Natural Resources Conservation Service

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

National Agronomy Manual

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Part 500 Authorities, Policies, and Responsibilities

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Part 500 Authorities, Policies, and Responsibilities

Subpart 500A Authority

500.00 Soil Conservation and Domestic Allotment Act of 1935

The basic legislation for soil and water conservation programs by the Natural Resources Conservation Service (NRCS) is the Soil Conservation and Domestic Allotment Act, Public Law 74–46 of 1935 (16 U.S.C. 590a-590f). This original act recognized that agronomy, the science of field crop production, is essential in fulfilling the agency's responsibilities. The Buchanan Amendment to the Agricultural Appropriations Bill for FY 1930 (Public Law 70-769) led to the enactment of Public Law 74-46. In 1933, the Soil Erosion Service was established as a temporary agency of the Department of the Interior. The agency was transferred to USDA in 1935 and named the Soil Conservation Service (SCS). In 1994, the Natural Resources Conservation Service was established by Public Law 103–354, the Department of Agriculture Reorganization Act (7 U.S.C. 6962).

The NRCS combines the authorities of the former Soil Conservation Service as well as five natural resource conservation cost-share programs previously administered by other USDA agencies. The mission of the NRCS is to provide leadership and administer programs to help people conserve, improve, and sustain our natural resources and environment. NRCS provides technical assistance through local conservation districts on a voluntary basis to land users, communities, watershed groups, Federal and State agencies, and other cooperators. The agency's work focuses on erosion reduction, water quality improvement, wetland restoration and protection, fish and wildlife habitat improvement, range management, stream restoration, water management, and other natural resource problems.

500.01 Purpose of the Agronomy Manual

The National Agronomy Manual (NAM) establishes policy for agronomy activities and provides technical procedures for uniform implementation of agronomy tools and applications.

Subpart 500B Agronomic policies

500.10 Location of policy

Agronomic policies are contained in specific parts and subparts of this National Agronomy Manual as appropriate.

500.11 Amendments to NAM

The NAM will be amended as needed, as additional research is completed, existing methods or procedures are updated, or as new technology is developed and approved for use in the NRCS. The national agronomist is responsible for updating this manual.

Subpart 500C Responsibilities of agronomists

500.20 Responsibilities of national, State, area, and field agronomists

The national agronomist, nutrient management, and pest management specialists at the national level, cooperating scientists for agronomy, and agronomists on the institutes and center staffs provide staff assistance in all NRCS programs and provide national leadership on NRCS agronomy related activities. They are responsible for assisting upper management in formulating and recommending national policies, procedures, and standards; technical leadership and guidance; quality control; national coordination of agronomy with other NRCS technical fields; and promoting and maintaining relations with groups and agencies that have common interest in agronomy.

State agronomists on technical support staffs in State offices provide staff assistance in all agronomy and related functions. They are responsible for:

- Assisting in developing State policies, procedures, and instructions, and coordinating them with other States within the region.
- Providing technical leadership and guidance to other agronomists and appropriate personnel within the State.
- Collaborating with other State staff members to ensure interdisciplinary action in all NRCS programs.
- Training field personnel.
- Participating in agronomy components of appraisals and reviews.
- Maintaining working relations with research centers and other cooperating agencies.
- Developing and revising of all aspects of Field Office Technical Guides related to agronomy.
- Providing assistance in interdisciplinary technical reviews of project plans, environmental impact statements, and other technical materials.
- Coordinating agronomy functions with other States in the region and across regional boundaries as appropriate.

Area or zone agronomists provide staff assistance in all NRCS programs. They are responsible for carrying out the requirements of conservation agronomy consistent with technical proficiency, training, interdisciplinary action, and quality control within their administrative area. In some cases, these agronomists may carryout some of the responsibilities of the state agronomists if so delegated.

Field office agronomists are usually in training positions. Training is provided by agronomists at the area or State level.

Agronomists in the above positions may provide specific functions through team or ad hoc assignments at a national, regional, or State level.

Each agronomist has the responsibility to develop their training needs inventory and to work with their supervisor to obtain technical training to improve their overall agronomic expertise.

Standards of performance for agronomists are contained in the NRCS Personnel Manual.

500.30 Technical information—preparing, transferring, and training

Agronomists use technical information that has been developed at centers, institutes, national, or State level and maintain technical materials for the administrative area they serve. State staff agronomists develop and review field office technical guide materials and ensure materials are technically correct, comprehensive, and useful to the end user. NRCS policy on preparing and maintaining technical guides is in Title 450-GM, Part 401. In addition, state agronomists are responsible for technical notes and other agronomy technical materials that are applicable to the State.

Agronomists issue technical information at the area, state, or national level. This may include original information, research notes, papers, or excerpts of such material. Agronomists are encouraged to submit articles for publication or presentation at professional meetings. Technical information presented or prepared for publication shall have an appropriate technical and or administrative review and include crediting of appropriate references.

Agronomists receive and provide training necessary to maintain technical competency at all administrative levels. Training includes but is not limited to National Employee Development Courses, workshops, conferences, and university courses.

500.40 Certification

Agronomists at all levels of the agency are encouraged to obtain professional certification(s). Examples of certification programs include the Certified Crop Adviser (CCA) and Certified Professional Agronomists (CPAg) under ARCPACS of the American Society of Agronomy, Certified Professional in Erosion and Sediment Control (CPESC) of the Soil and Water Conservation Society, and state pesticide applicator licenses. Continuing educational requirements of most certification programs provide excellent opportunities to stay abreast of advances in technology.

500.50 Affiliation with professional organizations

Agronomists at all levels are encouraged to be active members of professional scientific societies, such as the American Society of Agronomy, Soil Science Society of America, Crop Science Society of America, the Soil and Water Conservation Society. These organizations provide opportunities to interact with researchers at the national and State level and to stay current on the latest technology.

Part 501 Water Erosion

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Part 501 Water Erosion

Subpart 501A Introduction

501.00 Overview of Content in Part 501 Water Erosion

Part 501 presents Natural Resources Conservation Service (NRCS) policy and procedures for estimating soil erosion by water. It explains the types, the method used to estimate, and the control of soil erosion by water. NRCS technical guidance related to water erosion shall conform to policy and procedures set forth in this part.

The Agricultural Research Service (ARS) has primary responsibility for erosion prediction research within the U.S. Department of Agriculture (USDA). ARS is the lead agency for developing erosion prediction technology, including the Revised Universal Soil Loss Equation (RUSLE). The technology in RUSLE is documented to the publication Predicting Soil Erosion by Water: A Guide to Conservation Planning With Revised Universal Soil Loss Equation, U.S. Department of Agriculture Handbook 703, hereafter referred to as Agriculture Handbook 703.

Subpart 501B Water erosion

501.10 Forms of water erosion

Forms of soil erosion by water include sheet and rill, ephemeral gully, classical gully, and streambank. Each succeeding type is associated with the progressive concentration of runoff water into channels as it moves downslope. Sheet erosion, sometimes referred to as interrill erosion, is the detachment of soil particles by raindrop impact and the removal of thin layers of soil from the land surface by the action of rainfall and runoff. Rill erosion is the formation of small, generally parallel channels formed by runoff water. Rills usually do not re-occur in the same place. Ephemeral gullies are concentrated flow channels formed when rills converge to form shallow channels. They are alternately filled with soil by tillage operations and re-formed in the same general location by subsequent runoff events. Classical gullies are also concentrated flow channels formed when rills converge. These are well defined, permanent drainageways that cannot be crossed by ordinary farming operations.

Other forms of erosion that are related to soil erosion by water include stream channel and geologic. Stream channel erosion refers to the degradation of channels and waterways. Geologic erosion refers to long-term erosion effects, as opposed to accelerated erosion events discussed.

No reliable methods exit for predicting the rate of ephemeral gully, classical gully, stream channel, or geologic erosion. The remainder of this part deals only with prediction and control of sheet and rill erosion.

501.11 The water erosion process

The processes of accelerated erosion, within the context of sheet and rill erosion, are detachment, transport, and deposition of soil particles by raindrop impact and surface runoff.

Detachment is the removal of particles from the soil mass and is expressed in units, such as tons per acre. When soil particles are removed from the mass, these particles are referred to as sediment.

The movement of sediment downslope is sediment transport. A measure of sediment transport is sediment load. Sediment load on a slope increases with distance downslope where detachment is occurring. That is, detachment adds to the sediment load.

Where runoff is slowed at the base of a slope or by dense vegetation, deposition occurs, which is the transfer of sediment from the sediment load to the soil mass. That is, deposition removes sediment from the sediment load, and accumulates on the soil surface.

Two types of deposition, remote and local, occur. Remote deposition occurs some distance away from the origin of the sediment. Deposition at the toe of a concave slope, on the upper side of vegetative strips, and in terrace channels are examples of remote deposition. Local deposition is where sediment is deposited near, within several inches, of where it is detached. Deposition in microdepressions and in low gradient furrows are examples of local deposition.

Subpart 501C Estimating sheet and rill erosion

501.20 How, why, and by whom water erosion is estimated

NRCS estimates soil erosion by water as part of its technical assistance to land users. In conservation planning, erosion estimates are made for an existing management system and compared with alternative systems and with soil loss tolerance, T, values.

In addition to using soil loss estimates in conservation planning, they are also used to inventory natural resources, to evaluate the effectiveness of conservation programs and land treatment, and to estimate sediment production from fields that might become sediment yield in watersheds.

Since March 1995, NRCS has implemented RUSLE as the official tool for predicting soil erosion by water. NRCS continues to use USLE for certain provisions of Farm Bill programs and for its National Resources Inventory (NRI).

501.21 Methods of estimating sheet and rill erosion

Efforts to predict soil erosion by water started in the 1930’s. Cook (1936) identified the major variables that affect erosion by water. Zingg (1940) published the first equation for calculating field soil loss. Smith and Whitt (1947) presented a erosion-estimating equation that included most of the factors present in modern equations. The Musgrave equation (Musgrave 1947) was a soil loss equation developed for farm planning. Finally, an effort was initiated to develop a national equation from the various state and regional equations that existed in the 1950’s. In 1954, the Agricultural Research Service established the National Runoff and Soil Loss Data Center at Purdue University in West Lafayette, Indiana, to consolidate all available erosion data. Using the data assembled at the Data Center, Wischmeier and Smith (1965) developed the Universal Soil Loss Equation (USLE).

The USLE was a consolidation of several regional soil loss equations, and was based on summarizing and statistical analyses of more than 10,000 plot-years of basic runoff and soil loss data from 49 U.S. locations (Agriculture Handbook 703, 1997; Wischmeier and Smith 1965, 1978).

The USLE was designed to provide a convenient working tool for conservationists. It quantifies soil erosion as a product of six factors representing rainfall and runoff erosiveness, soil erodibility, slope length, slope steepness, cover-management practices, and supporting practices.

501.22 The Revised Universal Soil Loss Equation

Since March 1995, the Revised Universal Soil Loss Equation (RUSLE) is the tool NRCS uses to estimate soil loss by water (Agriculture Handbook 703.).

RUSLE predicts long-term average annual soil loss from sheet and rill erosion. RUSLE is an update of the Universal Soil Loss Equation (USLE). RUSLE contains a computer program to facilitate the calculations and the analysis of research data that were unavailable when Agricultural Handbook 282 (Wischmeier and Smith 1965) and Agricultural Handbook 537 (Wischmeier and Smith 1978) were completed.

501.23 Limitations of the equation

The term *Universal* distinguishes the USLE and RUSLE from State and regionally based models that preceded them. However, the use of the USLE and RUSLE is limited to situations where factors can be accurately evaluated and to conditions for which they can be reliably applied (Wischmeier 1978; Agriculture Handbook 703, 1997).

RUSLE predicts long-term average annual soil loss carried by runoff from specific field slopes under specified cover and management systems. It is substantially less accurate for the prediction of specific erosion events associated with single storms and short-term random fluctuations.

RUSLE also estimates sediment yield for the amount of eroded soil leaving the end of a slope with certain support practices (see 501.35). It does not predict sediment yield for the amount of sediment that is delivered to a point in a watershed, such as the edge of a field, that is remote from the origin of the detached soil particles. Nor does RUSLE predict erosion that occurs in concentrated flow channels.

501.24 Alternative methods of applying RUSLE

ARS released RUSLE in 1992 as a computer program in the DOS environment. The model calculates soil loss from a field slope using values for each factor and using data elements from climate, plant, and field operation data bases.

Since 1993, RUSLE has been implemented in many NRCS field offices in hardcopy form in the Field Office Technical Guide (FOTG). State and area agronomists have developed tables and charts containing values for each of the RUSLE factors. Since the RUSLE module in Field Office Computing System (FOCS) is no longer supported by the Information Technology Center, NRCS will continue to implement RUSLE technology using charts and tables in the FOTG.

501.25 Data needed to support RUSLE

RUSLE uses soil erodibility, K, values from the NASIS Soils Database. Climatic data is obtained from National Weather Service weather stations with reliable long-term data. State and area agronomists have developed cover and management factor, C, values for common cropping systems.

The crop data base in the DOS RUSLE program contains plant growth and residue production parameters. These variables for key crops are listed in chapter 7 of Agriculture Handbook 703. Values for many of these parameters are available in a data base for a wide variety of plants. A user interface, the Crop Parameter Intelligent Data System (CPIDS) (Deer-Ascough et al. 1995), allows the user to search the data base. The USDA, ARS, National Soil Erosion Research Laboratory, West Lafayette, Indiana, maintains CPIDS.

Development and maintenance of data bases used by NRCS in erosion prediction models are the responsibility of NRCS agronomists at the State and national levels. Refer to Part 509 in this Manual for more detailed information on data base management and instructions. The national agronomist maintains a data base management plan that identifies the process of developing and maintaining data bases needed to support RUSLE. Data bases for some States are available in electronic format on the Fort Worth server.

501.26 Tools for using RUSLE

Maps of rainfall and runoff factors, R and R_{eq} (see part 501.31) for the continental United States plus Hawaii are available in Agriculture Handbook 703, figures 2-1 to 2-5 and figures 2-15 and 2-16. Additional climate-related data and inputs are available in this chapter. Most states and Basin Areas have developed county-based climatic maps for their areas. These contain the greater detail that is desired when applying RUSLE to specific field situations, and are available in NRCS State offices.

Soil erodibility factor, K, values for RUSLE are available in the NASIS Soils Database and in other soils data bases and tables. In areas of the United States where K values are adjusted to account for seasonal variability, (Agriculture Handbook 703) tables are available in State offices that show how the values are rounded to the nearest class and subclass.

Four slope length and steepness, L and S, table options are available in RUSLE. LS values can be obtained from tables 4-1 to 4-4 in Agriculture Handbook 703. The RUSLE computer program also calculates LS factor values for both uniform and complex slopes.

Cover and management factor, C, values are available in electronic table format in tables in most State offices and in the Field Office Technical Guide. Hardcopy tables are available in most State offices.

Support practice factor, P, values are calculated using tables available in the FOTG in many states. Copies, where available, can be obtained from the State office. Table values for common stripcropping and buffer strip systems are available in the FOTG of some states.

Subpart 501D RUSLE factors

501.30 The average annual soil loss estimate, A

The long time average annual soil loss, A, is the computed spatial average soil loss and temporal average soil loss per unit of area, expressed in the units for K and for the period selected for R.

As applied by NRCS, the units for K and the period for R are selected so that A is expressed in tons per acre per year. RUSLE predicts the soil loss carried by runoff from specific field slopes in specified cover and management systems.

501.31 The rainfall and runoff erosivity factor, R

The rainfall and runoff erosivity factor, R, is the product of total storm energy times the maximum 30-minute intensity. Stated another way, the average annual total of the storm energy and intensity values in a given location is the rainfall erosion index, R, for the locality.

In dryland cropping areas of the Northwest Wheat and Range Region, the effect of melting snow, rain on snow, and/or rain on thawing soil poses unique problems. An equivalent R value, R_{eq}, is calculated for these areas to account for this added runoff.

501.32 The soil erodibility factor, K

The soil erodibility factor, K, is the soil-loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6-foot length of uniform 9 percent slope in continuous clean-tilled fallow.

In the eastern United States, in an area shown in figure 3-5, Agriculture Handbook 703, RUSLE adjusts the K value to account for seasonal variability caused by freeze-thaw cycles.

NRCS further modifies the seasonally adjusted K by rounding the value to the nearest K factor class or half-class (exhibit 501.1).

Rock fragments in the soil profile affect the soil erodibility factor 1/. The K value is adjusted upwards to account for rock fragments in the soil profile of sandy soils that reduce infiltration. No adjustment to the K value is recommended by NRCS for rocks in the profile of medium and heavy textured soils.

501.33 The slope length and steepness factors, L and S

The slope length factor, L, is the ratio of soil loss from the field slope length to soil loss from a 72.6-foot length under identical conditions.

The slope steepness factor, S, is the ratio of soil loss from the field slope gradient to soil loss from a 9 percent slope under otherwise identical conditions.

In erosion prediction as used by NRCS, the factors L and S are evaluated together, and LS values for uniform slopes can be selected from tables 4-1, 4-2, 4-3, and 4-4 in Agriculture Handbook 703.

The slope length is defined as the horizontal distance from the origin of overland flow to the location of either concentrated flow or deposition. Slope lengths normally do not exceed 400 feet because sheet and rill flows will almost always coalesce into concentrated flow paths within that distance. Lengths longer than 1,000 feet should not be used in RUSLE.

Slope length and steepness determinations are best made in the field. In conservation planning, the hillslope profile representing a significant portion of the field having the most severe erosion is often chosen. Slope lengths are best determined by pacing out flow paths and making measurements directly on the ground. Steep slopes should be converted to horizontal distances. Slope steepness determinations are best made in the field using a clinometer, Abney level or similar device. Chapter 4, Agriculture Handbook 703 contains additional guides for choosing and measuring slopes.

Most naturally occurring hillslope profiles are irregular in shape. When the slope profile is significantly curved (convex or concave, or sigmoid.convex at the shoulder and concave at the toe), the conservationist should represent it as a series of slope segments, using the irregular slope procedure in the RUSLE computer program.

501.34 The cover-management factor, C

The cover-management factor, C, is the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow.

The C factor is used most often to compare the relative impacts of management options on conservation plans.

The impacts of cover and management on soil losses are divided into a series of subfactors in RUSLE. These include the impacts of previous vegetative cover and management, canopy cover, surface roughness, and in some cases the impact of soil moisture.

In RUSLE, these subfactors are assigned values, and when multiplied together yield a soil loss ratio (SLR). Individual SLR values are calculated for each period over which the important parameters are assumed to remain constant. Each SLR value is then weighted by the fraction of rainfall and runoff erosivity, EI, associated with the corresponding period, and these weighted values are combined (summed) into an overall C factor value.

501.35 The support practice factor, P

The support practice factor, P, is the ratio of soil loss with a support practice like contouring, stripcropping,

1/ Rock fragments on the soil surface are accounted for in the C factor.

or terracing to soil loss with straight-row farming up and down the slope.

The contour P subfactor accounts for the beneficial effects of redirected runoff that modifies flow pattern because of ridges or oriented roughness that are partially or completely oriented along the contour.

The contour P subfactor includes the effects of storm severity, ridge height, off-grade contouring, slope length and steepness, infiltration, and soil cover and roughness.

The stripcropping P subfactor is a support practice where strips of clean-tilled or nearly clean-tilled crops are alternated with strips of close growing vegetation, or strips with relatively smooth tilled soil surfaces are alternated with strips with rough tilled surfaces.

The stripcropping P subfactor evaluates what are variously described as contour stripcropping, cross-slope stripcropping, field stripcropping, buffer strips and vegetated filter strips.

Terraces in RUSLE are support practices where high and large ridges of soil are constructed across the slope at intervals. These ridges and their accompanying channels intercept runoff and divert it around the slope or into a closed outlet. Terraces can affect sheet and rill erosion by reducing slope length and cause deposition in the terrace channel.

Tile drainage, under optimum conditions, can reduce erosion by reducing runoff. Because of a lack of support data, NRCS does not use the tile drainage subfactor in RUSLE, except in the Willamette Valley in the Oregon and Puget Sound basin in Washington.

In addition to the support practice factor, P, used in conservation planning, RUSLE estimates sediment yield for contour strips and terraces. The sediment yield, or delivery ratio, used in RUSLE is the ratio to the amount of sediment leaving the end of the slope length to the amount of sediment produced on the slope length.

Subpart 501E Principles of water erosion control

501.40 Overview of principles

The principle factors that influence soil erosion by water are climate, soil properties, topography, vegetative cover, and conservation practices. Climate and soil properties are conditions of the site and are not modified by ordinary management measures. Conservation treatment primarily involves manipulation of vegetative cover, modification of topography, and manipulation of soil conditions in the tillage zone.

The greatest deterrent to soil erosion by water is vegetative cover, living or dead, on the soil surface. Cover and cultural practices influence both the detachment of soil particles and their transport. Growing plants and plant residue absorb the energy of raindrops, decrease the velocity of runoff water, and help create soil conditions that resist erosion. Cultural practices that affect vegetative cover include crop rotations, cover crops, management of crop residue, and tillage practices.

501.41 Relation of control to RUSLE factors

In conservation planning, the cover and management factor, C, and the support practices factor, P, can be manipulated in RUSLE to develop alternatives for erosion reduction. In addition, where slope length is reduced with some terrace and diversion systems, the slope length and steepness factor, LS, will be reduced.

Using RUSLE technology, estimates of erosion reduction are illustrated in the subfactors of factor C.

Benefits to erosion control are achieved in the:
- prior land use subfactor by increasing the mass of roots and buried residue and increasing periods since soil disturbance,
- canopy cover subfactor by increasing the canopy cover of the field area and low raindrop fall height from the canopy,

- surface cover subfactor by increasing the ground cover of plant residue, and by permanent cover such as rock fragments,
- surface roughness subfactor by increasing the random surface roughness that ponds water, and thereby reduces the erosive effect of raindrops and traps sediment, and
- soil moisture subfactor by growing moisture-depleting crops. This benefit is only applied in RUSLE in the Northwest Wheat and Range Region of the western United States.

When support practices are applied, they become integral parts of a resource management system for controlling soil erosion by water. Contour farming, contour stripcropping, and conservation buffers form ridges on or near the contour that slow runoff and trap sediment. Terraces and diversions intercept concentrated runoff flows and, in many cases, shorten the length of slope.

Some erosion control practices, such as grassed waterways and water control structures, do not substantially reduce sheet and rill erosion. While these can be effective erosion control practices in a resource management system, they are not a part of the soil loss reduction that is estimated by RUSLE.

Subpart 501F References

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Acceptable class and half-class factor K values for use in RUSLE where K values are adjusted for seasonal variability.

Original K value [1/]	Minimum value [2/]	Maximum value [3/]	Acceptable class and half-class K factor values [4/]					
0.02	0.016	0.024	0.02					
0.05	0.04	0.06	0.05					
0.10	0.08	0.12	0.08	0.10	0.12			
0.15	0.12	0.18	0.12	0.15	0.17			
0.17	0.136	0.204	0.15	0.17	0.20			
0.20	0.16	0.24	0.17	0.20	0.22	0.24		
0.24	0.192	0.288	0.20	0.22	0.24	0.26	0.28	
0.28	0.224	0.336	0.24	0.26	0.28	0.30	0.32	
0.32	0.256	0.384	0.26	0.28	0.30	0.32	0.35	0.37
0.37	0.296	0.444	0.30	0.32	0.35	0.37	0.40	0.43
0.43	0.344	0.516	0.35	0.37	0.40	0.43	0.46	0.49
0.49	0.392	0.588	0.40	0.43	0.46	0.49	0.52	0.55
0.55	0.44	0.66	0.46	0.49	0.52	0.55	0.60	0.64
0.64	0.512	0.768	0.52	0.55	0.60	0.64	0.70	0.76

1/ Original K value from the soils data base for a specific map unit or soil component.
2/ Minimum value is 80% of the original K value, and is the cap for acceptable minimum class and half-class values.
3/ Maximum value is 120% of the original K value, and is the cap for the acceptable maximum class and half-class values.
4/ Acceptable class and half-class K factor values, were approved 4/15/94 by a joint committee of NRCS soil scientists and agronomists, under the leadership of H.R. Sinclair, lead soil scientist.

Part 502 Wind Erosion

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Part 502 Wind Erosion

Subpart 502A Introduction

502.00 Overview

Part 502 presents Natural Resources Conservation Service (NRCS) policy and procedures for estimating wind erosion. It explains the Wind Erosion Equation (WEQ) and provides guidance and reference on wind erosion processes, prediction, and control. NRCS technical guidance related to wind erosion conforms to policy and procedures in this part.

This part will be amended as additional research on wind erosion and its control is completed and published. The national agronomist is responsible for updating this chapter and coordinating wind erosion guidance with Agricultural Research Service (ARS).

NRCS cooperating scientists may supplement this manual. However, appropriate supplements prepared by cooperating scientists are to be submitted to the national agronomist for review and concurrence before issuance. State supplements are to be reviewed and approved by the national agronomist before being issued to field offices.

Understanding the erosive forces of wind is essential to the correct use of the Wind Erosion Equation and interpretation of wind erosion data. NRCS predicts erosion rates, assesses potential damage, and plans control systems for wind erosion.

The Agricultural Research Service has primary responsibility for erosion prediction research within the U.S. Department of Agriculture (USDA). Wind erosion research is conducted by the Wind Erosion Research Unit at Manhattan, Kansas, and the Cropping Systems Research Unit at Big Spring, Texas.

Subpart 502B Wind erosion

502.10 The wind erosion problem

Wind is an erosive agent. It detaches and transports soil particles, sorts the finer from the coarser particles, and deposits them unevenly. Loss of the fertile topsoil in eroded areas reduces the rooting depth and, in many places, reduces crop yield. Abrasion by airborne soil particles damages plants and constructed structures. Drifting soil causes extensive damage also. Sand and dust in the air can harm animals, humans, and equipment.

Some wind erosion has always occurred as a natural land-forming process, but it has become detrimental as a result of human activities. This *accelerated* erosion is primarily caused by improper use and management of the land (Stallings 1951).

Few regions are entirely safe from wind erosion. Wherever the soil surface is loose and dry, vegetation is sparse or absent, and the wind sufficiently strong, erosion will occur unless control measures are applied (1957 Yearbook of Agriculture). Soil erosion by wind in North America is generally most severe in the Great Plains. The NRCS annual report of wind erosion conditions in the Great Plains shows that wind erosion damages from 1 million to more than 15 million acres annually, averaging more than 4 million acres per year in the 10-state area. USDA estimated that nearly 95 percent of the 6.5 million acres put out of production during the 1930's suffered serious wind erosion damage (Woodruff 1975). Other major regions subject to damaging wind erosion are the Columbia River plains; some parts of the Southwest and the Colorado Basin, the muck and sandy areas of the Great Lakes region, and the sands of the Gulf, Pacific, and Atlantic seaboards.

In some areas, the primary problem caused by wind erosion is crop damage. Some crops are tolerant enough to withstand or recover from erosion damage. Other crops, including many vegetables and specialty crops, are especially vulnerable to wind erosion damage. Wind erosion may cause significant short-term economic loss in areas where erosion rates are below the soil loss tolerance (T) when the crops grown in that area are easily damaged by blowing soil (table 502–4).

502.11 The wind erosion process

The wind erosion process is complex. It involves detaching, transporting, sorting, abrading, avalanching, and depositing of soil particles. Turbulent winds blowing over erodible soils cause wind erosion. Field conditions conducive to erosion include

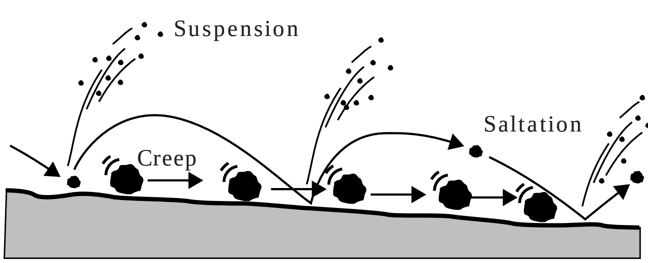
- loose, dry, and finely granulated soil;
- smooth soil surface that has little or no vegetation present;
- sufficiently large area susceptible to erosion; and
- sufficient wind velocity to move soil.

Winds are considered erosive when they reach 13 miles per hour at 1 foot above the ground or about 18 miles per hour at a 30 foot height. This is commonly referred to as the threshold wind velocity (Lyles and Krauss 1971).

The wind transports primary soil particles or stable aggregates, or both, in three ways (fig. 502-1):

Saltation—Individual particles/aggregates ranging from 0.1 to 0.5 millimeter in diameter lift off the surface at a 50- to 90-degree angle and follow distinct trajectories under the influence of air resistance and gravity. The particles/aggregates return to the surface at impact angles of 6 to 14 degrees from the horizontal. Whether they rebound or embed themselves, they initiate movement of other particles/aggregates to create the *avalanching* effect. Saltating particles are the abrading *bullets* that remove the protective soil crusts and clods. Most saltation occurs within 12 inches above the soil surface and typically, the length of a saltating particle trajectory is about 10 times the height. From 50 to 80 percent of total transport is by saltation.

Figure 502-1 The wind erosion process



Suspension—The finer particles, less than 0.1 millimeter in diameter, are dislodged from an eroding area by saltation and remain in the air mass for an extended period. Some suspension-sized particles or aggregates are present in the soil, but many are created by abrasion of larger aggregates during erosion. From 20 percent to more than 60 percent of an eroding soil may be carried in suspension, depending on soil texture. As a general rule, suspension increases downwind, and on long fields can easily exceed the amount of soil moved in saltation and creep.

Surface creep—Sand-sized particles/aggregates are set in motion by the impact of saltating particles. Under high winds, the whole soil surface appears to be creeping slowly forward as particles are pushed and rolled by the saltation flow. Surface creep may account for 7 to 25 percent of total transport (Chepil 1945 and Lyles 1980).

Saltation and creep particles are deposited in vegetated strips, ditches, or other areas sheltered from the wind, as long as these areas have the capacity to hold the sediment. Particles in suspension, however, may be carried a great distance.

The rate of increase in soil flow along the wind direction varies directly with erodibility of field surfaces. The increase in erosion downwind (avalanching) is associated with the following processes:

- the increased concentration of saltating particles downwind increases the frequency of impacts and the degree of breakdown of clods and crusts, and
- accumulation of erodible particles and breakdown of clods tends to produce a smoother (and more erodible) surface.

The distance required for soil flow to reach a maximum for a given soil is the same for any erosive wind. The more erodible the surface, the shorter the distance in which maximum flow is reached. Any factor that influences the erodibility of the surface influences the increase in soil flow.

Subpart 502C Estimating wind erosion

502.20 How, why, and by whom wind erosion is estimated

Using the Wind Erosion Equation (WEQ), NRCS estimates erosion rates to

- provide technical assistance to land users,
- inventory natural resources, and
- evaluate the effectiveness of conservation programs and conservation treatment applied to the land.

Wind erosion is difficult to measure. Wind moves across the land in a turbulent, erratic fashion. Soil may blow into, within, and out of a field in several directions in a single storm. The direction, velocity, duration, and variability of the wind all affect the erosion that occurs from a wind storm. Much of the soil eroding from a field bounces or creeps near the surface; however, some of the soil blown from a field may be high above the ground in a dust cloud by the time it reaches the edge of a field (Chepil 1963).

502.21 Methods of estimating wind erosion

No precise method of measuring wind erosion has been developed. However, various dust collectors, remote and in-place sensors, wind tunnels, sediment samplers, and microtopographic surveys before and after erosion have been used. Each method has its limitations. Research is continuing on new techniques and new devices, on modifications to older ones, and on means to measure wind erosion.

Estimates of wind erosion can be developed by assigning numerical values to the site conditions that govern wind erosion and expressing their relationships mathematically. This is the basis of the current Wind Erosion Equation (WEQ) that considers soil erodibility, ridge roughness, climate, unsheltered distance, and vegetative cover.

502.22 The wind erosion equation

The Wind Erosion Equation (WEQ) erosion model is designed to predict long-term average annual soil losses from a field having specific characteristics. With appropriate selection of factor values, the equation will estimate average annual erosion or erosion for specific time periods.

Development of the wind erosion equation

Drought and wind erosion during the l9th century caused wind erosion to be recognized as an important geologic phenomenon. By the late 1930's, systematic and scientific research into wind erosion was being pioneered in California, South Dakota, Texas, and in Canada and England. This research produced information on the mechanics of soil transport by wind, the influence of cultural treatment on rates of movement, and the influence of windbreaks on windflow patterns. *The Physics of Blown Sand and Desert Dunes*, (Bagnold 1941), is considered a classic by wind erosion researchers.

In 1947, USDA began the Wind Erosion Research Program at Manhattan, Kansas, in cooperation with Kansas State University. That program was started under the leadership of Austin W. Zingg, who was soon joined by W.S. Chepil, a pioneer in wind erosion research in Canada. The research project's primary purposes were to study the mechanics of wind erosion, delineate major influences on that erosion, and devise and develop methods to control it.

By 1954, Chepil and his coworkers began to publish results of their research in the form of wind erosion prediction equations (Chepil 1954; Chepil 1957; Chepil et al. 1955; Woodruff and Chepil 1956)

In 1959, Chepil released an equation

$$E = IRKFBWD$$

where:

E = quantity of erosion
I = soil cloddiness
R = residue
K = roughness
F = soil abradability
B = wind barrier
W = width of field
D = wind direction

Wind velocity at geographic locations was not addressed in this equation (Chepil 1959).

In 1962, Chepil's group released the equation

$$E = f(ACKLV)$$

where:

A = percentage of soil fractions greater than 0.84 millimeter.

Factors C, K, L, and V were the same as in the present equation although they were not handled the same (Chepil 1962). A C-factor map for the western half of the United States was also published in 1962 (Chepil et al. 1962).

In 1963, the current form of the equation, $E = f(IKCLV)$ was first released (Chepil 1963).

In 1965, the concept of preponderance in assessing wind erosion forces was introduced. See 502.34 for details on preponderance (Skidmore 1965 and Skidmore and Woodruff 1968).

In 1968, monthly climatic factors were published (Woodruff and Armbrust 1968). These are no longer used by NRCS. Instead, NRCS adopted a proposal for computing soil erosion by periods using wind energy distribution which was published in 1980 (Bondy et al. 1980). (See 502.24.) In 1981, the Wind Erosion Research Unit provided NRCS with data on the distribution of erosive wind energy for the United States and in 1982 provided updated annual C factors. (See exhibit 502-8.)

Although the present equation has significant limitations (see 502.23), it is the best tool currently available for making reasonable estimates of wind erosion. Currently, research and development of improved procedures for estimating wind erosion are underway in two broad categories:

- Improving the understanding of relationships of individual factors that influence wind erosion (including improvement of guidelines for the five factors of the present equation).
- Developing a new prediction model that will provide an erosion estimate by simulating processes of soil movement through time through a given space (Cole 1984).

The present Wind Erosion Equation is expressed as:

$$E = f(IKCLV)$$

where:

E = estimated average annual soil loss in tons per acre per year
f = indicates relationships that are not straight-line mathematical calculations
I = soil erodibility index
K = soil surface roughness factor
C = climatic factor
L = the unsheltered distance
V = the vegetative cover factor

The **I** factor, expressed as the average annual soil loss in tons per acre per year from a field area, accounts for the inherent soil properties affecting erodibility. These properties include texture, organic matter, and calcium carbonate percentage. **I** is the potential annual wind erosion for a given soil under a given set of field conditions. The given set of field conditions for which **I** is referenced is that of an isolated, unsheltered, wide, bare, smooth, level, loose, and noncrusted soil surface, and at a location where the climatic factor (C) is equal to 100. (For details on the **I** factor see 502.31).

The K factor is a measure of the effect of ridges and cloddiness made by tillage and planting implements. It is expressed as a decimal from 0.1 to 1.0. (For details on the K factor see 502.32.)

The C factor for any given locality characterizes climatic erosivity, specifically windspeed and surface soil moisture. This factor is expressed as a percentage of the C factor for Garden City, Kansas, which has a value of 100. (For details on the C factor see 502.33.)

The L factor considers the unprotected distance along the prevailing erosive wind direction across the area to be evaluated and the preponderance of the prevailing erosive winds. (For details on the L factor see 502.34.)

The V factor considers the kind, amount, and orientation of vegetation on the surface. The vegetative cover is expressed in pounds per acre of a flat small-grain residue equivalent. (For details on the V factor see 502.35.)

Solving the equation involves five successive steps. Steps 1, 2 and 3 can be solved by multiplying the factor values. Determining the effects of L and V (steps 4 and 5) involves more complex functional relationships.

Step 1: $E_1 = I$

Factor I is established for the specific soil. I may be increased for knolls less than 500 feet long facing into the prevailing wind, or decreased to account for surface soil crusting, and irrigation.

Step 2: $E_2 = IK$

Factor K adjusts E_1 for tillage-induced oriented roughness, K_{rd} (ridges) and random roughness, K_{rr} (cloddiness). The value of K is calculated by multiplying K_{rd} times $K_{rr.}$ ($K = K_{rd} \times K_{rr}$).

Step 3: $E_3 = IKC$

Factor C adjusts E_2 for the local climatic factor.

Step 4: $E_4 = IKCL$

Factor L adjusts E_3 for unsheltered distance.

Step 5: $E_5 = IKCLV$

Factor V adjusts E_4 for vegetative cover.

502.23 Limitations of the equation

When the unsheltered distance, L, *is sufficiently long, the transport capacity of the wind for saltation and creep is reached*. If the wind is moving all the soil it can carry across a given surface, the inflow into a downwind area is equal to the outflow for saltation and creep. The net soil loss is then only the suspension component. This does not imply a reduced soil erosion problem because, theoretically, there is still the estimated amount of soil loss in creep, saltation, and suspension leaving the downwind edge of the field.

Surface armoring by nonerodible gravel is not usually addressed in the **I** factor.

The equation does not account for snow cover or seasonal changes in soil erodibility. The equation does not estimate erosion from single storm events.

502.24 Alternative procedures for using the WEQ

The WEQ Critical Period Procedure is based on use of the Wind Erosion Equation as described by Woodruff and Siddoway in 1965 (Woodruff and Siddoway 1965). The conditions during the critical wind erosion period are used to derive the estimate of annual wind erosion.

- The Critical Wind Erosion Period is described as the period of the year when the greatest amount of wind erosion can be expected to occur from a field under an identified management system. It is the period when vegetative cover, soil surface conditions, and expected erosive winds result in the greatest potential for wind erosion.
- Erosion estimates developed using the critical period procedure are made using a single set of factor values in the equation to describe the critical wind erosion period conditions. Average annual estimates of erosion made using this method can be misleading since site conditions usually vary significantly during the year, and therefore cannot be described accurately by a single set of factor values.
- The critical period procedure is currently used for resource inventories. NRCS usually provides specific instructions on developing wind erosion estimates for resource inventories.
- The critical period procedure will not be used for conservation planning purposes except in cases where an acceptable version of the management period procedure is not available on field office computers. Where an acceptable version is available on field office computers, the management period procedure (described below) shall be used for estimating average annual rates of wind erosion.

The WEQ Management Period Procedure was published by Bondy, Lyles, and Hayes in 1980. It solves the equation for situations where site conditions have significant variation during the year or planning period and where different factor values must be used to describe these variable conditions. The management period procedure is more responsive to changing conditions throughout the cropping year than is the critical period procedure.

Comparisons should not be made between the soil erosion predictions made by the management period procedure and the critical period procedure. In other words, where a conservation system has been determined to be acceptable by the management period procedure and placed in a conservation plan or the FOTG, then only the management period procedure will be used to determine if other conservation systems, planned or applied, provide equivalent treatment.

Factor values are selected which describe management periods when cover and management effects are approximately uniform. The cropping system is divided into as many management periods as is necessary to describe the year or planning period accurately. Each management period is represented by a set of factor values representing conditions specific to that period of time. Erosive wind energy distribution is used to derive a weighted estimate of soil loss for the period. The general procedure is as follows:

- Solve for E in the basic equation (E = ƒ(IKCLV)) using management period values for I, K, L, and V, and the local annual value for C.
- Multiply the annual soil loss rate E obtained from management period values by the percentage of annual erosive wind energy that occurs during the management period to estimate average erosion for that management period.
- Add the management period amounts for the crop year, or add the period amounts for a total crop sequence and divide by the number of years in the sequence to estimate average annual wind erosion.

Exhibit 502–7a is an example of tables showing the expected monthly distribution of erosive wind energy at specific locations. The complete table is available for downloading at

http://www.weru.ksu.edu/nrcs/windparm.doc

Exhibit 502–7b shows how these values are used in the management period method computations. Erosive wind energy values are entered on the form in the column identified “% EWE”.

Estimates for management periods less than 1 year in duration are often useful in conservation planning. Examples include

- When crop damage (crop tolerance) during sensitive growth stages is the major concern.
- When a system or practice is evaluated for short-term effects.

States will use the management period procedure, within published guidelines, for conservation planning only. It will not be used for resource inventories unless specifically stated in instructions, or for determining the Erodibility Index under the conservation provisions of the Food Security Act of 1985 (FSA) as amended by the Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA).

Adjustments to the soil erodibility factor, **I**, of the wind erosion equation for temporary conditions, including irrigation or crusts, are to be used only with the management period method. The use of monthly preponderance data to determine equivalent field width is also applicable only to this procedure.

502.25 Data to support the WEQ

ARS has developed benchmark values for each of the factors in the WEQ. However, the NRCS is responsible for developing procedures and additional factor values for use of the equation. Field Office Technical Guides will include the local data needed to make wind erosion estimates.

ARS has computed benchmark C factors for locations where adequate weather data are available (Lyles 1983). C factors used in the field office are to reflect local conditions as they relate to benchmark C factors. Knowledge of local terrain features and local climate is needed to determine how point data can be extended and how interpolation between points should be done. See 502.33 for guidance.

ARS has developed soil erodibility **I** values based on size distribution of soil aggregates. Soils have been grouped by texture classes into wind erodibility groups. Wind erodibility group numbers are included in the NASI's data base.

For further discussion of benchmark data supporting factor values, refer to subpart 502D, WEQ factors.

502.26 Using WEQ estimates with USLE or RUSLE calculations

The WEQ provides an estimate of average wind erosion from the field width along the prevailing wind erosion direction (L) entered in the calculation; USLE or RUSLE provide an estimate of average sheet and rill erosion from the slope length (L) entered in that water erosion calculation. Although both wind and water erosion estimates are in tons per acre per year, they are not additive unless the two equations represent identical flow paths across identical areas.

502.27 Tools for using the WEQ

Graphs and tables for determining factor values are in Subpart 502G Exhibits.

E tables

The ARS WEROS (Wind Erosion) computer program has produced tables that give estimated erosion (E values) for most of the possible combinations of I, K, C, L, and V. Exhibit 502–1 is an example. See 502.30 for procedures to download E tables.

Use of the management period procedure can be simplified through the use of worksheets on which information for each management period is documented. Subpart 502F is to include sample wind erosion computations using the Management Period Procedure.

An acceptable WEQ calculator has been developed in Microsoft Excel, and is being adapted for use in many states. A copy of this spreadsheet can be obtained from the NRCS state agronomist in Albuquerque, New Mexico. Exhibit 502.7B shows an example of this spread sheet.

Trade names mentioned are for specific information and do not constitute a guarantee or warranty of the product by the Department of Agriculture or an endorsement by the Department over other products not mentioned.

Subpart 502D WEQ Factors

502.30 The wind erosion estimate, E

The wind erosion estimate, E, is the estimate of average annual tons of soil per acre that the wind will erode from an area represented by an unsheltered distance L and for the soil, climate, and site conditions represented by I, K, C, and V. The equation is an empirical formula. It was initially developed by relating wind tunnel data to observed field erosion for 3 years in the mid 1950's (Woodruff et al. 1976). The field data was normalized to reflect long-term average annual erosion assuming given conditions during the critical period without reference to change in those conditions through the year. The estimate arrived at by using the critical period procedure for estimating wind erosion does not track specific changes brought about by management and crop development; nor does it assume that critical period conditions exist all year. The calibration procedure accounted for minor changes expected to occur during a normal crop year at that time in history. The WEQ annual E is based on an annual C and field conditions during the critical wind erosion period of the year. This procedure does not account for all the effects of management.

The management period procedure for estimating wind erosion involves assigning factor values to represent field conditions expected to occur during specified time periods. Using annual wind energy distribution data, erosion can be estimated for each period of time being evaluated. The period estimates are summed to arrive at an annual estimate. Cropping sequences involving more than 1 year can be evaluated using this procedure. It also allows for a more thorough analysis of a management system and how management techniques affect the erosion estimate.

The new E tables can be downloaded from the WERU server, Manhattan, Kansas. These tables can be accessed in two ways:

- Through your WWW browser. To view, direct your web browser to:

  http://www.weru.ksu.edu/nrcs

  Download the Adobe Acrobat Reader (if not already installed on your browser) by clicking on the icon and installing per the installation instructions. When the Adobe Acrobat Reader is running on your browser you can click the PDF icon to view and print the table. When on the WERU Web page, copies of the files can be downloaded by clicking on the hypertext for the following:

etab.pdf for PDF or
etab.wpd (for WordPerfect) or
etab.ps for Postscript

- Through FTP—For those without a web browser but have FTP access, FTP to:

  ftp.weru.ksu.edu

  go to the appropriate directory, for example

  cd pub/nrcs/etables

  Be sure that you are in binary mode.

To download the table format of your choice, type:

get “etab.pdf” for PDF or
get “etab.wpd” for WordPerfect or
get “etab.ps” for Postscript

The appropriate E table will download to your computer. Exhibit 502-1 shows an example of an E table.

502.31 Soil erodibility index, I

I is the erodibility factor for the soil on the site. It is expressed as the average annual soil loss in tons per acre that would occur from wind erosion, when the site is:

- **Isolated –** incoming saltation is absent
- **Level –** knolls are absent
- **Smooth –** ridge roughness effects are absent and cloddiness is minimal
- **Unsheltered –** barriers are absent.
- At a location where the **C factor is 100**
- **Bare –** vegetative cover is absent
- **“Wide” –** the distance at which the flow of eroding soil reaches its maximum and does not increase with field size
- **Loose –** and non-crusted, aggregates not bound together, and surface not sealed.

The **I** factor is related to the percentage of nonerodible surface soil aggregates larger than 0.84 millimeters in diameter. For most NRCS uses, the **I** value is assigned for named soils based on wind erodibility groups (WEG). The WEG is included in the NASI's data base

If the soil name is not known, exhibit 502–2 can be used to determine the WEG from the surface soil texture.

To determine erodibility for field conditions during various management periods throughout the year, follow sieving instruction in exhibit 502–3. (Do not use this procedure to determine average annual **I** values.) A soil erodibility index based solely on the percentage of aggregates larger than 0.84 millimeters has several potential sources of error. Some of these follow:

- Relative erodibility of widely different soil may change with a change in wind velocity over the surface of the soil.
- Calibration of the equation is based on the volume of soil removed, but the erodibility index is based on weight.
- Differences in size of aggregates have considerable influence on erodibility but no distinction for this influence is made in table 1, exhibit 502–3.
- Stability of surface aggregates influences erodibility; large durable aggregates can become a *surface armor*; less stable aggregates can be abraded into smaller, more erodible particles.
- Surface crusting may greatly reduce erodibility; erodibility may increase again as the crust deteriorates (Chepil 1958).

***Knoll erodibility*—**Knolls are topographic features characterized by short, abrupt windward slopes. Wind erosion potential is greater on knoll slopes than on level or gently rolling terrain because wind flowlines are compressed and wind velocity increases near the crest of the knolls. Erosion that begins on knolls often affects field areas downwind.

Adjustments of the Soil Erodibility Index (**I**) are used where windward-facing slopes are less than 500 feet long and the increase in slope gradient from the adjacent landscape is 3 percent or greater. Both slope length and slope gradient change are determined along the direction of the prevailing erosive wind (fig. 502–2).

Table 502-1 Knoll erodibility adjustment factor for **I**

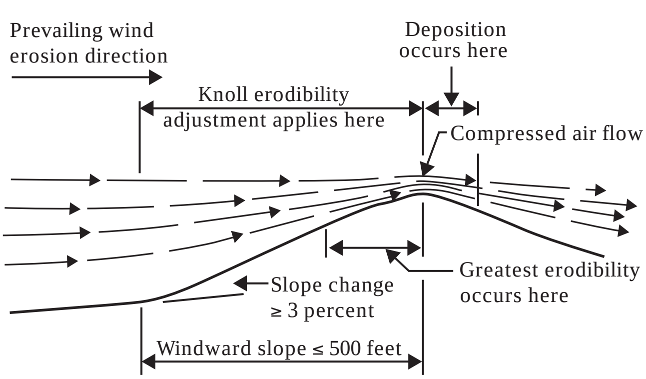
Percent slope change in prevailing wind erosion direction	A Knoll adjustment of **I**	B Increase at crest area where erosion is most severe
3	1.3	1.5
4	1.6	1.9
5	1.9	2.5
6	2.3	3.2
8	3.0	4.8
10 and greater	3.6	6.8

Table 502-1 contains knoll erodibility adjustment factors for the Soil Erodibility Index **I**. The **I** value for the Wind Erodibility Group is multiplied by the factor shown in column A. This adjustment expresses the average increase in erodibility along the knoll slope. For comparison, column B shows the increased erodibility near the crest (about the upper 1/3 of the slope), where the effect is most severe.

No adjustment of **I** for knoll erodibility is made on level fields, or on rolling terrain where slopes are longer and slope changes are less abrupt. Where these situations occur, the wind flow pattern tends to conform to the surface and does not exhibit the flow constriction typical of knolls.

Surface crusting—Erodibility of surface soil varies with changing tillage practices and environmental conditions (Chepil 1958). A surface crust forms when a bare soil is wetted and dried. Although the crust may be so weak that it has virtually no influence on the size distribution of dry aggregates determined by sieving, it can make the soil less erodible. The resistance of the crust to erosion depends on the nature of the soil, intensity of rainfall, and the kind and amount of cover on the soil surface. A fully crusted soil may erode only one-sixth as much as non-crusted soil. However, a smooth crusted soil with loose sand grains on the surface is more erodible than the same field with a cloddy or ridged surface.

Figure 502–2 Graphic of knoll erodibility



Under erosive conditions, the surface crust and surface clods on fine sands and loamy fine sands tend to break down readily. On silt loams and silty clay loams the surface crust and surface clods may be preserved, and the relative erosion may be as little as one-sixth of **I**. Other soils react somewhere between these two extremes (Chepil 1959).

Because of the temporary nature of crusts, no adjustment for crusting is made for annual estimates based on the critical wind erosion period method (Woodruff and Siddoway 1973). However, crust characteristics may be estimated and adjustment to **I** may be made for management period estimates when no traffic, tillage, or other breaking of crusts is anticipated. Such adjustments may be up to, but may not exceed the percentages shown in table 502–2.

Irrigation adjustments—The **I** values for irrigated soils, as shown in exhibit 502–2, are applicable throughout the year. **I** adjustments for irrigation are applicable only where assigned **I** values are 180 or less.

Adjustments based on dry sieving—Temporal changes in the surface fraction > 0.84 millimeter may be measured by dry sieving. These measurements may be used to establish a basis for adjusting **I** for conservation planning when sieving has been performed for each management period and for 3 years or more. The adjustment to **I** applies only to the respective time periods when the soil surface is influenced by changes in the nonerodible fraction. Therefore, the adjustment is used only with the management period procedure of estimating wind erosion. The procedure does expand the applicability of the equation to a management effect not previously addressed. When the **I** factor is adjusted based on the results of sieving, no additional

Table 502-2 **I** adjustment guidelines for crusts

WEG	I	Max. adj. mgt prd. factor 1/	Calculated I	Rounded I
1	310	.7	217	220
1	250	.7	175	180
1	220	.7	154	160
1	180	.7	126	134
1	160	.7	112	134
2	134	.7	67	86
3	86	.4	34	38
4	86	.4	34	38
4L	86	.4	34	38
5	56	.3	17	21
6	48	.3	14	21
7	38	.3	11	12

1/ The management period adjustment to **I** has not been validated by research and is based on NRCS judgment.

adjustment to **I** will be made for irrigated fields. Adjustments to **I**, based on sieving, should not be used without adequate supporting data. These adjustments reflect specific soil and management conditions and are only applicable in the area(s) from which samples were obtained and in areas that have similar soil and management conditions.

Use of adjusted soil erodibility **I** factor, arrived at by using standard rotary sieving procedures, is warranted provided it represents soil surface conditions during the appropriate management period. Adjustments may be made up to, but should not exceed, limits assigned for crusting in table 502-2.

The **I** factor adjustment may be used where applicable in determining whether an adequate conservation system is being followed. However, **I** factor adjustments are not to be used in the erodibility index (CI/T) when determining highly erodible land because this index is the potential erodibility and not an estimate of actual erosion.

Current instructions for the National Resources Inventory (NRI) are to be followed. These instructions do not allow for any adjustment of the **I** factor. This ensures uniformity between States and allows for trend analysis.

Studies to adjust **I** should be made systematically and include all related soil in a given area. Multiple-year soil sieving data is required before adjustments are to be considered.

The National Soil Survey Center must review and concur in any proposal to adjust **I** and arrange for laboratory assistance. Adjustments to **I** must also be approved by the National Soil Survey Center and correlated across state and regional boundaries before implementation. Any adjustment to **I** must be within the framework of the existing E tables.

Surface stability—A significant limitation of the **I** factor is that it does not account for changes in the soil surface over time that are caused by the dynamics of wind erosion. The erodibility of a bare soil surface is based on the interaction of the following:

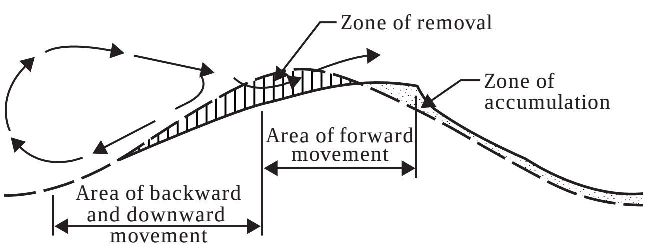
- Soils that have both erodible and nonerodible particles on the surface tend to stabilize if there is no incoming saltation. As the wind direction changes, the surface is disturbed, or the wind velocity increases, erosion may begin again.
- Saltation destroys crusts, clods, and ridges by abrasion.
- Fields tend to become more erodible as finer soil particles, which provide bonding for aggregation, are carried off in suspension.
- If the surface soil contains a high percentage of gravel or other nonerodible particles that are resistant to abrasion, the surface will become increasingly armored as the erodible particles are carried away. Desert pavement is the classic example of surface armoring. A surface with only nonerodible aggregates exposed to the wind will not erode further except as the aggregates are abraded.
- A surface may be virtually nonerodible and yet allow saltation and creep to cross unabated. A paved highway is an example. Other surfaces may be relatively stable and trap some, or all, of the incoming soil flow. Examples of this type of stability usually relate to some roughness, sheltering, or vegetative cover. A ridged field may trap a significant portion of the incoming soil flow until the furrows are filled and the surface loses its trapping capability. A vegetated barrier will provide a sheltered area downwind until the barrier is filled with sediment.

502.32 Soil roughness factor K, ridge and random roughness

K_{rd} is a measure of the effect of ridges made by tillage and planting implements. Ridges absorb and deflect wind energy and trap moving soil particles (fig. 502–3).

The K_r value is based on a standard ridge height to ridge spacing ratio of 1:4. Because of the difficulty of determining surface roughness by measuring surface obstructions, a standard roughness calibration using nonerodible gravel ridges in a wind tunnel was developed. This calibration led to the development of curves (fig. 502–4 and exhibit 502–4) that relate ridge roughness, K_r, to a soil ridge roughness factor, K_{rd}, (Skidmore 1965; Skidmore and Woodruff 1968; Woodruff and Siddoway 1965; and Hagen 1996).

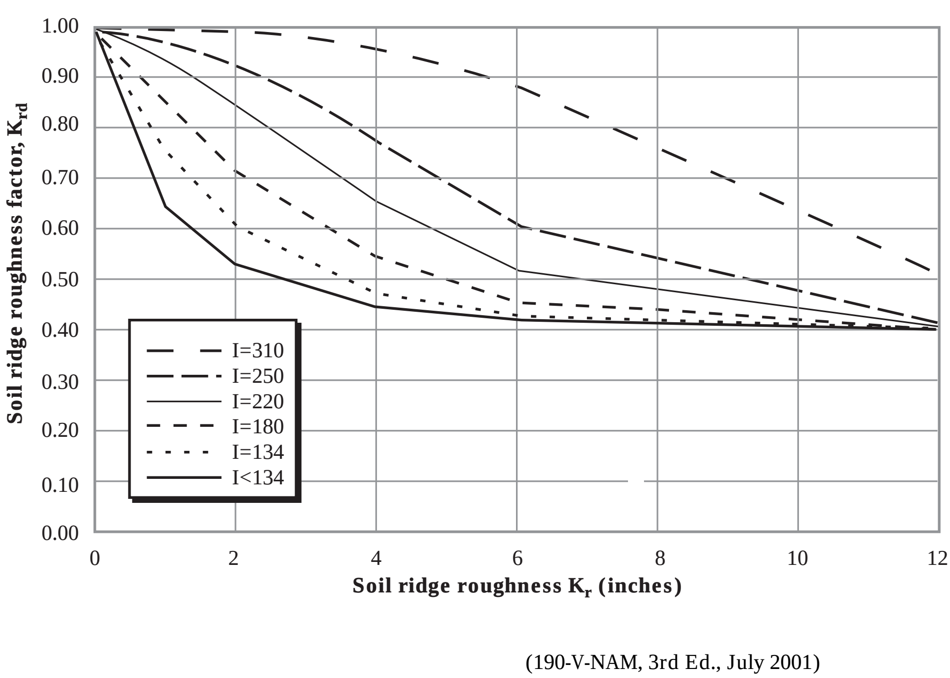
Figure 502–3 Detachment, transport, and deposition on ridges and furrows



The K_r curves are the basis for charts and tables used to determine K_{rd} factor values in the field (exhibits 502–4 and 502–5). The effect of ridges varies as the wind direction and erodibility of the soil change. To take into account the change in wind directions across a field, we consider the angle of deviation. The angle of deviation is the angle between the prevailing wind erosion direction and a line perpendicular to the row direction. The angle of deviation is 0 (zero) degrees when the wind is perpendicular to the row and is 90 degrees when the wind is parallel to the row. Following is an example of how the angle of deviation affects K_{rd} values: when evaluating a soil with an assigned **I** value of <134, and the prevailing erosive wind direction is perpendicular to ridges 4 inches high and 30 inches apart, then K_{rd} is 0.5. But when the prevailing erosive wind direction is parallel to those ridges, the K_{rd} value is 0.7. Random roughness, particularly in the furrows, significantly reduces wind erosion occurring from erosive winds blowing parallel to the ridges.

In 1996, ARS scientists provided a method for adjusting the WEQ K_{rd} factor with consideration for prepon-

Figure 502–4 Chart to determine soil ridge roughness factor, K_{rd}, from ridge roughness, K_r, (inches). Only this chart, representing an angle of deviation of 0°, will be used for the WEQ **critical period procedure**. When using the **management period procedure**, see exhibit 502–4 for graphs representing additional angles of deviation. Note: This graph represents erosive wind energy 60% parallel and 40% perpendicular to the prevailing erosive wind.
—Hagen 1996



$$K_r = \frac{4(h \times h)}{s}$$

where:
h = ridge height in inches
s = ridge spacing in inches

derance (erosive wind energy 60% parallel and 40% perpendicular to prevailing erosive wind direction) when using the Management Period Procedure. The use of preponderence recognizes that during the periods when the prevailing erosive winds are parallel to ridges, there are other erosive winds during the same period which are not parallel, thus making ridges effective during part of each period. Preponderance keeps the K factor value less than 1.0, when the **I** factor values are 134 or less. When estimating wind erosion rates by management periods, without the aid of a computer model, the prevailing wind erosion direction and a *default* preponderance are used for each period. This procedure more adequately addresses the effects of the ridges in wind erosion control since erosive wind directions may vary within each management period.

> **Note:** When using the WEQ Excel spreadsheet model, the actual preponderance, up to and including a value of 4, for the period will be used, rather than a default value.

The WEQ K_{rr} factor accounts for random roughness. Random roughness is the nonoriented surface roughness that is sometimes referred to as cloddiness. Random roughness is usually created by the action of tillage implements. It is described as the standard deviation (in inches) of the soil surface elevations, measured at regular intervals from a fixed, arbitrary plane above a tilled soil surface, after oriented (ridge) roughness has been accounted for. Random roughness can reduce erosion significantly. Note: The random roughness factor will only be used with the WEQ management period procedure.

Random roughness values have been developed for various levels of WEQ **I** factor values and surface random roughness (exhibit 502–6). Random roughness curves only adjust the K factors of a soil that has an **I** factor value of 134 and less.

The random roughness values used in the WEQ are the same random roughness values used in RUSLE. Random roughness (inches) from the machine operations data base in RUSLE can determine WEQ random roughness values (exhibit 502–7). However, keep in mind that these RUSLE random roughness values were determined for medium textured soils tilled at optimum moisture conditions for creating random roughness. Under most circumstances random roughness is determined by comparing a field surface to the random roughness (standard deviation) photos in the RUSLE handbook (Agriculture Handbook 703, appendix C).

> The photos in Agriculture Handbook 703, appendix C, are also on the Fort Collins server at the following address:
> **ftp://ftp.nrcs.usda.gov/divisions/esd/erosion**
>
> State agronomists should download, reproduce, and distribute the photographs to field offices.

