DRAFT

USER'S REFERENCE GUIDE

Revised Universal Soil Loss Equation
Version 2

(RUSLE2)

Prepared for
USDA-Agricultural Research Service
Washington, D.C.

May 15, 2008

Acknowledgements

RUSLE2 was developed cooperatively by the USDA-Agricultural Research Service (ARS), the USDA-Natural Resources Conservation Service (NRCS), and the Biosystems Engineering and Environmental Science Department of the University of Tennessee. Each project participant maintains a RUSLE2 Internet site directed toward their specific interests. Consult these sites for a list of the employees of these organizations who contributed to the development of RUSLE2. Contributors from several other organizations also participated in the development of RUSLE2.

The USDA-ARS was responsible for providing the erosion science on which RUSLE2 is based including the mathematical equations used in RUSLE2, core data values used to calibrate RUSLE2, scientific documentation, and a user's reference guide for RUSLE2.

The USDA-NRCS was the principal client for RUSLE2. The NRCS provided information to ensure that RUSLE2 could be easily used in their local field (district) offices. The NRCS also developed an extensive RUSLE2 operational (working) database, primarily for cropland. The NRCS has developed RUSLE2 templates and user guides specifically for their purposes.

The interests and needs of a wide variety of other users were considered during RUSLE2's development. RUSLE2 was developed to be land-use independent to give RUSLE2 the wide applicability range possible and to accommodate the needs of these users.

The University of Tennessee participated in the development of the mathematical equations used in RUSLE2, developed the computer science used in RUSLE2, and developed the RUSLE2 computer program. They also developed user guides and other RUSLE2 information for their clients.

This RUSLE2 User's Reference Guide was reviewed by USDA-Natural Resources Conservation Service technical specialists from several disciplines; Kenneth G. Renard (retired), USDA-Agricultural Research Service, Tucson, Arizona, and Seth Dabney, USDA-Agricultural Research Service, Oxford, Mississippi.

Preface

This RUSLE2 User's Reference Guide describes RUSLE2 in detail in semi-technical language. This Guide describes how RUSLE2 works, how to select input values, how to apply RUSLE2 to make erosion estimates for the wide range of conditions represented by RUSLE2, how to interpret values computed by RUSLE2, how to evaluate RUSLE2's adequacy for conservation and erosion control planning, RUSLE2's accuracy, and how to conduct sensitivity analysis with RUSLE2. This Guide also describes similarities and differences between RUSLE2 and the USLE and RUSLE1, widely used predecessor technologies, and how to select input values and make interpretations when comparing erosion values estimated by these technologies.

RUSLE2 is land use independent and applies to all land uses where soil erosion occurs by erosive forces applied to exposed mineral soil by raindrop impact and surface runoff produced by Hortonian overland flow. This User's Reference Guide is targeted to technical specialists, who in turn, can use the information in this Guide to develop application-specific RUSLE2 user guides.

This User Reference Guide provides information on contact agencies that can provide additional information on RUSLE2.

A companion RUSLE2 Science Documentation describes the mathematical procedures used in RUSLE2.

Disclaimer

The purpose of RUSLE2 is to guide and assist erosion-control planning. Erosion-control planners should consider information generated by RUSLE2 to be only one set of information used to make an erosion-control decision. RUSLE2 has been verified and validated, and every reasonable effort has been made to ensure that RUSLE2 works as described in RUSLE2 documentation available from the USDA-Agricultural Research Service. However, RUSLE2 users should be aware that errors may exist in RUSLE2 and exercise due caution in using RUSLE2.

Similarly, this RUSLE2 User's Reference Guide has been reviewed by erosion scientists and RUSLE2 users. These reviewers' comments have been faithfully considered in the revision of this document.

Every reasonable effort has been made to ensure that this document is accurate. The USDA-Agricultural Research Service alone is responsible for this document's accuracy and how faithfully the RUSLE2 computer program represents the information in this document.

Table of Contents

Glossary of Terms

Term	Description
10 yr EI	Storm EI with a 10-year return period
10 yr-24 hr EI	Storm EI for the 10 yr-24 hr precipitation amount
10 yr-24 hr precipitation	24 hour precipitation amount having a 10-year return period
Antecedent soil moisture subfactor	See cover-management subfactors.
Average annual, monthly, period, and daily erosion	RUSLE2 computes average daily erosion for each day of the year, which represents the average erosion that would be observed if erosion was measured on that day for a sufficiently long period. Average period, monthly, and annual erosion are sums of the average daily values.
Average erosion	Average erosion is the sediment load at a given location on the overland flow path divided by the distance from the origin of overland flow path to the location.
b value, also b_f value	Coefficient in equation for effect of ground cover on erosion; values vary daily with rill-interrill erosion ratio and residue type
Birth of biomass	Refers to the addition of live aboveground and root biomass simultaneous with the death during growth periods when canopy cover and root biomass is increasing
Buffer strips	Dense vegetation strips uniformly spaced along overland flow path; can cause much deposition
Burial ratio	Portion of existing surface (flat) cover mass that is buried by a soil *disturbing* operation; dry mass basis-not area covered basis
Calibration	Procedure of fitting an equation to data to determine numerical values for equation's coefficients
Canopy cover	Cover above soil surface; does not contact runoff; usually provided by vegetation
Canopy shape	Standard shapes used to assist selection of effective fall height values for waterdrops falling from canopy
Canopy subfactor	See cover-management subfactors.
Channel order	Relative position of a channel in a concentrated flow network
Climate description	Input values for variables used to represent climate (primarily temperature, precipitation, and erosivity density); stored in RUSLE2 climate database component under a location name
Concentrated flow area	Area on landscape where channel flow occurs; ends overland flow path
Conservation planning soil loss	A conservation planning erosion value that gives partial credit to deposition as soil saved; credit is function of location on overland flow path where deposition occurs
Contouring	Support erosion-control practice involving ridges-furrows that

	reduces erosion by redirecting runoff around hillslope
Contouring failure	Contouring effectiveness is lost where runoff shear stress exceeds a critical value
Contouring description	Row grade (steepness) used to describe contouring; stored in RUSLE2 contouring component database under name for contouring practice; ridge height in *operation* description used in cover-*management* description also key input in addition to row grade
Core database	RUSLE2 database that includes values for base conditions used to validate RUSLE2; input values for a new condition must be consistent with values in core database for similar conditions
Cover-*management* description	Values for variables that describe cover-management; includes dates, *operation* descriptions, *vegetation* descriptions, yields (vegetation production level), applied external residue (*residue* description) and amount applied; named and saved in RUSLE2 management component database
Cover-management subfactors (subfactors used in RUSLE2 listed below in italics)	Cover-management subfactor values used to compute detachment (sediment production) by multiplying subfactor values, subfactor values vary through temporally
Canopy	Represents how canopy affects erosion, function of canopy cover and effective fall height
Ground cover	Represents how ground cover affects erosion; primarily function of portion of soil surface covered
Surface roughness	Represents how soil surface roughness and its interaction with soil biomass affect erosion
Soil biomass	Represents how live and dead roots in upper 10 inches of soil and buried residue in upper 3 inches and less of soil affects erosion
Soil consolidation	Represents how a mechanical disturbance and it interaction with soil biomass affect erosion, erosion decreases over time after last disturbance as the soil consolidates (a soil bonding effect that occurs with wetting and drying of the soil-not a mechanical effect)
Ridging	Represents how ridges increase detachment (sediment production)
Ponding	Represents how a water layer on soil surface reduces erosion
Antecedent soil moisture	Represents how previous vegetation affects erosion by reducing soil moisture, used only in Req zone
Critical slope length	Location along a uniform overland flow path where contouring fails
Cultural practice	Erosion control practice, such as no-till cropping, where cover-management is used to reduce erosion
Curve number	An index used in NRCS curve number method to compute runoff; RUSLE2 computes curve number value as function of hydrologic

	soil group and cover-management conditions
Database	RUSLE2 database stores both input and output information in named descriptions
Dead biomass	Represents live above ground and root biomass that has been converted to dead biomass by *kill vegetation* process in an *operation* description; dead biomass decomposes
Dead root biomass	A *kill vegetation* process in an *operation* description converts live root biomass to dead root biomass, dead roots decompose at the same rate as surface and buried residue
Dead standing biomass	Represents live aboveground biomass converted to dead standing biomass by a *kill vegetation* process in an *operation* description; dead standing biomass does not contact soil surface; dead standing biomass decomposes more slowly than surface and subsurface dead biomass
Dead surface biomass	Represents surface biomass that resulted from live aboveground biomass being killed and flattened to become surface biomass, buried residue that has been brought to the soil surface by a soil disturbing process in an operation description, and material that has been applied as external residue; in contact with soil surface
Death of biomass	Refers to the loss of live aboveground and root biomass simultaneous with birth of live biomass during growth periods when canopy cover and root biomass is increasing; daily death of live aboveground biomass adds to surface residue pool and daily death of root biomass adds to dead root biomass pool
Decomposition	Loss of dead biomass as a function of material properties, precipitation, and temperature; decomposition rates for all plant parts and buried and surface biomass are equal; decomposition rate for standing residue is significantly decreased because of no soil contact
Deposition	Transfers sediment from sediment load being transported by runoff to soil surface; net deposition causes sediment load to decrease with distance along overland flow path; depends on sediment characteristics and degree that sediment load exceeds sediment transport capacity; enriches sediment load in fines; computed as a function of sediment particle class fall velocity, runoff rate, and difference between sediment load and transport capacity
Deposition portion	Portion of overland flow path where net deposition occurs
Detachment	Process that separates soil particles from soil mass by raindrops, waterdrops falling from vegetation, and surface runoff; net detachment causes sediment load to increase along overland flow path; detachment is non-selective with respect to sediment characteristics; computed as function of erosivity, soil erodibility, distance along overland flow path, steepness of overland flow path, cover-management condition, and contouring

