Appendix D: Facility Sizing Methodology and Resources

1. Santa Barbara Urban Hydrograph Method

The Santa Barbara Urban Hydrograph (SBUH) method is a single-event model that estimates a flow hydrograph for a representative rainfall event. The SBUH method was developed by the Santa Barbara County Flood Control and Water Conservation District. Applicable to urban areas, it converts design storm incremental rainfall depths into instantaneous unit hydrographs.

Elements of the SBUH Method

The SBUH method depends on several variables:

- Pervious (A_p) and impervious (A_{imp}) land areas
- Time of concentration (Tc) calculations
- Runoff curve numbers (CN) applicable to the site
- Design storms

Assumptions for these variables must be explained and justified in the design report.

Land Area

The total area, including the pervious and impervious areas within a drainage basin, shall be quantified in order to evaluate critical contributing areas and the resulting site runoff. Each area with a basin shall be analyzed separately and their hydrographs combined to determine the total basin hydrograph. Areas shall be selected to represent homogenous land use/development units.

Time of Concentration

Time of concentration, Tc, is the time for a theoretical drop of water to travel from the furthest point in the drainage basin to the facility being designed. In this case, Tc is derived by calculating the overland flow time of concentration and the channelized flow time of concentration. Tc depends on several factors, including ground slope, ground roughness, and distance of flow. The formula for determining Tc is found on 3. Standard Equations.

When calculating Tc, the following limitations apply:

- Overland sheet flow (flow across a flat area that does not form into channels or rivulets) shall not extend for more than 300 feet.
- For flow paths through closed conveyance facilities such as pipes and culverts, standard hydraulic formulas shall be used for establishing velocity and travel time
- Flow paths through lakes or wetlands may be assumed to be zero (i.e., $T_c = 0$).

Runoff Curve Numbers

Runoff curve numbers were developed by the NRCS after studying the runoff characteristics of various types of land. Curve numbers (CN) were developed to reduce diverse characteristics such as soil type, land usage, and vegetation into a single variable for use in runoff calculations. The runoff curve numbers approved by the District for water quantity/quality calculations are included in **Table 28**.

The curve numbers presented in **Table 28** are for wet antecedent moisture conditions. Wet conditions assume previous rainstorms have reduced the capacity of soil to absorb water. Given the frequency of storms in Clackamas County, wet conditions are most likely, and result in conservative hydrographic values.

Design Storm

The SBUH method also requires a design storm to perform the runoff calculations. For flow control calculations, the District uses an NRCS Type 1A 24-hour storm distribution. The rainfall depths for 2-year through 100-year storm events are shown in **Table 26**.

Table 26. WES Design Storms

Design Storm/Recurrence Interval (years)	24-Hour Rainfall Depth (inches)
Water Quality	1.0
2-year	2.4
5-year	2.85
10-year	3.2
25-year	4.0
50-year	4.13
100-year	4.8

2. Soils Information

Soils information can be found in the current NRCS Soil Survey for Clackamas County, Oregon. Soils information may be obtained electronically from the NRCS Soil Survey at https://websoilsurvey.nrcs.usda.gov/app/.

1. Select "Start WSS".
2. Under the "Area of Interest", use the State and County drop down menus to select Oregon and Clackamas and select "View" and the Area of Interest Interactive Map will show Clackamas County.
3. Use the Area of Interest Interactive Map to navigate to the project site location.
4. Determine the areas of the site that fall under each of the four hydrologic soil groups in **Table 27**.

Table 27. Hydrologic Soil Groups

Group A	Soils having a high infiltration rate (low runoff potential) when thoroughly wet (deep, well drained to excessively drained sands or gravelly sands)
Group B	Soils having a moderate infiltration rate when thoroughly wet (moderately deep or deep, moderately well drained, or well drained soils that have moderately fine texture to moderately coarse texture)
Group C	Soils having a slow infiltration rate when thoroughly wet (soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture)
Group D	Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet (clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material)

3. Standard Equations

MANNING'S EQUATION: (Open Channel Flow}

$$Q = \left(\frac{1.486}{n}\right) AR^{2/3} S^{1/2}$$

Manning's Equation for circular pipe flowing full

$$Q = \frac{0.463}{n} D^{2/3} S^{1/2}$$

$$V = \frac{0.590}{n} D^{2/3} S^{1/2}$$

$$V = \left(\frac{1.486}{n}\right) R^{2/3} S^{1/2}$$

Q *Quantity of flow*, cubic feet per second
V Velocity of flow, feet per second
n Manning's coefficient of roughness (see Table 29 and Table 30 of these Standards)
A Cross-sectional area, square feet
R Hydraulic radius (area of flow divided by wetted perimeter), feet
S Slope of the pipe or energy line, feet per foot
0 Diameter of pipe, feet

RATIONAL METHOD: (Stormwater Design Flows)

Q = CIA (Max. drainage area=100 acres-- Max. time: *60 minutes*)

Q Quantity of runoff, cubic feet per second
C Coefficient of runoff (ratio of runoff to rainfall), percent (See Table 29)
I Intensity of rainfall, inches per hour
A Area of tributary drainage basin, acres

GUTTER FLOW CAPACITY: (Manning's Equation Modified)

$$Q = 0.56 \frac{\frac{1}{Sx}}{n} S^{0.5} d^{2.67} \quad \text{or} \quad Q = \frac{0.56}{n} Sx^{1.67} S^{0.5} T^{2.67} \qquad V = \frac{1.12}{n} S^{0.5} Sx^{0.67} T^{2.67}$$

Q Quantity of flow, cubic feet per second
Sx Street cross slope, feet per loot
S Street longitudinal slope, feet per foot
n Manning's coefficient of roughness for the gutter, (normally 0.018)
D Depth of flow at the curb, test
T Total width of flow in the gutter, feet

TIME OF CONCENTRATION: (Overland Stormwater Flow)

Tt = L/60V (for conversion of velocity to travel time)

$Tc = T_{11} + T_{12} + \ldots T_{1m}$

$$Tt = \frac{0.42\,(nL)^{0.8}}{1.58\,(S)^{0.4}}$$ (Manning's kinematic solution for sheet flow less than 300 feet)

