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Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)

PREDICTING SOIL EROSION BY WATER: A GUIDE TO CONSERVATION PLANNING WITH THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE)

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ABSTRACT

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The Revised Universal Soil Loss Equation (RUSLE) is an erosion model predicting longtime average annual soil loss (A) resulting from raindrop splash and runoff from specific field slopes in specified cropping and management systems and from rangeland. Widespread use has substantiated the RUSLE's usefulness and validity. RUSLE retains the six factors of Agriculture Handbook No. 537 to calculate A from a hillslope. Technology for evaluating these factor values has been changed and new data added. The technology has been computerized to assist calculation. Thus soil-loss evaluations can be made for conditions not included in the previous handbook using fundamental information available in three data bases: CITY, which includes monthly precipitation and temperature, front-free period, annual rainfall erosivity (R) and twice monthly distributions of storm erosivity (E); CROP, including below-ground biomass, canopy cover, and canopy height at 15-day intervals as well as information on crop characteristics; and OPERATION, reflecting soil and cover disturbances that are associated with typical farming operations.

KEYWORDS: soil erosion, cropland, rangeland, rill erosion, interrill erosion, rainfall-runoff erosivity, soil erodibility, slope length, slope steepness, prior land use, surface cover, crop canopy, surface roughness, soil moisture, contouring, stripcropping, terracing, personal computer, residue decomposition

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CHAPTER 2. RAINFALL-RUNOFF EROSIVITY FACTOR (R)

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CHAPTER 2. CONTENTS

The rainfall and runoff factor (R) of the Universal Soil Loss Equation (USLE) was derived (Wischmeier 1959, Wischmeier and Smith 1958) from research data from many sources. The data indicate that when factors other than rainfall are held constant, soil losses from cultivated fields are directly proportional to a rainstorm parameter: the total storm energy (E) times the maximum 30-min intensity (I_{30}).

Rills and sediment deposits observed after an unusually intense storm have sometimes led to the conclusion that significant erosion is associated with only a few severe storms--that significant erosion is solely a function of peak intensities. However, more than 30 yr of measurements in many states have shown that this is not the case (Wischmeier 1962). The data show that a rainfall factor used to estimate average annual soil loss must include the cumulative effects of the many moderate-sized storms as well as the effects of the occasional severe ones.

The numerical value used for R in USLE and in RUSLE must quantify the effect of raindrop impact and must also reflect the amount and rate of runoff likely to be associated with the rain. The erosion index (R) derived by Wischmeier appears to meet these requirements better than any of the many other rainfall parameters and groups of parameters tested against the plot data. The local value of this index may be obtained directly from maps. However, the index does not include the erosive forces of runoff from snowmelt, rain on frozen soil, or irrigation. A procedure for evaluating R for locations where this type of runoff is significant is given in this chapter under "R Equivalent (R_{eq}) for Cropland in the Northwestern Wheat and Range Region."

In RUSLE, the computational scheme is identical to that used in USLE, with a few exceptions (as noted later).

EI PARAMETER

The value of EI for a given rainstorm equals the product of total storm energy (E) times the maximum 30-min intensity (I_{30}), where E is in hundreds · ft· tonf · $acre^{-1}$, and I_{30} is in in · h^{-1}. EI is an abbreviation for energy times intensity, and the term should *not* be considered simply an energy parameter. Data show that rainfall energy itself is not a good indicator of erosive potential. The storm energy indicates the volume of rainfall and runoff, but a long, slow rain may have the same E value as a shorter rain at much higher intensity. Raindrop erosion increases with intensity. The I_{30} component reflects the prolonged peak rates of detachment and runoff. The product term EI is a statistical interaction term that reflects how total energy and peak intensity are combined in each particular storm. Technically, the term indicates how particle detachment is combined with transport capacity. Appendix B illustrates how the calculations are made from recording-raingage data.

The relation of soil loss to the EI parameter is assumed to be linear, and the parameter's individual storm values are directly additive. The sum of the storm EI values for a given period is a numerical measure of the erosive potential of the rainfall within that period. The average annual total of the storm EI values in a particular locality is the rainfall erosion index (R) for that locality. Because of apparent cyclical patterns in rainfall data, early published values for rainfall erosion indices (for example, in Agriculture Handbook No. 537) were based on 22-yr station rainfall records. Longer records are advisable, especially when the coefficient of variation of annual precipitation is large.

Rain showers of less than 0.5 in were omitted from the erosion index computations, unless at least 0.25 in of rain fell in 15 min. Furthermore, a storm period with less than 0.05 in over 6 h was used to divide a longer storm period into two storms. Exploratory analyses showed that erosion from these light rains is usually too small for practical significance and that, collectively, they have little effect on the distribution of the annual EI or erosion. The cost of abstracting and analyzing 4,000 location-years of rainfall-intensity data used to develop the initial R-factor map was greatly reduced by adopting the threshold value of 0.5 in.

The energy of a rainstorm is a function of the amount of rain and of all the storm's component intensities. The median raindrop size generally increases with greater rain intensity (Wischmeier and Smith 1958), and the terminal velocities of free-falling waterdrops increase with larger drop size (Gunn and Kinzer 1949). Since the energy of a given mass in motion is proportional to velocity squared, rainfall energy is directly related to rain intensity. The relationship, based on the data of Laws and Parsons (1943), is expressed by the equation

$$e = 916 + 331 \log_{10} i, \qquad i \leq 3 \text{ in} \cdot \text{h}^{-1} \qquad [2\text{-}1]$$

$$e = 1074 \qquad i > 3 \text{ in} \cdot \text{h}^{-1} \qquad [2\text{-}2]$$

where e is kinetic energy in $\text{ft} \cdot \text{tonf} \cdot \text{acre}^{-1} \cdot \text{in}^{-1}$, and i is intensity in $\text{in} \cdot \text{h}^{-1}$ (Wischmeier and Smith 1958). A limit of $3 \text{ in} \cdot \text{h}^{-1}$ is imposed on i because median drop size does not continue to increase when intensities exceed $3 \text{ in} \cdot \text{h}^{-1}$ (Carter et al. 1974).

The corresponding SI metric-unit version of the equations are (Foster et al. 1981b, app. A)

$$e_m = 0.119 + 0.0873 \log_{10}(i_m) \qquad i_m \leq 76 \text{ mm} \cdot \text{h}^{-1} \qquad [2\text{-}3]$$

$$e_m = 0.283 \qquad i_m > 76 \text{ mm} \cdot \text{h}^{-1} \qquad [2\text{-}4]$$

where e_m has units of megajoule per hectare per millimeter of rainfall ($\text{MJ} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$).

Other investigators have also presented algorithms for computing the kinetic energy for drop distributions in other geographic areas of the continental United States [for example, McGregor and Mutchler (1977) in Mississippi, Carter et al. (1974) in the South Central United States, Tracy et al. (1984) in southeastern Arizona, and Rosewell (1983, 1986) in Australia].

Brown and Foster (1987) used a unit energy relationship of the form

$$e = e_{max}\left[1 - a\ \exp\ (-b \cdot i)\right] \qquad [2\text{-}5]$$

where

e_{max} = a maximum unit energy as intensity approaches infinity, and

a and b = coefficients.

Kinnell (1981, 1987) showed that this distribution described unit energy-intensity relationships in Zimbabwe and Florida. Additional work by Rosewell (1983, 1986) showed that the relationship also fit data in Australia, the McGregor and Mutchler (1977) data, and the Laws and Parsons (1943) data. Unfortunately, these applications showed some variability in the a and b coefficients. Brown and Foster stated in their analysis that they recommended

$$e_m = 0.29\left[1 - 0.72\ \exp\ (-0.05 i_m)\right] \qquad [2\text{-}6]$$

for calculating unit energy, where e_m has units of MJ · ha^{-1} · mm^{-1} of rain and i_m has units of mm · h^{-1}. Brown and Foster also stated that this equation is a superior analytical form by having a finite positive value at zero intensity as data show and approaching an asymptote at high intensities as a continuous function. The U.S. customary units equivalent of equation [2-6] is

$$e = 1099\left[1 - 0.72\ \exp\ (-1.27\ i)\right] \qquad [2\text{-}7]$$

where i has units of in · h^{-1} and e has units of ft· tonf · acre^{-1} · in^{-1}.

Then

$$R = \frac{\sum_{i-1}^{j} (EI_{30})_i}{N} \qquad [2\text{-}8]$$

where $(EI_{30})_i = EI_{30}$ for storm i, j = number of storms in an N year period.

These equations were used for developing the isoerodent maps of figures 2-1 to 2-4.

The isoerodent maps of figures 2-1 and 2-9 were developed from equations [2-1] and [2-2]. We recommend that all future calculations be made using equation [2-6] or equation [2-7], especially in other countries where RUSLE technology is being developed.

Sample calculations of EI_{30} are given in appendix B.

ISOERODENT MAPS

Local values of the rainfall erosion index may be taken directly from isoerodent maps or from the CITY database in the computer program as explained in chapter 7. The plotted lines on the maps are called isoerodents because they connect points of equal rainfall erosivity. Erosion index values for locations between the lines can be obtained by linear interpolation.

The original isoerodent map (Wischmeier and Smith 1965) was developed from 22-yr station rainfall records by computing the EI value for each storm that met the previously defined threshold criteria. Isoerodents were then located between these point values with the help of published rainfall intensity-frequency data (U.S. Weather Bureau 1958) and topographic maps. The 11 western states were omitted from the initial map because sufficient long-term recording-raingage records were not available for establishing lines of equal erosion index values.

The isoerodent map was extended with an estimation procedure to the Pacific Coast in 1976 and was printed in Agriculture Handbook No. 537. Results of investigations at the USDA-ARS National Soil Erosion Research Laboratory at Purdue University showed that the known erosion index values in the Western Plains States and the North Central States are approximated with reasonable accuracy by the equation $R = 27.38P^{2.17}$ where P is the 2-yr frequency, 6-h rainfall amount (Wischmeier 1974). Although the isoerodents developed were compatible with the few point values that had been established in the western United States, the isoerodents were not sufficiently accurate to reflect the known spatial variability of the mountain and valley topography of the region.

In an agreement between Oregon State University, U.S. Department of Agriculture's Soil Conservation Service (SCS) and Agricultural Research Service (ARS), and the National Weather Service, 713 stations were used to determine relationships between values of EI calculated on a 15-min measurement interval basis and on values of EI calculated for the same storm on a 60-min measurement interval basis. In contrast to the calculations in the eastern United States, all storms were included to calculate EI. Of these stations, 225 had record periods of 12 yr or longer and precipitation measurement resolutions of 0.01 in. Values of coefficient of determination (r^2) in excess of 0.8 were obtained by use of the model $(EI)_{15} = b[\ (EI)_{60}\ ]$.

Values of the regression parameter b ranged from 1.08 to 3.16, varying widely from one climatic zone to the next.

To supplement this work, 1,082 stations were used to calculate $(EI)_{60}$. Of these stations, 790 had 20-yr record lengths or longer. These data values were adjusted to a 15-min measurement interval using the correction cited above. Computed values of $(EI)_{60}$ for each 60-min station were multiplied by the average regression parameter b (computed for all 15-min stations in the climatic zone containing the 60-min station) to obtain equivalent 15-min values, $(EI)_{15}$. These values were then adjusted to an equivalent breakpoint basis by use of $R = 1.0667\ (R)_{15}$ (Weiss 1964). The resulting isoerodent map (R) was prepared by hand contouring the adjusted R values for stations with record periods of at least 20 yr. The resulting isoerodent maps for the West is a significant improvement over that available in Agriculture Handbook No. 537 (Wischmeier and Smith 1978). Seasonal EI distributions were developed for 84 climate zones in the western States. The maximum storm 10-yr-frequency EI values were calculated as part of the project. In this analysis, for areas where winter precipitation is predominantly snowfall, the snowfall months were excluded from the EI development. Thus, in the CITY database, the winter months show zero percent EI.

In Hawaii, isoerodent maps of figure 2-5 were computed by the use of class-A weather stations to compute R and by relating these values to National Weather Service intensity-frequency data for Hawaii. EI distribution data were also calculated for select Hawaiian stations to use in the calculation of seasonally weighted K values (ch. 3) and C values (ch. 5).

If the soil and topography were exactly the same everywhere, average annual soil losses from plots maintained in continuous fallow would be in direct proportion to these erosion index values.

R Values for Flat Slopes

Although the R factor is assumed to be independent of slope in the structure of RUSLE, splash erosion is less on low slopes. On flat surfaces, raindrops tend to be more buffered by water ponded on the soil surface than on steep slopes. Higher rainfall intensities that are correlated with higher R factors also tend to increase the depth of ponded surface water, which in turn protects the soil from rainfall impact (Mutchler 1970). To account for this soil protection by a ponded water layer on low slopes under high rainfall rates, the R factor should be adjusted using a relationship having the form (modified from Mutchler and Murphree 1985)

$$R_c = f\,(I,\ S) = f\,(R,\ S) \qquad [2\text{-}9]$$

where

R_c = rainfall erosivity adjustment factor,
f = function of ( ),
I = precipitation intensity,
S = slope steepness, and
R = RUSLE rainfall erosivity term.

To compute R_c assume that the 10-yr-frequency storm EI value provides an indication of storm intensity and therefore the amount of water ponded on the land surface. In this procedure, the 10-yr EI value of a CITY database is used with a runoff index (a constant CN = 78 was used) and Manning's equation to compute a flow depth ratio, y. This flow depth ratio is then used in the equation $R_c = \exp(-0.49 \cdot [y-1])$. Figure 2-6 is the result of such calculations for a variety of land slopes. For further discussion, refer to chapter 6.

EI DISTRIBUTION USED IN CALCULATION OF K FACTOR AND C FACTOR

To calculate the seasonal or average annual soil erodibility factor (K) and the seasonal or average annual cover-management factor (C), the distribution of EI is needed. In RUSLE, the EI distribution (as a percentage of the annual value) is used for twenty-four 15-d periods, corresponding with the 1st and 16th days of the month.

Figure 2-7 shows the 120 homogeneous climatic zones in the contiguous United States used in RUSLE. The EI distribution values for each of these zones have been determined and are available in the computer code. Table 2-1 shows the EI distributions for the 120 zones and 19 Hawaiian zones, as well as the equivalent EI distribution for the frozen soil area of the Northwestern Wheat and Range Region.

Most of the climatic zones in figure 2-7 also have a single station containing information on precipitation and temperature (by month), the frost-free period, and the annual R. For example, about 140 climate stations (including 19 in Hawaii) are in the computer files. A user of the computer files may want to enter additional climate data for a zone. In other instances, a user may have to enter a climate station into the program before making soil-loss estimates in that region. The climate zones of figure 2-7 represent uniform EI distributions rather than uniform precipitation data or temperature data or both. Thus, in the western United States, orographic trends may pose problems within many of the zones and the user may need to input the additional data to reflect the orographic differences.

Although 19 stations are included in the Hawaiian climatic data files, the tremendous variability in precipitation, R, and temperature are only partially included. Therefore, caution must be used when making soil-loss estimates with RUSLE in Hawaii.

EI DATA FOR 10-YR-FREQUENCY STORMS

In the P-factor calculation for contour farming (ch. 6), the 10-yr-frequency storm EI value is required. These 10-yr EI data are used to credit the effect of contour practices on the support practice value. The values were obtained from the data originally calculated for Agriculture Handbook No. 537 (Wischmeier and Smith 1978) involving 181 stations in the eastern United States and from about 1,000 stations used to develop the isoerodent values in the western United States. The maps of these isoerodent values are given in figures 2-9 to 2-12 for the eastern and western United States.

Site-specific data can be obtained by interpolation from these figures. In the RUSLE computer program (see ch. 7 for the subroutine CITY), these values are given for most stations or they can be obtained by interpolation using the figures.

R EQUIVALENT (R_{eq}) FOR CROPLAND IN THE NORTHWESTERN WHEAT AND RANGE REGION

In the dryfarmed cropland areas of the Northwestern Wheat and Range Region (Austin 1981) shown in figure 2-8, the effect of melting snow, rain on snow, and/or rain on thawing soil poses unique problems. Generally, measured soil-loss values in the regions devoted to winter wheat, spring wheat, spring barley, peas, and lentils are much greater than the value that might be expected from R values calculated with the conventional kinetic energy times maximum 30-min intensity (EI). Observations indicate that much of the soil loss occurs by rilling phenomena when the surface part of the soil profile thaws and snowmelt or rain occurs on the still partially frozen soil. To more accurately predict soil losses for this condition, an R_{eq} value has been calculated using the following procedures:

$$(R_{eq})_{wr} = \frac{A_{wr}}{K_{wr}\ (LS)_{wr}\ (SLR)_{wr}\ P_{wr}} \qquad [2\text{-}10]$$

where

$(R_{eq})_{wr}$ = equivalent R factor for winter rilling,
A_{wr} = soil loss over winter in rills alone (measured),
K_{wr} = rill soil erodibility for winter period (estimated),
$(LS)_{wr}$ = LS relationship,
$(SLR)_{wr}$ = soil loss ratio for rilling in winter period (estimated for field condition), and
P_{wr} = supporting practices factor.