Disaggregation	Mathematical procedure used to covert monthly precipitation and temperature values to daily values assuming that values vary linearly; daily precipitation values sum to monthly values; average of disaggregated daily temperature equal average monthly value
Diversion/terrace/ sediment basin	A set of support practices that intercept overland flow to end overland flow path length.
Diversions	Intercepts overland flow and directs it around hillslope in channelized flow; grade is sufficiently steep that deposition does not occur but not so steep that erosion occurs in the diversion
EI_{30}	Storm (rainfall) erosivity; product of storm energy and maximum 30-minute intensity; storm energy closely related to rain storm amount and partly to rainfall intensity
Enrichment	Deposition is selective, removing the coarse and dense particles, which leaves the sediment load with an increased portion of fine and less dense particles
Enrichment ratio	Ratio of specific surface area of sediment after deposition to specific surface area of soil subject to erosion
Ephemeral gully erosion	Erosion that occurs in concentrated flow areas
Eroding portion	Portion of overland flow path where net detachment (erosion) occurs
Erosivity	Index of rainfall erosivity at a location; closely related to rainfall amount and intensity; monthly erosivity is average annual sum of individual storm erosivity values in month; annual erosivity is average sum of values in year; storm rainfall amount must be ½ inch (12 mm) or more to be included in computation of erosivity
Erosivity density	Ratio of monthly erosivity to monthly precipitation amount
External residue	Material, usually biomass, added to soil surface or placed in the soil; affects erosion same as surface residue and buried residue from vegetation
Fabric (silt) fence	Porous fabric about 18 inches wide placed against upright posts on the contour; these barriers pond runoff and cause deposition; widely used on construction sites
Fall height (effective)	Effective fall height is the effective height from which waterdrops fall from canopy; depends on canopy shape, canopy density height gradient, and top and bottom canopy heights
Filter strip	A single strip of dense vegetation located at the end of an overland flow path; can induce high amounts of deposition
Final roughness	Soil surface roughness after roughness has decayed to unit plot conditions, primarily represents roughness provided by soil resistant clods
Flattening ratio	Describes how much standing residue that an operation flattens; ratio of standing residue mass before operation to standing residue mass after operation; depends on operation and residue; dry mass

	basis
Flow interceptors	Topographic features (ridges, channel) on an overflow path that collect overland flow and direct the runoff around hillslope; end overland flow path; diversions, terraces, and sediment basins are flow interceptors
Form roughness	Represents the hydraulic roughness provided by soil surface roughness, vegetation, and residue; reduces detachment and sediment transport capacity of runoff
Gradient terraces	Terraces on a uniform grade (steepness)
Grain roughness	Represents the hydraulic roughness provided by the soil; responsible for detachment and sediment transport by flow
Ground cover	Represents the portion of the soil surface covered by material in direct contact with soil; includes plant litter, crop residue, rocks, algae, mulch, and other material that reduces both raindrop impact and runoff (surface flow) erosivity
Ground cover subfactor	See cover-management subfactors
Growth chart	The collection of values that describe the temporal vegetation variables of live root biomass in upper 4 inches (100mm), canopy cover, fall height, and live ground cover; values are in a vegetation description
Hortonian overland flow	Overland flow generated by rainfall intensity being greater than infiltration rate; although flow may be concentrated in micro-channels (rills), runoff is uniformly distributed around hillslope
Hydraulic (roughness) resistance	Degree that ground cover, surface roughness, and vegetation slow runoff; varies daily as cover-management conditions change
Hydraulic element	RUSLE2 hydraulic elements are a channel and a small impoundment
Hydraulic element flow path description	Describes the flow path through a sequence of hydraulic elements, named and saved in RUSLE2 hydraulic element component database
Hydraulic element system description	Describes a set of hydraulic element paths that are uniformly spaced along the overland flow path described without the hydraulic element system being present; named and saved in RUSLE2 hydraulic path component database
Hydrologic soil group	Index of runoff potential of a soil profile at a given geographic location, at a particular position on the landscape, and with the presence or absence of subsurface drainage
Impoundment	A flow interceptor; impounds runoff; results in sediment deposition, represents typical impoundment terraces on cropland and small sediment basins on construction sites
Impoundment parallel terrace	Parallel terraces-impoundments (PTO) where terraces cross concentrated flow areas; impoundment drains through a riser into

	underground pipe
Incorporated biomass	Biomass incorporated (buried) in the soil by a *soil disturbing* operation; also biomass added to the soil from decomposition of surface biomass; amount added by decomposition of surface material is function of soil consolidation subfactor
Inherent organic matter	Soil organic matter content in unit-plot condition
Inherent soil erodibility	Soil erodibility determined by inherent soil properties; measured under unit-plot conditions (see soil erodibility)
Initial conditions	Cover-management conditions at the beginning of a no-rotation cover-management description
Initial input roughness	Soil surface roughness index value assigned to *soil disturbing* operation that occurs on the base condition of a silt loam soil with a large amount of biomass on and in the soil; actual initial roughness value used in computations is a function of soil texture, soil biomass, existing roughness at time of soil disturbance, and tillage intensity
Injected biomass	Biomass placed in the soil using an *add other residue/cover* process in a *soil disturbing* operation description (see *operation* processes); biomass is placed in lower half of disturbance depth
Interrill erosion	Erosion caused by water drop impact; not function of distance along overland flow path unless soil, steepness, and cover-management conditions vary; interrill areas are the spaces between rills where very thin flow occurs
Irrigation	Water artificially added to the soil to enhance seed germination and vegetation production
Land use independent	RUSLE2 applies to all situations where Hortonian overland flow occurs and where raindrop impact and surface runoff cause rill and interrill erosion of exposed mineral soil; the same RUSLE2 equations are used to compute erosion regardless of land use
Live aboveground biomass	Live aboveground biomass (dry matter basis); converted to standing residue (dead biomass) by a *kill vegetation* process in an *operation* description.
Live ground (surface) cover	Parts of live aboveground biomass that touches the soil surface to reduce erosion.
Live root biomass	RUSLE2 distributes input values for live root biomass in upper four inches of soil profile over a constant rooting depth of 10 inches for all vegetation types and growth stages. A *kill vegetation* process in an *operation* description converts live root biomass to dead root biomass. Primarily refers to fine roots that are produced annually; RUSLE2 uses live and dead root biomass in the upper 10 inches of soil profile to compute a value for the soil biomass subfactor
Local deposition	Deposition that occurs very near, within a few inches, from the point of detachment in surface roughness depressions and in

	furrows between ridges; given full credit for soil saved
Long term roughness	Soil surface roughness that naturally develops over time; specified as input in cover-*management* description; depends on vegetation characteristics (e.g., bunch versus sod forming grasses, root pattern near soil surface) and local erosion and deposition, especially by wind erosion; RUSLE2 computes roughness over time; develops fully by time to soil consolidation
Long term vegetation	Permanent vegetation like that on pasture, range, reclaimed mined land, and landfills; vegetation description can include temporal values starting on seeding date through maturity, any arbitrary date after seeding date, or only for the vegetation at maturity
Management alignment offset	Used to sequence cover-*management* descriptions along an overland flow path to create alternating strips
Mass-cover relationship	Equation used to compute portion of soil surface covered by a particular residue mass (dry basis)
Mass-yield relationship	Equation used to compute standing biomass (dry basis) of vegetation as a function of production (yield) level
Maximum 30-minute intensity	Average rainfall intensity over the continuous 30 minutes that contains the greatest amount in a rain storm
Non-erodible cover	Cover such as plastic, standing water, snow, and other material that completely eliminates erosion, material can be porous and disappear over time
Non-uniform overland flow path	Soil, steepness, and/or cover-management vary along an overland flow path; path is divided into segments where selections are made for each segment
NRCS curve number method	Mathematical procedure used in RUSLE2 to compute runoff using precipitation amount; a daily runoff value is computed using the 10 yr-24 hr precipitation amount. Daily runoff amount varies as daily curve number varies based on temporally varying cover-management conditions
NWWR	Northwest Wheat and Range Region; a region in the Northwestern US covering eastern Washington and Oregon, northern Idaho; see Req zone
Operation	An operation changes soil, vegetation, or residue; typically represents common farm and construction activities such as plowing, blading, vehicular or animal traffic, and mowing; also represents burning and natural processes like killing frost and germination of volunteer vegetation
Operation disturbance depth	Surface residue buried by a soil disturbing operation is a function of depth of soil disturbed by operation (operation disturbance depth)
Operation description	Information used to describe an operation; named and stored in the operation component of the RUSLE2 database
Operation processes	Processes used to describe an operation; describes how an operation changes cover-managements and soil conditions that affect erosion,

