Estimation of Peak Discharges for Rural, Unregulated Streams in Eastern Oregon

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State of Oregon
Water Resources Department

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By Richard M. Cooper, PE

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Estimation of Peak Discharges for Rural, Unregulated Streams in Eastern Oregon

By Richard M. Cooper, PE

Abstract

Methods for estimating the magnitudes of peak discharges at various frequencies were developed for rural, unregulated streams in eastern Oregon. Development of these methods had two parts: (1) fitting observed peak discharges to a theoretical probability distribution and (2) the development of equations to predict the magnitude of peak discharges at various frequencies. In the first part, logarithms of annual peak discharges were fitted to the Pearson type III probability distribution for each of 276 gaging stations in the study area. For each gaging station, based on its fitted probability distribution, estimates were made of the magnitudes of the peak discharges for recurrence intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years. All annual series of peak discharges used in this analysis were from rural, unregulated streams.

In fitting the probability distributions, estimates of station skew were improved by adjustment with a "generalized" skew value based on the skews for long-term stations in the area. The areal distribution of the generalized logarithmic skew coefficients of annual peak discharge for Oregon was determined using geographic information systems (GIS) techniques. The actual areal distribution is a GIS grid but is represented in this report as an isoline map. In practice, generalized logarithmic skew coefficients are determined from the grid, not the isoline map.

Eastern Oregon was divided into six "flood regions." For each region, prediction equations were developed for estimating peak discharges at ungaged sites for the selected recurrence intervals. The equations relate peak discharge to physical and climatologic watershed characteristics such as drainage area and precipitation intensity. The equations were derived by generalized least-squares regression using data for the 276 gaged watersheds. Average standard error of prediction for the equations ranged from 37.7 to 104 percent. The accuracy of the equations and limitations on their use are discussed. Use of the prediction equations in various circumstances is illustrated with examples.

Use of the prediction equations requires estimates of watershed characteristics. Because of the reliance in this analysis on GIS techniques, making appropriate and reliable estimates of watershed characteristics may be inconvenient for many users. To make the prediction equations as widely available as possible, the Oregon Water Resources Department has developed an interactive Web site utility to facilitate the use of the equations:

http://www.wrd.state.or.us/OWRD/SW/peak_flow.shtml

In preparation for doing the flood frequency analysis, the relative importance of the hydrologic processes contributing to peak discharges was determined. Annual peak discharges occurred most frequently in spring and were most likely the result of snowmelt. Rain falling on snow in the months from December to February was the second most frequent cause of annual peak discharges. Convective storms in late spring and summer were responsible for only a minor part of all annual discharges.

For peaks with the largest unit discharges (greater than 500 cfs per square mile), however, most occurred in mid-winter, most likely the result of rain on snow. The second largest number of large unit peak discharges occurred in late spring and summer. These peaks were due mostly to thunderstorms. The largest unit discharges (greater than 1,000 cfs per square mile) were all due to thunderstorms.

Thunderstorms were essentially unrepresented in the systematic record used to develop the prediction equations presented in this report. What impact this had on the estimation of peak discharges is unknown.

Severe thunderstorms were associated with watersheds of a particular type. The watersheds were small, mostly not forested, and relatively hot, dry, and low in elevation. A map showing areas of eastern Oregon most likely to be affected by a severe thunderstorm was developed.

Introduction

A study of the magnitude and frequency of peak discharges in eastern Oregon has been completed by the Oregon Water Resources Department with financial assistance from the Federal Emergency Management Agency, the Oregon Department of Transportation, and the Association of Oregon Counties, and with the cooperation of the U.S. Geological Survey. The study was undertaken to provide engineers and land managers with the information needed to make informed decisions about development in or near watercourses in the study area.

Much development takes place near rivers and streams and usually involves a variety of engineered structures. Some structures such as bridges and culverts, dams, levees, and floodways are within the stream banks and generally are exposed to streamflow at all times. Other structures such as homes, businesses or agricultural buildings are exposed to streamflow only during times of flooding. Safe and economical design of these structures and correct assessment of the hazards of development in flood plains require knowledge of the magnitude and frequency of the peak discharges of nearby streams.

Peak discharges have the potential to extensively damage any structure exposed to them. The extent to which a structure is designed to withstand the impacts of peak discharges depends on the risk failure of the structure poses to life and property. In some cases, failure of the structure is unacceptable. For example, a dam upstream of a populated area will be designed to withstand and function properly under the probable maximum flood.

Usually the failure of a structure is more likely to cause property damage than loss of life. In these cases, it may make economic sense to replace the structure periodically rather than build it to withstand any extreme flood. For example, a remote, rarely traveled road may be designed with the expectation that culverts under the road will wash out on average once in 10 to 25 years. As another example, homes on flood plains typically are required to be built above the elevation of the flood likely to occur on average once in 100 years. Because risk assessment is an important part of planning and design, the magnitude of peak discharges at various frequencies is needed.

This report provides techniques for estimating the magnitudes of peak discharges at a variety of frequencies or “return intervals”. A return interval is the number of years expected to pass “on average” between peak discharges of a given magnitude. For example, consider the gaging station on the John Day River at McDonald Ferry, Oregon (14048000). Annual peak discharges have been measured at this site for 98 years through 2003. A magnitude and frequency analysis, described later, estimates the 2-year peak discharge to be 12,400 cubic feet per second (cfs). The largest peak each year is expected to exceed this value half the time, that is, every two years on average. In fact, for the 98 years of record the annual peak discharge exceeded 12,400 cfs 45 times. Similarly, the 100-year peak discharge is 42,700 cfs and is expected to be exceeded one-percent of the time or once in a hundred years on average. For the 98 years of record, one annual peak discharge exceeded 42,700 cfs.

Purpose and Scope

This report describes the results of an analysis of the peak discharges of *rural* streams in Oregon east of the crest of the Cascade Range (fig. 1). A previous report described a similar analysis for rural streams west of the crest of the Cascade Range (Cooper, 2005).

The results of this study include (1) the magnitude of annual peak discharges for selected frequencies at 276 gaging stations, (2) the areal distribution within eastern Oregon of generalized logarithmic skew coefficients for annual peak discharges, and (3) sets of prediction equations relating the magnitude of peak discharges at selected frequencies to physical and climatological watershed characteristics such as drainage area or mean January precipitation. A set of frequency specific prediction equations was developed for each of six hydrologically similar regions within eastern Oregon. The prediction equations may be used at ungaged sites to make estimates of peak discharges.

The selected peak discharge frequencies are described by the recurrence interval at which the peak discharge is likely to recur. The selected recurrence intervals are the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year peak discharge. A 10-year peak discharge has a probability of exceedance in any year of 0.10 or 10 percent, and a 100-year peak discharge, a probability of exceedance of 0.01 or 1 percent.

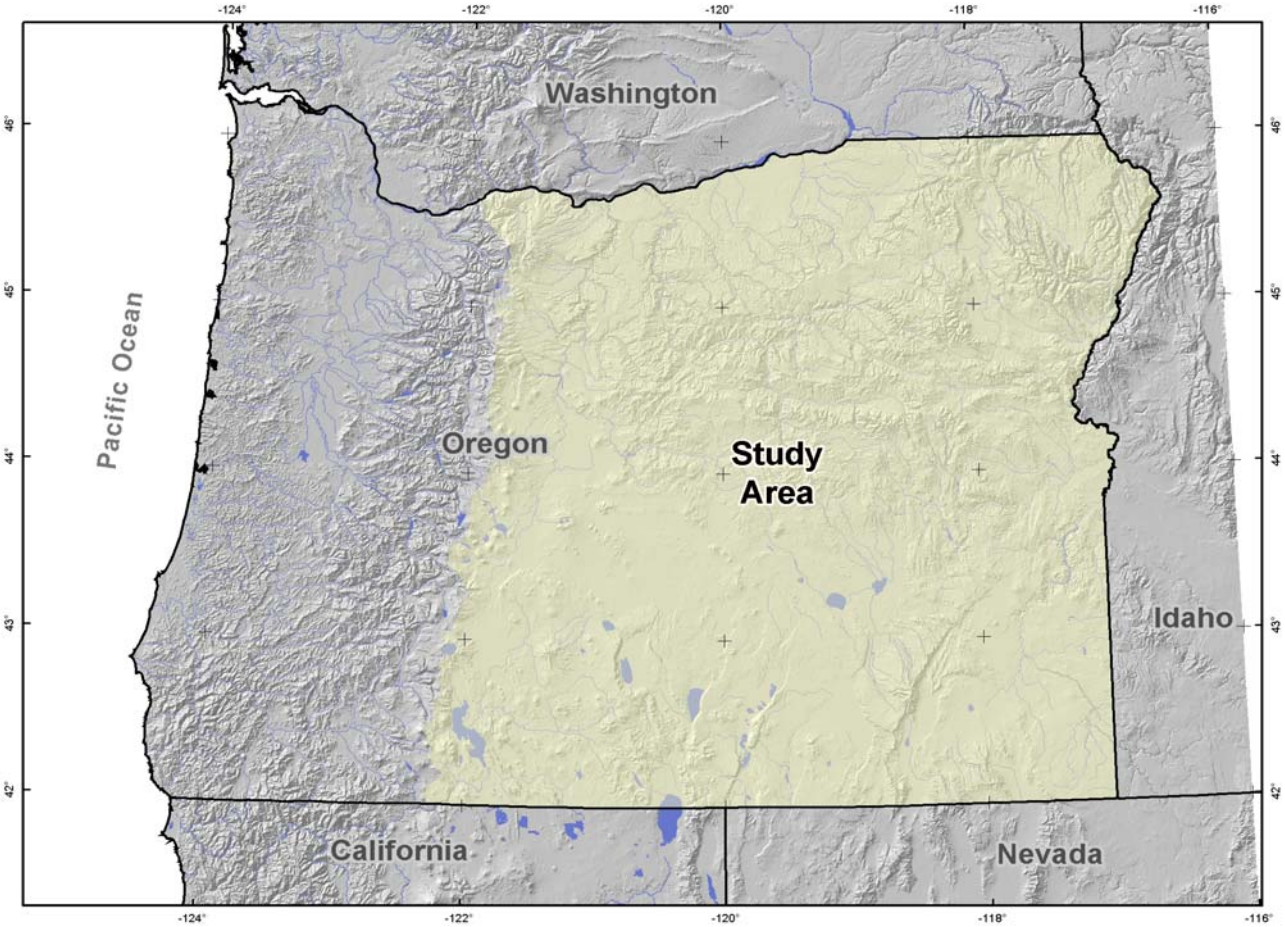


Figure 1. The study area in eastern Oregon.

The study described in this report is based on annual series of peak discharges for 276 gaging stations in eastern Oregon, southeastern Washington, western Idaho, northwestern Nevada, and northeastern California. The study had two parts: (1) a magnitude and frequency analysis, and (2) derivation of the prediction equations. In the magnitude and frequency analysis, a frequency distribution was fitted to the measured annual peak discharges of each gaging station. The fitted distribution was used to estimate the magnitude of annual peak discharges at selected frequencies. The prediction equations were derived using generalized least-squares regression analysis.

Although the analysis described in this report was based in part on gaging stations located in southeastern Washington, western Idaho, northwestern Nevada, and northeastern California, the resulting prediction equations are to be applied only to eastern Oregon. The out-of-State gaging stations were included to increase the information used in the derivation of the prediction equations, to reduce any edge effects in developing the generalized skew coefficients, and in some cases, because parts of the out-of-State gaging station watersheds lie in Oregon.

The prediction equations may be used to estimate peak flows for any stream. Be aware, however, that the prediction equations do not account for reservoir operations, diversion or urbanization. Many streams are affected by these factors. In these cases, the estimates of peak flow represent a hypothetical condition of the watershed, not the actual condition.

For peak discharges for urban watersheds, it is recommended that the prediction equations developed by Sauer and others (1983) be used. These prediction equations are applicable to urban areas anywhere in the United States. The equations

are included in the National Flood Frequency Program (Sauer, 2002).

The prediction equations require estimates of several physical characteristics of the watershed of interest. Most of these characteristics are estimated from regionalized data. These data are described later in the report and only the versions of the regionalized data described there should be used with the prediction equations. Sources for these data sets are listed elsewhere in the report. The best estimates of watershed characteristics are achieved by analyzing the regionalized data with geographic information systems (GIS) techniques rather than making the estimates manually from plotted isoline maps.

For these reasons, making appropriate and reliable estimates of watershed characteristics may be inconvenient for many users. To make the prediction equations as widely available as possible, the Oregon Water Resources Department has developed an interactive Web site utility to facilitate the use of the equations. The Web site and the options available there are described in a later section of the report.

Acknowledgements

This study was completed in part due to generous financial support from the Federal Emergency Management Agency (from both the National Dam Safety Program and the Federal Insurance and Mitigation Division), the Oregon Department of Transportation, and the Association of Oregon Counties. Their contributions are gratefully acknowledged.

Many thanks are due Ken Stahr who made numerous contributions. He has done the bulk of the GIS work. He delineated and digitized most of the watersheds, he managed all the various coverages and grids used to calculate watershed characteristics and calculated those characteristics, and he created several of the figures in this report. He is also largely responsible for developing a method for auto-delineation of watersheds. This method is used in a Web utility available from the Oregon Water Resources Department's Web site for estimating peak discharges at ungaged sites.

Bob Harmon is lead worker for GIS work in the Oregon Water Resources Department. He acquired the watershed characteristic grids and coverages used for this analysis and wrote the computer programs that calculate watershed characteristics.

Previous Studies

In the 1960s, the U.S. Geological Survey published a series of reports describing methods for determining the magnitude of floods at specified frequencies. These reports had the general title "Magnitude and Frequency of Floods in the United States". The U.S. Geological Survey previously had divided the continental United States into 14 large regions or "parts" of relatively similar hydrology, and each report in the series referred to one of these parts. Of interest here were the reports for Parts 10, 11, 13, and 14 - the Great Basin (Butler and others, 1966), Pacific slope basins in California (Young and Cruff, 1967), the Snake River basin (Thomas, Broom and Cummans, 1963), and Pacific slope basins in Oregon and the Lower Columbia River basin (Hulsing and Kallio, 1964), respectively.

In all of the reports, methods were described for determining the probable magnitude of peak discharges of any frequency between 1.1 (1.2 for part 11) and 50 years. The methods differed somewhat from one another, but had common elements. First, each gaging station used had more than 5 years of record and was unaffected by significant reservoir operations, diversions, or urbanization. Second, a frequency curve for each suitable gage was fitted visually to the annual peak discharges plotted on log-probability paper. Third, a regionalization of peak discharges was done by correlating a variety of watershed characteristics to one or more flood characteristics. Fourth, the study areas were divided into a number of sub-regions, a separate regionalization being made for each sub-region. Finally, the use of the prediction methods was limited to the range of the parameters used to develop the methods.

In all cases, all of the annual peak discharges used in the analysis were included in the report. The reports for parts 10, 13, and 14 included the watershed characteristics used to develop the prediction equations. For part 11, only some of the characteristics were included. For the analysis for part 10, 113 gaging stations were used, for part 11, 147 gaging stations, for part 13, 179 gaging stations and for part 14, 304 gaging stations.

Lystrom (1970) evaluated the streamflow-data program in Oregon. As part of that analysis, he

developed prediction equations for estimating peak discharge magnitudes for recurrence intervals of 2, 5, 10, 25, and 50 years. There were two sets of equations: one for western Oregon and one for eastern Oregon. Lystrom did not explicitly limit the use of the equations, but good practice would limit their application to the range of values exhibited by the characteristics of the watersheds used to develop the equations.

Lystrom's equations were derived by regressing peak discharges of a given frequency on watershed characteristics. Annual peak discharges were fitted to log-Pearson Type III distributions to obtain peak discharges of specified frequency. The regressions were done by ordinary least-squares. Standard errors of estimate ranged from 56 to 60 percent. The characteristics considered by Lystrom were drainage area, main-channel slope, percent area of lakes and ponds, mean watershed elevation, percent area of forest cover, mean annual precipitation, 2-year 24-hour precipitation intensity, mean minimum January temperature, and a soils index developed by the Soil Conservation Service. Of these, drainage area, percent area of lakes and ponds, mean annual precipitation, and the soils index appeared in the prediction equations Lystrom developed for eastern Oregon.

Lystrom's analysis was based on annual peak discharges for 222 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions were included in his report.

The Oregon Water Resources Department (1971) developed curves relating mean annual peak discharges to drainage area for 29 hydrologically similar regions in the State. Multipliers related the mean annual peak discharges to peak discharges for recurrence intervals of 1.01-, 1.05-, 1.25-, 2-, 5-, 20-, and 100-years. The analysis applied to all of western Oregon and parts of eastern Oregon. The curves were to be used for watersheds of less than 100 square miles.

The curves were developed from methods described by Hazen (1930). The only watershed characteristic required to use the curves was drainage area. The analysis was based on annual peak discharges for 120 gaging stations, most of which had more than 20 years of record.

Harris and Hubbard (1982) reported a method for estimating peak discharge magnitudes for unregulated streams in eastern Oregon for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Four sub-regions were defined: southeast, northeast, north central and eastern Cascades. A set of prediction equations was developed for each region. Harris and Hubbard did not explicitly limit the use of the equations, but, again, good practice would limit their application to the range of values exhibited by the characteristics of the watersheds used to develop the equations.

The equations were derived by regressing peak discharges of a given frequency on watershed characteristics. Annual peak discharges were fitted to log-Pearson Type III distributions to obtain peak discharges of specified frequency. The regressions were done by ordinary least-squares. Standard errors of estimate ranged from 58 to 93 percent. The characteristics considered were drainage area, main-channel slope, main-channel length, mean watershed elevation, percent area of lakes, percent forest cover, a soils index developed by the Soil Conservation Service, latitude of the gaging station, longitude of the gaging station, mean annual precipitation, 2-year 24-hour precipitation intensity, and mean minimum January temperature. Of these, only drainage area, main-channel length, mean annual precipitation, percent forest cover, and mean minimum-January temperature were used in the equations.

The analysis was based on annual peak discharges for 162 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions are included in Harris and Hubbard's report.

Campbell and others (1982) developed a method for predicting peak discharges on small, unregulated watersheds in Oregon for recurrence intervals of 10, 25, 50 and 100 years. Six sub-regions were defined. The four sub-regions in western Oregon were the same as those used by Harris and others (1979). In eastern Oregon, one sub-region was defined by watersheds in or near the upper Klamath River basin. A second sub-region was defined by watersheds in or near the John Day, Umatilla, Grande Ronde and Powder River basins. Watersheds used in the study ranged in size from 0.21 to 10.6 square miles.

In each region, annual peak discharge data from gaging stations with more than 20 years of record

were fitted to four frequency distributions: Gumbel, two-parameter log-normal, three-parameter log-normal, and log-Pearson Type III. The log-Pearson Type III distribution was determined to be best suited to all regions of the State.

Prediction equations were derived by regressing peak discharges of a given frequency (determined from fitting annual peak discharges to a log-Pearson Type III distribution) on watershed characteristics. The regressions were done using ordinary least-squares. Standard errors of estimate ranged from 60 to 89 percent for eastern Oregon. The characteristics considered were drainage area, mean watershed elevation, gage datum, main-channel slope, main-channel length, percent forest cover, latitude of the gaging station, longitude of the gaging station, mean annual precipitation, 2-year 24-hour precipitation intensity, and mean minimum January temperature. Of these, only drainage area was used in the equations for eastern Oregon.

The analysis was based on annual peak discharges for 80 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions were included in Campbell and others' report.

Thomas and others (1993) reported a method for estimating peak discharge magnitudes for unregulated streams in southwestern United States for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Their study area included much of eastern Oregon. Eight sub-regions were defined and a set of prediction equations was developed for each region. Watersheds in Oregon that coincide with their study area were all included in their region 2. Use of the equations was limited to watersheds with characteristics within the limits of the characteristics of the watersheds used to develop the prediction equations.

The prediction equations were derived by regressing peak discharges of a given frequency on watershed characteristics. Annual peak discharges were fitted to log-Pearson Type III distributions to obtain peak discharges of specified frequency. The regressions were done by generalized least-squares. Overall, standard errors of estimate ranged from 45 to 135 percent, but for region 2, they ranged from 61 to 72 percent. The characteristics considered were drainage area, main-channel slope, main-channel length, mean watershed elevation, elevation of the gage datum, percent forested area, latitude of the gage, longitude of the gage, mean annual precipitation, 100-year 24-hour precipitation intensity, mean annual free water-surface evaporation, distance from Gulf of Mexico, distance from Gulf of California, relation of gaged site to major orographic barriers, basin shape (length squared divided by area), potential vegetation at the gaged site, active channel width, channel slope of lower one-third of stream length, and an erodent factor. Of these, only drainage area, mean watershed elevation, mean annual precipitation, mean annual evaporation, and latitude and longitude of the gage had significant coefficients in the regressions. For region 2, only drainage area and mean watershed elevation had significant coefficients.

The analysis was based on annual peak discharges for 1,323 gaging stations with more than 10 years of record and unaffected by significant reservoir operations, diversions, or urbanization. The watershed characteristics for each of the gaging stations used in the regressions were included in the report.

Current Study

The current study improves on previous work in several important ways. Because of these improvements, the prediction equations developed for this study are considered more reliable than prediction equations previously reported for use in eastern Oregon and should be used in lieu of equations from previously published reports for eastern Oregon.

First, more gaging stations were used in this study than in other studies. Most other studies have used only peak discharge record published by the U.S. Geological Survey. This study includes peak discharge record published by the U.S. Geological Survey and the Oregon Water Resources Department.

Second, more than 20 years of streamflow record has been collected since the last comprehensive study for eastern Oregon (Harris and Hubbard, 1982). This new record includes continuation of record at existing stations and addition of record at new stations by both the U.S. Geological Survey and the Oregon Water Resources Department.

Third, generalized logarithmic skew coefficients for Oregon have been developed specifically for this

study. The most recent previous study (Harris and Hubbard, 1982) used the generalized logarithmic skew coefficients provided by the U.S. Water Resources Council in Bulletin 17A (1977). The new generalized skew coefficients are based on more peak discharge data than the previous analysis of generalized skew. In the 25 years since the previous analysis, new stations have been established and records at many previously existing stations have been extended.

Fourth, more watershed characteristics and better methods to estimate them are now available. Many physical and climatological characteristics of watersheds have been regionalized and put into digital formats in recent years. By using these regionalized characteristics in conjunction with GIS techniques, estimation of watershed characteristics is easier, more precise, more accurate, and more readily reproduced than previously possible.

Finally, other studies in Oregon have used ordinary least-squares regression to develop the prediction equations. This study uses a generalized least-squares analysis that accounts for unequal lengths and variances of streamflow records and cross-correlation between series of streamflow characteristics where ordinary least-squares regression does not.

Description of the Study Area

The study area includes all of Oregon east of the crest of the Cascade Range (fig. 1). Some of the gaging stations used in the analysis lie outside of the study area. These stations are located adjacent to the study area in southeastern Washington, western Idaho, northwestern Nevada and northeastern California. By physiography and climate, these out-of-State areas are extensions of the adjacent regions of the study area.

Eastern Oregon comprises two-thirds of the state. It lies in the rain shadow of the Coast and Cascade Ranges and is much drier than western Oregon. Over large areas of eastern Oregon, annual precipitation is less than 20 inches (G.H. Taylor, Oregon State Climatologist, written commun., 2002). In the extreme, the Alvord Desert east of the Steens Mountains has a mean annual precipitation of less than 4 inches. Mountainous regions in eastern Oregon receive upwards of 30 inches annually with areas of the Wallowa Mountains receiving more than 80 inches.

Much of the northern and eastern parts of eastern Oregon drain to the Pacific Ocean by way of the Columbia and Snake Rivers. Major drainages include the Deschutes, John Day, Umatilla, Grande Ronde, Powder, Malheur and Owyhee Rivers. Southwestern eastern Oregon also drains to the Pacific, in this case, by way of the Klamath River. The remainder of eastern Oregon has no outlet to the sea and is part of the Great Basin of the western United States. Major drainages include the Chewaucan and Silvies Rivers. Regions of eastern Oregon receiving less than about 15-20 inches of rain annually are generally without trees except along watercourses. The dominant vegetation is sagebrush or grass. Wetter areas tend to be forested except at higher elevations above the tree line.

Physiography

Principal physiographic features of the study area are the eastern Cascades, the Deschutes-Umatilla Plateau, the Blue Mountains, the High Lava Plains, the Owyhee Uplands, and the Basin and Range (fig. 2). With the exception of the High Lava Plains, these physiographic features are parts of larger features that extend into adjacent states.

Land surface elevations in eastern Oregon are generally over 3,000 feet. Only the Deschutes-Umatilla Plateau has lower elevations, the land surface dropping below 500 feet along the Columbia and Deschutes Rivers. Most of Oregon's high country occurs in the eastern part of the state. Extensive areas of the Wallowa, Elkhorn, Strawberry and Steens Mountains exceed 8,000 feet.

The Cascade Range parallels the Pacific coastline extending from British Columbia, across both Washington and Oregon, and into California to the Sierra Nevada. The elevation of the crest line of the Cascades is generally over 4,000 feet with several peaks exceeding 10,000 feet. In Oregon, the Cascade Range provides a continuous hydrologic divide along its length. Almost all watersheds draining the east side of the Cascades are tributary to just two streams: the Deschutes and Klamath Rivers.

The eastern Cascades are composed primarily of geologically recent andesite and basalt flows and volcanic tuff and ash deposits (Baldwin, 1981). Much of this rock is highly permeable and many streams are fed by large springs. In fact, some of the largest springs in the United States occur along the eastern side of the Cascades (Meinzer, 1927). This highly

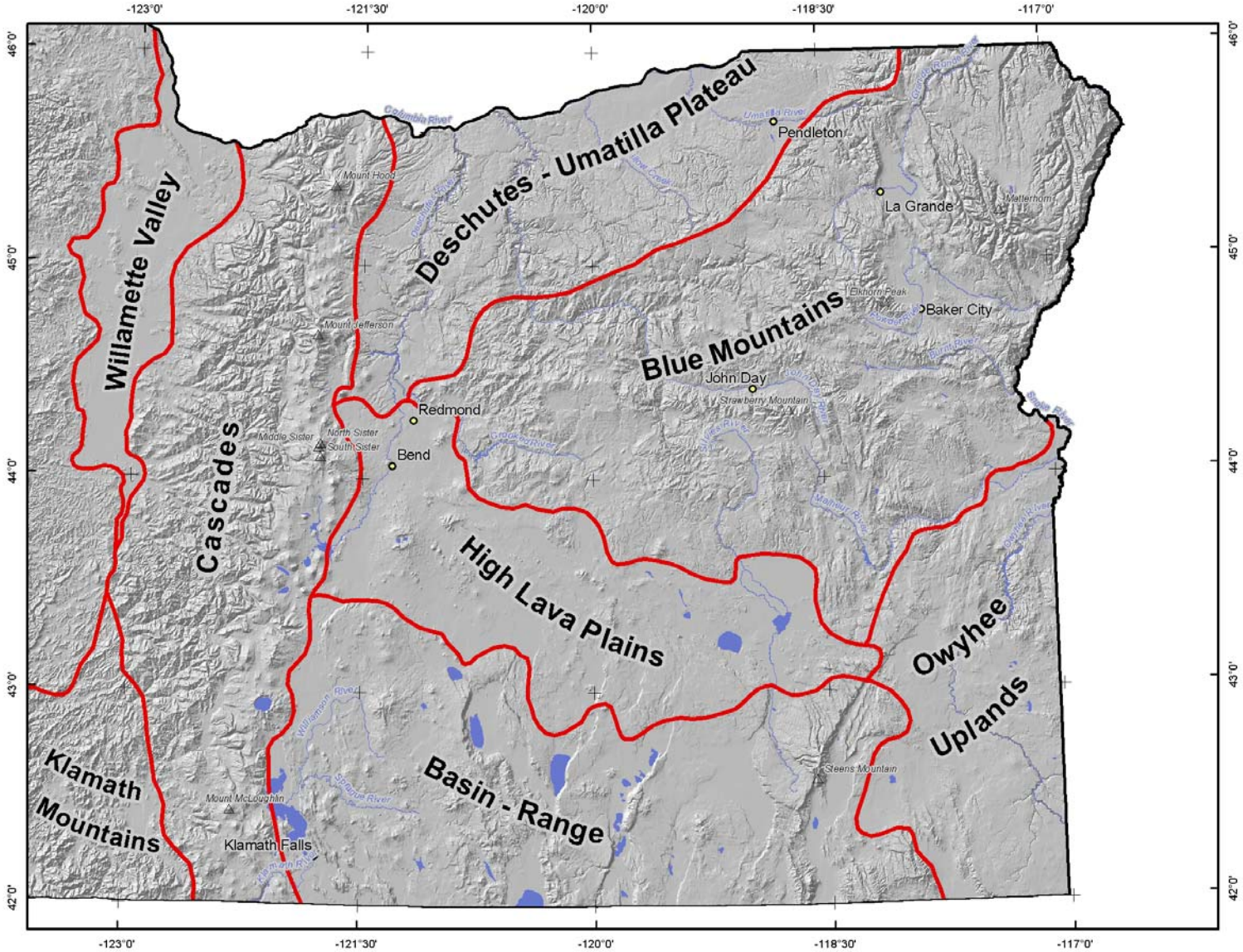


Figure 2. Physiographic features of Oregon. Physiographic regions are based on Dicken (1965) and Baldwin (1981).

permeable rock makes watershed boundaries uncertain in many areas (Gannet and others, 2000). In spite of relatively high precipitation, many areas show poor stream development because of the highly permeable rock.

The highest elevations in the eastern Cascades receive the most precipitation. Precipitation decreases rapidly with elevation from west to east. Vegetation also changes dramatically. The highest, wettest areas are heavily forested. As elevation and precipitation decrease, forest gives way to open stands of juniper and finally to sagebrush or grasslands. Much of the sagebrush and grassland areas are now in agricultural production.

The Deschutes-Umatilla Plateau in north-central Oregon is part of the much larger Columbia basin that also occupies much of eastern Washington. This region drains the northern side of the Blue Mountains. The land slopes gently to the north from elevations of 3,000 feet to a few hundred feet along the Columbia River.

Uplands of the Deschutes-Umatilla Plateau receive significant precipitation and stream networks are well developed. Lowlands are much drier, and few streams originate there. Streams crossing the lowland areas have cut deeply incised canyons. They include the Deschutes, John Day, and Umatilla Rivers and Willow and Butter Creeks. Upland areas, being the wettest, are the most heavily vegetated, and are forested. The lowlands, however, are sparely vegetated, dominated by sagebrush and grasslands. Much of these dry lowland areas is now used for agriculture.

The Blue Mountains of northeastern Oregon are comprised of several mountain ranges separated by faulted valleys and synclinal basins (Baldwin, 1981). Ranges include the Ochoco, Aldrich, Strawberry, Elkhorn, and Wallowa Mountains. The ranges are separated by the John Day, Grande Ronde, and Powder Rivers and their tributaries.

The Blue Mountains are rugged and steep sloped with high relief in many areas. The Wallowa Mountains, for example, have several peaks over 9,000 feet and extensive alpine areas. The Blue Mountains are the wettest area of eastern Oregon and stream networks are well developed. Most of the Blue Mountains is wet enough to support forest. Lowland valleys generally are not, and the vegetation is dominated by sagebrush and scattered grasslands. Lowland areas with access to water are in agricultural production.

The High Lava Plains region is located in the center of eastern Oregon between the Blue Mountains to the north and the Basin and Range to the south. The region has low relief and is lower in elevation than surrounding regions, though elevations still exceed 3,000 feet. Large lakes occupied much of this region during the Pleistocene. These lakes are gone from the western portion of the region, Christmas Lake and Fort Rock Valleys, but in the Harney Basin to the east, Harney and Malheur Lakes persist. The large expanses of relatively flat terrain are occasionally broken by cider cones and lava buttes. The west end of the region, however, is dominated by Newberry Crater, the remnants of a large shield volcano.

The High Lava Plains are very dry. There is almost no stream development in the region. The only perennial streams are Silver Creek and the Silves and Donner und Blitzen Rivers. These streams cross the plains, emptying into Malheur Lake, but they originate in the Blue and Steens Mountains. The dominant vegetation is sagebrush and grasslands with occasional areas of scattered junipers. Areas with access to water are used for agriculture.

The Owyhee Upland is located in the extreme southeastern part of Oregon. It is part of a large basin extending into Idaho. The basin slopes to the north and is drained by the Owyhee River. Elevations within Oregon are generally above 4,000 feet, with a few areas above 6,000 feet. Precipitation in this region is very low, most areas receiving less than 12 inches. Vegetation is sparse and is dominated by sagebrush and grasslands. Because of the low precipitation, stream development is minimal, and there are few perennial streams. The Owyhee River is deeply incised through this region.

The Basin and Range occupies the southern part of eastern Oregon. It is part of a much larger physiographic province extending into the southwestern United States. It is characterized by north trending fault-block mountains interspersed with internally draining basins (Baldwin, 1981). Major ranges include Winter Rim, Abert Rim, the Warner Mountains, Hart Mountain, Steens Mountain, and the Pueblo Mountains. Major basins include the Klamath, Goose Lake, and Summer Lake basins; Warner, Guano, and Catlow Valleys; and the Alvord Desert. Klamath, Summer, Abert, Goose and Warner Lakes are remnants of much larger Pleistocene lakes that once filled these basins.

The western portion of the Basin and Range region is much wetter than the eastern portion and is mostly forested. The eastern portion is vegetated by sagebrush and grasslands even in higher, wetter areas. Stream networks are poorly developed and there are few perennial streams. In the western portion, highly permeable rock and soil inhibit stream development, and in the east, low rainfall. Important streams are the Sprague and Chewaucan Rivers, Deep, Thomas, Honey, and Trout Creeks, and the Donner und Blitzen River.

Climate

Weather in Oregon is determined mostly by the behavior of the jet stream (Taylor and Hannan, 1999). In winter, the jet stream typically flows directly over the Pacific Northwest. This pattern pushes series of air masses from the Pacific Ocean over Oregon. Air masses are large bodies of air of relatively uniform temperature and moisture. Where air masses with different temperatures collide, called a front, stormy weather usually results. Because these colliding air masses are moist, they bring cloudy skies and precipitation to the northwest.

Most of the time, these air masses move over the State from the west. They bring mild temperatures and showers or low intensity rain. This pattern may dominate Oregon weather for weeks at a time. Occasionally, the jet stream directs air masses over Oregon from the subtropics to the southwest. This pattern brings warm temperatures and very wet weather. Oregon's wettest weather results from this pattern. Another occasional winter pattern directs air masses from the Gulf of Alaska over Oregon. This pattern brings cold temperatures and snow to low elevations.

In summer, the jet stream moves to the north and Oregon is typically under a ridge of high pressure. As a result, summers are warm and dry. In this pattern, air masses from California and from the Great Basin may bring relatively moist air into Oregon resulting in thunderstorms in eastern Oregon and the Cascades.

Although western and eastern Oregon are both under the influence of the same large-scale weather patterns, climates in the two regions are markedly different. This difference is a result of the Coast and Cascade Ranges that lie perpendicular to the path of the air masses arriving over Oregon from the Pacific. These mountains remove most of the moisture from the air masses as they pass to the east. Consequently, eastern Oregon is much drier than western Oregon.

The mountains restrict air movement from both east to west and west to east. As a result, weather in eastern Oregon is influenced less by the Pacific Ocean, and western Oregon is influenced less by air from the continent. Eastern Oregon is then both colder in winter than western Oregon and warmer in summer. The warmer summer temperatures make eastern Oregon prone to many more thunderstorms than western Oregon as well as to thunderstorms of greater intensity.

Rainfall due to frontal storms from the Pacific shows a pronounced seasonality in both western and eastern Oregon with the most precipitation from these storms occurring in December and January and the least in summer months. Because there are few thunderstorms in western Oregon, almost all precipitation is from these frontal storms, and occurs from November to April or May. In eastern Oregon, however, thunderstorms provide significant summer precipitation being nearly equal to that arising from winter storms. Rainfall patterns in eastern Oregon do not show a strong seasonality with relatively uniform rainfall from month to month. Even with the thunderstorms, rainfall amounts in eastern Oregon, both winter and summer, are much less than for western Oregon.

Characteristics of Peak Discharges

Peak discharges in the study area result primarily from three hydrological processes: (1) rainfall from frontal storms moving eastward from the Pacific Ocean, (2) snowmelt, and (3) rainfall from convective storms. Many peak discharges, including some of the largest peaks, result from a combination of processes, for example, warm rain falling on accumulated snow. For a few watersheds in the Cascade Range, annual peak discharges result from spring flow. Very rarely a peak discharge results from a glacial outburst. The most recent of these occurred in September 1998 from the White River Glacier on Mt. Hood.

Frontal Storms

Frontal storms occur mostly in winter and are regional in affect. Precipitation from these storms falls mostly as snow in eastern Oregon. Rain is most likely in October and November or in April and May.

Precipitation intensities for these storms tend to be low, but storms may last for several days. When the precipitation is in the form of rain, streamflow usually increases rapidly and then, after the front has passed, decreases gradually over several days. Maximum flows are sustained for only a short time – perhaps a few hours. When precipitation is in the form of snow, streamflow is likely to remain unchanged or decrease if temperatures are very low. Streamflows in eastern Oregon tend to be near annual minimums during the winter months. Annual peak discharges associated with rain only events are rare.

Snowmelt

Snowmelt usually occurs in spring and is responsible for most peak discharges in eastern Oregon though not the largest peaks. As the weather warms in the spring, as a general trend, streamflow from snowmelt increases gradually over several weeks. Eventually, as the snow pack diminishes, streamflow begins a gradual decline to base flow levels. The maximum streamflows associated with this general trend may be sustained for a week or more. Superimposed on this general trend are numerous short duration peaks due to diurnal temperature variation and to short periods of either rain or high temperatures. Maximum flows associated with these superimposed peaks are sustained only briefly. The overall peak discharge for the period will result from one of these superimposed peaks. The time of occurrence of maximum snowmelt depends on elevation - in March at lowest elevations and in June, or even July, at highest elevations

Convective Storms

Although convective storms may occur anytime, storms of greatest intensity occur in late spring or summer. Rainfall intensities for these storms may be high, but their durations are short. Streamflow hydrographs associated with convective storms rise and then decrease rapidly. Maximum flows are not sustained.

Floods from thunderstorms have other important characteristics. They are local, affecting only a small area, and although peak discharges may be very large, flow volumes are small and peak discharges attenuate quickly. The flash flood on Bridge Creek and its tributaries on July 13, 1956 (Hendricks, 1964) illustrates these points.

The flood flow resulted from brief, intense rainfall falling over a relatively small, un-forested area. These conditions resulted in a flood that concentrated quickly with high flow rates and unit runoff but small flood volume, only 2,700 acre-feet. The peak discharge was 54,500 cfs from Meyers Canyon and 14,400 cfs from Bridge Creek above Gable Creek (upstream of Meyers Canyon). However, the peak discharge in Bridge Creek 8.5 miles downstream from Meyers Canyon was only 16,300 cfs. The peak lasted only 10 to 15 minutes and the stage dropped 7 feet in around 2 hours.

This storm also generated an unknown amount of flow from Girds Creek, which is adjacent to Bridge Creek. Bridge and Girds Creeks are both tributaries of the John Day River. On July 14 between 3:30 and 4:00 PM, flow at McDonald Ferry on the John Day River increased from 1,400 cfs to 6,600 cfs, then receded slowly to 1,600 cfs by 10:00 am on July 15.

Sometimes convective storms in eastern Oregon produce no precipitation (G.H. Taylor, Oregon State Climatologist, written communication, 2004). These dry lightening storms result from air masses originating over the Gulfs of Mexico or California. As these air masses move north, they lose much of their moisture over the mountains of Arizona, New Mexico, Nevada and California. By the time they arrive here, they are relatively dry. They produce lightening over our mountains, but little rain.

Mixed Processes

Occasionally, storms from the subtropical Pacific bring rain to eastern Oregon even in mid winter. In these cases, rain often falls on snow and frozen ground, producing among the largest peak events in eastern Oregon. The storms of December 1964 and February 1996 were of this type. Rain on snow events may occur anytime from about November through May.

Spring Flow

A number of streams in eastern Oregon are strongly influenced by spring discharge. Generally, the watersheds of streams with significant springs have high groundwater recharge rates resulting in attenuated peak discharges and high base flows. A characteristic of streams influenced by spring flow is a low ratio of maximum to minimum discharges.

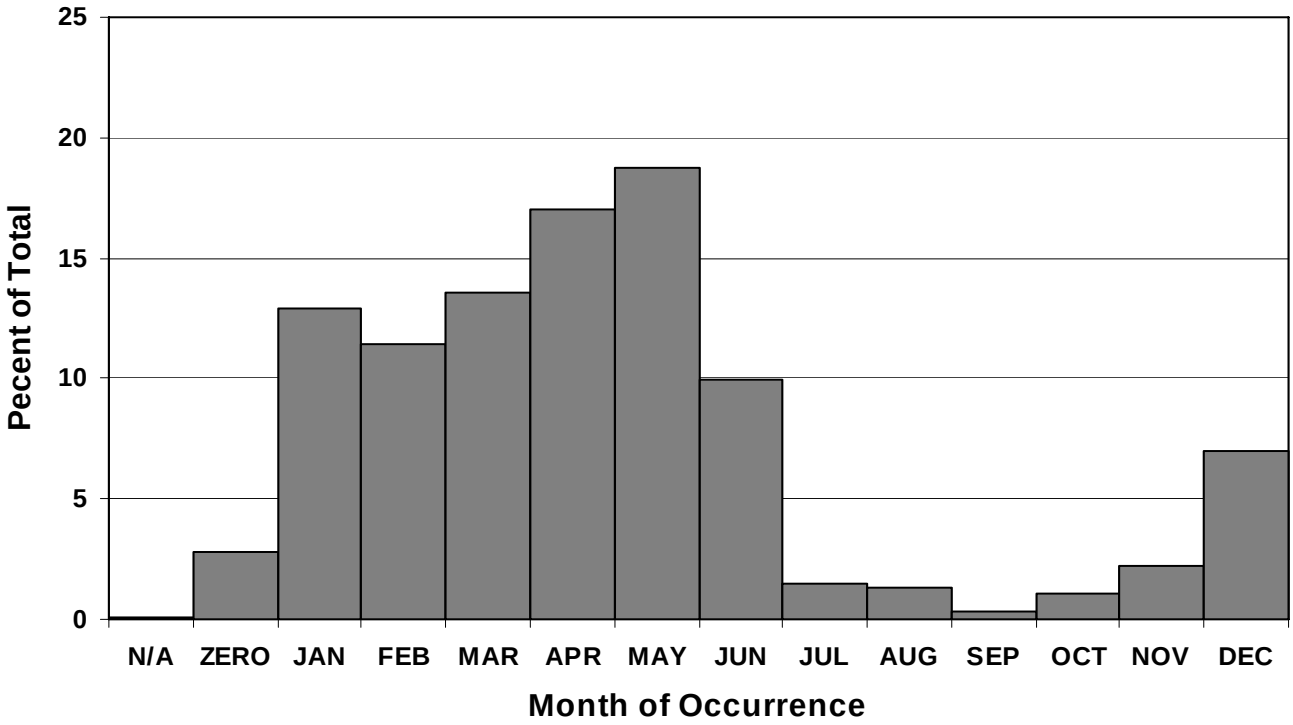


Figure 3. Distribution of monthly occurrence of 6,960 observed peak discharges. Zero is the percent of zero peaks (2.8 percent). N/A is the percent of peaks that are not zero, but for which the date of occurrence is unknown (0.1 percent).

Most of the larger, most strongly spring influenced streams are associated with the young, highly porous volcanic rock of the eastern slope of the Cascade Mountains and parts of the Klamath basin. For some of these watersheds, peak discharges are dominated by spring flow, with some peaks due entirely to spring flow. These peaks tend to occur in late summer and early fall. The timing and the magnitude of the peaks are related to the travel time of groundwater from time of recharge from snowmelt or rainfall to the time of discharge at the spring. The Deschutes River above Snow Creek near La Pine, OR (14050000) is an example of such a watershed.

Significant springs occurring in areas other than the Cascades are rare and tend not to dominate peak discharges, only contribute to it. Of the gaging stations considered for this study and located in these areas, only the South Fork Burnt River above Barney Creek near Unity, OR (13270800), the South Fork Walla Walla River (14010000 and 14010500), and Bridge Creek near Frenchglen, OR (10397000) have significant contributions from spring flow.

Relative Importance of Underlying Processes

An analysis was done to determine the relative importance of the hydrologic processes contributing to peak discharges. Although it is difficult to classify an individual peak as to the types of hydrologic processes it resulted from, some general conclusions about all peaks can be made. First, assume that the hydrologic processes associated with a peak discharge are related to its season of occurrence. For example, rain and rain on snow events are most likely in winter, snowmelt in spring and thunderstorms in summer. Unfortunately, none of these classifications is definitive, only likely. Still, an analysis of this type indicates the relative importance of the hydrologic processes contributing to peak discharges.

In order to see how peak discharges in eastern Oregon are distributed in time, they were grouped by their month of occurrence (fig. 3). All east side peak discharges unaffected by regulation or urbanization were included even if the associated gaging station did not qualify for inclusion in the flood frequency analysis. (Gaging stations excluded from the flood

frequency analysis but used here included those with fewer than 10 years of record or with too many zero peaks or peaks below the gage threshold.) In all, 6,960 peaks representing 340 watersheds were identified. Only peak discharges occurring on watersheds in eastern Oregon were included in this analysis; out-of-State peaks were not.

From the distribution of all peak discharges, it is clear that most annual peak discharges occurred in spring. These peaks were most likely due to snowmelt; though rain falling on already melting snow may have contributed. The second most number of peaks occurred in January and February. These mid-winter peaks were most likely due to warm rain falling on accumulated snow and frozen ground.

Fewer than 5 percent of all peak discharges occurred from July through October. These peaks were most likely due to thunderstorms, though some, like those in September of 1977, were due to frontal storms. Some of the peaks in May and June are known to be from thunderstorms, but what part is unknown.

Peaks with Large Unit Runoff

A similar analysis was done for the 89 peak discharge events with unit runoffs[1] greater than 100 cfs per square mile (table 1 and fig. 4). These largest peak discharges show a very different distribution from the set of all peaks. The largest number of large peaks occurred in mid-winter. These peaks most likely were the result of warm rain falling on snow and frozen ground. The chart shows that these rain-on-snow events were responsible for a significant portion of the largest unit peak discharges in eastern Oregon. The second largest number of large peaks occurred in late spring and summer. These peaks were due mostly to thunderstorms. The largest events in terms of unit runoff occurred because of these summer thunderstorms. The 89 peak discharges are plotted against area on figure 5. Peak discharges that plot above the 1,000 cfs per square mile line were most likely all due to thunderstorms.

The 89 largest peaks were plotted against five selected watershed characteristics (fig. 6). The watersheds associated with the 13 unit peak discharges greater than about 500 cfs per square mile have some interesting similarities. All have areas less than 50 square miles, mean annual precipitations less than 20 inches, mean watershed elevations less than 4,000 feet, mean maximum July temperatures greater than 80 degrees Fahrenheit, and percent forest cover less than 35 percent. Of the 13, 10 had percent forest cover of less than 1 percent.

The relationships of the other 76 large unit peak discharges to watershed characteristics are less clear. To get a better picture, the watersheds associated with the 89 largest unit peak discharges were scored based on the same five watershed characteristics used in figure 6.

Each watershed received one point for any of the following that are true: 1) drainage area less than 50 square miles, b) mean annual precipitation less than 20 inches, c) mean watershed elevation less than 4,000 feet, d) maximum July temperature greater than 80 degrees Fahrenheit, and e) forest cover less than 35 percent. The scoring for at least one of the watersheds is misleading. The peak discharge for Willow Creek at Heppner, OR (14034500) arose entirely from one tributary, Balm Fork. While Willow Creek scores a one, Balm Fork scores a five.

Table 2 summarizes the results of the watershed scoring. Some interesting patterns have emerged. First, watersheds prone to peaks with large unit discharges are likely to have multiple large peaks. The 89 large unit peak discharges were from just 45 watersheds. In fact, 58 of the unit peaks came from just 15 watersheds (Table 3).

Second, more watersheds with high unit discharges had high scores than low scores. Of the 45 watersheds, 28 (62 percent) had scores of 4 or 5 and 14 had scores of 0 to 2 (31 percent). Summer[2] peaks tended to occur on watersheds with high scores – 24 of 28 peaks had scores of 4 or 5 (86 percent) while only 3 of 28 had scores of 0 to 2 (11 percent). Winter peak discharges were about evenly divided between watersheds with high and low scores – 13 of 27 watersheds (48 percent) had

[1] Unit runoff is calculated simply by dividing the peak discharge by the watershed area. It is reported in cubic feet per second per square mile.

[2] For this analysis, summer is defined as May 1 to October 31, and winter is defined as November 1 to April 30

Table 1. Maximum observed peak discharges in eastern Oregon – unit discharge greater than 100 cfs per square mile.

[**Area**, drainage area, in square miles; **MAP**, mean annual precipitation, in inches; **Elevation**, mean watershed elevation, in feet; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Forest**, forest cover, in percent; **M**, month; **D**, day; **Y**, year; **Peak**, maximum observed annual peak discharge, in cubic feet per second; **Unit Peak**, maximum observed annual peak discharge divided by drainage area, in cubic feet per second per square mile]

Station Number	Station Name	Watershed Characteristics					Date of Occurrence			Peak	Unit Peak
		Area	MAP	Elevation	Mx Jul T	Forest	M	D	Y		
n/a	Lane Canyon near Nolin, OR	5.00	13.3	1320	88.6	0.1	7	26	1965	28500	5700
14045100	East Fork Cottonwood Creek tributary near Hamilton, OR	0.79	15.3	3620	81.1	33.6	5	15	1973	4140	5241
n/a	Meyers Canyon near Mitchell, OR	12.70	15.4	3400	84.0	21.1	7	13	1956	54500	4291
n/a	Butter Creek tributary near Echo, OR	0.33	10.2	1070	88.7	0.0	6	9	1948	1150	3485
14032100	Butter Creek tributary near Pine City, OR	1.50	10.5	1180	88.4	0.0	6	9	1948	5220	3480
13219300	Malheur River tributary near Harper, OR	0.10	9.6	2870	91.8	0.0	7	10	1970	238	2380
13219300	Malheur River tributary near Harper, OR	0.10	9.6	2870	91.8	0.0	6	8	1972	217	2170
14034480	Balm Fork near Heppner, OR	26.30	16.9	3170	80.9	0.4	6	14	1903	36000	1369
13219300	Malheur River tributary near Harper, OR	0.10	9.6	2870	91.8	0.0	7	4	1978	100	1000
n/a	Bridge Creek above Gable Creek near Mitchell, OR	15.00	17.2	3590	82.5	26.1	7	13	1956	14400	960
14032100	Butter Creek tributary near Pine City, OR	1.50	10.5	1180	88.4	0.0	8	14	1976	1240	827
14047470	Juniper Canyon tributary near Mikkalo, OR	1.90	11.4	1800	85.2	0.0	6	30	1978	1540	811
13219300	Malheur River tributary near Harper, OR	0.10	9.6	2870	91.8	0.0	1	19	1971	65	650
10395700	Donner und Blitzen River tributary near Frenchglen, OR	1.00	22.6	5480	78.5	12.4	1	15	1974	489	489
14095200	Sagebrush Creek tributary near Gateway, OR	10.70	11.1	2520	85.9	2.3	5	7	1957	5200	486
13219300	Malheur River tributary near Harper, OR	0.10	9.6	2870	91.8	0.0	12	23	1972	44	440
n/a	Speare Canyon near Nolin, OR	22.00	14.4	1680	87.9	0.0	7	26	1965	8500	386
14034500	Willow Creek at Heppner, OR	97.26	21.8	3560	77.8	25.7	6	14	1903	36000	370
n/a	Bridge Creek below Bear Creek near Mitchell, OR	45.00	15.0	3130	84.7	22.3	7	13	1956	16300	362
13219300	Malheur River tributary near Harper, OR	0.10	9.6	2870	91.8	0.0	7	12	1975	33	330
10395700	Donner und Blitzen River tributary near Frenchglen, OR	1.00	22.6	5480	78.5	12.4	3	2	1972	321	321
14048080	Buck Canyon near Klondike, OR	3.40	11.4	1750	83.4	0.0	8	26	1953	1030	303
10395700	Donner und Blitzen River tributary near Frenchglen, OR	1.00	22.6	5480	78.5	12.4	3	30	1969	300	300
14016080	Dry Creek tributary near Milton-Freewater, OR	1.20	18.9	1680	86.4	0.0	5	26	1971	348	290
14019120	North Fork Cold Springs Canyon tributary near Holdman, OR	2.90	14.7	1520	88.1	0.0	8	22	1978	820	283
14074600	Three Creek below Snow Creek Canal near Sisters, OR	3.04	53.3	6820	67.0	52.6	1	17	1971	836	275
14048080	Buck Canyon near Klondike, OR	3.40	11.4	1750	83.4	0.0	12	21	1964	904	266
14074900	Snow Creek near Sisters, OR	1.63	60.4	7190	65.6	32.4	1	18	1971	423	260
10395700	Donner und Blitzen River tributary near Frenchglen, OR	1.00	22.6	5480	78.5	12.4	3	30	1964	254	254
n/a	Birch Creek tributary (Jack Canyon) at Pilot Rock, OR	27.00	16.7	2500	85.3	0.0	6	22	1938	6300	233

Table 1. Maximum observed peak discharges in eastern Oregon – unit discharge greater than 100 cfs per square mile - continued.

[**Area**, drainage area, in square miles; **MAP**, mean annual precipitation, in inches; **Elevation**, mean watershed elevation, in feet; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Forest**, forest cover, in percent; **M**, month; **D**, day; **Y**, year; **Peak**, maximum observed annual peak discharge, in cubic feet per second; **Unit Peak**, maximum observed annual peak discharge divided by drainage area, in cubic feet per second per square mile]

Station Number	Station Name	Watershed Characteristics					Date of Occurrence			Peak	Unit Peak
		Area	MAP	Elevation	Mx Jul T	Forest	M	D	Y		
14016200	Pine Creek near Weston, OR	15.46	29.8	3240	80.3	49.7	12	5	1971	3450	223
14016300	Dry Creek above Little Dry Creek near Weston, OR	19.64	28.9	3010	80.5	43.4	1	24	1970	4180	213
14074900	Snow Creek near Sisters, OR	1.63	60.4	7190	65.6	32.4	12	10	1987	341	209
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	1	20	1972	20000	209
13286300	Waterspout Creek near Baker, OR	1.00	10.8	2950	87.5	0.0	7	10	1970	208	208
14048020	Grass Valley Canyon near Grass Valley, OR	8.10	12.5	2370	82.9	0.0	12	21	1964	1570	194
13272300	Job Creek tributary near Unity, OR	0.50	10.1	3980	86.2	0.0	4	15	1975	96	192
14016300	Dry Creek above Little Dry Creek near Weston, OR	19.64	28.9	3010	80.5	43.4	12	7	1973	3600	183
14047470	Juniper Canyon tributary near Mikkalo, OR	1.90	11.4	1800	85.2	0.0	6	9	1972	346	182
n/a	Alkali Canyon at Arlington, OR	56.00	14.2	1810	87.1	0.1	6	26	1927	10000	179
14047450	West Fork Dry Creek near Gooseberry, OR	0.80	12.9	2530	84.4	0.0	12	22	1964	134	168
14016080	Dry Creek tributary near Milton-Freewater, OR	1.20	18.9	1680	86.4	0.0	3	27	1981	200	167
13286300	Waterspout Creek near Baker, OR	1.00	10.8	2950	87.5	0.0	7	6	1981	165	165
13286300	Waterspout Creek near Baker, OR	1.00	10.8	2950	87.5	0.0	8	3	1976	165	165
10395700	Donner und Blitzen River tributary near Frenchglen, OR	1.00	22.6	5480	78.5	12.4	3	10	1966	159	159
14090500	Whitewater River near Grandview, OR	31.80	58.6	4690	73.5	86.7	12	11	1992	4800	151
14019400	Elbow Creek near Bingham Springs, OR	0.70	32.1	3400	78.9	45.7	1	25	1975	105	150
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	12	13	1977	14300	149
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	2	7	1996	13900	145
n/a	Warmsprings Creek near Mt Vernon, OR	2.73	16.1	4200	84.1	48.4	7	10	1956	393	144
14047450	West Fork Dry Creek near Gooseberry, OR	0.80	12.9	2530	84.4	0.0	8	15	1979	115	144
14019400	Elbow Creek near Bingham Springs, OR	0.70	32.1	3400	78.9	45.7	1	30	1965	99	141
14016300	Dry Creek above Little Dry Creek near Weston, OR	19.64	28.9	3010	80.5	43.4	1	19	1971	2760	141
14077800	Wolf Creek tributary near Paulina, OR	2.20	22.6	5140	78.1	70.1	12	22	1964	300	136
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	1	15	1974	13000	136
13287200	West Eagle Creek below Jim Creek near Baker, OR	15.72	49.7	6760	67.8	56.0	6	15	1974	2130	135
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	12	22	1933	12900	135
13231700	Canyon Creek tributary near Brogan, OR	1.20	11.9	4020	87.2	0.0	7	12	1975	150	125
14019400	Elbow Creek near Bingham Springs, OR	0.70	32.1	3400	78.9	45.7	6	20	1974	86	123
14079750	Crooked River tributary near Post, OR	0.30	13.2	3810	82.9	51.0	6	10	1969	36	120

Table 1. Maximum observed peak discharges in eastern Oregon – unit discharge greater than 100 cfs per square mile - continued.