When both random roughness and ridge roughness are present in the field, they are complimentary. When both are present, the K_{rd} factor for ridges and K_{rr} factor for random roughness will be multiplied together to obtain the total roughness K-factor.

Example problem: Take into consideration just one WEQ management period. The soil in the field being evaluated has an **I** value of 86. The field has just been fertilized with anhydrous ammonia using a knife applicator. Considering the height and spacing of the oriented roughness, the ridge roughness K_{rd} factor was determined to be 0.8. Using exhibit 502–7, under random roughness (inches), the anhydrous applicator has a core value of 0.6. Going into the random roughness (inches) graph (exhibit 502–6), on the horizontal axis to 0.6, and then vertically to the line representing an **I** factor of 86, the K_{rr} factor is rounded to 0.8. The total roughness value (K factor) is 0.8 x 0.8 = 0.64, then rounded to 0.6.

The major effects of random roughness on wind erosion are to raise the threshold wind speed at which erosion begins and to provide some sheltered area among the clods where moving soil can be trapped. Hence, when the effectiveness of random roughness increases the total K-value decreases.

Random roughness, particularly in the furrows, significantly reduces wind erosion occurring from erosive winds blowing parallel to the ridges.

Random roughness is subject to much faster degradation by rain or wind erosion than large tillage ridges. Therefore the WEQ management period, where random roughness is effective, may be of short duration.

For fields being broken out of sod, such as CRP, random roughness will be credited for erosion control.

The field surface is usually covered with the crowns of plants, their associated roots, and adhering soil. The total random roughness of the field should be compared to the photos in the RUSLE handbook and credited appropriately.

Surface roughening (emergency tillage)—In some situations, there is a need to control erosion on bare fields where the surface crust has been destroyed or where loose grains are on the surface and can abrade an existing crust. One method to reduce the erosion hazard on such fields is emergency or planned tillage to roughen the surface or increase nonerodible clods on the surface (random roughness). This may be accomplished by one or more of the following:

- Soil that characteristically forms a crust with loose sand grains on the surface may be worked to create clods. The loose grains fall into the crevices between clods. This is the principle of sand fighting used in some emergency tillage.
- The soil may be deep tilled to bring up finer textured soil material that will form more persistent clods.
- Irrigation increases the nonerodible fraction of a soil (exhibit 502–2).
- The surface may be worked into a ridge-furrow configuration that will trap loose, moving soil.
- The soil may be tilled in strips or in widely spaced rows to provide some degree of ridge and random roughness to break the flow of saltation and creep.

502.33 Climatic factor, C

The C factor is an index of climatic erosivity, specifically windspeed and surface soil moisture. The factor for any given location is based on long-term climatic data and is expressed as a percentage of the C factor for Garden City, Kansas, which has been assigned a value of 100 (Lyles 1983). In an area with a C factor of 50, for example, the IKC value would be only half of the IKC for Garden City, Kansas.

The climatic factor equation is expressed as:

$$C = 34.48 \times \frac{V^3}{(PE)^2}$$

where:

C = annual climatic factor
V = average annual wind velocity
PE = precipitation-effectiveness index of Thornthwaite
34.48 = constant used to adjust local values to a common base (Garden City, Kansas)

The basis for the windspeed term of the climatic factor is that the rate of soil movement is proportional to windspeed cubed. Several researchers have reported that when windspeed exceeds threshold velocity, the soil movement is directly proportional to friction velocity cubed which, in turn, is related to mean windspeed cubed (Skidmore 1976).

The basis for the soil moisture term of the climatic factor is that the rate of soil movement varies inversely with the equivalent surface soil moisture. Effective surface soil moisture is assumed to be proportional to the Thornthwaite precipitation-effectiveness index (PE) (Thornthwaite 1931). The annual PE index is the sum of the 12 monthly precipitation effectiveness indices. The formula is expressed as follows:

$$PE = \sum^{12} 115 \times \left[\frac{P}{(T-10)}\right]^{\frac{10}{9}}$$

where:

PE = the annual precipitation effectiveness index
P = average monthly precipitation
T = average monthly temperature

Exhibit 502–8 gives instructions to access the national C factor isoline map developed by NRCS in 1987. The map displays C factors for all areas of the conterminous United States and Alaska. The isolines were drafted to conform with local C factors calculated from 1951–80 weather data and were correlated across state and regional boundaries. Procedures for developing local C factors are explained in exhibit 502–8a.

1. Interpolation of WEQ climatic factors (C)—States may interpolate between county assigned C values to the nearest 5 units based on the National C Factor Isoline Map or the state C Factor Isoline Map in the Field Office Technical Guide (FOTG). When interpolating between

values, knowledge of the local climatic and topographic conditions is extremely useful since climatic conditions can vary disproportionately between C factor value isolines.

2. Where WEQ soil loss (E) tables have been developed with C factor increments greater than 5 units, a straight line interpolation to the nearest C factor value of 5 may be made from existing E tables. Straight line interpolations can also be made from the soil losses (E) calculated with approved WEQ computer software, when C factors programmed into the model are in increments greater than 5 units.

3. C factor interpolations are for the purpose of conservation planning only and are NOT to be used in determining or adjusting previous highly erodible land (HEL) designations. However, they may be used during status reviews to determine if an individual is actively applying a conservation system. Previous national policy, regarding the changing of prior HEL designations, remains in effect.

Effects of irrigation water on the C factor—When irrigation water is applied to a dry soil surface, a reduction in wind erosion can be expected. A specific procedure to directly adjust the climatic factor C for irrigation is not available. However, a procedure has been developed by researchers to adjust the Erosive Wind Energy (EWE) by the fraction of time during which the soil is considered wet and nonerodible because of irrigation. See 502.31 and exhibit 502–2.

The procedures that follow adjust the Erosive Wind Energy (EWE) value which planners are to use when estimating wind erosion on irrigated fields. This adjustment is for the WEQ Management Period Procedure. States where wind erosion is a concern should replace previous methods used to adjust for the effects of irrigation and utilize this procedure and the procedure for adjusting the **I** factor, for all plan revisions or new planning activities. This new procedure, however, does not impact designated highly erodible lands (HEL) or new determinations since management practices are not considered in the HEL formula.

Note: Irrigation adjustments to EWE and to the **I** factor, apply to fully irrigated fields and to fields that receive *supplemental* irrigation water.

- Research scientists have developed an Irrigation Factor (IF) that adjusts the EWE or period erosion loss to account for the effect of irrigation wetting the soil surface and making it less erodible. The IF takes into account the number of days in a management period, number of irrigation events during a management period, and a Texture Wetness Factor (TWF).
- To account for the *nonerodible wet* condition of various soil textures after irrigation, a TWF of 1, 2, or 3 is assigned to coarse, medium, and fine textured soil, respectively. See exhibit 502.2 for values assigned to the various soil groups.
- The IF is calculated with the following equation:
  IF = number of days in period minus (–) nonerodible wet days in period (NEWD), divided by the number of days in period. Nonerodible Wet Days (NEWD) are equal to the Texture Wetness Factor (TWF) times the number of irrigation events in the period.
- When using the WEQ to account for the effects of irrigation, multiply the EWE for the period by the IF.
- Example: A fine textured soil was irrigated three times during 45 days. Twelve percent of the annual EWE occurs during this period. Therefore:
  TWF = 3 for fine textured soil
  Number of irrigations during the period = 3
  NEWD = (3)(3) = 9
  IF = (45 days – 9)/45 = 0.80

  The adjusted EWE for 45 days is then determined by multiplying IF times the percentage of annual erosion wind energy during the period being evaluated.
  Adjusted EWE = (.80)(12%) = 9.6 %

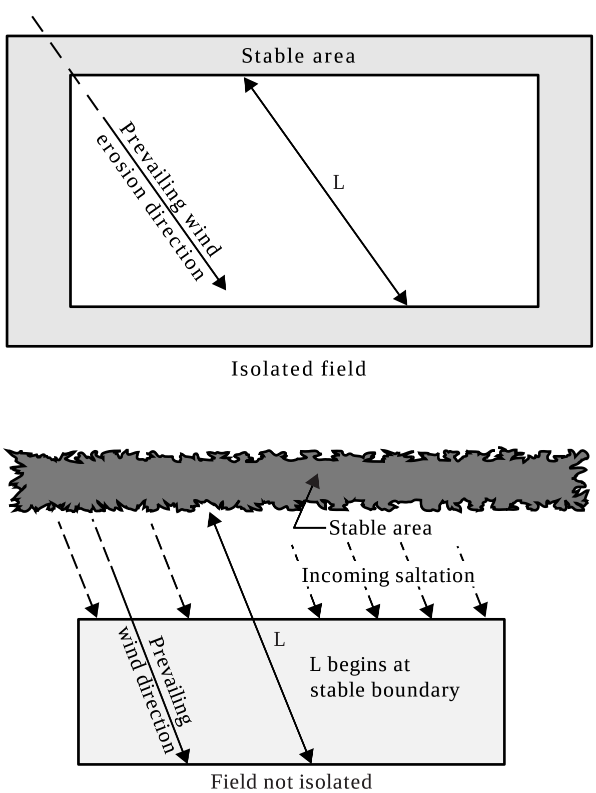
  Note: The EWE shall not be adjusted for any management period where irrigation does not occur.
- The WEQ factors (C & I) used to determine the Erodibility Index (EI), will not be adjusted when determining highly erodible land (HEL) on cropland that is irrigated.

502.34 Unsheltered distance, L

The L factor represents the unsheltered distance along the prevailing wind erosion direction for the field or area to be evaluated. Its place in the equation is to relate the *isolated, unsheltered, and wide* field condition of **I** to the size and shape of the field for which the erosion estimate is being prepared. Because V is considered after L in the 5-step solution of the equation (502.22), the unsheltered distance is always considered as if the field were bare except for vegetative barriers.

1. L begins at a point upwind where no saltation or surface creep occurs and ends at the downwind edge of the area being evaluated (figure 502–5). The point may be at a field border or stable area where vegetation is sufficient to eliminate the erosion process. An area should be considered stable only if it is able to trap or hold virtually all expected saltation and surface creep from upwind. If vegetative barriers, grassed waterways, or other stable areas divide an agricultural field being evaluated, each subdivision will be *isolated* and shall be evaluated as a separate *field*. Refer to the appropriate NRCS Conservation Practice Standards to determine when practices are of adequate width, height, spacing, and density to create a stable area.

Figure 502–5 Unsheltered distance L



2. When erosion estimates are being calculated for cropland or other relatively unstable conditions, upwind pasture or rangeland should be considered a stable border. However, if the estimate is being made for a pasture or range area, L should be determined by measuring from the nearest stable point upwind of the area or field in question (figure 502–6). The only case where L is equal to zero is where the area is fully sheltered by a barrier.

3. When a barrier is present on the upwind side of a field, measure L across the field along the prevailing wind erosion direction and subtract the distance sheltered by the barrier. Use 10 times the barrier height for the sheltered distance (figure 502–7).

4. When a properly designed wind stripcropping system is applied, alternate strips are protected during critical wind erosion periods by a growing

Figure 502–6 Unsheltered distance L, perennial vegetation (pasture or range)

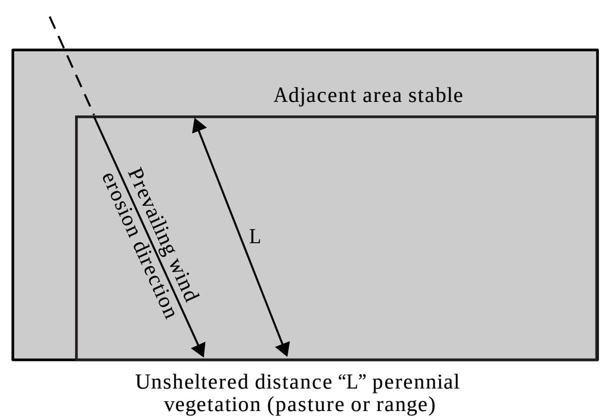
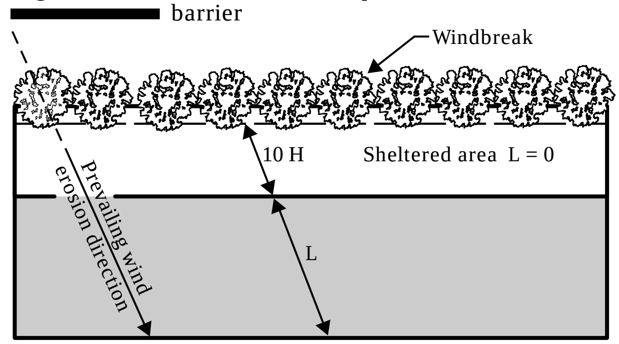


Figure 502-7 Unsheltered distaqnce L – windbreak or barrier



crop or by crop residue. These strips are considered stable. L is measured across each erosion-susceptible strip, along the prevailing wind erosion direction (figure 502-8).

The prevailing wind erosion direction is the direction from which the greatest amount of erosion occurs during the critical wind erosion period. The direction is usually expressed as one of the 16 compass points. When predicting erosion by management periods, the prevailing wind erosion direction may be different for each period (exhibit 502–7a).

Preponderance is a ratio between wind erosion forces parallel and perpendicular to the prevailing wind erosion direction. Wind forces parallel to the prevailing wind erosion direction include those coming from the exact opposite direction (180°). A preponderance of 1.0 indicates that as much wind erosion force is exerted perpendicular to the prevailing direction as along that direction. A higher preponderance indicates that more of the force is along the prevailing wind erosion direction. Wind patterns are complex; low preponderance indicates high complexity and as a result, less wind will be from the prevailing erosive wind direction than locations that have a high preponderance.

L can be measured directly on a map or calculated using a wind erosion direction factor:

- For uses of the Wind Erosion Equation involving a single annual calculation, L should be the measured distance across the area in the prevailing wind erosion direction from the stable upwind edge of the field to the downwind edge of the field. When the prevailing wind erosion direction is at an angle that is not perpendicular to the long side of the field, L can be determined by multiplying the width of the field by the appropriate conversion factor obtained from table 502-3.
- For management period calculations, wind erosion direction factors based on preponderance are to be used instead of a measured distance to determine L except
  - Where irregular fields cannot be adequately represented by a circle, square, or rectangle.
  - Where preponderance data are not available.

Steps to determine L for management period estimates:

1. Obtain local values for prevailing the wind erosion direction and preponderance (exhibit 502–7a).
2. Measure actual length and width of the field and determine the ratio of length to width.
3. Determine angle of deviation between prevailing wind erosion direction and an imaginary line perpendicular to the long side of the field.

Using data from steps 1 through 3, determine wind erosion direction factor from Wind erosion direction factor tables, exhibit 502–9. These are adjustment factors that account for prevailing wind erosion direction, preponderance of wind erosion forces, and size and shape of the field.

Multiply the width of the field by the wind erosion direction factor. This is the L for the field.

If a barrier is on the upwind side of the field, reduce L by a distance equal to 10 times the height of the barrier.

For circular fields, **L** = 0.915 times the diameter, regardless of direction or preponderance.

Figure 502–8 Unsheltered distance L, stripcropping system

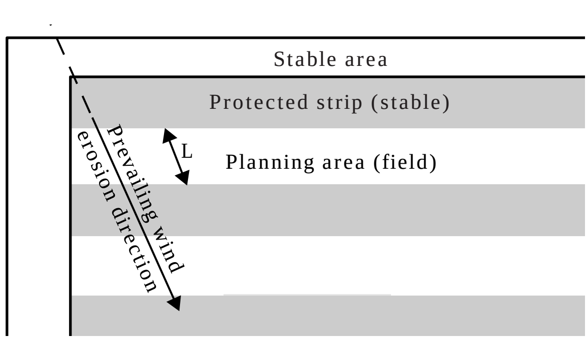


Table 502-3 Wind erosion direction factors [1/]

Angle of deviation [2/]	Adjustment factor
0	1.00
22.5°	1.08
45°	1.41
67.5°	2.61
90°	L = Length of field

1/ These adjustment factors are applicable when preponderance is not considered. L cannot exceed the longest possible measured distance across the field.
2/ Angle of deviation of the prevailing erosive wind from a direction perpendicular to the long side of the field.

502.35 Vegetative cover factor, V

The effect of vegetative cover in the Wind Erosion Equation is expressed by relating the kind, amount, and orientation of vegetative material to its equivalent in pounds per acre of small grain residue in reference condition Small Grain Equivalent (SGe). This condition is defined as 10 inch long stalks of small grain, parallel to the wind, lying flat in rows spaced 10 inches apart, perpendicular to the wind. Several crops have been tested in the wind tunnel to determine their SGe. For other crops, small grain equivalency has been computed using various regression techniques (Armbrust and Lyles 1985; Lyles and Allison 1980; Lyles 1981; Woodruff et al. 1974; Woodruff and Siddoway 1965). NRCS personnel have estimated SGe curves for other crops. SGe curves are in exhibit 502–10.

Position and anchoring of residue is important. In general, the finer and more upright the residue, the more effective it is for reducing wind erosion. Knowledge of these and other relationships can be used with benchmark values to estimate additional SGe values.

Research is underway to develop a method of estimating the relative erosion control value of short woody plants and other growing crops.

Several methods are used to estimate the kind, amount, and orientation of vegetation in the field. Often the task is to predict what will be in the field in some future season or seasons. Amounts of vegetation may be predicted from production records or estimates and these amounts are then reduced by the expected or planned tillage. It may be desirable to sample and measure existing residue to determine quantity of residue. Local data should be developed to estimate surface residue per unit of crop yield and crop residue losses caused by tillage.

The crown of a plant, its associated roots, and adhering soil should also be credited when doing transects to determine residue cover. Employees will need to use their best judgment when deciding which crop curve to use when converting from percent ground cover to mass and then selecting a curve to convert the residue mass to SGe. When in doubt, sudangrass residue curves may be the best selection to simulate crowns and associated root material.

If you encounter a crop, residue, or a type of vegetation for which an SGe curve has not been developed. exhibits 502–11 and 502–12 give procedures to develop an interim SGe curve. Any SGe curve developed in this way must be submitted to the National Agronomists or the Cooperating Scientist for wind erosion for approval.

Subpart 502E Principles of wind erosion control

502.40 General

Five principles of wind erosion control have been identified (Lyles and Swanson 1976; Woodruff et al. 1972; and Woodruff and Siddoway 1965). These are as follows:

- Establish and maintain adequate vegetation or other land cover.
- Reduce unsheltered distance along wind erosion direction.
- Produce and maintain stable clods or aggregates on the land surface.
- Roughen the land.
- Reshape the land to reduce erosion on knolls where converging windflow causes increased velocity and shear stress.

The *cardinal rule* of wind erosion control is to strive to keep the land covered with vegetation or crop residue at all times (Chepil 1956). This leads to several principles that should be paramount as alternative controls are considered:

- Return all land unsuited to cultivation to permanent cover.
- Maintain maximum possible cover on the surface during wind erosion periods.
- Maintain stable field borders or boundaries at all times.

502.41 Relation of control to WEQ factors

The Wind Erosion Equation (WEQ) was developed to relate specific field conditions to estimated annual soil loss. Of the five factors, two (**I** and C) are often considered to be *fixed* while the other three (K, L, and V) are generally considered *variable* or management factors. This is not precisely true.

The **I** factor is related to the percentage of dry surface soil fractions greater than 0.84 millimeters. Its derivation is usually based on the Wind Erodibility Group. However, if a special management condition is going to be maintained, such as crusts or irrigation, a modification of **I** is appropriate. Also, **I** is increased by a knoll erodibility factor where appropriate. See 502.31. This adjustment is not appropriate if the knoll condition is modified through landforming or use of barriers to protect the knoll.

Knoll erodibility adjustments to **I** relate to wind direction; low preponderance indicates that knoll erodibility will vary widely as wind direction changes.

Total K reflects the tilled ridge roughness and random roughness in a field. This is a management factor. Stability of tilled roughness is related, however, to soil erodibility, climate, and the other erosion factors.

Ridge roughness relates to ridge spacing in the wind erosion direction. Even with optimum orientation of rows, some of the winds will be blowing parallel to the rows when preponderance is low.

Random roughness relates to the nonoriented surface roughness that is often referred to as cloddiness. Random roughness is described as the standard deviation of elevation from a plane across a tilled area after taking into account oriented (ridge) roughness.

The C factor is based on long-term weather records. Conservation treatment should be planned to address the critical climatic conditions when high seasonal erosive wind energy is coupled with highly erodible field conditions.

The unsheltered distance L is a management factor that can be changed by altering field arrangement, stripcropping, or establishing windbreaks or other barriers. L is a function of field layout as it relates to prevailing wind direction and preponderance of erosive winds in the prevailing direction.

When preponderance values are high (more than 2.5 and approaching 4.0), conservation treatment should be concentrated on addressing potential erosion from the prevailing wind erosion direction.

When preponderance values are low (approaching 1.0), knowledge of local seasonal wind patterns becomes more important in planning treatment. Conservation treatment should be planned to allow for the effect of seasonal changes in the prevailing wind erosion direction.

A stable strip across an agricultural field divides the area into separate fields. Examples of stable areas include grass waterways, hedges and their sheltered area, brushy draws or ravines, roadways with grass borders, grass strips, and drainage or irrigation ditches.

To be considered stable, an area must be able to stop and hold virtually all of the expected saltation and surface creep. Be aware that an area may be stable during one crop stage, but not stable in other seasons.

V is the equivalent vegetative cover maintained on the soil surface. It is directly related to the management functions of crop establishment, tillage, harvesting, grazing, mowing, or burning.

502.42 Tolerances in wind erosion control

In both planning and inventory activities, NRCS compares estimated erosion to soil loss tolerance (T). T is expressed as the average annual soil erosion rate (tons/acre/year) that can occur in a field with little or no long-term degradation of the soil resource, thus permitting crop productivity to be sustained for an indefinite period.

Soil loss tolerances for a named soil are recorded on soil interpretation records.

The normal planning objective is to reduce soil loss by wind or water to T or lower. In situations where treatment for both wind and water erosion is needed, soil loss estimates using the WEQ and USLE or RUSLE are not added together to compare to T.

Additional impacts of wind erosion that should be considered are potential offsite damages, such as air and water pollution and the deposition of soil particles.

Crop tolerance to soil blowing may also be an important consideration in wind erosion control. Wind or blowing soil, or both, can have an adverse effect on growing crops. Most crops are more susceptible to abrasion or other wind damage at certain growth stages than at others. Damage can result from desiccation and twisting of plants by the wind.

Crop tolerance can be defined as the maximum wind erosion that a growing crop can tolerate, from crop emergence to field stabilization, without an economic loss to crop stand, crop yield, or crop quality.

(a) Blowing soil effects on crops

Some of the adverse effects of soil erosion and blowing soil on crops include:

- Excessive wind erosion that removes planted seeds, tubers, or seedlings.
- Exposure of plant root systems.
- Sand blasting and plant abrasion resulting in
  - crop injury
  - crop mortality
  - lower crop yields
  - lower crop quality
  - wind damage to seedlings, vegetables, and orchard crops.
- Burial of plants by drifting soil.

(b) Crop tolerance to blowing soil or wind

Many common crops have been caterorized based on their tolerance to blowing soil. These categories of some typical crops are listed in table 502-4. Crops may tolerate greater amounts of blowing soil than shown in table 502–4, but yield and quality will be adversly affected.

Subpart 502F Example problems

(Each state should develop example problems, common to their state, and insert in this section.) See exhibit 502–7b.

Table 502-4 Crop tolerance to blowing soil

Tolerant T	Moderate tolerance 2 ton/ac	Low tolerance 1 ton/ac	Very low tolerance 0 to 0.5 ton/ac
Barley	Alfalfa (mature)	Broccoli	Alfalfa seedlings
Buckwheat	Corn	Cabbage	Asparagus
Flax	Onions (>30 days)	Cotton	Cantaloupe
Grain Sorghum	Orchard crops	Cucumbers	Carrots
Millet	Soybeans	Garlic	Celery
Oats	Sunflowers	Green/snap beans	Eggplant
Rye	Sweet corn	Lima beans	Flowers
Wheat		Peanuts	Kiwi fruit
		Peas	Lettuce
		Potatoes	Muskmelons
		Sweet potatoes	Onion seedlings (<30 days)
		Tobacco	Peppers
			Spinach
			Squash
			Strawberries
			Sugar beets
			Table beets
			Tomatoes
			Watermelons

Subpart 502G Exhibits

Exhibit 502–1 Example E table

"E" tables for each combination of C & I factors are on the www browser: **http://www.weru.ksu.edu/nrcs.** Click on the hypertext for: **etable.doc** (for MS Word) and **etable.wpd** (for Word Perfect).

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR JANUARY, 1998

C = 100 SURFACE - K =1.00 I = 86

(L) UNSHELTERED DISTANCE IN FEET — (V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	86.0	75.3	60.7	46.4	28.4	16.8	8.8	4.6	2.5	1.1	0.3		
8000	86.0	75.3	60.7	46.4	28.4	16.8	8.8	4.6	2.5	1.1	0.3		
6000	86.0	75.3	60.7	46.4	28.4	16.8	8.8	4.6	2.5	1.1	0.3		
4000	86.0	75.3	60.7	46.4	28.4	16.8	8.8	4.6	2.5	1.1	0.3		
3000	85.6	74.9	60.4	46.1	28.2	16.6	8.7	4.6	2.5	1.1	0.3		
2000	82.7	72.3	58.1	44.2	26.9	15.7	8.1	4.2	2.3	1.0	0.3		
1000	76.4	66.5	53.1	40.0	24.0	13.7	6.9	3.5	1.9	0.7			
800	74.2	64.6	51.5	38.6	23.0	13.0	6.6	3.3	1.8	0.7			
600	69.3	60.1	47.7	35.4	20.9	11.6	5.7	2.8	1.5	0.5			
400	62.2	53.7	42.2	31.0	17.9	9.6	4.6	2.2	1.1				
300	57.6	49.6	38.7	28.1	16.0	8.4	4.0	1.9	0.9				
200	51.4	44.1	34.1	24.4	13.6	6.9	3.2	1.4	0.7				
150	45.6	38.9	29.8	21.0	11.4	5.6	2.5	1.1	0.3				
100	39.8	33.8	25.6	17.7	9.4	4.5	1.9	0.8	0.3				
80	36.6	31.0	23.3	16.0	8.4	3.9	1.6	0.5					
60	31.4	26.4	19.6	13.2	6.7	3.0	1.2	0.4					
50	27.9	23.4	17.2	11.4	5.7	2.4	0.9						
40	24.4	20.4	14.8	9.7	4.7	1.9	0.7						
30	21.0	17.4	12.5	8.0	3.8	1.5	0.5						
20	15.9	13.0	9.1	5.6	2.5	0.9							
10	9.4	7.5	5.1	2.9	1.2	0.3							

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR JANUARY, 1998

C = 100 SURFACE - K =0.90 I = 86

(L) UNSHELTERED DISTANCE IN FEET — (V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	77.4	67.5	54.0	40.7	24.4	14.0	7.1	3.6	2.0	0.7			
8000	77.4	67.5	54.0	40.7	24.4	14.0	7.1	3.6	2.0	0.7			
6000	77.4	67.5	54.0	40.7	24.4	14.0	7.1	3.6	2.0	0.7			
4000	76.8	66.9	53.5	40.3	24.2	13.8	7.0	3.6	1.9	0.7			
3000	75.8	66.0	52.7	39.6	23.7	13.5	6.8	3.5	1.9	0.7			
2000	73.4	63.9	50.8	38.1	22.6	12.8	6.4	3.2	1.7	0.6			
1000	67.2	58.2	46.0	34.1	19.9	11.0	5.4	2.6	1.4	0.5			
800	64.7	56.0	44.1	32.5	18.9	10.3	5.0	2.4	1.3				
600	59.7	51.5	40.3	29.4	16.8	8.9	4.3	2.0	1.0				
400	55.0	47.3	36.7	26.5	14.9	7.8	3.6	1.7	0.8				
300	51.0	43.7	33.8	24.2	13.4	6.8	3.1	1.4	0.7				
200	44.7	38.1	29.1	20.5	11.1	5.4	2.4	1.0	0.3				
150	39.1	33.2	25.1	17.4	9.2	4.3	1.8	0.8	0.2				
100	34.5	29.1	21.8	14.8	7.7	3.5	1.4	0.5					
80	31.2	26.3	19.5	13.1	6.7	2.9	1.2	0.4					
60	25.9	21.7	15.8	10.4	5.1	2.1	0.8						
50	23.1	19.2	13.9	9.0	4.3	1.8	0.7						
40	20.7	17.1	12.3	7.8	3.7	1.5	0.5						
30	17.2	14.1	10.0	6.2	2.8	1.1							
20	12.7	10.3	7.1	4.3	1.9	0.4							
10	6.2	4.9	3.2	1.7	0.6								

Exhibit 502–2 Wind erodibility groups and soil erodibility index

Soil texture [1]	EWE texture wetness factor [2]	Predominant soil texture class of surface layer	Wind Erodibility Group (WEG)	Soil Erodibility Index (**I**) (ton/ac/yr) [3]	Soil Erodibility Index (**I**) for irrigated soils (ton/ac/yr) [3]
C	1	Very fine sand, fine sand, sand, or coarse sand	1	310 [4] 250 220 180 160	310 250 220 160 134
C	1	Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic soil materials	2	134	104
C	1	Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam	3	86	56
F	3	Clay, silty clay, non-calcareous clay loam, or silty clay loam with more than 35% clay	4	86	56
M	2	Calcareous loam and silt loam or calcareous clay loam and silty clay loam	4L	86	56
M	2	Non-calcareous loam and silt loam that has less than 20% clay, or sandy clay loam, sandy clay, and hemic organic soil materials	5	56	38
M	2	Non-calcareous loam and silt loam that has more than 20% clay, or non-calcareous clay loam that has less than 35% clay	6	48	21
M	2	Silt, non-calcareous silty clay loam that has less than 35% clay, and fibric organic soil material	7	38	21
—	—	Soils not susceptible to wind erosion because of coarse surface fragments or wetness	8	—	—

1/ Soil texture, C = Coarse; M = Medium; F = Fine
2/ Texture wetness factor for adjustment of Erosive Wind Energy (EWE) for the period (Irrigated fields only).
3/ The soil erodibility index is based on the relationship of dry soil aggregates greater than 0.84 millimeters to potential soil erosion. Value for irrigated soils is applicable throughout the year. Values for irrigated soils determined by E.L. Skidmore, USDA, ARS, Wind Erosion Research Unit, Manhattan, Kansas.
4/ The **I** factor for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an **I** value of 220 as an average figure. For coarse sand with gravel, use a low figure. For very fine sand without gravel, use a higher value.

Exhibit 502–3 Sieving instructions

Soil sieving has become increasingly important because of USDA's emphasis on advancing erosion prediction technology. Soil samples can be sieved using either a flat or a rotary sieve. The flat sieve method is useful in making onsite field determinations. However, the results are not as consistent as those achieved by the electric motor-driven rotary sieve. If the objective is to gather scientific data, consistency is important, and rotary sieving should be the chosen method.

(a) Equipment needs

- A standard number 20 flat sieve or access to a properly designed rotary sieve.
- A device for weighing samples.
- A square-nosed scoop or shovel.
- Worksheet for sieving of dry aggregates (example follows).

(b) Procedure

1. Take samples only when the soil is reasonably dry. If the soil sticks to the scoop, postpone the sampling until the soil dries sufficiently. If sieving is being done to verify the **I** factor assigned to a soil, samples should be taken during the normal wind erosion period in an area that is smooth, bare, not crusted, not sheltered by windbreaks or barriers, and at a location in the field far enough downwind for avalanching to occur. If the objective is to estimate erodibility for a specific field condition, select a smooth, bare, unsheltered area with the desired conditions. In all cases, avoid compacted or vegetated areas.

2. Use the square-nosed scoop to collect a sample from the soil surface. Try to avoid sampling more deeply than approximately 1 inch. Several small scoops may be more representatives than one larger scoop of soil.

3. Gently place the sample (about 2 lb) into a padded container for transporting to a sieving location. Fill in the appropriate blanks on the form to specify field conditions and other data. If the soil sample will be done in the field with a flat sieve, proceed.

4. Weigh the sieve (including receiver) and record for later use. Place about 2 pounds of the sample on the No. 20 sieve. Remove loose vegetation without fracturing soil aggregates.

5. Determine gross weight of the sample and sieve. Subtract the weight of the sieve to determine net weight of the sample.

6. Remove the receiver and shake the sieve 50 times using moderate force. Do not bounce the sample or shake so hard that you break down the clods. Place the sieve over the receiver and shake again 50 times. If more than 0.5 ounce collects in the receiver, empty the receiver and repeat the process. If more than 0.5 ounce is again in the receiver, repeat the process again. Do not exceed a total of 200 shakes. Discard material in the receiver and weigh the sieve, receiver, and remaining aggregates in the sieve. Determine the weight of soil aggregates greater than 0.84 millimeter in diameter. Divide the weight of the sieved sample by the total weight of the soil sample to determine percentage of aggregates that exceed 0.84 millimeter.

7. Refer to table that follows to arrive at soil erodibility when using the percentage of nonerodible aggregates.

Exhibit 502–3 Sieving instructions—Continued

Table 1 Soil erodibility index **I** in tons/acre determined by percentage of nonerodible fractions.
[Dry soil fractions greater than 0.84 millimeters]

% units—>	0	1	2	3	4	5	6	7	8	9
Tens	ton/ac	ton/ac	ton/ac	ton/ac	ton/ac	ton/ac	ton/ac	ton/ac	ton/ac	ton/ac
0	—	310	250	220	195	180	170	160	150	140
10	134	131	128	125	121	117	113	109	106	102
20	98	95	92	90	88	86	83	81	79	76
30	74	72	71	69	67	65	63	62	60	58
40	56	54	52	51	50	48	47	45	43	41
50	38	36	33	31	29	27	25	24	23	22
60	21	20	19	18	17	16	16	15	14	13
70	12	11	10	8	7	6	4	3	3	2
80	2	—	—	—	—	—	—	—	—	—

Exhibit 502–3 Sieving instructions—Continued

ARS and NRCS Data Worksheet for Sieving of Dry Aggregates

Cooperative Soil Sieving Project

1. Field Office: ________________________ 2. Date:________________________
3. County:________________________ 4. Sampled by: ________________________
5. Sample site number:________________________ 6. Soil Survey Sheet number:________________
7. Site location:____
8. Symbol and map unit name:________________________________
9. Erosion: (yes/no) ____________________ 10. Tillage: ________________________
11. Ridge height (inches):________________
12. Ridge spacing:____________________ 13. Crust thickness:____________________
14. Date(s) and amount(s) of precipitation:________________________
15. Total precipitation:________________________________
16. Kind of ground cover:________________________________
17. Status of ground cover:________________________________
19. Amount (lb):________________________ 20. Percent ground cover: ________________
21. Percent canopy: ____________________
22. Row pattern: ________________________ Row direction (Azimuth): ________________
23. Is field irrigated: (yes/no) ______________ 24. Type of irrigation: ________________
25. Annual irrigation applied (inches):________________________

26. Samplers comments:

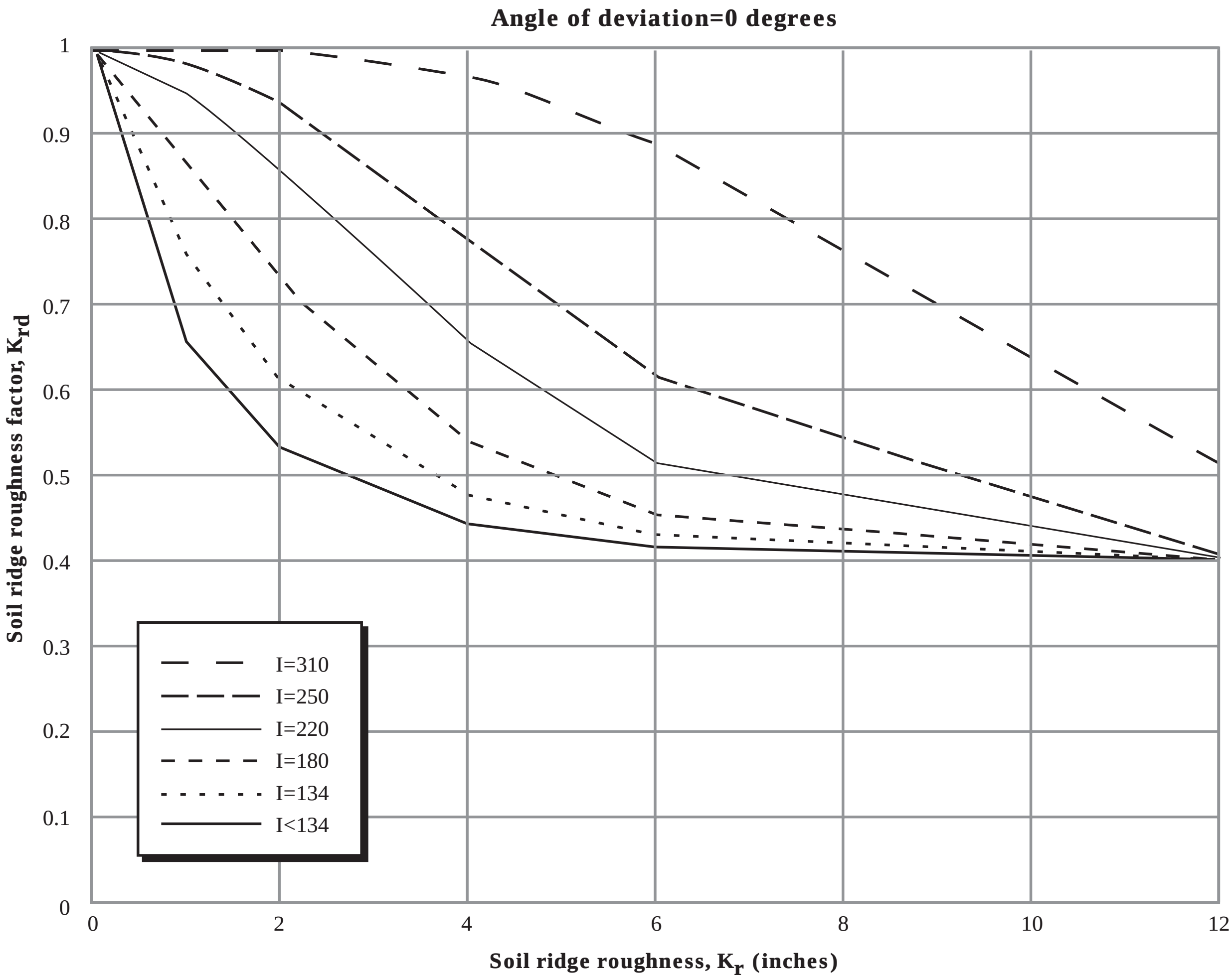
To be completed by ARS
Sieving date: ____________ Sieved by: ________________________

Soil weight, wet:________; Soil weight, dry; __________; Percent moisture _________

Seive size (mm)	<0.42	.42-.84	.84-2.83	2.83-6.4	6.4-12.7	>12.7	%>0.84
1st seiving (weight							
Percent of total							
2nd seiving (weight)							
Percent of total							

Resulting **I** value: __________
Siever's comments:

Exhibit 502–4 Ridge roughness factor, K_{rd}



Note: Erosive wind energy is assumed to be 60% parallel and 40% perpendicular to prevailing erosive wind.

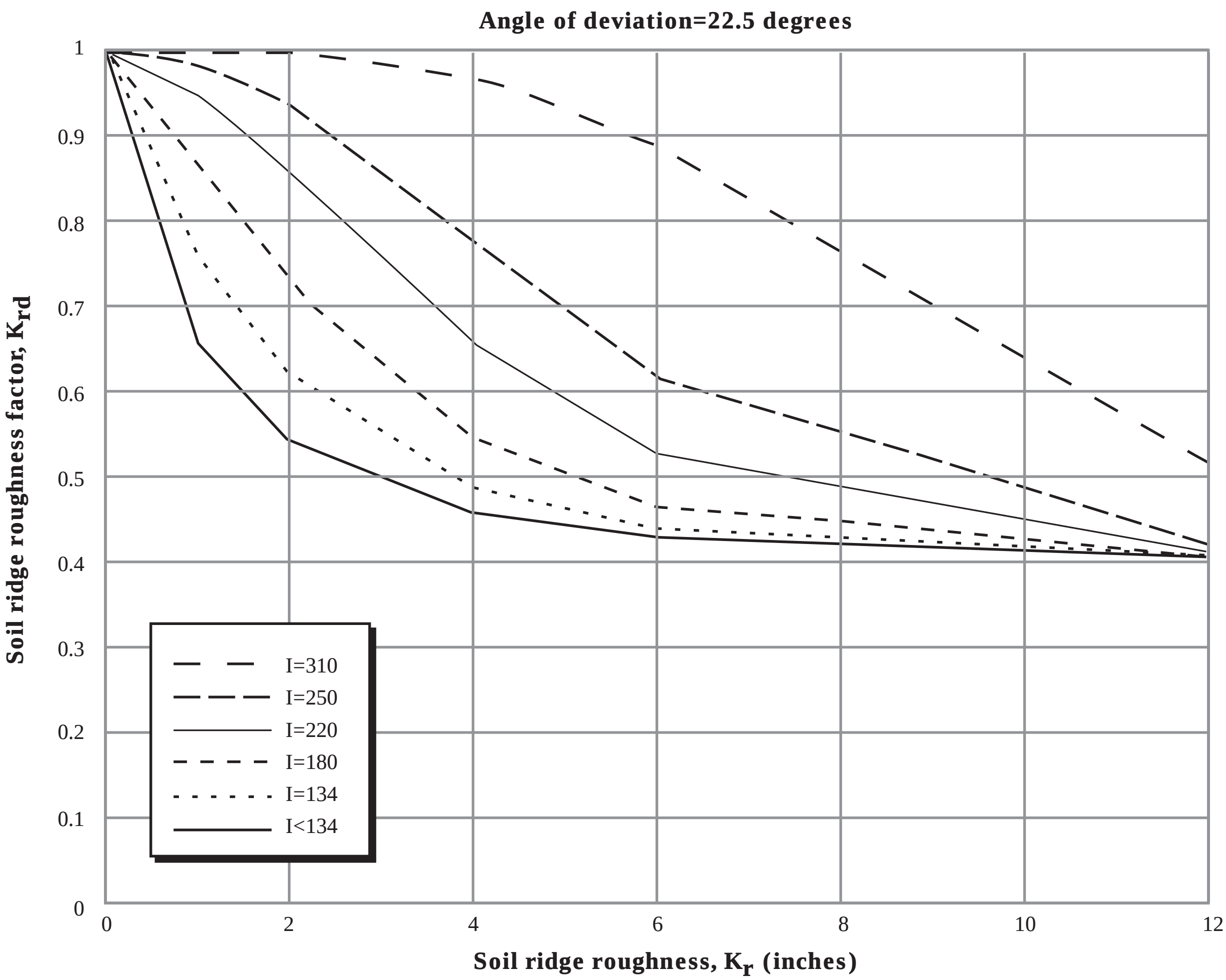
$$K_r = \frac{4(h \times h)}{s}$$

where:

h = ridge height in inches

s = ridge spacing in inches

Exhibit 502–4 Ridge roughness factor, K_{rd}—Continued



Note: Erosive wind energy is assumed to be 60% parallel and 40% perpendicular to prevailing erosive wind.

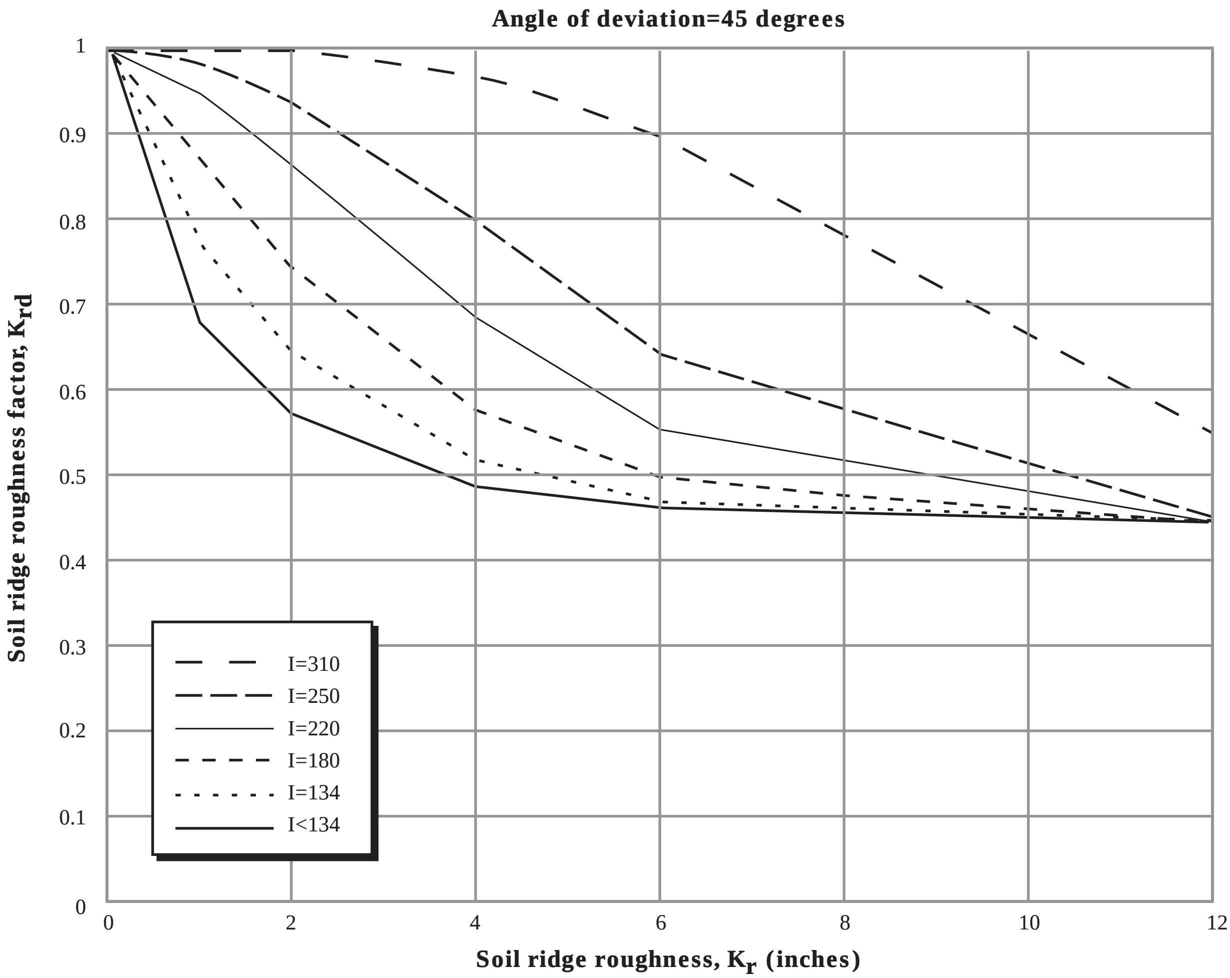
$$K_r = \frac{4(h \times h)}{s}$$

where:

h = ridge height in inches

s = ridge spacing in inches

Exhibit 502–4 Ridge roughness factor, K_{rd}—Continued

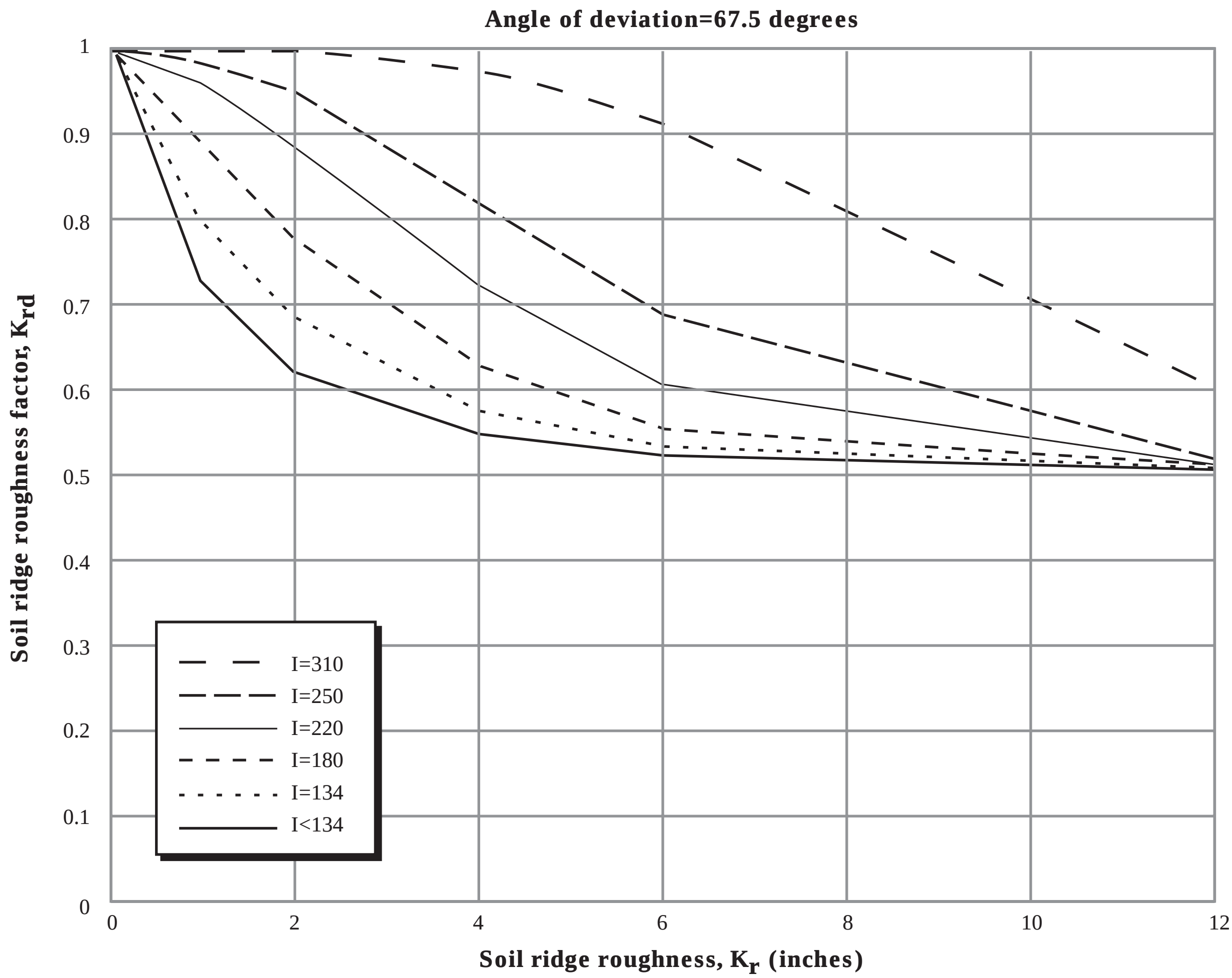


Note: Erosive wind energy is assumed to be 60% parallel and 40% perpendicular to prevailing erosive wind.

$$K_r = \frac{4(h \times h)}{s}$$

where:
h = ridge height in inches
s = ridge spacing in inches

Exhibit 502–4 Ridge roughness factor, K_{rd}—Continued



Note: Erosive wind energy is assumed to be 60% parallel and 40% perpendicular to prevailing erosive wind.

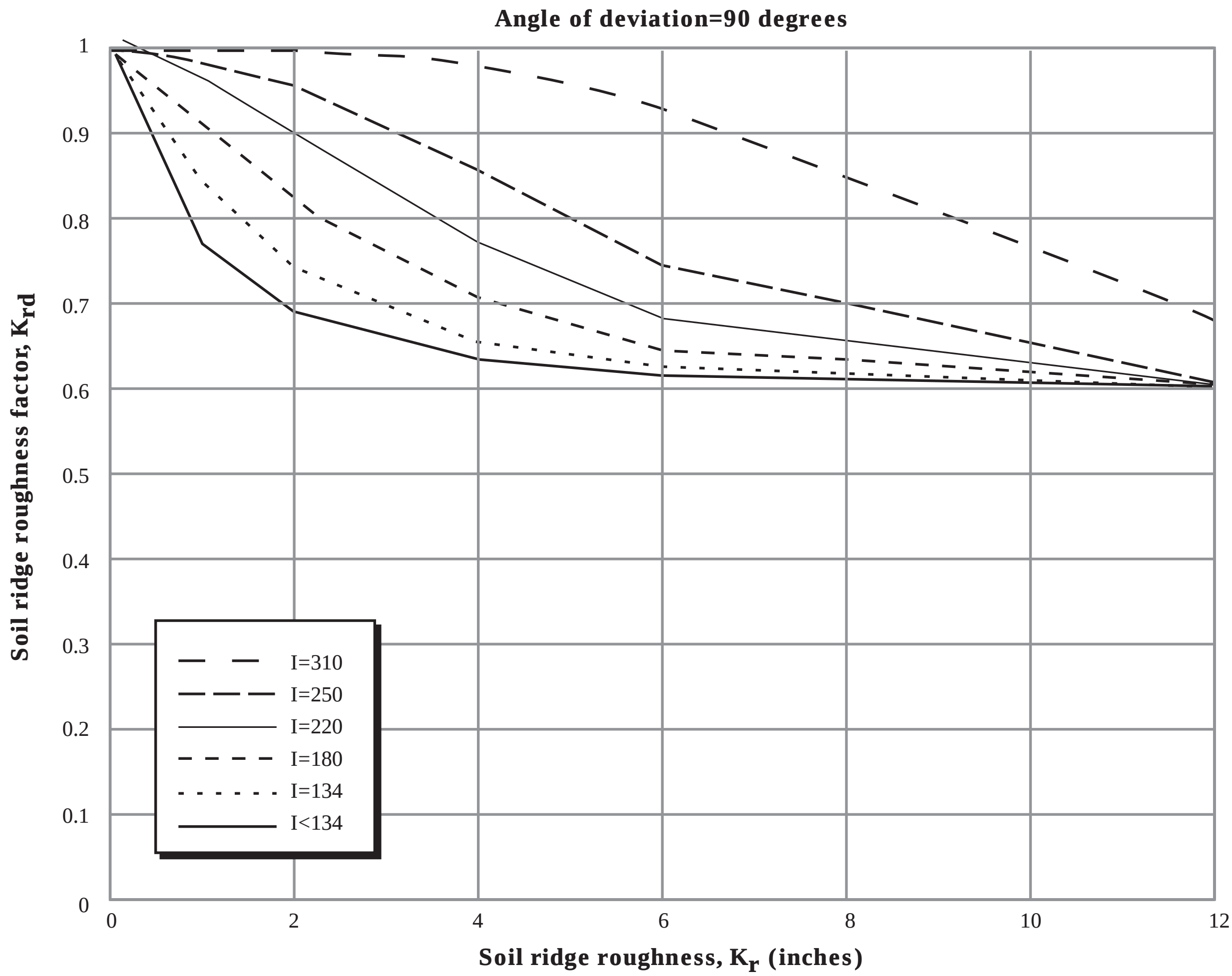
$$K_r = \frac{4(h \times h)}{s}$$

where:

h = ridge height in inches

s = ridge spacing in inches

Exhibit 502–4 Ridge roughness factor, K_{rd}—Continued



Note: Erosive wind energy is assumed to be 60% parallel and 40% perpendicular to prevailing erosive wind.

$$K_r = \frac{4(h \times h)}{s}$$

where:

h = ridge height in inches

s = ridge spacing in inches

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables

Table 502–5A	Angle of deviation = 0 degrees; **I** = <134
Table 502–5B	Angle of deviation = 22.5 degrees; **I** = <134
Table 502–5C	Angle of deviation = 45 degrees; **I** = <134
Table 502–5D	Angle of deviation = 67.5 degrees; **I** = <134
Table 502–5E	Angle of deviation = 90 degrees; **I** = <134
Table 502–5F	Angle of deviation = 0 degrees; **I** = 134
Table 502–5G	Angle of deviation = 22.5 degrees; **I** = 134
Table 502–5H	Angle of deviation = 45 degrees; **I** = 134
Table 502–5I	Angle of deviation = 67.5 degrees; **I** = 134
Table 502–5J	Angle of deviation = 90 degrees; **I** = 134
Table 502–5K	Angle of deviation = 0 degrees; **I** = 180
Table 502–5L	Angle of deviation = 22.5 degrees; **I** = 180
Table 502–5M	Angle of deviation = 45 degrees; **I** = 180
Table 502–5N	Angle of deviation = 67.5 degrees; **I** = 180
Table 502–50	Angle of deviation = 90 degrees; **I** = 180
Table 502–5P	Angle of deviation = 0 degrees; **I** = 220
Table 502–5Q	Angle of deviation = 22.5 degrees; **I** = 220
Table 502–5R	Angle of deviation =45 degrees; **I** = 220
Table 502–5S	Angle of deviation = 67.5 degrees; **I** = 220
Table 502–5T	Angle of deviation = 90 degrees; **I** = 220
Table 502–5U	Angle of deviation = 0 degrees; **I** = 250
Table 502–5V	Angle of deviation = 22.5 degrees; **I** = 250
Table 502–5W	Angle of deviation = 45 degrees; **I** = 250
Table 502–5X	Angle of deviation = 67.5 degrees; **I** = 250
Table 502–5Y	Angle of deviation = 90 degrees; **I** = 250
Table 502–5Z	Angle of deviation = 0 degrees; **I** = 310
Table 502–5AA	Angle of deviation =22.5 degrees; **I** = 310
Table 502–5BB	Angle of deviation = 45 degrees; **I** = 310
Table 502–5CC	Angle of deviation = 67.5 degrees; **I** = 310
Table 502–5DD	Angle of deviation =90 degrees; **I** = 310

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5A Angle of deviation = 0 degrees; **I** = <134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
24	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
30	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
36	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
38	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
40	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5B Angle of deviation = 22.5 degrees; **I** = <134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.8	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
24	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
30	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
36	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
38	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
40	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5C Angle of deviation = 45 degrees; **I** = <134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.8	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	0.8	0.7	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	0.9	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
24	0.9	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
30	0.9	0.8	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
36	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
38	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
40	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5D Angle of deviation = 67.5 degrees; **I** = <134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
14	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
18	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
20	0.9	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
24	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
30	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
36	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
38	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
40	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5E Angle of deviation = 90 degrees; **I** = <134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
10	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
14	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
18	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
20	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
24	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
30	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
36	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
38	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
40	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5F Angle of deviation = 0 degrees; **I** = 134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
24	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
30	1.0	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
36	1.0	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
38	1.0	0.9	0.8	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
40	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5G Angle of deviation = 22.5 degrees; **I** = 134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
24	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
30	1.0	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
36	1.0	0.9	0.8	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
38	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
40	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.
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Table 502–5H Angle of deviation = 45 degrees; **I** = 134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.9	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.9	0.8	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
20	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
30	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
36	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
38	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4
40	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5I Angle of deviation = 67.5 degrees; **I** = 134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.9	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
14	0.9	0.8	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
18	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
20	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
24	1.0	0.9	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
30	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
36	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
38	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
40	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5J Angle of deviation = 90 degrees, I = 134

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
10	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
14	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
18	1.0	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
20	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
24	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
30	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
36	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6
38	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6
40	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5K Angle of deviation = 0 degrees; **I** = 180

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	1.0	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
30	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
36	1.0	0.9	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
38	1.0	0.9	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4
40	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5L Angle of deviation = 22.5 degrees; **I** = 180

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	0.9	0.8	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
30	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
36	1.0	0.9	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
38	1.0	0.9	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4
40	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5M Angle of deviation = 45 degrees; **I** = 180

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
20	1.0	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
30	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
36	1.0	0.9	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4
38	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4
40	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5N Angle of deviation = 67.5 degrees; **I** = 180

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10	1.0	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
14	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
18	1.0	0.9	0.8	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
20	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
24	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
30	1.0	0.9	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
36	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5
38	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5
40	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5O Angle of deviation = 90 degrees; **I** = 180

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
10	1.0	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
14	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
18	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
20	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
24	1.0	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
30	1.0	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6
36	1.0	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6
38	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6
40	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5P Angle of deviation = 0 degrees; **I** = 220

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
30	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4
36	1.0	1.0	0.9	0.9	0.8	0.7	0.5	0.5	0.4	0.4	0.4	0.4
38	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4
40	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5Q Angle of deviation = 22.5 degrees; **I** = 220

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	1.0	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
30	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4
36	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4
38	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4
40	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5R Angle of deviation = 45 degrees; **I** = 220

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
24	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4
30	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4
36	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4
38	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4
40	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5S Angle of deviation = 67.5 degrees; **I** = 220

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.9	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
14	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
18	1.0	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
20	1.0	1.0	0.9	0.8	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
24	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
30	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5
36	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5
38	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5
40	1.0	1.0	1.0	0.9	0.8	0.7	0.7	0.6	0.5	0.5	0.5	0.5

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5T Angle of deviation = 90 degrees; **I** = 220

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
10	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
14	1.0	1.0	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
18	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
20	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
24	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6
30	1.0	1.0	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6
36	1.0	1.0	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.6	0.6
38	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6
40	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5U Angle of deviation = 90 degrees; **I** = 250

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	1.0	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	0.9	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4
30	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4
36	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.5	0.5	0.4	0.4	0.4
38	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4
40	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5V Angle of deviation = 22.5 degrees; **I** = 250

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	1.0	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	0.9	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	0.9	0.8	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4
24	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4
30	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4
36	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.5	0.5	0.4	0.4	0.4
38	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4
40	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5W Angle of deviation = 45 degrees; **I** = 250

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	1.0	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	1.0	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	0.9	0.8	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4
24	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.4
30	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4
36	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4
38	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4
40	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5X Angle of deviation = 67.5 degrees; **I** = 250

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.9	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10	1.0	1.0	0.8	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
14	1.0	1.0	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
18	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
20	1.0	1.0	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
24	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5
30	1.0	1.0	1.0	0.9	0.9	0.8	0.6	0.6	0.5	0.5	0.5	0.5
36	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5
38	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5
40	1.0	1.0	1.0	1.0	0.9	0.8	0.8	0.7	0.6	0.5	0.5	0.5

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5Y Angle of deviation = 90 degrees; **I** = 250

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	0.9	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
10	1.0	1.0	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
14	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
18	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6
20	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6
24	1.0	1.0	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6
30	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6
36	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6
38	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6
40	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5Z Angle of deviation = 0 degrees; **I** = 310

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	1.0	0.9	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	1.0	1.0	0.9	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	1.0	1.0	0.9	0.8	0.6	0.4	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4
24	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4
30	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.4
36	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4
38	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4
40	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.6	0.5	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5AA Angle of deviation = 22.5 degrees; **I** = 310

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	1.0	0.9	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	1.0	1.0	0.9	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.4	0.4	0.4	0.4	0.4
20	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4
24	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4
30	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.4
36	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4
38	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.7	0.6	0.5	0.4
40	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.6	0.5	0.4

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5BB Angle of deviation = 45 degrees; **I** = 310

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	1.0	1.0	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4
14	1.0	1.0	1.0	1.0	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4
18	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.4
20	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.5	0.5	0.4	0.4	0.4
24	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.4
30	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.6	0.5	0.5	0.4
36	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5
38	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.6	0.5	0.5
40	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.5	0.5

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–5 Ridge roughness factor, K_{rd}, tables—Continued

Table 502–5CC Angle of deviation = 67.5 degrees; **I** = 310

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	1.0	0.9	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10	1.0	1.0	1.0	0.9	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
14	1.0	1.0	1.0	1.0	0.9	0.7	0.5	0.5	0.5	0.5	0.5	0.5
18	1.0	1.0	1.0	1.0	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.5
20	1.0	1.0	1.0	1.0	0.9	0.9	0.7	0.6	0.5	0.5	0.5	0.5
24	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.5	0.5	0.5	0.5
30	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.5
36	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.6	0.6	0.5
38	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.5
40	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.5

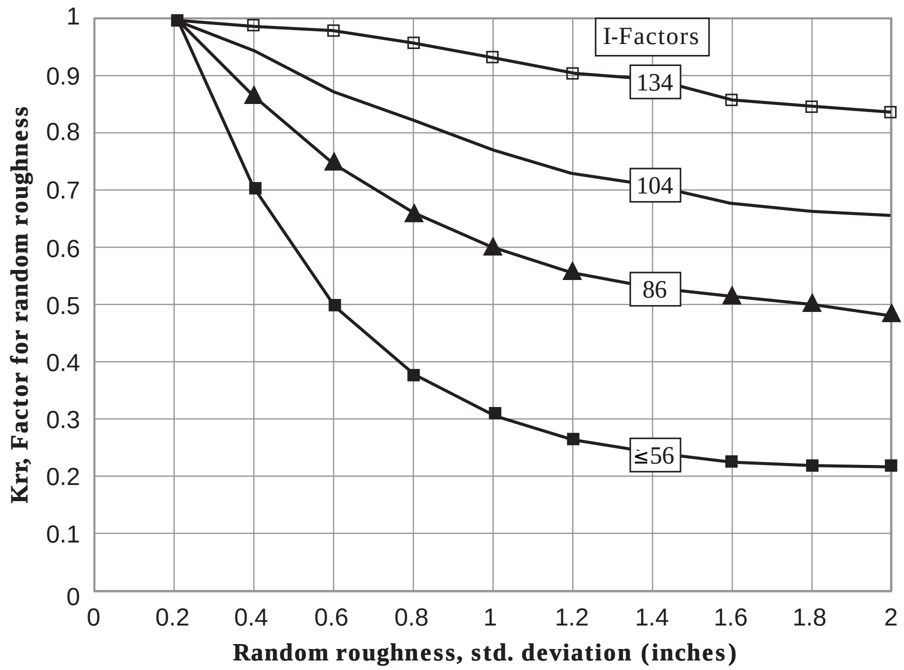
These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Table 502–5DD Angle of deviation = 90 degrees; **I** = 310

Ridge spacing (inches)	Ridge height (inches) 1	2	3	4	5	6	7	8	9	10	11	12
7	1.0	1.0	1.0	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
10	1.0	1.0	1.0	0.9	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.6
14	1.0	1.0	1.0	1.0	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6
18	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6
20	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6
24	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6
30	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.6
36	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.6
38	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.7	0.7	0.6
40	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.8	0.7	0.6

These values are based on conditions in which erosive wind energy is 60% parallel and 40% perpendicular to prevailing erosive wind.

