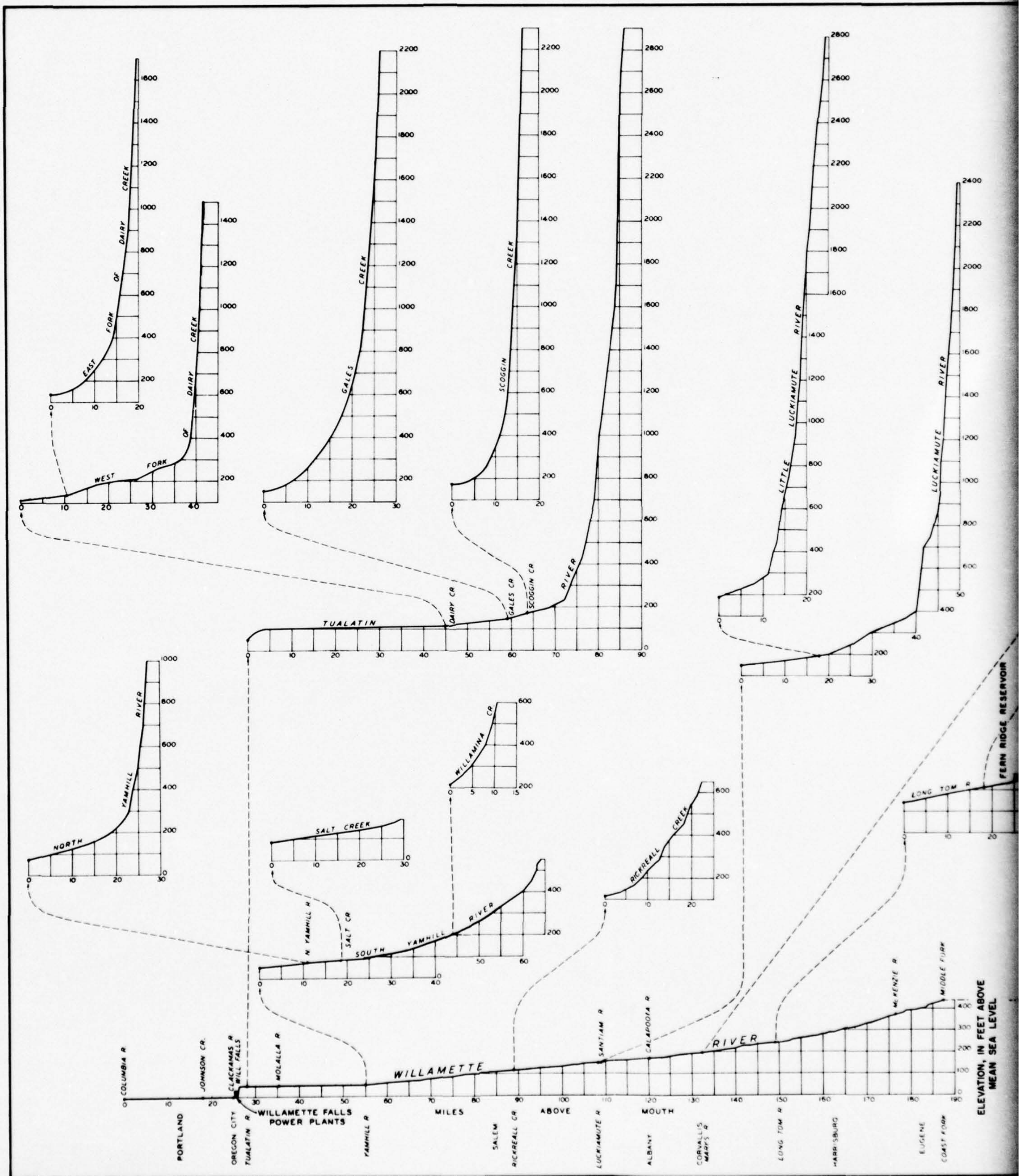
STREAM PROFILES

Stream profiles are graphic portrayals of the longitudinal profile of a stream, showing elevation versus stream mileage. They are useful for analyzing the relationships between gradient and other stream characteristics. Stream gradient is a significant drainage-basin characteristic that influences unit-hydrograph lag time, defined as the time interval between the broad peaks of effective rainfall and of direct runoff. Gradient also influences bedload and streambed aggradation and degradation.

Figures IV-31 to -33 are profiles of the water surface for low flows. These profiles were developed by the Corps of Engineers (v. V, 1951) for Willamette Basin streams. Profiles have also been published for selected streams in Willamette Basin by the U. S. Geological Survey (Jones and Helland, 1948).

The major tributaries of Willamette River rise in the Cascade Range at elevations of 5,000 feet or more and enter the main stream from the east. West-side tributaries head at much lower elevations and generally carry less flow than the east-side tributaries. The mountain portions of the stream channels are characterized by "V"-shaped canyons with rapids, pools, and some waterfalls. After the tributary streams reach the valley floor, their channels widen and they flow at low gradients to their mouths.

Slopes of low-water profiles vary along the course of the Willamette. The 26-mile reach from Oregon City to the mouth of the Willamette is affected by tides and by backwater from high stages on Columbia River. The flat gradient of the Willamette between the mouth of Yamhill River and Oregon City is caused partly by backwater from check gates at Willamette Falls. The profile of Willamette River upstream from Yamhill River is typical for a stream with an unstable bed; the streambed consists of a series of long, deep pools and short, steep riffles. The steepest gradients are near the headwaters.



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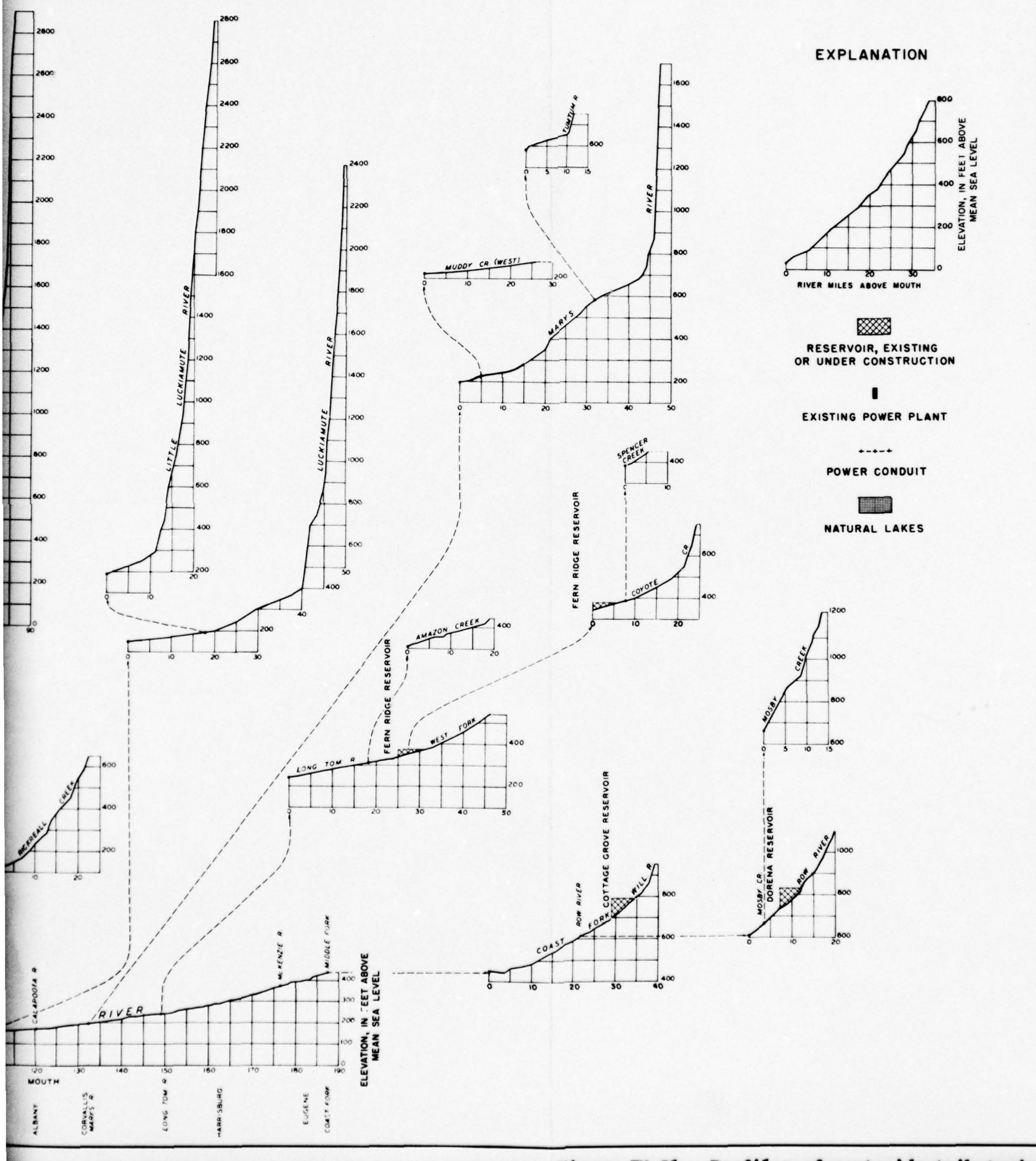
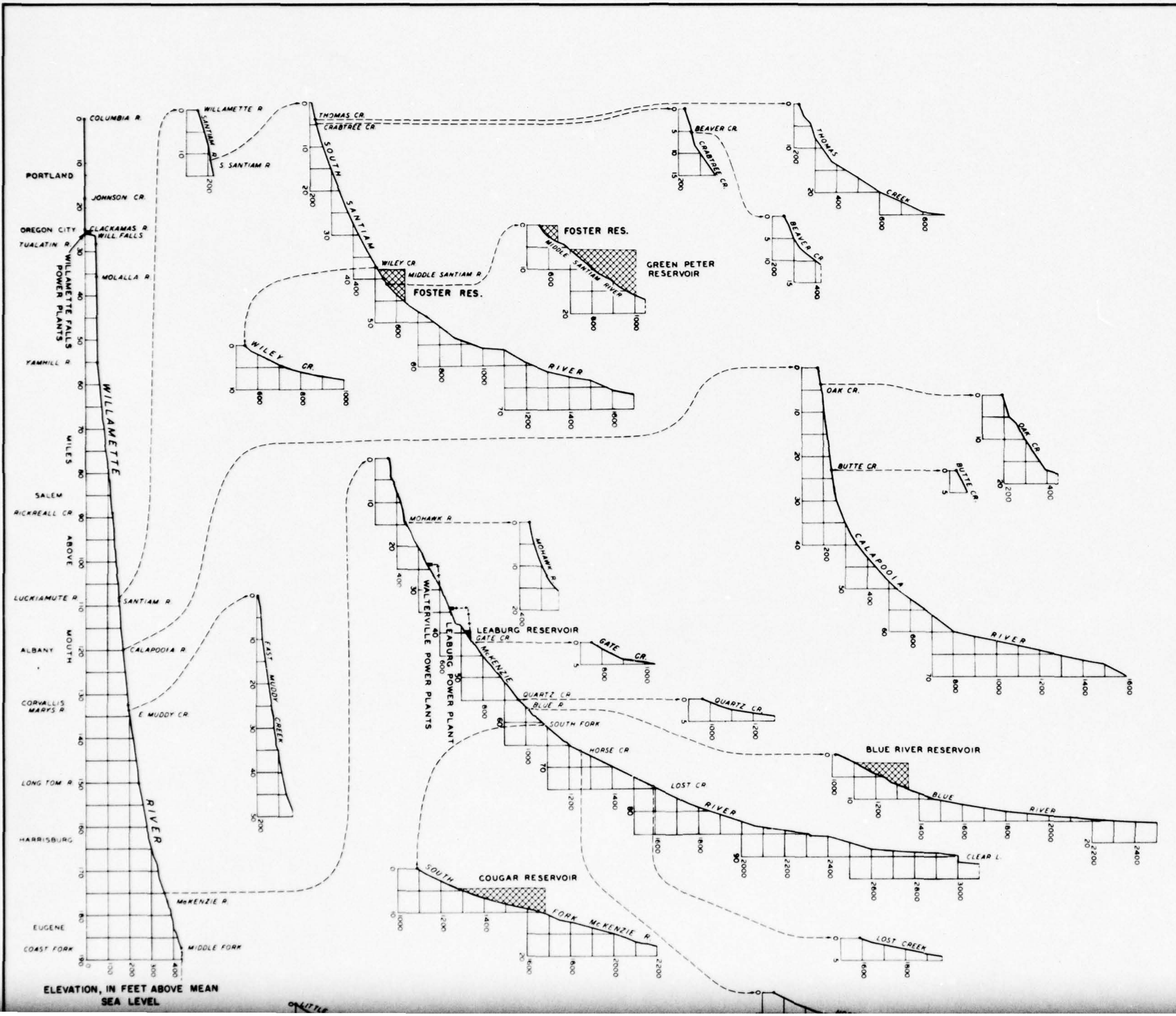


Figure IV-31. Profiles of west-side tributaries of Willamette River.


WILLAMETTE RIVER
COLUMBIA R.
PORTLAND
JOHNSON CR.
OREGON CITY
CLACKAMAS R.
WILL FALLS
TUALATIN R.
WILLAMETTE FALLS POWER PLANTS
MOLALLA R.
YAMHILL R.
MILES ABOVE MOUTH
SALEM
RICKREALL CR.
LUCKIAMUTE R.
SANTIAM R.
ALBANY
CALAPOOIA R.
CORVALLIS
MARYS R.
E MUDDY CR.
LONG TOM R.
HARRISBURG
McKENZIE R.
EUGENE
COAST FORK
MIDDLE FORK
ELEVATION, IN FEET ABOVE MEAN SEA LEVEL
WILLAMETTE R.
SANTIAM R.
S. SANTIAM R.
THOMAS CR.
CRABTREE CR.
SOUTH SANTIAM RIVER
WILEY CR.
MIDDLE SANTIAM R.
FOSTER RES.
GREEN PETER RESERVOIR
MIDDLE SANTIAM RIVER
BEAVER CR.
THOMAS CREEK
WILEY CR.
EAST MUDDY CREEK
MOHAWK R.
WALTERVILLE POWER PLANTS
LEABURG POWER PLANT
LEABURG RESERVOIR
GATE CR.
McKENZIE RIVER
QUARTZ CR.
BLUE R.
SOUTH FORK
HORSE CR.
LOST CR.
CLEAR L.
BLUE RIVER RESERVOIR
BLUE RIVER
COUGAR RESERVOIR
SOUTH FORK McKENZIE R.
LOST CREEK
OAK CR.
BUTTE CR.
CALAPOOIA RIVER
LITTLE

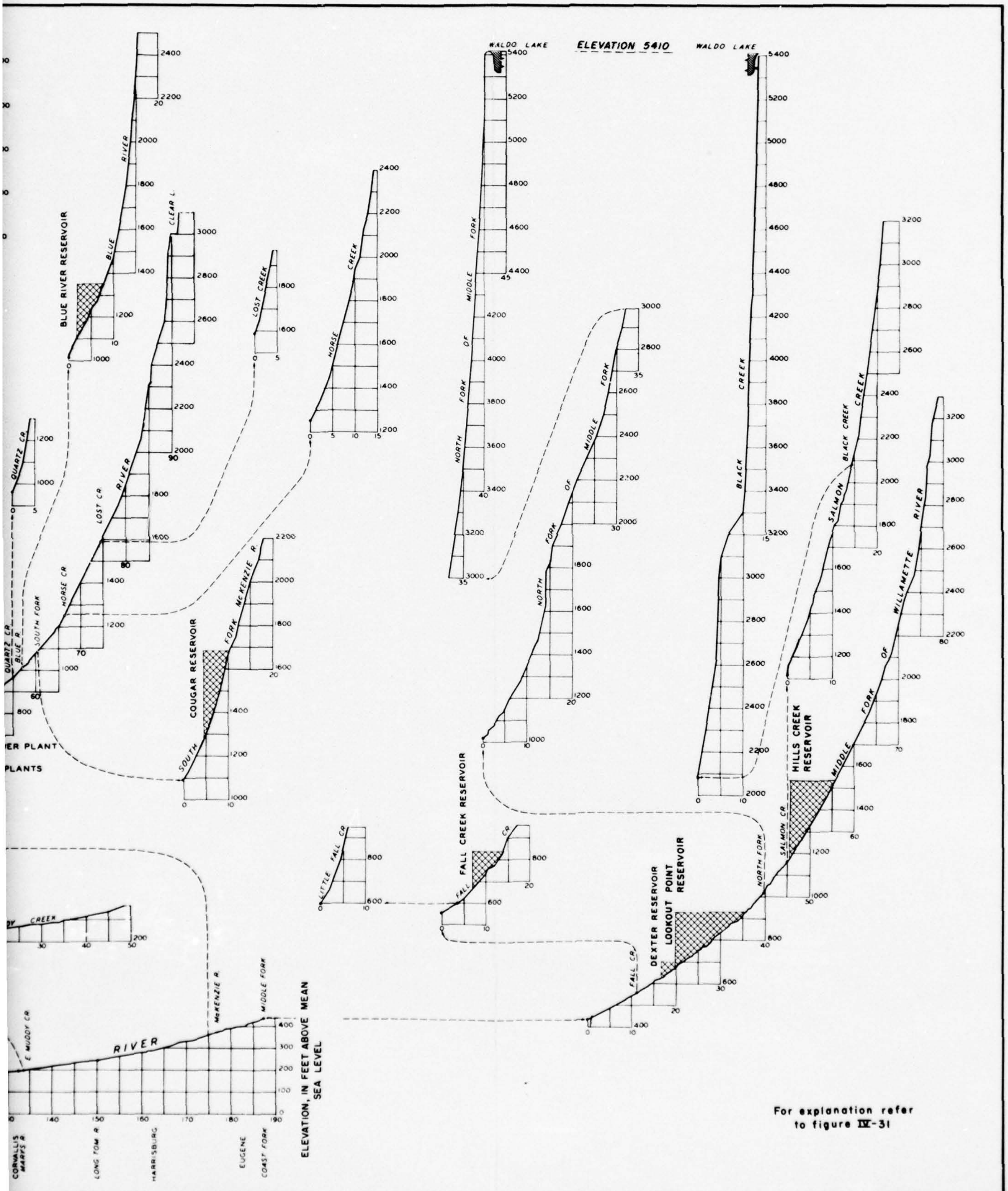
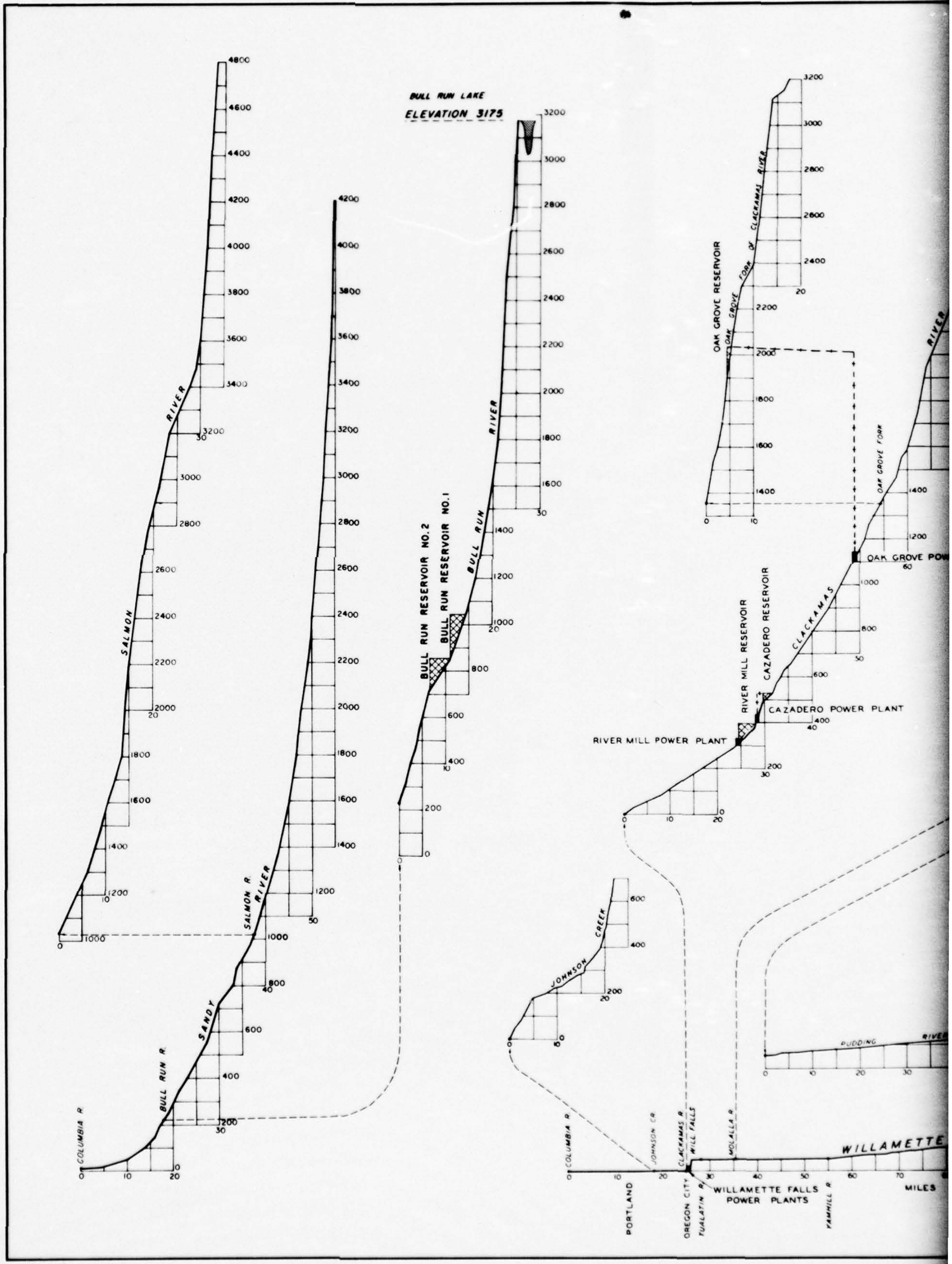


Figure IV-32. Profiles of east-side streams (Middle Fork to South Santiam Rivers).



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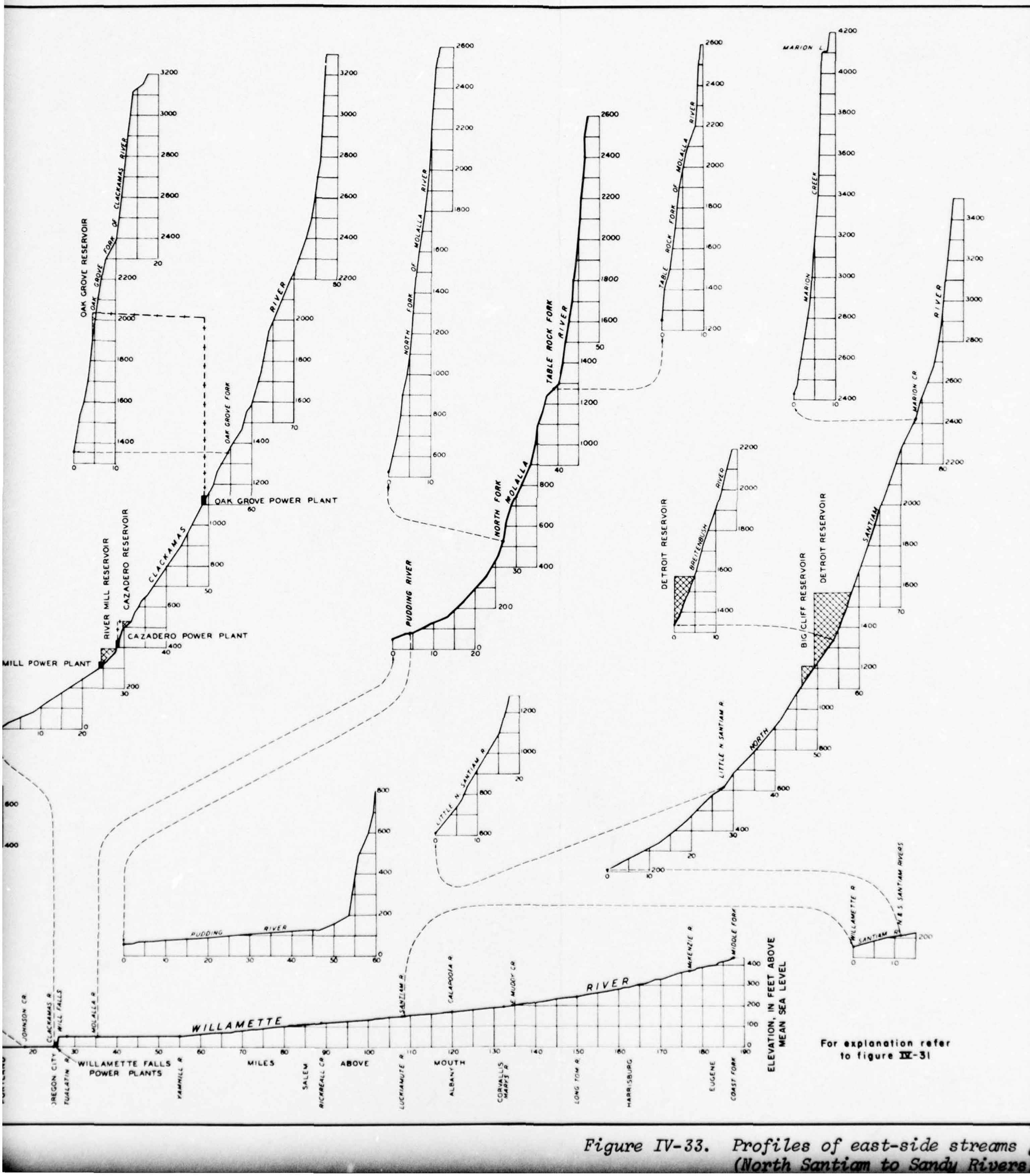

Figure IV-33. Profiles of east-side streams (North Santiam to Sandy Rivers).

TIME OF TRAVEL OF WATER

Knowledge of the time of travel of water is necessary for intelligent management and control of streams. Stream temperature can be modified by releasing cool water from reservoirs, but time of travel must be known to determine the size of the release needed. If a harmful contaminant were accidentally introduced into a stream, it would be desirable to know when the contaminant might arrive at critical points downstream. Time of travel also affects the biochemical oxygen demand of a stream, because the oxygen deficit is related to time of flow.

In the past, only a small amount of time-of-travel information was available for Willamette Basin streams--either from theoretical computations of mean velocity or by timing the movement of waste releases from industrial plants. To obtain more accurate and complete data, time-of-travel studies were made using a dye tracer at low, medium, and high flows. Travel-time charts in this presentation show the travel time of the peak concentration of the dye tracer.

The graphs of travel rate versus discharge are not applicable to the travel of flood waves or flood crests, which generally travel at different rates than do the water particles.

Reaches Studied

Studies were made in stream reaches below key dams where the flows are closely controlled by reservoirs. These reaches were: Middle Fork and Willamette River from Dexter Dam to Willamette Falls; Coast Fork Willamette River from Cottage Grove Dam to the mouth; McKenzie River from Trail Bridge Dam to the mouth; Middle and South Santiam Rivers from Green Peter damsite to the mouth; and North Santiam and Santiam Rivers from Big Cliff Dam to the mouth. Time-of-travel study reaches are shown on Map IV-4, and typical flows for the reaches are presented in Table IV-4.

Travel-Rate Graphs

Time-of-travel data were used to develop graphs of travel rate versus discharge for each subreach; an example from Middle Fork Willamette River is shown in Figure IV-34. These graphs show how travel rate varies with discharge. Graphs for individual subreaches are presented in a hydrologic atlas prepared by Harris (1968). Rate instead of travel time is used in the graphs because rate is easily applied to any part of a subreach. Discharges were obtained from records at gaging stations in or adjacent to the subreaches studied.

Graphs were generally well defined, but a few were poorly defined because of channel changes caused by floods between the time of the low- and medium-flow studies. New channels cut by floodwater were shorter or longer than old ones so that travel times for the two studies were inconsistent.

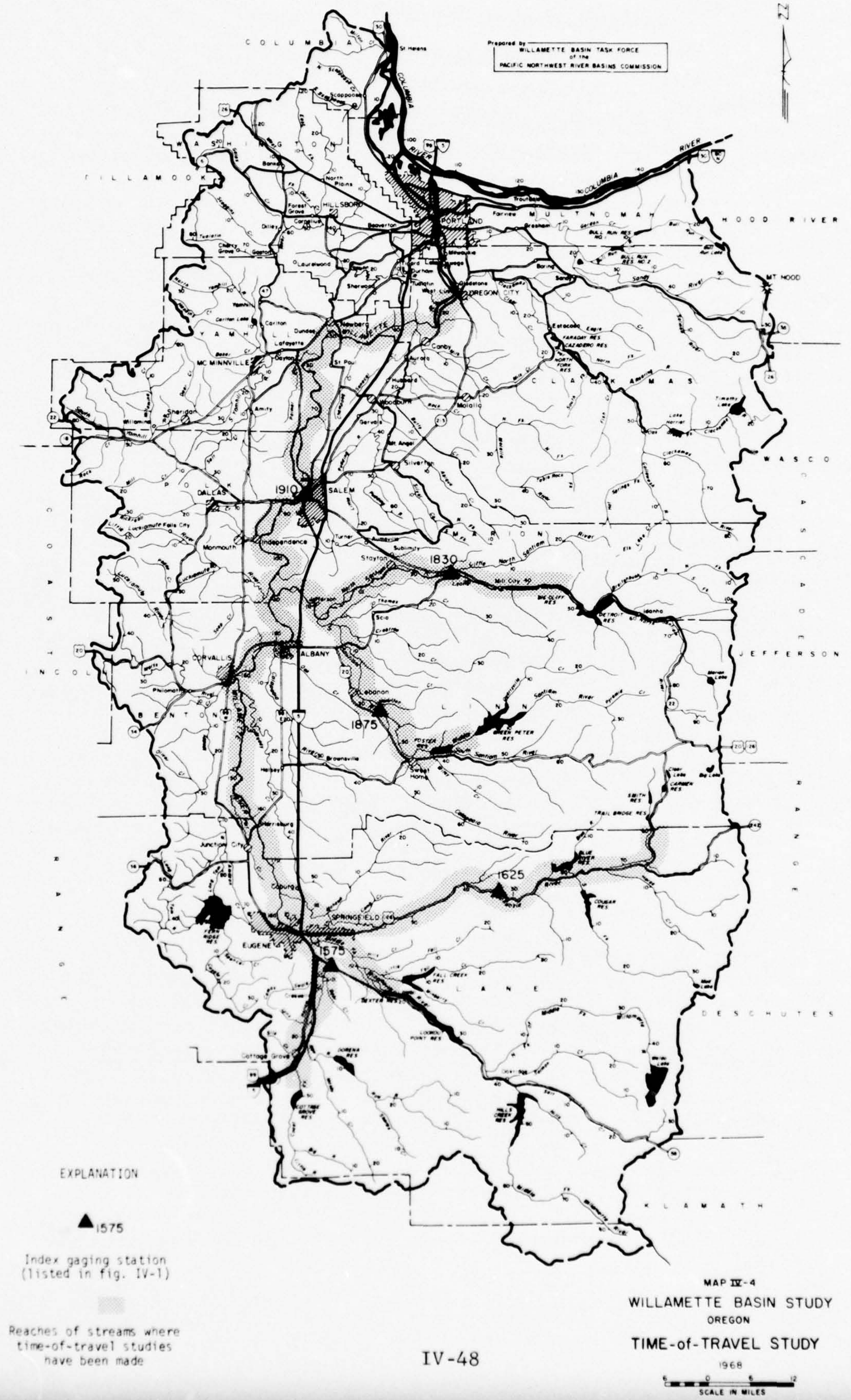
Prepared by
WILLAMETTE BASIN TASK FORCE
of the
PACIFIC NORTHWEST RIVER BASINS COMMISSION
PORTLAND
OREGON CITY
SALEM
ALBANY
CORVALLIS
EUGENE
SPRINGFIELD
1910
1830
1875
1625
1575
EXPLANATION
1575
Index gaging station
(listed in fig. IV-1)
Reaches of streams where
time-of-travel studies
have been made
MAP IV-4
WILLAMETTE BASIN STUDY
OREGON
TIME-of-TRAVEL STUDY
1968
SCALE IN MILES

Table IV-4

Lengths of study reaches and selected flows at index gaging stations

River	Index gaging station	Length of study reach (miles)	Selected flows at index gaging stations (cubic feet per second) [1/] Low	Medium	High
Coast Fork Willamette	1575 (Goshen)	29.4	200	1,700	6,600
McKenzie	1625 (Vida)	77.9 [2/]	1,700	4,000	8,200
North Santiam and Santiam	1830 (Mehama)	57.3	800	3,300	8,500
Middle and South Santiam	1875 (Waterloo)	45.7	600	2,900	8,500
Middle Fork and Willamette	1910 (Salem)	176.1	6,500	23,000	68,000

1/ *Low flow is the minimum scheduled flow to be anticipated nearly 100 percent of the time after all streamflow-regulation projects (U.S.Army, Corps of Engineers, 1951, pl. III-10) are completed. Medium flow is the average flow of record at the gaging station. High flow is the median 30-day annual high flow at each station (median of the annual values of highest mean discharge for 30 consecutive days).*

2/ *To alternate month.*

Typical Travel-Time Graphs

Graphs of travel time versus stream distance for high, medium, and low flows were developed from the relationship of travel rate to discharge for each stream studied (Figures IV-35 to -39). The flows given on the graphs are the same as those of Table IV-4 and apply to the subreaches in the vicinity of the index stations. Typical concurrent upstream and downstream flows were obtained from records at other gaging stations in the reaches. The corresponding travel-rate graphs were used to determine travel time in the subreaches.

Because patterns of flow may be affected by reservoir regulation and by varying distribution of flows in the several tributaries, actual travel times can deviate from those shown on the graphs. Therefore, the graphs should not be used for forecasting travel times precisely.

The graphs illustrate the range in observed travel times as well as the variability of travel times for future expected flows in the reaches. Steep lines indicate slow travel rates and the flatter lines show faster travel rates.

A notable change in travel rate occurs on Willamette River below the mouth of Yamhill River (Figure IV-36). Velocities downstream from that point are very slow at low flows; the effect is less apparent at higher flows. The slower velocities result from ponding caused by the Willamette Falls check gates which regulate the river level and the discharge.

Artificial channels affect travel times in a few reaches. At low flows, travel rates are faster through Leaburg canal and Walterville canal than through the McKenzie River channel (Figure IV-37). As flows increase and more water moves through the natural stream course, travel rates become faster in the river channel than in the canals.

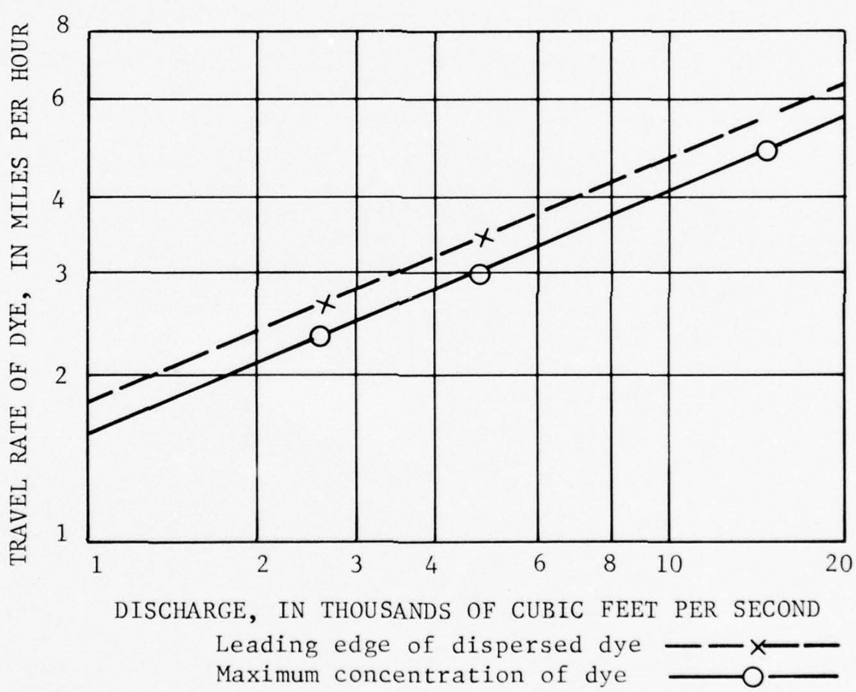

Figure IV-34. Rate of travel for average reach discharge, Middle Fork Willamette River between Dexter Dam and confluence with Coast Fork Willamette River.