[**Area**, drainage area, in square miles; **MAP**, mean annual precipitation, in inches; **Elevation**, mean watershed elevation, in feet; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Forest**, forest cover, in percent; **M**, month; **D**, day; **Y**, year; **Peak**, maximum observed annual peak discharge, in cubic feet per second; **Unit Peak**, maximum observed annual peak discharge divided by drainage area, in cubic feet per second per square mile]

Station Number	Station Name	Watershed Characteristics					Date of Occurrence			Peak	Unit Peak
		Area	MAP	Elevation	*Mx Jul T*	Forest	M	D	Y		
14120000	Hood River at Tucker Bridge near Hood River, OR	278.37	75.8	3350	71.3	77.1	12	22	1964	33200	119
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	12	12	1955	11300	118
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	2	23	1986	11200	117
14046650	Carrol Creek near Mitchell, OR	0.30	14.5	3820	82.8	42.5	6	10	1969	35	117
14113200	Mosier Creek near Mosier, OR	41.40	31.3	2190	79.7	85.9	12	23	1964	4790	116
14046650	Carrol Creek near Mitchell, OR	0.30	14.5	3820	82.8	42.5	2	6	1979	34	113
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	11	24	1960	10800	113
14016080	Dry Creek tributary near Milton-Freewater, OR	1.20	18.9	1680	86.4	0.0	3	2	1972	135	113
14021600	Nelson Creek at Pendleton, OR	2.60	13.6	1450	88.2	0.2	8	22	1978	290	112
14016300	Dry Creek above Little Dry Creek near Weston, OR	19.64	28.9	3010	80.5	43.4	1	6	1969	2190	112
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	11	23	1942	10600	111
14048040	Gordon Hollow at De Moss Springs, OR	8.90	11.3	1980	82.4	0.0	12	21	1964	984	111
14092750	Shitike Creek at Peters Pasture near Warm Springs, OR	22.21	66.0	4860	72.4	89.7	2	7	1996	2430	109
14047470	Juniper Canyon tributary near Mikkalo, OR	1.90	11.4	1800	85.2	0.0	1	12	1980	207	109
13269200	Moores Hollow tributary near Weiser, Id	0.90	11.0	2840	92.7	0.0	8	10	1965	98	109
14021600	Nelson Creek at Pendleton, OR	2.60	13.6	1450	88.2	0.2	1	30	1965	278	107
14016200	Pine Creek near Weston, OR	15.46	29.8	3240	80.3	49.7	2	14	1981	1640	106
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	12	12	1946	10100	105
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	12	27	1998	10100	105
13177885	Pole Creek tributary near McDermitt, NV	1.00	13.5	5500	85.0	0.0	1	21	1972	105	105
14021600	Nelson Creek at Pendleton, OR	2.60	13.6	1450	88.2	0.2	2	6	1979	270	104
14121000	Hood River near Hood River, OR	331.99	70.3	3090	72.3	73.6	1	6	1923	34000	102
14016200	Pine Creek near Weston, OR	15.46	29.8	3240	80.3	49.7	1	24	1970	1580	102
14090400	Whitewater River near Camp Sherman, OR	22.87	68.3	5140	71.4	82.2	2	7	1996	2320	101
14047450	West Fork Dry Creek near Gooseberry, OR	0.80	12.9	2530	84.4	0.0	9	18	1969	81	101
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	12	25	1980	9680	101
14118500	West Fork Hood River near Dee, OR	95.79	86.2	3140	71.9	84.2	12	28	1945	9660	101
14019400	Elbow Creek near Bingham Springs, OR	0.70	32.1	3400	78.9	45.7	3	19	1976	70	100
14093700	Woods Hollow at Ashwood, OR	1.40	13.6	3190	83.2	24.5	2	7	1979	140	100

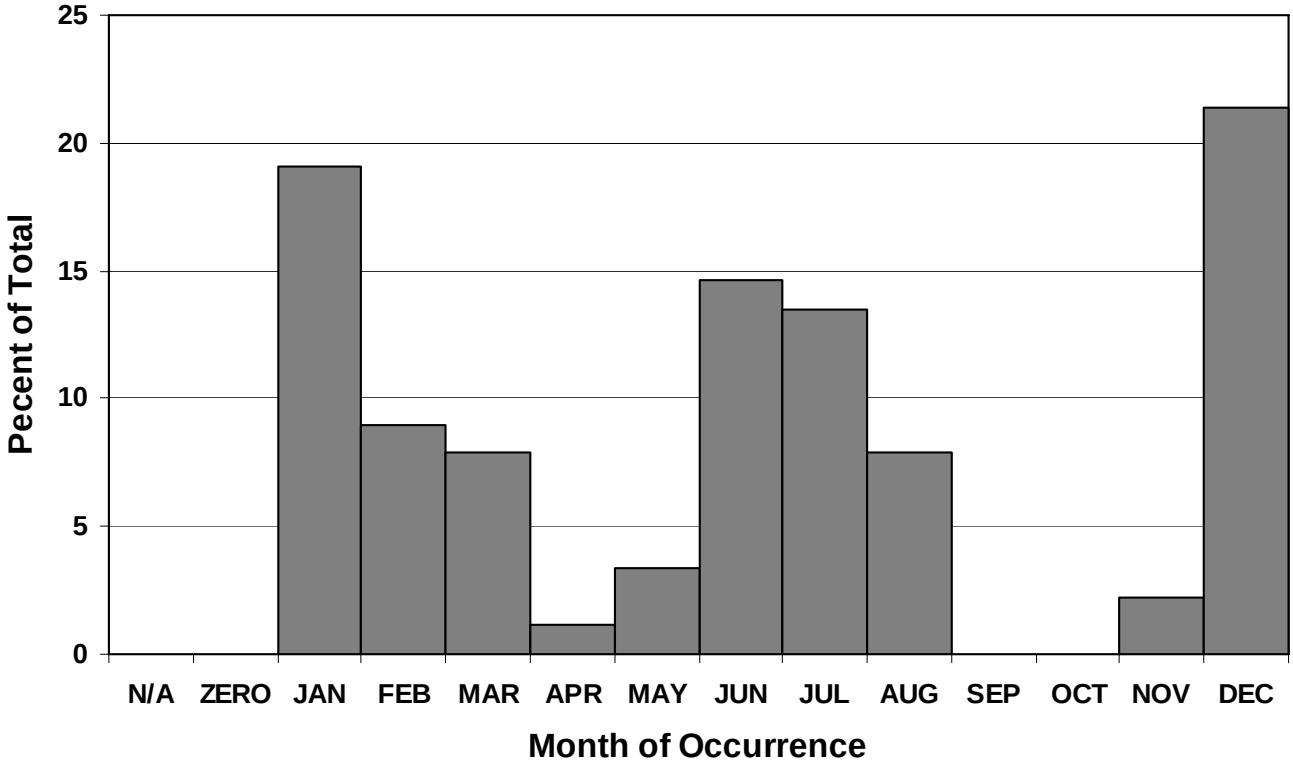


Figure 4. Monthly distribution of occurrence of the 89 observed peaks with unit discharges greater than 100 cfs per square mile. There are no zero peaks or peaks with an unknown date of occurrence.

Table 2. The watersheds associated with the 89 largest unit peak discharges were scored based on five watershed characteristics. Each watershed received one point for any of the following that are true: 1) drainage area less than 50 square miles, b) mean annual precipitation less than 20 inches, c) mean watershed elevation less than 4,000 feet, d) mean maximum July temperature greater than 80 degrees Fahrenheit, and e) forest cover less than 35 percent.

Watershed Score	All Peaks		Summer Peaks May 1 to October 31*		Winter Peaks November 1 to April 30	
	Number of Watersheds	Number of Peaks	Number of Watersheds	Number of Peaks	Number of Watersheds	Number of Peaks
0	0	0	0	0	0	0
1	9	21	1	1	8	20
2	5	13	2	2	5	11
3	3	8	1	1	2	7
4	5	6	4	4	2	2
5	23	41	20	28	10	13
Totals	45	89	28	36	27	53

* There are no peaks in October and only one in September.

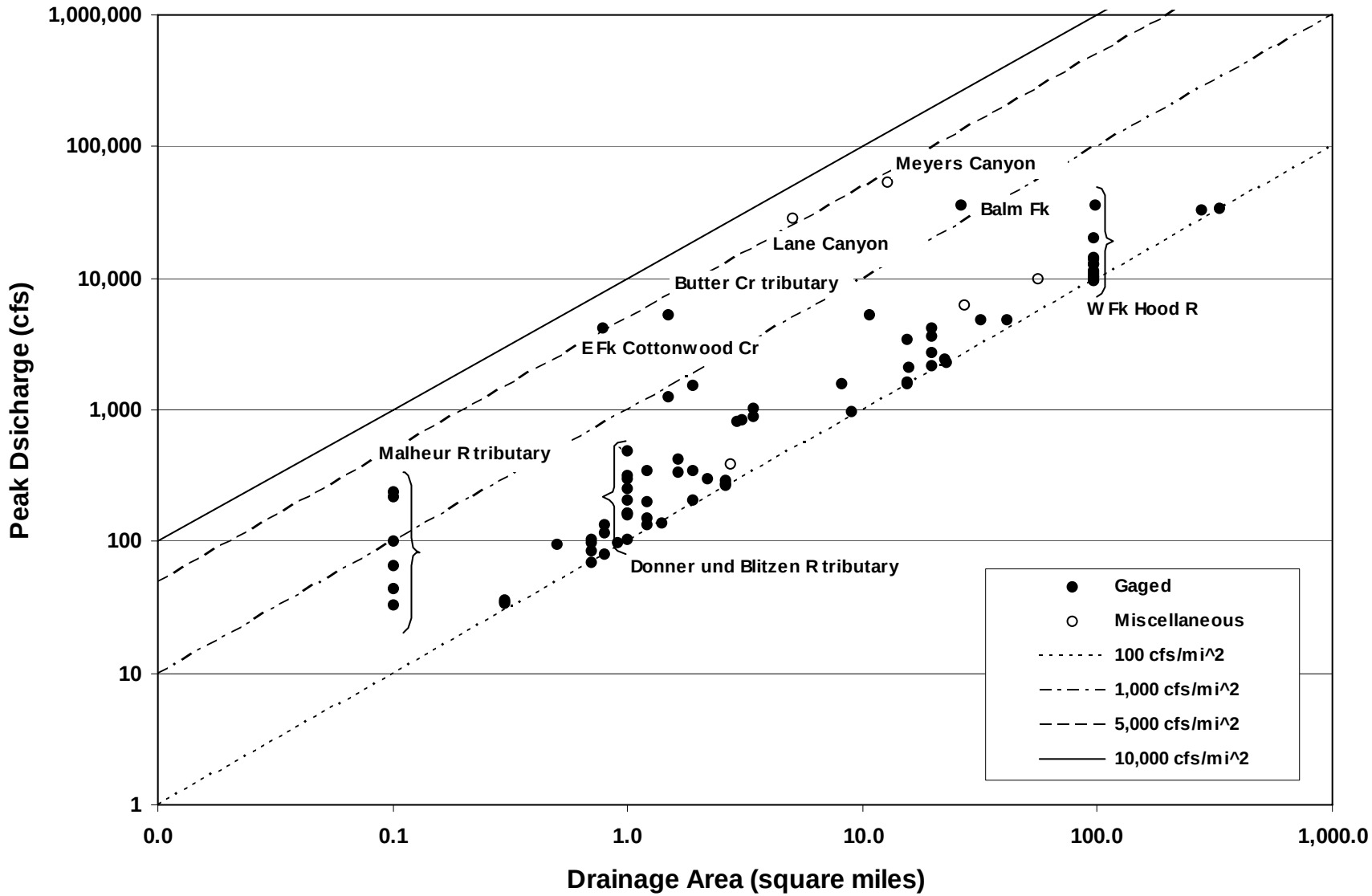
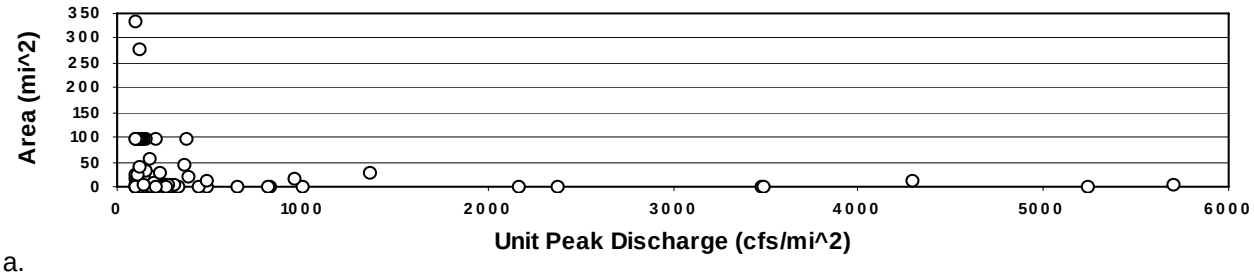
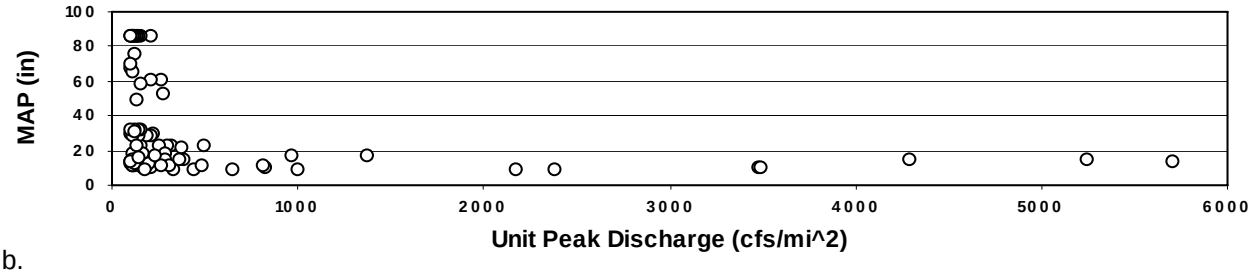


Figure 5. Observed annual peaks with unit discharges greater than 100 cfs/mi^2 plotted against area. Peak discharges above 1,000 cfs/mi^2 were most likely all due to thunderstorms.



a.



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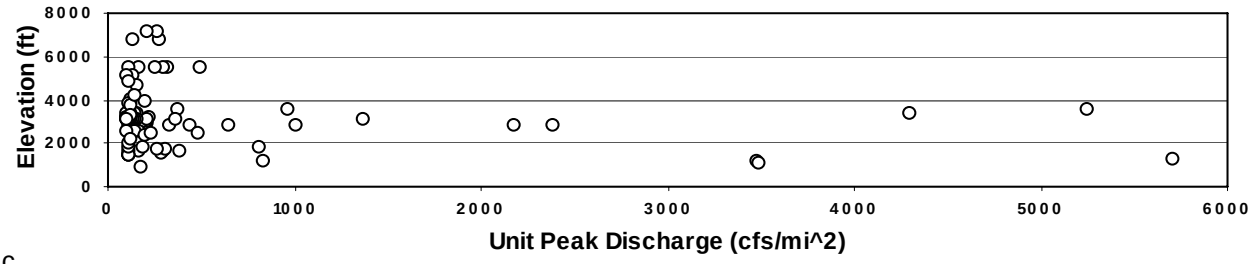

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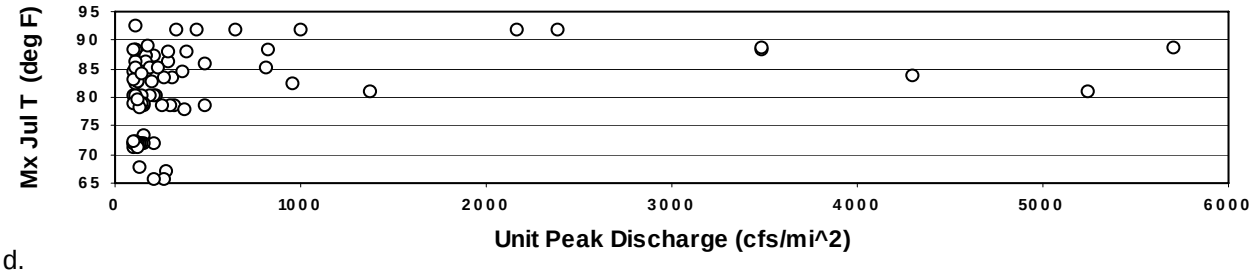

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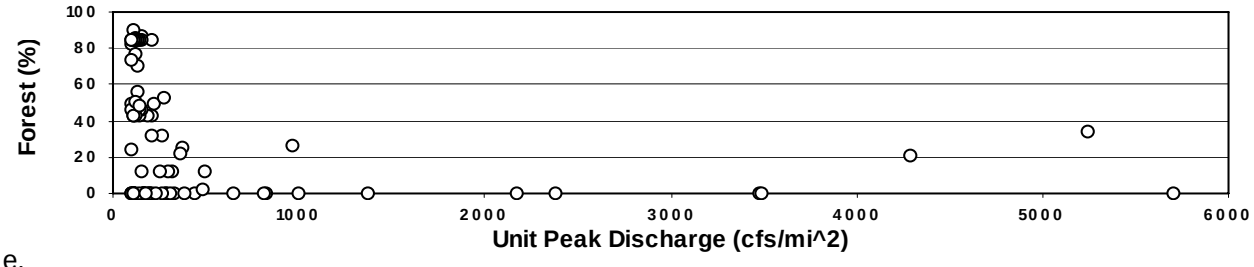

e.

Figure 6. The 89 largest unit peak discharges for eastern Oregon plotted against selected watershed characteristics: a) drainage area, in square miles, b) mean annual precipitation (MAP), in inches, c) mean watershed elevation, in feet, d) mean maximum July temperature, in degrees Fahrenheit, and e) forest cover, in percent.

Table 3. Watersheds with multiple large unit peak discharges (greater than 100 cfs per square mile) from a total of 89 such peaks.

Gage Number	Gaging Station Name	Number of Peaks		
		Summer May 1 to October 30*	Winter November 1 to April 30	Total
14118500	West Fork Hood River near Dee, OR	0	13	13
13219300	Malheur River tributary near Harper, OR	4	2	6
10395700	Donner und Blitzen River tributary near Frenchglen, OR	0	5	5
14019400	Elbow Creek near Bingham Springs, OR	1	3	4
14016300	Dry Creek above Little Dry Creek near Weston, OR	0	4	4
13286300	Waterspout Creek near Baker, OR	3	0	3
14047470	Juniper Canyon tributary near Mikkalo, OR	2	1	3
14021600	Nelson Creek at Pendleton, OR	1	2	3
14047450	West Fork Dry Creek near Gooseberry, OR	2	1	3
14016080	Dry Creek tributary near Milton-Freewater, OR	1	2	3
14016200	Pine Creek near Weston, OR	0	3	3
14032100	Butter Creek tributary near Pine City, OR	2	0	2
14046650	Carrol Creek near Mitchell, OR	1	1	2
14048080	Buck Canyon near Klondike, OR	1	1	2
14074900	Snow Creek near Sisters, OR	0	2	2
Totals	15 Watersheds	18	40	58

* There are no peaks in October and only one in September.

scores of 0 to 2 while 12 of 27 watersheds (44percent) had scores of 4 or 5. In other words, watersheds with high scores are likely to have peaks either summer or winter, while watersheds with low scores are likely to have peaks only in winter. Of watersheds with multiple peaks, five had winter peaks only, two had summer peaks only, and eight had both winter and summer peaks.

Most of the 36 summer peak discharges resulted from thunderstorms. By delineating on a map of the State the watershed characteristics previously associated with these peaks, the areas prone to severe thunderstorms can be identified. On figure 7, areas of the State are delineated with mean annual precipitation less than 20 inches (horizontal blue hatching), mean maximum July temperatures greater than 80 degrees Fahrenheit (diagonal red hatching), and mean watershed elevations less than 4,000 feet (diagonal green hatching). Also delineated are areas of forest (solid light green).

Thunderstorm prone areas on figure 7 are those areas with little or no forest cover where all three hatched areas overlap. They are in north central and far eastern Oregon. Also shown on figure 7 are the locations of the 36 largest summer peaks, i.e., those peaks most likely to have resulted from a thunderstorm..

Note that on figure 7, the summer peak for West Eagle Creek below Jim Creek near Baker, OR (#2) falls well outside the thunderstorm prone area. The peak was mostly, if not entirely, the result of snowmelt. Temperatures were over 90 degrees Fahrenheit throughout much of northeastern Oregon at the time. The mean flow for both the day before and the day after was 1,220 cfs, and on the day of the peak, 1,600 cfs. The instantaneous peak was only 2,130 cfs. If a thunderstorm was involved with this peak, it contributed only part of the flow.

In terms of unit discharge, eastern Oregon has experienced only a few extreme events. Only 13 peak discharges, out of nearly 7,000, are known to have exceeded 500 cfs per square mile. The highest recorded unit peak discharge was 5,700 cfs per square mile from Lane Canyon near Nolin, OR on July 26, 1965. This unit peak discharge is among the largest recorded in the United States.

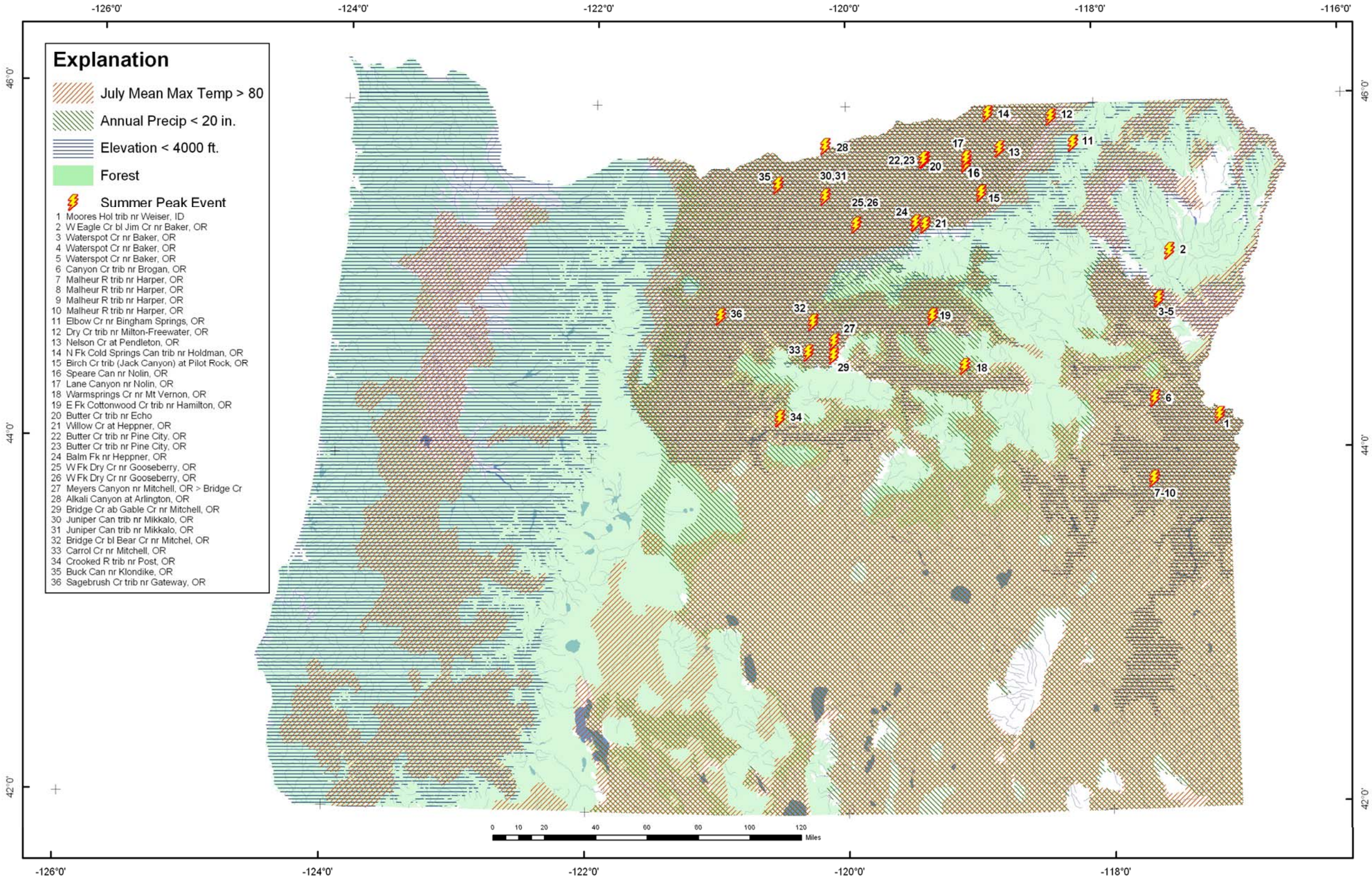

Figure 7. Thunderstorm prone areas of eastern Oregon. Thunderstorms are most likely to occur in areas with little or no forest cover where July mean maximum temperatures are above 80 degrees Fahrenheit, mean annual precipitation is below 20 inches and mean watershed elevation is below 4,000 feet.

Without exception, the 13 largest of the large unit peak discharges scored five based on their watershed characteristics. With one exception, these 13 largest of the large unit peaks occurred in summer. The 12 summer peaks are most likely the result of thunderstorms. The low elevations and small drainage areas of the watersheds and the very high discharges make it unlikely the peaks resulted from snow melt.

The one winter peak was from the watershed above the gaging station Malheur River tributary near Harper, OR (13219300). The other three peak discharges for this watershed occurred in summer. Remarkably, this watershed accounted for 4 of the 13 largest unit peak discharges and 6 of the largest 89 largest unit peak discharges. As will be discussed later, this watershed is not like other watersheds in the area. In forming the prediction equations, it was an extreme outlier at every return interval.

One other watershed had more than one peak in the top 13. Butter Creek tributary near Pine City, OR (14032100) contributed two peaks.

Two storms accounted for 4 of the largest 13 unit peak discharges. A thunderstorm on June 9, 1948 caused the peaks on Butter Creek tributary near Echo, OR and Butter Creek tributary near Pine City, OR. A thunderstorm on July 13, 1958 caused the peaks on Meyers Canyon near Mitchell, OR, and Bridge Creek above Gable Creek near Mitchell, OR. This second storm also caused a large unit peak discharge for Bridge Creek below Bear Creek near Mitchell. OR, but this peak did not make the top 13.

Frequency of Thunderstorms

Large unit peak discharges due to thunderstorms are not well represented in the systematic record. In fact, among the gaging stations used in this study, they have almost no representation. Recall from the previous section that the analysis of the characteristics of peak discharges included more gaging stations and measurement sites than were used in the flood frequency analysis (340 vs. 194[3], respectively). If the analysis were restricted to just the peaks associated with the 194 gaging stations in eastern Oregon used in the flood frequency analysis there would be 6,074 peaks instead of 6,960. Although the reduction in the number of peaks is almost 13 percent, the distribution of peaks by month is similar (fig. 8).

What is not similar is the representation of the very largest unit peak discharges. Among the peak discharges associated with the 194 gaging stations, only 36 have unit discharges greater than 100 cfs per square mile. Of these, only one has a unit discharge in excess of 500 cfs per square mile. Large unit peak discharges due to thunderstorms are essentially unrepresented in the flood frequency analysis. What impact this has on the estimation of peak discharges is unknown.

There appears to be two reasons for this under representation: 1) extreme thunderstorms are infrequent, and 2) the watersheds where these extreme floods are most likely to occur are unlikely to be systematically measured or gaged. Extreme floods resulting from thunderstorms are associated with watersheds of a particular type (Figure 7 and Table 2). These watersheds do not generate much streamflow, being dry much of every year and often having years without any streamflow at all. Because they have little streamflow, these watersheds are seldom gaged. When measured, as with the crest stage gage program of the 1960s, 1970s, and 1980s, the resulting annual series often has too many zero peaks to be fitted to a log-Pearson Type III distribution. The fitting of the log-Pearson Type III distribution to an annual series of peak discharges is described later in the report.

Historic Floods

The occurrence of regional and flash floods in eastern Oregon have been described in a number of reports. Particularly helpful was “The Oregon Weather Book, a State of Extremes” (Taylor and Hatton, 1999). Several USGS reports provided useful descriptions of floods, particularly those arising from thunderstorms. A report by the US Army Corps of Engineers (1978) described flash floods in the Willow Creek Basin in detail.

[3] In total, 276 gaging stations were included in the flood frequency analysis. Of these, 194 were actually in eastern Oregon. The rest were in California, Nevada, Idaho and Washington.

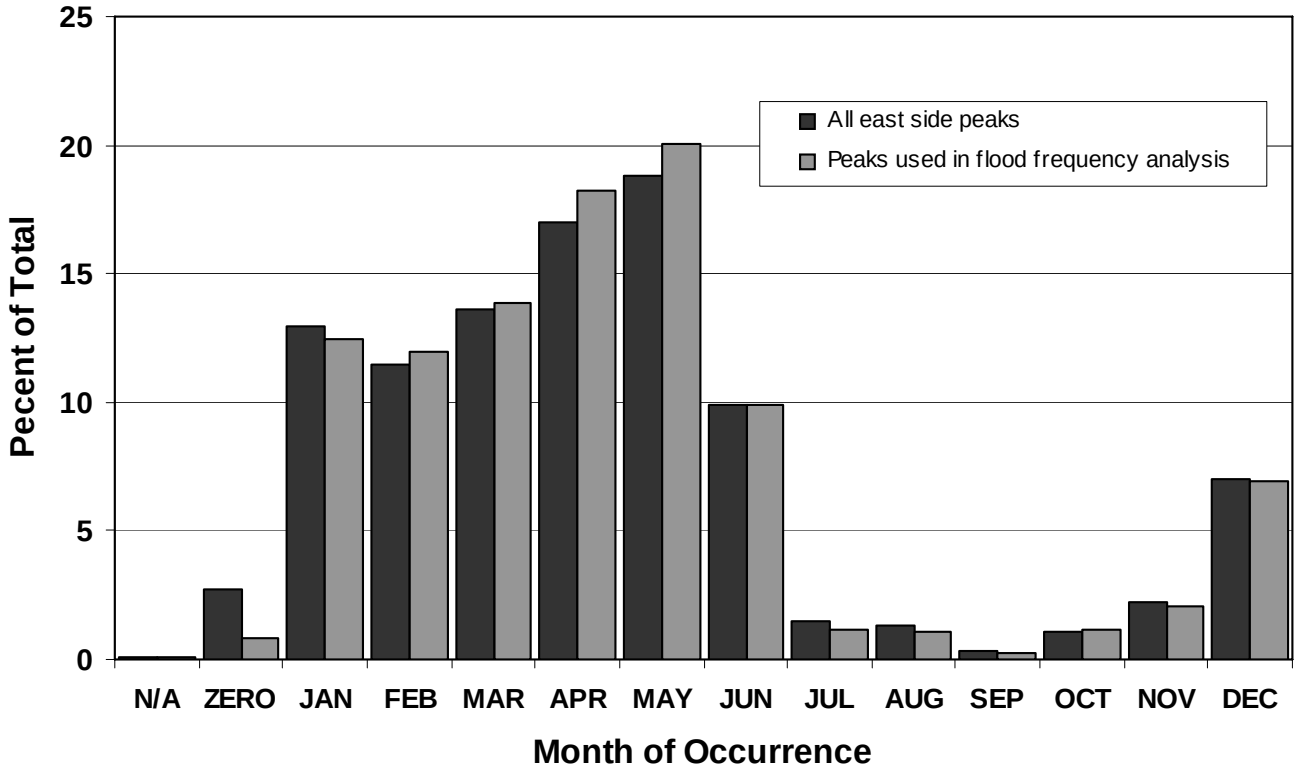

Figure 8. A comparison of the monthly distributions of occurrence of all east side peaks and the peaks used in the flood frequency analysis.

Not all significant high water events are found in these reports, however. To identify other periods of high water, each annual peak discharge for the 276 gaging stations was analyzed to determine its approximate recurrence interval. This analysis revealed a number of significant high streamflow events otherwise unreported. They are briefly described below. The underlying hydrologic processes of these events were not determined, however. Table 4 lists the 55 peak discharges greater than the 100-year event for their respective gaging station.

Little is known about floods in eastern Oregon prior to 1900. What little evidence of flooding is available suggests that flash floods, while not common, probably occurred regularly in some areas. No reports of regional flooding were found. The U.S. Army Corps of Engineers (1978) reported five flash floods occurring from 1881 to 1900 in the Willow Creek drainage in Morrow County, and Taylor and Hatton (1999) reported a flash flood on Bridge Creek near Mitchell on June 2, 1894. It is interesting to note that all five floods in the Willow Creek drainage also occurred in June. Neither report provides information about flow rates or flood volumes.

None of these flash floods was wide spread, each affecting only limited stream reaches. Given that the population in the region was sparse and streamflow records very few, and that the effects of these floods tended to be local, other flash floods probably occurred but went unreported because they caused little or no damage, or simply were unobserved.

Possibly the best-known flood in eastern Oregon occurred on June 14, 1903. This flash flood destroyed much of the town of Heppner and killed more than 200 people (U.S. Army Corps of Engineers, 1978; Hubbard, 1991; Taylor and Hatton, 1999). The flood originated from a thunderstorm centered over Balm Fork, a tributary of Willow Creek. Balm Fork enters Willow Creek just upstream of Heppner. The flow rate at Heppner was 36,000 cfs making the unit discharge from Balm Fork almost 1,400 cfs per square mile. While this flood is well known because of the number of deaths and the

Table 4. Observed peak discharges in eastern Oregon greater than a 100-year event.

[**Area**, drainage area, in square miles; **M**, month; **D**, day; **Y**, year; **Peak**, observed annual peak discharge, in cubic feet per second; **Unit Peak**, observed annual peak discharge divided by drainage area, in cubic feet per second per square mile; **X 100**, the ratio of the observed peak discharge to the estimated 100-year peak discharge]

Station Number	Station Name	Area	Date of Occurrence			Peak	Unit Peak	X 100
			M	D	Y			
14034480	Balm Fork near Heppner, OR	26.3	6	14	1903	36,000	1370	20.4
14034500	Willow Creek at Heppner, OR	97.3	6	14	1903	36,000	370	10.7
10403500	Silver Creek above Suntex, OR	260	4	14	1904	1,760	6.8	1.03
13275500	Powder River near Baker, OR	216	3	20	1910	1,820	8.4	1.01
10406500	Trout Creek near Denio, NV	85.5	8	1	1933	470	5.5	1.07
13325000	East Fork Wallowa River near Joseph, OR	10.3	7	25	1937	450	43.7	1.40
13320000	Catherine Creek near Union, OR	103	5	27	1948	1,740	16.9	1.07
14032000	Butter Creek near Pine City, OR	287	2	21	1949	3,800	13.2	1.03
14050500	Cultus River above Cultus Creek near La Pine, OR	19.6	5	31	1956	178	9.1	1.03
14054500	Brown Creek near La Pine, OR	20.4	8	4	1956	104	5.1	1.04
14054500	Brown Creek near La Pine, OR	20.4	12	11	1956	101	5.0	1.01
14081800	Ahalt Creek near Mitchell, OR	2.3	12	21	1964	122	53.0	1.18
10384000	Chewaucan River near Paisley, OR	267	12	22	1964	6,490	24.3	1.24
11494800	Brownsworth Creek near Bly, OR	2.2	12	22	1964	66	30.0	1.09
14038500	John Day River at Prairie City, OR	230	12	22	1964	2,400	10.4	1.02
14077800	Wolf Creek tributary near Paulina, OR	2.2	12	22	1964	300	136	1.34
14078000	Beaver Creek near Paulina, OR	451	12	22	1964	12,800	28.4	1.71
10370000	Camas Creek near Lakeview, OR	66.1	12	23	1964	3,190	48.3	1.65
10378500	Honey Creek near Plush, OR	167	12	23	1964	11,000	65.8	1.65
13214000	Malheur River near Drewsey, OR	944	12	23	1964	12,000	12.7	1.09
13216500	North Fork Malheur River above Beulah Reservoir near Beulah, OR	342	12	23	1964	3,970	11.6	1.02
14048000	John Day River at McDonald Ferry, OR	7630	12	24	1964	42,800	5.6	1.00
14091500	Metolius River near Grandview, OR	318	12	24	1964	7,530	23.7	1.04
14052000	Deer Creek above Crane Prairie Reservoir near La Pine, OR	13.0	12	25	1964	200	15.4	1.24
14055500	Odell Creek near Crescent, OR	37.9	12	25	1964	1,100	29.1	1.61
11501000	Sprague River near Chiloquin, OR	1,600	12	26	1964	14,900	9.3	1.08

Table 4. Observed peak discharges in eastern Oregon greater than a 100-year event – continued.

[**Area**, drainage area, in square miles; **M**, month; **D**, day; **Y**, year; **Peak**, observed annual peak discharge, in cubic feet per second; **Unit Peak**, observed annual peak discharge divided by drainage area, in cubic feet per second per square mile; **X 100**, the ratio of the observed peak discharge to the estimated 100-year peak discharge]

Station Number	Station Name	Area	Date of Occurrence			Peak	Unit Peak	X 100
			M	D	Y			
11502500	Williamson River below Sprague River near Chiloquin, OR	3,000	12	26	1964	16,100	5.4	1.08
13319000	Grande Ronde River at La Grande, OR	691	1	30	1965	14,100	20.4	1.33
14042500	Camas Creek near Ukiah, OR	121	1	30	1965	3,840	31.8	1.04
14118500	West Fork Hood River near Dee, OR	95.8	1	20	1972	20,000	209	1.10
13287200	W Eagle Creek below Jim Creek near Baker, OR	15.7	6	15	1974	2,130	136	1.00
13272300	Job Creek tributary near Unity, OR	0.5	4	15	1975	96	192	1.24
13288200	Eagle Creek above Skull Creek near New Bridge, OR	156	7	12	1975	5,310	34.0	1.14
14037500	Strawberry Creek above Slide Creek near Prairie City, OR	7.0	5	31	1983	354	50.9	1.14
13283600	Wolf Creek above Wolf Creek reservoir near North Powder, OR	30.9	5	13	1984	1,350	43.7	1.15
13275200	Deer Creek above Phillips Lake near Sumpter, OR	33.4	4	15	1989	1,240	37.2	1.05
14020740	Moonshine Creek near Mission, OR	4.6	2	7	1996	247	53.7	1.31
14090400	Whitewater River near Camp Sherman, OR	22.9	2	7	1996	2,320	101	1.61
14091500	Metolius River near Grandview, OR	318	2	7	1996	8,430	26.6	1.16
14095500	Warm Springs River near Simnasho, OR	106	2	7	1996	4,670	44.0	1.88
14097100	Warm Springs River near Kahneeta Hot Springs, OR	525	2	7	1996	22,600	43.0	1.00
13324300	Lookingglass Creek near Looking Glass, OR	77.1	2	9	1996	2,120	27.5	1.15
13332500	Grande Ronde River at Rondowa, OR	2,590	2	9	1996	28,400	11.0	1.10
13333000	Grande Ronde River at Troy, OR	3,310	2	9	1996	51,800	15.7	1.10
14088000	Lake Creek near Sisters, OR	20.9	2	10	1996	589	28.1	1.04
10384000	Chewaucan River near Paisley, OR	267	1	1	1997	7,010	26.3	1.34
13292000	Imnaha River at Imnaha, OR	621	1	1	1997	20,200	32.5	1.79
14051000	Cultus Creek above Crane Prairie reservoir near La Pine, OR	35.0	1	2	1997	386	11.0	1.01
14055600	Odell Creek near La Pine, OR	49.3	1	2	1997	778	15.8	1.13
11502500	Williamson River below Sprague River near Chiloquin, OR	3,000	1	5	1997	17,100	5.7	1.15
13330500	Bear Creek near Wallowa, OR	67.0	5	30	2003	2150	32.1	1.03

damage done, other flash floods in Oregon have had greater unit runoffs.

High streamflows occurred in the Cascade Range near Mount Jefferson and Mount Hood on January 6 and 7, 1923. Peak discharges in the White and Hood Rivers exceeded 50-year events and in the Metolius River, the peak discharge exceeded the 25-year event.

The earliest report of an eastern Oregon flood with regional effects was for an event that occurred March 31 to April 1, 1931 (Hubbard, 1991; Taylor and Hatton, 1999). This flood was a rain on snow event affecting most of the Cascade Range and the Blue Mountains. All of western Oregon was also affected. Hubbard estimated the recurrence intervals to be from 10 to 50 years.

High streamflows occurred throughout the Blue Mountains March 18 – 20, 1932. Return intervals for peak discharges were from 10 to 50 years.

Heavy warm rains falling on snow caused flooding in northwestern and north-central Oregon from December 21 – 24, 1933 (Taylor and Hatton, 1999). Affected areas in eastern Oregon were in the Hood River basin, the lower Deschutes and John Day Rivers and the Umatilla River. Recurrence intervals for affected steams were 10 to 25 years.

High peak discharges occurred in streams in northeast Oregon December 12 – 15, 1946. In the Umatilla River basins and parts of the North Fork John Day basin estimated recurrence intervals for affected streams were from 10 to 25 years. For the forks of the Walla Walla River, recurrence intervals exceeded 50 years.

On June 9, 1948, a thunderstorm near Echo Oregon caused very high discharges in two unnamed tributaries to Butter Creek (Hulsing and Kallio, 1964). The larger flow was 5,220 cfs from a drainage area of 1.4 square miles. The smaller flow was 1,150 cfs from 0.33 square miles. The unit discharges were 3,730 and 3,480 cfs per square mile, respectively.

A thunderstorm on June 17, 1950 over Balm Canyon, a tributary to Rhea Creek, caused a discharge of 2,700 cfs from the 28 square mile drainage (Wells, 1954; Hulsing and Kallio, 1964). The unit discharge was 96.4 cfs per square mile. Balm Canyon should not be confused with Balm Fork, the source of the 1903 Heppner flood.

Warm weather from March 25 – 28 and again in the first week of April 1952, led to melting of much of an above-normal snow pack in northeastern and north-central Oregon (Wells, 1959a). Maximum discharges exceeded previous highs for many streams. No recurrence intervals were reported, but the current analysis shows this event was no more than a 10- or 25-year event in most locations. However, for the Malheur River near Drewsey, OR (13214000) and the John Day River near Prairie City, OR (14036800), the recurrence interval was more than 50 years and for the Silvies River near Burns, OR (10393500), more than 100 years.

A thunderstorm on August 10, 1952 over the upper end of Eightmile Canyon near the town of Eightmile caused a flash flood with a unit discharge of over 200 cfs per square mile (Wells, 1959a). The contributing area of Eightmile Canyon above Eightmile is about 10 square miles. High flow lasted only 1 to 1.5 hours and then receded rapidly.

A thunderstorm on August 26, 1953 near Klondike Oregon resulted in a flash flood in Bull Run Canyon (Wells, 1959b). The discharge was 1,030 cfs from a contributing area of 3.9 square miles or 264 cfs per square mile.

A thunderstorm on August 28, 1953 near Lexington Oregon caused a peak discharge of 1,740 cfs in Black Horse Creek (Wells, 1959b; Hulsing and Kallio, 1964). The contributing area was 23.4 square miles and the unit discharge 74.4 cfs per square mile. This same storm generated discharges of 2,110 cfs in Eightmile Canyon 10 miles south of Ione and 3,240 cfs from Clark Canyon 0.7 mile downstream from Fuller Canyon near Lexington (Wells, 1959b). Neither drainage areas nor unit discharges are reported for these two watersheds.

A series of storms from December 1955 to January 1956 caused widespread flooding in most of California, western Nevada, western Oregon and parts of Idaho. In eastern Oregon, the Klamath River and its tributaries, the Chewaucan River, and Thomas and Deep Creeks were affected. Warm temperatures and rain at high elevation melted much of the accumulated snow pack, resulting in record-breaking streamflows for many streams (Wells, 1962; Hofmann and Rantz, 1963). Recurrence intervals varied from 10 to 50 years, depending on location (Hubbard, 1991).

High streamflows occurred in a number of streams in the Blue Mountains on May 8 and 9, 1956. Return

intervals for peak discharges were from 10 to 50 years.

A thunderstorm centered near Mt. Vernon, Oregon, occurred on July 10, 1956 (Hendricks, 1964). Rainfall and hail from the storm generated high discharges in Beech Creek, and its tributary, Warm Springs Creek. The peak discharge on Warm springs Creek was 393 cfs from a contributing area of 2.73 square miles. The peak discharge on Beech Creek was 929 cfs from an estimated contributing area of 12.5 square miles (out of 113 squares miles total for Beech Creek). The unit discharges were 144 and 74.3 cfs per square mile, respectively.

One of the largest unit discharges ever measured in the United States resulted from a thunderstorm near Mitchell Oregon on July 13, 1956 (Hendricks, 1964). The storm generated runoff in parts of both the Bridge and Girds Creek watersheds. The most flow occurred from Meyers Canyon where the discharge was estimated to be 54,500 cfs from a drainage area of 12.7 square miles. The unit discharge was 4,290 cfs per square mile.

Rain falling on snow and frozen ground caused flooding in eastern Washington, eastern Oregon and southern Idaho from February 24 – 28, 1957 (Hendricks, 1963). In Oregon, flooding was confined to the Malheur and Powder River basins and Prairie Creek in the Grande Ronde basin. Flooding on the Malheur was most severe. The current analysis shows the recurrence interval for the Malheur River near Drewsey, OR (13214000) was about 100 years and for Bully Creek near Vale, OR (13227000), in excess of 50 years.

Flooding occurred in the Powder, Burnt, Malheur, and Owyhee basins and near Lakeview during the period January 31 to February 5, 1963 as the result of a sudden thaw and moderate rain on snow (Rostvedt, 1968). Based on peak streamflow data available as of 1963, recurrence intervals for some streams near Lakeview were estimated to be in excess of 50 years (Rostvedt, 1968). The current analysis shows that the recurrence intervals were probably less than 50 years except for Honey Creek near Plush, OR (10378500), where the recurrence interval was well in excess of 50 years. In eastern Oregon, floods in 1964 and 1996 generally exceeded the 1963 flood.

The floods that occurred in December 1964 and January 1965 were extreme (Waananen, and others, 1971). All of Oregon, northern California, and parts of Idaho and southern Washington were affected. Many streams had peak discharges in excess of a 100-year event. Beaver Creek near Paulina, OR (14078000), Camas Creek near Lakeview, OR (1037000), and Odell Creek near Crescent, OR (14055500) had peak discharges in excess of the 500-year event.

The storms and resulting flooding are remarkable both because of the high discharges and because of the very large area affected. Discharges on many streams in Oregon were the highest recorded up to that time and on many of those streams the 1964 flood remains the highest on record. On many other streams, only the 1996 flood exceeds that of 1964.

The floods were caused by three major storms occurring between December 19 and January 31. The greatest of these occurred December 19 – 23. All of the storms were from the southwest bringing torrential warm rains. Peak discharges were substantially increased from snowmelt due to warm temperatures and strong winds.

The greatest recorded peak for any stream in eastern Oregon for this flood period was 42,800 cfs at the gaging station on the John Day River at McDonald Ferry, OR (14048000). By the current analysis, this flow corresponds to a 100-year event. It is interesting to note that for this event the discharge from the 7,630 square mile John Day watershed was less than the discharge from the 12.7 square mile Meyers Canyon watershed during the thunderstorm of July 13, 1956.

The highest known unit discharge in Oregon resulted from a thunderstorm that occurred July 26, 1965 near Nolin, Oregon (Hubbard, 1991; Taylor and Hatton 1999; Rostvedt, 1970). High flows occurred in several watersheds in the vicinity, but the highest discharge by far was in Lane Canyon. The flow at the mouth of the canyon (5.04 square miles) was estimated to be 28,500 cfs – a remarkable 5,650 cfs per square mile. Neighboring Speare Canyon generated 14,600 cfs from a total watershed area of 23.0 square miles. However, based on the degree and location of erosion in the watershed, only the upper watershed contributed.

Thunderstorms on the evening of June 9, 1969 brought heavy rain to areas east of John Day and near Heppner, Oregon (Reid, 1975). Peak discharge in the John Day River near John Day, OR (14038530) was 5,830 cfs. Based on peak flow records available at the time, the reported discharge had a recurrence interval greater than 50 years. The

current analysis shows the recurrence interval was probably less than 50 years.

For the June 9 event, Shobe Canyon had the highest peak discharge of any tributary in the Willow Creek basin. The discharge was 2,660 cfs from a contributing area of 6.22 square miles. The unit discharge was 428 cfs per square mile. For Willow Creek, a peak discharge of 6,680 cfs occurred the next day, June 10.

Most of the annual peak discharges reported for eastern Oregon for 1970 occurred January 22 – 27. While a few peaks had recurrence intervals between 10 and 25 years, most were below 10 years. The peak discharge for Lone Rock Creek near Lone Rock, OR (140473800), however, was greater than a 50-year event.

High peak discharges occurred January 17 – 20, 1971, throughout eastern Oregon and accounted for most of the annual peaks that year. A few peaks had recurrence intervals between 10 and 50 years, but most were below 10 years.

Most of the annual peak discharges reported for eastern Oregon for 1974 occurred January 12 – 19. A few peaks had recurrence intervals between 10 and 25 years, but most were below 10 years. The peak discharge for Ramsey Creek near Dufer, OR (14104100) and the Imnaha River at Imnaha, OR (13292000) were greater than 50-year events.

Snowmelt in the Wallowa Mountains in mid June 1974 caused high peak discharges in most streams in the area. Peak discharges for several streams had recurrence intervals of 50 years. The annual peak for West Eagle Creek below Jim Creek near Baker, OR (13287200) had a recurrence interval in excess of 100 years.

High streamflows occurred throughout the Umatilla River basin on January 25, 1975. Recurrence intervals for affected streams ranged from 10 to 50 years.

A thunderstorm on August 14, 1976 near Echo Oregon resulted in a flash flood in a Butter Creek tributary – the same tributary that was the site of the flash flood on June 9, 1948 (see description above). For the 1976 event, the peak discharge was 1,240 cfs or 827 cfs per square mile.

High streamflows occurred over most of eastern Oregon December 13 – 15, 1977. In some locations, peak discharges had recurrence intervals of 10 – 25 years. The recurrence intervals for the White River near Government Camp, OR (14097200), West Fork Hood River near Dee, OR (14118500), and Lake Creek near Sisters, OR (14088000) were in excess of 25 years.

Heavy warm rain on December 25, 1980 brought high streamflows to the Hood River basin and Cascade tributaries to the lower Deschutes River. Recurrence intervals for peaks on affected streams were generally only 10 to 15 years. The peak on Squaw Creek near Sisters, however, had a recurrence interval of greater than 50 years. This storm also was responsible for a debris flow that flowed down Polallie Creek eventually blocking the East Fork of the Hood River at their confluence (Hubbard, 1991; Taylor and Hatton, 1999). The lake that formed behind the debris dam was breached within minutes causing flooding and extensive damage downstream on the East Fork.

Heavy rain on snow and warm temperatures brought flooding to the Klamath River and its tributaries February 21 – 22 1982 (Hubbard, 1991; Taylor and Hatton, 1999). The peak discharges on the Sprague and Williamson Rivers were 25- to 50-year events.

High streamflows occurred in the Wallowa Mountains May 30, 1984. Peak discharges on several streams were in excess of the 10-year event. The peak for Catherine Creek near Union, OR (14032000) was greater than a 25-year event.

Heavy rainfall and melting snow caused widespread flooding February 22 – 23, 1986 (Taylor and Hatton, 1999). In eastern Oregon, many streams had peak discharges with recurrence intervals of 10 to 25 years. The peak discharge for the Grande Ronde at Rondowa, OR (13332500) was nearly a 50-year event.

Heavy rain falling on snow from May 19 – 20, 1991 caused flooding in the John Day, Grande Ronde, and Umatilla basins (Taylor and Hatton, 1999). Recurrence intervals for peak discharges in the affected area were generally from 10 to 25 years.

Mild temperatures and heavy rain falling on an above average snow pack during March 1993 resulted in high peak discharges in the Malheur and Owyhee basins and parts of the John Day basin (Taylor and Hatton, 1999). Recurrence intervals for peak

discharges in the affected area were from 10 to 50 years.

During the period February 5 – 9, 1996, warm temperatures and intense rain falling on a deep snow pack combined to create severe flooding throughout the northern part of Oregon (Taylor and Hatton, 1999). In many areas, flood magnitudes were generally comparable to or greater than those of the 1964 flood. While flooding was not as widespread in eastern Oregon, some streams experienced very high streamflows. Recurrence intervals for peak discharges on the Whitewater, Warm Springs, Metolius, and Grande Ronde Rivers were greater than 100 years.

From December 30, 1996 to January 5, 1997, warm moist air from the subtropical Pacific passed over the entire northwest (Taylor and Hatton, 1999). Heavy rain, warm temperatures, and rapid snowmelt caused flooding over much of the region. Estimated recurrence intervals for peak discharges for several widely spaced streams in Oregon exceeded 50 years. Discharge in the Imnaha River at Imnaha, OR (13292000) exceeded the 100-year discharge by twice. For the Chewaucan River near Paisley, OR (10384000), the peak discharge was 1.3 times the 100-year discharge.

High streamflows occurred in a number of streams in the Cascade Range near Mount Jefferson and Mount Hood on November 25 and 26, 1999. Return intervals for peak discharges were from 10 to 50 years.

Magnitude and Frequency Analysis

For a site where peak discharges have been systematically measured, the magnitude of peak discharges can be related to frequency by fitting the measured peaks to a theoretical probability distribution. From the probability distribution, the magnitude of the peak discharge at any frequency can be estimated. In practice, however, it is seldom reasonable to make estimates of flood magnitudes for return intervals greater than about 500 years.

For this study, the logarithms of annual series of peak discharges at 276 streamflow gaging stations in eastern Oregon, southeastern Washington, southwestern Idaho, northwestern Nevada, and northeastern California (Appendix A) were fitted to the Pearson Type III distribution following guidelines established by the Interagency Advisory Committee on Water Data (1982). These guidelines are commonly known as Bulletin 17B. Where the logarithms of the annual peak discharges are used, the fitted Pearson type III distribution is referred to as the log-Pearson type III distribution.

The log-Pearson Type III frequency distribution requires three parameters: the mean, standard deviation, and skew[4] of the logarithms of the annual series of peaks being fitted. The parameters define a smooth trend line through the observed peak discharges when plotted on a log-probability plot (i.e., the logarithm of the magnitude of each annual peak discharge plotted against its probability of occurrence). However, some peak discharges do not fit the general trend of observed peak discharges. Because the data are ranked, these outliers always occur at the high or low ends of the distribution. The log-Pearson type III distribution usually cannot fit both the general trend of the observed peak discharges and the outliers. This distorted fit typically does a poor job of representing the high end of the distribution and may significantly over- or under-estimate the largest peak discharges.

Following procedures recommended in Bulletin 17B, the parameters of the log-Pearson type III distribution are adjusted for the effects of high and low outliers as well as for historic peaks, for zero-flow peaks[5], and for peaks below the gage threshold. It is beyond the scope of this report to discuss these adjustments, but for those interested, they are treated in detail in Bulletin 17B.

Even after adjustment for outliers, the station skew value may be poorly defined for short record gaging stations. A better estimate of the skew coefficient is obtained by taking a weighted average of the adjusted station skew and a “generalized” skew

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[4] The mean is a measure of the central tendency of the distribution, the standard deviation is a measure of the dispersion of the distribution about the mean, and the skew is a measure of the asymmetry of the distribution. A distribution with a skew of zero is symmetrical.

[5] For some watersheds, in some years, there is no streamflow. The annual peak discharge in those years is zero.

based on the skew coefficients for long-term stations in the area.

Although generalized logarithmic skew coefficients for the United States are provided with Bulletin 17B, Bulletin 17B recommends that generalized skew coefficients be developed for each area of concern. If the newly developed generalized skew coefficients have a mean squared error less than that of the generalized skew coefficients provided by Bulletin 17B, the newly developed skew coefficients should be used in lieu of those provided in Bulletin 17B.

Generalized skew coefficients for Oregon were developed as part of this study. These generalized skew coefficients were combined with station skew values to obtain weighted skew estimators for each station. The weighted skew values were used in fitting the Pearson type III distributions. These topics are discussed in detail later in the report.

In general, fitting the theoretical Pearson type III distribution to the logarithms of the observed peak discharges was straightforward and produced good results. Of the 276 gaging stations, 141 required adjustment for high or low outliers or historic or zero peak discharges. Peak discharge statistics for the gaging stations are listed in Appendix B. Statistics include length of record; number of historical peaks; user defined high and low outlier thresholds; number of high and low outliers; number of zero flow peaks and peaks below the gage threshold; the station, Bulletin 17B, generalized, and weighted skews used in fitting the distribution; and the statistics from the trend analysis. The meaning and significance of these statistics can be found in Bulletin 17B.

A visual check of the “goodness of fit” of the theoretical Pearson type III distribution to the logarithms of the annual peak discharges was made for each of the 276 gaging stations. Four gaging stations originally considered for inclusion in this analysis were rejected based on this visual check. The fitted distributions did not reasonably approximate the actual distribution of observed peak discharges.

To make the check, the theoretical distribution and the observed peak discharges were plotted on a log-probability plot. (Appendix C discusses how the plotting position was determined for the probability axis.) The log-Pearson type III distribution generally plots as a curved line. The sense and degree of curvature is determined by the skew coefficient. Curvature is concave upward when the skew coefficient is positive and concave downward when it is negative. When the skew coefficient is zero, the distribution plots as a straight line. An example plot for the gaging station on the Middle Fork John Day River at Ritter, OR (14044000) is shown in Figure 9.

Peak discharge magnitudes at selected frequencies are obtained from the log-Pearson type III distribution by this equation:

$$\log Q = \overline{X} + KS \quad \text{.....} (1)$$

where

$\overline{X}$ = the mean of the logarithms of the peak discharges,

K = a factor that is a function of the skew coefficient of the logarithms of the peak discharges and the selected frequency, and

S = the standard deviation of the logarithms of the peak discharges.

Values of K can be obtained from Appendix 3 of Bulletin 17B. The table requires the skew coefficient and the frequency.

The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year peak discharges for the 276 gaging stations are listed in Appendix D.