Exhibit 502–6 Random roughness factor, K_{rr}



Graph to convert random roughness heights (standard deviation in inches) to WEQ K-subfactors for random roughness. K subfactors vary by **I** factors assigned to soil groups.

Random roughness is defined as the standard deviation (in inches) of the soil surface elevations, measured at regular intervals from a fixed arbitary plane above a tilled soil surface, after oriented roughness has been considered.

Random roughness photos and associated random roughness (standard deviation) values are in Predicting Soil Erosion by Water: A Guide to Conservation Planning With Revised Universal Soil Loss Equation (RUSLE), 1997, Agriculture Handbook 703, appendix C, or can be downloaded at

ftp://ftp.nrcs.usda.gov/divisions/esd/erosion

Exhibit 502–6 Random roughness factor, K_{rr}—Continued

Table 502–6 Table converts random roughness heights (standard deviation in inches to WEQ **K** sub-factors ($\mathbf{K_{rr}}$) for random roughness. $\mathbf{K_{rr}}$ values vary by **I** factors assigned to soil Wind Erodibility Groups.

	Random roughness (standard deviation, inches)									
	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
I Factors	$\mathbf{K_{rr}}$ **values**									
>134	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
134	1.00	0.99	0.98	0.96	0.93	0.91	0.98	0.96	0.85	0.84
104	1.00	0.94	0.88	0.82	0.78	0.74	0.71	0.69	0.67	0.66
86	1.00	0.87	0.76	0.67	0.61	0.57	0.54	0.52	0.50	0.48
56 or less	1.00	0.71	0.50	0.38	0.31	0.27	0.25	0.23	0.23	0.22

Exhibit 502–7 Random roughness (standard deviation) core values

This information on core values is from Predicting Soil Erosion by Water: A Guide to Conservation Planning With Revised Universal Soil Loss Equation (RUSLE), 1997, Agriculture Handbook 703.

Parameter values of *core* cropland field operations may be used in the Wind Erosion Equation for random roughness. However the use of the random roughness photos in Agriculture Handbook 703, in appendix C, may be
preferable, especially where roughness is caused by residual sod material such as the crowns of plants that has
attached roots and soil.

The following core values are typical and representative for field operations in medium textured soils tilled at optimum moisture conditions. Many of the machines may differ by cropping region, farming practice, soil texture, or other conditions. Refer to the random roughness photos in the handbook and adjust to values that seem most appropriate. The photos and associated random roughness (standard deviation) values in the Agriculture Handbook 703 can be downloaded at:

ftp://ftp.nrcs.usda.gov/divisions/esd/erosion

State agronomists can reproduce and distribute copies of the photographs to Field Offices.

Field operations	Random roughness (standard deviation in inches)
Chisel, sweeps	1.20
Chisel, straight point	1.50
Chisel, twisted shovels	1.90
Cultivator, field	0.70
Cultivator, row	0.70
Cultivator, ridge till	0.70
Disk, 1-way	1.20
Disk, heavy plowing	1.90
Disk, tandem	0.80
Drill, double disk	0.40
Drill, deep furrow	0.50
Drill, no-till	0.40
Drill, no-till into sod	0.30
Fertilizer applicator, anhyd knife	0.60
Harrow, spike	0.40
Harrow, tine	0.40
Lister	0.80
Manure injector	1.50
Moldboard plow	1.90
Mulch treader	0.40
Planter, no-till	0.40
Planter, row	0.40
Rodweeder	0.40
Rotary hoe	0.40
Vee ripper	1.20

The Wind Erosion Research Unit, ARS, Manhattan, Kansas, published new wind erosion **C** factors in 1983. This information, based on 1941-80 recorded weather data, updated previously published maps.

Exhibit 502–7a Example of erosive wind data available for specific locations

KS CHANUTE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	180	0	180	180	180	180	180	180	180	180	180	180
PREPONDERANCE	4.0	2.3	2.5	3.5	4.6	4.2	3.6	3.7	4.5	4.8	5.2	3.4
EROSIVITY (EWE)	7.9	7.3	17.5	30.2	17.9	2.5	.7	1.5	1.6	2.0	5.6	5.1
CUMULATIVE EWE	7.9	15.3	32.8	63.0	81.0	83.4	84.1	85.6	87.2	89.3	94.9	100.0

KS CONCORDIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	0	338	158	180	180	180	180	180	180	338	338
PREPONDERANCE	3.4	2.7	2.7	2.0	2.8	3.4	3.8	4.1	5.8	5.3	3.0	2.5
EROSIVITY (EWE)	8.9	9.5	19.8	18.4	7.4	5.4	3.7	3.3	3.8	6.2	5.9	7.6
CUMULATIVE EWE	8.9	18.4	38.2	56.6	64.0	69.5	73.1	76.5	80.3	86.5	92.4	100.0

KS DODGE_CITY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	0	0	180	180	180	180	180	180	180	0	0
PREPONDERANCE	6.6	3.4	2.7	3.1	3.6	5.8	4.1	4.7	5.7	5.5	3.4	3.8
EROSIVITY (EWE)	7.3	8.5	17.3	16.5	9.1	7.7	4.5	3.2	5.6	6.5	6.5	7.4
CUMULATIVE EWE	7.3	15.8	33.1	49.6	58.7	66.4	70.9	74.1	79.6	86.2	92.6	100.0

KS FT.RILEY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	180	180	180	180	180	180	180	180	202	180	180	202
PREPONDERANCE	5.2	3.6	3.9	3.0	6.0	7.9	5.4	4.1	4.8	4.9	3.6	1.9
EROSIVITY (EWE)	5.3	6.3	20.6	18.5	10.1	4.9	2.2	3.1	5.4	10.0	5.7	7.8
CUMULATIVE EWE	5.3	11.7	32.3	50.8	60.9	65.8	68.0	71.1	76.4	86.4	92.2	100.0

KS GOODLAND	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	338	338	338	338	158	180	158	158	180	338	337	337
PREPONDERANCE	3.3	3.8	3.4	3.6	2.3	2.4	2.1	2.9	3.2	3.6	3.6	4.4
EROSIVITY (EWE)	5.1	7.4	19.2	16.9	9.7	8.8	4.4	4.1	6.0	5.2	7.3	6.0
CUMULATIVE EWE	5.1	12.5	31.7	48.5	58.2	67.0	71.4	75.5	81.5	86.7	94.0	100.0

KS HUTCHINSON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	0	0	180	180	180	180	180	180	180	0	0
PREPONDERANCE	4.5	3.4	3.2	2.9	3.8	5.1	4.9	3.5	4.5	5.1	4.1	4.3
EROSIVITY (EWE)	7.9	10.2	12.3	15.5	9.5	10.1	3.9	3.5	6.2	7.6	6.8	6.6
CUMULATIVE EWE	7.9	18.1	30.4	45.9	55.3	65.4	69.3	72.8	79.0	86.6	93.4	100.0

KS OLATHE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	180	338	180	202	180	180	202	202	202	180	180	180
PREPONDERANCE	2.4	1.8	1.8	2.2	2.7	3.6	3.7	4.4	5.5	2.6	1.9	2.0
EROSIVITY (EWE)	8.3	7.4	27.9	26.7	7.7	1.9	.7	.6	1.0	4.9	4.9	7.9
CUMULATIVE EWE	8.3	15.7	43.6	70.4	78.1	80.0	80.7	81.3	82.3	87.2	92.1	100.0

KS RUSSELL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	0	0	0	202	202	202	202	202	180	0	0
PREPONDERANCE	3.3	2.9	2.6	1.9	2.7	3.0	3.1	3.4	4.2	3.1	2.8	2.4
EROSIVITY (EWE)	6.9	8.9	14.8	14.5	8.4	5.9	4.8	6.2	7.3	7.2	8.2	6.9
CUMULATIVE EWE	6.9	15.8	30.7	45.1	53.5	59.4	64.2	70.4	77.6	84.8	93.1	100.0

KS SALINA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	0	0	180	180	180	180	180	180	180	180	0
PREPONDERANCE	5.8	2.4	3.0	2.9	4.6	5.4	3.7	4.6	6.4	4.6	4.0	3.0
EROSIVITY (EWE)	7.4	8.8	19.6	19.8	11.5	4.2	2.2	5.2	6.5	4.9	5.8	4.2
CUMULATIVE EWE	7.4	16.2	35.8	55.6	67.1	71.3	73.4	78.6	85.1	90.0	95.8	100.0

KS TOPEKA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	0	180	180	180	180	180	180	180	180	338	180
PREPONDERANCE	2.4	2.6	1.4	1.8	2.6	3.5	3.4	3.2	4.2	2.2	1.6	2.4
EROSIVITY (EWE)	6.8	12.0	29.6	21.1	5.9	3.6	1.2	.9	1.1	4.9	5.2	7.6
CUMULATIVE EWE	6.8	18.8	48.4	69.6	75.5	79.1	80.3	81.2	82.3	87.2	92.4	100.0

Exhibit 502–7b Example of wind erosion calculation using the *management period procedure*

NRCS - WEQ CALCULATIONS, Version 5

Producer: **Iam Windy** Planner: **mas** Location: **Mose Lake** Tract: **123** Field: **1**

Crop Rotation: **Corn** Climate Data Station: **WA, MOSES LAKE, old** Site **"C"** Value: **50**

Tillage Direction (NS/EW): **ns** Length/width ratio: **1** Field Direction (NS/EW): ew Field Width (Ft.): **2640**

Irrigation (Y or N): **y** Soil "I": 134 Wind Erodibility Group: **2** (1-7) TWF: **1** (see instr.)

Sum Period Erosion (t/ac): **6.9** No. Yrs in Rotation: **1.0** Av. Annual Wind Erosion: **6.9** (t/ac/yr)

Mgt Periods		Irr.	Soil	Ridge Roughness				R Roug	Unsheltered Distance				SGe	Erosion			
Dates		No. of	"I"	Dev.	Ht.	Sp.	"Krd"	"Krr"	Dev.	Prep.	WED	"L"	"V"	"E"	EWE	"IF"	Loss
Begin	End	(#)	(t/ac)	(deg)	(in.)	(in.)	(factor)	(factor)	(deg)	(factor)	(factor)	(ft)	(lbs/ac)	(t/ac)	(%)	(%)	(t/ac)
1/1/99	1/2/99	0	104	90.0	0	0	1.0	0.99	0.0	2.5	1.02	2693	3422	0.0	0.3	1.00	0.00
1/2/99	3/15/99	0	104	90.0	0	0	1.00	1.00	0.0	2.5	1.02	2693	2703	0.0	24.9	1.00	0.00
3/15/99	3/15/99	0	104	45.0	0	0	1.00	0.98	45.0	1.3	1.03	2719	1437	4.0	0.0	1.00	0.00
3/15/99	4/1/99	0	104	45.0	0	0	1.0	1.00	45.0	1.3	1.03	2719	1361	5.3	8.5	1.00	0.45
4/1/99	4/1/99	0	104	45.0	0	0	1.0	0.88	45.0	1.1	1.03	2719	57	43.8	0.0	1.00	0.00
4/1/99	4/10/99	0	104	45.0	0	0	1.0	0.99	45.0	1.1	1.03	2719	54	49.8	4.3	1.00	2.12
4/10/99	4/15/99	0	104	45.0	3	30	0.7	0.98	45.0	1.1	1.03	2719	34	33.8	2.4	1.00	0.80
4/15/99	4/30/99	2	104	45.0	3	30	0.7	0.99	45.0	1.1	1.03	2719	33	34.5	7.1	0.87	2.12
4/30/99	5/15/99	6	104	45.0	3	30	0.7	1.00	45.0	1.1	1.03	2719	37	34.6	4.4	0.60	0.92
5/15/99	5/15/99	0	104	0.0	3	30	0.7	0.97	90.0	1.1	1.03	2719	26	33.2	0.0	1.00	0.00
5/15/99	5/30/99	12	104	0.0	3	30	0.7	1.00	90.0	1.1	1.03	2719	114	32.5	4.3	0.20	0.28
5/30/99	6/14/99	12	104	0.0	3	30	0.7	1.00	90.0	1.1	1.03	2719	448	23.7	4.5	0.20	0.21
6/14/99	6/29/99	12	104	45.0	3	30	0.7	1.00	45.0	1.2	1.03	2719	5291	0.0	4.6	0.20	0.00
6/29/99	10/15/99	38	104	45.0	3	30	0.7	1.00	45.0	1.2	1.03	2719	6999	0.0	17.2	0.65	0.00
10/15/99	11/1/99	0	104	90.0	0	0	1.0	1.00	0.0	1.6	1.03	2719	6999	0.0	3.7	1.00	0.00
11/1/99	11/1/99	0	104	90.0	0	0	1.0	0.98	0.0	1.6	1.03	2719	3613	0.0	0.0	1.00	0.00
11/1/99	12/31/99	0	104	90.0	0	0	1.0	1.00	0.0	1.6	1.03	2719	3422	0.0	13.7	1.00	0.00

Exhibit 502–8 C Factor map, United States

Electronic version

An electronic version of this map is located at

http://imsweb.ftw.nrcs.usda.gov/maps/c_values.html

Instruction for use:

1. After the map loads, click on the "zoom +" icon.

2. Select the area of interest on the map. Position your mouse pointer on that area, click, and hold the left mouse button, and outline the area to be enlarged.

3. Repeat step 2 until you recognize county boundaries of and can see county names of C factor values.

   If you cannot read the C factor value associated with the isoline, do step 4.

4. Click on the "i" icon, then click on the isoline on the map. A table will appear at the bottom of the screen. The C value for that isoline is in the C value box.

Exhibit 502–8a Procedures for developing local C factors

Agriculture Research Service provided calculated values of **C** at benchmark locations—sites where available weather data included average monthly precipitation and temperature and average annual wind velocity. Data was obtained from the National Climatic Center at Asheville, North Carolina, from the Wind Energy Resource Atlas, and from other sources.

To supplement the benchmark **C** values provided by ARS, NRCS extended the estimation of **C** to many more local weather stations. Where recorded precipitation and temperature data were available, including 1951-80 NOAA weather data. An estimate of average annual wind velocity was used to calculate **C**. Wind velocity isoline maps were prepared from available data, and used as supporting information to estimate local wind velocities. The influence of topography on local climate was also considered.

Precipitation and temperature data was used to calculate the precipitation-effectiveness (PE) index at various locations, using the equation:

$$PE = \sum^{12} 115 \times [P/(T-10)]^{10/9}$$

where:
PE is the precipitation-effectiveness index
P is average monthly precipitation [1/] (inches)
T is average monthly temperature [2/] (degrees F)

1/ When the average monthly precipitation is less than 0.5 inches, use 0.5
2/ When average monthly temperature is less than 28.4 °F, use 28.4

The PE index was used to represent surface soil moisture, together with estimated local wind velocities, in the general equation to calculate C:

$$C = 34.48 \times V^3/(PE)^2$$

where:
C is the annual climatic factor
V is average annual wind velocity

Estimated local **C** values, calculated as described above, were recorded on state and regional maps and used as a basis to locate **C** value isolines. The benchmark values provided by ARS were not changed unless there was reason to believe that station data was not reliable.

The mathematical formulas can be solved manually or by use of computer software available for wind erosion from the NRCS cooperating scientist and most State Offices. The following page shows an example of the calculations.

Exhibit 502–8a Procedures for developing local C factors—Continued

Table 502–8 Annual effective PE and estimated C

Constraints: Monthly P => 0.5 inches
Monthly T => 28.4 degrees F

LOCATION: Norton, Kansas COUNTY: Norton

DATE: 09/26/97

Month	P	adj P	T	adj T	T - 10	PE
January	0.41	0.5	26.7	28.4	18.4	2.1
February	0.6	0.6	32.6	32.6	22,6	2.0
March	1.33	1.33	39.7	39.7	29.7	3.7
April	1.83	1.83	52.4	52.4	42.4	3.5
May	3.42	3.42	62.3	62.3	52.3	5.6
June	3.68	3.68	72.2	72.2	62.2	5.0
July	3.35	3.35	77.8	77.8	67.8	4.1
August	2.61	2.61	76.3	76.3	66.3	3.2
September	2.16	2.16	66.8	66.8	56.8	3.1
October	1.41	1.41	55.7	55.7	45.7	2.4
November	0.73	0.73	40.3	40.3	30.3	1.8
December	0.46	0.5	31.1	31.1	21.1	1.8
Average annual	21.99		52.8			38.3

Estimated **V** = 13
Estimated **C** = 51.8

Exhibit 502–9 Wind erosion direction factor tables

Table 502–9A Wind erosion direction factor; angle of deviation [1/] = 0 degrees

Prepon-dence	Field length/width ratio 1:1	2:1	4:1	8:1	10:1	12:1	16:1
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.30	1.45	1.53	1.56	1.58	1.62
1.4	1.03	1.20	1.28	1.32	1.35	1.37	1.40
1.6	1.03	1.14	1.18	1.20	1.22	1.23	1.25
1.8	1.03	1.10	1.11	1.12	1.13	1.14	1.15
2.0	1.02	1.07	1.07	1.07	1.08	1.08	1.08
2.2	1.02	1.05	1.05	1.05	1.05	1.05	1.05
2.4	1.02	1.04	1.04	1.04	1.04	1.04	1.04
2.6	1.01	1.03	1.03	1.03	1.03	1.03	1.03
2.8	1.01	1.02	1.02	1.02	1.02	1.02	1.02
3.0	1.01	1.02	1.02	1.02	1.02	1.02	1.02
3.2	1.01	1.01	1.01	1.01	1.01	1.01	1.01
3.4	1.01	1.01	1.01	1.01	1.01	1.01	1.01
3.6	1.00	1.01	1.01	1.01	1.01	1.01	1.01
3.8	1.00	1.01	1.01	1.01	1.01	1.01	1.01
4.0	1.00	1.01	1.01	1.01	1.01	1.01	1.01

See footnote at end of table.

Exhibit 502-9 Wind erosion direction factor tables—Continued

Table 502–9B Wind erosion direction factor; angle of deviation [1] = 22.5 degrees

Prepon-dence	Field length/width ratio 1:1	2:1	4:1	8:1	10:1	12:1	16:1
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.37	1.50	1.61	1.64	1.66	1.70
1.4	1.03	1.27	1.36	1.44	1.46	1.47	1.50
1.6	1.03	1.22	1.26	1.30	1.32	1.33	1.35
1.8	1.03	1.18	1.20	1.21	1.22	1.23	1.24
2.0	1.04	1.16	1.16	1.16	1.16	1.16	1.17
2.2	1.05	1.14	1.14	1.14	1.14	1.14	1.14
2.4	1.06	1.13	1.13	1.13	1.13	1.13	1.13
2.6	1.06	1.13	1.13	1.13	1.13	1.13	1.13
2.8	1.07	1.12	1.12	1.12	1.12	1.12	1.12
3.0	1.07	1.12	1.12	1.12	1.12	1.12	1.12
3.2	1.07	1.12	1.12	1.12	1.12	1.12	1.12
3.4	1.08	1.12	1.12	1.12	1.12	1.12	1.12
3.6	1.08	1.11	1.11	1.11	1.11	1.11	1.11
3.8	1.08	1.11	1.11	1.11	1.11	1.11	1.11
4.0	1.08	1.11	1.11	1.11	1.11	1.11	1.11

See footnote at end of table.

Exhibit 502-9 Wind erosion direction factor tables—Continued

Table 502–9C Wind erosion direction factor; angle of deviation 1/ = 45 degrees

Prepon- dence	Field length/width ratio 1:1	2:1	4:1	8:1	10:1	12:1	16:1
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.44	1.63	1.72	1.75	1.77	1.81
1.4	1.03	1.42	1.57	1.62	1.65	1.67	1.70
1.6	1.03	1.42	1.52	1.55	1.57	1.58	1.61
1 8	1.03	1.42	1.49	1.51	1.52	1.53	1.55
2 0	1.03	1.42	1.48	1.49	1.49	1.49	1.50
2.2	1.02	1.42	1.48	1.48	1.48	1.48	1.48
2.4	1.02	1.42	1.48	1.48	1.48	1.48	1.48
2.6	1.01	1.42	1.48	1.48	1.48	1.48	1.48
2.8	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.0	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.2	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.4	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.6	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.8	1.01	1.42	1.48	1.48	1.48	1.48	1.48
4.0	1.01	1.42	1.48	1.48	1.48	1.48	1.48

See footnote at end of table.

Exhibit 502-9 Wind erosion direction factor tables—Continued

Table 502–9D Wind erosion direction factor; angle of deviation [1/] = 67.5 degrees

Prepon-dence	Field length/width ratio 1:1	2:1	4:1	8:1	10:1	12:1	16:1
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.49	1.80	1.94	1.98	2.00	2.04
1.4	1.03	1.52	1.90	2.03	2.07	2.08	2.12
1.6	1.03	1.55	1.98	2.13	2.15	2.16	2.20
1.8	1.03	1.58	2.08	2.23	2.25	2.26	2.30
2.0	1.04	1.62	2.17	2.35	2.36	2.37	2.40
2.2	1.05	1.65	2.27	2.48	2.49	2.49	2.50
2.4	1.06	1.68	2.37	2.61	2.61	2.61	2.61
2.6	1.06	1.71	2.42	2.71	2.71	2.71	2.71
2.8	1.07	1.72	2.44	2.77	2.77	2.77	2.77
3.0	1.07	1.73	2.45	2.82	2.82	2.82	2.82
3.2	1.07	1.74	2.46	2.85	2.85	2.85	2.85
3.4	1.08	1.75	2.47	2.87	2.87	2.87	2.87
3.6	1.08	1.75	2.48	2.89	2.89	2.89	2.89
3.8	1.08	1.76	2.48	2.90	2.90	2.90	2.90
4.0	1.08	1.76	2.49	2.91	2.91	2.91	2.91

See footnote at end of table.

Exhibit 502-9 Wind erosion direction factor tables—Continued

Table 502–9E Wind erosion direction factor; angle of deviation 1/ = 90 degrees

Prepon- dence	Field length/width ratio 1:1	2:1	4:1	8:1	10:1	12:1	16:1
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.50	1.90	2.10	2.16	2.23	2.32
1.4	1.03	1.55	2.10	2.40	2.50	2.60	2.75
1.6	1.03	1.66	2.30	2.70	2.87	3.00	3.25
1.8	1.03	1.80	2.55	3.10	3.32	3.50	3.85
2.0	1.02	1.96	2.78	3.50	3.84	4.08	4.56
2.2	1.02	2.00	3.06	4.05	4.47	4.80	5.40
2.4	1.02	2.00	3.35	4.63	5.12	5.60	6.40
2.6	1.01	2.00	3.56	5.30	5.93	6.50	7.60
2.8	1.01	2.00	3.74	5.85	6.64	7.50	8.90
3.0	1.01	2.00	3.92	6.51	7.60	8.80	10.6
3.2	1.01	2.00	4.00	6.89	8.20	9.30	11.5
3.4	1.01	2.00	4.00	7.08	8.40	9.60	11.8
3.6	1.00	2.00	4.00	7.26	8.60	9.90	12.3
3.8	1.00	2.00	4.00	7.45	8.91	10.3	12.8
4.0	1.00	2.00	4.00	7.64	9.20	10.6	13.3

1/ Angle of deviation is the difference between prevailing wind erosion direction and a line perpendicular to the long side of the field or strip (0 degrees is perpendicular to the long side). Multiply the Wind Erosion Direction Factor times the width of the field to determine L distance. For circular fields L = .915 times the diameter regardless of direction or preponderance.

Exhibit 502-10 Flat small grain equivalent charts

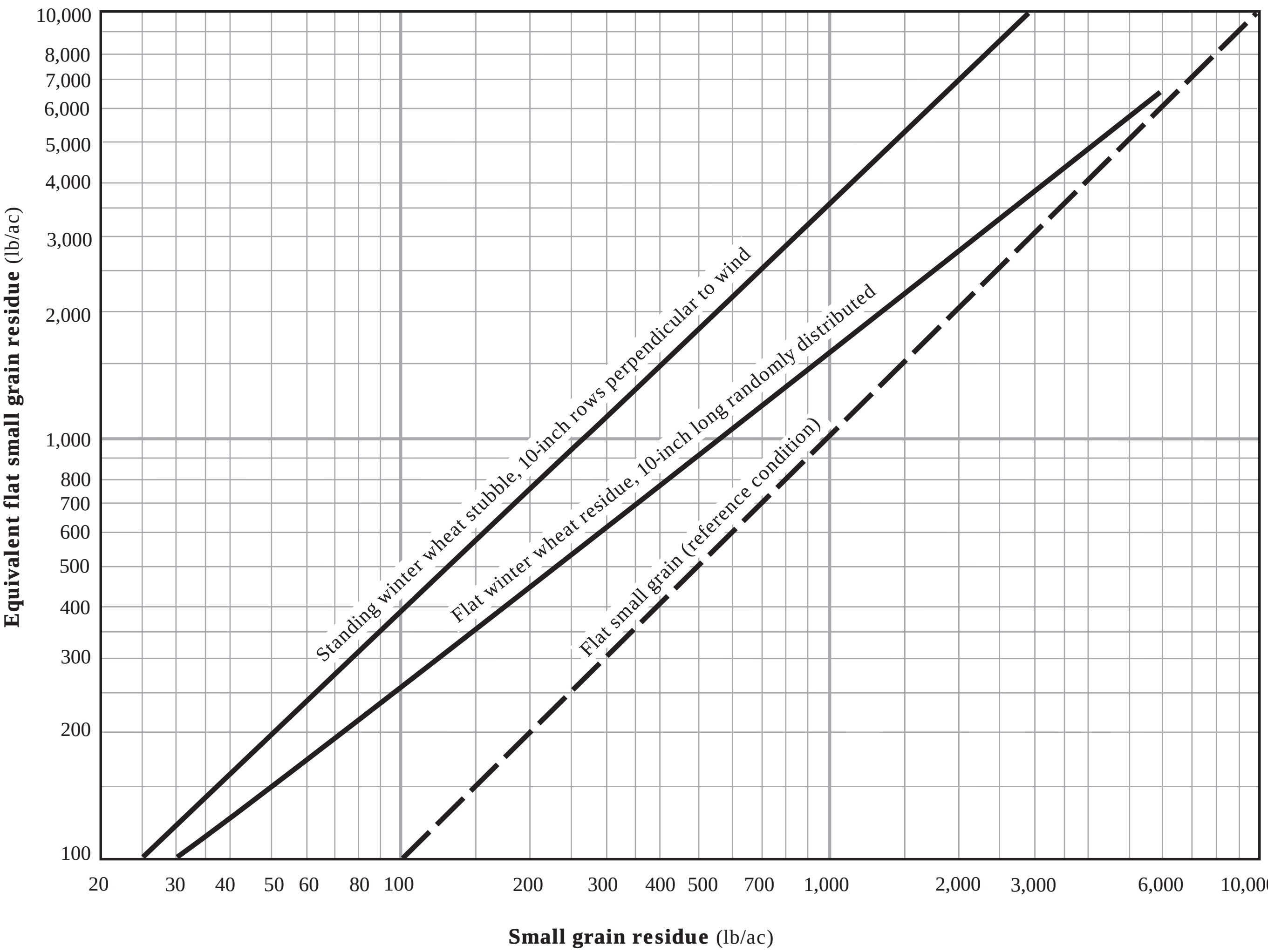
Index to flat small grain equivalent charts

Vegetation	Figure	Vegetation	Figure
Alfalfa	b-l	Needleandthread	d-1, 4, 8
Barley	a-1, 2	Oats	a-1, 2
Beans, dry	b-2	Peanuts	b-12, 13, 14
Beets, sugar	b-15	Potato	b-15
Big bluestem	d-1, 3, 4, 5	Range grasses and mixtures	d-1–8
Blue grama	d-1, 3, 4, 6, 7, 8		
Buckwheat	b-5	Rape	b-16
Buffalograss	d-1, 2, 4, 5, 7, 8	Rye	a-1, 2
Corn	a-3, 4, 5, 6	Safflower	b-17
Cotton	b-6, 7, 8, c-l	Sesame	b-12
Dry beans	b-2	Sideoats grama	d-1, 4
Flax	b-9	Sorghum	a-4, 5, 6, 8
Guar	b-12	Soybeans	b-2, 3, 4
Lentils	b-2	Sudan	a-9
Little bluestem	d-1, 3, 4, 6	Sugar beets	b-15
Manure	c-2	Sunflower	b-18
Millet	a-7	Switchgrass	d-3, 6
Mint	b-10	Turnip	b-10
Mustard	b-ll	Western wheatgrass	d-1, 2, 4, 5, 8
		Wheat	a-1, 2
		Winter peas	b-2

Figure	Chart
a–1	Small grain residue (use for wheat, barley, rye, and oats)
a–2	Growing small grain
a–3	Corn residue
a–4	Corn and grain sorghum silage stubble
a–5	Growing corn and grain sorghum
a–6	Growing corn and grain sorghum; days after emergence
a–7	Millet stubble and residue
a–8	Grain sorghum and residue
a–9	Sudangrass stubble and residue
b–1	Alfalfa residue
b–2	Dry bean, lentil, soybean, and winter pea residue
b–3	Growing soybeans
b–5	Buckwheat residue
b–6	Cotton residue
b–7	Growing cotton
b–8	Growing cotton; days after emergence
b–9	Flax residue
b–10	Reserved for turnip and mint residue)
b–11	Mustard residue
b–12	Peanut, guar, and sesame residue
b–13	Growing peanuts
b–14	Growing peanuts; days after emergence
b–15	Potato or sugar beet residue
b–16	Rape residue
b–17	Safflower residue
b–18	Sunflower residue
c–1	Cotton burs
c–2	Manure
d–1	Overgrazed range mixtures
d–2	Overgrazed big bluestem, western wheatgrass, and buffalograss
d–3	Overgrazed little bluestem, switchgrass, and blue grama
d–4	Properly grazed range grass mixtures
d–5	Properly grazed big bluestem, etc
d–6	Properly grazed little bluestem, etc
d–7	Ungrazed blue grama and buffalograss
d–8	Undergrazed western wheatgrass, needleandthread, blue grama, and buffalograss mixtures

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a–1 Flat small grain equivalents of small grain residue (use for wheat, barley, rye, oats)

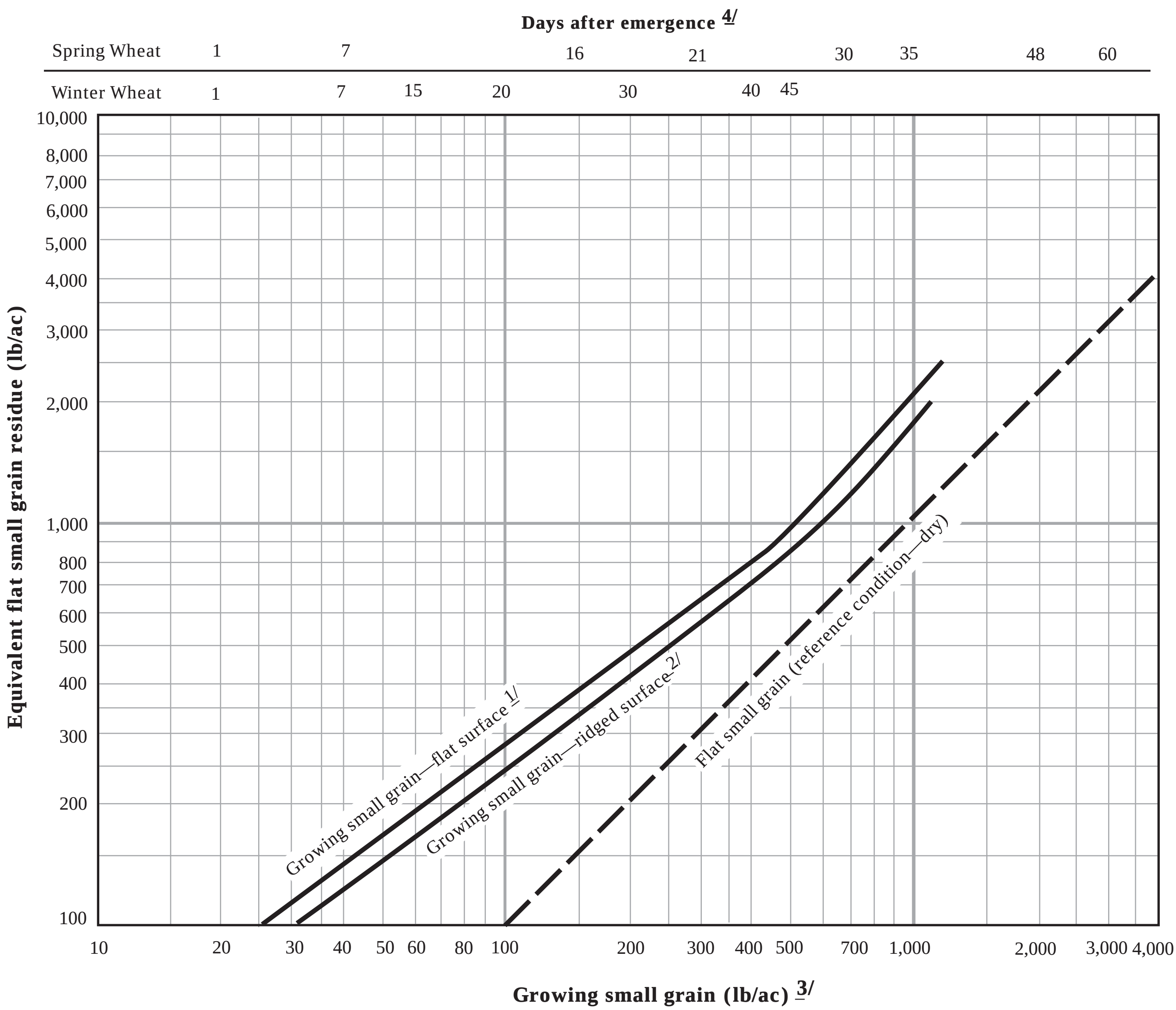


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction. Residue is washed, air dried, and placed as described for the wind tunnel tests.

Source: Lyles and Allison — Trans. ASAE 1981, 24 (2): 405-408.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a-2 Flat small grain equivalents of growing small grain

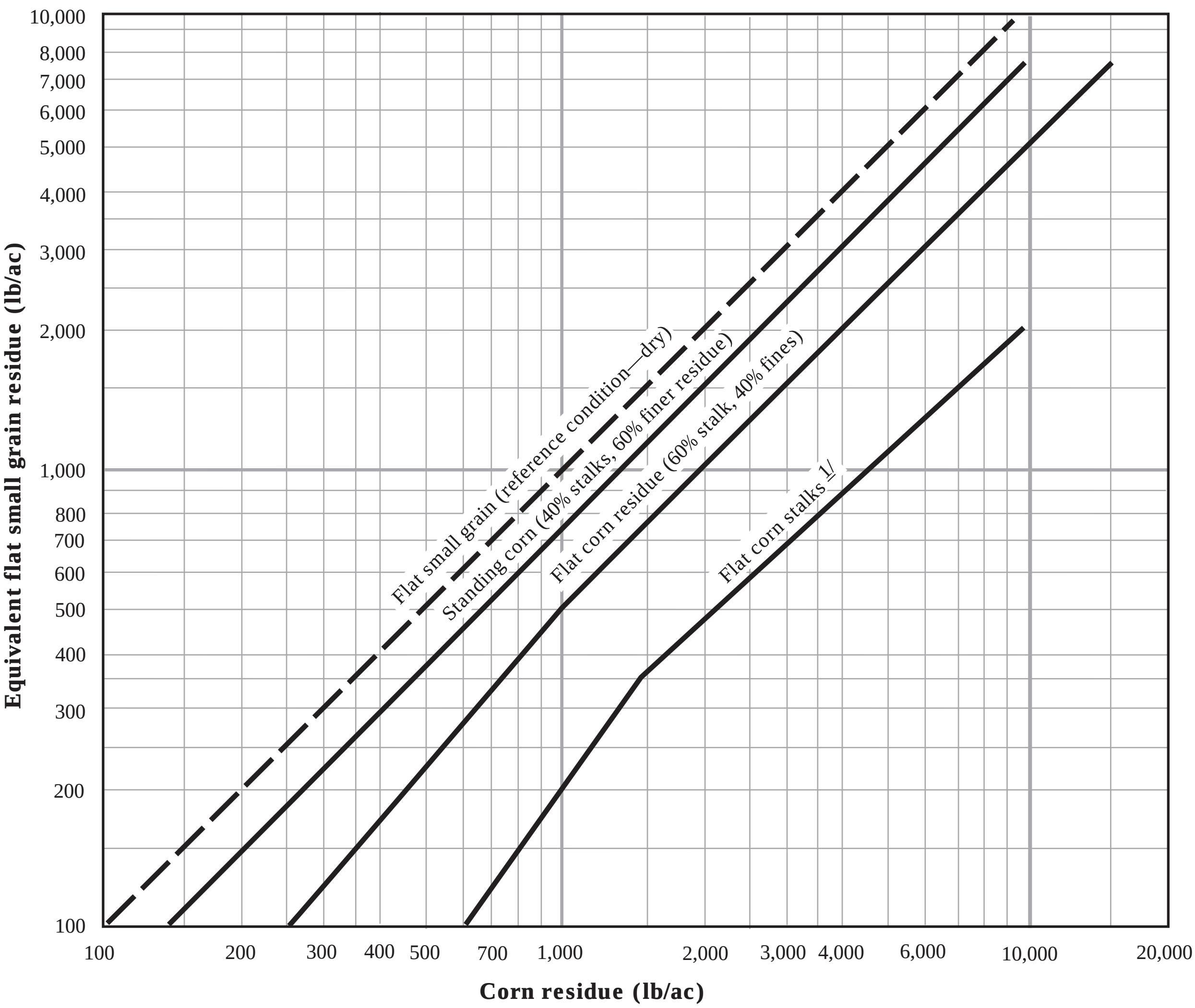


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

1/ Siddway, F.H., W.S. Chepil, and D.V. Armburst 1965.
2/ Estimates by best judgment of SCS personnel.
3/ Air-dry weights of growing winter wheat from emergence to winter dormancy.
4/ Crop growth, in days after emergence, from Central SD, 1996.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a-3 Flat small grain equivalents of corn residue

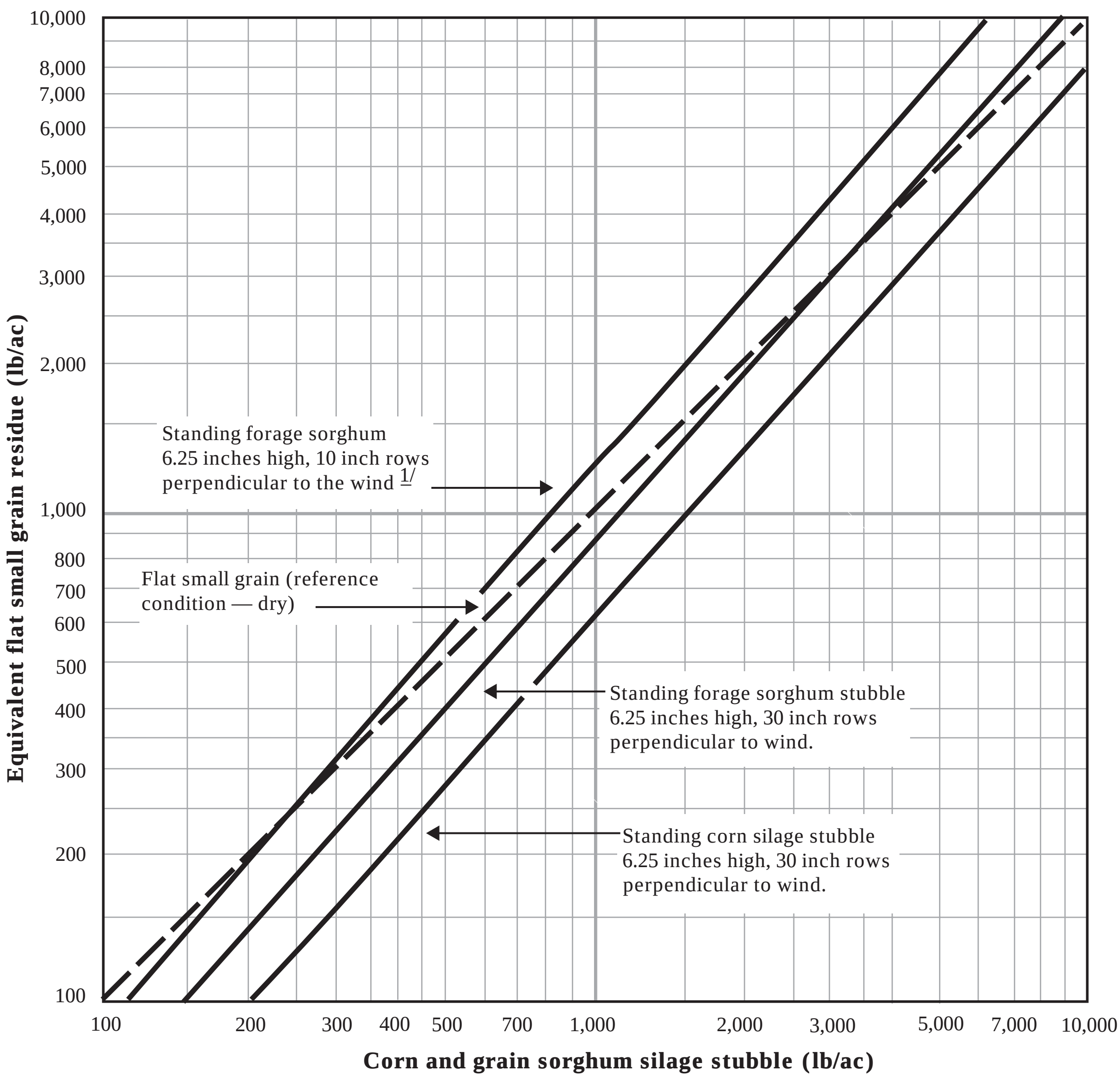


Source: Lyles and Allison, Transcript ASAE 1981, 24 (2): 405-408.

1/ Flat to 2,000 lbs, standing to 3,500 lbs. Extended by NRCS.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a-4 Flat small grain equivalents of corn and grain sorghum silage stubble

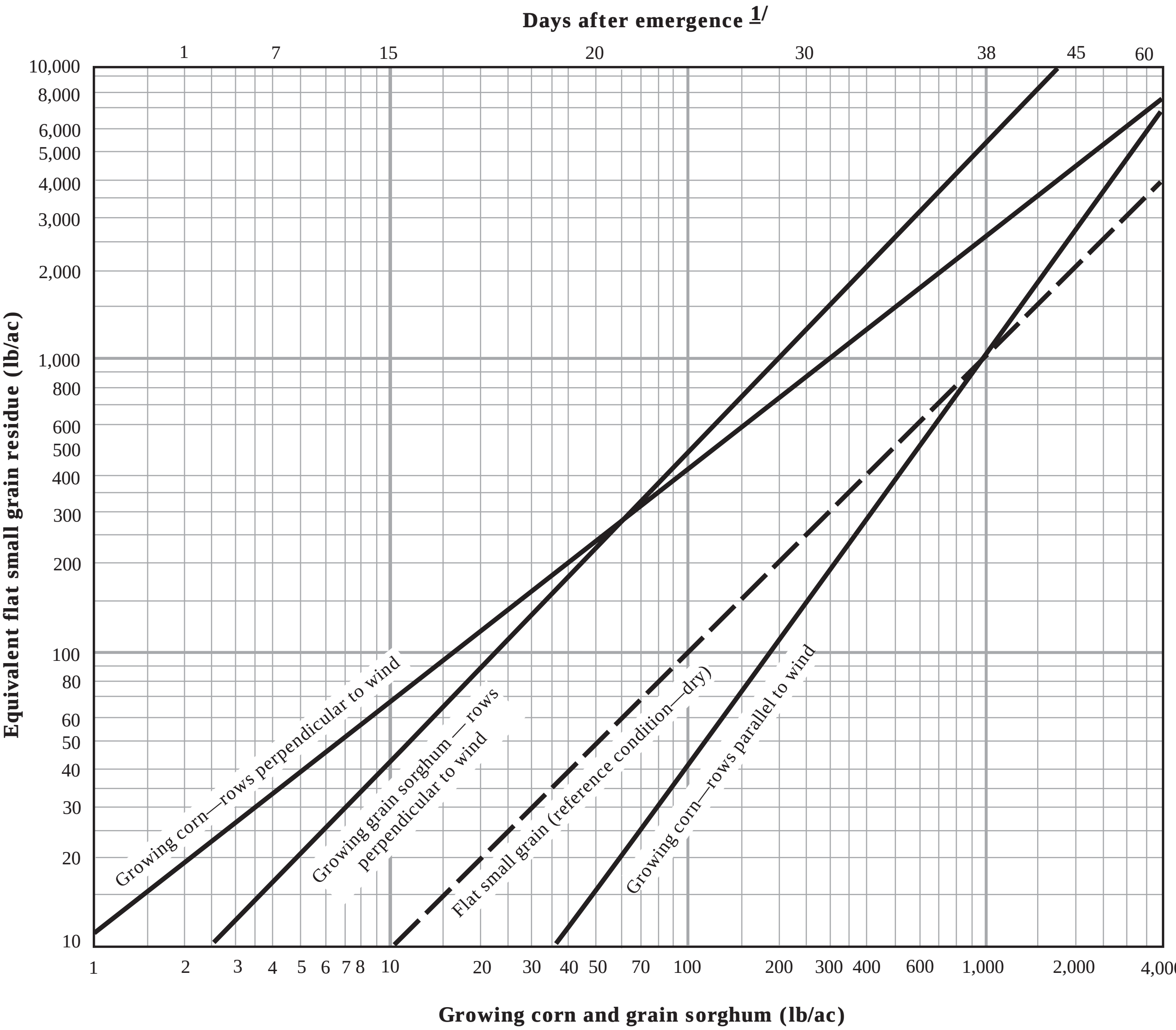


Source: Lyles and Allison — Trans. ASAE 1981, 24 (2): 405-408. Residue weights are washed, air dried, and placed as described for the wind tunnel tests.

1/ Field experience in the Northern Plains indicates the ratio of residue to grain is higher when crops, such as forage sorghum, are grown in narrow row seedings. Research is not available at this time to confirm this observation. Until research is available, the residue production values may be increased 30 percent when crops are planted in rows less than 20 inches apart. The line for standing forage sorghum 6.25 inches high with 10 inch rows includes an increase of 30 percent over the values for 30 inch rows.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a-5 Flat small grain equivalents of growing corn and grain sorghum

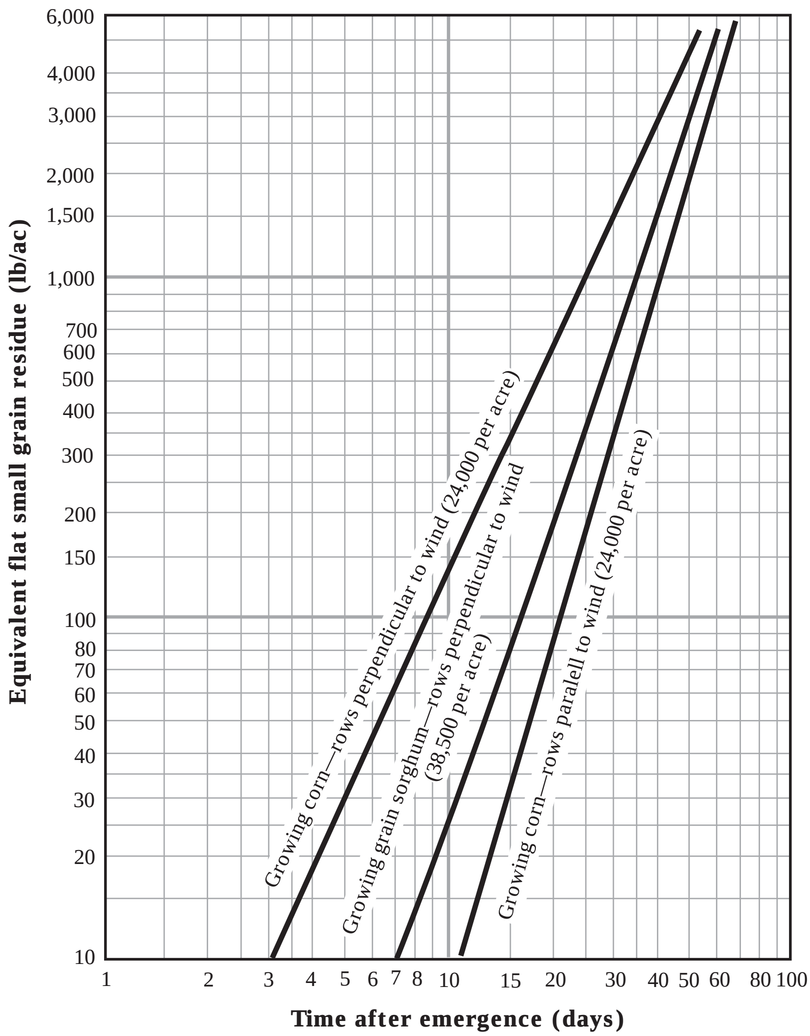


Source: Armburst and Lyles, 1984—unpublished.

1/ Natural Resources Conservation Service data from Central South Dakota, 1996.

Exhibit 502-10 Flat small grain equivalent charts—Continued

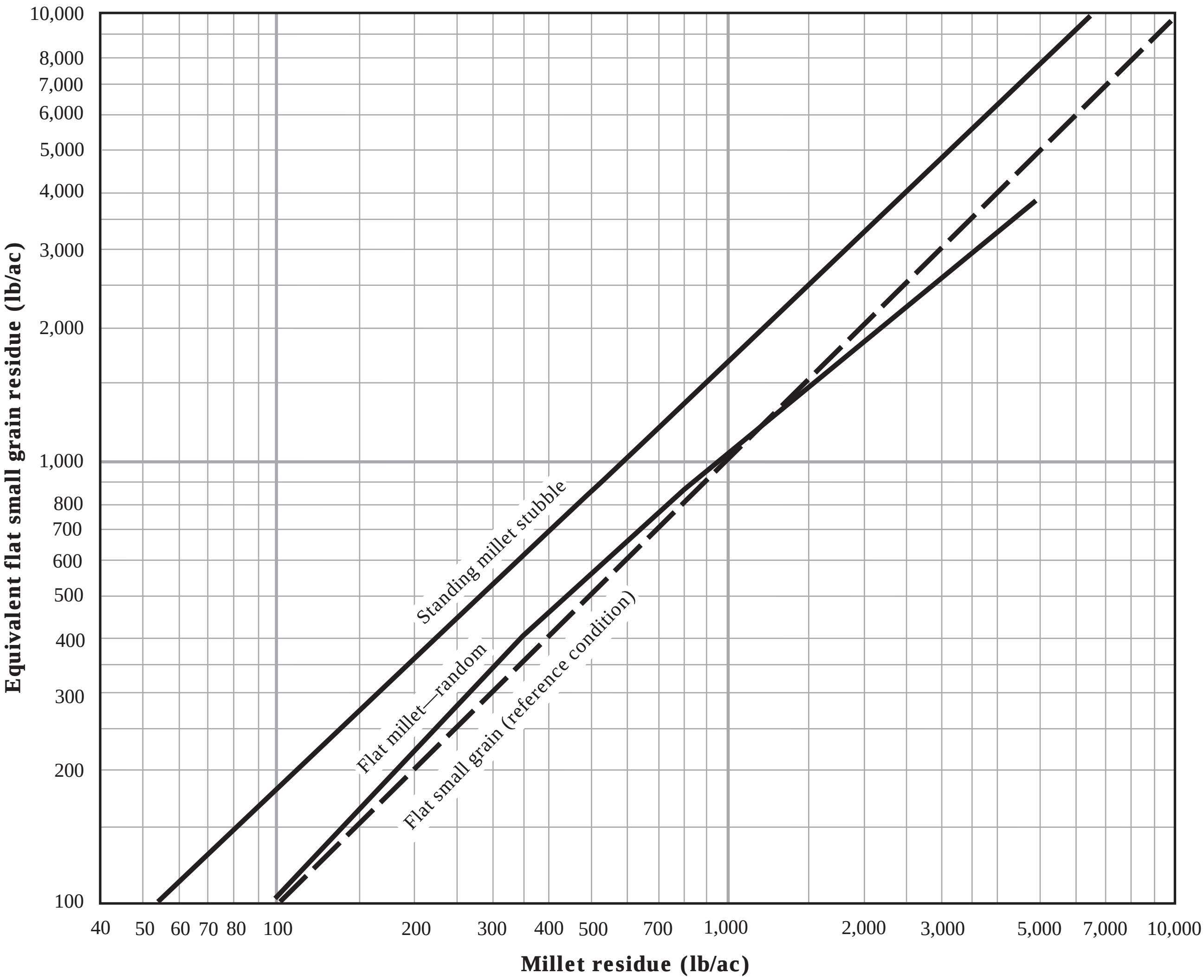
Figure a-6 Flat small grain equivalents of growing corn and grain sorghum; days after emergence



Source: Armburst and Lyles, 1984—unpublished.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a-7 Flat small grain equivalents of millet stubble and residue

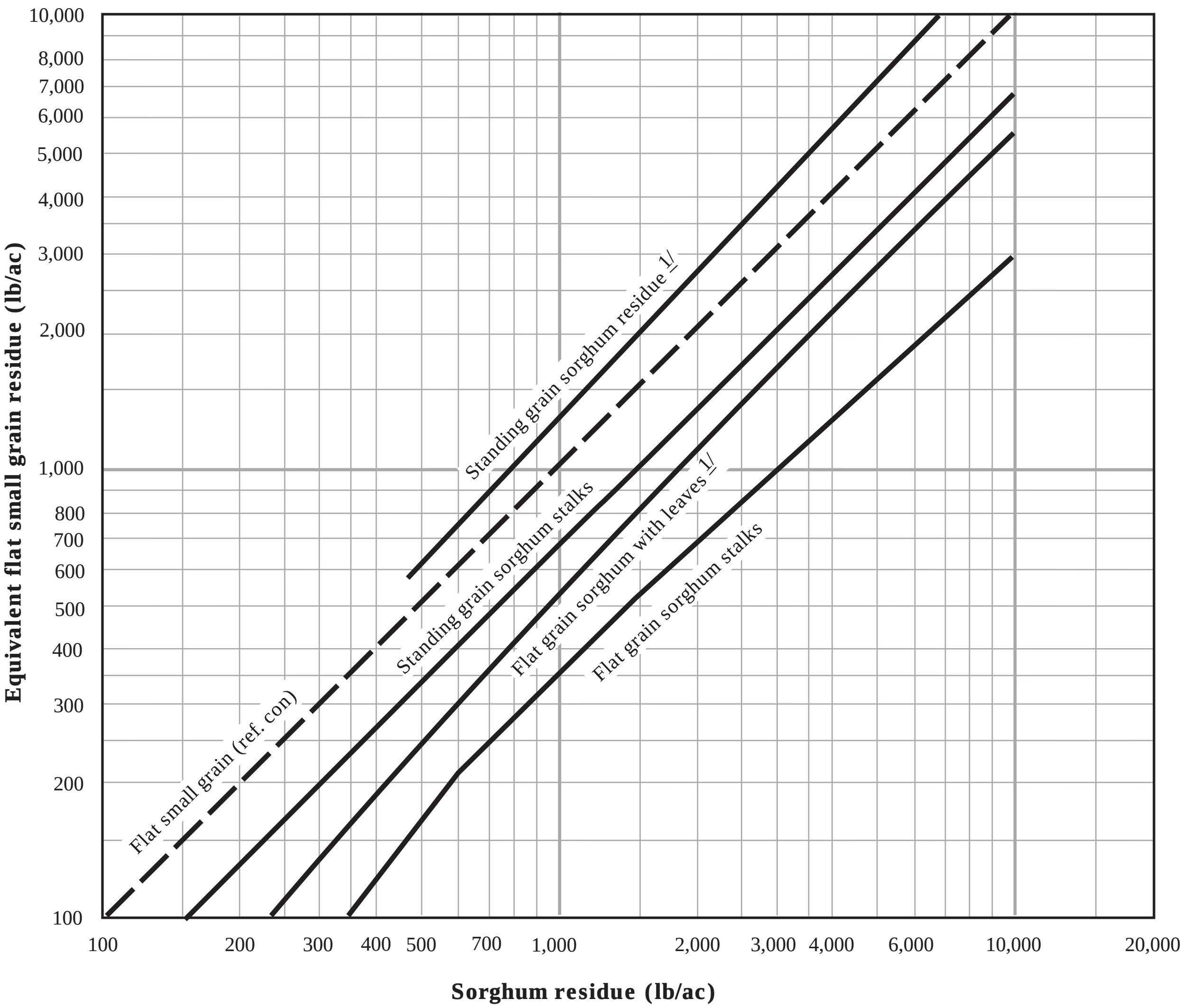


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Leon Lyles — ARS memorandum, January 25, 1985.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a-8 Flat small grain equivalents of grain sorghum and residue

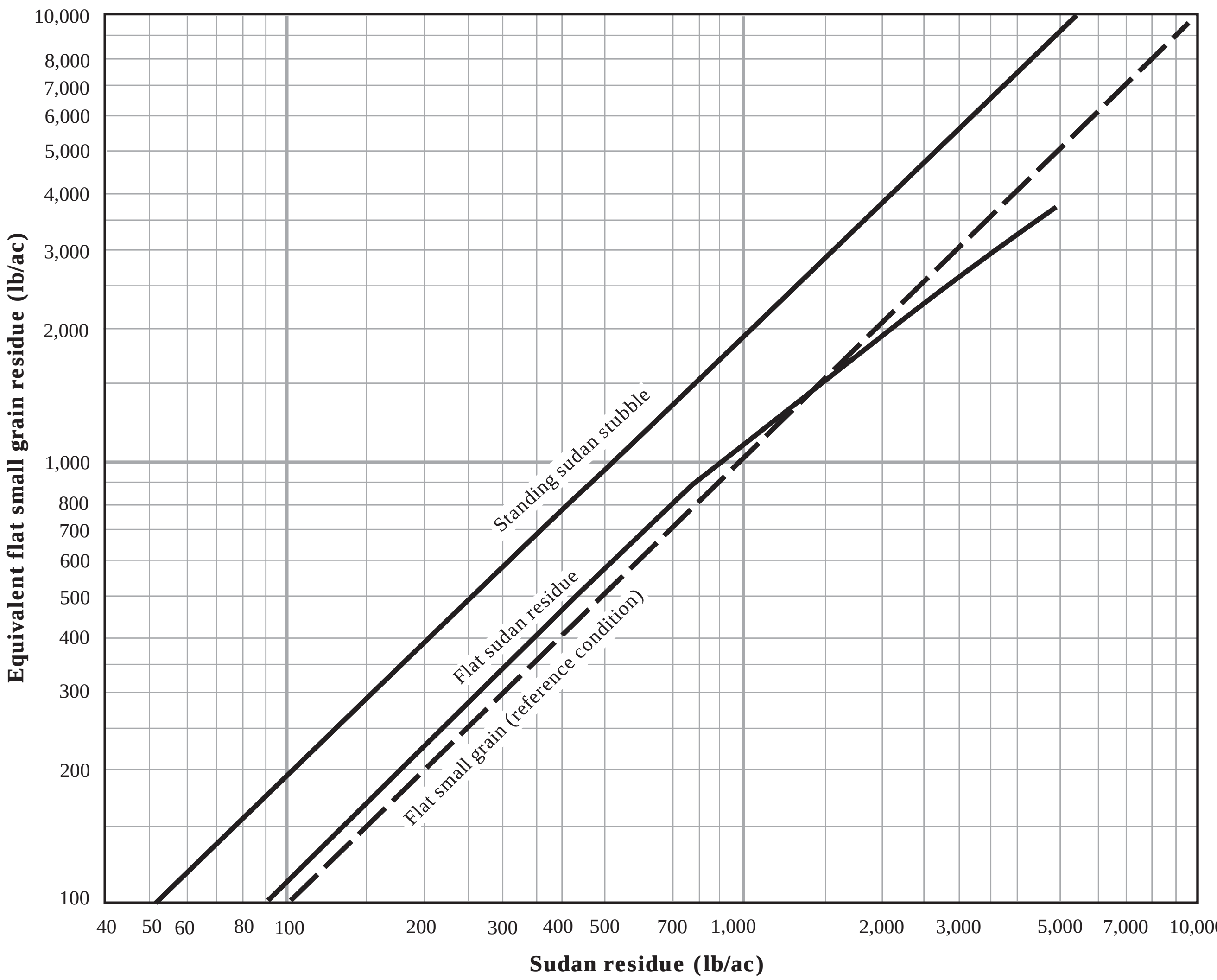


Source: Lyles and Allison — Trans. ASAE 1981, 24 (2): 405-408.