(processes used in RUSLE2 listed below in italics)	net result of an operation depends on sequence of processes used to describe a particular operation
No effect	Has no effect on computations; commonly used to reference dates in a cover-*management* description and to cause RUSLE2 to display information for a particular set of dates
Begin growth	Tells RUSLE2 when to begin using data from a particular *vegetation* description
Kill vegetation	Converts live aboveground biomass to standing residue and to convert live root biomass to dead root biomass
Flatten standing residue	Converts a portion of the standing residue to surface residue
Disturb (soil) surface	Mechanically disturbs soil (removes consolidation effect for portion of soil surface disturbed); required to bury surface residue; resurfaces buried residue; creates soil surface roughness and ridges; required to inject external residue directly into the soil
Add other cover	Adds external residue to the soil surface and/or places it in the soil
Remove live above ground biomass	Removes a portion of the live aboveground biomass, leaves a portion of the affected biomass as standing and surface (flat) residue
Remove residue/cover	Removes a portion of standing and surface (flat) residue
Add nonerodible cover	Adds nonerodible cover such as plastic, standing water, snow, or other material that allows no erosion for portion of soil surface covered; nonerodible cover disappears over time, cover can be porous; nonerodible cover has no residual effect, not used to represent erosion control blankets and similar material.
Remove nonerodible cover	Removes nonerodible cover, nonerodibile cover has no residual effect
Operation speed	Surface residue buried by a *soil disturbing* operation is a function of operation speed.
Overland flow path	Path taken by overland flow on a smooth soil surface from its point of origin to the concentrated flow area that ends the overland flow path; runoff is perpendicular to hillslope contours
Overland flow path description	Described by steepness values, *soil* descriptions, and cover-*management* descriptions for segments along an overland flow path; a uniform profile (overland flow path) is where steepness, soil, and cover-management do not vary with distance along overland flow path, a convex profile is where steepness increases with distance along the overland flow path; a concave profile is where steepness decreases with distance along the overland flow

	path; a complex profile is a combination of convex, concave, and/or uniform sub-profiles; description involves segment lengths and segment steepness; Soil and cover-management can vary along overland flow paths
Overland flow path length	Distance along the overland flow path from the origin of overland flow to the concentrated flow area (channel) that intercepts runoff to terminate overland flow; does not end where deposition begins (see USLE slope length and steepness)
Overland flow path segments	Overland flow path is divided into segments to represent spatial variability along an overland flow path; conditions are considered uniform within each segment
Overland flow path steepness	Steepness along the overland flow path; not hillslope steepness (see USLE slope steepness)
Permeability index	Index for the runoff potential of the unit-plot soil condition; used in RUSLE2's soil erodibility nomographs; inversely related to hydrologic soil group
Plan description	Collection of RUSLE2 *profile* (overland flow path) descriptions; used to computed weighted averages for a complex area based on the portion of the area that each profile represents; description named and saved in plan component of RUSLE2 database
Ponding subfactor	See cover-management subfactors
Porous barriers	Runoff flows through a porous barrier; does not affect overland flow path length; typically slows runoff to cause deposition; examples are stiff grass hedges, grass filter strips, fabric (silt) fences, gravel dams, and straw bales
Precipitation amount	Includes all forms of precipitation; RUSLE2 disaggregates input monthly values into daily values to compute residue decomposition and temporal soil erodibility
Production (yield) level	A measure of average annual vegetation live aboveground biomass production; user defines yield measure and preferred units on any moisture content basis; input value used to adjust values in a *vegetation* description at a base yield; maximum canopy cover in *base vegetation* description must be less than 100 percent
Profile (overland flow path) description	Information used to describe profile (overland flow path); includes names for location, topography, soil, cover-management, and support practices used to make a particular RUSLE2 computation; *profile* descriptions are named and stored in the profile component of the RUSLE2 database
Profile shape	See overland flow path description
Rainfall (storm) energy	Computed as sum of products of unit energy and rainfall amount in storm intervals where rainfall intensity is assumed uniform; storm energy is closely related to rain storm amount
Rainfall intensity	Rainfall rate express as depth (volume of rainfall/per unit area) per unit time

Relative row grade	Ratio of row grade to average steepness of overland flow path
Remote deposition	Deposition that occurs a significant distance (tens of feet) from the point where the sediment was detached; examples include deposition by dense vegetation strips, terraces, impoundments, and toe of concave overland flow paths; only partial credit is given to remote deposition as soil saved; credit depends on location of deposition along overland flow path; very little credit is given for deposition near end of overland flow path
Req	Equivalent erosivity for the winter months in the Req zone, used to partially represent Req effect
Req effect	Refers to Req equivalent erosivity; erosion per unit rainfall erosivity in the winter period in the Req zone is much greater than in summer period; increased Req winter effect is mainly because of a greatly increased soil erodibility; effect partially results from an elevated soil water content, increased runoff, and soil thawing
Req zone	Region where erosion is elevated in the winter months because of the Req effect, region is primarily in eastern WA and OR, portions of ID, CA, UT, CO, and limited area in other western US states
Residue	Has multiple meanings in RUSLE2; generally refers to dead biomass, such as crop residue, created when vegetation is killed; plant litter from senescence; and applied mulch material such as straw, wood fiber, rock, and erosion control blankets used on construction sites; material is assumed to be biomass that decomposes; also used to represent material like rock that does not decompose by setting a very low decomposition coefficient value
Residue description	Values used to describe residue; named and stored in the residue component of the RUSLE2 database
Residue type	Refers to fragility and geometric residue characteristics; affects residue amount buried and resurfaced by of an operation; affects degree that residue conforms to surface roughness; affects erosion control on very steep slopes
Resurfacing ratio	Portion (dry mass basin) of the buried residue in the soil disturbance depth that a *soil disturbing* operation brings to the soil surface; function of residue and operation's *soil disturbing* properties
Retardance	Degree that vegetation (live aboveground biomass) and standing residue slows runoff; varies with canopy cover; function of production (yield) level; part of vegetation description
Ridge height	Height of ridges created by a *soil disturbing* operation; major variable, along with row grade, that determines contouring effectiveness; decays as a function of precipitation amount and interrill erosion
Ridge subfactor	See cover-management subfactors
Rill erosion	Caused by overland flow runoff; increases with distance along the

	overland flow path
Rill to interrill erosion ratio	Function of slope steepness, rill to interrill soil erodibility, and how cover-management conditions affect rill erosion different from interrill erosion
Rock cover entered in *soil* description	Rock cover entered in the soil description; represents naturally occurring rock on soil surface; operations do not affect this rock cover, rock cover created by an operation that *adds other cover* (rock residue) is treated as external residue; *soil disturbing* operations bury and resurface rock added as external residue
Root biomass	See dead and live root biomass
Root sloughing	Annual decrease in root biomass; RUSLE2 adds the decrease in live root biomass to dead residue biomass pool
Rotation	Refers to whether a list of *operation* descriptions in a cover-*management* description is repeated in a cycle; length of cycle is rotation duration; list of *operation* descriptions are repeated until average annual erosion value stabilizes; eliminates need to specify initial conditions for rotations; operation descriptions in a no-rotation cover-management descriptions are sequentially processed a single time; first operation descriptions in cover-*management* description establish initial conditions in a no-rotation cover-*management* description
Rotation duration	Time (cycle duration) before the list of operation descriptions in a rotation type cover-*management* description repeats; rotation duration is time period over which RUSLE2 makes its computations in a no-rotation cover-*management* description
Rotational strip cropping	A rotation type cover-*management* description that involves periods of dense vegetation that are sequenced along the overland flow path to create strips of alternating dense vegetation that cause deposition
Row grade	Grade along furrows separated by ridges; usually expressed as relative row grade
Runoff	Computed using NRCS curve number method and the 10 yr-24 hour precipitation amount; used to compute contouring effect, contouring failure (critical slope length), and deposition by porous barriers, flow interceptors, and concave overland flow paths
Sediment basin	Small impoundment typical of those used on cropland and construction sites; discharge is usually through a perforated riser that completely drains basin in about 24 hours
Sediment characteristics	Deposition computed as a function of sediment characteristics, which are particle class diameter and density and the distribution of sediment among particle classes
Sediment particle classes	RUSLE2 uses sediment particle classes of primary clay, silt, and sand and small and large aggregate; diameter of aggregate classes and the distribution of sediment among particle classes at point of detachment are computed as function of soil texture; RUSLE2