Peak Discharge Data

The data used in this study are the annual series of peak discharges for the 276 gaging stations. An “annual series” of peak discharges represents the largest instantaneous peak for each year of record, reported in cubic feet per second (cfs). Peaks were measured at both continuous record sites and at crest-stage gage sites that record only the maximum peak discharge for each year. These measurement sites represent watersheds not significantly affected by reservoir operations, diversions, or urbanization. All sites have 10 or more years of measured peak discharges through water-

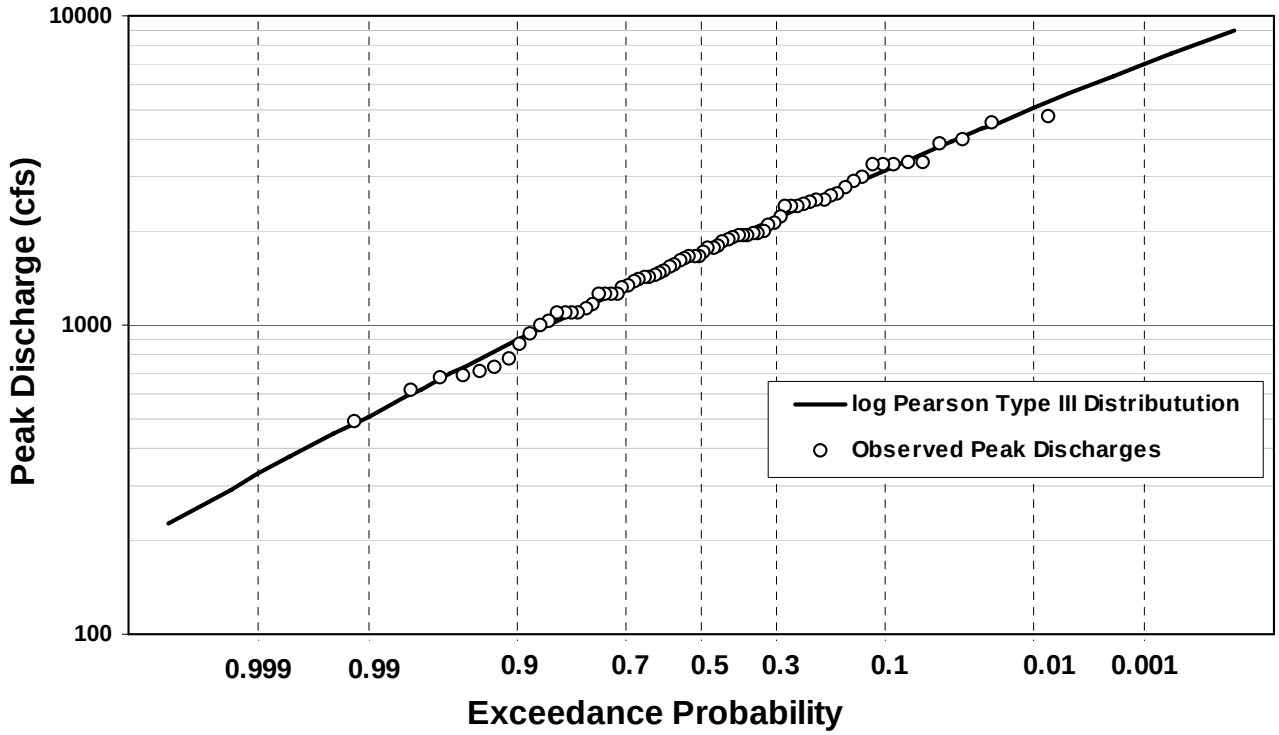


Figure 9. Log-Pearson Type III distribution fitted to measured peak discharges for the gaging station Middle Fork John Day River at Ritter, OR (14044000).

year 2003. The peak discharges used in this study were measured and reported by the U.S. Geological Survey and the Oregon Water Resources Department. All peak discharge data used in the analysis are available from the Oregon Water Resources Department (webmaster@wrd.state.or.us), and all peaks except those originating with the Oregon Water Resources Department are available from the U.S. Geological Survey (info-or@usgs.gov).

Quality Assurance

No effort was made to directly check the accuracy of peak discharges reported for the various gaging stations. It was assumed that adequate checks were made by the agency responsible for the peak estimates. However, a few scriveners' errors were discovered during the analysis. Unusual results in fitting the probability distributions or in doing the regression analysis were sometimes the result of erroneous peak values. In the first case, erroneous peaks caused the absolute value of the skew parameter of the distribution to be large. In the second case, erroneous peaks lead to large residuals in forming the prediction equations. In both cases, the observed peaks were examined for errors and corrected as necessary.

Assumptions of the Magnitude and Frequency Analysis

Assumptions of the magnitude and frequency analysis are that the peaks in any systematic series are random and that they are all derived from the same population. These assumptions mean (1) that the value of one peak does not depend on the value of a preceding peak, and (2) that all peaks arise from the same processes, e.g., as the result of rain from a frontal-storm as opposed to rain from a convective storm or as the result of snowmelt. Implicit in the second assumption is that the processes are not changing in time. For example, it is assumed that weather may vary from year to year, but that climate is not steadily getting wetter or drier, or warmer or colder. Other factors are also assumed to remain constant; that land use, for example, does not change substantially over the period the measurements are made.

Random Peak Discharges

A usual test for randomness is to check each series of annual peaks for a statistically significant linear correlation, i.e., a trend (Thomas and others, 1993; Wiley and others, 2000). A significant trend suggests that systematic, nonrandom changes in peak discharge characteristics are occurring in time. A trend test is not definitive; it is cause for investigation, not necessarily for the elimination of a gaging station from the analysis.

Peak discharges from the 276 gaging stations were tested for linear correlation. The resulting information was analyzed in two ways: 1) to check for regional, climate dependent trends, and 2) to check for local trends resulting from significant physical changes to a watershed. Local changes include human caused changes due to land use or water management as well as natural changes such as a volcanic eruption. Local trends that can be attributed to physical changes in the watershed may require all or part of a gaging station's period of record to be removed from consideration.

In the regional analysis, no consistent long-term trend was found, although there is evidence of a regional fluctuation of peak discharges between wet and dry periods. This fluctuation led to a higher than expected number of significant trends in long-term gaging station records. The evidence is too weak, however, to support a strong conclusion as to whether the fluctuations are truly periodic or what the period might be. Locally, no significant trend could be linked to physical changes in the associated watershed.

No gaging stations were eliminated from consideration based on the trend analysis. The details of the trend analysis are found in Appendix E.

Mixed Populations

For many watersheds in eastern Oregon, more than one hydrologic process may generate peak discharges. Most commonly, peaks result from snowmelt in spring or warm winter rain falling on accumulated snow. A few peaks result from rain from frontal storms in the summer or fall. More rarely, a peak results from a thunderstorm in late spring or summer. Finally, for a few watersheds in the Cascade Mountains where large springs dominate streamflow, annual peaks often occur in late summer and fall. While it is convenient to think of these processes as giving rise to distinct populations of peaks, the processes occur in unpredictable combinations and the populations overlap considerably. For example, rain-on-snow events probably form a continuum from pure rain to pure snowmelt.

For those watersheds where more than one hydrologic process generates peak discharges, the log-Pearson Type III distribution may poorly fit the distribution of annual peaks. When plotted on log-probability paper, a mixed population of peaks may show a sharp break in slope or a curve that reverses direction. The fitted distribution often has a large skew coefficient. If the peaks in these cases are separated into homogeneous populations, log-Pearson Type III distributions fitted to the separate populations may be significantly different from one another. In such cases, the distributions may be combined by the method described by Crippen (1978).

Often, however, the distribution of a mixed population of peaks does not exhibit a break in slope or a curve that reverses direction. If the distribution is well approximated by a log-Pearson Type III distribution, and if each of the separate populations is well represented in the mixed population, then there is no benefit to dividing the peaks into separate populations. The log-Pearson Type III distribution fitted to the mixed population will be close to the composite distribution calculated from the separate populations (Advisory Committee on Water Information, 2002).

The distributions of peak discharges for watersheds in eastern Oregon are generally well approximated by a log-Pearson Type III distribution, and there is no need to do a composite analysis based on separate populations. The exception is probably for peaks due to severe thunderstorms. While peaks from most thunderstorms appear to be distributed like peaks from snowmelt or rain-on-snow, very limited evidence suggests that peaks from severe thunderstorms are not. Unfortunately, there are so few of these peaks in the systematic record, it is not possible to determine the frequency characteristics of the population (see Relative Importance of Underlying Processes).

The peaks for all gaged watersheds used in the study were sorted into their months of occurrence in order to identify watersheds likely to have mixed

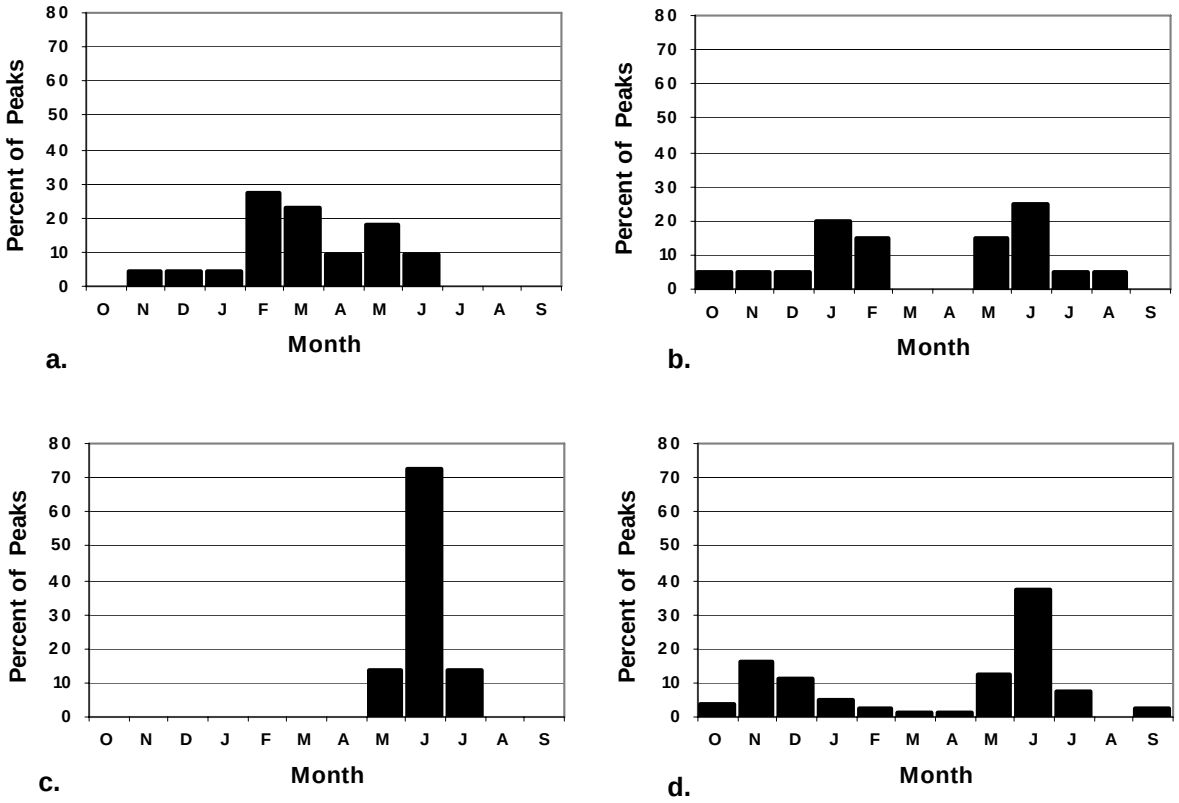


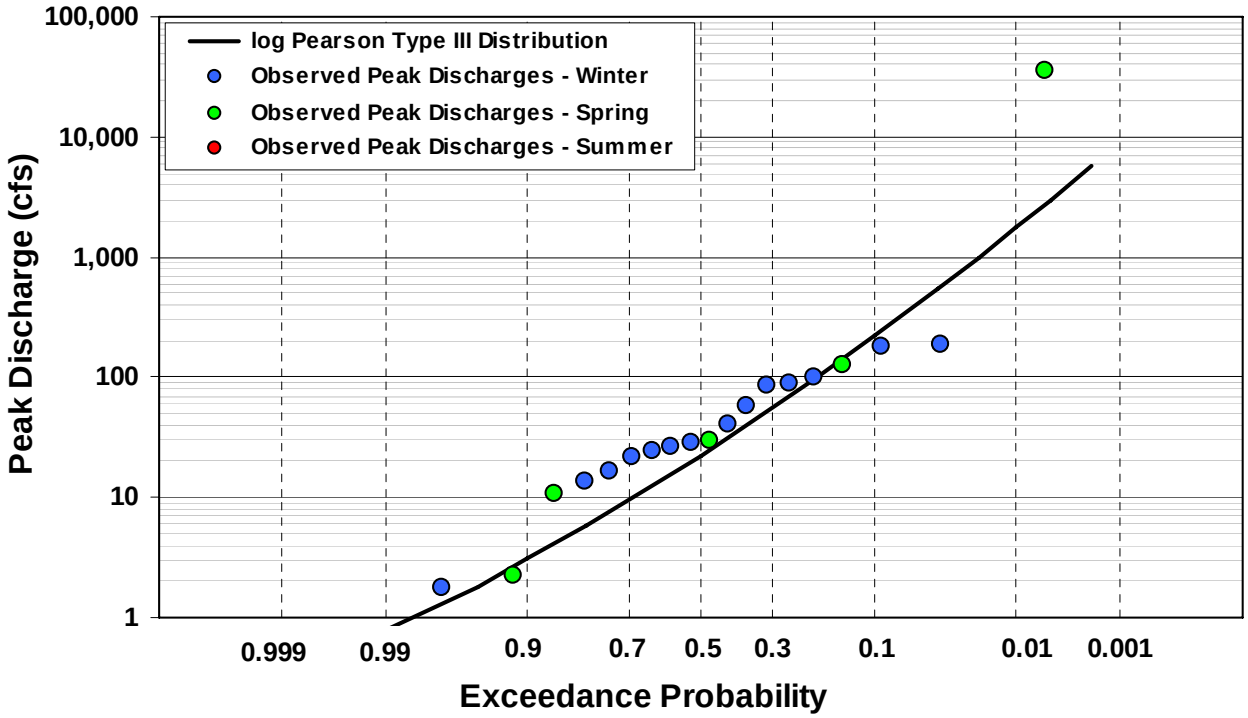
Figure 10. Distributions of the monthly occurrences of annual peak discharges for four gaging stations: a) Balm Fork near Heppner, OR (14034480), b) Willow Creek at Arlington, OR (14036000), c) East Fork Wallowa River near Joseph, OR (13325000), and d) Squaw Creek near Sisters, OR (14075000).

populations. This analysis assumes that the type of peak is related to the season of occurrence. This assumption is not definitive, but it holds generally. Rain-on-snow events generally occur in winter (October to March), snowmelt generally occurs in spring (April to June), and thunderstorms generally occur in summer (July to September). Some spring-dominated watersheds in the Cascades do not hold to these generalities at all. Their peaks occur in late summer and early fall and are not directly related to any of these meteorologic processes.

Figure 10 shows the monthly distributions for four watersheds. Three of the watersheds were selected because the monthly distributions were bimodal: Balm Fork near Heppner, OR (14034480), Willow Creek at Arlington, OR (14036000), and Squaw Creek near Sisters, OR (14075000). A bimodal monthly distribution is an indication of a mixed population of peaks. Balm Fork also includes a peak due to a severe thunderstorm. The fourth watershed, East Fork Wallowa River near Joseph, OR (13325000), was selected because it has several summer peaks and no winter peaks.

Log-probability plots of the peak discharges for the four gaged watersheds are shown in figure 11. The peaks are identified by their season of occurrence. Also shown is the log-Pearson Type III distribution fitted to the peak discharges. The distributions of the peak discharges for 3 of the 4 watersheds do not show breaks in slope or curves that reverse direction. The fitted log-Pearson Type III distributions for these watersheds are all reasonable. The remaining watershed, Balm Fork, may show a break in slope.

Balm Fork provides the single example of a peak due to a severe thunderstorm for any gaged watershed used in this study. The one high outlier represents the Heppner flood of June 1903. Its plotting position is based on a known historic period of 100 years. In fact, the frequency of an event of this magnitude on Balm Fork is unknown, and there is not sufficient



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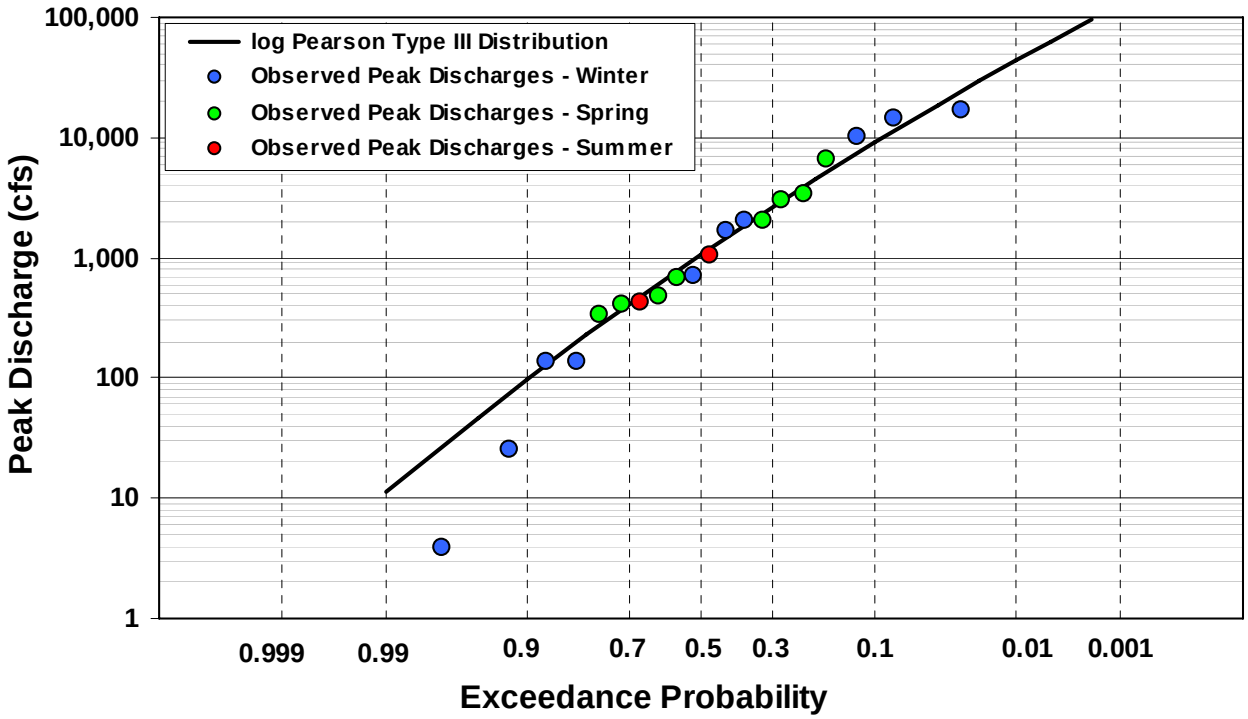
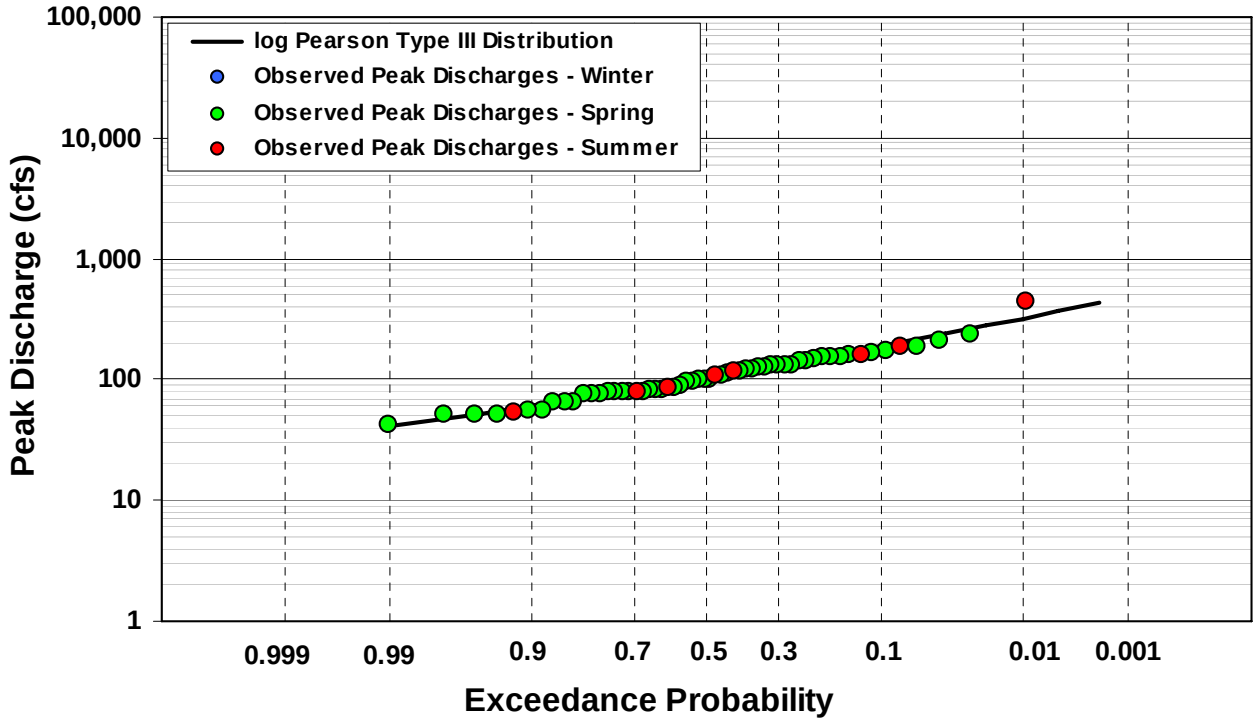


b.

Figure 11. Distributions of annual peak discharges for four gaging stations: a) Balm Fork near Heppner, OR (1403448), b) Willow Creek at Arlington, OR (14036000), c) East Fork Wallowa River, OR (1332500), and Squaw Creek near Sisters, OR (14075000). Peak discharges are identified



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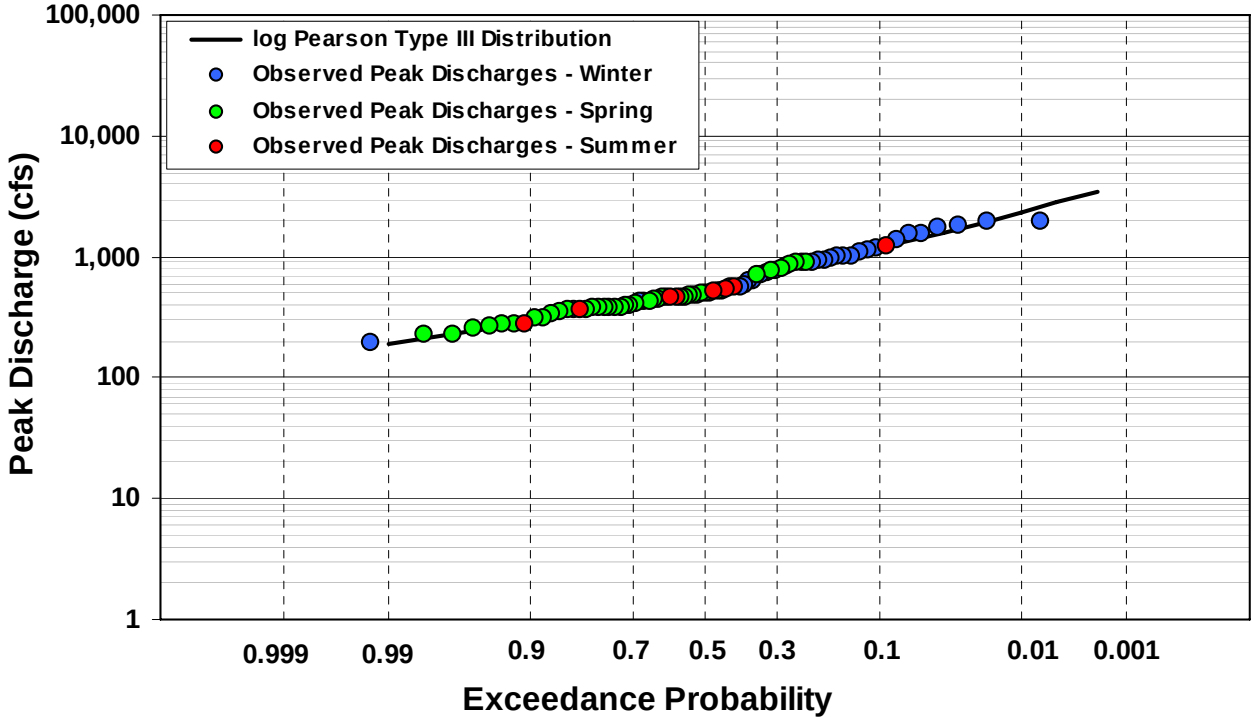


d.

Figure 11 - continued. by their season of occurrence: winter is November to March, spring, is April to June, and summer is July to September. Also shown are the log-Pearson Type III distributions that were fitted to the peaks.

information to determine the frequency. For the peak to fall on the fitted line, it would have to have a frequency on the order of once in 1,000 or so years. If a peak of this magnitude occurs more often than this, as seems likely, then the peak represents a break in slope and indicates a population of thunderstorms that should be considered separately.

Because there are not enough annual peak discharges representing severe thunderstorms, a typical frequency analysis cannot be performed. Unfortunately, there are not good alternatives. It is sometimes possible to obtain accounts of past floods through old newspapers, journals, histories, and interviews with local residents. While these accounts may accurately report the time of occurrence, information regarding peak stages or flow rates is often vague or missing. Flood peaks can also be synthesized based on assumed rainfall intensities and watershed runoff characteristics. The uncertainties associated with these methods are high and largely not quantifiable. For an example of how these methods were put to use in the Willow Creek basin in north central Oregon, see the report by the U.S. Army Corps of Engineers (1978).

Correcting for Low Peak Discharges not identified as Low Outliers

In some cases, low peak discharges have a pronounced negative effect on the fit of the log-Pearson Type III distribution to an annual series of peaks. Where two or more low peak discharges occur, the test for low outliers from Bulletin 17B often sets the low outlier threshold too low to catch all the outliers. On a log-probability plot, these low peak discharges give the distribution a strong downward curve, and there is often a sharp break in slope (fig. 12). Unless these low outliers are censored, the fit of the log-Pearson Type III distribution is compromised with the upper end of the distribution poorly defined and often overestimated.

These low peak discharges may represent a separate population of peaks, but there is no benefit to treating them as such, as they do not provide any information about the *magnitude* of peak discharges at the upper end of the distribution. However, the low peaks do provide information about the *frequency* of the peak discharges at the upper end. The peaks below the low threshold are used with any zero peaks in a conditional probability adjustment as described in Bulletin 17B, Appendix 5.

Where low peak discharges caused a poor fit of the log-Pearson Type III distribution to a series of annual peaks, the low outlier threshold was increased to improve the fit to the upper end of the annual peaks. The Advisory Committee on Water Information (2002) offers suggestions on how to determine how many low peak discharges to eliminate. In general, low peaks are eliminated one at a time until the conditional probability distribution based on the remaining peaks stops changing significantly. Figure 12 shows examples of how the fit of the log-Pearson Type III distribution was improved for three gaging stations: Currier Creek near Paisley, OR (11497800), the Silvies River near Seneca, OR (10392300), and the East Fork Quinn River near McDermitt, NV (10353000).

Generalized Skew

The skew coefficient of an annual series of peaks is sensitive to extreme values, especially when records are short. A more accurate estimate of the skew coefficient is obtained by weighting the station skew with a generalized skew value based on the skew coefficients of nearby long-term gaging stations. The weighting is based on the relative mean-square errors of the station and generalized skew and is given by this equation:

$$G_W = \frac{MSE_{\bar{G}}(G) + MSE_G(\bar{G})}{MSE_{\bar{G}} + MSE_G} \quad \text{.....(2)}$$

Where

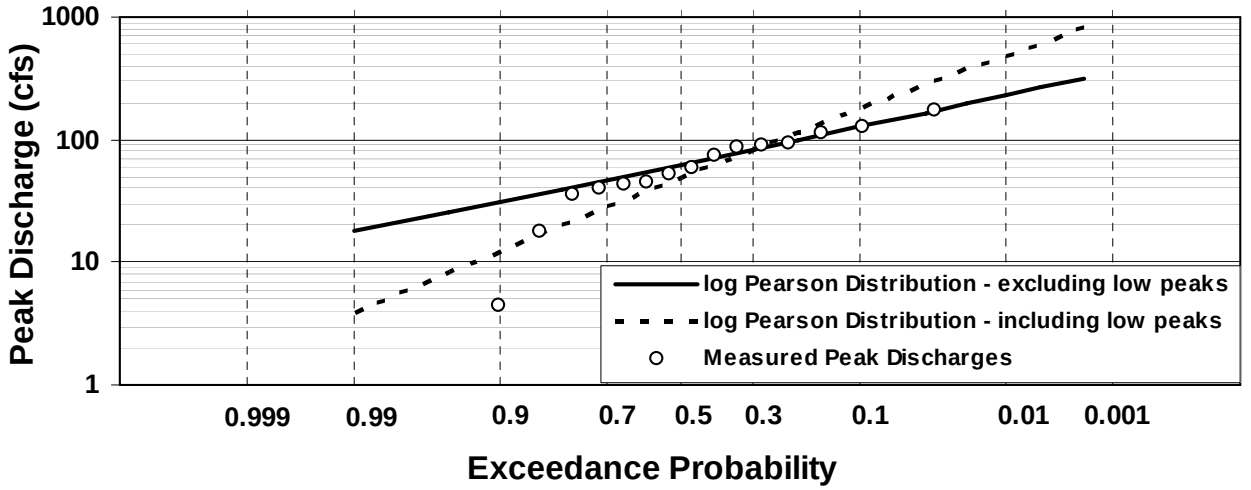
G_W = weighted skew coefficient,

G = adjusted station skew,

$\bar{G}$ = generalized skew,

$MSE_{\bar{G}}$ = mean-square error of the generalized skew, and

MSE_G = mean-square error of the station skew.



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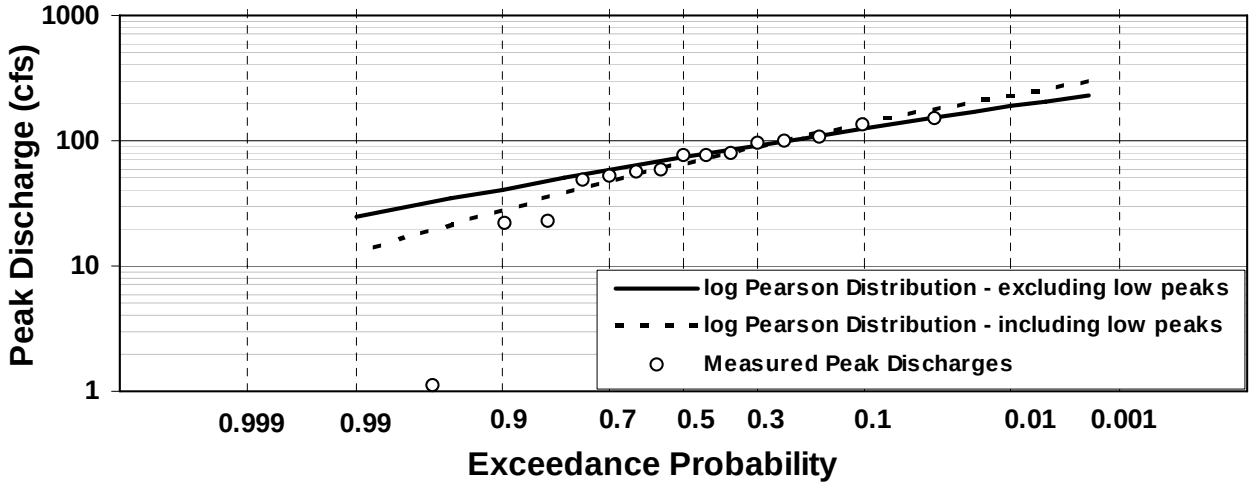

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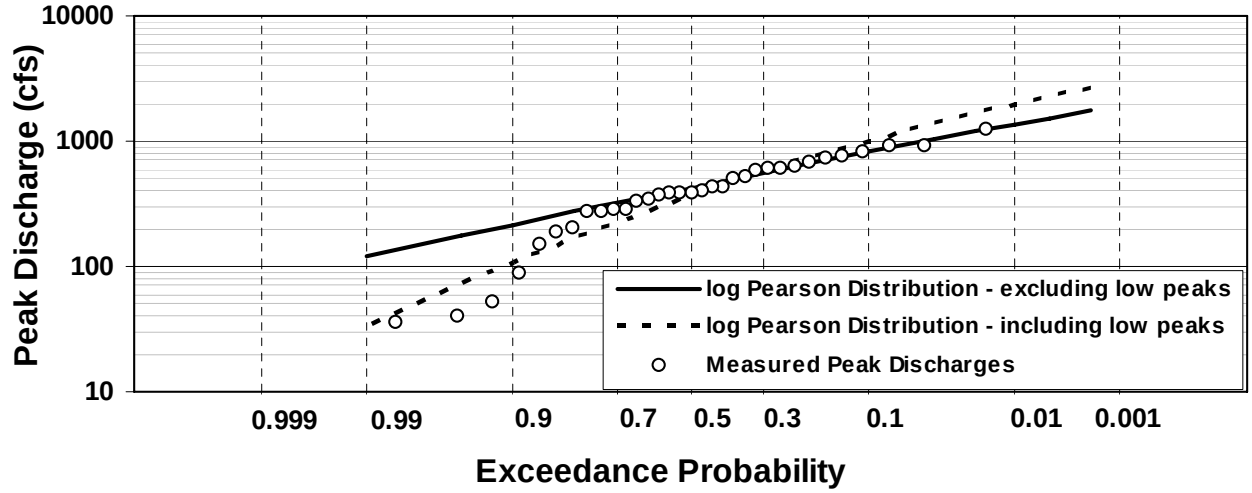

c.

Figure 12. The effect of low peaks on the fit of the log-Pearson Type III distribution to the peak discharges for three gaging station: a) Currier Creek near Paisley, OR (11497800), b) Silvies River near Seneca, OR (10392300), and c) East Fork Quinn River near McDermitt, NV (10353000).

Included with Bulletin 17B is a map of the generalized logarithmic skew coefficients of annual maximum streamflows for the entire United States. Although many peak discharge frequency studies use this map to obtain generalized skew values, Bulletin 17B recommends that users of the guide develop their own generalized skew coefficients for their area of interest using the procedures outlined in the bulletin.

Bulletin 17B outlines three methods for developing generalized skew coefficients: (1) drawing skew isolines on a map, (2) developing skew prediction equations, and (3) using the mean of station skew values. These generalized skews are to be developed using at least 40 stations with 25 or more years of record. The isoline map is drawn by hand from station skews plotted at the centroid of their watersheds. The prediction equations are developed to relate station skews to predictor variables that include the physical or climatological characteristics of the watersheds.

For this analysis, all three methods were tried. For the isoline method, rather than drawing the map by hand as suggested by Bulletin 17B, the map was drawn using GIS techniques, by the method described by Lumia and Baevsky (2000). How this method was adapted for this analysis is described in the next section. For the skew prediction equation method, useful equations could not be developed. There is not a good linear correlation between station skew and any of the available watershed characteristics.

The analyses were done statewide and were based on 267 gaging stations with more than 25 years of record in Oregon, southern Washington, western Idaho, northwestern Nevada, and northern California. The skews used in each analysis were the station skews adjusted for the effects of high and low outliers, zero peak discharges, and peak discharges below the gage threshold (see Bulletin 17B).

The isoline and average skew methods were evaluated based on a comparison of their mean-square errors to that of the generalized skew map provided with Bulletin 17B, the method with the smallest mean-square error being preferred. Mean-square errors for the isoline method and for the generalized skew map of Bulletin 17B were calculated by estimating the skew at each of the long-term stations by each method, squaring the difference between the station skew and the generalized skew, and taking the mean of the squared differences:

$$MSE = \frac{\sum_{i=1}^{n} (G_i - \overline{G_i})^2}{n} \quad \text{.....(3)}$$

where

MSE = mean-square error,

G_i = station skew for gaging station i,

$\overline{G_i}$ = generalized skew for gaging station i,

n = number of stations.

For the method where the generalized skew is estimated as the mean of all station skews, the mean-square error was simply the variance of the station skews.

The mean-square error for the isoline method (MSE = 0.112) was significantly smaller than for either the mean of all stations skews (MSE = 0.222) or the generalized skew from Bulletin 17B (MSE = 0.302 for all of the United States or MSE = 0.227 for the area of the generalized skew analysis).

Developing Generalized Skew Isolines

Lumia and Baevsky's (2000) method assigns skew values to cells of a grid overlaid on the area of interest. The isolines are drawn from this grid. The grid values are estimated by a weighted average of the skews of nearby long-term gaging stations. The station skews, plotted at the centroids of their watersheds, are weighted by their distance from the grid cell and by their length of record. The closer the centroid of the watershed and the longer the station record, the more weight the station skew is given in the calculation. Lumia and Baevsky used the ARC/Info (Environmental Systems Research Institute, Inc., Redlands, California) routine GRID IDW to determine the skew value at each cell (Y.H. Baevsky, U.S. Geological Survey, written commun., 2001), and used that routine's default values for grid spacing, 10,000 meters, and number of stations, 12 (R. Lumia, U.S. Geological Survey, written commun., 2001). LATTICECONTOUR was used to determine the isolines.

This study also used these routines, however, the grid spacing and number of stations were varied to see the effect on the resulting skew isoline map. As the grid spacing decreases, the isolines become

increasingly angular and blocky. As the number of stations decreases, the number of isolines increases and peaks and valleys appear around some stations. The gradients near these stations become increasingly steep.

The generalized skew map selected for this study was based on a grid spacing of 20,000 meters and 12 stations. The part of the map for eastern Oregon is shown in figure 13. This map was selected because it had the smallest mean square error while having skew isolines that are smooth and with no peaks or valleys. This map offers considerable improvement in mean-square error over either the generalized skew map provided by Bulletin 17B or the average of the skews of the 267 stations.

Figure 13 is provided for illustration only. A GIS (ARC/INFO) grid of the generalized skew coefficients may be obtained from the Oregon Water Resources Department (webmaster@wrd.state.or.us). It is recommended that generalized skew for a watershed be determined from this grid (using a GIS overlay analysis) rather than from a plotted map of generalized skew isolines.

Estimation of Magnitude and Frequency of Peak Streamflows at Ungaged Sites

Peak discharges for an ungaged watershed may be estimated from prediction equations that relate peak discharge to climatologic and physical characteristics of the watershed (Thomas, 1969; Riggs, 1973). The prediction equations are derived using multiple linear-regression techniques. This generalization or regionalization of peak discharges from measured to unmeasured watersheds is known as a "regional regression analysis".

For this study, a combination of regression techniques was used to derive the prediction equations. A preliminary analysis using ordinary least-squares regression was conducted to define flood regions of homogeneous hydrology and to determine which climatological and physical characteristics of the watersheds would be most useful in the prediction equations. The final prediction equations were derived using generalized least-squares regression (Tasker and others, 1986; Tasker and Stedinger, 1989) using the computer model, GLSNET (version 2.5), developed by the U.S. Geological Survey (2000).

Flood Regions

When using regression techniques to derive prediction equations, the accuracy of the equations may be improved by doing the derivations for regions of relatively uniform hydrology, called herein, flood regions. Six flood regions were defined for this study (fig. 14).

The first flood region defined for eastern Oregon was for the east slope of the Cascade Mountains – region 1. This region is unique in that its peak discharges have lower ratios of maximum to minimum peak discharges than do other regions[6] (Figure 15). Three characteristics of the region cause these low ratios: 1) it has much greater accumulations of snow than other areas, 2) it has numerous small lakes, and 3) its geology is characterized by young, highly porous, volcanic rock with large areas of cinder and pumice, and blocky lava flows. Because of the geology, peak discharges often are affected by spring flow and hydrologic boundaries are indeterminate.

Watersheds with springs, snow accumulation, and lakes have low ratios of maximum to minimum discharges because of short-term storage of precipitation with a gradual release to streamflow.

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[6] It is often difficult to calculate the ratio of maximum to minimum discharge using the observed minimum discharge for a stream. Many streams in eastern Oregon naturally have entire years with no flow – the annual peak discharge is zero. In these cases, the ratio of maximum to minimum discharges is undefined. In other cases, the low discharge is affected by diversion. In these cases, the calculated ratio is larger than the actual ratio. Here, we use the 95 percent exceedance natural streamflow as the measure of minimum discharge. These values are calculated by the Department for many watersheds in Oregon for use in the Water Availability Program (Cooper, 2002). This flow characteristic has the advantages of seldom being zero and of having been corrected for diversion. The disadvantage is that the values are only available for gaging stations with continuous record.

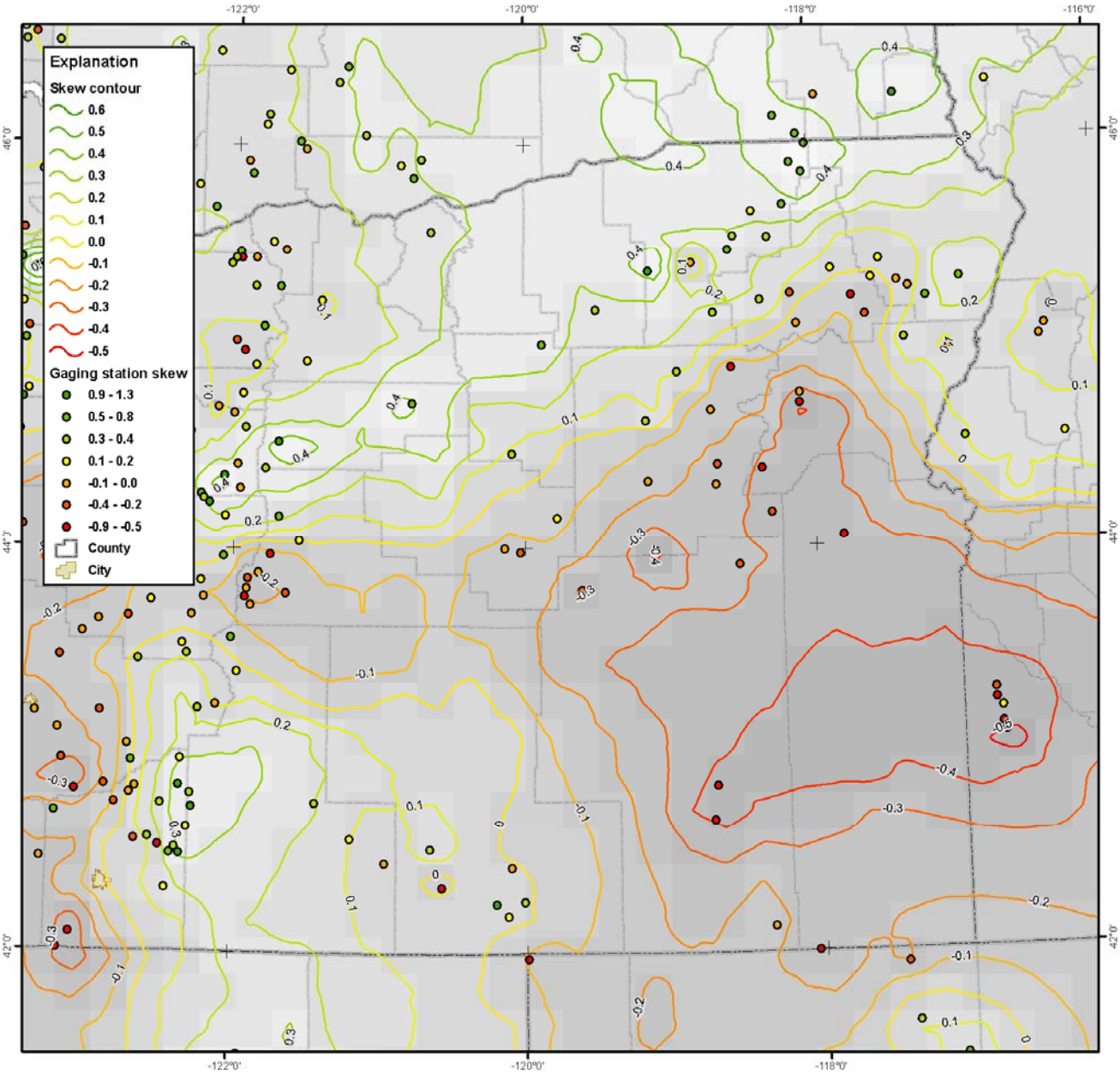

Figure 13. Generalized logarithmic skew coefficients for eastern Oregon. The isoline interval is 0.1. The colored circles represent skew coefficients of long-term gaging stations and are located at the centroids of their respective watersheds. The shaded background represents the GIS grid on which the isolines are based. Darker shades represent negative skews, and lighter shades, positive skews. The value of the skew coefficient for each grid cell was calculated as a weighted average of nearby gaging station skews.

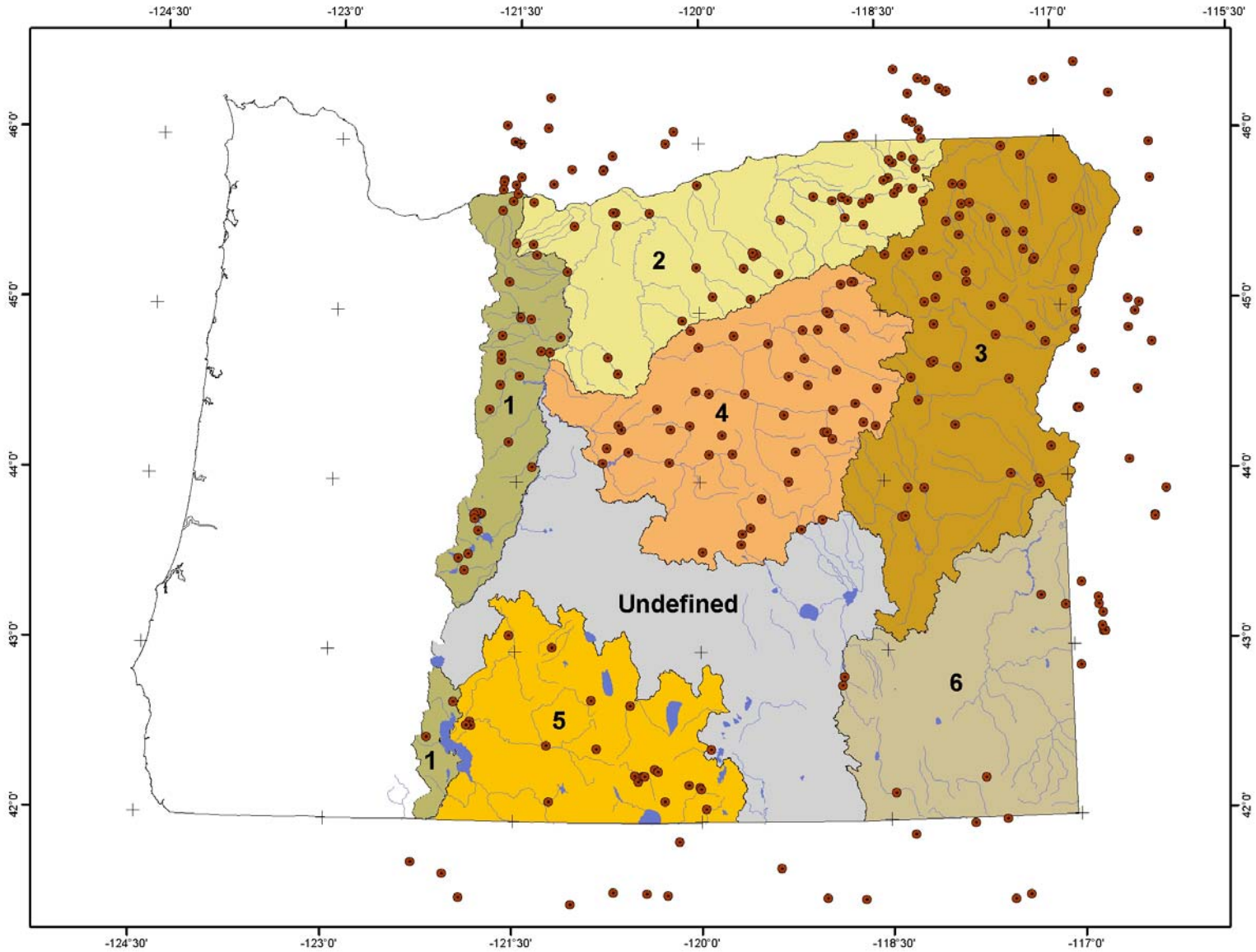

Figure 14. Flood regions of eastern Oregon. The dots represent gaging station locations. Note the poor stream development and lack of gaging stations in the undefined area.

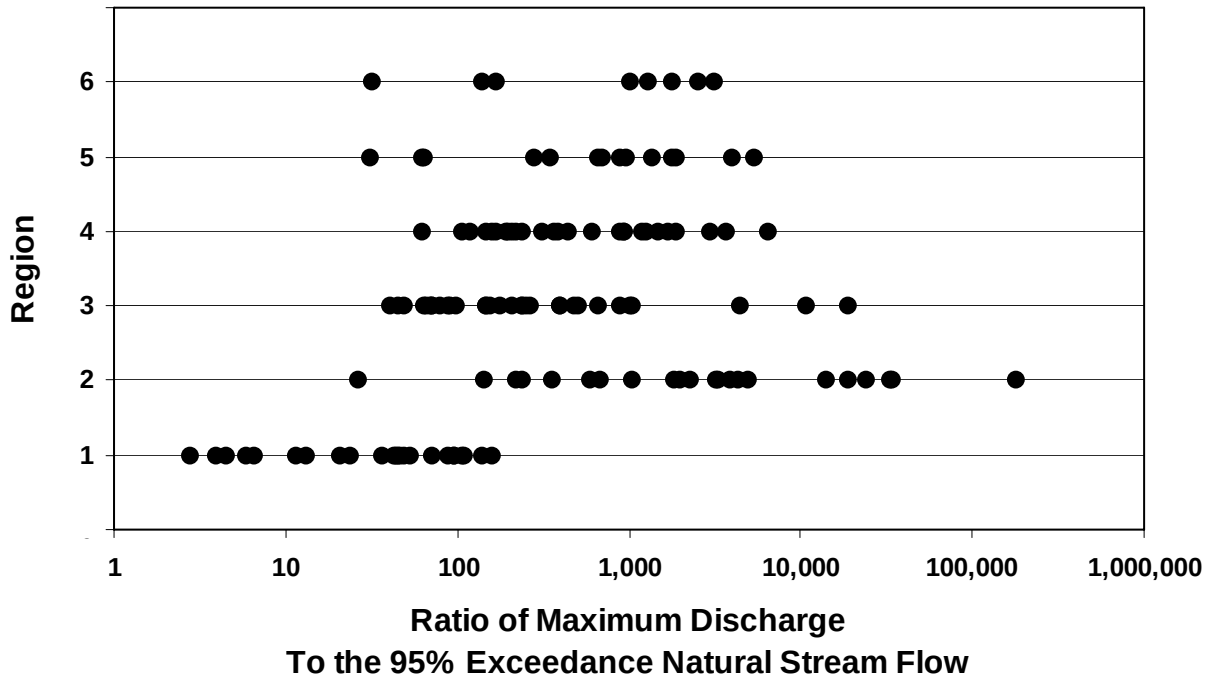

Figure 15. A plot of the ratio of maximum discharge to the 95 percent exceedance streamflow for selected gages from each region. Shown are gaging stations in Oregon with more than 10 years of continuous record and for which the 95 percent exceedance natural streamflow is greater than zero.

Streams with high ratios of maximum to minimum streamflows have limited capacity for storage, and peak discharges are dominated by direct runoff from rainfall.

The rest of eastern Oregon was divided into regions based on a simple cluster analysis (Wiley and others, 2000). First, an ordinary least-squares regression was done using 100-year peak discharges as the response variable and drainage area as the only predictor variable. Then, the residuals from the regression were plotted at the centroids of their respective watersheds on a map of the study area (fig. 16). Clusters of residuals of similar sign and magnitude were presumed to indicate areas of similar hydrology and were defined as flood regions. As much as possible, natural hydrologic boundaries were used to define regions to avoid splitting river basins into parts. In some cases, splitting basins was unavoidable, e.g., the Deschutes and John Day River basins.

These regions represent areas of similar hydrology. Separate sets of prediction equations were derived for each of these regions. Table 5 shows how gaging stations are distributed among the regions and how gaging stations are distributed by watershed area within each region.

Region 1 comprises the watersheds of all streams arising on the east side of the Cascade Mountains. These streams include the Hood, White, Warm Springs, Metolius, Little Deschutes, and upper Deschutes Rivers. The region includes all of the east side of the Cascade Mountains.

Region 2 occupies roughly the area previously defined as the Deschutes-Umatilla Plateau. It includes all of the Umatilla River, Willow Creek, tributaries of the John Day River below Bridge Creek, east side tributaries of the Deschutes River below the Crooked River, and tributaries of the Columbia River between the Deschutes and the Hood Rivers. These streams primarily drain the north slope of the Blue Mountains.

Region 3 comprises all Snake River tributaries in Oregon except the Owyhee River. Major streams are the Grande Ronde, Imnaha, Powder, Burnt, and Malheur River and numerous smaller watersheds. Region 3 occupies the eastern half of the Blue Mountains. The region includes all of the Wallowa

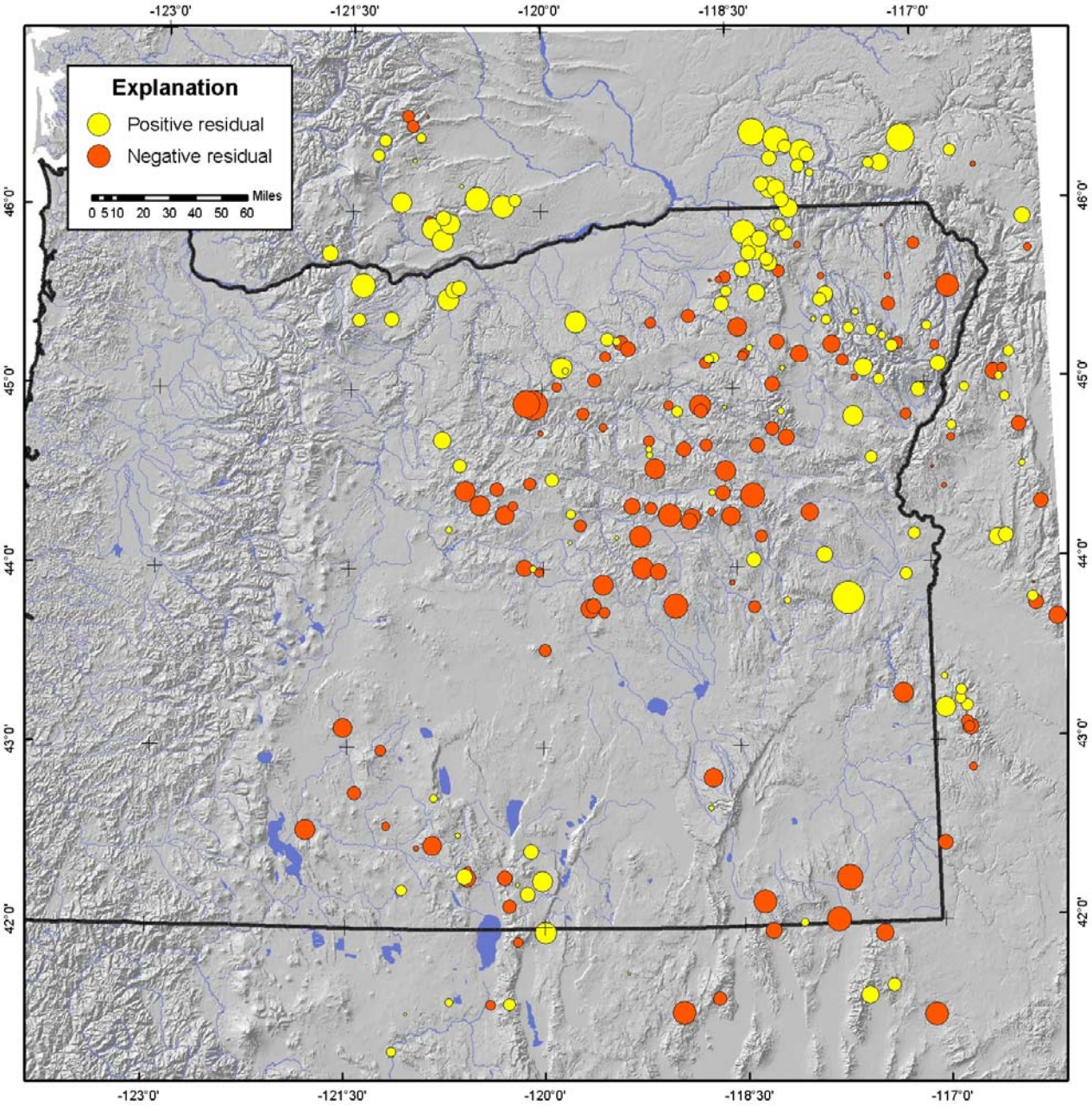

Figure 16. Residuals from a regression of 100-year peak discharges on area for all gaging stations in eastern Oregon except those in the Cascade Range (flood region 1). The size of each circle is proportional to the absolute value of the residual. Negative residuals are shown in red, and positive residuals, in yellow.

Table 5. Number of gages and their average record length by area and region.

	Region 1		Region 2		Region 3		Region 4		Region 5		Region 6	
Area	**Number of gages**	**Average record length**	**Number of gages**	**Average record length**	**Number of gages**	**Average record length**	**Number of gages**	**Average record length**	**Number of gages**	**Average record length**	**Number of gages**	**Average record length**
square miles		years		years		years		years		years		Years
< 1	0	N/A	3	19.3	5	13.8	0	N/A	2	11.0	2	22.5
1 – 3	0	N/A	5	18.2	9	13.1	7	13.9	5	13.8	1	19.0
3 – 10	2	12.5	12	16.4	12	13.4	11	19.6	3	15.3	3	13.7
10 – 30	12	37.2	6	18.7	12	25.1	8	16.1	4	17.8	7	25.4
30 – 100	12	39.6	12	32.3	15	31.7	6	17.5	6	18.2	4	34.5
100 – 300	10	24.9	11	43.7	10	33.7	7	26.9	5	57.6	4	59.3
300 – 1000	5	63.2	6	38.2	9	48.8	5	53.0	1	56.0	1	24.0
1000 – 3000	0	N/A	3	48.3	2	46.5	5	44.2	2	85.0	0	N/A
> 3000	0	N/A	0	N/A	2	35.0	2	86.5	0	N/A	0	N/A
Total	41	36.9	58	29.3	76	27.1	51	27.3	28	29.7	22	31.0

Mountains and the eastern slopes of the Elkhorn and Greenhorn Mountains.

Region 4 occupies the western part of the Blue Mountains. Major streams include the John Day River and its tributaries above Bridge Creek, the Crooked and Silvies Rivers and Silver Creek. The region includes all of the Ochoco and Strawberry Mountains and the western slopes of the Elkhorn and Greenhorn Mountains.

Region 5 occupies the southeastern corner of Oregon and includes the Owyhee Upland and the eastern third of the Basin and Range. Major streams are the Owyhee and Donner und Blitzen Rivers and Trout Creek. The region includes the Pueblo and Steens Mountains.

Region 6 occupies the western third of the Basin and Range. Major streams include the Williamson, Sprague, Sycan and Chewaucan Rivers and Thomas, Bridge and Drews Creeks. The region includes Winter Rim, and Yamsay and Gearhart Mountains.