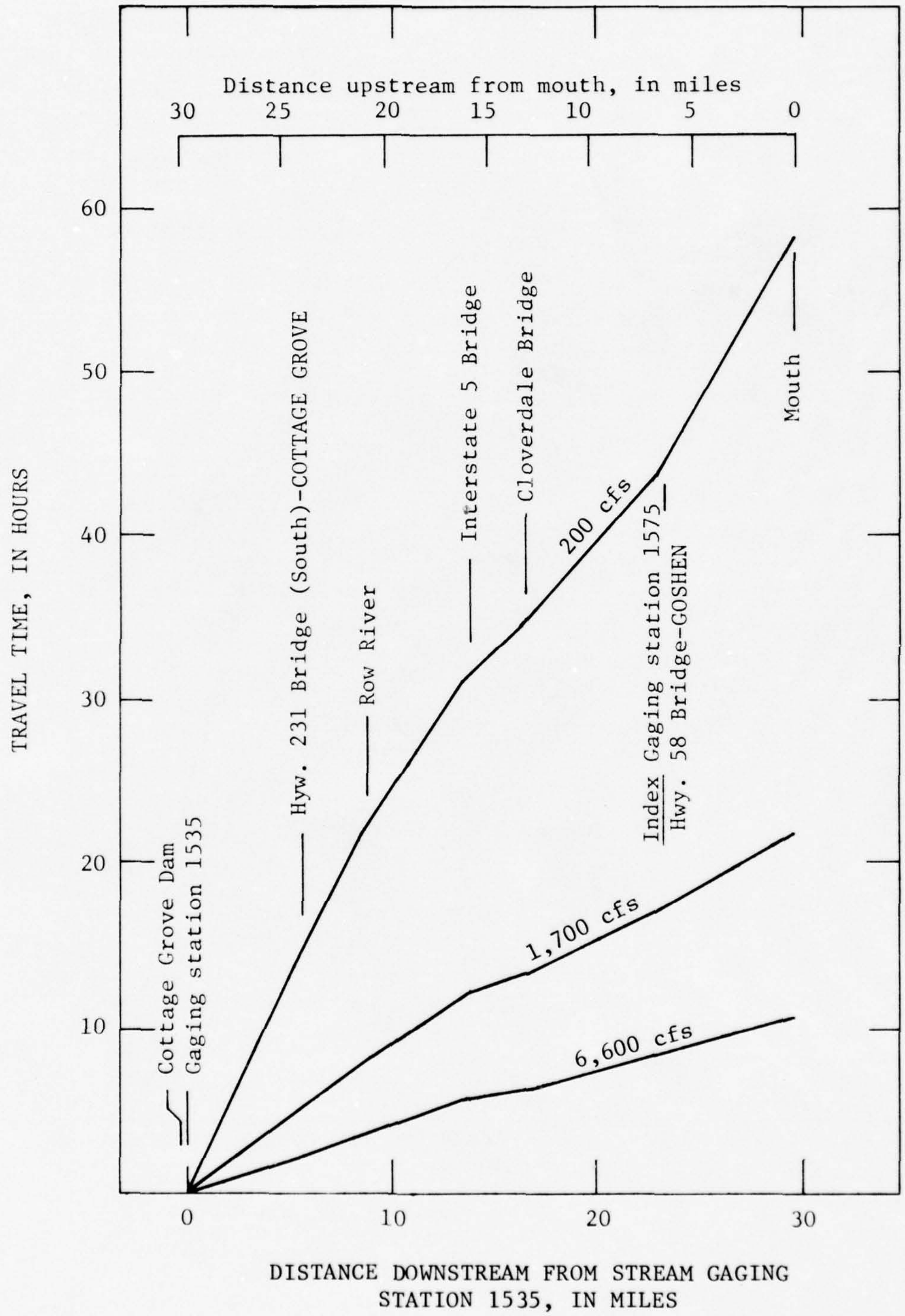

Figure IV-35. Time of travel of Coast Fork Willamette River for selected discharges near Goshen.

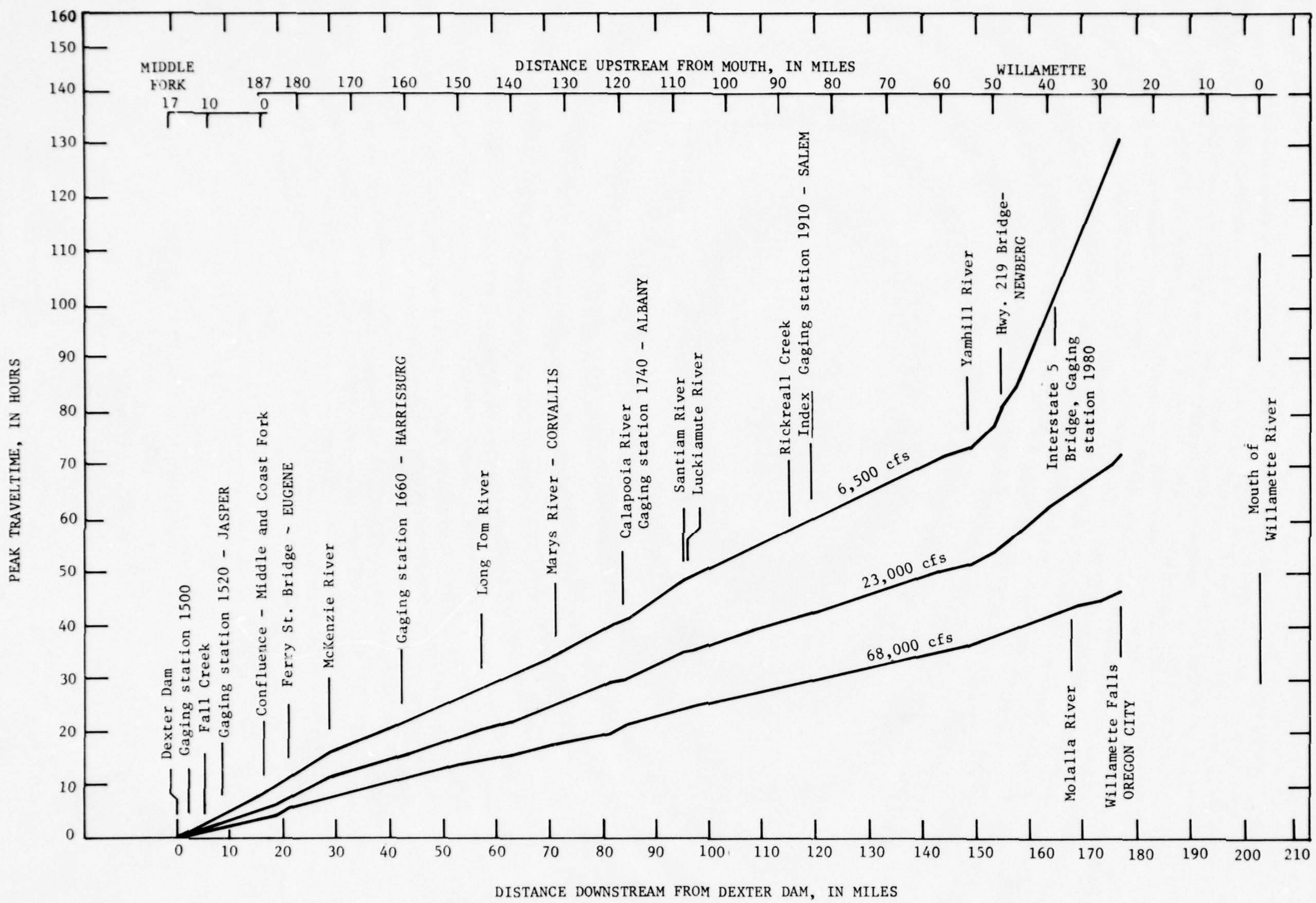

Figure IV-36. Time of travel of Middle Fork and main stem Willamette Rivers for selected discharges at Salem.

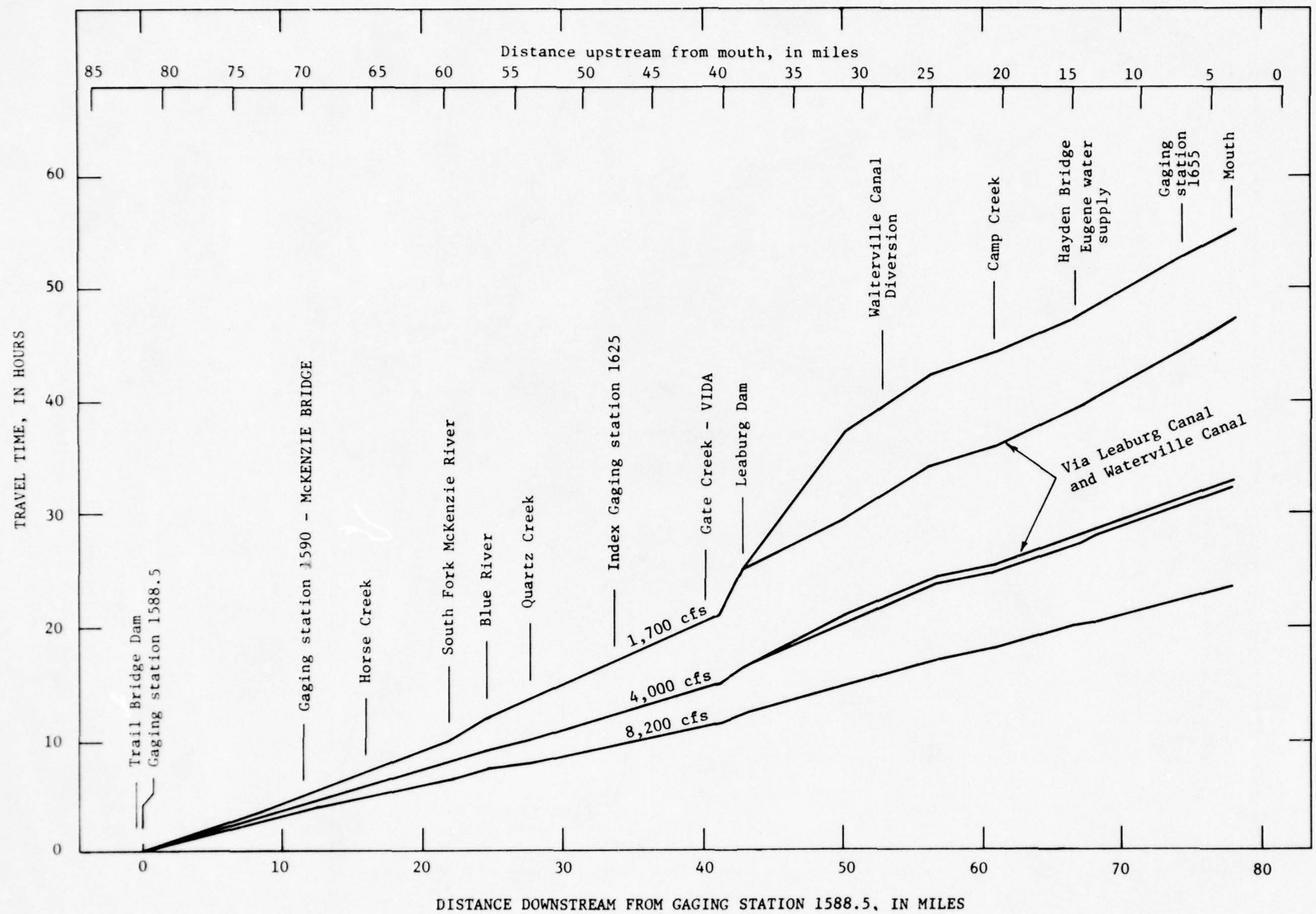

Figure IV-37. Time of travel of McKenzie River for selected discharges near Vida.

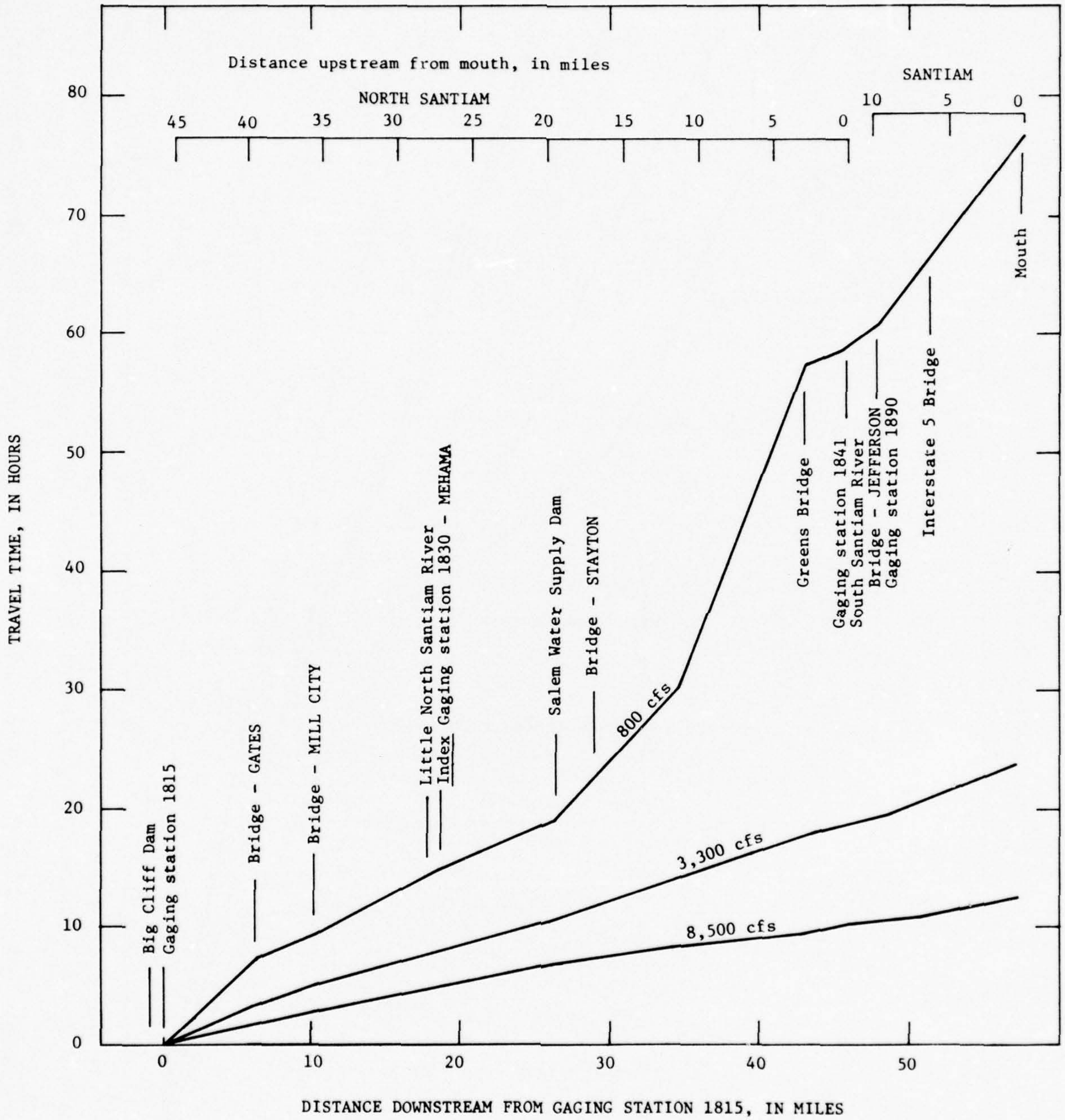

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Figure IV-38. Time of travel of North Santiam and Santiam Rivers for selected discharges at Mehama.

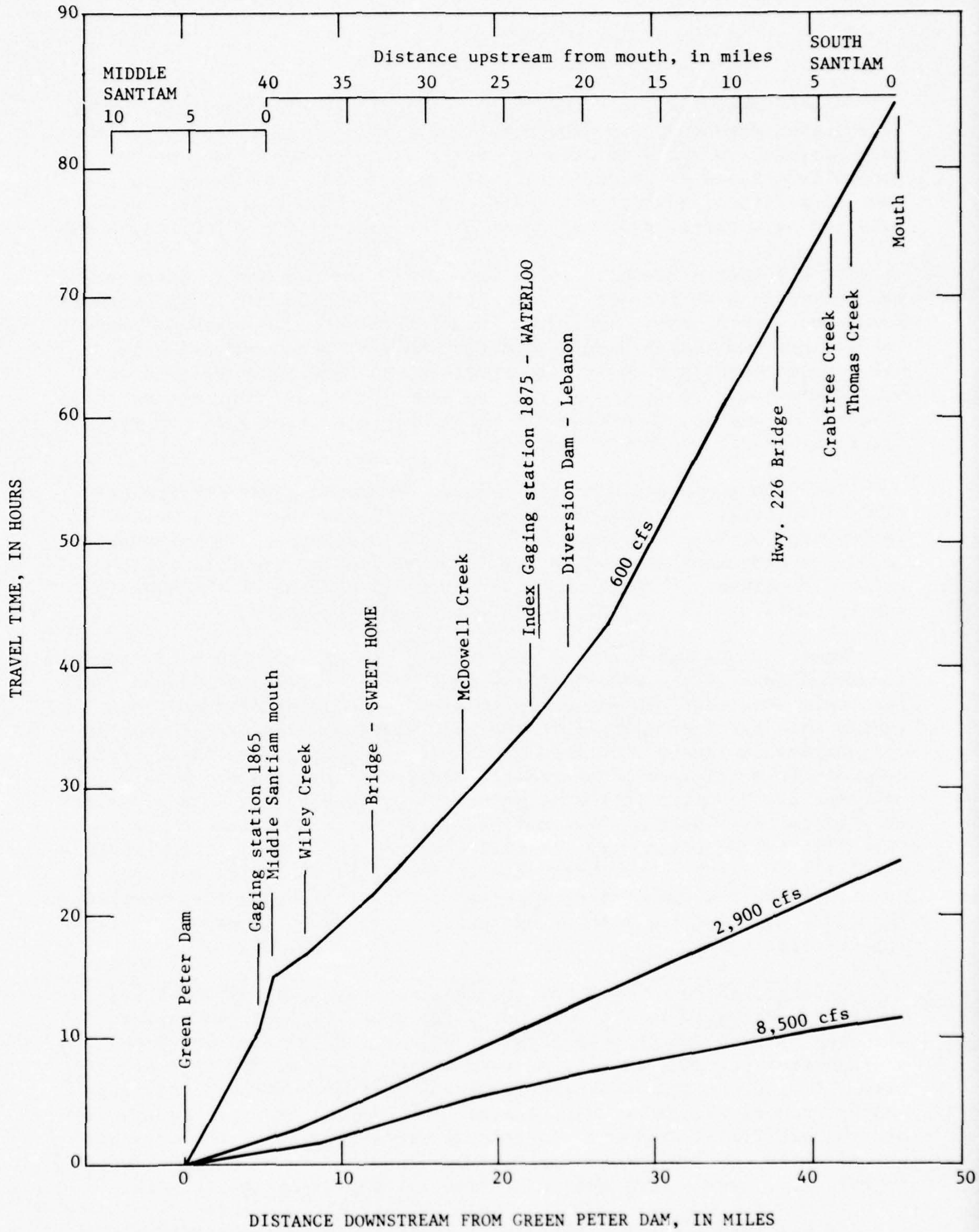


Figure IV-39. Time of travel of Middle Santiam and South Santiam Rivers for selected discharges at Waterloo.

GROUND WATER

Ground water is water that occurs beneath the land surface, under hydrostatic pressure, and that completely fills all pore spaces of the rock material in which it occurs. Other forms of subsurface water, not generally classed as ground water, are soil moisture and water in the zone of aeration, both of which are under less than hydrostatic pressure and only partly fill the pores of the material in which they occur.

In Willamette Basin, a large volume of water occurs in underground reservoirs in a variety of rocks: silt, sand and gravel, conglomerate, sandstone, shale, tuff, and lava. Some of these rocks, such as loose, uniform-grained coarse sand or gravel, are very permeable (that is, water moves through them readily) because the openings are large and well connected. Other rocks, such as shale or dense lava, are comparatively impermeable; they transmit water very slowly because the pore spaces are small or poorly connected.

The widespread use of large volumes of ground water for irrigation, industrial, and domestic purposes, as in northern Willamette Valley and the Portland area, reflects its importance. In Willamette Basin, ground-water reservoirs supply 40 percent of the irrigation water, 18 percent of the industrial water, 12 percent of the municipal water, and about 95 percent of the rural domestic water.

Where ground water occurs unconfined, the upper surface of the saturated zone is the water table--the level at which water would stand in a well that taps the saturated zone. Ground water also may occur in bodies that are "perched"--that is, held above an unsaturated zone by an impermeable layer. Confined ground water occurs where an aquifer is overlain by a relatively impermeable layer that retards the upward movement of the water so that pressure is exerted by the head of water in the aquifer. Because the confined water is under pressure greater than that of the atmosphere, it will rise above the base of the confining layer in a well that penetrates the aquifer containing the confined water. Where the combination of pressure and topography is favorable, the water may rise above the land surface, resulting in naturally flowing artesian wells.

Underground reservoirs, or aquifers, receive replenishment (recharge) principally from the infiltration of water from the surface. Recharge is from direct precipitation on the land surface and from seepage from streams, lakes, and ponds which are also fed by precipitation. Ground water is discharged naturally through springs and seeps and by evaporation and transpiration. The pumping of water from wells and the artificial drainage of wetlands are artificial discharges of ground water. Under natural conditions, recharge to an aquifer system is balanced, over a long period of time, by the discharge from it.

In Willamette Basin, recharge is entirely from precipitation that falls within the basin. The rate of recharge is controlled largely by the infiltration capability of the recharge areas; hence the rate varies widely over the basin, depending on many hydraulic and environmental factors. Recharge is low in the Coast Range because of the steep slopes and dense rocks. Slopes are also steep in the Cascades but the rocks, particularly the young lavas, accept water readily, so recharge rates are high there. In the valley, slopes are gentle and rocks are moderately to highly permeable, so that infiltration and recharge rates are moderate to high.

Because of the diversity of hydraulic and environmental factors, recharge for the basin is difficult to estimate. In the French Prairie area in northern Willamette Valley, annual recharge has been estimated to be about 18 inches (Price, 1967b), and in Tualatin Valley from about 11 to 18 inches (Hart and Newcomb, 1965, p. 40-41). The lava in the High Cascades allows a large part of the precipitation to infiltrate--in places perhaps as much as 80 percent of the 60- to 140-inch annual precipitation. Stearns (1929, p. 187) has estimated ground-water discharge from a small lava area in McKenzie Subbasin to equal more than three feet of recharge over the area. Total recharge, which would include this discharge plus any loss by evapotranspiration directly from the ground-water reservoir, would therefore be considerably more than three feet. Considering the diversity of conditions and factors in the basin, one foot per year is believed to be a conservative estimate for recharge over the basin. At that rate, annual recharge in the entire basin would be about 7.7 million acre-feet. If recharge for the valley-lowland part of the basin were 1.5 feet, annual recharge would total about 2.5 million acre-feet for that area.

Aquifers in sedimentary and volcanic rocks are the major ground-water reservoirs in Willamette Basin. These aquifers are the consolidated and unconsolidated sand and gravel layers in the valley fill of Willamette and Tualatin Valleys, lavas of the Columbia River Group that form the hills and mountains around Portland and near Salem and underlie parts of the valley from Albany to Columbia River, and the young lava rocks of the High Cascades (see Table III-1).

Ground-water supplies in the valley fill and Columbia River lavas have been developed extensively, but in most places the valley fill contains substantial amounts of water that are available for additional development. Thus, those supplies might be considered as part of the water supply available to meet the water needs of the basin. Even in areas where annual recharge to ground water might not be adequate for anticipated long-range requirements, the great volume of ground water in storage represents a "reserve" that could be drawn on as an interim supply for short-term needs. In many places in the valley, ground water could be used in conjunction with surface-water supplies. During years when runoff is deficient, ground water could be used to supplement the streamflow.

According to Bodhaine and others (1965, p. 89), volcanic aquifers of the Cascade Range are not likely to be exploited for development of ground water in the foreseeable future, because they are located in a remote, unsettled area of rugged terrain. However, these aquifers serve the important hydrologic function of sustaining the low flows of streams. The great volume of ground water stored in those rocks might be tapped by tunnels to augment streamflow during periods of drought.

Subsurface geologic data can be used to estimate the total volume of water in the valley-fill aquifer beneath the lowlands of the basin. Unconsolidated and semiconsolidated water-bearing materials extend to depths of more than a hundred feet in the southern part of the valley and to several hundred feet in the northern part. With a specific yield of 15 percent, nearly 5,000 acre-feet of water would be available from each 50 feet of saturated material underlying each square mile. Thus, a 50-foot zone beneath the 2,500-square-mile lowland part of the valley would contain at least 12 million acre-feet of available water. Assuming that half this water could be recovered economically, the total volume of ground water that could be managed in a 50-foot zone of the valley fill would be about six million acre-feet.

The specific yield of the lavas in the Columbia River Group is small--about one percent. At this value, each square mile would contain 640 acre-feet of water for each 100 feet saturated. The entire unit, which extends over about a thousand square miles in the basin, may contain about 600,000 acre-feet of recoverable water.

The huge volume of ground water in the aquifers of the basin represents a part of the water resource that might be managed. Bodhaine and others (1965, p. 89-91, 184) have estimated that ground-water additions to the "dependable" supply for Willamette Basin may be nearly two million acre-feet annually. Effective management might be accomplished by increasing the pumpage so as to draw water levels down during dry seasons and thus provide more space to receive recharge during wet seasons when streamflow is high. In some places, artificial-recharge techniques might be used to manage the ground-water resource. Except for the west-side business district of Portland and parts of Tualatin Valley, aquifers in the basin can yield, on a sustained basis, several times as much water as is now being pumped from them. With proper management, the ground-water resource of Willamette Basin could supply water at several times the present rate, which is about 250,000 acre-feet per year.

PROBLEMS

The use, movement, or control of water by man causes water problems that must be solved if the water resources are to be used most efficiently and economically. Because of the unique features of its occurrence, certain problems are peculiar to ground water. In Willamette Valley, ground-water problems are neither severe nor widespread, but at places there are problems of (1) variability of supply, (2) overdevelopment, (3) mineralized water, (4) pollution, (5) drainage, and (6) alterations of the natural environment.

Variability of Supply

The quantity of water available varies from meager in parts of the Coast Range to copious in parts of the valley and Cascade Range. The variability of supply is described in detail for individual subbasins in the following section on availability of ground water.

Overdevelopment

Overdevelopment means that the use of water exceeds the supply available perennially from recharge or that water cannot move through the aquifer toward local areas of pumping as fast as it is pumped out. Local overdevelopment generally results from a large number of wells pumping too much water in a small area. As a result, water levels in wells in the local area continue to fall and eventually the yields of wells decline; in extreme cases, some wells may fail or mineralized water may move into the aquifer. The remedy is to reduce local pumping of ground water or to space the wells so that the pumping is spread over a larger area. In Willamette Basin, the aquifers in the Columbia River Group have in the past been overdeveloped locally at Salem, in parts of Tualatin Valley, and in the downtown area of Portland. On a regional basis the basalt is not fully developed.

Mineralized Water

Naturally occurring mineralized ground water is a problem in parts of the basin. Excessive arsenic has been found in ground water in the Eugene-Cottage Grove area. In parts of northern Willamette Valley and the foothills of the Coast and Cascade Ranges, iron in ground water exceeds the amount recommended for drinking water in standards of the Public Health Service. Mineralized water underlies fresh ground water throughout most of the basin, but in most areas should not be a problem in the development and use of ground water from the valley fill. However, local peculiarities in geologic structure have allowed mineralized water to move into fresh-water aquifers in Portland and Tualatin Valley. At many places in the Coast Range, where the shallow rocks are so impervious that they do not contain usable quantities of ground water, deeper zones have mineralized water. Mineralized water also is discharged from some springs in the foothills of both the Cascade and Coast Ranges. The section on quality of ground water contains further details on mineralized water.

Pollution

Pollution results from the introduction of objectionable substances into the ground water. In some suburban areas near all the major cities, domestic sewage is disposed into the ground through septic tanks and cesspools. This practice presents a potential pollution problem in those areas and in other places where houses are concentrated, such as along Sandy River. Pollution also may result from disposal of industrial and commercial wastes into the ground, into pits and wells, or into surface ponds excavated in pervious materials.

Drainage

Problems of drainage occur where the water table is near the ground surface or where the near-surface deposits drain slowly, as do silt and clay. The application of irrigation water to such areas may cause waterlogging so that artificial-drainage works may be necessary. In some places, artificial-drainage works have been necessary for non-

Photo IV-3. Tile laid in trenches may be needed to drain fields where the water table is near the surface.

irrigated agriculture. Areas with poor drainage characteristics can be identified on the map showing hydrologic soils groups (Map III-1).

Alterations of Natural Environment

Problems may result from changes of natural environment by artificial-drainage works or by construction of buildings and paved areas. The artificial drainage of wetlands and natural lakes may lower the water table and reduce the amount of ground water available locally. However, artificial drainage in Willamette Valley has had no adverse effect on ground-water supplies.

In urbanized areas, construction may alter surface features substantially. In places, nearly half the land surface may be covered by buildings and pavement, thus reducing the area through which infiltration can take place. This alters the recharge-discharge regimen and the volume of ground water available may be reduced. No significant changes to ground-water bodies definitely related to urban effects have been noted in Willamette Basin, probably because under natural conditions a large volume of potential infiltration is "rejected" during each wet season. In the west-side business district of Portland, continually declining water levels may result from urban changes, from local concentration of pumping draft, or from a reduction in the amount of recharge contributed by the river.

AVAILABILITY

In this section, the availability of ground water is described in terms of the yield to be expected from wells that are constructed to obtain the maximum quantity of water from the aquifers available at the site. In some places, exploration and testing may be needed to find a site for a well where the aquifer is most productive. For alluvial sand and gravel aquifers, the best well sites generally are where the sand and gravel is thick, well-sorted, and has the highest permeability.

The information in this section is based on data from wells that have already been drilled and put into use. Geologic data have been used to extend the interpretation of availability into areas where no wells now exist. Thus, large areas in the Cascade and Coast Ranges are described from the records of a few widely spaced wells and from available geologic data. As more wells are drilled in the mountains, more specific information will become available on local differences in the availability of water, and some areas may prove to have significantly different ground-water potential from that now indicated. Geologic units are described briefly in Part II and their hydrologic characteristics are summarized in Table III-1.

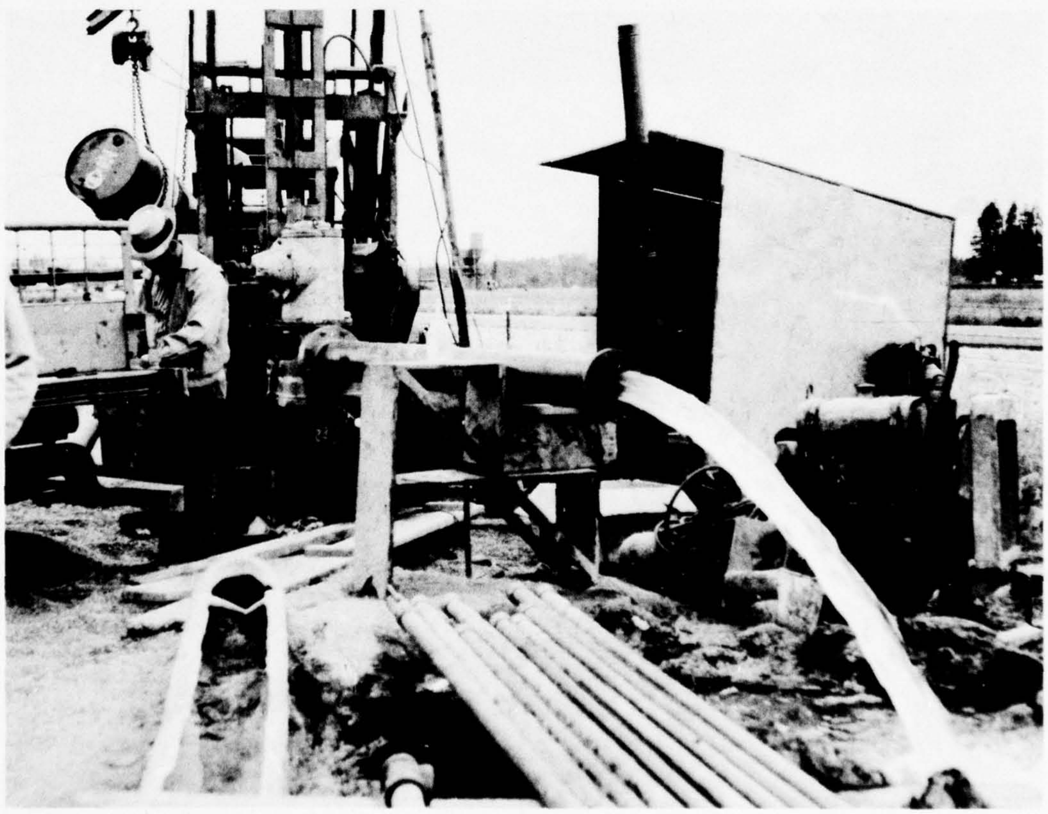


Photo IV-4. A new screened, gravel-packed well for Woodburn is tested at more than 1,000 gpm.

Photo IV-5. A deep well supplies water to irrigate this pasture in the Tualatin Valley.

In the presentations following, the availability of ground water in Willamette Basin is described for each of the 11 subbasins, and for areas delineated on the accompanying subbasin maps. Each area is identified by a letter which indicates the principal aquifers and their lithologies on the accompanying map and table. A number identifies areas that were further subdivided (example: area E-1, Map IV-5).

Coast Fork Subbasin

Ground-water supplies in most of Coast Fork Subbasin are adequate for domestic, stock, or small commercial supplies. However, only a few wells of large yield are known--mostly from alluvial deposits in the northern part. In a few places, wells less than 200 feet deep have been reported to be "dry" and others to have water too salty for use or to contain objectionable amounts of arsenic. Ground-water sources supply most of the domestic and farm needs in addition to the municipal supply for Creswell, but there is no large-scale irrigation or industrial use of ground water. The general availability of ground water is shown on Map IV-5 and given in Table IV-5.

Most aquifers in Coast Fork Subbasin yield only small quantities of water. In the mountains in the western part, even domestic and stock supplies are difficult to obtain; holes drilled to depths of several hundred feet have been "dry" or yield only mineralized water.

Arsenic in quantities exceeding the limit recommended for drinking water occurs in the area around Creswell and southward along the Coast Fork to Township 23 South and up Mosby Creek and Row River near Dorena Reservoir (Goldblatt, Van Denburgh, and Marsland, 1963). The excessive arsenic seems to be more prevalent in water from wells more than 100 feet deep which tap pyroclastic rocks.

Drainage is a problem in several low areas, such as the Camas Swale area which is underlain by clayey soil. Natural drainage is toward the center of the swale, and ditches have been dug to alleviate the drainage problem. Low areas along Coast Fork Willamette River and Row River, below Cottage Grove and Dorena Reservoirs, respectively, also have drainage problems.

Middle Fork Subbasin

Water needs are small because large parts of Middle Fork Subbasin are unpopulated, and the population is small both at Oakridge and at the lower end of the subbasin--the two most populous areas. Water is obtained largely from the abundant ground-water supply in aquifers in the downstream parts of stream valleys. Most of the water is used for domestic and municipal supply; only a few hundred acres are irrigated. The availability of ground water by areas is shown on Map IV-6 and in Table IV-6.

Two thermal mineral spring groups--McCredie Springs on Salt Creek and Kitson Hot Springs on Hills Creek--have been developed for health resorts. Water from both springs is highly mineralized sodium chloride water that is also high in boron and fluoride (Madison, 1966).

Except for valley areas, where most of the people live, ground-water supplies are small in Middle Fork Subbasin. Yields of wells have been too small for adequate domestic supplies at some places in the mountains.

Excessive arsenic has not been reported from ground water in Middle Fork Subbasin, although pyroclastic rocks in the western part are similar to those that contain high arsenic water in Coast Fork Subbasin. Water from the deeper wells in the western part of Middle Fork Subbasin should be tested to determine if it contains a high arsenic concentration.

Drainage problems have been reported for the alluvial valley below Dexter Dam, probably resulting from the shallow water table and flat gradient.

McKenzie Subbasin

McKenzie Subbasin has abundant ground water in the alluvial deposits along stream valleys and probably also in the young lava of the High Cascades. Ground water is used to irrigate about 3,000 acres at the lower end of the subbasin, for municipal supplies at Coburg and Marcola, and for domestic supplies throughout the subbasin. There is very little industrial use of ground water, and total use is small. The general availability of ground water is shown on Map IV-7 and in Table IV-7.

Inadequate natural drainage is a problem in the agricultural lands along the alluvial valleys. It results from the combination of a high water table and soils with poor drainage characteristics.

In the Springfield suburban area, a contamination problem may result from the widespread use of septic tanks to dispose of domestic sewage. Because the extent and severity is not now known, detailed study of this problem is needed.

Long Tom Subbasin

Ground water is used extensively for suburban domestic supplies in Long Tom Subbasin, which contains much of the Eugene-Springfield urban area. There also is considerable commercial and industrial use of ground water in the Eugene area. The largest use of ground water, however, is for irrigation--about 700 wells supply water to irrigate nearly 14,000 acres, mostly from alluvial deposits. The marine sediments and older volcanic rocks, which form the foothills and mountains, are poor aquifers; in places, wells drilled more than 200 feet into these rocks have been dry. The general availability of ground water in the subbasin is shown on Map IV-8 and in Table IV-8.

Water supply is deficient in parts of Long Tom Subbasin. Ground water is inadequate to supply large-scale irrigation in area A-2 (Map IV-8), although the area could sustain increased ground-water use for small-scale irrigation. On the east side of Willamette River between Harrisburg and Coburg, ground-water supplies are reported to be inadequate for irrigation during late summer; part of the problem in this area may be due to well deterioration. Ground-water supplies are also deficient for irrigation in the lower foothills adjacent to the valley (area E). In parts of the mountains, ground-water supplies are inadequate even for domestic needs.

Arsenic in quantities exceeding the recommended limit for drinking water occurs in ground water in the headwaters of Spencer Creek, southwest of Eugene. The geologic units that contain this high arsenic water extend northwestward along the eastern side of Fern Ridge Reservoir; in that area (area A-2), arsenic may occur in wells drilled more than 100 feet deep into volcanic bedrock.

Drainage is a problem in lowland parts of area A-1 and would be a potential problem in much of area A-2 if water were imported for widespread irrigation.

In much of the Eugene suburban area, the disposal of domestic sewage into septic tanks poses a pollution problem that should be studied in detail.