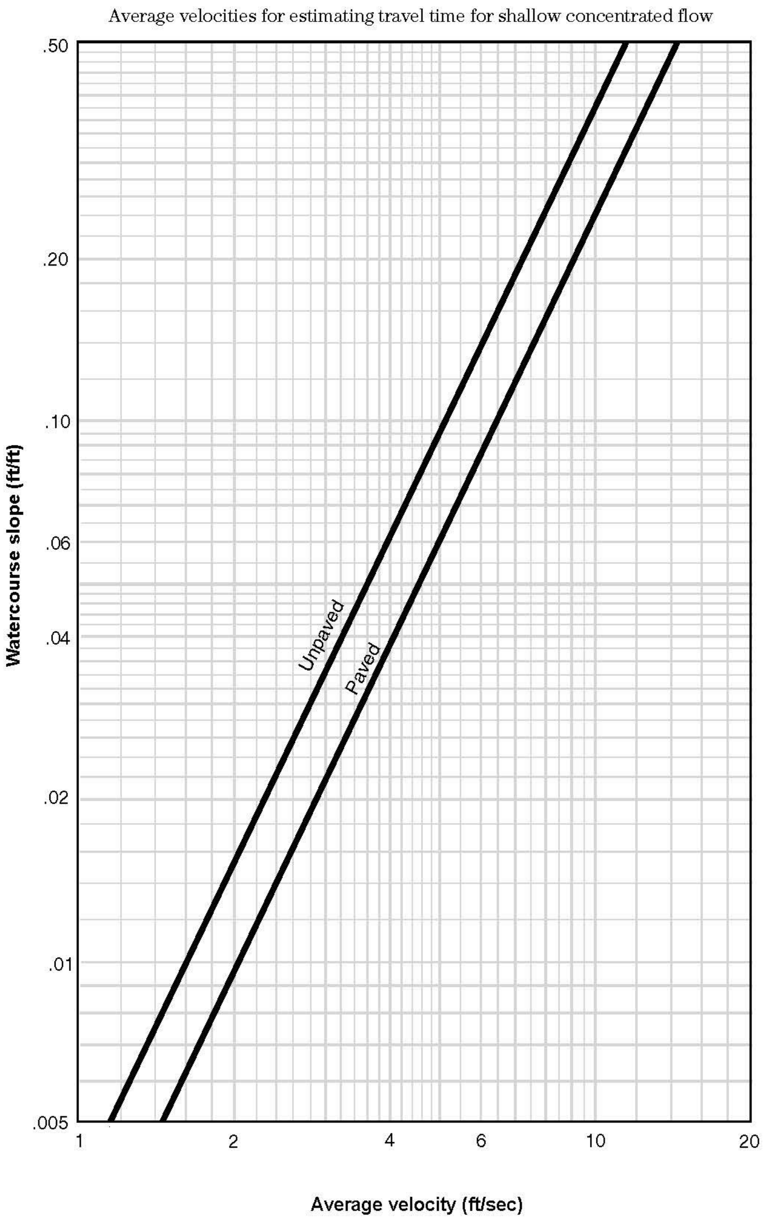
$V = 16.1345\,(S)^{0.5}$ (Unpaved surfaces)
$V = 20.3282\,(S)^{0.5}$ (Paved surfaces)

Shallow concentrated flow for slopes less than 0.005 ft/ft. For steeper slopes, see Figure 13.

Tt Travel time, minutes
L Flow length, feet
V Average veracity of flow, *feet per second*
60 Conversion factor from seconds to minutes
Tc *Total time of concentration, minutes* {minimum Tc = 5.0 minutes)
n Manning's roughness coefficient for various surfaces, (see Table 29 and Table 30)
S Slope of the hydraulic grade line (land or watercourse slope), feet per foot
1.58 A factor derived from Ref. No. 8 (P2, from 2-year, 24-hr precipitation chart, for the Portland, Oregon area [P 2°·5 = 2.5°·5=1.58])

Figure 13. Average Velocities for Shallow Concentrated Flow

Figure from Technical Release 55: Urban Hydrology for Small Watersheds, published by the United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division (1986, updated 1999).



[1] Figure from Technical Release 55: Urban Hydrology for Small Watersheds, published by the United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division (1986, updated 1999).

Table 28. Runoff Curve Numbers[2]

	Curve Numbers for Hydrological Soil Groups			
Description	**A**	**B**	**C**	**D**
Open space (lawns, parks, golf courses, cemeteries)				
Poor condition (< 50% grass coverage)	68	79	86	89
Fair condition (50 to 75% grass coverage)	49	69	79	84
Good condition (>75% grass coverage)	39	61	74	80
Impervious Areas				
Paved areas (parking lots, roofs, driveways)	98	98	98	98
Streets and roads				
Paved with curbs	98	98	98	98
Paved with open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Urban Districts				
Commercial and business (85% impervious)	89	92	94	95
Industrial (72% impervious)	81	88	91	93
Residential districts by average lot size				
1/8 acre or less (65% impervious)	77	85	90	92
1/4 acre (38% impervious)	61	75	83	87
1/3 acre (30% impervious)	57	72	81	86
1/2 acre (25% impervious)	54	70	80	85
Woods (Good Hydrologic Condition)	70*			

** CN for Predeveloped Forest Condition is assumed to be equivalent to Woods condition with Hydrologic Soil Group C.*

[2] Urban Hydrology for Small Watersheds (TR-55), USDA Soil Conservation Service Engineering Division (1986).

Table 29. Runoff Coefficients for Developed Areas (Average Impervious Area Percent for Typical Land Uses, Ground Slopes, and Hydrological Soil Groups)