The soil loss from rills (A_{wr}) was measured after the winter erosion season from strips on selected fields along a 45- to 50-mi transect across eastern Washington and northern Idaho for a period of 10 yr. This area was subsequently divided into four zones for presentation and interpretation. Similar soil-loss measurements were made in five counties in north-central Oregon for 5 yr (although data were not collected for each county every year). Soil-loss measurements in southeastern Idaho were made for 4 yr. Thus, the rill soil-loss measurements represent a potential of 10 data points.

The winter erodibility value might be obtained by use of the variable K procedure (ch. 3) and by use of the average value of K for the winter period.

However, in RUSLE, K_{av} (EI-weighted average annual K value) is used throughout the entire year; there is no provision for use of an average K value for a particular portion of the year. Therefore, for consistency, K_{av} was used to calculate $(R_{eq})_{wr}$.

The Northwestern Wheat and Range Region LS relationships in RUSLE (ch. 4) were developed from only the Palouse transect data (eastern Washington and northern Idaho). The following LS relationships were used for $(R_{eq})_{wr}$ calculation:

$$(LS)_{wr} = \left[\frac{\lambda}{72.6}\right]^{0.5} (10.8 \sin\theta + 0.03) \qquad s < 9\% \qquad [2\text{-}11]$$

$$(LS)_{wr} = \left[\frac{\lambda}{72.6}\right]^{0.5} \left[\frac{\sin\theta}{0.0896}\right]^{0.6} \qquad s \geq 9\% \qquad [2\text{-}12]$$

Values of $(LS)_{wr}$ were calculated for each segment of the measured slope based on the contributing area above the segment and the segment steepness.

The soil-loss ratio $(SLR)_{wr}$ was calculated from the following factors:

(1) The rotation was assigned a soil-moisture factor using (see ch. 5) ww/p = 0.88, ww/sf = 1.0, wr = 0.5, and ww/sb = 0.72.

(2) Surface residue effect was calculated from a residue effectiveness curve [exp (-0.05 · % cover)].

(3) Growing cover effect was obtained from [1 - fraction of land surface covered by canopy]. Growing cover was generally less than 10% and often less than 5%.

(4) Surface roughness effect was assigned values from 0.7 to 1.2 based on field observations. Most values used were about 1.1.

(5) Incorporated residue effect was obtained from [exp (-0.00045 · lb acre^{-1} residue incorporated at a shallow depth)]. Shallow incorporated residue was assumed to be half of the residue incorporated less decomposition.

The soil-loss ratio $(SLR)_{wr}$ was then computed as the product of these five factors.

The winter support practices factor (P_{wr}) was assumed to be unity. Thus, $(R_{eq})_{wr}$ was calculated for each year for each zone or county by averaging all segment values.

The individual zone $(R_{eq})_{wr}$ was averaged over the years of record to obtain a zonal average value. The data points were reduced from 10 to 7 based on the number of segments and strips in a zone or county in a given year and on the number of years of data in a zone or county. The three points deleted were all from north-central Oregon. These average values were subsequently correlated against published annual precipitation for corresponding zones to obtain

$$\left(R_{eq}\right)_{wr} = -110.3 + 10.78\ P \qquad r^2 = 0.98 \tag{2-13}$$

where P = annual precipitation (in).

Adjustment for Interrill and Non-Winter Soil Loss

Measurements of the rill to interrill ratio soil loss in the Northwestern Wheat and Range Region vary greatly. For example, rill-erosion measurements near the Columbia Plateau Conservation Research Center near Pendleton, Oregon, indicate about a 95% rill soil loss. A rule of thumb based on the old Pullman Conservation Field Station (PCFS) plots near Pullman, Washington, was that 75% of the soil loss came from rill erosion. Recent measurements over a 4-yr period from continuous fallow plots at the PCFS indicate that 85-90% of the soil loss came from rill erosion. In other instances (and varying with treatments), the attempts to separate interrill losses from total soil loss have been essentially unsuccessful. Thus, a somewhat arbitrary ratio of 90% rill loss and 10% interrill soil loss was assumed to adjust the $(R_{eq})_{wr}$ to estimate the total winter equivalent R, $(R_{eq})_{wt}$.

Then

$$\left(R_{eq}\right)_{wt} = \left(R_{eq}\right)_{wr} \cdot \frac{100}{90} \tag{2-14}$$

The nonwinter component of soil loss was estimated in two ways, each of which gives a ratio of roughly 5% of the annual R_{eq} occurring during the nonwinter periods. Thus, we estimate total annual soil loss as

$$R_{eq} = \left(R_{eq}\right)_{wr} \cdot \frac{100}{90} \cdot \frac{100}{95} \qquad [2\text{-}15]$$

and finally

$$R_{eq} = -129.0 + 12.61P \qquad [2\text{-}16]$$

For lower precipitation areas of the Northwest Wheat and Range Region with a frozen soil erosion problem, the following relationship will provide a smooth transition from the R_{eq} to the non-R_{eq} zone:

$$R_{eq} = 1.602 \exp(0.2418\ P) \qquad 7.5 < P < 15.0 \qquad [2\text{-}17]$$

Equation 2-17 should be used for $P \leq 15.0$.

The P and R_{eq} maps for the cultivated areas farmed with winter wheat, spring wheat, spring barley, peas, or lentils in the Northwestern Wheat and Range Region are shown in figures 2-13 to 2-16. The small-grain areas include higher elevation forest and grazing land as well as the cultivated valleys and lower slopes. In general, winter wheat is not grown where P is greater than about 35 in. Thus, no R_{eq} values greater than 320 ($P = 35.6$ in) are plotted in figures 2-15 and 2-16.

It was necessary to distribute the R_{eq} throughout the year. The nonwinter component (5% of the total) was distributed uniformly from April 1 through September 30. The winter component (95% of the total) was distributed from October 1 through March 31. Based on historical soil-loss data from PCFS, the period of major erosivity was assigned to late January and early February. Erosivity then tapered gradually to October 1 and more steeply to March 31 (see Pullman, WA, CITY database for the R_{eq} distribution data).

RAINFALL EROSIVITY IN A COLD MOUNTAINOUS CLIMATE

Data analysis from the precipitation network in southwestern Idaho indicate major problems in assessing the erosivity index. The problems are not uniquely different from those in the Northwestern Wheat and Range Region (area of winter wheat, spring barley, peas, and lentils). RUSLE (and also its predecessor USLE) was designed to account for the effects of raindrop impact and subsequent overland flow on soil erosion (Cooley et al. 1988). In much of the western United States, precipitation occurring as snow should also be accounted for if representative EI estimates are to be produced.

Cooley et al. (1988) found that snowfall accounted for only a minor portion (4%) of EI based on annual precipitation values at low-elevation valley sites. However, at high elevation sites, snowfall accounted for most (up to 71%) of the annual precipitation. Therefore, it is important to use only the rainfall portion of annual precipitation when determining EI in areas where snowfall is significant, rather than using total annual precipitation.

Elevation was observed to have a relatively minor influence on summer (rain) EI values. Summer storms are mainly produced by air-mass thunderstorms and tend to be more random in location and smaller in areal extent than are frontal storms.

The consideration of all storms in estimating EI, rather than only storms that result in more than 0.5 in rainfall [per Wischmeier and Smith (1978) procedure], increased EI by 28-59% on the Reynolds Creek watershed. However, runoff and erosion data for evaluating the significance of these increases were not available.

Cooley et al. (1988) also tested several methods of computing average annual R involving 2-yr-frequency, 6-h-duration precipitation for comparison with long-term breakpoint-data R values (table 2-2). In mountain and range topography like that of southwestern Idaho, caution must be exercised in selecting storm values because snow events can affect the value. Cooley et al. (1988) observed that the storm value decreased by 5-34% when snowfall was eliminated from the annual data set. R decreased by 4-42% when snowfall was removed; that is, summer values were used instead of annual values.

SOUTHWESTERN AIR-MASS THUNDERSTORM

Precipitation gages operated by ARS in Arizona and New Mexico were used to compute EI data for areas dominated by air-mass thunderstorms. Of particular interest is the fact that EI during the summer period amounted to 85-93% of the annual total, which was 50-81 hundreds · ft· tonf · (acre · in · yr)$^{-1}$ (Renard and Simanton 1975).

In still other efforts, Simanton and Renard (1982) calculated the EI for a storm on the 57.7-sq-mi Walnut Gulch Experimental watershed in southeastern Arizona. Figure 2-17 shows the isohyetal values of precipitation determined for the 100 recording raingages for the event of July 22, 1964, and the corresponding isoerodent map. It should be noted that the isoerodent lines have little correlation with the isohyetal lines. An intense air-mass thunderstorm near the upper end of the area caused nearly 100 units of EI whereas only a short distance away (about 5 mi), the EI was less than 50% of the storm maximum.

Figure 2-18 illustrates the annual isohyetal map and the annual isoerodent (R) map, including the data of figure 2-17 plus the other storms occurring during the year. The highly variable rainfall illustrated in figures 2-17 and 2-18 is very typical of air-mass-thunderstorm country as shown on the isoerodent map. The 1.9 ratio of maximum to minimum annual precipitation and the 4.0 ratio of maximum to minimum R are normal occurrences.

The significance of these illustrations is that a single raingage and the EI calculations from it may be inadequate indicators of the soil loss at any specific point unless the precipitation record is collected at that site.

LIMITATIONS IN WINTER R FACTORS

Agriculture Handbook No. 537 suggests that the rainfall erosivity value (R) might be adjusted by multiplying the precipitation falling in the form of snow by 1.5 and then adding the product to EI, the kinetic energy times maximum 30-min intensity. This calculation has been used in the past at some locations, but we currently do not support this approach in RUSLE. The redistribution of snow by drifting, sublimation, and reduced sediment concentrations in snowmelt confuses the problem tremendously. But data are not presently available to support this approximation. Therefore, the developers of RUSLE recognized the weakness of ignoring the problem (except in the cropland areas of the Northwestern Wheat and Range Region where the R_{eq} data are being used).

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Table 2-1.
EI as percentage of average annual value computed for geographic areas shown in figure 2-7[1] [2]

EI	Periods																						
number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.0	4.3	8.3	12.8	17.3	21.6	25.1	28.0	30.9	34.9	39.1	42.6	45.4	48.2	50.8	53.0	56.0	60.8	66.8	71.0	75.7	82.0	89.1	95.2
2	0.0	4.3	8.3	12.8	17.3	21.6	25.1	28.0	30.9	34.9	39.1	42.6	45.4	48.2	50.8	53.0	56.0	60.8	66.8	71.0	75.7	82.0	89.1	95.2
3	0.0	7.4	13.8	20.9	26.5	31.8	35.3	38.5	40.2	41.6	42.5	43.6	44.5	45.1	45.7	46.4	47.7	49.4	52.8	57.0	64.5	73.1	83.3	92.3
4	0.0	3.9	7.9	12.6	17.4	21.6	25.2	28.7	31.9	35.1	38.2	42.0	44.9	46.7	48.2	50.1	53.1	56.6	62.2	67.9	75.2	83.5	90.5	96.0
5	0.0	2.3	3.6	4.7	6.0	7.7	10.7	13.9	17.8	21.2	24.5	28.1	31.1	33.1	35.3	38.2	43.2	48.7	57.3	67.8	77.9	86.0	91.3	96.9
6	0.0	0.0	0.0	0.5	2.0	4.1	8.1	12.6	17.6	21.6	25.5	29.6	34.5	40.0	45.7	50.7	55.6	60.2	66.5	75.5	85.6	95.9	99.5	99.9
7	0.0	0.0	0.0	0.0	0.0	1.2	4.9	8.5	13.9	19.0	26.1	35.4	43.9	48.8	53.9	64.5	73.4	77.5	80.4	84.8	89.9	96.6	99.2	99.7
8	0.0	0.0	0.0	0.0	0.0	0.9	3.6	7.8	15.0	20.2	27.4	38.1	49.8	57.9	65.0	75.6	82.7	86.8	89.4	93.4	96.3	99.1	100.0	100.0
9	0.0	0.8	3.1	4.7	7.4	11.7	17.8	22.5	27.0	31.4	36.0	41.6	46.4	50.1	53.4	57.4	61.7	64.9	69.7	79.0	89.6	97.4	100.0	100.0
10	0.0	0.3	0.5	0.9	2.0	4.3	9.2	13.1	18.0	22.7	29.2	39.5	46.3	48.8	51.1	57.2	64.4	67.7	71.1	77.2	85.1	92.5	96.5	99.0
11	0.0	5.4	11.3	18.8	26.3	33.2	37.4	40.7	42.5	44.3	45.4	46.5	47.1	47.4	47.8	48.3	49.4	50.7	53.6	57.5	65.5	76.2	87.4	94.8
12	0.0	3.5	7.8	14.0	21.1	27.4	31.5	35.0	37.3	39.8	41.9	44.3	45.6	46.3	46.8	47.9	50.0	52.9	57.9	62.3	69.3	81.3	91.5	96.7
13	0.0	0.0	0.0	1.8	7.2	11.9	16.7	19.7	24.0	31.2	42.4	55.0	60.0	60.8	61.2	62.6	65.3	67.6	71.6	76.1	83.1	93.3	98.2	99.6
14	0.0	0.7	1.8	3.3	6.9	16.5	26.6	29.9	32.0	35.4	40.2	45.1	51.9	61.1	67.5	70.7	72.8	75.4	78.6	81.9	86.4	93.6	97.7	99.3
15	0.0	0.0	0.0	0.5	2.0	4.4	8.7	12.0	16.6	21.4	29.7	44.5	56.0	60.8	63.9	69.1	74.5	79.1	83.1	87.0	90.9	96.6	99.1	99.8
16	0.0	0.0	0.0	0.5	2.0	5.5	12.3	16.2	20.9	26.4	35.2	48.1	58.1	63.1	66.5	71.9	77.0	81.6	85.1	88.4	91.5	96.3	98.7	99.6
17	0.0	0.0	0.0	0.7	2.8	6.1	10.7	12.9	16.1	21.9	32.8	45.9	55.5	60.3	64.0	71.2	77.2	80.3	83.1	87.7	92.6	97.2	99.1	99.8
18	0.0	0.0	0.0	0.6	2.5	6.2	12.4	16.4	20.2	23.9	29.3	37.7	45.6	49.8	53.3	58.4	64.3	69.0	75.0	86.6	93.9	96.6	98.0	100.0
19	0.0	1.0	2.6	7.4	16.4	23.5	28.0	31.0	33.5	37.0	41.7	48.1	51.1	52.0	52.5	53.6	55.7	57.6	61.1	65.8	74.7	88.0	95.8	98.7
20	0.0	9.8	18.5	25.4	30.2	35.6	38.9	41.5	42.9	44.0	45.2	48.2	50.8	51.7	52.5	54.6	57.4	58.5	60.1	63.2	69.6	76.7	85.4	92.4
21	0.0	7.5	13.6	18.1	21.1	24.4	27.0	29.4	31.7	34.6	37.3	39.6	41.6	43.4	45.4	48.1	51.3	53.3	56.6	62.4	72.4	81.3	88.9	94.7
22	0.0	1.2	1.6	1.6	1.6	1.6	1.6	2.2	3.9	4.6	6.4	14.2	32.8	47.2	58.8	69.1	76.0	82.0	87.1	96.7	99.9	99.9	99.9	99.9
23	0.0	7.9	15.0	20.9	25.7	31.1	35.7	40.2	43.2	46.2	47.7	48.8	49.4	49.9	50.7	51.8	54.1	57.7	62.8	65.9	70.1	77.3	86.8	93.5
24	0.0	12.2	23.6	33.0	39.7	47.1	51.7	55.9	57.7	58.6	58.9	59.1	59.1	59.2	59.2	59.3	59.5	60.0	61.4	63.0	66.5	71.8	81.3	89.6
25	0.0	9.8	20.8	30.2	37.6	45.8	50.6	54.4	56.0	56.8	57.1	57.1	57.2	57.6	58.5	59.8	62.2	65.3	67.5	68.2	69.4	74.8	86.6	93.0