Santiam Subbasin

Santiam Subbasin has an abundant supply of ground water, principally in the alluvial deposits in the valley. More than 1,000 wells supply ground water to irrigate about 27,000 acres. Except for a few isolated places in the foothills and Western Cascade Range, wells yield amounts of water adequate for domestic and stock supplies, although in parts of the Cascades wells must be drilled to depths of several hundred feet. The availability of ground water in various parts of the subbasin is shown on Map IV-9 and in Table IV-9.

Willamette River gains water from ground-water seepage, but the amount of seepage has not been measured. Major tributary streams, such as North and South Santiam Rivers, lose part of their flow to the ground-water reservoir where they emerge from the mountains. For instance, during low flow South Santiam River loses about 30 cfs where it crosses its alluvial fan near Lebanon.

In a small area in the loop of Santiam River southeast of Jefferson (area A-1, Map IV-9), yields of irrigation wells are reported to decline during the pumping season. Alluvial deposits in this area are thin and contain only about 25 feet of saturated gravel, part of which is dewatered during the irrigation season. Part of the decreased yield may be caused by deterioration of the wells from encrustation or plugging. The declining yields do not seem to be due to local overdevelopment.

The widespread occurrence of fine-grained surficial deposits, combined with a shallow water table, causes drainage problems in parts of the valley. One such area is the alluvial fan, bounded by Oak Creek and South Santiam River, extending from Lebanon to Willamette River. Drainage problems likely will be acute in other areas as well, unless adequate drainage facilities are built to accompany the development of widespread irrigation. The problem would be most critical in areas served by imported surface water because the pumping of ground water lowers the water table and aids drainage. The hydrologic soils map (Map III-1) shows areas where drainage hazards will be greatest.

Coast Range Subbasin

Coast Range Subbasin is poorly supplied with ground water. The marine and volcanic rocks forming the mountains are so impermeable in places that they do not yield enough water for a domestic supply. In other places, the shallowest ground water found has been too salty to use. However, the alluvial deposits form highly productive aquifers along Willamette River and in the northern part of the subbasin. Water seeping from these aquifers helps to maintain the dry-season flow of Yamhill and Willamette Rivers. These aquifers furnish most of the water for more than 16,000 acres irrigated from wells and for the 10 communities supplied by ground water. Despite heavy pumping, water-level fluctuations are seasonal, indicating that withdrawal is replenished during the rainy season. The general availability of ground water in the subbasin is shown on Map IV-10 and Table IV-10.

The greatest ground-water problem is availability--supplies are small to meager throughout most of the subbasin. Supplies are not adequate for irrigation, industrial, or public supply in the western part of Willamette Valley south of Corvallis, in the valleys of all the major tributary streams, nor in the lower foothills. In the higher foothills and mountains of the Coast Range, even small supplies of ground water for domestic and stock use are difficult to obtain and available information is not adequate to predict sites, depth, or geologic zones that would be most favorable for wells. In the mountains, many wells yield less than two gpm, most yield less than five; dry holes have been drilled in several places, and in other places the shallowest ground water found has been too mineralized for use. Mineralized water has also been found in wells drilled into marine rocks at places along the margins of Willamette Valley.

In the northern part of area B (Map IV-10), the pumping of sand causes excessive wear of pumping equipment and shortens the life of wells. As in the French Prairie area (Pudding Subbasin), this problem might be alleviated by constructing wells with properly designed gravel envelopes and well screens.

Subsurface disposal of domestic wastes may have polluted shallow ground-water bodies in local areas around the cities and towns. This problem needs further study to determine its extent.

Drainage is a problem in tributary stream valleys, where the surface is flat and soils have low permeabilities. The State Water Resources Board (1963, p. 79) estimated that 123,000 acres in the subbasin have drainage problems.

Pudding Subbasin

Ground water is abundant in the Willamette Valley portion of Pudding Subbasin, occurs in small to moderate quantities in the foothills, and occurs in small quantities in the mountains. Ground water is used for irrigation of nearly 34,000 acres; for the municipal supply of 14 communities with a combined population of more than 17,000; and for the domestic supply of most of the rural and suburban homes in the subbasin. In French Prairie (area B-2 and part of area B-1, Map IV-11), ground water in storage within 200 feet of the surface is estimated to be about three million acre-feet (Price, 1967b, p. 61-64). In the same area, it is estimated that annual replenishment to the aquifer is about 160,000 acre-feet--eight times the present rate of pumping. For most of the subbasin, no evidence of overdevelopment, such as declining water levels, has been noted; for the valley area, withdrawals are much less than estimates of recharge. Therefore, pumpage in the subbasin could be increased several times. The general availability of ground water in Pudding Subbasin is shown on Map IV-11 and in Table IV-11.

Pudding Subbasin has some of the best ground-water reservoirs in Willamette Basin, but also has a number of ground-water problems. Only small to moderate supplies of water are available in parts of the Molalla Slope (area B-4, Map IV-11) and the lower foothills (area D-1). In some parts of the foothills and mountains, ground water at shallow depth is not adequate for domestic and stock supplies.

Mutual interference between wells is a problem in several areas of concentrated pumping, such as near Woodburn (Price, 1967b, p. 72). Interference and overdraft formerly were problems in the Salem Hills (area C), where wells tapping the basalt aquifer were heavily pumped prior to 1961.

In the foothills north of Stayton and Turner, where a number of irrigation wells pump large quantities of water from the basalt aquifer, water levels have been declining for several years, which indicates that the aquifer is locally overdeveloped.

In the northwestern part of French Prairie (area B-2), the valley-fill aquifer contains much sand and has a relatively low permeability; drawdowns in individual wells are great and pumping lifts are high. Many wells yield large amounts of sand which reduces the life of the wells and pumping equipment. The problems of both excessive drawdown and pumping of sand might be solved by constructing wells using properly designed gravel envelopes and well screens.

The subbasin has several water-quality problems. Ground water in much of the area contains iron in concentrations exceeding the limits recommended for drinking water (see section on chemical quality of ground water). The contamination of shallow ground-water zones by septic-tank effluent is a potential problem in the heavily populated areas. In an area near Keizer, disposal to the ground of industrial wastes having a high sulfate content has caused local contamination of the ground water (Price, 1967b, p. 73-75). This contamination occurred about 20 years ago and is gradually lessening through dispersion and dilution from recharge.

Drainage is a problem in flat-lying areas in the Willamette Valley part of the subbasin, where the State Water Resources Board estimates that 100,000 acres need artificial drainage. Large-scale irrigation is likely to aggravate this problem.

Tualatin Subbasin

Aquifers in Tualatin Valley and in the hills on the east and southeast flanks of Tualatin Subbasin contain large volumes of ground water, but commonly yield at only small to moderate rates. Aquifers in the mountains along the west and northwest parts of the subbasin generally yield only meager supplies. Individual wells that yield water at rates sufficient for large-scale irrigation, public-supply, or industrial uses are scattered around the margins of the valley and in the hills along the eastern side. All the small cities in the eastern part of the subbasin use ground water for public supply, but the many water districts serving the suburban housing areas on the east side of the subbasin use imported surface water.

Ground-water pumpage from the valley-fill aquifers could safely be increased severalfold, although individual wells generally will yield only 10 to 25 gpm. To obtain maximum yields from the valley fill, wells should be of a large diameter, packed with gravel, and equipped with screen or commercially perforated pipe. Several wells constructed in this fashion yield at least 100 gpm--more than twice the yield of other wells in the same local area (Hart and Newcomb, 1965, p. 50-51). The general availability of ground water in Tualatin Subbasin is shown on Map IV-12 and Table IV-12.

Generally, wells must penetrate at least 200 feet into the basalt of the Columbia River Group to yield a few hundred gallons per minute. Most wells of large yield penetrate into the basalt aquifer 300 to 400 feet (Hart and Newcomb, 1965, p. 34). Total pumpage from the basalt of the Columbia River Group could be increased above the present rate if spread over a broad area, although the aquifer may be overdeveloped locally in parts of the subbasin.

The most important ground-water problem in Tualatin Subbasin is the nonavailability of large amounts of water at any given place. Irrigation wells are widely scattered, are costly to drill because of their depth and the character of the aquifer rock, and many have yields adequate to irrigate only small tracts.

In most of the hill and mountain areas, dependable small supplies of ground water are not available at shallow depths for domestic use, although in many areas dependable supplies can be obtained from wells that are several hundred feet deep. In the Coast Range (western and northern) part of the subbasin, many domestic wells yield only a few gallons per minute, and in some places wells nearly 500 feet deep have yielded no usable ground water.

The basalt of the Columbia River Group is the only aquifer in the subbasin capable of yielding water to wells at a high rate. The overall storage capacity of the basalt is small and, where several wells of large yield are closely spaced, water can be pumped from the basalt aquifer faster than it is replenished, causing local overdevelopment. Declining water levels in the basalt near Tigard may indicate that the basalt aquifer is overdeveloped in this area (Sceva and DeBow, 1966, p. 12, 13).

In parts of the Coast Range, ground water is reported to contain excessive concentrations of iron and to be very hard. At several places in Tualatin Valley, deep wells have yielded water too salty for use. In parts of Portland, just east of the subbasin, overpumping the basalt of the Columbia River Group has allowed mineralized water to move into the basalt aquifer from underlying marine beds. Since geologic and hydrologic conditions are similar in Tualatin Subbasin, mineralized water is a potential problem there.

The valley-fill deposits are generally fine grained and the water table in much of the valley is shallow, so that drainage problems are widespread. The importation of water for irrigation of extensive areas likely will cause the drainage problem to increase in area and severity. Therefore, studies of soil drainage should accompany planning for irrigation of large tracts.

Clackamas Subbasin

Clackamas Subbasin contains moderate supplies of ground water. Since these generally occur at depths of several hundred feet, they are not used extensively. In many places, additional ground water in quantities adequate for small-scale irrigation or industrial supply could be developed, particularly from wells that tap gravel in the Troutdale Formation in the area west of Sandy and Estacada. The abundance of ground water in the High Cascades (area U, Map IV-13), is indicated by the high low-flow rates, which in places are more than two cfs per square mile--among the highest rates in Willamette Basin. The availability of ground water in Clackamas Subbasin is shown on Map IV-13 and in Table IV-13.

The principal ground-water problem in Clackamas Subbasin is availability. Large yields suitable for irrigation or industrial supply can be obtained at only a few places. Quantities of ground water adequate for domestic supply can be obtained nearly everywhere, but in large parts of the subbasin only from wells several hundred feet deep. The necessity to drill wells to this depth beneath the uplands plus the high cost of lifting water from these great depths make both the exploration for and the development of irrigation supplies in those areas costly.

Other problems reported in Clackamas Subbasin by the State Water Resources Board (1965, p. 53) are excessive hardness of ground water, "rust" from wells, and contamination of shallow, improperly constructed wells by septic-tank effluents.

Columbia Subbasin

The alluvial and terrace areas of Columbia Subbasin contain abundant ground water, which is heavily pumped for industrial, irrigation, and domestic uses. Supplies are much smaller in the hill and mountain areas, but wells several hundred feet deep have yields adequate for domestic uses in most places. Throughout the subbasin, present use of ground water is much less than the potential supply, and use could safely be increased except in part of the west-side business district in Portland. The general availability of ground water in Columbia Subbasin is shown on Map IV-14 and in Table IV-14.

Probably the most serious ground-water problem is the local overdevelopment of the Troutdale and basalt aquifers in the west-side business district of Portland; water levels in both aquifers have declined steadily for several years. Heavy pumping has lowered the water table so that it is now lower than Willamette River throughout the year (Brown, 1963, p. 08). Part of the lowering of the water table may be caused by reduced recharge, because a large percentage of the land surface is now covered by buildings and paved surfaces, thus preventing local infiltration of precipitation. Under natural conditions, these aquifers discharged water by seepage into Willamette River except during flood periods when water infiltrated from the river into the aquifer.

In the same area, the return to the aquifers of water warmed by air-cooling of buildings has raised the temperature of ground water several degrees. Since the warmer water is less effective as a cooling agent, more may be pumped, aggravating the overdevelopment problem.

Another problem related to overdevelopment of ground water in the basalt of the Columbia River Group is the encroachment of mineralized water into the basalt from the underlying sedimentary rocks as a result of reduced pressure head in the basalt aquifer. Also, the overlap of pumping cones of closely spaced wells produces mutual interference between the wells and results in increased pumping lifts.

Problems of water quality are evident in several parts of the subbasin. On Sauvie Island, water in some of the lower-lying areas is reported to be of poor quality for domestic purposes because of excessive iron and sulfur content (State Water Resources Board, 1965, p. 49). Elsewhere on the island, water too salty for use has been found. Mineralized water, unsuitable for either drinking or irrigation, has been found in the marine rocks in the Portland Hills and in the mountains in the northwestern part of the subbasin. Several public-supply wells at Lake Oswego produce water high in iron, and water from one well is very hard and high in dissolved solids.

In parts of Sauvie Island, "heaving sand" in the aquifer has prevented the completion of some wells. Altering the method of well construction and using fabricated well strainers might help to alleviate the problem.

Drainage is a problem in the low-lying areas, such as Sauvie Island and the flood plain of Columbia River, where the water table is only a few feet beneath the land surface.

The widespread practice in the suburban area east of Portland of disposing of domestic sewage through septic tanks and cesspools may cause a pollution problem. The extent to which this sewage-disposal practice may have contaminated local water sources should be studied in detail.

Sandy Subbasin

Sandy Subbasin contains an abundance of ground water, but it has been little developed in most places because water needs are small and surface water is available. Ground-water supplies are adequate for domestic or stock supplies everywhere in the subbasin, although wells must be drilled to depths of several hundred feet in the deeply eroded Western Cascades. Wells yield several hundred gallons per minute west of Sandy River, along Columbia River near Troutdale, and along Sandy River near Brightwood and Rhododendron. In these areas, large supplies of good quality water can be obtained even from relatively closely spaced wells. In the High Cascades, a high percentage of the precipatation infiltrates the young volcanic rocks and is discharged into streams so that their base flows are high--one to two cfs per square mile. Properly constructed wells drilled several hundred feet to the main water table should produce at least 200 gpm, and in places probably would produce 1,000 gpm.

Even in those areas where ground water has been developed, water use could be increased substantially; for the basin as a whole, use could be increased severalfold. The general availability of ground water in the subbasin is shown on Map IV-15 and in Table IV-15.

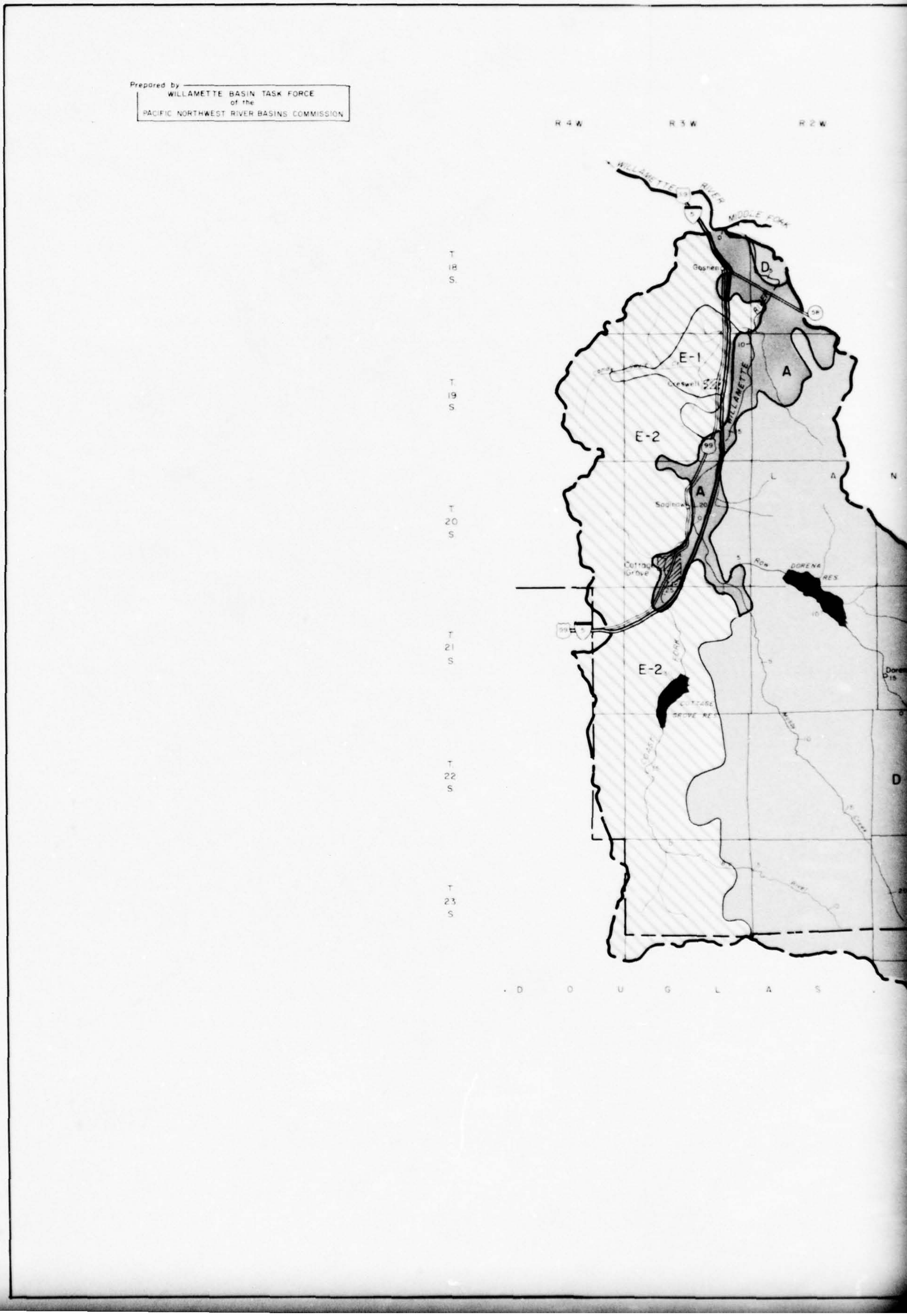
No problems of availability, competition between users, or interference between wells are evident. The great depth to water-bearing zones in much of the subbasin and the high cost of drilling wells in the resistant lava and consolidated gravel beds are deterrents to the development of ground-water supplies for domestic and other uses.

The mineral quality of ground water is good, but there are problems of ground-water contamination. The State Water Resources Board reports (1965, p. 52, 53) that improper disposal of sewage to the ground has caused pollution problems in the area between Gresham and the Sandy River (areas B-1 and B-2, Map IV-15) and along Sandy River from Cherryville to near Government Camp (area A-3).

Table IV-5

Availability of ground water, Coast Fork Subbasin

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm): Range of present wells	Yields of largest capacity wells (gpm): Expectable	Potential for increased use	Remarks
A	Alluvial deposits (sand, gravel, clay)	70-140	50-150	50-200	50	Small	Potential yield of wells is low because of clay that is interspersed with the gravel.
D	Little Butte Volcanic Series (mostly pyroclastics)	Several hundred	100-350	10-50	50	Small	Exploration required to find sites where well yields would be greatest. Few data available for most of the area.
E-1	Sandstone	do.	200	200 (one well)	Locally 200	Small	Limited to Camas Swale area.
E-2	Marine rocks, lava, and pyroclastic rocks	do.	100-260	10	10	Small, because of low well yields	Locally wells yield only 1-2 gpm, and "dry holes" have been drilled in places. Water from pyroclastic rocks contains excessive arsenic in places.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T. 23 S
WILLAMETTE RIVER
MIDDLE FORK
Goshen
D
E-1
A
Creswell
WILLAMETTE
E-2
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Saginaw
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DORENA RES
L A N
E-2
COTTAGE GROVE RES
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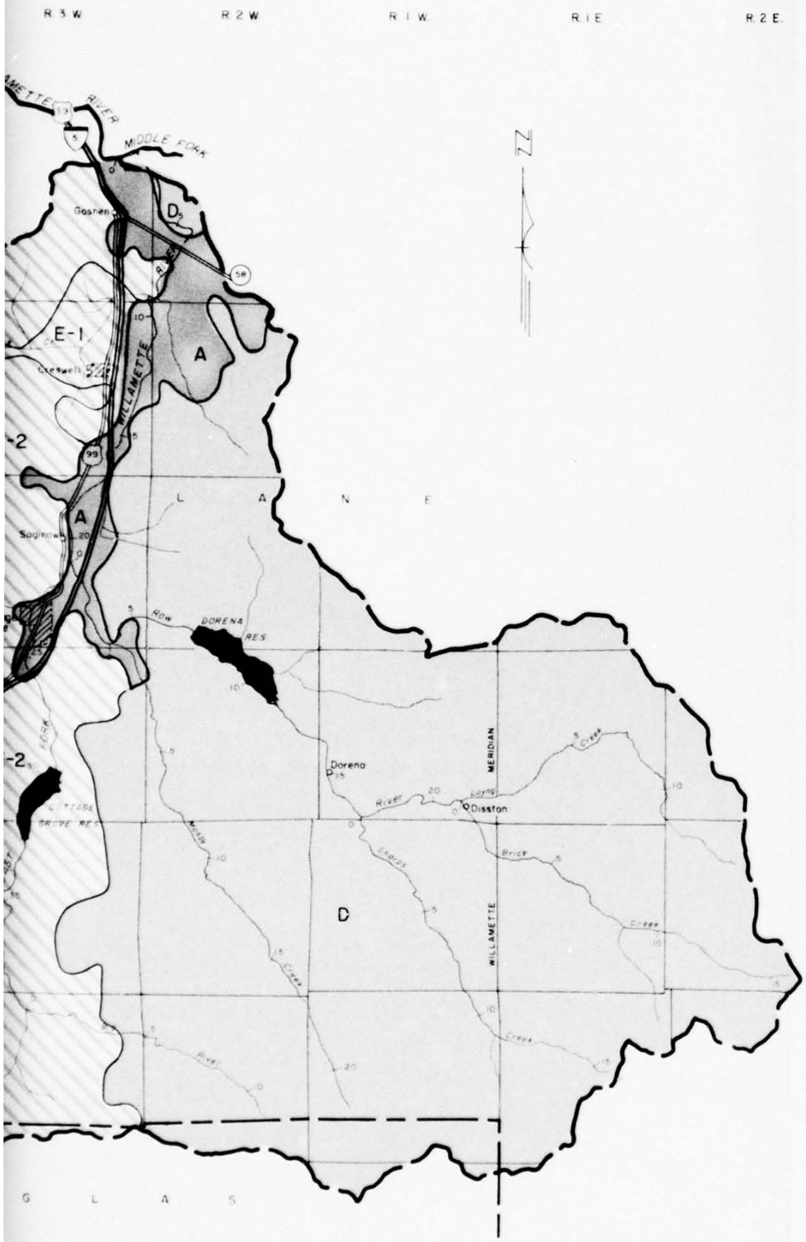
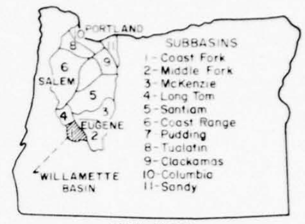




KEY MAP
SHOWING SUBBASINS

EXPLANATION

A

Aquifers, alluvial sand and gravel. Yield 50 gpm, locally up to 200 gpm

D

Aquifers, marine rocks and Little Butte Volcanic Series. Yield 10-20 gpm

E-1

Aquifers, marine sandstone and alluvium. Yield 10-20 gpm, locally up to 200 gpm

E-2

Aquifers, marine and older volcanic rocks. Yield about 10 gpm, locally less than 2 gpm

MAP IV-5
COAST FORK
WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

SCALE IN MILES

Table IV-6

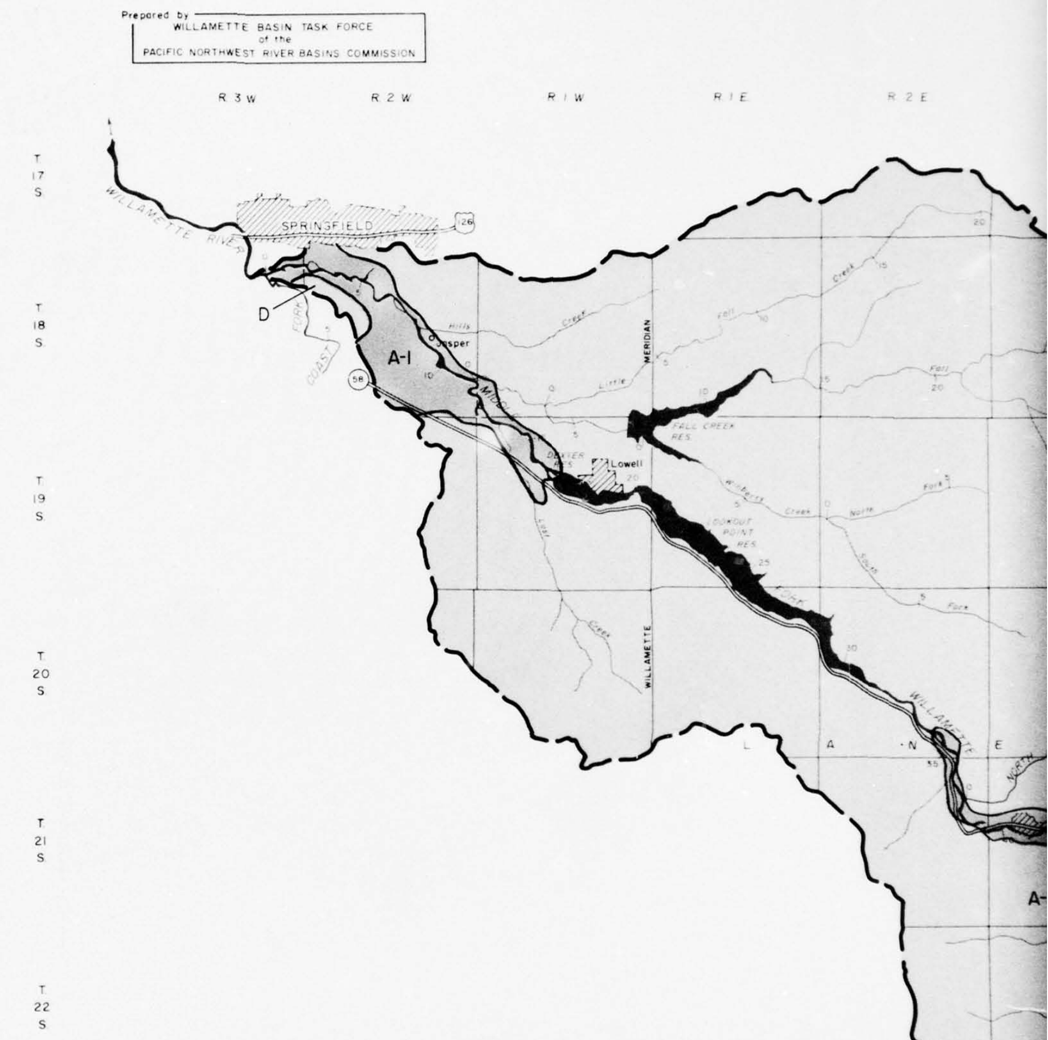
Availability of ground water, Middle Fork subl

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm)		Pote incr
				Range of present wells	Expectable	
A-1	Alluvial deposits (sand and gravel)	50-100	25-100	150-500	500	Several t use
A-2	Alluvial deposits (bouldery gravel)	200+	100-200+	As much as 600	500	
D	Little Butte Volcanic Series (lava and tuff), marine sandstone	--	20-350	10-20	Locally 50	Small
U	Young volcanic rocks (lava)	Several hundred	No known wells	None	Few hundred	Large

IV-6

water, Middle Fork subbasin

est capacity gpm) Expectable	Potential for increased use	Remarks
500	Several times present use	Heavy pumping of alluvial aquifers, which are connected to streams, could reduce flow of adjacent rivers.
500	do.	Do.
Locally 50	Small	McCredie Springs and Kitson Hot Springs are thermal mineral springs that issue from bedrock. No data available for most of the area.
Few hundred	Large	Numerous springs and large base flows of streams indicate considerable potential for development. No data available for most of the area.



EXPLANATION

A-1

Aquifer, alluvial sand and gravel. Yields generally 500 gpm

A-2

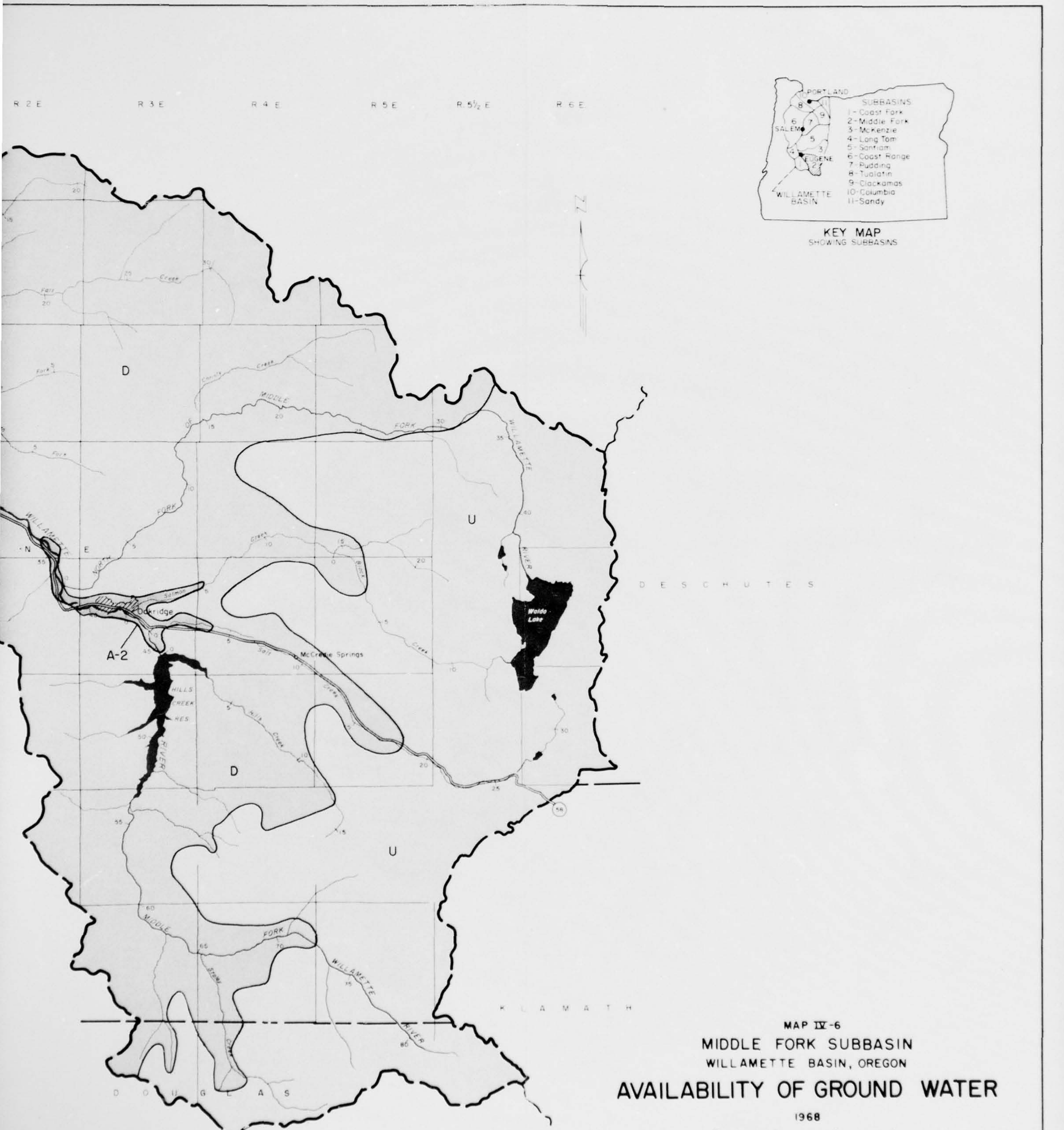
Aquifer, coarse alluvial gravel and boulders. Yields more than 500 gpm

D

Aquifers, *marine rocks and* Little Butte Volcanic Series. Yield 10-20 gpm

U

Aquifers, young lavas of High Cascades. Yield unknown, but probably several hundred gallons per minute



MAP IV-6

MIDDLE FORK SUBBASIN

WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

SCALE IN MILES

Table IV-7

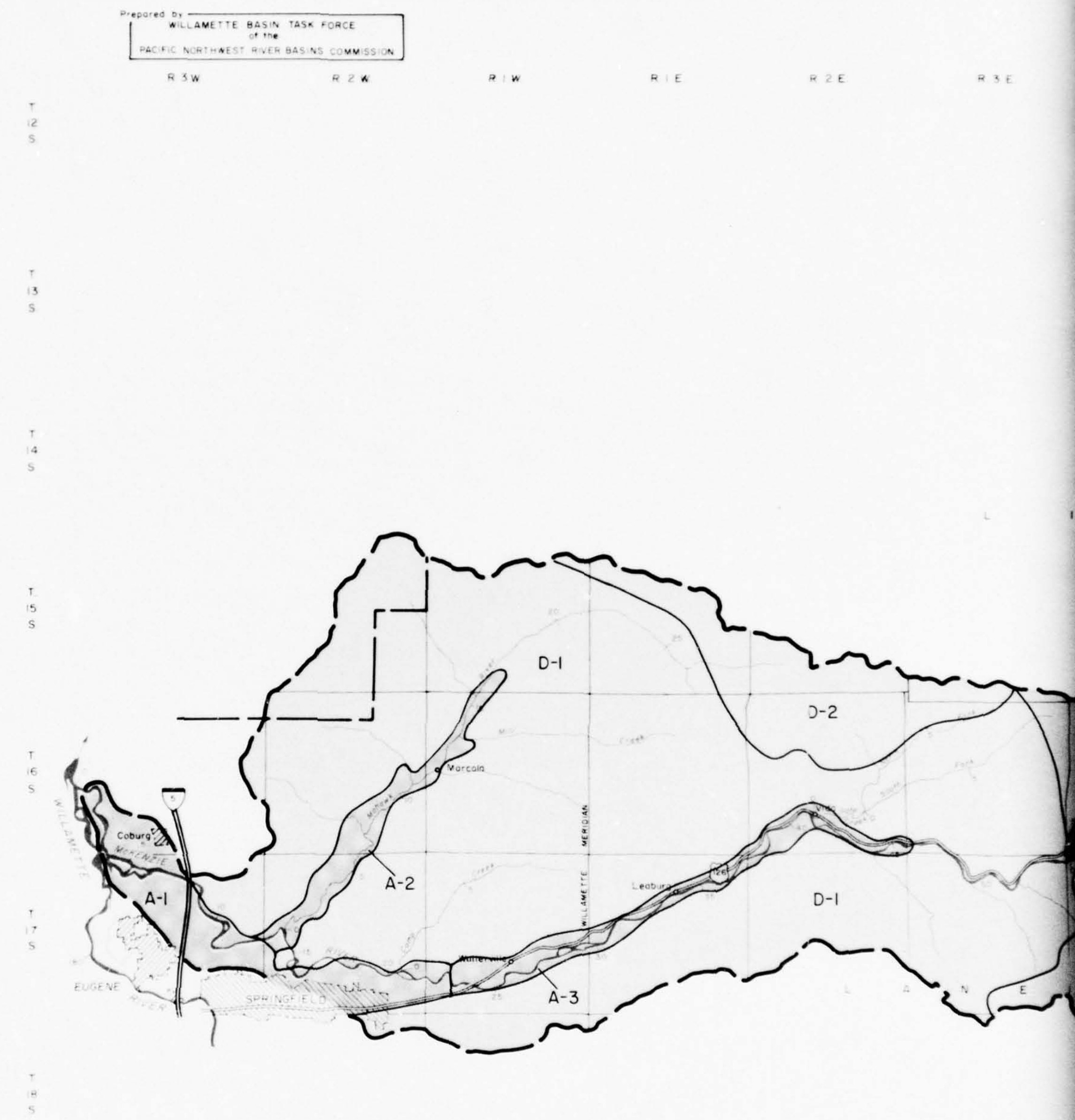
Availability of ground water, McKenzie subbasin

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm)		Poten incre
				Range of present wells	Expectable	
A-1	Alluvial deposits (bouldery sand and gravel, silty, clayey)	50-100	30-180	250-1,000	500+	Several t rate
A-2	Alluvial deposits (sand and gravel)	50-125	30-150	Locally 120	200	Large inc
A-3	Alluvial deposits (bouldery sand and gravel)	50-75	30-75	50-140	200-500	do.
A-4	do.	50-125	20-140	50-550	do.	do.
D-1	Little Butte Volcanic Series (pyroclastics)					
	Marine rocks (sandstone and shale)	Several hundred	100-200	10-20	50-100	Small, be of most low
D-2	Sardine Formation (lava and pyroclastics)					
U	Young volcanic rocks	Several hundred	--	--	Several hundred	Large

enzie subbasin

city

ble	Potential for increased use	Remarks
	Several times present rate	Because of hydraulic connection of aquifer with streams, heavy pumping of wells could reduce streamflow.
	Large increase	Do.
	do.	Do.
	do.	Do.
	Small, because yields of most wells are low	Careful exploration needed to find most favorable sites for wells. Few data from much of the area.
l d	Large	Large springs indicate sizable ground-water potential. Belknapp Hot Springs group flow total of 75 gpm; combined flow of Olallie, Lost, and Great Springs is about 230 cfs. For large supply, wells wouid need to be several hundred feet deep. Few data available.