% Impervious	Soil Type	Drainage Area Slope			Typical Land Use
		Under <5%	5% to 10%	Over 10%	
0-10	A	0.19	0.24	0.29	Open Spaces, Parks, Cemeteries, Playgrounds
	B	0.24	0.30	0.36	
	C	0.29	0.36	0.44	
	D	0.33	0.43	0.52	
11-20	A	0.26	0.31	0.36	Residential (1 unit/20,000 square feet or greater)
	B	0.30	0.37	0.43	
	C	0.35	0.42	0.50	
	D	0.39	0.48	0.57	
21-30	A	0.34	0.39	0.44	Residential (1 unit/10,000 square feet)
	B	0.37	0.44	0.50	
	C	0.41	0.49	0.56	
	D	0.45	0.54	0.62	
31-40	A	0.41	0.46	0.51	Residential (1 unit/5,000 – 7,000 square feet)
	B	0.44	0.50	0.56	
	C	0.47	0.55	0.61	
	D	0.51	0.59	0.67	
41-50	A	0.49	0.54	0.59	Residential (1 unit/less than 5,000 square feet)
	B	0.52	0.57	0.63	
	C	0.55	0.61	0.67	
	D	0.57	0.65	0.72	
51-60	A	0.56	0.61	0.66	Mixed-Use Residential
	B	0.58	0.64	0.70	Residential Streets
	C	0.61	0.67	0.74	Schools/Campuses
	D	0.63	0.70	0.77	
61-70	A	0.64	0.69	0.74	Mixed Use Residential
	B	0.66	0.72	0.77	Mixed-Use Commercial
	C	0.67	0.74	0.80	Collector Streets
	D	0.69	0.76	0.82	
71-80	A	0.71	0.76	0.81	Mixed Use Residential
	B	0.72	0.78	0.83	Mixed-Use Commercial
	C	0.73	0.80	0.85	Arterial Streets
	D	0.75	0.81	0.87	Hospitals
81-90	A	0.79	0.84	0.89	Commercial Centers
	B	0.80	0.85	0.90	High Density Residential
	C	0.81	0.86	0.91	
	D	0.81	0.87	0.92	
91-100	A	0.86	0.91	0.96	Commercial Centers
	B	0.87	0.92	0.97	High Density Residential
	C	0.87	0.92	0.97	Arterial Streets
	D	0.88	0.92	0.97	

❶ Any of the runoff coefficients may be adjusted to the nearest 0.05 to reflect any departure from these typical values. Any adjustment must be applied uniformly throughout a drainage area.

❷ Soil Types: A = gravel and sandy loam; B = light clay and silt loam; C = tight clay.

❸ The land uses are typical for a given percent of impervious surface. Where there is or will be any significant variation from typical conditions, another percentage range should be used.

Source: City of Portland, 2020 Sewer and Drainage Facilities Manual

Table 30. Runoff Coefficients for Undeveloped Areas (General Surface Characteristics, Ground Slope, and Hydrologic Soil Groups)

Surface Characteristics	**Soil Type**	**Drainage Area Slope**		
		Under 5%	**5% to 10 %**	**Over 10%**
Woodland	A	0.10	0.15	0.20
	B	0.15	0.25	0.30
	C	0.30	0.35	0.40
Lawn, Pasture, and Meadow	A	0.15	0.20	0.25
	B	0.25	0.30	0.35
	C	0.30	0.40	0.50
Cultivated Land	A	0.25	0.35	0.50
	B	0.40	0.55	0.70
	C	0.50	0.65	0.80
Gravel Areas and Walks				
Loose		0.30	0.40	0.50
Packed		0.70	0.75	0.80
Pavement and Roof		0.90	0.95	1.00

4. Hydraulics

The following figures are from the Oregon Department of Transportation Hydraulics Design Manual (2014), Chapter 7, Appendix A.

Figure 14. Rainfall I-D-R Curve Zone Map

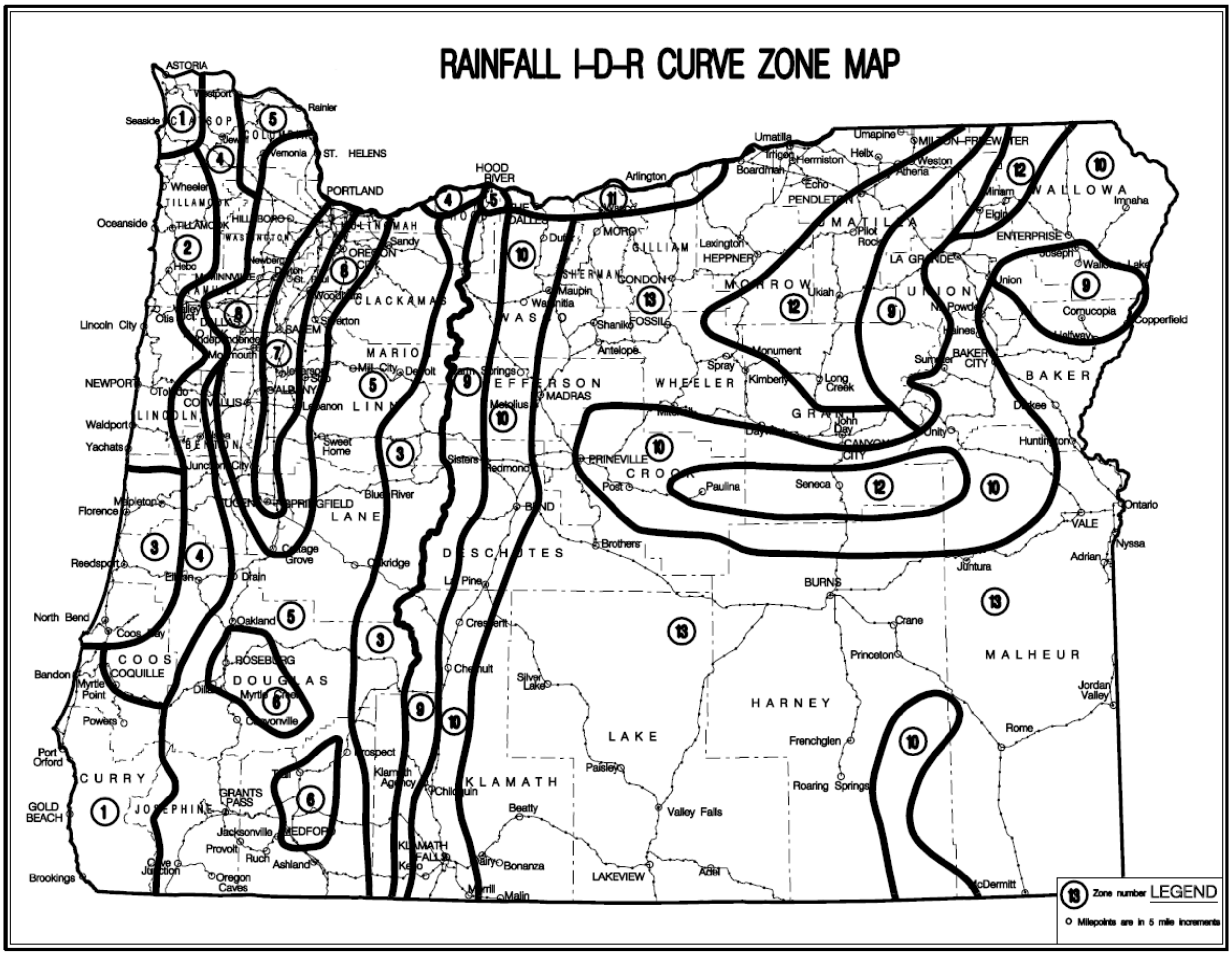


Figure 15. Rainfall Intensity Recurrence Curves (Zone 5)