Table 2-1—Continued

EI	Periods																						
number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
26	0.0	2.0	5.4	9.8	15.6	21.5	24.7	26.6	27.4	28.0	28.7	29.8	32.5	36.6	44.9	55.4	65.7	72.6	77.8	84.4	89.5	93.9	96.5	98.4
27	0.0	0.0	0.0	1.0	4.0	5.9	8.0	11.1	13.0	14.0	14.6	15.3	17.0	23.2	39.1	60.0	76.3	86.1	89.7	90.4	90.9	93.1	96.6	99.1
28	0.0	0.0	0.0	0.0	0.2	0.5	1.5	3.3	7.2	11.9	17.7	21.4	27.0	37.1	51.4	62.3	70.6	78.8	84.6	90.6	94.4	97.9	99.3	100.0
29	0.0	0.6	0.7	0.7	0.7	1.5	3.9	6.0	10.5	17.9	28.8	36.6	43.8	51.5	59.3	68.0	74.8	80.3	84.3	88.8	92.7	98.0	99.8	99.9
30	0.0	0.0	0.0	0.0	0.0	0.2	0.8	2.8	7.9	14.2	24.7	35.6	45.4	52.2	58.7	68.5	77.6	84.5	88.9	93.7	96.2	97.6	98.3	99.6
31	0.0	0.0	0.0	0.0	0.0	0.2	1.0	3.5	9.9	15.7	26.4	47.2	61.4	65.9	69.0	77.2	86.0	91.6	94.8	98.7	100.0	100.0	100.0	100.0
32	0.0	0.1	0.1	0.1	0.1	0.6	2.2	4.3	9.0	14.2	23.3	34.6	46.3	54.2	61.7	72.9	82.5	89.6	93.7	98.2	99.7	99.9	99.9	99.9
33	0.0	0.0	0.0	0.0	0.0	0.6	2.3	4.2	8.8	16.1	30.0	46.9	57.9	62.8	66.2	72.1	79.1	85.9	91.1	97.0	98.9	98.9	98.9	98.9
34	0.0	0.0	0.0	0.0	0.0	1.8	7.3	10.7	15.5	22.0	29.9	35.9	42.0	48.5	56.9	67.0	76.9	85.8	91.2	95.7	97.8	99.6	100.0	100.0
35	0.0	0.0	0.0	0.0	0.0	2.5	10.2	15.9	22.2	27.9	34.7	43.9	51.9	56.9	61.3	67.3	73.9	80.1	85.1	89.6	93.2	98.2	99.8	99.8
36	0.0	0.0	0.0	0.0	0.0	0.9	3.4	6.7	12.7	18.5	26.6	36.3	46.0	53.5	60.2	68.3	75.8	82.6	88.3	96.3	99.3	99.9	100.0	100.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.9	9.1	19.1	26.7	36.3	47.9	61.4	75.1	84.5	92.3	96.0	99.1	100.0	100.0	100.0	100.0
38	0.0	0.0	0.0	1.1	4.3	7.2	11.0	13.9	17.9	22.3	30.3	43.1	55.1	61.3	65.7	72.1	77.9	82.6	86.3	90.3	93.8	98.4	100.0	100.0
39	0.0	0.0	0.0	0.0	0.0	1.6	6.5	11.0	17.8	24.7	33.1	42.8	50.3	54.9	59.7	68.9	78.1	83.6	87.5	93.0	96.5	99.2	100.0	100.0
40	0.0	0.0	0.0	0.0	0.0	1.5	6.2	10.1	16.3	23.3	32.5	42.2	50.1	55.6	60.5	67.5	74.3	79.4	84.1	91.1	95.8	99.1	100.0	100.0
41	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.4	1.1	6.8	22.9	40.1	54.9	63.8	70.7	81.5	89.8	96.3	98.7	99.2	99.3	99.4	99.4	99.7
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	5.2	17.3	33.8	53.2	66.5	75.9	87.6	93.7	97.5	99.0	99.7	100.0	100.0	100.0	100.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	2.7	9.5	21.9	42.7	58.6	71.1	84.6	91.9	97.1	99.0	99.8	100.0	100.0	100.0	100.0
44	0.0	1.7	2.3	2.4	2.4	2.4	2.4	2.7	3.5	7.6	18.5	34.3	52.5	64.0	72.3	83.3	90.0	95.1	97.3	98.5	98.9	98.9	98.9	99.2
45	0.0	0.2	0.2	0.3	0.3	0.4	0.6	0.8	1.4	3.7	10.2	22.6	41.8	54.0	64.5	78.7	88.4	96.0	98.7	99.4	99.7	99.7	99.8	99.9
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	2.6	7.5	19.6	32.9	48.9	63.0	73.5	83.3	89.5	95.6	98.3	99.6	100.0	100.0	100.0	100.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.6	5.8	17.0	33.0	52.5	66.4	75.7	85.5	91.3	96.5	98.8	100.0	100.0	100.0	100.0	100.0
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	8.1	15.4	27.8	40.7	52.6	61.1	69.3	82.6	92.0	98.0	100.0	100.0	100.0	100.0
49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.7	8.3	20.0	27.5	35.6	44.6	46.0	70 2	81.3	89.2	93.6	98.5	100.0	100.0	100.0	100.0
50	0.0	0.0	0.0	0.0	0.0	0.1	0.4	2.4	8.2	13.7	23.8	38.8	55.1	66.1	73.6	81.8	87.7	93.8	97.0	99.4	100.0	100.0	100.0	100.0

Table 2-1—Continued

EI	Periods																							
number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
51	0.0	0.0	0.0	0.0	0.0	0.3	1.0	3.1	8.7	18.8	35.8	49.6	60.4	70.2	77.0	84.0	88.8	93.8	96.6	99.1	100.0	100.0	100.0	100.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	2.5	6.8	17.5	29.8	46.1	60.5	72.7	86.0	92.8	96.8	98.4	99.7	100.0	100.0	100.0	100.0
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.0	9.5	24.2	35.3	48.0	63.1	76.1	87.7	93.5	97.2	98.6	99.5	99.8	99.9	100.0	100.0
54	0.0	0.0	0.0	0.0	0.0	0.2	0.7	2.4	7.2	14.7	27.2	37.2	47.3	58.8	67.6	74.0	79.2	86.7	92.6	97.9	99.8	99.9	100.0	100.0
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	5.4	13.3	25.5	31.6	38.8	52.5	66.8	75.5	81.2	87.9	92.8	98.3	100.0	100.0	100.0	100.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	5.1	11.4	22.3	29.5	38.5	51.1	65.2	77.8	85.6	91.7	95.0	98.7	100.0	100.0	100.0	100.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	3.5	9.2	21.5	31.0	43.5	60.4	75.1	86.1	91.6	96.2	98.1	99.4	99.9	99.9	100.0	100.0
58	0.0	0.0	0.0	0.0	0.0	0.2	0.9	2.9	8.0	13.2	21.0	29.1	38.0	45.9	54.5	65.4	74.8	82.1	87.5	95.4	98.8	99.7	100.0	100.0
59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	8.9	15.6	24.2	31.1	38.3	46.0	54.9	64.2	73.2	81.9	88.5	95.7	98.6	99.4	99.7	99.7
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.5	4.0	9.5	13.3	20.5	33.6	52.8	66.5	76.7	88.1	94.2	98.6	100.0	100.0	100.0	100.0
61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	5.0	8.5	15.5	29.8	41.8	46.0	49.2	56.0	65.1	71.6	78.6	91.1	97.3	99.3	100.0	100.0
62	0.0	0.0	0.0	0.1	0.3	0.8	2.1	3.6	6.5	9.7	13.7	16.5	20.8	27.3	40.1	56.9	72.6	83.4	89.4	95.5	98.1	99.6	100.0	100.0
63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.7	7.8	13.3	15.8	19.9	29.0	46.8	64.7	78.3	88.8	93.9	98.5	100.0	100.0	100.0	100.0
64	0.0	0.0	0.0	0.7	2.8	7.4	12.4	14.4	15.6	17.3	19.4	21.0	24.4	32.3	48.0	61.4	72.1	81.9	87.0	90.1	92.4	98.1	100.0	100.0
65	0.0	3.6	7.0	9.6	11.4	13.0	14.4	16.3	17.7	18.4	19.3	20.5	23.6	32.0	50.0	66.2	77.2	85.4	88.8	90.4	91.3	92.7	94.8	97.0
66	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.1	2.2	3.6	6.0	7.6	11.1	19.8	38.9	59.7	74.4	83.2	88.1	94.6	97.7	99.4	100.0	100.0
67	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.9	1.6	1.9	2.4	5.0	12.1	24.8	48.3	73.6	86.5	92.0	94.3	96.6	97.9	99.5	100.0	100.0
68	0.0	2.3	4.5	7.8	10.4	12.0	13.3	16.3	17.7	18.1	18.2	18.3	18.4	19.9	24.5	35.0	54.4	69.4	78.6	85.7	89.2	91.9	93.9	97.0
69	0.0	2.0	3.7	5.7	7.8	10.5	12.4	13.7	14.3	14.7	15.1	15.7	17.1	22.7	36.7	50.4	63.6	75.0	81.8	87.8	90.8	93.2	94.9	97.5
70	0.0	0.5	0.7	1.0	1.3	1.7	2.2	2.8	3.4	3.9	4.7	5.4	7.4	15.7	36.5	55.8	70.3	80.9	86.4	90.9	93.4	96.4	98.1	99.4
71	0.0	0.7	1.2	1.6	2.1	2.8	3.3	3.6	4.0	4.5	5.6	6.5	9.1	18.5	40.6	59.7	74.0	86.3	91.7	94.7	96.0	96.7	97.3	98.8
72	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.7	0.8	1.3	3.5	9.9	24.7	51.4	71.5	83.6	93.8	97.7	99.2	99.8	99.9	99.9	100.0
73	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.6	1.3	4.1	11.5	18.1	28.3	40.2	54.1	67.0	77.2	87.7	93.3	97.5	99.1	99.6	99.8	100.0
74	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	1.2	2.7	6.4	10.2	18.4	31.0	50.7	68.7	81.2	91.6	96.1	98.4	99.2	99.8	100.0	100.0
75	0.0	0.1	0.1	0.1	0.2	0.5	1.3	1.9	3.0	4.1	6.6	10.0	17.6	28.3	44.7	59.4	71.6	83.9	90.3	94.7	96.7	98.8	99.6	99.9

Table 2-1—Continued

EI	Periods																						
number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
76	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.6	1.3	2.0	3.5	4.9	8.4	17.4	37.3	57.5	72.9	83.7	89.5	95.8	98.4	99.6	100.0	100.0
77	0.0	0.2	0.3	0.3	0.4	0.8	1.5	2.0	2.8	3.9	5.9	7.2	10.3	21.5	46.5	66.3	78.3	86.5	90.8	96.0	98.2	99.1	99.5	99.8
78	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	1.6	3.8	8.9	13.2	21.8	35.8	56.6	75.4	86.0	92.9	95.9	98.2	99.2	99.8	100.0	100.0
79	0.0	0.0	0.0	0.0	0.0	0.2	0.7	1.3	2.7	5.8	12.7	18.8	28.8	41.6	58.4	75.7	86.5	94.2	97.3	98.9	99.5	99.9	100.0	100.0
80	0.0	0.6	1.2	1.6	2.1	2.5	3.3	4.5	6.9	10.1	15.5	19.7	26.6	36.4	51.7	67.5	79.4	88.8	93.2	96.1	97.3	98.2	98.7	99.3
81	0.0	0.1	0.1	0.2	0.4	0.5	0.8	0.9	1.5	3.9	9.9	12.8	18.2	30.7	54.1	77.1	89.0	94.9	97.2	98.7	99.3	99.6	99.7	99.9
82	0.0	0.0	0.1	0.1	0.2	0.2	0.5	1.2	3.1	6.7	14.4	20.1	29.8	44.5	64.2	83.1	92.2	96.4	98.1	99.3	99.7	99.8	99.8	99.9
83	0.0	0.0	0.1	0.1	0.1	0.3	0.9	1.6	3.5	8.3	19.4	30.0	44.0	59.2	72.4	84.6	91.2	96.5	98.6	99.5	99.8	99.9	100.0	100.0
84	0.0	0.0	0.1	0.1	0.2	0.3	0.6	1.7	4.9	9.9	19.5	27.2	38.3	52.8	68.8	83.9	91.6	96.4	98.2	99.2	99.6	99.8	99.8	99.9
85	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	3.0	6.0	11.0	23.0	36.0	49.0	63.0	77.0	90.0	95.0	98.0	99.0	100.0	100.0	100.0	100.0
86	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	3.0	6.0	11.0	23.0	36.0	49.0	63.0	77.0	90.0	95.0	98.0	99.0	100.0	100.0	100.0	100.0
87	0.0	0.0	0.0	0.0	1.0	1.0	2.0	3.0	6.0	10.0	17.0	29.0	43.0	55.0	67.0	77.0	85.0	91.0	96.0	98.0	99.0	100.0	100.0	100.0
88	0.0	0.0	0.0	0.0	1.0	1.0	2.0	3.0	6.0	13.0	23.0	37.0	51.0	61.0	69.0	78.0	85.0	91.0	94.0	96.0	98.0	99.0	99.0	100.0
89	0.0	0.0	1.0	1.0	2.0	3.0	4.0	7.0	12.0	18.0	27.0	38.0	48.0	55.0	62.0	69.0	76.0	83.0	90.0	94.0	97.0	98.0	99.0	100.0
90	0.0	1.0	2.0	3.0	4.0	6.0	8.0	13.0	21.0	29.0	37.0	46.0	54.0	60.0	65.0	69.0	74.0	81.0	87.0	92.0	95.0	97.0	98.0	99.0
91	0.0	0.0	0.0	0.0	1.0	1.0	1.0	2.0	6.0	16.0	29.0	39.0	46.0	53.0	60.0	67.0	74.0	81.0	88.0	95.0	99.0	99.0	100.0	100.0
92	0.0	0.0	0.0	0.0	1.0	1.0	1.0	2.0	6.0	16.0	29.0	39.0	46.0	53.0	60.0	67.0	74.0	81.0	88.0	95.0	99.0	99.0	100.0	100.0
93	0.0	1.0	1.0	2.0	3.0	4.0	6.0	8.0	13.0	25.0	40.0	49.0	56.0	62.0	67.0	72.0	76.0	80.0	85.0	91.0	97.0	98.0	99.0	99.0
94	0.0	1.0	2.0	4.0	6.0	8.0	10.0	15.0	21.0	29.0	38.0	47.0	53.0	57.0	61.0	65.0	70.0	76.0	83.0	88.0	91.0	94.0	96.0	98.0
95	0.0	1.0	3.0	5.0	7.0	9.0	11.0	14.0	18.0	27.0	35.0	41.0	46.0	51.0	57.0	62.0	68.0	73.0	79.0	84.0	89.0	93.0	96.0	98.0
96	0.0	2.0	4.0	6.0	9.0	12.0	17.0	23.0	30.0	37.0	43.0	49.0	54.0	58.0	62.0	66.0	70.0	74.0	78.0	82.0	86.0	90.0	94.0	97.0
97	0.0	1.0	3.0	5.0	7.0	10.0	14.0	20.0	28.0	37.0	48.0	56.0	61.0	64.0	68.0	72.0	77.0	81.0	86.0	89.0	92.0	95.0	98.0	99.0
98	0.0	1.0	2.0	4.0	6.0	8.0	10.0	13.0	19.0	26.0	34.0	42.0	50.0	58.0	63.0	68.0	74.0	79.0	84.0	89.0	93.0	95.0	97.0	99.0
99	0.0	0.0	0.0	1.0	1.0	2.0	3.0	5.0	7.0	12.0	19.0	33.0	48.0	57.0	65.0	72.0	82.0	88.0	93.0	96.0	98.0	99.0	100.0	100.0
100	0.0	0.0	0.0	0.0	1.0	1.0	2.0	3.0	5.0	9.0	15.0	27.0	38.0	50.0	62.0	74.0	84.0	91.0	95.0	97.0	98.0	99.0	99.0	100.0