	computes how deposition changes the distribution of sediment particle classes
Sediment load	Mass of sediment transported by runoff per unit hillslope width
Sediment transport capacity	Runoff's capacity for transporting sediment, depends on runoff rate, overland flow path steepness, and hydraulic roughness; deposition occurs when sediment load is greater than transport capacity
Sediment yield	Sediment load at the end of the flow path represented in a RUSLE2 computation; flow path ends at overland flow path unless hydraulic elements (channel or impoundment) are represented in RUSLE2 computation; sediment yield for site only if RUSLE2 flow path ends at site boundary
Segments	The overland flow path divided into segments to represent spatial variation of steepness, soil, and cover-management
Senescence	Decrease in vegetation canopy cover; senescence adds biomass to surface (flat) residue unless RUSLE2 is instructed that a decrease in canopy cover, such as leaves drooping, does not add to surface residue
Shear stress applied by overland flow	Function of runoff rate and steepness of overland flow path; total runoff shear stress is divided into two parts of shear stress acting on the soil (grain roughness) and shear stress acting on surface residue, surface roughness, live vegetation, and standing residue (form roughness); shear stress acting on the soil is used to compute sediment transport capacity, total shear stress is used to compute contouring failure
Short term roughness	Roughness created by a soil disturbing operation; decays over time as a function of precipitation amount and interrill erosion
Slope length exponent	Exponent in equation used to compute rill-interrill erosion as a function of distance along overland flow path; function of rill to interrill erosion ratio.
Soil biomass subfactor	See cover-management subfactors
Soil consolidation effect	Represents how wetting/drying and other processes cause soil erodibility to decrease over time following a mechanical soil disturbance; increase in soil bulk density (mechanical compaction) not the major cause; affects accumulation of biomass in upper 2 inch (50 mm) soil layer and effect of soil biomass on runoff and erosion
Soil consolidation subfactor	See cover-management subfactors
Soil description	Describes inherent soil properties that affect erosion, runoff, and sediment characteristics at point of detachment; named and saved in soil component of RUSLE2 database
Soil disturbance width	Portion of the soil surface disturbed; weighted effects of disturbance computed as a function of erosion on disturbed and

	undisturbed area used to compute effective values for time since last disturbance, effective surface roughness, and effective ground cover
Soil disturbing operation	*Operation* description that contains *disturb soil* process
Soil erodibility	RUSLE2 considers two soil erodibility effects, one based on inherent soil properties and one based on cover-management; inherent soil erodibility effect represented by K factor value empirically determined from erosion on unit plot; part related to cover-management is represented in cover-management subfactors
Soil erodibility nomograph	Mathematical procedure used to compute a K factor value, i.e., inherent soil erodibility
Soil loss	Proper definition is the sediment yield from a uniform overland flow path divided by the overland flow path length; loosely used as the net removal of sediment from an overland flow path segment
Soil loss from eroding portion	Net removal of sediment from the eroding portion of the overland flow path
Soil loss tolerance (T)	Erosion control criteria; conservation planning objective is that "soil loss" be less than soil loss tolerance T value; special considerations must be given to non-uniform overland flow paths to avoid significantly flawed conservation and erosion control plans
Soil mechanical disturbance	Mechanical soil disturbance resets soil consolidation effects; *disturb soil* process must be included in an operation description to create surface roughness and ridges and to place biomass into the soil
Soil saved	Portion of deposited sediment that is credited as soil saved; computed erosion is reduced by soil saved to determine a conservation planning soil loss value; credit depends on location of deposition along overland flow path
Soil structure	Refers to the arrangement of soil particles in soil mass; used to compute soil erodibility (K) factor values
Soil texture	Refers to the distribution of primary particles of sand, silt, and clay in soil mass subject to erosion
Standing residue	Created when live vegetation is killed; decomposes at a reduced rate; falls over at a rate proportional to decomposition of surface residue
Strip/barrier description	Support practice; describes porous barriers; named and stored in the strip/barrier component of the RUSLE2 database
Subfactor method	See cover-management subfactors
Subsurface drainage description	Support practice that lowers water table to reduce soil water content, runoff, and erosion; RUSLE2 uses difference between hydrologic soil groups for drained and undrained conditions to compute erosion as affected by subsurface drainage
Support practices	Erosion control practice used in addition to cultural erosion control

	practices, hence a support practice; includes contouring, filter and buffer strips, rotational strip cropping, silt (fabric) fences, stiff grass hedges, diversions/terraces, gravel dams, and sediment basins
Surface (flat) residue	Material in direct contact with the soil surface, main source is plant litter, crop residue, and applied mulch (external residue).
Surface roughness	Random roughness; combination of soil peaks and depressions that pond runoff; created by a *soil disturbing* operation, decays as a function of precipitation amount and interrill erosion
Surface roughness index	A measure of soil surface roughness; standard deviation of surface elevations measured on a 1 inch grid about mean elevation; effect of ridges and land steepness removed from measurements
Surface roughness subfactor	See cover-management subfactors
Temperature	Input as average monthly temperature; disaggregated into daily values; used to compute biomass decomposition and temporal soil erodibility
Template	Determines the computer screen configuration of RUSLE2 and inputs and outputs; determines the complexity of field situations that can be described with RUSLE2
Terraces	Flow interceptors (channels) on a sufficiently flat grade to cause significant deposition
Three layer profile schematic	Some RUSLE2 templates include a overland flow path schematic having individual layers to represent cover-management, soil, and topography; used to graphically divide the overland flow path into segments to represent complex conditions
Tillage intensity	Degree that existing soil surface roughness affects roughness left by a *soil disturbing* operation
Tillage type	Identifies the relative position within soil profile where a soil disturbing operation initially places buried residue, also relates to how operation redistributes buried residue and dead roots
Time to soil consolidation	Time required for 95 percent of the soil consolidation effect to be regained after a soil disturbing operation
Topography	Refers to steepness along the overland flow path and the length of the overland flow path
Uniform slope	Refers to an overland flow path where soil, steepness, and cover-management do not vary along the overland flow path
Unit rainfall energy	Energy content of rainfall per unit of rainfall; function of rainfall intensity
Unit plot	Base condition used to determine soil erodibility; reference for effects of overland flow path steepness and length; cover-management, and support practices; continuous tilled fallow (no vegetation; tilled up and downhill, maintained in seedbed conditions; topographic, cover-management, support practice factor values equal 1 for unit plot condition; land use independent, i.e.,

	applies to all land uses including undisturbed land such as pasture, range, and forest lands
USLE slope length and steepness	Distance from origin of overland flow to a concentrated flow area (e.g., terrace or natural waterway) or to the location where deposition occurs; USLE soil loss is sediment yield from this length divided by length (mass/area); USLE steepness is steepness of the slope length; uniform actual overland flow path is often represented with uniform steepness
Validation	Process of ensuring that RUSLE2 serves its intended purpose as a guide to conservation and erosion control planning.
Vegetation description	Information used by RUSLE2 to represent the effect of vegetation on erosion; includes temporal values in growth chart, retardance, and biomass-yield information; named and stored in vegetation component of RUSLE2 database
Verification	Process of ensuring RUSLE2 correctly solves the mathematical procedures in RUSLE2
Worksheet description	Form in RUSLE2 program; used to compare conservation and erosion control practices for a given site; used to compare *profile* descriptions; named and saved in the worksheet component of the RUSLE2 database

1. WELCOME TO RUSLE2

Version 2 of the Revised Universal Soil Loss Equation (**RUSLE2**) estimates soil loss, sediment yield, and sediment characteristics from rill and interrill (sheet and rill) erosion caused by rainfall and its associated overland flow. **RUSLE2** uses factors that represent the effects of climate (erosivity, precipitation, and temperature), soil erodibility, topography, cover-management, and support practices to compute erosion. RUSLE2 is a mathematical model that uses a system of equations implemented in a computer program to estimate erosion rates. The other major component of RUSLE2 is a database containing an extensive array of values that are used by the RUSLE2 user to describe a site-specific condition so RUSLE2 can compute erosion values that directly reflect conditions at a particular site.

RUSLE2 is used to evaluate potential erosion rates at specific sites, guide conservation and erosion control planning, inventory erosion rates over large geographic areas, and estimate sediment production on upland areas that might become sediment yield in watersheds. **RUSLE2 is land use independent. It can be used on cropland, pastureland, rangeland, disturbed forestland, construction sites, mined land, reclaimed land, landfills, military lands, and other areas where mineral soil is exposed to raindrop impact and surface overland flow produced by rainfall intensity exceeding infiltration rate (i.e., Hortonian overland flow)**.

The RUSLE2 computer program, a sample database, user instructions, a slide set that provides an overview of RUSLE2, and other supporting information are available for download from the USDA-Agricultural Research Service (ARS) Official RUSLE2 Internet Site at http://www.ars.usda.gov/Research/docs.htm?docid=6010. The University of Tennessee also maintains a RUSLE2 Internet site where older versions of the RUSLE2 can be downloaded and where additional RUSLE2 information is available. The address is www.rusle2.org. The USDA-Natural Resources Conservation Service (NRCS) also provides and distributes information on RUSLE2 including databases and other materials that it uses to apply RUSLE2 in each of its county level offices across the US. Contact the NRCS Internet site at http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm or contact the NRCS state agronomist in your state to obtain NRCS information on RUSLE2. The NRCS Internet site contains an extensive RUSLE2 database that must be used in NRCS-related applications involving RUSLE2. Information in this database can also be downloaded for other RUSLE2 applications as well. Other organizations that use RUSLE2 may also have RUSLE2 Internet sites that contain databases for their specific RUSLE2 applications.

2. WHY UPGRADE FROM RUSLE1 TO RUSLE2?

RUSLE2 is a second generation of RUSLE1, but it is not simply an enhancement of RUSLE1. **RUSLE2** is a new model with new features and capabilities. If you are using any version of RUSLE1, you should upgrade to **RUSLE2.** **RUSLE2** uses a modern, powerful graphical user interface instead of the text-based interface of RUSLE1. ***RUSLE2** can be used in either US customary units or SI units.* **RUSLE2** can globally switch between the two systems of units or the units on individual variables can be changed to one of several units. Those who work with metric units will find **RUSLE2** much easier to use than RUSLE1. **RUSLE2** can also manipulate attributes of variables, which includes graphing, changing units, and setting number of significant digits. **RUSLE2** is much more powerful than RUSLE1, has improved computational procedures, and provides much more output useful for conservation planning than does RUSLE1.