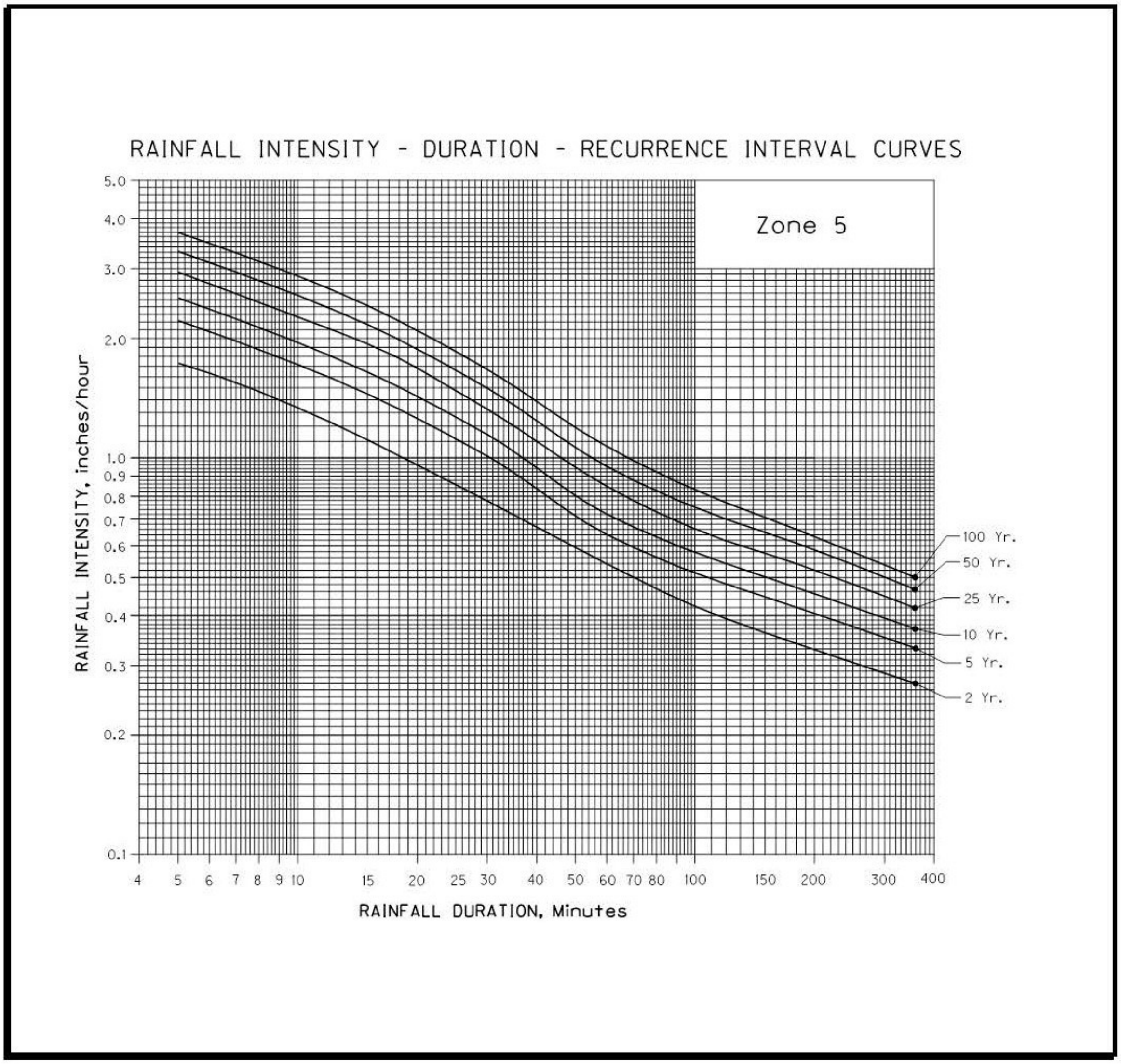


Figure 16. Rainfall Intensity Recurrence Curves (Zone 7)