Table 2-1—Continued

EI	Periods																							
number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
101	0.0	0.0	0.0	1.0	2.0	3.0	4.0	6.0	9.0	14.0	20.0	28.0	39.0	52.0	63.0	72.0	80.0	87.0	91.0	94.0	97.0	98.0	99.0	100.0
102	0.0	0.0	1.0	2.0	3.0	4.0	6.0	8.0	11.0	15.0	22.0	31.0	40.0	49.0	59.0	69.0	78.0	85.0	91.0	94.0	96.0	98.0	99.0	100.0
103	0.0	1.0	2.0	3.0	4.0	6.0	8.0	10.0	14.0	18.0	25.0	34.0	45.0	56.0	64.0	72.0	79.0	84.0	89.0	92.0	95.0	97.0	98.0	99.0
104	0.0	2.0	3.0	5.0	7.0	10.0	13.0	16.0	19.0	23.0	27.0	34.0	44.0	54.0	63.0	72.0	80.0	85.0	89.0	91.0	93.0	95.0	96.0	98.0
105	0.0	1.0	3.0	6.0	9.0	12.0	16.0	21.0	26.0	31.0	37.0	43.0	50.0	57.0	64.0	71.0	77.0	81.0	85.0	88.0	91.0	93.0	95.0	97.0
106	0.0	3.0	6.0	9.0	13.0	17.0	21.0	27.0	33.0	38.0	44.0	49.0	55.0	61.0	67.0	71.0	75.0	78.0	81.0	84.0	86.0	90.0	94.0	97.0
107	0.0	3.0	5.0	7.0	10.0	14.0	18.0	23.0	27.0	31.0	35.0	39.0	45.0	53.0	60.0	67.0	74.0	80.0	84.0	86.0	88.0	90.0	93.0	95.0
108	0.0	3.0	6.0	9.0	12.0	16.0	20.0	24.0	28.0	33.0	38.0	43.0	50.0	59.0	69.0	75.0	80.0	84.0	87.0	90.0	92.0	94.0	96.0	98.0
109	0.0	3.0	6.0	10.0	13.0	16.0	19.0	23.0	26.0	29.0	33.0	39.0	47.0	58.0	68.0	75.0	80.0	83.0	86.0	88.0	90.0	92.0	95.0	97.0
110	0.0	1.0	3.0	5.0	7.0	9.0	12.0	15.0	18.0	21.0	25.0	29.0	36.0	45.0	56.0	68.0	77.0	83.0	88.0	91.0	93.0	95.0	97.0	99.0
111	0.0	1.0	2.0	3.0	4.0	5.0	6.0	8.0	11.0	15.0	20.0	28.0	41.0	54.0	65.0	74.0	82.0	87.0	92.0	94.0	96.0	97.0	98.0	99.0
112	0.0	0.0	0.0	1.0	2.0	3.0	4.0	5.0	7.0	12.0	17.0	24.0	33.0	42.0	55.0	67.0	76.0	83.0	89.0	92.0	94.0	96.0	98.0	99.0
113	0.0	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	13.0	17.0	22.0	31.0	42.0	52.0	60.0	68.0	75.0	80.0	85.0	89.0	92.0	96.0	98.0
114	0.0	1.0	2.0	4.0	6.0	8.0	11.0	13.0	15.0	18.0	21.0	26.0	32.0	38.0	46.0	55.0	64.0	71.0	77.0	81.0	85.0	89.0	93.0	97.0
115	0.0	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	14.0	19.0	26.0	34.0	45.0	56.0	66.0	76.0	82.0	86.0	90.0	93.0	95.0	97.0	99.0
116	0.0	1.0	3.0	5.0	7.0	9.0	12.0	15.0	18.0	21.0	25.0	29.0	36.0	45.0	56.0	68.0	77.0	83.0	88.0	91.0	93.0	95.0	97.0	99.0
117	0.0	1.0	2.0	3.0	4.0	5.0	7.0	9.0	11.0	14.0	17.0	22.0	31.0	42.0	54.0	65.0	74.0	83.0	89.0	92.0	95.0	97.0	98.0	99.0
118	0.0	1.0	2.0	3.0	5.0	7.0	10.0	14.0	18.0	22.0	27.0	32.0	37.0	46.0	58.0	69.0	80.0	89.0	93.0	94.0	95.0	96.0	97.0	97.0
119	0.0	2.0	4.0	6.0	8.0	12.0	16.0	20.0	25.0	30.0	35.0	41.0	47.0	56.0	67.0	75.0	81.0	85.0	87.0	89.0	91.0	93.0	95.0	97.0
120	0.0	1.0	2.0	4.0	6.0	7.0	9.0	12.0	15.0	18.0	23.0	31.0	40.0	48.0	57.0	63.0	72.0	78.0	88.0	92.0	96.0	97.0	98.0	99.0
[2]121	0.0	8.0	16.0	25.0	33.0	41.0	46.0	50.0	53.0	54.0	55.0	56.0	56.5	57.0	57.8	58.0	58.8	60.0	61.0	63.0	66.5	72.0	80.0	90.0
122	0.0	7.0	14.0	20.0	25.5	33.5	38.0	43.0	46.0	50.0	52.5	54.5	56.0	58.0	59.0	60.0	61.5	63.0	65.0	68.0	72.0	79.0	86.0	93.0
123	0.0	4.0	8.0	12.0	17.0	23.0	29.0	34.0	38.0	44.0	49.0	53.0	56.0	59.0	62.0	65.0	69.0	72.0	75.0	79.0	83.0	88.0	93.0	96.0
124	0.0	4.0	9.0	15.0	23.0	29.0	34.0	40.0	44.0	48.0	50.0	51.0	52.0	53.0	55.0	57.0	60.0	62.0	64.0	67.0	72.0	80.0	88.0	95.0
125	0.0	7.0	12.0	17.0	24.0	30.0	39.0	45.0	50.0	53.0	55.0	56.0	57.0	58.0	59.0	61.0	62.0	63.0	64.0	66.0	70.0	77.0	84.0	92.0

Table 2-1—Continued

EI	Periods																							
number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
126	0.0	9.0	16.0	23.0	30.0	37.0	43.0	47.0	50.0	52.0	54.0	55.0	56.0	57.0	58.0	59.0	60.0	62.0	64.0	67.0	71.0	77.0	86.0	93.0
127	0.0	8.0	15.0	22.0	28.0	33.0	38.0	42.0	46.0	50.0	52.0	53.0	53.0	53.0	53.0	54.0	55.0	57.0	59.0	63.0	68.0	75.0	83.0	92.0
128	0.0	8.0	15.0	22.0	29.0	34.0	40.0	45.0	48.0	51.0	54.0	57.0	59.0	62.0	63.0	64.0	65.0	66.0	67.0	69.0	72.0	76.0	83.0	91.0
129	0.0	9.0	16.0	22.0	27.0	32.0	37.0	41.0	45.0	48.0	51.0	53.0	55.0	56.0	57.0	57.0	58.0	59.0	61.0	64.0	68.0	73.0	79.0	89.0
130	0.0	10.0	20.0	28.0	35.0	41.0	46.0	49.0	51.0	53.0	55.0	56.0	56.0	57.0	58.0	59.0	60.0	61.0	62.0	65.0	69.0	74.0	81.0	90.0
131	0.0	8.0	15.0	22.0	28.0	33.0	38.0	41.0	44.0	47.0	49.0	51.0	53.0	55.0	56.0	58.0	59.0	60.0	63.0	65.0	69.0	75.0	84.0	92.0
132	0.0	10.0	18.0	25.0	29.0	33.0	36.0	39.0	41.0	42.0	44.0	45.0	46.0	47.0	48.0	49.0	51.0	53.0	56.0	59.0	64.0	70.0	80.0	90.0
133	0.0	8.0	16.0	24.0	32.0	40.0	46.0	51.0	54.0	56.0	57.0	58.0	58.0	59.0	59.0	60.0	60.0	61.0	62.0	64.0	68.0	74.0	83.0	91.0
134	0.0	12.0	22.0	31.0	39.0	45.0	49.0	52.0	54.0	55.0	56.0	56.0	56.0	56.0	57.0	57.0	57.0	57.0	58.0	59.0	62.0	68.0	77.0	88.0
135	0.0	7.0	15.0	22.0	30.0	37.0	43.0	49.0	53.0	55.0	57.0	58.0	59.0	60.0	61.0	62.0	63.0	65.0	67.0	70.0	74.0	79.0	85.0	92.0
136	0.0	11.0	21.0	29.0	37.0	44.0	50.0	55.0	57.0	59.0	60.0	60.0	60.0	60.0	61.0	61.0	61.0	62.0	63.0	64.0	67.0	71.0	78.0	89.0
137	0.0	10.0	18.0	25.0	30.0	39.0	46.0	51.0	54.0	57.0	58.0	59.0	59.0	60.0	60.0	60.0	61.0	62.0	63.0	64.0	67.0	72.0	80.0	90.0
138	0.0	11.0	22.0	31.0	39.0	46.0	52.0	56.0	58.0	59.0	60.0	61.0	61.0	61.0	61.0	62.0	62.0	62.0	63.0	64.0	66.0	71.0	78.0	89.0
139	0.0	8.0	14.0	20.0	25.0	32.0	37.0	42.0	47.0	50.0	53.0	55.0	56.0	58.0	59.0	61.0	63.0	64.0	66.0	68.0	71.0	76.0	85.0	93.0
[3]140	0.0	13.0	28.0	43.0	56.0	65.0	69.0	69.4	69.7	70.1	70.4	70.8	71.1	71.5	71.9	72.2	72.6	73.0	73.3	73.6	74.0	76.0	81.0	89.0

[1] Periods are 15-d beginning January 1.

[2] Zones 121-139 are for stations in Hawaii.

[3] Zone 140 is the R_{eq} distribution for Pullman, WA.

Table 2-2.
Average annual and summer EI and 2-yr-frequency 6-h-duration precipitation computed from actual data in southwestern Idaho. Data for EI are compared with data in methods of Wischmeier (1974), Simanton and Renard (1982), Cooley (1980), and Cooley et al. (1988).

			R (hundreds ft · tonf · acre^{-1} · yr^{-1})									
	Precipitation 2-yr 6-h storm[2] (inches)		Observed EI		Wischmeier (1974)[3] $27.38P^{2.17}$		Simanton and Renard (1982) $27.38P^{1.62}$		Cooley (1980)[4] $13.00P^{2.15}$		Cooley et al. (1988) $22.17P^{2.56}$	
Site[1]	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer	Annual
057	0.71	0.75	10.5	10.9	12.6	14.3	15.6	17.0	6.2	6.9	9.2	10.6
127	.75	.83	9.5	11.3	14.3	17.7	17	20	6.9	8.6	10.6	13.8
116	.79	.91	10	14.6	16	21.7	18.5	23.2	7.8	10.5	12.1	17.4
155	.83	1.06	16	31	17.7	30.9	20	30.1	8.6	14.8	13.8	36.9
176	.83	1.22	14.2	45.3	17.7	41.8	20	37.7	8.6	19.9	13.8	36.9
163	.91	1.38	17.3	59.3	21.7	54.6	23.2	45.8	10.5	25.9	17.4	50.6

[1] Site elevation: 057 is 3,885; 127 is 5,410; 116 is 4,770; 155 is 5,410; 176 is 6,802, and 163 is 7,100 ft above m.s.l.

[2] Determined from actual gage data. NOAA Atlas 2 (Miller et al. 1973) would not permit defining the orographic results shown.

[3] Wischmeier (1974) and Ateshian (1974) agree within about 2%.

[4] Includes precipitation during winter periods in the form of snow, a questionable computation according to Cooley et al. (1988).

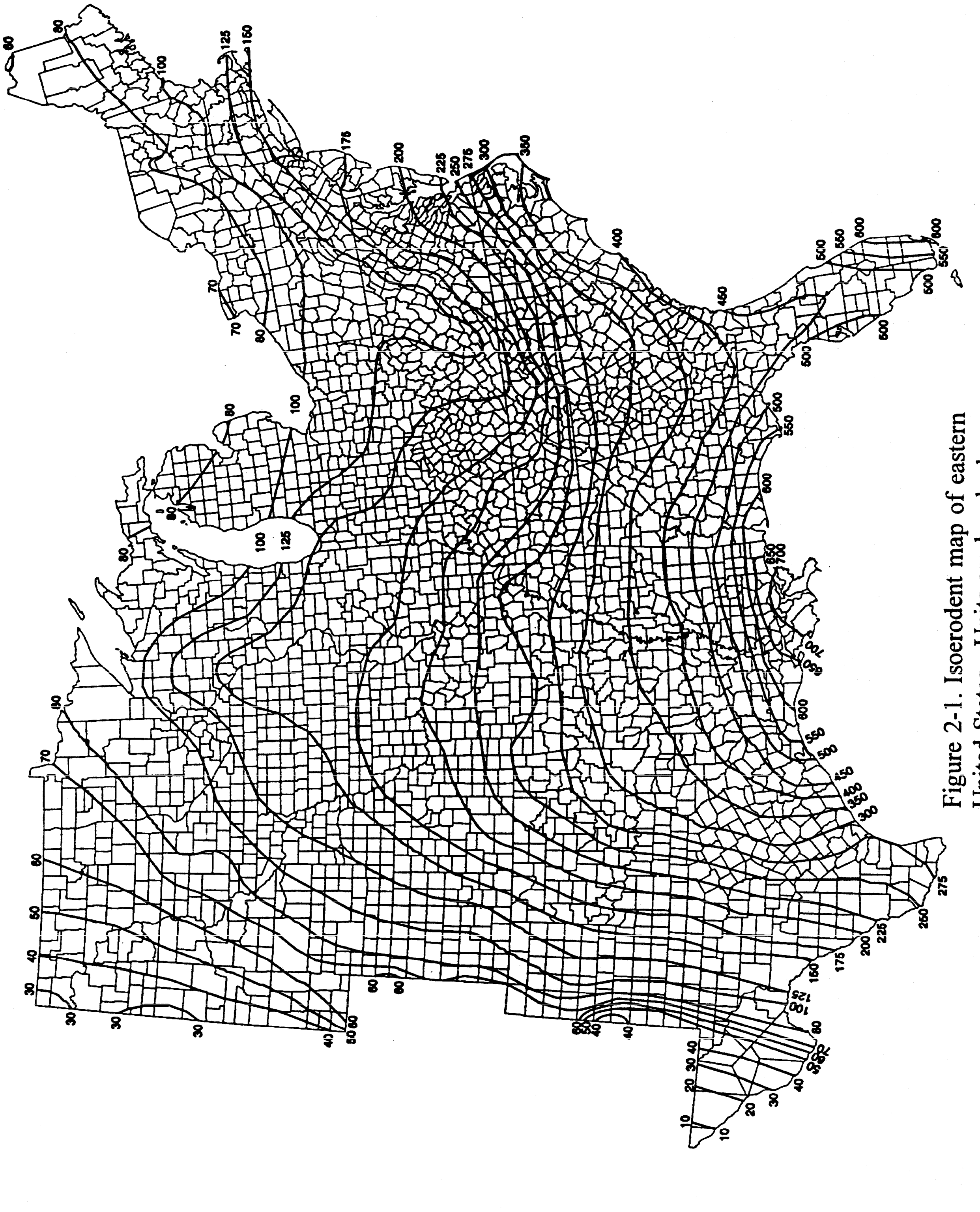


Figure 2-1. Isoerodent map of eastern United States. Units are hundreds ft·tonf·in(ac·h·yr)$^{-1}$.