Note that the area occupied by the High Lava Plains and the middle third of the Basin and Range is not included in a flood region. This area is not represented by any gaging stations. Prediction equations developed for surrounding regions can be expected to perform poorly in this undefined area.

Watershed Characteristics

Ninety-two watershed characteristics were available for this study (Appendix F). For each gaging station, the 92 watershed characteristics were estimated using the GIS computer program ARC/INFO 7.2.1 (Environmental Systems Research Institute, Inc., Redlands, California).

In a GIS analysis of watershed characteristics, each characteristic is associated with either a coverage (vector data) or a grid (raster data). For this study, the elevation grid (digital elevation model) came from the National Center for Earth Resources Observation & Science (1999). The precipitation and temperature grids came from the Oregon Climate Service (G.H. Taylor, Oregon State Climatologist, written commun., 2000, 2001). The soils coverage came from the National Cartography and Geospatial Center (1994). The climatologic characteristic grids from the Oregon Climate Service were generated using PRISM (Daly and others, 1997). PRISM stands for Parameter-elevation Regressions on Independent Slopes Model.

Table 6. Watershed characteristics used in the regression analysis.

[Units: mi^2, square miles; ft, feet; in, inches; in/hr, inches per hour; °, degrees; °F, degrees Fahrenheit]

Characteristic	Units	Data type	Scale or resolution	Source
Drainage area	mi^2	vector	1:24,000	Water Resources Department
Mean watershed slope	°	grid	30 m	U.S. Geological Survey
Maximum watershed aspect	°	grid	30 m	U.S. Geological Survey
Mean watershed elevation	ft	grid	30 m	U.S. Geological Survey
Mean January precipitation	in	grid	4,000 m	Oregon Climate Service
Mean July precipitation	in	grid	4,000 m	Oregon Climate Service
2-year 24-hour precipitation intensity	in	grid	3,000 m	Oregon Climate Service
Annual snowfall	in	grid	4,000 m	Oregon Climate Service
Mean minimum January temperature	°F	grid	4,000 m	Oregon Climate Service
Mean minimum July temperature	°F	grid	4,000 m	Oregon Climate Service
Mean maximum January temperature	°F	grid	4,000 m	Oregon Climate Service
Mean maximum July temperature	°F	grid	4,000 m	Oregon Climate Service
Soil storage capacity	in	vector	1:250,000	Natural Resources Conservation Service
Soil permeability	in/hr	vector	1:250,000	Natural Resources Conservation Service
Soil depth	in	vector	1:250,000	Natural Resources Conservation Service

To begin, each watershed was delineated from U.S. Geological Survey 1:24000 scale topographic maps and digitized into a coverage of all watersheds. The locations of the outlet and the centroid, the area, and the perimeter of each watershed were calculated directly from this coverage. For other characteristics, the watershed coverage was over-laid on the respective coverage or grid. Stream length and percent area of lakes and ponds were determined from an overlay of the hydrography coverage. For all others, the value of the characteristic was calculated as its average over the area of the watershed. The GIS analysis of watershed characteristics was implemented using an Arc Macro Language script. The script is available from the Oregon Water Resources Department on request (webmaster@wrd.state.or.us).

Most of the 92 characteristics were not used in the regression analysis. Some of the characteristics, such as the location of the centroid of a watershed, perimeter length or minimum watershed elevation, are poorly (or not at all) related to streamflow. Others, such as percent of a watershed above 3,000 feet, tend to cluster at one or two values. For example, most eastern Oregon watersheds have 100 percent of their area above 3,000 feet. Many of the characteristics, including the various monthly precipitation or temperature characteristics, are highly correlated with each other and using combinations of these values in a regression analysis does not add information. Based on these considerations and some trial regressions using ordinary least-squares, 15 characteristics were selected for the regression analysis (Table 6). These 15 characteristics for each of the 276 gaged watersheds used in the regional regression analysis are given in Appendix G.

The selected 15 characteristics were checked for collinearity. Matrices of the correlation coefficients for the characteristics of the watersheds for each of the three flood regions are shown in Tables 7, 8, 9, 10, 11, and 12. High correlation coefficients (absolute values greater than about 0.80) were detected. None of these pairs of characteristics were allowed to appear together in a prediction equation. The largest correlation coefficient for any pair of

Table 7. Correlation matrix of explanatory variables for the 41 gaging stations of region 1, east slope of the Cascade Range.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

	Area	Slope	Aspect	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mn Jul T	Mx Jan T	Mx Jul T	Soil C	Soil P	Soil D
Area	1.00														
Slope	0.16	1.00													
Aspect	0.18	0.35	1.00												
Elev	-0.69	-0.29	-0.10	1.00											
Jan P	-0.03	0.38	0.33	-0.15	1.00										
Jul P	-0.31	0.00	-0.01	0.37	0.66	1.00									
I24-2	-0.22	0.18	0.28	0.17	**0.91**	**0.83**	1.00								
Snow	-0.41	-0.06	0.02	0.53	0.63	**0.86**	**0.81**	1.00							
Mn Jan T	0.24	0.53	0.29	-0.65	0.30	-0.28	-0.04	-0.44	1.00						
Mn Jul T	0.31	0.44	0.41	-0.69	0.24	-0.37	-0.07	-0.51	**0.94**	1.00					
Mx Jan T	0.16	-0.02	-0.16	-0.17	-0.53	-0.68	-0.64	-0.56	0.22	0.18	1.00				
Mx Jul T	0.40	-0.09	-0.13	-0.43	-0.56	**-0.86**	-0.74	**-0.83**	0.34	0.39	**0.83**	1.00			
Soil C	0.13	-0.13	0.07	-0.28	0.15	0.12	0.18	0.15	-0.12	0.06	-0.22	-0.18	1.00		
Soil P	-0.38	-0.34	-0.46	0.56	-0.17	0.24	0.04	0.42	-0.73	-0.78	-0.08	-0.27	0.00	1.00	
Soil D	-0.13	0.09	0.30	-0.14	0.51	0.17	0.45	0.26	0.19	0.28	-0.30	-0.22	0.51	0.10	1.00

Table 8. Correlation matrix of explanatory variables for the 58 gaging stations of region 2, north-central eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

	Area	Slope	Aspect	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mn Jul T	Mx Jan T	Mx Jul T	Soil C	Soil P	Soil D
Area	1.00														
Slope	0.28	1.00													
Aspect	-0.12	-0.07	1.00												
Elev	0.24	0.68	-0.37	1.00											
Jan P	0.19	0.55	-0.05	0.44	1.00										
Jul P	0.25	0.79	0.15	0.61	0.43	1.00									
I24-2	0.21	0.65	-0.05	0.51	**0.97**	0.58	1.00								
Snow	0.33	0.64	-0.22	0.75	**0.86**	0.55	**0.87**	1.00							
Mn Jan T	-0.09	-0.15	0.33	-0.59	-0.09	0.06	-0.05	-0.28	1.00						
Mn Jul T	-0.22	-0.43	0.33	-0.79	-0.32	-0.25	-0.37	-0.54	0.77	1.00					
Mx Jan T	-0.12	-0.47	0.20	-0.71	-0.69	-0.38	-0.69	-0.79	0.56	0.62	1.00				
Mx Jul T	-0.20	-0.42	0.44	**-0.83**	-0.43	-0.39	-0.48	-0.77	0.42	0.63	0.73	1.00			
Soil C	-0.25	-0.20	0.50	-0.60	-0.15	-0.08	-0.16	-0.48	0.37	0.51	0.31	0.65	1.00		
Soil P	0.19	-0.14	-0.10	-0.09	0.48	-0.05	0.38	0.32	0.12	0.19	-0.27	-0.18	-0.09	1.00	
Soil D	-0.15	-0.35	0.11	-0.43	0.09	-0.23	0.07	-0.24	0.16	0.19	0.12	0.31	0.51	0.39	1.00

Table 9. Correlation matrix of explanatory variables for the 76 gaging stations of region 3, northeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

	Area	Slope	Aspect	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mn Jul T	Mx Jan T	Mx Jul T	Soil C	Soil P	Soil D
Area	1.00														
Slope	0.36	1.00													
Aspect	-0.16	0.01	1.00												
Elev	0.20	0.60	-0.04	1.00											
Jan P	0.26	0.73	0.04	0.73	1.00										
Jul P	0.17	0.49	0.16	0.72	0.62	1.00									
I24-2	0.20	0.63	0.18	0.71	**0.92**	**0.80**	1.00								
Snow	0.29	0.65	0.06	**0.86**	**0.89**	**0.82**	**0.92**	1.00							
Mn Jan T	0.16	-0.06	0.10	-0.40	-0.11	-0.27	-0.11	-0.24	1.00						
Mn Jul T	-0.05	-0.20	-0.03	-0.70	-0.44	-0.78	-0.59	-0.70	0.60	1.00					
Mx Jan T	0.01	-0.50	0.11	-0.72	-0.67	-0.55	-0.65	-0.72	0.44	0.52	1.00				
Mx Jul T	-0.21	-0.52	0.00	**-0.83**	-0.70	**-0.86**	**-0.81**	**-0.88**	0.14	0.77	0.66	1.00			
Soil C	0.01	-0.37	0.02	-0.22	-0.20	-0.15	-0.13	-0.08	0.46	0.08	0.20	-0.03	1.00		
Soil P	0.12	0.13	-0.02	0.30	0.24	0.22	0.22	0.32	-0.18	-0.27	-0.16	-0.23	-0.10	1.00	
Soil D	-0.16	-0.48	-0.07	-0.34	-0.35	-0.29	-0.31	-0.24	0.20	0.11	0.21	0.19	0.69	0.37	1.00

Table 10. Correlation matrix of explanatory variables for the 51 gaging stations of region 4, central eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

	Area	Slope	Aspect	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mn Jul T	Mx Jan T	Mx Jul T	Soil C	Soil P	Soil D
Area	1.00														
Slope	-0.09	1.00													
Aspect	0.11	0.07	1.00												
Elev	-0.14	0.13	-0.18	1.00											
Jan P	-0.13	0.42	-0.01	0.58	1.00										
Jul P	-0.09	0.05	-0.11	0.16	0.46	1.00									
I24-2	-0.14	0.10	0.00	0.36	0.72	0.64	1.00								
Snow	0.02	0.19	-0.03	**0.87**	0.76	0.22	0.47	1.00							
Mn Jan T	-0.33	0.05	0.00	-0.63	-0.19	-0.01	-0.06	-0.62	1.00						
Mn Jul T	-0.04	0.14	-0.07	-0.31	-0.13	-0.16	-0.28	-0.25	0.59	1.00					
Mx Jan T	0.02	-0.09	0.21	-0.78	-0.40	0.03	-0.19	-0.75	0.48	0.13	1.00				
Mx Jul T	0.29	-0.14	0.12	-0.52	-0.69	-0.45	-0.63	-0.60	-0.02	0.09	0.50	1.00			
Soil C	-0.22	0.27	-0.13	0.34	0.51	0.45	0.36	0.45	0.02	-0.09	-0.43	-0.68	1.00		
Soil P	0.26	0.23	0.05	0.50	0.47	0.19	0.11	0.53	-0.46	-0.06	-0.29	-0.25	0.24	1.00	
Soil D	-0.01	0.14	0.03	0.32	0.32	0.24	0.37	0.32	-0.05	-0.24	-0.37	-0.45	0.74	0.17	1.00

Table 11. Correlation matrix of explanatory variables for the 28 gaging stations of region 5, southwest eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

	Area	Slope	Aspect	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mn Jul T	Mx Jan T	Mx Jul T	Soil C	Soil P	Soil D
Area	1.00														
Slope	0.17	1.00													
Aspect	-0.04	0.16	1.00												
Elev	-0.07	0.64	0.01	1.00											
Jan P	-0.12	0.34	0.02	0.26	1.00										
Jul P	0.16	0.47	0.26	0.56	0.25	1.00									
I24-2	-0.11	0.33	0.10	0.39	0.78	0.71	1.00								
Snow	-0.03	0.46	0.08	0.59	0.79	0.64	**0.88**	1.00							
Mn Jan T	-0.21	-0.09	-0.31	0.10	-0.14	-0.32	-0.28	-0.35	1.00						
Mn Jul T	-0.15	0.05	-0.19	0.01	-0.34	-0.56	-0.65	-0.58	0.78	1.00					
Mx Jan T	-0.03	-0.43	-0.49	-0.61	-0.52	-0.56	-0.58	-0.68	0.17	0.26	1.00				
Mx Jul T	-0.04	-0.58	-0.33	**-0.81**	-0.54	-0.78	-0.72	**-0.81**	0.09	0.34	**0.85**	1.00			
Soil C	0.28	-0.15	0.42	-0.09	0.34	0.48	0.57	0.44	-0.53	-0.74	-0.55	-0.39	1.00		
Soil P	0.01	0.03	0.29	0.18	0.39	0.62	0.69	0.49	-0.37	-0.61	-0.55	-0.47	0.72	1.00	
Soil D	0.20	0.27	0.55	0.18	0.26	0.69	0.51	0.44	-0.46	-0.54	-0.57	-0.53	0.63	0.56	1.00

Table 12. Correlation matrix of explanatory variables for the 22 gaging stations of region 6, southeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Correlation coefficients greater than 0.8 are in bold face.]

	Area	Slope	Aspect	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mn Jul T	Mx Jan T	Mx Jul T	Soil C	Soil P	Soil D
Area	1.00														
Slope	0.25	1.00													
Aspect	-0.03	-0.31	1.00												
Elev	-0.04	-0.01	0.22	1.00											
Jan P	-0.13	-0.02	0.01	0.48	1.00										
Jul P	-0.41	-0.20	0.27	0.17	0.57	1.00									
I24-2	-0.04	-0.16	0.25	0.56	**0.91**	0.53	1.00								
Snow	0.11	-0.01	0.27	0.76	0.78	0.34	**0.90**	1.00							
Mn Jan T	0.50	0.10	0.27	0.32	-0.03	-0.39	0.24	0.42	1.00						
Mn Jul T	0.62	0.41	0.09	0.23	-0.24	-0.46	-0.08	0.16	**0.84**	1.00					
Mx Jan T	0.48	0.00	0.20	-0.14	-0.53	-0.65	-0.30	-0.14	0.72	0.74	1.00				
Mx Jul T	0.03	0.33	-0.31	-0.71	-0.70	-0.36	**-0.84**	**-0.83**	-0.27	0.12	0.29	1.00			
Soil C	0.00	0.17	-0.06	-0.08	0.08	0.17	0.13	0.19	0.19	0.10	-0.06	0.02	1.00		
Soil P	-0.48	-0.41	0.04	0.11	-0.01	0.34	-0.10	-0.14	-0.51	-0.45	-0.33	0.01	-0.45	1.00	
Soil D	-0.49	-0.08	-0.14	-0.03	-0.24	0.16	-0.39	-0.26	-0.42	-0.34	-0.29	0.25	0.03	0.56	1.00

characteristics used in the final prediction equations was -0.67.

The area determined for each gaged watershed from the spatial analysis was compared to the published value. Where significant differences occurred, the delineation of the watershed was checked. A number of errors were discovered in this way. The distribution of gaged watersheds by area and region is shown in Table 5.

Description of the Watershed Characteristics

All characteristics represent the watershed upstream of the gaging station, or other point of interest, that contributes to peak discharges. The watershed is delineated based on topography as shown on U.S. Geological Survey 1:24,000-scale topographic maps.

Drainage area is the size of the watershed in square miles.

Mean watershed slope is calculated as the average of the slopes of all the cells of the digital elevation model found within the watershed boundaries. In this case, slope is given as a percent of vertical or 90 degrees. For example, a 0% percent slope is horizontal, a 50% slope is 45 degrees from horizontal, and a 100% percent slope is vertical.

Mean watershed aspect is calculated as the average of the aspects of all the cells of the digital elevation model found within the watershed boundaries. Aspect is given as a compass direction, for example, 0° is north facing and 180° is south facing.

Mean elevation is calculated as the average of the elevations of all the cells of the digital elevation model found within the watershed boundaries. It is reported in feet.

Mean January precipitation, mean July precipitation, 24-hour 2-year precipitation intensity, and annual snowfall are calculated as the average of the values of all the cells of their respective coverages found within the watershed boundary. All are reported in inches. Each of the coverages represents averages for water years 1961 to 1990.

Mean January minimum temperature, mean July minimum temperature, mean January maximum temperature, and mean July maximum temperature are calculated as the average of the values of all the cells of their respective coverages found within the watershed boundary. All are reported in degrees Fahrenheit. Each of the coverages represents averages for water years 1961 to 1990.

Soil capacity is the maximum volume of water the soil is expected to hold. It is calculated as the area weighted average of the soil capacity for all the soils found within the watershed boundary. Soil capacity for a given soil is its porosity times its depth. Soil capacity is reported in inches.

Soils permeability is the rate at which water is expected to infiltrate the soil. It is calculated as the area weighted average of the infiltration rate for all the soils found within the watershed boundary. It is reported in inches per hour.

Soil depth is the depth of soil to bedrock averaged over the watershed. It is reported in inches.

Selection of Gaging Stations

Within the study area and adjacent parts of Washington, Idaho, Nevada and California there are around 450 to 500 gaging stations where peak discharges have been systematically recorded. Of these, 299 stations had more than 10 years of record and were in rural watersheds unaffected by significant diversion, regulation or urbanization. Twenty-three of these stations were eliminated for a variety of reasons.

Two gaging stations in northern Nevada considered for inclusion in flood region 6 were dropped because they so profoundly leveraged the fit of the regression line. Little Humboldt River near Paradise Valley, NV (10329000) and Quinn River near McDermitt, NV (10353500) have drainages areas much larger than other stations in the region and significantly lower yields. Including them in the regression resulted in underestimating peak discharges at stations with smaller drainage areas.

Four gaging stations were eliminated because reasonable fits to the log-Pearson Type III distribution could not be made. These stations were Dry Creek at the mouth near Clarkston, WA (13343450), South Fork John Day River near Dayville, OR (14039500),

Donnely Creek tributary near Service Creek, Or (14046400), and Wildcat Creek near Prineville, OR (14082400).

The location of the gaging station Dry Lake tributary at Perez, CA (11487700) could not be determined. Published information about the station location (latitude and longitude, physical description, public land survey, and drainage area) could not be reconciled with any actual watershed on 1:24,000 scale topographic maps.

The Williamson River below Sheep Creek near Lenz, OR (11491400) was eliminated because it was an extreme low outlier in any regression trial in which it appeared. The watershed is extremely unproductive. All reported peaks have unit discharges of less than 1.0 cfs per square mile suggesting large losses to regional groundwater. The watershed is in an area of deep pumice deposits.

The Williamson River near Klamath Agency, OR (11493500), the Sycan River near Beatty, OR (11499000), and Sycan River below Snake Creek near Beatty, OR (1199100) were eliminated because of natural streamflow regulation. The first gaging station is located at the outlet of Klamath Marsh and the other two are below Sycan Marsh. Also the Williamson River gaging station represents a watershed with unit peak discharges of less than 1.0 cfs per square mile. Much of the watershed has deep deposits of pumice from eruptions of Mount Mazama suggesting large losses to regional groundwater.

The South Fork Burnt River above Barney Creek near Unity, OR (13270800) was eliminated because it is unlike other streams in region 3. It has an unproductive watershed with unit peak discharges that are low in comparison to other streams in the region. The South Fork Burnt River is known to have significant contributions from spring flow. The ratio of maximum peak discharge to the 95 percent exceedance streamflow is low (12, compared to the next lowest ratio in the region, 41) suggesting that peak discharges are attenuated due to high groundwater recharge rates in the watershed.

The Malheur River tributary near Harper, OR (13219300) was also eliminated because it is unlike other stream in region 3. In this case, the watershed generates very high runoff. It has recorded 6 of the 89 largest unit peak discharges reported in eastern Oregon. When included in a regression analysis for the region, its residual is over 5 standard deviations from the mean. It has very high leverage and a pronounced effect of the fit of the regression line, causing the resulting predication equation to overestimate peak discharges for small watersheds.
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Two gaging stations, the Deschutes River at Mecca, OR (14093500) and the Deschutes River at Moody near Biggs, OR (14103000), were eliminated because they could not be assigned to any one region. The upper Deschutes River and east flowing tributaries from the Cascades are in region 1. The rest of the Deschutes basin is divided between regions 2 and 4.

In several cases, gaging stations occur near each other on the same stream reach. In 9 of these cases, one or other of each pair was eliminated: Deep Creek at Adel, OR (10374500), Grande Ronde River at Elgin, OR (13324000), Asotin Creek near Asotin, OR (13334500), South Fork Walla Walla River near Milton, OR (14010500), Umatilla River at Gibbon, OR (14020500), Umatilla River above McKay Creek near Pendleton, OR (14022000), Butter Creek at Foleys Bridge near Echo, OR (14032050), Rock Creek above Cayuse Canyon near Condon, OR (14047400), and White River above Trout Creek near Trout Lake, WA (14121400). For each pair, estimated peak discharges at the upstream station are greater than at the downstream station. The apparent decrease in discharge occurs not because of stream losses, but because of uncertainty in estimating the peak discharges. For each pair, only the station considered the most reliable was retained. The stations were judged on their length and quality of record and their fit to the probability distribution.

The Regression Analysis

A regional regression analysis is based on the assumption that streamflow is related to various watershed characteristics. For example, streamflow increases with watershed size, other factors like precipitation being equal. A 100-square mile watershed produces more runoff than a 25-square mile watershed.

As an example, the relationship between 100-year peak streamflows and watershed area for region 3 is shown in Figure 17. The line shown on the plot

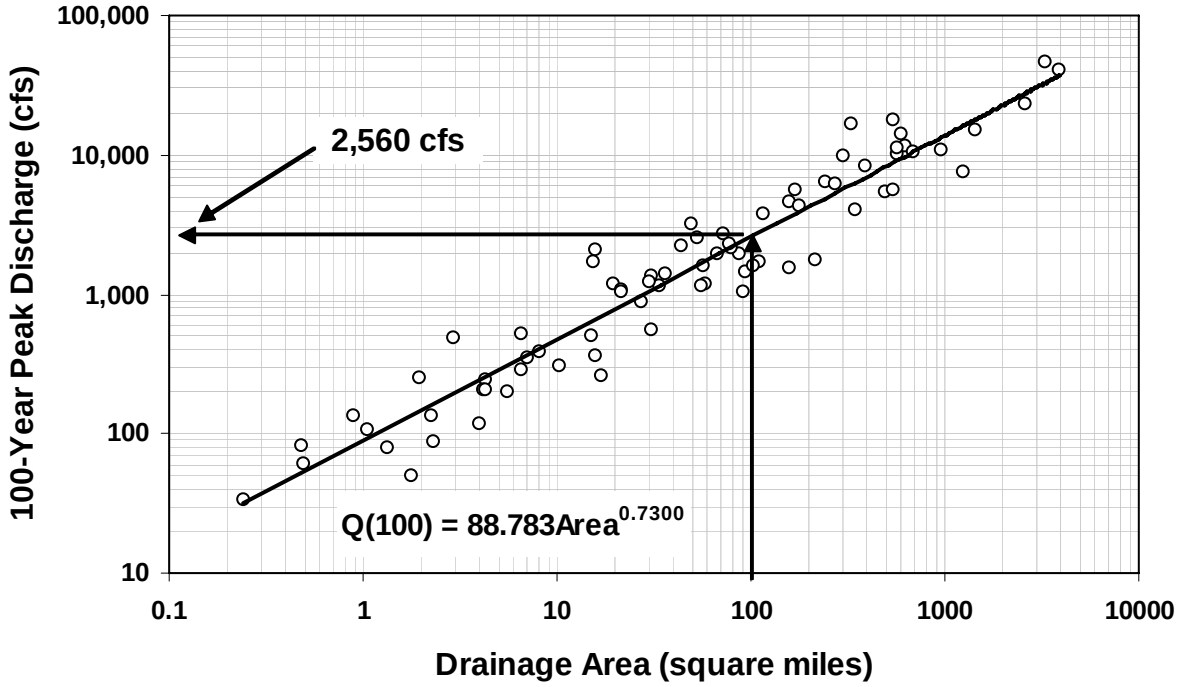

Figure 17. A simple regional regression model. 100-year peak discharges are plotted against watershed area for Region 3. The line (i.e., the model) through the data points was fitted by ordinary least squares regression analysis and is represented mathematically by the equation shown on the chart. Based on this model, a watershed of 100 square miles has a 100-year peak discharge of about 2,560 cfs.

minimizes the sum of the squared differences between the line and the points. The line "models" the relationship between streamflow and watershed area. It can be used to predict the streamflow for a watershed given its area. The variation about the line is due, in part, to other watershed characteristics not included in the model.

Similar relationships exist between peak discharge and other watershed characteristics (Table 6), each characteristic accounting for part of the variability in streamflow. These relationships can be quantified in a mathematical form. For this analysis, a linear relationship is assumed between streamflow and watershed characteristics. The linear mathematical model takes the form

$$y = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_m x_m \quad \text{.....} (4)$$

where y represents streamflow and x_1, x_2, . . ., x_m represent the *m* watershed characteristics. The regression coefficients, b_1, b_2, . . ., b_m, define the relationship among variables and are determined from the data.

The data consist of *n* observations of y and x_m, from which *n* equations of the type of Equation 4 can be written. The regression coefficients are determined by minimizing the sum of the squared differences between the actual values of y and the values of y estimated by the *n* equations. The equations resulting from this minimization are called the normal equations.

While regression analysis assumes a linear relationship between the response and predictor variables, the true relationship for peak streamflows is nonlinear. A log-transformation of peak discharges and watershed characteristics allows the nonlinear relationship to be modeled by a linear relationship (Riggs, 1968, 1973).

The nonlinear model of the relationship between streamflow and watershed characteristics looks like this

$$y = 10^{b_0} x_1^{b_1} x_2^{b_2} \cdots x_m^{b_m} \quad \text{.....} (5)$$

A logarithmic transformation of Equation 5 yields the linear relationship

$$\log(y) = b_0 + b_1 \log(x_1) + b_2 \log(x_2) + \cdots + b_m \log(x_m) \quad \text{..... (6)}$$

Previous studies in Oregon have used ordinary least-squares regression to derive the prediction equations. Ordinary least-squares regression assumes that peak discharge records are equally reliable, i.e., of the same length and variance, and that concurrent flows at any pair of stations are independent. These conditions are seldom met in practice.

Tasker and Stedinger (1989) proposed an operational generalized least-squares model for deriving prediction equations for streamflow characteristics such as peak discharge. This model accounts for the unequal lengths and variances of peak discharge records and cross-correlation between series of streamflow characteristics. Tasker and others (1986) showed that generalized least-squares, compared to ordinary least-squares, provides (1) estimates of regression parameters with smaller mean square errors, (2) relatively unbiased estimates of the variance of the regression parameters, and (3) a more accurate estimate of the model error.

Defining the Prediction Equations

Only some of the 15 watershed characteristics are correlated with peak discharge. Since only correlated watershed characteristics can explain the observed variability in peak discharges, there is no benefit to including all characteristics in a prediction equation. The goal, then, is to find the prediction equation that explains as much of the observed variability in peak discharges as possible with the fewest number of watershed characteristics.

With 15 watershed characteristics, the number of possible prediction equations is 2^{15} –1 or 32,767. Rather than test all possible prediction equations, a backward-step analysis may be used to determine the best prediction equation. In a backward step analysis, a regression is done using all candidate watershed characteristics. The characteristic that has the least significant coefficient is eliminated and the regression is run again. This process is repeated until only one characteristic remains.

Each regression is associated with a set of watershed characteristics and their respective coefficients, and each set of characteristics and coefficients represents a candidate prediction equation. The best prediction equation generally is considered to be the combination of watershed characteristics that gives the smallest model error while its regression coefficients are all significantly different from zero. The significance of the regression coefficients is determined by a statistical test (Student's t-test was used).

The null hypothesis, H_o, is that the coefficient in question is equal to zero. The statistical test determines the probability, P, that the coefficient is *not* different from zero. H_o is rejected, and the coefficient retained, for small values of P. In this analysis, H_o is rejected for P less than 0.05.

The computer program used to do the generalized least squares regressions (GLSNET, version 2.5), limits the number of predictor variables to 9, so the set of 15 watershed characteristics had to be reduced to 9 or fewer for each region. First, highly correlated pairs of watershed characteristics ($r \geq 0.8$) were identified for each region. A regression was done for each characteristic from each pair. Only the characteristic with the most significant regression coefficient was retained. Second, regressions were done using ordinary least squares analysis to determine the characteristics most likely to be significantly correlated to peak discharge from among the remaining characteristics.

To be certain that the selected set of characteristics did not exhibit significant collinearity, two tests were done. In the first test, a quantity called the *variance inflation factor* (VIF) was determined for each watershed characteristics used in a generalized least squares regression for each region (Chatterjee and others, 2000). If the predictor variable X_j is regressed on all other predictor variables in the characteristic set, then

$$VIF_j = \frac{1}{1 - R_j^2} \quad \text{..... (7)}$$

where

R_j^2 = the square of the multiple correlation coefficient that results from the regression of X_j on the other predictor variables.

The further VIF_j deviates from one, the stronger is the indication of collinearity between X_j and the other predictor variables. Chatterjee and others (2000) suggest that a VIF in excess of 10 indicates that multicollinearity may interfere with estimation of the regression coefficients. The results of this test are shown in Table 13. None of the VIFs were greater than 10. The largest was 5.40.

In the second test, principal components were used to determine the presence of multicollinearity (Chatterjee and others, 2000). In determining the principal components, eigenvalues were calculated. Two quantities based on the eigenvalues are indicators of multicollinearity. The first is the condition number, which is simply the square root of the maximum eigenvalue divided by the minimum eigenvalue. The second quantity is the sum of the reciprocals of the eigenvalues. Chatterjee and others (2000) suggest that significant collinearity is indicated when the condition number exceeds 15 and when the sum of reciprocals of the eigenvalues exceeds five times the number of predictor variables, or 45 for all regions. The results of this test are shown in Table 14. None of the condition numbers exceeded 15, the largest being only 5.56. None of the sums of reciprocals exceeded 45, the largest being only 22.0.

When the set of nine or fewer characteristics was determined for each region, a backward step analysis was done using the 100-year peak discharges. The results of the backward-step analyses for regions 1, 2, 3, 4, 5, and 6 are shown in tables 15, 16, 17, 18, 19, and 20, respectively.

The set of characteristics determined for the 100-year peak discharges was used for all frequencies. If a backward step analysis is done independently at each frequency, the resulting prediction equations may incorporate different predictor variables. While this may lead to the smallest model errors for each equation, it may lead to undesirable results overall. Specifically, flood magnitude may not vary smoothly with frequency - a plot of magnitude versus frequency likely will show discontinuities. It is even possible that the magnitude of a high frequency event will exceed the magnitude of a low frequency event. For example, the 10-year event could be larger than the 25-year event.

The final prediction equations are shown by region, in Tables 21, 22, 23, 24, 25, and 26. Maps of all of the characteristics used in the prediction equations are shown in figures 18, 19, 20, 21, 22, 23, 24 and 25. These maps are for illustration only. It is strongly recommended that estimates of watershed characteristics be made from the digital grids and coverages described in Appendix F using GIS techniques.

Accuracy of the Prediction Equations

Measures of the accuracy of the prediction equations are average prediction error (Wiley and others, 2000) and equivalent years of record (Hardison, 1971). These measures are reported in Tables 20, 21, 22, 23, 24, and 25 for all prediction equations developed in this analysis. The average prediction error ranged from 37.7 to 104 percent over the six flood regions. Equivalent years of record varied from 1.2 to 20.1 years. Flood region 6 had the highest average prediction errors.

The average prediction error is the square root of the sum of the squared standard error of the model and the average squared standard error of sampling *in log units*. Model error is the uncertainty due to a model that does not account for all the variability in peak discharges. Sampling error is the uncertainty due to estimating model parameters from a sample, i.e., not from the whole population (Tasker and Stedinger, 1989). For all prediction equations, the model error is larger than the error due to sampling. The contribution of the sampling error to the total error, or average prediction error, ranges from about two percentage points for region 2 to about eight percentage points for region 6.

In practical terms, the small sampling error compared to the large model error means increasing the length of record available for estimating the peak discharges at gaged watersheds will not significantly decrease the average error of prediction. More benefit would result from improving the models by increasing the accuracy with which current watershed characteristics are estimated or by adding new characteristics to account for previously unaccounted for variability. The preceding comment does not mean that estimates of peak discharge at individual gaging stations could not be improved by additional years of record. Estimates at short record stations likely would be improved by additional record.

An equivalent number of years of record is the number of years of actual record required to give the same accuracy as a prediction equation. It is also used as a weighting factor in estimating peak

Table 13. Variance inflation factors (VIFs) for the characteristic sets used in the generalized least squares regressions for each region. A VIF in excess of 10 suggests that multicollinearity is significant enough to interfere with estimation of coefficients in the regression. All VIF calculated for these data sets are considerably less than 10.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 24-hour 2-year precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Watershed Characteristic	**Region 1**	**Region 2**	**Region 3**	**Region 4**	**Region 5**	**Region 6**
Area	2.57	1.22	1.35	1.39	1.30	1.62
Slope	1.42	-----	2.69	1.44	-----	2.64
Aspect	2.09	1.60	1.19	1.08	2.43	1.67
Elev	4.67	-----	3.93	-----	3.70	2.94
Jan P	-----	1.96	3.43	2.96	1.77	3.73
Jul P	-----	2.03	2.36	-----	4.28	2.73
I24-2	-----	-----	-----	-----	-----	-----
Snow	2.37	-----	-----	-----	-----	-----
Mn Jan T	-----	1.50	-----	1.45	1.49	2.68
Mn Jul T	-----	-----	-----	-----	-----	-----
Mx Jan T	1.59	-----	2.74	-----	5.40	-----
Mx Jul T	-----	3.01	-----	3.24	-----	5.90
Soil C	1.75	2.74	-----	3.91	-----	-----
Soil P	2.56	2.09	1.62	1.73	2.52	2.73
Soil D	2.21	20.1	1.94	2.50	3.43	-----

Table 14. A principal component analysis of possible multicollinearity among the characteristics sets used in the generalized least squares regressions for each region. A condition number greater than 15 is an indication that multicollinearity is significant enough to interfere with estimation of regression coefficients. Similarly, significant multicollinearity is indicated if the sum of reciprocals of the eigenvalues is larger than five times the number of predictor variables – in this case, 45. These results indicate that multicollinearity is not a factor in estimating regression coefficients for prediction equations in any region.

Parameter	**Region 1**	**Region 2**	**Region 3**	**Region 4**	**Region 5**	**Region 6**
Condition Number	4.16	3.68	4.33	3.95	5.56	4.90
Sum of Reciprocals	17.4	16.0	19.2	16.2	21.6	22.0

Table 15. Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 1, east slope of the Cascade Range.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Snow,** mean annual snowfall, in inches; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P** soil permeability, in inches per hour; **Soil D**, in soil depth, in inches; -----, variable removed. Selected model is indicated by the shaded area.]

Predictor Variable	Step								
	a	b	c	d	e	f	g	h	i
	Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero.								
Area	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Slope	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-----
Aspect	0.805	0.719	-----	-----	-----	-----	-----	-----	-----
Elev	0.027	0.007	0.006	0.002	0.001	0.000	0.000	-----	-----
Snow	0.738	0.752	0.782	-----	-----	-----	-----	-----	-----
Mx Jan T	0.552	0.541	0.542	0.395	-----	-----	-----	-----	-----
Soil C	0.328	0.312	0.332	0.271	0.210	0.132	-----	-----	-----
Soil P	0.492	0.470	0.309	0.287	0.291	-----	-----	-----	-----
Soil D	0.891	-----	-----	-----	-----	-----	-----	-----	-----
Model error - log units	0.033903	0.032650	0.031608	0.0305565	0.030289	0.030447	0.031886	0.048486	0.15765
Model error – percent	44.4	43.5	42.7	41.9	41.7	41.9	42.9	54.1	114
Sampling error - percent	26.0	24.3	22.9	21.1	19.4	18.0	16.4	16.6	22.3
Prediction error - percent	52.7	50.9	49.4	47.8	46.7	46.2	46.5	57.4	119
Equivalent years of record	4.6	4.9	5.1	5.5	5.7	5.9	5.8	4.0	1.3

Table 16. Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 2, north-central eastern Oregon.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches; -----, variable removed. Selected model is indicated by the shaded area.]

Predictor Variable	Step								
	a	b	c	d	e	f	g	h	i
	Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero.								
Area	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aspect	0.561	0.578	-----	-----	-----	-----	-----	-----	-----
Jan P	0.007	0.005	0.005	0.005	0.006	0.001	0.009	-----	-----
Jul P	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.008	-----
Mn Jan T	0.510	0.522	0.537	0.407	-----	-----	-----	-----	-----
Mx Jul T	0.582	0.538	0.576	-----	-----	-----	-----	-----	-----
Soil C	0.131	0.102	0.121	0.018	0.013	0.003	-----	-----	-----
Soil P	0.845	-----	-----	-----	-----	-----	-----	-----	-----
Soil D	0.406	0.372	0.339	0.393	0.395	-----	-----	-----	-----
Model error - log units	0.024631	0.023911	0.023914	0.022934	0.022729	0.022550	0.028716	0.041504	0.049299
Model error – percent	37.4	36.8	36.4	36.0	35.8	35.6	40.6	49.6	57.7
Sampling error - percent	27.6	25.9	24.8	23.4	22.0	20.6	20.0	19.0	16.8
Prediction error - percent	47.6	46.0	45.0	43.7	42.8	41.8	45.9	54.0	57.9
Equivalent years of record	16.1	17.0	17.6	18.5	19.2	20.1	17.1	12.9	11.5

Table 17. Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 3, northeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; inches; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Selected model is indicated by the shaded area.]

Predictor Variable	Step								
	a	b	c	d	e	f	g	h	i
	Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero.								
Area	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Slope	0.938	0.939	-----	-----	-----	-----	-----	-----	-----
Aspect	0.353	0.336	0.333	0.320	0.277	0.281	0.351	0.368	-----
Elev	0.302	0.262	0.261	0.261	0.268	0.218	0.469	-----	-----
Jan P	0.846	0.843	0.799	0.773	-----	-----	-----	-----	-----
Jul P	0.992	-----	-----	-----	-----	-----	-----	-----	-----
Mx Jan T	0.427	0.421	0.417	0.426	0.322	0.301	-----	-----	-----
Soil P	0.717	0.715	0.717	0.574	0.584	-----	-----	-----	-----
Soil D	0.859	0.857	0.830	-----	-----	-----	-----	-----	-----
Model error - log units	0.041158	0.040345	0.039563	0.038834	0.038160	0.037658	0.037719	0.037387	0.037262
Model error – percent	49.4	48.8	48.3	47.8	47.4	47.0	47.1	46.8	46.4
Sampling error - percent	23.0	21.8	20.5	19.4	17.9	16.8	15.7	13.6	11.8
Prediction error - percent	55.6	54.5	53.4	52.4	51.4	50.5	50.2	49.2	48.5
Equivalent years of record	5.2	5.4	5.7	5.8	6.1	6.3	6.3	6.6	6.8

Table 18. Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 4, central eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Jan P**, mean January precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C,** soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Selected model is indicated by the shaded area.]

Predictor Variable	Step								
	a	b	c	d	e	f	g	h	i
	Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero.								
Area	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Slope	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.034	-----
Aspect	0.340	0.360	0.443	-----	-----	-----	-----	-----	-----
Jan P	0.000	0.000	0.000	0.000	0.000	0.000	0.003	-----	-----
Mn Jan T	0.022	0.013	0.013	0.011	0.016	-----	-----	-----	-----
Mx Jul T	0.258	0.252	0.374	0.303	-----	-----	-----	-----	-----
Soil C	0.388	0.389	-----	-----	-----	-----	-----	-----	-----
Soil P	0.869	-----	-----	-----	-----	-----	-----	-----	-----
Soil D	0.002	0.002	0.001	0.001	0.000	0.000	-----	-----	-----
Model error - log units	0.031101	0.030189	0.029969	0.029620	0.029693	0.034143	0.050593	0.061133	0.067009
Model error – percent	42.3	41.7	41.5	41.2	41.3	44.6	55.5	61.9	65.3
Sampling error - percent	24.8	23.5	22.3	21.1	20.1	19.5	20.0	18.8	16.8
Prediction error - percent	50.2	48.8	48.0	47.1	46.7	49.4	60.0	65.7	68.3
Equivalent years of record	5.2	5.5	5.7	5.9	6.0	5.4	3.8	3.3	3.1

Table 19. Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 5, southwest eastern Oregon.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T,** mean maximum July temperature, in degrees Fahrenheit; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches. Selected model is indicated by the shaded area.]

Predictor Variable	Step								
	a	b	c	d	e	f	g	h	i
	Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero.								
Area	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aspect	0.848	0.827	0.865	-----	-----	-----	-----	-----	-----
Elev	0.013	0.007	0.001	0.001	0.001	0.000	0.003	-----	-----
Jan P	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.003	-----
Jul P	0.065	0.029	0.025	0.021	0.045	0.008	-----	-----	-----
Mn Jan T	0.179	0.160	0.147	0.135	0.191	-----	-----	-----	-----
Mx Jan T	0.864	0.874	-----	-----	-----	-----	-----	-----	-----
Soil P	0.278	0.264	0.231	0.214	-----	-----	-----	-----	-----
Soil D	0.969	-----	-----	-----	-----	-----	-----	-----	-----
Model error - log units	0.023054	0.021239	0.019644	0.018220	0.019070	0.020119	0.029643	0.044803	0.066105
Model error – percent	36.1	34.5	33.1	31.9	32.6	33.6	41.3	51.8	64.8
Sampling error - percent	29.8	28.1	26.0	24.4	23.2	22.1	22.5	23.0	22.7
Prediction error - percent	48.0	45.5	43.0	40.9	40.7	40.9	47.9	57.9	70.2
Equivalent years of record	8.5	9.3	10.3	11.2	11.1	11.0	8.2	5.8	4.2

Table 20. Backward-step generalized least-squares regression analysis for 100-year peak discharges for Region 6, southeast eastern Oregon.

[**Area**, drainage area, in square miles; **Slope**, mean watershed slope, in percent; **Aspect**, mean watershed aspect, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil P**, soil permeability, in inches per hour. Selected model is indicated by the shaded area.]

Predictor Variable	Step								
	a	b	c	d	e	f	g	h	i
	Table values represent the probability that the coefficient for the predictor variable is **not** significantly different from zero.								
Area	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Slope	0.554	0.532	0.325	0.310	-----	-----	-----	-----	-----
Aspect	0.149	0.126	0.104	0.090	0.137	0.021	0.020	0.007	-----
Elev	0.553	0.405	0.476	-----	-----	-----	-----	-----	-----
Jan P	0.196	0.139	0.147	0.191	0.158	0.485	-----	-----	-----
Jul P	0.223	0.202	0.214	0.198	0.176	-----	-----	-----	-----
Mn Jan T	0.351	0.327	0.166	0.085	0.082	0.202	0.200	-----	-----
Mx Jul T	0.869	-----	-----	-----	-----	-----	-----	-----	-----
Soil P	0.679	0.633	-----	-----	-----	-----	-----	-----	-----
Model error - log units	0.077814	0.071058	0.066508	0.064061	0.064550	0.69177	0.066936	0.070277	0.10940
Model error – percent	71.5	67.6	65.0	63.6	63.9	66.6	65.3	67.2	88.7
Sampling error - percent	54.3	49.6	45.2	41.4	38.1	35.3	30.9	27.4	26.9
Prediction error - percent	97.8	90.3	84.5	80.3	78.3	78.9	75.0	74.9	95.7
Equivalent years of record	3.6	4.1	4.5	4.9	5.1	5.1	5.6	5.5	3.8

Table 21. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 1, eastern slope of the Cascade Range.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet.]

Prediction equation					Percent standard error of the model, in percent	Average standard error of sampling, in percent	Average prediction error, in percent	Average equivalent years of record
Q(2)	= 0.7516	$Area^{0.8787}$	$Slope^{1.984}$	$(Elev/1,000)^{-1.069}$	46.3	14.9	49.1	1.2
Q(5)	= 1.986	$Area^{0.8392}$	$Slope^{1.981}$	$(Elev/1,000)^{-1.315}$	38.6	13.3	41.1	2.4
Q(10)	= 3.262	$Area^{0.8181}$	$Slope^{1.982}$	$(Elev/1,000)^{-1.454}$	37.4	13.5	40.1	3.5
Q(25)	= 5.352	$Area^{0.7980}$	$Slope^{2.011}$	$(Elev/1,000)^{-1.599}$	38.5	14.4	41.5	4.7
Q(50)	= 7.195	$Area^{0.7870}$	$Slope^{2.027}$	$(Elev/1,000)^{-1.688}$	40.4	15.4	43.7	5.4
Q(100)	= 9.242	$Area^{0.7783}$	$Slope^{2.045}$	$(Elev/1,000)^{-1.765}$	42.9	16.4	46.5	5.8
Q(500)	= 17.73	$Area^{0.7636}$	$Slope^{2.088}$	$(Elev/1,000)^{-1.912}$	50.2	19.2	54.6	6.1

Table 22. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 2, north-central eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **Soil C,** soil storage capacity, in inches.]

Prediction equation					**Percent standard error of the model, in percent**	**Average standard error of sampling, in percent**	**Average prediction error, in percent**	**Average equivalent years of record**
Q(2)	= 31.63	$Area^{0.7947}$	$Jan\ P^{1.335}$	$Jul\ P^{-0.5420}$	$Soil\ C^{1.337}$	58.9	19.7	63.2	2.1
Q(5)	= 149.5	$Area^{0.7783}$	$Jan\ P^{1.037}$	$Jul\ P^{-0.7030}$	$Soil\ C^{1.615}$	41.0	17.0	44.9	5.8
Q(10)	= 252.6	$Area^{0.7706}$	$Jan\ P^{0.8967}$	$Jul\ P^{-0.8129}$	$Soil\ C^{1.622}$	35.0	16.8	39.3	10.4
Q(25)	= 367.6	$Area^{0.7617}$	$Jan\ P^{0.7737}$	$Jul\ P^{-0.9569}$	$Soil\ C^{1.556}$	32.7	17.8	37.7	16.1
Q(50)	= 444.9	$Area^{0.7559}$	$Jan\ P^{0.7050}$	$Jul\ P^{-1.059}$	$Soil\ C^{1.499}$	33.5	19.1	39.1	18.9
Q(100)	= 520.6	$Area^{0.7507}$	$Jan\ P^{0.6468}$	$Jul\ P^{-1.154}$	$Soil\ C^{1.445}$	35.6	20.6	41.8	20.1
Q(500)	= 702.7	$Area^{0.7407}$	$Jan\ P^{0.5300}$	$Jul\ P^{-1.348}$	$Soil\ C^{1.330}$	44.2	24.6	51.7	19.6

Table 23. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 3, northeast eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles.]

Prediction equation	Percent standard error of the model, in percent	Average standard error of sampling, in percent	Average prediction error, in percent	Average equivalent years of record
$Q(2) = 21.83\ Area^{0.7546}$	56.8	10.9	58.2	1.3
$Q(5) = 36.80\ Area^{0.7459}$	47.3	10.1	48.6	2.5
$Q(10) = 47.68\ Area^{0.7431}$	44.8	10.2	46.1	3.6
$Q(25) = 61.90\ Area^{0.7415}$	44.3	10.7	45.8	5.2
$Q(50) = 72.81\ Area^{0.7408}$	45.1	11.2	46.8	6.1
$Q(100) = 84.03\ Area^{0.7402}$	46.7	11.8	48.5	6.8
$Q(500) = 111.9\ Area^{0.7388}$	52.2	13.3	54.3	7.7

Table 24. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 4, central eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Slope**, mean watershed slope, in degrees; **Jan P**, mean January precipitation, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Soil D**, soil depth, in inches.]

Prediction equation			Percent standard error of the model, in percent	Average standard error of sampling, in percent	Average prediction error, in percent	Average equivalent years of record
Q(2)	= 1.051	$Area^{0.8723}\ Slope^{-0.8984}\ Jan\ P^{2.381}\ Mn\ Jan\ T^{2.169}\ Soil\ D^{-1.257}$	48.6	18.5	52.7	1.4
Q(5)	= 11.54	$Area^{0.8576}\ Slope^{-0.8858}\ Jan\ P^{2.025}\ Mn\ Jan\ T^{1.983}\ Soil\ D^{-1.530}$	42.1	17.2	46.1	2.3
Q(10)	= 28.15	$Area^{0.8509}\ Slope^{-0.8835}\ Jan\ P^{1.857}\ Mn\ Jan\ T^{1.981}\ Soil\ D^{-1.665}$	40.5	17.5	44.7	3.3
Q(25)	= 58.27	$Area^{0.8445}\ Slope^{-0.8857}\ Jan\ P^{1.699}\ Mn\ Jan\ T^{2.043}\ Soil\ D^{-1.782}$	40.1	18.3	44.7	4.5
Q(50)	= 83.98	$Area^{0.8407}\ Slope^{-0.8904}\ Jan\ P^{1.610}\ Mn\ Jan\ T^{2.117}\ Soil\ D^{-1.865}$	40.5	19.2	45.5	5.3
Q(100)	= 109.2	$Area^{0.8375}\ Slope^{-0.8971}\ Jan\ P^{1.538}\ Mn\ Jan\ T^{2.205}\ Soil\ D^{-1.941}$	41.3	20.1	46.7	6.0
Q(500)	= 152.8	$Area^{0.8316}\ Slope^{-0.9183}\ Jan\ P^{1.416}\ Mn\ Jan\ T^{2.449}\ Soil\ D^{-2.097}$	44.2	22.3	50.5	7.1

Table 25. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 5, southwest eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit.]

Prediction equation			Percent standard error of the model, in percent	Average standard error of sampling, in percent	Average prediction error, in percent	Average equivalent years of record
Q(2)	= 0.4165	$Area^{0.6647}\ (Elev/1,000)^{2.888}\ Jan\ P^{-1.375}\ Jul\ P^{-0.6152}$	48.7	22.0	54.5	1.7
Q(5)	= 0.2788	$Area^{0.7052}\ (Elev/1,000)^{3.441}\ Jan\ P^{-1.542}\ Jul\ P^{-0.7073}$	40.0	18.9	42.1	3.7
Q(10)	= 0.2226	$Area^{0.7254}\ (Elev/1,000)^{3.738}\ Jan\ P^{-1.612}\ Jul\ P^{-0.7485}$	33.3	18.7	38.7	5.9
Q(25)	= 0.1694	$Area^{0.7468}\ (Elev/1,000)^{4.075}\ Jan\ P^{-1.687}\ Jul\ P^{-0.7908}$	31.7	19.6	37.8	8.6
Q(50)	= 0.1397	$Area^{0.7608}\ (Elev/1,000)^{4.302}\ Jan\ P^{-1.736}\ Jul\ P^{-0.8185}$	32.2	20.7	38.8	10.1
Q(100)	= 0.1174	$Area^{0.7737}\ (Elev/1,000)^{4.505}\ Jan\ P^{-1.781}\ Jul\ P^{-0.8428}$	33.6	22.1	40.9	11.0
Q(500)	= 0.08444	$Area^{0.8011}\ (Elev/1,000)^{4.892}\ Jan\ P^{-1.863}\ Jul\ P^{-0.8859}$	39.3	25.9	48.1	11.4

Table 26. Prediction equations for estimating peak discharges for ungaged watersheds in flood region 6, southeast eastern Oregon.

[**Q(n)**, discharge in cubic feet per second for the n-year recurrence interval; **Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees.]

Prediction equation			Percent standard error of the model, in percent	Average standard error of sampling, in percent	Average prediction error, in percent	Average equivalent years of record
Q(2)	= 29.38	$Area^{0.7718}\ (Aspect/100)^{-2.200}$	94.6	32.1	104	1.2
Q(5)	= 75.05	$Area^{0.7796}\ (Aspect/100)^{-2.556}$	76.0	27.6	83.6	1.9
Q(10)	= 112.5	$Area^{0.7873}\ (Aspect/100)^{-2.664}$	69.7	26.4	76.2	2.8
Q(25)	= 164.7	$Area^{0.7977}\ (Aspect/100)^{-2.749}$	66.2	26.1	73.2	4.1
Q(50)	= 207.8	$Area^{0.8051}\ (Aspect/100)^{-2.808}$	66.0	26.6	73.3	4.9
Q(100)	= 255.6	$Area^{0.8120}\ (Aspect/100)^{-2.872}$	67.2	27.4	74.9	5.5
Q(500)	= 389.6	$Area^{0.8267}\ (Aspect/100)^{-3.039}$	73.5	30.1	82.5	6.3

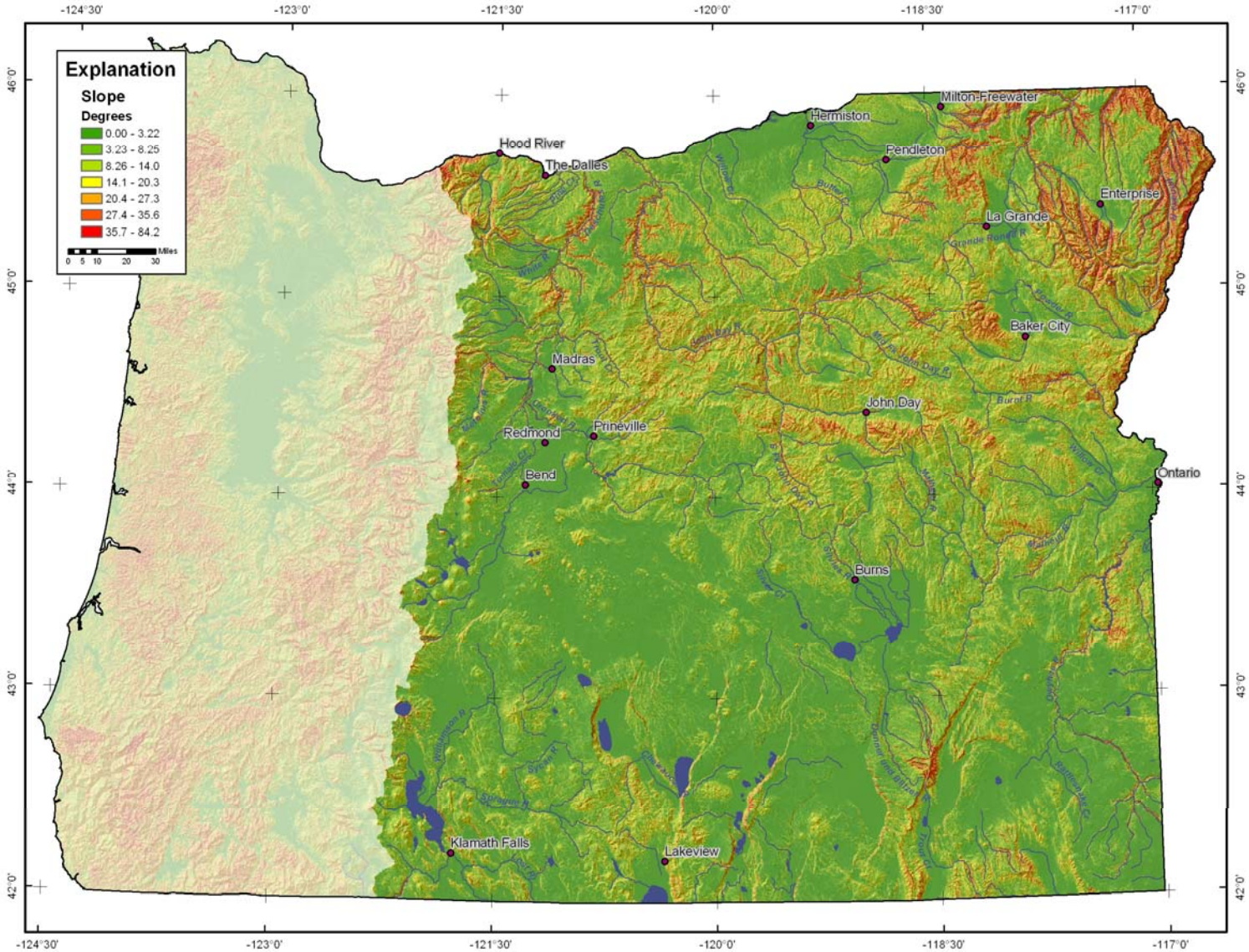

Figure 18. Areal distribution of slope.

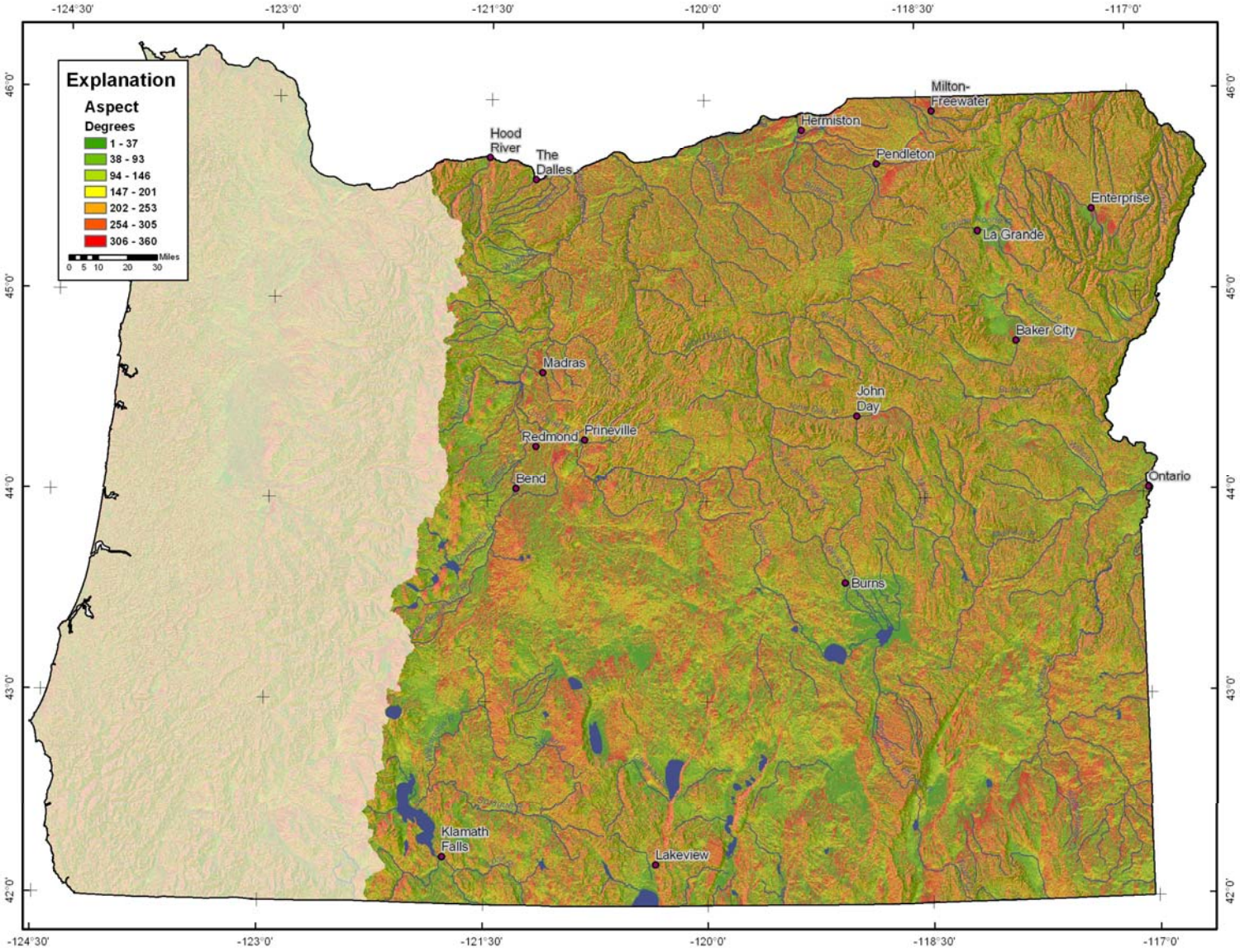

Figure 19. Areal distribution of aspect.