Even though **RUSLE2** appears quite different on the computer screen from RUSLE1, it has many similarities with RUSLE1. The general approach is the same and many of the values in the database are the same for **RUSLE2** and RUSLE1. Thus, conversion from RUSLE1 to **RUSLE2** should be relatively easy.

3. ABOUT RUSLE2 USER'S GUIDES AND DATABASES

3.1. RUSLE2 User Instructions

RUSLE2 is a straight forward, easily used computer program that is best learned by using it. A set of user instructions is available on the **USDA-Agricultural Research Service (ARS)** RUSLE2 Internet site http://www.ars.usda.gov/Research/docs.htm?docid=6010 to help you get started with RUSLE2. A self-guided tutorial is available on the **University of Tennessee** http://bioengr.ag.utk.edu/rusle2/tutorial.htm to help you learn the mechanics and operation of the **RUSLE2** computer program. The **USDA-Natural Resources Conservation Service (NRCS)** Internet site http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm provides instructional material and database information that helpful for any RUSLE2 user, but is required for NRCS-related **RUSLE2** applications. Also, other organizations provide training and instructional materials targeted to a specific land use such as construction sites that you can also use to learn RUSLE2.

3.2. RUSLE2 Database

The **RUSLE2** download on the USDA-ARS RUSLE2 Internet site includes a sample database. This sample database should only be used to help you become acquainted with **RUSLE2** and how it works. This database is not intended for use in actual **RUSLE2** applications. You can obtain that database information by downloading from the USDA-Natural Resources Conservation Service (NRCS) national **RUSLE2** database or from another database having values that have been properly established for your purpose. You can download information from the NRCS national **RUSLE2** database by contacting the Internet site http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. Additional information can be obtained by contacting the State Agronomist in each NRCS State Office.

Values in your **RUSLE2** operational database must be based on the **RUSLE2 core database** (see **Section 16**). Values in your operational database must be consistent with those in the core database to ensure that **RUSLE2** give expected results and to ensure consistency in **RUSLE2** applications among clients, locations, and other situations where similar erosion estimates are expected. This consistency is very important when **RUSLE2** is used by a national agency where adequacy of the erosion prediction technology is partly judged on consistency of estimates. The NRCS national **RUSLE2** database has been extensively reviewed to ensure consistency, minimal error, and expected erosion values computed with **RUSLE2**. Make sure that the same quality control has been used in the preparation of other **RUSLE2** databases that you might use for the source of data in your **RUSLE2** operational database.

Some values in the RUSLE1 database can be used in **RUSLE2** and directly transferred to the **RUSLE2** database using procedures included in **RUSLE2.** However, the best approach is download values from a quality-controlled **RUSLE2** database, such as the NRCS national **RUSLE2** database, rather than transfer values from a RUSLE1 database. Values for several input variables are different in **RUSLE2** from those in RUSLE1. Also, new input variables have been added to **RUSLE2** that are not in RUSLE1. Furthermore, core values, including those for rainfall erosivity, in the **RUSLE2** database have updated based on new analysis.

3.3. RUSLE2 HELP

The **RUSLE2** computer program contains an extensive set of **HELP** information. Most of the **HELP** information is arranged by variable within **RUSLE2**. Information on a particular variable can be obtained at the location within **RUSLE2** where the variable occurs.

3.4. RUSLE2 Slide Set

A **slide set** is available with the **RUSLE2** download at the ARS RUSLE2 Internet site. This **slide set** provides an extensive overview of **RUSLE2**. The speaker notes that accompany many of the slides provide additional background. Also, slides can be used for **RUSLE2** training and for making presentations on **RUSLE2**.

3.5. RUSLE2 User Reference Guide

This **User's Reference Guide** describes **RUSLE2**, its factors, selection of input values, and application of **RUSLE2**. The **Table of Contents** lists the topics covered by the **User's Guide.** Rather than reading the entire **User's Guide**, specific topics can be selected from the **Table of Contents** and individually reviewed. Also, the **Glossary of Terms** provides information on specific topics.

This **User's Reference Guide** is intended to serve as a **reference** for RUSLE2 technical specialists rather than a guide for the routine RUSLE2 user. User guides and manuals for these users should be developed for specific applications based on information in this **Guide**.

3.6. Getting Started

Like all other hydrologic models, **RUSLE2** requires a proper approach for selecting input values, running the model, and interpreting its output values. **RUSLE2** has particular limitations that must be considered. Before applying **RUSLE2,** you should become well acquainted with **RUSLE2** and its factors by reviewing the **RUSLE2 Slide Set**. After installing **RUSLE2**, run the sample database that can be downloaded with **RUSLE2** that includes several example overland flow path profiles. Change selected variables including location, soil, overland flow path length and steepness, and cover-management and support practices in these examples to help learn the mechanics of the **RUSLE2** computer program and to help learn how main inputs affect computed erosion and other output variables. Start out with the uniform slope templates rather than the complex slope templates.

3.7. Scientific and Technical Documentation

The **RUSLE2** Scientific Documentation describes the equations and mathematical procedures used in RUSLE2. It is available from the USDA-Agricultural Research Service
http://www.ars.usda.gov/SP2UserFiles/Place/64080530/RUSLE/RUSLE2_Science_Doc.pdf.

4. CUSTOMER SUPPORT

If needed information is not available in **RUSLE2** documentation, contact one of the **RUSLE2** experts. The USDA-Agricultural Research Service (ARS) is the lead research agency, in cooperation with the University of Tennessee, that developed **RUSLE2**. The USDA-Natural Resources Conservation Service (NRCS), the major user of **RUSLE2,** has much experience in RUSLE2 applications and developed extensive database information for many different types of applications of **RUSLE2** across the US and other locations. Contact your NRCS State Agronomist to obtain additional databases, information, and direct assistance on **RUSLE2** applications.

RUSLE2 Contacts

Topic: Science and new applications

Seth M. Dabney, Research Agronomist
USDA-Agricultural Research Service
National Sedimentation Laboratory
P.O. Box 1157
Oxford, Mississippi, 38655, USA
Telephone: 662-232-2975
Email: seth.dabney@ars.usda.gov

Topic: Computer program, interface, and linking to RUSLE by other programs

Daniel C Yoder, Professor
Department of Biosystems and Environmental Science
P.O. Box 1071
Knoxville, TN, 37901, USA
Telephone: 865-974-7116
Email: dyoder@utk.edu

Topic: NRCS databases and applications

Dave Lightle, Conservation Agronomist
USDA-Natural Resources Conservation Service
National Soil Survey Center
100 Centennial Mall North, Room 152
Lincoln, NE 68508-3866, USA
Telephone: 402-437-4008
Email: dave.lightle@lin.usda.gov

5. ABOUT RUSLE2

5.1. Fundamental Definitions

RUSLE2 uses several important terms to describe erosion (see **Glossary of Terms**). In the mid-1940's, W. D. Ellison defined erosion as, "... a process of detachment and transport of soil particles."[1] **Detachment** is the separation of soil particles from the soil mass and is expressed in units of mass/area. Soil particles separated from the soil mass are referred to as **sediment**. Sediment movement downslope is sediment transport, described as **sediment load** expressed in units of mass/width of slope. The sediment load at the end of the **RUSLE2** hillslope profile is defined as sediment yield or sediment delivery. **Deposition**, expressed as mass/area, is the accumulation of sediment on the soil surface.

Detachment transfers sediment from the soil mass to the sediment load so that sediment load increases along the hillslope where detachment occurs. Conversely, deposition transfers sediment from the sediment load to the soil mass with a corresponding accumulation of sediment on the soil surface. Deposition is a selective process that **sorts** sediment. This process **enriches** the sediment load in fines in comparison to the soil where detachment originally produced the sediment.

RUSLE2 considers two types of deposition, local and remote. **Local deposition** is sediment deposited very near, within a few inches of where it was detached. Deposition in micro-depressions (**surface roughness**) and in low gradient furrows is an example of local deposition. The difference between local detachment and local deposition is called **net detachment** (or **net deposition**). **Remote deposition** is sediment deposited some distance, 10's of feet (several meters) from the origin of the sediment. Deposition on the toe of a concave slope, at the upper side of vegetative strips, and in terrace channels is an example of remote deposition. **Full credit for soil saved** is taken in **RUSLE2** for local deposition. Only **partial credit** that depends on the location of the deposition is given to remote deposition for soil saved. Sediment deposited at the end of an overland flow path is given very little credit as soil saved.

5.2. Hillslope Overland Flow Path (Hillslope Profile) as the Base Computational Unit in RUSLE2

The base **RUSLE2** computational unit is a single overland flow path along a hillslope profile as illustrated in Figure 5.1. An **overland flow path** is defined as the path that runoff flows from the origin of overland flow to where it enters a major flow concentration. **Major flow concentrations** are locations on the landscape where sides of a hillslope intersect to collect overland flow in defined channels. **Ephemeral or**

[1] Ellison, W.D. 1947. Soil erosion studies. Agricultural Engineering. 28:145-146.

classical gully erosion occurs in these channels. These defined channels are distinguished from **rills** in two ways. Rills tend to be parallel and are sufficiently shallow that they can be obliterated by typical farm tillage and grading operations as a part of construction activities. When the rills are reformed, they occur in new locations determined by **microtopograpy** left by soil disturbing operations like tillage. In contrast, concentrated flow areas occur in the same locations, even after these channels are filled by tillage. Location of these channels is determined by **macrotopography** of the landscape.