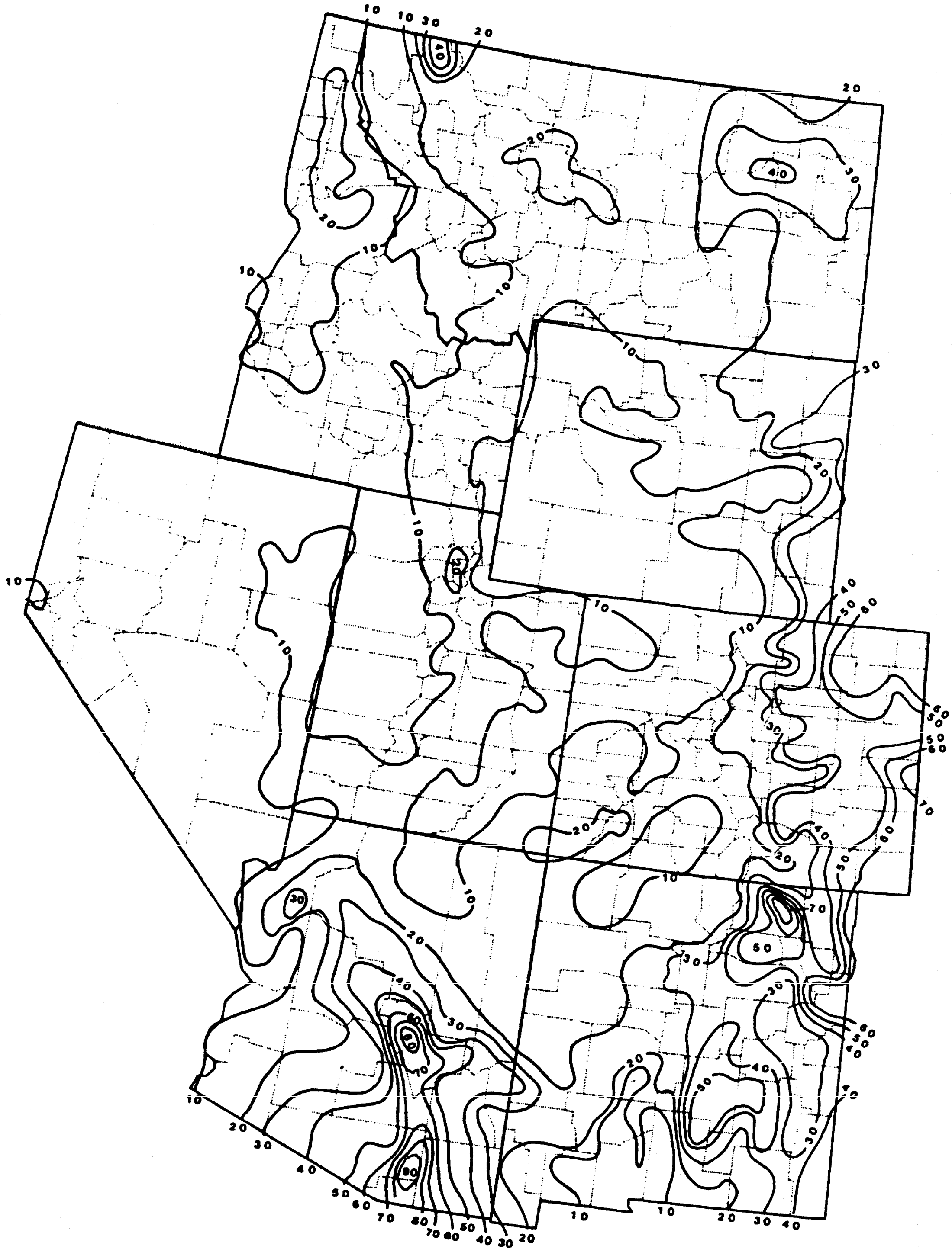


Figure 2-2. Isoerodent map of western United States. Units are hundreds ft·tonf·in(ac·h·yr)$^{-1}$.

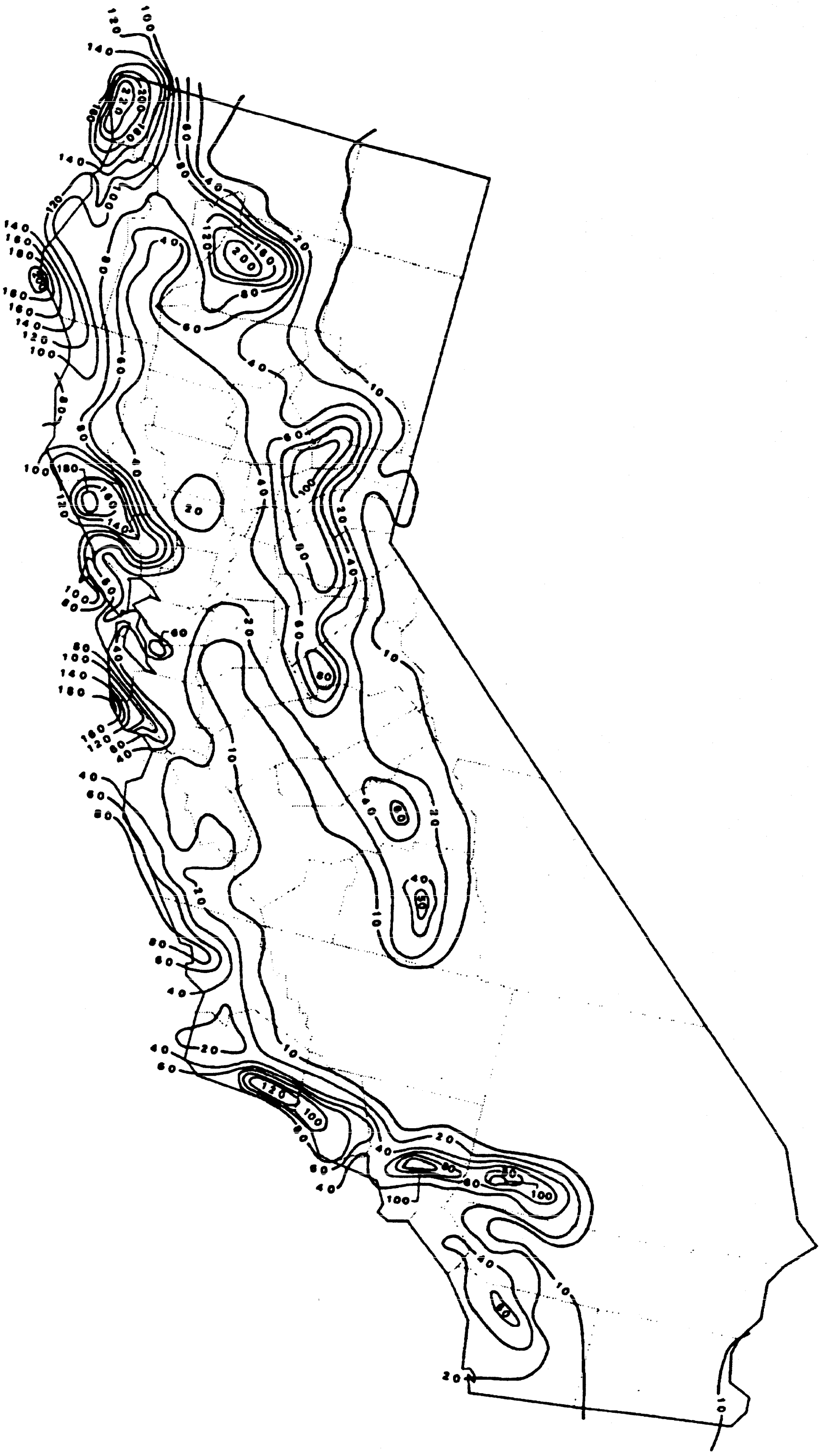


Figure 2-3. Isoerodent map of California. Units are hundreds ft·tonf·in(ac·h·yr)$^{-1}$.

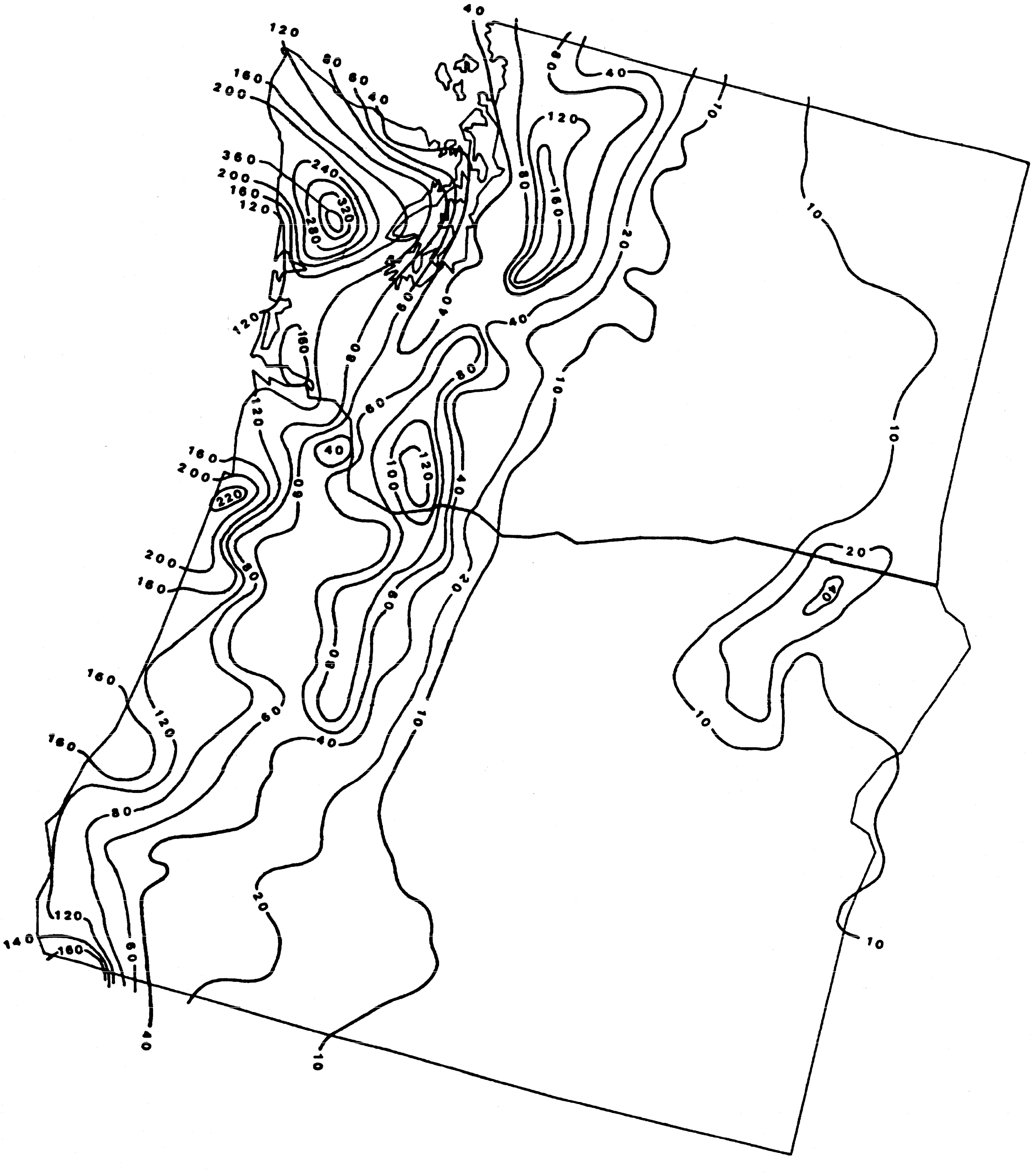


Figure 2-4. Isoerodent map of Oregon and Washington. Units are hundreds ft·tonf·in(ac·h·yr)$^{-1}$.

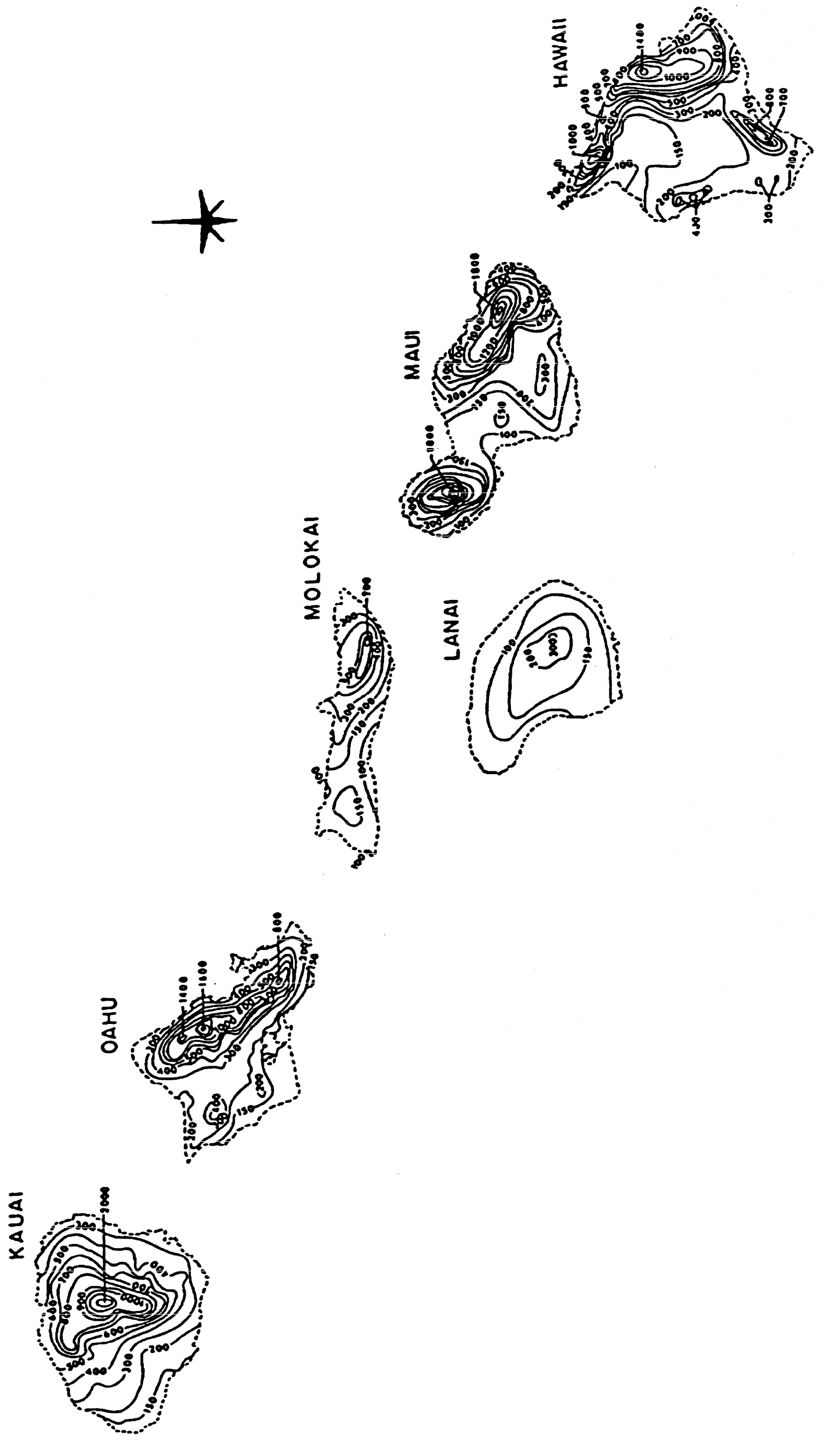


Figure 2-5. Isoerodent map of Hawaii. Units are hundreds ft·tonf·in(ac·h·yr)$^{-1}$.