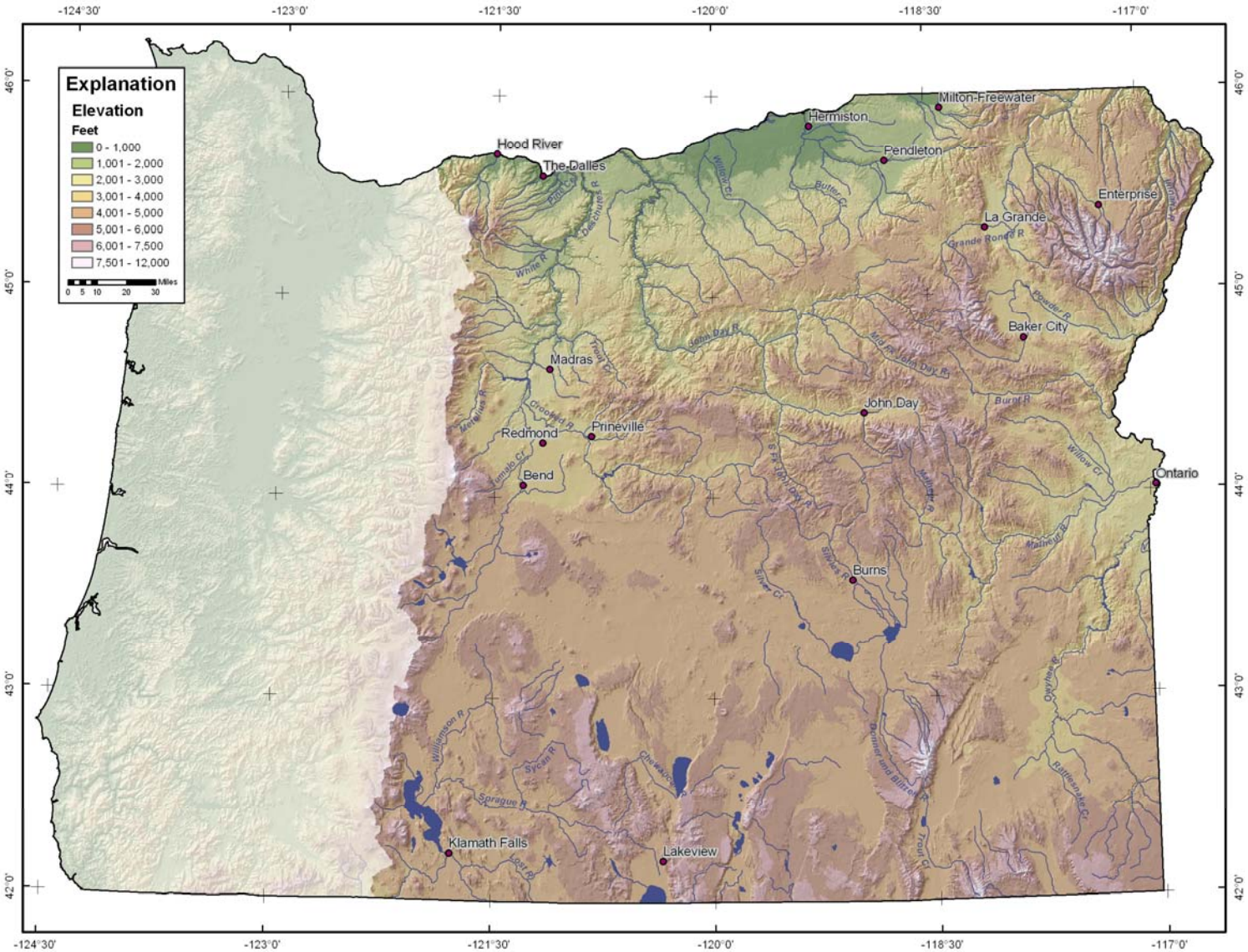

Figure 20. Elevation.

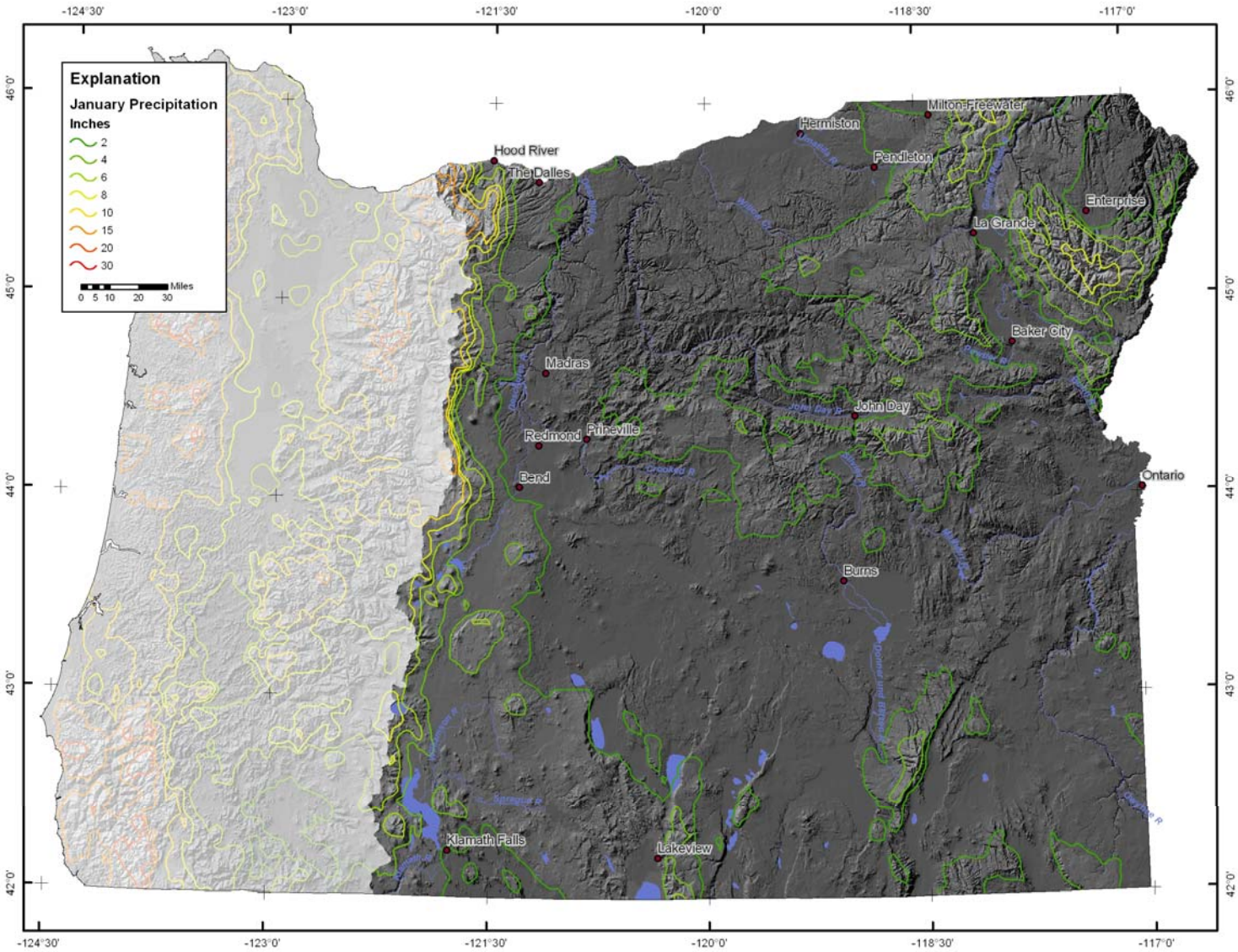

Figure 21. Mean January precipitation (1961-1990). The isolines are superimposed on both a shaded relief map of elevation and the GIS grid of the mean January precipitation on which the isolines are based. Darker areas represent lower precipitation amounts.

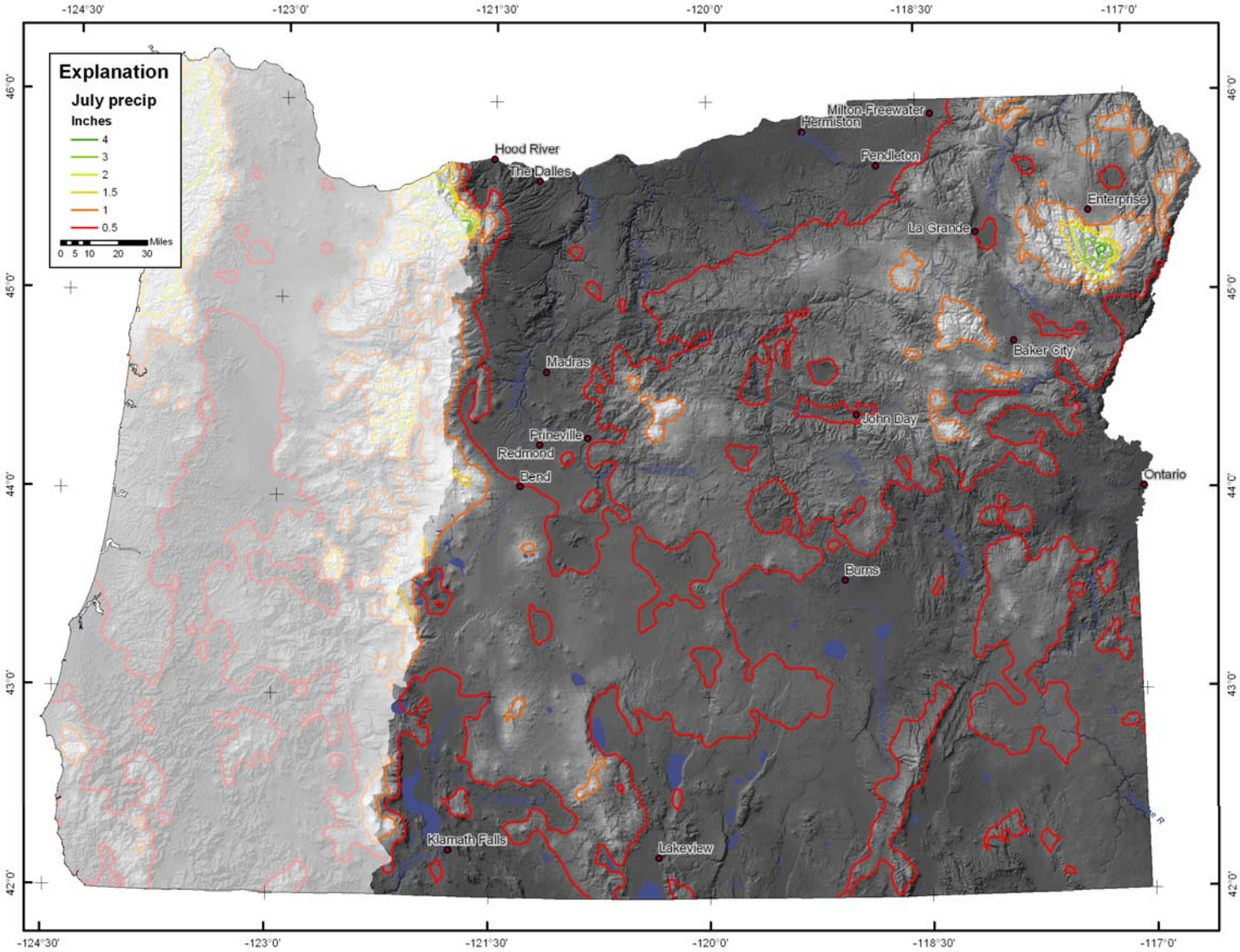

Figure 22. Mean July precipitation (1961-1990). The isolines are superimposed on both a shaded relief map of elevation and the GIS grid of the mean July precipitation on which the isolines are based. Darker areas represent lower precipitation amounts.

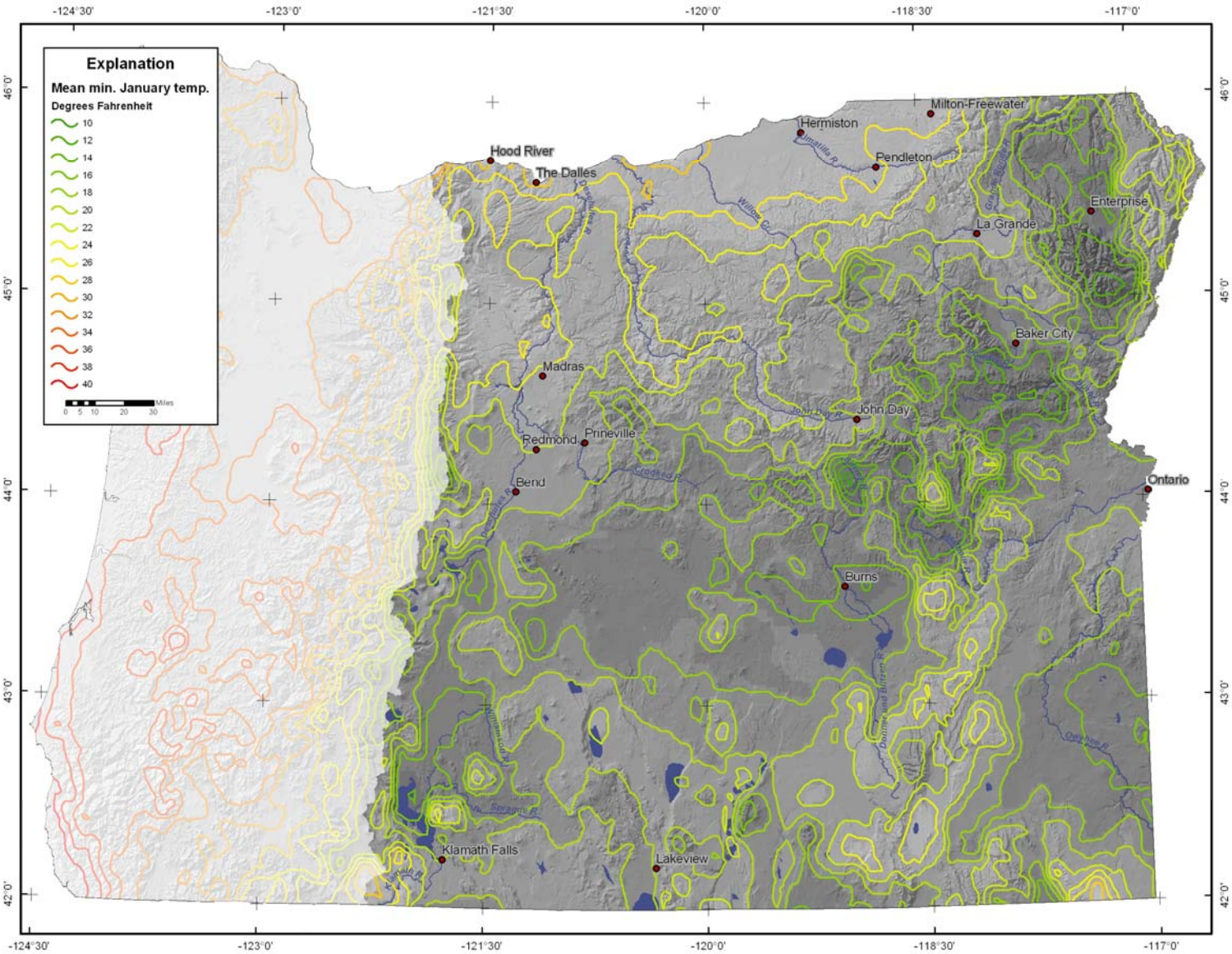

Figure 23. Mean minimum January temperature (1961-1990). The isolines are superimposed on both a shaded relief map of elevation and the GIS grid of the mean minimum January temperatures on which the isolines are based. Darker areas represent higher temperatures.

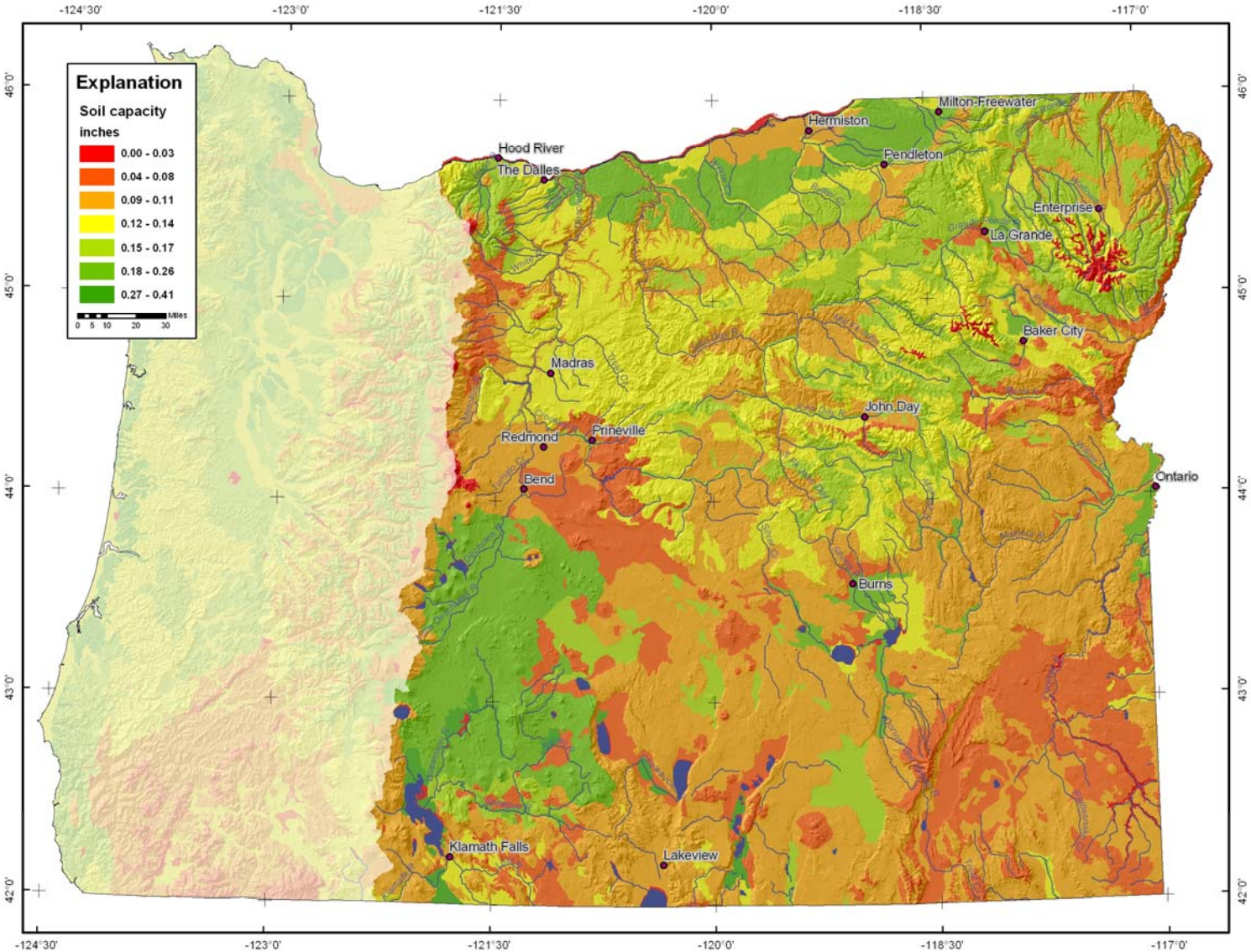

Figure 24. Areal distribution of soil storage capacity.

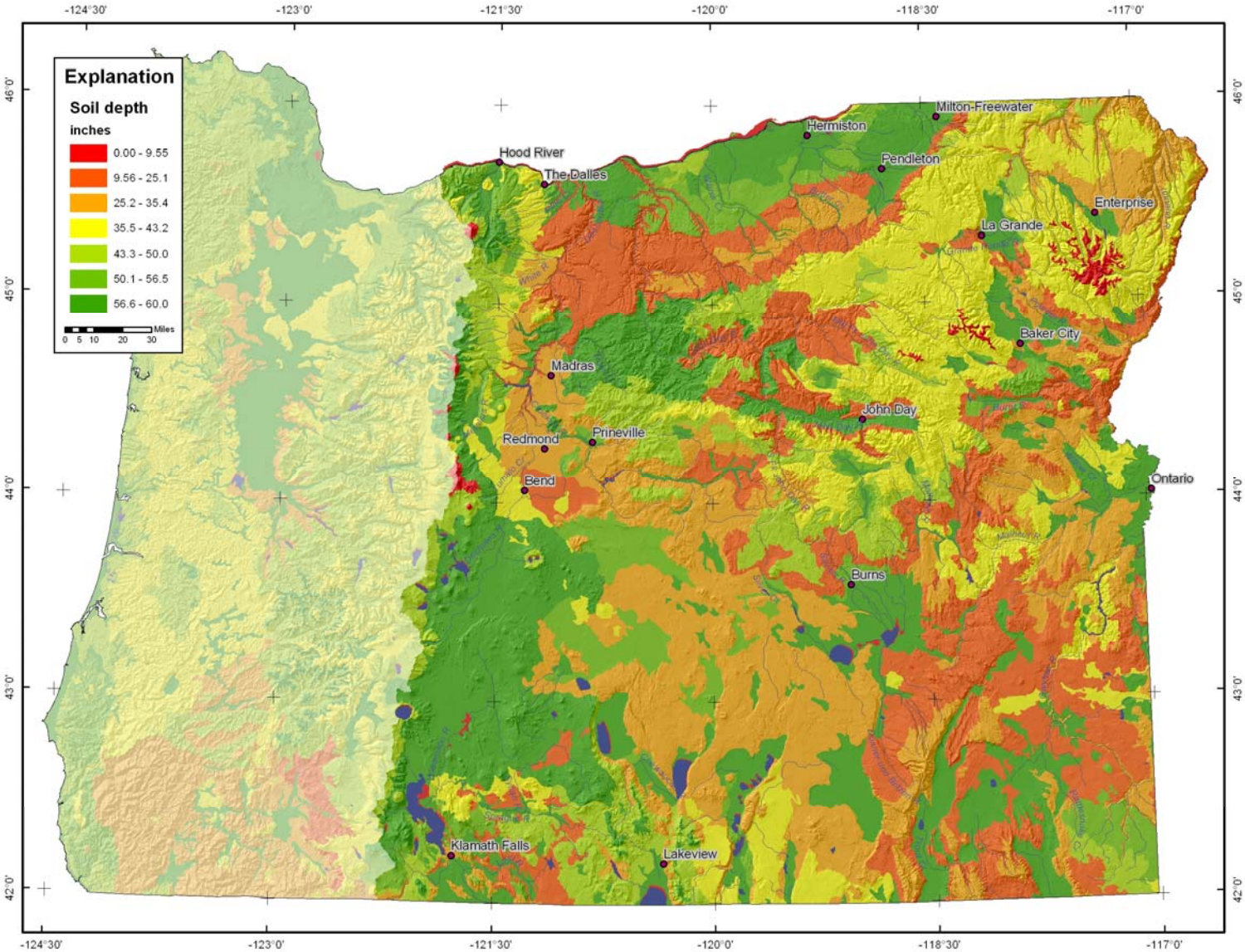

Figure 25. Areal distribution of soil depth.

discharges at gaging stations (Equation 8 – discussed in the next section). Hardison (1971) describes the calculation involved in estimating an equivalent number of years of record.

Estimating Peak Discharges

The procedure for estimating peak streamflows depends on whether the location of interest is gaged or ungaged, and if ungaged, whether it is near a gaged location on the same stream.

Gaged Locations

If the watershed of interest is one of the gaged watersheds listed in Appendix D, the frequency specific discharges may be read directly from the table. For Oregon gaging stations, the table gives three discharges at every frequency. The first discharge, designated S, is based on the systematic and historical streamflow record and is estimated by the guidelines of Bulletin 17B. The second, designated R, is estimated from the appropriate prediction equation given in Tables 21, 22, 23, 24, 25, or 26. The third discharge, designated W, is a weighted average of the first two discharges (Wiley and others, 2000):

$$Q_W = \frac{(Q_S N + Q_R E)}{(N + E)} \quad \text{.....} (8)$$

where

Q_W = the weighted discharge,

Q_S = the discharge from the log-Pearson Type III distribution fitted to annual series of peak discharges at the gaging station,

Q_R = the discharge estimated from the regional regression analysis,

N = the number of years of peak discharge record, and

E = the equivalent years of record.

All discharges are at a selected frequency and are in cubic feet per second.

For example, the weighted 100-year peak discharge at the gaging station Strawberry Creek above Slide Creek near Prairie City, OR (14037500) is 305 cfs. The station (S) and prediction equation estimated (R) discharges are 311 cfs and 169 cfs, respectively.

Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) recommends using the weighted discharge (W) as the estimate of peak discharge at the gaging station because its variance is less than the variance of either estimate (S or R). The weighting is discussed in detail in Appendix 8 of Bulletin 17B.

Limitations on the Use of Gaging Station Peak Discharges

Streamflows at some of the gaging stations used in this report are now regulated. The peak discharges estimated from the frequency analysis and reported in Appendix D are based on peak discharges observed before the streams were regulated. The peak discharge estimates for each station represent the stream in its unregulated state, not its current regulated condition. The currently regulated stations are identified in Appendix D.

Ungaged Locations

If the watershed of interest is ungaged, the frequency specific discharge is calculated from the appropriate prediction equation given in Table 21, 22, 23, 24, 25, or 26. For example, for an ungaged watershed in region 2, the 100-year peak discharge is given by

$$Q_{100} = 520.6\, Area^{0.7507}\, JanP^{0.6468}\, JulP^{-1.154}\, SoilC^{1.445} \quad \text{.....} (9)$$

where

Q_{100} = the 100-year peak discharge in cubic feet per, second,

$Area$ = the drainage area of the watershed in square miles,

$JanP$ = the January precipitation in inches,

$JulP$ = the July precipitation in inches, and

$SoilC$ = the mean soil storage capacity, inches.

West Birch Creek above Jack Canyon is an ungaged watershed in Region 2. The watershed above Jack Creek has a drainage area of 86.25 square miles, mean January precipitation of 2.85 inches, mean July

precipitation of 0.647 inches, and a soil storage capacity of 0.128 inches. Substituting these values into Equation 9 yields

$$Q_{100} = 520.6x86.25^{0.7507}2.85^{0.6468}0.647^{-1.154}0.128^{1.445}$$

$$Q_{100} = 2{,}470\,\text{cfs.}$$

Limitations on the Use of the Prediction Equations

The prediction equations may be used to estimate peak flows for any stream. However, the prediction equations do not account for reservoir operations, diversion, urbanization, and in most cases, significant contributions from spring flow. (See the next section for a discussion on spring flow). Many streams are affected by these factors. In these cases, the estimates of peak flow represent a hypothetical condition of the watershed, not the actual condition.

Unless the user intends to predict peak discharges for the hypothetical condition of a watershed, the prediction equations should be used only on rural, unregulated streams and where streamflow arises primarily from storm runoff or snowmelt rather than spring flow. They should not be used where there are significant areas of impervious surface due to pavement or buildings, or where streams have been lined or diverted through culverts or artificial channels. They also should not be used for streams regulated by reservoirs, diversion, or large natural lakes. Also to be avoided are streams with large losses to ground water.

In all cases, hypothetical or not, the equations should not be used for watersheds that have characteristics that fall outside the range of characteristics of the watersheds used to develop the prediction equations. The ranges of characteristics for these watersheds are given in table 27.

Use of the Prediction Equations for Streams with Significant Spring Flow

The regression analysis assumes that the processes underlying peak discharges can be generalized from stream to stream. For direct runoff and snowmelt, peak discharges are a function of factors like watershed area, elevation, and precipitation intensity. However, the physical properties of a watershed that result in significant spring-flow tend to be local and unique, and the affected stream tends to be unlike its neighbors. A spring, for example, may be the result of a fault or a lava flow.

Typically, prediction equations based on a regression analysis are not useful for estimating peak discharges for streams dominated by spring flow. In a regression analysis, such a stream is often an outlier and is eliminated from the regression as it increases the standard error without improving the prediction equation. The resulting equation is, of course, a poor predictor of peak discharge on any spring-dominated stream in the region.

For regions 2 to 6, the prediction equations should not be used for streams where springs make significant contributions to peak discharge. These occasions will be rare, however. Only one such gaged stream was eliminated from a regression analysis - the South Fork Burnt River above Barney Creek near Unity, OR (13270800) from region 3. This was the only gaged stream in region 3 with a significant contribution from spring flow and is unlike its neighbors. The prediction equations for region 3 significantly over-predict for this stream.

Springs are widespread in region 1, and peak discharges are significantly affected. Unlike other regions, however, spring dominated peaks do not appear as outliers in the regressions. In fact, the standard errors for prediction equations in the region are among the lowest of the six regions. The low standard errors and lack of outliers strongly suggest that the physical properties of the watersheds that contribute to springs are well distributed over the region and that the prediction equations may be used to predicted peak discharges for ungaged watersheds.

Caution is advised, however. The prediction equations for region 1 relate peak discharge to watershed area, slope, and elevation. It is unclear how these characteristics relate to the underlying geology and the hydrogeologic processes determining spring flow. Characteristics such as slope and elevation are well integrated regionally, while the locations of lava flows and deposits of pumice and cinder are not likely to be so well integrated. Since watershed boundaries may be indeterminate in the region, area is also suspect as a predictor variable.

Table 27. Ranges of selected characteristics for gaged east side watersheds by region.

Region	Number of stations	Drainage area, in square miles	Mean watershed slope, in degrees	Mean watershed aspect, in degrees	Mean watershed elevation, in feet	Mean January precipitation, in inches	Mean July precipitation, in inches	Mean minimum January temperature, in degrees Fahrenheit	Mean soil capacity, in inches	Mean soil depth, in inches
1	41	4.64 – 525	5.03 – 19.3	-----	2770 – 6060	-----	-----	-----	-----	-----
2	58	0.293 – 1630	-----	-----	-----	1.52 – 7.97	0.234 – 1.28	-----	0.102 – 0.196	-----
3	76	0.240 – 3870	-----	-----	-----	-----	-----	-----	-----	-----
4	51	1.70 – 7630	5.35 – 22.6	-----	-----	1.37 – 5.28	-----	16.4 – 23.1	-----	21.3 – 50.7
5	28	0.609 – 2992	-----	-----	4850 – 7050	1.78 – 4.46	0.197 – 0.915	-----	-----	-----
6	22	0.152 – 453	-----	133 – 244	-----	-----	-----	-----	-----	-----

If the underlying geology is reasonably uniform and hydrologic boundaries do not differ greatly from watershed boundaries based on elevation, then area, slope and elevation may be reasonable predictor variables. Slope would work much the same for groundwater as for surface water - discharge is dependent on head gradient. Elevation may be related to rapidity of recharge. Snow melts more rapidly at low elevation and more slowly at high elevation. The correlation in this case would be negative. In the prediction equations for region 1, elevation is negatively correlated.

Ungaged Location, near a Gaging Station on the Same Stream

If an ungaged watershed is on the same stream as a gaged watershed listed in this report, and the ungaged watershed has an area between 0.50 and 1.50 times the area of the gaged watershed, peak discharges at the ungaged site may be calculated from the peak discharges at the gaged site by this equation (Thomas and others, 1993; Sumioka, 1997):

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right)^a \quad \text{.....} \quad (10)$$

where

Q_u = the estimated discharge for the ungaged watershed,

Q_g = the discharge from the log-Pearson Type III distribution fitted to annual series of peak discharges at the gaging station,

A_u = the area of the ungaged watershed,

A_g = the area of the gaged watershed, and

a = the exponent of area from one of the prediction equations in Table 21, 22, 23, 24, 25, or 26.

All discharges are at a selected frequency and are in cubic feet per second. The exponent is from the prediction equation for the selected region and frequency.

Equation 10 should be used only if the gaged and ungaged watersheds have similar characteristics. If the watersheds differ appreciably in topography, vegetative cover, or geology, the peak discharge estimates should be made by way of the appropriate prediction equations.

Consider the Middle Fork of the John Day River. This stream, at its mouth, is ungaged, and peak discharges could be estimated by the prediction equations for region 4. However, there is a gaging station, Middle Fork John Day River at Ritter (14044000), 14.9 miles upstream. Selected characteristics for the gaged and ungaged watersheds are given in Table 28. The watersheds are similar and use of Equation 10 is appropriate.

From Table 24 for the 100-year peak discharge for region 4, the area coefficient is 0.8375. Taking the areas from Table 28 and the 100-year peak discharge for the gaging station on the Middle Fork John Day River from Appendix D, then making the substitutions into Equation 10,

$$Q_u = 5{,}200 \left(\frac{791}{523} \right)^{0.8375}$$

$$Q_u = 7{,}350 \text{ cfs}$$

Making Estimates of Peak Discharge at the Oregon Water Resources Department Web Site

At the Oregon Water Resources Department Web site (http://www.wrd.state.or.us/), a user can make estimates of peak discharge magnitudes at the selected frequencies by one of four methods:

1. Selecting from among about 2,600 watersheds (both western and eastern Oregon) for which the physical characteristics are already known,
2. Manually entering the required watershed characteristics,
3. Submitting a user-delineated watershed, or
4. Using a utility on the Web site to auto-delineate the watershed.

Because of the inherent difficulties in independently estimating watershed characteristics, it is strongly recommended the user take advantage of options 1, 3, and 4 listed above rather than option 2. In all cases, a report

Table 28. Selected characteristics for the ungaged watershed Middle Fork John Day River at the mouth and for the gaged watershed Middle Fork John Day River at Ritter, OR (14044000).

Watershed characteristic	Ungaged watershed	Gaged watershed
	Middle Fork John Day River at the mouth	Middle Fork John Day River at Ritter, OR (14044000)
Area, in square miles	791	523
Slope, in degrees	11.9	12.9
Mean January precipitation, in inches	2.56	2.93
Mean minimum January temperature, in degrees	18.7	17.8
Soils depth to bedrock, in inches	33.0	38.4

detailing peak discharges and how they were determined for the specified watershed is returned to the user.

Selecting among already delineated watersheds (Option 1) is done onscreen using interactive maps. For manual input (Option 2), a form is provided. If the user supplies the watershed delineation (Option 3), it must be submitted as a "shape file" in Oregon Lambert coordinates. A shape file is an open specification for a GIS theme developed by Environmental Systems Research Institute, Inc.

For Option 4, the user need only select a point on a stream where the magnitude of a specified peak discharge is desired. Selection of the point is done interactively from topographic maps displayed onscreen. Nothing further is required from the user. Delineation of the watershed above the selected point, determination of the watershed characteristics, and calculation of the peak discharges are done automatically. The auto-delineation program, however, *does not* account for the effects of reservoir operations, diversion or urbanization.

Please refer to Oregon Water Resources Department's Web site for more information:

http://www.wrd.state.or.us/surface_water/flood/index.shtml

The user may also obtain, online, the peak discharge characteristics for the 276 gaging stations used in this study. In addition to the discharge magnitudes given in Appendix D of this report, the online version includes the 95 percent confidence intervals.

Summary

An analysis of the magnitude and frequency of peak discharges in eastern Oregon has been completed with financial assistance from the Federal Emergency Management Agency, the Oregon Department of Transportation, and the Association of Oregon Counties, and with the cooperation of the U.S. Geological Survey. The study was undertaken to provide engineers and land managers with the information needed to make informed decisions about development in or near watercourses in the study area.

This report describes the results of an analysis of the peak discharges of *rural* streams in Oregon east of the Cascade crest. The results of the analysis include (1) the magnitude of annual peak discharges for selected frequencies at 276 gaging stations, (2) generalized logarithmic skew coefficients for eastern Oregon, and (3) sets of equations relating the magnitude of peak discharges at selected frequencies to physical watershed characteristics such as drainage area or mean watershed elevation. There is a set of frequency specific prediction equations for each of six hydrologically homogeneous "flood regions" within eastern Oregon. The selected frequencies are described by the interval at which a peak discharge of given magnitude is likely to recur. The recurrence intervals are 2, 5, 10, 25, 50, 100, and 500 years.

The annual peak discharges at the 276 streamflow gaging stations in eastern Oregon, southwestern Washington, and northwestern California were fitted to the log-Pearson Type III. The parameters of the Pearson type III distribution were adjusted for the effects of high and low outliers, for historic peaks, for zero peaks, and for peaks below the gage threshold

based on guidelines in Interagency Advisory Committee on Water Data's Bulletin 17B. Station skew values also were adjusted by a "generalized" skew value based on the skews for long-term stations in the area.

The areal distribution of the generalized logarithmic skew coefficients of annual peak discharge for Oregon was determined using GIS techniques. Generalized skew coefficients derived from the distribution were used to improve estimates of skew for short record gaging stations. The areal distribution is a GIS grid but is represented in this report as an isoline map. In practice, generalized skew coefficients are determined from the grid, not the isoline map. The grid is available on request (webmaster@wrd.state.or.us).

In developing the prediction equations, an analysis was done to determine the relative importance of the hydrologic processes contributing to peak discharges. Annual peak discharges occur most frequently in spring and are most likely the result of snowmelt. Rain falling on snow in the months from December to February is the second most frequent cause of peak discharges. Convective storms in late spring and summer are responsible for only a minor part of all peak discharges.

For peaks with the largest unit discharges (greater than 500 cfs per square mile), however, most occur in mid-winter, the result of rain on snow. The second largest number of large peaks occurs in late spring and summer. These peaks are due mostly to thunderstorms. The largest unit discharges (greater than 1,000 cfs per square mile) are all due to thunderstorms.

Thunderstorms are essentially unrepresented in the systematic record used to develop the prediction equations presented in this report. What impact this has on the estimation of peak discharges is unknown.

Severe thunderstorms are associated with watersheds of a particular type. The watersheds are small, not forested, and relatively hot, dry, and low in elevation. A map showing areas of eastern Oregon most likely to be affected by a severe thunderstorm was developed.

A combination of regression techniques was used to derive the prediction equations. A preliminary analysis using ordinary least-squares regression was conducted to define flood regions of homogeneous hydrology and to determine which climatological and physical characteristics of the watersheds would be most useful in the prediction equations. The final prediction equations were derived using generalized least-squares regression. The computer model, GLSNET (version 2.5), developed by the U.S. Geological Survey was used to do the generalized least-squares regression analysis. Average standard error of prediction for the equations for the three flood regions ranged from 37.7 to 104 percent. Equivalent years of record varied from 1.2 to 20.1 years.

The prediction equation may be used to estimate peak flows for any stream. However, the prediction equations do not account for reservoir operations, diversion or urbanization. Many streams are affected by these factors. In these cases, the estimates of peak flow represent a hypothetical condition of the watershed, not the actual condition.

Use of the prediction equations requires estimates of several physical and climatological characteristics of the watershed in question. Because the watershed characteristics can be difficult to estimate, the Oregon Water Resources Department has developed an interactive utility, available on its Web site, to facilitate the use of the equations. The user need only select a site on a stream from an onscreen interactive map and the magnitude of floods at various frequencies will be reported for that location.

To use the interactive utility, go online to this Web address:

http://www.wrd.state.or.us/

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Appendix A. Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis.

Station Number	Station Name	Flood Region	Hydrologic Unit	Latitude Decimal Degrees	Longitude Decimal Degrees
10329500	Martin Creek near Paradise Valley, NV	6	16040109	41.535	117.417
10330300	Mullinex Creek near Paradise Valley, NV	6	16040109	41.511	117.540
10352300	Jackson Creek tributary near McDermitt, NV	6	16040201	42.233	117.739
10352500	McDermitt Creek near McDermitt, NV	6	16040201	41.967	117.834
10353000	East Fork Quinn River near McDermitt, NV	6	16040201	41.983	117.583
10353600	Kings River near Orovada, NV	6	16040201	41.907	118.308
10353700	Leonard Creek near Denio, NV	6	16040202	41.528	118.712
10353750	Mahogany Creek near Summit Lake, NV	6	16040202	41.542	119.015
10360900	Bidwell Creek below Mill Creek near Fort Bidwell, CA	5	18080001	41.882	120.174
10361700	Badger Creek tributary near Vya, NV	6	17120008	41.722	119.372
10366000	Twentymile Creek near Adel, OR	5	17120007	42.072	119.962
10370000	Camas Creek near Lakeview, OR	5	17120007	42.216	120.101
10371000	Drake Creek near Adel, OR	5	17120007	42.200	120.011
10371500	Deep Creek above Adel, OR	5	17120007	42.189	120.001
10378500	Honey Creek near Plush, OR	5	17120007	42.425	119.922
10384000	Chewaucan River near Paisley, OR	5	17120006	42.685	120.569
10390400	Bridge Creek near Thompson Reservoir, OR	5	17120005	43.025	121.200
10392300	Silvies River near Seneca, OR	4	17120002	44.175	119.214
10392800	Crowsfoot Creek near Burns, OR	4	17120002	43.899	119.497
10393500	Silvies River near Burns, OR	4	17120002	43.715	119.176
10393900	Devine Can near Burns, OR	4	17120001	43.772	119.004
10396000	Donner Und Blitzen River near Frenchglen, OR	6	17120003	42.791	118.867
10397000	Bridge Creek near Frenchglen, OR	6	17120003	42.844	118.849
10402800	Claw Creek near Riley, OR	4	17120004	43.726	119.593
10403000	Silver Creek near Riley, OR	4	17120004	43.692	119.658
10403500	Silver Creek above Suntex, OR	4	17120004	43.633	119.667
10406500	Trout Creek near Denio, NV	6	17120009	42.156	118.458
11339995	Cottonwood Creek above Cottonwood Reservoir near Lakeview, OR	5	18020001	42.272	120.532
11340500	Cottonwood Creek near Lakeview, OR	5	18020001	42.235	120.501
11340950	Thomas Creek above Barnes Spring near Lakeview, OR	5	18020001	42.267	120.467
11341000	Thomas Creek near Lakeview, OR	5	18020001	42.267	120.450
11341050	Cox Creek below Salt Creek near Lakeview, OR	5	18020001	42.307	120.375
11341100	Salt Creek near Lakeview, OR	5	18020001	42.293	120.346
11341200	Crane Creek near Lakeview, OR	5	18020001	42.118	120.290
11342945	Thomas Creek near Cedarville, CA	5	18020002	41.564	120.268
11342960	North Fork Pit River tributary near Alturas, CA	5	18020002	41.576	120.435
11348080	Big Sage Reservoir tributary near Alturas, CA	5	18020002	41.583	120.699
11348560	Turner Creek tributary near Canby, CA	5	18020002	41.513	121.040
11484000	Miller Creek near Lorella, OR	5	18010204	42.117	121.217
11489350	Horsethief Creek near McDoel, CA	5	18010205	41.688	122.053
11489500	Antelope Creek near Tennant, CA	1	18010205	41.547	121.917
11491800	Mosquito Creek near Shevlin, OR	5	18010201	43.094	121.547
11494800	Brownsworth Creek near Bly, OR	5	18010202	42.428	120.839

Appendix A. Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Station Number	Station Name	Flood Region	Hydrologic Unit	Latitude Decimal Degrees	Longitude Decimal Degrees
11497500	Sprague River near Beatty, OR	5	18010202	42.447	121.237
11497800	Currier Creek near Paisley, OR	5	18010202	42.715	120.881
11501000	Sprague River near Chiloquin, OR	5	18010202	42.585	121.849
11501300	Crystal Creek near Chiloquin, OR	5	18010202	42.563	121.839
11502500	Williamson River below Sprague River near Chiloquin, OR	5	18010201	42.565	121.878
11504000	Wood River at Fort Klamath, OR	1	18010203	42.700	121.983
11505550	Lost Creek near Rocky Point, OR	1	18010203	42.493	122.192
11516900	Little Shasta River near Montague, CA	1	18010207	41.753	122.299
13172666	West Fork Reynolds Creek near Reynolds, ID	6	17050103	43.070	116.760
13172668	East Fork Reynolds Creek near Reynolds, ID	6	17050103	43.070	116.750
13172680	Reynolds Creek at Tollgate Weir near Reynolds, ID	6	17050103	43.100	116.770
13172720	Macks Creek near Reynolds, ID	6	17050103	43.230	116.790
13172735	Salmon Creek near Reynolds, ID	6	17050103	43.270	116.790
13172740	Reynolds Creek at Outlet Weir near Reynolds, ID	6	17050103	43.180	116.760
13172800	Little Squaw Creek tributary near Marsing, ID	6	17050103	43.364	116.921
13172900	Succor Creek near Jordan Valley, OR	6	17050103	43.235	117.057
13178000	Jordan Creek above Lone Tree Creek near Jordan Valley, OR	6	17050108	42.874	116.953
13182100	Drago G near Rockville, OR	6	17050110	43.294	117.254
13207000	Spring Valley Creek near Eagle, ID	3	17050114	43.739	116.300
13207500	Dry Creek near Eagle, ID	3	17050114	43.732	116.304
13213800	Cottonwood Creek near Drewsey, OR	3	17050116	43.950	118.303
13213900	Malheur River tributary near Drewsey, OR	3	17050116	43.781	118.358
13214000	Malheur River near Drewsey, OR	3	17050116	43.785	118.331
13216500	North Fork Malheur River above Beulah Reservoir near Beulah, OR	3	17050116	43.948	118.173
13226500	Bully Creek at Warmsprings near Vale, OR	3	17050118	44.019	117.460
13228000	Malheur River at Vale, OR	3	17050117	43.981	117.239
13228300	Lytle Creek near Vale, OR	3	17050117	43.957	117.226
13229400	Lost Valley Creek tributary near Ironside, OR	3	17050119	44.314	117.903
13248900	Cottonwood Creek near Horseshoe Bend, ID	3	17050122	43.893	116.202
13250600	Big Willow Creek near Emmett, ID	3	17050122	44.074	116.486
13250650	Fourmile Creek near Emmett, ID	3	17050122	44.073	116.487
13251300	West Branch Weiser River near Tamarack, ID	3	17050124	45.021	116.435
13251500	Weiser River at Tamarack, ID	3	17050124	44.947	116.382
13252500	East Fork Weiser River near Council, ID	3	17050124	44.761	116.258
13253500	Weiser River at Starkey, ID	3	17050124	44.850	116.444
13260000	Pine Creek near Cambridge, ID	3	17050124	44.590	116.737
13261000	Little Weiser River near Indian Valley, ID	3	17050124	44.489	116.390
13267000	Mann Creek near Weiser, ID	3	17050124	44.392	116.894
13267100	Deer Creek near Midvale, ID	3	17050124	44.391	116.880
13269200	Moores Hollow tributary near Weiser, ID	3	17050201	44.169	117.125
13269300	North Fork Burnt River near Whitney, OR	3	17050202	44.601	118.256
13272300	Job Creek tributary near Unity, OR	3	17050202	44.464	118.200
13274600	Burnt River tributary at Durkee, OR	3	17050202	44.575	117.446

Appendix A. Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Station Number	Station Name	Flood Region	Hydrologic Unit	Latitude Decimal Degrees	Longitude Decimal Degrees
13275105	Powder River at Hudspeth Lane near Sumpter, OR	3	17050203	44.685	118.091
13275200	Deer Creek above Phillips Lake near Sumpter, OR	3	17050203	44.692	118.063
13275500	Powder River near Baker, OR	3	17050203	44.656	117.875
13281200	Rock Creek near Haines, OR	3	17050203	44.910	118.056
13282400	Anthony Creek below North Fork near North Powder, OR	3	17050203	45.044	118.125
13283600	Wolf Creek above Wolf Creek Reservoir near North Powder, OR	3	17050203	45.066	118.032
13285900	Big Creek below Burn Creek near Medical Springs, OR	3	17050203	45.010	117.575
13286300	Waterspout Creek near Baker, OR	3	17050203	44.836	117.547
13287200	West Eagle Creek below Jim Creek near Baker, OR	3	17050203	45.050	117.467
13288200	Eagle Creek above Sc near New Bridge, OR	3	17050203	44.881	117.253
13289100	Immigrant G near Richland, OR	3	17050203	44.786	117.135
13289600	East Brownlee Creek at Brownlee Ranger Station, ID	3	17050201	44.736	116.838
13289960	Wildhorse River at Brownlee Dam, ID	3	17050201	44.852	116.890
13290150	North Pine Creek near Homestead, OR	3	17050201	45.090	116.896
13290190	Pine Creek near Oxbow, OR	3	17050201	44.954	116.873
13291200	Mahogany Creek near Homestead, OR	3	17060102	45.204	116.868
13291400	Deer Creek near Imnaha, OR	3	17060102	45.550	116.792
13292000	Imnaha River at Imnaha, OR	3	17060102	45.563	116.833
13315500	Mud Creek near Tamarack, ID	3	17060210	44.997	116.348
13316500	Little Salmon River at Riggins, ID	3	17060210	45.413	116.325
13316800	North Fork Skookumchuck Creek near White Bird, ID	3	17060209	45.726	116.205
13317200	Johns Creek near Grangeville, ID	3	17060209	45.938	116.201
13318100	McIntyre Creek near Starkey, OR	3	17060104	45.328	118.449
13318500	Grande Ronde River near Hilgard, OR	3	17060104	45.317	118.267
13318800	Grande Ronde River at Hilgard, OR	3	17060104	45.339	118.243
13319000	Grande Ronde River at La Grande, OR	3	17060104	45.346	118.124
13320000	Catherine Creek near Union, OR	3	17060104	45.156	117.774
13320400	Little Creek at High Valley near Union, OR	3	17060104	45.213	117.775
13321300	Ladd Can near Hot Lake, OR	3	17060104	45.193	118.013
13322300	Dry Creek near Bingham Springs, OR	3	17060104	45.636	118.115
13323500	Grande Ronde River near Elgin, OR	3	17060104	45.513	117.926
13323600	Indian Creek near Imbler, OR	3	17060104	45.433	117.822
13323700	North Fork Clarks Creek near Elgin, OR	3	17060104	45.541	117.811
13324150	Rysdam Can tributary near Minam, OR	3	17060104	45.615	117.796
13324300	Lookingglass Creek near Looking Glass, OR	3	17060104	45.732	117.864
13325000	East Fork Wallowa River near Joseph, OR	3	17060105	45.272	117.210
13325500	Wallowa River above Wallowa Lake near Joseph, OR	3	17060105	45.283	117.200
13329500	Hurricane Creek near Joseph, OR	3	17060105	45.337	117.292
13329700	Trout Creek tributary near Chico, OR	3	17060105	45.597	117.260
13329750	Trout Creek tributary at Enterprise, OR	3	17060105	45.439	117.283
13330000	Lostine River near Lostine, OR	3	17060105	45.439	117.426
13330500	Bear Creek near Wallowa, OR	3	17060105	45.527	117.551
13331500	Minam River at Minam, OR	3	17060105	45.620	117.726

Appendix A. Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Station Number	Station Name	Flood Region	Hydrologic Unit	Latitude Decimal Degrees	Longitude Decimal Degrees
13332500	Grande Ronde River at Rondowa, OR	3	17060106	45.727	117.783
13333000	Grande Ronde River at Troy, OR	3	17060106	45.946	117.448
13333050	Buford Creek near Flora, OR	3	17060106	45.890	117.283
13333100	Doe Creek near Imnaha, OR	3	17060106	45.747	117.022
13334700	Asotin Creek below Kearney G near Asotin, WA	3	17060103	46.326	117.152
13335050	Asotin Creek at Asotin, WA	3	17060103	46.341	117.055
13341100	Cold Springs Creek near Craigmont, ID	3	17060306	46.236	116.518
13342450	Lapwai Creek near Lapwai, ID	3	17060306	46.427	116.804
14010000	South Fork Walla Walla River near Milton, OR	2	17070102	45.830	118.169
14010800	North Fork Walla Walla River near Milton Freewater, OR	2	17070102	45.885	118.185
14011000	North Fork Walla Walla River near Milton, OR	2	17070102	45.902	118.282
14011800	Couse Creek near Milton-Freewater, OR	2	17070102	45.869	118.366
14013000	Mill Creek near Walla Walla, WA	2	17070102	46.008	118.118
14013500	Blue Creek near Walla Walla, WA	2	17070102	46.058	118.136
14015900	Spring Creek tributary near Walla Walla, WA	2	17070102	46.104	118.189
14016000	Dry Creek near Walla Walla, WA	2	17070102	46.122	118.236
14016080	Dry Creek tributary near Milton-Freewater, OR	2	17070102	45.885	118.391
14016200	Pine Creek near Weston, OR	2	17070102	45.779	118.403
14016500	East Fork Touchet River near Dayton, WA	2	17070102	46.279	117.901
14016600	Hatley Creek near Dayton, WA	2	17070102	46.281	117.894
14016650	Davis Hollow near Dayton, WA	2	17070102	46.300	117.953
14017000	Touchet River at Bolles, WA	2	17070102	46.274	118.221
14017040	Thorn Hollow near Dayton, WA	2	17070102	46.347	118.065
14017070	East Fork McKay Creek near Huntsville, WA	2	17070102	46.363	118.132
14017200	Badger Hollow near Clyde, WA	2	17070102	46.416	118.338
14017500	Touchet River near Touchet, WA	2	17070102	46.042	118.683
14018500	Walla Walla River near Touchet, WA	2	17070102	46.028	118.729
14019400	Elbow Creek near Bingham Springs, OR	2	17070103	45.713	118.198
14020000	Umatilla River above Meacham Creek near Gibbon, OR	2	17070103	45.720	118.322
14020300	Meacham Creek at Gibbon, OR	2	17070103	45.689	118.356
14020740	Moonshine Creek near Mission, OR	2	17070103	45.661	118.564
14020800	Mission Creek at St Andrews Mission, OR	2	17070103	45.635	118.622
14020900	Wildhorse Creek near Athena, OR	2	17070103	45.766	118.443
14021000	Umatilla River at Pendleton, OR	2	17070103	45.672	118.792
14021980	Patawa Creek at West Boundary near Pendleton, OR	2	17070103	45.653	118.744
14022200	North Fork McKay Creek near Pilot Rock, OR	2	17070103	45.507	118.616
14022500	McKay Creek near Pilot Rock, OR	2	17070103	45.549	118.773
14025000	Birch Creek at Rieth, OR	2	17070103	45.653	118.879
14026000	Umatilla River at Yoakum, OR	2	17070103	45.678	119.033
14032000	Butter Creek near Pine City, OR	2	17070103	45.544	119.311
14034250	Glade Creek tributary near Bickleton, WA	2	17070101	46.069	120.206
14034325	Alder Creek near Bickleton, WA	2	17070101	45.997	120.275
14034370	Willow Creek tributary near Heppner, OR	2	17070104	45.228	119.333

Appendix A. Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Station Number	Station Name	Flood Region	Hydrologic Unit	Latitude Decimal Degrees	Longitude Decimal Degrees
14034470	Willow Creek above Willow Creek Lake, near Heppner, OR	2	17070104	45.341	119.515
14034480	Balm Fork near Heppner, OR	2	17070104	45.332	119.540
14034500	Willow Creek at Heppner, OR	2	17070104	45.351	119.549
14034800	Rhea Creek near Heppner, OR	2	17070104	45.261	119.623
14036000	Willow Creek near Arlington, OR	2	17070104	45.753	120.010
14036800	John Day River near Prairie City, OR	4	17070201	44.319	118.557
14037500	Strawberry Creek above Slide Creek near Prairie City, OR	4	17070201	44.342	118.656
14038500	John Day River at Prairie City, OR	4	17070201	44.454	118.717
14038530	John Day River near John Day, OR	4	17070201	44.419	118.903
14038550	East Fork Canyon Creek near Canyon City, OR	4	17070201	44.246	118.911
14038600	Vance Creek near Canyon City, OR	4	17070201	44.289	118.978
14038602	Canyon Creek near Canyon City, OR	4	17070201	44.290	118.956
14038750	Beech Creek near Fox, OR	4	17070201	44.568	119.108
14038900	Fields Creek near Mt Vernon, OR	4	17070201	44.393	119.307
14039200	Venator Creek near Silvies, OR	4	17070201	43.999	119.275
14040500	John Day River at Picture Gorge, near Dayville, OR	4	17070201	44.521	119.625
14040600	Mountain Creek near Mitchell, OR	4	17070201	44.535	120.029
14040700	Whisky Creek near Mitchell, OR	4	17070201	44.522	119.922
14040900	Bruin Creek near Dale, OR	4	17070202	44.898	118.793
14041000	Desolation Creek near Dale, OR	4	17070202	44.989	118.919
14041500	North Fork John Day River near Dale, OR	4	17070202	44.999	118.940
14041900	Line Creek near Lehman Springs, OR	4	17070202	45.169	118.711
14042000	Camas Creek near Lehman, OR	4	17070202	45.171	118.731
14042500	Camas Creek near Ukiah, OR	4	17070202	45.157	118.819
14043800	Bridge Creek near Prairie City, OR	4	17070203	44.542	118.540
14043850	Cottonwood Creek near Galena, OR	4	17070203	44.653	118.865
14043900	Granite Creek near Dale, OR	4	17070203	44.894	119.014
14044000	M Fork John Day River at Ritter, OR	4	17070203	44.889	119.140
14044100	Paul Creek near Long Creek, OR	4	17070203	44.724	119.132
14044500	Fox Creek at Gorge near Fox, OR	4	17070202	44.619	119.262
14046000	North Fork John Day River at Monument, OR	4	17070202	44.814	119.431
14046250	Ives Can near Spray, OR	4	17070204	44.860	119.714
14046300	Big Service Creek near Service Creek, OR	4	17070204	44.894	120.070
14046500	John Day River at Service Creek, OR	4	17070204	44.794	120.006
14047100	Butte Creek near Fossil, OR	4	17070204	44.954	120.137
14047350	Rock Creek tributary near Hardman, OR	2	17070204	45.078	119.569
14047380	Lone Rock Creek near Lonerock, OR	2	17070204	45.092	119.886
14047390	Rock Creek above Whyte Park near Condon, OR	2	17070204	45.265	120.021
14048000	John Day River at McDonald Ferry, OR	4	17070204	45.588	120.408
14048040	Gordon Hollow at De Moss Springs, OR	2	17070204	45.514	120.682
14048300	Spanish Hollow at Wasco, OR	2	17070105	45.589	120.694
14048310	Spanish Hollow tributary at Wasco, OR	2	17070105	45.592	120.715
14050000	Deschutes River below Snow Creek near La Pine, OR	1	17070301	43.814	121.776