1/ Leafy residue estimates by NRCS North Central agronomists. (Flat to 2,500 lbs. standing stalks to 3,500 lbs.) November 1984.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure a-9 Flat small grain equivalents of sudangrass stubble and residue

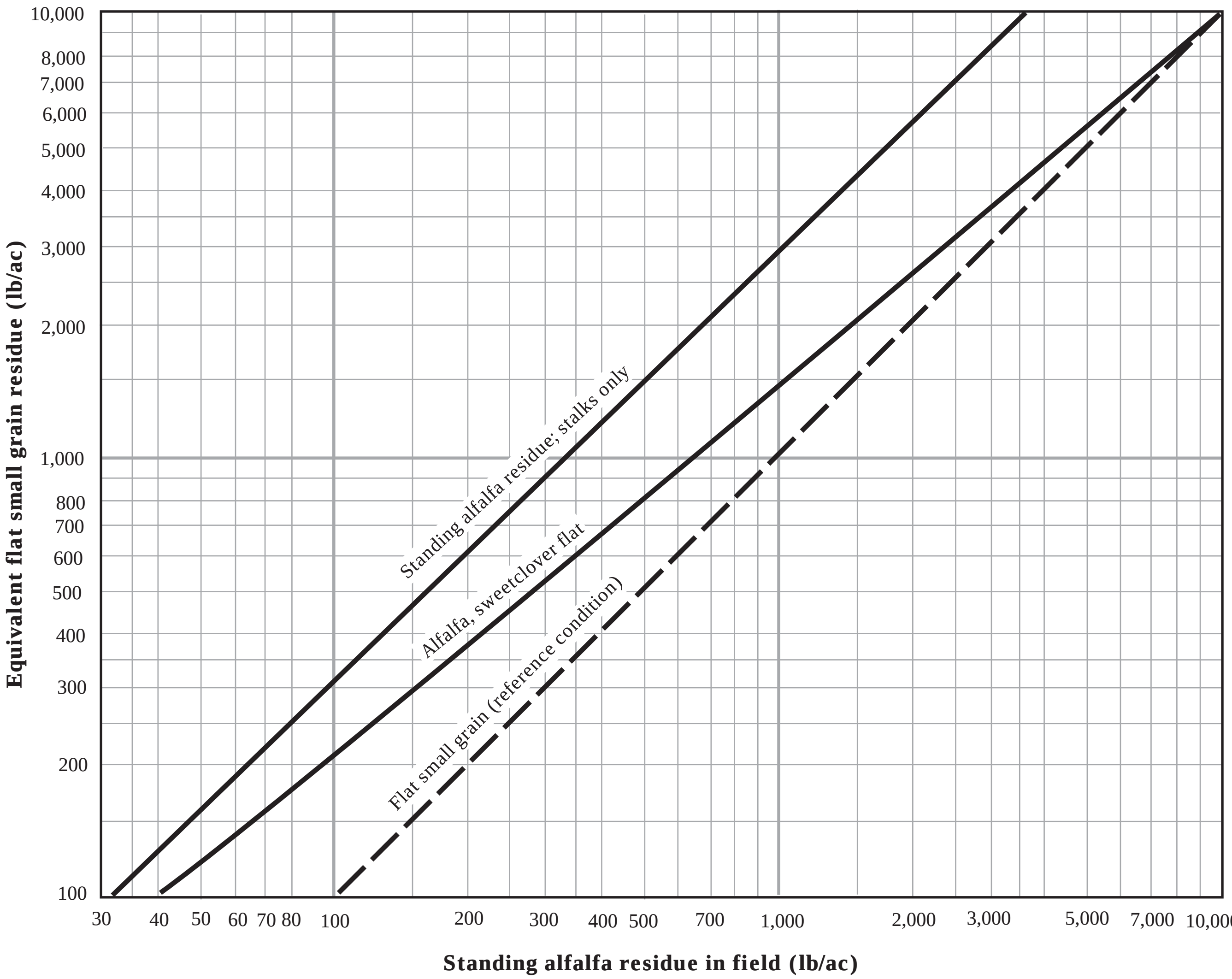


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Leon Lyles, ARS, Memorandum, January 25, 1985.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-1 Flat small grain equivalents of alfalfa residue

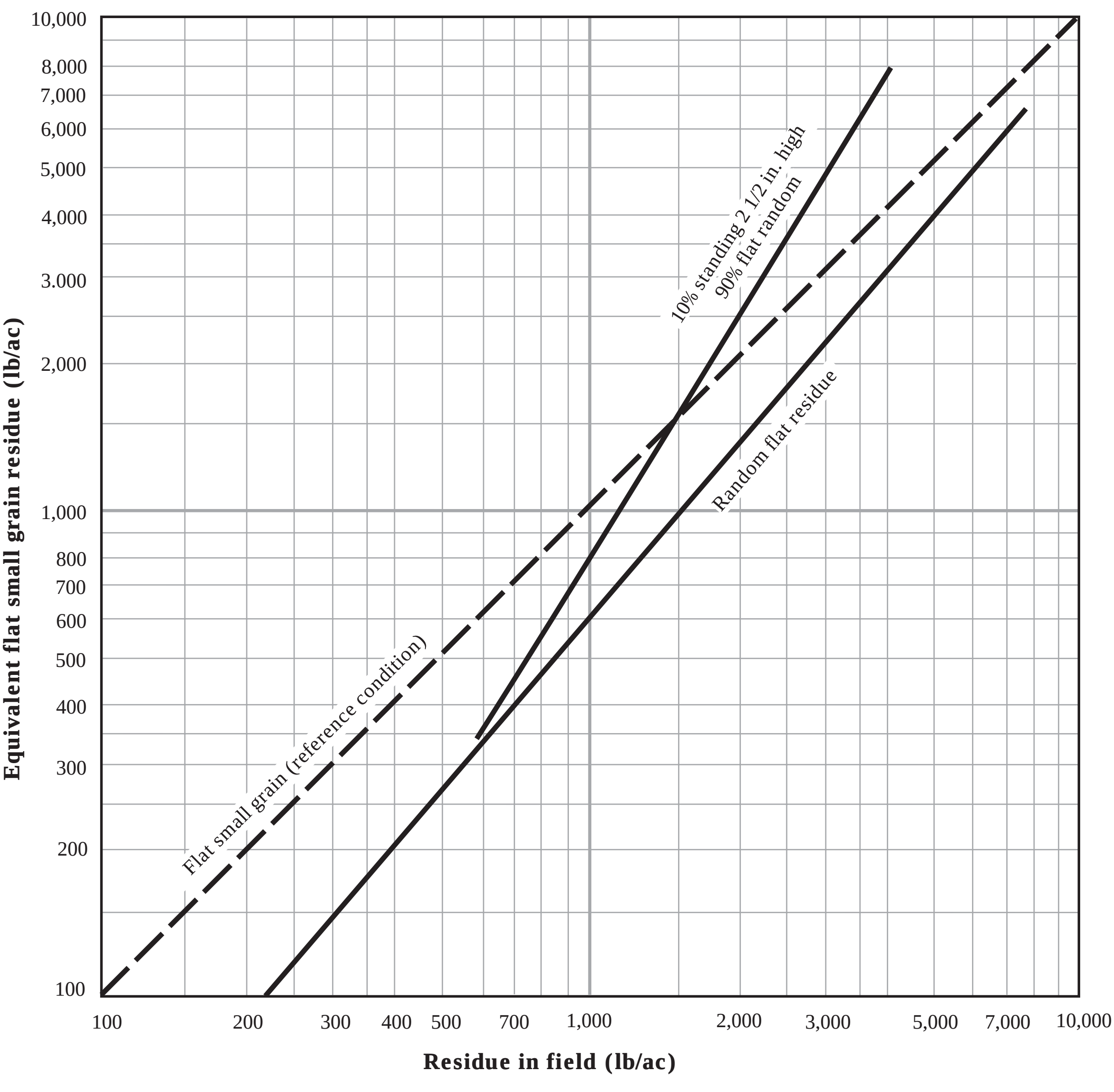


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Unpublished coefficients provided by Leon Lyles, ARS. Wind Erosion Research Unit, Manhattan, Kansas.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-2 Flat small grain equivalents of dry bean, lentil, soybean,[1/] and winter pea residue



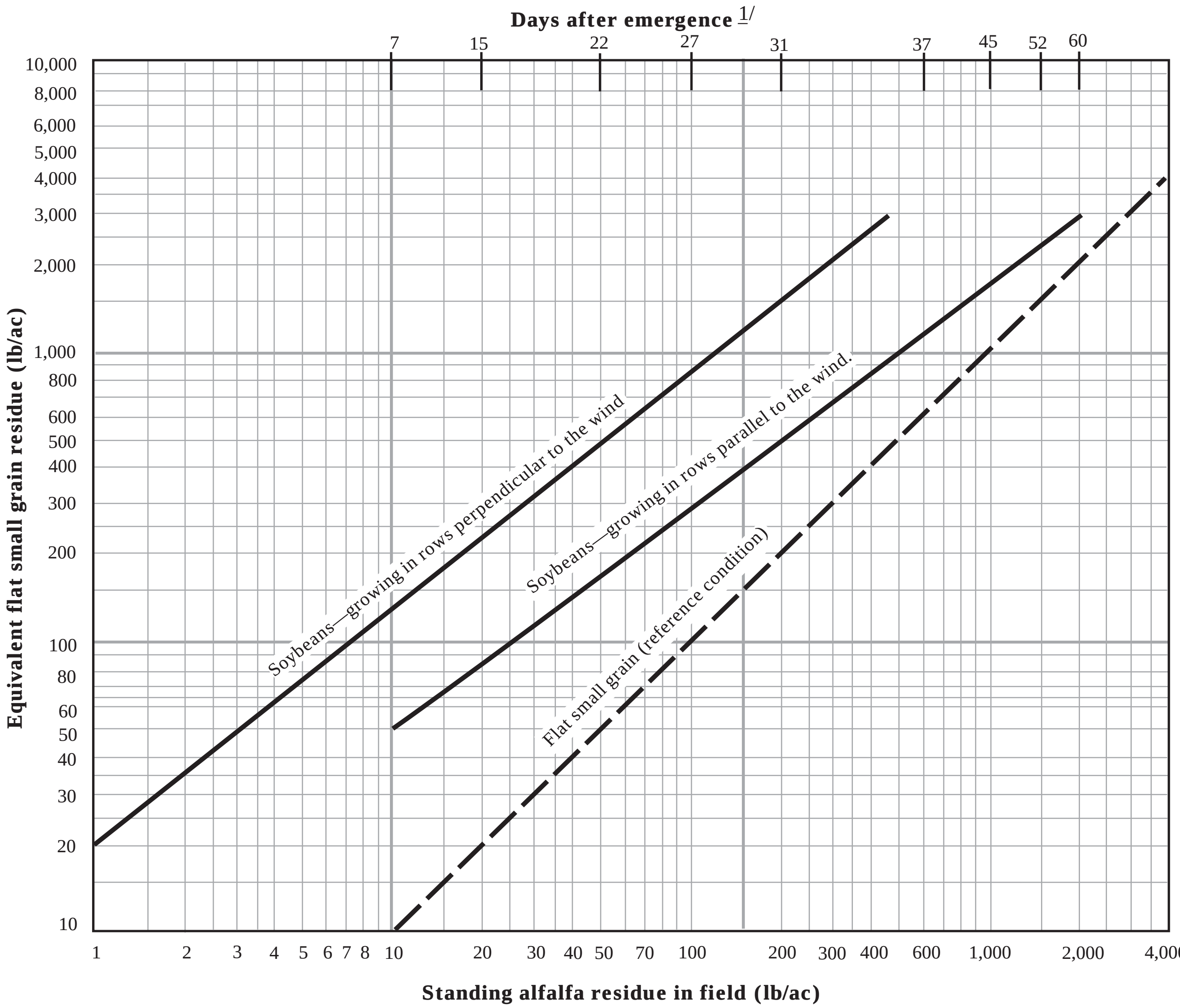
Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to direction, stalks oriented to wind direction.

Source: Best Judgment Estimates by NRCS, North Central Agronomists, November 1984.

1/ Soybeans—Lyles and Allison, Trans. ASAE. 1981, 24(2) 405-408.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-3 Flat small grain equivalents of growing soybeans

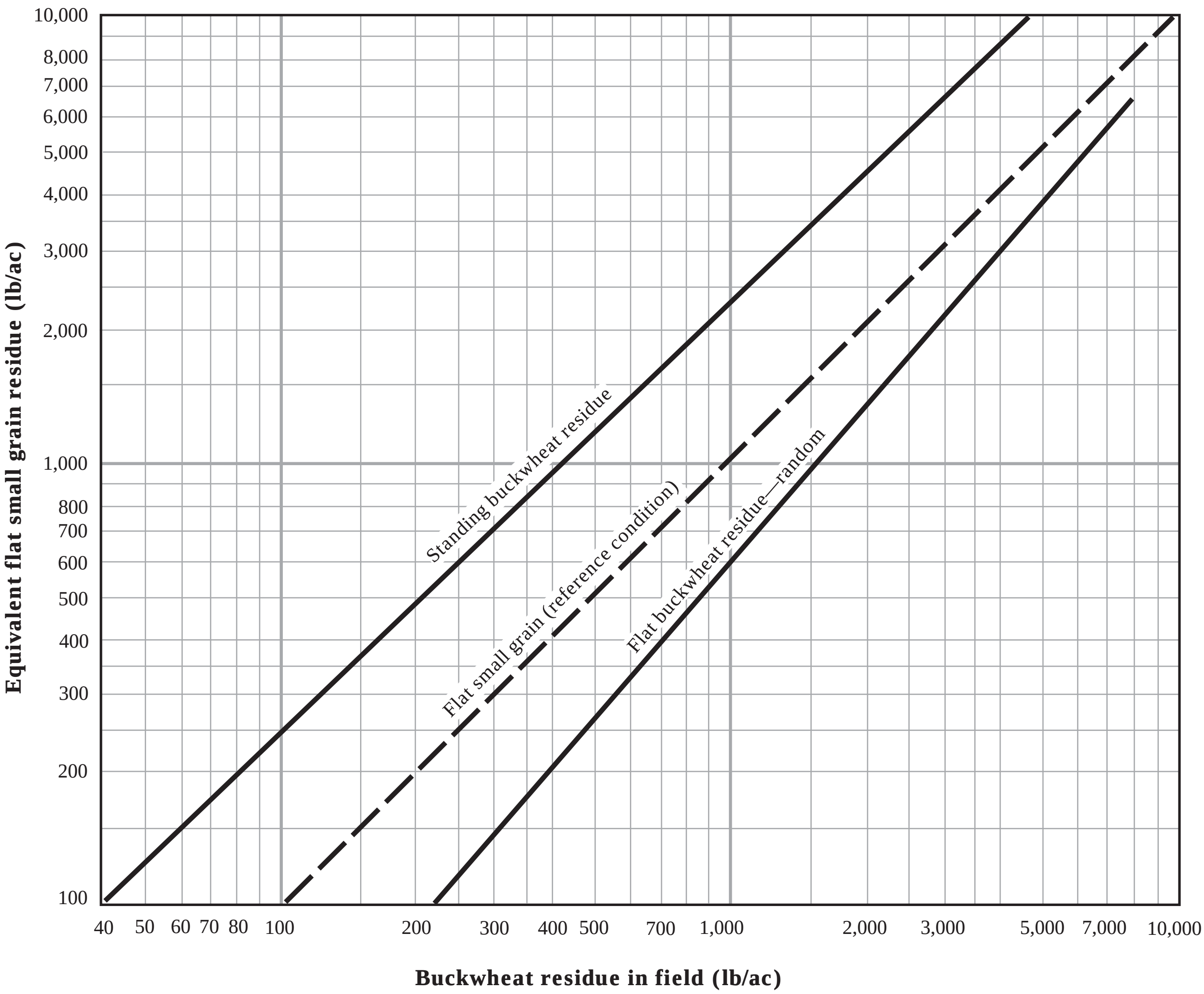


Source: Armburst and Lyles, 1984–unpublished.

1/ Data from central South Dakota, 1996.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-5 Flat small grain equivalents of buckwheat residue

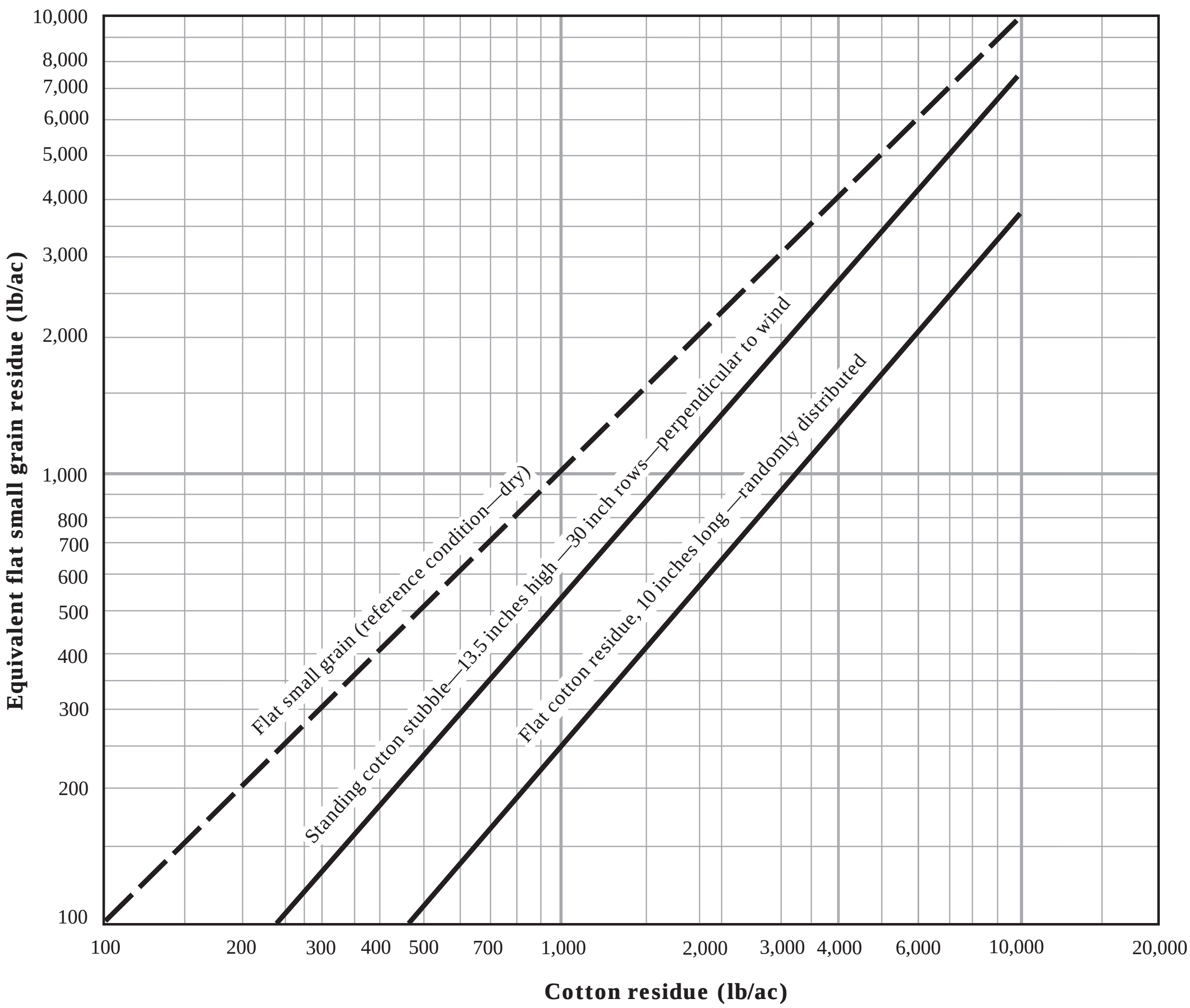


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Best judgment estimates by NRCS, North Central agronomists, November 1984.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-6 Flat small grain equivalents of cotton residue



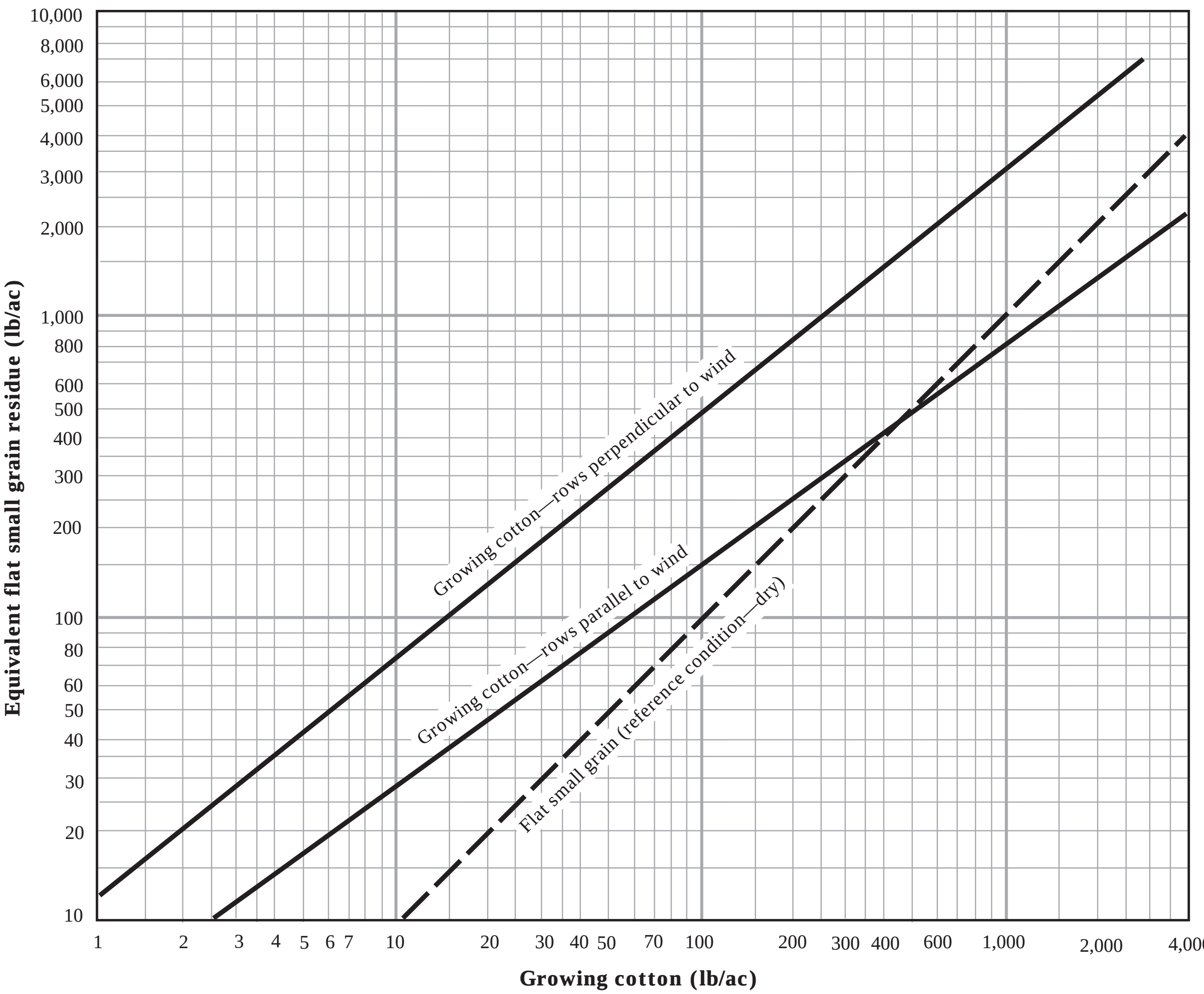
Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison, Trans ASAE, 1981, 24(2): 405-408.

Residue weights are washed and dried, placed as described for wind tunnel test.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-7 Flat small grain equivalents of growing cotton

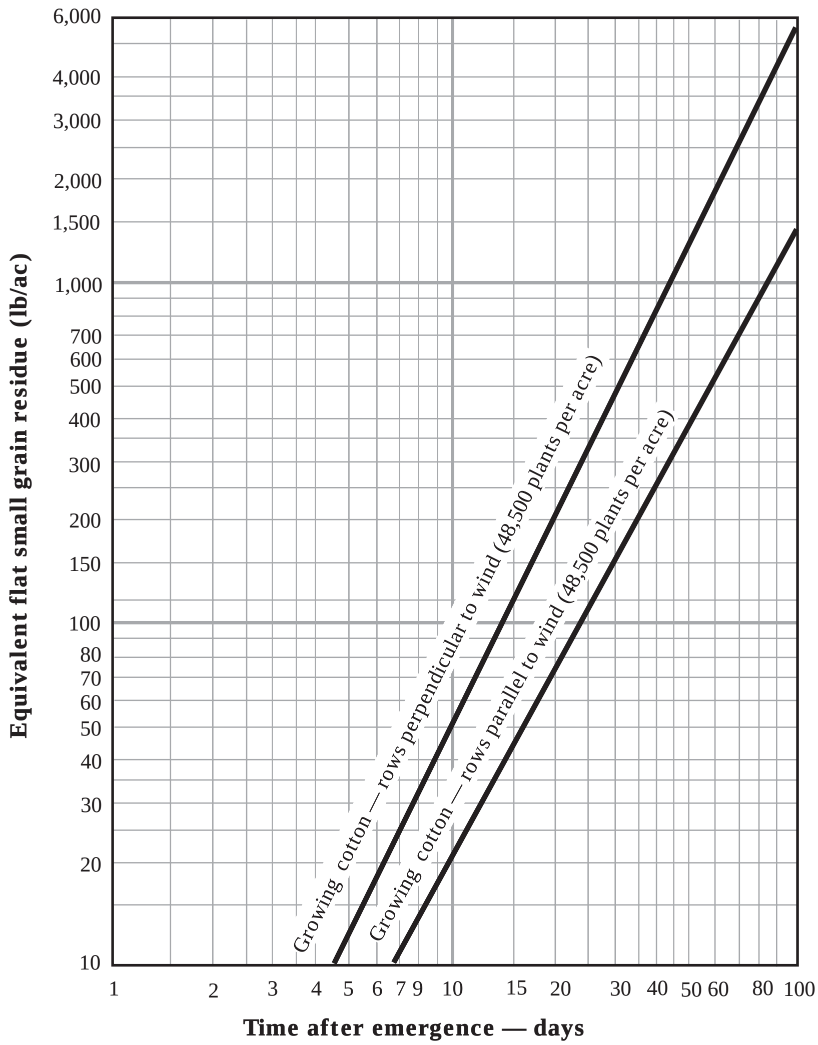


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Armburst and Lyles, 1984 — unpublished.

Exhibit 502-10 Flat small grain equivalent charts—Continued

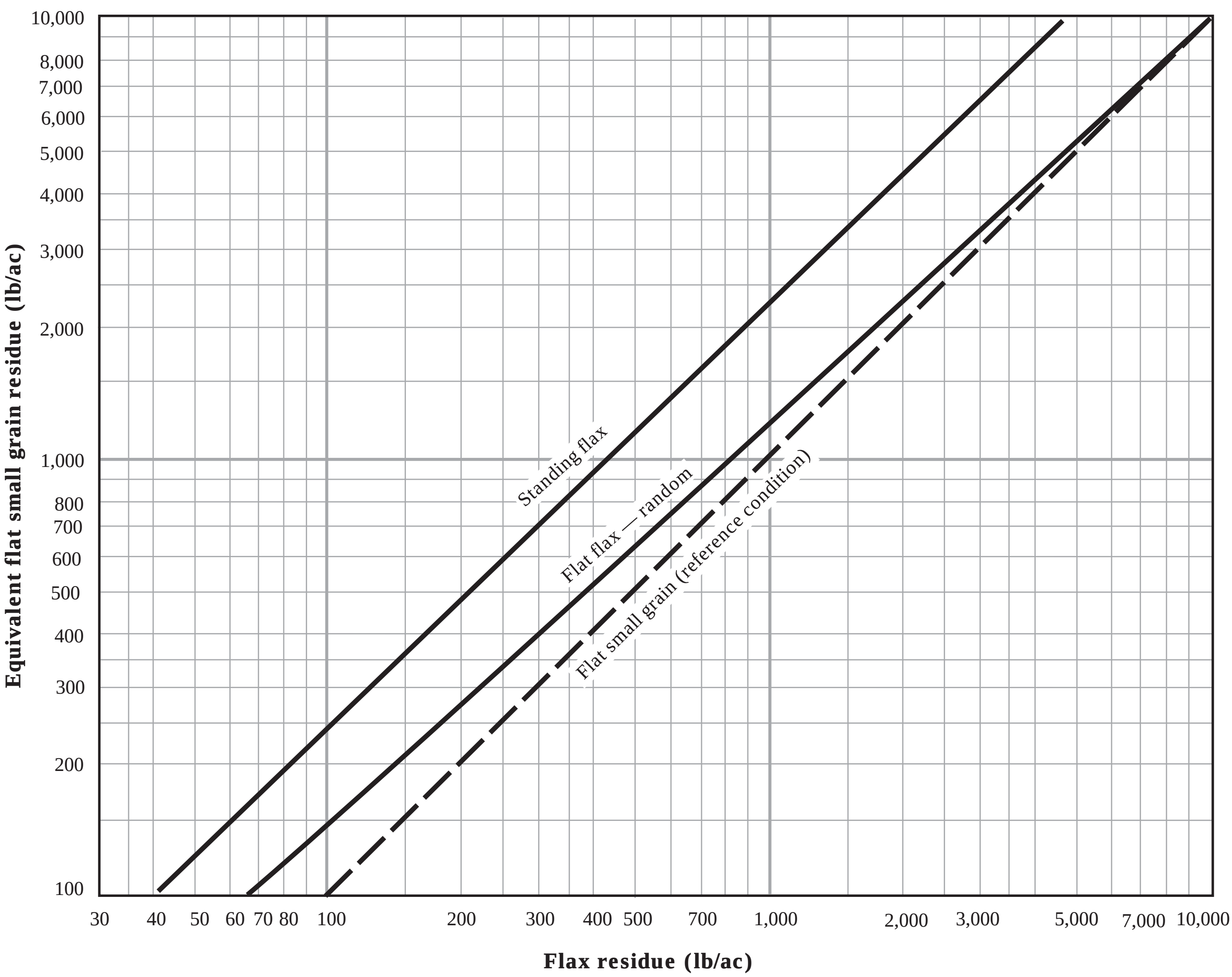
Figure b-8 Flat small grain equivalents of growing cotton; days after emergence



Source: Armburst and Lyles, ARS, 1984 —unpublished.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-9 Flat small grain equivalents of flax residue



Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Best judgment estimates by NRCS, North Central agronomists. November 1984.

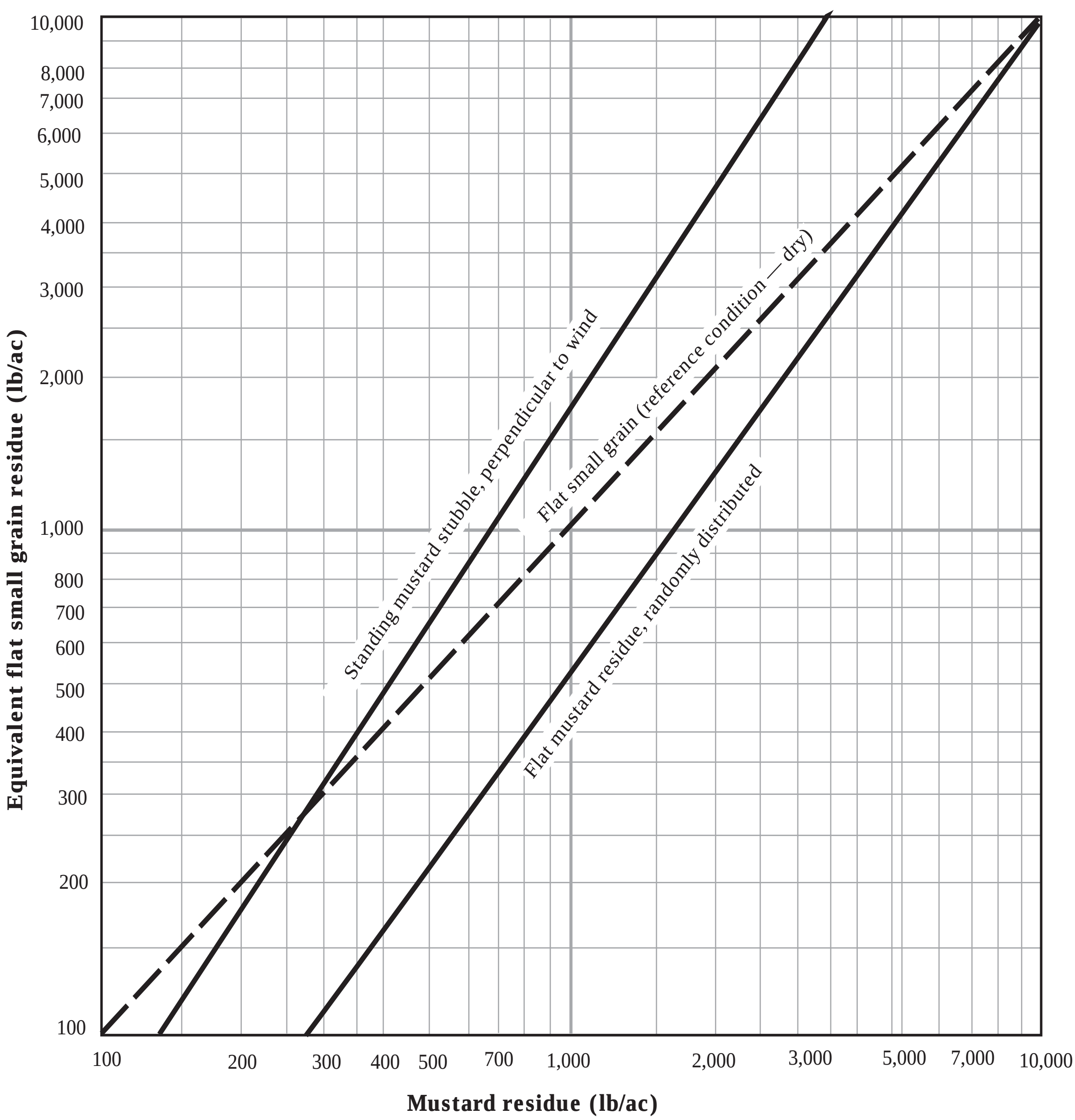
Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-10 Turnip and mint residue

(Reserved)

Exhibit 502-10 Flat small grain equivalent charts—Continued

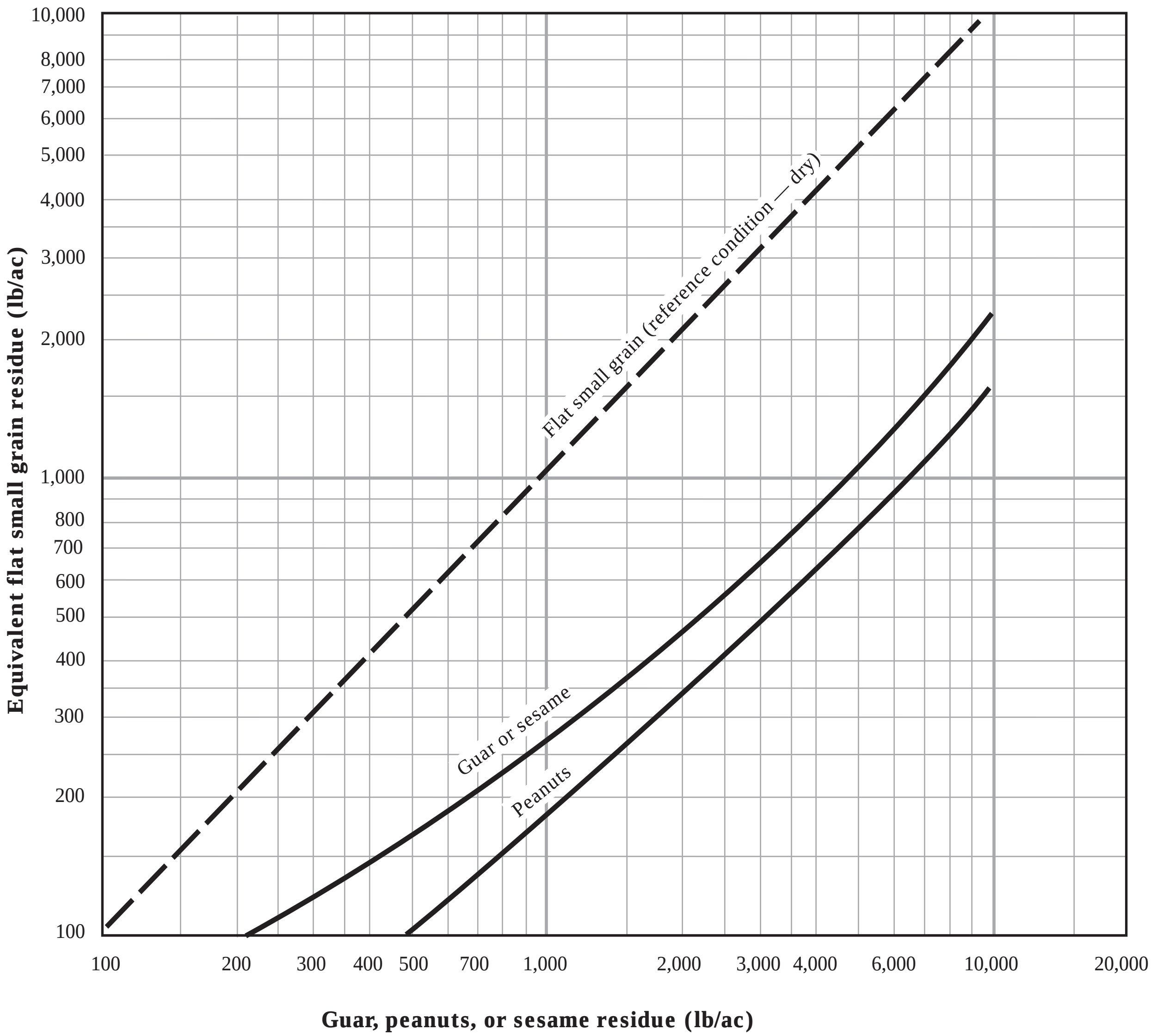
Figure b-11 Flat small grain equivalents of mustard residue



Source: Best judgment estimates by NRCS West agronomists, 1983.

Exhibit 502-10 Flat small grain equivalent charts—Continued

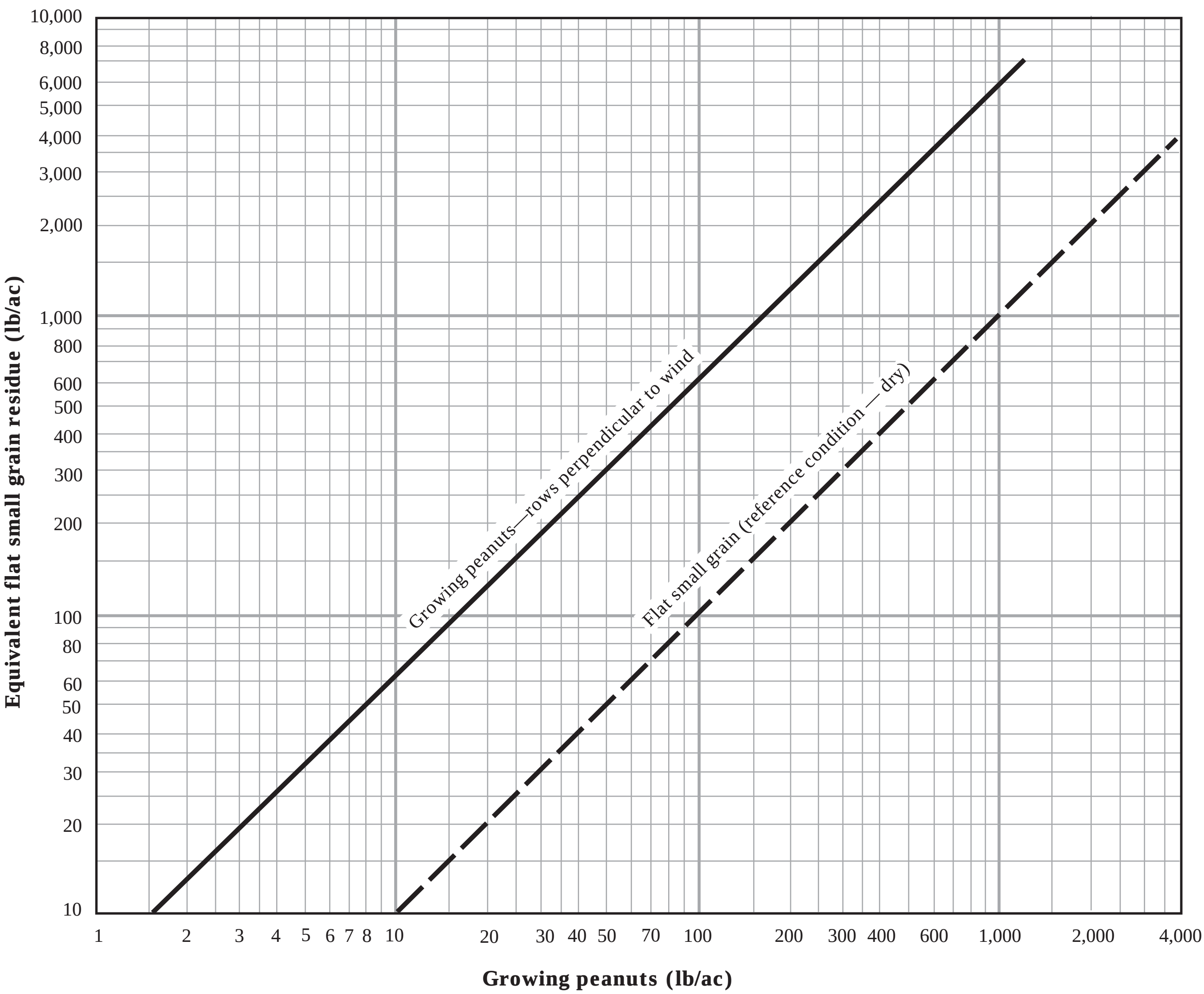
Figure b-12 Flat small grain equivalents of peanuts, guar, and sesame residue



Source: Best judgment estimates by NRCS.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-13 Flat small grain equivalents of growing peanuts

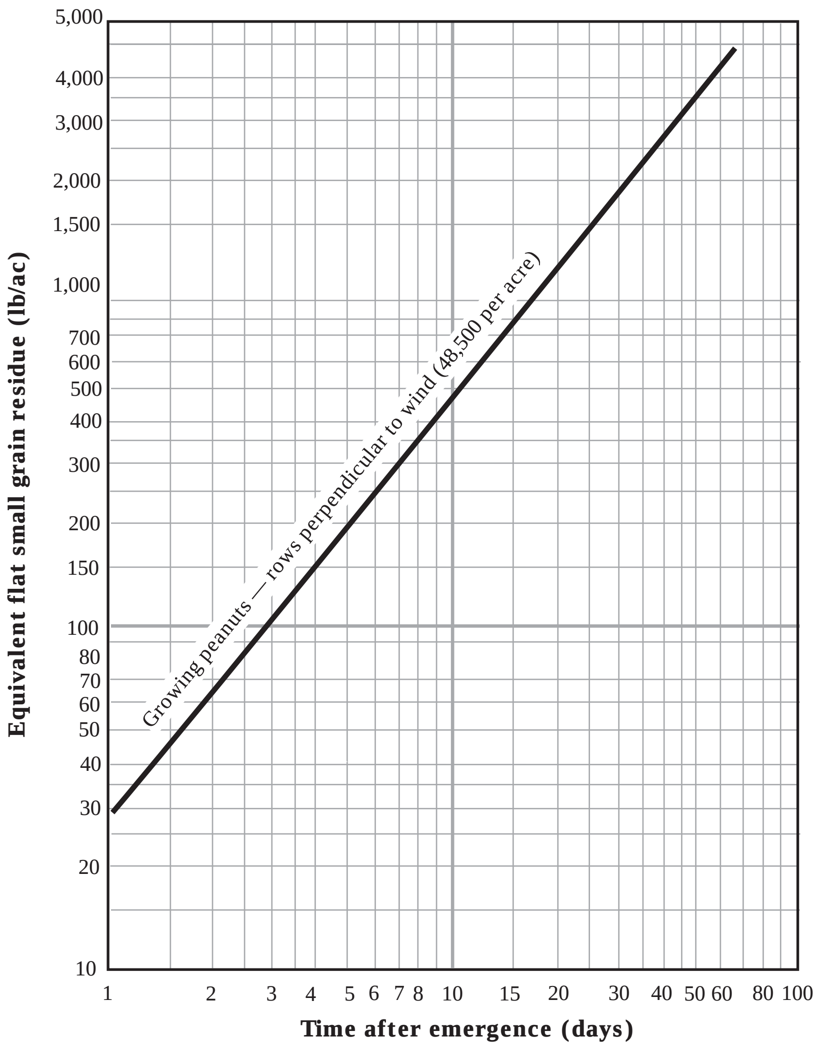


Reference condition: Dry small grain stalks 10 inches long lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Armburst and Lyles, 1984 — unpublished.

Exhibit 502-10 Flat small grain equivalent charts—Continued

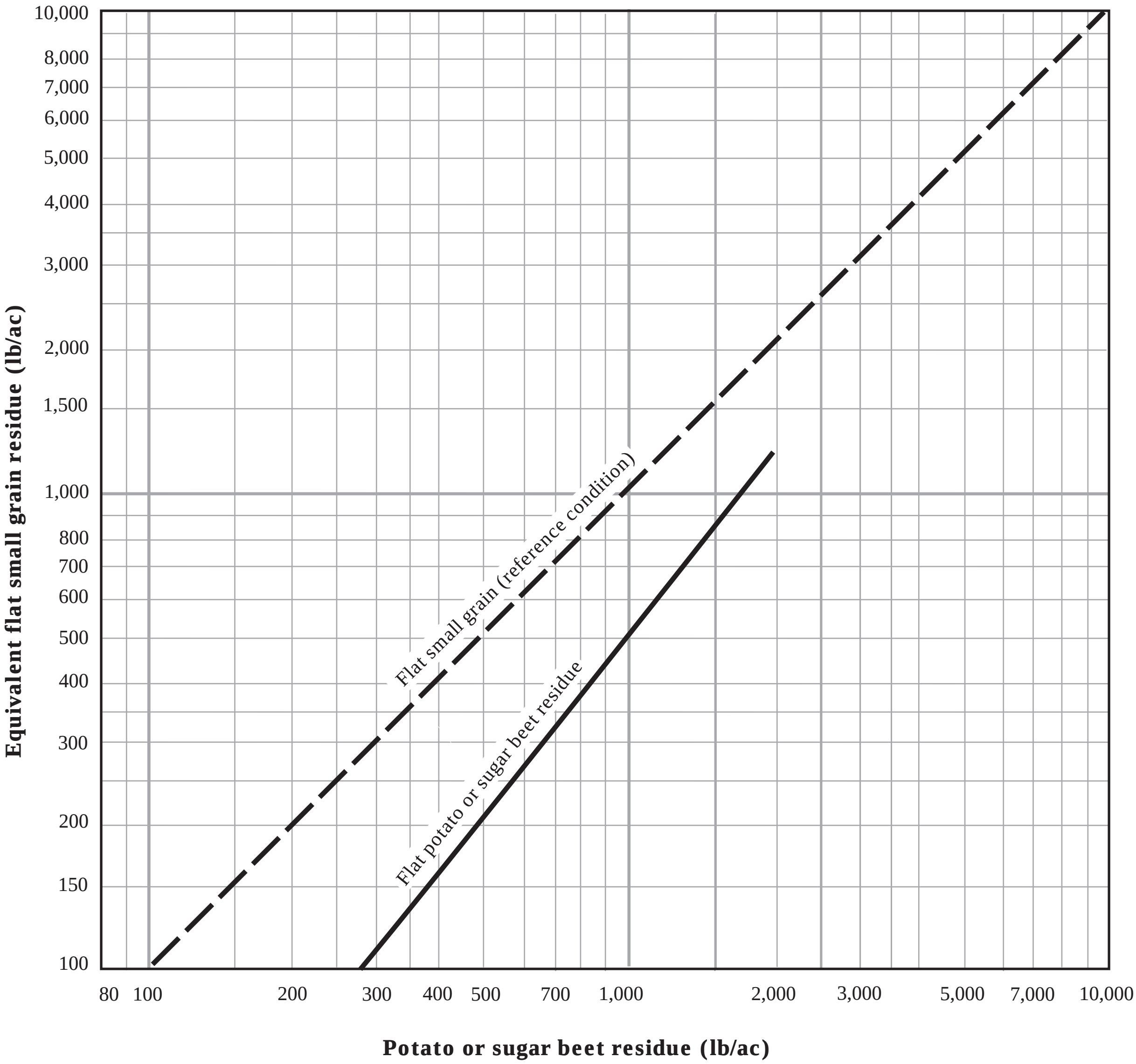
Figure b-14 Flat small grain equivalents of growing peanuts; days after emergence



Source: Armburst and Lyles, 1984 — unpublished.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-15 Flat small grain equivalents of potato or sugar beet residue

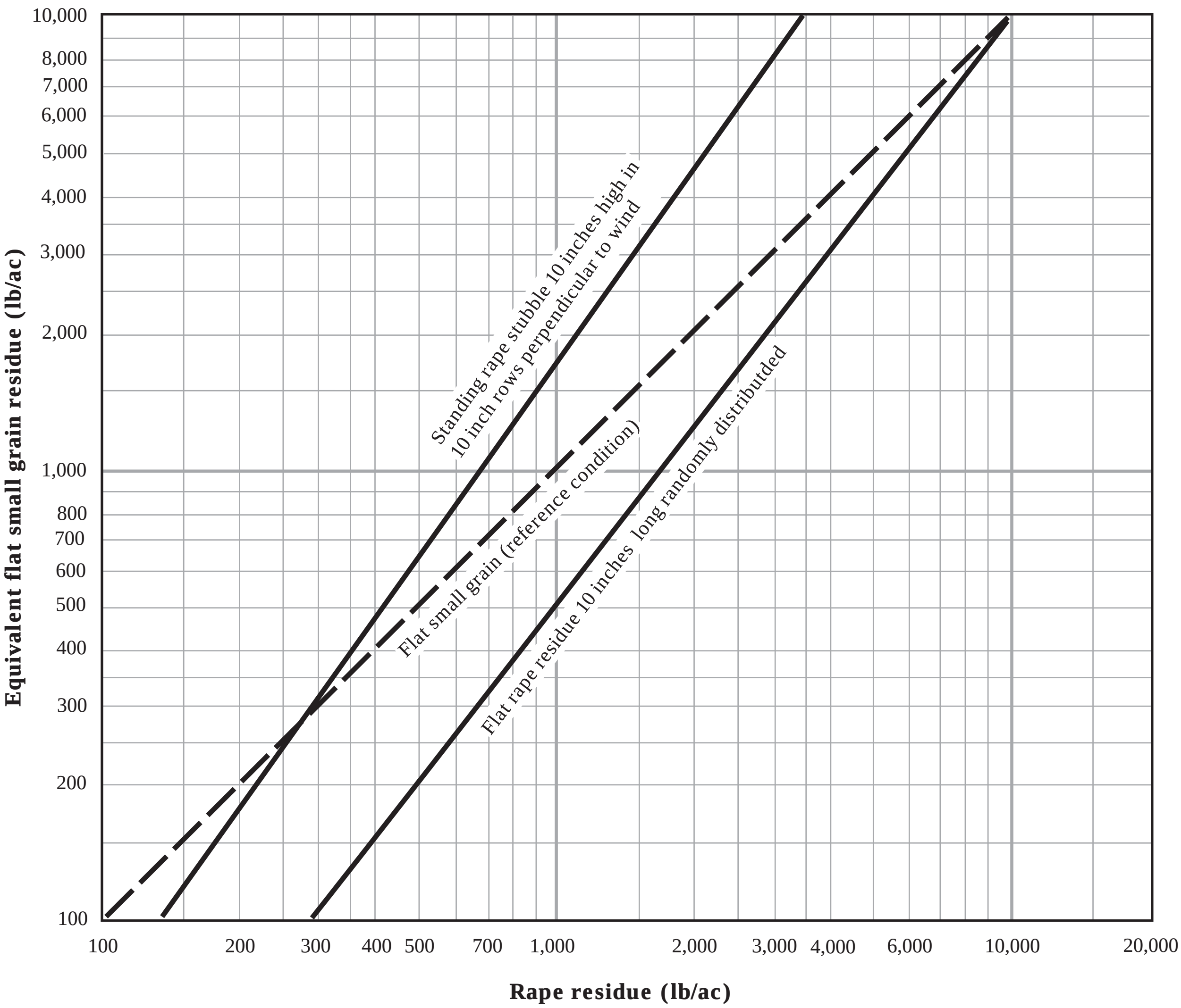


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Best judgment estimates by NRCS, North Central agronomists, November 1984.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-16 Flat small grain equivalents of rape residue

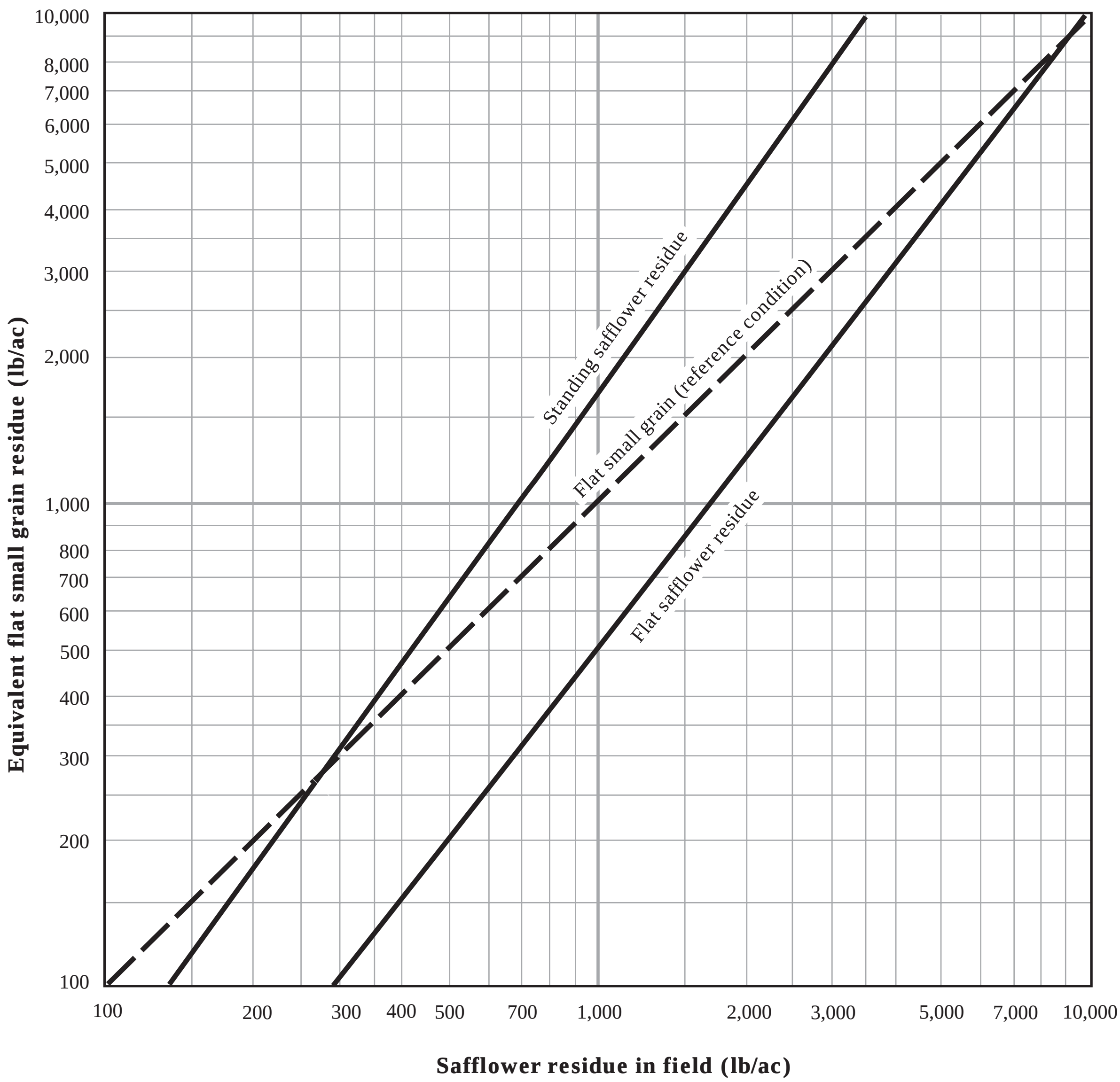


Source: Lyles and Allison — Trans. ASAE 1981, 24 (2): 405-408.