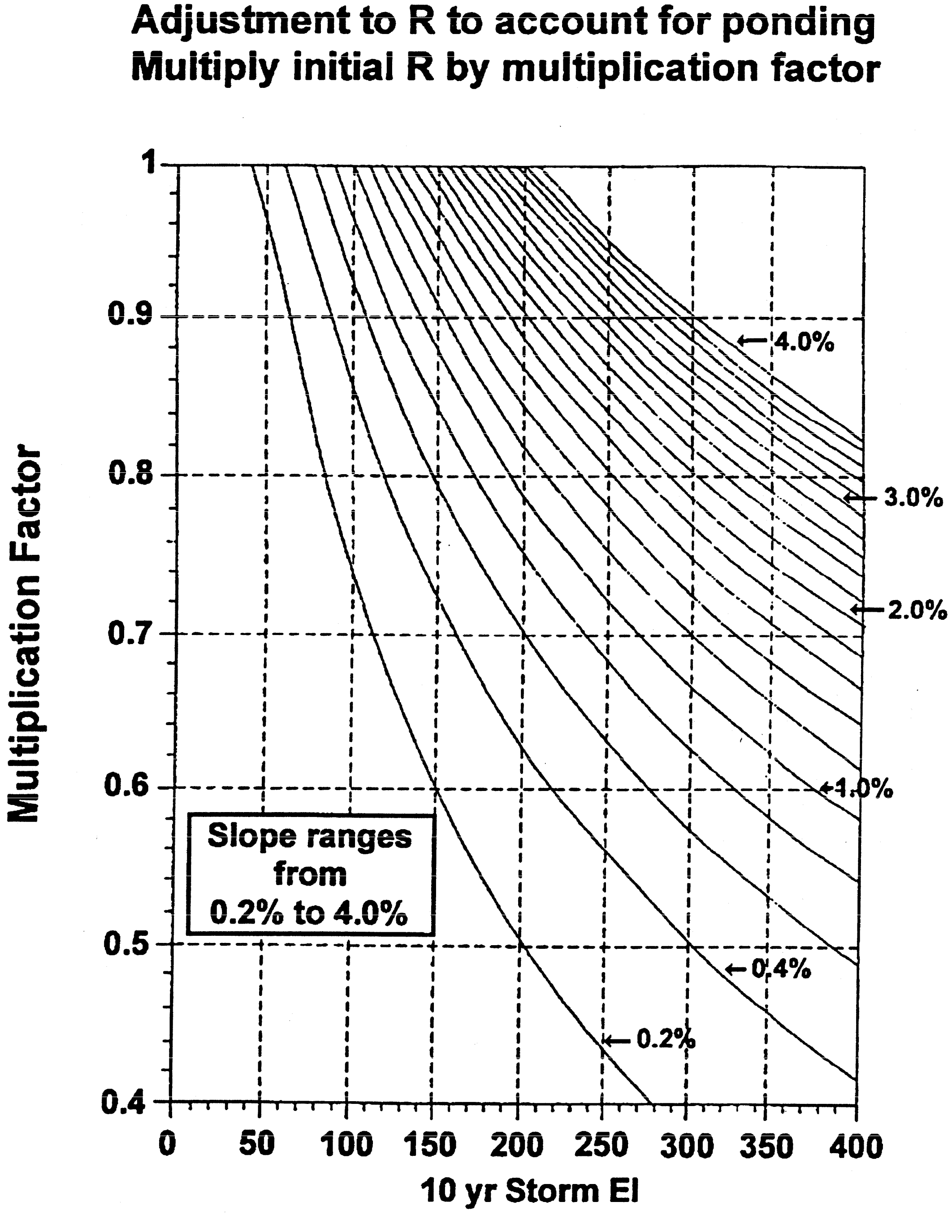


Figure 2-6. Corrections for R factor for flat slopes and large R values to reflect amount of rainfall on ponded water

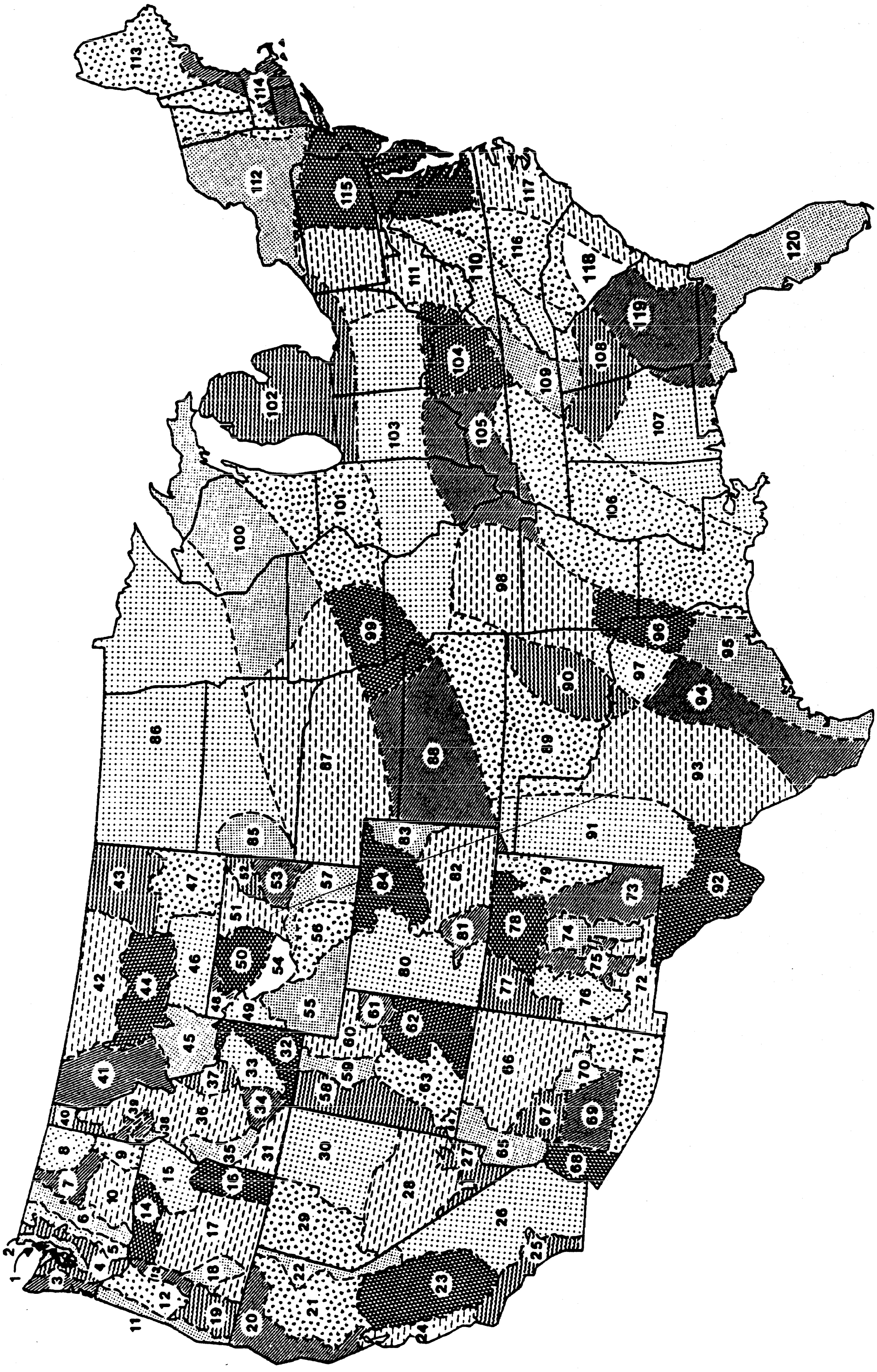
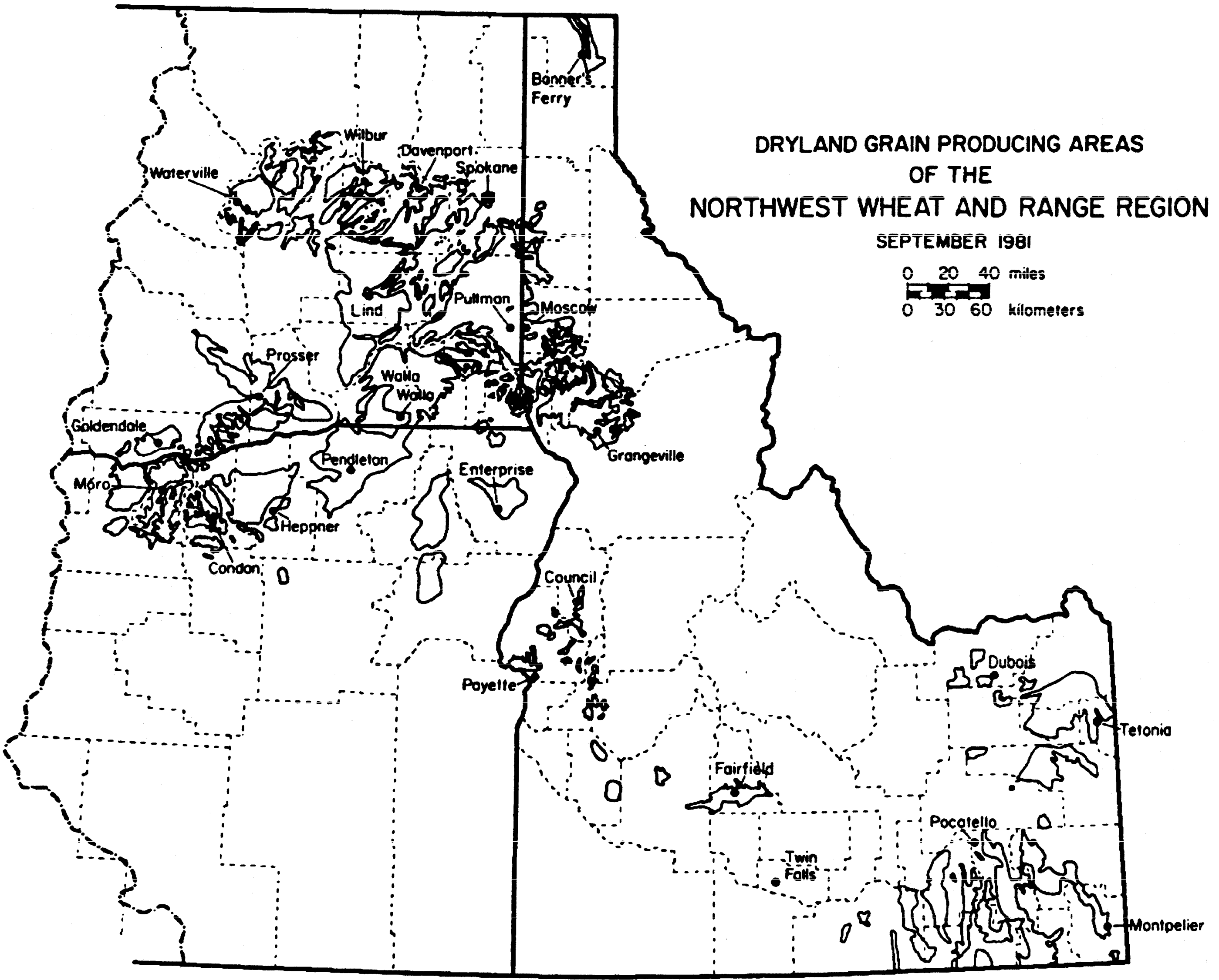


Figure 2-7. EI distribution zones for contiguous United States



USDA-ARS, Pullman, WA

Figure 2-8. Location map of the cropland area of Northwestern Wheat and Range Region (adapted from Austin 1981)

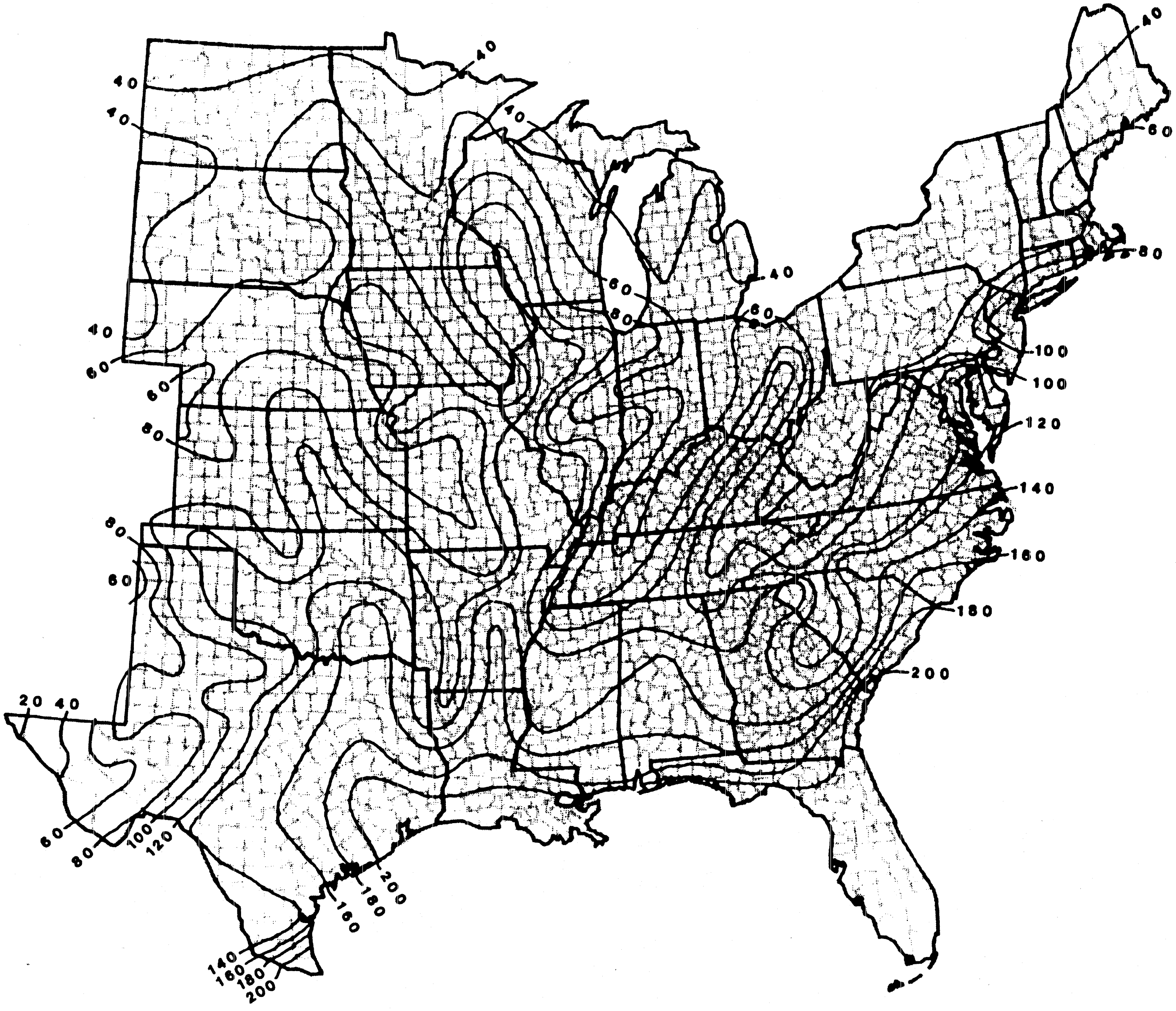


Figure 2-9. Ten-yr-frequency single-storm erosion index for eastern

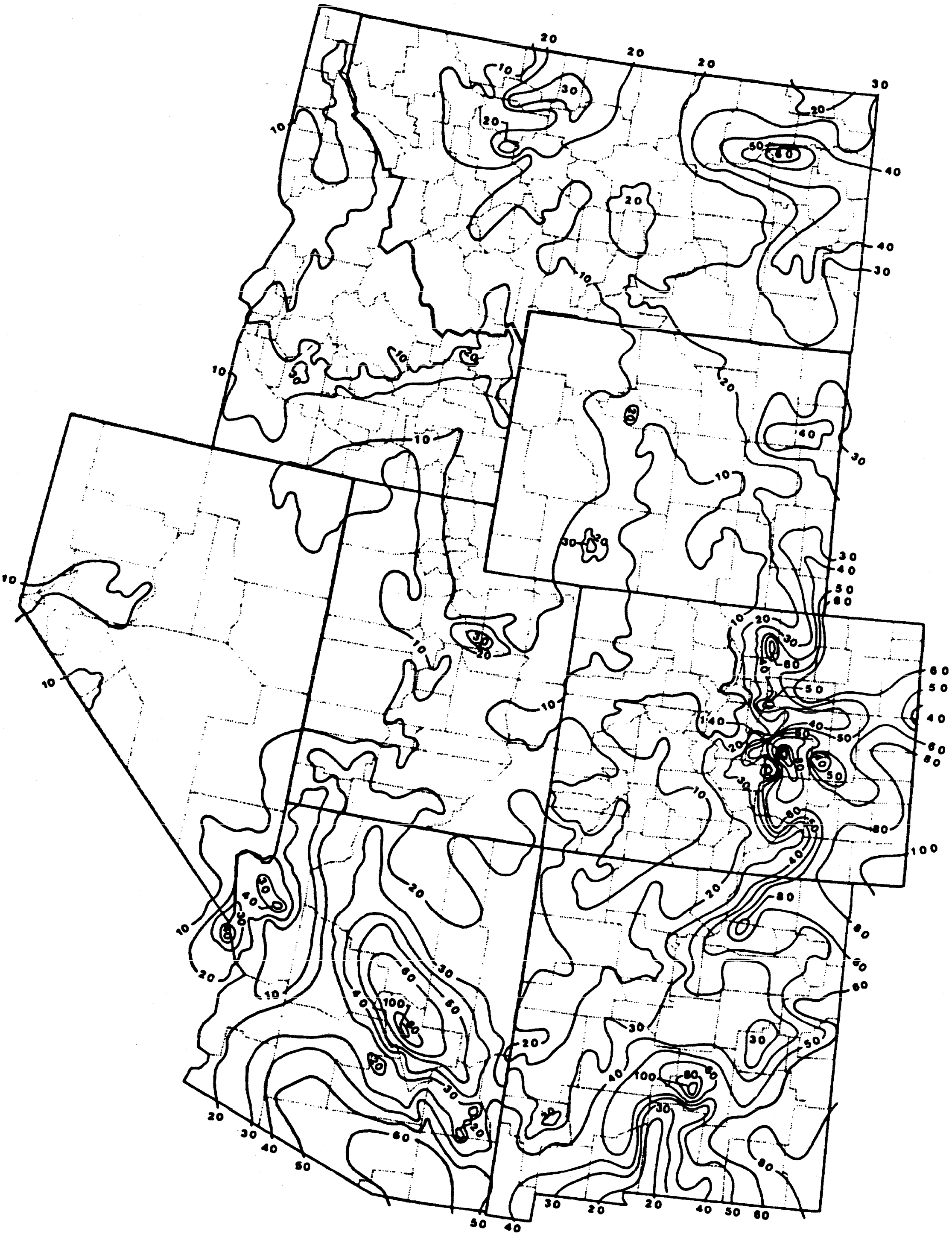


Figure 2-10. Ten-yr-frequency single-storm erosion index for western United States. Units are hundreds ft·tonf·in(ac·h)$^{-1}$.