An infinite number of overland flow paths exist on any landscape. A particular overland flow path (**hillslope profile**), such as the one labeled **A** in Figure 5.1, is chosen for the one on which the conservation plan is to be based. The overland flow path (profile) that represents the 1/4 to 1/3 most erodible part of the area is often the profile selected for

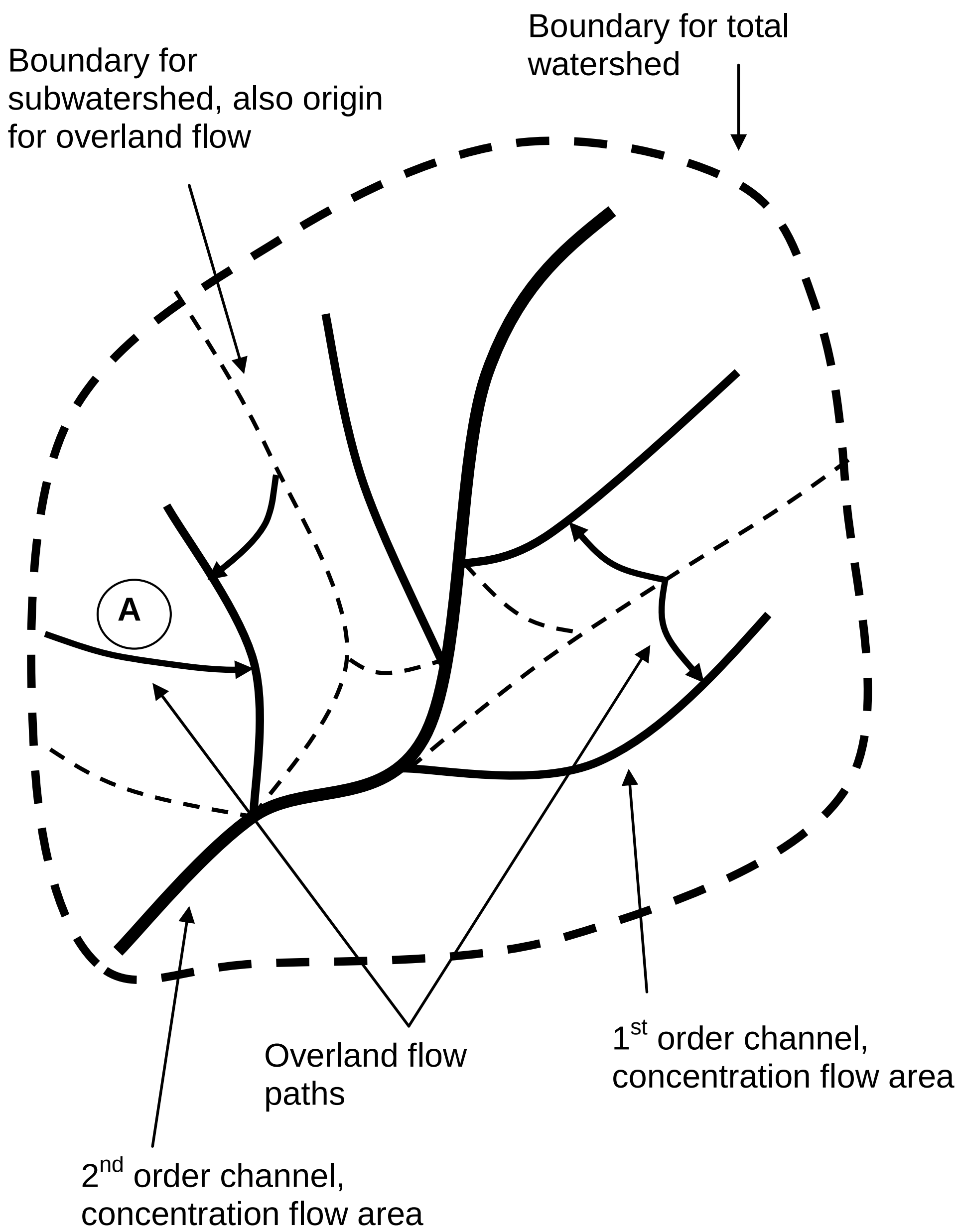

Figure. 5.1. Overland flow paths in a typical application of RUSLE2

applying RUSLE2 when the **conservation planning** objective is to protect the soil resource from degradation by excessive erosion. **RUSLE2** is used to estimate erosion for this profile for each of several alternative land use practices that might be used at the site. Those practices that give a RUSLE2 estimated soil loss that meets the **conservation planning** criteria are considered to provide acceptable erosion control. Organizations such as the NRCS have specific guidelines on how **RUSLE2** is to be used in their programs.

The first step in describing the selected profile is to identify a base point on the hillslope through which the overland flow path is passes. The overland flow path through that point, such as profile **A** in Figure 5.1, is described by dividing the slope into segments and specifying distance and steepness for each segment. The overland path is traced from the origin of overland flow through the base point to where the overland flow is terminated by a concentrated flow channel as illustrated in Figure 5.1.

Figure 5.2 shows the shape of a typical overland flow path on a common natural landscape. This **complex** hillslope profile has an upper **convex** section and a **concave** lower section. This profile has two important parts. The upper part is the **eroding portion** where **net erosion** occurs, and the lower part is the **depositional portion** where **net deposition** occurs. The average erosion rate on the eroding portion of the hillslope is defined as **soil loss** (mass/area). Soil loss on the eroding portion of the landscape degrades the soil on that portion of the landscape and the landscape itself. A typical conservation planning objective is to reduce soil loss to a rate less than **soil loss tolerance (T)** or another quantitative planning criterion. Keeping soil loss to less than T protects the soil so that its productive capacity is maintained and the landscape as a whole is protected from excessive erosion.

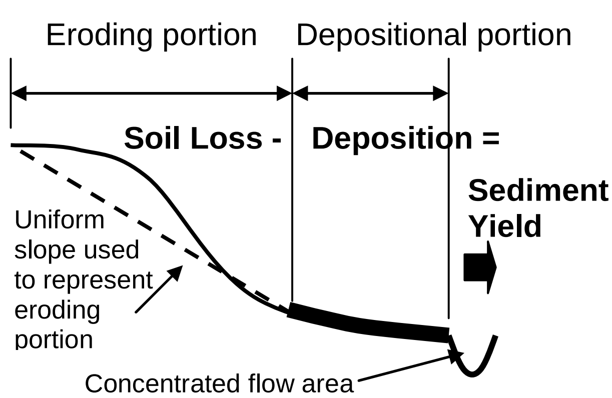

Figure 5.2. Complex hillslope, convex-concave profile

Sediment yield from the hillslope profile and the site is also an important conservation planning consideration. Excessive sediment leaving a site can cause downstream sedimentation and water quality problems. Sediment yield is less than soil loss by the amount of deposition. The sediment yield computed by **RUSLE2** is the sediment leaving the overland flow path represented in **RUSLE2**. This sediment yield will be the sediment yield for the site only if the **RUSLE2** flow path ends at the boundary of the site.

Many conservation-planning applications involve only the eroding portion of the hillslope, which can be approximated by a **uniform slope** as illustrated in Figure 5.2. The **slope length (overland flow path length)** in this application is the distance from the origin of overland flow to where deposition begins, which is the traditional definition of **slope length** in the USLE and RUSLE1. However, soil loss estimated using a uniform slope of the same average steepness and slope length as a non-uniform shaped profile will differ from the average erosion rate for the non-uniform profile, sometimes by as much as 15%. The difference is especially important on convex shaped hillslopes where the erosion rate near the end of the overland flow path can be much larger than the erosion rate at the end of a uniform profile. Deposition like that in Figure 5.2 for concave hillslope sections does not occur on the **uniform** and **convex** shaped hillslopes illustrated in Figure 5.3. Sediment yield equals soil loss on those profiles.

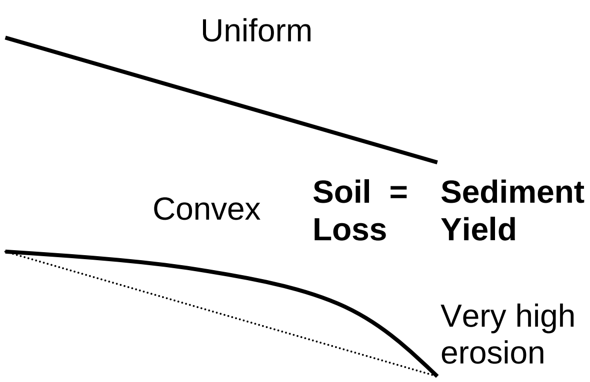

Figure 5.3. Sediment yield equals soil loss on uniform and convex slopes

Another important **complex** hillslope shape is shown in Figure 5.4 where a **concave** section occurs in the middle of the hillslope. A field example is a cut slope-road-fill slope that is common in hilly terrain being logged. **Deposition** can occur on the mid-section of the hillslope where the roadway is located if steepness of the roadway is sufficiently flat. Soil loss occurs on the cut slope and downslope on the fill slope in situations where overland flow from the cut slope continues across the roadway onto the fill slope. Although the steepness and length of the fill slope is the same as that for the upper cut slope, erosion rate is much greater on the fill slope than on the cut slope because of increased overland flow. Although the USLE and RUSLE1 cannot easily describe this hillslope, **RUSLE2** easily determines appropriate **overland flow path lengths**, and computes **erosion** on the two **eroding portions** of the overland flow path, **deposition** on the **depositional portion** of the overland flow path, and **sediment yield** from the overland flow path. Note that the **overland flow path** used in RUSLE2 does not end where deposition begins for this overland flow path.