Residue weights are washed, air dried, and placed as described.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure b-17 Flat small grain equivalents of safflower residue

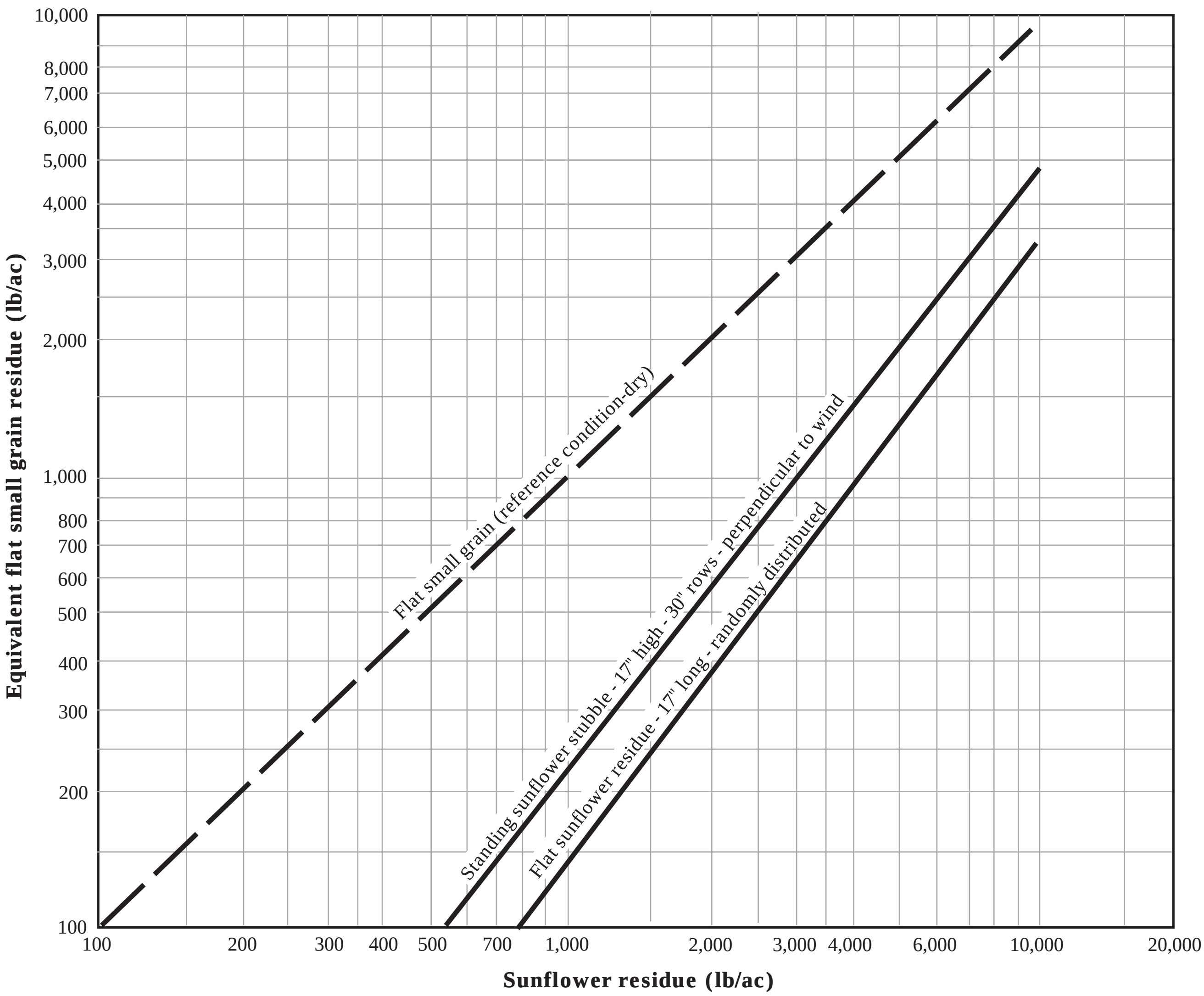


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Best judgment estimates by NRCS, North Central agronomists, November 1984.

Exhibit 502-10 Flat small grain equivalent charts—Continued

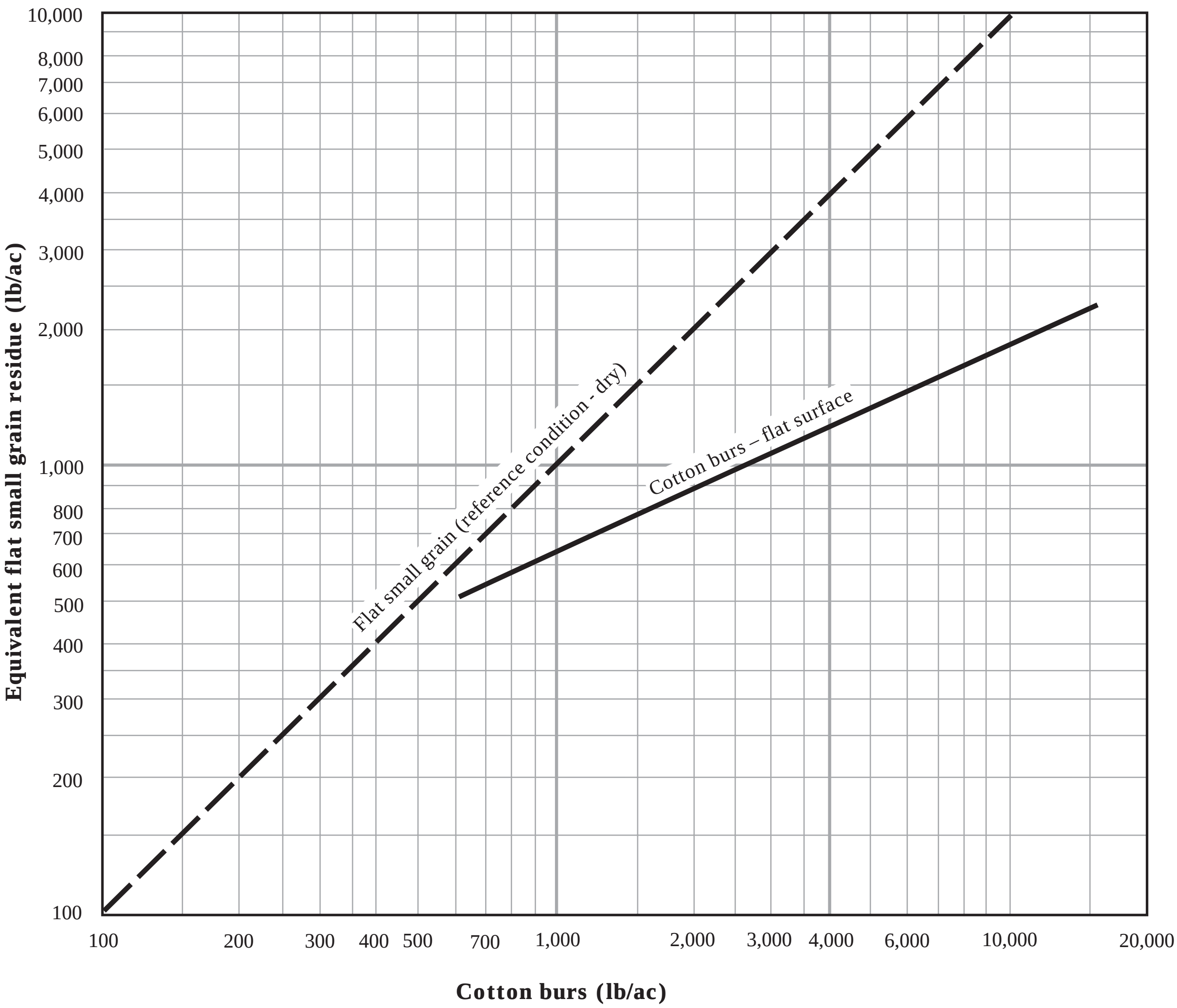
Figure b-18 Flat small grain equivalents of sunflower residue



Source: Lyles and Allison, Trans. ASAE 1981, 24(2): 405-408.
Residue wts. are washed, air dried, and placed as described for wind tunnel test.

Exhibit 502-10 Flat small grain equivalent charts—Continued

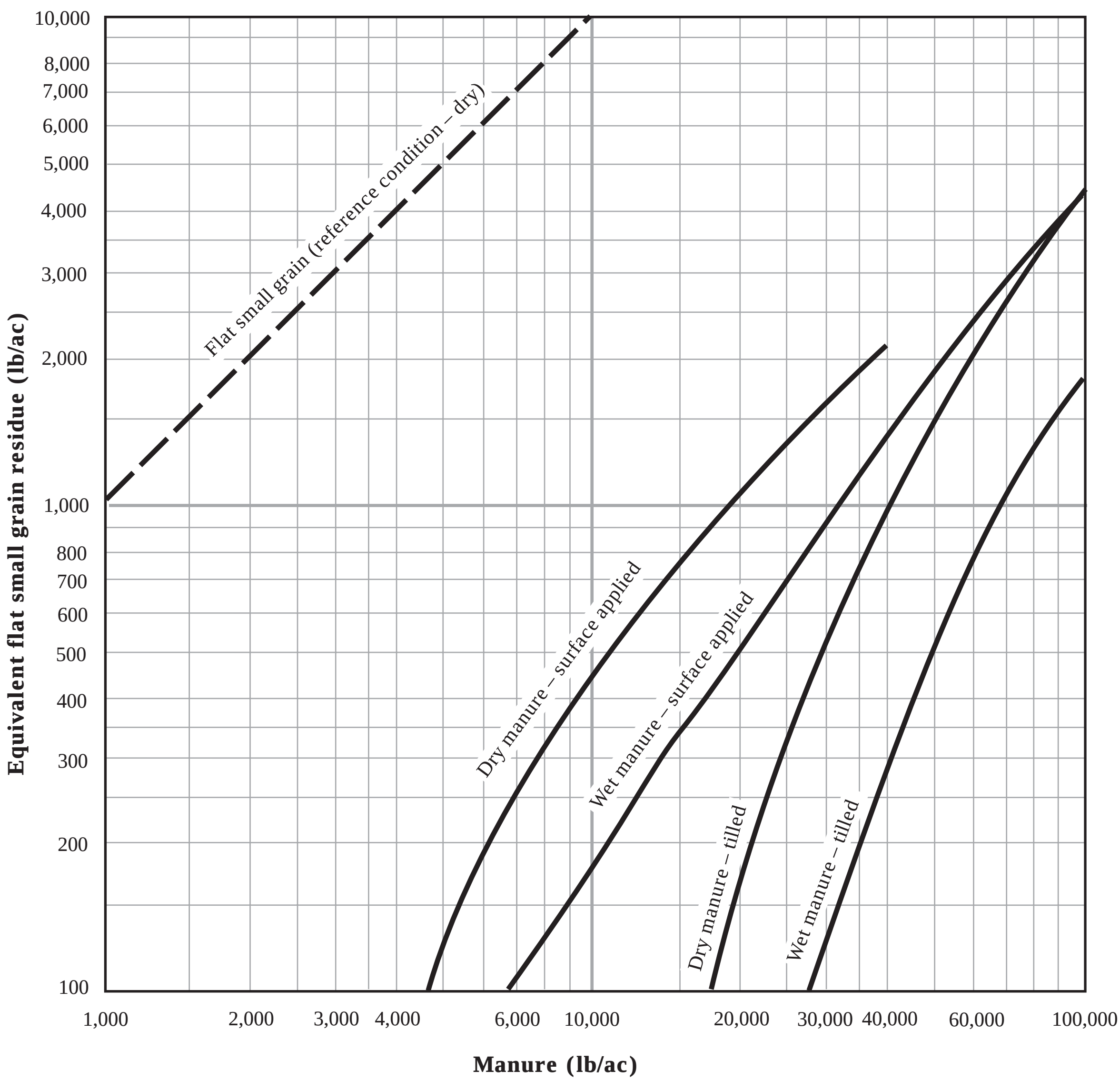
Figure c-1 Flat small grain equivalents of cotton burs



Source: Research by D.W. Fryear, ARS, Big Spring, Texas.

Exhibit 502-10 Flat small grain equivalent charts—Continued

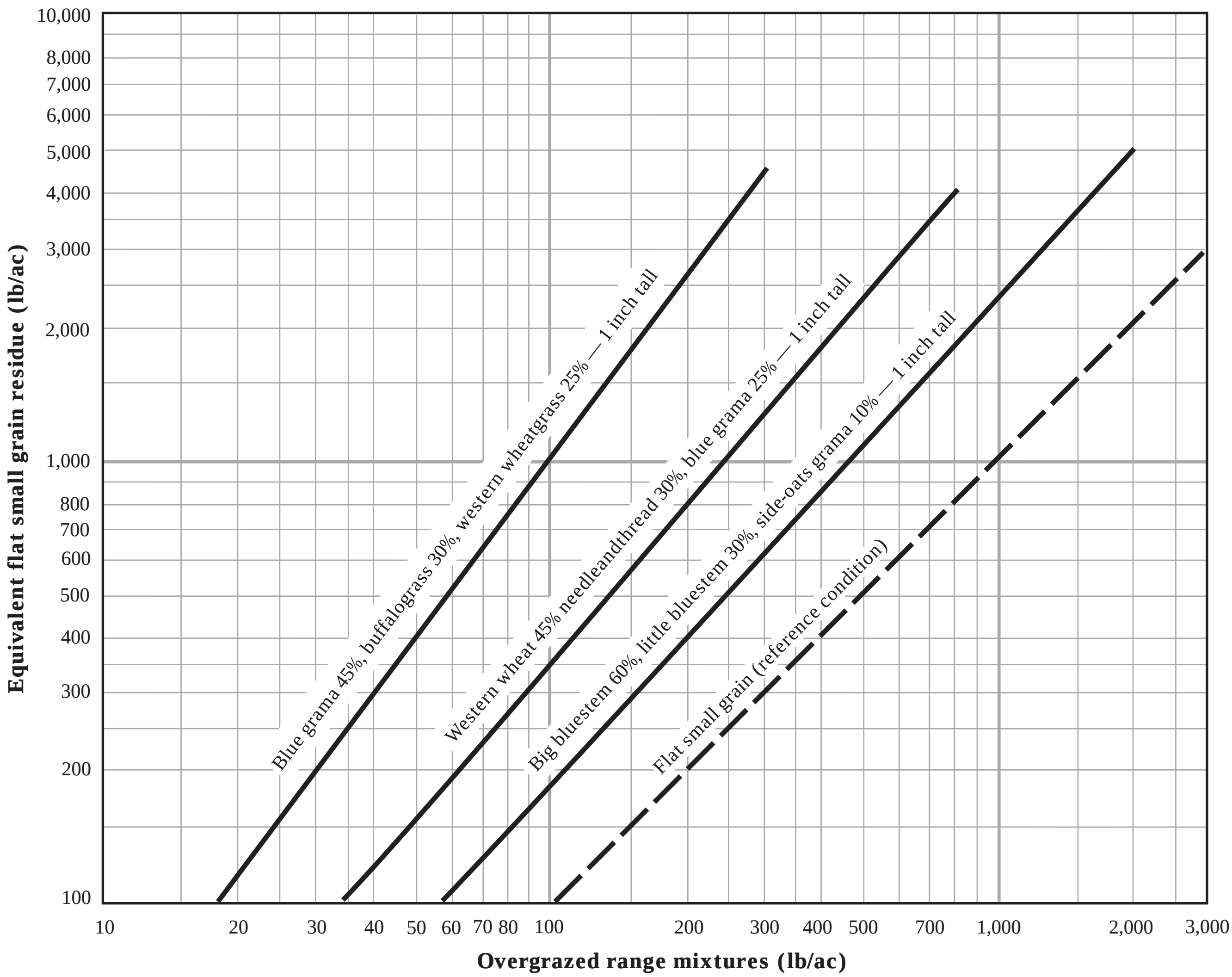
Figure c-2 Flat small grain equivalents of manure



Source: Woodruff, N.P., L. Lyles, J.D. Dickerson, and D.V. Armbrust. 1974 Journal Soil and Water Conservation 19(3), pages 127–129.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-1 Flat small grain equivalents of overgrazed range mixtures—big bluestem, little bluestem, sideoats grama, western wheatgrass, needleandthread, blue grama, and buffalograss

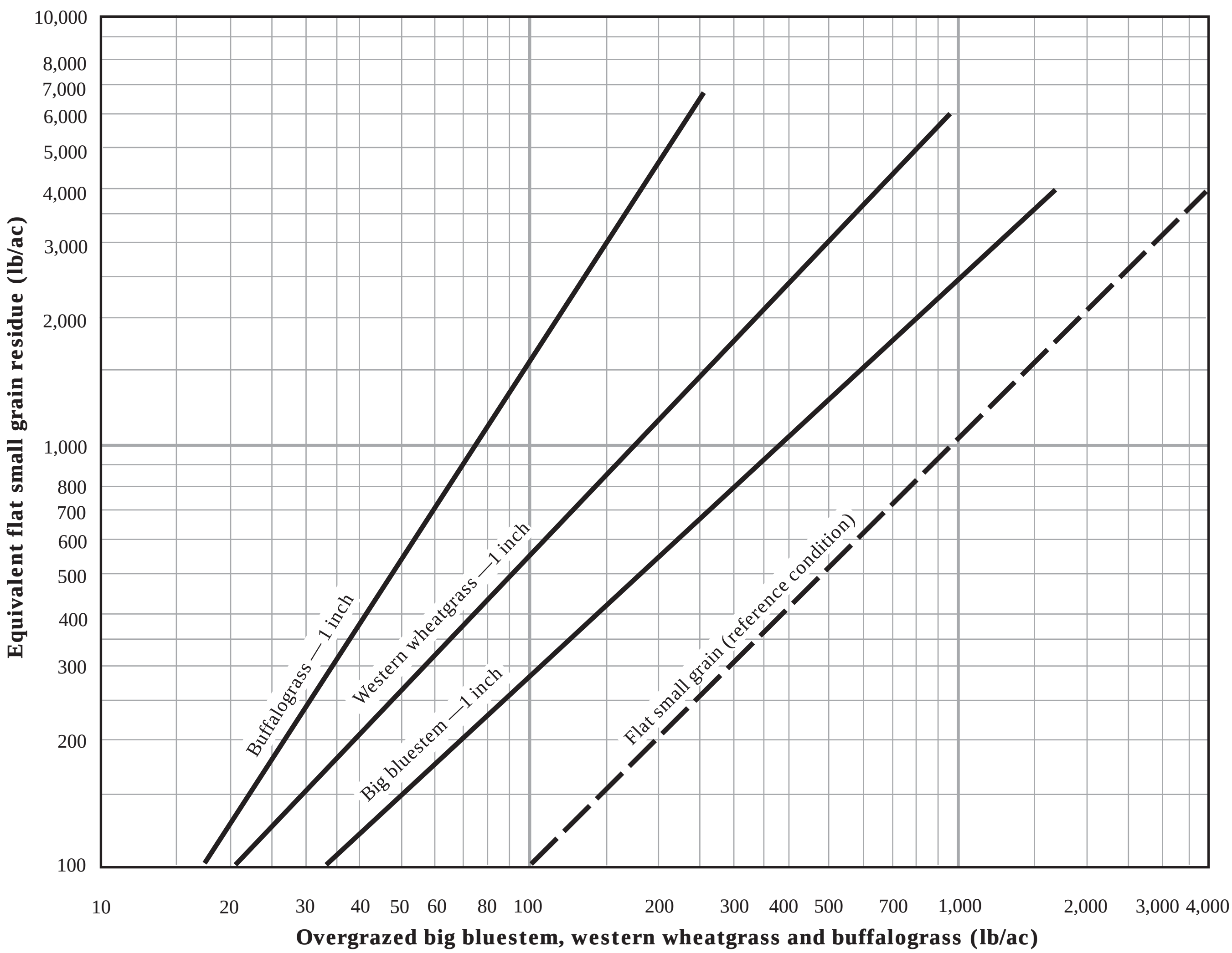


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison — 1980 Journal Range Management, 33(2), pages 143–146.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-2 Flat small grain equivalents of overgrazed big bluestem, western wheatgrass, and buffalograss

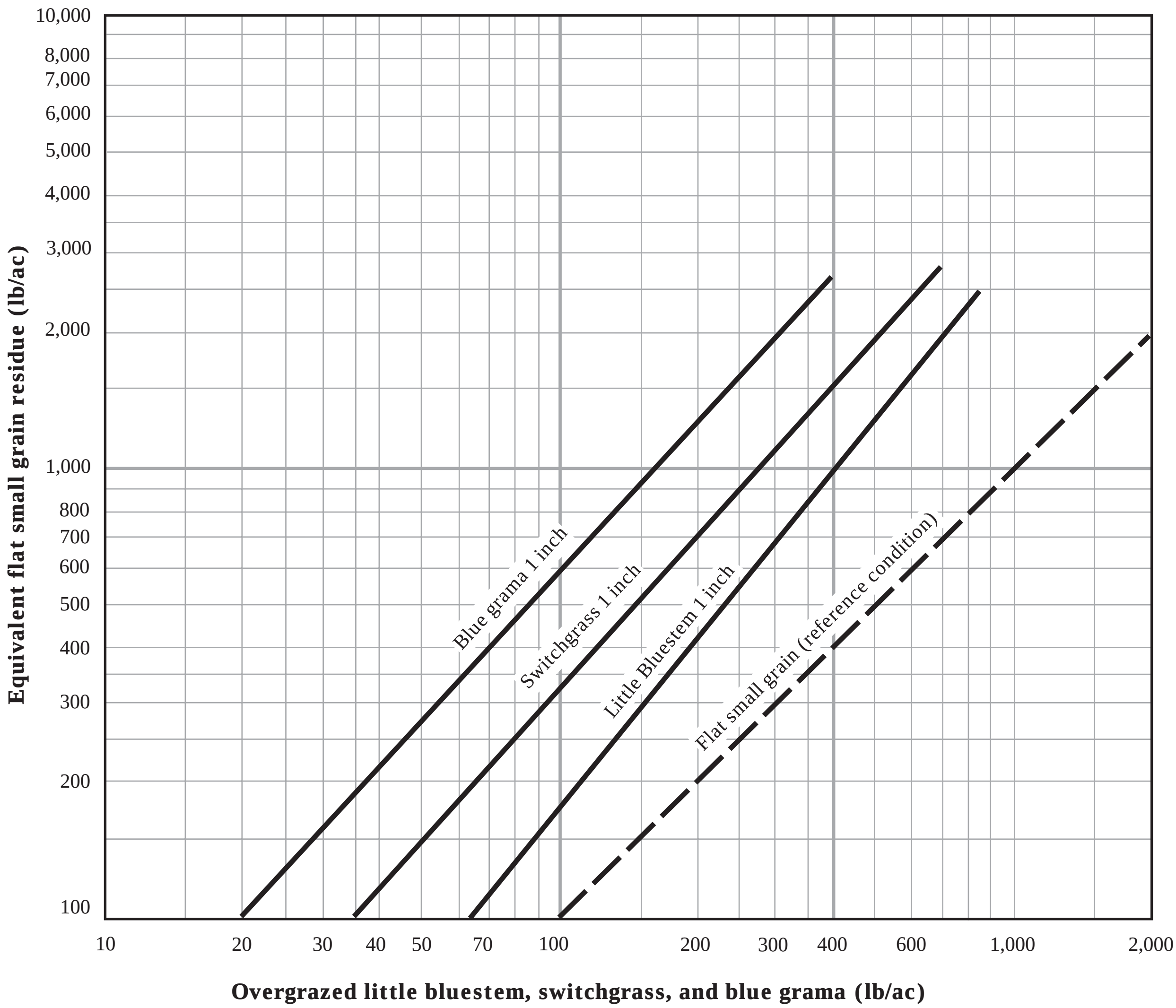


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soil surface in 10-inch rows, rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison — 1980 Journal Range Management, 33(2), pages 143–146.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-3 Flat small grain equivalents of overgrazed little bluestem, switchgrass, and blue grama

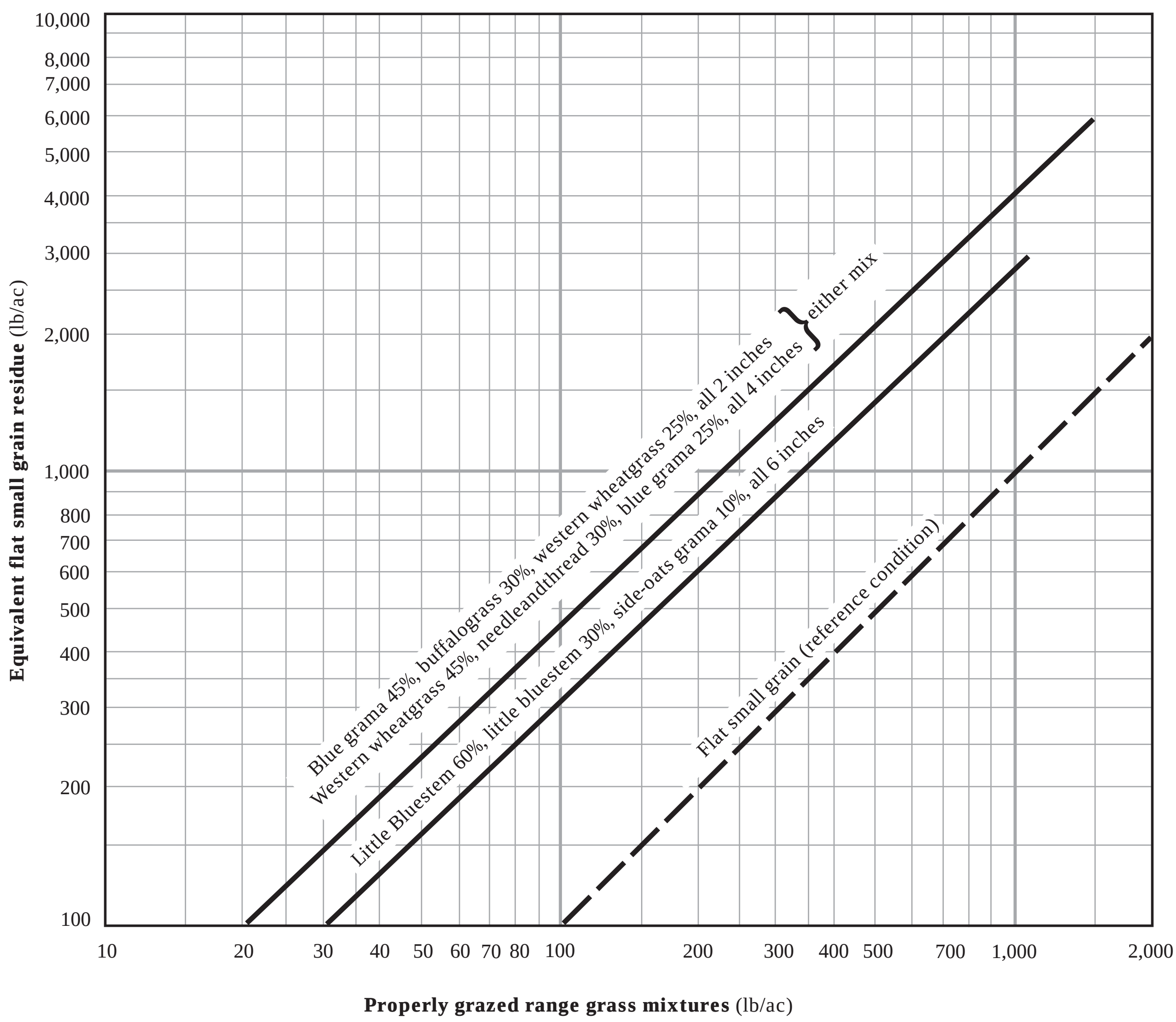


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soils surface in 10 inch rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison – 1980 Journal Range Management, 33(2), pages 143–146.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-4 Flat small grain equivalents of properly grazed range grass mixture

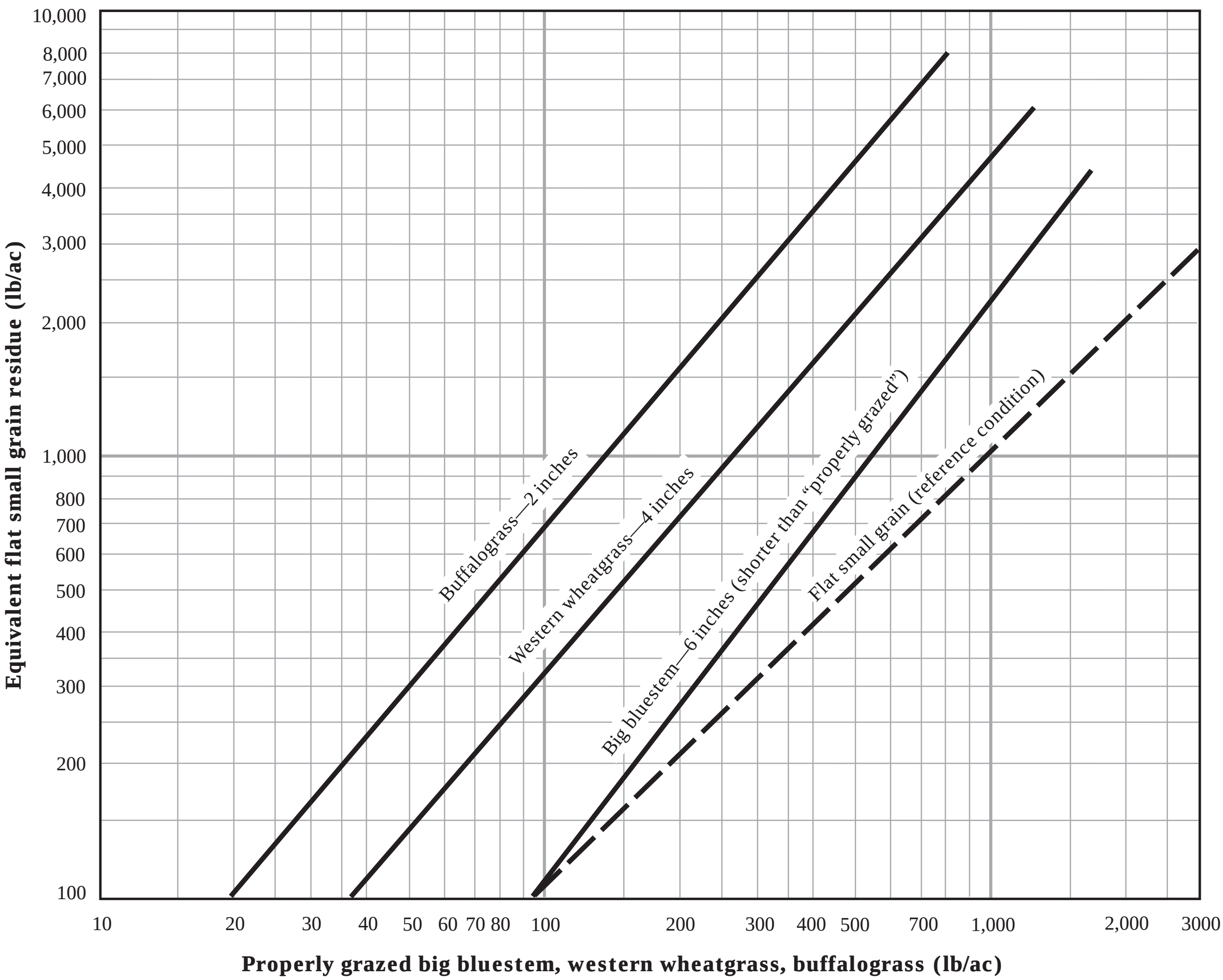


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soils surface in 10-inch rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison – 1980 Journal Range Management, 33(2), pages 143–146.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-5 Flat small grain equivalents of properly grazed big bluestem, western wheatgrass, and buffalograss

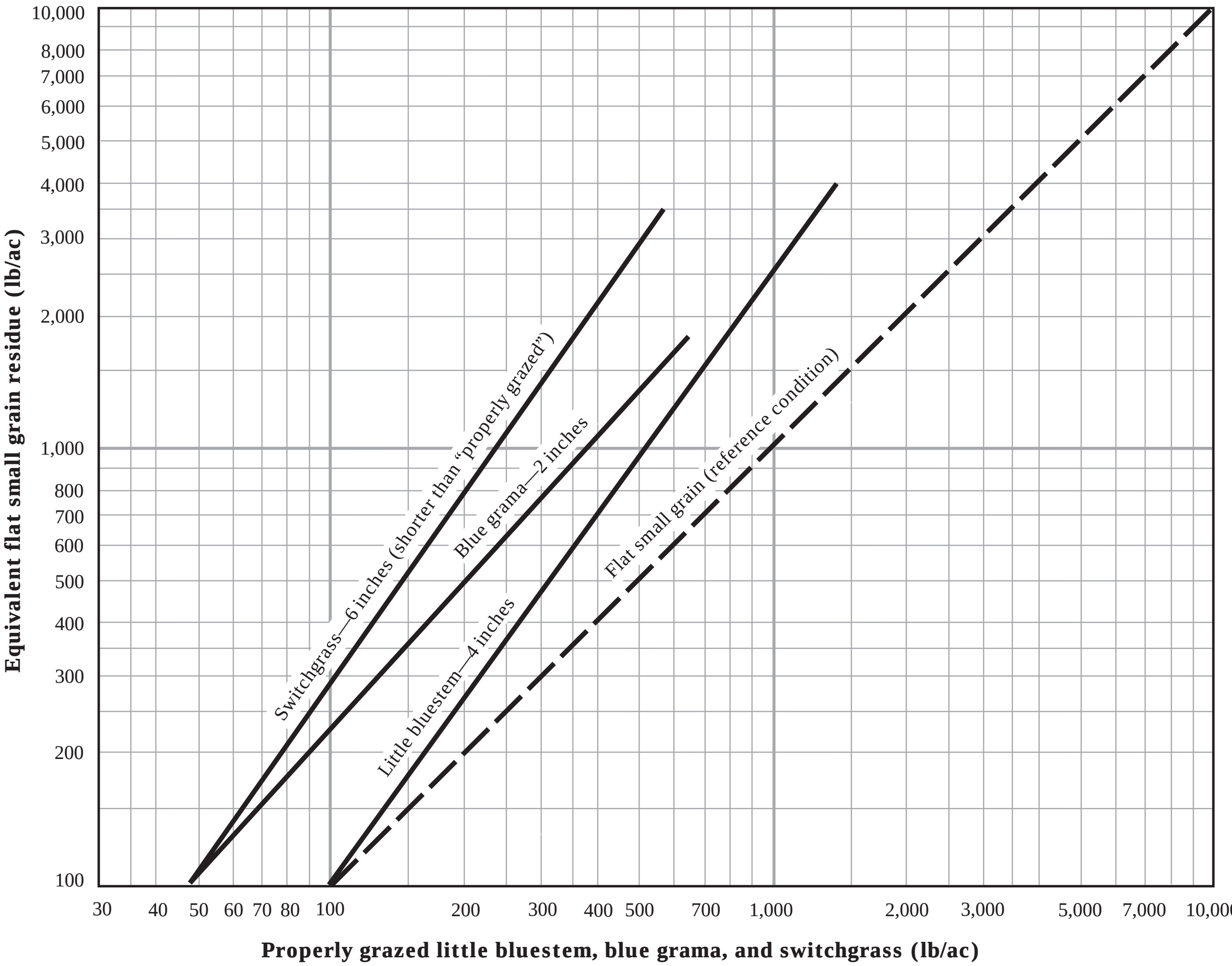


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soils surface in 10 inch rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison, 1980, Journal Range Management, 33(2), pages 143–146.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-6 Flat small grain equivalents of properly grazed little bluestem, blue grama, and switchgrass

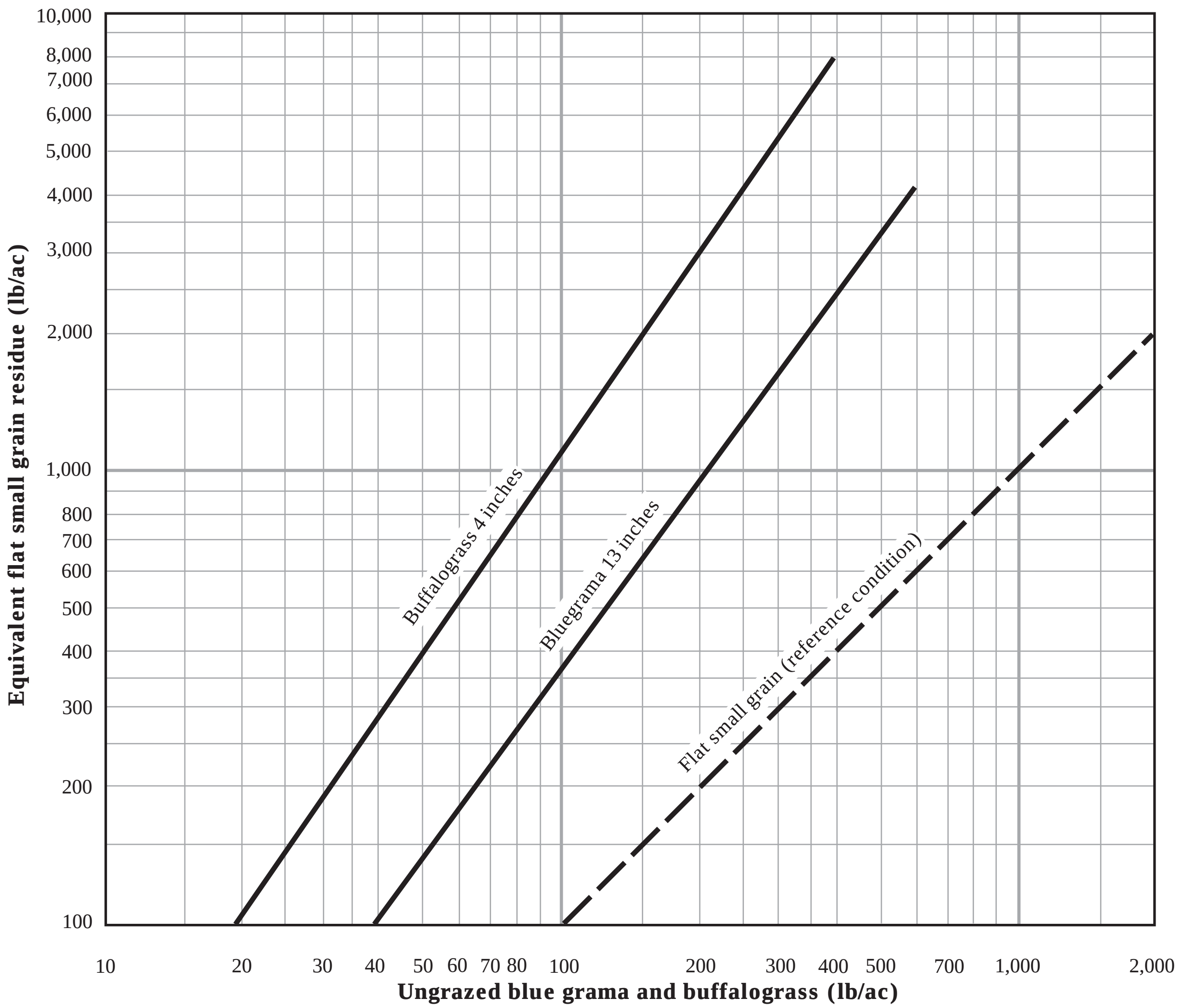


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soils surface in 10 inch rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison, 1980, Journal Range Management, 33(2), pages 143–146.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-7 Flat small grain equivalents of ungrazed blue grama and buffalograss

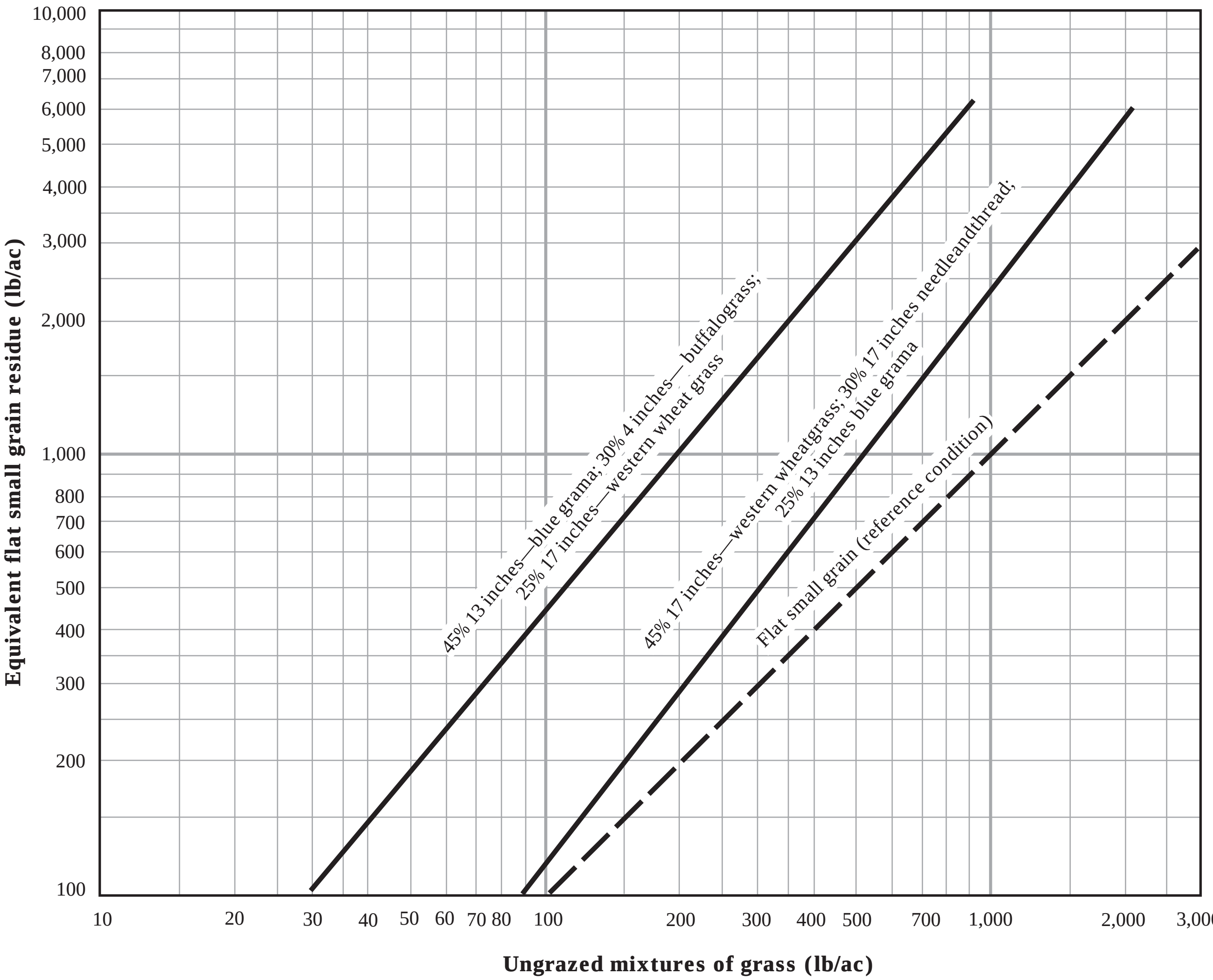


Reference condition: Dry small grain stalks 10 inches long, lying flat on the soils surface in 10 inch rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison, 1980, Journal Range Management, 33(2), pages 143–146.

Exhibit 502-10 Flat small grain equivalent charts—Continued

Figure d-8 Flat small grain equivalents of ungrazed western wheatgrass, needleandthread, blue grama, and buffalograss mixtures



Reference condition: Dry small grain stalks 10 inches long, lying flat on the soils surface in 10 inch rows perpendicular to wind direction, stalks oriented to wind direction.

Source: Lyles and Allison, 1980, Journal Range Management, 33(2), pages 143–146.

Exhibit 502-11 Estimating small grain equivalents for untested vegetation

Background

Small grain equivalents (SGe) expresses the effectiveness of residue or growing crops in resisting wind erosion, as compared with a reference condition. Agricultural Research Service has established benchmark SGe values for several common crops by wind tunnel testing. The research indicates that effectiveness of vegetative material is the result of vegetative roughness and is a function of residue weight, average stalk diameter, specific weight of stalk, orientation relative to the ground surface (standing or flat), and spatial distribution. Spatial distribution relates to plant population, row spacing, and row direction relative to wind flow.

Conservation planners frequently need to estimate the effectiveness of vegetation or residue for which small grain equivalence has not been determined. In the absence of wind tunnel tests or predictive equations, it may be desirable for NRCS to develop interim *best judgment* SGe curves based on judgment and field experience as a basis for consistent estimates. This can be done with confidence when the relationships are understood. The general principles are:

- Standing residue is more effective than an equal weight of flat residue.
- Fine residue is more effective, pound for pound, than coarse residue.
- Given equal diameter and equal pounds per acre, residue that has low specific weight (density) is more effective than residue with high density.
- Rows perpendicular to wind are more effective than rows parallel to wind.
- Dense stands are more effective than thin stands.

Several of the SGe curve charts in exhibit 502–10 were developed using the procedure described below. The footnotes with each figure identify which curves are *best judgments* by NRCS and which are from published sources resulting from wind tunnel research by ARS. Interim curves developed using similar procedures are to be submitted to the national agronomist or to an NRCS Cooperating Scientist located at an ARS Research Unit, for technical review and approval for trial use.

Procedure

1. Use only the SGe curves developed and published by ARS in exhibits 502–10, figures a–1 through d–8 as benchmark values.

2. Select one or more benchmark crops having physical characteristics similar to the crop in question. For purposes of comparison, give preference to SGe curves from published sources and minimize use of curves based on *best judgment* estimates.

3. Array the selected crop and the benchmark crops in order of apparent effectiveness on a pound-for-pound basis. Use comparative physical characteristics such as stalk diameter and density for guidance. If possible, *bracket* the crop in question between two benchmark crops.

4. By interpolation from benchmark curves, estimate and plot a curve for the crop in question. Estimate at least two SGe values, representing low and high levels of residue, to establish the slope of the curve.

Example (This procedure was used to develop the SGe curve for standing flax, figure b-9.):

Crop

Flax, standing stubble

Benchmark crops with similar characteristics—winter wheat; other similar crops that have curves available for comparison—millet.

Comparative characteristics and effectiveness: flax stubble (6-inch height) is assumed to be finer and denser than small grains and millet. Standing flax is assumed less effective than standing millet (4-inch height) because of stubble height that relates to thinner stands (pound for pound).

Estimated small grain equivalents SGe value (by interpolation):

Pounds residue	**SGe**, Winter wheat (figure a-1)	**SGe**, Flax (estimated)	**SGe**, Millet (figure a-7)
200	750	480	360
500	1,800	1,200	850
2,000	7,000	4,400	3,200

Additional note

Some predictive equations have been developed to estimate the SGe of vegetative material. To use these equations, diameter and specific weight must be known, as well as the amount and orientation of the material. Contact the state or national agronomist for assistance in using these procedures.

Exhibit 502-12 Estimating small grain equivalents of mixed vegetative cover that has two or more components

Background

When the wind tunnel is used to determine small grain equivalents of vegetative cover, the material tested is usually uniform in size, density, and orientation. Vegetative cover found in the field, however, frequently includes two or more components that are not alike. Common combinations are (l) part standing and part flat, (2) part course and part fine, or (3) part growing and part dead.

SGe values for mixed cover can be determined in the wind tunnel. However, there are too many possible combinations for development of practical field guides. When SGe conversion curves represent uniform components, the reference values can be combined to estimate SGe for any mixture of vegetative cover.

The following procedure is recommended for estimating SGe of mixed vegetative cover.

Procedure

1. Describe each major type of vegetative cover and estimate the percentage of total air-dry weight made up of each component.

2. Using the appropriate conversion curve, and total air-dry weight of all the vegetative cover, determine the SGe value of each component cover type.

3. Multiply the SGe value of each component by that component's percentage of total air-dry weight.

4. Add the products. The sum of the products is the weighted SGe for the mixed cover.

Example crop:
Winter wheat, 2,500 lb residue (air-dry weight) after harvest. 1,500 lb (60 percent) is standing stubble and 1,000 lb (40 percent) is flat randomly distributed straw.

Calculation:

Standing winter wheat:

2,500 lb = 8,500 lb SGe x 0.60 = 5,100 lb

Flat winter wheat:

2,500 lb = 3,300 lb SGe x 0.40 = 1,320 lb

Weighted average:

SGe = 6,420 lb

Exhibit 502–13 Crop yield — residue conversions

(This section reserved, to be developed)

Exhibit 502–14 Residue reduction by tillage

(This section reserved, to be developed)

Exhibit 502–15 E Tables: Soil loss from wind erosion in tons per acre per year

(Insert appropriate E tables for local values of the climatic factor, C)

Exhibit 502–16 Wind physics

(This section reserved, to be developed)

Exhibit 502–17 Wind erosion control exhibits

(This section reserved, to be developed)

Subpart 502H References

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Part 503 Crop Production

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Subpart 503A Crop rotation

503.00 Definition

A crop rotation is a sequence of different crops grown in a recurrent sequence over a given number of years. In some rotations a crop may occupy the land two years in succession. Crop rotations can vary in one or more of the following ways (Beck 1990):

- Plant family – grass vs. broadleaf
- Life cycle – annual vs. biennial vs. perennial
- Season of growth – winter annual vs. spring/ summer annual
- Rooting depth – shallow vs. moderate vs. deep
- Residue production – light vs. heavy
- Residue type – fragile vs. non-fragile
- Water use efficiency – high vs. low

To realize the greatest benefits, a crop rotation should not have the same annual crop grown 2 years in succession and should alternate plant families. This minimizes the potential for build-up and carryover of insect and disease populations, and maintains some degree of diversity in the cropping system.

503.01 Benefits of crop rotations

Properly designed crop rotations provide many benefits, and give producers more management options for their cropping systems. Conservation planners, when working with producers to develop a conservation management system, should emphasize the importance of maintaining the planned sequence of crops in the rotation. The benefits that accrue from the rotation, such as erosion reduction and pest management, depend on the crops being grown in the designated order. Crop rotations can help address the following resource concerns:

Pest management — Rotations can reduce the incidence and severity of weeds, insects, and diseases in a cropping system. When a different crop is grown each year, a different host crop is present that is usually not compatible with pest problems that may have carried over from the previous year. Because of this, the levels of any given pest are kept at levels that make them easier to manage. A crop rotation allows the use of different management strategies for pest problems. Herbicides and insecticides with differing modes of action can be used, reducing the possibility that some species will become resistant to chemical control. Different crops each year may allow tillage to be used to control pests, further reducing the need for chemical controls (Sprague and Triplett 1986).

Erosion control — Cropping systems that consist of continuous row crops and excessive tillage have a higher potential for wind or water erosion than rotations that include closely-spaced row crops or perennial crops. Different crops have different growth and development periods so that one crop may provide protection from erosive forces during a period of the year that another may not. Closely-spaced row crops, such as small grains or narrow-row soybeans, or perennial crops provide more canopy and surface cover than wide-row crops and reduce the potential for erosion.

Surface residue — Such residue is one of the most effective erosion control measures available. High residue-producing crops following low residue-producing crops help maintain higher levels of crop residue on the soil surface. Good residue management, such as using mulch tillage or no-till, can help maximize the amount of crop residue on the surface during critical erosion periods.

Soil quality — Cropping systems with hay or pasture crops in rotation produce greater soil aggregate stability than systems that have continuous grain crops. In systems that have all grain crops, greater aggregate stability occurs with crops that produce higher amounts of residue (Unger 1994). In Kansas, rotations that alternate sorghum with soybeans result in greater organic C levels in the soil than with continuous soybeans (Unger 1994).

Nutrient management — Crop rotations that have forage legumes or legume cover crops preceding grain crops can reduce the need for nitrogen (N) fertilizer for the grain crop. Average corn yields of 160 bushels per acre have been obtained with corn following alfalfa (Triplett et al. 1979). Leguminous cover crops can replace an estimated 60 to 70 pounds of N per acre (Hargrove 1986). Small grain crops following legumes can scavenge the nitrogen fixed by the legume, reducing the potential for N losses by leaching.

Water management – Dryland cropping systems can take advantage of stored soil moisture by alternating shallow and deep-rooted crops. For example, many areas in the Great Plains alternate winter wheat, a shallow-rooted crop, with safflower, a deep-rooted crop.

Livestock feed production – For livestock operations, crop rotations that include hay and pasture can provide a major portion, and in some cases, all of the livestock forage and feed. Additional information on planning crop rotations for livestock operations is in the National Range and Pasture Handbook, chapter 5, section 2.

Subpart 503B Tillage systems

503.10 Introduction

The tillage system is an integral part of the cropping management system for a farm. The type, number, and timing of tillage operations have a profound effect on soil, water and air quality. Tillage systems vary widely depending on the crops, climate, and soils. Depending on the type of implements used, implement adjustment, and number of trips made the affect on crop residue may very greatly. NRCS planners should be familiar with the tillage systems in their area, and how the application of these systems affects the resources.

503.11 Conservation tillage

Conservation tillage as defined by the Conservation Technology Information Center is any tillage and planting system in which at least 30 percent of the soil surface is covered by plant residue after planting. This practice reduces soil erosion by water or, where soil erosion by wind is the primary concern, at least 1,000 pounds per acre of flat small-grain residue equivalent are left on the soil surface during the critical wind erosion period.

(a) Residue management practices

Residue management practices that typically meet the conservation tillage definition include:

No-till and strip-till — Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year-round, while growing crops in narrow slots, or tilled or residue-free strips in soil previously untilled by full-width inversion implements. The soil is left undisturbed from harvest to planting except for nutrient injection. Planting or drilling is done in a narrow seedbed or slot made by coulter(s), row cleaners, disk openers, in-row chisels, or rototillers, with no more than one third of the row width disturbed. Weed control is done primarily with herbicides; row cultivation for emergency weed control should utilize undercutting operations that minimize residue burial.

Ridge-till — Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year-round, while growing crops on pre-formed ridges alternated with furrows protected by crop residue. The soil is left undisturbed from harvest to planting except for nutrient injection. Planting is done in a seedbed prepared on ridges with sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weed control is done with herbicides or cultivation or both. Ridges are rebuilt during row cultivation.

Mulch-till — Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round, while growing crops where the entire field surface is tilled prior to planting. Tillage tools such as chisels, field cultivators, disks, sweeps, or blades are used. Weed control is done with herbicides or cultivation, or both.

(b) Crop residue management

Despite considerable acceptance of these definitions there is still some confusion as to the meaning of conservation tillage. Crop residue management is defined as:

> Any tillage and planting system that uses no-till, ridge-till, mulch-till, or other systems designed to retain all or a portion of the previous crop's residue on the soil surface. The amount required depends on other conservation practices applied to the field and the farmer's objectives.

Tillage systems, whether a conservation tillage system or some other system that retains little if any residue, is an important part of a crop production system. Crop response to various tillage systems is variable and the variability if often difficult to explain because so many aspects of crop production are influenced by tillage. In addition, weather variability is an additional factor which influences crop production from one year to the next. Items to consider in designing a conservation tillage system include the following:

Soil temperature — Crop residue insulates the soil surface from the sun's energy. This may be a plus at planting time or may delay planting and/or lead to poorer germination. If this is a concern, the use of planter attachments to remove residue from the row area will improve the situation. Later in the growing season crop residue on the soil surface may lower the soil temperature, resulting in increased crop growth and yield.

Allelopathy — This refers to toxic effects on a crop because of decaying residue from the same crop or closely related crop. Crop rotation can eliminate this problem. The use of planter attachments to remove the residue from the row area may reduce the problem. Allelopathic effects can also be beneficial by reducing competition from some weeds.

Moisture — When crop residue is on the soil surface, evaporation is reduced and water infiltration is increased. Although this may be a disadvantage at planting time in some areas, the extra soil moisture may increase yields if a dry period is encountered later in the growing season. No-till systems often have more water than conventional systems available for transpiration later in the growing season, resulting in increased yields.

Organic matter and aggregation — Soil organic matter tends to stabilize at a certain level for a specific tillage and cropping system system. Each tillage pass stirs the soil, resulting in the oxidation of decaying residues and organic matter. If residue is left on the soil surface, such as no-till or ridge-till systems, the decomposition is much slower, resulting in increased organic matter levels in the upper few inches.

Soil density — All tillage systems have some effect on soil density. Systems that disturb the plow layer by inversion tillage or mixing and stirring temporarily decrease soil density. However, after the soil is loosened by tillage, the density gradually increases due to wetting and drying, wheel traffic, and secondary tillage operations. By harvest the soil density has returned to almost the same density as before tillage operations started. Cropping management systems that use several tillage operations can create a compacted layer at the bottom of the plow layer. If the compaction is excessive, then drainage is impeded, plant root growth is restricted, there is reduced soil aeration, herbicide injury may increase, and nutrient uptake may be restricted.

No-till systems have a higher soil density at planting time than other systems because the plow layer is not disturbed to form a seedbed. This higher density seldom has any effect on germination, emergence and subsequent crop growth. Many times the crop will benefit from this because these soils retain more available moisture.

Stand establishment — Regardless of tillage system uniform planting depth, good seed to soil contact, and proper seed coverage is needed to obtain a good stand. Coulter and/or row cleaners may be needed to ensure a good stand in a no-till system. In addition, extra weight and heavy-duty down-pressure springs may be needed for the planter or drill to penetrate undisturbed soil, especially under less than ideal moisture conditions.

Fertilizer placement **—** Starter fertilizer (nitrogen and phosphorus) is generally recommended to help overcome the affects of lower soil temperatures at planting time. If fertility levels (P, K, and pH) are at maintenance levels before switching to a conservation tillage system, fertility should not be a problem. In a no-till system surface application of phosphorus and lime will result in stratification of these nutrients, but this has not shown to affect crop yield. It is generally recommended that nitrogen be knifed into the soil in a no-till system, or a nitrogen stabilizer be used. Surface-applied nitrogen may volatilize and be lost if a rain does not move the nitrogen into the soil profile shortly after application.

Weed control **—** Controlling weeds is essential for profitable production systems. With less tillage, herbicides and crop rotations become more important in obtaining adequate weed control. Weed identification, herbicide selection, application rate, and timing are important. A burn-down may be needed in no-till and ridge-till systems. A change in weed species can be expected in no-till and ridge-till systems. Perennials may become more evident but usually can be controlled with good management. The combination of post-applied herbicides and bioengineered crops has made weed control much easier, even in a no-till system.

Insect management **—** Regardless of tillage system, effective insect-management guidelines and tactics are available. Different tillage systems may affect *potential* insect pressure, but management addresses this.

Disease control **—** Residue on the soil surface offers the potential for increased disease problems. However, there are numerous strategies to overcome this problem. Crop rotation or the selection of disease-resistant hybrids may nullify this *potential* problem.

Crop yields — Weather has more affect on crop yields than does the tillage system used. Crop yields generally are better when a crop rotation is utilized, especially in no-till system.

Production costs — All of the related costs associated with various tillage systems must be analyzed to evaluate the profitability.

Machinery and labor costs — Total cost for machinery and labor per acre usually decrease as the amount of tillage is reduced. If the size of the power units can be decreased (no-till system) then the savings can be even more dramatic. No-till equipment (planters, drills, nutrient injection equipment) may be more expensive than that needed for conventional equipment. No-till producers have been able to farm more acres than conventional tillage producers without additional labor because of the increased efficiency.

Subpart 503C Nutrient management

(Under development)

Subpart 503D Pest management

(Under development)

Subpart 503E Crop residue

503.40 Benefits of managing crop residue

Crop residue management is paramount to improving soil health. Without residue left on or only partially incorporated in the soil surface, there will be continued degradation of soil organic matter levels and soil health will not be maximized. Lower soil organic matter leads to lower cation exchange capacity, lower pH, lower water holding capacity, greater susceptibility to soil erosion, and poorer soil structure. Poor soil structure results in less pore space, decreased infiltration, and increased surface runoff.

Soil organic matter is an extremely important component of a productive soil. Because organic matter has many exchange sites it is capable of buffering many soil reactions. For example, by holding hydrogen ions, their content is reduced in soil solution that results in less soil acidity. At a pH near neutral (pH 7.0), plant nutrients are most available. In addition, organic matter increases soil aggregate stability and thereby reduces detachment by falling raindrops and surface runoff. Declining levels of soil organic matter over time is a strong indicator of declining soil health.

Research in Morris, Minnesota, (Riecosky 1995) reported that as much carbon (C) was lost to the atmosphere as CO_2 in just 19 days after moldboard plowing wheat residue as was produced by the crop. Carbon is the key component of soil organic matter and serves as an energy source for microbial activity.

Tillage stirs the soil similar to *poking a fire* that results in more rapid loss of carbon. Therefore, the primary reason organic matter levels of continuous cultivated soils have declined to less than half of their original level is directly related to tillage and the resulting loss of carbon to the atmosphere. Therefore, to increase organic matter levels of the soil, crops that produce large amounts of residue should be grown, and a significant reduction in tillage must first occur coupled with keeping a significant portion of the previous crop's residue on the soil surface.

503.41 Crop residue production

(Under development)

503.42 Crop residue retention

(Under development)

503.43 Estimating crop residue cover

The line transect method — The line transect method has been proven effective in estimating the percent of the ground surface covered by plant residue at any time.

Estimates of percent cover are useful for determining the impact of residue on sheet and rill erosion. They cannot be used directly for determining the impact of residue on wind erosion.

Estimates of percent cover obtained using the line transect method to evaluate the impact of residue on sheet and rill erosion are most accurate when the residue is lying flat on the soil surface and is evenly distributed across the field.

The following is the recommended procedure for using the line transect method:

1. Use a commercially available 50- or 100-foot long cable, tape measure, or any other line that has 100 equally spaced beads, knots, or other gradations (marks) at which to sight.

2. Select an area that is representative of the field as a whole and stretch the line out across the crop rows. The line may be oriented perpendicular to the rows, or in a direction that is at least 45 degrees off the row direction (fig. 503–1).

   The locations in the field where the line is stretched out to make measurements should be selected randomly from among the areas of the field that are typical of the entire field. End rows, field borders, and parts of the field that appear different are probably not typical of the entire field and should be avoided.

3. Walk along the line, stopping at each mark. Position the eye directly over the mark, and look down at it. When sighting, do not look at the entire mark. Rather look at a single point on each mark.

   A point has an area about like the end of a needle. On commonly used equipment, the knots, beads, or gradations have much larger areas than the end of a needle. A measurement is not based on whether or not some portion of a mark is over the residue. It is based on whether or not a specific point associated with the mark is over residue.

   If using a commercially available beaded line, one way to accomplish the above is to select as the point of reference the place along the line where a bead begins.