Appendix A. Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Station Number	Station Name	Flood Region	Hydrologic Unit	Latitude Decimal Degrees	Longitude Decimal Degrees
14050500	Cultus River above Cultus Creek near La Pine, OR	1	17070301	43.818	121.794
14051000	Cultus Creek above Crane Prairie Reservoir near La Pine, OR	1	17070301	43.821	121.823
14052000	Deer Creek above Crane Prairie Reservoir near La Pine, OR	1	17070301	43.805	121.838
14053000	Charlton Creek above Crane Prairie Reservoir near La Pine, OR	1	17070301	43.781	121.835
14054500	Brown Creek near La Pine, OR	1	17070301	43.713	121.803
14055500	Odell Creek near Crescent, OR	1	17070301	43.548	121.961
14055600	Odell Creek near La Pine, OR	1	17070301	43.576	121.880
14061000	Big Marsh Creek Hoey Ranch near Crescent, OR	1	17070302	43.478	121.914
14073000	Tumalo Creek near Bend, OR	1	17070301	44.088	121.372
14075000	Squaw Creek near Sisters, OR	1	17070301	44.234	121.566
14077500	North Fork Beaver Creek near Paulina, OR	4	17070303	44.167	119.733
14077800	Wolf Creek tributary near Paulina, OR	4	17070303	44.278	119.817
14078000	Beaver Creek near Paulina, OR	4	17070303	44.164	119.922
14078200	Lizard G tributary near Hampton, OR	4	17070303	43.589	119.983
14078400	Lookout Creek near Post, OR	4	17070304	44.311	120.240
14078500	North Fork Crooked River above Deep Creek, OR	4	17070304	44.333	120.083
14079500	Crooked River at Post, OR	4	17070304	44.117	120.250
14079800	Crooked River above Prineville Reservoir near Post, OR	4	17070304	44.178	120.583
14080500	Crooked River near Prineville, OR	4	17070304	44.114	120.794
14080600	Dry Creek near Prineville, OR	4	17070305	44.203	120.760
14081800	Ahalt Creek near Mitchell, OR	4	17070305	44.433	120.351
14083000	Ochoco Creek above Mill Creek near Prineville, OR	4	17070305	44.308	120.644
14083500	Mill Creek near Prineville, OR	4	17070305	44.336	120.667
14088000	Lake Creek near Sisters, OR	1	17070301	44.426	121.725
14090350	Jefferson Creek near Camp Sherman, OR	1	17070301	44.572	121.638
14090400	Whitewater River near Camp Sherman, OR	1	17070306	44.718	121.635
14091500	Metolius River near Grandview, OR	1	17070301	44.626	121.482
14092750	Shitike Creek at Peters Pasture near Warm Springs, OR	1	17070306	44.751	121.632
14092885	Shitike Creek below Wolford Can near Warm Springs, OR	1	17070306	44.772	121.304
14093000	Shitike Creek at Warm Springs, OR	1	17070306	44.764	121.232
14093600	Trout Creek below Amity Creek near Ashwood, OR	2	17070307	44.639	120.674
14093700	Woods Hollow at Ashwood, OR	2	17070307	44.736	120.753
14095500	Warm Springs River near Simnasho, OR	1	17070306	44.969	121.476
14096300	Mill Creek near Badger Butte near Warm Springs, OR	1	17070306	44.862	121.626
14096850	Beaver Creek below Quartz Creek near Simnasho, OR	1	17070306	44.959	121.393
14097100	Warm Springs River near Kahneeta Hot Springs, OR	1	17070306	44.857	121.149
14097200	White River near Government Camp, OR	1	17070306	45.178	121.575
14100800	Jordan Creek near Tygh Valley, OR	1	17070306	45.341	121.346
14101500	White River below Tygh Valley, OR	1	17070306	45.242	121.094
14104100	Ramsey Creek near Dufur, OR	2	17070105	45.401	121.380
14104500	Fifteenmile Creek near Rice, OR	2	17070105	45.511	121.037
14107000	Klickitat River above West Fork near Glenwood, WA	2	17070106	46.265	121.244
14110000	Klickitat River near Glenwood, WA	2	17070106	46.089	121.258

Appendix A. Peak flow gaging stations in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Station Number	Station Name	Flood Region	Hydrologic Unit	Latitude Decimal Degrees	Longitude Decimal Degrees
14111800	West Prong Little Klickitat River near Goldendale, WA	2	17070106	45.925	120.720
14112000	Little Klickitat River near Goldendale, WA	2	17070106	45.844	120.795
14112200	Little Klickitat River tributary near Goldendale, WA	2	17070106	45.837	120.797
14112500	Little Klickitat River near Wahkiacus, WA	2	17070106	45.844	121.059
14113000	Klickitat River near Pitt, WA	2	17070106	45.757	121.209
14113200	Mosier Creek near Mosier, OR	2	17070105	45.649	121.376
14113400	Dog River near Parkdale, OR	1	17070105	45.408	121.519
14118500	West Fork Hood River near Dee, OR	1	17070105	45.599	121.635
14120000	Hood River at Tucker Bridge near Hood River, OR	1	17070105	45.656	121.547
14121000	Hood River near Hood River, OR	1	17070105	45.700	121.511
14121300	White Salmon River below Cascades Creek near Trout Lake, WA	1	17070105	46.102	121.604
14121500	Trout Lake Creek near Trout Lake, WA	1	17070105	46.006	121.539
14122000	White Salmon River near Trout Lake, WA	1	17070105	45.992	121.492
14123000	White Salmon River at Husum, WA	1	17070105	45.797	121.483
14123500	White Salmon River near Underwood, WA	1	17070105	45.753	121.526
14124500	Little White Salmon River at Willard, WA	1	17070105	45.781	121.625
14125000	Little White Salmon River above Lapham Creek Willard, WA	1	17070105	45.767	121.628
14125500	Little White Salmon River near Cook, WA	1	17070105	45.724	121.633

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
10329500	1922-1999	76	0	0	0	0	0	0	0	0	0.233	0.233	0.063	0.161	0.134	0.087
10330300	1962-1979	18	0	0	0	0	50	4	0	0	-1.644	-0.383	0.053	-0.064	-0.092	0.595
10352300	1969-1981	12	0	0	0	0	0	0	0	3	0.265	-0.042	-0.242	-0.198	-0.171	0.440
10352500	1949-1999	51	0	0	0	0	0	0	0	0	-0.439	-0.439	-0.256	-0.340	-0.057	0.553
10353000	1949-1981	33	0	0	0	0	200	6	0	0	-1.228	0.012	-0.192	-0.106	-0.009	0.938
10353600	1963-1995	24	51	0	0	1	0	0	0	0	0.919	0.678	-0.221	0.570	-0.113	0.441
10353700	1961-1980	19	0	0	0	0	0	0	0	0	0.051	0.051	-0.151	-0.090	-0.035	0.833
10353750	1988-1999	12	0	0	0	0	0	0	0	0	-0.115	-0.115	-0.148	-0.141	0.351	0.112
10360900	1961-1982	22	0	0	0	0	0	0	0	0	0.051	0.051	-0.062	-0.025	-0.013	0.933
10361700	1962-1978	17	0	0	0	0	0	0	1	0	0.255	0.201	-0.152	-0.057	-0.165	0.354
10366000	1963-1998	34	0	0	0	0	0	1	0	0	-0.752	-0.480	-0.093	-0.473	-0.014	0.906
10370000	1913-1972	25	69	0	0	1	0	0	0	0	1.182	0.857	0.033	0.404	0.220	0.123
10371000	1915-1973	26	0	0	0	0	0	0	0	0	0.228	0.228	0.011	0.086	0.277	0.047
10371500	1923-2000	72	0	0	0	0	0	0	0	0	0.015	0.015	0.013	0.014	0.179	0.026
10378500	1910-1998	77	0	0	0	0	0	0	0	0	-0.095	-0.095	0.006	-0.055	0.053	0.495
10384000	1914-2000	83	0	0	0	0	0	1	0	0	-0.012	0.257	0.110	0.197	0.179	0.017
10390400	1965-1982	17	0	0	0	0	50	7	0	0	1.046	-0.077	0.152	0.088	-0.498	0.005
10392300	1967-1981	15	0	0	0	0	25	3	0	0	-2.641	-0.036	-0.225	-0.176	-0.019	0.921
10392800	1966-1979	14	0	0	0	0	0	0	0	0	-0.389	-0.389	-0.190	-0.235	0.354	0.078
10393500	1906-1997	86	0	0	0	0	200	3	0	0	-0.938	-0.444	-0.281	-0.373	0.009	0.899
10393900	1965-1981	13	0	0	0	0	0	1	0	1	-1.336	-1.078	-0.291	-0.427	-0.494	0.019
10396000	1911-2003	77	0	0	0	0	0	0	0	0	-0.496	-0.496	-0.409	-0.456	0.067	0.388
10397000	1911-1970	39	0	0	0	0	0	0	0	0	-0.501	-0.501	-0.413	-0.448	-0.009	0.932
10402800	1967-1977	11	0	0	0	0	0	1	0	0	-1.719	-0.355	-0.296	-0.307	-0.309	0.186
10403000	1952-1980	29	0	0	0	0	0	0	0	0	-0.666	-0.666	-0.280	-0.405	0.039	0.764
10403500	1904-1925	18	0	0	0	0	0	0	0	0	-0.106	-0.106	-0.268	-0.221	0.066	0.704
10406500	1911-1997	74	0	0	0	0	0	0	0	0	-0.070	-0.070	-0.177	-0.113	0.037	0.643
11339995	1981-2000	16	0	0	0	0	0	0	0	0	0.460	0.460	-0.031	0.089	0.427	0.021

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
11340500	1909-1919	10	0	0	0	0	0	0	0	0	-0.564	-0.564	-0.015	-0.113	-0.467	0.060
11340950	1946-1958	13	0	0	0	0	0	0	0	0	-0.087	-0.087	-0.031	-0.044	0.359	0.088
11341000	1912-1958	25	0	0	0	0	0	0	0	0	-0.447	-0.447	-0.029	-0.162	0.300	0.036
11341050	1977-1988	10	0	0	0	0	0	1	0	0	-1.976	-0.368	0.034	-0.040	-0.200	0.421
11341100	1964-1981	18	0	0	0	0	0	1	0	1	-1.871	-0.047	0.034	0.010	-0.367	0.033
11341200	1966-1981	16	0	0	0	0	0	1	0	0	-0.858	-0.343	0.046	-0.052	-0.326	0.078
11342945	1963-1973	11	0	0	0	0	0	0	0	0	0.332	0.332	0.041	0.098	-0.278	0.234
11342960	1963-1973	11	0	0	0	0	50	4	0	0	-1.208	-0.409	0.041	-0.046	0.127	0.586
11348080	1963-1973	11	0	0	0	0	60	3	0	0	-1.810	-0.751	0.074	-0.077	0.018	0.938
11348560	1963-1973	11	0	0	0	0	0	1	0	0	-1.488	-0.007	0.165	0.129	-0.315	0.178
11484000	1910-1920	11	0	0	0	0	0	0	0	0	0.169	0.169	0.076	0.095	-0.257	0.271
11489350	1963-1973	11	21	0	0	1	0	0	0	0	1.243	1.026	0.192	0.385	-0.183	0.432
11489500	1953-1979	27	0	0	0	0	0	0	0	0	0.447	0.447	0.324	0.365	-0.088	0.518
11491800	1965-1981	16	0	0	0	0	0	0	1	0	-0.606	-0.606	0.248	-0.428	-0.377	0.042
11494800	1965-1981	14	83	0	0	1	0	0	0	0	0.942	0.621	0.074	0.575	-0.181	0.368
11497500	1914-2001	56	0	0	0	0	0	0	0	0	-0.105	-0.105	0.059	-0.028	0.091	0.322
11497800	1965-1982	17	0	0	0	0	20	3	0	0	-1.408	0.053	0.099	0.086	-0.273	0.126
11501000	1921-2003	83	0	0	0	0	0	0	0	0	0.048	0.048	0.127	0.077	0.093	0.215
11501300	1965-1981	17	0	0	0	0	0	1	0	0	-1.111	0.209	0.267	0.251	-0.081	0.649
11502500	1917-2003	87	0	0	0	0	0	0	0	0	0.270	0.270	0.175	0.232	0.053	0.468
11504000	1913-1936	22	0	0	0	0	0	1	0	0	-0.434	0.185	0.350	0.298	-0.382	0.013
11505550	1966-1982	17	0	0	0	0	0	0	0	0	-0.576	-0.576	0.316	-0.487	-0.221	0.217
11516900	1958-1978	21	83	0	0	1	0	0	0	0	1.373	0.711	0.147	0.434	-0.091	0.565
13172666	1965-1978	14	0	0	0	0	0	1	0	0	-0.855	-0.231	-0.537	-0.465	-0.077	0.702
13172668	1963-1993	31	0	0	0	0	0	0	0	0	-0.691	-0.691	-0.537	-0.588	0.002	0.986
13172680	1966-1993	28	0	0	0	0	50	2	0	0	-1.257	-0.693	-0.478	-0.546	-0.153	0.252
13172720	1964-1990	27	0	0	0	0	0	0	0	0	-0.514	-0.514	-0.447	-0.469	-0.214	0.118
13172735	1964-1993	30	0	0	0	0	0	0	0	0	-0.596	-0.596	-0.435	-0.489	-0.216	0.093

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
13172740	1963-1993	31	0	0	0	0	0	0	0	0	-0.358	-0.358	-0.573	-0.494	-0.299	0.018
13172800	1961-1980	19	0	0	0	0	0	0	4	0	-0.369	-0.582	-0.422	-0.464	-0.018	0.914
13172900	1966-1979	14	0	0	0	0	0	0	0	0	-0.046	-0.046	-0.452	-0.353	0.033	0.870
13178000	1946-1971	24	48	0	0	1	0	0	0	0	0.223	0.012	-0.416	-0.198	0.105	0.471
13182100	1970-1981	12	0	0	0	0	10	2	1	0	-1.751	-1.102	-0.459	-0.564	0.198	0.369
13207000	1955-1982	18	0	0	0	0	0	0	0	0	-0.023	-0.023	-0.270	-0.198	0.163	0.344
13207500	1955-1982	15	0	0	0	0	50	5	0	0	-0.408	-0.634	-0.273	-0.355	0.124	0.520
13213800	1968-1991	24	0	0	0	0	0	1	0	0	-1.335	-0.723	-0.311	-0.430	-0.341	0.020
13213900	1964-1982	19	0	0	0	0	10	2	2	0	-0.742	-0.027	-0.322	-0.233	-0.211	0.207
13214000	1921-1998	73	0	0	0	0	0	1	0	0	-0.520	-0.229	-0.293	-0.257	0.072	0.368
13216500	1937-1998	59	0	0	0	0	0	0	0	0	-0.349	-0.349	-0.335	-0.342	0.150	0.094
13226500	1904-1985	41	0	0	0	0	0	0	0	0	-0.584	-0.584	-0.345	-0.439	0.177	0.103
13228000	1904-1919	11	0	0	0	0	0	0	0	0	0.184	0.184	-0.345	0.033	-0.382	0.102
13228300	1969-1982	14	0	0	0	0	0	0	0	0	0.378	0.378	-0.362	0.096	-0.177	0.378
13229400	1967-1978	12	0	0	0	0	10	2	2	0	-1.274	-0.508	-0.307	-0.348	-0.321	0.147
13248900	1961-1980	19	0	0	0	0	51	6	0	1	0.549	-0.322	-0.229	-0.255	0.024	0.888
13250600	1962-1997	22	24	1	2,100	1	0	1	0	0	-2.471	-0.196	-0.129	-0.151	0.229	0.135
13250650	1962-1971	10	0	0	0	0	50	2	0	0	-0.785	-0.143	-0.172	-0.167	0.156	0.531
13251300	1960-1977	18	0	0	0	0	0	1	0	0	-1.827	0.209	0.089	0.122	0.126	0.466
13251500	1937-1997	38	0	0	0	0	0	0	0	0	-0.033	-0.033	0.061	0.019	0.185	0.102
13252500	1933-1943	10	0	0	0	0	0	0	0	0	0.637	0.637	0.093	0.586	0.180	0.469
13253500	1939-1949	11	37	1	2,800	0	0	0	0	0	0.021	0.072	0.076	0.074	0.055	0.815
13260000	1939-1997	24	0	0	0	0	0	0	0	0	0.672	0.672	0.133	0.645	0.033	0.823
13261000	1924-1971	38	42	1	2,230	0	0	0	0	0	-0.016	0.150	0.115	0.131	0.098	0.385
13267000	1937-1965	28	0	0	0	0	0	0	0	0	0.229	0.229	0.166	0.189	0.058	0.664
13267100	1962-1971	10	0	0	0	0	0	1	0	0	-0.772	0.180	0.134	0.143	0.135	0.587
13269200	1964-1979	14	0	0	0	0	0	1	1	0	-0.556	0.121	-0.213	-0.132	-0.011	0.956
13269300	1965-1994	18	0	0	0	0	600	8	0	0	-1.400	-0.480	-0.226	-0.292	-0.033	0.850

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
13272300	1967-1979	13	0	0	0	1	0	0	0	0	0.812	-0.314	-0.314	-0.089	-0.144	0.494
13274600	1967-1979	13	0	0	0	0	0	0	1	0	-0.309	-0.371	-0.074	-0.139	0.282	0.180
13275105	1981-1999	18	0	0	0	0	0	0	0	0	-0.747	-0.747	-0.275	-0.390	0.124	0.472
13275200	1968-1999	31	0	0	0	0	0	0	0	0	-0.106	-0.106	-0.282	-0.212	0.105	0.405
13275500	1904-1967	52	0	0	0	0	0	0	0	0	-0.581	-0.581	-0.322	-0.436	-0.042	0.658
13281200	1977-1999	23	0	0	0	0	0	0	0	0	-0.427	-0.427	-0.228	-0.289	-0.214	0.153
13282400	1963-1978	15	0	0	0	0	0	0	0	0	-0.431	-0.431	-0.060	-0.148	-0.029	0.882
13283600	1974-2000	27	0	0	0	1	0	1	0	0	-0.596	-0.106	-0.067	-0.081	-0.285	0.037
13285900	1963-1979	17	0	0	0	0	0	0	0	0	-0.274	-0.274	-0.144	-0.179	0.155	0.385
13286300	1969-1982	14	0	0	0	0	20	3	2	0	-0.584	-0.346	-0.085	-0.145	-0.056	0.780
13287200	1968-1986	19	0	0	0	1	0	0	0	0	0.897	0.897	-0.056	0.175	0.088	0.598
13288200	1958-1997	40	0	0	0	1	0	0	0	0	0.328	0.328	0.129	0.213	0.000	1.000
13289100	1964-1981	14	0	0	0	0	40	2	0	1	-1.824	0.636	0.111	0.576	-0.022	0.912
13289600	1962-1971	10	0	0	0	0	0	0	0	3	0.609	0.210	0.124	0.140	0.180	0.469
13289960	1979-1994	15	0	0	0	0	0	0	0	0	0.238	0.238	0.115	0.145	-0.295	0.125
13290150	1965-1979	13	0	0	0	0	0	0	0	0	-0.105	-0.105	0.200	0.130	-0.256	0.222
13290190	1967-1996	30	0	0	0	0	0	1	0	0	-0.956	-0.037	0.114	0.054	-0.240	0.063
13291200	1965-1975	10	0	0	0	0	0	0	0	0	0.005	0.005	0.200	0.162	-0.067	0.788
13291400	1965-1979	10	0	0	0	0	0	0	2	0	0.202	-0.023	0.180	0.141	0.045	0.856
13292000	1929-2003	75	0	0	0	1	0	0	0	0	0.703	0.703	0.216	0.456	0.109	0.165
13315500	1937-1971	26	0	0	0	0	0	0	0	0	-0.096	-0.096	0.025	-0.018	-0.065	0.642
13316500	1948-2000	47	0	0	0	0	0	1	0	0	-0.416	-0.066	0.076	0.005	-0.105	0.300
13316800	1960-1971	12	0	0	0	1	0	0	0	0	1.094	1.094	0.177	0.327	0.303	0.170
13317200	1961-1972	12	0	0	0	0	0	0	0	0	-0.101	-0.101	0.181	0.120	-0.030	0.891
13318100	1966-1979	14	0	0	0	0	0	0	0	0	0.190	0.190	0.270	0.251	0.429	0.033
13318500	1938-1956	19	0	0	0	0	0	0	0	0	0.482	0.482	0.133	0.227	0.164	0.326
13318800	1967-1981	15	0	0	0	0	0	1	0	0	-1.106	0.233	0.136	0.160	0.000	1.000
13319000	1904-1988	80	0	0	0	0	0	1	0	0	-0.100	0.219	0.130	0.182	0.054	0.482

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
13320000	1912-1999	76	0	0	0	0	0	0	0	0	-0.258	-0.258	-0.092	-0.187	-0.055	0.478
13320400	1948-1979	26	76	0	0	0	0	1	0	0	-0.788	-0.562	-0.087	-0.334	-0.296	0.034
13321300	1953-1972	16	0	0	0	0	0	0	0	0	-0.421	-0.421	-0.023	-0.121	0.092	0.619
13322300	1965-1979	14	0	0	0	0	0	1	0	0	-0.487	0.223	0.265	0.255	0.110	0.582
13323500	1956-1981	26	0	0	0	0	0	1	0	0	-0.720	-0.280	0.082	-0.042	-0.068	0.627
13323600	1938-1950	13	0	0	0	0	0	0	0	0	0.103	0.103	0.028	0.045	0.103	0.625
13323700	1966-1983	17	0	0	0	0	0	0	0	0	-0.293	-0.293	0.111	0.004	0.162	0.365
13324150	1967-1979	13	0	0	0	0	0	0	1	0	-0.464	-0.523	0.113	-0.350	-0.065	0.759
13324300	1983-2003	21	59	0	0	1	0	0	0	0	0.725	0.424	0.418	0.421	0.024	0.880
13325000	1925-1982	58	0	0	0	1	0	0	0	0	0.451	0.451	0.094	0.267	0.146	0.105
13325500	1924-1940	13	0	0	0	0	0	0	0	0	-0.039	-0.039	0.089	0.059	0.282	0.180
13329500	1915-1978	56	0	0	0	0	0	0	0	0	-0.172	-0.172	0.072	-0.055	0.242	0.008
13329700	1967-1982	13	0	0	0	0	0	0	2	0	-0.101	-0.253	0.118	0.035	0.130	0.537
13329750	1967-1977	11	0	0	0	0	0	0	1	0	-0.192	-0.271	0.072	0.004	-0.455	0.052
13330000	1913-2003	75	0	0	0	0	0	1	0	0	-0.401	-0.091	0.055	-0.032	0.051	0.515
13330500	1915-2003	71	0	0	0	0	0	0	0	0	0.098	0.098	0.029	0.069	0.152	0.061
13331500	1913-2003	39	0	0	0	0	0	0	0	0	0.076	0.076	-0.001	0.034	-0.058	0.602
13332500	1927-1996	67	0	0	0	0	0	0	0	0	0.098	0.098	0.108	0.103	0.115	0.168
13333000	1945-2003	59	0	0	0	0	0	0	0	0	0.230	0.230	0.159	0.196	-0.036	0.689
13333050	1967-1981	15	0	0	0	0	0	0	0	0	0.186	0.186	0.340	0.302	0.077	0.691
13333100	1965-1979	15	0	0	0	0	0	1	0	0	-0.766	0.393	0.191	0.239	-0.181	0.347
13334700	1960-1996	30	0	0	0	0	0	0	0	0	0.691	0.691	0.435	0.519	-0.039	0.762
13335050	1990-1999	10	0	0	0	0	0	0	0	0	0.144	0.144	0.424	0.371	0.467	0.060
13341100	1961-1981	18	0	0	0	0	0	0	0	0	-0.457	-0.457	0.283	-0.361	-0.170	0.323
13342450	1975-2000	25	0	0	0	0	0	1	0	0	-0.347	0.132	0.283	0.230	-0.073	0.607
14010000	1903-1991	69	0	0	0	0	0	0	0	0	0.545	0.545	0.476	0.511	0.115	0.161
14010800	1970-1991	22	0	0	0	0	0	0	0	0	-0.115	-0.115	0.494	0.296	-0.208	0.175
14011000	1930-1969	38	0	0	0	0	0	0	0	0	0.523	0.523	0.482	0.498	-0.028	0.801

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
14011800	1966-1978	12	0	0	0	0	300	5	0	0	-1.009	0.148	0.405	0.350	0.030	0.891
14013000	1914-1999	64	0	0	0	1	0	0	0	0	0.523	0.523	0.484	0.503	0.033	0.702
14013500	1940-1971	31	0	0	0	0	100	2	0	0	-0.203	0.439	0.444	0.442	-0.071	0.574
14015900	1955-1974	20	0	0	0	0	5	3	0	0	0.342	0.093	0.439	0.109	0.085	0.600
14016000	1949-1967	18	0	0	0	0	0	0	0	0	-0.230	-0.230	0.439	-0.194	-0.333	0.053
14016080	1967-1982	16	0	0	0	0	0	0	3	0	0.211	0.002	0.432	0.026	0.076	0.682
14016200	1966-1985	20	0	0	0	0	0	1	0	0	-1.153	-0.771	0.373	-0.735	-0.069	0.672
14016500	1944-1968	21	71	0	0	1	0	0	0	0	0.779	0.166	0.362	0.250	-0.229	0.147
14016600	1955-1974	20	0	0	0	0	0	0	0	0	-0.721	-0.721	0.334	-0.659	0.196	0.226
14016650	1957-1975	19	21	1	305	0	0	0	0	0	-0.137	-0.027	0.323	0.210	-0.041	0.804
14017000	1925-1989	43	0	0	0	0	0	1	0	0	-0.692	-0.098	0.359	0.143	-0.081	0.445
14017040	1962-1976	15	0	0	0	0	0	0	0	0	-0.670	-0.670	0.318	-0.601	0.029	0.882
14017070	1963-1977	15	0	0	0	0	0	0	0	0	0.253	0.253	0.357	0.331	-0.057	0.765
14017200	1955-1974	20	0	0	0	0	5	2	0	0	-1.115	0.654	0.405	0.471	-0.026	0.871
14017500	1942-1965	16	0	0	0	0	0	0	0	0	0.106	0.106	0.380	0.307	0.209	0.258
14018500	1949-1999	49	0	0	0	0	0	0	0	0	0.151	0.151	0.404	0.279	-0.122	0.215
14019400	1965-1979	13	0	0	0	0	0	1	0	0	-2.063	0.788	0.373	0.456	-0.013	0.951
14020000	1933-2003	70	0	0	0	0	0	0	0	0	0.356	0.356	0.370	0.362	0.101	0.216
14020300	1976-2003	28	0	0	0	0	0	0	0	0	0.014	0.014	0.263	0.167	-0.024	0.859
14020740	1992-2003	12	71	0	0	1	0	0	0	0	0.751	0.146	0.303	0.213	-0.031	0.889
14020800	1958-1979	17	0	0	0	0	0	1	0	0	-0.781	-0.056	0.303	0.203	-0.132	0.458
14020900	1967-1978	12	0	0	0	0	200	3	0	0	-1.567	0.421	0.372	0.382	-0.121	0.583
14021000	1904-2003	67	0	0	0	0	0	0	0	0	0.056	0.056	0.325	0.169	0.043	0.611
14021980	1992-2003	12	0	0	0	0	0	0	0	0	0.084	0.084	0.302	0.255	-0.182	0.411
14022200	1974-2003	30	0	0	0	0	0	1	0	0	-0.577	-0.033	0.303	0.169	-0.131	0.309
14022500	1927-2001	74	0	0	0	0	0	0	0	0	0.221	0.221	0.277	0.245	0.076	0.341
14025000	1928-2001	57	0	0	0	0	0	0	0	0	-0.059	-0.059	0.166	0.044	0.022	0.809
14026000	1905-1926	22	0	0	0	0	0	0	0	0	0.096	0.097	0.281	0.221	-0.091	0.554

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
14032000	1929-2004	76	0	0	0	0	0	0	0	0	0.727	0.727	0.385	0.553	0.059	0.454
14034250	1961-1976	16	0	0	0	0	3	2	2	0	-1.968	0.209	0.336	0.303	-0.159	0.390
14034325	1963-1977	15	0	0	0	0	0	1	0	0	-2.456	0.560	0.308	0.366	-0.048	0.805
14034370	1960-1979	15	0	0	0	0	0	0	1	0	-0.472	-0.522	0.299	0.109	0.077	0.691
14034470	1983-2003	21	0	0	0	0	0	0	0	0	-0.087	-0.087	0.311	0.185	-0.205	0.193
14034480	1983-2003	21	100	1	36,000	0	0	0	0	0	-0.594	0.343	0.297	0.325	-0.257	0.103
14034500	1949-1982	32	100	1	36,000	0	50	3	0	0	-0.069	1.815	0.308	0.719	-0.121	0.331
14034800	1961-2001	38	0	0	0	0	60	4	0	0	-0.476	0.183	0.281	0.239	-0.165	0.144
14036000	1961-1979	19	21	1	17,000	0	0	1	0	0	-0.761	-0.292	0.331	-0.262	-0.006	0.972
14036800	1965-1979	14	0	0	0	0	0	0	0	0	-0.693	-0.693	-0.220	-0.321	-0.313	0.119
14037500	1931-2002	70	0	0	0	0	0	0	0	0	-0.019	-0.019	-0.220	-0.100	0.175	0.032
14038500	1940-1968	28	0	0	0	0	0	0	0	0	0.709	0.709	-0.224	0.069	-0.048	0.721
14038530	1969-2003	33	0	0	0	0	0	0	0	0	-0.124	-0.124	-0.214	-0.177	-0.207	0.091
14038550	1965-1979	15	0	0	0	0	0	1	0	0	-1.212	-1.138	-0.210	-0.846	-0.295	0.125
14038600	1964-1979	14	0	0	0	0	0	0	0	1	0.084	0.020	-0.167	-0.121	-0.253	0.208
14038602	1981-2002	22	0	0	0	0	0	0	0	0	-0.366	-0.366	-0.208	-0.256	-0.130	0.397
14038750	1965-1979	12	0	0	0	0	9	3	0	1	-0.938	-0.275	-0.111	-0.145	-0.412	0.062
14038900	1967-1979	13	0	0	0	0	0	0	1	0	-0.566	-0.623	-0.129	-0.231	0.000	1.000
14039200	1967-1979	13	0	0	0	0	0	1	0	0	-2.779	-0.925	-0.370	-0.476	-0.179	0.393
14040500	1927-2002	75	0	0	0	0	0	0	0	0	-0.103	-0.103	-0.161	-0.127	0.071	0.367
14040600	1967-2001	32	0	0	0	0	0	1	0	0	-0.439	-0.031	0.107	0.050	-0.347	0.005
14040700	1969-1979	11	0	0	0	0	0	0	1	0	0.022	-0.061	0.011	-0.004	-0.491	0.036
14040900	1969-1981	12	0	0	0	0	20	2	0	0	-2.641	0.456	0.079	0.156	0.326	0.141
14041000	1950-1961	12	14	1	930	1	0	0	0	0	-0.094	-0.261	-0.001	-0.062	-0.030	0.891
14041500	1930-1958	29	0	0	0	0	0	0	0	0	-0.512	-0.512	-0.069	-0.220	0.341	0.009
14041900	1965-1979	15	0	0	0	0	0	0	0	0	-0.075	-0.075	0.216	0.142	-0.039	0.841
14042000	1951-1969	19	0	0	0	0	0	0	0	0	0.557	0.557	0.194	0.290	-0.345	0.039
14042500	1915-2002	75	0	0	0	0	0	0	0	0	0.279	0.279	0.185	0.238	-0.022	0.784

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System -atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General -ized	Weight-ed	Kendall's tau	Signifi-cance level
14043800	1964-1979	15	0	0	0	0	0	0	0	0	0.107	0.107	-0.212	-0.131	0.320	0.096
14043850	1965-1979	15	0	0	0	0	0	0	0	0	-0.016	-0.016	-0.112	-0.087	0.038	0.842
14043900	1965-1979	10	0	0	0	0	0	1	0	1	-1.846	-0.375	0.127	0.035	-0.270	0.278
14044000	1930-2003	74	0	0	0	0	0	0	0	0	-0.195	-0.195	-0.106	-0.157	0.161	0.042
14044100	1969-1979	11	0	0	0	0	0	0	0	1	-0.553	-0.623	0.100	-0.560	-0.636	0.006
14044500	1931-1958	28	0	0	0	0	0	1	0	0	-0.268	0.306	0.062	0.148	0.236	0.078
14046000	1925-2003	79	0	0	0	0	0	0	0	0	0.243	0.243	0.057	0.166	0.128	0.096
14046250	1968-1979	11	0	0	0	0	0	1	1	0	-0.962	-0.316	0.189	-0.274	0.382	0.102
14046300	1969-1979	11	0	0	0	0	0	0	0	1	0.084	-0.001	0.307	0.243	-0.455	0.052
14046500	1926-2003	75	0	0	0	0	0	0	0	0	-0.083	-0.083	0.004	-0.048	0.085	0.282
14047100	1974-2002	27	0	0	0	0	0	0	0	0	-0.118	-0.118	0.307	0.151	0.069	0.615
14047350	1965-1979	14	0	0	0	0	20	2	0	1	-1.058	-0.554	0.244	0.068	-0.363	0.071
14047380	1966-2002	36	0	0	0	0	0	1	0	0	-0.579	0.087	0.399	0.264	-0.206	0.077
14047390	1976-1989	14	0	0	0	0	0	0	0	0	-0.089	-0.089	0.358	0.249	0.407	0.043
14048000	1894-2003	98	0	0	0	0	0	0	0	0	-0.096	-0.096	0.106	-0.026	0.032	0.643
14048040	1959-1981	21	0	0	0	0	0	0	5	0	-0.149	-0.417	0.250	-0.392	0.029	0.853
14048300	1959-1979	21	0	0	0	0	0	1	5	0	-1.572	0.201	0.263	0.244	0.029	0.853
14048310	1968-1979	12	0	0	0	0	0	1	3	0	-1.790	-0.781	0.263	-0.326	0.109	0.623
14050000	1938-1997	58	0	0	0	0	0	0	0	0	-0.596	-0.596	-0.103	-0.330	-0.082	0.361
14050500	1923-1997	55	0	0	0	0	0	0	0	0	-0.146	-0.146	-0.194	-0.169	-0.048	0.603
14051000	1924-1997	61	0	0	0	0	0	0	0	0	-0.239	-0.239	-0.214	-0.227	0.104	0.237
14052000	1924-1997	60	0	0	0	0	0	1	0	0	-0.454	-0.188	-0.230	-0.208	0.011	0.903
14053000	1938-1991	49	0	0	0	0	0	1	1	0	-0.829	-0.570	-0.266	-0.397	-0.163	0.099
14054500	1923-1997	58	0	0	0	0	0	0	0	0	-0.082	-0.082	-0.233	-0.151	-0.027	0.761
14055500	1933-1976	44	60	0	0	1	0	0	0	0	0.859	0.703	-0.045	0.291	0.072	0.490
14055600	1970-2004	35	45	0	0	1	0	0	0	0	0.675	0.620	-0.060	0.217	-0.303	0.011
14061000	1912-1958	32	0	0	0	0	0	0	0	0	0.031	0.031	0.017	0.023	0.297	0.017
14073000	1914-1980	67	0	0	0	0	0	0	0	0	0.134	0.134	-0.024	0.066	0.128	0.125

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
14075000	1916-2004	81	0	0	0	0	0	0	0	0	0.464	0.464	0.199	0.345	0.078	0.302
14077500	1942-1954	13	0	0	0	0	0	0	0	0	-0.272	-0.272	-0.081	-0.124	0.297	0.158
14077800	1965-1979	15	70	0	0	1	0	0	0	0	0.991	0.642	-0.015	0.306	-0.200	0.299
14078000	1943-1985	43	70	0	0	1	0	0	0	0	0.121	-0.037	-0.081	-0.055	-0.001	0.992
14078200	1965-1982	17	0	0	0	0	0	0	2	0	-0.237	-0.342	-0.177	-0.220	-0.066	0.710
14078400	1966-1979	14	0	0	0	0	0	1	1	0	-1.374	-0.576	0.053	-0.085	0.253	0.208
14078500	1942-1970	12	0	0	0	0	0	0	0	0	0.578	0.578	0.058	0.162	0.182	0.411
14079500	1909-1993	28	0	0	0	0	0	0	0	0	-0.209	-0.209	-0.096	-0.137	0.333	0.013
14079800	1961-1998	13	0	0	0	0	0	0	0	0	-0.060	-0.060	-0.081	-0.076	0.231	0.272
14080500	1909-1960	26	0	0	0	0	0	0	0	0	-0.150	-0.150	-0.071	-0.099	0.065	0.643
14080600	1969-1979	10	0	0	0	0	0	0	2	0	0.381	-0.004	-0.004	0.025	-0.180	0.469
14081800	1956-1979	23	70	0	0	1	20	3	4	0	-3.141	0.690	0.236	0.454	-0.008	0.957
14083000	1918-1933	13	0	0	0	0	100	2	0	0	-1.159	0.036	0.180	0.146	-0.116	0.581
14083500	1918-1932	12	0	0	0	0	100	3	0	0	-0.768	-0.264	0.301	0.182	0.091	0.681
14088000	1915-1997	79	0	0	0	0	0	0	0	0	0.249	0.249	0.337	0.286	0.078	0.309
14090350	1984-2003	20	0	0	0	0	0	0	0	0	0.430	0.430	0.246	0.298	0.227	0.162
14090400	1983-2003	20	79	0	0	1	0	0	0	0	0.743	0.149	0.233	0.182	0.211	0.194
14091500	1913-2003	83	0	0	0	1	0	0	0	0	0.832	0.832	0.333	0.576	0.099	0.187
14092750	1983-2003	20	0	0	0	0	0	0	0	0	0.273	0.273	0.231	0.243	0.168	0.299
14092885	1976-1996	21	0	0	0	0	0	0	0	0	0.252	0.252	0.225	0.233	0.114	0.469
14093000	1912-2003	17	0	0	0	0	200	1	0	0	-0.243	-0.243	0.233	0.224	0.353	0.048
14093600	1966-1990	22	0	0	0	0	500	8	0	0	-0.634	0.252	0.342	0.314	0.091	0.554
14093700	1960-1979	20	0	0	0	0	0	0	5	0	0.884	0.595	0.425	0.471	-0.065	0.689
14095500	1984-2003	19	79	0	0	1	0	0	0	0	1.395	1.045	0.110	0.501	0.029	0.861
14096300	1984-2003	20	0	0	0	0	0	0	0	0	0.186	0.186	0.127	0.145	0.427	0.008
14096850	1984-2003	20	0	0	0	0	0	0	0	0	0.126	0.126	0.116	0.119	-0.069	0.672
14097100	1973-2003	31	0	0	0	0	0	0	0	0	0.145	0.145	0.145	0.145	-0.140	0.269
14097200	1970-1981	12	0	0	0	0	1,000	4	0	0	-0.955	0.462	0.183	0.240	-0.030	0.891

Appendix B. Peak-discharge statistics for gaging stations used in the regional regression analysis - continued.

Station number	Period of record	Length of record		High Peaks			Low Peaks				Skew				Trend analysis	
		System-atic	Histor-ical	Histor-ical	User thresh-old	High outlier	User thresh-old	Low outlier	Zero peaks	Below thresh-old	Station	Bulletin 17B	General-ized	Weight-ed	Kendall's tau	Signifi-cance level
14100800	1965-1979	13	0	0	0	0	0	0	0	0	0.563	0.563	0.164	0.248	-0.156	0.458
14101500	1918-1990	73	0	0	0	0	0	1	0	0	-0.226	0.061	0.137	0.091	-0.015	0.853
14104100	1965-1981	15	0	0	0	1	0	0	0	0	1.003	1.003	0.164	0.329	0.211	0.274
14104500	1947-1983	17	0	0	0	0	0	0	0	0	0.186	0.186	0.196	0.193	0.147	0.410
14107000	1945-1999	42	0	0	0	0	0	1	0	0	-0.337	0.480	0.294	0.371	0.043	0.688
14110000	1910-1979	69	0	0	0	0	0	1	0	0	-0.065	0.314	0.284	0.300	0.118	0.152
14111800	1961-1975	15	0	0	0	0	0	0	0	0	0.467	0.467	0.291	0.332	0.219	0.255
14112000	1911-1978	27	0	0	0	0	0	0	0	1	0.261	0.228	0.305	0.278	0.171	0.210
14112200	1960-1988	29	0	0	0	0	0	0	1	0	0.627	0.593	0.295	0.394	0.010	0.940
14112500	1945-1981	36	0	0	0	0	500	2	0	0	-1.292	0.140	0.298	0.231	0.072	0.539
14113000	1910-1999	74	0	0	0	0	0	0	0	0	0.194	0.194	0.286	0.233	0.007	0.926
14113200	1964-1981	18	0	0	0	0	0	1	0	0	-1.295	0.353	0.153	0.207	-0.007	0.970
14113400	1960-1971	12	0	0	0	0	0	0	0	0	0.761	0.761	0.151	0.580	0.333	0.131
14118500	1914-1999	67	0	0	0	0	0	1	0	0	-0.655	-0.080	0.160	0.022	0.092	0.272
14120000	1898-2003	44	0	0	0	0	0	1	0	0	-0.747	-0.179	0.159	0.002	-0.099	0.342
14121000	1914-1964	51	0	0	0	0	0	0	0	0	0.145	0.145	0.159	0.152	-0.082	0.393
14121300	1958-1978	21	0	0	0	0	0	0	0	0	0.058	0.058	0.206	0.159	0.257	0.103
14121500	1910-1969	12	0	0	0	0	0	0	0	0	0.089	0.089	0.196	0.173	0.121	0.583
14122000	1929-1967	13	0	0	0	0	0	0	0	0	0.309	0.309	0.202	0.226	0.128	0.542
14123000	1910-1962	26	41	0	0	1	0	0	0	0	0.807	0.689	0.197	0.385	-0.142	0.310
14123500	1916-1999	78	0	0	0	0	0	0	0	0	-0.146	-0.146	0.193	-0.009	0.077	0.316
14124500	1945-1961	17	0	0	0	0	2,000	1	0	0	-0.452	0.048	0.161	0.129	-0.281	0.115
14125000	1950-1963	14	0	0	0	0	0	0	0	0	0.641	0.641	0.161	0.265	-0.287	0.152
14125500	1957-1977	21	0	0	0	0	2,100	4	0	0	-0.281	0.402	0.159	0.230	0.205	0.193

Appendix C

Plotting Position

For this study, plotting positions for the observed peak discharges were determined following the recommendations of Cunnane (1978).

Many plotting position formulae are special cases of the general formula:

$$F_i = \frac{i - \alpha}{N + 1 - 2\alpha} \quad \text{(C-1)}$$

where

i = the rank of the peak discharge, the largest peak being number 1,

F_i = the probability associated with peak i,

N = the number of peak discharges, and

α = a constant greater than 0 and less than 1.

The value of α determines how well the calculated plotting positions fit a given theoretical distribution. For example, the Hazen formula, α equal to 0.5, gives a good approximation of the extreme value distribution. Plotting positions for the Weibell distribution, recommended by Bulletin 17B, are obtained from Equation C-1 setting α equal to 0.0.

Cunnane (1978) gives recommendations for unbiased plotting positions for a variety of theoretical probability distributions. For the Pearson Type-III distribution Cunnane recommends α be between 0.44 and 0.375. For this analysis, α has been given a value of 0.4075, the average of 0.44 and 0.375.

Reference

Cunnane, C., 1978, Unbiased plotting-positions – A review: Journal of Hydrology, v. 37, p. 205-222.

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
10329500 [a]	S	400	1060	1810	3220	4710	6670	13700
10330300 [a]	S	244	574	892	1420	1910	2500	4260
10352300	S	3.9	9.6	15.0	23.8	31.8	41.1	68.1
	R	19.5	37.4	51.8	72.0	87.6	103	141
	W	4.6	11.8	19.6	32.6	44.1	56.8	89.8
10352500 [a]	S	473	1220	1930	3070	4080	5220	8390
10353000 [a]	S	427	656	818	1030	1190	1360	1770
10353600 [a]	S	31.7	75.2	125	224	335	489	1110
10353700 [a]	S	87.0	206	321	512	689	898	1530
10353750 [a]	S	13.7	30.6	46.1	70.6	92.5	117	189
10360900 [a]	S	153	267	358	488	595	712	1020
10361700 [a]	S	16.9	55.1	102	194	293	425	893
10366000	S	2230	4970	7250	10500	13100	15900	22600
	R	1560	3330	4950	7560	9940	12700	20500
	W	2190	4750	6790	9720	12200	14900	22000
10370000	S	457	735	961	1300	1600	1940	2910
	R	360	680	960	1390	1770	2180	3330
	W	450	727	961	1330	1650	2010	3040
10371000	S	487	1270	2130	3710	5320	7390	14500
	R	947	1990	2920	4410	5770	7310	11700
	W	506	1350	2260	3870	5440	7370	13600
10371500	S	1350	2770	4030	6030	7830	9910	15900
	R	1120	2300	3360	5070	6600	8350	13400
	W	1340	2730	3960	5890	7620	9620	15500
10378500	S	453	1210	2020	3460	4890	6650	12400
	R	1040	2130	3110	4660	6060	7660	12200
	W	463	1250	2100	3590	5040	6800	12300
10384000	S	933	1690	2340	3340	4220	5230	8180
	R	853	1660	2380	3510	4500	5620	8780
	W	930	1690	2340	3360	4260	5300	8280
10390400	S	54.7	108	156	232	300	379	612
	R	64.4	105	137	185	224	265	370
	W	55.3	108	152	217	273	335	513
10392300	S	72.8	104	125	150	169	188	231
	R	61.4	103	135	180	215	252	346
	W	71.9	104	126	156	179	202	258
10392800	S	49.7	72.2	86.9	105	118	131	161
	R	78.8	119	147	185	215	247	324
	W	50.8	74.8	91.6	113	130	146	185
10393500	S	1260	2190	2860	3730	4390	5060	6610
	R	964	1670	2180	2860	3370	3890	5080
	W	1250	2170	2830	3680	4320	4970	6480

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
10393900	S	6.1	14.4	21.7	32.4	41.4	51.1	75.8
	R	13.7	26.4	36.6	51.1	62.8	75.2	106
	W	6.7	16.0	24.4	37.0	47.4	58.5	86.5
10396000	S	1360	2210	2770	3470	3980	4470	5550
	R	391	813	1180	1720	2170	2650	3890
	W	1350	2180	2730	3410	3910	4390	5470
10397000	S	89.4	175	241	329	398	469	636
	R	56.1	107	149	210	258	307	423
	W	88.7	173	236	321	387	454	614
10402800	S	226	467	667	957	1200	1450	2110
	R	160	308	427	595	732	877	1240
	W	215	427	589	812	990	1180	1660
10403000	S	592	1040	1360	1770	2090	2400	3130
	R	489	867	1160	1560	1880	2210	3040
	W	587	1020	1340	1740	2050	2370	3110
10403500	S	569	865	1070	1320	1510	1700	2140
	R	525	945	1270	1720	2090	2460	3410
	W	565	874	1100	1400	1630	1870	2460
10406500	S	111	186	241	317	378	441	601
	R	246	527	767	1120	1410	1720	2530
	W	113	193	257	350	426	507	710
11339995	S	141	364	603	1040	1490	2060	3990
	R	161	284	388	543	675	818	1200
	W	143	346	532	818	1080	1380	2350
11340500 [b]	S	238	303	344	392	426	458	531
	R	210	375	514	723	899	1090	1610
	W	233	323	403	529	633	740	988
11340950	S	255	413	530	690	818	952	1290
	R	197	351	480	673	837	1020	1490
	W	247	397	513	683	826	982	1390
11341000	S	183	341	466	644	791	948	1360
	R	201	358	490	688	855	1040	1520
	W	185	343	471	656	810	977	1410
11341050	S	200	378	525	745	932	1140	1710
	R	261	474	651	914	1140	1380	2020
	W	209	403	572	824	1040	1270	1880
11341100	S	51.0	77.9	97.3	123	144	165	218
	R	57.5	94.3	124	165	199	234	323
	W	51.4	80.0	102	133	159	185	248
11341200	S	91.8	145	184	236	277	320	427
	R	86.6	147	198	272	334	400	572
	W	91.4	145	187	246	295	346	475

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
11342945 [a]	S	58.9	84.2	102	125	144	162	209
11342960 [a]	S	71.1	92.8	107	123	135	147	174
11348080 [a]	S	110	146	169	196	217	236	281
11348560 [a]	S	20.6	32.0	40.6	52.6	62.3	72.7	99.8
11484000	S	2300	3410	4200	5270	6110	6990	9210
	R	707	1320	1830	2600	3260	3980	5960
	W	1870	2500	2930	3620	4260	5010	7090
11489350 [a]	S	42.0	89.6	138	223	309	419	796
11489500 [a]	S	232	460	677	1040	1400	1830	3240
11491800	S	15.2	26.4	34.3	44.5	52.1	59.7	77
	R	21.3	31.1	38.4	48.2	55.6	63.1	80.8
	W	15.5	26.9	35.0	45.4	53.1	60.7	78.2
11494800	S	27.1	34.9	40.4	48.0	54.0	60.3	76.6
	R	41.8	69.7	92.4	126	153	183	257
	W	27.9	38.4	48	62.6	74.5	86.6	115
11497500	S	1280	2400	3340	4740	5940	7260	10900
	R	1250	2430	3450	5040	6420	7980	12300
	W	1270	2410	3360	4800	6040	7430	11200
11497800	S	62.1	98.8	127	165	197	230	319
	R	40.6	67.3	89.1	121	147	176	247
	W	60.6	94.3	119	153	182	213	295
11501000	S	2060	4040	5780	8510	11000	13800	21900
	R	2280	4540	6540	9670	12400	15500	24500
	W	2070	4080	5860	8680	11200	14100	22400
11501300	S	23.1	37.8	49.6	66.9	81.7	98.2	144
	R	35.0	52.6	66.0	84.1	98.0	112	146
	W	23.7	39.4	52.3	70.9	86.1	102	145
11502500	S	2910	5080	6900	9660	12100	14900	22800
	R	2760	5470	7880	11600	14900	18700	29400
	W	2900	5110	7000	9940	12500	15500	23900
11504000	S	370	434	475	525	561	597	679
	R	377	551	670	822	938	1060	1350
	W	370	439	486	546	591	634	734
11505550	S	84.7	127	153	184	206	226	270
	R	55.0	83.7	103	129	148	167	215
	W	82.8	121	145	173	193	212	256
11516900 [a]	S	178	377	578	940	1310	1780	3420
13172666 [a]	S	5.3	9.0	11.5	14.6	16.9	19.1	24
13172668 [a]	S	4.3	6.6	8.1	9.9	11.1	12.2	14.5
13172680 [a]	S	176	279	345	424	479	531	642
13172720 [a]	S	87.6	218	336	512	661	821	1230
13172735 [a]	S	66.6	192	316	514	688	882	1400

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
13172740 [a]	S	341	914	1450	2270	2980	3750	5750
13172800 [a]	S	10.6	33.2	56.8	96.4	133	174	289
13172900	S	743	1870	2920	4560	6010	7620	12000
	R	252	544	792	1160	1460	1780	2630
	W	685	1620	2350	3360	4180	5070	7510
13178000 [a]	S	1960	2950	3630	4480	5120	5760	7250
13182100	S	25.0	36.2	43.0	50.7	55.8	60.6	70.4
	R	15.8	32.1	45.2	63.2	77.2	91.7	127
	W	24.7	36.0	43.1	51.8	58.1	64.1	77
13207000 [a]	S	68.3	197	334	578	816	1100	2000
13207500 [a]	S	173	335	460	634	771	914	1260
13213800	S	357	857	1300	1960	2510	3110	4660
	R	437	711	912	1180	1380	1590	2100
	W	362	840	1230	1770	2190	2640	3750
13213900	S	32.1	51.5	65.2	82.9	96.4	110	143
	R	40.0	67.0	86.6	112	132	152	203
	W	32.9	53.9	69.7	90.9	107	124	164
13214000	S	2070	3940	5410	7500	9190	11000	15500
	R	3840	6090	7750	9950	11600	13400	17600
	W	2090	4000	5520	7660	9390	11200	15700
13216500	S	938	1650	2160	2850	3370	3910	5170
	R	1780	2860	3640	4680	5490	6310	8330
	W	952	1690	2230	2970	3540	4110	5480
13226500	S	1830	4670	7280	11300	14800	18500	28400
	R	2490	3980	5070	6520	7630	8770	11600
	W	1860	4590	6910	10200	12700	15500	22400
13228000 [b]	S	6970	13200	18500	26600	33600	41600	63900
	R	11100	17500	22100	28300	33100	38100	50000
	W	7520	14200	19700	27300	33400	39800	56200
13228300	S	97.2	182	253	364	460	570	884
	R	89.6	149	192	248	291	336	446
	W	95.7	171	227	304	364	428	597
13229400	S	16.8	28.5	36.9	47.8	56	64.2	83.6
	R	34.7	58.1	75.2	97.5	115	132	176
	W	19.2	35.3	48.6	66.9	80.8	94.9	128
13248900 [a]	S	75.6	141	193	265	322	383	537
13250600 [a]	S	973	1510	1890	2380	2750	3130	4050
13250650 [a]	S	132	270	388	566	717	885	1340
13251300 [a]	S	38.7	58.4	72.8	92.5	108	125	167
13251500 [a]	S	483	719	886	1110	1280	1460	1900
13252500 [a]	S	54.1	64.6	71.8	80.9	87.9	95.1	113
13253500 [a]	S	1000	1570	2000	2590	3070	3580	4900

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
13260000 [a]	S	252	419	567	804	1030	1290	2130
13261000 [a]	S	741	1110	1380	1750	2040	2350	3140
13267000 [a]	S	430	680	873	1150	1380	1620	2290
13267100 [a]	S	66.2	105	135	178	213	251	351
13269200	S	18.8	38.9	56.3	82.7	106	131	202
	R	20.0	33.8	43.8	56.8	66.8	77.1	103
	W	19.1	37.1	50.7	68.5	82.4	96.9	134
13269300	S	649	995	1180	1370	1480	1570	1720
	R	760	1230	1570	2030	2370	2730	3610
	W	654	1010	1230	1470	1630	1780	2070
13272300	S	12.9	25.0	35.2	50.2	63.1	77.3	116
	R	12.4	21.1	27.4	35.6	41.9	48.4	64.5
	W	12.9	24.4	33.5	46	56.1	66.8	95
13274600	S	18.5	49.5	81.8	138	192	258	462
	R	35.9	60.2	77.9	101	119	137	182
	W	21.8	53.4	79.9	116	144	173	250
13275105	S	527	826	1020	1270	1450	1620	2010
	R	663	1070	1370	1770	2080	2390	3160
	W	532	844	1060	1340	1550	1750	2220
13275200	S	276	482	636	846	1010	1180	1610
	R	309	505	648	836	981	1130	1500
	W	277	483	637	845	1010	1180	1590
13275500	S	725	1050	1250	1480	1640	1790	2120
	R	1260	2030	2590	3330	3900	4490	5920
	W	733	1070	1290	1560	1760	1950	2350
13281200	S	332	507	624	771	879	986	1230
	R	220	361	463	598	702	809	1070
	W	328	498	610	751	856	961	1210
13282400	S	248	336	393	462	512	560	670
	R	290	474	608	785	922	1060	1410
	W	249	345	411	498	563	627	776
13283600	S	304	500	646	845	1000	1170	1590
	R	289	472	606	783	918	1060	1400
	W	304	499	642	838	992	1150	1560
13285900	S	204	355	468	625	750	880	1210
	R	265	433	556	718	843	971	1290
	W	207	362	480	641	769	900	1230
13286300	S	55.8	115	165	242	307	381	581
	R	20.7	35.0	45.4	58.9	69.3	79.9	106
	W	46.9	81.9	103	128	148	170	228

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
13287200	S	592	922	1170	1520	1810	2120	2940
	R	173	285	367	474	557	642	851
	W	573	870	1080	1360	1590	1830	2480
13288200	S	2020	2690	3150	3750	4200	4660	5800
	R	987	1590	2030	2620	3070	3530	4670
	W	2000	2660	3100	3680	4120	4570	5700
13289100	S	91.8	130	160	202	238	278	387
	R	89.4	148	191	247	291	335	445
	W	91.5	133	166	214	253	295	407
13289600 [a]	S	87	165	232	338	432	540	857
13289960 [a]	S	885	1590	2180	3070	3850	4720	7220
13290150	S	67.6	134	194	289	376	477	781
	R	48.9	81.6	105	137	161	185	246
	W	65.9	125	172	240	296	358	531
13290190	S	2550	4130	5330	7020	8390	9850	13700
	R	1610	2570	3280	4220	4950	5690	7510
	W	2520	4030	5150	6670	7890	9190	12600
13291200	S	70.6	102	125	155	179	204	267
	R	63.5	106	137	177	208	240	318
	W	70	103	127	160	186	214	283
13291400	S	5.2	9.8	13.8	20	25.5	31.7	50.1
	R	33.3	55.8	72.2	93.7	110	127	169
	W	7.6	17.2	27.4	43.1	56.1	69.6	104
13292000	S	2630	4220	5530	7530	9280	11300	17100
	R	2800	4460	5680	7300	8550	9820	13000
	W	2630	4220	5540	7510	9230	11200	16800
13315500 [a]	S	199	280	334	404	456	508	633
13316500 [a]	S	4860	6650	7840	9340	10500	11600	14200
13316800 [a]	S	136	218	283	378	460	551	807
13317200 [a]	S	95.7	207	313	490	657	859	1490
13318100	S	13.2	21	27.2	36.1	43.6	51.8	74.5
	R	33.7	56.5	73.1	94.8	111	129	171
	W	14.1	23.9	32.5	45.4	56.2	67.6	97.2
13318500	S	2190	3010	3590	4360	4950	5570	7130
	R	2360	3770	4790	6160	7220	8300	10900
	W	2190	3080	3740	4640	5360	6110	7940
13318800	S	2340	3200	3790	4560	5150	5750	7230
	R	2530	4040	5140	6610	7740	8890	11700
	W	2360	3290	3990	4950	5700	6480	8360
13319000	S	3230	4870	6080	7770	9130	10600	14400
	R	3010	4800	6110	7850	9190	10600	13900
	W	3230	4870	6090	7770	9130	10600	14300