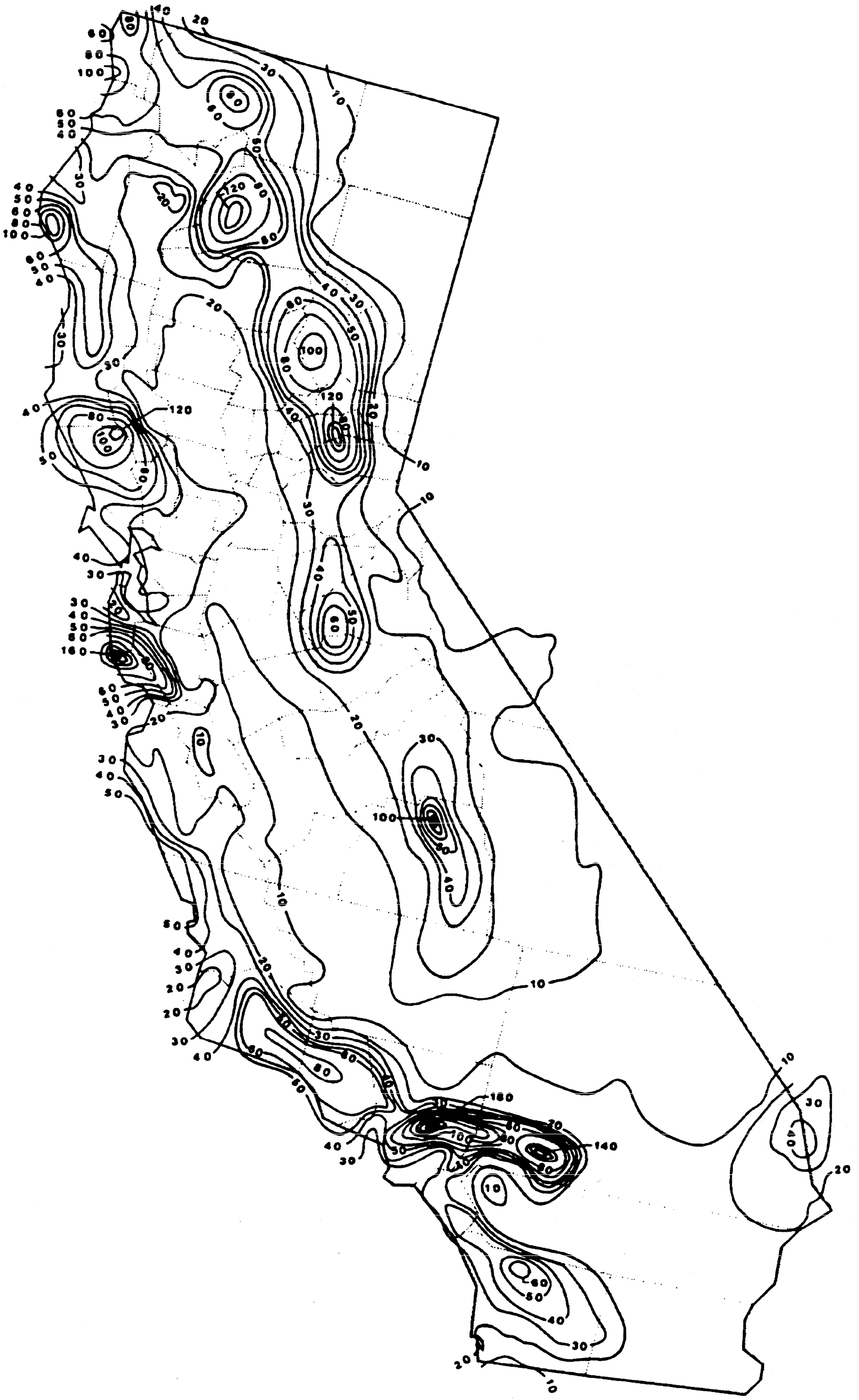


Figure 2-11. Ten-yr-frequency single-storm erosion index for California. Units are hundreds ft·tonf·in(ac· h)$^{-1}$.

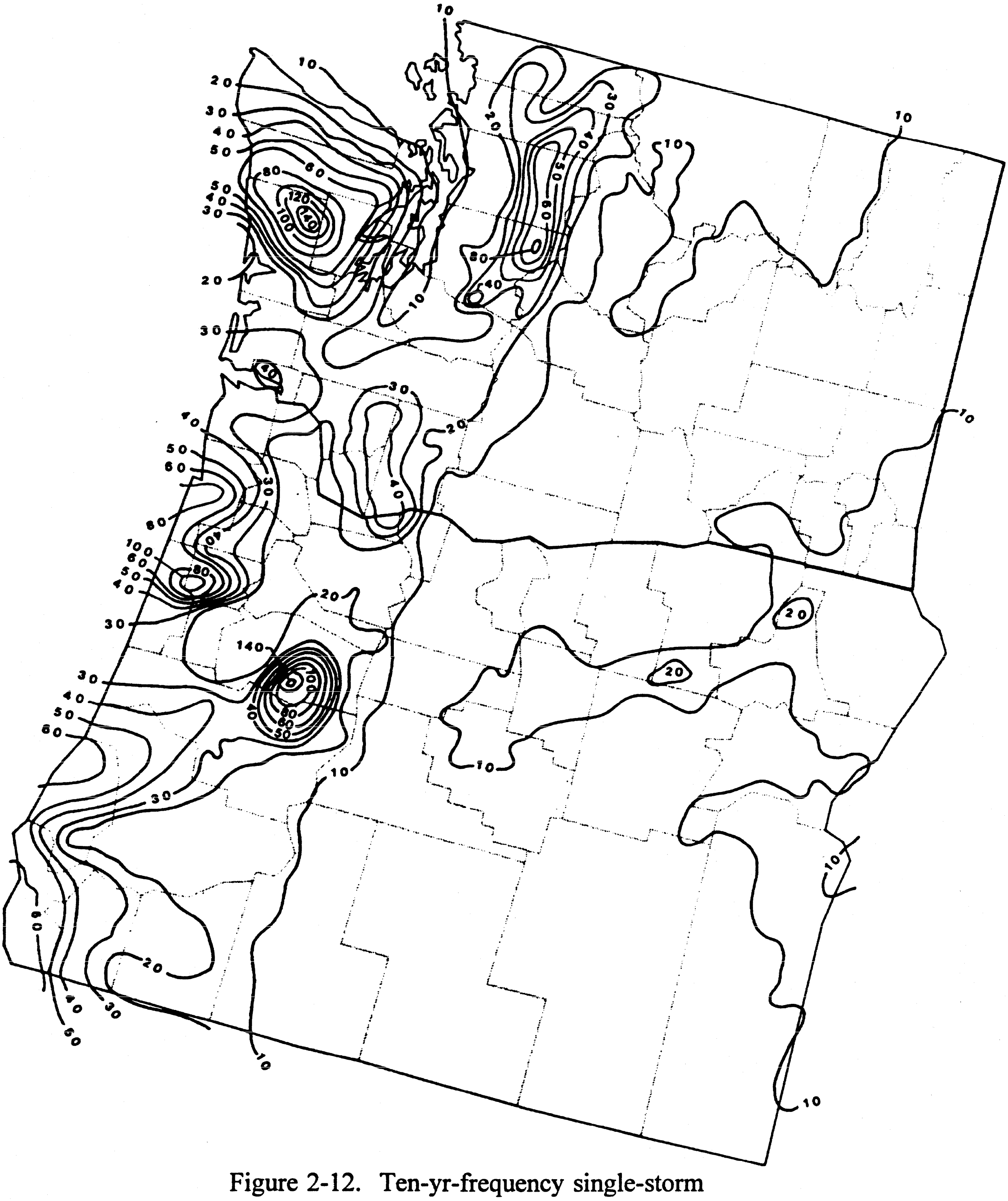


Figure 2-12. Ten-yr-frequency single-storm erosion index for Oregon and Washington. Units are hundreds ft·tonf·in(ac·h)$^{-1}$.

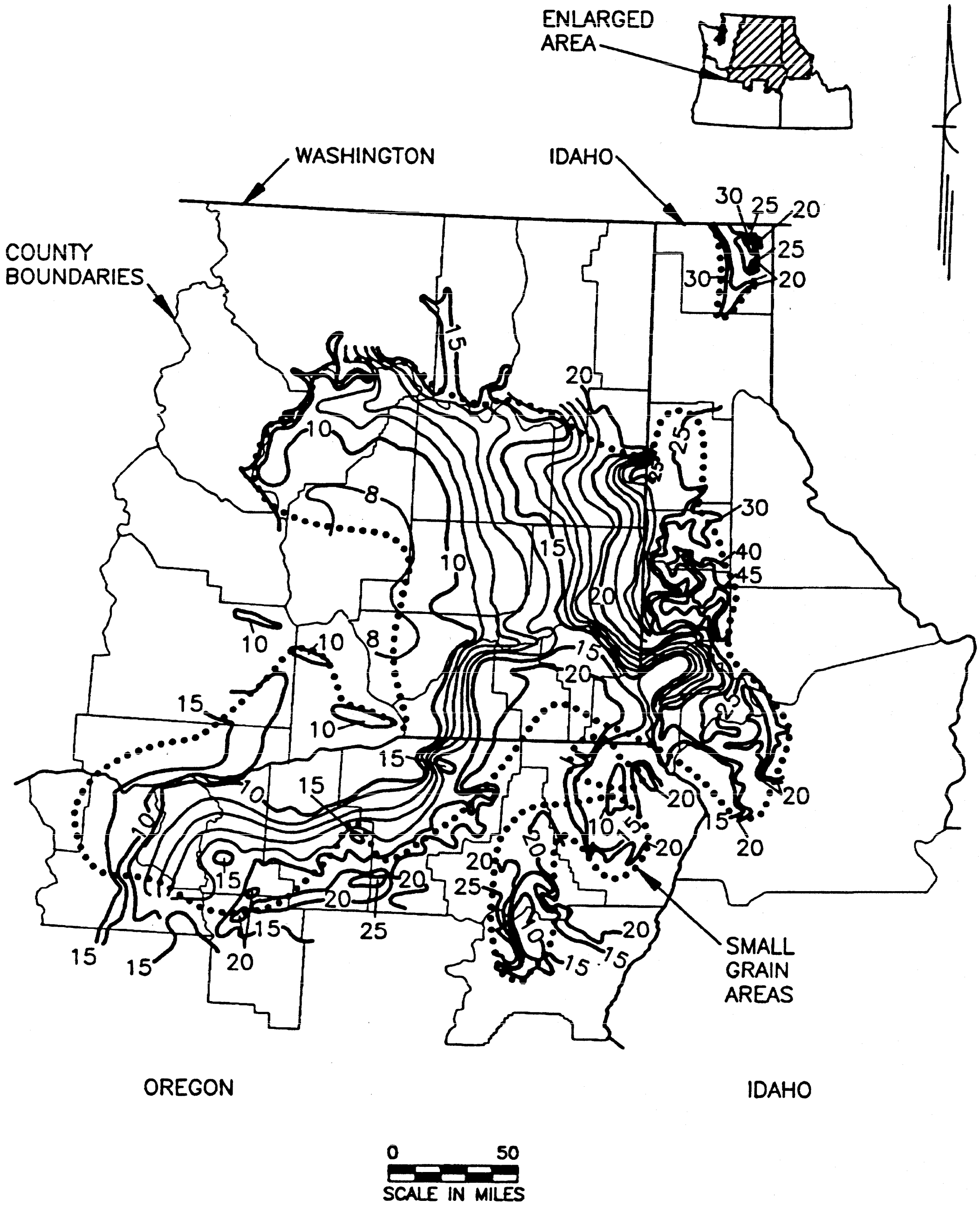


Figure 2-13. Precipitation map (inches) used to calculate R_{eq} in Washington, Oregon, and northern Idaho for small-grain areas of Northwestern Wheat and Range Region. Precipitation units are inches.

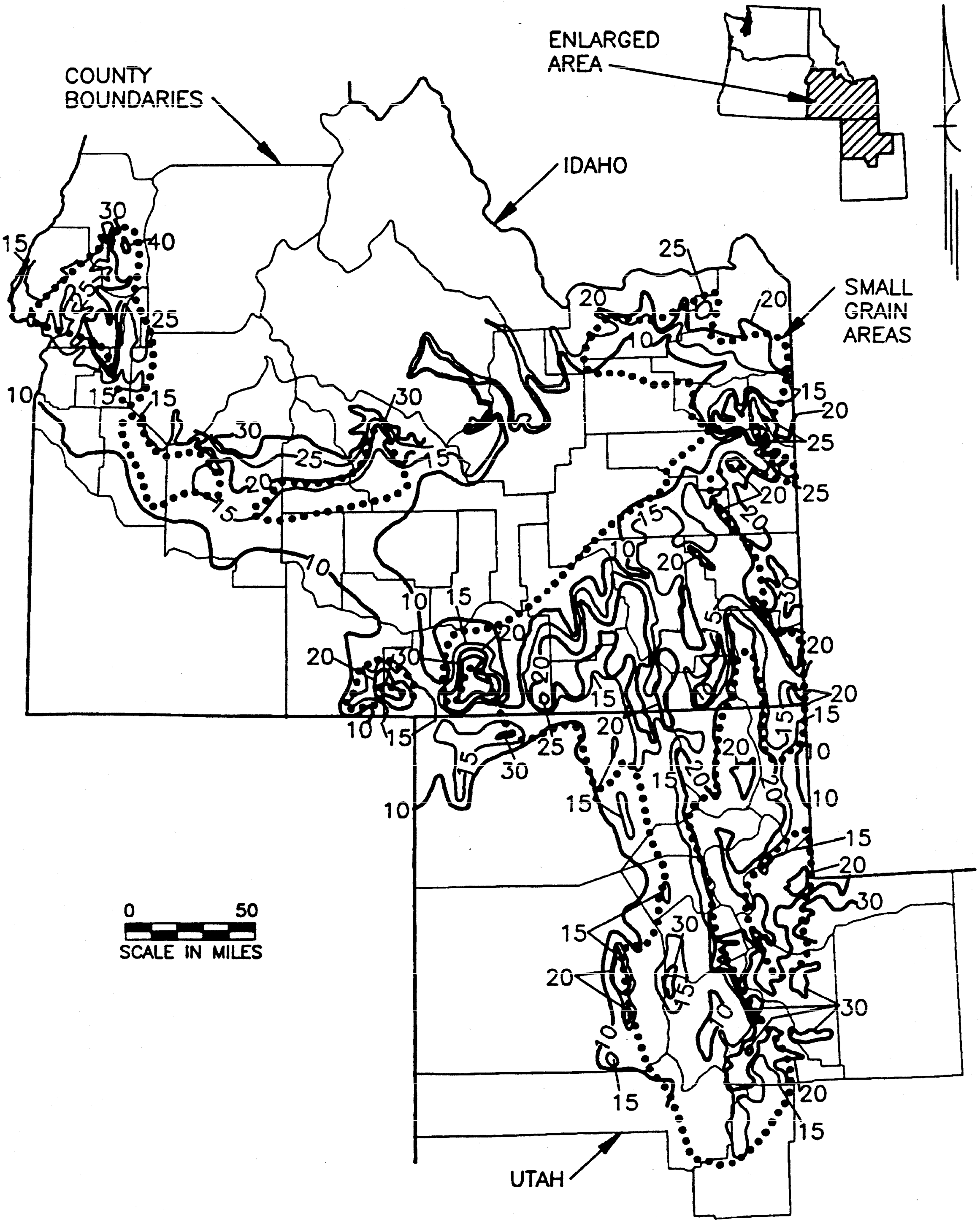


Figure 2-14. Precipitation map (inches) used to calculate R_{eq} in southern Idaho and Utah for small-grain areas of Northwestern Wheat and Range Region. Precipitation units are inches.