4. Determine the percent residue cover by counting the number of points at each mark along the line under which residue is seen. Count only from one side of the line for the single, selected point count at each mark. Do not move the line while counting.

   Count only that residue that is large enough to intercept raindrops. A rule of thumb is to count only residue that is 3/32 inch in diameter or larger (fig. 503–2). When using a line with 100 points, the percent residue cover is equal to the number of points under which residue is seen.

Figure 503–1 Acceptable orientations for residue measurement lines

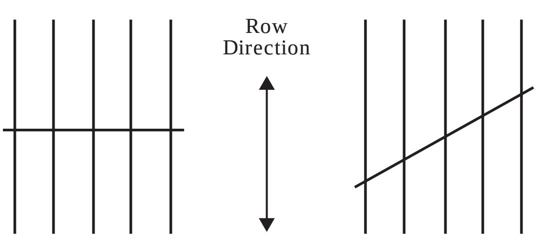
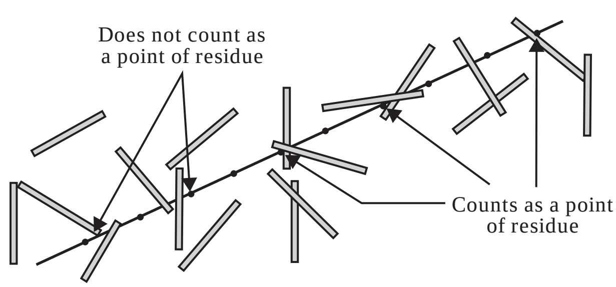


Figure 503–2 Counting residue pieces along a line transect



5. Three to five transects should be done in each field, using the procedure described in steps 1 through 4. Five transects are recommended.

   With five measurements, estimates of percent residue cover are accurate to within ±15 percent of the mean. Three measurements will give estimates accurate to within ± 32 percent of the mean.

   For example, if the mean of five measurements was 50 percent cover, you could be confident (at the 95% confidence level) that the true mean was between 42 percent and 57 percent cover. For a 30 percent cover average based on five measurements, you could be confident that the true value was between 25 percent and 34 percent cover.

6. The documentation of individual transects and computations made to determine average percent residue amounts should be done in a professional manner.

   Documentation should be done in a way that permits easy tracking from the field measurements to the final answer.

   The development and use of a documentation worksheet is recommended. Example worksheet formats are illustrated at the end of this section.

Subpart 503F References

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Exhibit 503–1 Example worksheet for recording crop residue measurement

Crop residue measurement worksheet (for use with the line transect method)		
State ______________	County ______________	
Land user ______________	Opid ______________	Tract ________

Field no. ________ Planned residue level _______ percent Residue type ______________

Transect number	Total number of points 1/	Number of points with residue 2/	Percent residue this transect
1			
2			
3			
4			
5			
Average percent residue for field			

Field no. ________ Planned residue level _______ percent Residue type ______________

Transect number	Total number of points 1/	Number of points with residue 2/	Percent residue this transect
1			
2			
3			
4			
5			
Average percent residue for field			

1/ To achieve the degree of accuracy quoted in the NAM-recommended procedure for using the line transect method, each transect must be based on looking at a total of at least 100 points.

2/ Attach a map or sketch showing the location of each line transect within the field. All measurements shall be made using the line transect procedure contained in the National Agronomy Manual.

Data collector	Title	Date

Exhibit 503–2 Example worksheet for recording crop residue measurement

Crop residue measurement worksheet
(for use with the line transect method)

State ______________________________	County _________________	
Land user __________________________	Opid ____________________	Tract _________

Field no. ________ Planned residue level _______ percent Residue type _______________

Field no.	crop	Residue kind	Planned amount	Planned tillage system

Residue field measurements 1/ 2/

Field no.	Transect number (record number of counts with residue) 1	2	3	4	5	Average residue for field

1/ To achieve the degree of accuracy quoted in the NAM-recommended procedure for using the line transect method, each transect must be based on looking at a total of at least 100 points.
2/ Attach a map or sketch showing the location of each line transect within the field. All measurements shall be made using the line transect procedure contained in the National Agronomy Manual.

d

______________________	______________________	______________
Data collector	Title	Date

Part 504 Water Management

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Subpart 504A Managing soil moisture on nonirrigated lands

504.00 Soil moisture management overview

Soil moisture management in dryland agriculture is an integral factor in producing a viable crop production system. Climatic factors, crop selection, rotational influences, tillage system as well as inherent soil characteristics all interrelate in assessing the availability of adequate water necessary for a selected crop rotation.

504.01 Soil characteristics

Physical soil characteristics have a major impact on the infiltration, movement, and storage of water within the soil profile. These characteristics include soil texture, bulk density, structure, pore space, organic matter content, salinity, and sodicity as well as other inherent soil characteristics.

(a) Water infiltration

Water infiltration is the process of water entering the soil from the soil surface. Infiltration rates are affected by tillage practices, amounts of surface residue, soil water content, surface sealing, soil organic matter, soil macropore development, salinity, and sodicity. Infiltration rates change during a rainfall event and typically become slower over time. They typically also decrease over the growing season because of cultivation and harvest equipment. This is especially true if operations are done at higher soil-water levels. Macropores, or preferential flow paths, such as cracks or wormholes, substantially influence infiltration, and the internal soil drainage. Infiltration rates are also affected by water quality; for example, suspended sediment, temperature, salinity, and sodicity all affect water surface tension.

(b) Soil texture

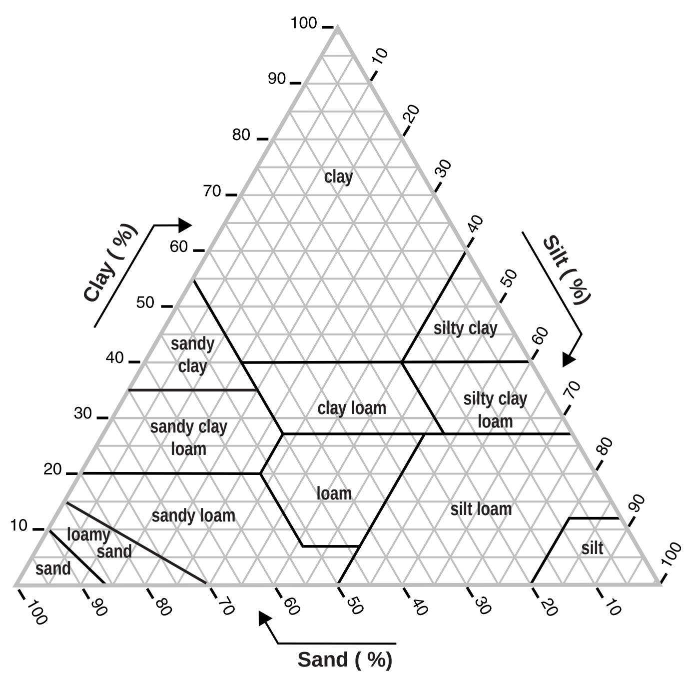
Soil texture refers to the weight proportion of the soil separates (sand, silt, and clay) for analysis. It defines the fineness or coarseness of a soil. Particle sizes larger than 2 mm are considered rock fragments, and those that are less than 2 mm are the fine earth fraction. The fine earth fraction is determined from a laboratory particle-size distribution. The fraction classed as rock or coarse fragments is determined by the proportion of the soil volume they occupy. Rock fragment classes are used to modify soil textures. Medium-textured soils with a high clay and silt content hold the most water, while fine-textured soils generally hold more water than coarse-textured soils. Water in clay soils can be held at a greater tension that reduces its availability to plants.

Figure 504-1 displays what is commonly referred to as the USDA textural triangle. It describes the proportions of sand, silt, and clay in the basic textural classes. Texture determines the amount of surface area on the soil particles within the soil mass. Clay and humus both exist in colloidal state and have an extremely large surface area per unit weight. They carry surface electrical charges to which ions and water are attracted.

(c) Soil structure

Soil structure is the arrangement and organization of soil particles into natural units of aggregation. Weakness planes that persist through cycles of wetting and drying and cycles of freezing and thawing separate

Figure 504-1 The USDA textural triangle describes the proportions of sand, silt, and clay in the basic textural classes



these units. Structure influences air and water movement, root development, and nutrient supply.

Structure type refers to the particular kind of grouping that predominates in a soil horizon. Single-grained and massive soils are structureless. In single-grained soil, such as loose sand, water percolates rapidly. Water moves slowly through most clay soil. A more favorable water relationship occurs in soil that has prismatic, blocky, and granular structure. Platy structure in fine and medium soils impedes the downward movement of water.

Structure can be improved with cultural practices, such as reducing tillage, improving internal drainage, liming or adding sulfur to soil, using grasses or deep rooted crops in rotation, incorporating crop residue, and adding organic material or soil amendments. Structure can be destroyed by heavy tillage equipment or excess operations.

Texture, root activity, clay mineralogy, percent organic matter, microbial activity, and the freeze-thaw cycle all play a part in aggregate formation and stability. Some aggregates are quite stable upon wetting, and others disperse readily. Soil aggregation helps maintain stability when wet, resist dispersion caused by the impact from rain, maintain soil intake rate, and resist surface water and wind erosion.

(d) Soil bulk density

Bulk density is the weight per unit volume of dry soil, which includes the volume of solids and pore space. Units are expressed as the weight at oven-dry and volume at field capacity water content, expressed as grams per cubic centimeter (g/cc) or pounds per cubic foot (lb/ft^3). Bulk density is used to convert water measurements from a weight basis to a volume basis. Other factors affecting soil bulk density include freeze/thaw process, plant root growth and decay, wormholes, and organic matter.

(e) Organic matter

Soil organic matter is the organic fraction of the soil. It includes plant and animal residue at various stages of decomposition, and cells and tissues of soil organisms. Organic matter directly influences soil structure, soil condition, soil bulk density, water infiltration, plant growth and root development, permeability, total water holding capacity, biological activity, oxygen availability, nutrient availability, and tilth, as well as many other factors that make the soil a healthy natural resource for plant growth. Organic matter has a high cation adsorption capacity, and its decomposition releases plant nutrients including nitrogen, phosphorous, and sulfur. Site specific organic matter values should always be used for planning and managing cropping systems. Published values often are from sites that were managed quite differently.

(f) Soil water holding capacity

The potential for a soil to hold water is an important factor in designing a crop production system. Total water held by a soil is called water-holding capacity. However, not all soil water is available for extraction by plant roots. The volume of water available to plants that a soil can store is referred to as available water capacity (AWC).

Available water capacity is the traditional term used to express the amount of water held in the soil available for use by most plants. It is dependent on crop rooting depth and several soil characteristics. Units of measure are expressed in various terms:

- Volume unit as inches of water per inch or per foot of soil depth
- Gravimetric percent by weight
- Percent on a volume basis

In fine textured soils and soils affected by salinity, sodicity, or other chemicals, a considerable volume of soil water may not be available for plant use.

Soil-water potential, more correctly, defines water available to plants. It is the amount of work required per unit quantity of water to transport water in soil. In the soil, water moves continuously in the direction of decreasing potential energy or from higher water content to lower water content. The concept of soil-water potential replaces arbitrary terms such as gravitational, capillary, and hygroscopic water. Total water potential consists of several components. It is the sum of matric, solute, gravitational, and pressure potential.

For practical reasons, the terms and concepts of field capacity and permanent wilting point are normally used. Units of bars and atmospheres are generally used to express suction, tension, stress, or potential of soil water.

Field capacity—This is the amount of water a well-drained soil holds after free water has drained because of gravity. For coarse textured soil, drainage occurs soon after a rain event because of relatively large pores and low soil particle surface tension. In fine textured soil, drainage takes much longer because of smaller pores and their horizontal shape. Major soil properties that affect field capacity are texture, organic matter content, structure, bulk density, and strata within the profile that restrict water movement. Generally, fine textured soil holds more water than coarse textured soil. Some soils, such as some volcanic and organic soils, are unique in that they can retain significant volumes of water at tensions less than one-tenth bar, thereby giving them a larger available water capacity.

An approximation of field capacity soil-water content level can be identified in the laboratory. It is the water retained in a soil when subjected to a tension of one-tenth atmosphere (bar) for sandy soils and one-third atmosphere for other finer textured soils.

Field capacity water content level can be estimated in the field immediately following a rain, after free water has drained through the soil profile. Some judgment is necessary to determine when free water has drained and field capacity has been reached. Free water in coarse textured soil (sandy) can drain in a few hours. Medium textured (loamy) soil takes about 24 hours, and fine textured (clayey) soil may take several days.

***Permanent wilting point*—**This is the soil-water content at which most plants cannot obtain sufficient water to prevent permanent tissue damage. The lower limit to the available water capacity has been reached for a given plant when it has so exhausted the soil moisture around its roots as to have irrecoverable tissue damage, thus yield and biomass are severely and permanently affected. The water content in the soil is then said to be the permanent wilting percentage for the plant concerned.

Experimental evidence shows that this water content point does not correspond to a unique tension of 15 atmospheres for all plants and soils. The quantity of water a plant can extract at tensions greater than this figure appears to vary considerably with plant species, root distribution, and soil characteristics. Some plants show temporary plant moisture stress during hot daytime periods and yet have adequate soil moisture. In the laboratory, permanent wilting point is determined at 15 atmospheres tension. Unless plant specific data are known, any water remaining in a soil at greater than 15 atmospheres tension is considered unavailable for plant use.

Major soil characteristics affecting the available water capacity are texture, structure, bulk density, salinity, sodicity, mineralogy, soil chemistry, and organic matter content. Of these, texture is the predominant factor in mineral soil. Because of the particle configuration in certain volcanic ash soil, the soil can contain very high water content at field capacity levels. This provides a high available water capacity value. Table 504–1 displays average available water capacity based on soil texture.

The available water capacity value shown in soil survey reports, the Field Office Technical Guide, or the National Soil Survey Information System account for the estimated volume of coarse fragments for the specific soil series. However, in an onsite investigation any additional coarse fragments found in the soil profile must be accounted for. Coarse fragments of volcanic material, such as pumice and cinders, can contain water within the fragments themselves, but this water may not be available for plant use because of the restricted root penetration and limited capillary water movement. Adjustment to the available water capacity based upon this additional field information should be made.

Different soils hold and release water differently. When soil-water content is high, very little effort is required by plant roots to extract moisture. As each unit of moisture is extracted, the next unit requires more energy. This relationship is referred to as a soil moisture release characteristic. The tension in the plant root must be greater than that in the soil at any water content to extract the soil water. Typically with most field crops, soil moisture is not the limiting factor for crop yield when water is available at less than 5 atmospheres in medium or fine textured soils. At soil-water tensions of more than about 5 atmospheres, plant yield or biomass is reduced in medium to fine textured soils.

(g) Soil pore space

Soil is composed of soil particles, organic matter, water, and air. Pore space allows the movement of water, air, and roots. Dense soil has a low AWC because of decreased pore space. Density can make AWC differences of -50 percent to +30 percent compared to average densities. Sandy soils generally have bulk densities greater than soils with high clay content. Sandy soils have less total pore space than silt and clay soils. Gravitational water flows through sandy much faster because the pores are much larger. Clayey soils hold more water than sandy soils because clay soils have a larger volume of small, flat-shaped pore spaces that hold more capillary water. Clay soil particles are flattened or plate-like in shape, thus, soil-water tension is also higher for a given volume of water. When the percent clay in a soil increases over about 40 percent, AWC is reduced even though total soil-water content may be greater. Permeability and drainability of soil are directly related to the volume, size and shape of pore space.

Uniform plant root development and water movement in soil occurs when the soil profile bulk density is uniform, a condition that seldom exists in the field. Generally, soil compaction occurs in all soils where tillage implements and wheel traffic are used. Compaction decreases pore space, decreasing root development, oxygen content, water movement and availability.

(h) Soil depth

Soil depth is the dimension from the soil surface to bedrock, hardpan, or water table; to a specified soil depth; or to a root growth restrictive layer. The deeper the soil and plant roots, the more soil-water storage is available for plant use. Crop rooting depth and the resulting total AWC control the length of time plants can go between rainfall events before reaching moisture stress. Equipment compaction layers or naturally-occurring impervious layers restrict the downward movement of water and root penetration.

An abrupt change in soil texture with depth can restrict downward water movement. For example, coarse sand underlying medium or fine textured soil requires saturation at the textural interface before

Table 504-1 Available Water Capacity (AWC) by soil texture

Texture symbol	Texture	AWC range (in/in)	AWC range (in/ft)	Estimated typical AWC (in/ft)
COS	Coarse sand	0.01 - 0.03	0.1 - 0.4	0.25
S	Sand	0.01 - 0.03	0.1 - 0.4	0.25
FS	Fine sand	0.05 - 0.07	0.6 - 0.8	0.75
VFS	Very fine sand	0.05 - 0.07	0.6 - 0.8	0.75
LCOS	Loamy coarse sand	0.06 - 0.08	0.7 - 1.0	0.85
LS	Loamy sand	0.06 - 0.08	0.7 - 1.0	0.85
LFS	Loamy fine sand	0.09- 0.11	1.1 - 1.3	1.25
LVFS	Loamy very fine sand	0.10 - 0.12	1.0 - 1.4	1.25
COSL	Coarse sandy loam	0.10 - 0.12	1.2 - 1.4	1.3
SL	Sandy loam	0.11 - 0.13	1.3 - 1.6	1.45
FSL	Fine sandy loam	0.13 - 0.15	1.6 - 1.8	1.7
VFSL	Very fine sandy loam	0.15 - 0.17	1.8 - 2.0	1.9
L	Loam	0.16 - 0.18	1.9 - 2.2	2.0
SIL	Silt loam	0.19 - 0.21	2.3 - 2.5	2.4
SI	Silt	0.16 - 0.18	1.9 - 2.2	2.0
SCL	Sandy clay loam	0.14 - 0.16	1.7 - 1.9	1.8
CL	Clay loam	0.19 - 0.21	2.3 - 2.5	2.4
SICL	Silty clay loam	0.19 - 0.21	2.3 - 2.5	2.4
SC	Sandy clay	0.15 - 0.17	1.8 - 2.0	1.9
SIC	Silty clay	0.15 - 0.17	1.8 - 2.0	1.9
C	Clay	0.14 - 0.16	1.7 - 1.9	1.8

substantial amounts of water will move into the coarser soil below. When a coarse textured soil abruptly changes to a medium or fine textured soil, a temporary perched water table develops above the less permeable soil. Stratified soils or shallow soils over hardpans or bedrock can also hold excess gravitational water at the interface. The excess water can move upward because of the increased soil particle surface tension as the soil water in the upper profile is used by plants or capillary action resulting from surface evaporation. Thus, an otherwise shallow soil with low total AWC can have characteristics of a deeper soil.

(i) Water tables

Water tables can be a barrier for root development because of restricted oxygen availability. Providing artificial drainage of poorly drained soils increases soil depth for potential root development. Adequate soil drainage must be present for sustained growth of most plants.

In other situations, where water tables are not a barrier to root development, planned water table control and management of shallow ground water can supply all or part of the seasonal crop water needs. The water must be high quality, salt free, and held at or near a constant elevation. The water table level should be controlled to provide water according to crop needs.

(j) Chemical properties

The physical and chemical weathering of materials on the Earth's surface form soil. These materials may have been rock, or they may have been other materials that were transported from somewhere else and deposited over rock. Exposure of the surface to water, oxygen, organic matter, and carbon dioxide brings about chemical alterations to the material. Oxidation, reduction, hydration, hydrolysis, and carbonation contribute to chemical and physical changes in the surface material. If it is rock, the material gradually breaks down into smaller particles, forming a mineral soil. If it is a transported material, such as glacial till or loess, weathering can affect soil chemistry and mineralogy. The chemical and mineralogical composition of the soil varies with respect to depth or horizon. Weathering intensity decreases with depth from the surface. The longer the weathering has proceeded, the thicker the weathered layer and the greater the dissimilarity from the original material. In mineral soils, organic matter content generally decreases with depth.

The colloidal fraction (diameter less than 0.001 mm) of the soil plays an important part in the chemistry of the soil. Microbiological activity is greatest near the surface where oxygen, organic matter content, and temperature are the highest.

Cation Exchange Capacity (CEC) is the total amount of cations held in a soil in such a way that they can be removed by exchanging with another cation in the natural soil solution, expressed in milliequivalents per 100 grams of oven-dry soil (meq/100 gm). The cation exchange capacity is a measure of the ability of a soil to retain cations, some of which are plant nutrients. It is affected primarily by the kind and amount of clay and organic matter. Soils that have low CEC hold fewer cations and may require more frequent applications of fertilizers than soils with high CEC. See Soil survey reports, the Field Office Technical Guide, or the National Soil Survey Information System for CEC estimates for specific soil series.

(k) Saline soil effects

Salt-affected soils are generally classified as follows, using electrical conductivity of the soil-water extract, EC_e, as the basis:

Salinity	EC_e
Nonsaline	0–2 dS/m
Very Slight	2 - 4 dS/m
Slight	4 - 8 dS/m
Moderate	8 - 16 dS/m
Strong	> 16 dS/m

Salts in the soil-water solution decrease the amount of water available for plant uptake. Table 504–2 displays AWC values adjusting for effect of salinity versus texture. ECe is defined as the electrical conductivity of the soil-water extract corrected to 77 °F (25 °C). Units are expressed in millimhos per centimeter (mmho/cm) or decisiemens per meter (dS/m); 1 mmho/cm = 1 dS/m.

As water is evaporated from the soil surface or used by plants, salt within the soil-water solution are left behind either on the ground surface or within the soil profile. Leaching with excess water through the soil profile can reduce accumulated saline salts.

504.02 Crop characteristics

(a) Response to water, crop yield, and quality

Crop response to available water is dependent not only on the genetic characteristics and requirements of the plant but also on the environmental constraints to which it is subjected. Soil moisture is only one component needed to achieve desired crop yield and quality. Soil water within a desirable depletion range (preferably less than 5 bars tension) generally provides the expected yield and quality. The effect on yield and quality depends on how severe and during which period of crop growth water deficit occurs. In addition, some crops require less water to initially produce a minimum yield, are more efficient at utilizing available water, or go through their growth cycle during periods of reduced environmental stress. Brown and Carlson (1990) relate that barley was more productive, under the same environmental conditions as winter wheat, spring wheat, oats, and safflower. Barley was more efficient than other crops at converting plant available water to grain because of its water to grain conversion efficiency, its lower water requirements to initially produce the first unit of yield, and its early season maturity, avoiding environmental stresses that reduce yield potential.

Other management factors that limit maximum productivity are crop selection, previous crop, weed problems, soil fertility, and planting date also limit the crops ability to use available water.

(b) Crop water requirements

Crop evapotranspiration (ET_c), sometimes called crop consumptive use, is the amount of water that plants use in transpiration and building cell tissue plus water evaporated from an adjacent soil surface. Crop evapotranspiration is influenced by several major factors: plant temperature, ambient air temperature, solar radiation (sunshine duration/intensity), wind speed/movement, relative humidity/vapor pressure, and soil-water availability. Seasonal local crop water use requirements are essential for planning crop production systems.

Table 504-2 Available water capacity adjustments because of salinity 1/

Soil texture	Electrical conductivity (EC_e x10^3) 0	2	4	6	8	10	12	14
	Available water capacity (in/in) 2/							
Clay	.14 - .16	.13 - .15	.12 - .14	.11 - .13	.10 - .12	.09 - .11	.07 - .08	.04 - .05
Silty clay	.15 - .17	.14 - .16	.13 - .15	.12 - .14	.11 - .12	.09 - .11	.07 - .08	.04 - .05
Sandy clay	.15 - .17	.14 - .16	.13 - .15	.12 - .14	.11 - .12	.09 - .11	.07 - .08	.04 - .05
Silty clay loam	.19 - .21	.18 - .20	.17 - .18	.15 - .17	.14 - .15	.12 - .13	.09 - .10	.06 - .07
Clay loam	.19 - .21	.18 - .20	.17 - .18	.15 - .17	.14 - .15	.12 - .13	.09 - .10	.06 - .07
Sandy clay loam	.14 - .16	.13 - .15	.12 - .14	.11 - .13	.10 - .12	.09 - .11	.07 - .08	.04 - .05
Silt loam	.19 - .21	.18 - .20	.17 - .18	.15 - .17	.14 - .15	.12 - .13	.09 - .10	.06 - .07
Loam	.16 - .18	.15 - .17	.14 - .16	.13 - .15	.12 - .13	.10 - .11	.08 - .09	.05 - .06
Very fine sandy loam	.15 - .17	.14 - .16	.13 - .15	.12 - .14	.11 - .12	.09 - .11	.07 - .08	.04 - .05
Fine sandy loam	.13 - .15	.12 - .14	.11 - .13	.11 - .12	.09 - .11	.08 - .09	.06 - .07	.04 - .05
Sandy loam	.11 - .13	.10 - .12	.10 - .11	.09 - .11	.08 - .09	.07 - .08	.05 - .06	.03 - .04
Loamy very fine sand	.10 - .12	.10 - .11	.09 - .11	.08 - .09	.07 - .08	.06 - .07	.04 - .05	.02 - .03
Loamy fine sand	.09 - .11	.09 - .10	.08 - .10	.07 - .09	.06 - .08	.06 - .07	.04 - .05	.03 - .04
Loamy sand	.06 - .08	.06 - .08	.06 - .07	.05 - .06	.04 - .06	.04 - .05	.03 - .04	.02 - .03
Fine sand	.05 - .07	.05 - .07	.05 - .06	.04 - .06	.04 - .05	.03 - .04	.02 - .03	.02

1/ Compiled by NRCS, National Soil Survey Laboratory, Lincoln, NE
2/ 15 mmhos conductivity results in a 75-95% reduction in available water capacity

504.03 Methods for determining crop evapotranspiration

(a) Direct measurement of crop evapotranspiration

Direct measurement methods for ET_c include

- aerodynamic method,
- detailed soil moisture monitoring,
- lysimetry,
- plant porometers, and
- regional inflow-outflow measurements.

All these methods require localized and detailed measurements of plant water use. Detailed soil moisture monitoring in controlled and self-contained devices (lysimeters) is probably the most commonly used. Little long-term historical data outside of a few ARS and university research stations are available.

(b) Estimated crop evapotranspiration (ET_c)

More than 20 methods have been developed to estimate the rate of crop ET based on local climate factors. The simplest methods are equations that generally use only mean air temperature. The more complex methods are described as energy equations. They require real time measurements of solar radiation, ambient air temperature, wind speed/movement, and relative humidity/vapor pressure. These equations have been adjusted for reference crop ET with lysimeter data. Selection of the method used for determining local crop ET depends on

- location, type, reliability, timeliness, and duration of climatic data;
- natural pattern of evapotranspiration during the year; and
- intended use intensity of crop evapotranspiration estimates.

Although any crop can be used as the reference crop, clipped grass is the reference crop of choice. Some earlier reference crop research, mainly in the West, used 2-year-old alfalfa (ET_r). With grass reference crop (ET_o) known, ET estimates for any crop at any stage of growth can be calculated by multiplying ET_o by the appropriate crop growth stage coefficient (k_c), usually displayed as a curve or table. The resulting value is called crop evapotranspiration (ET_c). The following methods and equations used to estimate reference crop evapotranspiration (ET_o). ET_o methods and equations are described in detail in the Engineering Field Handbook, Part 623, Chapter 2, Irrigation Water Requirements (1990). The reference crop used is clipped grass. Crop coefficients are based on local or regional growth characteristics. The Natural Resources Conservation Service (NRCS) recommends the following methods:

Temperature method

- FAO Modified Blaney-Criddle (FAO Paper 24)
- Modified Blaney-Criddle (SCS Technical Release No. 21)

Energy method

- Penman-Monteith method

Radiation method

- FAO Radiation method (FAO Paper 24)

Evaporation pan method

The FAO Modified Blaney-Criddle, Penman-Monteith, and FAO Radiation equations represent the most accurate equations for these specific methods. They are most accurately transferable over a wide range of climate conditions.

The intended use, reliability, and availability of local climatic data may be the deciding factor as to which equation or method is used.

For estimation of monthly and seasonal crop water needs, a temperature-based method generally proves to be quite satisfactory. The FAO Modified Blaney-Criddle equation uses long-term mean temperature data with input of estimates of relative humidity, wind movement, and sunlight duration. This method also includes an adjustment for elevation. The FAO Radiation method uses locally measured solar radiation and air temperature.

Crop ET and related tables and maps can be included to replace or simplify crop ET calculations. These maps and tables would be locally developed, as needed.

(c) Critical growth periods

Plants must have ample moisture throughout the growing season for optimum production and the most efficient use of water. This is most important during critical periods of growth and development. Most crops are sensitive to water stress during one or more critical growth periods in their growing season. Moisture stress during a critical period can cause an irreversible loss of yield or product quality. Critical periods must be considered with caution because they depend on plant species as well as variety. Some crops can be moderately stressed during noncritical periods with no adverse effect on yields. Other plants require mild stress to set and develop fruit for optimum harvest time (weather or market). Critical water periods for most crops are displayed in table 504-3.

(d) Rooting depth

The soil is a storehouse for plant nutrients, an environment for biological activity, an anchorage for plants, and a reservoir for water to sustain plant growth. The amount of water a soil can hold available for plant use is determined by its physical and chemical properties.

The type of root system a plant has is fixed by genetic factors. Some plants have taproots that penetrate deeply into the soil, while others develop many shallow lateral roots. The depth of the soil reservoir that holds water available to a plant is determined by that plant's rooting characteristics and soil characteristics including compaction layers and water management. The distribution of the plant roots determines its moisture extraction pattern. Typical rooting depths for various crops grown on a deep, well drained soil with good water and soil management are listed in table 504-4. With good soil management and growing conditions, crops can root much deeper (table 504–5).

For annual crops, rooting depths vary by stage of growth and should be considered in determining the amount of soil water available.

For most plants, the concentration of moisture absorbing roots is greatest in the upper part of the root zone (usually in the top quarter). Extraction is most rapid in the zone of greatest root concentration and where the most favorable conditions of aeration, biological activity, temperature, and nutrient availability occur. Water also evaporates from the upper few inches of the soil; therefore, water is diminished most rapidly from the upper part of the soil. This creates a high soil-water potential gradient.

In uniform soils that are at field capacity, plants use water rapidly from the upper part of the root zone and more slowly from the lower parts. About 70 percent of available soil water comes from the upper half of a uniform soil profile. Any layer or area within the root zone that has a low AWC or increased bulk density affects root development and may be the controlling factor for soil moisture availability.

Variations and inclusions are in most soil map units, thus uniformity should not be assumed. Field investigation is required to confirm or determine onsite soil characteristics including surface texture, depth, slope, and potential and actual plant root zone depths.

Soil texture, structure, and condition help determine the available supply of water in the soil for plant use and root development. Unlike texture, structure and condition of the surface soil can be changed with management.

Very thin tillage pans can restrict root development in an otherwise homogenous soil. Never assume a plant root zone. Observe root development of present or former crops.

Numerous soil factors may limit the plant's genetic capabilities for root development. The most important factors are:

- soil density and pore size or configuration,
- depth to restrictive or confining layers,
- soil-water status,
- soil aeration,
- nutrient availability,
- water table,
- salt concentrations, and
- soil-borne organisms that damage or destroy plant root system.

Root penetration can be extremely limited into dry soil, a water table, bedrock, high salt concentration zones, equipment and tillage compaction layers, dense fine texture soils, and hardpans. When root development is restricted, it reduces plant available soil-water use and consequent storage, which in turn limits crop production.

High soil densities that can result from tillage and farm equipment seriously affect root penetration. Severe compacted layers can result from heavy farm equipment, tillage during higher soil moisture level periods, and from the total number of operations during the crop growing season. In many medium to fine textured soils, a compacted layer at a uniform tillage depth causes roots to be confined above the compacted layer at depths usually less than 6 to 10 inches from the surface. Roots seek the path of least resistance, thus do not penetrate a compacted dense layer except through cracks. Every tillage operation causes some compaction. Even very thin tillage pans restrict root

Table 504-3 Critical periods for plant moisture stress

Crop	Critical period	Comments
Alfalfa	At seedling stage for new seedlings, just after cutting for hay, and at start of flowering stage for seed production.	Any moisture stress during growth period reduces yield. Soil moisture is generally reduced immediately before and during cutting, drying, and hay collecting.
Beans, dry	Flowering through pod formation.	
Broccoli	During head formation and enlargement.	
Cabbage	During head formation and enlargement.	
Cauliflower	During entire growing season.	
Cane berries	Blossom through harvest.	
Citrus	During entire growing season.	Blossom and next season fruit set occurs during harvest of the previous crop.
Corn, grain	From tasseling through silk stage and until kernels become firm.	Needs adequate moisture from germination to dent stage for maximum production. Depletion of 80% or more of AWC can occur during final ripening period without impacting yield.
Corn, silage	From tasseling through silk stage and until kernels become firm.	Needs adequate moisture from germination to dent stage for maximum production.
Corn, sweet	From tasseling through silk stage and until kernels become firm.	
Cotton	First blossom through boll maturing stage.	Any moisture stress, even temporary, ceases blossom formation and boll set for at least 15 days after moisture again becomes available.
Cranberries	Blossom through fruit sizing.	
Fruit trees	During the initiation and early development period of flower buds, the flowering and fruit setting period (may be the previous year), the fruit growing and enlarging period, and the pre-harvest period.	Stone fruits are especially sensitive to moisture stress during last two weeks before harvest.
Grain, small	During boot, bloom, milk stage, early head development and early ripening stages.	Critical period for malting barley is at soft dough stage to maintain a quality kernel.
Grapes	All growth periods, especially during fruit filling.	See vine crops.
Peanuts	Full season.	
Lettuce	Head enlargement to harvest.	Water shortage results in a sour and strong lettuce.

Table 504-3 Critical periods for plant moisture stress—Continued

Crop	Critical period	Comments
Melons	Blossom through harvest.	
Milo	Secondary rooting and tillering to boot stage, heading, flowering, and grain formation through filling.	
Onions, dry	During bulb formation, near harvest.	
Onions, green	Blossom through harvest stress.	Strong and hot onions can result from moisture.
Nut trees	During flower initiation period, fruit set, and mid-season growth.	Pre-harvest period is not critical because nuts form during mid-season period.
Pasture	During establishment and boot stage to head formation.	
Peas, dry	At start of flowering and when pods are swelling.	
Peas, green	Blossom through harvest.	
Peppers	At flowering stage and when peppers are swelling.	
Potato	Flowering and tuber formation to harvest.	Low-quality tubers result if moisture stress during tuber development and growth.
Radish	During period of root enlargement.	Hot radishes can be the result of moisture stress.
Sunflower	Flowering to seed development.	
Sorghum, grain	Secondary rooting and tillering to boot stage, heading, flowering, and grain formation through filling.	
Soybeans	Flowering and fruiting stage.	
Strawberries	Fruit development through harvest.	
Sugar beets	At time of plant emergence, following thinning, and 1 month after emergence.	Temporary leaf wilt on hot days is common even with adequate soil water content.
Sugarcane	During period of maximum vegetative growth.	
Tobacco	Knee high to blossoming.	
Tomatoes	When flowers are forming, fruit is setting, and fruits are rapidly enlarging.	
Turnips	When size of edible root increases rapidly up to harvest.	Strong tasting turnips can be the result of moisture stress.
Vine crops	Blossom through harvest.	
Watermelon	Blossom through harvest.	

development and can confine roots to a shallow depth, thereby limiting the depth for water extraction. This is probably most common with row crops where many field operations occur and with hayland when soils are at high moisture levels during harvest.

Subsoiling when the soil is dry can fracture compacted layers. However, unless the cause of compaction (typically tillage equipment itself), the number of operations, and the method and timing of the equipment's use are changed, compaction layers will again develop. Only those field operations essential to successfully growing a crop should be used. Extra field operations require extra energy (tractor fuel), labor, and cost because of the additional wear and tear on equipment. Necessary tillage operations should only be performed when the soil surface from 0 to 2 inches or 0 to 3 inches in depth is dry enough not to cause soil smearing or compaction. The lightest equipment with the fewest operations necessary to do the job should be used.

Table 504-4 Depth to which roots of mature crops will extract available water from a deep, uniform, well-drained soil under average unrestricted conditions (depths shown are for 80% of the roots)

Crop	Depth (ft)	Crop	Depth (ft)
Alfalfa	5	Milo	2 - 4
Asparagus	5	Mustard	2
Bananas	5	Onions	1 - 2
Beans, dry	2 - 3	Parsnips	2 - 3
Beans, green	2 - 3	Peanuts	2 - 3
Beets, table	2 - 3	Peas	2 - 3
Broccoli	2	Peppers	1 - 2
Berries, blue	4 - 5	Potatoes, Irish	2 - 3
Berries, cane	4 - 5	Potatoes, sweet	2 - 3
Brussels sprouts	2	Pumpkins	3 - 4
Cabbage	2	Radishes	1
Cantaloupes	3	Safflower	4
Carrots	2	Sorghum	4
Cauliflower	2	Spinach	1 - 2
Celery	1 - 2	Squash	3 - 4
Chard	1 - 2	Strawberries	1 - 2
Clover, Ladino	2 - 3	Sudan grass	3 - 4
Cranberries	1	Sugar beets	4 - 5
Corn, sweet	2 - 3	Sugarcane	4 - 5
Corn, grain	3 - 4	Sunflower	4 - 5
Corn, seed	3 - 4	Tobacco	3 - 4
Corn, silage	3 - 4	Tomato	3
Cotton	4 - 5	Turnips	2 - 3
Cucumber	1 - 2	Watermelon	3 - 4
Eggplant	2	Wheat	4
Garlic	1 - 2		
Grains & flax	3 - 4		
Grapes	5	**Trees**	
Grass pasture/hay	2 - 4	Fruit	4 - 5
Grass seed	3 - 4	Citrus	3 - 4
Lettuce	1 - 2	Nut	4 - 5
Melons	2 - 3		

For site specific planning and design, never assume a plant root zone depth. Use a shovel or auger to observe actual root development pattern and depth with cultural practices and management used. The previous crops or even weeds will generally show root development pattern restrictions.

504.04 Tillage systems effect on water conservation

(a) Comparisons of water conservation under different residue management systems

Tillage practices influence soil moisture throughout the growing season. Reduced-tillage or no-till systems

Table 504-5 Maximum rooting depth of mature crops seeded on fallow from 1976 to 1979 at Fort Benton, MT

Crop	Root depth (Feet)
Alfalfa, vernal	20
Argentine rape	4
Barley	5
Flax	5
Mustard, yellow	4
Safflower	7
Sunflower	6
Wheat, winter	6
Wheatgrass	9

decrease evaporation losses, if the residue remains on the soil surface. Both surface roughness and residue slow water runoff, allowing more time for infiltration. In addition, surface residue prevents soil surface sealing, thus increasing infiltration and soil water stored. The net effect of tillage systems that leave surface residue is less variation in soil water during the summer months and more plant available water.

Evaporation—a primary source of water loss during the first half of the growing season before the crop canopy closes. Crop residue on the soil surface shades the soil surface and reduces the amount of solar energy absorbed, thereby reducing soil temperatures and evaporation. Residue also reduce air velocity at the soil surface, slowing the rate at which evaporation occurs. Residue cover offers the greatest reduction in evaporation when the soil is moist and not yet shaded by the crop. Unger and Parker (1968) reported that the cumulative evaporation after 16 weeks was 57 percent less when wheat residue remained on the surface rather than mixed into the soil.

The difference in cumulative evaporation between bare soil and soil with a residue cover is related to the frequency and amount of rainfall. For small, infrequent rainfall events, the two soil surfaces show little difference in cumulative evaporation. However, with larger more frequent rains, less evaporation occurs from soil protected by surface residue than from bare soil. In stubble covered wheat field, evaporation ranges from 60-75 percent of that occurring from bare soil. Evaporation from the soil depends on water rising to the surface by capillary action as the soil dries. Shallow incorporation of residue reduces this capillary action however; leaving residue on the soil surface generally reduces evaporation more than shallow incorporation.

Water infiltration—the process of water entering the soil at the soil/air interface. Crop residue affects soil infiltration by intercepting raindrop energy and the associated soil sealing or ponding that occurs thereby increasing infiltration and reducing the amount of runoff. Simulated rainfall studies in Ohio show that infiltration increases with surface residue (table 504-6). Although the infiltration rate was initially greater on the plowed field than the bare no-till field, the residue in the no-till field enabled faster water infiltration.

Runoff—tillage systems that leave crop residue on the soil surface generally reduce runoff. The factors that influence the differences in runoff are soil characteristics, weather patterns, the presence of macropores, management, and the amount and kind of residue. The residue characteristics that affect water infiltration also affect runoff by increasing the time to initiation of runoff and lowering runoff rates. Residue on the soil surface increases the surface roughness of the soil, reduces runoff velocities, and causes ponding that further delays runoff. In addition, surface residue obstructs and diverts runoff, increasing the length of time in the downslope flow path allowing more time for infiltration.

Another important point is the effect of having both standing and flat residues present. The presence of standing and flat residues reduces the likelihood that small localized flow areas will combine into larger networks, and decreases the velocity and overall transport of runoff from the field. If the climate and soil conditions exclude macropore development and traffic causes unrelieved reductions in infiltration, runoff rates can increase even with high residue crop production systems such as no-till, particularly in the early years of the systems before surface organic matter has time to accumulate.

Gilley (1986, 1987) and co-workers conducted a series of studies evaluating the effect of different types and amounts of residue on runoff rates. Five rates of corn residue were spread on the soil surface at 0, 10, 31, 51, and 83 percent ground cover (0, 1, 1.12, 3.36, 6.73, and 13.45 mg/ha). Rainfall was applied at a rate of

Table 504-6 Effect of tillage and corn residue on infiltration using simulated rainfall (Triplett et al. 1968)

Treatment	----------Total infiltration after 1 hour (inches)---------- Initial run	Wet run [1]
Plowed, bare	0.71	0.41
No-tillage, bare [2]	0.48	0.25
No-tillage, 40% cover	0.92	0.53
No-tillage, 80% cover	1.73	1.37

1 Wet run took place 24 hr after initial run.
2 Residue cover was removed for research purposes.

28 millimeters per hour on days 1, 2, and 3 of the study. Average runoff rates were 15.6, 10.7, 6.0, 1.8, and 0 millimeters per hour for the 0, 10, 31, 51, and 83 percent residue covers, respectively. Runoff rates were also studied for sorghum and soybean residues at a rainfall rate of 48 millimeters per hour. The runoff rate for soybean decreased by 68 percent as residue cover increased from 0 to 56 percent; the runoff rate for sorghum decreased by 73 percent as residue cover increased from 0 to 44 percent.

Snow catch—Maximizing snow catch is a vital conservation measure in the northern Great Plains, since snow constitutes 20 to 25 percent of the annual precipitation. Stubble height management is a tool used to maximize snow catch. Taller stubble retains more snow, increasing soil water content. Bauer and Black (1990) in a 12 year study reported that increasing small grain stubble height from 2 to 15 inches increased soil water content to a depth of 5 feet by 1.6 inches. Increasing the snow catch on a field can also increase spring melt runoff depending on the early spring soil infiltration characteristics. However, in soils on which annual crops are grown, infiltration of snowmelt occurs 80 to 90 percent of the time because the soil is usually frozen while dry or not frozen as deeply due to the snow coverage to permit infiltration. Greb (1979) reported that the efficiency of storing meltwater is often double that of storing water received as rain.

Water storage—Soil moisture savings is of great importance in regions of low rain fall and high evapotranspiration, on soil low in water holding capacity, and in years with below normal rainfall. In the Corn Belt, excessive soil moisture in the spring months often has a negative effect on crop growth since it slows soil warming and delays planting. However, on soils where drought stress often occurs during the summer months, having more available water during crop pollination and seed filling usually offsets these early season negative effects. Seed zone soil moisture also aids in plant establishment and growth in dry areas of the United States. For a high percentage of the farmland, moisture savings should be a primary reason for producers to consider reduced tillage systems.

Research on the effects of reducing tillage and increasing surface residue have indicated that high amounts of surface residue results in increased soil water stored. Unger (1978) reported that high wheat residue levels resulted in increased water storage during the fallow period and the increased subsequent grain sorghum the following year. Similar results of water storage under high residue conditions, shown in table 504-7, summarized by Greb (1983) for 20 crop-years from four locations.

Management changes in the Great Plains since 1916 have improved soil water storage, fallow efficiency (percentage of the precipitation received during the fallow period and stored as soil water), and small grain yields. However, fallow efficiencies up to 40 percent were reported in the 1970's and have not improved beyond this value. Furthermore, subsequent research in the Great Plains with modern no-till wheat-fallow systems indicates that most of the moisture received is stored early in the year, after crop harvest, and very little soil water is stored beyond the first of July. This information indicates that reducing or eliminating fallow from the rotation, intensifying the cropping pattern, and utilizing the soil moisture stored through the rotation is a means of taking advantage of our increased capability to store water earlier in the cropping cycle with high residue crop production systems.

Excessive soil water—Soil properties that affect water infiltration, permeability, and drainage must always be properly assessed when making residue management decisions. Research in the Corn Belt has shown that no-till management systems on some poorly drained soils has resulted in lower yields compared to the yields of conventionally tilled systems. Continued research has shown, however after 18 years of continued no-till that yields are now equal or greater than conventionally tilled systems. The initial yield reductions on these poorly drained soils may

Table 504-7 Net soil-water gain at the end of fallow as influenced by straw mulch rates at four Great Plains locations

Location	Years reported	---- Mulch rate (mg/ha) ---- 0	2.2	4.4	6.6
Bushland, TX	3	7.1	9.9	9.9	10.7
Akron, CO	6	13.4	15.0	16.5	18.5
North Platte, NE	7	16.5	19.3	21.6	23.4
Sidney, MT	4	5.3	6.9	9.4	10.2
Mean		10.7	12.7	14.5	15.7
Gain with mulch			2.0	3.8	5.0

Note: Soil water gain units = centimeter.

have been attributed to a number of factors. The positive yield response after continuous no-till on these soils may be attributed to the development of internal drainage characteristics such macropores, increases in organic matter, better surface soil structure, and the use of disease resistant cultivars.

When dealing with heavier residue amounts from the preceding crop it may be necessary in no-till situations to use residue managers that move the residue to the side of the seed trench. Poorly drained soils are not easily adapted to high residue systems and may need to be managed with limited till systems such as ridge-till or fall and spring strip-till methods. Some warm-season species such as corn or sunflower respond to warm, clean seedbed conditions. This may also be accomplished including crops in the rotation that produce lower amounts of dark colored residue or the inclusion of cover crop. (Refer to Subpart 506B, Suitability for crop production systems.)

(b) Cropping system intensity

Improving the relative efficiency of water use in crop production systems has been a major goal in achieving more productive modern crop production systems. Reducing water losses in cropping systems by changes in tillage systems, residue management, crop selection and sequence has achieved more intense rotations and greater water use efficiency (WUE).

Water use efficiency can be defined as the dry matter produced divided by the growing season evapotranspiration (ET) and expressed in units of dry matter per unit of water for a given crop in that system. Since water losses in a system such as runoff and drainage are often unknowns, ET is replaced by a value comprised of soil water used during the growing season plus growing season precipitation. This relationship can be shown as in the following equation.

WUE = Dry Matter Yield/((Soil water at planting – Soil water at harvest) + growing season precipitation)

The result of the calculation is not exactly identical to situations where true ET is known because not all the precipitation received during the growing season does enter or stay in the soil. This overestimate of water available to the plant, however is valuable to quantify the efficiency of crops grown on a systems basis for a given climate.

Changes in cropping systems by decreasing tillage, increasing surface residues, making conscious decisions on residue orientation, as well as, strategically placing crops in rotations have produced these changes in water use efficiency. Cropping system intensification has improved the WUE, and has increased the productivity of crop production systems in the Great Plains. Three-year systems increased WUE in every climate regime in Texas, Kansas, and Colorado (table 504-8). The WUE for the 3-year rotation winter wheat-corn-fallow averaged 196 pounds per acre per inch, compared with an average WUE of 140 pounds per acre per inch for winter wheat-fallow.

Continuous cropping may be a viable option for producers in areas where fallow has traditionally been a part of a cropping sequence. With high residue management the inclusion of annual forages, such as sorghums, millet, field peas, or small grains, would increase the producers flexibility to maximize WUE. Crop choice affects WUE of the crop production system because each species has a different potential for production. Optimizing WUE in a particular crop production system requires choosing crops with the highest potential WUE for your particular environment.

Several predictive tools (water-use-production functions) have been developed to assist producers in crop selection in several environments across the Great Plains. Black et al. (1981) suggested that a flexible cropping strategy would provide efficient water use to control saline seeps in the northern Great Plains. Flexible cropping is defined as seeding a crop when stored soil water and rainfall probabilities are favorable for satisfactory yield, or fallowing when prospects are unfavorable. Available soil water can be estimated by measuring moist soil depth with a soil moisture probe or other soil sampling equipment. Brown et al. (1981) have developed soil water guidelines and precipitation probabilities for barley and spring wheat for flexible cropping systems in Montana and North Dakota.

When considering a flexible cropping system a producer should evaluate the amount of plant-available soil water at seeding time, the precipitation probabilities for the seasonal needs of a given crop, and management factors such as variety, crop rotation, weed and insect problems, soil fertility, and planting date. Current information in the Great Plains at various locations includes yield water-use-production functions for winter wheat, spring wheat, barley, oats, millet, corn, sunflower, dry beans, canola, crambe, soybean, and safflower given soil moisture and rainfall-probability information (Brown and Carlson 1990; Vigil et al. 1995; Nielson 1995). This information can assist a producer in crop selection in a given year, however users of these water use/yield relationships need to understand that the final crop yield is influenced by the timing of precipitation as well as the amount of water used.

504.05 Saline seeps

(a) Development of saline seeps

Saline seep describes a salinization process accelerated by dryland farming practices. Saline seep is an intermittent or continuous saline water discharge at or near the soil surface downslope from a recharge area under dryland farming conditions that reduces or eliminates crop growth in the affected area because of increased soluble salt concentration in the root zone. Saline seeps are differentiated from other saline soil conditions by their recent and local origin, saturated root zone in the soil profile, shallow perched water table, and sensitivity to precipitation and cropping systems. In the recharge area, water percolates to zones of low hydrologic conductivity at depths of 2 to 60 feet below the soil surface and flows internally

Table 504-8 Water use efficiency of 3-year no-till cropping systems and continuous spring wheat as compared with no-till spring wheat and winter wheat-fallow systems at various locations across the Great Plains (Peterson et al. 1996)

System	WUE, lb/acre per in	Location
Spring wheat/Fallow	130	Minot, ND
Cont. spring wheat	119	Do.
Spring wheat/Fallow	78	Williston, ND
Cont. spring wheat	125	Do.
Winter wheat/ Fallow	155	Sterling and Stratton, CO
Winter wheat/ Corn/ Fallow	202	Do.
Winter wheat/ Fallow	156	Akron, CO
Winter wheat/ Corn/ Fallow	250	Do.
Winter wheat/Fallow	144	Tribune, KS
Winter wheat/Sorghum/ Fallow	201	Do.
Winter wheat/ Fallow	128	Walsh, CO
Winter wheat/ Sorghum/ Fallow	148	Do.
Winter wheat/Fallow	87	Bushland, TX
Winter wheat/Sorghum/Fallow	156	Do.
Spring wheat/Fallow	104	Average
Winter wheat/Fallow	140	Average
Cont. spring wheat	122	Average
Winter wheat/Corn/Fallow	196	Average
Wheat/Sorghum/Fallow	181	Average

downslope to emerge at the point where the transport layer approaches the soil surface or soil permeability is reduced.

The saline-seep problem stems from surface geology, above-normal precipitation periods, and farming practices that allow water to move beyond the root zone.

Under native vegetation, grasses and forbs used most of the water before it had a chance to percolate below the root zone to the water table. With sod plow-up, subsoils became wetter and fallow kept the land relatively free of vegetation for months at a time. Beginning in the forties, soil water storage efficiency during fallow improved with the advent of large tractors, good tillage equipment, effective herbicides, and timely tillage operations. This extra water filled the root zone to field capacity and allowed some water to move to the water table and downslope to emerge as a saline seep.

Several factors that may individually or in combination contribute water to shallow water tables include: fallow, high precipitation periods, poor surface drainage, gravelly and sandy soils, drainageways, constructed ponds and dugouts, snow accumulation, roadways across natural drainageways, artesian water, and crop failures resulting in low use of stored soil water. Saline-seep formation begins with a root zone filled to its water-holding capacity. Some of this water runs off the surface, some evaporates, and the rest moves into the soil. Once the soil is filled to field capacity, any additional water that moves through the root zone may contribute to saline seepage.

Water percolating through salt-laden strata dissolves salts and eventually forms a saline water table above an impermeable or slowly permeable layer. The underground saline water migrates downslope and dissolves more salts, adding to the perched water table at the site of the seep. Whenever, the water table rises to within 3 feet of the surface the water plus dissolved salts then move to the soil surface by capillary action were the discharge water evaporates, concentrating salt on or near the soil surface. As a result, crop growth in the affected area is reduced or eliminated and the soil is too wet to be farmed.

(b) Identification of saline seeps

Early detection and diagnosis of a saline-seep problem are important in designing and implementing control and reclamation practices to prevent further damage. By early detection, a producer may be able to change his or her cropping system to minimize the damage. Detection of discharge areas may be accomplished by visual or by electrical conductivity detection. Visual symptoms of an impending saline seep may include

- vigorous growth of kochia or foxtail barley in small areas where the soil would normally be too dry to support weed growth,
- scattered salt crystals on the soil surface,
- prolonged periods of soil surface wetness in small areas,
- poor seed germination or rank wheat or barley growth accompanied by lodging in localized areas,
- stunted trees in a shelterbelt accompanied by leaf chlorosis, or
- a sloughed hillside in native vegetation adjacent to a cultivated field.

Soil electrical conductivity (EC), which is proportional to soil salinity, can be determined in the field using resistivity. This technique can be used to identify and confirm an encroaching or developing saline seep. Soil salinity in the discharge area may be low near the soil surface, but increases considerably with depth. Once the discharge area is identified, the next step is to locate the recharge area. Most remedial treatments for controlling the seep must be applied to the recharge area, which is always at a higher elevation than the discharge area. The approximate size of the recharge area must be determined to be successful. Most recharge areas are within 2,000 feet and many are within 100 to 600 feet of the discharge area, depending on the geology involved.

Several procedures for identifying the recharge area include: visual, soil probing, soil surveys, drilling, soil resistivity, and electromagnetic techniques. Even if the previously mentioned equipment is not available, a visual approximation of the recharge area can be made, and strategies implemented to correct the saline-seep problem. Some facts to remember are that the recharge areas are higher in elevation than the seep or discharge area, the recharge areas are generally within 2,000 feet of the discharge areas, and that seeps in glacial till areas expand downslope, laterally, and upslope toward the recharge area. Saline seeps in non-glaciated areas tend to expand downslope, away from the discharge area. After the recharge area has been located, a management plan should be designed to control the saline-seep problem.

(c) Effects of salinity on yields

Saline soil is a term used to characterize soil containing sufficient salts to adversely affect the growth of most crop plants. One or more of the following may cause these adverse effects:

- Direct physical effects of salts in preventing soil water uptake by the plant roots because of increased osmotic tension.
- Direct chemical effects of salt in disrupting the nutritional and metabolic processes of the plant.
- Indirect effect of salt in altering soil structure, permeability, and aeration.

Agricultural crops differ significantly in their response to excessive concentrations of soluble salts in the root zone. This ability of the plant to produce economic yields in a saline environment is termed salt tolerance. Crop selection is one of the primary options available to growers to maximize productivity under saline conditions. Table 504-9 lists the salinity threshold and yield decrease of several selected agricultural crops. The threshold salinity level is the maximum allowable salinity that does not reduce yield below that of nonsaline conditions. The yield decrease is reported as a percent yield reduction for every whole unit increase in salinity measured as electrical conductivity (EC) mmho/cm. For example, alfalfa yields decrease about 7.3 percent per unit of salinity increase above 2.0 mmho/cm. Therefore, at a soil salinity of 5.4 mmho/cm, alfalfa yield would be 25 percent lower than at soil salinity levels less than 2.0 mmho/cm.

Crop production has been reduced on approximately 2 million dryland acres in the northern Great Plains of the United States and Canada. Brown (1982) reported that this production loss on 2 million acres in the northern Great Plains could be translated into $120 million in lost annual farm income.

(d) Management practices for control of saline seeps

Saline-seeps are caused by water moving below the root zone in the recharge area. Because of this movement of water though the recharge area, there will be no permanent solution to the saline-seep problem unless control measures are applied to the recharge area. These measures vary according to the soil texture and underlying geologic material, water table fluctuations, depth to the low hydraulic conductivity zone, occurrences of potholes and poorly drained areas, and annual precipitation and frequency of high precipitation periods.

Two general procedures are available for managing saline-seeps: either make agronomic use of the water for crop production before it percolates below the root zone; or mechanically drain either surface or subsurface water before it reaches the discharge area. Mechanical drainage is generally not performed either because of current farm bill legislation or because of constraint that subsurface water is excessively contaminated with salts and downstream disposal is difficult because of physical or legal limitations. How-

Table 504-9 Salt tolerance of selected crops [1/]

Common name	Botanical name	Salt tolerance threshold (mmhos/cm)	Yield decline (% per mmhos/cm)
Alfalfa	*Medicago sativa*	2.0	7.3
Barley	*Hordeum vulgare*	8.0	5.0
Sorghum	*Sorghum bicolor*	6.8	16.0
Soybean	*Glycine max*	5.0	20.0
Wheat	*Triticum aestivum*	6.0	7.1
Wheatgrass, tall	*Agropyron elongatum*	7.5	4.2
Wildrye, beardless	*Leymus triticoides*	2.7	6.0

1/ Maas and Hoffman (1977) and Maas (1990) ever, before any control measures are implemented an evaluation of the land capability class should be determined. All control measures should be compatible with the land capability class involved.

The most effective solution to the saline-seep problem is to use as much of the current precipitation as possible for crop or forage production before it percolates beyond the root zone. Forage crops, such as alfalfa, use more water than cereal grains and oil crops because they have deep root systems, are perennial, and have longer growing seasons. Planting alfalfa in the recharge area of a saline seep is often the most effective way to draw down stored subsoil moisture and stop water flow to a saline-seep. Alfalfa can use all current precipitation plus a substantial amount of water from the deep subsoil. Halvorson and Reule (1976), (1980) found that alfalfa growing on approximately 80 percent of the recharge area effectively controlled several saline seeps. They also found that a narrow buffer strip of alfalfa (occupying less than 20 percent of the recharge area) on the immediate upslope side of a seep did not effectively control the water in the discharge area. Grasses may also effectively draw down subsurface water if the depth to the low hydraulic conductivity zone is less than 15 feet. After terminating alfalfa or grass production, the recharge area should be farmed using a flexible cropping system.

Flexible cropping is defined as seeding a crop when stored soil water and rainfall probabilities are favorable for satisfactory yield or fallowing when prospects are unfavorable. Available soil water can be estimated by measuring moist soil depth with a soil moisture probe or other soil sampling equipment. Black et al. (1981) suggested that this cropping strategy would provide efficient water use to control saline seeps in the northern Great Plains. Brown et al. (1981) have developed soil water guidelines and precipitation probabilities for barley and spring wheat for flexible cropping systems in Montana and North Dakota.

When considering a flexible cropping system a producer should evaluate the amount of plant-available soil water at seeding time, the precipitation probabilities for the seasonal need of a given crop, and management factors such as variety, crop rotation, weed and insect problems, soil fertility, and planting date. Current information in the northern Great Plains at various locations includes yield water-use-production functions for winter wheat, spring wheat, barley, oats, millet, corn, sunflower, dry beans, canola, crambe, soybean, and safflower, given soil moisture and precipitation information. Oilseeds such as safflower or sunflower included in the rotation utilize residual subsoil moisture below the normal rooting depth of small grains while disrupting disease and pest cycles associated with cereal grain production. After successful application of control measures to the recharge area, the seep area and surrounding area can then be seeded to a grass or grass/legume mixture tolerant to the saline conditions present in the discharge area. A return to a cropping system that does not adequately utilize stored soil water in the recharge area may reactivate the seep.

Once the water flow from the recharge area to the seep has been stopped or controlled and the water table in the seep has dropped enough to permit cultivation, cropping in the seep area can begin. Crop selection is important when initiating crop production on the discharge area. In the northern Great Plains, six-row barley is the most salinity-tolerant cereal available, and it is normally the first crop seeded. As the reclamation processes continues, comparing yields in and outside the seep area can be used to monitor progress. The water table depth should be closely monitored during the reclamation period.

Another approach that can be used on discharge areas is to manage salt-tolerant grasses seeded on the area. If the water table is above 4 feet the grasses should be mowed and completely removed to prevent excess snow accumulation and the subsequent rise in the water table. If the water table is below 4 feet, the grass can be left to catch snow. The resulting snowmelt will leach the salt downward into the soil and improve subsequent grass growth. Snow trapping using grass strips or crop stubble will enhance water movement through the profile in the discharge area and hasten the reclamation process. These practices will not be effective until hydrologic control is achieved in the recharge area and the water table is significantly lowered in the discharge area. Research and farmer experience have shown that yields will generally return to normal in 3 to 5 years.

In saline-seep areas, observation wells are useful for monitoring water table levels during the control, reclamation, and post-reclamation periods. Water tables fluctuate seasonally and annually. Reclaimed saline seeps may be reactivated by a significant rise in the water table, which persists for several weeks or months. If a saline water table is less than 3 feet below the soil surface, saline water can move to the surface by capillary rise and create a salt problem. To alleviate this problem, monitoring wells at least 10 feet in depth should be installed in discharge areas, along drainage-ways, and in recharge areas. Ideally, the water table should be at least 6 feet in depth. Water table levels should be monitored monthly, especially during and after snowmelt, and rainy seasons. A rising water table that persists into the summer months indicates that cropping practices should be intensified to increase soil water use.