In addition to computing how slope shape affects erosion, RUSLE2 can also compute how variations in soil and management along a hillslope profile affect erosion.

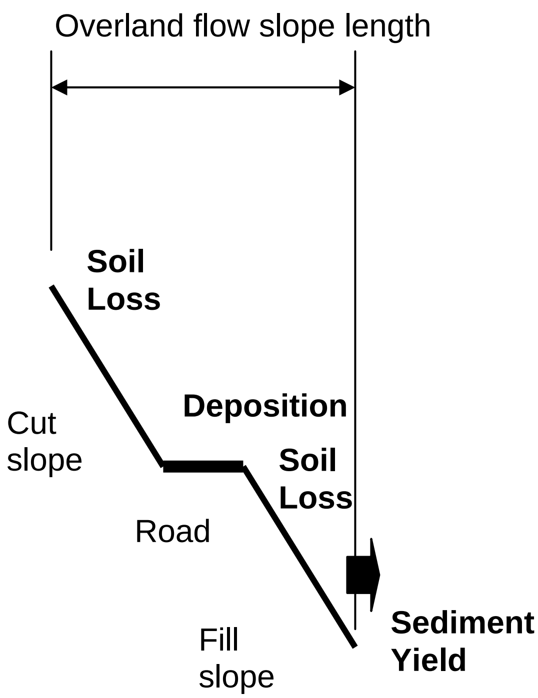

Figure 5.4. Soil loss, deposition, and sediment yield from a complex slope, concave-convex shape.

5.3. Does RUSLE2 Not Apply to Certain Conditions?

5.3.1. Rill erosion or concentrated flow erosion?

RUSLE2 does not apply to concentrated flow areas where ephemeral gully erosion occurs. **Whether or not RUSLE2 applies to particular eroded channels is not determined by size or depth of the channels.** The determination depends on whether the channels in the field situation would be included if RUSLE2 plots were to be placed on that landscape. The core part of **RUSLE2** that computes **net detachment** (**sediment production**) is empirically derived from data collected from plots like those illustrated in Figures 5.5 and 5.6. The length of these plots typically was about 75 ft (25 m) and width ranged from 6 ft (2 m) to about 40 ft (13 m) wide with plots as wide as 150 ft (50 m) at one location. These plots were always placed on the sides of the hillslope where overland flow occurred, not in the swales where concentrated flow occurs. Thus, RUSLE2 can estimate soil loss for rills 15 inches (375 mm) deep on sides of hillslopes because these rill would be in plots placed on this part of the landscape but not erosion from a 4 inch (100 mm) deep ephemeral gully or 10 ft (3 m) deep classical gully in a concentrated flow area because plots were not be placed in these locations.

5.3.2. Can RUSLE2 be Used to Estimate Sediment Yield from Large Watersheds?

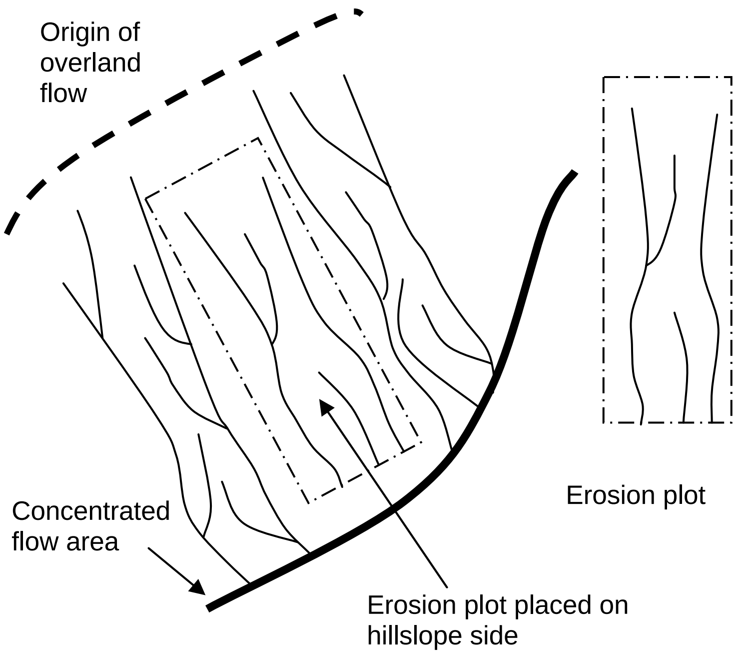

Figure 5.5. Relation of erosion plots to landscape

Sediment yield from most large watersheds is often less than sediment production within the watershed. Thus, much sediment is deposited within a typical watershed. **RUSLE2**, in contrast to the USLE and RUSLE1, can estimate the deposition that occurs on the overland flow portion of the landscape. This deposition, up to 75 percent of the sediment produced on the eroding portion of the hillslope, can be substantial on many hillslopes. **If RUSLE2 is used to estimate sediment yield in watersheds, it should be applied only to the eroding portion of the landscape to compute a soil loss comparable to that computed by the USLE. Otherwise, a different set of sediment delivery ratio values from those used by the USLE would have to be used with RUSLE2 to take into account deposition on overland flow areas.**

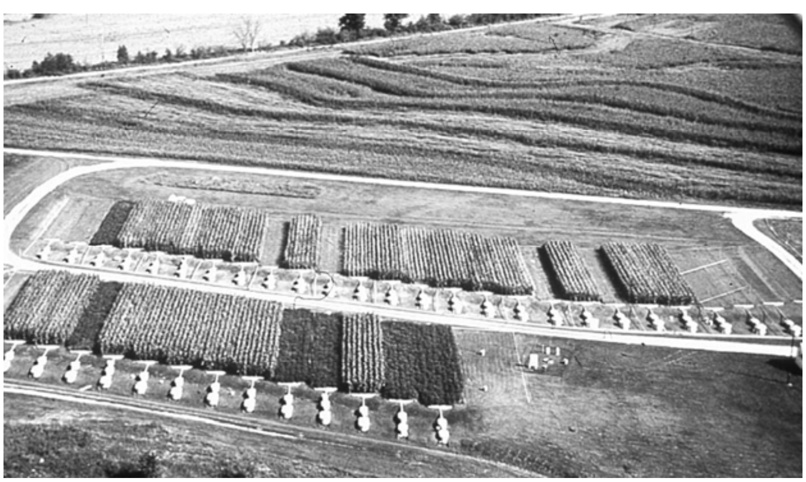

Figure 5.6. Erosion plots 12 ft wide (3.65 m) and 72.6 ft (22.1 m) long near Columbia, MO.

In addition to the sediment produced by interrill and rill erosion on upland areas (estimated by **RUSLE2)**, erosion in concentrated flow areas (ephemeral gullies), classical gullies, stream channels, and mass movement of material into channels are other major sources of sediment that contribute to sediment yield, which are not estimated by **RUSLE2**.

5.3.3. Estimating Soil Loss with RUSLE2 for Large Areas

RUSLE2 can be used to estimate soil loss for large areas. The approach is to select sample points over the inventory area where RUSLE2 will be applied to compute soil loss. These sample points should be selected according to the requirements of the inventory, giving special attention to required accuracy and how soil loss estimates will be aggregated according to soil, topography, land use, and conservation practice. RUSLE2 can be applied in several ways. One way is to estimate a "point" soil loss at the sample point. A slope length[2] to the point and values for steepness, soil, and cover and management at each sample point are determined. A slope segment 1 ft (0.3 m) long at the end of the slope length along with the other RUSLE2 input values for the segment are used in RUSLE2 to compute soil loss at the point.

Another approach is to determine a slope length through the point that extends to the location that deposition begins or to a concentrated flow area if deposition does not occur. Values for conditions along the slope length are used in RUSLE2 to compute a soil loss for the slope length. A limitation of this approach is that soil loss values cannot be aggregated based on conditions that vary along a slope length, such as multiple soil types.
A third approach, which was used by USDA-NRCS for the National Resources Inventory (NRI), uses the slope length through the point to either deposition or a concentrated flow area and conditions at the point to compute soil loss. This approach does not provide an estimate of soil loss at the point. Soil loss values cannot be aggregated for variables that are related to position on the slope. For example, the same soil loss is computed at the top of slope as at the bottom of slopes when slope steepness is the same for both locations.[3] A major advantage of computing soil loss for the entire slope length is that the number of sample points needed to obtain an accurate estimate of average soil loss for the area is significantly reduced. However, this procedure can not be used where the main variables, such soil erodibility or steepness, depend on landscape position.

An approach that absolutely should not be used is to determine spatially averaged values for slope length and steepness, soil, and cover-management conditions for the inventory area and use these values in RUSLE2 to compute a single soil loss value for the area. Soil loss estimates by this method are inaccurate because of nonlinearities in the RUSLE2 equations. No simple, universally applicable method can be developed to select the proper input values for this method. The issue is directly related to the proper

---

2 Slope length refers to the traditional USLE definition of slope length, which applies to the eroding portion of the RUSLE2 overland flow path length.