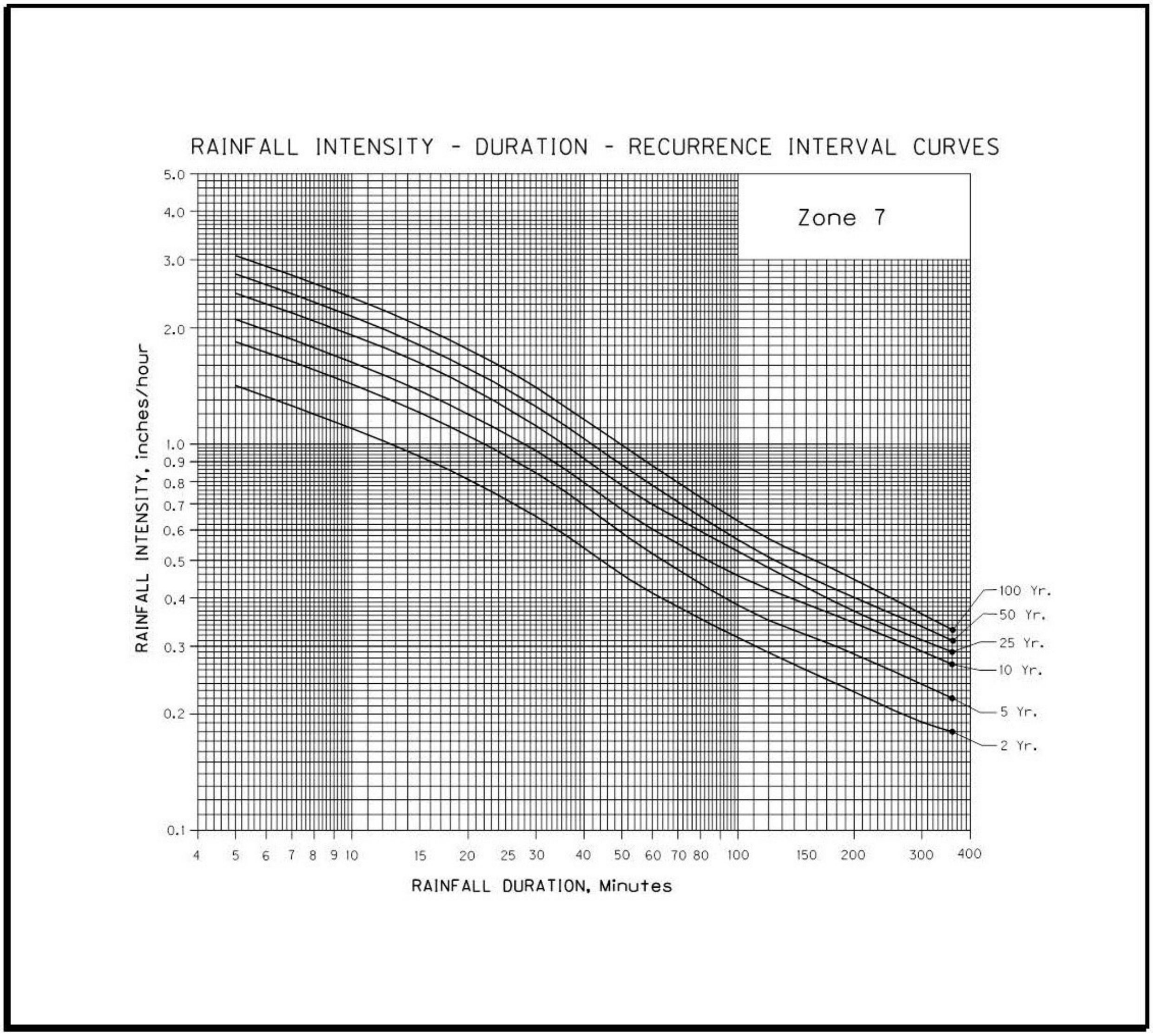
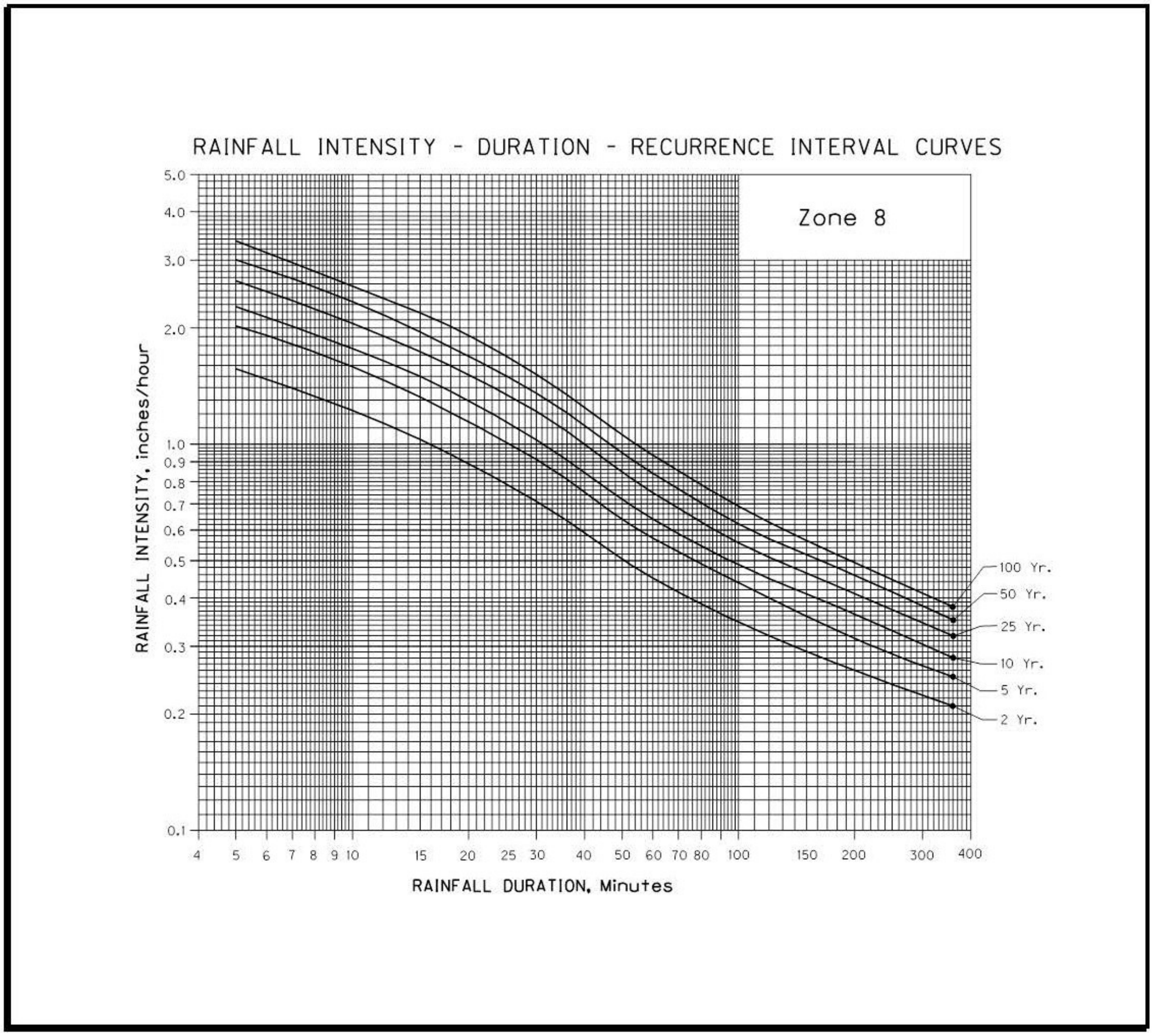


Figure 17. Rainfall Intensity Recurrence Curves (Zone 8)



5. NOAA Isopluvial Maps

The following figures are from the Precipitation-Frequency Atlas of the Western United States (Volume X – Oregon), published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service (1973).