Subpart 504B References

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Part 506 Plant Attributes

Contents:

Subpart 506A Vegetative stabilization

506.00 Structures

Structures are engineered earthen water retention, conveyance, or other conservation practice components. This section deals with establishing vegetation on typical erosion control structures such as Public Law 566 dams, diversions, waterways, emergency watershed program structures, and others. These structures are designed and constructed for soil and slope stability with vegetative treatment to protect and maintain the integrity of the structure.

506.01 General considerations

Plants—Protecting structures is typically accomplished with grasses enhanced by a legume component for some nitrogen generation. Landscaping with shrubs and trees blend structures into surrounding landforms. Species and cultivar selection and effective planting techniques are key to successful establishment. Select plants to meet the existing site conditions including internal soil drainage, soil texture and percent fine particles present, organic matter, density, pH and nutrients available from the soil, exposure and aspect, temperature zone, and plant hardiness factors. Recommended plant lists are available in each state.

Proper plant selection to meet the existing and future site use will minimize future maintenance. Avoid using plants known to be invasive, such as kudzu, multiflora rose, or phragmites, and use native plants where effective.

Soil—Soil is the medium in which seeds germinate and roots grow. The condition of the soil may well determine the success or failure of seedings or plantings. Soil texture, structure, tilth, organic matter, drainage, and chemical composition need to be reviewed to be certain that compatible plants have been selected. Soil amendments should be specified to meet site and plant needs.

If topsoil is salvaged onsite, use it on the most sensitive area(s) of the structure, such as emergency spillways or faces of dams. Blend the topsoil into the surface of the structure to avoid a sharp contrast between compacted fill material and the topsoil.

Water and wind management—Potential erosion problems need to be considered when selecting appropriate species and techniques of establishment. Water as rainfall or snowmelt, spring ice flows in streams, surface runoff, or seepage areas may require special attention. Proper water management may include diversions and waterways to be established, or may require subsurface drains to dry out the seeps. Exposed areas subject to wind should be treated with adequate protection to insure establishment of the planting. This may include mulch anchoring or temporary windbreaks or using wind barrier plants.

Combinations of geotextiles or bioengineering (live fascines, brush mattresses) may be desirable to handle special conditions of erosive water velocities or areas of temporary high flows.

Land use—Land use surrounding the structure(s) should be evaluated to blend the disturbed area into as natural setting as possible. Plantings should be planned based on anticipated growth and appearance of the species. Blending structures with the environment will enhance the visual appearance and present a positive effect to the public.

Geology—Geologic investigations include the overburden material and the underlying parent material. Bedrock, changes of soil texture at various depths, and saline areas can be addressed early in planning process when identified from the geologic review.

Existing vegetation—Existing vegetation can provide potential species that should be included in the seeding of constructed structures. It may be desirable to select species from several successional stages to include in the revegetation plan. Using the species existing on surrounding areas will help blend the structure with aesthetically pleasing results. Caution is offered because often the surrounding vegetation is on undisturbed soil and may not perform well on the problem area. Where local ecotypes are available commercially, these may be preferred sources of plant material.

Present and proposed use—Consideration of the proposed future use of the structure is important in species selection. If people and vehicles will be using the area, traffic patterns should be planned. Paths should be designed to minimize erosion potential. Plants that impede recreational activities, such as vines or dense, tangled growth, should be avoided. Select vegetation that will enhance the long-term use of the area as well as provide erosion control cover needed. For example, if fishing will be allowed after a large dam is constructed, leave some grass areas without shrubs at the water's edge.

Climate—Select species for the local climate —Rainfall and temperature vary greatly within a state. Exposure to wind may create a sandblasting problem on the plants or may result in desiccation of the plants. Site aspect (north facing slopes) may result in several degrees difference in temperature. The USDA Plant Hardiness Zone Map, Misc. Pub. No. 1475, 1990, can serve as a general guide for selecting plants. The Plant Zone map may be veiwed on-line at

http://www.usna.usda.gov/Hardzone/

However, local conditions may offer protection or may create exposure that will influence the plant performance.

Shade tolerance—Where structures will be shaded for part or all day, be sure the species are tolerant for the anticipated condition. If canopy cover closure is anticipated in the future, then include appropriate ground cover species to meet the future site condition.

Site preparation—The area before construction should be reviewed to select and preserve any highly desirable plants or section of plants near the perimeter or edge of the construction zone. Endangered, threatened, or declining species considerations must be met before construction. Install any temporary wind or water control measures. If topsoil or other organic matter is available onsite, salvage as much as is economically feasible. Do not waste it by burial or other loss.

506.02 Seeding and planting process

As construction is completed or at intervals during construction, seeding should be accomplished. Daily or other time interval seedings may be mandatory where site location or local laws require this. Frequently, daily seedings are planned for temporary erosion control until the work for the entire project is completed. Then the areas will be reseeded to permanent vegetation at an appropriate planting date.

Seedbed preparation—The objective in seedbed preparation is to create a condition where seed can be planted, emerging seedlings will have a favorable microenvironment, and the surface area will be such as to allow the type of maintenance required to support protective vegetative cover.

During this operation, soil amendments (lime, gypsum, fertilizer) should be applied. Also, remove large stones (generally greater than 4 to 6 inches in diameter, or 1 to 2 inches for a lawn) and debris that will hinder seeding or planting and future operations and maintenance.

Seedbed scarification may be required unless seeding is accomplished within 24 hours of final grading. Sand and gravel (sites with less than 20% fines passing a 200 mesh) do not require scarification as long as moisture is adequate. When the surface soil is powdery, the soil is too dry for seeding. If clumps of mud stick to the planting equipment, the soil is too wet unless a hydroseeder or other suitable equipment is used.

Areas of compaction should be determined and ripped or scarified to a depth of 9 to 12 inches minimum to create a more favorable rooting zone. Topsoil (if available) should be applied and blended with the surface of the structure. All tillage operations should be performed on or as close to the contour as possible. The balance of the area should be scarified or loosened to a minimum of 3 inches to allow good soil to seed contact. Scarification may be waived if the seeding is accomplished immediately after the final grading is finished and site conditions warrant this approach.

506.03 Seed, plant, and amendment application rates

Seed and plant rates—General seeding rates and planting quantities of selected species or mixtures are available in a State's Field Office Technical Guide (FOTG), Section IV, Critical Area Planting Standard 342.

Seed or plant specifications, or both—For contracting and obtaining desired seed quality, specify genus, species, cultivar (if any), specific inoculant, and pure live seed or minimum seed germination. Federal and state seed laws are used for proper labeling and noxious weed seeds. Use the American Nurseryman Standards for describing shrub and tree quality, size and type of plant material.

Time of seeding or planting—Specify appropriate planting dates. Spring seedings may be adequate where normal rainfall is available. However, the effect of annual weeds and midsummer droughts should be considered. Fall seedings in many parts of the country have the advantage of more reliable precipitation and favorable temperatures. In addition, in the northern states, the annual weeds are generally winter killed.

Cool-season grasses generally do best when seeded in the fall. However, many times construction will be completed during periods of the year when seedings should not be made. Temporary seeding or mulching should be made and the permanent seeding made at the optimum time of year for the species used.

Warm-season grasses are normally seeded in the spring. Some fall seedings are successful providing weather conditions remain cold and the seed remains dormant. In general, warm-season grasses should have about 100 days of growing season remaining after planting.

The use of irrigation on structures can be useful if care is taken to apply only amounts necessary. If the expertise is not available at the site to monitor the water management, irrigation water induced erosion can occur. Steep slopes (3:1 or steeper) are generally too hazardous to set pipe and operate the system on, plus the erosion potential is too great.

Soil amendments—Acid soil should generally have the pH adjusted to 5.5 or higher for grasses and 6.0 if legumes are to be used. This will allow the rhizobium bacteria associated with legume roots to function. The resultant pH planned for, will depend on the plant species selected and long-term goal of species composition. Generally ground agricultural limestone, either calcitic (high Ca) or dolomitic (high Mg) is used. The most desirable ratio is a Ca:Mg ratio of 10:1; however wider ratios are acceptable. High pH or saline soil may require gypsum ($CaSO_4.2H_2O$) application. All nutrients for normal plant growth need to be determined via soil analysis. Deficient and potentially toxic elements require evaluation. Adjust amendments accordingly. Add only the amount of nutrients required to produce adequate vegetative cover.

Method of seeding or planting—Many techniques are available that have proven successful. Site conditions will dictate options.

Steep slopes require methods of blowing, broadcasting, or water application with seed (sometimes soil amendments) suspended within. For hydroseeders, coverage is limited by the size of equipment, wind conditions, and stream load. Centrifugal seeding equipment requires dry weather conditions and limited wind interference. High velocity blowers are normally used for sites where it is difficult to hold seed in place, or sites that are inaccessible by large equipment. Blowers will force some of the seed into the soil and crevices for germination. Soil must be moist. Some delicate seeded species may experience seed damage.

Another technique for steep slopes is to use a track type bulldozer to incorporate seed and amendments. Operate the bulldozer up and down the slope. The cleat tracks create areas in which seed may be trapped. Soil migrating down the slope will cover the seed and the indentations in the bank hold additional moisture. This works well on sands and gravel.

Calibration of these units is difficult. Experienced operators usually will be able to uniformly apply seed by estimating the land area and apply tank loads at acceptable rates. Hydroseeders frequently add green colored hydromulch to mark the area covered.

On flatter areas, additional equipment is available to better place the seed into the soil and in arid regions, to better take advantage of soil moisture.

Imprinting works well to allow for deep placement of seed, This allows for access to moisture and affords the germinating seedling some wind protection.

Special grass drills with packing wheels and other special features are available. Warm season grass boxes are available to handle the fluffy prairie grass seed. These units have devices within the boxes to prevent the *bridging* of seed, resulting in even seed flow.

Herbaceous material such as bermudagrass or American beachgrass or trees requires special knowledge of the plant requirements and handling. Internal heating of this material frequently occurs during shipping and storage. The damage to the growing points may go undetected by an untrained person until the plants do not grow. During delivery and planting, every effort to keep the plants cool and moist is crucial for good survival and growth.

Mulching — Mulching is an important process in establishing vegetation (especially cool-season grasses) on structures or other critical areas. Mulch cover will help maintain favorable moisture, prevent soil movement from raindrop impact, hold seed in place, and maintain cooler, more constant soil temperatures. Mulch should be applied immediately after seeding (within a few hours or less). It should be uniformly applied, to the amount specified.

Mulch material (table 506–1) is not all equal in providing the optimum conditions for germinating seeds. Small grain straw is hard to beat! This material generally has few weed seeds and provides the best results of any tested material. Grass or mixed legume and grass hay is good but frequently has weed and hay seeds that will also grow. This may provide severe competition to the desired seeded species for moisture, nutrients, and light. This is a problem with warm-season grass plantings. It does not make much sense to use certified seed and then throw weedy mulch over the seeding. Other fibrous material such as coconut fiber, excelsior fiber and wood fiber all may be used. Economics will sometimes dictate which mulch material is used. Many latex compounds and commercial products will control erosion and hold seed in place under some moisture and temperature regimes.

Mulch material can be selected from the list below. Use appropriate materials for the location.

The optimum mulch material for cool season grasses and legumes is small grain straw at 4,000 pounds per acre, anchored with 500 to 750 pounds wood fiber hydromulch. This will provide optimum conditions for rapid germination and establishment.

Table 506-1 Common mulch material

Mulch material	Quality standard	Application rate	Remarks
Hay, small grain straw	Air-dried; free of mold; free of noxious weeds.	2 tons per acre.	Subject to wind blowing unless anchored; cover about 90% of soil surface.
Wood excelsior	Green or air-dried burred wood fiber.	2 tons per acre.	Decomposes slowly; subject to blowing unless anchored; pack aged in 80-90 lb bales.
Wood fiber cellulose	Partially digested wood fiber; usually with green dye and a dispersing agent.	2,000 lb per acre.	Apply with hydroseeder; used as an anchoring material for mulches subject to blowing.
Jute mat - twisted yarn	Undyed, unbleached plain weave; warp 78 ends/yd; weft 41 ends/yd; 60–90 lb rolls.	48 in x 50 yd or 48 in x 75 yd.	Use without additional mulch; secure as per manufacturers' specification.
Excelsior wood fiber mats	Interlocking web of excelsior fibers with photodegradable plastic netting.	48- x 100-inch 2-sided plastic or 48- x 180-inch 1-sided plastic.	Use without additional mulch; secure as per manufacturers' specification.
Straw or coconut or combined mats	Photodegradable plastic net on one or two sides.	6.5 x 83.5 ft, 81 rolls per acre.	Designed to withstand fiber individually specific water velocities.

Mulch anchoring—Once mulch is applied, it must remain in place. Few if any of the seeded species will establish in bare areas from which the mulch has moved. On critical sites that are droughty and wind swept, mulch anchoring must be performed to obtain uniform establishment. The cost of establishing erosion control cover is frequently justified, and reducing the area needing reseeding offsets this cost. Mulch anchoring material selection and application rate is important to establish some species.

Material for anchoring fibrous material ranges from wood fiber hydromulch to latex compounds to asphalt emulsion, to mesh netting, to mulch blankets. All are excellent for specific situations. Follow manufactures recommendations for use. Selection is dependent on the intended use, cost, and available labor or equipment.

A wide assortment of implements is available to anchor mulch by incorporating some of the mulch into the soil surface.

Ultimately, the local growing conditions will dictate the outcome of the seeding. If a short-term drought occurs as the seed is germinating, allowing the mulch to be blown around or removed from the site during this time may result in a seeding failure. This is especially critical on droughty soils and for spring seedings.

506.04 Disturbed land

(a) Planning principles

Vegetative treatment of disturbed land areas requires some planning to overcome many potential problems. These include water and wind management concerns, sedimentation, potential limiting or excess elements on site, intended land use, length of time the area or partial area must be exposed for continued construction, existing slope and planned slope and slope length, and presence or absence of vegetation. The kind of soil and drainage class will influence the type of plant desired.

Water and wind concerns must be dealt with before establishing vegetation. Plants tolerant to wind may be used to protect areas before establishing more permanent and desirable species, or temporary wind breaks (wind fence) may be used. Plants tolerant of inundation or wetness may be required along with regrading or shaping portions of the site to divert or retain water.

If grading of the site is necessary, then include salvage of topsoil and plants as possible. Shape and grade for intended future use. Areas used for sports (soccer fields) require considerably more attention and detail than an area being reclaimed for wildlife habitat.

The cause for the site to be barren or nearly so requires detective work. Past use or history of industry may provide clues to possible problems resulting in lack of vegetation. Old garage areas or motor pool areas may have petroleum contamination or battery acid spills. Mining operations may have *dumps* associated with them, in which chemicals associated with the industry were disposed of in *dumps*. By asking questions about the past use, one can then begin piecing the puzzle together. Testing for residual material or chemicals is the only way to confirm what is present or absent.

Soil physical barriers such as restrictive or compacted layers in the rooting zone need to be identified and corrected. Soil sample analysis for particle size distribution may be required. Several plants may be available for use on soil that has 40 percent fines but fewer are suitable if the fines are less than 15 percent. Select plants for the long term, not ones that will grow well for 1 or 2 years. For example, use of ryegrass and cool season grasses on sand and gravel areas will grow and provide temporary cover. However, when the fertilizer is depleted and moisture becomes deficient, the cool season plants will die off. If switchgrass and other warm season grasses are used, they will persist for more than 20 years while natural succession occurs.

Fertility levels need to be assessed before selecting the appropriate plants. Percent organic matter, potentially toxic levels of elements, and pH are interrelated, and they need to be quantified before treatment.

The natural plant succession for the area should be considered, especially when selecting species to use. It may be desirable to select species from several successional stages to include in the revegetation plan. Use plants that blend to the surrounding areas. Avoid selecting invasive species.

Biotechnical or bioengineering options should be evaluated for unstable slopes. The use of live fascines or brush layering techniques should be considered in lieu of more expensive stone gabion baskets and riprap. Chapters 16 and 18 of the Engineering Field

Handbook detail these techniques.

(b) Unique critical areas

Strip-mined areas—strip mining is the removal of overburden to gain access to some mineral or fuel. The spreading or dumping of this material frequently exposes contaminants. The coal mining in the Appalachian Mountains frequently exposes sulfur and iron that results in sulfuric acid formation. This sulfur and iron material is best covered as the mining operations progress. The soil pH can be extremely low so the plants selected must be tolerant to potential aluminum toxicity. Because of exposure, slope, and rock, these sites are frequently very droughty.

The sequence of mining operations can be the best management practice and provide for minimizing future toxic areas through proper closing of mined areas. This requires saving the overburden and replacing it on the surface in proper sequence before vegetating the area.

Coastal and inland sands and sand dunes—Areas of blowing sand need wind erosion control measures. This may be accomplished using plants such as American beachgrass or with windbreaks or by other physical structures. On inland sands, planting single or double rows of American beachgrass or other appropriate plants, perpendicular to the prevailing wind, will provide the wind protection for establishing more permanent vegetation. Spacing between rows should be ten times the anticipated height of the plants after one growing season. Wait 1 year for seeding the permanent vegetation.

Subpart 506B Suitability for crop production systems

506.20 Suitability for crop production

Crop selection in a properly designed rotation is critical to maximize rotational benefits. A properly designed crop rotation provides an excellent tool in breaking insect, weed and disease cycles (Refer to Part 503, Subpart A, Crop rotation).

In the past 10 years there has been a major shift in agriculture toward crop production systems using higher amounts of surface residue. In the United States between 1989 and 1997, there has been a 13.5 percent increase in cropland acres involved in some form of residue management. During this same time period the acres in no-till crop production systems have increased 10.1 percent. One of the consequences of this change in crop production systems, is that less seedbed modification though tillage is occurring and a greater reliance on crop selection and variety or hybrid characteristics is necessary. Conservation tillage or no-till methods require changes in machinery, fertility programs, and pesticide use. In addition to these changes, crop and seed selection must also be reevaluated. Again selecting a more desirable variety or hybrid should not be a substitution for properly designed crop rotation.

After a proper rotation has been designed, two primary areas of crop selection need to be evaluated in depth: variety or hybrid performance and after harvest seedbed characteristics for the next crop in the rotation.

(a) Variety or hybrid performance characteristics

Desirable variety or hybrid characteristics for crop production systems using higher amounts of surface residue vary among crops as to their importance. However, some common characteristics are selecting the highest-quality seed available, the right maturity for the geographic area, good early season emergence, good early season seedling vigor, consistent performance across soil types, vigorous root development and superior defensive characteristics.

Of these characteristics, choosing high-quality seed, those with the right maturity for the geographic area, and that consistent performance are not just characteristics for high residue situations but are universal among tillage systems. However, because of the cooler and wetter seedbeds normally encountered in high residue situations, these characteristics are not only important but may also need to be modified. An example would be a warm-season grass such as corn. Selecting hybrids 5 to 10 days earlier in maturity may be necessary when planting into heavy residues. In addition, consistent performance across kinds of soil is important because it is a sign that the hybrid can withstand stress under varied environmental conditions.

Early season emergence and seedling vigor become of greater importance specifically with warm-season crop species when cooler, wetter soil conditions are the rule. Selecting varieties or hybrids with good early emergence and early seedling vigor is necessary where soil conditions that have more stored soil moisture and will be cooler and wetter. Crops under these conditions must germinate quickly and have good early season growth potential to provide the necessary competitive edge required against early weed competition.

The selection of varieties or hybrids that can develop vigorous root systems without the help from conventional cultivation is also a very important characteristic for reduce till or no-till system. Some hybrids or varieties also produce a stronger stem or stalk that translates into consistent performance and may contribute to a more durable residue cover following harvest. When selecting varieties and hybrids for superior root and stem characteristics, inquire whether these characteristics have been evaluated under reduce till or no-till conditions.

Tolerance to common insect and disease can be important depending on the area and crop rotation. This can be especially true when the crop to be planted in the rotation is closely related to the preceding crop such a cool-season grass planted into a cool-season grass. Another example might be planting soybeans in field with heavy surface residues and poorly drained soils. Evaluating soybean varieties for phytophthora root rot resistance may be a major advantage in these fields. An important point to mention again is that the selection of varieties with insect or disease tolerance is not a substitution for rotation.

(b) After harvest seedbed characteristics for the next crop in the rotation

The amount, color, resistance to decay, and stubble height of residue left after harvest modify the microenvironmental conditions in the field. These variable residue characteristics can either be used to a production advantage or can be an obstacle if not properly incorporated into a cropping system. In addition, cover crops maybe used to modify the planting environment. (Refer to Subpart 508C, Soil management)

Modification of the seedbed conditions conducive for the crop to be planted has been done previously with tillage either conventionally and more recently by building ridges (ridge-till) or fall and spring strip till methods.

The condition of the seedbed not only depends on characteristics of the residue in the field but on the conditions conducive to the crop to be planted. Residue levels and color affect soil temperatures, therefore rotations where the crop to be planted follows the dark colored residue that is produced by oilseed and legume crops will speed soil warm up. Some warm-season species such as corn or sunflower respond to warm, clean seedbed conditions. This maybe accomplished solely by the preceding crop residue. An example might be planting corn into soybean residue which in relative terms is dark colored and at lower levels in the amount produced. After soybeans, the seedbed for subsequent crops will be mellow, warm, and very conducive to fast, uniform emergence. When dealing with heavier residue amounts from the preceding crop it may be necessary in no-till situations to use of residue managers that move the residue of to the side of the seed trench.

Other crop species may benefit from the micro-environmental conditions produced when high amounts of surface residue are present. Cold soil conditions when seeding winter wheat are not a concern, however surface moisture and sufficient standing stubble to catch snow are important factors to consider. In fact, sufficient soil surface residue is beneficial to prevent the soil from drying out or cooling down too rapidly and extending winter wheat growth into the fall. For another example, soybeans are sensitive to heat, drought, and high soil temperatures. Heavier surface residue levels increase soybean performance under these conditions.

When higher amounts of surface residues are desirable for crop production, the inclusion of a crop with more durable residue characteristics may be necessary. As surface residues increase, microbial populations at the surface of the soil also increase the rate of decay of these residues. The inclusion of crop that have portions of the plant that are more resistant to decay such as corn, sorghum, or sunflowers will facilitate building higher surface residue levels.

Stubble height of previous crop residues can be very beneficial in increasing soil moisture and can increase the survival of fall-planted crops. In the northern Great Plains, increasing stubble height produces a more effective snow catch, and increases the soil available water for crop production. Higher combining heights, or the use of stripper headers, have been used for this purpose. In addition, taller heights also increase the survival of winter wheat and increased the effective range of the crop further north. The maximum winter wheat hardiness is obtained with winter wheat planted into standing small grain stubble. However, when winter wheat is planted following another small grain, varieties with tolerance to leaf spotting diseases should be considered in some environments. This situation has allowed the selection of less winter hardy, higher yielding varieties, with tolerance to leaf diseases, to be planted further north in the winter wheat range.

Part 507 Cropland Conservation Management Systems

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Part 507 Cropland Conservation Management Systems

Subpart 507A Major cropland practices

507.00 Cropland conservation management systems

Carter and Dale (1955, 1974) studied many of the civilizations that have existed in the past sixty centuries. The book *Topsoil and Civilization* recounts their findings and characterization saying that "civilized man has marched across the face of the earth and left a desert as his footprints." One of the essential historical elements was that a civilization only remained in one location for approximately 1,000 to 1,500 years before declining. More than 30 civilizations advanced and then deteriorated as their agrarian systems weakened because of three factors. These were desertification, mismanaged soils, and a depletion of the requirements for crop growth. The authors note though that there were three exceptions. These included the Indus Valley, in present-day Pakistan; Mesopotamia; and the Nile Valley. There are three factors attributable to the continued development of these three civilizations. They include

- lack of soil erosion by water due to low rainfall and flat topography;
- adequate soil fertility; and
- dependable water supply in the form of irrigation.

Desertification has not been limited to the past nor limited to certain world locations. In the United States it was estimated in 1981 that about 225 million acres were subject to ongoing desertification processes (Sheridan, 1981). Its symptoms include serious soil erosion rates, soil and water salinization, declining ground water and surface water supplies, and depredation of native vegetation. Our past lessons in dealing with croplands have recognized that intensive use of the soil has resulted in reduced yields primarily because of diminished organic matter (Reicosky, et al. 1995). Within the Great Plains of the United States, soil degradation has resulted from widespread application of fallow and tillage (Bauer and Black 1981; Haas, et al. 1957).

Just as with other land uses, the development of sustainable cropland conservation management systems involves effective conservation planning. This conservation planning process views the agroecosystem as an integration of complex natural physical, chemical, and biological functions. Our look back at history should convince us that undertakings to *manage* agroecosystems as a natural resource must consider the entire system rather than just the parts. Nothing less than managing for the *whole* or health of the agroecosystem is acceptable. Managing for the health of the agroecosystem requires acceptance of a holistic approach to conservation planning to achieve some degree of sustainability.

The same general principles that Hugh Hammond Bennett set forth in 1947 are still applicable in the development of effective conservation management systems on cropland. The principles are summarized as follows:

- Consideration and focus on the producer's goals. As a part of this goal setting process, an evaluation is made of the producer's farm and livestock facilities, machinery, and economic situation. The product of this principle results in the establishment of three action statements that further define the goal. The statements are
  - the quality of life that the producer wants derived from the agroecosystem;
  - the forms of production and management tools required to deliver the quality of life; and,
  - a description as to what the farm's landscape or the desired future condition is to look like (Savory 1988).

  Also, the description includes the producer's expectation of the farm's production ability to be sustained.
- Evaluation of the needs and capability of each cropland acre.
- Incorporate the producer's willingness to implement and adapt new technology and practices.
- Consideration of the landscapes relationship and function to the entire farm and watershed.
- Continued presence of the conservationists with the producer. In any holistic approach to management of the agroecosystem there is a requisite for monitoring and assessment of the function of the system.

In addition, there will be assessment indicators and events that will demand re-planning. In many cases the specific management tools will need to be altered, or in some cases a current tool is abandoned and a different one implemented.

507.10 Cropland conservation management systems — humid east

507.11 Typical cropland resource concerns

One or more of the resource problems listed are a concern on cropland in the humid east of the United States.

- Erosion from water or wind, or both
- The condition of the soil (its tilth, its health)
- Soil compaction
- Available water (too much, too little)
- Pests (weeds, insects, diseases)
- Soil/plant nutrient management
- Water quality of the runoff or ground water, or both
- Pesticide management, selection, drift, leaching, runoff, and resistance
- Economics
- Compliance with USDA programs and other Federal, State,and locals laws

507.12 Purposes, effects, and impacts of the major cropland

Practices/treatments used to address the resource concerns about cropland situations often have complimentary effects on the resource concerns. For example, by selecting a rotation of different crops (conservation crop rotation practice) to meet soil erosion, soil condition, and producer needs; the practice also has complimentary effects on reducing weed, disease, and insect pressures (pest management practice). Likewise, a practice/treatment selected to treat one concern may have an adverse effect on another resource concern. For example, the use of the no-till practice may be effective to reduce erosion, improve soil condition, and reduce nutrient and pesticide runoff; but no-till may have an adverse effect on the production system if a proper crop rotation and nutrient and pest management are not implemented at the same time. Therefore, as a cropland management system is planned, it is critical to understand all the effects of the practices/treatments being considered on the total production system.

Table 507-1 has examples of some of the major purposes and expected effects of the most commonly used practices/treatments on cropland. The purposes identified are expressed in the National Practice Standards as well as additional purposes/effects for local consideration.

Conservation management systems for cropland include a combination of practices/treatments necessary to address existing and anticipated soil, water, air, plant, animal, and human resource concerns, and treat all the concerns to a minimum acceptable level. Cropland involves the growing of annual or a mixture of annual and perennial crops. To produce crops requires the continued management of soil, water, air, plants, and their associated components to meet the objectives of the producer and to maintain a sustainable production base.

A large number of potential practices/treatments can be used on cropland. However, there are few major practices/treatments that form the foundation (or core) of most cropland conservation management systems. The major practices/treatments that form the core of cropland management systems involve those that relate to the

- selection and rotation of crops,
- tillage or planting system (crop establishment),
- residue management,
- fertility management, and
- pest management.

Other major practices/treatments include irrigation management, surface and subsurface water management, contouring, buffer strips, and filter strips.

To successfully produce crops in an economical and sustainable manner requires an accurate assessment of the resources' (soil, water, air, plants, animals, human) capabilities and limitations. The core practices of crop rotation, timing and type of tillage, how the residue is managed, nutrient management, and pest management are almost always involved to address the capabilities and limitations (resource concerns) of any cropland management system.

Table 507-1 Example of major purposes and expected effects of commonly used conservation practices/treatments on cropland

Practice/treatments and National Practice Standard code	Purposes and effects
Conservation crop rotation Code 328	Reduce sheet, rill, and wind erosion Produce needed feed for livestock Produce needed residue for soil organie matter Manage soil nutrient levels Improve soil condition, tilth, health Manage or break pest cycles, or both Improve wildlife food and cover
Residue management Code 329 series No-till and strip-till (A) Mulch till (B) Ridge-till (C)	Reduce sheet, rill, and wind erosion Improve air quality (reduced dust and soil particlate in the air) Improve soil condition, tilth, health Improve soil available water content Reduce nutrient and pesticide runoff Reduce sedimentation Reduce trips across the field (compaction potential) Reduce time demands for seedbed preparation Reduce cost of equipment and field operations Improve wildlife cover
Residue management, Code 344 Seasonal	Reduce sheet, rill, and wind erosion Provide residue for livestock grazing Provide food and cover for wildlife Manage available soil water Reduce runoff during selected times of the year
Contour farming Code 330	Reduce sheet and rill erosion Reduce power requirements Improve soil available water content Reduce surface runoff Redice nutrient and pesticide runoff Safety during field operations
Contour buffer strips Code 332 Contour stripcropping Code 585 Field stripcropping Code 586	Reduce sheet, rill, and wind erosion Improve soil condition, tilth, health Improve soil available water content Reduce surface runoff Reduce nutrient and pesticide runoff Reduce sedimentation Reduce power requirements

Table 507-1 Example of major purposes and expected effects of commonly used conservation practices/treatments on cropland—Continued

Practice/treatments and National Practice Standard code	Purposes and effects
Nutrient management Code 590	Provide the necessary nutrients for plant growth Manage soil fertility a desirable and economic levels Reduce nutrient leaching and runoff
Pest management Code 595	Manage weeds, insects, and diseases within established threshold levels Reduce pesticide runoff and leaching Reduce pest tolerance and resistance to cultural, biological, and chemical treatments
Filter strips Code 393	Reduce offsite sedimentation Reduce nutrient and pesticide runoff Biologically treat runoff Improve infiltration and treatment of runoff Provide food and cover for wildlife

Other common practices/treatments used in cropland management systems include

- cover crops,
- cross wind strips,
- waste utilization,
- subsoiling,
- terraces,
- subsurface drainage,
- surface drainage,
- grassed waterways, and
- water and sediment control basins (control concentrated flow/gully erosion).

Regardless of what is categorized as core practices/ treatments or major practices/treatments, cropland management systems must address the following:

- Crop(s) to be grown within the resource capabilities and limitations.
- Producer's needs and concerns.
- How will the crop(s) be established (timing/type of tillage and planting).
- How will the residue be managed.
- Adequate nutrients for the crops.
- Control of pests (weeds, insects, and diseases).
- Managing the soil water.
- Sustainability of the production base.

The first step in developing a cropland management system is to fully assess the resource capabilities and limitations (a resource assessment) and determine the producer's capabilities, limitations, and objectives. This will establish the baseline to begin to build an effective conservation management system for cropland. One must also keep in mind that although different cropland systems may have the same practices planned, the treatment within those practices may be different to meet different purposes. In addition, cropland systems with the same combination of practices but planned for different purposes may have different effects on the resources and concerns.

507.13 Economics of the major agronomic practices/ treatments

To assess the economics of the agronomic practices is often difficult. The traditional method used to assess the economics of various agronomic practices is to compare different methods to achieve a given treatment or purpose. For example, a seedbed must be prepared for planting. One method would be to use mulch-till and compare that cost to using no-till. It is critical that the costs involved in agronomic practices/ treatments be carefully analyzed. For example, in the mulch-till vs. no-till scenario mentioned previously, if the producer owns both mulch-till tools and no-till tools, one can only evaluate operation and maintenance costs of the equipment because the costs of the equipment are already incurred regardless of the system used.

Most agronomic type practices/treatments do not require a direct outlay of cash. Many of the practices and treatments are often more of a change in management techniques rather than a formal installation.

To select the most cost-effective cropland management system, first develop two or more alternative management systems that adequately treat the resources and meet the producer's objectives. Then assess the total costs to implement each system vs. the expected impacts and returns.

Generally speaking, agronomic practices do not cost; they pay. The key is to plan and apply the combination of practices/treatments that address the management style of the producer and will result in use of the land within its capability.

507.20 Resource concerns and effects-dryland regions of the Great Plains and western United States

In discussing major cropland management practices within the Great Plains and western regions of the United States, a distinction must be made between the term's *dryland* and *rain fed*. Rain-fed agricultural systems can be used to describe agricultural systems that exclude irrigation as a water source and generally fall into two categories. The first category of rain-fed agricultural systems are those that emphasize maximum crop yields, significant production inputs, and disposal of excess water, while the second category of rain-fed agricultural systems characterize the *dryland* systems (Stewart 1988; Stewart and Burnett 1987).

Several investigators have proposed various definitions of *dryland* or dry farming (Duley and Coyle 1955; Hargreaves 1957; Higbee 1958). Common to all definitions, these "dryland" systems are those which describe production techniques under limited precipitation and usually severe resource concern constraints. The resource constraints include soil erosion by both wind and water; periods of water stress of significant duration; and limited production inputs. Another distinction is that the *dryland* systems focus on crop yield sustainability and water conservation/water harvesting techniques. To further define *dryland* Oram (1980) has suggested six criteria to be used in describing dryland regions and systems:

1. Occurrence of very high intensity rainstorms.
2. Potential evapotranspiration exceeds the precipitation for a minimum of 7 months during the year.
3. Decreased reliability and increased precipitation variability as annual precipitation decreases.
4. Low total annual precipitation accompanied with at least one pronounced dry season.
5. Large annual precipitation variations from year-to-year.
6. Large monthly variations in precipitation.

507.21 Defining and describing dryland regions

A number of attempts have been made to quantitatively describe and categorize dryland regions. The older accepted approaches generally included some form of the Thornthwaite precipitation effectiveness index (P-E) are presented and reviewed elsewhere (Brengle 1982).

Stewart (1988) reviews two methods hereby referred to as the FAO method and the UNESCO (United Nations Educational, Scientific and Cultural Organization) method. Based on the length of growing season the FAO method delineates dryland climatic regions as dry, arid, and semiarid. The UNESCO method delineates four dryland zones (hyperarid, arid, semiarid, subhumid) based on an index, called the climatic aridity index. Both methods use daily values of precipitation (P) and potential evapotranspiration (ETp). Since daily values are evaluated, an appropriate energy balance method for estimating ETp for short time steps should be used. This would include the Penman method or one of its several variations based on local conditions and available data.

FAO Method. The length of the growing period in the FAO method is the number of days that have a mean daily temperature greater than 44 degrees Fahrenheit (6.5 °C) during the year when P is greater than 50 percent of ETp (0.5 ETp), plus the number of days required to use about 4 inches (10 cm) of stored soil profile water. Regions classified as dry are those where P never exceeds 0.5 ETp; arid where the length of the growing period is between 1 and 74 days; and, semiarid where the growing period is between 75 and 119 days.

UNESCO Method. The UNESCO method uses the climatic aridity index. The climatic aridity index (CAI) is the ratio of the precipitation (P) to the potential evapotranspiration (ETp) (CAI=P/ETp). The four climatic zones are delineated in table 507-2.

507.22 Regional resource settings of dryland cropping areas of the United States

In the United States and Canada, six distinct dryland-farming regions can be identified. The six regions are the Southern Great Plains, Central Great Plains, Northern Great Plains, Canadian Prairies, Pacific Northwest, and the Pacific Southwest (fig. 507-1). Also shown are the five specific areas of dryland production.

Common to all of the regions is the non-beneficial use of soil water through evaporation and the practice of summer fallow. There are, however, a number of general distinctions other than crop adaptability that can be made between the regions. The distribution and types (snow versus rainfall) of precipitation differ greatly. Snow management can be used effectively to increase soil water storage in the northern regions. Detailed descriptions of these regions are in Cannell and Dregne (1983).

Table 507-2 Climatic zone delineation

Zone	CAI
Hyperarid	CAI < 0.03
Arid	O.03 <CAI < 0.20
Semiarid	0.20 < CAI < 0.50
Subhumid	0.5 0< CAI < 0.75

507.23 Principles and guidelines of dryland conservation Management systems

(a) Basic principles

In natural ecosystems the successional process advances until something limits it. Moreover, as succession continues, the complexity, diversity, and stability increases (Savory 1988). The result of a complex, diverse, and stable ecosystem is increased productivity. Secondly, everything that occurs within an ecosystem can be described in terms of the effectiveness, or lack of effectiveness in the water cycle, nutrient cycle, succession itself, and the flow of carbon (energy) through the ecosystem.

The same concepts can certainly be applied to dryland agroecosystems. The successional process in a natural system is analogous to the sequence of crops in rotation. Like natural systems, the successional process of dryland systems can advance until something limits it. In most cases, this limiting factor is climate. The holistic approach, though, teaches us that there may be additional limitations. The most common of these include economics and market forces.

The underlying principles directed at the development of a sustainable dryland cropping system include three elements. These elements are:

- rotation intensity,
- rotation diversity, and
- management.

First, any given crop rotation must have a crop succession of sufficient intensity to assure maximum use of effective precipitation.

Secondly, the crop rotation must have sufficient diversity, which is central to the whole-system management philosophy. Agroecosystem diversity is more than the interaction and manifestation of physical and biochemical processes. It includes all of the concepts related to not only the promotion of effective nutrient cycling and expansion of disease and weed control strategies. Diversity also considers human and economic factors, in that the crop rotation must have

Figure 507–1 Major dryland regions and production areas of the United States and Canada. (Cannel and Dregne 1988)

sufficient diversity for distributing workloads and economic risks. Gleissman (1998) outlines six specific benefits and characteristics of diverse agroeco-systems. The following can be identified and applied to the dryland areas:

- Greater stability and diminished external input requirements. Stability not only includes the lack of fluctuating crop yields; but also includes the ability to spread out workload and fixed costs; and the reduction in weather and price risks.
- Greater harvestable biomass production potential.
- Larger soil carbon pool resulting from increased total biomass.
- Diminished need for external nutrient inputs resulting from efficient nutrient cycling.
- Reduced risk of economic crop loss resulting from greater species diversity.
- Increased opportunity to break insect and disease cycles; and potential for effective application biological control strategies.

Thirdly, the crop rotation that has sufficient intensity and diversity must be managed properly. The proper management levels include using tillage and planting methods that reduce soil disturbance and renewing dependence on cultural practices that will reduce reliance on costly technology.

(b) Intensity

The intensity of crop rotations in the dryland areas of the United States can be based on the water use patterns of the various crops (Beck and Doerr 1992; Beck 1997). The higher the water use the greater the intensity. Crops can be divided into high water use crops and low water use crops. High water use crops are those full-season summer-grown crops such as corn, sunflower, soybean, and cotton. Low water use crops are those classified as short-season and cool-season crops. Examples include small grains, flax, millet, and lentils.

The application of the method gives arbitrary increasing values with increasing crop water use; respectively. That is,

- fallow (no crop water use) has a zero (0) value;
- low water use crops has a value of one (1); and
- high water use crops has a value of two (2).

The intensity is equal to the sum of all of the crop water-use values, divided by the number of crops and fallow in the rotation. For example, a winter wheat-fallow rotation has an intensity of only 0.50 (0+1=1 divided by 2); and a spring wheat-winter wheat-corn-sunflower rotation has an intensity of 1.50 (1+1+2+2=6 divided by 4).

(c) Diversity

Ecologists have developed several measures of diversity. The most widely used procedures are the Shannon, Simpson, and Margalef diversity indices (Gleissman, 1998). The Natural Resources Conservation Service, formerly Soil Conservation Service, has made several attempts at describing the influence of crops and tillage on productivity and sustainability (Soil Conservation Service 1976; King 1977). A much simplified and holistic approach to describing diversity has been proposed by Beck (1996). The diversity index accounts for the different crop types and their intervals within the rotation. The crop types considered are as follows:

- Cool-season grasses (winter wheat, spring barley)
- Warm-season grasses (corn, millet, sorghum)
- Cool-season broadleaf (flax, lentils, canola)
- Warm-season broadleaf (soybean, cotton, dry bean, sunflower)

In addition, the index accounts for ecological considerations such as those relating to weed and disease pressures, as well as workload distribution and the conflicts between operational interferences. These include planting interference of one crop with the harvest of another crop in the rotation. Diversity values generally range from –0.50 (winter wheat-fallow) to nearly 4.0 for highly diverse rotations such as spring wheat-winter wheat-soybean-corn.

Both the intensity and diversity indices, as defined, offer tools that can be used to evaluate rotations. The utility of these tools is particularly useful during the initial planning phases.

507.24 Factors in planning dryland cropping systems

The following factors need to be considered in planning dryland-cropping systems:

- Evaluation of the historic precipitation patterns and rainfall probabilities.
- Crop marketability and potential profitability.
- Determination of insect cycles and potential disease organisms.
- Crop water use patterns.
- Assess snow management opportunities.
- Weed control options and evaluation of ability to rotate herbicide types.
- Optimum row widths.
- Potential phytotoxicity.
- Equipment needs.

507.25 Major cropping systems and technologies for the dryland regions of the United States

As previously mentioned, the resource constraints of the dryland regions of the United States are three-fold:

- soil erosion by both wind and water;
- periods of water stress of significant duration; and,
- limited production inputs.

Probably the most important factor affecting the constraint associated with limited production inputs is soil fertility. The inability to make precise fertilizer recommendations under diverse and variable precipitation patterns comprises efforts in obtaining maximum economic returns.

The focus of dryland systems is on crop yield sustainability and water conservation/water harvesting techniques. Thus, the sequence of crops and the characteristics of each crop control every other aspect of the cropping system.

Briefly, table 507-3 identifies the major crops, crop rotations, and management technologies.

Table 507–3 Major cropping systems and water and soil conservation management technologies for U.S. dryland agricultural regions

U.S. dryland agricultural regions	Cropping systems: Crops	Cropping systems: Crop rotations	Water and soil conservation management technologies	
Southern Great Plains	Winter Wheat (WW) Grain Sorghum (SO) Cotton (OC) Sunflower (SF) Forage Sorghum (SD) Alfalfa (AL) Guar (GU) OC-SF	con't OC con't WW WW-fallow WW-SO/SD-fallow WW-OC-fallow con't SO/SD WW(3)-OC(3)-fallow	• No-tillage • Weed Control • Summer fallow • Vertical mulching • Terrace • Contouring • Furrow diking • Furrow blocking	• Bench terraces • Mulch-tillage • Alternate irrigation/dryland • Variable rate planting • Delayed planting dates • Nutrient management • Pest management
Central Great Plains	Winter Wheat (WW) Grain Sorghum (SO) Sunflower (SF) Forage Sorghum (SD) Grain Corn (CG) Millet (MO) Dry bean (BD) con't BD	WW-fallow WW-SO/SD-fallow WW-CG-fallow WW-SF-fallow con't SO/SD WW-MO-fallow SF/SG-BD	• No-tillage • Mulch-tillage • Terrace • Contouring • Weed control • Summer fallow	• Snow management –tall wheatgrass barriers –annual crop barriers • Nutrient management • Stripcropping • Pest management
Northern Great Plains	Barley (BA) Winter Wheat (WW) Spring Wheat (WS) Oats (OT) Flax (FL) Safflower (SA) Sunflower (SF) Grain Corn (CG) Soybean (SB) Alfalfa (AL) Millet (MO)	WW/WS-fallow BA-fallow WW/WS-BA-fallow WS-WW-fallow WW-BA-SB WS-SF/SA/SB WS-OT-SF/SA/FL-BA WS-WW-CG-SB/SF BA-WW-CG-SB/SF WW-CG-MO-fallow WW-SF-fallow CG-SB WS-FL/SF/SA-fallow BA-CG	• No-tillage • Mulch-tillage • Summer fallow • Weed control	• Snow management –tall wheatgrass barriers –annual crop barriers –field shelterbelts/ tree windbreaks –bench terraces w/ grassed dikes • Nutrient management • Stripcropping • Pest management
Pacific Northwest	Spring Lentil (LDs) Winter Lentil (LDw) Spring Barley (BAs) Rapeseed (RB) Green Pea (PG) Austrian Winter Pea (AW) Winter Wheat (WW) Spring Wheat (WS) Spring Pea (PF)	WW-LDs/PF WW-LDw BAs-fallow BAs-PF RB-fallow PG-RB AW-WW-BAs WW-AW-BAs/WS WS-fallow WW-fallow	• Slot mulching • No-tillage • Mulch tillage • Summer fallow • Weed control • Terrace • Contouring	• Nutrient management • Stripcropping • Pest management
Pacific Southwest	Winter Wheat (WW) Pasture (PT) Spring Barley (BAs)	WW-fallow WW-PT-fallow BAs-fallow BAs-BAs-fallow	• Water harvesting • Summer fallow • No-tillage • Mulch tillage	• Terrace • Snow melt control w/ flyash • Weed control • Pest management • Nutrient management

Subpart 507B References

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Part 508 Soils

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508.30 Soil conditioning index for cropland management systems—background

(a) Regional versions of the Soil Conditioning Index

In 1964, Wayne Austin published Conservation Agronomy Technical Note No. 27, “Soil Conditioning Rating Indices for Major Irrigated and Non-Irrigated Crops Grown in the Western United States,” through the then SCS West National Technical Center (WNTC), Portland, Oregon. This Technical Note was revised by J.W. Turelle in 1967, and again reprinted by F.L. Brooks in 1974.

A.D. King and others prepared a shorter version in 1986 through the South National Technical Center (SNTC), Fort Worth, Texas.

(b) A National Version

This version of the rating procedure adapts the concept for use nationwide, by introducing the effects of climate on organic matter decomposition at various geographic locations. The latest version of the Soil Conditioning Index is available as an Excel spreadsheet at

ftp://ftp.nssc.nrcs.usda.gov/pub/lightle/scifiles/

The important components of the Index (SCI) include
- the amount of organic material returned to the soil,
- the effects of the tillage and planting system on organic matter decomposition, and
- the effect of predicted erosion associated with the management system.

Rating values for these variables were determined subjectively, and are described below.

(c) The concept

For much of its history, NRCS (formerly SCS) worked primarily on the problem of soil erosion on agricultural and other lands. Predictive/evaluation tools such as the Universal Soil Loss Equation (USLE) and the Wind Erosion Equation (WEQ) enhanced conservation planning for erosion control.

New concepts of planning developed in the 1990's broadened the planning approach to consider five resources—soil, water, air, plant, and animal—and multiple resource concerns associated with each resource.

One area of concern is degradation of soil quality through processes that are influenced by management. One such concern is organic matter decline under cultivation. The Soil Conditioning Index is a tool to predict the consequences of management actions on the state of soil organic matter.

Precedents for this predictive tool are in WNTC Technical Note No. 27 (1964) and the SNTC version developed in 1986, discussed in 508.30 (a).

This version of the Index predicts organic matter change qualitatively, not quantitatively. It predicts one of three outcomes — organic matter decline, organic matter increase, or organic matter equilibrium.

The procedure depends on the assumption that the amount of biomass that must be returned, to maintain equilibrium, is directly proportional to rate of decay. In moist climates, decomposition is more rapid than in dry climates, thus more biomass is needed. The same is true comparing warm to cool climates. *Maintenance amounts* of crop residue at locations throughout the United States were calculated based on this assumption.

The Index considers organic material (biomass) produced and returned to the soil, the influence of climate on organic matter decay, the influence of tillage, and the influence of erosion.

Decomposition functions of Revised Universal Soil Loss Equation (RUSLE) were used to estimate relative rates of plant residue decomposition at different locations. Climate at each location is expressed as average monthly precipitation and average monthly temperature.

(d) Components of the Soil Conditioning Index

A combination of effects causes degradation of soil condition. Wind and water erosion remove fine soil particles, organic matter, and plant nutrients, thus reducing productivity and the ability of the soil to hold water. Excessive tillage accelerates erosion and organic matter decay, and causes compaction. Crop rotations which produce low amounts of residue, and/

or which involve extensive residue removal, result in inadequate amounts of organic material returned to the soil.

The formula for the Soil Conditioning Index is:

$$SCI = OM + FO + ER$$

where:

SCI is the Soil Conditioning Index: Soil Conditioning Index estimates the combined effect of three variables on trends in soil organic matter. Soil organic matter trends are assumed to be an indicator of improvement or degradation of soil condition.

OM is organic material: This component accounts for the effect of organic material returned to the soil. Organic material from plant or animal sources may be either grown and retained on the site or imported to the site.

FO is field operations: This component accounts for the effect of field operations that stimulate organic matter breakdown. Tillage, planting, fertilizer application, spraying and harvesting crush and shatter plant residues and aerate or compact the soil. These effects increase the rate of residue decomposition and affect the placement of organic material in the soil profile.

ER is erosion: This component accounts for the effect of removal or sorting, or both, of surface soil material by the sheet, rill, or wind erosion processes that are predicted by water and wind erosion models. It does NOT account for the effect of concentrated flow erosion such as ephemeral or classic gullies. Erosion contributes to loss of organic matter and decline in long-term productivity.

(e) Using the Soil Conditioning Index to evaluate conservation practices and systems

The Soil Conditioning Index tool predicts the effect of management systems on soil organic matter. Soil organic matter level is a primary indictor of soil condition. It affects such soil characteristics and processes as cation exchange, aggregate stability, water holding capacity, and soil biological activity. Soil condition is the degree to which a soil maintains the ability to accept, store and release water, nutrients, and energy, to promote and sustain root growth, to sustain soil biological and chemical processes, and to resist erosion, compaction, and other management impacts.

(i) The Index evaluates the effect of farming practices on soil organic matter. The Index expresses whether the cropping sequence, soil disturbing operations, and other management inputs tend to increase or decrease soil organic matter under a given climatic regime.

(ii) Similar to the way in which water and wind erosion models are used to assess the effects of management systems on water and wind erosion, the Soil Conditioning Index is a tool to estimate the effect of the same management systems on the physical condition of the soil resource. Like erosion models, it has broader application than any single practice, but can be used to evaluate how changes in single practices influence the effect of the management system on the soil resource.

(iii) Because erosion (the present or a planned system) is one of the variables considered, erosion estimates using RUSLE or WEQ, or both, are part of the Soil Conditioning Index procedure.

When the crop rotation is managed as part of a system to maintain or improve soil condition, criteria for design of the rotation should include the use of high-residue crops in cropping sequences. The rotation should be supplemented as needed by additional sources of organic matter such as cover crops, green manure crops, or animal manure.

Management of plant residue to maintain or improve soil condition includes limitations on residue removal by any means including grazing.

Management of field operations to maintain or improve soil condition involves limiting the number of tillage operations and the degree of soil disturbance by each operation.

Any combination of practices that help stabilize the site by controlling erosion within specified limits conserves soil organic matter. These systems may include any of the practices discussed above, as well as supporting practices such as terraces, stripcropping, or windbreaks.

508.31 The benchmark condition

This kind of predictive tool requires a point of reference or *benchmark*. A situation was selected where the impact on organic matter of various management systems and production levels could be determined from the research. The selected location was the experiment station at Renner, Texas, from 1948 to 1959.

The benchmark condition is a specific combination of organic material produced by the crop rotation, tillage and planting operations, and associated erosion that resulted in maintaining soil organic matter at a steady state during 12 years of research (Laws, 1961). The same three variables are the basis for determining maintenance amounts of crop residues and calculating the Soil Conditioning Index at any location when compared to the benchmark condition as a point of reference.

The time and location define the climate during the period of the research. Published papers tell us about the crops grown, production levels, tillage and residue management, and associated organic matter trends. Reasonable assumptions can also be made about amounts of erosion under the research conditions. Research results at Renner are described throughout this section, and are summarized in table 508.5.

508.32 Basis for the organic matter (OM) component

(a) Background

This subfactor is based on the amount of organic material returned to the soil (residue, roots, cover crops, green manure crops, animal waste) for organic matter maintenance or restoration. The maintenance amount is the assumed amount, expressed as Residue Equivalent Value (see 508.32(c)), that must be returned to the soil annually to maintain soil organic matter at a constant level (neither increasing nor decreasing).

Table 508.1 shows the maintenance amounts, for locations throughout the United States, that apply when tillage and erosion are similar to conditions during the Blacklands Farming Systems Studies at Renner, Texas, 1948–59. The Organic Material Subfactor (OM) = 0 when these conditions apply [see 508.35(a)(1)(i)]. The maintenance amount varies by climate, based on precipitation and temperature that govern biomass production and rates of decay. These are the maintenance amounts used to calculate the Soil Conditioning Index.

(b) The organic material budget

(1) Amount returned to the soil

(i) Amount produced on the site—Crop sequence and management affect organic matter maintenance. The kind of crops grown, their yields, removal of products from the field, and management of remaining residues, all affect the amount of organic material returned to the system, and soil organic matter levels.

(ii) Amount added or lost—Accounting for additions of organic material such as manure or mulch.

Residue removed at harvest or during the non-crop season include harvest for silage, grazing of crop aftermath, removal for bedding, burning, and similar practices. These losses are accounted for when estimating residue returned.

Physical losses not accounted for are those caused by shattering, materials blown from the field by wind or carried off the field by runoff water.

(iii) Root mass—Calculations of residue produced include estimated root mass to a depth of 4 inches. These estimates are based on the ratio of maximum root mass in the top 4 inches to above ground residue produced at harvest, taken from the RUSLE data base (see table 508.6 — RUSLE crop parameter data).

(2) Climatic effects on decomposition of organic material

(i) Climate, particularly temperature and precipitation, affects plant growth, biological activity, and organic matter decomposition.

(ii) An inverse relationship exist between mean annual temperature and the level of organic matter in regions of comparative rainfall. Higher temperatures stimulate microbial decomposition more than they stimulate plant growth. The decay processes that break down organic matter are more rapid in warmer climates and go on for a longer period during the year.

(iii) Organic matter levels also vary with precipitation. Both plant growth and rates of organic matter decay are higher where rainfall is high. Relatively little organic matter is found in arid soils where vegetation is sparse, because the raw materials are lacking.

(c) Determining the maintenance amount at Renner, Texas

(1) Maintenance amounts of crop residues are based on results of the Blacklands Farming Systems studies at the Renner research station, 1948-59.

(i) Residue production and trends in soil organic matter

Table 508.5 summarizes the crop rotations used in the Renner experiments, the amount of above ground crop residues produced, and the effect on soil organic matter content. System 8 (wheat-cotton-sorghum, not fertilized) and System 9 (wheat-cotton-sorghum, fertilized, manure added) are the basis for the conclusions in this paper. System 8 produced an average of 3,865 pounds of aboveground crop residue per year, and percent organic matter declined 0.14 percent during the 12-year experiment (1948 to 1959).

Wheat 5,114 lb/ac/yr x 4 yr = 20,456 lb/ac
Cotton 3,015 lb/ac/yr x 4 yr = 12,060 lb/ac
Grain sorghum 3,466 lb/ac/yr x 4 yr = 13,864 lb/ac
Total crop residue = 46,380 lb/ac
Average crop residue = (46,380 lb/ac)/12 yr = 3,865 lb/ac/yr

System 9 produced an average of 4,189 pounds of aboveground crop residue per year. In addition, each plot received four applications of manure, totaling 20 tons per acre. Assuming open lot manure at 50 percent moisture content, dry matter applied = 10 tons per acre. Percent organic matter increased 0.64 percent during the 12 year experiment.

Wheat 5,318 lb/ac/yr x 4 yr = 21,272 lb/ac
Cotton 3,237 lb/ac/yr x 4 yr = 12,948 lb/ac
Grain sorghum 4,013 lb/ac/yr x 4 yr = 16,052 lb/ac
Manure 5,000 lb dry matter/ac/yr x 4 yr = 20,000 lb/ac
Total crop residue + manure = 70,272 lb/ac
Average crop residue + manure = (70,272 lb/ac)/12 yr = 5,856 lb/ac/yr

(2) Estimating the maintenance amount

(i) The maintenance amount at Renner was estimated by analysis of System 8 and System 9. (See table 508.5.)

(ii) Percent organic matter (OM) increased 0.78 percent with 1991 pounds additional aboveground residue. Interpolating, OM loss/gain = 0 (steady state) when aboveground biomass = 4,222 lb.

[(.14/.78) x 1991] + 3,865 = 4,222 lb

(iii) Factoring the amount of residue supplied by each crop and manure equally gives the following:

Wheat [(.14/.78) x 204] + 5,114 = 5,151 lb/ac/yr x 4 yr = 20,604 lb/ac
Cotton [(.14/.78) x 222] + 3,015 = 3,055 lb/ac/yr x 4 yr = 12,220 lb/ac
Grain Sorghum [(.14/.78) x 547] + 3,466 = 3,564 lb/ac/yr x 4 yr = 14,256 lb/ac
Manure [(.14/.78) x 5,000] + 0 = 897 lb/ac/yr x 4 yr = 3,588 lb/ac
Total crop residue + manure = 50,668 lb/ac
Average crop residue + manure = (50,668 lb/ac)/12 yr = 4,222 lb/ac/yr

(iv) Adjustment for root mass. The values calculated above are increased to account for root mass in the upper 4 inches, using root mass adjustments from table 508.6.

Wheat 5,151 lb/ac x 1.259 = 6,485 lb/ac
Cotton 3,055 lb/ac x 1.118 = 3,415 lb/ac
Grain sorghum 3,564 x 1.291 = 4,601 lb/ac
Manure 897 x 1.0 = 897 lb/ac
Total above and below ground residue + manure = 15,398 lb/ac
Average all residue + manure = (15,398 lb/ac)/3 yr = 5,133 lb/ac/yr

(v) 5,133 pounds per acre per year is the calculated amount of above and below ground residue, including manure, at which organic matter content of the Renner plots stabilized. See 508.32(d)(3) for conversion to Residue Equivalent Value (REV).

(d) Residue equivalent values

To deal with variability in the rate of decomposition between various classes of crop residues, Residue Equivalent Values (REV) were developed to convert all crop residues to a common standard. Crop Group C, which includes corn, grain sorghum, and sunflower is used as the standard because these crops are commonly grown throughout much of the United States, and because the RUSLE decomposition coefficient (0.016) is intermediate in value among eight major crop groups. The Residue Equivalent Value of any plant material is its mass expressed as the equivalent mass of Crop Group C residue, based on relative annual decomposition rates. The following conversion factors for eight crop groups at Renner, Texas are calculated from their relative decomposition rates at Renner.

	Crop groups and crops	Conversion to REV
A	Small grains, except NW wheat and range region:	1.27
	Oats	
	Barley	
	Flax	
	Manure, surface application, straw or newspaper bedding	
	Millet	
	Rye	
	Wheat, spring	
	Wheat, winter	
B	Cotton; burley tobacco; peanuts:	1.01
	Cotton	
	Peanuts	
	Sugarcane	
	Tobacco	
C	Corn; grain sorghum; sunflower:	1.00
	Canola	
	Corn	
	Safflower	
	Sorghum	
	Sudan	
	Sunflower	
	Tomato plantain	
D	Small grains, except NW wheat and range region; canola; grasses:	0.97
	CRP grassland	
	PNW barley	
	PNW winter wheat	
	Bromegrass	
	Manure, swine, beef and dairy, open lots and buildings, no bedding	
	Orchardgrass	
	Ryegrass cover	
D	Small grains—*Continued*	0.97
	Tall fescue	
	Winter cover	
E	Legumes:	0.96
	Alfalfa	
	Broccoli	
	Cabbage	
	Red clover	
F	Soybeans; sugar beets:	0.94
	Beans, field	
	Cauliflower	
	Soybean	
	Strawberry	
	Sugarbeets	
G	Vegetables and specialty crops:	0.93
	Asparagus	
	Beans, green-snap	
	Beans, lima	
	Carrot	
	Cucumber	
	Lentils	
	Manure, swine, beef and dairy, settling basin	
	Muskmelon	
	Native cover, PR	
	Peas	
	Peppers	
	Potato, sweet	
	Potato, white	
	Pumpkin	
	Radish	
	Squash, summer	
	Tomato, fresh market	
	Tomato, processing	
	Watermelon	
H	Manure, surface application, poultry litter:	0.93

Examples of finding Residue Equivalent Values:

3,200 lb soybean residue x 0.94
= 3,008 lb Residue Equivalent Value (REV)

4,000 lb wheat residue x 1.27 = 5,080 lb REV

Applying these conversion factors to the maintenance amounts of aboveground residue at Renner (calculated above) gives the following:

Wheat 6,485 lb x 1.27 = 8,236 lb REV
Cotton 3,415 lb x 1.01 = 3,449 lb REV
G Sorg 4,601 lb x 1.00 = 4,601 lb REV
Manure 897 lb x 0.97 = 870 lb REV
Total residue + manure expressed as REV
= 17,156 lb/ac
Average residue + manure expressed as REV
(17,156 lb/ac)/3 yr = 5,719 lb/ac/yr

The maintenance amount of above and below ground residue at Renner has a calculated Residue Equivalent Value of 5,719 lb/ac/yr when tillage and erosion are similar to conditions during the research. Maintenance amounts and REV conversion factors at other locations in the United States are shown in table 508.1.