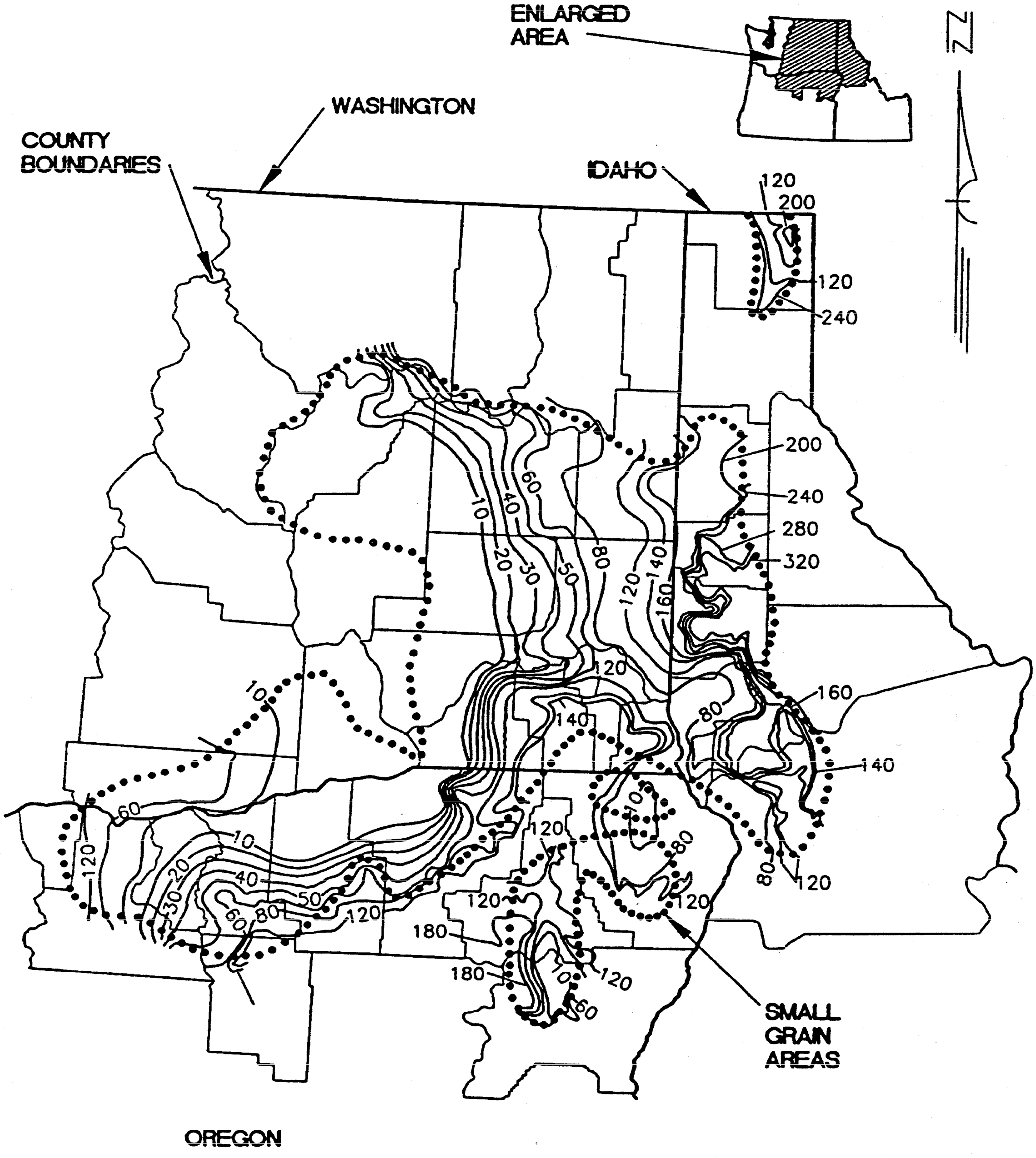


Figure 2-15. R_{eq} for cropland areas of Washington, Oregon, and northern Idaho in and adjacent to Northwestern Wheat and Range Region (Note: Some irregular contour intervals are used to preserve clarity). R_{eq} units are hundreds ft·tonf·in(ac·h)$^{-1}$.

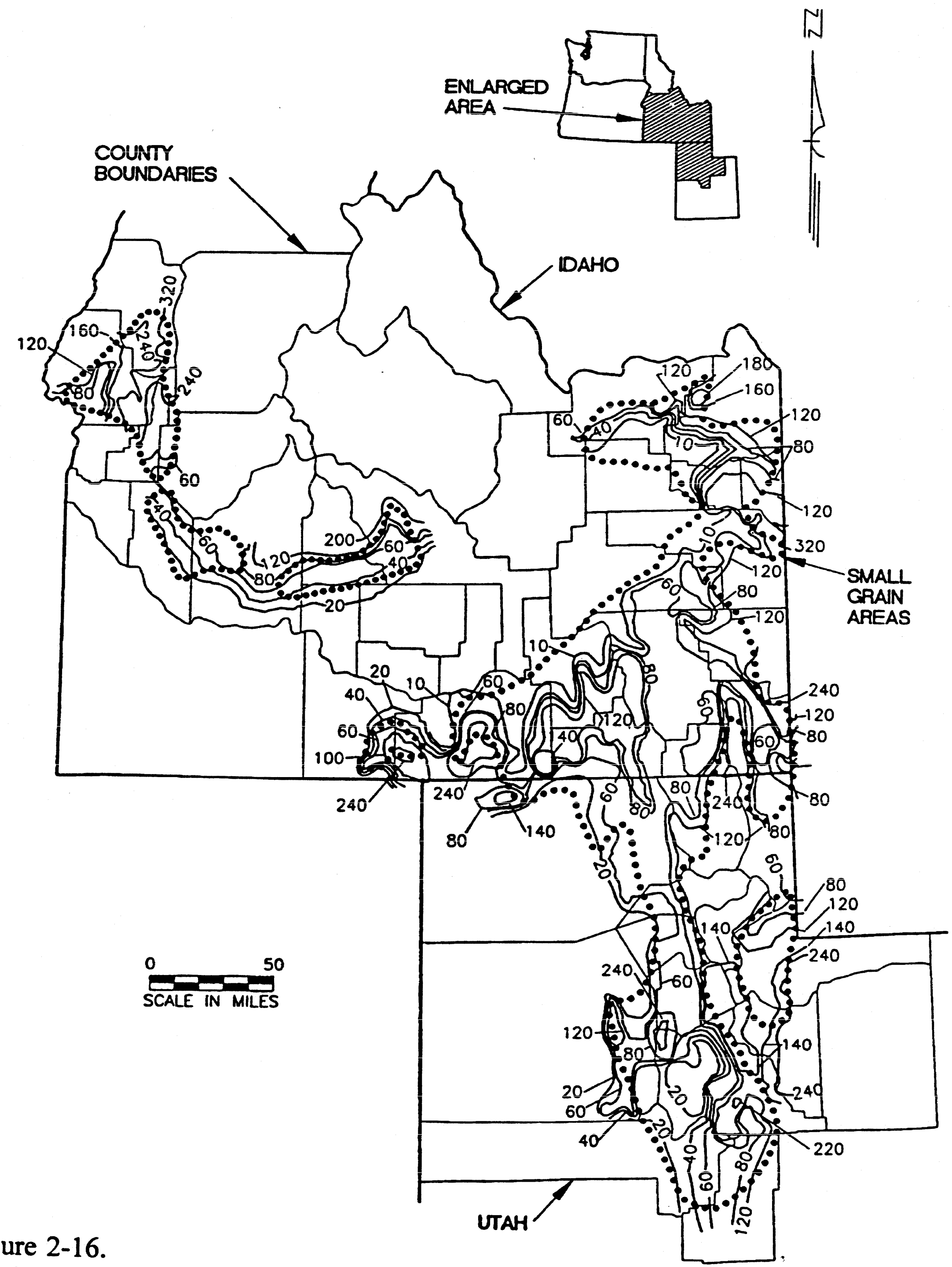


Figure 2-16.
R_{eq} for cropland areas of southern Idaho and Utah in and adjacent to Northwestern Wheat and Range Region (Note: Some irregular contour intervals are used to preserve clarity). R_{eq} units are hundreds ft·tonf·in(ac·h)$^{-1}$.

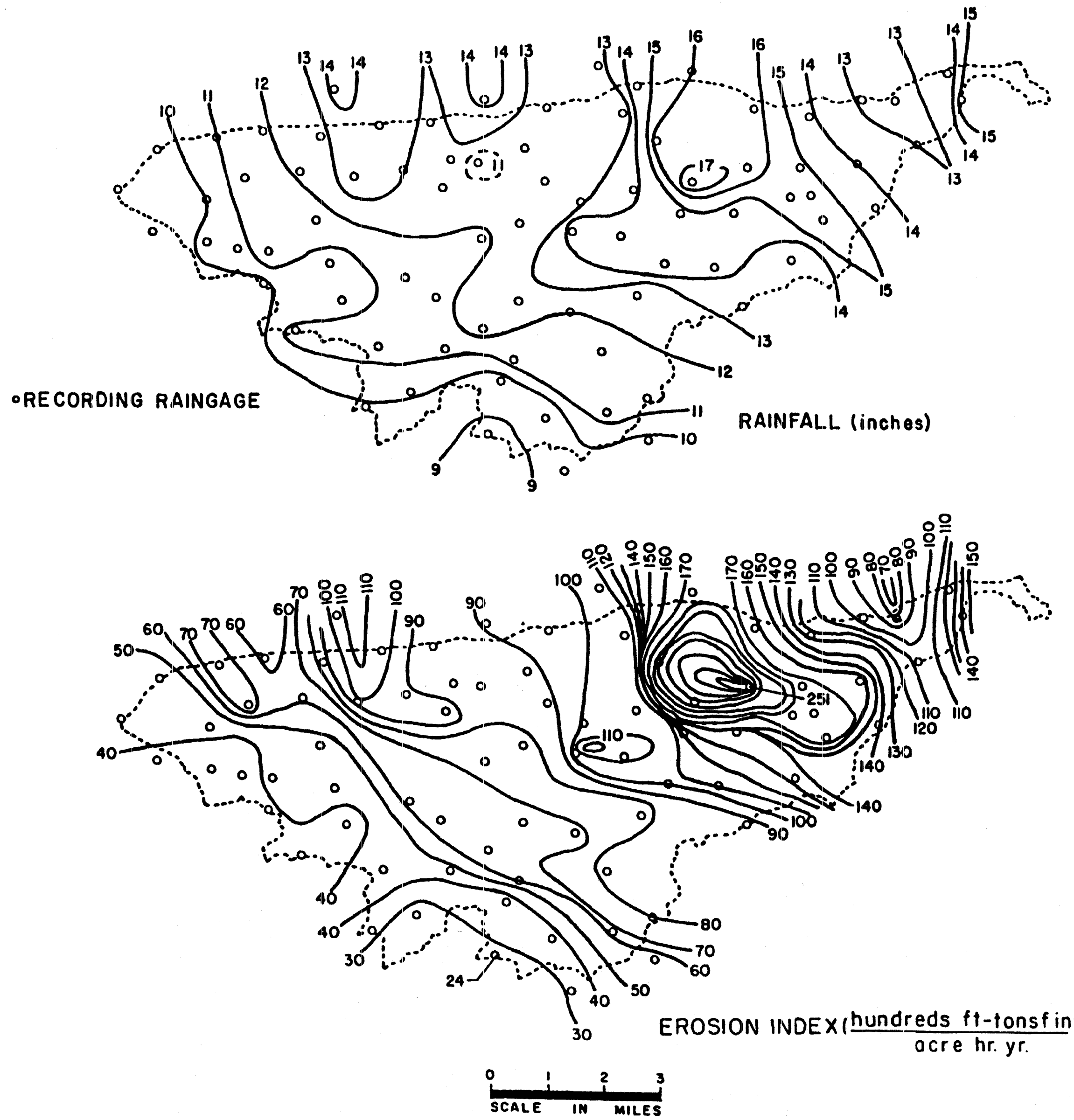


Figure 2-17. Storm precipitation (top) and isoerodent (bottom) values for storm of 7/22/64 on

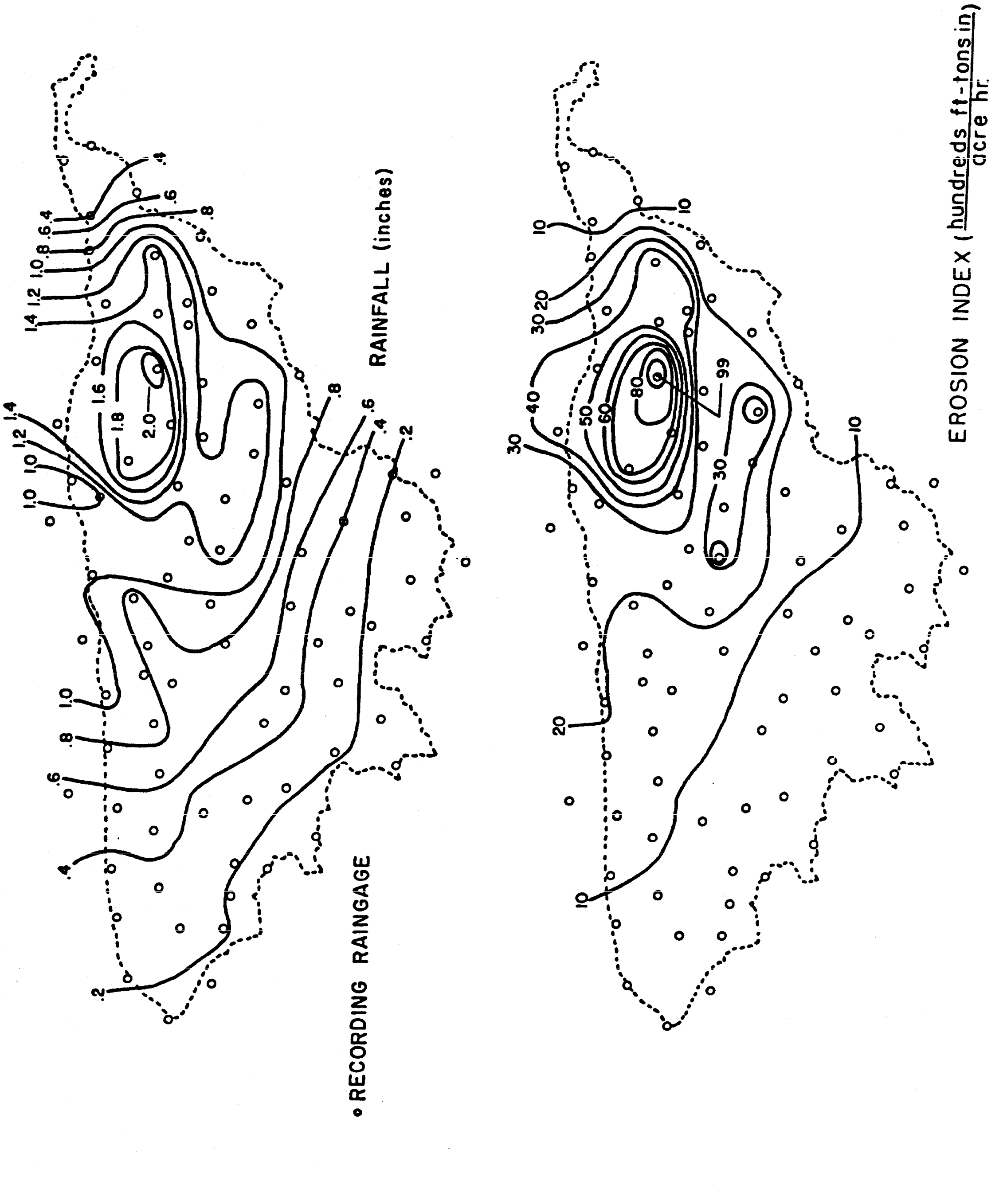


Figure 2-18. Annual precipitation (top) and isoerodent (bottom) maps for 1964 on Walnut Gulch Experimental Watershed