EXPLANATION

A-1

Aquifer, alluvial sand and gravel. Yields more than 500 gpm

A-2

Aquifers, alluvial sand, gravel, and silt. Yield 200 gpm

A-3, A-4

Aquifers, alluvial sand and gravel. Yield 200-500 gpm

D-1

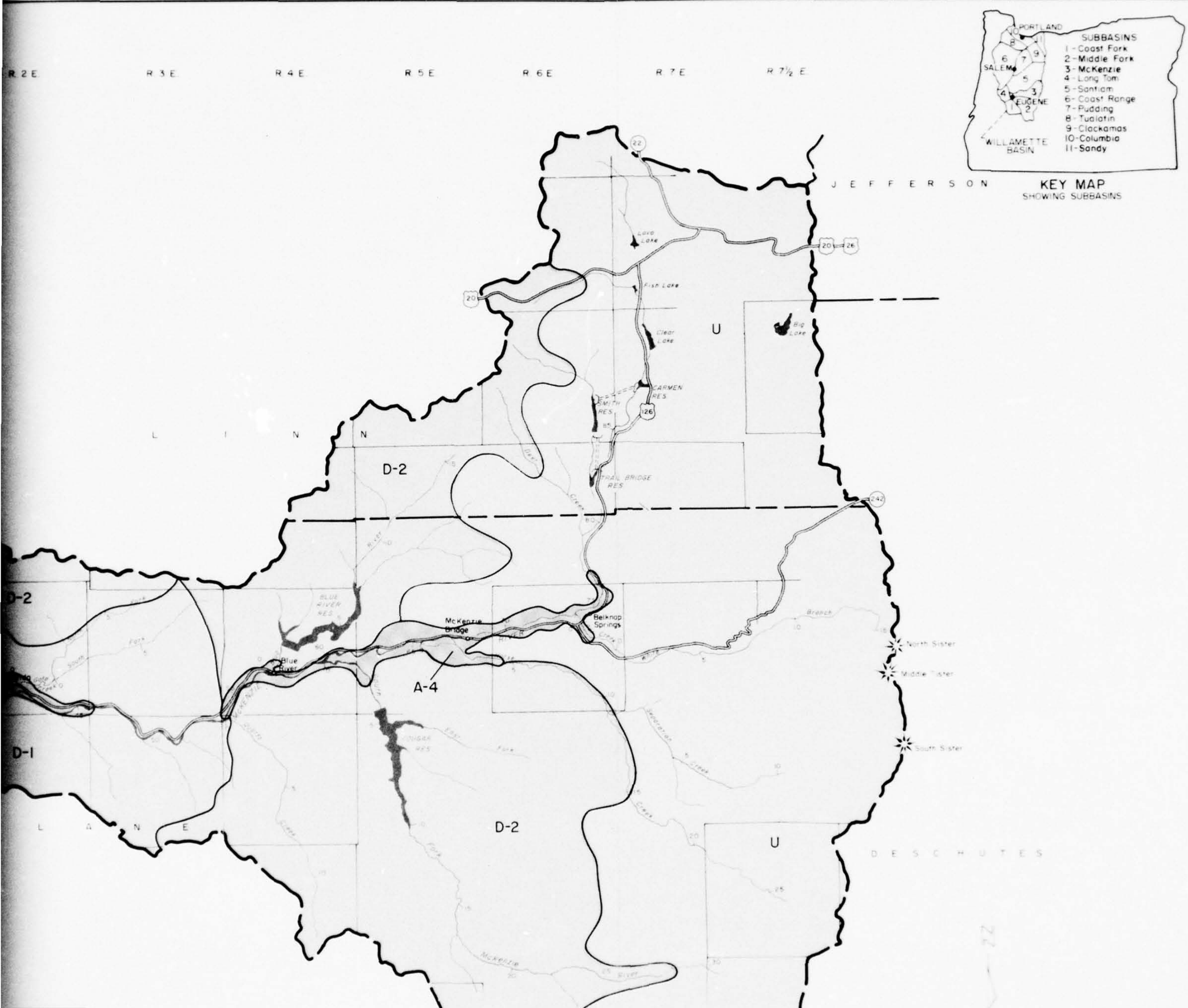
Aquifers, marine rocks and Little Butte Volcanic Series. Yield 10-20 gpm, locally 100 gpm

D-2

Aquifer, Sardine Formation. Yields 10-20 gpm, locally 100 gpm

U

Aquifers, young lavas of High Cascades. Groun water not developed in the area, but wells shoul produce several hundred gallons per minute



D-1

...cks and Little Butte Volcanic
...0 gpm, locally 100 gpm

D-2

...ormation. Yields 10-20 gpm,

U

...vas of High Cascades. Ground
...d in the area, but wells should
...ndred gallons per minute

MAP IV-7
McKENZIE SUBBASIN
WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

SCALE IN MILES

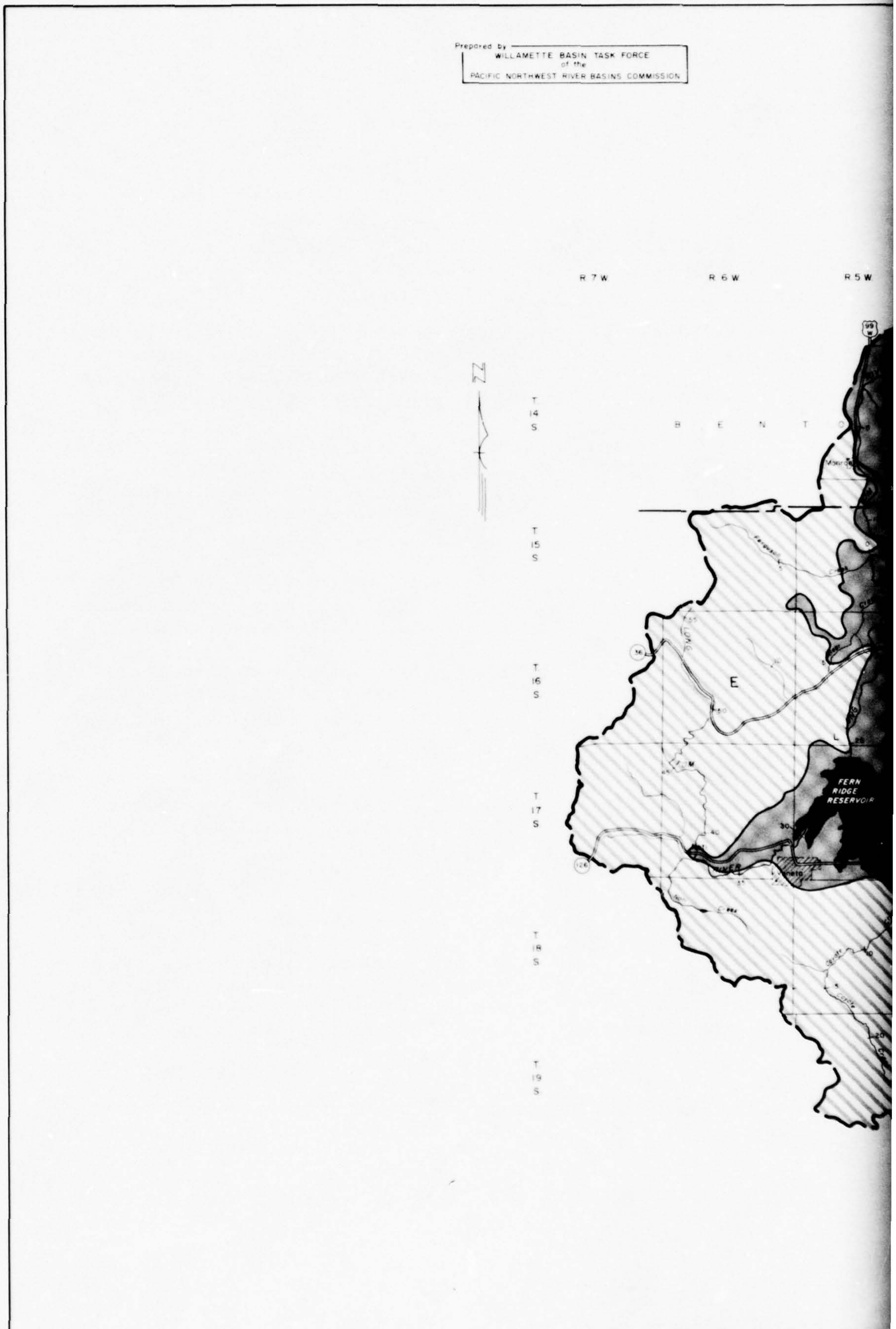
Table IV-8
Availability of ground water, Long Tom subbasin

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm): Range of present wells	Yields of largest capacity wells (gpm): Expectable	Pote incr
A-1	Alluvial deposits (sand and gravel, locally silty)	30-125	20-150	150-800	500+	Several t use west ette Ri east of
A-2	Alluvial deposits (sand and gravel mixed with silt and clay)	70-140	20-140	50-300	100	Moderate; pumpage
E	Marine sediments	--	40-240	20-60	0-20	Small, be well yi
	Volcanic rocks	--	do.	0-20		

ng Tom subbasin

acity

able	Potential for increased use	Remarks
+	Several times present use west of Willamette River; small east of river	Depth to water less than 10 ft. Aquifer hydraulically connected to stream: large increase in pumping could reduce seepage or induce infiltration from river and reduce its flow. Area east of river already heavily pumped.
	Moderate; present pumpage is small	Water table at about 10 ft is in hydraulic connection with Fern Ridge Reservoir. A large increase in pumping near the reservoir could induce infiltration from it.
0	Small, because of low well yields	Well yield only 1-2 gpm in many places, and "dry holes" have been drilled locally.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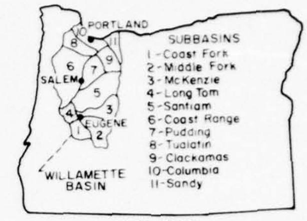
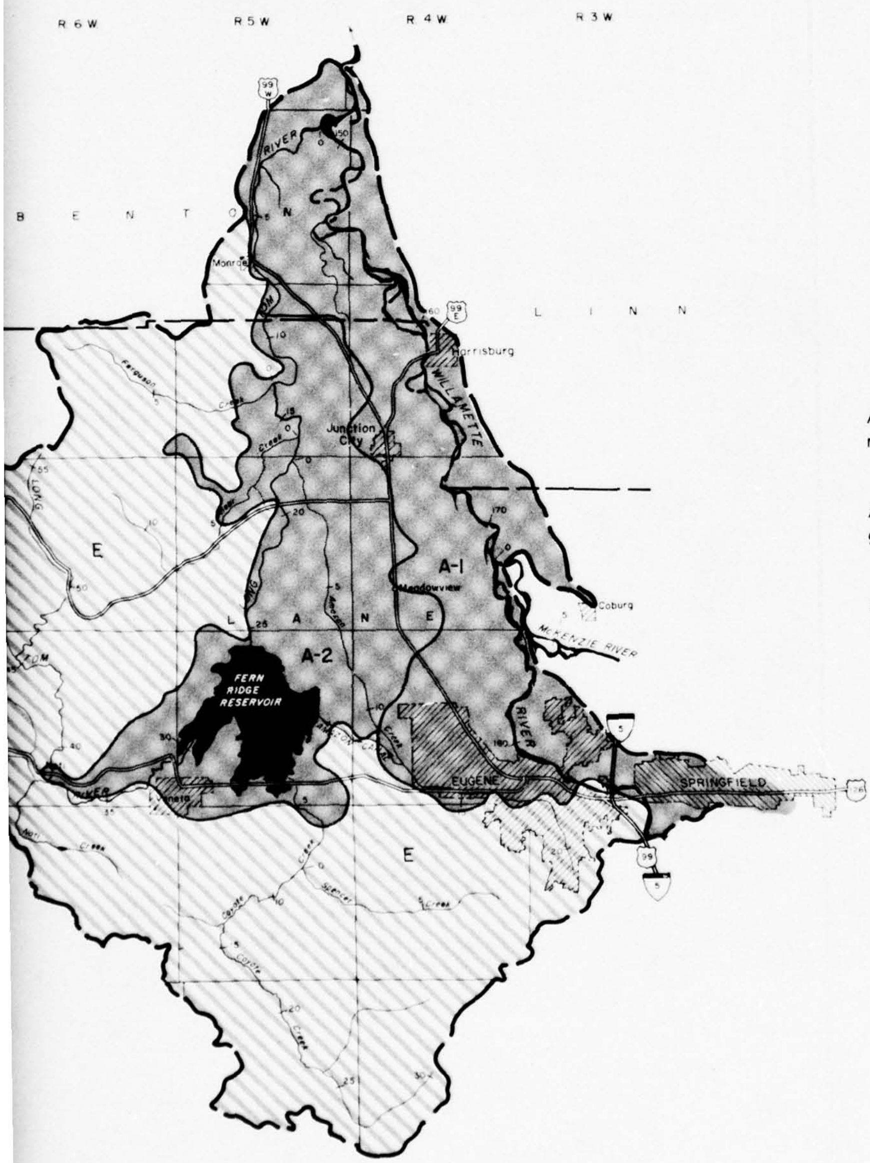


KEY MAP
SHOWING SUBBASINS



EXPLANATION

A-1

Aquifer, alluvial sand and gravel. Yields 500 gpm or more

A-2

Aquifer, alluvial sand, gravel, and silt. Yields 50 gpm, locally 300 gpm

E

Aquifers, marine and older volcanic rocks. Yield 10-20 gpm, locally less than 2 gpm

MAP IV-8

LONG TOM SUBBASIN

WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

3 0 3 6
SCALE IN MILES

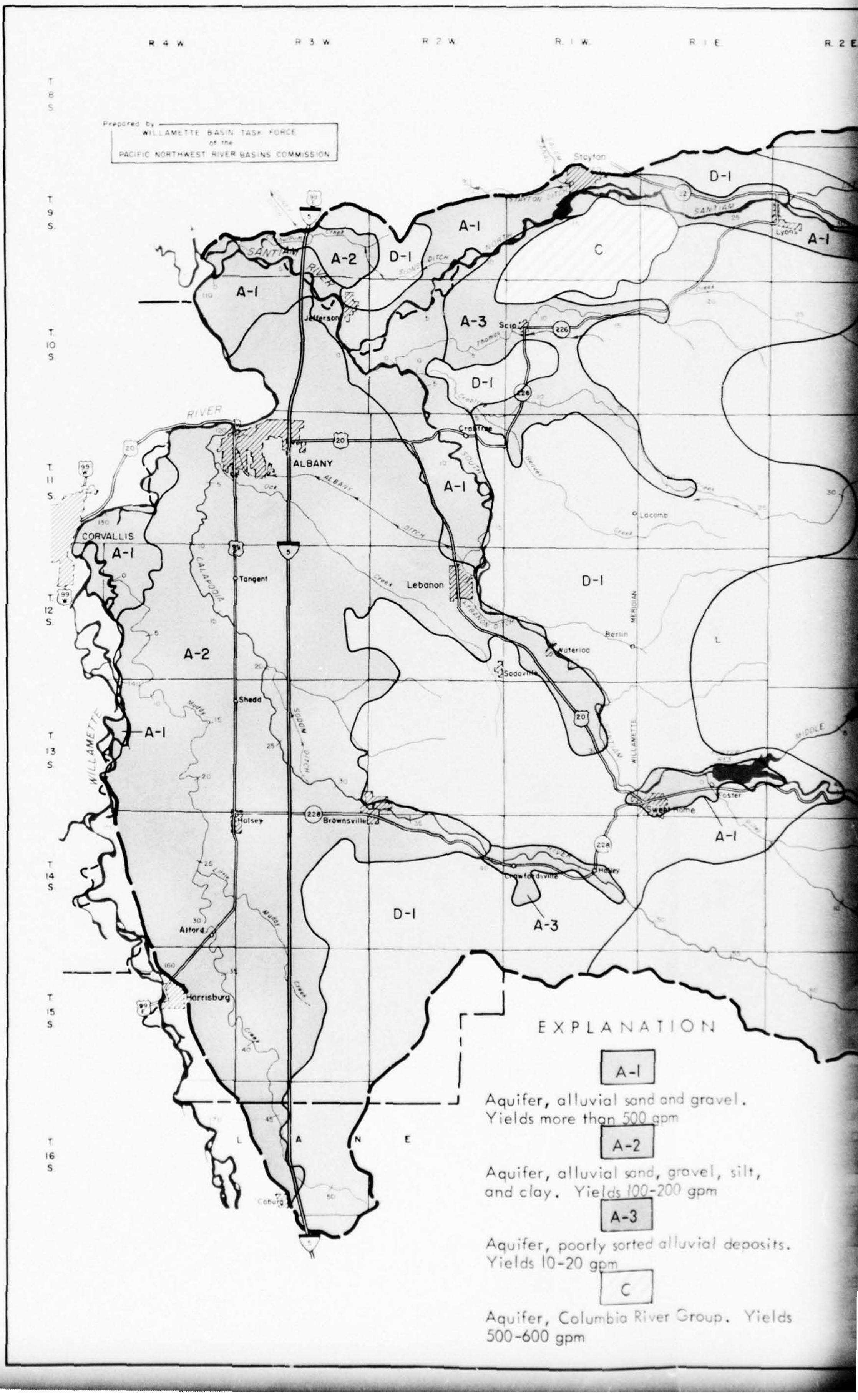
Table IV-9
Availability of ground water, Santiam subbasin

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm): Range of present wells	Yields of largest capacity wells (gpm): Expectable	Poten incre
A-1	Alluvial deposits (sand and gravel)	30-50	Generally 50	150-800	500+	Several t use
A-2	Alluvial deposits (sand and gravel, containing silt and clay locally)	25-135	20-160	50-700	100-200	do. small a Jeffers
A-3	Alluvial deposits (poorly sorted sand, gravel, silt, and clay)	50-100	50-100	10-50	50, locally 100	Moderate, yields relativ
C	Columbia River basalt	As much as 300	200-300	Several hundred	500	Small
D-1	Columbia River basalt					
	Marine sandstone	Several hundred	As much as 230	Locally 50	Locally 50-100	Small
	Little Butte Volcanic Series					
D-2	Sardine Formation (lava and pyroclastics)	do.	As much as 650	Locally 100	do.	do.
U	Young volcanic rocks	Several hundred	No known wells	--	Several hundred	Large

Table IV-9

ground water, Santiam subbasin

...s of largest capacity wells (gpm)			
...ge of ...nt wells	Expectable	Potential for increased use	Remarks
...0-800	500+	Several times present use	Depth to water generally less than 10ft. Because of hydraulic connection of aquifer with streams, heavy pumping of wells could reduce streamflow.
...0-700	100-200	do. (except small area near Jefferson)	Depth to water less than 20 ft. Because of hydraulic connection of aquifer with streams, heavy pumping of wells near streams would reduce streamflow.
...10-50	50, locally 100	Moderate, because yields of wells are relatively small	Exploration needed to locate best well sites. Heavy pumping of wells adjacent to streams could reduce streamflow.
...everal ...undred	500	Small	Aquifer has limited areal extent and storage; therefore, can sustain little additional development.
...ocally 50	Locally 50-100	Small	Careful exploration needed to locate most favorable sites for wells. Few data available.
...ocally 100	do.	do.	do.
--	Several hundred	Large	The large ground-water contribution to base flow indicates potential. Regional water table likely to be at depth of several hundred feet. Few data available.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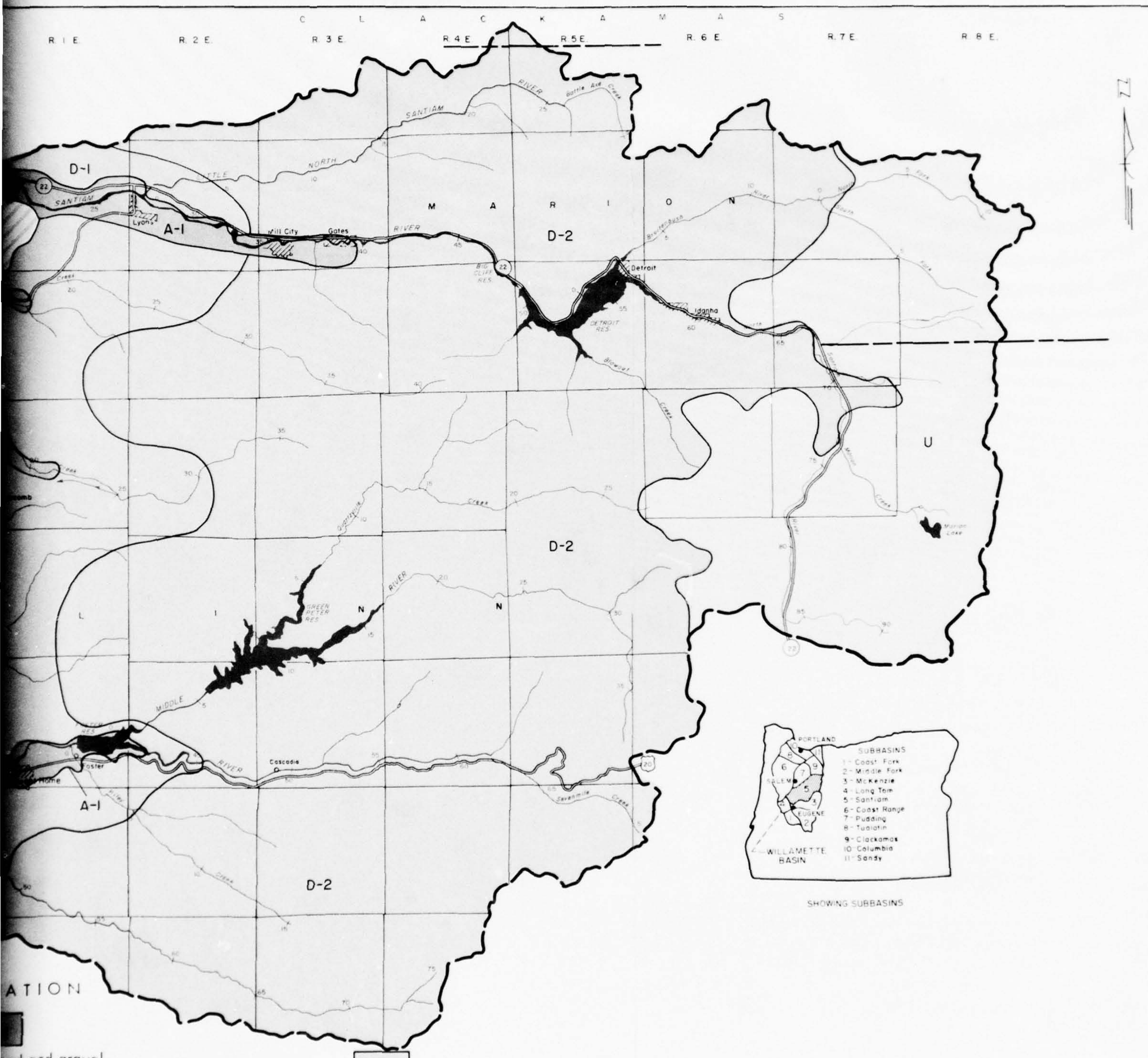
Tangent
Lebanon
Lacomb
Berlin
Waterloo
Sodaville
Shedd
Halsey
Brownsville
Sweet Home
Foster
Crawfordsville
Holley
Alford
Harrisburg
Coburg
SANTIAM RIVER
RIVER
WILLAMETTE
CALAPOOIA
ALBANY DITCH
SODOM DITCH
STAYTON DITCH
MIDDLE
MERIDIAN
L A N E
A-1
A-2
A-3
C
D-1
L
EXPLANATION
A-1
Aquifer, alluvial sand and gravel. Yields more than 500 gpm
A-2
Aquifer, alluvial sand, gravel, silt, and clay. Yields 100-200 gpm
A-3
Aquifer, poorly sorted alluvial deposits. Yields 10-20 gpm
C
Aquifer, Columbia River Group. Yields 500-600 gpm



ATION

nd and gravel.
0 gpm

nd, gravel, silt,
0-200 gpm

ted alluvial deposits.

River Group. Yields

D-1

Aquifers, Columbia River Group, Little Butte Volcanic Series, marine rocks, and piedmont deposits. Yield 10-20 gpm, locally 100 gpm

D-2

Aquifers, largely Sardine Formation. Yield 10-20 gpm, locally 100 gpm

U

Aquifers, young lavas of High Cascades. Yield unknown, but probably several hundred gallons per minute

MAP IV-9

SANTIAM SUBBASIN

WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

0 3 6
SCALE IN MILES

WBTF-5-1082a-LL

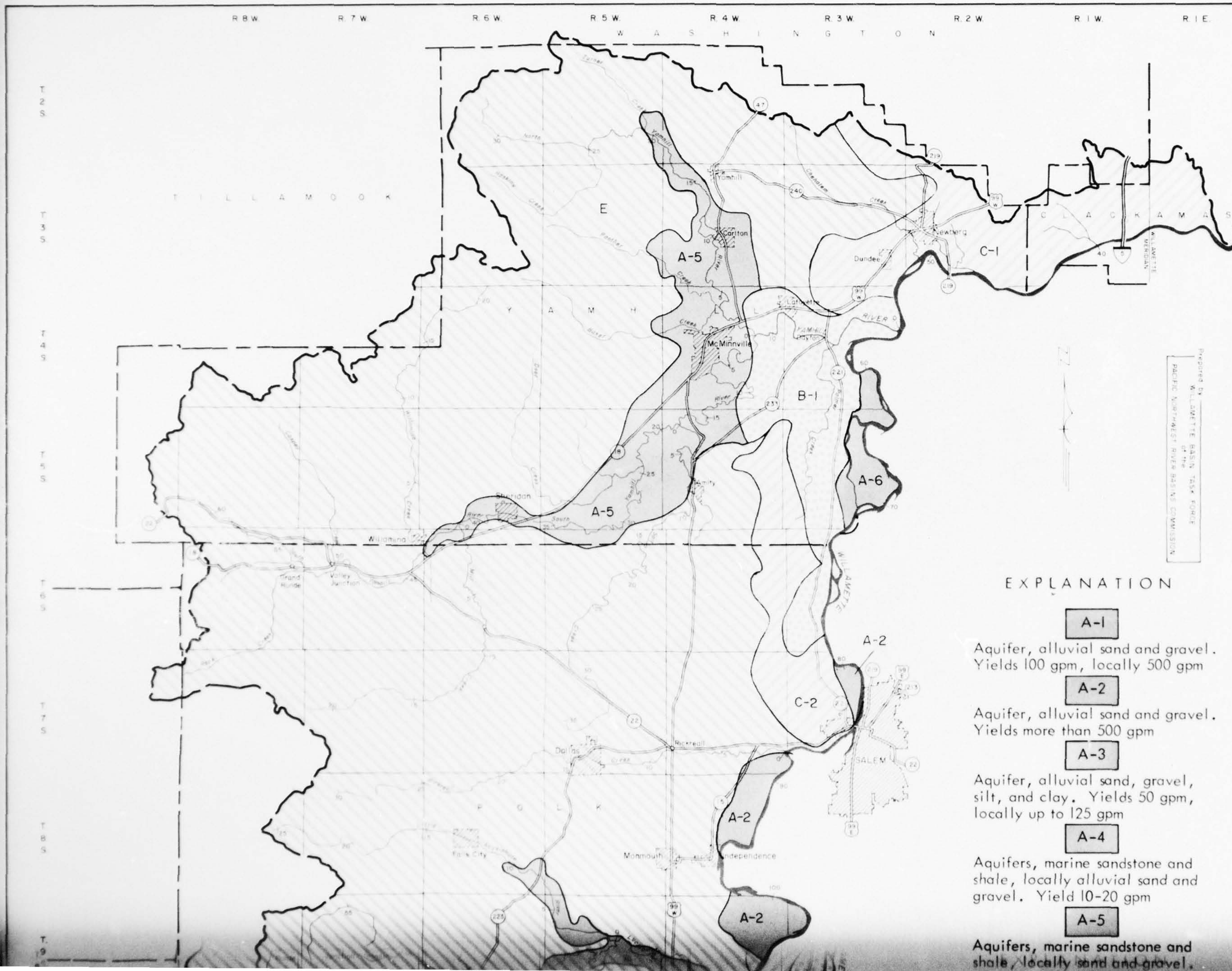
Table IV-10
Availability of ground water, Coast Range

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm): Range of present wells	Expectable	
A-1	Alluvial deposits (sand and gravel, containing silt and clay)	50-100	20-100	100-450	100, locally 400	Sever
A-2	Alluvial sand and gravel	40-70	40-70	300-1,000	500+	
A-3	Alluvial deposits (silt and clay, containing lenses of sand and gravel)	50-130	20-139	25-125	25, locally 50	Moder of
A-4	Alluvial clay and gravel	Generally 30, locally 50	20-50	20 or less	Up to 20	Small wel
	Marine sandstone	Several hundred	As much as 200	10	10	
A-5	Alluvial deposits (silt and clay; gravel lenses)	0-100	0-100	40-220	Generally 50, locally 100	
A-6	Alluvial deposits (sand and gravel)	40-70	40-200	300-1,000	500+	Seve us
	Troutdale Formation (clay, sand, gravel)	As much as 150	As much as 200	300-1,000	500+	
B	Alluvial deposits and Troutdale Formation (clay and sand, containing gravel)	40-300	30-300	100-900	Several hundred	
C-1	Columbia River basalt	Several hundred	As much as 250	100	100	Mode it
C-2	do.	do.	As much as 550	75-170	100-200 (east side of area)	
E	Marine sandstone and volcanic rocks	do.	As much as 400	20 or less	5	Smal we

e IV-10
l water, Coast Range subbasin

capacity

xpectable	Potential for increased use	Remarks
00, locally 400	Several times present use	Depth to water generally less than 20 ft. Aquifer hydraulically connected to river; therefore, heavy pumping may reduce streamflow.
500+	do.	Do.
5, locally 50	Moderate, because yields of wells are small	Locations of sand and gravel lenses are unpredictable; therefore, exploration needed to find most favorable well sites.
Up to 20	Small, because of low well yields	Supplies generally adequate for domestic and stock needs only.
10	do.	Do.
enerally 50, ocally 100	do.	Exploration needed to locate favorable sites for wells.
500+	Several times present use	Depth to water 10-20 ft. Aquifer hydraulically connected to river; therefore, heavy pumping may affect streamflow.
500+	do.	Do.
Several hundred	do.	Depth to water 20-50 ft. Ground-water seepage contributes to river flow, and heavy pumping could reduce this seepage.
100	Moderate, because of limited storage capacity	Exploration needed to locate most favorable sites for wells.
100-200 (east side of area)	do.	Water table several hundred feet deep in west part. Many domestic wells tap shallow perched zones.
5	Small, because of low well yields	Geologic units are poorly permeable, and in many places "dry holes" have been drilled or wells yield supplies too small or too mineralized for domestic needs.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WASHINGTON
TILLAMOOK
YAMHILL
POLK
CLACKAMAS
WILLAMETTE MERIDIAN
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Valley Junction
Dallas
Rickreall
Monmouth
Independence
Falls City
SALEM
WILLAMETTE
RIVER
E
A-5
C-1
B-1
A-6
C-2
A-2
EXPLANATION
A-1
Aquifer, alluvial sand and gravel. Yields 100 gpm, locally 500 gpm
A-2
Aquifer, alluvial sand and gravel. Yields more than 500 gpm
A-3
Aquifer, alluvial sand, gravel, silt, and clay. Yields 50 gpm, locally up to 125 gpm
A-4
Aquifers, marine sandstone and shale, locally alluvial sand and gravel. Yield 10-20 gpm
A-5
Aquifers, marine sandstone and shale, locally sand and gravel.

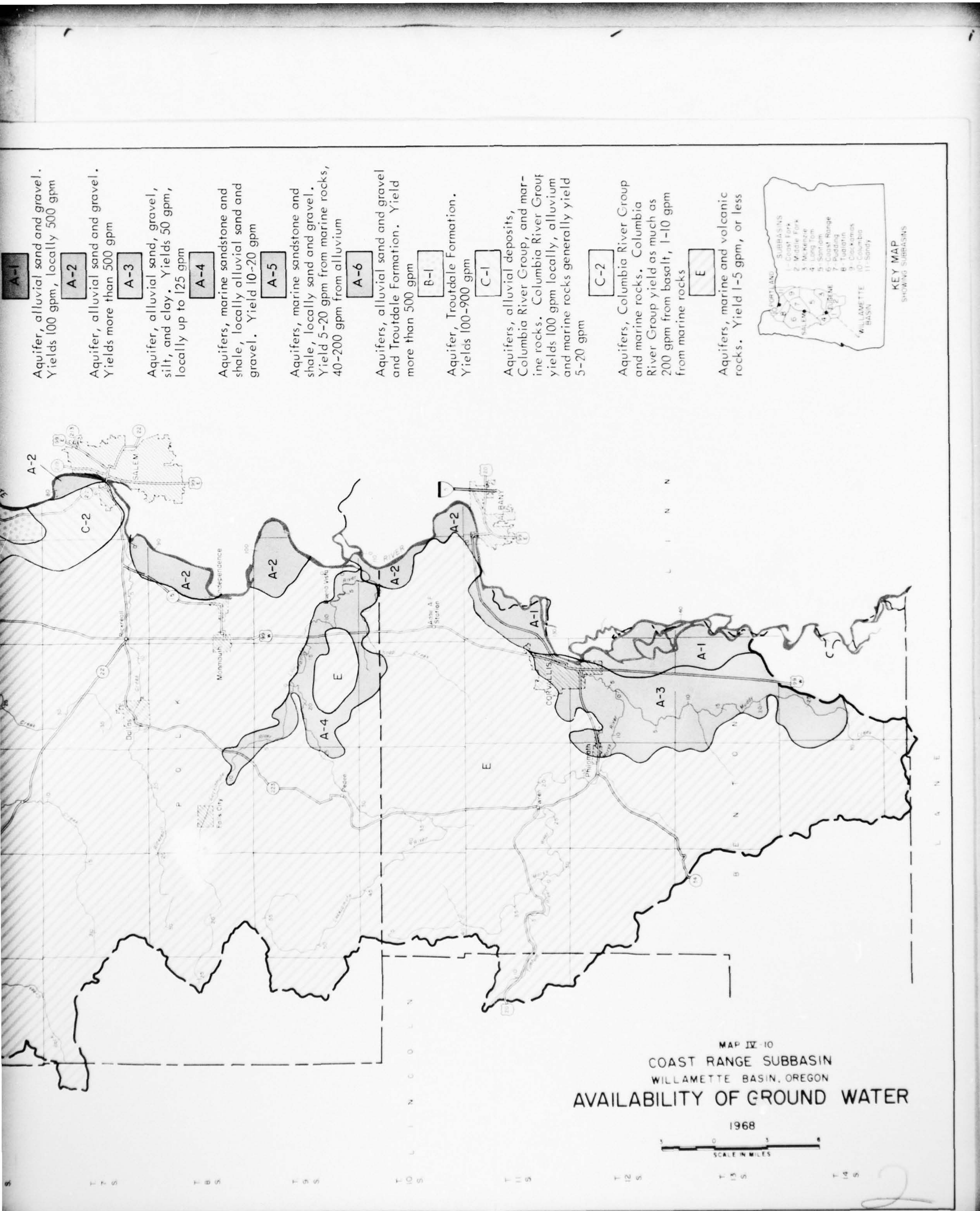

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Table IV-11

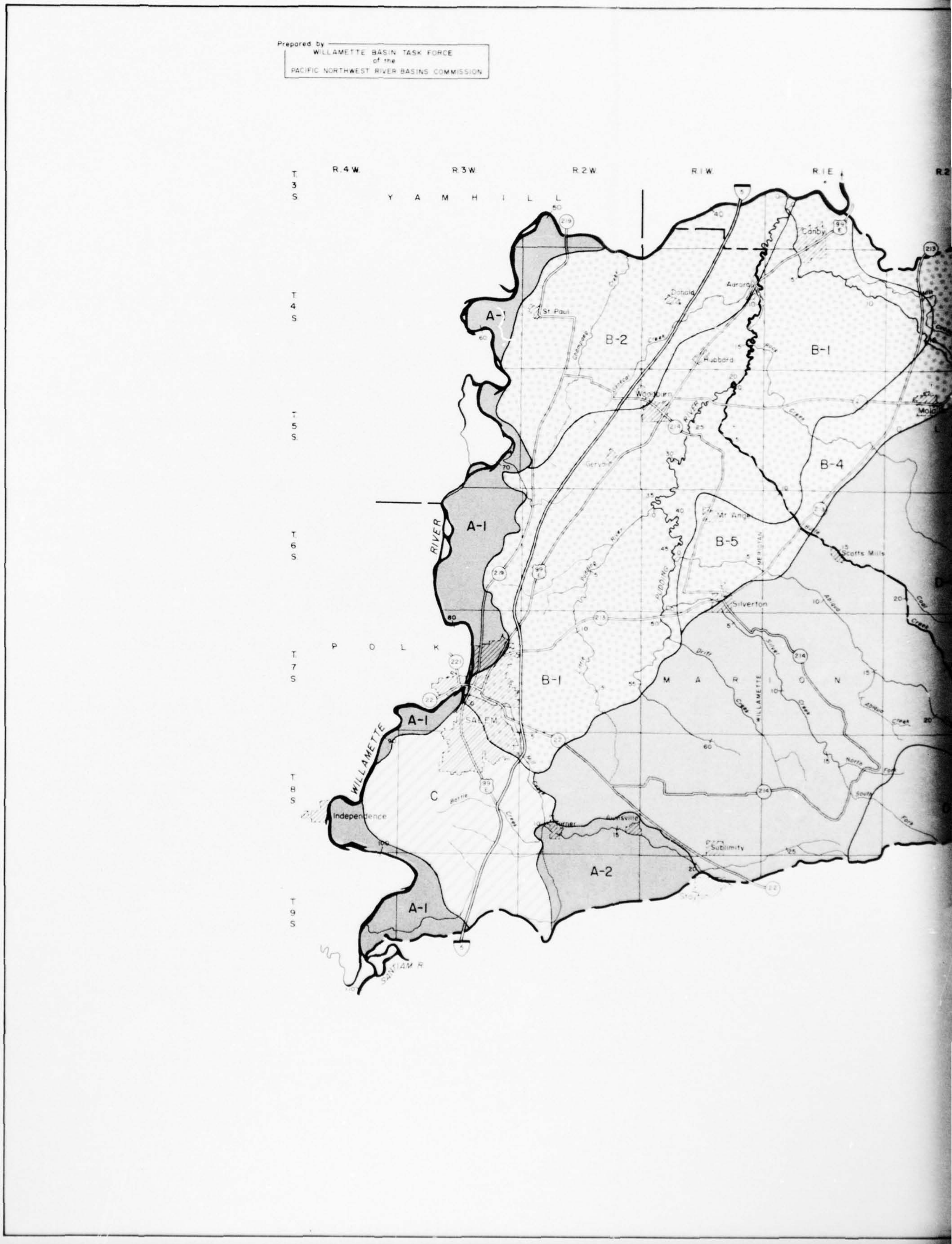
Availability of ground water, Puddin

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm): Range of present wells	Yields of largest capacity wells (gpm): Expectable
A-1	Alluvium and terrace deposits (sand and gravel)	50-90	50-90	200-1,000	500-1,000
A-2	Alluvium (sand and gravel)	50-110	50-110	100-300 (few 500)	200
B-1	Troutdale (sand and gravel)	Generally 200-250, max 500	200-500	50-1,500	500 (1,000 in south)
B-2	Troutdale (largely sand)	do.	do.	100-500	300
B-3	Young volcanics	70-240	70-200	Locally 40	50
	Troutdale	70-450	70-440	Locally 60	do.
B-4	Troutdale (sand and gravel)	Several hundred	40-500	Locally 450	50-200
	Columbia River basalt	do.	170-220	Locally 50	50-200
	Marine sandstone	do.	80-300	do.	50-100
	Little Butte Volcanic Series	do.	90-430	Locally 100	do.
B-5	Troutdale (sand and gravel)	do.	60-220	Locally 350	Few hundred
	Columbia River basalt	do.	70-630	Locally 650	do.
C	Columbia River basalt	do.	200-500	Locally 600	Locally 500
	Marine sandstone	do.	200-300	Few gpm	20 or less
D-1	Sardine Formation	do.	100-300	Locally 50	Locally 100
	Columbia River basalt	do.	do.	100-1,000	100-1,000
	Little Butte Volcanic Series	do.	do.	Locally 50	Locally 100
	Marine rocks	do.	do.	do.	Locally 50
D-2	Sardine, Columbia River basalt, Little Butte Volcanic Series	do.	do.	Locally 100	Locally 100

Table IV-11

f ground water, Pudding subbasin

largest capacity lls (gpm) Expectable	Potential for increased use	Remarks
500-1,000	Several times present use	Depth to water 10-20 ft. Ground water seeps into the Willamette River, and large increase in pumping may reduce this seepage.
200	Large	Aquifer connected hydraulically to river. Heavy pumping from wells may reduce streamflow.
500 (1,000 in south)	Several times present use	Depth to water 10-40 ft. Large quantity of ground water contributed to base flow of streams. Concentrated pumping may reduce this seepage substantially.
300	Large	Depth to water 10-40 ft. Wells pump sand locally.
50	Some increase	Young volcanics contain perched water. Yields of wells small and unpredictable in both aquifers.
do.	do.	
50-200	Moderate to large	Wells in Troutdale have highest yields in west part of area. Yields of wells in other aquifers are unpredictable; therefore, exploration needed to select most favorable well sites.
50-200	Moderate	
50-100	do.	
do.	do.	
Few hundred	Some increase	Exploration needed to find favorable well sites.
do.	do.	Do.
Locally 500	Small	Aquifer already heavily developed and subject to overdevelopment because of low storage capacity.
20 or less	do.	Adequate only for domestic or stock supplies.
Locally 100	Small, because of low yields	In south part of area the water levels in the basalt aquifer are declining. Exploration needed in all aquifers to select most favorable well sites.
100-1,000	Fully developed in south	
Locally 100	Small	
Locally 50	do.	
Locally 100	Substantial increase	Exploration required to find most favorable well sites. Few data available.