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
13320000	S	751	1010	1170	1360	1500	1630	1930
	R	721	1170	1490	1920	2260	2600	3430
	W	750	1010	1180	1380	1530	1670	2000
13320400	S	115	182	227	284	326	368	463
	R	175	289	371	480	563	649	860
	W	117	187	238	304	353	403	517
13321300	S	95.2	140	171	210	240	270	340
	R	175	288	371	479	562	648	859
	W	101	158	204	269	319	369	488
13322300	S	36.2	47.1	54.4	63.8	71	78.3	96
	R	26.8	45.1	58.4	75.8	89.2	103	137
	W	35.7	46.9	54.9	65.6	74	82.7	104
13323500	S	3340	4530	5310	6280	6990	7700	9350
	R	4740	7520	9550	12300	14300	16500	21700
	W	3380	4700	5640	6900	7860	8820	11000
13323600	S	422	588	700	845	955	1070	1340
	R	221	362	465	601	705	812	1080
	W	406	559	660	791	893	999	1260
13323700	S	165	391	616	998	1360	1810	3190
	R	171	282	362	468	549	633	839
	W	165	378	570	862	1120	1400	2240
13324150	S	22.9	39.5	51.4	67.1	78.9	90.9	119
	R	22.4	37.8	49	63.6	74.8	86.3	115
	W	22.9	39.2	50.9	66	77.5	89.2	117
13324300	S	753	1010	1190	1440	1640	1850	2380
	R	579	940	1200	1550	1820	2100	2770
	W	747	1010	1190	1450	1660	1880	2440
13325000	S	103	152	188	238	279	322	437
	R	126	208	267	346	406	468	621
	W	103	153	189	241	282	327	443
13325500	S	822	1180	1430	1760	2020	2280	2920
	R	378	616	790	1020	1200	1380	1820
	W	805	1140	1370	1670	1900	2140	2730
13329500	S	537	734	863	1020	1140	1260	1530
	R	281	460	591	763	895	1030	1370
	W	535	730	857	1020	1130	1250	1530
13329700	S	8.3	13.5	17.4	22.8	27.2	31.9	44.1
	R	7.4	12.7	16.5	21.5	25.3	29.2	39
	W	8.2	13.2	17	22.2	26.3	30.5	41.3
13329750	S	28	58.3	85.5	129	168	213	345
	R	64.9	108	139	180	212	245	325
	W	33.5	71.8	106	153	191	231	332

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
13330000	S	1560	1930	2150	2420	2600	2780	3180
	R	547	889	1140	1470	1720	1980	2620
	W	1560	1910	2130	2390	2570	2750	3160
13330500	S	929	1240	1440	1700	1890	2090	2540
	R	521	847	1080	1400	1640	1890	2500
	W	925	1230	1430	1690	1880	2080	2540
13331500	S	3120	4080	4700	5470	6040	6600	7900
	R	1360	2190	2790	3590	4210	4840	6390
	W	3080	4010	4610	5350	5900	6450	7770
13332500	S	9640	13600	16400	20100	22900	25800	33000
	R	8230	12900	16400	21000	24600	28300	37200
	W	9620	13600	16400	20100	23000	26000	33300
13333000	S	14700	22000	27400	34700	40700	47000	63500
	R	9890	15500	19700	25200	29500	33900	44500
	W	14700	21800	27000	34100	39800	45900	61700
13333050	S	11.7	20.3	27.7	39	49.1	60.7	94.7
	R	12.8	21.7	28.2	36.6	43.1	49.8	66.3
	W	11.8	20.5	27.8	38.4	47.3	57.1	84.2
13333100	S	39.3	70.5	97.2	139	176	218	343
	R	79.8	133	171	221	260	300	398
	W	43	80.8	114	164	206	250	367
13334700 [a]	S	398	909	1470	2550	3710	5280	11300
13335050 [a]	S	801	2100	3630	6700	10100	14800	33400
13341100 [a]	S	49.3	109	160	235	298	366	540
13342450 [a]	S	817	1740	2630	4150	5620	7420	13200
14010000	S	777	1190	1520	2010	2440	2920	4310
	R	883	1310	1630	2080	2430	2790	3680
	W	778	1190	1520	2020	2440	2910	4240
14010800	S	465	739	956	1270	1540	1840	2670
	R	594	926	1180	1540	1820	2110	2840
	W	470	757	994	1340	1620	1920	2720
14011000	S	482	806	1080	1520	1920	2390	3800
	R	606	957	1240	1650	1980	2330	3230
	W	485	816	1100	1550	1930	2370	3660
14011800	S	365	613	821	1140	1420	1740	2670
	R	237	453	642	931	1180	1450	2210
	W	348	568	747	1030	1280	1570	2410
14013000 [a]	S	868	1520	2090	3030	3890	4930	8180
14013500 [a]	S	320	526	699	966	1200	1480	2280
14015900 [a]	S	22.5	75.8	145	294	467	710	1680
14016000 [a]	S	549	1140	1660	2420	3080	3810	5770

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14016080	S	30.7	93.8	169	317	476	688	1450
	R	21.5	58.8	97.5	164	228	305	547
	W	28.6	77.9	126	208	290	394	745
14016200	S	669	1450	2040	2790	3350	3880	5030
	R	178	345	491	716	909	1120	1720
	W	615	1150	1400	1710	1990	2320	3240
14016500 [a]	S	815	1300	1670	2220	2680	3180	4570
14016600 [a]	S	79.6	179	258	364	445	525	706
14016650 [a]	S	9.1	47.1	116	311	600	1090	3810
14017000 [a]	S	2570	4220	5510	7370	8930	10600	15200
14017040 [a]	S	37.1	107	174	277	363	456	690
14017070 [a]	S	55.1	190	381	827	1390	2260	6230
14017200 [a]	S	50.5	179	372	854	1500	2550	7910
14017500 [a]	S	3660	6580	9130	13100	16800	21000	33800
14018500 [a]	S	5990	11200	15800	23200	30000	37900	62300
14019400	S	57	76	89.6	108	123	138	178
	R	18.1	36	51.5	75.4	96	119	183
	W	52.1	65.7	75.7	93.4	110	129	180
14020000	S	2000	3030	3830	4980	5950	7010	9920
	R	1370	2170	2810	3710	4420	5170	7080
	W	1990	3000	3750	4840	5740	6750	9520
14020300	S	2300	3710	4800	6380	7690	9120	13000
	R	1600	2740	3660	4980	6050	7180	10100
	W	2260	3590	4580	5990	7170	8480	12100
14020740	S	68.2	96.7	117	144	166	188	246
	R	54.8	102	143	208	264	326	497
	W	66.1	98.2	129	179	221	267	382
14020800	S	57.2	96.1	127	174	213	258	381
	R	42.6	79.6	116	176	230	292	474
	W	55.9	92.6	124	175	221	273	420
14020900	S	377	566	712	921	1100	1290	1820
	R	165	327	475	708	913	1140	1800
	W	344	489	606	805	990	1200	1800
14021000	S	5270	8580	11200	14900	18100	21500	30800
	R	3790	6950	9600	13500	16700	20100	29400
	W	5230	8480	11000	14700	17800	21200	30600
14021980	S	130	268	399	619	831	1090	1910
	R	142	303	472	769	1050	1380	2420
	W	133	284	443	723	989	1310	2280
14022200	S	657	1010	1280	1650	1950	2270	3120
	R	489	893	1220	1670	2030	2410	3400
	W	649	997	1260	1650	1970	2310	3200

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14022500	S	1370	2450	3380	4820	6100	7580	11900
	R	1010	1920	2710	3890	4880	5960	8920
	W	1360	2420	3310	4680	5880	7270	11400
14025000	S	564	1040	1430	2020	2520	3090	4660
	R	866	1780	2650	4060	5300	6710	10800
	W	573	1090	1570	2360	3050	3800	5810
14026000 [b]	S	6360	10100	12900	17100	20500	24300	34400
	R	4770	9040	12800	18500	23300	28600	43300
	W	6240	9880	12900	17600	21600	26100	37900
14032000	S	329	709	1110	1860	2640	3680	7540
	R	727	1570	2410	3760	4970	6360	10500
	W	338	760	1240	2150	3070	4220	8170
14034250 [a]	S	7.4	15.7	23.8	37.8	51.5	68.5	125
14034325 [a]	S	204	448	698	1150	1610	2190	4230
14034370	S	8.1	15.6	22.1	32.3	41.4	51.9	82.4
	R	20.3	40.6	57.3	81.5	101	123	180
	W	8.6	18	27.7	43.7	57.2	71.8	110
14034470	S	166	299	412	584	736	909	1410
	R	279	560	824	1240	1600	2000	3140
	W	174	340	512	800	1050	1320	2050
14034480	S	22.3	96.3	218	544	1000	1770	5830
	R	82.5	195	314	519	711	940	1650
	W	26	116	252	531	835	1250	2930
14034500 [b]	S	200	473	795	1460	2240	3350	8120
	R	331	690	1040	1590	2070	2630	4230
	W	204	495	837	1500	2190	3100	6610
14034800	S	272	521	746	1110	1440	1830	3030
	R	293	632	967	1510	1990	2540	4150
	W	273	534	787	1210	1600	2050	3360
14036000	S	1080	4520	9170	18900	29700	44100	94900
	R	1690	4280	7020	11700	16100	21400	37900
	W	1150	4440	8070	14300	20300	27700	53000
14036800	S	72.7	115	144	180	207	233	294
	R	195	255	293	340	375	409	489
	W	76.1	122	154	196	227	257	326
14037500	S	94.7	147	185	234	272	311	407
	R	79.8	106	121	141	155	169	200
	W	94.6	147	183	231	267	305	395
14038500	S	609	985	1270	1670	2000	2360	3280
	R	884	1270	1520	1840	2070	2290	2810
	W	616	997	1290	1690	2010	2350	3210

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14038530	S	1340	2550	3540	4950	6120	7390	10700
	R	1310	1950	2390	2950	3370	3790	4790
	W	1340	2520	3430	4680	5680	6730	9370
14038550	S	176	241	275	310	332	350	384
	R	80.4	129	163	206	238	270	342
	W	170	231	262	295	316	336	376
14038600	S	18	27.8	34.7	43.8	50.8	57.9	75.3
	R	16.3	30.2	41.3	57.3	70.4	84.5	121
	W	17.8	28.1	35.9	46.7	55.5	64.8	88
14038602	S	287	468	596	763	890	1020	1320
	R	217	365	470	608	712	817	1060
	W	283	459	582	740	859	980	1270
14038750	S	11.8	18.7	23.6	30	35	40.1	52.5
	R	8.7	14.8	19.5	26.1	31.5	37.1	51.7
	W	11.5	18.1	22.7	29	34	39.2	52.2
14038900	S	67.1	124	168	230	279	331	464
	R	82.3	148	201	278	342	412	600
	W	68.3	127	173	239	293	351	499
14039200	S	54.4	75.9	88.7	103	113	123	142
	R	30.1	52	68.1	89.6	106	123	163
	W	52.6	73.4	85.9	101	112	123	147
14040500	S	2760	4630	6040	7960	9480	11100	15100
	R	2970	4790	6140	7960	9390	10900	14500
	W	2760	4640	6040	7960	9470	11100	15000
14040600	S	144	250	335	457	560	673	978
	R	249	369	457	578	674	775	1030
	W	147	255	342	467	571	684	985
14040700	S	33.5	74.7	114	177	237	307	518
	R	47.8	86.4	117	161	199	240	352
	W	34.9	76.6	114	173	224	282	448
14040900	S	33.9	44.1	50.8	59.3	65.7	72.1	87.3
	R	49.9	73.6	90.5	113	131	150	196
	W	34.8	46.5	55.1	66.8	76	85.4	108
14041000	S	699	911	1040	1210	1320	1440	1690
	R	869	1220	1460	1780	2020	2270	2880
	W	710	939	1100	1300	1450	1600	1960
14041500	S	3060	4490	5440	6630	7500	8360	10300
	R	2720	3770	4470	5390	6090	6800	8510
	W	3050	4460	5380	6530	7370	8200	10100
14041900	S	28.3	45.8	59.4	78.9	95.1	113	160
	R	23.9	37.8	48.2	62.6	74	86.2	117
	W	27.9	44.7	57.3	74.9	89.1	104	145

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14042000	S	638	1010	1310	1740	2100	2510	3630
	R	449	686	864	1110	1310	1510	2050
	W	620	965	1220	1580	1870	2190	3060
14042500	S	1040	1600	2030	2630	3140	3680	5150
	R	721	1080	1340	1690	1970	2260	3010
	W	1030	1580	1990	2560	3030	3540	4890
14043800	S	40	59	71.9	88.3	101	113	142
	R	55.4	82.1	101	125	143	162	208
	W	40.8	60.9	75.1	93.7	108	122	157
14043850	S	47.8	68.1	81.6	98.8	112	124	155
	R	23.2	37.6	48.3	62.8	74.4	86.4	116
	W	45	63	74.5	89.2	101	112	141
14043900	S	20.5	38.4	53.4	76.2	96	118	180
	R	14.6	32.6	48.7	73.8	96.1	121	193
	W	19.4	36.9	52	75.3	96	120	186
14044000	S	1720	2570	3160	3910	4470	5040	6380
	R	1690	2570	3180	3980	4590	5210	6680
	W	1720	2570	3160	3910	4480	5050	6400
14044100	S	13.3	39.2	64.4	104	139	176	273
	R	19.5	38.8	55.1	79.7	101	124	188
	W	14.6	39	60.2	90.9	116	144	217
14044500	S	412	797	1140	1680	2160	2730	4410
	R	355	543	685	881	1040	1200	1620
	W	409	775	1080	1540	1940	2380	3640
14046000	S	9130	14400	18500	24200	29000	34100	47700
	R	7560	11600	14500	18500	21700	25000	33200
	W	9100	14300	18300	23900	28400	33300	46300
14046250	S	24.6	47.8	66.3	92.6	114	137	194
	R	9.1	17.1	23.9	34.1	42.7	52.3	78.4
	W	20.9	37.4	48.8	64.2	76.8	90.4	127
14046300	S	4	6.7	9	12.4	15.4	18.7	28.1
	R	9.3	16.6	22.6	31.2	38.3	45.9	65.7
	W	4.6	8.4	11.9	17.5	22.3	27.6	42
14046500	S	12200	19400	24700	31800	37400	43300	58000
	R	10700	16900	21400	27600	32600	37700	50800
	W	12200	19300	24500	31500	37000	42800	57200
14047100	S	6.3	12.6	18.3	27.5	36	45.9	75.8
	R	18	31.3	42	57.5	70.3	84	120
	W	7	14.3	21.3	32.6	42.8	54.4	87.6
14047350	S	55.6	87.6	112	145	171	200	273
	R	28	64	100	160	213	275	460
	W	51.4	80.7	107	152	192	238	362

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14047380	S	312	522	694	951	1170	1420	2130
	R	187	431	672	1060	1400	1800	2950
	W	302	507	688	986	1250	1560	2420
14047390	S	879	1720	2490	3740	4910	6300	10600
	R	492	1100	1720	2750	3690	4770	8020
	W	805	1480	2090	3140	4120	5300	8940
14048000	S	12400	19500	24600	31500	37000	42700	57000
	R	12600	20200	26000	34200	40800	47800	65800
	W	12500	19500	24700	31700	37200	43100	57700
14048040	S	162	447	727	1180	1590	2050	3320
	R	63.4	195	348	635	928	1300	2550
	W	134	318	485	791	1100	1490	2770
14048300	S	83.7	184	284	460	632	847	1560
	R	66.2	199	352	636	925	1290	2510
	W	79	191	323	577	834	1160	2220
14048310	S	64.4	179	295	489	667	874	1470
	R	54.6	164	289	523	761	1060	2070
	W	60.7	170	291	516	743	1030	1950
14050000	S	245	345	408	483	537	587	699
	R	543	768	916	1100	1250	1400	1760
	W	246	350	416	496	553	607	726
14050500	S	88.5	114	130	148	161	173	200
	R	38.2	60.1	75.4	95	110	125	161
	W	87.6	112	127	145	158	170	198
14051000	S	106	173	220	283	331	380	498
	R	103	157	194	241	277	314	402
	W	106	172	219	281	328	376	492
14052000	S	48.7	76.9	96.5	122	141	161	208
	R	53.3	83.6	105	133	154	175	228
	W	48.8	77	96.8	123	142	162	209
14053000	S	18.9	32.5	42.2	54.7	64.1	73.5	95.1
	R	37.7	58.9	73.7	92.5	107	121	156
	W	19.1	33.2	43.3	56.5	66.4	76.2	98.8
14054500	S	51.5	66.1	74.9	85.4	92.8	99.9	115
	R	46.3	72.1	89.9	113	130	147	189
	W	51.5	66.2	75.5	86.7	94.7	102	119
14055500	S	238	340	414	515	595	681	904
	R	176	262	321	396	454	513	658
	W	237	337	408	505	583	666	879
14055600	S	300	399	466	554	621	689	856
	R	226	335	410	505	579	654	838
	W	298	395	462	549	616	685	854

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14061000	S	276	398	481	590	674	759	967
	R	237	355	437	542	622	705	909
	W	276	396	478	586	669	753	961
14073000	S	474	641	753	894	1000	1110	1360
	R	272	399	486	597	682	770	986
	W	470	632	739	874	976	1080	1330
14075000	S	562	905	1180	1600	1950	2360	3490
	R	477	690	836	1020	1170	1320	1690
	W	561	902	1180	1580	1930	2310	3410
14077500	S	612	781	885	1010	1090	1180	1360
	R	557	915	1190	1570	1880	2210	3070
	W	607	799	935	1120	1270	1420	1790
14077800	S	63.7	97.2	123	160	190	224	314
	R	30.9	47.2	59.7	77.2	91.6	107	148
	W	61.4	91.7	114	144	169	196	269
14078000	S	1400	2590	3560	4970	6170	7480	11000
	R	1890	3320	4410	5940	7170	8480	11800
	W	1420	2620	3610	5060	6280	7600	11100
14078200	S	18.4	64.1	120	227	340	484	966
	R	44.5	100	150	225	291	364	561
	W	21	70.9	128	227	320	429	753
14078400	S	48.4	70.6	85.8	105	120	135	170
	R	50	77.4	97.1	123	144	165	217
	W	48.6	71.8	88.3	110	128	145	188
14078500	S	1390	1760	2000	2300	2520	2740	3260
	R	1000	1470	1810	2270	2630	3000	3940
	W	1350	1710	1960	2290	2550	2820	3490
14079500	S	4040	6700	8670	11300	13400	15600	21100
	R	4630	8410	11300	15500	18800	22400	31400
	W	4080	6870	9010	12000	14400	17000	23500
14079800	S	4150	8050	11300	16300	20500	25100	37900
	R	4690	8480	11400	15600	18900	22500	31500
	W	4220	8140	11400	16000	19900	24000	34900
14080500 [b]	S	3530	5350	6620	8280	9550	10800	14000
	R	4800	8800	11900	16400	19900	23700	33400
	W	3620	5680	7280	9550	11400	13300	18100
14080600	S	192	311	401	526	627	734	1010
	R	127	252	358	519	658	815	1250
	W	177	293	385	523	641	773	1140
14081800	S	37.3	51.9	62.7	77.7	89.9	103	138
	R	37.6	55.4	68.5	86.4	101	116	156
	W	37.3	52.1	63.2	78.7	91.4	105	141

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14083000	S	353	534	668	853	1000	1160	1570
	R	443	720	924	1200	1410	1640	2170
	W	361	561	717	937	1110	1300	1770
14083500	S	149	235	301	395	473	557	782
	R	112	189	246	324	384	445	594
	W	144	226	287	372	440	512	698
14088000	S	159	244	309	402	479	564	792
	R	143	231	297	384	452	523	701
	W	159	244	309	401	478	562	787
14090350	S	363	520	635	793	920	1050	1410
	R	619	953	1200	1530	1790	2070	2790
	W	374	556	700	901	1060	1230	1650
14090400	S	414	638	806	1040	1230	1440	1990
	R	728	1130	1430	1830	2160	2500	3400
	W	426	674	871	1150	1370	1610	2220
14091500	S	2590	3590	4350	5420	6310	7280	9900
	R	3410	5020	6160	7670	8860	10100	13400
	W	2610	3630	4420	5540	6460	7460	10100
14092750	S	652	1120	1510	2100	2620	3200	4870
	R	453	713	907	1170	1380	1600	2170
	W	637	1060	1380	1850	2250	2690	3940
14092885	S	661	1290	1870	2820	3690	4730	7940
	R	847	1370	1770	2310	2750	3210	4400
	W	677	1310	1850	2660	3350	4150	6440
14093000	S	568	861	1080	1390	1640	1910	2630
	R	1170	1930	2500	3300	3940	4630	6400
	W	643	1090	1480	2040	2490	2960	4140
14093600	S	598	1190	1750	2690	3590	4680	8190
	R	320	689	1040	1600	2090	2630	4210
	W	565	1060	1470	2140	2770	3530	5930
14093700	S	2.5	11.3	27.1	73	143	270	1040
	R	8.3	22.6	39	69.9	101	140	271
	W	3.3	15.5	33.5	70.9	112	168	397
14095500	S	394	711	1000	1480	1930	2490	4250
	R	629	995	1260	1620	1900	2190	2930
	W	411	754	1060	1520	1920	2380	3740
14096300	S	353	607	813	1120	1380	1670	2470
	R	338	532	675	867	1020	1180	1580
	W	352	598	789	1060	1280	1530	2200
14096850	S	587	1550	2600	4580	6620	9270	18500
	R	929	1520	1960	2570	3060	3570	4880
	W	627	1540	2370	3640	4760	6060	10000

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14097100	S	2400	5250	8000	12700	17200	22600	39900
	R	2820	4320	5390	6810	7940	9120	12100
	W	2420	5110	7440	11000	14100	17700	28600
14097200	S	1650	2340	2830	3500	4030	4590	6010
	R	974	1550	1990	2590	3070	3590	4930
	W	1560	2170	2600	3190	3690	4210	5600
14100800	S	103	259	431	757	1100	1550	3180
	R	259	450	604	824	1000	1200	1700
	W	117	296	479	781	1060	1390	2430
14101500	S	2940	5110	6860	9420	11600	14000	20600
	R	4240	6740	8610	11200	13300	15500	21200
	W	2970	5190	6980	9590	11800	14200	20700
14104100	S	54.4	111	165	258	348	459	822
	R	85.2	130	172	240	300	365	545
	W	55.4	113	166	253	334	429	731
14104500	S	1610	2710	3600	4920	6050	7310	10800
	R	1170	2520	3930	6460	8910	11900	21300
	W	1560	2660	3720	5600	7390	9460	15400
14107000 [a]	S	1880	2640	3210	3990	4620	5290	7060
14110000 [a]	S	3170	4520	5510	6880	7970	9140	12200
14111800 [a]	S	110	231	349	555	757	1010	1850
14112000 [a]	S	1010	2050	3030	4670	6240	8150	14300
14112200 [a]	S	25.5	58.8	94.6	162	232	325	662
14112500 [a]	S	3190	6240	9020	13500	17700	22700	38000
14113000 [a]	S	7860	14700	20700	30100	38700	48800	78800
14113200	S	668	1600	2580	4350	6160	8460	16400
	R	1000	1970	2900	4480	5970	7730	13000
	W	686	1660	2660	4400	6080	8160	15000
14113400	S	35	54.6	70.7	95.5	117	143	217
	R	49.1	81	105	138	163	190	256
	W	36	57.8	76.6	105	128	155	228
14118500	S	6520	9430	11500	14100	16100	18200	23300
	R	3810	6300	8280	11100	13400	16000	22800
	W	6470	9330	11300	13900	16000	18100	23300
14120000	S	10300	16100	20300	26000	30500	35200	47000
	R	6930	10800	13700	17800	21100	24700	34200
	W	10200	15800	19800	25100	29400	33900	45400
14121000	S	9620	15600	20200	26800	32300	38300	54400
	R	7920	12500	16000	20900	24900	29300	40800
	W	9580	15400	19900	26300	31600	37400	52900
14121300 [a]	S	693	967	1160	1410	1610	1810	2310
14121500 [a]	S	1570	2190	2620	3200	3640	4100	5240

Appendix D. Estimated peak discharges for gaged watersheds in Eastern Oregon and surrounding states used in the regional regression analysis - continued.

Estimate types: (S) systematic and historical record, (R) regionalized regression equations, and (W) weighted average of S and R.

Station number	Estimate type	Peak discharges in cubic feet per second for the indicated recurrence interval						
		2	5	10	25	50	100	500
14122000 [a]	S	1960	2790	3390	4200	4840	5510	7230
14123000 [a]	S	2790	4150	5200	6690	7940	9300	13000
14123500 [a]	S	4620	6950	8600	10800	12500	14200	18500
14124500 [a]	S	2790	3360	3720	4150	4460	4760	5440
14125000 [a]	S	2520	3170	3600	4140	4550	4960	5950
14125500 [a]	S	3250	5280	6890	9240	11200	13400	19500

[a] Station is located outside the State of Oregon.

[b] Stream flow at this station site is now regulated.

Appendix E

Test for Random Peak

A usual test for randomness is to check each series of annual peaks for a statistically significant linear correlation, i.e., a trend (Thomas et al., 1994; Wiley et al., 2000). A significant trend suggests that systematic, non-random changes in peak discharge characteristics are occurring in time. A trend test is not definitive; it is cause for investigation, not necessarily for the elimination of a gaging station from the analysis.

All 276 gaging stations were tested for linear correlation. The resulting information was analyzed in two ways: 1) to check for regional, climate dependent trends, and 2) to check for local trends resulting from significant physical changes to a watershed. Local changes include human caused changes due to land use or water management as well as natural changes such as a volcanic eruption. Local trends that can be attributed to physical changes in the watershed may require all or part of a gaging station's period of record to be removed from consideration.

Almost all gaging station records exhibit some degree of linear correlation. Most of these trends result from natural random variation in peak flows, not from either long-term climate change or physical changes to the watershed. A statistical test determines which of the trends is significant, that is, the least likely to have occurred by chance. These unlikely trends represent the gaging station records to be investigated.

A significant trend does not necessarily mean a series of peaks is non-random. For any group of gaging stations, a few of the annual series will have significant trends by chance. The level of significance of the statistical test determines how many of these significant but chance trends are to be expected. For example, for a 0.05 level of significance, about five percent of stations should show a significant trend.

Although all significant trends should be investigated for physical changes to the gaging station's watersheds, regional trends require that a greater number of significant trends occur than are expected by chance.

In the regional analysis, no consistent long-term trend was found, although there is evidence of a regional fluctuation of peak discharges between wet and dry periods. This fluctuation led to a higher than expected number of significant trends in long-term gaging station records. The evidence is too weak, however, to support a strong conclusion as to whether the fluctuations are truly periodic or what the period might be. Locally, no significant trend could be linked to physical changes in the associated watershed[1].

The Statistical Test - Kendall's tau, a nonparametric measure of linear correlation, was used to determine the degree and direction of correlation, and the correlation's statistical significance, for each of the 276 annual series of peaks. A positive value of tau indicated a positive correlation, and a negative value, a negative correlation. Small values of the probability associated with tau indicated a significant correlation. Calculations of Kendall's tau and its associated probability for each series were made using the algorithm given by Press et al. (1986). Appendix B shows the value of tau and its associated probability for each gaging station.

Test for Significance - Statistical significance was determined by a two-sided test at the 0.05 level. For this test, the null hypothesis, H_o, states there is no trend. H_o is accepted if the probability associated with tau is greater than 0.05 and is rejected otherwise. By chance, five percent of the gaging stations should show a significant trend. The significant, but chance, trends should be about half positive and half negative.

Checking for Regional Trends – In an initial check for regional trends, only the 86 gaging stations with more than 30 years of record were used. These long-term records were considered least likely to be

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[1] No watersheds known to be significantly affected by regulation or diversions were included in the analysis.

Table E-1. The distribution of trends in annual peak data among watersheds in eastern Oregon by flood region. Trends were determined for watersheds with more than 30 years of record.

Region	Watersheds with Positive Trends		Watersheds with Negative Trends		Watersheds with Trends		Number of Watersheds
	Number	Percent	Number	Percent	Number	Percent	
1	1	5.3	1	5.3	2	10.6	19
2	0	0.0	0	0.0	0	0.0	19
3	1	11.0	0	0.0	1	11.0	21
4	2	18.0	1	9.1	3	27.3	11
5	2	28.6	0	0.0	2	28.6	7
6	0	0.0	1	11.1	1	11.1	9
All	6	7.0	3	3.5	9	10.5	86

affected by random variation in the annual series of peak discharges. By chance, five percent of the gaging stations (4 to 5 stations) should show a significant trend.

Table E-1 summarizes the results of the test for significance for the long-term stations. Nine stations (10.5) percent showed a significant trend. Of these, six showed a positive trend and three a negative trend. Region 5 had the highest percentage of significant trends (28.6 percent) and region 2, the fewest (0.0 percent).

More significant trends occurred than were expected by chance and most were positive. The six positive trends had periods of record beginning before 1940. The negative trends had periods of record beginning after 1960 (Table E-2). Figure E-1 shows the trend lines for representative gaging stations from each group. These results suggest that, for these gaging stations, peak discharges are not entirely random; that they exhibit long-term fluctuations between wet and dry periods – dry around 1930 and wet around 1960.

The pattern shown by these gaging stations is not as strong as that shown by gaging stations in western Oregon (Cooper, 2005), but being dry in 1930 and wet in 1960 is consistent with the pattern in western Oregon. The eastern Oregon pattern is also consistent with observations made about precipitation in Oregon by Taylor and Hannan (1999) who suggest alternating periods of relatively high and low rainfall. Based on long-term precipitation records from the coast and in Portland, weather was cool and wet from 1896 to 1916, warm and dry from 1916 to 1946, cool and wet from 1946 to 1976, and warm and dry from 1976 to 1995. After 1995 appears to be the beginning of another wet period.

If peak discharges are in fact subject to serial correlation due to long-term fluctuations in weather, it should be possible to demonstrate that the direction and the statistical significance of a trend are functions of the length of the record on which it is based and the record's location in time. In order to make this test, all record lengths must be the same. To that end, for all 276 gaging stations, all possible records of 10, 20, 30, 40, 50, 60, 70, and 80 years were identified and Kendal's tau determined[2]. A long-term gage contributes a number of records in this scheme. For example, a gaging station with 50 years of data yields 21 records 30 years in length. The total number of sampled records varies as a function of sample record length – the longer the sample, the fewer the possible records (Table E-3).

Table E-3 shows trend direction and number of significant trends as a function of record length for eastern Oregon. The same information for western Oregon is included for comparison. For both sides of the state, trend direction and statistical significance are functions of sample record length. For eastern Oregon, trends are about equally positive and negative for record lengths of 20 years or less, but the percentage of positive trends increases rapidly with increasingly longer records. Trends for gaging stations in western Oregon exhibit a similar pattern though the increase in the percentage of positive trends begins at 40 years of record, not 20 years.

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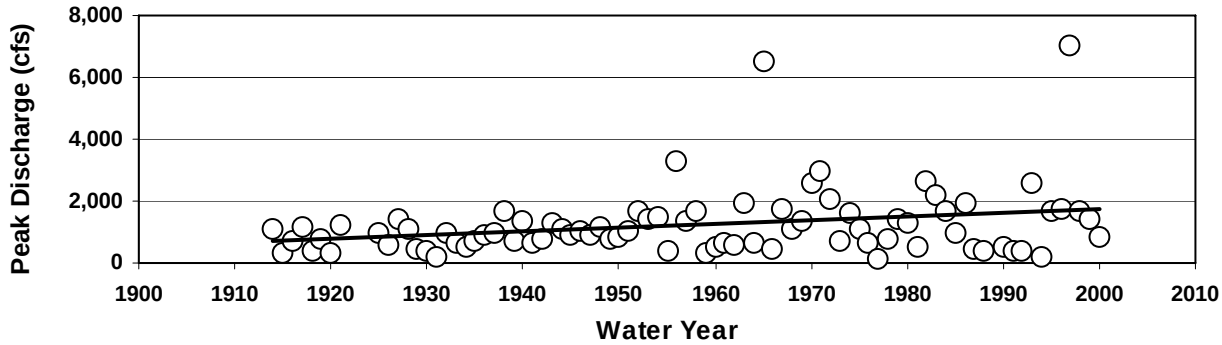
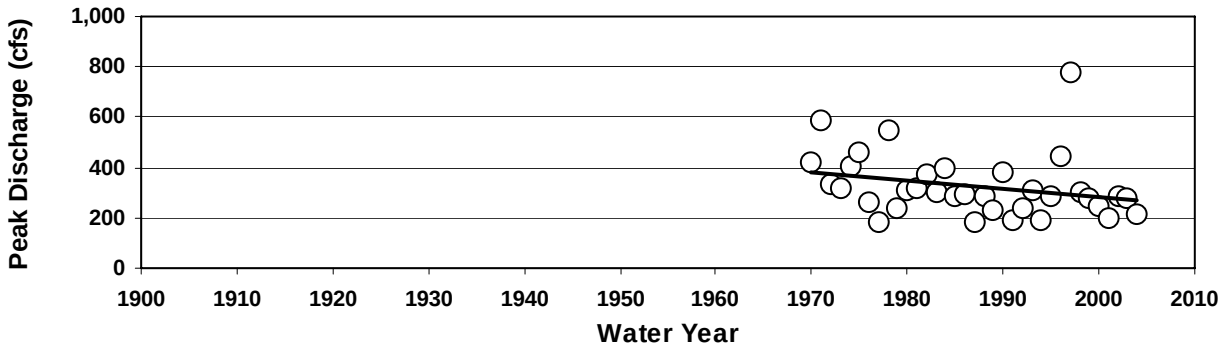
[2] For this test, records with gaps longer than five years were not considered.



a.



b.

Figure E-1. Examples of gaging station peaks with significant trends (a) the Chewaucan River near Paisley, OR (10384000) and (b) Odell Creek near La Pine, OR (14055600).

Table E-2. The 9 gaging stations with significant trends and more than 30 years of record. The list is sorted on the beginning year of the period of record.

Gage Number	Period of Record	Number of Peaks	Trend Direction	Region
14061000	1912-1914, 1928-1930, 1932-1946, 1947-1958	32	+	1
10384000	1912-1921, 1925-2000	83	+	5
13329500	1915, 1924-1978	56	+	3
10371500	1923, 1930-2000	72	+	5
14044000	1930-2003	74	+	4
14037500	1931-1967, 1970-2002	70	+	4
13172740	1963-1993	31	-	3
14040600	1967-1972, 1974-1979,1981-1989, 1991-2001	32	-	4
14055600	1970-2004	31	-	1

Table E-3. Trend direction and number of significant trends as a function of record length.

Eastern Oregon							
Record Length	Number of Observations	Trend Direction				Significant Trends	
		Positive	Negative	Zero	% Positive	Number	Percent
10	5294	2695	2559	40	50.9	376	7.1
20	3245	1692	1498	55	52.1	214	6.6
30	2195	1303	878	14	59.4	129	5.9
40	1515	1017	492	6	67.1	129	8.5
50	967	726	239	2	75.1	135	14.0
60	512	447	65	0	87.3	69	13.5
70	152	147	5	0	96.7	18	11.8
80	33	33	0	0	100	4	12.1
Western Oregon*							
Record Length	Number of Observations	Trend Direction				Significant Trends	
		Positive	Negative	Zero	% Positive	Number	Percent
10	6761	3332	3361	68	49.3	289	4.3
20	3794	1777	1936	81	46.8	161	4.2
30	2184	1083	1087	14	49.6	149	6.8
40	1214	614	592	8	50.6	161	13.3
50	641	375	265	1	58.5	109	17.0
60	285	186	98	1	65.3	59	20.7
70	96	71	25	0	74.0	35	36.5
80	30	28	2	0	93.3	13	43.3

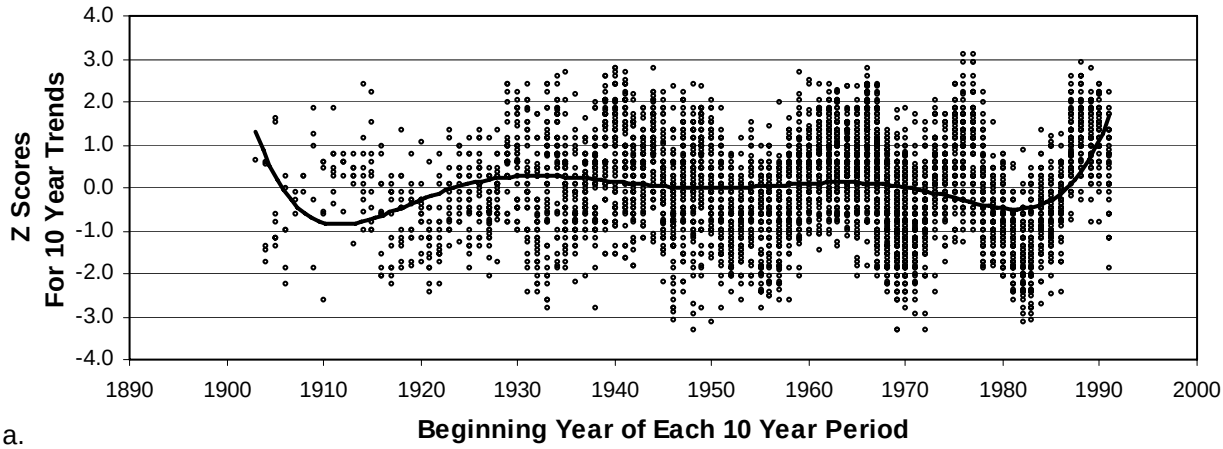
* From Cooper, 2005

Again from Table E-3, for eastern Oregon for record lengths of 30 years or less, the percentage of significant trends is about what is expected by chance. For record lengths of more than 30 years, the percentage of significant trends increases with record length to about 50 or 60 years and then remains relatively constant at a little over 10 percent for longer records. This pattern is similar to the pattern shown by trends in western Oregon, except that for western Oregon the number of significant trends continues to increase with record length. Also the percentages of significant trends at longer record lengths are much greater for western Oregon than for eastern Oregon.

In Figure E-2, for each record length, the number of standard deviations Kendall's tau departs from the mean (i.e., its z score) is plotted against the beginning year of the period of record. Plotted in this way, tau gives the direction of the trend and is proportional to its statistical significance. All records of a given length are plotted on the same chart. The solid black line on each chart is a sixth order polynomial fitted to the plotted points. Each represents the trend of its associated z scores.

Figure E-2 shows that the likelihood a trend will be in a certain direction or will be significant or both varies as both a function of length of record and the record's place in time. For example, for records 40 years in length (Figure E-2d) a record beginning between 1912 and 1947, or after 1959, is more likely to be positive than negative, and if beginning before 1912 or between 1947 and 1959, more likely to be negative. Significant trends (tau more than about two standard deviations from the mean) are most likely to occur near the maximum and minimum points of the fitted line: 1930 and 1955.

The longer the length of record, the more the record's place in time affects direction and significance. At



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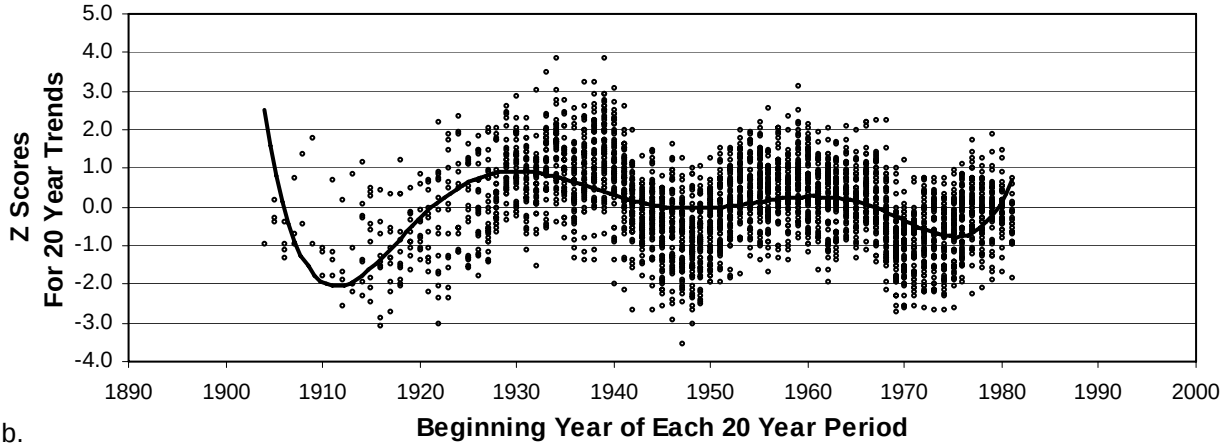

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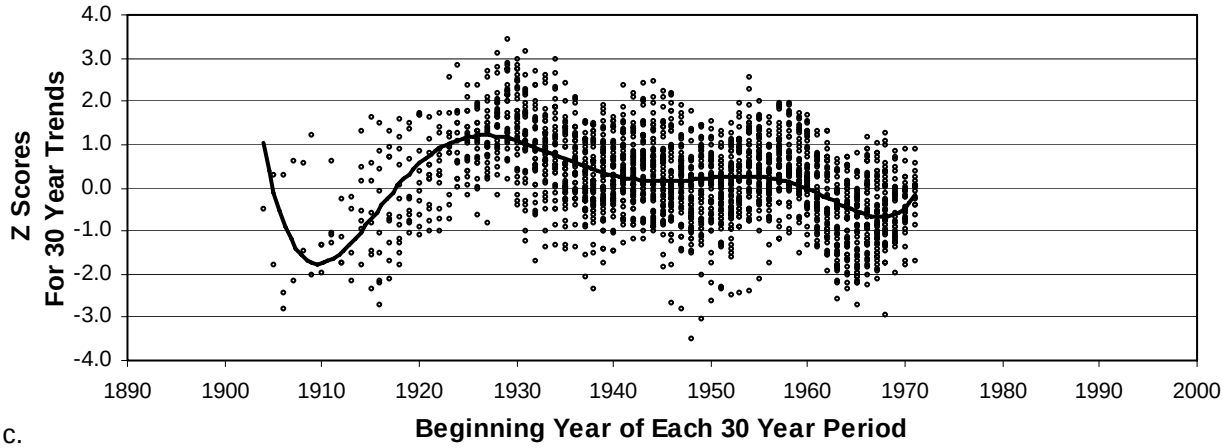
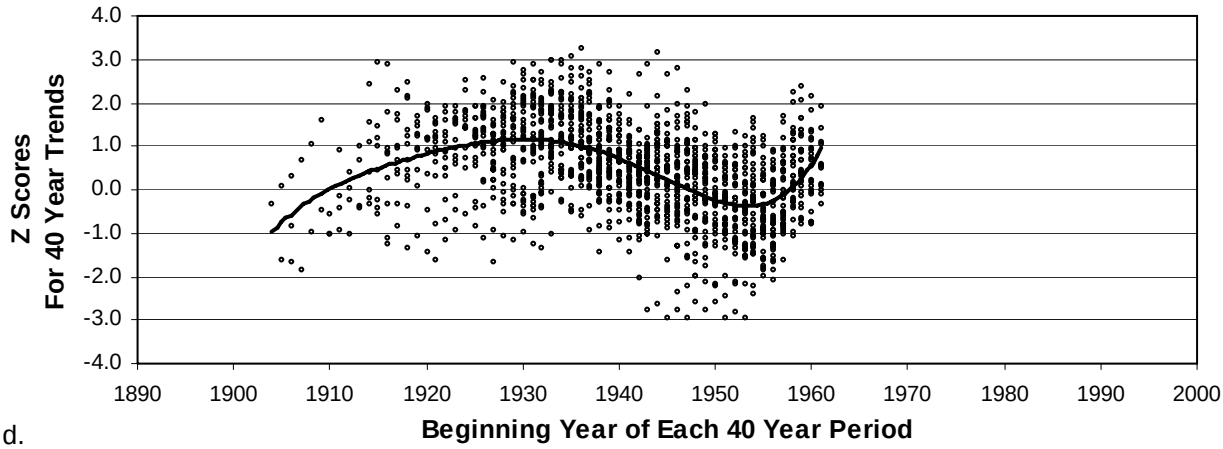


c.

Figure E-2. These charts show how Kendal's tau varies in time and as a function of the length of the period of record. The number of standard deviations Kendall's tau departs from the mean (i.e., its z score) for the specified periods of record is plotted against the beginning year of each period. Plotted in this way, tau gives the direction of the trend, and is proportional to its statistical significance, for the period of record



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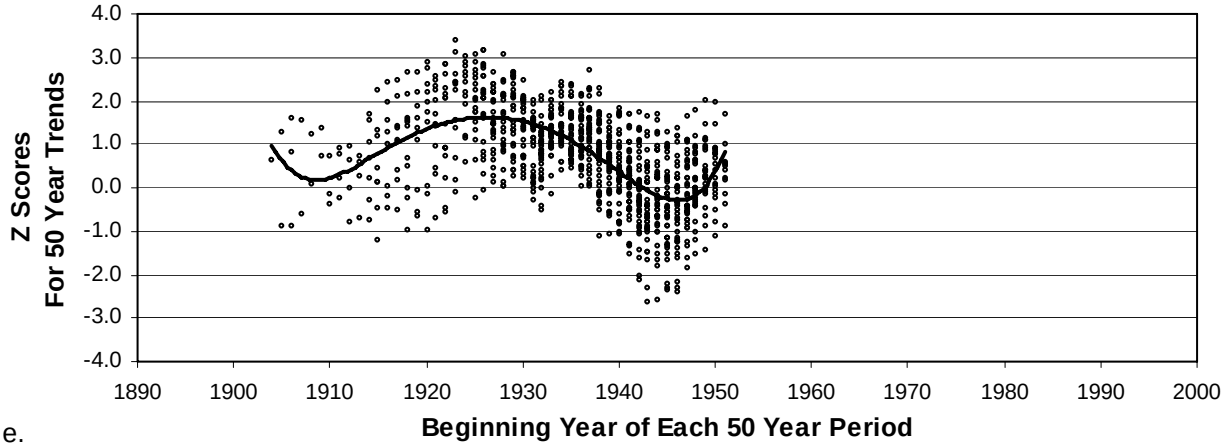

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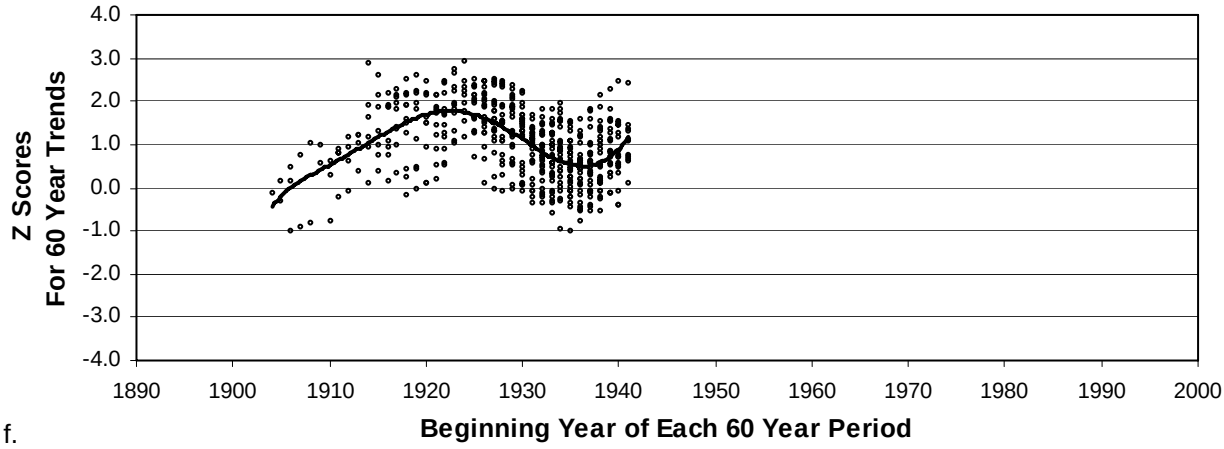

f.

Figure E-2 - continued. that follows its plotted position. The solid line on each chart is a sixth order polynomial fitted to the plotted points. The charts are for uniform periods of record of a) 10 years, b) 20 Years, c) 30 years, d) 40 years, e) 50 years, and f) 60 years.

short record lengths, the trend line is relatively flat. At records lengths of about 30 or 40 years, the trend line begins to take on a roughly sinusoidal shape. The sinusoidal shape of the trend line is more pronounced for trends in western Oregon (see Figure E-2, Cooper, 2005).

The sinusoidal trend lines of the z scores in Figure E-2 suggest that the linear trends on which the z scores are based fluctuate between positive and negative. These region wide fluctuations explain the over abundance of significant trends in the long-term gages and the grouping of positive and negative trends shown in Table E-2. They also explain why the percentage of significant trends and the number of positive trends both increase with record length (Table E-3).

To understand how the z scores of the linear trends relate to the original time series of peak discharges, it is helpful to look at the behavior of z scores of linear trends sampled from a theoretical, perfectly sinusoidal population. A sine curve with a period of 60 years and beginning in 1880 was sampled for all possible periods of lengths of 10, 20, 30, 40, 50, and 60 years. Kendall's tau and the associated z score were calculated for each sample. The population curve and the z scores of the trend lines for each period of record are plotted in Figure E-3. The z scores based on the samples from the sine curve (Figure E-3) behave in a fashion similar to the z scores from the actual peak discharges (Figure E-2). The z scores are sinusoidal in both cases and their periods shorten as the length of sampled record increases. Also the most significant trends occur near the maximum and minimum points of the curves.

Note that when the length of the sampled record is half that of the period of the population curve, the z scores and the population curve are exactly 180 degrees out of phase. This means that for periods beginning in wet years trend lines will tend to be negative, and beginning in dry years, positive.

For the z scores for actual peak discharges, the z scores and the sine curve are 180 degrees out of phase for a period of 76 years and a period of record of about 35 years (Figure E-4). These results are identical to those found for western Oregon (Cooper, 2005). In Figure E-4, the time line is divided into wet and dry periods. The breaks occur where the two sinusoidal curves meet as they cross zero. Interestingly, these periods match reasonably well those observed by Taylor and Hannan (1999).

Although this analysis suggests a periodicity to peak discharges, less than one complete period is represented in the record. Whether these observed fluctuations are truly periodic with a constant period remains to be seen. Further, the data points are scattered widely about the trend lines indicating that a trend line of the z scores for any single gaging station may vary considerably from the trend line for z scores from all gaging stations (Figure E-5). So, while the fluctuations appear to have a general, regional basis, locally there is considerable variation.

Based on this analysis, it is concluded that while the time series of peak discharges exhibit some serial correlation, the correlation is due to fluctuations between wet and dry periods and not to a continuous upward or downward trend. Over the long term, peak discharge characteristics remain constant. Further, it is concluded that the available peak discharge records represent long-term peak discharge characteristics; that they adequately represent the variability exhibited by peak discharges over the long-term.

Checking for Local Trends – Table E-4 summarizes the results of the tests for significance for all 276 stations. For these stations, 29 (10.5 percent) showed a significant trend. Of these, 15 showed a positive trend and 14, a negative trend. Region 5 had the highest percentage of significant trends (28.6 percent), and region 2, the fewest (1.7 percent). While the number of significant trends exceeds that expected by chance, the trends are not predominately either positive or negative. The excess of significant trends is attributed to the fluctuations discussed in the previous section. The 29 gaging stations with significant trends were examined to determine if the trends were the result of physical changes in the associated watersheds. Since no physical cause could be determined for any of the trends, the trends were assumed to be due to chance alone, and the 29 gaging stations were retained in the analysis.

References

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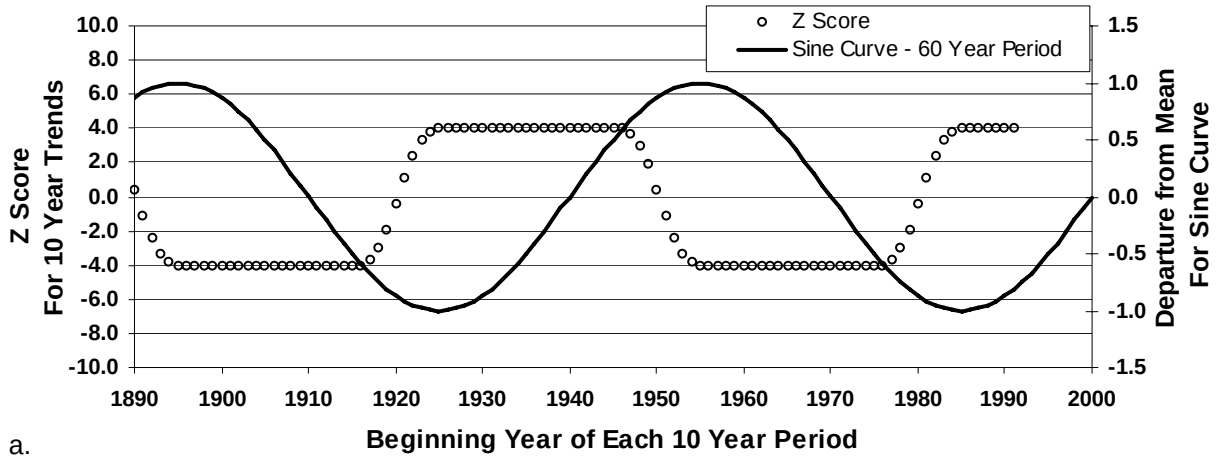
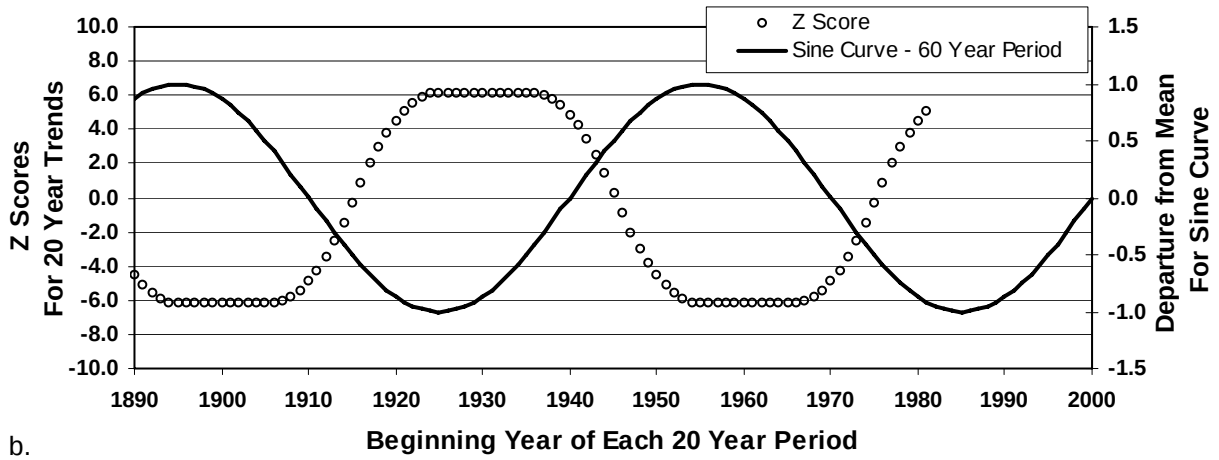
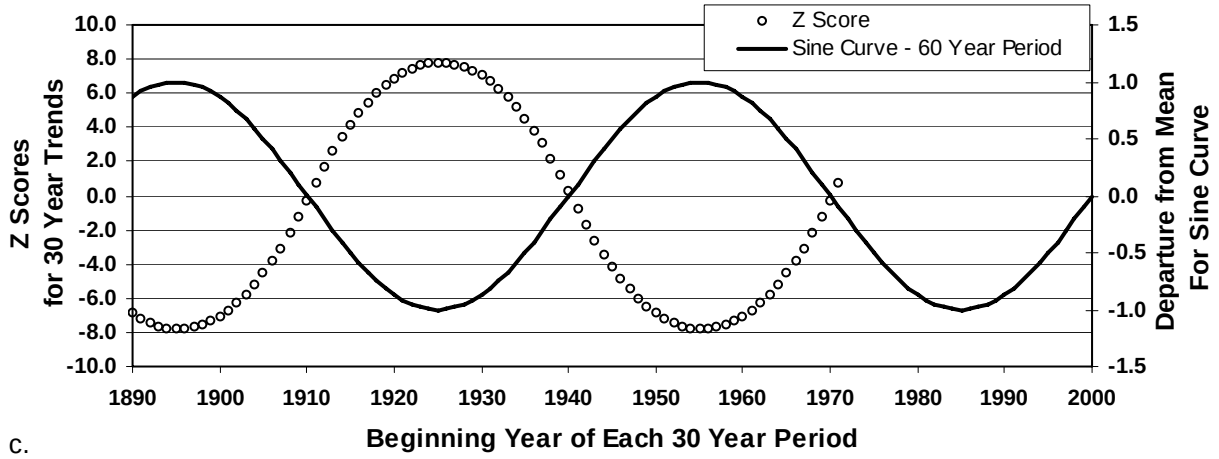


a.

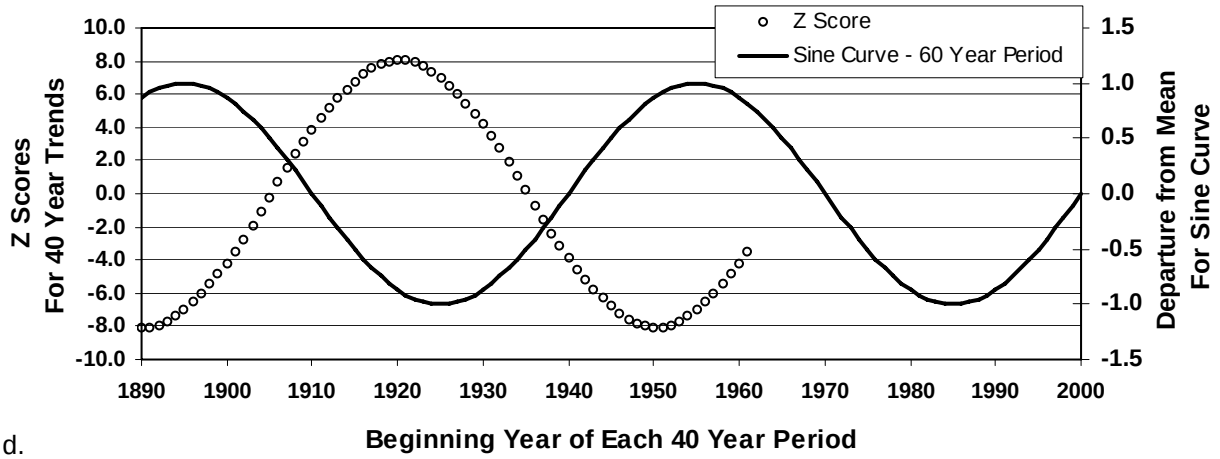


b.