Figure 18. Isopluvials of 2-YR, 24-HR Precipitation in Tenths of an Inch

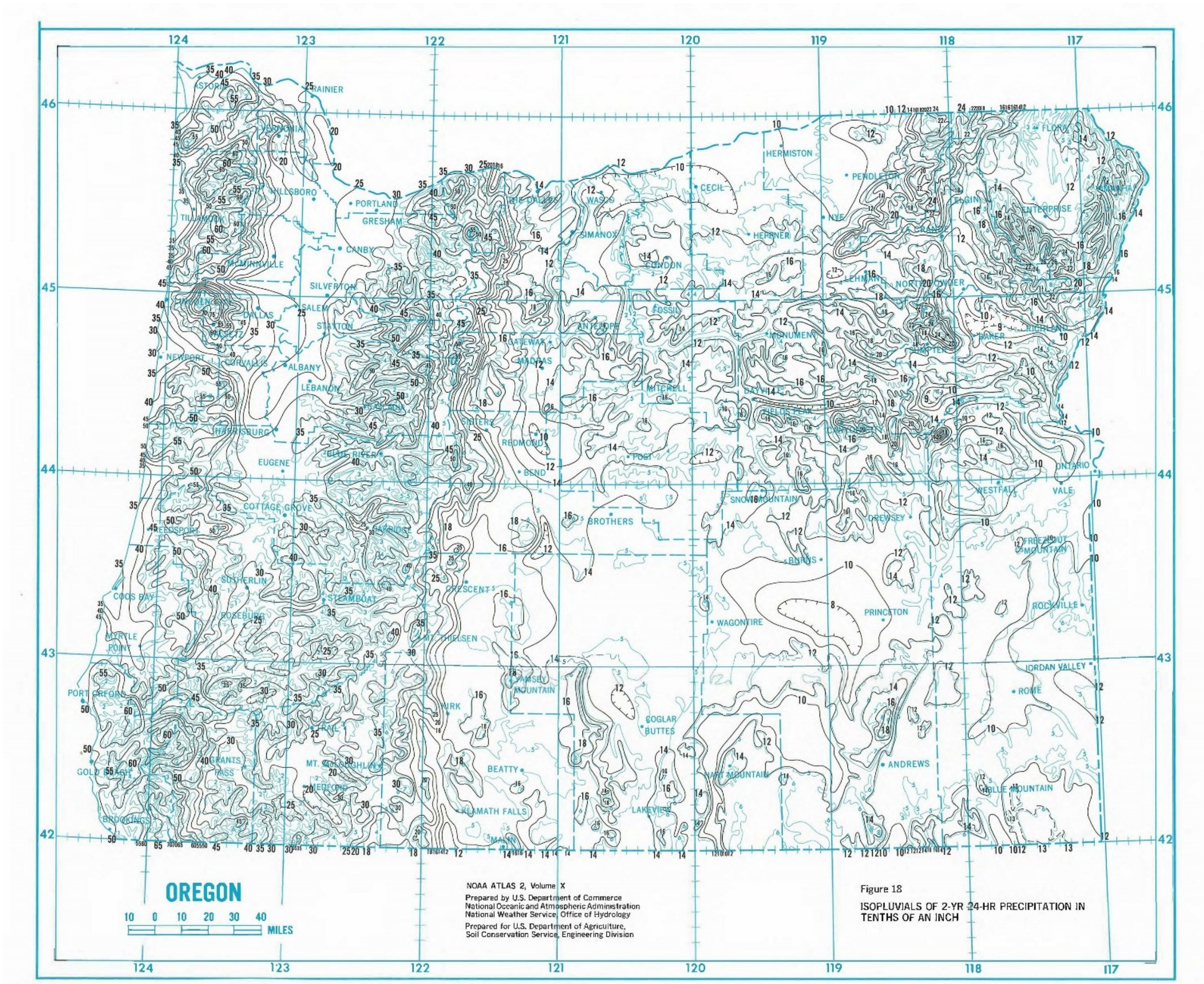


Figure 19. Isopluvials of 5-yr, 24-hr Precipitation in Tenths of an Inch

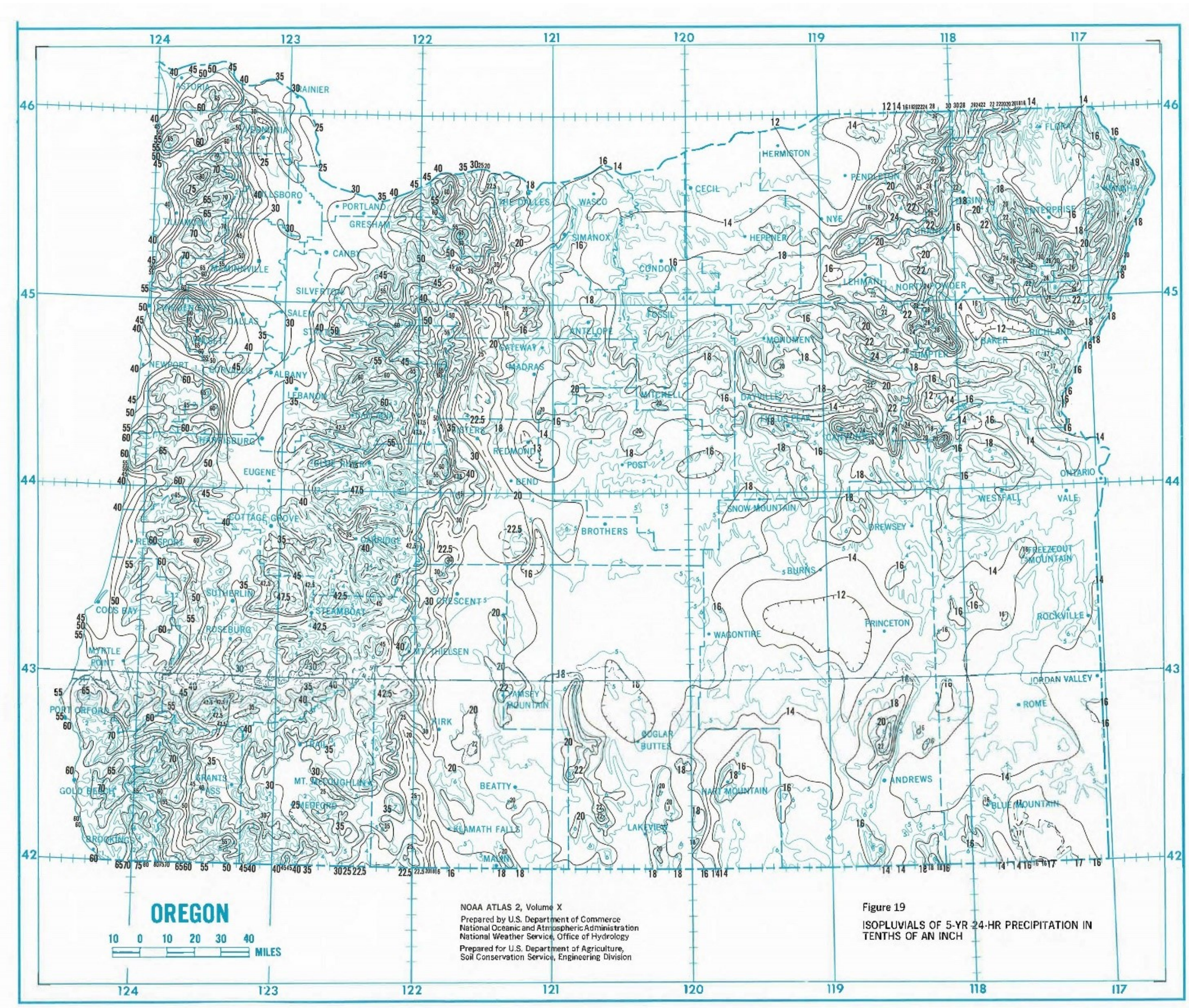