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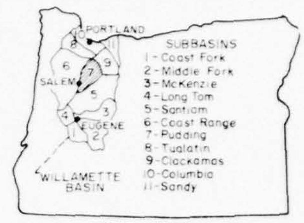
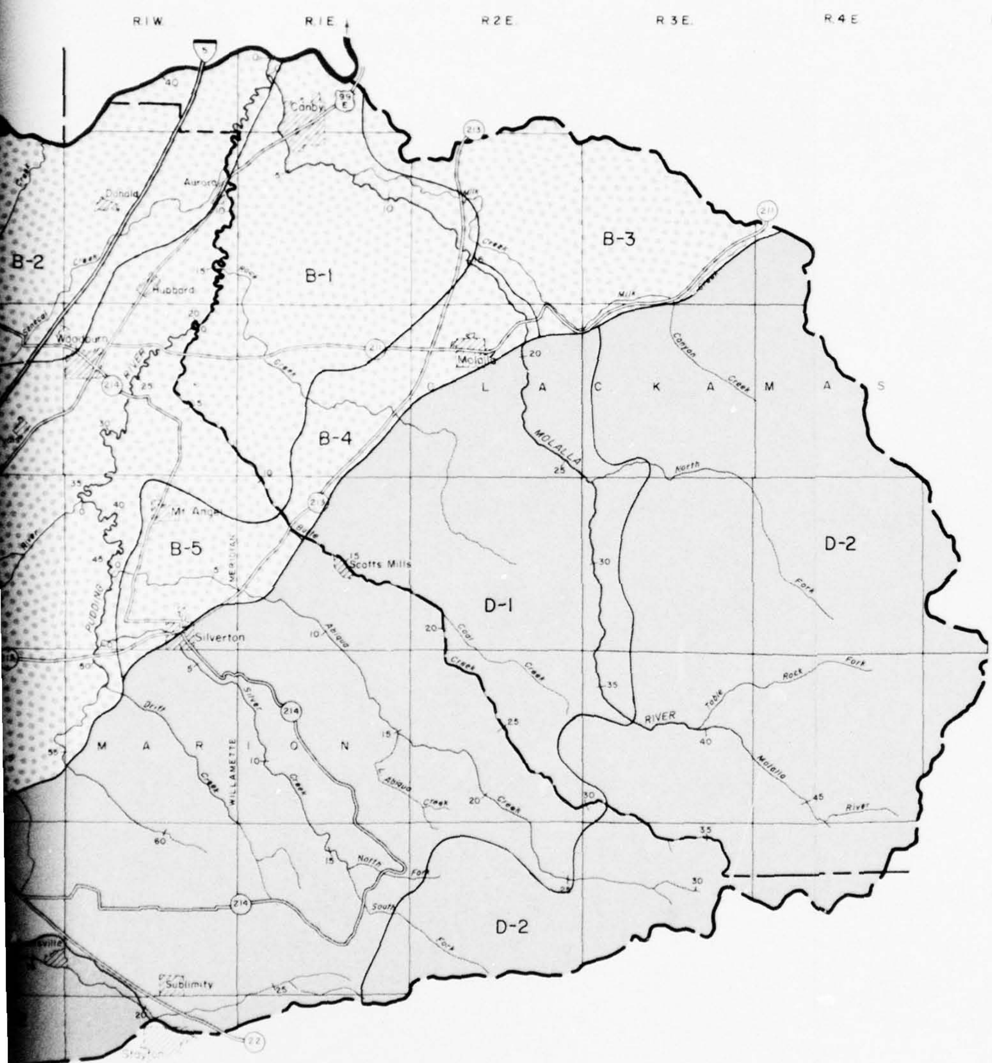


KEY MAP
SHOWING SUBBASINS



EXPLANATION

A-1

Aquifers, alluvial sand and gravel, locally Troutdale Formation. Yield more than 500 gpm

A-2

Aquifer, alluvial sand and gravel. Yields 100-300 gpm, locally 500 gpm

B-1

Principal aquifer, sandstone and conglomerate of Troutdale Formation. Yields 500 gpm or more

B-2

Principal aquifer, sand and thin gravel lenses of Troutdale Formation. Yields 100-300 gpm, locally 500 gpm

B-3

Aquifers, Troutdale Formation and young lava. Yield 10-50 gpm

B-4

Aquifers, Troutdale Formation, Columbia River Group, Little Butte Volcanic Series, and marine rocks. Yield 5-50 gpm, locally as much as 400 gpm from Troutdale

B-5

Aquifers, Troutdale Formation and Columbia River Group. Yield 200-600 gpm

C

Aquifers, Columbia River Group and marine rocks. Yield 5-20 gpm from basalt, locally up to 600 gpm; 5-10 gpm from marine rocks

D-1

Aquifers, marine rocks, Columbia River Group, Little Butte Volcanic Series, and Sardine Formation. Yield generally 5-50 gpm, locally less than 2 gpm. In southwestern part, wells in basalt yield 100-1,000 gpm

D-2

Aquifers, marine rocks, Sardine Formation, and locally Little Butte Volcanic Series or Columbia River Group. Yield 5-20 gpm, locally 100 gpm

MAP IV-11

PUDDING SUBBASIN

WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

3 0 3 6
SCALE IN MILES

Table IV-12
Availability of ground water, Tualatin subbasin

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm): Range of present wells	Yields of largest capacity wells (gpm): Expectable	Potenti[al] increas[e]
A-1	Valley fill (sand and gravel)	1,000+	50-200	50-100	100	Large incre[ase]
	Columbia River basalt	Several hundred	450-600	100-200	200	Small incre[ase]
A-2	Valley fill (sand)	do.	Few hundred	Few	50	Large incre[ase]
	Columbia River basalt	do.	500-1,000	100-450	200+	Small incre[ase]
A-3	Valley fill (silt and clay with sand lenses)	do.	Few hundred	Few	Small	Small, beca[use] well yiel[ds]
	Columbia River basalt	do.	300-700	100-600	600 or less	Small
C-1	do.	do.	100-700	250-400	400	Moderate
	Young volcanic rocks	300 or less	100-300	Locally 50	50	Small
C-2	Columbia River basalt	Several hundred	200 (perched zones), 500+ locally to main saturated zone	200-400	400	Small
C-3	do.	do.	100-400	Locally 50	500 or less	Large incre[ase]
E	Older volcanic and marine rocks	--	100-300	10 or less	10	Small, bec[ause] well yiel[ds]

Table IV-12

of ground water, Tualatin subbasin

elds of largest capacity wells (gpm)			
Range of esent wells	Expectable	Potential for increased use	Remarks
50-100	100	Large increase	Exploration and careful well construction needed for maximum yield.
100-200	200	Small increase	Basalt has small storage capacity.
Few	50	Large increase	Careful well construction needed for maximum yield.
100-450	200+	Small increase	Basalt nearest land surface around edges of area.
Few	Small	Small, because of low well yields	
100-600	600 or less	Small	Water levels are declining locally in Fanno Creek valley.
250-400	400	Moderate	Many domestic wells of small yield (10-40 gpm).
Locally 50	50	Small	Restricted to small area northeast of Beaverton, where young volcanic rocks lie beneath the water table.
200-400	400	Small	Water level declining in small area near Tigard.
Locally 50	500 or less	Large increase	Perched-water zones furnish water to shallow wells locally, and to springs.
10 or less	10	Small, because of low well yields.	Many wells yield less than 5 gpm; dry holes common, some 500 ft deep.

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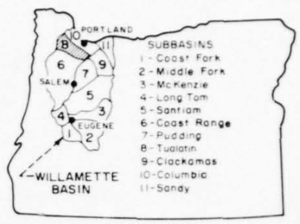
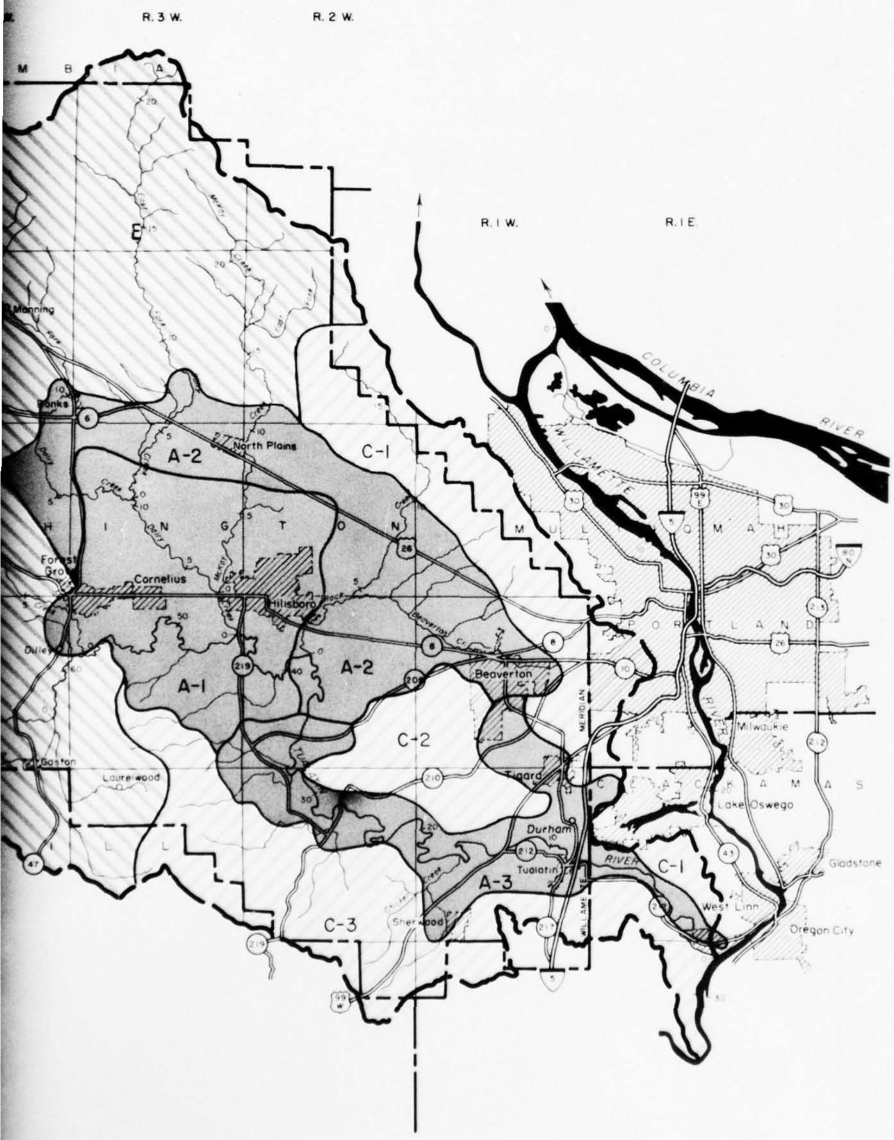


KEY MAP
SHOWING SUBBASINS



EXPLANATION

A-1

Aquifers, sand and gravel in valley fill, locally Columbia River Group. Yield 50-100 gpm from valley fill, 100-600 gpm from basalt

A-2

Aquifers, sand and gravel in valley fill, locally Columbia River Group. Yield up to 50 gpm from valley fill, 100-600 gpm from basalt

A-3

Aquifers, sand and gravel in valley fill, locally Columbia River Group. Yield 5-10 gpm from valley fill, 100-600 gpm from basalt

C-1, C-2, C-3

Aquifer, Columbia River Group. Yields 2-20 gpm from perched zones, 10-400 gpm from main saturated zone

E

Aquifers, marine and older volcanic rocks, locally alluvium. Yield 2-10 gpm from marine and older volcanic rocks which locally are dry, 50 gpm locally from Columbia River Group, 5-50 gpm from alluvium

MAP IV-12

TUALATIN SUBBASIN

WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

SCALE IN MILES

Table IV-13

Availability of ground water, Clackamas sub

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm)		Poter incre
				Range of present wells	Expectable	
B-1	Troutdale (cemented sand and gravel)	Several hundred	450 or less	50-150	100+	Several ti use
B-2	do.	500 or less	400 or less	70-130	100	Moderate; largely purposes
B-3	do.	Several hundred	40-500	40-300	100-300	Large
B-4	do.	do.	40-400	40-400	100-300	d
D	Sardine Formation, Columbia River basalt	do.	400 or less	40-60	50, locally 100	Moderate
U	Young volcanic rocks	do.	60-150	20-30	Several hundred	Large; ess untapped

Table IV-13

y of ground water, Clackamas subbasin

of largest capacity wells (gpm)			
e of t wells	Expectable	Potential for increased use	Remarks
150	100+	Several times present use	In southeastern part, shallow domestic wells tap terrace deposits.
130	100	Moderate; present use largely for domestic purposes	Depth to regional water table generally more than 100 ft. Many domestic wells obtain water from shallow perched zones in Troutdale or overlying piedmont deposits.
300	100-300	Large	Wells several hundred feet deep needed for maximum yield.
400	100-300	do.	Do.
60	50, locally 100	Moderate	Exploration needed to find most favorable well sites.
30	Several hundred	Large; essentially untapped at present	Springs and high base flows of streams indicate potential. Wells would need to be several hundred feet deep for large yields.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Sandy
Gladstone
Carver
Oregon City
Redland
Beavercreek
Eagle Creek
Estacada
WILLAMETTE RIVER
CLACKAMAS
RIVER
Faraday Lake
CAZADERO RES.
NORTH FORK RES.
North Fork Clackamas River
South Fork Eagle Creek
Roaring River
South Fork Clackamas River
Oak Grove Fork Clackamas
Lake Harriet
Hot Springs Fork
Collawash River
Elk Lake Creek
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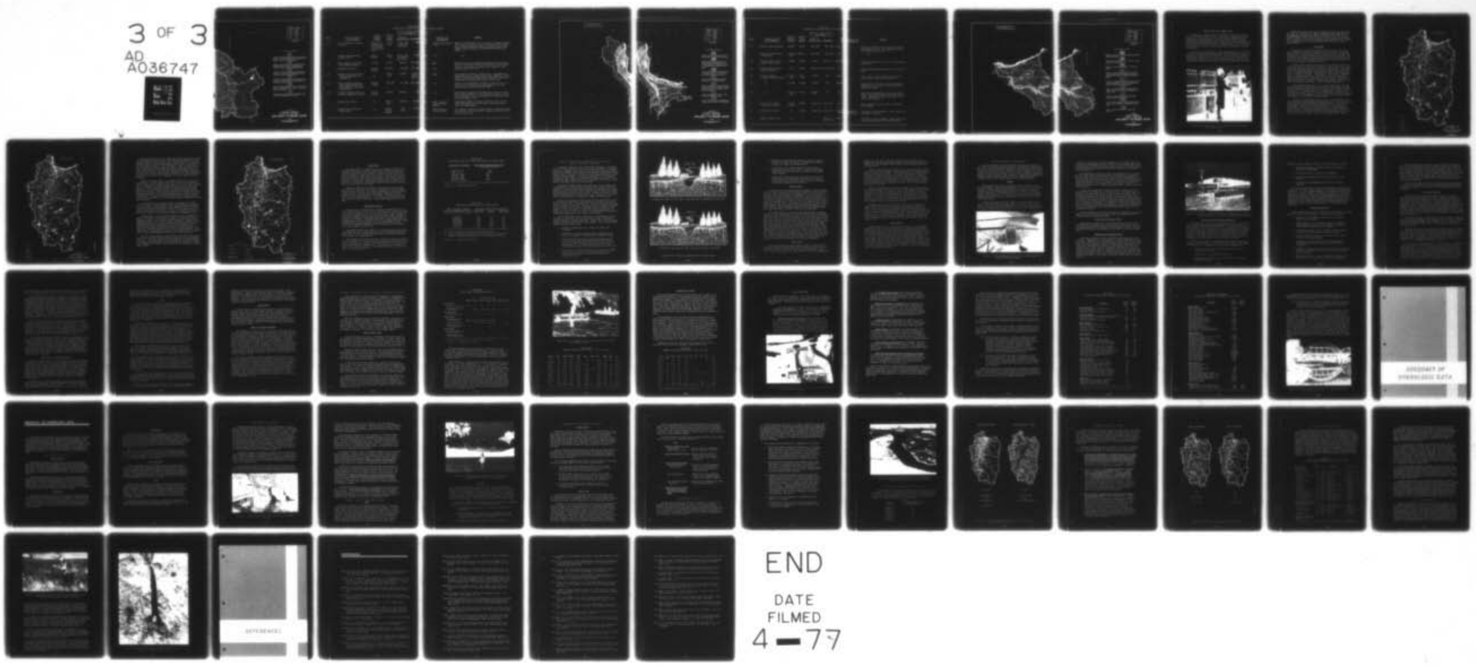

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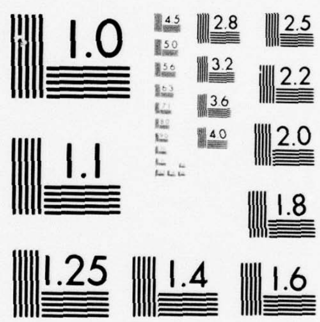

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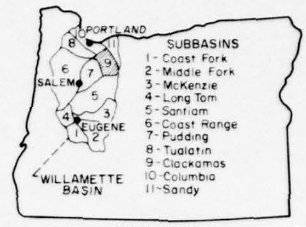


KEY MAP
SHOWING SUBBASINS

EXPLANATION

B-1

Aquifers, Troutdale Formation and alluvial sand and gravel. *Yield at least 100 gpm from Troutdale*, 10-20 gpm locally from alluvial deposits

B-2

Aquifers, Troutdale Formation and perched zones in piedmont deposits. Yield at least 100 gpm from Troutdale, small yields from piedmont deposits

B-3

Aquifers, Troutdale Formation and perched zones in young lava. Yield up to 500 gpm from Troutdale, 10-40 gpm locally from perched zones

B-4

Aquifers, Troutdale Formation and perched zones in young lava. Yield 50-100 gpm from Troutdale, 10-40 gpm from perched zones

D

Aquifers, Sardine Formation, locally Columbia River Group or Little Butte Volcanic Series. Yield 10-20 gpm, locally 100 gpm

U

Aquifer, young volcanic rocks. Expectable yields up to several hundred gallons per minute

MAP IV-13

CLACKAMAS SUBBASIN
WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

SCALE IN MILES

Table IV-14

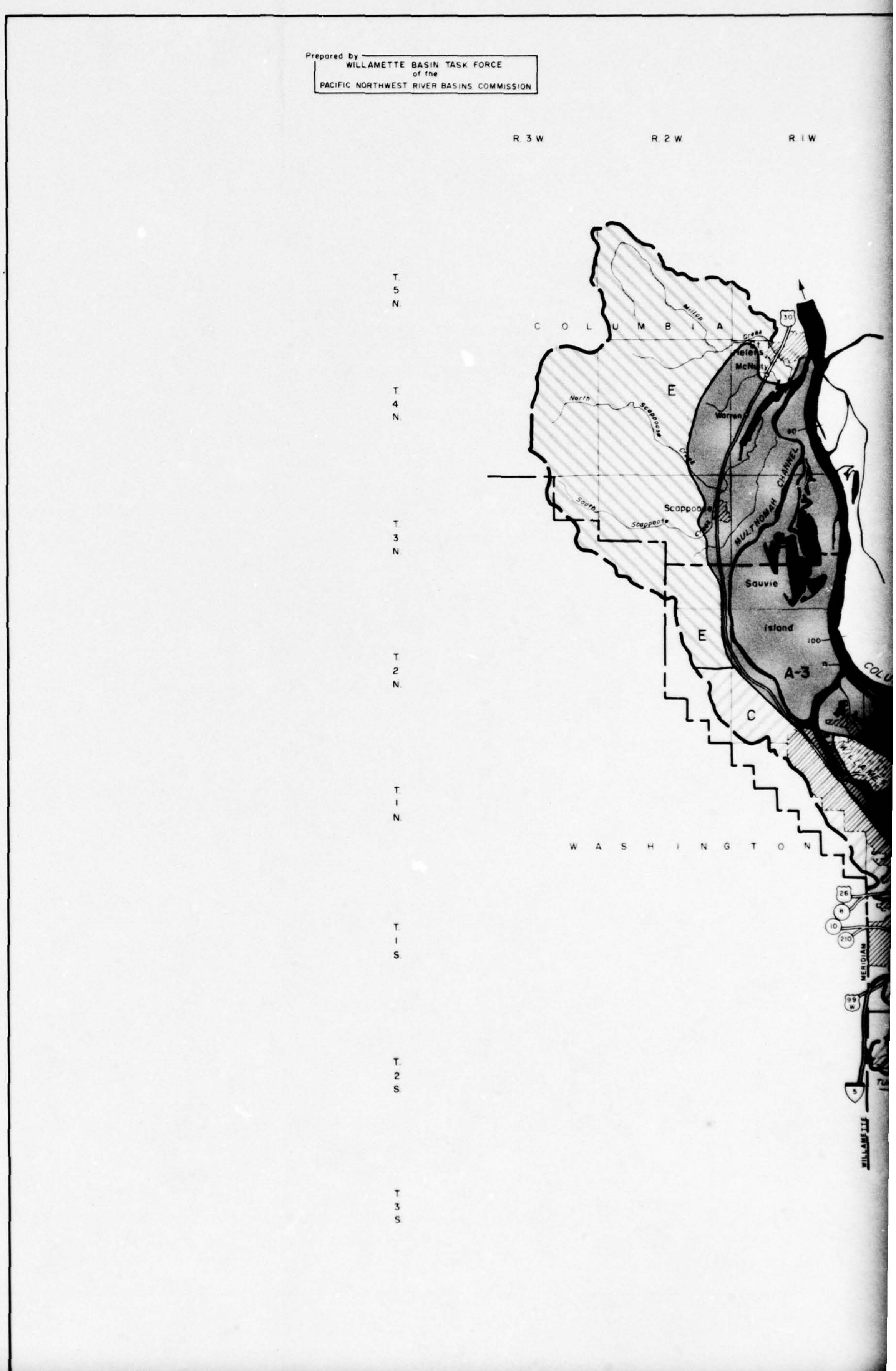
Availability of ground water,

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacit[y] wells (gpm)	
				Range of present wells	Expectable
A-1	Alluvial deposits (sand and gravel)	Maximum 125 along Willamette and 200 along Columbia River	200 or less	Up to 1,500 (1,000 from Qal alone)	1,000+
	Troutdale (cemented sand, gravel, silt)	Several hundred	300 or less	Up to 1,500 (1,000 from Qal alone)	1,000+
A-2	Terrace deposits and Troutdale (sand and gravel)	60-400	60-420	100-750	100-1,000
	Columbia River basalt	Several hundred	300-930	50-1,000	50-1,000
A-3	Alluvial sand and gravel and Troutdale sandstone and conglomerate	do.	200 or less	100-300	50-500, locally small
B-1	Terrace deposits (sand and gravel) and Troutdale Formation (mudstone, sandstone, conglomerate)	Maximum 1,300	80-1,100	50-1,500	500-1,000
B-2	Troutdale (cemented sand and gravel); young lava, locally	Several hundred	130-970	100-320	500
C	Columbia River basalt	do.	1,000 or less	100-350	100-400
E	Columbia River basalt and marine rocks	do.	Locally several hundred	20 or less	10-20

4
r, *Columbia subbasin*

ity

le	Potential for increased use	Remarks
00+	Several times present rate	Depth to water generally only a few feet. Because of hydraulic connection of aquifer with the Willamette and Columbia Rivers, heavy pumping may induce infiltration from streams. Pumping should be spaced to develop maximum ground-water yield.
00+	do.	Do.
00	None	Both aquifers heavily pumped in Portland west-side business district, where water levels have declined in recent years. Aquifers could support additional small pumpage at north and south ends of the area.
00	do.	
	Large	Large supplies available at most places. "Quicksand" and mineralized water at shallow depths limit supplies on Sauvie Island. Near streams, aquifers have hydraulic connection to streams, and heavy pumping may induce infiltration.
00	do.	Depth to water table more than 100 ft in much of area, but only 30 ft in northwest part. Many domestic wells tap perched zones at less than 100-ft depth.
00	do.	Most domestic supplies from perched zones in lava or Troutdale at less than 300 ft. To tap entire Troutdale, section wells would have to be several hundred feet deep, and would have high pumping lifts.
00	Small, because of limited storage capacity	Exploration needed to find most favorable sites for wells, which should penetrate at least 200 ft below main water table for large supplies.
0	Small, because of low well yields	Most domestic supplies from perched zones. Mineralized water occurs locally at shallow depths. Depths of wells vary with altitude and terrain.



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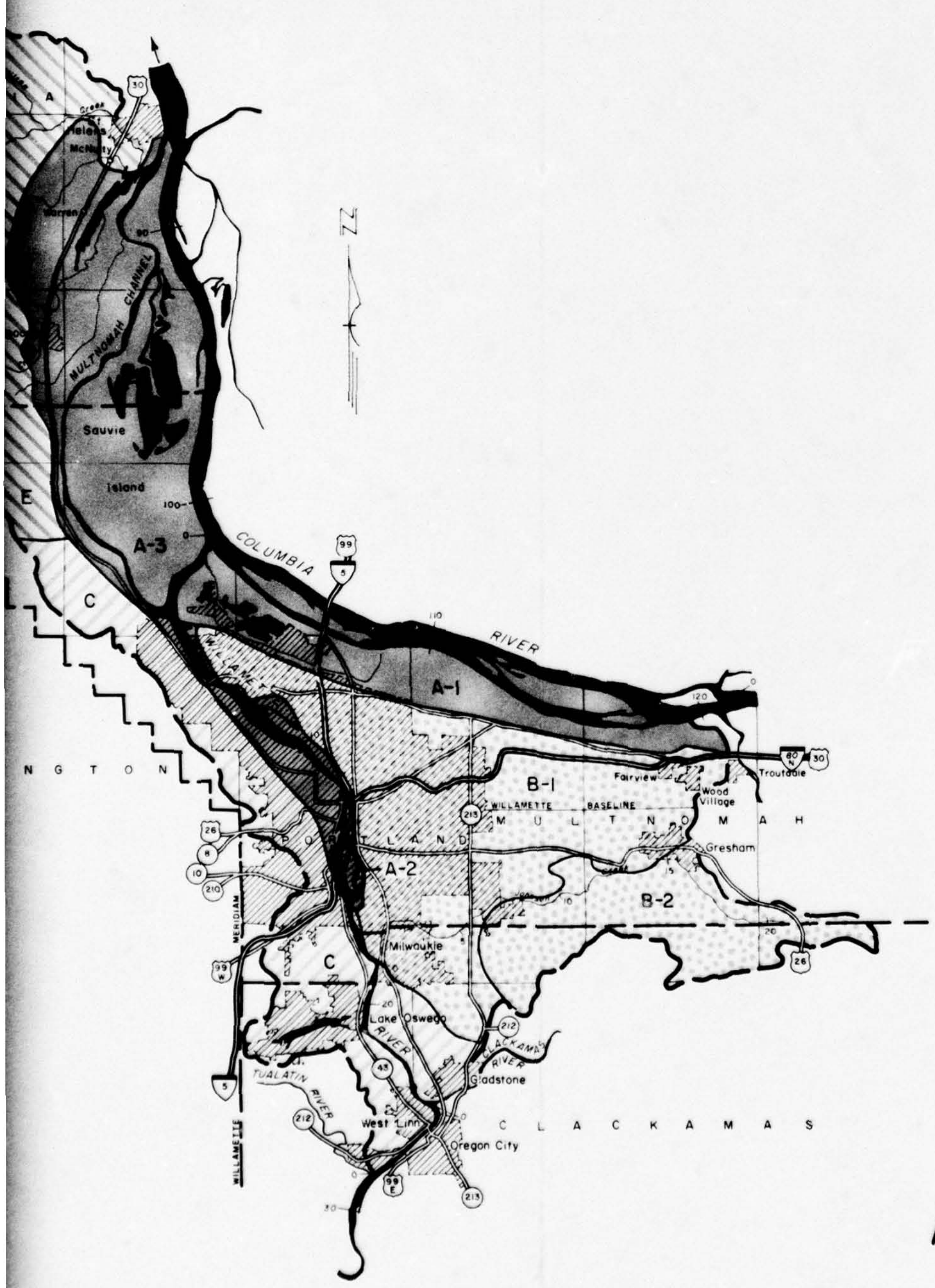

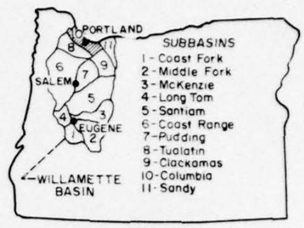

KEY MAP
SHOWING SUBBASINS

EXPLANATION

A-1

Aquifers, alluvium and underlying Troutdale Formation. Yield at least 1,000 gpm

A-2

Aquifers, Columbia River Group, Troutdale Formation, and terrace deposits. Yield 50-1,000 gpm from basalt, as much as 1,000 gpm from Troutdale-terrace deposits

A-3

Aquifers, alluvial sand and gravel, locally Troutdale Formation. Yield, 50-500 gpm, locally small on Sauvie Island

B-1

Aquifers, Troutdale Formation and terrace deposits. Yield 500-1,000 gpm

B-2

Aquifers, Troutdale Formation and perched zones in young lava or Troutdale. Yield 500 gpm from Troutdale, 2-20 gpm locally from perched zones

C

Aquifer, Columbia River Group. Yields 5-15 gpm, 100-400 gpm locally

E

Aquifers, perched zones in Columbia River Group and marine rocks. Yield 2-20 gpm

MAP IV-14

COLUMBIA SUBBASIN

WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

3 0 3 6
SCALE IN MILES

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Table IV-15

Availability of ground water, Sandy subbasi

Area	Principal aquifers and lithology	Aquifer thickness (feet)	Depth of wells (feet)	Yields of largest capacity wells (gpm) Range of present wells	Expectable	Po in
A-1	Alluvium (sand and gravel)	100-200	50-100	300-1,000	500-1,000	Large
	Troutdale (cemented sand and gravel)	As much as 400	100-540	300-1,000	500-1,000	do.
A-2	Alluvial deposits (sand, gravel, silt, clay)	50-200	50-200	15-100	Locally 50	Moderate
A-3	Alluvial deposits (sand, gravel, boulders)	50-175	30-230	Locally 385	Locally 500	do.
B-1	Troutdale Formation (cemented sand and gravel)	As much as 500	400 or less	120-500	500	Large
B-2	do.	150-900	30-500	50-300	300	Moderate
B-3	do.	As much as 300	50-350	Maximum 20	100	do.
C	Columbia River basalt and Sardine Formation	Several hundred	100-200	Locally 50	Locally 50	do.
D	Columbia River basalt	do.	70-570	Locally 20	Locally 50	Small, l low w
U	Younger volcanic rocks	do.	--	--	200, locally 1,000	Large

ential for reased use	Remarks
	Because of hydraulic connection of aquifer with the Willamette River, heavy pumping may induce infiltration from the river.
	Do.
	Yields low because of silt and clay interspersed with gravel.
	Coarse, bouldery glacial outwash in east part of area.
	Water table at 100- to 200-ft depth; many domestic wells tap shallow perched zones.
	Many domestic wells tap shallow perched zones. Aquifer thin and yields of wells small along Sandy River canyon.
	Main water table probably at more than 100-ft depth. Many domestic wells tap shallow perched zones. Exploration needed to find most favorable sites for wells.
	Only a few wells in area, along the Columbia River Highway.
cause of l yields	Few wells in area at present. Water levels more than 200 ft in places.
	Few wells in area at present. Wells several hundred feet deep required for maximum yields.