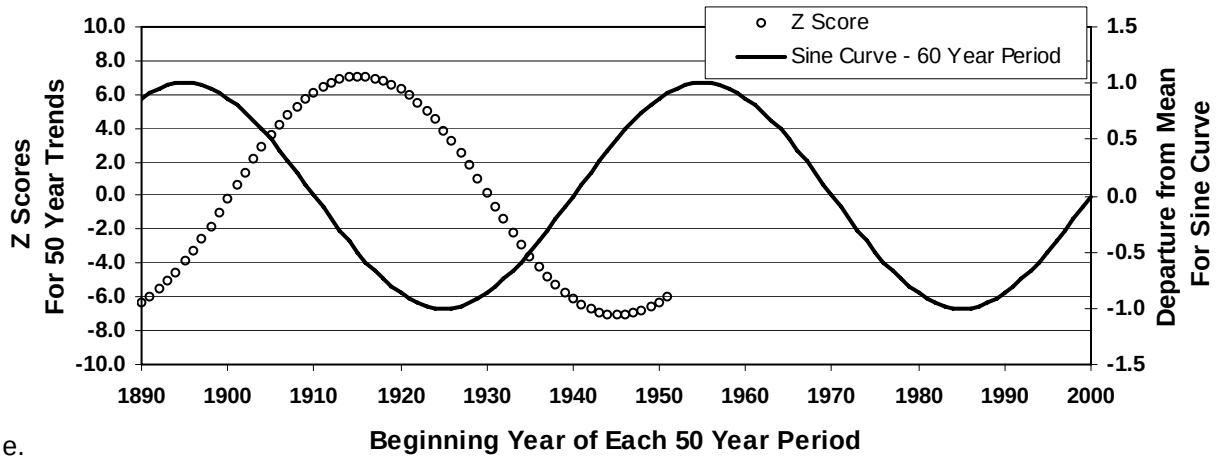


c.

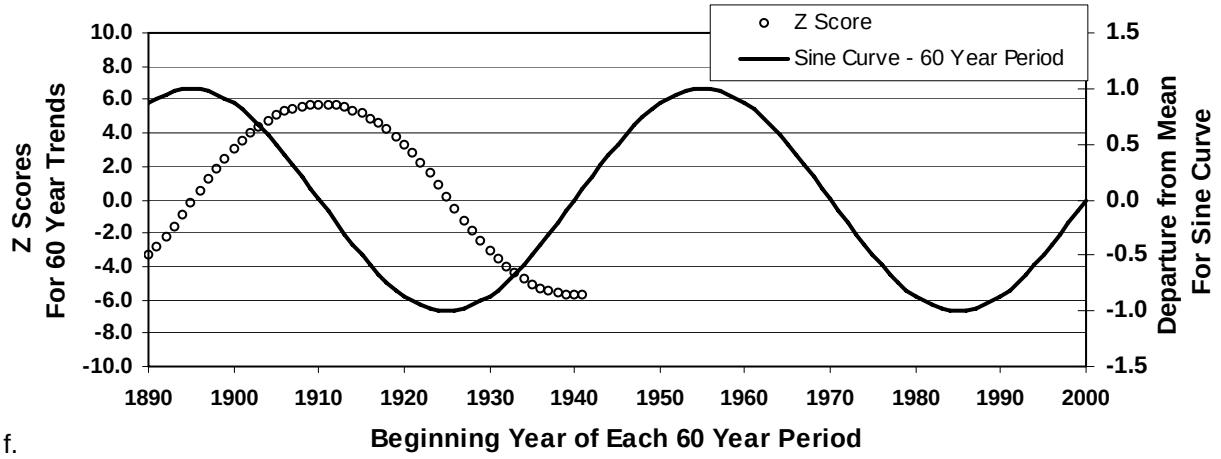
Figure E-3. Kendall's tau was calculated for samples of specified length taken from a population based on a sine curve with a period of 60 years and beginning in 1880 (blue line). The values of the population represent departures from a mean of zero. Z scores for the tau values are shown plotted against time. These z scores



d.



e.



f.

Figure E-3 – continued. exhibit behavior similar to the z scores in Figure E-2. Note that when the length of the sample is half the period of the sine curve, the two curves are 180 degrees out of phase.

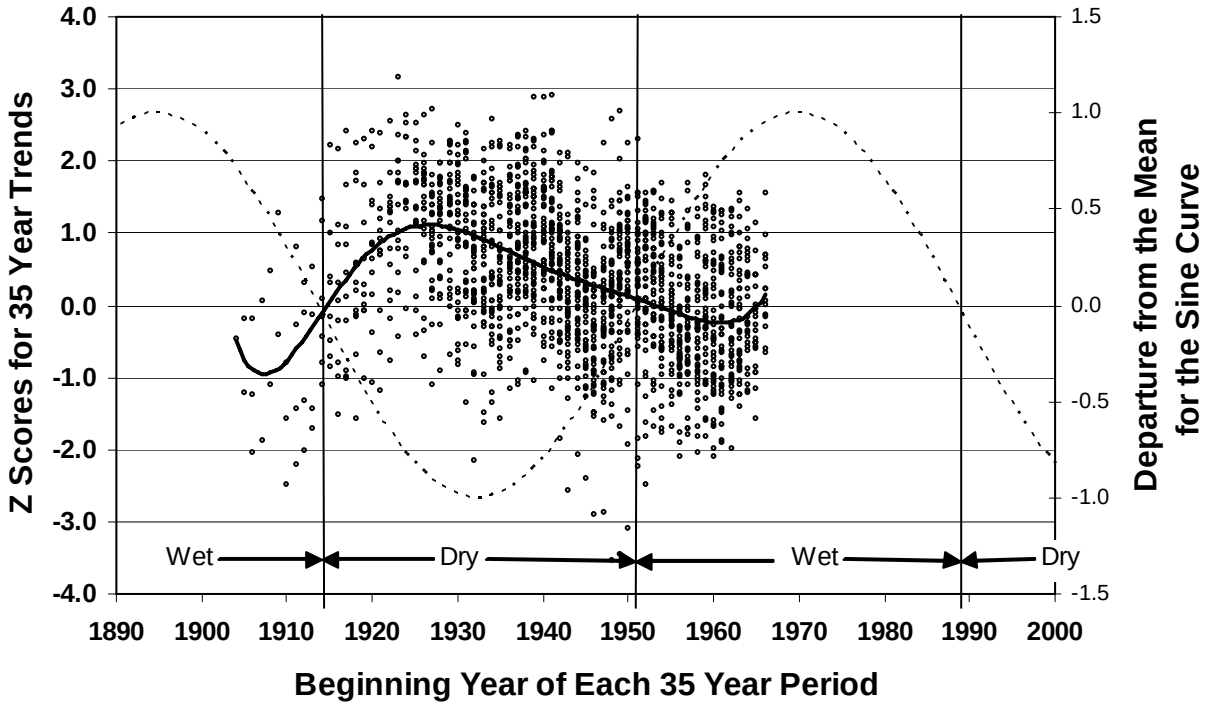


Figure E-4. Z scores for Kendall's tau calculated for all possible periods of 35 years are plotted against the beginning year of each period. The solid curved line is a fourth order polynomial fitted to the plotted points. The dashed line is a sine curve with a period of 75 years and beginning in 1876. The parameters of the sine curve and the length of record were selected so that the two curves were 180 degrees out of phase. The boundaries of the wet and dry periods are located where the two curves cross each other and zero.

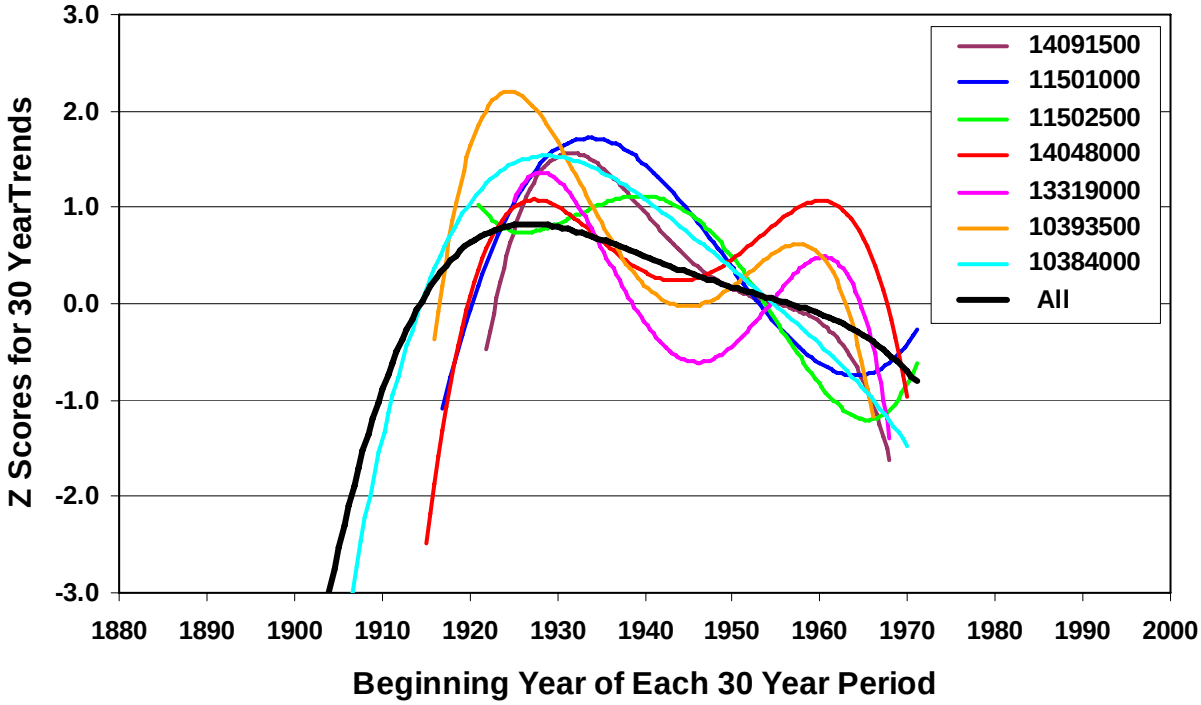


Figure E-5. Trend lines of z scores for the seven gaging stations with the longest periods of record compared to the trend line for z scores of all gaging stations.

Table E-4. The distribution of trends in annual peak data among watersheds in eastern Oregon by flood region. Trends were determined for watersheds with more than 10 years of record.

Region	Watersheds with Positive Trends		Watersheds with Negative Trends		Watersheds with Trends		Number of Watersheds
	Number	Percent	Number	Percent	Number	Percent	
1	3	7.3	2	4.9	5	12.2	41
2	1	1.7	0	0.0	1	1.7	58
3	2	2.6	3	3.9	5	6.6	76
4	4	7.8	5	9.8	9	17.6	51
5	5	17.9	3	10.7	8	28.6	28
6	0	0.0	0	4.5	1	4.5	22
All	15	5.4	14	5.1	29	10.5	276

Appendix F. Available Watershed characteristics.

[Units: **mi^2** = square miles, **ft** = feet, **in** = inches, **in/hr** = inches per hour, % = percent; ^{o} = degrees, ^{o}**F** = degrees Fahrenheit]

Characteristic	Units	Data type	Scale or resolution	Source
Latitude of the outlet	^{o}	vector	1:24,000	Oregon Water Resources Department
Longitude of the outlet	^{o}	vector	1:24,000	Oregon Water Resources Department
Latitude of the centroid	^{o}	vector	1:24,000	Oregon Water Resources Department
Longitude of the centroid	^{o}	vector	1:24,000	Oregon Water Resources Department
Drainage area	mi^2	vector	1:24,000	Oregon Water Resources Department
Stream length	mi	vector	1:24,000	US Geological Survey
Perimeter	mi	vector	1:24,000	Oregon Water Resources Department
Area of lakes and ponds	%	vector	1:24,000	US Geological Survey
Minimum watershed elevation	ft	grid	30 m	US Geological Survey
Maximum polygon elevation	ft	grid	30 m	US Geological Survey
Maximum watershed elevation	ft	grid	30 m	US Geological Survey
Maximum relief	ft	grid	30 m	US Geological Survey
Mean watershed slope	^{o}	grid	30 m	US Geological Survey
Mean watershed aspect	^{o}	grid	30 m	US Geological Survey
Mean watershed elevation	ft	grid	30 m	US Geological Survey
Area above 3000 feet	%	grid	30 m	US Geological Survey
Area above 4000 feet	%	grid	30 m	US Geological Survey
Area above 5000 feet	%	grid	30 m	US Geological Survey
Area above 6000 feet	%	grid	30 m	US Geological Survey
Mean soils storage capacity	in	vector	1:250,000	Natural Resource Conservation Service
Mean soils mean permeability	in/hr	vector	1:250,000	Natural Resource Conservation Service
Mean soils depth to bedrock	in	vector	1:250,000	Natural Resource Conservation Service
Mean annual precipitation	in	grid	4,000 m	Oregon Climate Service
Mean January precipitation	in	grid	4,000 m	Oregon Climate Service
Mean February precipitation	in	grid	4,000 m	Oregon Climate Service
Mean March precipitation	in	grid	4,000 m	Oregon Climate Service
Mean April precipitation	in	grid	4,000 m	Oregon Climate Service
Mean May precipitation	in	grid	4,000 m	Oregon Climate Service
Mean June precipitation	in	grid	4,000 m	Oregon Climate Service
Mean July precipitation	in	grid	4,000 m	Oregon Climate Service
Mean August precipitation	in	grid	4,000 m	Oregon Climate Service
Mean September precipitation	in	grid	4,000 m	Oregon Climate Service
Mean October precipitation	in	grid	4,000 m	Oregon Climate Service
Mean November precipitation	in	grid	4,000 m	Oregon Climate Service
Mean December precipitation	in	grid	4,000 m	Oregon Climate Service
Precipitation intensity 2-year 1-day	in	grid	3,000 m	Oregon Climate Service
Precipitation intensity 2-year 2-day	in	grid	3,000 m	Oregon Climate Service
Precipitation intensity 2-year 3-day	in	grid	3,000 m	Oregon Climate Service
Precipitation intensity 2-year 4-day	in	grid	3,000 m	Oregon Climate Service
Precipitation intensity 2-year 5-day	in	grid	3,000 m	Oregon Climate Service
Mean annual snow fall	in	grid	4,000 m	Oregon Climate Service
Mean January snow fall	in	grid	4,000 m	Oregon Climate Service
Mean February snow fall	in	grid	4,000 m	Oregon Climate Service
Mean March snow fall	in	grid	4,000 m	Oregon Climate Service
Mean April snow fall	in	grid	4,000 m	Oregon Climate Service
Mean May snow fall	in	grid	4,000 m	Oregon Climate Service

Appendix F. Available Watershed characteristics - continued.

[Units: **mi^2** = square miles, **ft** = feet, **in** = inches, **in/hr** = inches per hour, % = percent; ^{o} = degrees, ^{o}**F** = degrees Fahrenheit]

Characteristic	Units	Data type	Scale or resolution	Source
Mean June snow fall	in	grid	4,000 m	Oregon Climate Service
Mean July snow fall	in	grid	4,000 m	Oregon Climate Service
Mean August snow fall	in	grid	4,000 m	Oregon Climate Service
Mean September snow fall	in	grid	4,000 m	Oregon Climate Service
Mean October snow fall	in	grid	4,000 m	Oregon Climate Service
Mean November snow fall	in	grid	4,000 m	Oregon Climate Service
Mean December snow fall	in	grid	4,000 m	Oregon Climate Service
Mean annual minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean January minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean February minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean March minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean April minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean May minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean June minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean July minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean August minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean September minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean October minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean November minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean December minimum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean annual temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean January temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean February temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean March temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean April temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean May temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean June temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean July temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean August temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean September temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean October temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean November temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean December temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean annual maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean January maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean February maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean March maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean April maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean May maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean June maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean July maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean August maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean September maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean October maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean November maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service
Mean December maximum temperature	^{o}F	grid	4,000 m	Oregon Climate Service

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
10329500	176.00	13.60	167	6220	2.87	0.429	1.20	93.2	21.5	36.6	51.8	80.6	0.095	1.12	40.0
10330300	26.90	18.40	133	6050	2.72	0.382	1.17	88.3	19.6	35.8	49.4	80.5	0.102	1.47	39.9
10352300	6.74	5.49	235	5460	1.51	0.511	1.00	46.0	20.4	37.9	49.6	82.3	0.092	2.83	54.1
10352500	225.00	10.20	164	5890	2.19	0.330	1.06	53.7	20.9	37.6	52.0	83.2	0.098	0.77	25.1
10353000	137.00	12.90	180	6120	2.97	0.478	1.26	90.7	25.4	38.2	54.3	80.0	0.093	0.78	33.7
10353600	20.10	24.80	194	6500	2.73	0.363	1.17	76.0	21.1	36.6	51.7	80.5	0.082	1.39	32.0
10353700	51.10	19.50	184	6180	1.61	0.417	0.93	46.3	18.4	38.3	53.5	86.0	0.085	2.09	32.6
10353750	14.00	17.50	199	7180	1.96	0.617	1.05	69.0	19.9	35.0	51.7	80.2	0.099	1.48	44.2
10360900	25.60	25.40	147	6690	4.46	0.442	1.54	139.0	19.5	37.5	46.4	77.2	0.089	3.36	39.1
10361700	7.68	6.79	178	6160	1.46	0.323	0.91	45.8	16.6	36.4	45.6	80.3	0.084	1.70	49.0
10366000	189.00	5.49	168	5820	2.01	0.369	1.01	54.4	22.2	38.6	49.3	80.6	0.099	1.37	38.8
10370000	66.20	8.68	166	6240	3.82	0.423	1.33	101.0	20.0	37.9	45.3	78.0	0.107	1.62	46.8
10371000	71.30	4.45	197	5930	1.78	0.414	0.98	48.0	19.1	39.6	46.6	81.4	0.106	0.90	37.8
10371500	254.00	6.96	168	6140	3.09	0.425	1.23	84.9	20.4	38.4	46.4	78.9	0.105	1.30	42.4
10378500	168.00	6.47	144	5950	2.53	0.416	1.14	70.1	20.6	38.8	46.1	80.3	0.096	1.27	35.2
10384000	267.00	10.80	167	6040	2.93	0.733	1.46	101.0	19.5	38.9	43.1	78.4	0.120	3.76	47.9
10390400	10.90	7.91	159	6210	3.92	0.915	1.83	138.0	20.6	36.3	44.7	76.2	0.182	15.00	60.0
10392300	18.30	10.90	159	5510	2.23	0.603	0.95	86.6	19.8	33.8	46.8	75.9	0.166	1.14	42.3
10392800	8.29	6.92	149	5780	3.00	0.377	1.26	140.0	18.9	32.3	43.8	71.3	0.140	0.85	45.2
10393500	913.00	8.09	173	5180	1.85	0.567	0.91	76.8	16.4	35.2	43.4	80.0	0.144	1.05	44.5
10393900	5.11	5.51	206	5380	1.64	0.616	0.93	78.0	17.7	36.9	41.9	81.1	0.135	0.86	42.9
10396000	206.00	9.00	200	6200	3.34	0.577	1.50	120.0	21.4	36.5	49.5	76.4	0.092	1.16	21.8
10397000	29.40	6.09	244	5890	2.73	0.504	1.34	82.8	21.1	36.8	48.5	77.2	0.092	1.16	22.0
10402800	72.70	5.85	185	5110	1.65	0.609	0.96	66.5	17.6	36.3	43.6	81.1	0.122	0.87	37.1
10403000	224.00	6.72	183	5160	1.87	0.548	1.01	77.5	18.0	34.9	45.8	79.4	0.128	0.87	39.9
10403500	269.00	6.78	178	5140	1.80	0.553	0.98	73.5	18.0	34.9	46.3	79.7	0.127	0.87	39.4
10406500	85.60	13.00	181	6040	2.24	0.368	1.12	62.6	21.1	37.0	51.6	80.8	0.086	1.26	30.6

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
11339995	22.60	13.40	146	6200	3.16	0.728	1.50	108.0	20.0	39.6	44.2	77.9	0.100	1.86	48.3
11340500	32.50	12.30	149	5960	3.00	0.655	1.41	96.8	20.0	39.7	45.0	78.9	0.100	1.78	47.0
11340950	30.10	12.00	166	6000	2.97	0.704	1.42	103.0	19.7	39.2	43.7	78.2	0.100	1.74	46.9
11341000	30.80	11.90	166	5980	2.96	0.696	1.41	102.0	19.7	39.2	43.8	78.4	0.100	1.72	46.9
11341050	34.40	9.95	172	5480	2.71	0.414	1.14	69.8	20.5	38.2	48.1	81.4	0.099	0.98	40.7
11341100	5.19	12.50	198	5620	3.46	0.407	1.24	88.3	20.7	37.4	48.3	79.2	0.097	1.28	40.3
11341200	11.30	15.90	192	6230	4.37	0.465	1.49	129.0	21.7	37.2	47.0	76.4	0.098	1.51	43.5
11342945	0.98	23.50	174	7050	2.79	0.681	1.37	84.7	21.4	38.4	47.6	77.7	0.072	10.20	34.0
11342960	2.43	5.40	231	4850	2.11	0.303	1.02	48.0	19.1	41.0	47.4	85.0	0.076	0.95	50.5
11348080	2.60	1.48	118	5070	2.35	0.315	1.13	54.6	20.2	41.7	46.6	85.0	0.080	1.17	27.8
11348560	0.61	0.44	120	4910	2.83	0.197	1.18	59.2	23.6	42.3	47.7	85.4	0.080	0.83	24.1
11484000	272.00	3.99	178	5180	2.88	0.511	1.18	62.4	21.4	40.4	47.6	81.0	0.095	1.37	38.1
11489350	9.76	5.80	176	5290	2.63	0.436	1.23	39.4	23.6	39.8	49.6	81.3	0.092	2.29	48.0
11489500	19.20	13.90	176	6010	8.88	0.454	2.19	139.0	28.4	40.4	53.9	81.9	0.050	1.93	49.4
11491800	2.34	1.35	196	5080	3.35	0.581	1.49	96.6	17.3	38.4	40.2	81.3	0.180	16.10	60.0
11494800	2.18	14.80	174	6600	2.88	0.858	1.60	120.0	20.2	38.0	44.1	76.0	0.100	1.61	44.2
11497500	529.00	6.33	188	5390	2.61	0.628	1.34	80.3	19.8	39.2	44.5	79.7	0.129	3.74	44.4
11497800	2.43	2.81	262	6660	3.12	0.885	1.60	127.0	20.2	35.0	43.3	72.8	0.187	11.00	59.5
11501000	1590.00	5.36	180	5250	2.76	0.607	1.38	76.8	19.3	38.7	43.6	80.0	0.154	5.46	46.5
11501300	5.77	9.21	217	5040	4.17	0.403	1.59	99.8	18.6	38.5	42.6	79.7	0.170	3.56	38.1
11502500	2990.00	4.78	168	5170	3.21	0.580	1.48	95.7	18.4	38.5	42.1	79.8	0.181	8.88	52.1
11504000	71.80	8.62	172	5440	6.34	0.556	2.26	253.0	18.8	37.2	41.7	74.8	0.205	9.15	56.7
11505550	13.60	7.24	199	6060	6.99	1.030	2.86	216.0	21.9	37.0	44.3	72.4	0.094	2.85	50.7
11516900	46.60	10.90	190	5750	3.41	0.437	1.48	61.3	22.6	35.7	46.5	76.3	0.081	4.70	48.1
13172666	0.19	7.95	140	6800	4.21	0.709	1.38	87.6	15.4	34.1	45.0	78.4	0.090	2.58	42.9
13172668	0.15	7.32	226	6830	4.17	0.709	1.36	87.3	15.4	34.1	45.0	78.3	0.090	2.58	42.9
13172680	21.10	13.30	174	6040	3.97	0.650	1.32	80.7	15.2	34.3	45.3	79.3	0.088	1.80	36.4

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
13172720	12.50	12.30	141	4880	1.81	0.433	0.92	27.8	16.5	35.8	47.8	83.6	0.090	1.57	37.0
13172735	13.90	14.90	153	4940	1.78	0.415	0.92	27.3	16.6	36.0	48.1	84.3	0.090	1.08	34.2
13172740	91.90	11.80	172	5010	2.35	0.483	1.01	39.5	16.4	35.6	47.6	82.8	0.088	1.97	36.9
13172800	1.80	8.54	160	4460	1.69	0.461	0.94	30.3	16.5	36.5	47.2	86.6	0.088	2.09	38.8
13172900	83.80	10.80	178	5280	2.23	0.520	1.02	49.5	16.0	35.7	47.6	84.1	0.093	2.06	43.7
13178000	453.00	11.30	174	5790	2.73	0.580	1.14	63.6	15.9	35.0	48.3	80.8	0.086	1.59	33.6
13182100	3.05	23.10	196	4690	2.23	0.574	1.07	50.3	16.2	35.6	46.8	84.7	0.104	0.71	37.5
13207000	19.20	14.80	204	4020	2.75	0.520	1.06	65.0	19.7	34.6	55.4	88.3	0.125	1.75	45.0
13207500	57.80	15.20	203	3990	2.77	0.522	1.06	68.3	19.5	34.4	55.1	87.9	0.120	2.92	47.8
13213800	53.00	9.20	156	5220	2.63	0.476	1.03	73.6	19.6	32.3	54.2	80.7	0.126	0.89	37.9
13213900	2.23	7.14	155	3850	1.38	0.354	0.71	20.7	13.4	34.6	49.1	89.0	0.110	0.63	42.9
13214000	944.00	8.98	168	4850	2.07	0.442	0.91	59.5	16.5	34.7	48.7	83.0	0.124	0.90	36.3
13216500	342.00	12.20	172	5360	2.80	0.628	1.03	84.0	17.4	33.6	49.6	79.7	0.122	1.05	33.4
13226500	534.00	10.30	165	4140	1.42	0.451	0.71	33.8	18.4	34.6	53.7	86.2	0.097	0.58	30.1
13228000	3870.00	9.30	170	4350	1.63	0.457	0.81	39.1	18.7	35.5	51.7	85.0	0.108	0.96	32.6
13228300	6.50	8.55	182	2710	1.33	0.354	0.71	15.0	20.1	37.5	54.6	93.1	0.090	0.40	25.8
13229400	1.85	7.73	165	4150	1.44	0.471	0.67	40.3	14.5	32.9	52.0	84.9	0.108	0.84	33.6
13248900	6.94	14.40	175	3890	2.75	0.505	1.04	52.4	19.1	34.8	54.3	88.8	0.130	0.60	41.7
13250600	48.90	13.40	192	4140	3.36	0.605	1.14	46.9	21.9	35.8	56.3	86.9	0.093	0.36	21.4
13250650	6.26	13.20	204	3800	3.06	0.569	1.11	41.3	21.9	36.1	56.7	88.0	0.090	0.30	18.2
13251300	3.93	15.60	133	4950	4.76	0.833	1.45	106.0	15.9	31.6	47.5	78.3	0.090	0.57	29.7
13251500	36.40	12.90	164	4660	4.29	0.790	1.36	99.9	13.6	31.2	46.0	79.7	0.097	1.20	34.1
13252500	2.24	15.50	160	6890	7.11	1.050	1.87	195.0	13.6	31.5	42.7	74.2	0.061	13.40	43.6
13253500	115.00	15.30	179	4910	4.82	0.842	1.45	117.0	13.1	31.4	44.8	79.0	0.091	1.22	31.2
13260000	55.20	14.80	175	4760	4.84	0.654	1.42	79.9	17.1	32.7	50.5	80.1	0.092	0.65	30.4
13261000	79.40	15.30	211	5320	4.41	0.792	1.38	121.0	16.4	33.0	46.5	79.0	0.062	9.96	36.7
13267000	56.00	18.00	164	4870	4.59	0.675	1.35	82.8	18.7	31.7	51.8	78.7	0.092	0.54	28.4

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
13267100	4.29	9.30	185	3260	3.16	0.404	1.03	43.8	17.2	33.5	56.9	90.4	0.148	0.61	44.0
13269200	0.89	9.55	166	2840	1.34	0.283	0.71	18.3	18.7	35.8	60.7	92.7	0.108	0.70	44.3
13269300	110.00	10.80	169	4900	3.15	0.843	1.06	95.4	16.9	32.0	45.6	77.7	0.167	1.12	47.6
13272300	0.48	4.24	120	3980	1.11	0.472	0.59	27.4	13.5	33.8	44.6	86.2	0.130	1.70	56.3
13274600	1.94	8.97	217	2980	1.14	0.396	0.71	20.8	18.0	34.9	51.5	87.1	0.127	1.21	58.9
13275105	92.20	15.00	156	5410	3.09	1.000	1.07	96.7	16.6	32.9	44.8	75.8	0.136	1.13	39.2
13275200	33.50	20.70	190	5820	3.37	1.010	1.12	98.0	15.5	33.9	44.2	75.8	0.128	1.03	34.8
13275500	216.00	14.90	167	5210	2.93	0.963	1.07	81.5	14.7	33.3	44.4	77.3	0.136	1.15	39.9
13281200	21.30	25.00	174	6930	4.37	1.230	1.14	172.0	15.4	35.8	41.8	73.3	0.085	1.28	26.8
13282400	30.80	16.60	159	6120	4.66	0.890	1.29	170.0	17.3	33.4	43.9	72.3	0.137	1.68	40.7
13283600	30.60	14.20	154	5090	3.45	0.789	1.18	107.0	19.5	31.1	47.1	72.1	0.154	1.32	41.7
13285900	27.30	14.40	192	5070	4.75	0.888	1.51	150.0	20.4	30.4	47.6	73.1	0.167	1.08	42.1
13286300	0.94	5.77	160	2950	1.05	0.472	0.71	20.0	18.2	35.2	50.5	87.5	0.120	1.17	58.8
13287200	15.60	20.70	184	6760	6.60	1.150	1.96	282.0	16.5	30.2	41.4	67.8	0.117	1.21	33.5
13288200	156.00	21.60	183	5750	6.52	0.984	1.86	239.0	15.4	31.2	43.0	72.6	0.116	0.86	30.2
13289100	6.48	14.50	187	3620	3.59	0.587	1.25	59.3	16.8	34.8	51.0	87.4	0.084	0.43	23.1
13289600	7.37	24.30	210	5920	5.69	0.759	1.61	108.0	16.3	31.4	46.5	74.8	0.090	0.57	29.7
13289960	177.00	16.30	195	5040	5.26	0.810	1.55	105.0	18.1	31.5	50.9	77.9	0.090	0.77	32.2
13290150	2.91	19.00	199	5070	5.88	0.702	1.68	121.0	20.8	32.2	53.4	78.9	0.170	1.07	42.5
13290190	297.00	15.30	165	4290	4.70	0.605	1.46	116.0	16.2	34.1	49.3	83.6	0.131	1.20	36.5
13291200	4.12	18.70	158	5190	4.94	0.742	1.57	122.0	21.0	31.1	51.5	74.6	0.170	1.07	42.5
13291400	1.75	21.40	206	5050	2.60	1.080	1.22	70.8	22.0	32.0	52.1	74.8	0.115	0.74	34.2
13292000	622.00	19.90	179	5140	3.91	1.120	1.50	132.0	19.1	31.6	48.2	73.4	0.129	0.90	34.1
13315500	15.10	15.70	162	4750	4.11	0.789	1.33	99.0	12.6	31.0	44.9	80.3	0.091	0.67	30.4
13316500	561.00	18.50	181	5440	5.23	0.997	1.58	149.0	13.4	30.7	44.8	76.8	0.079	3.59	30.1
13316800	15.30	17.20	210	5030	3.88	1.860	1.63	118.0	13.4	33.4	43.0	78.1	0.070	3.04	23.5
13317200	6.63	6.53	252	3920	2.43	1.670	1.51	87.1	17.8	35.3	46.7	79.8	0.148	1.26	54.6

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
13318100	1.78	7.22	176	4500	3.24	0.735	1.34	71.9	21.7	35.5	48.0	76.4	0.170	1.07	42.5
13318500	495.00	11.50	174	4750	3.16	0.843	1.30	85.7	20.3	36.2	46.6	75.0	0.154	1.25	41.0
13318800	543.00	11.40	173	4670	3.15	0.826	1.30	83.5	20.4	36.1	46.9	75.3	0.154	1.24	41.0
13319000	686.00	11.50	174	4580	3.17	0.790	1.31	80.5	20.7	35.9	47.4	75.7	0.153	1.23	40.6
13320000	103.00	15.80	194	5280	4.97	1.020	1.67	182.0	19.2	31.4	45.3	72.1	0.155	1.13	40.2
13320400	15.80	13.00	218	5150	4.99	1.070	1.80	170.0	18.7	33.7	43.9	73.5	0.159	1.16	41.3
13321300	15.80	8.63	190	4130	2.45	0.675	1.14	53.9	21.4	34.6	49.4	75.9	0.100	0.57	26.4
13322300	1.32	16.60	172	4450	6.07	0.850	1.94	117.0	22.6	32.8	48.7	73.5	0.127	2.02	41.3
13323500	1250.00	10.50	169	4220	3.11	0.776	1.31	78.9	20.9	35.5	47.6	77.4	0.152	1.29	42.5
13323600	21.40	12.10	198	5640	5.91	1.130	1.99	212.0	20.3	32.3	45.8	71.0	0.156	1.28	41.8
13323700	15.30	10.10	201	4390	3.97	0.796	1.42	114.0	18.9	33.3	44.6	77.7	0.164	0.97	42.7
13324150	1.04	5.16	216	3540	2.82	0.589	1.18	65.8	17.2	34.3	42.8	82.4	0.140	0.60	43.3
13324300	77.10	12.00	154	4380	5.87	0.855	1.84	111.0	21.2	32.9	46.7	75.8	0.139	1.38	39.8
13325000	10.20	25.50	197	7700	7.14	3.640	2.58	373.0	13.4	29.6	37.1	64.7	0.069	0.76	20.1
13325500	43.70	26.00	176	7530	7.07	3.280	2.54	369.0	13.5	29.7	37.2	64.6	0.082	0.90	24.0
13329500	29.60	29.00	169	7460	7.25	2.590	2.60	392.0	13.7	29.5	37.6	64.6	0.076	0.74	21.3
13329700	0.24	7.07	237	4520	1.47	0.699	1.02	51.8	14.2	34.8	42.2	79.0	0.164	1.02	41.5
13329750	4.23	6.54	206	4160	1.02	0.748	0.95	37.1	14.2	34.5	43.1	81.6	0.110	0.59	32.5
13330000	71.40	25.50	168	6900	6.54	1.740	2.27	331.0	14.8	30.2	39.2	65.9	0.120	1.14	33.3
13330500	67.00	24.30	174	5940	5.98	1.210	1.92	257.0	17.0	31.2	42.0	69.4	0.146	1.19	39.0
13331500	239.00	23.00	175	5700	5.97	1.130	1.92	250.0	16.9	31.3	41.7	70.5	0.134	1.08	36.0
13332500	2590.00	12.80	173	4510	3.72	0.929	1.45	117.0	18.8	34.1	45.1	76.5	0.145	1.30	40.7
13333000	3310.00	13.90	174	4410	3.78	0.936	1.44	112.0	18.8	34.0	45.1	77.0	0.145	1.25	40.4
13333050	0.49	1.61	188	4420	2.08	0.813	1.03	62.9	15.9	33.2	42.8	79.0	0.170	0.66	44.1
13333100	5.58	8.15	179	4510	1.52	0.839	0.97	45.0	20.3	33.3	49.0	75.4	0.170	1.07	42.5
13334700	171.00	19.30	170	3750	2.82	0.869	1.16	65.1	24.0	35.5	53.0	76.9	0.112	0.97	32.8
13335050	325.00	15.10	161	3360	2.47	0.827	1.08	55.4	23.3	35.7	52.7	79.7	0.116	0.93	32.5

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
13341100	8.03	5.28	167	4050	1.93	1.170	1.17	83.9	17.8	34.2	44.6	77.0	0.157	1.21	54.9
13342450	269.00	10.70	181	3150	1.93	1.050	1.10	69.1	20.5	35.7	48.6	80.5	0.143	0.87	51.2
14010000	61.80	24.40	186	4280	6.88	0.896	2.04	120.0	22.5	32.7	47.0	75.3	0.145	1.51	41.0
14010800	34.70	22.70	193	3930	6.59	0.819	1.96	95.3	23.3	34.1	47.1	78.5	0.153	1.22	39.9
14011000	42.90	22.50	193	3650	6.09	0.765	1.87	86.3	23.7	34.7	47.7	79.4	0.144	1.09	36.6
14011800	19.90	14.10	193	3060	4.04	0.605	1.49	63.6	25.0	36.2	50.1	80.8	0.154	0.94	38.4
14013000	58.60	26.60	186	3940	7.37	1.000	2.07	108.0	22.5	33.4	45.3	78.1	0.156	1.25	40.9
14013500	17.40	20.90	196	3130	5.88	0.698	1.79	54.8	24.4	36.2	47.7	83.2	0.163	1.18	43.0
14015900	1.87	6.79	225	1820	3.16	0.551	1.24	23.8	26.5	38.8	54.6	87.0	0.198	1.38	59.0
14016000	46.50	12.20	208	2380	4.45	0.634	1.51	39.6	25.6	37.8	51.8	85.4	0.183	1.49	53.5
14016080	1.18	3.13	217	1680	2.32	0.366	1.11	23.6	26.5	39.2	53.9	86.4	0.195	1.26	58.7
14016200	15.50	11.30	209	3240	3.86	0.619	1.47	67.2	24.8	36.0	49.6	80.3	0.153	0.77	37.8
14016500	107.00	21.00	194	3810	6.17	1.280	1.90	90.1	23.6	35.0	46.8	80.3	0.169	1.36	49.2
14016600	3.76	12.00	219	2950	3.71	0.779	1.31	33.3	24.6	37.9	51.1	84.5	0.196	1.17	55.0
14016650	2.97	10.10	226	2460	2.76	0.604	1.18	21.2	25.1	39.3	53.3	86.2	0.196	1.29	59.1
14017000	363.00	15.20	199	2930	4.40	0.890	1.50	52.4	24.6	37.1	50.5	83.5	0.182	1.33	53.4
14017040	3.51	9.65	208	2040	2.39	0.541	1.05	16.6	25.7	39.9	55.3	87.1	0.200	1.26	59.1
14017070	4.72	9.46	208	1920	2.34	0.539	1.02	16.5	25.7	39.7	55.5	87.3	0.196	1.27	59.2
14017200	4.21	11.40	204	1740	1.87	0.395	0.94	13.5	24.8	38.2	56.2	87.5	0.180	1.31	59.4
14017500	755.00	11.60	197	2120	3.08	0.644	1.20	32.2	25.3	38.4	53.7	85.9	0.183	1.45	55.1
14018500	1630.00	11.60	197	2080	3.31	0.602	1.27	37.0	25.5	38.2	53.4	85.4	0.172	1.49	52.5
14019400	0.69	27.80	146	3350	4.33	0.644	1.55	74.4	24.2	35.5	48.9	78.9	0.160	1.13	40.8
14020000	131.00	21.80	183	3970	5.67	0.789	1.85	106.0	23.4	33.8	49.1	75.4	0.148	1.45	41.0
14020300	176.00	19.40	183	3900	4.82	0.706	1.65	94.8	22.5	34.3	49.9	77.0	0.157	1.28	41.3
14020740	4.70	14.00	195	2910	3.92	0.713	1.40	64.5	25.0	37.8	52.3	81.3	0.134	0.94	33.0
14020800	4.55	14.60	187	2800	3.60	0.604	1.33	56.3	25.1	38.4	53.1	82.4	0.115	0.69	25.9
14020900	15.30	10.40	206	3010	3.62	0.566	1.43	59.2	24.9	36.7	50.1	81.7	0.149	0.72	36.8

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
14021000	638.00	13.90	189	2990	3.97	0.614	1.45	67.2	24.0	36.7	50.9	81.0	0.160	1.32	45.7
14021980	31.50	6.74	242	1980	2.47	0.456	1.07	31.8	25.4	39.7	53.8	85.6	0.117	2.53	47.2
14022200	50.80	14.50	191	3280	4.14	0.798	1.46	78.3	24.1	37.2	51.4	79.4	0.166	1.09	41.7
14022500	179.00	15.70	191	3270	3.45	0.658	1.32	64.5	23.6	37.5	50.8	79.8	0.150	1.22	39.7
14025000	285.00	11.30	175	3030	2.49	0.574	1.09	44.1	24.0	40.2	50.0	80.4	0.133	1.39	35.4
14026000	1270.00	12.60	187	2860	3.28	0.583	1.28	55.4	24.2	38.1	51.1	81.5	0.149	1.42	42.2
14032000	287.00	11.50	180	3140	2.12	0.564	0.95	35.2	23.8	38.9	49.4	80.9	0.135	0.92	27.8
14034250	0.29	5.55	187	2810	2.28	0.315	0.90	29.0	21.9	35.8	52.3	81.7	0.140	1.50	32.8
14034325	8.26	4.78	148	3270	2.47	0.321	0.94	31.8	21.3	35.2	51.7	80.4	0.140	1.50	32.8
14034370	1.10	16.20	229	4320	3.73	0.847	1.39	96.3	22.1	33.6	46.9	71.6	0.170	1.07	42.5
14034470	68.00	14.80	181	3770	2.64	0.676	1.12	58.3	23.1	36.2	47.9	76.4	0.134	0.91	31.0
14034480	26.30	12.50	181	3170	1.77	0.528	0.91	25.2	24.1	38.7	49.3	80.9	0.128	0.87	24.9
14034500	97.30	14.10	180	3560	2.37	0.627	1.05	48.1	23.4	37.0	48.4	77.8	0.133	0.93	29.6
14034800	114.00	13.30	187	3750	2.03	0.638	1.03	44.0	23.7	37.0	47.8	76.8	0.130	0.82	29.6
14036000	861.00	8.35	181	2310	1.60	0.402	0.88	21.9	25.2	39.5	52.5	83.9	0.153	1.28	38.2
14036800	17.50	18.50	174	6220	5.02	0.780	1.49	161.0	17.2	36.1	43.8	76.0	0.145	1.47	41.1
14037500	6.97	22.60	165	6920	5.28	0.660	1.48	187.0	16.8	35.3	43.4	75.1	0.139	1.52	40.3
14038500	230.00	15.30	188	5260	3.53	0.696	1.14	112.0	16.7	35.9	44.2	79.1	0.142	1.37	41.0
14038530	390.00	14.20	185	5000	3.13	0.654	1.04	94.2	17.5	36.1	44.8	79.9	0.134	1.25	39.5
14038550	24.70	20.00	205	5760	3.10	0.621	1.00	103.0	16.5	34.8	44.1	77.3	0.141	1.14	37.1
14038600	4.96	19.60	163	5050	2.20	0.618	0.85	61.8	20.2	35.9	48.3	79.5	0.119	1.18	32.8
14038602	86.20	18.60	191	5340	2.74	0.601	0.96	93.1	16.7	35.3	44.5	78.4	0.131	1.05	34.1
14038750	1.70	11.70	170	5110	2.34	0.590	0.82	55.8	20.4	35.4	45.9	77.8	0.170	1.07	42.5
14038900	17.70	21.90	177	4960	2.47	0.572	0.94	69.2	21.7	35.5	49.4	77.7	0.120	0.97	28.2
14039200	11.10	11.40	207	5520	2.29	0.621	1.03	104.0	17.2	33.8	43.1	77.0	0.167	1.07	42.0
14040500	1690.00	14.80	183	4640	2.34	0.569	0.93	66.6	19.3	36.8	46.1	80.8	0.131	1.00	37.5
14040600	27.40	10.30	184	5110	3.20	0.825	1.42	69.8	20.4	35.6	45.1	74.9	0.162	1.00	40.0

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
14040700	2.27	5.91	164	4300	2.73	0.663	1.18	58.6	19.7	36.9	45.9	78.4	0.131	0.70	27.3
14040900	4.57	10.90	217	5230	3.43	0.714	1.13	93.0	19.6	36.4	44.6	73.9	0.165	1.14	42.3
14041000	108.00	10.80	186	5270	3.64	0.737	1.15	102.0	18.7	35.7	43.9	74.4	0.152	1.27	40.8
14041500	534.00	14.50	182	5420	3.65	0.811	1.18	109.0	18.6	34.7	44.7	74.3	0.146	1.32	40.0
14041900	2.30	7.86	190	4560	2.83	0.886	1.23	71.7	19.9	37.5	45.2	74.2	0.170	1.07	42.5
14042000	60.80	6.70	179	4690	2.68	0.986	1.25	71.3	20.4	37.6	45.9	73.8	0.165	1.14	42.2
14042500	121.00	8.67	183	4730	2.84	0.948	1.25	74.1	20.1	37.5	45.4	73.6	0.162	1.16	42.3
14043800	6.97	12.90	157	5310	3.45	0.758	1.16	120.0	18.5	35.0	45.6	78.3	0.167	1.12	42.3
14043850	3.78	10.50	154	5110	2.66	0.668	0.91	64.6	19.3	35.6	44.4	78.8	0.167	1.12	42.3
14043900	1.80	9.28	183	4110	1.85	0.630	0.87	37.8	20.0	38.4	44.4	79.8	0.100	0.89	21.3
14044000	523.00	12.80	183	4780	2.93	0.719	1.02	87.2	17.8	35.6	44.0	79.0	0.144	0.99	38.4
14044100	3.52	9.48	101	4540	1.90	0.572	0.82	43.1	20.7	37.3	45.2	80.0	0.137	0.76	29.6
14044500	92.60	6.88	188	4820	2.27	0.456	0.80	52.4	20.8	36.2	46.0	78.2	0.154	1.22	50.7
14046000	2530.00	11.70	178	4540	2.65	0.699	1.03	69.1	19.7	36.5	45.1	77.9	0.140	1.03	36.7
14046250	2.87	14.30	237	3520	1.79	0.551	0.94	28.1	23.1	39.3	47.6	82.9	0.121	0.77	37.7
14046300	5.52	19.90	183	3970	1.81	0.560	1.04	25.7	22.6	38.5	45.6	80.2	0.140	0.85	45.2
14046500	5140.00	13.00	179	4440	2.41	0.633	0.99	62.1	20.0	37.1	45.9	79.7	0.133	0.96	36.3
14047100	8.34	16.10	169	3890	1.89	0.580	1.07	25.3	22.7	38.4	45.2	79.5	0.140	0.85	45.2
14047350	6.23	11.00	185	4120	1.97	0.667	1.05	45.0	24.0	36.7	47.4	75.7	0.133	0.86	41.0
14047380	68.80	10.20	176	4130	1.81	0.649	1.03	37.5	22.4	36.5	45.5	76.3	0.142	0.82	45.2
14047390	308.00	12.00	178	3640	1.70	0.601	0.99	31.8	23.0	37.3	46.9	78.2	0.124	0.80	33.0
14048000	7630.00	13.10	179	3920	2.14	0.585	0.98	48.7	21.2	37.7	47.2	80.7	0.132	0.89	36.9
14048040	8.83	4.21	153	1980	1.52	0.276	0.83	17.8	24.4	38.2	53.6	82.4	0.180	1.29	59.1
14048300	8.17	2.92	180	1540	1.64	0.276	0.87	14.0	25.2	39.1	54.3	83.8	0.180	1.29	59.1
14048310	6.18	3.47	179	1590	1.68	0.276	0.89	14.7	25.0	38.9	54.0	83.4	0.180	1.29	59.1
14050000	115.00	8.65	187	5760	10.10	1.220	3.12	333.0	20.6	35.2	41.2	69.6	0.092	4.43	41.3
14050500	16.80	5.03	162	5160	8.93	1.130	2.88	260.0	21.5	36.6	44.4	72.4	0.104	4.81	48.6

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
14051000	33.40	6.15	137	5240	8.59	1.270	2.92	273.0	22.0	35.8	43.4	71.1	0.118	6.28	48.4
14052000	14.50	6.44	134	5310	7.96	1.280	2.68	263.0	21.5	35.2	43.4	71.3	0.127	6.79	51.2
14053000	15.10	5.37	131	5400	7.88	1.230	2.63	263.0	21.7	34.9	43.0	71.3	0.108	5.18	48.9
14054500	20.40	5.10	121	5190	6.31	0.931	2.14	200.0	20.9	35.8	43.8	73.3	0.138	7.46	52.9
14055500	36.50	8.06	133	5630	7.76	1.020	2.64	252.0	21.5	35.6	40.8	71.9	0.079	3.31	40.7
14055600	46.80	8.10	144	5500	7.42	0.900	2.46	231.0	21.4	36.1	41.1	72.5	0.099	4.87	44.1
14061000	48.50	7.98	150	5270	6.18	0.785	2.23	211.0	20.0	38.3	40.4	74.7	0.142	8.59	53.3
14073000	48.30	8.94	142	5700	5.59	1.080	2.04	183.0	21.0	34.9	42.2	71.8	0.080	6.14	42.2
14075000	55.40	11.40	149	5920	8.31	1.220	2.64	288.0	19.7	35.1	39.7	69.8	0.065	6.61	39.3
14077500	65.20	6.87	196	4660	2.65	0.513	1.02	63.6	19.6	37.0	46.1	82.0	0.112	1.10	33.6
14077800	2.14	11.00	215	5140	3.19	0.581	1.16	78.7	22.2	36.1	47.2	78.1	0.124	0.81	39.2
14078000	451.00	6.97	187	4580	2.25	0.534	1.02	62.1	18.1	36.6	44.7	82.1	0.104	1.23	30.9
14078200	19.40	6.92	162	4900	1.37	0.572	0.80	42.4	18.6	37.1	46.1	82.6	0.092	1.12	28.0
14078400	7.20	8.36	117	5570	2.84	0.978	1.32	71.3	18.7	35.5	44.9	76.8	0.140	0.85	45.2
14078500	161.00	7.10	160	5130	2.86	0.961	1.32	66.7	19.5	35.8	45.0	77.3	0.137	0.88	44.0
14079500	1990.00	5.83	173	4660	1.86	0.602	0.96	50.1	17.9	36.9	44.9	81.9	0.107	1.29	32.8
14079800	2240.00	6.34	174	4630	1.85	0.605	0.96	49.3	18.0	37.0	44.9	81.8	0.109	1.25	33.1
14080500	2550.00	6.65	175	4600	1.79	0.597	0.95	47.3	18.1	37.1	44.8	81.8	0.106	1.24	32.7
14080600	14.50	5.35	216	4370	1.92	0.545	1.06	35.2	20.6	39.0	43.9	81.3	0.080	0.67	27.0
14081800	2.29	8.53	172	5160	3.40	1.300	1.51	77.8	20.7	35.2	44.5	75.1	0.170	1.07	42.5
14083000	200.00	12.70	191	4550	2.33	0.783	1.20	50.5	18.9	36.7	42.7	79.6	0.130	0.83	41.4
14083500	70.70	15.80	183	4560	2.14	0.668	1.14	44.5	18.7	36.9	41.9	80.0	0.134	0.83	43.4
14088000	21.10	8.14	151	4430	8.58	0.841	2.18	264.0	22.0	37.1	42.7	74.1	0.088	9.42	55.6
14090350	27.90	16.30	147	5120	8.26	1.060	2.45	211.0	23.0	37.2	43.6	72.0	0.075	5.94	45.5
14090400	22.90	19.30	148	5140	10.30	1.070	2.85	253.0	23.7	36.9	45.1	71.4	0.073	5.22	44.1
14091500	319.00	11.70	142	4170	6.22	0.747	1.85	151.0	23.3	38.0	44.2	76.5	0.092	6.09	51.2
14092750	22.20	15.00	148	4860	9.90	1.020	2.76	228.0	24.7	37.3	46.6	72.4	0.083	6.56	50.7

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
14092885	75.30	10.10	142	3560	5.61	0.571	1.71	106.0	25.2	39.4	48.2	80.1	0.093	3.19	40.5
14093000	105.00	9.72	145	3200	4.60	0.490	1.48	80.3	25.2	40.5	48.5	82.8	0.101	2.46	40.5
14093600	119.00	13.10	183	4360	2.07	0.686	1.12	38.2	20.2	37.7	43.2	79.9	0.137	0.71	48.5
14093700	1.43	11.50	149	3190	1.57	0.394	0.95	15.9	22.6	40.3	45.2	83.2	0.130	0.37	56.6
14095500	106.00	7.66	156	3730	7.22	0.709	1.99	155.0	24.6	37.2	47.3	75.2	0.083	4.67	48.2
14096300	25.80	12.00	163	4770	10.80	1.030	2.94	246.0	24.7	36.6	46.2	71.6	0.087	7.76	53.8
14096850	145.00	7.35	166	3090	4.43	0.377	1.39	70.1	25.3	39.0	49.8	79.8	0.088	2.28	41.3
14097100	525.00	7.53	160	3300	5.42	0.487	1.61	97.3	25.1	38.9	48.7	79.3	0.092	2.99	43.5
14097200	40.40	15.70	164	4220	8.11	0.934	2.16	199.0	24.5	34.8	46.9	68.7	0.095	3.20	46.8
14100800	8.97	14.70	143	3770	5.81	0.465	1.65	101.0	25.9	37.0	50.5	75.1	0.128	2.72	50.7
14101500	398.00	9.85	150	2960	4.77	0.419	1.45	84.3	24.5	37.8	50.0	78.5	0.119	2.10	42.4
14104100	3.92	10.40	134	3860	6.88	0.635	1.99	136.0	26.5	37.0	51.1	72.9	0.113	3.25	52.0
14104500	175.00	8.83	184	2350	3.13	0.295	1.13	41.1	24.5	38.8	50.2	81.5	0.135	1.33	35.0
14107000	152.00	14.00	175	4690	6.80	0.794	1.93	156.0	22.9	32.6	46.6	70.3	0.106	2.71	52.7
14110000	360.00	12.40	159	4520	7.97	0.833	2.10	176.0	23.8	33.2	46.8	70.7	0.102	2.89	52.9
14111800	10.30	10.90	134	4060	4.75	0.316	1.39	76.5	19.4	34.2	43.0	79.1	0.122	1.74	53.4
14112000	81.50	8.37	176	3090	4.31	0.276	1.30	54.9	20.7	35.1	45.3	81.0	0.144	1.42	54.7
14112200	0.73	4.67	250	1910	3.71	0.234	1.19	34.2	22.6	36.5	48.2	83.4	0.168	1.22	53.6
14112500	281.00	6.55	190	2540	4.41	0.254	1.31	52.5	22.1	36.0	46.8	81.9	0.153	1.36	51.9
14113000	1300.00	8.46	176	3050	6.11	0.441	1.66	98.8	23.6	35.5	47.4	78.2	0.134	1.99	53.2
14113200	41.40	12.90	168	2180	5.51	0.281	1.60	62.2	26.0	38.9	52.5	79.8	0.158	1.51	49.8
14113400	4.64	10.10	182	5180	11.80	1.110	3.20	308.0	25.7	35.0	48.8	68.2	0.150	3.74	60.0
14118500	95.80	18.10	177	3140	13.30	1.350	3.25	208.0	25.2	36.2	48.8	71.9	0.150	2.47	49.9
14120000	278.00	15.80	171	3350	11.70	1.070	2.99	223.0	25.0	36.0	49.0	71.3	0.147	2.57	51.8
14121000	332.00	15.00	175	3090	11.00	0.952	2.84	200.0	25.2	36.4	49.5	72.4	0.148	2.39	51.9
14121300	29.60	14.30	213	5190	14.80	1.620	3.52	353.0	24.6	33.5	49.5	66.9	0.108	1.92	52.0
14121500	67.00	9.92	151	3570	12.40	1.370	3.10	178.0	26.0	35.9	50.4	73.4	0.115	2.75	52.5

Appendix G. Selected characteristics for gaged watersheds used in the regional regression analysis – continued.

[**Area**, drainage area, in square miles; **Aspect**, mean watershed aspect, in degrees; **Slope**, mean watershed slope, in degrees; **Elev**, mean watershed elevation, in feet; **Jan P**, mean January precipitation, in inches; **Jul P**, mean July precipitation, in inches; **I24-2**, 2-year 24-hour precipitation intensity, in inches; **Snow**, annual snowfall, in inches; **Mn Jan T**, mean minimum January temperature, in degrees Fahrenheit; **Mx Jan T**, mean maximum January temperature, in degrees Fahrenheit; **Mn Jul T**, mean minimum July temperature, in degrees Fahrenheit; **Mx Jul T**, mean maximum July temperature, in degrees Fahrenheit; **Soil C**, soil storage capacity, in inches; **Soil P**, soil permeability, in inches per hour; **Soil D**, soil depth, in inches]

Station number	Watershed characteristics														
	Area	Aspect	Slope	Elev	Jan P	Jul P	I24-2	Snow	Mn Jan T	Mx Jan T	Mn Jul T	Mx Jul T	Soil C	Soil P	Soil D
14122000	177.00	10.40	171	3930	11.90	1.150	2.93	212.0	25.3	35.1	49.6	72.3	0.110	2.66	52.5
14123000	296.00	10.20	173	3340	10.70	0.852	2.64	172.0	25.1	35.6	49.6	74.8	0.114	2.83	54.2
14123500	386.00	10.70	175	3000	9.89	0.729	2.47	149.0	25.0	35.8	49.8	76.0	0.121	2.51	54.2
14124500	114.00	12.30	166	2970	12.90	0.740	3.03	153.0	25.5	35.2	50.2	74.2	0.101	3.30	55.7
14125000	116.00	12.30	165	2940	12.90	0.733	3.02	152.0	25.5	35.2	50.2	74.3	0.102	3.26	55.7
14125500	134.00	12.60	166	2770	12.50	0.691	2.96	142.0	25.7	35.7	50.4	75.1	0.104	3.01	55.7