Figure 20. Isopluvials of 10-yr, 24-hr Precipitation in Tenths of an Inch

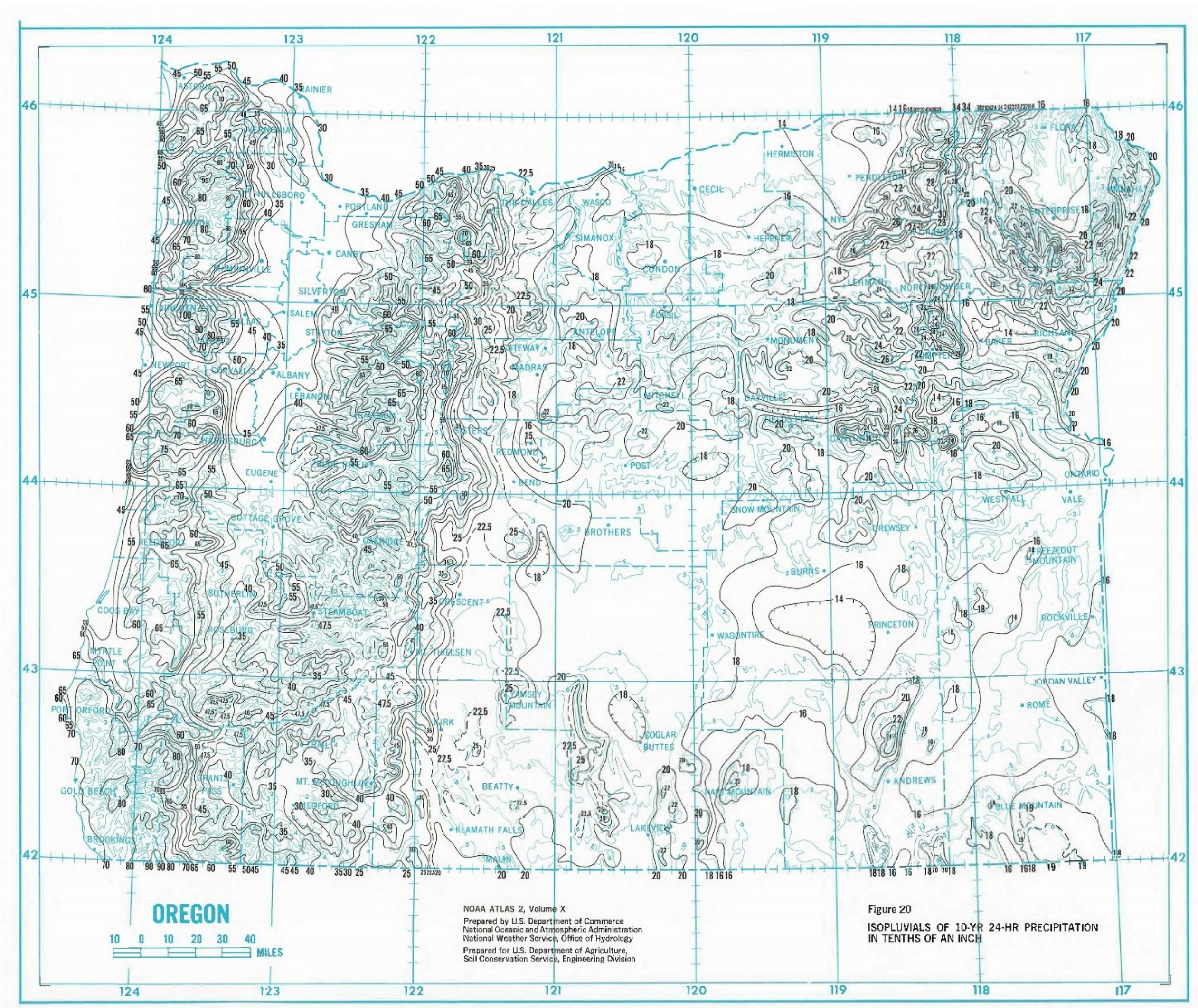


Figure 21. Isopluvials of 25-yr, 24-hr Precipitation in Tenths of an Inch