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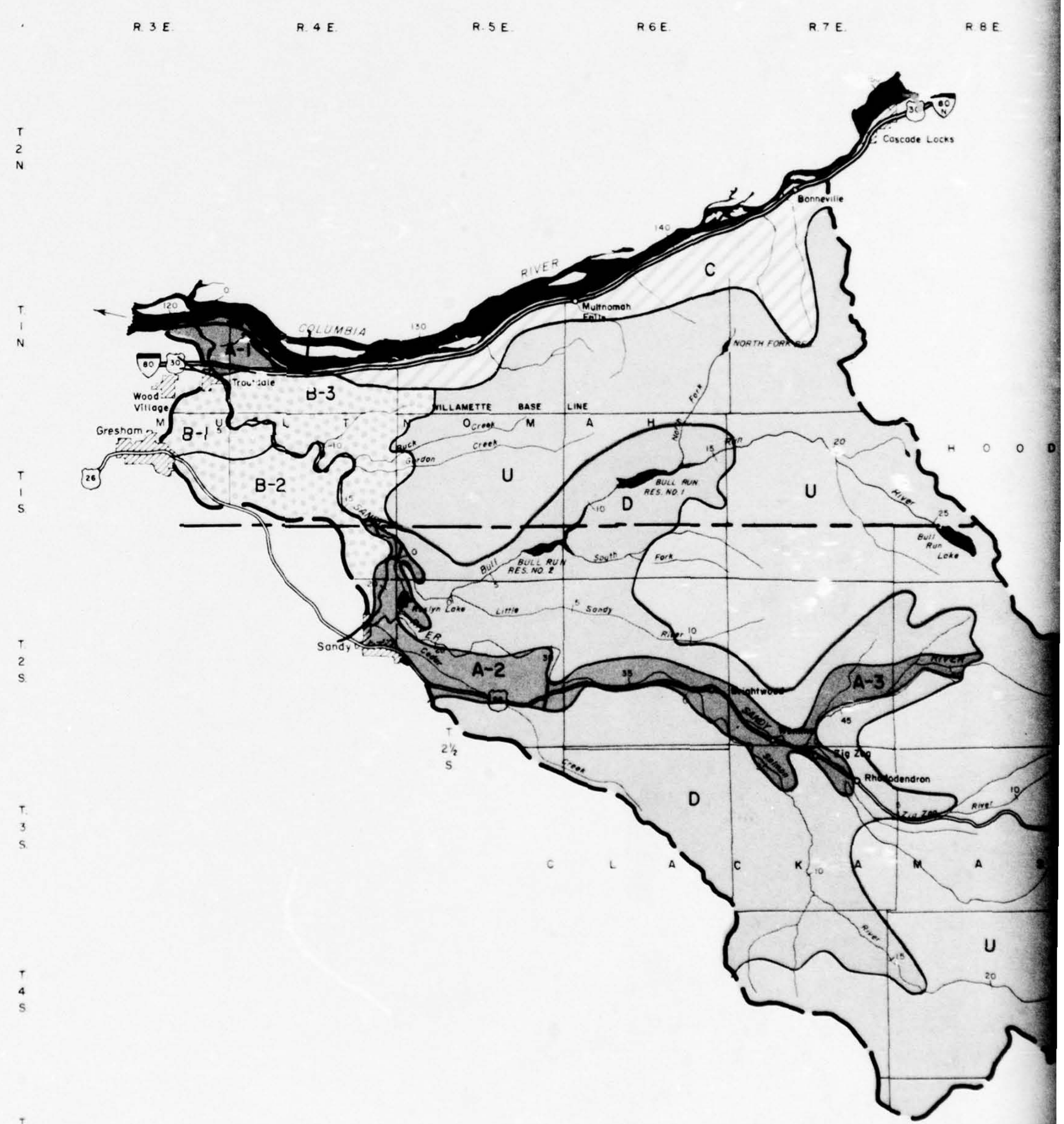
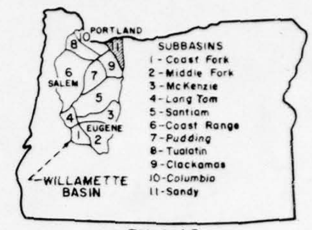
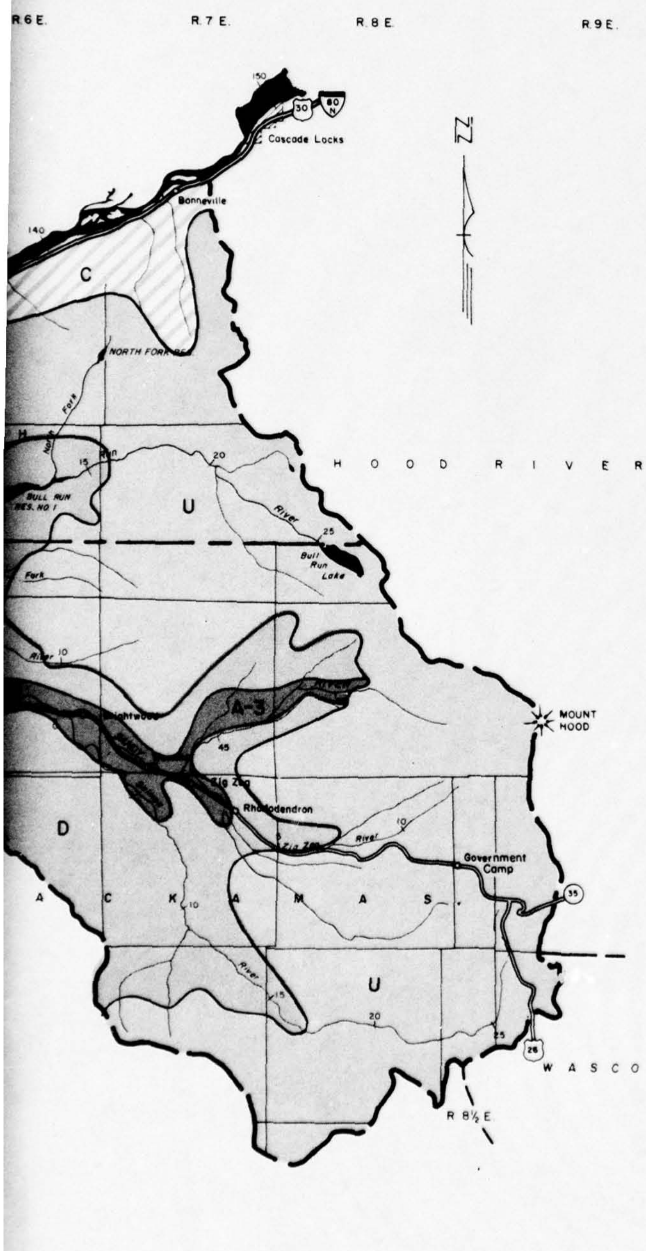




KEY MAP
SHOWING SUBBASINS



EXPLANATION

A-1

Aquifers, alluvium and underlying Troutdale Formation. Yield 500-1,000 gpm

A-2

Aquifer, alluvial sand, gravel, silt, and clay. Yields generally less than 50 gpm

A-3

Aquifer, alluvial gravel and boulders. Yields up to 500 gpm

B-1

Aquifers, Troutdale Formation and locally perched zones in piedmont or terrace deposits. Yield as much as 500 gpm from Troutdale, 5-20 gpm from perched zones

B-2

Aquifers, Troutdale Formation, perched zones in piedmont or terrace deposits. Yield up to 300 gpm from Troutdale, 5-20 gpm from perched zones

B-3

Aquifers, Troutdale Formation, locally piedmont deposits. Yield as much as 100 gpm, 5-20 gpm from perched zones

C

Aquifer, Columbia River Group (not developed). Expectable yields at least 50 gpm

D

Aquifer, Sardine Formation, Columbia River Group, and local alluvial deposits. Yields generally 10-50 gpm

U

Aquifer, young volcanic rocks. Yields at least 200 gpm

MAP IV-15

SANDY SUBBASIN

WILLAMETTE BASIN, OREGON

AVAILABILITY OF GROUND WATER

1968

SCALE IN MILES

CHEMICAL QUALITY OF GROUND WATER

Ground water of good quality is available throughout Willamette Basin. The concentrations of most constituents are within the limits recommended for drinking water by the U. S. Public Health Service (1962). The chemical quality of most ground water is also suitable for industrial and agricultural use. However, excessive concentrations of some dissolved minerals, notably iron and arsenic, occur in places. Saline water occurs in a few wells and springs, principally from bedrock sources.

In this section, water-quality data are presented for the basin as a whole because areal coverage is irregular and information is not sufficient for a description by subbasins. This description is based on the chemical-quality data in a U. S. Geological Survey compilation report (Madison, 1966). Samples were collected primarily for detailed ground-water investigations, mostly in the valley area north of Salem.

Photo IV-6. Water samples are analyzed for their content of mineral constituents.

Ground-water reports that include chemical-quality data have been published for Tualatin Valley (Hart and Newcomb, 1965), East Portland area (Hogenson and Foxworthy, 1965), west-side business district at Portland (Brown, 1963), French Prairie area (Price, 1967b), Eola-Amity Hills area (Price, 1967a), and Willamette Valley (Piper, 1942). Reports are in preparation for the Molalla-Salem Slope area and the lower Santiam Basin.

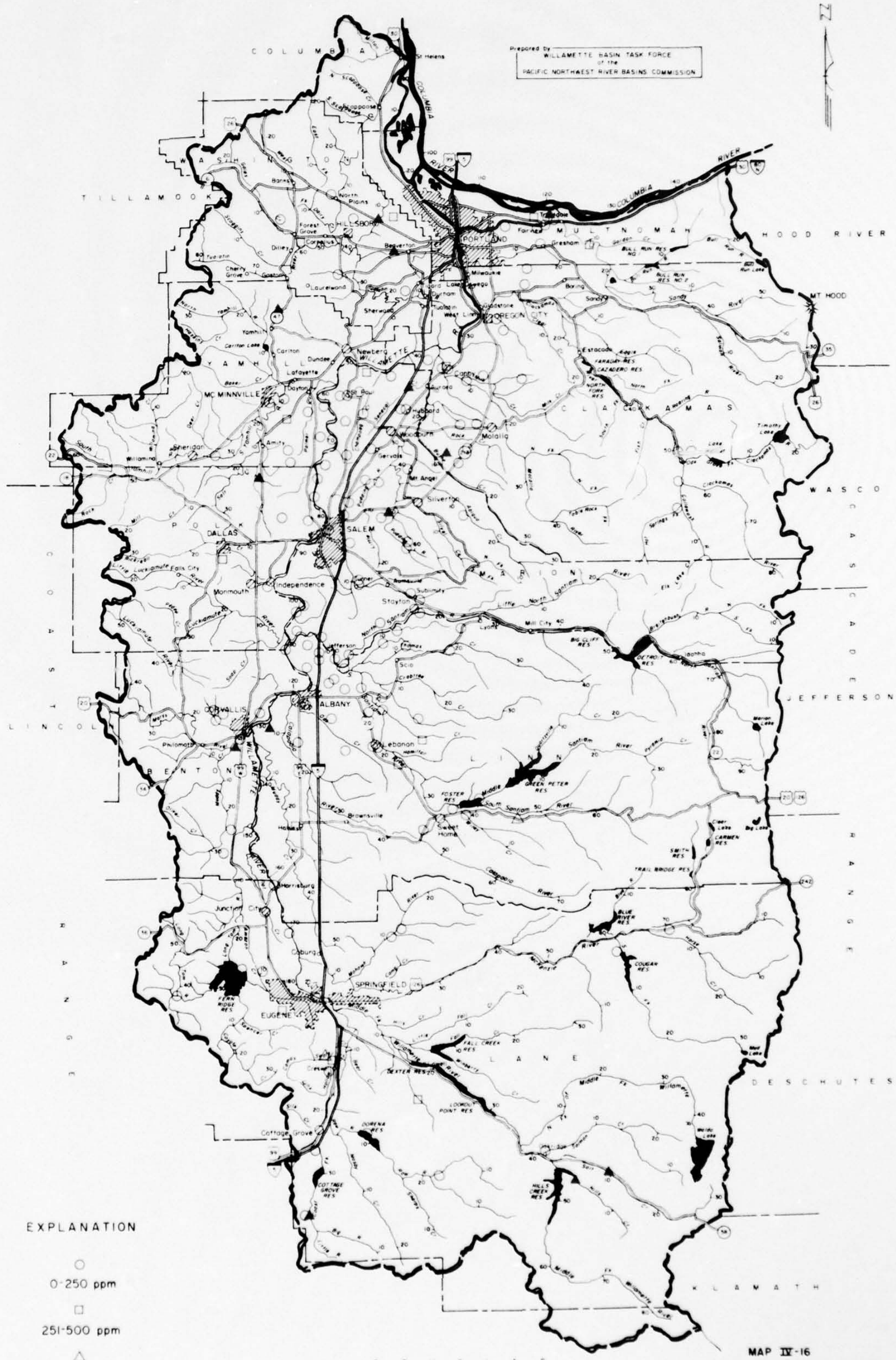
Fresh Water

Fresh water is arbitrarily defined as water having a dissolved-solids content of less than 1,000 ppm. Ninety percent of the ground-water samples analyzed from Willamette Basin fall into the fresh-water category; most of the fresh-water samples have less than 500 ppm. The dissolved solids consist principally of calcium and sodium bicarbonate and silica. Map IV-16 shows the distribution of dissolved-solids content of ground waters throughout the basin.

No single area contains all hard or all soft waters. Wells that yield both types are scattered throughout the basin (Map IV-17). Hardness-of-water values range from two to more than 180 ppm. Ground water in the unconsolidated deposits of Willamette Valley commonly contains from 30 to 160 ppm hardness. Water from the consolidated sedimentary rocks is commonly very hard, containing more than 180 ppm. Hardness in water is caused principally by compounds of calcium and magnesium. Other constituents--iron, manganese, aluminum, barium, strontium, and free-acid--also cause hardness. However, they are not present in the basin in quantities sufficient to have any appreciable effect.

Silica content ranges from 5.7 to 72 ppm. One-third of the samples analyzed had silica values between 40 and 50 ppm (Figure IV-40). Silica in these concentrations is not significant to humans, livestock, or fish, nor is it of importance in irrigation water. However, for industrial use, high-silica content is undesirable in boiler-feed water, contributing to the formation of boiler scale and also forming troublesome deposits on the blades of steam turbines.

Ground water in Willamette Basin contains little fluoride. Analyses show that fluoride contents of all but one of the fresh-water samples analyzed are less than the recommended maximum. Most of the ground water contains less fluoride than the optimum concentration recommended by the U. S. Public Health Service. A concentration of about 1.0 ppm of fluoride in drinking water lessens the incidence of dental cavities in children's teeth, but amounts greater than 1.5 ppm may cause the dental defect known as mottled enamel (Dean, 1943).



EXPLANATION

○ 0-250 ppm

□ 251-500 ppm

△ 501-1000 ppm

▲ More than 1000 ppm

MAP IV-16

WILLAMETTE BASIN STUDY

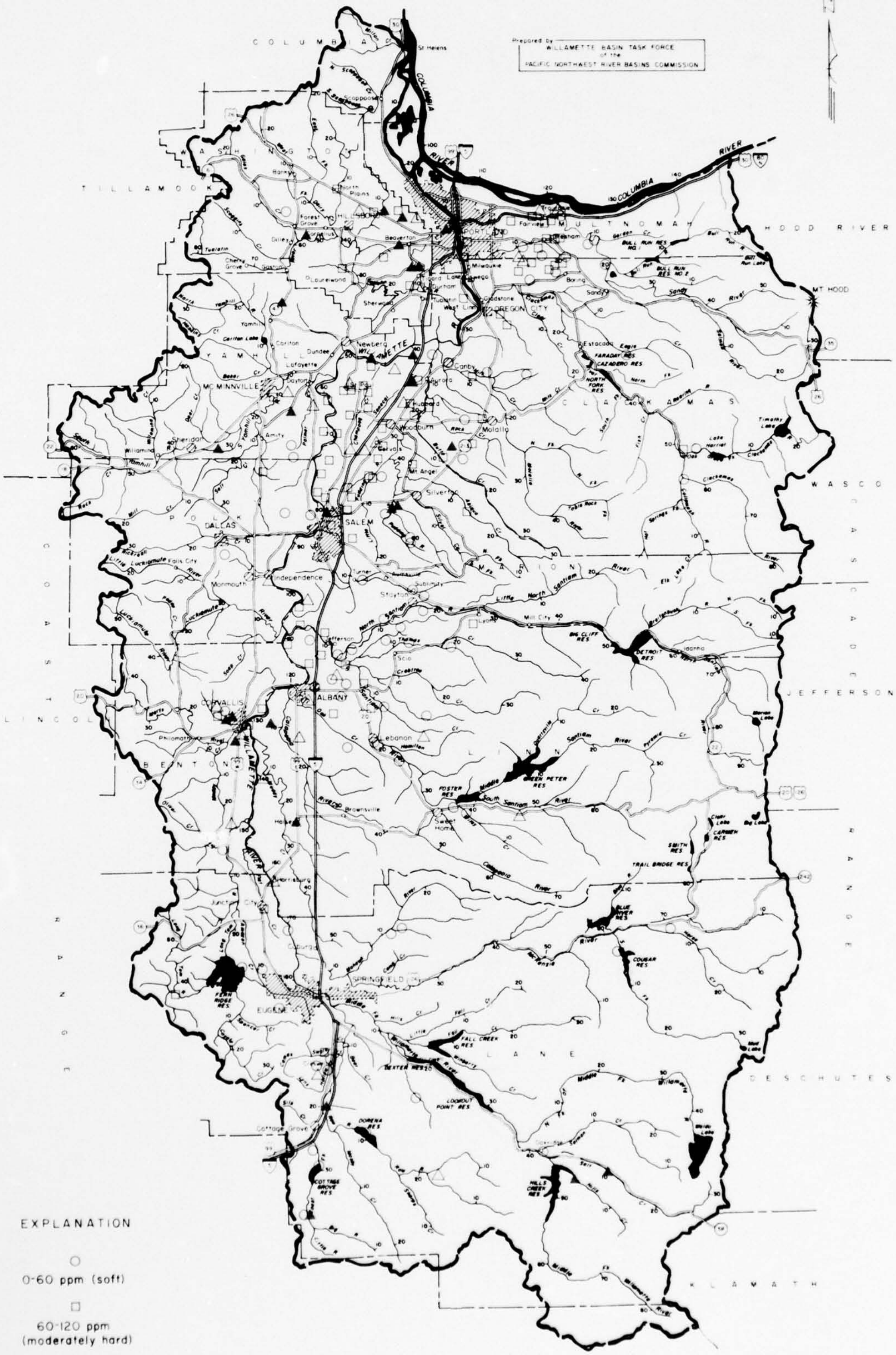
OREGON

DISSOLVED SOLIDS CONTENT IN GROUND WATER

1968

SCALE IN MILES

WBTF-0-1089ac-LL



EXPLANATION

○ 0-60 ppm (soft)

□ 60-120 ppm (moderately hard)

△ 121-180 ppm (hard)

▲ More than 180 ppm (very hard)

MAP IV-17

WILLAMETTE BASIN STUDY

OREGON

HARDNESS OF GROUND WATER

1968

SCALE IN MILES

WBTF-O-1090 oc-L

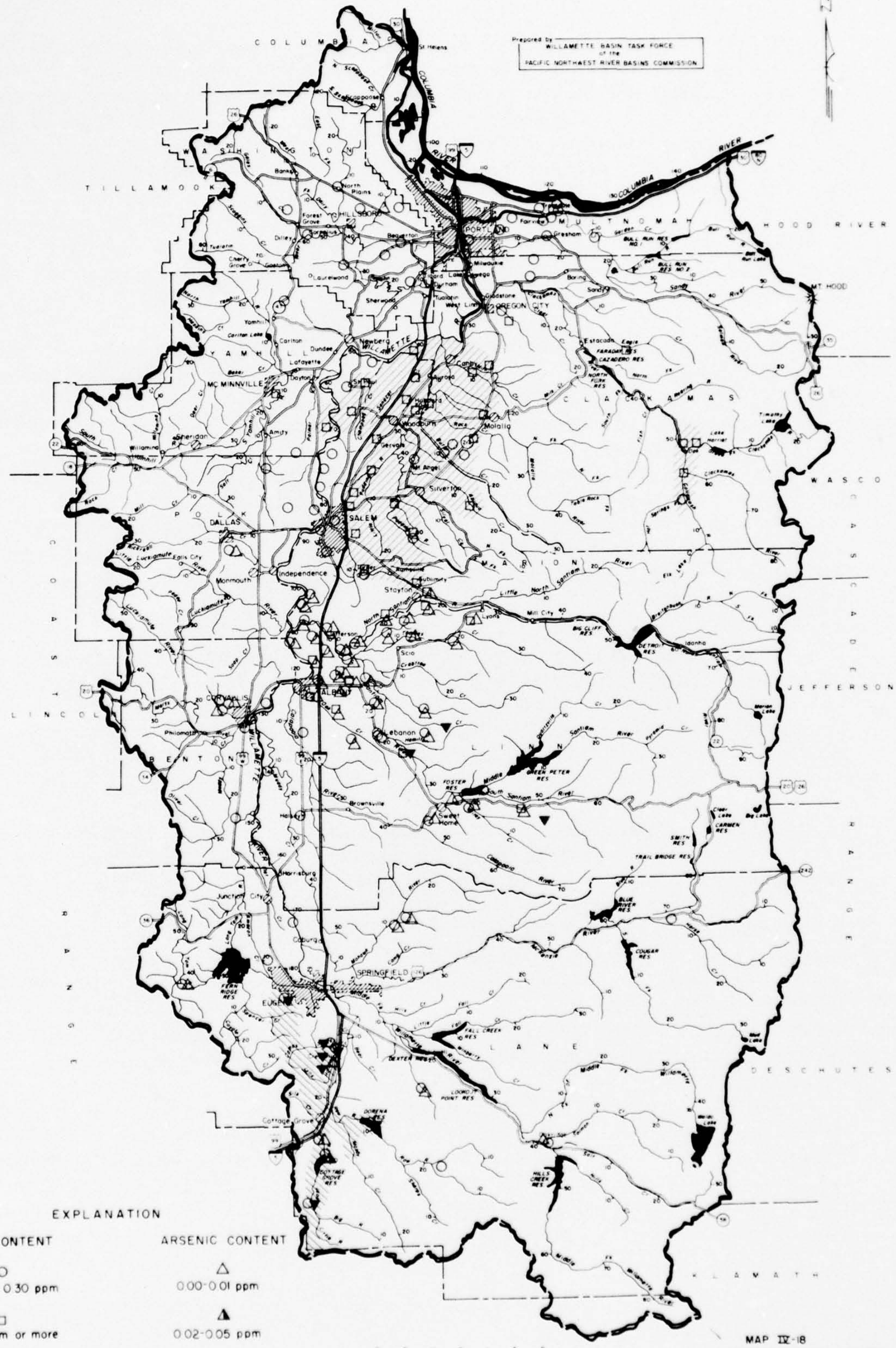
Map IV-18 shows areas in the basin where high concentrations (more than 0.30 ppm) of iron are found. The 0.30 ppm concentration is the maximum recommended for drinking water. Excess iron in water commonly separates out as a reddish-brown sludge when the water is exposed to air and allowed to stand. Iron also imparts a taste to water and may stain cooking utensils and laundered fabrics. Many wells north of Salem yield water that contains iron concentrations higher than 0.30 ppm. Several wells in the vicinity of Portland yield water containing excessive iron. Other areas may have excessive iron concentrations in ground water, but data are not adequate for a more complete areal description.

Arsenic in natural water is rare (Map IV-18), and its occurrence in ground water of Lane County is one of a very few of its kind reported. This unusual occurrence of arsenic in well water was discussed by E. L. Goldblatt and others (1963), who related it to a local geologic unit called the Fisher Formation of Eocene and Oligocene age (included in this presentation in the Little Butte Volcanic Series). The lateral extent of this formation, primarily in central Lane County, marks the principal area where ground water has an excessive arsenic concentration. Few data on arsenic concentrations in other parts of the basin are available, but the problem may be more widespread than has been recognized.

The maximum limit of nitrate content recommended for drinking water is 45 ppm. Willamette Basin has no areas with large concentrations of nitrate in ground water. Where moderate amounts of nitrate are found, the wells are shallow so that the water they tap may be easily contaminated by fertilizers, sewage, or seepage from barnyards. None of the nitrate values reported exceeds the recommended limit.

Orthophosphate occurs in varying amounts in wells throughout the basin. Its source is uncertain, and there is no apparent relation between occurrence or concentration and the aquifer. Weathering of phosphate-bearing rocks releases soluble phosphates in water, but the phosphates tend to be redeposited instead of remaining in solution. Large orthophosphate concentrations are commonly attributed to pollution from sewage containing detergents. Waters that have been treated for hardness removal may also contain added phosphates. Another source of orthophosphate might be from percolation of irrigation water in areas where phosphate fertilizer is used extensively.

The high orthophosphate concentrations found north of Salem generally occur in wells more than 200 feet deep that tap the Troutdale Formation. Available information is insufficient to indicate whether the source of high phosphate is phosphate-bearing rocks in the Troutdale, seepage from volcanic rocks, fertilizer, or detergents in septic-tank effluent.



EXPLANATION

IRON CONTENT	ARSENIC CONTENT
○ Less than 0.30 ppm	△ 0.00-0.01 ppm
□ 0.30 ppm or more	▲ 0.02-0.05 ppm
Area where iron content may exceed 0.35 ppm	▼ More than 0.05 ppm
	Area where high arsenic content may be found

MAP IV-18

WILLAMETTE BASIN STUDY

OREGON

IRON AND ARSENIC IN GROUND WATER

1968

SCALE IN MILES

WBTF-0-1091ac-LL

Saline Water

Willamette Valley is underlain at various depths by bedrock that contains saline water (more than 1,000 ppm of dissolved solids), but available information is not adequate to define the depth zones nor areal occurrence of saline water in the basin. In some areas, saline water has migrated upward into younger rocks so that water in them is brackish or saline. Saline water is reported in wells in Portland, in parts of Tualatin Valley, in Willamette Valley north of Salem, and at Gladstone. In addition, some springs discharge saline water from bedrock in several areas in the basin.

Analyses of saline-water samples show that the waters are chemically unfit for many uses. The water is predominantly of the sodium and calcium chloride type and is highly mineralized. Dissolved-solids content as high as 18,500 ppm has been found in Washington County. Hardness values range from 106 to 11,700 ppm. Fluoride concentration is low (less than 0.8 ppm) except for two springs in Lane County that have 2.8 and 3.4 ppm of flouride. Silica values range from 12 to 68 ppm.

Suitability for Use

On the basis of drinking water standards recommended by the U. S. Public Health Service, water with less than 500 ppm of dissolved solids is suitable for domestic uses. Water in the 500 to 1,000 ppm range can be used for drinking, but may have an objectionable taste. Except for water with excessive arsenic, most ground water in Willamette Basin is suitable for drinking. Recommended limits for several constituents in drinking water are given in Table IV-16; the recommended fluoride limits are influenced by air temperature, and are given in Table IV-17.
IV-16; the recommended fluoride limits are influenced by air temperature, and are given in Table IV-17.

Most ground water in the basin is of excellent quality for irrigation, according to the rating method of the U. S. Salinity Laboratory Staff (1954, p. 80). Mineralized ground water from bedrock zones may be too saline for irrigation use.

Most ground water in the basin can be used for industrial purposes without preliminary treatment, except for industries that require a low silica concentration. Tolerance for dissolved-mineral concentration in water varies with each industrial use. The quality of the water at a specific site should, therefore, be checked before water is used for a specific industrial purpose.

Table IV-16

Recommended limits for several constituents in drinking water

Constituent or Property	Recommended Concentration Limits (parts per million)
Arsenic (As)	0.01
Iron (Fe)	0.30
Sulfate (SO_4)	250
Chloride (Cl)	250
Nitrate (NO_3)	45
Dissolved solids	500

Source: U. S. Public Health Service

Table IV-17

Recommended fluoride limits for drinking water

Annual Average of Maximum Daily Air Temperatures (°F) 1/	Recommended Fluoride Limits (ppm) 2/		
	Lower Limit	Optimum	Upper Limit
50.0-53.7	0.9	1.2	1.7
53.8-58.3	0.8	1.1	1.5
58.4-63.8	0.8	1.0	1.3
63.9-70.6	0.7	0.9	1.2
70.7-79.2	0.7	0.8	1.0
79.3-90.5	0.6	0.7	0.8

1/ *Should be based on more than five years of record.*

2/ *Average concentrations greater than two times the optimum values constitute grounds for rejection of the drinking-water supply.*

Source: U. S. Public Health Service

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

In previous sections, water is discussed according to its occurrence as either ground water or surface water, because its availability from one environment or the other has an important bearing on development plans. However, because water infiltrates the land surface rather readily, there is actually a continual interchange between water on the surface and underground. In some places ground water is discharged continuously into streams, in other places streams lose water to the ground-water body, and in still others streams may either lose or gain water at different times (see Figure IV-40).

Interchange between surface and ground water occurs commonly in topographically low places where the water table intersects the land surface. In those places, lakes and marshes or springs may be surface manifestations of the water table, and the level of these water bodies fluctuates with the adjacent water table. Streams in alluvial valleys, such as the Willamette, are also direct local extensions of the water table, which fluctuates in response to changes in stream stage.

Part of the precipitation that seeps into the ground moves laterally through the rocks and is discharged into streams within a short distance of the point of infiltration. Nearly all rocks transmit some water to streams in this way. The amount of water transmitted depends on many factors, one of the most important being the ability of the aquifer to receive recharge. A large part of the ground-water discharge in an area is into the streams. During dry-weather periods this discharging ground water is the base flow of streams.

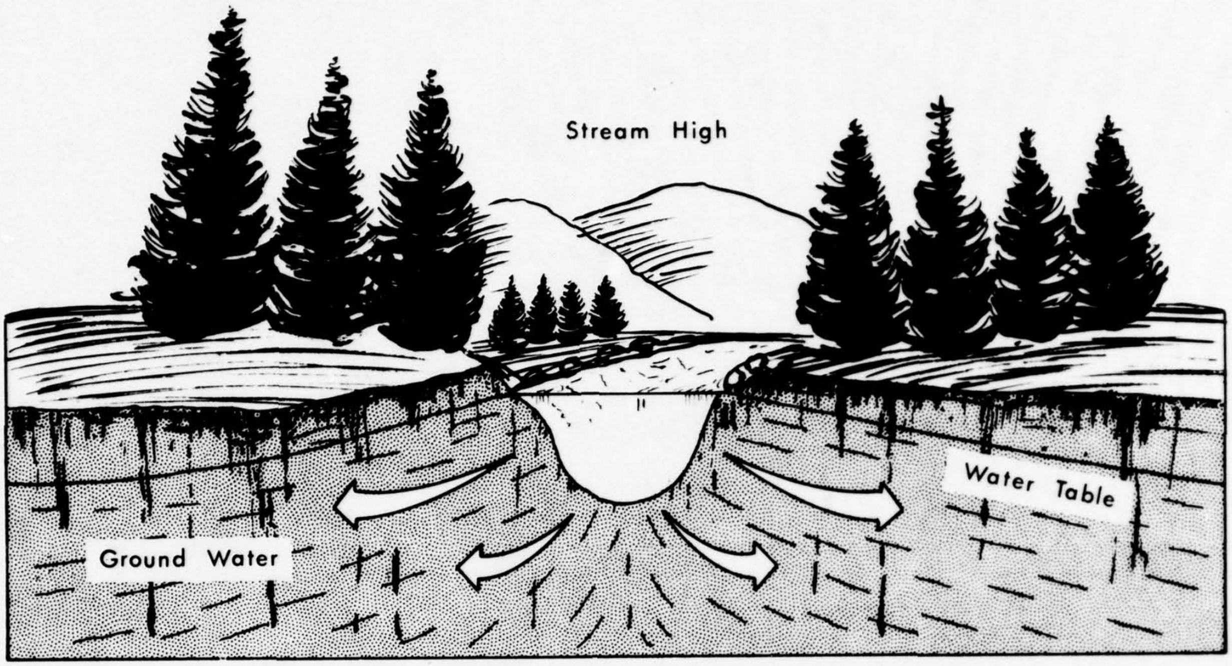
The interrelations between the surface- and ground-water bodies represent a system that, over a long period of time, establishes a regimen related to climatic conditions. Changes that alter the system require adjustments to establish a new regimen. Some of the probable changes and their effects are:

1. Pumping of ground water near streams may deplete the streamflow.

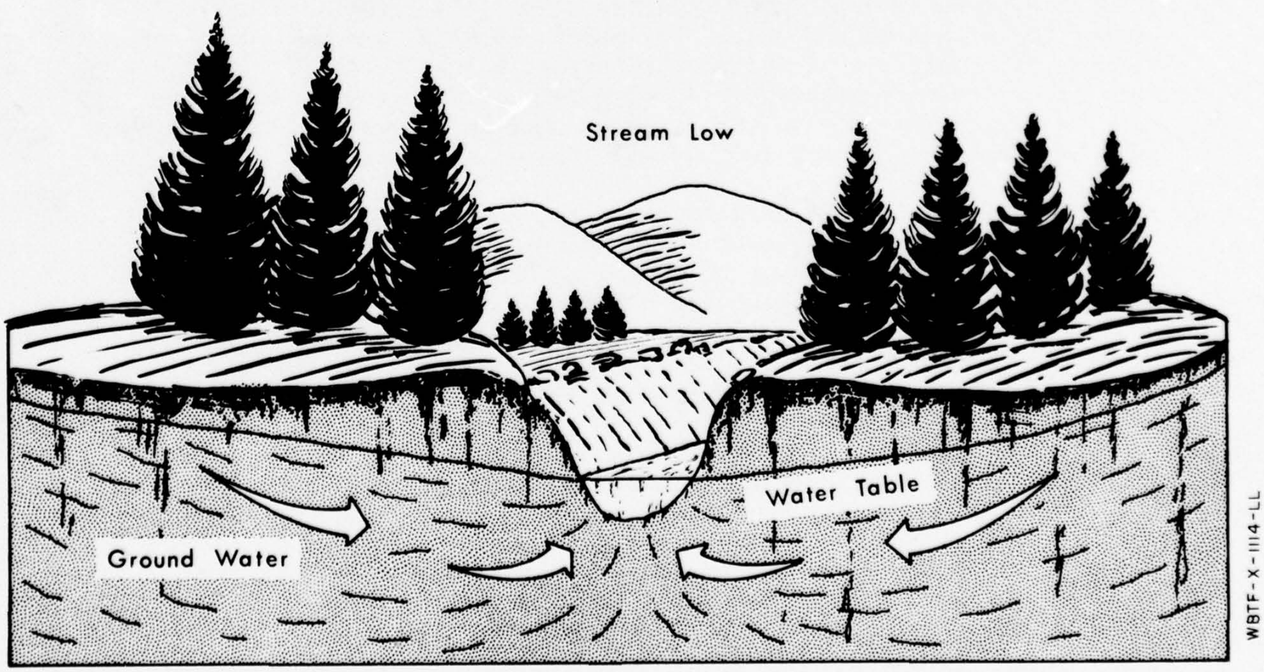
2. Ground-water reservoir storage might be manipulated, by artificial recharge, to increase water supplies in summer.

3. Irrigation with water from surface-water reservoirs may raise the water table and increase ground-water seepage to streams. When the water table is raised, ground-water storage capacity is reduced and increased runoff from precipitation results; evapotranspiration also is increased.

4. Loss of water from unlined canals may create new wet lands, build up the water table, and cause increased seepage of ground water to streams and increased discharge by evapotranspiration.



A--Stream level higher than water table--stream water seeps into adjacent ground water body



B.--Stream level lower than water table--ground water seeps into stream channel

Figure IV-40. Relation of ground water and surface water.

5. Drainage of marshes and wet lands may lower the adjacent water table, reduce the amount of ground-water seepage to streams, and reduce evapotranspiration.

6. An increase in the minimum summer flow (and stage) of streams may hold the water table at higher levels during summer and decrease the volume of ground water draining to the streams.

7. Flood-control regulation that lowers the flood stage of tributaries in the autumn may delay the rise of the water table beneath the flood plains in the winter by reducing early-winter recharge from floodflows.

MOUNTAIN AREAS

In large areas of the Cascade and Coast Ranges, streams commonly flow in V-shaped canyons deeply entrenched below the local water table. In these areas, ground water is discharged into streams almost continuously, but that discharge may be masked by the large volume of overland runoff during periods of high flow. The base flow in an area is directly related to the ability of the local rocks to infiltrate, store, and transmit water. Base flow for Coast Range streams is small--generally less than 0.2 cfs per square mile--because the marine and older volcanic rocks have both low porosity and permeability. In contrast, streams that drain young volcanic rocks in the High Cascades have large base flows--from 0.5 to 2.0 cfs per square mile.

In the High Cascades, the surface water-ground water relations around the lakes and marshes differ markedly from those in the deeply incised streams of the Western Cascades. The water table in the permeable volcanic rocks lies several hundred feet below land surface, and the lakes, marshes, and wet lands are perched upon the surface. Many lakes have no surface outlets, their excess water draining through the porous lava and into streams at lower altitudes perhaps many miles away. Some streams lose or gain sizable quantities of water locally where they cross permeable zones in the lava. For instance, at times McKenzie River loses all the flow in its channel just upstream from Tamolitch Falls, but the flow reappears at the base of the falls where the channel intersects the permeable zone in the lava (see Figure IV-10). When more detailed streamflow records become available for small streams in the High Cascades, the interchange of water between the young lavas and the local streams will be better understood.

VALLEY AREAS

The unconsolidated alluvial materials along the flood plains in the valleys generally have a water table connected directly with surface-water bodies. The water table is slightly above the level of water in the streams and at the same level as the water in sloughs and ponds. The many oxbow lakes and sloughs along the flood plains of Willamette, Long Tom, and Calapooia Rivers, and the marshes along both Muddy Creeks and Willamette River represent such local extensions of the water table.

In most parts of Willamette Valley, the water table slopes toward the streams, with ground-water seepage adding to the streamflow (Piper, 1942, p. 34-40; Price, 1967b). The annual ground-water contribution to the flow of Pudding River and of Willamette River between Salem and McMinnville is more than 500 acre-feet per square mile. At that rate, the annual seepage in the 400-square-mile northern Willamette Valley lowland would be more than 200,000 acre-feet. Streams in the southern part of Willamette Valley appear to gain less flow from ground water than those in the north.

Where the ground-water reservoir discharges into streams, pumping water from the ground can lower the water table enough to reduce seepage into the streams. If pumping is heavy, the water table may be lowered so far that the natural gradient is reversed and the streams lose water. In either case, depletion of streamflow results (Figure IV-40). In contrast, the application of large amounts of irrigation water imported to the local alluvial area can build up the water table and increase the rate of seepage into streams.

Although most streams in the valley gain water by seepage of ground water, some lose flow where they cross alluvial fans at the edges of the foothills. This phenomenon has been noted during low flows in Silver and Abiqua Creeks near Silverton, in Long Tom River and Coyote Creek near Fern Ridge Reservoir, and in South Santiam River near Lebanon; also, it probably occurs elsewhere. Many streams may lose water in this way during high-water periods, particularly during the first high-water stages in the fall when the water table is still relatively low.

BANK STORAGE

"Bank storage" refers to the water that seeps into streambanks during high stages and seeps out again as the water surface declines. Bank storage effects are well illustrated in downtown Portland, where for many years the water level in a well located three-tenths of a mile east of Willamette River fluctuated with the river stage (Brown, 1963, p. 8, pl. 2). Several hundred acre-feet of water may be cycling through bank storage along each mile of Willamette River (Newcomb and Brown, 1961). Much of this water remains in the banks for only a short time, draining out as soon as the flood stage has passed. This effect is probably confined largely to the flood plains of the Willamette and its principal tributaries and is not a significant source of replenishment to the principal aquifers.

MANAGEMENT PROGRAMS

The total quantity of water naturally available in the basin is ultimately controlled by the precipitation. The amount of water available thus varies considerably from place to place and from time to time. It has been found necessary to redirect the natural supply of water by storage and artificial recharge, so that it may be available in greater quantity or better quality. Other practices, resulting from modern technological advances, hold promise as effective management tools for attacking future water-resource problems in certain situations.