Continuously updated versions of the tables of data for the worksheets are located at:
ftp://ftp.nssc.nrcs.usda.gov/pub/lightle/scifiles

(e) Determining the maintenance amount at other locations

The maintenance amount of crop residues determined above is applicable at Renner under the field conditions that existed at the research plots during the years of the research. At other locations, this amount is adjusted to account for differences in climate (monthly average precipitation and temperature). The adjusted amount is applicable when soil disturbance by tillage and the amount of erosion are similar to those conditions during the research at Renner.

When the effects of tillage and other field operations are more severe than the system used on the Renner plots, the amount of crop residue needed for maintenance of organic matter is correspondingly greater. When these effects are less severe, the maintenance amount is correspondingly less. In the same way, the amount needed for maintenance is greater when predicted erosion exceeds the estimated erosion on the Renner plots (4 tons/ac/yr), and is less when predicted erosion is less than 4 tons per acre per year. The following procedure was used to establish maintenance amounts and subfactor values:

- As discussed, the maintenance amount at Renner, Texas, was determined to be 5,719 lbs of above and belowground residue (Residue Equivalent Value).
- Using the C factor routines of RUSLE, the annual decay rate of Crop Group C (corn, grain sorghum, sunflower) residue at Renner, Texas (30.95 inches average annual precipitation and 65.1 degrees mean annual temperature) was calculated.
- Annual decay rates of Crop Group C residue at other locations were then calculated in the same manner. Assuming that the average annual amount of residue needing to be returned is directly proportional to annual rates of decay:
  - The maintenance amount at any location = [(decay at the location)/(decay at Renner, TX)] x 5719, and
  - The subfactor value (OM) at the location = [residue returned (REV) - maintenance amount (REV)] x [1.0/maintenance amount (REV)].

508.33 Basis for the field operations (FO) component

(a) Background

Tillage increases the rate of decay as well as the hazard of organic matter loss caused by erosion. The frequency, depth, and aggressiveness of each tillage operation determine the magnitude of the effects on aeration, lifting, shattering or compaction. Clean tillage systems consisting of one deep primary and two or more secondary operations result in the most soil disturbance. Noninversion tillage (mixing or undercutting), involving fewer tillage trips and retaining more residues on the surface, results in slower decay rates as well as less loss to erosion. No-till systems result in the least soil disturbance.

(b) The Soil Disturbance Rating (SDR)

Each soil disturbing field operation was evaluated for its impact on **Inversion, Mixing, Lifting, Shattering, Aeration,** and **Compaction**. Each of these six impacts was subjectively assigned a value of 0 through 5, with 0 being no impact and 5 being severe impact.

See table 508.2. The Soil Disturbance Rating (SDR) for each field operation is the sum of the six impact values.

(c) The Soil Disturbance Rating at Renner

The Soil Disturbance Rating (SDR), cumulative and average annual, at the Renner, Texas research plots is calculated as follows:

Soil distrubance operations	Rating (SDR)*
Year 1: Grain sorghum	
Chop cotton stalks	3
Tandem disk (finishing)	18
Tandem disk (finishing)	18
Planter, runner shoe	1
Row crop cultivate (multiple sweeps)	19
Row crop cultivate (single sweep)	16
Harvest	5
Year 2: Winter wheat	
Shred sorghum residue	3
Buzzard wing sweeps	21
Tandem disk (finishing)	18
Tandem disk (finishing)	18
Drill wheat, hoe opener	17
Harvest	5
Year 3: Cotton	
Tandem disk (primary tillage)	26
Tandem disk (finishing)	18
Tandem disk (finishing)	18
Planter, runner shoe	1
Row crop cultivate (multiple sweeps)	19
Row crop cultivate (multiple sweeps)	19
Row crop cultivate (multiple sweeps)	19
Row crop cultivate (single sweeps)	16
Harvest	5
Cumulative Soil Disturbance Rating (SDR)	303

Average Annual SDR = 303/3 = 101

*Soil Disturbance Rating (SDR) values are in table 508.2

508.34 Basis for the erosion (ER) component

(a) Estimated erosion at Renner

Actual erosion, 1948 to 1959, on the Renner research plots is unknown. Erosion levels at about 4 tons per acre per year are assumed to have occurred, based on the following RUSLE calculation:

Rainfall factor R = 290.

Soil: Houston black clay, soil erodibility factor K = 0.32 adjusted to 0.29; soil loss tolerance T = 5 tons/ac/yr

Estimated slope: 1% x 300 ft, slope factor LS = 0.17.

Crop rotations and field operations as described above, estimated cropping-management factor C = 0.286.

Straight-row farming, support practice factor P = 1.0.

Estimated erosion = 290 x 0.29 x 0.17 x 0.286 x 1.0 = 4.0 tons/ac/yr

508.35 Subfactor values and their relationship

(a) Subfactor values

The value = 0 is assigned for conditions at assumed equilibrium (soil organic matter maintained, neither increasing nor decreasing). Conditions that tend to decrease soil organic matter, compared to the benchmark condition at Renner, are assigned negative values; those that tend to increase soil organic matter compared to the benchmark condition are assigned positive values. The range of values is described below.

(b) Organic Material (OM) subfactor

The subfactor value = 0 (equilibrium) at Renner when above and belowground biomass (grown on the site or applied) = approximately 5,719 pounds of Residue Equivalent Value (REV). At other locations this maintenance amount is adjusted for climate (precipitation and temperature).

The subfactor value = 0 at the adjusted maintenance amount for the location. The subfactor value = -1.0 (minus 100%) when above and belowground biomass = 0. All other positive and negative values are proportionate to this relationship.

Organic Material (OM) subfactor values are calculated as follows:

[Residue returned (REV)
– maintenance amount (REV)]
x (1.0/maintenance amount)

Field Operations (FO) subfactor :
Field operations (tillage and planting systems) are assigned positive or negative values based on the number, type, and severity of tillage operations compared with the system used at Renner.

The subfactor value = 0 for the system used on the Renner research plots (SDR =101).
The subfactor value = +1.0 (plus 100%) when no soil disturbance occurs (SDR = 0). All other positive and negative values are proportionate to this relationship.

Field Operations (FO) subfactor values are in table 508.3.

Erosion (ER) subfactor :
The subfactor value = 0 when predicted erosion is 4 tons per acre per year, and = +1.0 (plus 100%) when predicted soil loss = 0. Estimated erosion in excess of 4 tons per acre per year, is assigned negative values.

The organic matter enrichment of eroded sediment decreases as erosion increases and rills become more dominant, because organic matter is greatest at the surface. Therefore the appropriate erosion subfactor relationship is curvilinear.

Erosion (ER) subfactor values are in table 508.4.

Relative weighting of subfactor values
The Soil Conditioning Index is the sum of the three subfactor values, weighted for their relative importance. The weighting factors are:

Organic material	40%
Field Operations	40%
Erosion	20%

508.36 Calculating the Soil Conditioning Index

(a) To determine the maintenance amount of crop residue at your location
Table 508.1 gives the maintenance amount of crop residue at selected locations in pounds per acre per year, expressed as Residue Equivalent Value (REV), when the subfactor values for Field Operations (FO) and Erosion (ER) = 0 (Reference Condition).

(b) To evaluate the present cropping-management system
Determine the Organic Material subfactor:
Determine the total amount of residue produced on the site by the crop rotation (crop yield x pounds per unit of yield x residue to yield ratio). Adjust for root mass. Residue production parameters for various crops as used in RUSLE are in table 508.6. Adjust for any residue removed from or added to the site.

Convert residue amounts for each crop to Residue Equivalent Value (REV). REV conversion factors for seven crop groups are given for selected locations in table 508.1.

Divide total REV for the crop rotation by number of years in the rotation to determine average annual REV.

Calculate the Organic Material (OM) subfactor value. [Residue Returned (REV) – Maintenance Amount (REV)]x[1.0/Maintenance Amount (REV)]

Determine the Field Operations subfactor:
List all field operations (tillage, planting, fertilizing, cultivating, etc.). Find the Soil Disturbance Rating (SDR) for each operation in table 508.2. Total the Soil Disturbance Rating values and divide the cumulative total by the number of years in the rotation to determine average annual Soil Disturbance Rating.

Find the corresponding field operations (FO) subfactor value in table 508.3.

Determine the Erosion subfactor:
Determine predicted average annual erosion using RUSLE or WEQ, or both, if applicable.

Find the corresponding Erosion (ER) subfactor value in table 508.4.

Calculate the Soil Conditioning Index (SCI):

SCI = (OM x 0.4) + (FO x 0.4) + (ER x 0.2)

If the SCI value is negative, soil organic matter is predicted to be decreasing, and corrective measures should be planned. If the SCI value is zero or positive, soil organic matter is predicted to be stable or increasing.

(c) To evaluate one or more alternative systems:

To formulate alternatives, plan changes in the cropping-management system that will address negative subfactor values. For example:

- If the Organic Material (OM) subfactor is negative, plan for additional high residue crops in the rotation, and/or limit residue removal.
- If the Field Operations (FO) subfactor is negative, plan changes in the tillage/planting system to reduce the number and/or severity of field operations.
- If the Erosion (ER) subfactor is negative, consider supporting practices such as terracing, strip cropping, etc., as well as changes in the crop rotation or field operations.

Describe the alternative system (rotation and field operations) and follow the same procedure as "(b) To evaluate the present cropping-management system" above.

(d) Example problem

Site information

Location: Lincoln, NE
Soil: Sharpsburg silty clay loam
Soil loss tolerance T = 5 tons/ac/yr
Slope: 6% x 200 ft
Supporting conservation practices: None
Maintenance amount (table 508.1):
5455 lb/ac/ yr, REV
Crop rotation:
Year 1 - Corn, 125 bu/ac
Year 2 - Drilled soybeans, 35 bu/ac
Residue management:
All residues returned, 5399 lb/ac/yr, REV
Organic Material subfactor OM
[(RP - MA)/MA] = -0.01

Present management system

Fall mulch tillage
Year 1
Chisel plow, straight points
Tandem finishing disk
Field cultivator, w/sweeps
Plant corn, double disk opener
Harvest

Year 2
Chisel plow, straight points
Tandem finishing disk
Field cultivator, w/ sweeps
Drill soybeans, double disk opener
Harvest

Cumulative Soil Disturbance Rating SDR
(table 508.2) = 138
Average annual SDR = 138/2 = 69
Field Operations subfactor FO (table 508.3)
= +0.31
Predicted erosion = 10.5 tons/ac/yr
Erosion subfactor ER (table 508.4) =–1.28
Soil Conditioning Index SCI
= OM x 0.4 + FO x 0.4 + ER x 0.2
= (-0.01 x 0.4) + (0.31 x 0.4) + (-1.28 x 0.2)
= -0.004 + 0.124 - 0.256 = (-)0.136

The SCI value is negative. Soil organic matter is predicted to be decreasing, and corrective measures should be planned. Erosion is the major factor affecting organic matter loss. Some alternatives are:

- change to a no-till system, which will reduce erosion and minimize soil disturbance, or
- apply measures such as terracing and contour farming to reduce erosion.

Alternative management system

No till
Year 1
Broadcast fertilizer
Plant corn, >2-inch fluted coulters
Harvest
Year 2
Drill soybeans, single disk opener
Harvest
Cumulative Soil Disturbance Rating SDR (table 508.2) = 26
Average Annual SDR = 26/2 = 13
Field Operations Subfactor FO (table 508.3) = +0.87
Predicted erosion = 3.2 t/ac/yr. Erosion Subfactor ER (table 508.4) = +0.25

Soil Conditioning Index SCI
= OM x 0.4 + FO x 0.4 + ER x 0.2
= (–0.01 x 0.4) + (0.87 x 0.4) + (0.25 x 0.2)
= -0.004 + 0.348 + 0.05 = +0.39
The SCI value is positive. Soil organic matter is predicted to be increasing, and this alternative is suitable.

508.37 Calibration of the Soil Conditioning Index to other research sites

Research data from locations in the Corn Belt (Clarinda, Iowa) and the Northern Great Plains (Culbertson, Montana) was used to test the Soil Conditioning Index procedure under varying conditions of crops, tillage, and climate. The index agreed, within reasonable limits, with results of the research.

At Clarinda, Iowa, under a continuous corn rotation that ran for 12 years, cornstalk residue grown on the plots were removed each fall after grain harvest. Chopped residue were then artificially applied in amounts of O, 1,785, 3,569, 7,139, and 14,278 pounds per acre per year. A system of moldboard plowing and clean tillage was used. Erosion was estimated to average 5.6 tons/acre/year. Under these conditions, organic carbon decreased when 3,569 pounds per acre per year of residue was applied, and increased when 7,139 pounds per acre per year was applied. By interpolation, organic carbon stabilized when about 5,156 pounds per acre per year was applied under the research conditions. When 5,156 pounds of above ground residue is returned (OM subfactor = +0.08), tillage includes fall moldboard plowing followed by two spring tillage operations (FO subfactor = +0.11), and erosion is 5.6 tons/acre/year (ER subfactor =-0.30), the Soil Conditioning Index = +0.01.)

Research at Culbertson on a spring wheat—summer fallow system maintained organic matter at a constant level when only 316 pounds per acre per year of wheat residue was returned in alternate years. Slow decomposition because of the relatively cool dry climate, subsurface tillage, and low erosion rates helped offset the effect of low residue amounts. In this experiment, four residue levels were established in the spring following harvest by removing or adding wheat straw —0, 1,500, 3,000, and 6,000 pounds per acre. Tillage to control weeds during the summer fallow year usually consisted of five operations with a V-blade. A tandem disk operation was performed in the following spring just before planting. With 316 pounds of residue returned in alternate years (OM subfactor = -0.82), stubble mulch fallow (FO subfactor = +0.41), and erosion of 1 ton/ acre/ year (ER subfactor = +0.75), the Soil Conditioning Index = -0.02.

Subpart 508D References

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Table 508.1 Maintence amounts (residue equivalent pounds) and Residue Equivalent Value factors

City code	Location	State	Mainten-ance amount including roots	Small grains except Pacific NW and manure with bedding material	Cotton, sugarcane, tobacco, and peanuts	Corn, grain sorghum, canola, safflower and sun-flower	Forage grasses, winter cover, manure-open lots and Pacific NW small grains	Legumes cabbage, and broccoli	Soybeans, field beans, sugar beets, cauli-flower, and straw-berries	Vege-tables, specialty crops and manure settling basin	Poultry litter
				Residue Equivalent Value converstion factors							
			Reference condition	Crop Group A	Crop Group B	Crop Group C	Crop Group D	Crop Group E	Crop Group F	Crop Group G	Crop Group H
1001	Birmingham	AL	5943	1.19	1.01	1.00	0.98	0.98	0.97	0.97	0.96
1002	Mobile	AL	6053	1.14	1.01	1.00	0.99	0.99	0.98	0.98	0.98
1003	Montgomery	AL	5960	1.18	1.01	1.00	0.98	0.98	0.97	0.97	0.97
2150	Big Delta	AK	3652	1.64	1.04	1.00	0.90	0.73	0.79	0.73	0.64
2151	Big Delta Irr	AK	4024	1.59	1.04	1.00	0.91	0.80	0.81	0.76	0.68
2340	Fairbanks WSO	AK	3047	1.71	1.05	1.00	0.89	0.62	0.75	0.68	0.57
2341	Fairbanks Irr	AK	4194	1.57	1.04	1.00	0.92	0.83	0.82	0.77	0.70
[illegible]430	Homer WSO	AK	[illegible]	1.65	1.04	1.00	[illegible]	0.72	0.78	0.72	0.63
	Kenai	AK		[illegible]	1.04	1.00		[illegible]	0.78	0.72	[illegible]
	[illegible] Edgerton				1.05	[illegible]			0.75	0.68	

This data is excerpted from this table in sciver11.xls. The latest version of the Soil Conditioning Index is located at:

ftp://ftp.nssc.nrcs.usda.gov/pub/lightle/scifiles/latest revisions/

City code	Location	State	Reference condition	Crop Group A	Crop Group B	Crop Group C	Crop Group D	Crop Group E	Crop Group F	Crop Group G	Crop Group H
503[illegible]			4163				0.92	[illegible]			[illegible]
50424	[illegible]	[illegible]	2754	[illegible]		[illegible]	0.88	0.85			0.54
50512	Lande[illegible]	WY	3596	1.65		1.00	0.90	0.87	[illegible]	[illegible]	0.63
50680	Rawlins	WY	3056	1.71	1.05	1.00	0.89	0.86	0.75	0.69	0.57
50720	Rock Springs	WY	2996	1.72	1.05	1.00	0.89	0.86	0.75	0.68	0.56
51001	Washington	DC	5774	1.25	1.01	1.00	0.97	0.97	0.95	0.94	0.94
80000	Guam	PB	6132	1.08	1.00	1.00	1.00	1.00	0.99	0.99	0.99
80040	Koror	PB	6145	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80080	Majuro	PB	6143	1.06	1.00	1.00	1.00	1.08	1.00	1.00	1.00
80100	Pago Pago	PB	6142	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80120	Pohnpei	PB	6143	1.06	1.00	1.00	1.00	1.08	1.00	1.00	1.00
80130	Kosrae	PB	6144	1.06	1.00	1.00	1.00	1.08	1.00	1.00	1.00
80140	Chuuk	PB	6144	1.06	1.00	1.00	1.00	1.08	1.00	1.00	1.00
80180	Yap	PB	6143	1.06	1.00	1.00	1.00	1.08	1.00	1.00	1.00
81000	Guam Irr.	PB	6136	1.07	1.00	1.00	1.00	1.08	1.00	0.99	0.99

Table 508.2 Soil Disturbance Ratings

Operation number	Field operations	- - - - - - - - Soil disturbing actions - - - - - - - Inver-sion	Mixing	Lifting	Shat-tering	Aera-tion	Compac-tion	Soil Disturbance Rating
1	Aerator, ground driven knife aerator	1	1	2	3	4	1	12
2	Anhydous applicator w/ knife and w/ coulter	1	2	1	2	1	1	8
3	Anhydrous applicator w/ knife (wide)	2	3	2	3	2	1	13
4	Baler, forage harvester	0	0	0	0	0	3	3
5	Bed/lister/hill (wide beds)	5	5	5	5	5	4	29
6	Bedder, lister, hipper single row	4	4	3	5	5	2	23
7	Bury drip irrigation line	1	2	1	2	1	1	8
8	Chisel plow, deep chisel, straight point	3	4	4	4	5	2	22
9	Chisel plow, deep chisel, twisted point	4	4	5	5	5	2	25
10	Chisel plow, sweeps	2	3	5	4	4	3	21
11	Chisel/sweep-rod; first oper. after MB plow	2	4	5	4	4	4	23
12	Chisel; straight points (12-inch spacing)	2	4	4	4	5	2	21
[illegible]	Chisel; straight points (18-in[illegible]acing)	2	3	4	[illegible]	4	2	19
[illegible]	Chisel; straight points [illegible]	2	2	[illegible]	[illegible]	[illegible]	2	[illegible]
[illegible]	[illegible]el; straight poi[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]

This data is excerpted from this table in sciver11.xls. The latest version of the Soil Conditioning Index is located at:

ftp://ftp.nssc.nrcs.usda.gov/pub/lightle/scifiles/latest revisions

126	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]
127	Sh[illegible]	[illegible]	[illegible]	0	0	0	[illegible]	3
128	Skew tr[illegible]backward	[illegible]	1	1	2	1	2	8
129	Skew treader, frontward	3	3	2	2	3	1	14
130	Slip plow	1	2	2	4	4	1	14
131	Sprayer	0	0	0	0	0	3	3
132	Subsoil; >30 inch spacing	1	2	2	4	5	1	15
133	Subsoil; 18-30 inch spacing	1	2	2	5	5	1	16
134	Swather, mower-conditioner	0	0	0	0	0	3	3
135	Sweep plow; <24 inch blade width N	0	0	5	5	4	3	17
136	Sweep plow; >24 inch blade width N	0	0	5	5	3	3	16
137	Torpedo rows, run rows w/ tractor	0	0	0	3	0	4	7
138	Transplanter (vegetable seedlings)	0	1	0	1	1	3	6
139	Undercutter (8-12-inch sweeps)	0	0	5	5	4	3	17
140	V-blade	0	0	5	5	3	3	16
141	Vee ripper/subsoiler	1	2	2	5	5	1	16
142	Weed with machete (PB)	0	1	0	0	1	0	2

Table 508.3 Field operations subfactor

Average annual soil distri-bution rating	Field operations subfactor value	Average annual soil distri-bution rating	Field operations subfactor value	Average annual soil distri-bution rating	Field operations subfactor value	Average annual soil distri-bution rating	Field operations subfactor value	Average annual soil distri-bution rating	Field operations subfactor value
0	1.00	46	0.55	92	0.09	138	-0.37	184	-0.82
1	0.99	47	0.54	93	0.08	139	-0.38	185	-0.83
2	0.98	48	0.53	94	0.07	140	-0.39	186	-0.84
3	0.97	49	0.52	95	0.06	141	-0.40	187	-0.85
4	0.96	50	0.51	96	0.05	142	-0.41	188	-0.86
5	0.95	51	0.50	97	0.04	143	-0.42	189	-0.87
6	0.94	52	0.49	98	0.03	144	-0.43	190	-0.88
7	0.93	53	0.48	99	0.02	145	-0.44	191	-0.89
8	0.92	54	0.47	100	0.01	146	-0.45	192	-0.90
9	0.91	55	0.46	101	0.00	147	-0.46	193	-0.91
10	0.90	56	0.45	102	-0.01	148	-0.47	194	-0.92
11	0.89	57	0.44	103	-0.02	149	-0.48	195	-0.93
12	0.88	58	0.43	104	-0.03	150	-0.49	196	-0.94
13	0.87	59	0.42	105	-0.04	151	-0.50	197	-0.95
14	0.86	60	0.41	106	-0.05	152	-0.51	198	-0.96
15	0.85	61	0.40	107	-0.06	153	-0.52	199	-0.97
16	0.84	62	0.39	108	-0.07	154	-0.53	200	-0.98
17	0.83	63	0.38	109	-0.08	155	-0.54	201	-0.99
18	0.82	64	0.37	110	-0.09	156	-0.55	202	-1.00
19	0.81	65	0.36	111	-0.10	157	-0.55	203	-1.01
20	0.80	66	0.35	112	-0.11	158	-0.56	204	-1.02
21	0.79	67	0.34	113	-0.12	159	-0.57	205	-1.03
22	0.78	68	0.33	114	-0.13	160	-0.58	206	-1.04
23	0.77	69	0.32	115	-0.14	161	-0.59	207	-1.05
24	0.76	70	0.31	116	-0.15	162	-0.60	208	-1.06
25	0.75	71	0.30	117	-0.16	163	-0.61	209	-1.07
26	0.74	72	0.29	118	-0.17	164	-0.62	210	-1.08
27	0.73	73	0.28	119	-0.18	165	-0.63	211	-1.09
28	0.72	74	0.27	120	-0.19	166	-0.64	212	-1.10
29	0.71	75	0.26	121	-0.20	167	-0.65	213	-1.11
30	0.70	76	0.25	122	-0.21	168	-0.66	214	-1.12
31	0.69	77	0.24	123	-0.22	169	-0.67	215	-1.13
32	0.68	78	0.23	124	-0.23	170	-0.68	216	-1.14
33	0.67	79	0.22	125	-0.24	171	-0.69	217	-1.15
34	0.66	80	0.21	126	-0.25	172	-0.70	218	-1.16
35	0.65	81	0.20	127	-0.26	173	-0.71	219	-1.17
36	0.64	82	0.19	128	-0.27	174	-0.72	220	-1.18
37	0.63	83	0.18	129	-0.28	175	-0.73	221	-1.19
38	0.62	84	0.17	130	-0.29	176	-0.74	222	-1.20
39	0.61	85	0.16	131	-0.30	177	-0.75	223	-1.21
40	0.60	86	0.15	132	-0.31	178	-0.76	224	-1.22
41	0.59	87	0.14	133	-0.32	179	-0.77	225	-1.23
42	0.58	88	0.13	134	-0.33	180	-0.78	226	-1.2
43	0.57	89	0.12	135	-0.34	181	-0.79	227	-1.25
44	0.56	90	0.11	136	-0.35	182	-0.80	228	-1.26
45	0.55	91	0.10	137	-0.36	183	-0.81	229	-1.27

Table 508.3 Field operations subfactor—Continued

Average annual soil distri-bution rating	Field operations subfactor value
230	-1.28
231	-1.29
232	-1.30
233	-1.31
234	-1.32
235	-1.33
236	-1.34
237	-1.35
238	-1.36
239	-1.37
240	-1.38
241	-1.39
242	-1.40
243	-1.41
244	-1.42
245	-1.43
246	-1.44
247	-1.45
248	-1.46
249	-1.47
250	-1.48
251	-1.49
252	-1.50
253	-1.51
254	-1.52
255	-1.53
256	-1.54
257	-1.55
258	-1.55
259	-1.56
260	-1.57
261	-1.58
262	-1.59
263	-1.60
264	-1.61
265	-1.62
266	-1.63
267	-1.64
268	-1.65
269	-1.66
270	-1.67
271	-1.68
272	-1.69
273	-1.70
274	-1.71
275	-1.72
276	-1.73
277	-1.74
278	-1.75
279	-1.76
280	-1.77
281	-1.78
282	-1.79
283	-1.80
284	-1.81
285	-1.82
286	-1.83
287	-1.84
288	-1.85
289	-1.86
290	-1.87
291	-1.88
292	-1.89
293	-1.90
294	-1.91
295	-1.92
296	-1.93
297	-1.94
298	-1.95
299	-1.96
300	-1.97
301	-1.98
302	-1.99
303	-2.00
304	-2.01
305	-2.02
306	-2.03
307	-2.04
308	-2.05
309	-2.06
310	-2.07
311	-2.08
312	-2.09
313	-2.10
314	-2.11
315	-2.12
316	-2.13
317	-2.14
318	-2.15
319	-2.16
320	-2.17
321	-2.18
322	-2.19
323	-2.20
324	-2.21
325	-2.22
326	-2.23
327	-2.24
328	-2.25
329	-2.26
330	-2.27
331	-2.28
332	-2.29
333	-2.30
334	-2.31
335	-2.32
336	-2.33
337	-2.34
338	-2.35
339	-2.36
340	-2.37
341	-2.38
342	-2.39
343	-2.40
344	-2.41
345	-2.42
346	-2.43
347	-2.44
348	-2.45
349	-2.46
350	-2.47
351	-2.48
352	-2.49
353	-2.50
354	-2.51
355	-2.52
356	-2.53
357	-2.54
358	-2.55
359	-2.55
360	-2.56
361	-2.57
362	-2.58
363	-2.59
364	-2.60
365	-2.61
366	-2.62
367	-2.63
368	-2.64
369	-2.65
370	-2.66
371	-2.67
372	-2.68
373	-2.69
374	-2.70
375	-2.71
376	-2.72
377	-2.73
378	-2.74
379	-2.75
380	-2.76
382	-2.78
383	-2.79
384	-2.80
385	-2.81
386	-2.82
387	-2.83
388	-2.84
389	-2.85
390	-2.86
391	-2.87
392	-2.88
393	-2.89
394	-2.90
395	-2.91
396	-2.92
397	-2.93
398	-2.94
399	-2.95
400	-2.96
401	-2.97
402	-2.98
403	-2.99
404	-3.00

Table 508.4 Erosion subfactors

Rate of erosion	Erosion value	Rate of erosion	Erosion value	Rate of erosion	Erosion value	Rate of erosion	Erosion value
0.00	1.00	11.75	-1.48	23.50	-2.95	34.50	-3.77
0.25	0.94	12.00	-1.52	23.75	-2.98	34.75	-3.79
0.50	0.88	12.25	-1.56	24.00	-3.00	35.00	-3.80
0.75	0.81	12.50	-1.60	24.25	-3.03	35.25	-3.81
1.00	0.75	12.75	-1.64	24.50	-3.05	35.50	-3.82
1.25	0.69	13.00	-1.68	24.75	-3.08	35.75	-3.83
1.50	0.63	13.25	-1.72	25.00	-3.10	36.00	-3.84
1.75	0.56	13.50	-1.76	25.25	-3.12	36.25	-3.85
2.00	0.50	13.75	-1.80	25.50	-3.14	36.50	-3.86
2.25	0.44	14.00	-1.84	25.75	-3.16	36.75	-3.87
2.50	0.38	14.25	-1.88	26.00	-3.18	37.00	-3.88
2.75	0.31	14.50	-1.92	26.25	-3.20	37.25	-3.89
3.00	0.25	14.75	-1.96	26.50	-3.22	37.50	-3.90
3.25	0.19	15.00	-2.00	26.75	-3.24	37.75	-3.91
3.50	0.13	15.25	-2.03	27.00	-3.26	38.00	-3.92
3.75	0.06	15.50	-2.06	27.25	-3.28	38.25	-3.93
4.00	0.00	15.75	-2.09	27.50	-3.30	38.50	-3.94
4.25	-0.05	16.00	-2.12	27.75	-3.32	38.75	-3.95
4.50	-0.10	16.25	-2.15	28.00	-3.34	39.00	-3.96
4.75	-0.15	16.50	-2.18	28.25	-3.36	39.25	-3.97
5.00	-0.20	16.75	-2.21	28.50	-3.38	39.50	-3.98
5.25	-0.25	17.00	-2.24	28.75	-3.40	39.75	-3.99
5.50	-0.30	17.25	-2.27	29.00	-3.42	40.00	-4.00
5.75	-0.35	17.50	-2.30	29.25	-3.44		
6.00	-0.40	17.75	-2.33	29.50	-3.46		
6.25	-0.45	18.00	-2.36	29.75	-3.48		
6.50	-0.50	18.25	-2.39	30.00	-3.50		
6.75	-0.55	18.50	-2.42	30.25	-3.52		
7.00	-0.60	18.75	-2.45	30.50	-3.53		
7.25	-0.65	19.00	-2.48	30.75	-3.55		
7.50	-0.70	19.25	-2.51	31.00	-3.56		
7.75	-0.75	19.50	-2.54	31.25	-3.58		
8.00	-0.80	19.75	-2.57	31.50	-3.59		
8.25	-0.85	20.00	-2.60	31.75	-3.61		
8.50	-0.90	20.25	-2.63	32.00	-3.62		
8.75	-0.95	20.50	-2.65	32.25	-3.64		
9.00	-1.00	20.75	-2.68	32.50	-3.65		
9.25	-1.05	21.00	-2.70	32.75	-3.67		
9.50	-1.10	21.25	-2.73	33.00	-3.68		
9.75	-1.15	21.50	-2.75	33.25	-3.70		
10.00	-1.20	21.75	-2.78	33.50	-3.71		
10.25	-1.24	22.00	-2.80	33.75	-3.73		
10.50	-1.28	22.25	-2.83	34.00	-3.74		
10.75	-1.32	22.50	-2.85	34.25	-3.76		
11.00	-1.36	22.75	-2.88				
11.25	-1.40	23.00	-2.90				
11.50	-1.44	23.25	-2.93				

Table 508.5 The effects of the farming systems on crop yields, residue production, and maintenance of the soil organic matter (Texas A&M, Renner Research Station, published research)

System number	Crop grown	Crop grown (lb/acre)	- - - - Residue returned - - - - By crop (lb/acre)	By system (lb/acre)	- - - Organic matter - - - At start (percent)	At 12 years (percent)	Total residue (ton/acre)
8	Wheat	984	5,114				
	Cotton	762	3,015				
	Sorghum	2,410	3,466	3,865	3.34	3.2	23.2
9	Wheat	1,128	5,318				
	Cotton	870	3,237				
	Sorghum	2,945	4,013	4,189	3.53	4.17*	44.9**

*Increase or decrease is statistically significant at a probability of 5%.
**Includes 5 tons of manure applied to row crops after 1954.

Table 508.6 RUSLE crop parameter data

Crop code number	Crop name	Harvest units	Yield	Pounds per unit	Residue: yield ratio	Above ground residue (lb)	Surface decomp. coeff.	Subsurface decomp. coeff.	Roots in top 4 inches (lb)	Root-mass adjust-ment	Crop group
1	alf; fall seed	tons	1.5	2000	0.15	450	0.02	0.02	1300	3.889	E
2	alf; spring seed	tons	1.5	2000	0.15	450	0.0200	0.0200	2500	6.556	E
3	alf; summer seed	tons	1.5	2000	0.15	450	0.0200	0.0200	1300	3.889	E
4	alf; y1 reg(spr seed	tons	1.5	2000	0.15	450	0.0200	0.0200	2300	6.111	E
5	alf; y1 reg(sum seed	tons	1.5	2000	0.15	450	0.0200	0.0200	2100	5.667	E
6	alf; y1 sen (oat sil	tons	0.5	2000	1	1000	0.0200	0.0200	2250	3.250	E
7	alf; y1 sen(spr seed	tons	1.5	2000	0.15	450	0.0200	0.0200	2500	6.556	E
8	alf; y1 sen(sum seed	tons	0.1	2000	1	200	0.0200	0.0200	2500	13.500	E
9	alf; y1 senesc (oat)	tons	0.5	2000	1	1000	0.0200	0.0200	2000	3.000	E
10	alf; y2 regrowth	tons	1.5	2000	0.15	450	0.0200	0.0200	3000	7.667	E
11	alf; y2 regrowth 3T	tons	1	2000	0.15	300	0.0200	0.0200	2000	7.667	E
12	alf; y2 senescence	tons	0.15	2000	1	300	0.0200	0.0200	3500	12.667	E
13	alf; y3 regrowth	tons	1.75	2000	0.15	525	0.0200	0.0200	3500	7.667	E
14	alf; y3 regrowth 3T	tons	1	2000	0.15	300	0.0200	0.0200	2300	8.667	E
15	alf; y3 senescence	tons	1.75	2000	0.15	525	0.0200	0.0200	3500	7.667	E
	alfalfa 2d year	to[illegible]	[illegible]75	2000	0.15	525	[illegible]	0.0200	3000	6.714	[illegible]
	[illegible]lfa established			2000	0.15	52[illegible]		[illegible]200	3500	7.667	
	[illegible]seeding year				0.15				2500	6.[illegible]	
	[illegible]mer				0.1[illegible]				[illegible]00		

This data is excerpted from this table in sciver11.xls. The latest version of the Soil Conditioning Index is located at:

ftp://ftp.nssc.nrcs.usda.gov/pub/lightle/scifiles/latest revisions

Crop code number	Crop name	Harvest units	Yield	Pounds per unit	Residue: yield ratio	Above ground residue (lb)	Surface decomp. coeff.	Subsurface decomp. coeff.	Roots in top 4 inches (lb)	Root-mass adjust-ment	Crop group
72[illegible]							[illegible]080				
726	[illegible]	bu	45				0.0080	[illegible]			A
727	whea[illegible]	bu	45	6[illegible]		[illegible]590	0.0080	0.008[illegible]		[illegible]33	A
728	wheat; w[illegible]grpa	bu	45	60		4590	0.0080	0.0080	[illegible]	1.980	A
729	wheat; winterseedCOT	bu	45	60	1.1111	3000	0.0080	0.0080	1000	1.333	A
730	wheat; w mid south	bu	45	60	1.7	4590	0.0080	0.0080	1200	1.261	A
731	wint. cover;early MD	lb	4000	1	1	4000	0.0170	0.0170	1200	1.300	D
732	winter cover early NE	lb	4600	1	1	4600	0.0170	0.0170	1300	1.283	D
733	winter cv inter 2	bu	45	60	0.5556	1500	0.0170	0.0170	850	1.567	D
734	winter cv inter 3	bu	45	60	0.7407	2000	0.0170	0.0170	1000	1.500	D
735	winter cv inter midS	bu	45	60	1.1111	3000	0.0170	0.0170	1200	1.400	D
736	winter cvr mid south	lb	4000	1	1	4000	0.0170	0.0170	1100	1.275	D
737	winter sm. gr. cover	lb	4000	1	1	4000	0.0170	0.0170	908	1.227	D
738	winter sm. gr. sil PA	lb	4000	1	0.25	1000	0.0170	0.0170	1200	2.200	D
739	winter sm. gr. silage	lb	4000	1	0.2	800	0.0170	0.0170	1200	2.500	D
740	winter wheat	bu	45	60	1.7	4590	0.0080	0.0080	1200	1.261	A

Soil Conditioning Index Worksheet

Version 10 September 15, 1999

Producer: **Location:** **Staff:**

Tract: **Field:**

A. Site Information

Location code: (From City Tab) **City:** **Rainfall Factor R:** (RUSLE)

Soil: **Soil Erodibility Factor K (adjusted Kf) :** (RUSLE)

Slope, Length & Percent (LS factor) : (RUSLE)

Maintenance Amount: **"Residue Equivalent Values" (REV) :** lbs./ac

B. Management Information

Number of Yrs in Rotation: **Crop Rotation:**

Tillage System: **Crop Mgt Factor C:** (RUSLE)

Support Conservation Practices: **Support Practice Factor P:** (RUSLE)

C. Organic Material (OM)

(From Crop Tab)

Crop #	Crop	Yield	Harv Unit/Ac	Wt Harv Unit (lbs)	Res: Yield Ratio	Res Prod	Root Mass Adjust	Biomass Prod	Biomass Removed or Added	Total Biomass	Crop Group	REV Conv	REV lbs/ac

TOTAL REV:	
NO. YEARS IN ROT.:	
AVE. ANNUAL (RP):	
MAINT. AMNT. (MA):	
SUBFACTOR (OM):	

D. Field Operations (FO)

(From Operation Tab)

Soil Disturbance Rating (SDR)

Op #	Operation Name	SDR	Op #	Operation Name	SDR

Total SDR for Rotation: ____ Average Annual SDR: ____

Field Operations Subfactor (FO), Table 3:

E. Erosion (ER)

Predicted Erosion: Sheet & Rill: ____ RUSLE Calc.: ____ Wind: ____ Irrigation: ____

Total Avg Annual Erosion: ____ ton/ac

Erosion Subfactor (ER) Table 4: ____

F. Soil Conditioning Index

SCI = OM*0.4 + FO*0.40 + ER*0.20

Soil Conditioning Index = ____

G. Notes:

H. Recommendations:

Conversions

Soil weight =	2,000,000 pounds per acre furrow slice (one acre to a depth of 6 2/3 in.)
Soil organic matter (humus) =	Soil organic carbon x 1.72
Soil organic carbon =	Soil organic matter x 0.58
Weight of residue x 0.30 =	Soil organic matter
OM content of eroded sediment =	Soil OM x 1.5

Annual rate of soil organic matter (humus) decay:

Loam or clay loam . . . . 2.5% of total soil reserve
Sandy loam . . . . 3.5% of total soil reserve
Loamy sand . . . . 4.5% of total soil reserve

Part 509 Data Management

Contents:

Subpart 509A Introduction and responsibilities

509.00 Background

Natural Resources Conservation Service' s agronomic data exists in both electronic and hard copy formats, and is maintained at many different locations by a large number of people. There is no organized network among those who maintain the data to facilitate data sharing and to ensure against duplication of effort in data collection. Coordination is needed among all those in NRCS who collect, use, and manage data to share similar data sets that may apply in more than one state or region. This will reduce workloads and ensure data accuracy and integrity.

A large portion of the agronomic data used by NRCS is in data files developed for the implementation of various tools at the State and field office level, such as erosion prediction, nutrient management, and pest management tools.

509.01 Responsibilities

The national agronomist is responsible for preparation of national policy and instructions pertaining to data management.

The cooperating scientists for water and wind erosion are responsible for developing and maintaining data for the implementation and application of erosion prediction models. They work directly with the national database coordinator for RUSLE2 and WEPS in developing and maintaining the databases used in these models. They provide national coordination in developing Climate Zones, Crop Management Zones, Crop Management Templates, and assist in assigning dates of operations used in developing Crop Management Templates for erosion prediction tools.

The national nutrient management specialist is responsible for developing and maintaining databases for assisting States with implementation and application of nutrient management tools.

The national pest management specialist is responsible for developing and maintaining databases for assisting States with implementation and application of pest management tools.

The national database coordinator for RUSLE2 and WEPS is responsible for maintaining the national Vegetation and Operation databases used in these erosion prediction models. He/she assists in the coordination of Climate Zones, Crop Management Zones, dates of operations used in developing Management Templates, Crop Management Templates, and associated guidelines used in the Templates, and works closely with other national specialists to minimize duplication of effort in the Agency's data collection efforts.

RUSLE/WEPS regional contacts serves as the liaisons with other agronomists and erosion specialists in the regions and with the cooperating scientists for wind and water erosion. They are responsible for maintaining consistency, both within regions and between regions, in data used erosion prediction tools.

At the State level, the appropriate State specialist (agronomist, nutrient/pest management specialist, or water quality specialist) is responsible for proper use of NRCS databases in field office applications. They are also responsible for identifying different or additional types of data needed at the field level.

Subpart 509B Database management

509.10 Databases for erosion prediction tools

(a) Crop and field operations databases

An initial set of plant and operation data records has been developed under the leadership of Agricultural Research Service. These data records serve as guides for developing additional plant data records. Additional data records will be added to include all plant types and field implements and operations needed by NRCS. A national set of databases for each model, known as the NRCS Crop Database and the NRCS Operation Database, will be maintained by the Agency. These official NRCS databases are to be used in RUSLE2 and WEPS 1.0 by NRCS field offices. The data records for the operations used and crops grown in the local area will be downloaded from the official databases onto field office computers.

The national database coordinator will manage the official NRCS databases. The coordinator is responsible for adding, modifying, and revising all parameter values in the Crop and Operation Databases. Agronomists or designated erosion specialists, in coordination with the RUSLE/WEPS regional contacts, can submit additions or revisions to the NRCS Crop or Operation databases. If additional crop or operation records or revisions of existing records are needed, States will furnish any available data inputs to the database coordinator through their regional contact. The database coordinator will coordinate the development of the record and issue it for peer review and eventual posting to the official NRCS database. All agronomists or designated erosion specialists will be notified when new records have been posted.

(b) Climate databases

For RUSLE2, the average monthly temperature and precipitation from one designated climate station will be used to represent each Climatic Zone. Local climate data records will be developed using these temperature and precipitation values, but location-specific R factor and 10-year storm EI values will be used in that local climate record. The national database coordinator will provide national coordination and assist the States in developing local climate records. Only official NRCS RUSLE2 Climate Databases are to be used by NRCS field offices. The data records needed for the local area will be downloaded from the official NRCS Climate Database onto field office computers.

Either simulated climate data (using WINDGEN and CLIGEN weather generators imbedded in the model) or actual climate data (stored in the model) will be used in WEPS 1.0.

(c) Soil databases

A soil data download from the National Soils Information System (NASIS) will be created and placed on the field office computer in a Microsoft Access database in conjunction with the Customer Service Toolkit. This database will contain soil data to be used in that field office as inputs for RUSLE2 and WEPS 1.0. The soil database downloaded to each field office will be the official NRCS Soil Database and will be updated only as supported by agency policy.

509.14 Pesticide properties database

The pesticide properties database is used by the National Agricultural Pesticide Risk Analysis (NAPRA) model and the Windows-Pesticide Screening Tool (WIN_PST). These environmental risk screening tools are used to predict the potential for pesticides to move with water and eroded soil/organic matter and affect nontarget organisms.

The national pest management specialist works with the Agricultural Research Service and representatives of companies that produce pesticides to keep this database current.

509.15 Plant nutrient content database

The Plant Nutrient Content Database contains estimates of the nitrogen, phosphorus, and potassium content in plant biomass for many agricultural crops.

This information is useful to nutrient management planners who need estimates of plant nutrient content to develop nutrient management plans. It becomes particularly valuable when nutrients are applied in quantities that are a function of the nutrient content of plant biomass.

The national nutrient management specialist will work with the Agricultural Research Service and Land Grant Universities to update and expand this database.

Glossary

A factor The computed longtime average annual soil loss carried by runoff from specific field slopes in specified cropping and management systems. It is expressed in the RUSLE model in tons/acre/year.

Abrasion Breakdown of clods, crusts, and plant material by the impact of particles moved by wind in saltation. The impacting particles may also abrade. Abrasion causes soil aggregates to break down progressively as wind erosion continues.

Accelerated erosion Erosion of soil resulting from disturbance of the natural landscape. It results largely from the consequences of human activity, such as tillage, grazing and removal of vegetative cover.

Aggregate stability The ability of a soil aggregate to resist various destructive forces, such as tillage, abrasion by wind or flowing water, or raindrop force.

Aggregation, soil The cementing or binding together of primary soil particles (sand, silt, and clay) into a secondary unit, which unit contributes to the soil structure.

Air-dry weight Weight of a substance after it has been allowed to dry to equilibrium with the atmosphere.

Angle of deviation The angle between prevailing wind erosion direction and a line perpendicular to: (1) the long side of the field or strip, when determining unsheltered distance using a wind erosion direction factor, or (2) row direction when determining effect of wind direction on the ridge roughness factor.

Available water holding capacity The capacity of a soil to hold water in a form available to plants, usually expressed in inches of water per inch of soil depth. Commonly defined as the amount of water held between field capacity and wilting point.

Avalanching The increase in rate of soil flow with distance downwind across an area being eroded by wind.

Buffer strip A narrow strip of grass or other close-growing vegetation that, when placed along the contour on a slope, traps sediment that was produced on the hillslope above.

C factor – Water erosion Cover and management factor in RUSLE. It combines the effects of prior land use, crop canopy, surface cover, surface roughness, and soil moisture to predict a soil loss ratio for a crop or other vegetation, cropping period, or season.

C Factor – Wind erosion Climatic factor in WEQ. It is an index of climatic erosivity, specifically wind speed and surface soil moisture. The factor for any given location is based on long-term climatic data and is expressed as a percentage of the C factor for Garden City, KS, which has been assigned a value of 100.

Calcareous soil Soil containing sufficient free calcium carbonate or magnesium carbonate to effervesce visibly when treated with cold 0.1 N hydrochloric acid. High content of lime (up to about 5 percent), particularly in the clay fraction, appreciably increases erodibility by wind.

Classical gully erosion Erosion caused by the action of runoff water in concentrated flow channels. These flow channels are well-defined, permanent drainageways that cannot be crossed by ordinary farming operations.

Climatic erosivity The relative influence of climate on field erodibility by wind in different regions, specifically the effects of average windspeed and effective soil surface moisture

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Clod A compact, coherent mass of soil greater than 2 millimeters in equivalent diameter, often created by tillage or other mechanical disturbance of the soil.

Coarse fragments Rock or mineral particles greater than 2 millimeters in diameter.

Contour farming The practice of using ridges and furrows left by tillage to redirect runoff from a path directly downslope to a path around the hillslope.

Critical wind erosion period Period of the year when the greatest amount of wind erosion can be expected to occur from a field under an identified management system. It is the period when the combination of vegetative cover, soil surface conditions, and expected erosive winds result in the greatest potential for wind erosion.

Crop residue management Maintaining stubble, stalks, and other crop residue on the soil surface or partially incorporated into the surface layer to reduce erosion, conserve soil moisture, and improve soil tilth.

Crop tolerance to wind erosion Ability of crop plants to tolerate wind blown soil particles when in the seedling stage or exposure of plant roots where soil is eroded away, or burial of plants by drifting soil, or desiccation and twisting of plants by the wind.

Crust A thin surface layer, where aggregates are bound together and the surface is sealed. It is more compact and mechanically stable than the soil material immediately beneath it. Crust is characterized by its dense, platey structure that becomes less distinct with depth until it merges with the soil below. Crust is a transitory condition.

Deposition The accumulation of eroded soil material on the land surface when the velocity of the transporting agent (wind or water) is reduced.

Desert pavement A non-erodible soil surface devoid of erodible materials or consisting of gravel or stones left on the land surface. It occurs in desert regions as a result of the removal of fine materials by wind or water erosion. Desert pavement is virtually non-erodible.

Detachment The removal of transportable fragments of soil material from the soil mass by an eroding agent, usually falling raindrops, running water, wind, or windblown soil particles. Detachment is the process that makes soil particles or aggregates available for transport.

Drought year Any year when precipitation is less than 80 percent of the long-term normal.

Dry aggregate A compound or secondary air-dry soil particle that is not destroyed by dry sieving.

Dust storm A strong turbulent wind carrying large amounts of soil particles in suspension.

E tables Tables, derived from computer solutions (WEROS) of the Wind Erosion Equation, that display values of average annual wind erosion per acre (E) for various combinations of soil erodibility (I), ridge roughness (K), climate (C), unsheltered distance (L), and vegetative cover (V).

Ephemeral gully erosion Erosion that occurs from the action of runoff water which concentrates in shallow flow channels when rills converge. These flow channels are alternately filled with soil by tillage operations and re-formed in the same general location by subsequent runoff events.

Erodibility The susceptibility of soil to erode. Soils with low erodibility include fine textured soils high in clay that are resistant to detachment, and coarse textured soils high in sand that have low runoff. Soils having a high silt content are highly susceptible to erosion. The K factor in RUSLE expresses the erodibility of soil.

Erosive wind energy The capacity of winds above the threshold velocity to cause erosion. Erosive Wind Energy is a function of the cube of windspeed and the duration of erosive winds.

Erosive wind energy distribution The distribution of erosive wind energy over time at any geographic location.

Erosivity The energy (amount) and intensity of rainstorms that cause soil to erode. Erosivity includes the effects of raindrop impact on the soil and the amount and rate of runoff likely to be associated with the rain.

Fibric organic soil materials The least decomposed of all the organic soil materials containing very high amounts of fiber that are well preserved and readily identifiable as to botanical origin.

Field capacity (Field water capacity) The content of water, on a mass or volume basis, remaining in a soil two to three days after being saturated with water, and from which free drainage is negligible.

Geologic erosion The wearing away of the earth's surface by the forces of water and wind. Sometimes referred to as natural erosion, it is responsible for the natural topographic cycles, as it wears away higher points of elevation and constructs valleys and alluvial plains.

Hemic Organic Soil Materials Intermediate in degree of decomposition between the less decomposed fibric and the more decomposed sapric materials.

Isolated Field A field where the rate of soil flow is zero at the windward edge of the field due to the presence of a stable border. An isolated field is not protected by barriers and is exposed to open wind velocities. The Wind Erosion Equation applies to conditions on an isolated field.

Isoline A line on a map or chart along which there is a constant value of a variable such as wind velocity or climatic erosivity.

K factor - Water Erosion Soil erodibility factor in RUSLE that quantifies the susceptibility of soil particles to detachment and movement by water. The K value is the soil-loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6-ft length of uniform 9 percent slope in continuous clean-tilled fallow.

K Factor – Wind Erosion The soil roughness factor K, for WEQ. It is a measure of the effect of oriented roughness (ridges) and random roughness (cloddiness) on erosion. See Random Roughness and Ridge Roughness

Knoll An abrupt change in topography characterized by windward slope change greater than 3 percent and windward slope less than 500 feet long.

Knoll Erodibility The increase in wind erosion potential resulting from the compression of wind flowlines and accompanying increased velocity over the crest of knolls. A knoll erodibility factor is used to adjust estimated erosion where these conditions occur.

Loess Soil material transported and deposited by wind, consisting predominantly of silt-sized particles.

LS factor The RUSLE factor that accounts for the combined effects of length and steepness of slope on soil loss. The factor value represents the ratio of soil loss on a given slope length and steepness to soil loss from a slope that has a length of 72.6-ft and a steepness of 9 percent, where all other conditions are the same.

Management Period A period of time during a cropping sequence when cover and management effects are approximately uniform or otherwise result in uniform rates of erosion during the period.

Mulch Tillage Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round, while growing crops where the entire field surface is tilled prior to planting.

No-till/Strip till Managing the amount, orientation and distribution of crop and other plant residues on the soil surface year-round, while growing crops in narrow slots, or tilled or residue free strips in soil previously untilled by full-width inversion implement

Northwestern Wheat and Range Region (NWRR) Areas of non-irrigated cropland in the Pacific Northwest and mountainous regions of the west. It includes portions of eastern Washington, north central Oregon, northern and southeastern Idaho, western Montana, western Wyoming, northern Utah and northern California. Rainfall and erosion processes in this region are dominated by winter events.

Organic soil A soil that contains a high percentage (greater than 20 percent) of organic matter throughout the solum.

Oven-dry weight The weight of a substance after it has been dried in an oven at 105 degrees C, to equilibrium.

P factor The support practice factor in RUSLE. It is a measure of the soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage. On cultivated land, support practices considered in RUSLE include contouring, stripcropping, buffer strips, and terraces. These practices principally effect erosion by modifying the flow pattern, grade or direction of surface runoff and by reducing the amount and rate of runoff.

Permanent wilting point (Wilting coefficient) The largest water content of a soil at which indicator plants, growing in that soil, wilt and fail to recover when placed in a humid chamber. Often estimated by the soil water content at –1.5 MPa (-15 bars) soil matric potential.

Precipitation- effectiveness (PE) index An index of the effectiveness of precipitation, calculated from mean monthly precipitation and mean monthly temperature at a specific geographical location. A modified P-E index is used to represent effective surface soil moisture in calculation of the WEQ climatic factor C.

Preponderance A ratio which expresses how much of the erosive wind energy occurs parallel to the prevailing wind erosion direction, as compared to the amount of erosive wind energy occurring perpendicular to the prevailing direction. A preponderance of 1.0 indicates that as much wind erosion force occurs perpendicular to the prevailing direction as occurs parallel to that direction. A higher preponderance indicates more of the force is parallel to the prevailing wind erosion direction.

Prevailing wind direction The direction from which winds most commonly occur. This may not be the same as the prevailing wind erosion direction.

Prevailing wind erosion direction The direction of erosive winds where there is potential for the greatest amount of soil to be moved, relative to the erosive force of winds from other directions.

R equivalent (Req) factor The factor used in place of the RUSLE R factor in the Northwestern Wheat and Range Region of the U.S. to measure the unique effects of melting snow, rain on snow, and/or rain on thawing soil. Much of this soil loss occurs by rilling when the surface part of the soil profile thaws and snowmelt or rain occurs on the still partially frozen soil.

R factor The rainfall and runoff factor in RUSLE that accounts for the energy and intensity of rainstorms. It is a measure of total storm energy times the maximum 30-minute intensity.

Random roughness The standard deviation of the soil surface elevations when changes because land slope or nonrandom (oriented) tillage marks are removed from consideration. Roughness ponds water in small, localized depressions and reduces erosivity of raindrop impact and surface water flow.

Reference condition A standard wind tunnel condition for small grain equivalent determination where small grain stalks 10 inches long are lying flat on the soil surface in 10-inch rows which are perpendicular to the wind direction, with stalks oriented parallel to the wind direction.

Relative field erodibility An index of relative erodibility under field conditions. Wind tunnel erodibility is adjusted for the effect of unsheltered distance and of the resistance of soil textural classes to breakdown of surface crusts by abrasion and avalanching. Compared to the wind tunnel, erodibility of a field surface is greater because the longer unsheltered distance allows abrasion and avalanching to occur.

Ridge roughness The degree of oriented roughness determined by the height and width of ridges formed by tillage and planting implements. Ridges provide sheltered zones that trap moving soil particles.

RUSLE Revised Universal Soil Loss Equation. An empirical model that predicts long-term average annual soil loss for a given set of climatic conditions, on a defined land slope, and under a specified cropping and tillage management system. RUSLE is an update of the USLE, and contains a computer program to facilitate calculations.

Saltation Soil movement in wind where particles skip or bounce along the soil surface in response to wind forces. Particles in the size range from 0.1 to 0.5 mm (0.004 to 0.02 in) usually move in this manner.

Sapric organic soil materials The most highly decomposed of the organic materials, having the highest bulk density, least amount of plant fiber, and lowest water content at saturation.

Seasonally variable K factor The average annual soil erodibility K factor value that has been adjusted to reflect the temporal variability associated with freezing and thawing or wetting and drying cycles during the year.

Sheet erosion A form of water erosion in which a very thin layer is removed from the soil surface by detachment and overland flow.

Small grain equivalent (SGe) The wind erosion control equivalent of vegetative cover, compared to a small grain standard. The standard (reference condition) is defined as small grain stalks 10 inches long lying flat on the soil surface in 10-inch rows which are perpendicular to the wind direction, with stalks oriented parallel to the wind direction. The small grain equivalent value is a function of kind, amount, and orientation of growing plants or plant residues on the soil surface.

Soil erodibility index (I) The potential soil loss, in tons per acre per year, from a wide, level, unsheltered, isolated field with a bare, smooth, loose, and non-crusted surface, under climatic conditions like those in the vicinity of Garden City, Kansas.

Soil loss tolerance (T) T is expressed as the average annual soil erosion rate (tons/acre/year) that can occur in a field with little or no long-term degradation of the soil resource thus permitting crop productivity to be sustained for an indefinite period of time.

Soil surface moisture Adsorbed water films surrounding surface soil particles that increase the soil resistance to erosion. In developing the climatic factor, soil surface moisture is assumed to be proportional to the Thornthwaite Precipitation-Effectiveness (P-E) Index.

Sorting Separation of various size classes of soil particles or aggregates during wind erosion. Soils tend to become coarser in response to continued sorting by erosion.

Stable border A stable border defines the upwind boundary of an isolated field. It is an area with sufficient protection to prevent saltation from starting, and capable of trapping and holding incoming saltation from eroding areas upwind, thus preventing saltating soil particles from entering areas downwind.

Surface armor A layer of coarse fragments or other non-erodible particles resistant to abrasion that remain on the soil surface after the removal of fine particles by erosion.

Surface creep Soil movement by wind in which the coarser fractions are transported by rolling and sliding along the ground surface, primarily by the impact of particles in saltation rather than by direct force of the wind. Particles greater than 0.5 mm (0.02 in) in size are usually moved in this manner.

Suspension Soil movement in wind whereby the finer fractions are transported over long distances floating in the windstream. Suspension is usually initiated by the impact of saltating particles. Particles moving in this manner are usually less than 0.1 mm (0.004 in) in size. Many suspension-size particles are created by abrasion during erosion.

Threshold Velocity The minimum velocity at which wind will begin moving soil particles from a smooth, bare, non-crusted surface. The threshold velocity is usually considered to be 13 mph at 1 foot above the soil surface, or 18 mph at 30 feet height.

Transport The movement of detached soil material across the land surface or through the air by wind or running water. Transport of soil particles in wind is by three modes: (l) saltation, (2) suspension, and (3) surface creep.

Transport capacity The maximum amount of soil material that can be carried by wind or running water under given conditions.

Trap strip A strip of grass or other erosion-resisting vegetation, planted between cultivated strips or fields and having sufficient width, height, and density to trap and store incoming saltation. Trap strips are usually not tall enough to create significant barrier effects.

Unit plot A standard plot used to experimentally determine factor values in USLE and RUSLE. It is arbitrarily defined as being 72.6-feet long, with a uniform slope of 9 percent, in continuous fallow, tilled up and down the slope.

Unsheltered distance The distance across an erodible field, measured along the prevailing wind erosion direction, beginning at a stable border on the upwind side and continuing downwind to a non-erodible or stable area, or to the downwind edge of the area being evaluated.

Unsheltered field A field or portion of a field characterized by the absence of windbreaks or barriers and fully exposed to open wind velocity.

USLE Universal Soil Loss Equation. An empirical model that predicts long-term average annual soil loss for a given set of climatic conditions, on a defined land slope, and under a specified cropping and tillage management system.

Vegetative wind Barrier Narrow strips of annual or perennial vegetation planted at intervals across fields for wind erosion control, snow management, or protection of sensitive crops. Barriers have sufficient height and density to create a sheltered zone downwind. In the protected zone, wind velocities are reduced enough to prevent saltation from beginning. Vegetative barriers may also trap incoming saltation, but this is a secondary function.

Water erosion The detachment, transport, and deposition of soil particles by rainfall and runoff.

Wide field Any field with sufficient width to allow the rate of soil flow to reach the maximum that an erosive wind can sustain. This distance is the same for any erosive wind. It varies only and inversely with erodibility of the field surface. That is, the more erodible the surface, the shorter the distance in which maximum flow is reached.

Wind erodibility group A grouping of soils that have similar properties affecting their resistance to wind erosion.

Wind erosion The detachment, transport, and deposition of soil by wind.

Wind erosion direction factor A numerical factor used to calculate the equivalent unsheltered distance. The factor accounts for field shape (length/width ratio), field width, preponderance, and angle of deviation of the prevailing wind erosion direction from a line perpendicular to the long side of the field or strip.

Wind erosion equation (WEQ) An equation used to estimate wind erosion and design wind erosion control systems. $E = f(IKCLV)$ where E is the average annual soil loss expressed in tons per acre per year; I is the soil erodibility; K is the soil ridge roughness factor; C is the climatic factor; L is the equivalent unsheltered distance across the field along the prevailing wind erosion direction; and V is the equivalent vegetative cover.

Wind stripcropping A method of farming whereby erosion-resistant crop strips are alternated with strips of erosion-susceptible crops or fallow. Erosion-resistant strips reduce or eliminate saltation and act as soil traps designed to reduce soil avalanching. Strips are perpendicular or nearly so to the direction of erosive winds.

Wind tunnel A duct in which experimental situations are created and tested by exposure to air streams under controlled conditions. Both laboratory and portable field wind tunnels are used in wind erosion research.

Windbreak A living barrier of trees or combination of trees and shrubs designed to reduce wind erosion, conserve energy or moisture, control snow deposition, or provide shelter for livestock or wildlife. When used to control wind erosion, windbreaks deflect wind forces and reduce wind velocity in the downwind sheltered zone below the threshold required for initiation of soil movement.