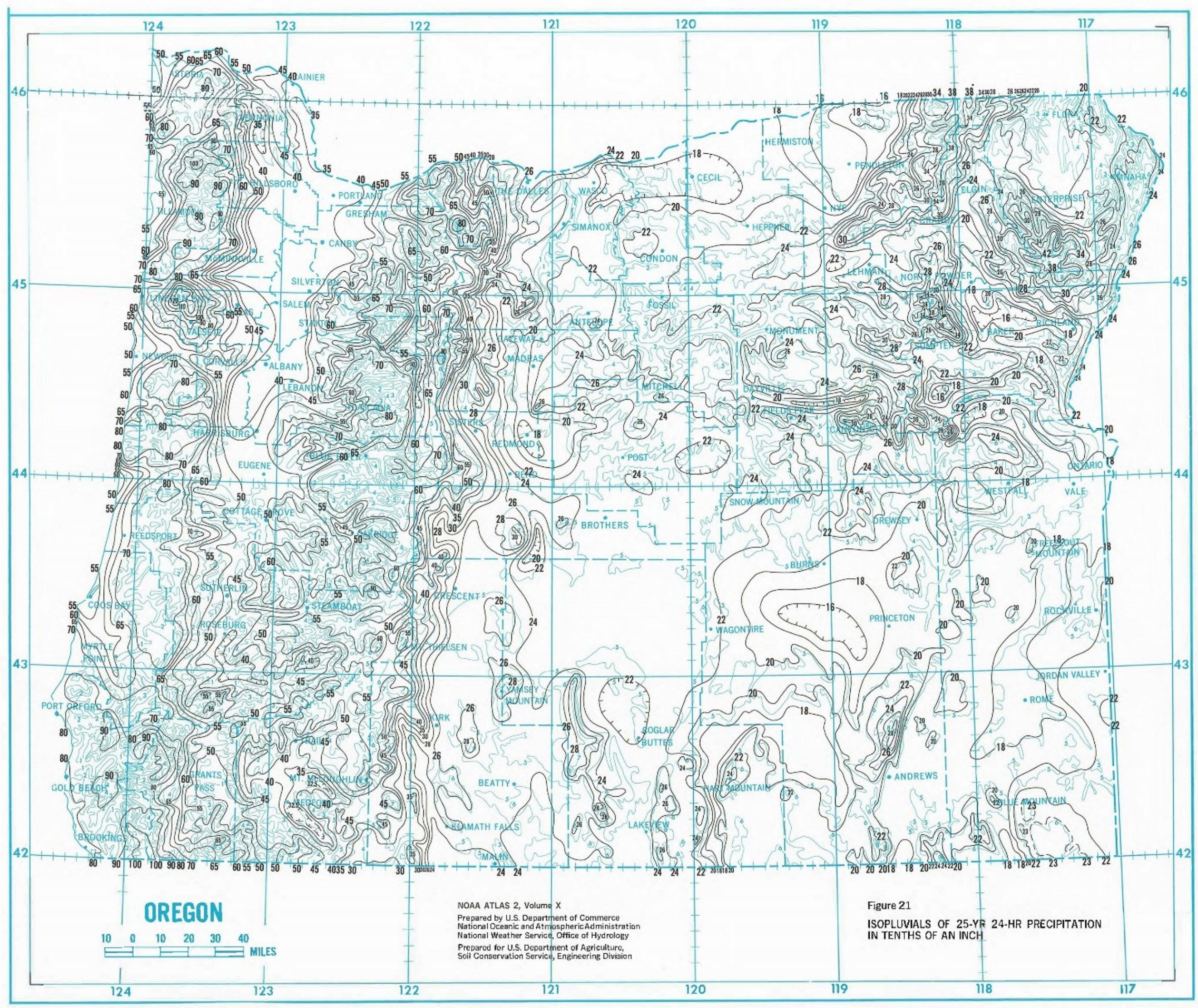


Figure 22. Isopluvials of 50-yr, 24-hr Precipitation in Tenths of an Inch

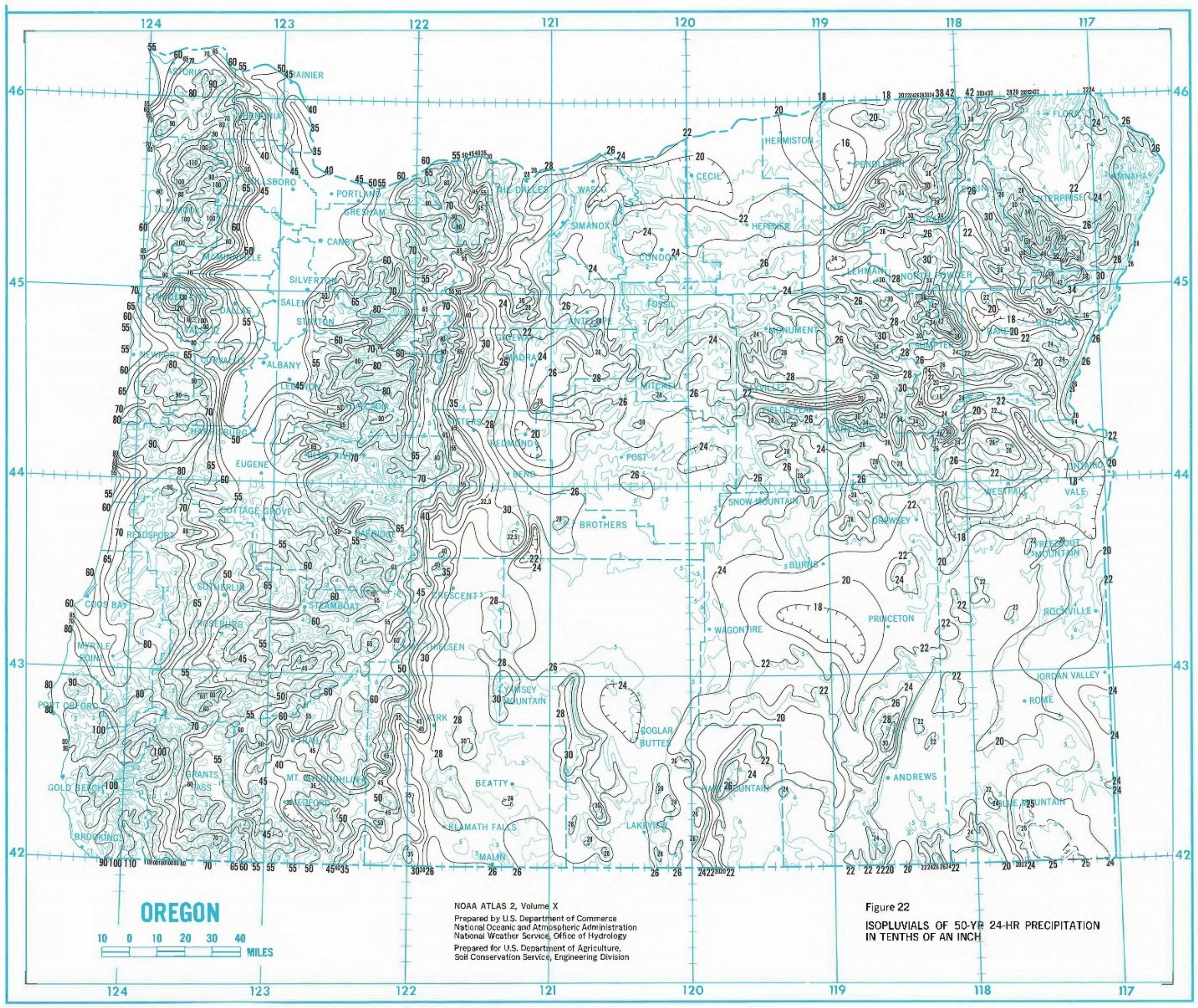


Figure 23. Isopluvials of 100-yr, 24-hr Precipitation in Tenths of an Inch