STORAGE

Storage generally refers to water held either naturally or by artificial works. The combined hydrologic effects of natural storage--glaciers, snowpack, natural lakes, and water in channel storage--are integrated in the streamflow and described in detail in a previous section. Therefore, the following discussion is limited to storage in manmade lakes and reservoirs. In the basin, manmade reservoirs range from small farm ponds to major multipurpose reservoirs, such as Ferr Ridge and Detroit.

In 1964, there were more than 3,000 farm ponds and small reservoirs in the basin (Census of Agriculture). The ponds range in size from 1 to 10 acres and are used primarily for stock-water supplies, and the small reservoirs are used primarily for local water supplies and

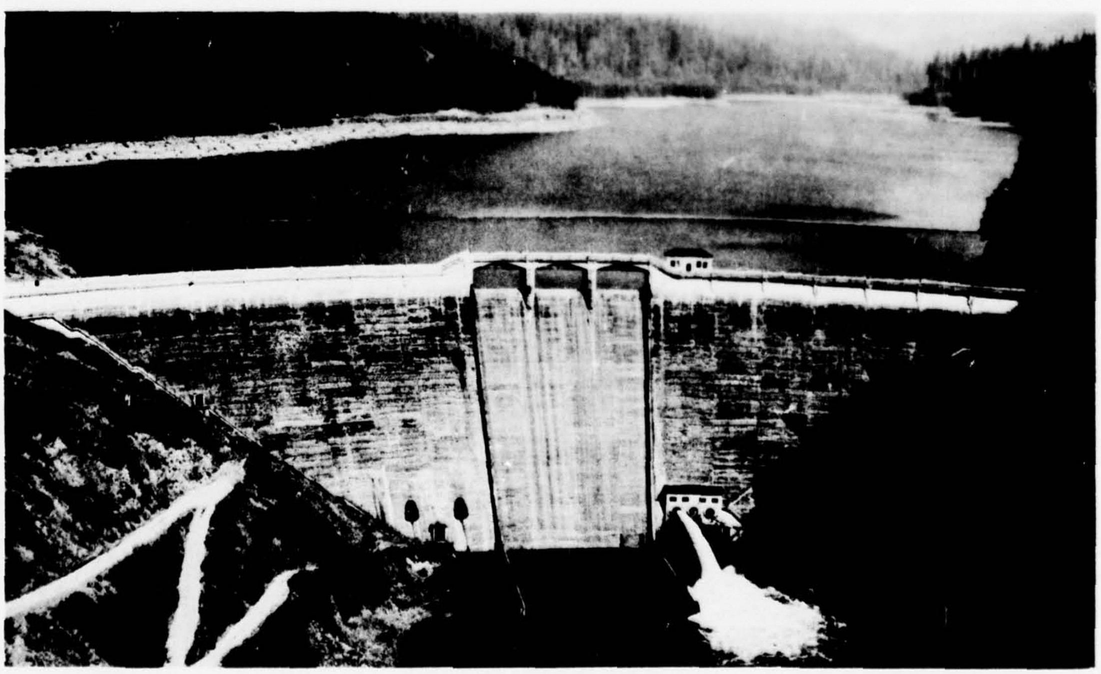


Photo IV-7. Lake Ben Morrow on Bull Run River stores water for Portland's municipal supply.

irrigation. Both serve to modify streamflows. As of 1968, there were 11 major multiple-purpose reservoir projects and 28 single-purpose reservoir projects in the basin with 300 acre-feet or more of usable capacity. Pertinent information concerning the larger reservoirs in the basin is shown in Table I-1.

Many problems of regulation result from multiple uses in a storage project. High runoff occurs principally from November through March. The reservoirs should be held low to regulate floods during that time. In the spring, the same storage space can be filled for conservation uses during the low-water season. To serve the various needs, careful planning and operation of the storage project is required. Sometimes a conflict of interest can be removed by adding another project to provide other benefits.

Filling the storage space reserved for flood regulation starts about the first of February. By the end of May, in a normal year, the Willamette reservoirs are filled to their maximum capacities. The use of this stored water can then be allotted to the various authorized multipurpose uses for the coming season. Water stored in power projects, in excess of the amounts required to maintain minimum flows downstream, can be retained in storage until the Northwest hydro system requires the water for generation--normally in September. To facilitate power generation and still serve the authorized navigation function, the nonpower reservoirs are drawn down first, which adversely affects their use for recreation activities.

Possible changes in reservoir operation plus potential future development to serve all water users result from this investigation--the Willamette Basin Comprehensive Study.

SUPPRESSION OF NATURAL LOSSES

Approximately 25 percent of the precipitation that falls on Willamette Basin is consumed by uses of man and by natural processes, such as evapotranspiration and evaporation from lakes and streams. Some of the natural processes are nonbeneficial and result in losses of usable water.

Nonbeneficial Consumptive Uses

Usable water supplies can be increased through reduction of nonbeneficial consumptive use by phreatophytes (water-loving plants) such as willows. These plants, covering about one percent of the basin, grow where the water table is shallow--in swamps, along streams, and around reservoirs. Phreatophytes consume 50 to 100 percent more water than do agricultural crops. Some of the methods available for control or eradication of these plants are mechanical or hand cutting, burning and plowing, and chemical clearing. The reduction of losses would not appreciably increase the total water supply of Willamette Basin, but controlling phreatophytes where water is in short supply might be justified locally.

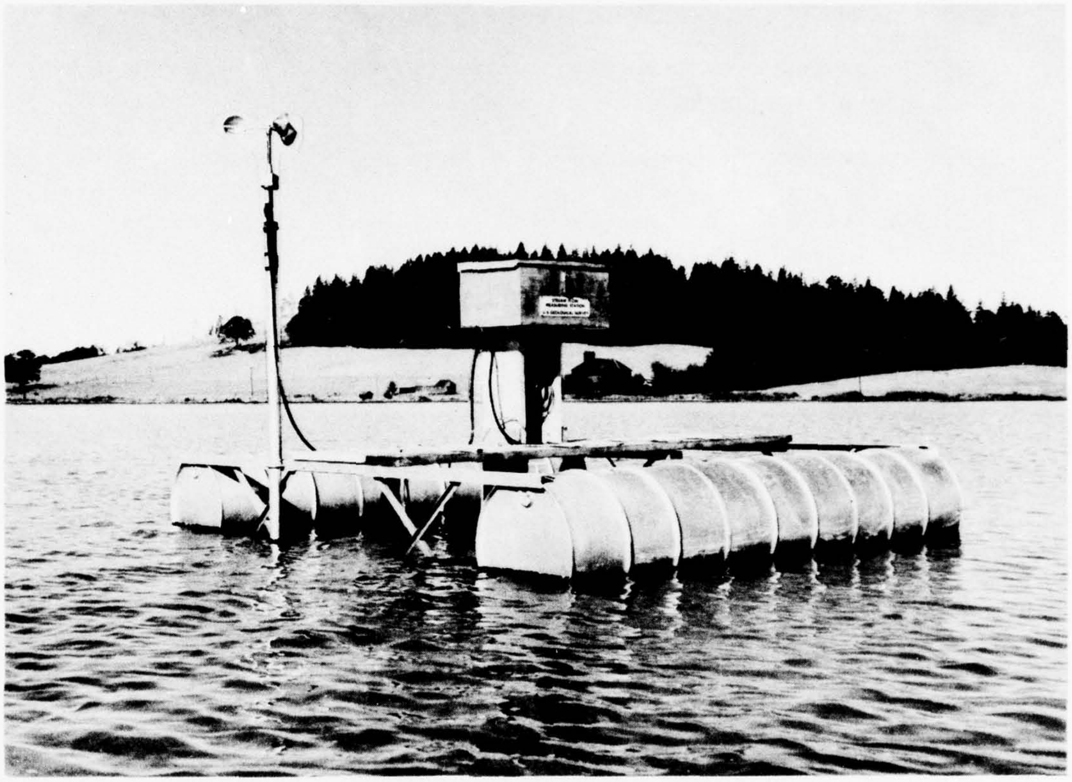


Photo IV-8. Instruments measure wind velocity, temperature, and other factors that affect the rate of evaporation from a reservoir.

Lake and Reservoir Evaporation Losses

The evaporation loss at existing reservoirs in the basin averages about 30 inches during May through October--the period when losses could probably be reduced most effectively. Although the evaporation losses are not large in proportion to total basin runoff, the loss may be a significant part of the firm water supply developed by reservoir storage. For example, May-October evaporation losses at Fern Ridge Reservoir exceed reservoir inflow by as much as 20,000 acre-feet or even more. The total surface area of reservoirs, lakes, and ponds is approximately 85 square miles, or 0.7 percent of the basin.

There are many means of reducing reservoir evaporation losses. Methods, limited to physical and economic justification, which should be considered in the planning stage of storage development are:

1. Selecting storage sites with relatively small ratios of surface area to volume.

2. Storing water in ground-water reservoirs.

3. Constructing carryover-storage reservoirs at the highest available elevation.

Methods to reduce evaporation after reservoir construction include:

1. Improving existing or potential reservoirs by reduction of surface area (diking).

2. Protecting reservoir surfaces with windbreaks.

3. Covering the reservoirs with fixed or floating covers or roofs.

4. Using surface films (monomolecular films) on reservoir surfaces.

The use of monomolecular films shows the greatest promise because it does not call for a large investment in structures or extensive installation. It has the added advantage of not interfering with other uses of the reservoir, such as recreation and navigation. Field experiments indicate that presently developed methods can reduce evaporation 10 to 30 percent at costs of from $35 to $90 per acre-foot of water saved. With continuing experimentation and study, methods may be improved and costs reduced. Reduction of evaporation might be considered as a future water-saving possibility for Willamette Basin reservoirs.

WEATHER MODIFICATION

Weather modification covers a broad range of activities in various stages of research and development. These activities include:

1. Dispersion of supercooled fogs which has already been tested in pilot studies.

2. Cloud seeding of moist airmasses as they are lifted by mountain ranges, a technique that appears to produce at least modest increases in winter snowfall.

3. Suppression of hail, a field in which a national program of research and development is now being planned.

4. Attempts to modify hurricanes, the feasibility of which has not yet been demonstrated.

5. Attempts to increase precipitation from summer showers and thunderstorms, which seem to offer some promise of success.

6. Attempts to influence the paths of storms to help alleviate drought, the feasibility of which may require a decade or more to determine.

7. Determination of the extent of inadvertent modification by the emission of fossil-fuel gases into the atmosphere.

Weather modification could have a profound effect on Willamette Basin if cloud seeding were used to stimulate rainfall over agricultural areas that are short of water during critical times in the summer. The increased yield of crops would undoubtedly offset the cost of cloud seeding. Modification of the weather during periods of high snow and rainfall could prevent or greatly reduce ravaging floods such as those in December 1964 and January 1965. However, several years of intensive investigation are needed before cloud-seeding techniques can be accurately evaluated.

In fiscal year 1965, there was an experimental weather-modification project in the basin to use cloud seeding for obtaining economic or operational benefits, but results of these experiments are not yet available.

ARTIFICIAL RECHARGE

Artificial recharge is the deliberate addition of water to a ground-water reservoir (aquifer) in order to conserve or regulate quantity, quality, and temperature of the available ground-water supply. Direct artificial recharge is accomplished either by surface spreading or by subsurface injection. Surface spreading consists of diverting water over permeable material or into pits or basins dug into permeable material. Subsurface injection is the addition of water directly into a ground-water reservoir through shafts or wells. Artificial recharge is not a technique for increasing the total water supply, but it can be used to make more water available at more convenient times and places.

In surface spreading, most ponds will require periodic cleaning to remove the trapped sediment. When recharge wells are used, the aquifer near the well may be clogged with sediment, air, or by chemical or bacterial action (Price and others, 1965; Sniegocki, 1963; Foxworthy and Bryant, 1967).

Problems may result from recharging with water different in chemical quality or temperature from the water occurring naturally in the aquifer. Water of different chemical quality may cause the precipatation of solids from the water, cause volume changes in the clays, or adversely affect the suitability of the water for certain uses. Changes in water temperature can affect the use of the water, particularly if it is withdrawn for heating or cooling.

Criteria for several factors must be satisfied for an artificial-recharge operation to be successful. It must be possible to add a usable quantity of water to an underground reservoir and to recover a substantial part of it for use. Artificial recharge also must be a more economical and perhaps a more easily managed solution to the local water-supply problem than other possible solutions. Generally, if recharge is to be by injection, the water must be free of sediment and air, chemically compatible with the water in the aquifer, and should be chlorinated to prevent the growth of nuisance bacteria.

After the system is designed, it should be operated on a trial basis to test its feasibility and its effect on the local hydrologic system.

In Willamette Basin, artificial recharge is practiced at Springfield and in downtown and northeast Portland. At Springfield, water from Willamette River is pumped into recharge wells during the summer to supplement natural infiltration from the river to the well field. In downtown Portland, several buildings are air conditioned by two- or three-well systems in which water is pumped from one well through the system and discharged into another well; in most installations, the water is pumped from a deep basalt aquifer and discharged into a shallower gravel aquifer. In northeast Portland, ground water used to cure concrete is returned to a gravel aquifer through the same well from which it is pumped; also, a large part of the precipitation falling on the concrete plant collects in a sump and drains into the well.

To be suitable for artificial recharge, an aquifer must rapidly transmit the recharged water away from the injection site. Suitable aquifer materials generally are: gravel; sand and gravel; vesicular or scoriaceous volcanic rocks; and cavernous, highly jointed, or fragmented rocks. In Willamette Basin, the most suitable rocks for artificial recharge are: volcanic rocks of the Columbia River Group, young volcanic rocks of the High Cascades, sand and gravel of the Troutdale Formation, terrace alluvium, and the young alluvial deposits.

If the aquifer is separated from the surface by impermeable zones, as is the Troutdale Formation and basalt of the Columbia River Group at many places in Willamette Basin, then the only feasible artificial-recharge technique is through injection wells. Spreading methods can be used where the water-bearing zones have a direct hydraulic connection with the surface. However, the areas where spreading might be feasible are also areas in alluvial valleys where natural recharge fully replenishes the aquifer each winter. Therefore, artificial recharge is likely to be used as a management tool for only the deeper lying aquifers in the basin.

APPLICATIONS OF NUCLEAR EXPLOSIVES

Nuclear explosives may be used to modify the natural environment in which water occurs, either to create storage space for water on or beneath the land surface, to modify the openings in rocks to increase the ease and rate at which ground water moves, or to modify the channels in which water flows over the land surface. Piper and Stead (1965) list three limitations that must be satisfied--(1) a maximum of useful work must be accomplished at minimum cost; (2) blast effects, ground shock, and prompt radiations must be tolerable in inhabited areas involved; and (3) radioactive products must not be dispersed promiscuously.

Because water is readily available at most places in Willamette Basin and the limitations for nuclear detonations severely restrict their use, explosive nuclear energy does not seem to be a useful tool for development of water in this area at the present time. It might have some future application to the development of ground water for specialized installations in the areas of dense rocks of the Coast Range, but even there conventional surface storage will likely be a more feasible solution to water-supply problems.

REUSE

The reuse of water in regions with highly developed economics is inevitable because man eventually will appropriate and use all the water available. Both ground and surface water will be used many times as they move through the hydrologic cycle. As the need for water increases and the ready supply becomes progressively less, the recycling of supplies will become necessary, especially for large water users. These users also will be required to restore the water to a level of quality suitable for further use before discharging it. The time has passed when the utilitarian value of water could be partly or totally destroyed by a single use.

Considerable progress has been made in the conservation and restoration of water so that it may be reused. In the past, water withdrawn from a stream for cooling purposes was used only once, then returned at appreciably higher temperatures; the closed-system heat exchangers now in use require only makeup water for evaporation losses and do not discharge the waste heat to a stream. The pulp and paper industry, the major Willamette Basin water user, has reduced its water requirements by using each gallon three times before discharging it. The food-processing industry uses each gallon an average of 1.2 times. Most other industrial and processing plants now route water through various operations in order of decreasing quality requirements.

Total reuse of Willamette River water is not necessary at this time. In-channel water uses include power generation, recreation, fishery, wildlife, transportation, and residual-waste assimilation. Uses for withdrawn water include domestic, municipal, industrial, irrigation, and mining; the quantities of return flow differ for each.

The in-channel water uses generally do not harm the quality of the water, except that used to assimilate residual wastes. The reuse of water returned to a stream after municipal or industrial use is facilitated by the capacity of the stream to break down and assimilate the residual wastes. The time required for the stream to recover its quality level depends on the quantity and concentration of the wastes, and on the volume, velocity, temperature, and dissolved-oxygen content of the stream.

The amount of water withdrawn from a stream or well by municipalities and industries varies throughout the year, and return flows may be as low as 30 percent during dry periods. About 80 percent of the water withdrawn annually by municipalities is returned via its sanitary sewer system to the stream.

Tertiary (complete) sewage treatment makes possible the immediate reuse of municipal and industrial waste water. Recycling of water through a municipal water system has rarely been necessary in the United States. Reuse to this extreme has not been necessary in Willamette Basin and probably never will be; however, to treat increasing quantities of residual wastes, increased reuse of the water will be necessary. This reuse will make the adequate treatment of wastes more important so that the stream environment will be suitable for assimilation and self-purification.

DESALINATION

In recent years, the desalination of water has been widely heralded as the solution to water-supply problems in coastal areas or in interior areas where the only unused water is mineralized. Several workable methods of desalination that have been developed are: (1) distillation using fuel, (2) distillation with solar energy, (3) membrane processes, (4) freezing, and (5) other chemical, electrical, or physical methods. Desalination plants are not likely to be a solution to water-supply problems in the Willamette Basin in the foreseeable future, if ever.

FOREST WATERSHED MANAGEMENT

The management practices on forest land within Willamette Basin may have an influence on hydrology or contribute to the technical hydrologic knowledge of the basin. Upper Clackamas River has been selected as a "barometer" watershed, one that will provide a basis for determining the effect of management practices on hydrology. Information from this watershed will be applied to other watersheds to improve water quality, quantity, timing of runoff, and other hydrologic aspects. One of the objectives of forest management is to protect, restore, and improve the hydrologic capacity of the lands. This includes practices of (1) increasing storage of soil moisture, (2) reducing overland flow of water and erosion, (3) protecting, restoring, and improving natural stream channels, and (4) manipulating vegetative cover to protect and improve the water yield.

The future management of forest watersheds in the basin can appreciably improve their hydrologic condition. Water quantity, quality, and the timing of runoff may be altered favorably by (1) the modification and alteration of vegetation--including scientifically designed timber-cutting units, species-composition changes, and phreatophyte removal; (2) the use of artificial and natural barriers to modify snow accumulation and melt; (3) the modification of evaporation and transpiration losses by vegetative manipulation, snow barriers, induced avalanches, and evaporative suppressants; and (4) the use of dark materials strewn on glaciers and late-season snowdrifts to induce melting to supplement low flows.

WATER RIGHTS AND LEGAL RESTRICTIONS

Legal regulation of water-resources development is accomplished in Oregon through a system of water rights, by legislative withdrawals, by Oregon State Engineer orders, and by programs of the State Water Resources Board. All water rights, to both surface and ground water, are based on the doctrines of prior appropriation and beneficial use. Under the doctrine of appropriation, the "first in time is the first in right" to the extent of the quantity of water that is applied to beneficial use. Water rights are administered by the office of the State Engineer, but because surface-water and ground-water rights stem from different legislative acts, they are presented separately in the following discussion.

Generally speaking, the use of water for domestic, municipal, irrigation, and industrial purposes is considered to be consumptive use. Use for power, mining, recreation, fish life and wildlife, and pollution abatement is considered to be nonconsumptive. In Willamette Valley, 1/80 cfs (5.6 gpm) is, under ordinary conditions, considered to be sufficient to irrigate one acre. For a single family, 1/100 cfs (4.5 gpm) is considered to be sufficient for domestic needs.

SURFACE-WATER RIGHTS

Oregon Water Laws--the code for regulating surface-water rights--were enacted by the State Legislature on February 24, 1909. These laws provide that "all water within the State from all sources of water supply belong to the public." The law states that nothing in the code can be construed to take away or impair the vested right of any person to the use of surface water that was initiated prior to passage of the act.

Before the water code was enacted, water could be appropriated by any prospective user for beneficial use. Such appropriation created a vested right to the extent that water was actually applied to beneficial use; however, the vested right was considered abandoned if water were not used for a continuous period of one, two, or ten years, depending on the particular facts involved.

A claim to a vested right, based on a showing of use prior to February 24, 1909, and continued use thereafter can be determined and made a matter of record only through the legal process of adjudication. Adjudication involves several administrative steps by the office of the State Engineer and is completed by court decree. Without such proceedings, the value of most rights, both early and late, remains in doubt.

Final adjudication has been completed for only eight streams in Willamette Basin, as shown in Table IV-18. Two others--Rickreall Creek and Luckiamute River--are in the beginning stages of adjudication. Many other streams in the basin need adjudication to determine valid rights, to resolve the discrepancies between apparent vested rights and current use, and to determine the amount of water available for future appropriation and use.

Table IV-18
Water rights on adjudicated streams

	Adjudicated water rights						
	Domestic (cfs)	Municipal (cfs)	Industrial (cfs)	Irrigation (acres)	Power (cfs)	Storage (acre-feet)	Other (cfs)
Santiam subbasin:							
Calapooia River (Linn County)	0.03	--	--	90	35	--	--
North Santiam River (Linn and Marion Counties)	--	34.74[a/]	15.65[b/]	26,286	2,027	25.0	65.20[c/]
Coast Range subbasin:							
Mill Creek (Yamhill County)	--	--	--	14.3	--	--	--
Pudding subbasin:							
Bachert and Netter Creeks (Clackamas County)	(Rights allowed for domestic and stock use only)						
Mill Creek (Marion County)	--	2.5[d/]	4.39	408	1,006	--	25.0[e/]
Unnamed Willamette River tributary (Marion County)	--	--	--	3.6	--	--	--
Tualatin subbasin:							
Tualatin River (Washington and adjacent counties)	.7	--	.66	--	57.5	2.55	--
Unnamed Tualatin River tributary (Washington County)	--	--	--	45	--	--	--

a/ Includes 1.2 mgd institutional use. b/ Includes 5.0 cfs for medicinal use.

c/ Fish life. d/ Institutional use. e/ Recreation.

The State Engineer issues permits and certificates for water rights that were initiated after the enactment of the water code. As of July 1965, 28,970 cfs of water had been appropriated in Willamette Basin through both adjudication and permit. Rights for consumptive uses total 6,059 cfs and for nonconsumptive uses total 22,911 cfs (Table IV-19).

Under Oregon law, a water right developed and perfected is valid and subject to loss by abandonment only. If the owner of a perfected certified right ceases to use water for five successive years, the water right shall be considered to be abandoned. Before August 1955, it was necessary to initiate court proceedings to declare a water right abandoned. Laws passed in August 1955 permit the State Engineer to accept voluntary authorization of abandonment by the owner of a water right or to initiate cancellation proceedings through administrative action. However, many rights remain in effect because no steps have been taken to cancel them, even though they apparently have been abandoned. Unused and uncancelled water rights preclude an accurate quantitative appraisal of the available water resources and reflect on the value of all water rights. As of June 1964, only 58 rights affecting irrigation of 1,710 acres in the basin had been cancelled under the provisions of the August 1955 law.

Photo IV-9. The Willamette River swirls about salmon fishermen below Willamette Falls.

Table IV-19

Summary of surface-water rights, in cfs, July 1965

Subbasin	Domestic	Municipal	Industrial	Irrigation	Power	Mineral	Fish Life	Recreation	Wildlife	Total
Coast Fork	1.365	22.910	38.990	85.245	9.644	4.500	0.760	0.020	0.010	163.444
Middle Fork	3.126	22.530	44.010	31.097	--	--	92.020	0.950	0	193.763
McKenzie	5.237	312.360	25.820	1,493.655	10,383.274	--	155.460	0.760	--	12,446.566
Long Tom	1.775	35,675	18,000	135.120	0.320	--	0.310	36.890	1.200	229.290
Santiam	0.164	172.072	94.773	1,049.946	1,707.800	2.000	234.050	7.350	1.040	3,325.195
Coast Range	11.672	101.130	89.135	589.868	70.000	--	9,757	7.120	2.150	880.352
Pudding	5.485	24.460	39.240	511.823	363.086	--	40.290	12.930	0.010	1,005.324
Tualatin	9.100	25.220	31.715	350.662	69.230	--	12,410	0.452	0.340	499.129
Clackamas	4.877	137.986	6,822	60.493	9,400.950	--	122.666	3.520	0	9,737.324
Columbia	5.276	86.770	16.964	236.476	20.740	--	11.659	0.710	4.670	383.365
Sandy	7.820	14.690	29.900	9.563	14.600	--	46.550	2.790	0	125.913
Total	61.397	937.833	505.379	4,553.948	22,039.724	6.500	783.972	73.492	9.420	28,989.665

GROUND-WATER RIGHTS

The Oregon Ground Water Act of 1955 provides for a system of appropriating ground water, of establishing ground-water rights, and of ensuring the beneficial use of ground water without waste, excessive water-level drawdown, or deterioration or depreciation of the supply. This act does not require water rights for watering livestock, nor for irrigating lawns or noncommercial gardens that do not exceed one-half acre. Also, water rights are not required for single or group domestic uses not exceeding 15,000 gpd (gallons per day) nor for any single industrial or commercial use not exceeding 5,000 gpd. The use not covered by water rights constitutes a considerable annual withdrawal of water.

The ground-water law states that permits for appropriation of water from ground-water sources will be issued and regulated by the State Engineer. The registration of ground water that was in use before passage of the act essentially provides for vested water rights for those uses. However, registration rights are not considered final until the ground-water basin or area has been adjudicated--a legal procedure not yet applied to ground water in the Willamette Basin. Most of the ground-water irrigation use (the largest use in Willamette Basin) was established before passage of the act and therefore is covered by prior registrations rather than by subsequently issued water-right permits. The early registrations bear little relationship to the acreage irrigated by ground water at the present time (see discussion of irrigation water rights in Appendix F - Irrigation).

Ground-water rights in the basin totaled 2,484 cfs in 1965, of which all but 8 cfs are for consumptive uses (Table IV-20).

Table IV-20
Summary of ground-water rights, in cfs, July 1965

Subbasin	Domestic	Municipal	Industrial	Irrigation	Power	Fish life	Recreation	Wildlife	Total
Coast Fork	0.011	3.543	1.169	11.228	0.400	-	-	0.040	16.391
Middle Fork	-	24.660	0.089	18.651	-	-	-	-	43.400
McKenzie	0.009	16.890	0.535	76.889	-	-	-	-	94.323
Long Tom	0.261	3.713	3.951	361.394	-	-	-	-	369.319
Santiam	0.109	54.928	8.311	494.942	-	2.200	-	-	560.490
Coast Range	1.028	17.361	6.783	350.591	-	-	-	-	375.763
Pudding	2.071	52.045	31.780	604.806	-	1.560	0.330	1.448	694.040
Tualatin	0.027	12.861	5.408	50.181	-	-	-	-	68.477
Clackamas	-	4.710	2.059	20.913	-	1.410	-	-	29.092
Columbia	1.328	35.056	128.690	55.905	-	-	0.446	-	221.425
Sandy	-	0.670	3.116	7.582	-	-	0.300	-	11.668
Total	4.844	226.437	191.891	2,053.082	0.400	5.170	1.076	1.488	2,484.388

Note: Ground-water rights include registered and permit wells.

LEGAL RESTRICTIONS

Legal actions restricting the use of the waters of Willamette Basin fall into three categories: Oregon State Legislative Withdrawals, Oregon State Engineer Orders, and Oregon State Water Resources Board Programs. Restrictions on various streams in the basin are as follows:

The oldest and largest single restriction is on Bull Run and Little Sandy Rivers. In 1891, the Oregon State Legislature withdrew these waters for municipal use by Portland. About 90,000 acre-feet is diverted annually from these streams to supply water to an estimated population of 573,000.

Sandy River and its tributaries (except Beaver, Buck, Big, and Trout Creeks) were withdrawn for protection of fish life by the Oregon State Legislature in 1953. However, appropriation and use of these waters (except Hackett Creek) are allowed for domestic, stock, municipal, public park, and recreational purposes. In addition, all tributaries except in the main channel below Big Creek are open for appropriation and storage from December 1 to June 1 of each water year.

Photo IV-10 Water from Bull Run River is diverted at the headworks for Portland's municipal supply.

The Columbia Gorge streams that form the waterfalls near the Columbia River Highway were withdrawn from appropriation by the Oregon State Legislature in 1915, except for appropriation of water below the falls for fish culture by the Fish Commission of Oregon.

Johnson Creek and its tributaries were withdrawn for protection of fish life by the Oregon State Legislature in 1935. However, the tributaries are open to appropriation and storage from December 1 to June 1 of each water year. A bill passed by the 1965 Oregon State Legislature modifies this withdrawal by allowing appropriation and use of Crystal Springs Creek and tributaries when flow measured at the mouth is more than 10 cfs.

Scappoose Creek was withdrawn for protection of fish life by the Oregon State Legislature in 1953. However, appropriation and use of these waters are allowed for domestic, stock, municipal, public park, and recreational purposes.

McNulty Creek was withdrawn from appropriation by the Oregon State Legislature in 1951. However, appropriation for storage is permitted during the period from November 1 to March 31 of each water year in reservoirs not constructed in the channel of McNulty Creek below a line 1 mile west of the range line between Ranges 1 and 2 West, Willamette Meridian.

Milton Creek and tributaries were withdrawn from appropriation by the Oregon State Legislature in 1951. However, appropriation for domestic use is permitted, and appropriation from storage is permitted from November 1 to April 30 of each water year.

North and South Forks of Silver Creek and tributaries were withdrawn from appropriation or condemnation, except for public park purposes, by the Oregon State Legislature in 1931. This withdrawal was amended by the 1965 legislature to allow appropriation, diversion, or interruption from November 1 to June 1 of each water year.

When a stream becomes overappropriated and the Oregon State Engineer deems it necessary, he issues an order withdrawing the stream from further appropriation. He also may issue orders restricting certain streams for municipal supply uses. At present, 28 State Engineer orders restrict the appropriation of water in Willamette Basin (see Map IV-19).

Limitations may be imposed on the appropriation of water from a ground-water area when evidence indicates the probability of wasteful use, undue interference between wells, seriously declining water levels, or deterioration of water quality. Depending on the circumstances, the State Engineer may deny future permits, restrict water use by certain permittees, or initiate proceedings for declaring the area to be a critical ground-water area. Before the designation of a critical ground-water area, a public hearing must be held to present documentary evidence concerning problems and conditions in the area. After such a hearing and if such action seems warranted, the State Engineer may declare the area to be a critical ground-water area and issue an order prescribing action to alleviate the problem. As of December 1967, no critical ground-water areas had been declared in the Willamette Basin.

The Oregon State Water Resources Board also imposes restrictions on the use of the waters of Willamette Basin through its adopted water-use programs.

If the people of Oregon are to realize the maximum benefit from their water resources, it is essential that a program of water use and control be formulated and enforced. Programs of the State Water Resources Board are authorized specifically in ORS 536.300 (1) and (2) which state:

"(1) The board shall proceed as rapidly as possible to study: existing water resources of this State; and means and methods of conserving and augmenting such water resources; existing and contemplated needs and uses of water for domestic, municipal, irrigation, power development, industrial, mining, recreation, wildlife, and fish life uses and for pollution abatement, all of which are declared to be beneficial uses, and all other related subjects, including drainage and reclamation.

"(2) Based upon said studies and after an opportunity to be heard has been given to all other State agencies which may be concerned, the board shall progressively formulate an integrated, coordinated program for the use and control of all the water resources of this State and issue statements thereof."

Water-use programs have been formulated and adopted by the Oregon State Water Resources Board for Upper, Middle, and Lower Willamette Basins. These programs state exactly what uses are permitted and where they are allowed. The State Water Resources Board program permits only certain uses in specific areas, as shown on Map IV-19.

Table IV-21

Stipulated minimum flows, Willamette Basin streams

Stream Point	Natural Flow[1/] (cfs)	Storage Release (cfs)
Coast Fork Subbasin:		
Coast Fork Willamette River above Row River	15	100
Row River at mouth	40	150
Coast Fork Willamette River at mouth	40	250
Middle Fork Subbasin:		
Middle Fork Willamette River above North Fork of Middle Fork	285	690
North Fork of Middle Fork Willamette River at mouth	115	
Fall Creek at mouth	40	470
Middle Fork Willamette River at mouth	640	1,475
McKenzie Subbasin:		
South Fork McKenzie River at mouth	200	230
Blue River at mouth	30	350
McKenzie River at gage 14-1625, near Vida	1,400	580
Gate Creek at mouth	20	
Mohawk River at mouth	20	
McKenzie River at I-5 Highway bridge	1,025	700
Long Tom Subbasin:		
Long Tom River at gage 14-1700, at Monroe		370
Santiam Subbasin:		
Calapooia River at gage 14-1720, at Holley	30	340
Calapooia River at gage 14-1735, at Albany	20	340
South Santiam River at gage 14-1850, below Cascadia	50	
Middle Santiam River at gage 14-1865, near Foster	110	260
Wiley Creek at mouth	10	
South Santiam River at gage 14-1875, at Waterloo	170	930
North Santiam River at gage 14-1780, near Detroit	345	
North Santiam River at gage 14-1815, at Niagara	500	640
Little North Santiam River at gage 14-1825, near Mehama	40	
North Santiam River at gage 14-1830, at Mehama	580	640
North Santiam River at gage 14-1841 near Jefferson	430	640
Santiam River at gage 14-1890, at Jefferson	330	1,570
Santiam River at mouth	320	1,570
Coast Range Subbasin:		
Marys River at gage 14-1710, near Philomath	10	
Marys River at mouth	5	
Luckiamute River at gage 14-1895, near Hoskins	10	
Luckiamute River at gage 14-1900, at Pedee	20	
Luckiamute River at gage 14-1905, near Suver	25	
Luckiamute River at mouth	20	
Rickreall Creek at gage 14-1907, near Dallas	5	
South Yamhill River at gage 14-1925, near Willamina	20	
Willamina Creek at gage 14-1930, near Willamina	20	
South Yamhill River at gage 14-1940, near Whiteson	15	
North Yamhill River at gage 14-1970, at Pike	10	
Yamhill River at gage (site) 14-1975, at Lafayette	15	
Pudding Subbasin:		
Pudding River at gage 14-2010, near Mount Angel	10	
Pudding River at gage 14-2020, at Aurora	35	
Molalla River at gage 14-1985, near Wilhoit	35	
Molalla River at gage 14-2000 near Canby	60	

1/ Several values are shown where stipulated minimum flows vary seasonally.

Table IV-21--Continued

Stipulated minimum flows, Willamette Basin streams

Stream Point	Natural Flow1/ (cfs)	Storage Release (cfs)
Tualatin Subbasin:		
Tualatin River at mile 70	10-65-20	
Seine Creek at mouth	2-25-8	
Tanner Creek at mouth	1-9	
Tualatin River at gage 14-2035, near Dilley	15	
Gales Creek at mouth	12-100-35	
Gales Creek at mile 12	8-70	
Beaver Creek at mouth	1-17-3	
Little Beaver Creek at mouth	1	
North Fork Gales Creek at mouth	1.5-25-3	
South Fork Gales Creek at mouth	1-20-2	
East Fork Dairy Creek at mile 13	12-50-25	
Denny Creek at mouth	2-15-3	
Plentywater Creek at mouth	1-5-2	
McKay Creek at mile 15.5	4-36	
East Fork McKay Creek at mouth	2	
McFee Creek at or near Gulf Canyon Creek	2-12	
Tualatin River at gage 14-2075, at West Linn	15-30-20	
Clackamas Subbasin:		
Lowe Creek at mouth	2-8	
Pinhead Creek at mouth	50-75	
Clackamas River at gage 14-2080, at Big Bottom	150-240	
Collawash River at mouth	75-250-200	
East Fork Collawash River at mouth	10	
Elk Lake Creek at mouth	15	
Hot Springs Fork Collawash River at mouth	15-75	
Oak Grove Fork Clackamas River at mouth	10	
Clackamas River at gage 14-2095, above Three Lynx	400	
Roaring River at mouth	40-100	
Fish Creek at mouth	15-60	
Fish Creek at Wash Creek	3	
Wash Creek at mouth	3-25-10	
Eagle Creek at mouth	40-125-100	
North Fork Eagle Creek at mouth	10-45-30-20	
Deep Creek at mouth	10-35-20	
North Fork Deep Creek at mouth	1-20-3	
Tickle Creek at mouth	4-30-6	
Clear Creek at mouth	20-40	
Clear Creek at Viola	15-25	
Columbia Subbasin:		
Milton Creek at Salmon Creek	25	
Cox Creek at mouth	6	
Salmon Creek at mouth	5	
North Scappoose Creek at mouth	5-40-20	
Alder Creek at mouth	1-8-3	
Cedar Creek at mouth	1-6-3	
Chapman Creek (Lizzie Creek) at mouth	1-6-3	
North Fork of North Scappoose Creek at mouth	1-7-3	
Sierkes Creek (Deep Creek) at mouth	0.5-7	
South Fork of North Scappoose Creek at mouth	1-8-4	
South Scappoose Creek at Raymond Creek	5-25-12	
Gourlay Creek at mouth	0.5-10-2	
Raymond Creek at mouth	0.5-8-1	
Willamette River:		
Willamette River at gage 14-1740, at Albany	1,750	3,140
Willamette River at gage 14-1910, at Salem	1,300	4,700
Willamette River at gage 14-1980, at Wilsonville	1,500	4,700

In formulating the water-resources program under subsection (2) of ORS 536.300, the board is directed to take into consideration the following additional declaration of policy as stated in ORS 536.300 (7):

> "(7) The maintenance of minimum perennial streamflows sufficient to support aquatic life and to minimize pollution shall be fostered and encouraged if existing rights and priorities under existing laws will permit."

The State Water Resources Board has set minimum perennial streamflows at 96 locations in Willamette Basin. When streamflow falls to those minimum levels, no appropriations of water may be made by any State agency or public corporation of the State except for domestic or livestock use. Map IV-19 shows the extent to which minimum flows have been set in the basin. Table IV-21 lists the minimum flow points and the flows established at each. At some locations, one flow value from natural flow has been set; at other locations one flow value has been set to be maintained from natural flow and another to be maintained from storage releases. Seasonal minimum perennial flows have been set in the lower basin, where at places as many as four flow values have been set for different times of the year. The Oregon State Water Resources Board's program documents--Upper, Middle, and Lower Willamette Basins--show exact location of the flow points and values set at these points.

Photo IV-11. The Santiam River mirrors the bridge at Jefferson during low flow.

PART V

ADEQUACY OF HYDROLOGIC DATA

ADEQUACY OF HYDROLOGIC DATA

The hydrologic descriptions in this appendix are based on the data collected as part of the regular programs of various agencies. There is considerable variation in the quantity and areal distribution of data, and some descriptions are necessarily more generalized than others. Coverage is best for streamflow, stream temperatures, and climatic data in Willamette Valley (but not the mountain areas). The greatest deficiencies are for data on evaporation, sediment, mineral quality of surface and ground water, and the lakes and glaciers of the High Cascades.

CLIMATIC DATA

PRECIPITATION

Comparisons of observed yearly runoff from several Willamette tributary watersheds with mean annual precipitation (from isohyetal maps) show that additional precipitation data are needed for the mountain areas. The lack of precipitation data for the middle and higher altitudes of both the Coast and Cascade Ranges is due to the few, if any, potential precipitation observers who live in the mountainous sections.

Through the cooperative efforts of the Oregon State Engineer's office and the Weather Bureau, a program has been started to install additional storage-type precipitation gages in and around Willamette Basin. However, more sites and observers for precipitation gages are badly needed. Through cooperation of Federal, State, municipal, and private agencies that have operations and installations in the mountains of Willamette Basin, additional data could be obtained.

TEMPERATURE

Temperature data are primarily from the more populated lowlands where the network of long-term stations is adequate. Temperature data are difficult to obtain for mountain areas because of the lack of observers. Therefore, estimates of temperatures over much of the mountains must be made from the few existing high-altitude temperature stations or from upper-air soundings made at the Salem Weather Bureau Airport station.

EVAPORATION

Published evaporation data are available for five stations, all in the central to southern part of the basin--Oregon State University (at Corvallis), Cottage Grove Dam, Detroit Dam Powerhouse, Dorena Dam, and Fern Ridge Dam. Elevations of these stations range from 200 to 1,300 feet. The only evaporation data for high elevation are from Odell Lake at about 4,800 feet elevation just outside the extreme southeastern boundary of Willamette Basin. There are no evaporation data for stations in the northern part of the basin.

Both evaporation and evapotranspiration measurements are needed throughout the basin to plan and to operate water-development projects. The Forest Service is making evapotranspiration studies for forested areas in McKenzie Subbasin. The Corps of Engineers has made some studies of evaporation losses from their reservoirs.

SOLAR RADIATION

Only one published solar-radiation record (at Oregon State University) is available for Willamette Basin. Within the past year, the Corps of Engineers has undertaken radiation measurements at several of its reservoirs to establish a heat budget for the reservoir-evaporation studies. The Environmental Science Services Administration (Weather Bureau) has no near-future plans at this time for installing radiation-detection equipment at stations in the basin.

WIND

Detailed wind observations are taken hourly and recorded instantaneously at three Weather Bureau stations in the basin--Portland, Salem, and Eugene. Wind direction and speed are logged hourly during the fire-weather season--generally May through September--at numerous Federal, State, and county forest headquarters offices and lookout stations. This wind information is primarily for operational use; therefore, records are not published and generally are not available for planning purposes.

Additional wind data are needed for planning the construction of powerlines, microwave towers, and many other types of structures. Wind data for the higher altitudes are especially needed.

STREAMFLOW DATA

Stream-gaging stations generally can be grouped into two categories--hydrologic stations and water-management stations. Hydrologic stations, identified as either primary or secondary, are used to obtain the stage and discharge data needed for general water-resources inventory and planning. Primary hydrologic stations are intended to run indefinitely and to show time trends that furnish the key to general coverage of the region. Secondary hydrologic stations are intended to be operated only long enough to establish the flow characteristics of the watersheds they gage, relative to and by correlation with some primary hydrologic station. Water-management stations are used for operation of an existing project, for design of a proposed project, or for administrative and legal purposes. A single station may function as both a hydrologic and a water-management station.

Although the general flow regime at ungaged sites can be deduced from an adequate network of stream-gaging stations, it is difficult to make reliable estimates of discharge at these sites for extreme events, such as flood or drought. For that reason, supplemental flood-peak and low-flow data are obtained at designated partial-record or miscellaneous measurement sites.

The quantitative appraisal of the streamflow in Willamette Basin is based on hydrologic data from 154 gaging stations, from 24 flood-peak, partial-record stations, and from miscellaneous-measurement sites.

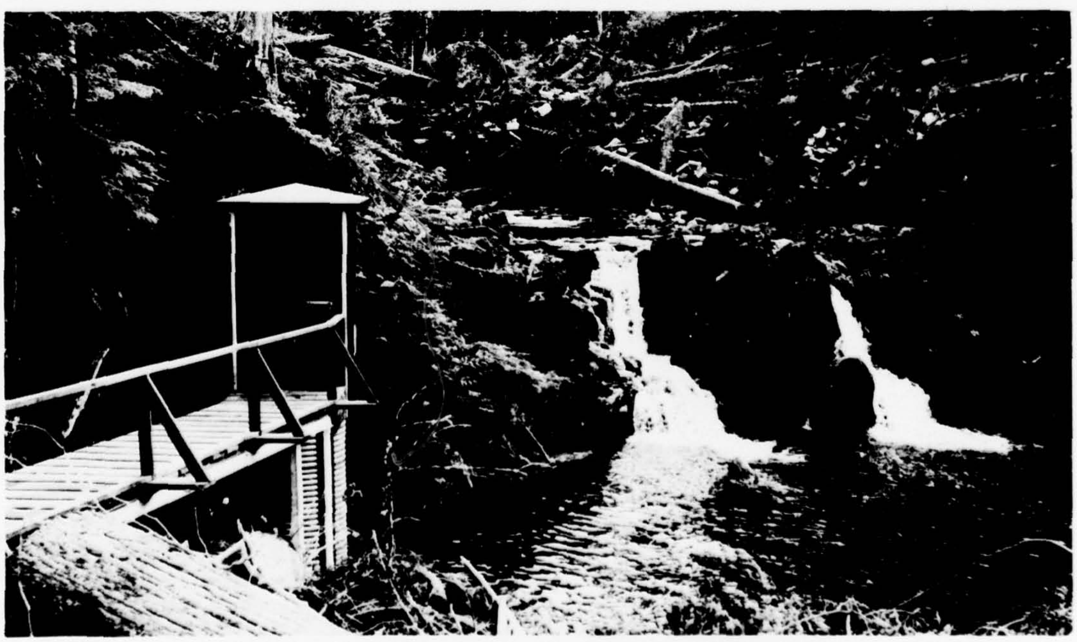


Photo V-1. Gaging stations are needed on both small and large streams.

Of the 154 gaging stations, 27 are classified as primary hydrologic stations, 27 as secondary hydrologic stations, and 68 as water-management stations of hydrologic significance. The remaining 32 stations are not now in operation and have records too short to be useful for other than hydrologic reconnaissance.

The quantitative appraisal of the streamflow in Willamette Basin is based on hydrologic data from 154 gaging stations, from 24 flood-peak, partial-record stations, and from 56 miscellaneous-measurement sites. Of the 154 gaging stations, 27 are classified as primary hydrologic stations, 27 as secondary hydrologic stations, and 68 as water-management stations of hydrologic significance. The remaining 32 stations are not now in operation and have records too short to be useful other than for hydrologic reconnaissance.

The primary-station network is reasonably adequate for the appraisal in this appendix. However, about one-fourth of these stations are becoming increasingly affected by flow regulation and will have limited value as primary stations in the future. To obtain the data needed for future water-resource development, about 25 to 30 long-term stations should be established at sites where natural flow can be measured. These can be either new stations or reclassified secondary stations.

Satisfactory correlations with primary stations were obtained for only 17 of the 27 secondary hydrologic stations and for 29 of the 49 water-management stations that have more than 5 years of record. Continued operation of existing secondary stations and expansion of the secondary-station network are needed to provide areal coverage for future studies. About 35 additional secondary hydrologic stations should be established on selected small streams, both on the valley floor and in the mountains. Water-management stations are normally established as needed, and therefore the network of these stations may be considered adequate.

To provide wide areal coverage of flow extremes, particularly low flow, a total of about 300 partial-record stations are needed throughout the basin. At the low-flow sites, discharge should be measured through a range as high as the probable mean annual value. Correlation techniques can then be used to estimate mean annual discharge and to deduce low-flow frequency relations at the measuring sites.

L A K E   A N D   G L A C I E R   D A T A

LAKES

Data are available on the surface areas and volumes of the many natural lakes in the basin, but additional data are needed. All lakes larger than 20 acres in surface area should be inventoried to obtain data on their areas, depths, volumes of water, bottom profiles, sources of water, outlets, water temperatures, chemical quality, and geologic setting. The inventory data could be used to select representative lakes for more detailed studies of fluctuations in level, volume of water, temperature, quality, and inflow and outflow. These studies should relate the lakes to local streams and ground-water bodies.

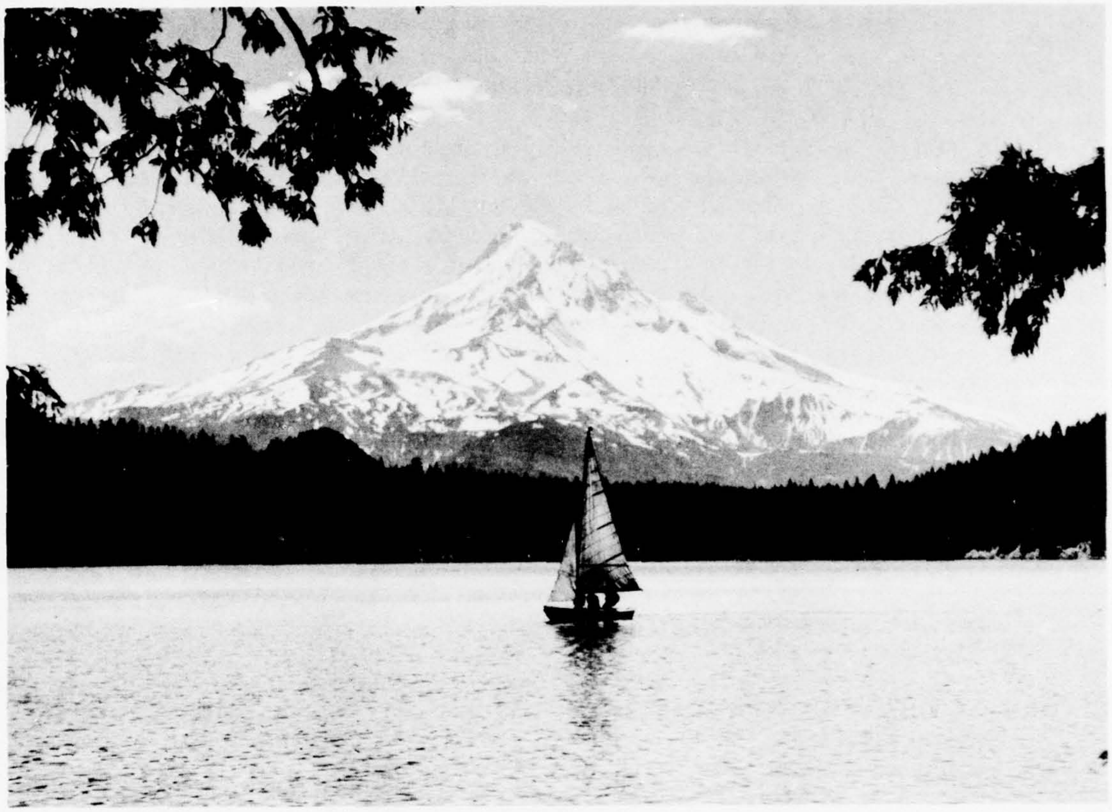


Photo V-2. Natural lakes are common in the High Cascades, and snowfields mask Mount Hood glaciers.

GLACIERS

Scientific data for the glaciers on the slopes of Mount Hood, Mount Jefferson, and Three Sisters have been collected for many years by members of the Mazamas organization and by individuals. These data consist of (1) measurements of glacier movements, surface profiles, retreat of glacier termini, and changes in thickness, and (2) estimates of glacier areas. These observations provide a valuable record which shows that the glaciers have been retreating during the last 60 years.

A systematic program of hydrologic-data collection for the Willamette Basin glaciers is needed. Such a program should include:

1. Measuring the present areas of the glaciers, using aerial photographs.

2. Determining whether the glaciers are increasing or decreasing in size over a longtime period by remeasuring the areas periodically perhaps every 5 or 10 years.

3. Measuring the melt-water runoff from typical glaciers.

CHEMICAL-QUALITY DATA

SURFACE WATER

The amount and relative ratios of the major dissolved ions in surface waters of the basin are known or can be accurately estimated. However, practically no data are available on the minor constituents (metal ions such as zinc, copper, arsenic; organics; pesticides and insecticides; and phosphates) whose importance will be greater as water use becomes more varied. Basic data on the occurrence and distribution of the minor constituents are needed now to establish a base for defining future water-quality changes and water suitability as water use increases.

Water problems may develop in specific areas as all types of water use increase. Continuing investigations will be needed to delineate problem areas as they develop and to provide the information required to prevent gross deterioration of the now excellent mineral quality of the basin's surface waters.

The following sampling network should be established to define and monitor the mineral quality of the basin's surface waters:

1. A reconnaissance-type sampling program of 25 to 50 sampling sites within the basin to define the present occurrence and distribution of the minor elements.

2. Periodic sampling stations at 5 to 10 key sites throughout the basin to show long-term changes in relation to stream-flow and economic development. The samples should be analyzed for major constituents and minor elements.

3. At least one additional daily sampling station on Willamette River below Salem to monitor future changes in water quality.

GROUND WATER

The available data on ground water quality for Willamette Basin are adequate only for areas around Portland, in Tualatin Valley, and in the northern part of Willamette Valley. The lack of chemical-quality information prevents detailed appraisal of the ground-water quality.

Increases in the use of ground water will no doubt be accompanied by many problems. The widespread practice of underground disposal of domestic sewage and the increased use of fertilizers and insecticides could raise the dissolved-solids content of the ground water. The use of ground water for heating and cooling could cause local changes in its temperature. A basic-data program is needed to monitor ground-water quality and obtain water-quality information sufficient to relate the water quality to aquifers. Where possible, samples for analysis should be collected from specific aquifers where geologic conditions are known. Waters from all water-bearing formations should be sampled.

After the establishment of a water-quality network, only partial analyses for important constituents will be needed for monitoring purposes. Data gathered during this phase, however, should be comprehensive enough to give early warning of pollution and water-quality deterioration. Special emphasis should be placed on areas of rapid industrial, agricultural and population growth.

Areas recommended for collection of chemical-quality data on ground water are given in the following tabulation:

Area	
1. Southern Willamette Valley	
Eugene-Salem	Alluvial deposits and bedrock
Eugene-Cottage Grove	Alluvial deposits and bedrock
2. Northern Willamette Valley	Alluvial deposits, basalt of the Columbia River Group, marine rocks, and Troutdale Formation.
3. Lower Willamette Subarea	
Tualatin Valley and adjacent hills	Alluvial and terrace deposits, basalt of the Columbia River Group, Troutdale Formation, and marine rocks.
East Portland Area	Piedmont and terrace deposits, basalt of the Columbia River Group, and Troutdale Formation
West Portland Business District	Basalt of the Columbia River Group and Troutdale Formation
4. Additional wells throughout basin to identify and check new problem areas	

SEDIMENT DATA

Information concerning the movement of sediment by streams is inadequate for orderly development of water resources in the basin. Existing data indicate that the concentration, discharge, and particle size of sediments differ significantly among streams of the basin. However, the data are not sufficiently detailed to define the areal and time variations in sediment discharge that are needed for planning and for predicting future water quality.

The sediment data collected by the Corps of Engineers during 1948-51 at 21 sites in the basin have been used several times in the appraisal of sediment transport. These studies should be updated and additional studies should be made at other sites to provide more adequate coverage. The quantity and character of sediments transported by the principal tributaries should be determined. Few sediment data are available for some rivers on which power, flood-control, and water-storage projects are now planned. Information is needed for planning these and future project development.

The following investigations are recommended for the basin:

1. Reservoir sediment-accumulation surveys for a few index-type reservoirs, to be made at least once every 10 years. These reservoirs should be selected so that sediment yields for the various source areas of the basin can be determined. In conjunction with the reservoir surveys, sediment-discharge data should be obtained at sites above and below the reservoirs to compare yield values.

2. Daily stations to determine total sediment load including bedload. These stations should be established and operated for an indefinite period of time at two or more sites in the basin. Data from these stations would be used to define long-term trends and to correlate data from short-term periodic stations.

3. Sediment-discharge measurements during high-discharge periods at about 30 sites in the basin to define sediment-discharge rating curves. These measurements should continue for 3 or 4 years or until the curves are reasonably well defined. To identify changes with time, data should be collected to redefine the rating curves every 10 years. Suspended-sediment discharge should also be measured periodically at 8 of the 30 sites; these data would be correlated with data from the daily-load stations. Data should be collected to evaluate the bedload at each site.

4. Results of the above studies to be summarized and reported every 10 years.

5. Sediment data for the solution of special problems to be collected as needed and the results reported as soon as findings are complete.

Photo V-3. Sediment-laden floodwater from the Willamette River flows into clearer water of the Columbia.

STREAM-TEMPERATURE DATA

Stream-temperature data are reasonably sufficient for many streams in Willamette Basin. The profiles in the section on "Midsummer Stream Temperatures" are based on the period 1954-62, but several thermograph stations have been established since then; however, thermographs are needed at 34 additional sites, as tabulated below:

Subbasin	Additional Thermographs Recommended
Coast Fork	2
McKenzie	2
Long Tom	2
Santiam	14
Coast Range	8
Pudding	3
Tualatin	1
Clackamas	2

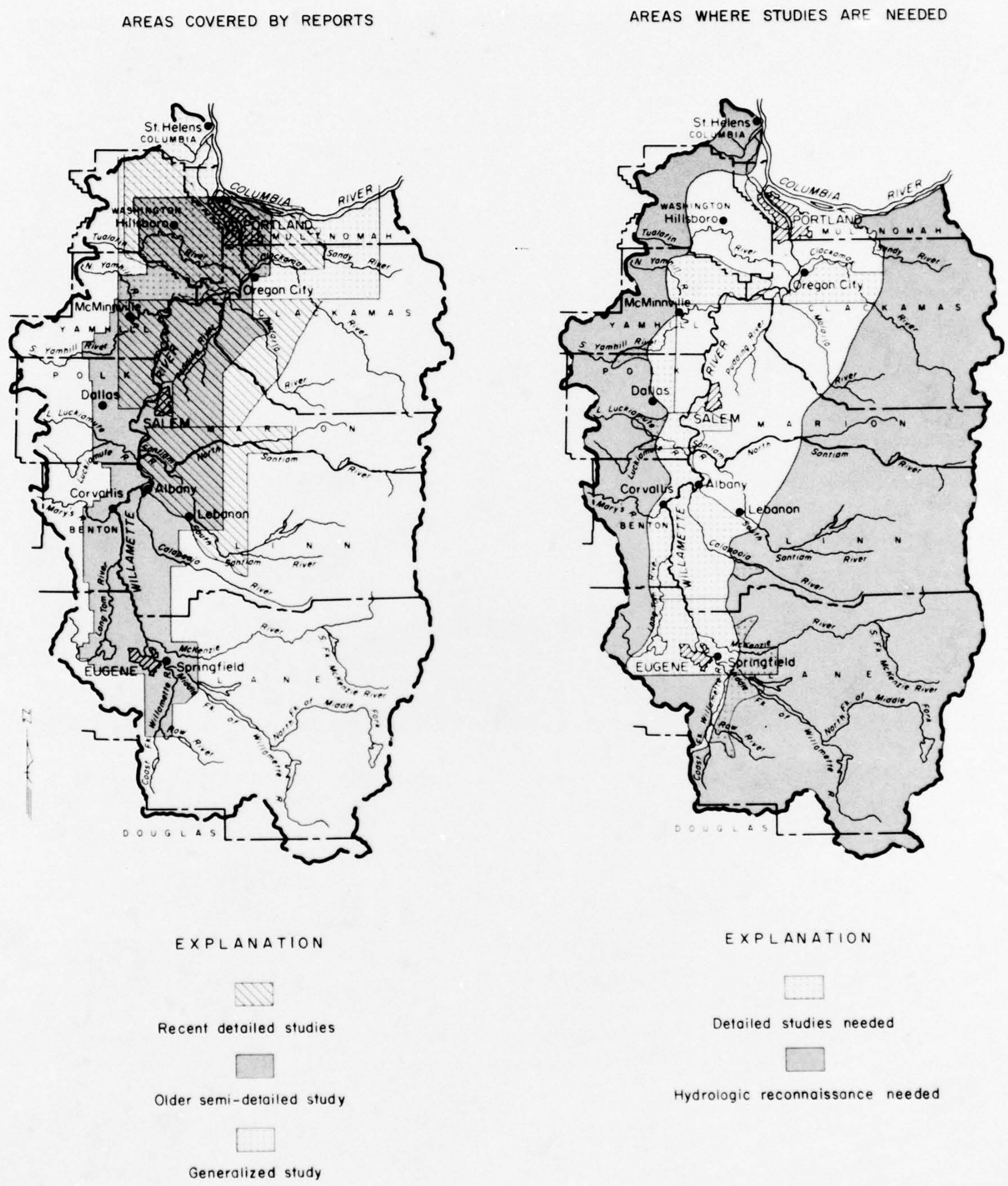


Figure V-1. Areas covered by ground-water reports, and areas needing ground-water studies.

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G R O U N D - W A T E R   D A T A

Modern detailed ground-water studies have been made of only about one-sixth of the basin. The ground-water resources in the valley part of the basin were described in a semidetailed report about 30 years ago. Special studies have been made of ground-water problems in the west-side business district at Portland and of artificial-recharge possibilities and problems in the Salem Heights area. The areas where ground-water investigations have been or are being made are shown on Figure V-1.

Additional ground-water data are needed to provide a background for the orderly development and fullest use of the water resources. To obtain this information, the following program is suggested:

1. Hydrologic reconnaissance of undeveloped areas, and rapid geohydrologic appraisals to obtain information on ground-water resources, low flows of streams, and significant environmental factors such as geology and precipitation. Such studies are needed in the Coast and Cascade Ranges outside the foothill areas that are already included in more detailed investigations now underway or completed.

2. Detailed studies in: Northwest Portland area, Oregon City area, Newberg-North Yamhill River area, Upper valley of South Yamhill River area, Luckiamute River area, Corvallis-Harrisburg area, Eugene-Springfield area, and Coast Fork and Middle Fork valleys (Figure V-1). These studies would be similar to those made in the Molalla Slope and French Prairie areas. Information should be obtained on the occurrence, movement, and quality of ground water and its relation to environmental factors. Semiquantitative estimates should be made of the rates of replenishment, use, and availability of ground water for development.

3. Special studies of problems or to provide information for a specific purpose. These would include: Continuing inventories of water levels and water use; investigations of artificial-recharge possibilities; ground water available for emergency water supplies in urban areas such as Portland, Salem, Albany-Corvallis, and Eugene-Springfield; and effects of environmental changes on occurrence, replenishment, and quality of ground water, particularly those induced by urbanization, highway construction, waste disposal (particularly through subsurface injection), irrigation of large areas from reservoirs, reservoir construction, drainage of wet lands, and deforestation.

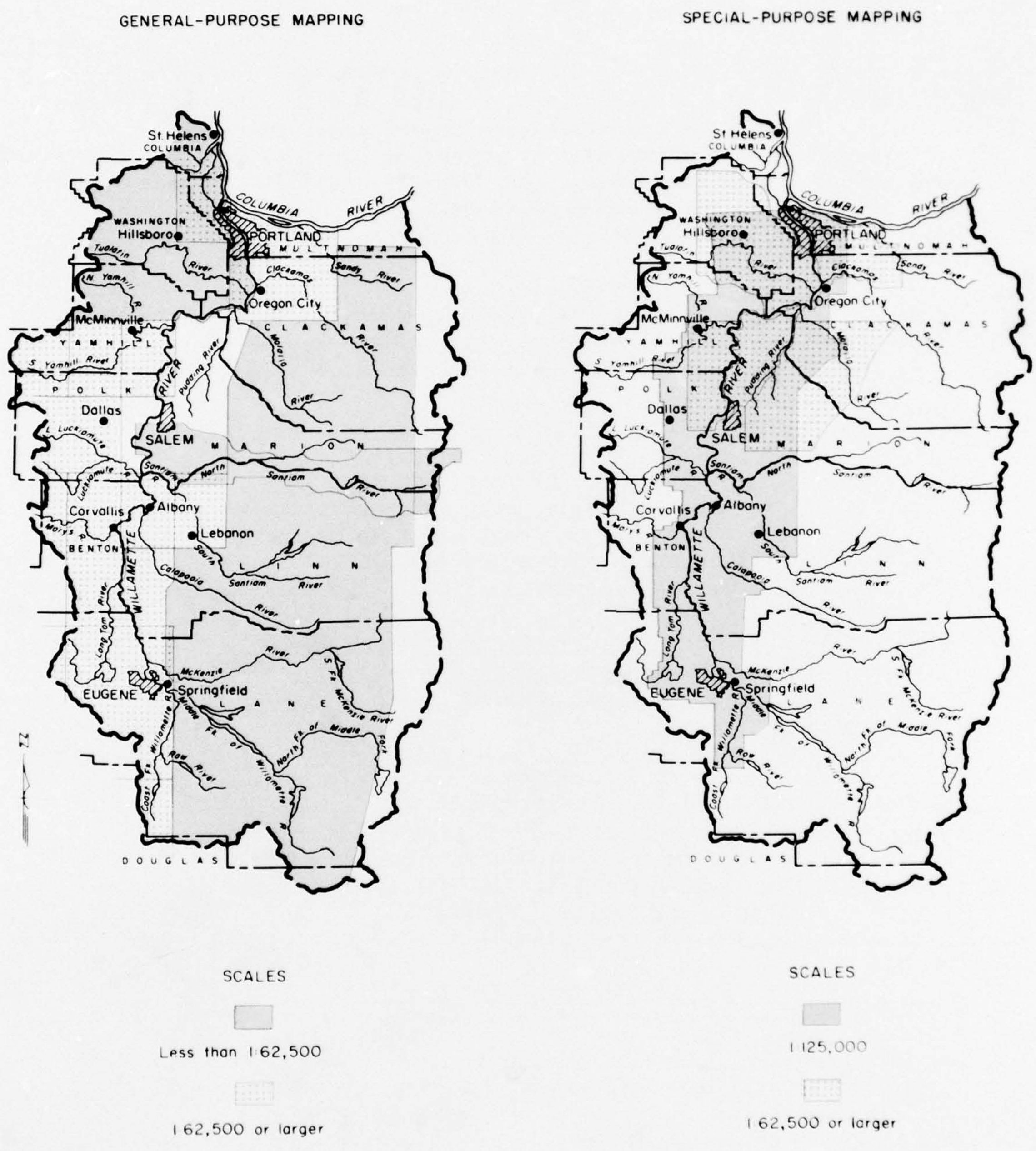

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Figure V-2. Available general-purpose geologic mapping.

G E O L O G I C   M A P P I N G

Geologic data have many applications in interpretation of the hydrologic characteristics of an area. The best recognized is the direct relation between geology, particularly subsurface geology, and the occurrence of ground water. Because of the importance of streamflow discharged from rocks, geologic data are of considerable value in interpreting gaging-station records and in studying low flow. Geologic mapping is a prerequisite to mapping the soils and classifying their hydrologic characteristics. These characteristics, in turn, affect the use of the land for different agricultural purposes and indicate requirements for artificial drainage or the suitability of the land for irrigation. Detailed geologic mapping is needed for land stability studies at dam sites and along canals, and for locating construction materials. For most purposes, subsurface geologic data are as important as surface data.

Table V-1
Geologic mapping available for Willamette Basin

Location in Basin	Area (sq mi)	Scale	Author and Date	Publication
General-Purpose Maps:				
Eastern half of basin	7,050	1:250,000	Peck and others, 1964	USGS Prof. Paper 449
Northwest corner of basin	1,370	1:192,000	Warren and others, 1945	USGS OM 42
Salem-North Santiam River area	800	1:125,000	Thayer, 1939	ODGMI Bull. 15
Portland area	700	1:96,000	Treasher, 1942	ODGMI Map
Dallas and Valsetz quads	325	1:62,500	Baldwin, 1964	ODGMI Bull. 35 (Rev.)
Albany quad	210	1:62,500	Allison, 1953	ODGMI Bull. 37
Lebanon quad	210	1:62,500	Allison and Felts, 1956	ODGMI quad
Portland area	560	1:62,500	Trimble, 1963	USGS Bull. 1119
Southwest corner of basin	630	1:62,500	Vokes and others, 1951	USGS OM 110
Marys Peak and Alsea quads	110	1:62,500	Baldwin, 1955	USGS OM 162
Sheridan and McMinnville quads	425	1:62,500	Baldwin and others, 1955	USGS OM 155
Spirit Mountain quad	135	1:48,000	Baldwin and Roberts, 1952	USGS OM 129
West-central part of valley	265	1:62,500	Vokes and others, 1954	USGS OM 150
Special-Purpose Maps (Ground Water):				
Tualatin Valley area	820	1:48,000	Hart and Newcomb, 1965	USGS WSP 1697
East Portland area	230	1:62,500	Hogenson and Foxworthy, 1965	USGS WSP 1793
Salem-Molalla Slope area	640	1:48,000	Hampton, 1966	USGS open-file map
French Prairie area	200	1:48,000	Price, 1967	USGS WSP 1833
Eola-Amity Hills area	230	1:48,000	Price, 1967	USGS WSP 1847
Special-Purpose (Engineering and Planning):				
Tualatin Valley region	600	1:48,000	Schlicker and Deacon, 1967	ODGMI Bull. 60

Available geologic maps for Willamette Basin areas are classed as either general purpose or special purpose. General-purpose maps present basic information on the areal geology, whereas special-purpose maps provide information in more detail for a specific, more limited use. Areas covered by general-purpose maps resulting from geologic studies and mapping projects of the U. S. Geological Survey and the Oregon Department of Geology and Mineral Industries are shown on Figure V-2 and listed in Table V-1.

The entire basin is included in a generalized geologic map at a scale of 1:500,000 (Wells and Peck, 1961). More than half the basin (in the Western Cascades) is mapped at a scale of 1:250,000 (Peck and others, 1964). In addition, about 2,900 square miles is covered by recent mapping at 1:62,500 or larger scale, and about 2,200 square miles at scales between 1:62,500 and 1:250,000. Table V-1 and Figure V-2 show the available general-purpose mapping, which covers about 80 percent of the basin. Valley areas and the adjacent part of the foothills in the northern part of the basin (about one-sixth of the basin) are covered by special-purpose mapping at a scale of 1:62,500 or larger for ground-water studies (Figure V-2).

A systematic mapping program is needed to provide general- and special-purpose geologic maps for additional areas in the basin. General-purpose, large-scale maps should be prepared first for the remaining valley areas; these maps are not so urgently needed elsewhere although they would be useful in low-flow and runoff studies. The maps would provide background data for construction planning and for ground-water reconnaissance studies.

Special-purpose maps, for more detailed ground-water evaluation and appraisal, would be an integral part of the planned series of ground-water investigations. In addition, special-purpose mapping is needed for land-stability studies, principally in urban areas. Because landslides, some several square miles in area, are common in parts of the basin, areas of unstable ground should be mapped, and the conditions of geology, structure, and topography that produce these areas should be described. The need for data on land stability applies to all construction work--not just that connected with hydrologic facilities.

SOILS MAPPING

Modern, progressive soil-survey reports are an excellent source of information needed to make the best use of our land resources. They provide not only basic data on the soil genesis, morphology, and classification, but also list important physical characteristics and recommended management practices. The soil-survey work program has been accelerated nationwide and in Oregon and Willamette Valley. Modern soil surveys have been completed by the Soil Conservation Service for Marion and Yamhill Counties. Surveys of Benton and Washington Counties are scheduled for completion by about 1968. The only published soil-survey reports for the Willamette Basin are the old Bureau of Soils reports,

Photo V-4. Modern soils mapping provides basic information needed for comprehensive utilization of land resources.

most of which were published between 1920 and 1930. The Oregon State University Department of Soils, with aid and counsel of the Soil Conservation Service, U. S. Department of Agriculture, recently compiled and published the "Willamette Basin General Soil Association Map and Report, Segment I: Lowlands and Foothills." Segment II of the report, covering the mountain areas, is in preparation.

To date, the Soil Conservation Service has mapped the soils on 2.65 million acres of privately owned land. Willamette Basin has approximately 6.8 million acres of forest land, cropland, and rangeland, of which about 4.3 million are private lands and 2.5 million are public lands, mostly in national forests. Soils maps are needed of 1.65 million acres of private lands and 1.7 million acres of public lands.

The U. S. Forest Service has completed soils mapping of the national forest lands in the Bull Run, Sandy, and Salmon River drainages, the H. J. Andrews Experimental Forests; and the Clackamas River drainage, a total of approximately 790,000 acres. Current plans are to map the soils of another 475,000 acres by the mid-1970's.

Soils data are essential to meet the needs of basic goals for the development of water and related land resources. An accelerated program is needed to provide soils maps to the resource planner, the city planner, the landowner, and others. Maps are needed of an additional 3.4 million acres to provide background material for comprehensive planning of projects and programs.

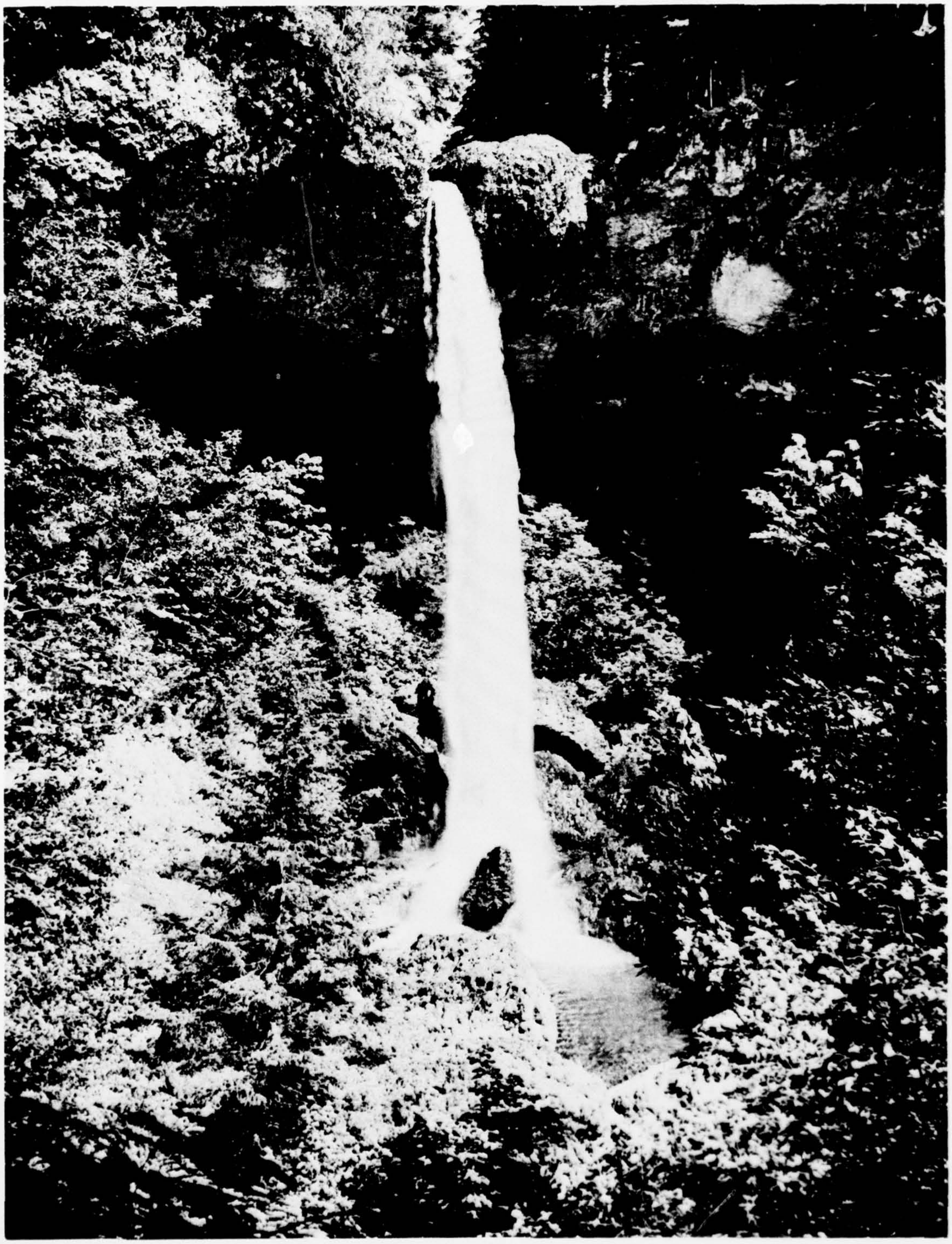

Photo V-5. North Fork of Silver Creek cascades 146 feet at North Falls, in Silver Falls State Park.

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