3 For discussion of the mathematics related to this approach, see Foster, G.R. 1985. Understanding ephemeral gully erosion (concentrated flow erosion). In: Soil Conservation, Assessing the National Resources Inventory. National Academy Press. Washington, D.C. pp. 90-125.

mathematical procedures for spatial integration, which is exactly the reason why RUSLE2 is much superior mathematically to the USLE or RUSLE1 as discussed below.

5.4. Equation Structure of RUSLE2

RUSLE2 uses an equation structure similar to the Universal Soil Loss Equation (USLE) and RUSLE1. RUSLE2 computes long-term average soil loss on each *ith* day as:

$$a_i = r_i k_i l_i S c_i p_i \quad \textbf{[5.1]}$$

where: a_i = long-term average soil loss for the *ith* day, r_i = erosivity factor, k_i = soil erodibility factor, l_i = soil length factor, S = slope steepness factor, c_i = cover-management factor, p_i = supporting practices factor, all on the *ith* day.[4] The slope steepness factor S is the same for every day and thus does not have a subscript. To emphasize, values for these factors are long–term averages for a particular day—not for the year, which is the reason that lower case symbols are used rather than upper case as in RUSLE1 and USLE. Equation 5.1 is exactly like the USLE except that it computes soil for a given day rather than an annual soil loss.

RUSLE2 computes deposition when sediment load exceeds transport capacity on overland flow profiles like the one illustrated in Figure 5.2 using:

$$D_p = (V_f / q)(T_c - g) \quad \textbf{[5.2]}$$

where: D_p = deposition, V_f = fall velocity of the sediment in still water, q = overland flow (runoff) rate per unit width of flow, T_c = sediment transport capacity, and g = sediment load. **RUSLE2** computes runoff rate using the 10-yr, 24 hr storm amount, the NRCS curve number method, and a runoff index (curve number) computed from cover-management variables. **RUSLE2** computes sediment transport capacity using:

$$T_c = K_T q s \quad \textbf{[5.3]}$$

where: s = sine of the slope angle and K_T = a transport coefficient computed as a function of cover-management variables. The steady state conservation of mass equation is to compute sediment load as:

$$g_{out} = g_{in} + \Delta x D \quad \textbf{[5.4]}$$

where: g_{out} = sediment load leaving the lower end of a segment on the slope, g_{in} =

---

4 Lower case letters are used to denote daily variables in comparison to the upper case letters used in the USLE and RUSLE1 that denote average annual values.

sediment load entering the upper end of the segment, Δx = length of segment, and D = net detachment or deposition within the segment. The sign convention is "+" for detachment because detachment adds to the sediment load, and "-" for deposition because it reduces the sediment load. Equation 5.4 is graphically illustrated in Figure 5.7.

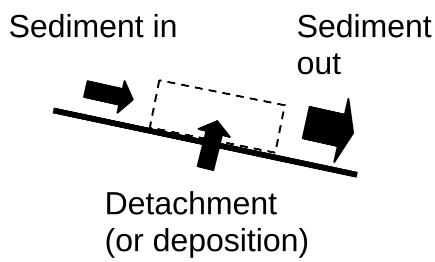

Figure 5.7. Schematic of conservation of mass equation for computing sediment load along the slope

Equations 5.2-5.4 are solved for each of the five particle classes of primary clay, primary silt, small aggregate, large aggregate, and primary sand. The distribution among these classes at the point of detachment is computed by RUSLE2 as a function of soil texture. The wide range in fall velocity for sediment particle classes allows equation 5.2 to compute the sorting of sediment where coarse and dense sediment are deposited first, which enriches the sediment load in fines and less dense particles.

Average annual soil loss is computed as:

$$A = \left(\sum_{i=a}^{365m} a_i \right) \Big/ m \qquad \textbf{[5.5]}$$

where: A = average annual soil loss, m = number of years in the analysis period, and 365m = the number of days per year. The value for m is 1 for continuous vegetation on range, pasture, and other lands where conditions are the same year after year, while m = the number of years of cropping-management rotations on cropland and the number of years following a disturbance such as construction, logging, grading of a reclaimed surface mine, or closing of a land fill where conditions are changing year to year.

For comparison, RUSLE1 is:

$$A = RLSP \left\{ \left[\sum_{k=1}^{24m} \left(f_k k_k \right) \right] \Big/ m \right\} \left[\sum_{k=1}^{24m} \left(f_k c_k \right) \right] \Big/ m \qquad \textbf{[5.6]}$$

where: R = average annual erosivity, f_k = distribution of erosivity by half month period, L = slope length factor, P = supporting practices factor, and k = index for the half month period. The 24 in equation 5.6 is the number of half month periods in a year. Values for the terms K and C are computed from:

$$K = \left[\sum_{k=1}^{24m} \left(f_k k_k \right) \right] \Big/ m \qquad \textbf{[5.7]}$$

and:

$$C = \left[\sum_{k=1}^{24m} \left(f_k c_k \right) \right] \Big/ m \qquad \textbf{[5.8]}$$

Values for K and C were computed and placed in tables so that RUSLE1 could be used in a "paper version" as A=RKLSCP. A computer program for RUSLE1 is also available to compute K, C, and P factor values from basic subfactor variables along with a procedure for computing soil loss for non-uniform shaped overland flow paths.

The USLE is:

$$A = RKLSP \left[\sum_{j=1}^{N} \left(f_j c_j \right) \right] \Big/ m \qquad \textbf{[5.9]}$$

where: j = the index for crop stage periods and N = the number of crop stages over the analysis period. A crop stage period is one where the cover-management factor c can be assumed to be constant. Values for C were computed from:

$$C = \left[\sum_{j=1}^{N} \left(f_j c_j \right) \right] \Big/ m \qquad \textbf{[5.10]}$$

Values for C were placed in tables so that the USLE could be used easily in a "paper version" as A=RKLSCP.

The numerical integration used in RUSLE2 to solve equations 5.1 and 5.5 is much superior to the approximations used in RUSLE1 and the USLE. The difference in soil loss estimates between RUSLE2 and the other equations can be as much as 15 percent because of differences in the mathematical integration procedures. Modern computers are readily available to solve complex equations to eliminate the need for a "paper version" of RUSLE2. The equations and procedures in RUSLE2 are too complex for a "paper version." Although RUSLE2 can compute C factor values, RUSLE2 does not use the standard RKLSCP factor values to compute erosion.

The USLE, introduced in the early 1960's and revised in 1978,[5] was totally empirical, having been derived from more than 10,000 plot years of data from natural runoff plots and an estimated equivalent of 2,000 plot-years of data from rainfall simulator plots. The strength of the USLE is its empiricism, which is also its weakness. The USLE cannot be applied to situations where empirical data are not available for a specific field condition to derive appropriate factor values. Also, the USLE subfactor procedure for non-cropland (Table 10, AH537) is missing important variables including soil surface roughness and biomass production level.

Federal legislation in the 1980's required erosion prediction technology applicable to almost every cropland use, a requirement that the USLE could not meet. A "subfactor" method that estimates values for the cover-management factor C allows RUSLE1 to be applied to any land use. Process-based equations were also added to estimate the values for the support practice factor P so that soil loss could be estimated for modern strip cropping systems that could be estimated with the USLE. Data needed to derive USLE P factor values were not available for these systems. This hybrid approach of starting with an empirical structure and then adding process-based equations where empirical data were limited greatly increased the power of RUSLE1 over the USLE.

RUSLE2 significantly expands on this hybrid approach by combining the best of empirical-based and process-based erosion prediction technologies. Modern theory on erosion processes of detachment, transport, and deposition of soil particles by raindrop impact and surface runoff was used to derive **RUSLE2** relationships where the required equations could not be derived from empirical data. **RUSLE2** is well-validated erosion prediction technology that builds on the success of the USLE and RUSLE1. **RUSLE2** validation is described in **Section 17**.

5.5. Major Factors Affecting Erosion

The four major factors affecting interrill and rill erosion are: (1) climate, (2) soil, (3) topography, and (4) land use.

5.5.1. Climate

Rainfall drives interrill and rill erosion. The most important characteristics of rainfall are rainfall intensity (how hard it rains) and rainfall amount (how much it rains). Soil loss is high in Mississippi where much intense rainfall occurs, whereas soil loss is low in the deserts of Nevada where very little rainfall occurs. Thus, rainfall erosivity varies by location. Specifying the location of a site identifies the erosivity at the site.

---

5 Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall-erosion losses: A guide to conservation planning. U.S. Dept. of Agriculture, Agriculture Handbook # 537.

5.5.2. Soil

Some soils are naturally more erodible than are other soils. Erosion by raindrop impact is not easily seen, but varying degrees of rilling indicate differing erodibility among soils. Knowledge of basic soil properties such as texture provides an indication of erodibility. For example, soils high in clay and sand have low erodibilities while soils high in silt have high erodibilities. Soils are mapped and named as map units and components that make up map units. Soil properties, including erodibility, are assigned by soil component and map unit. These properties are, in effect, specified when the name of a soil mapping unit is selected. Soils on highly disturbed lands like reclaimed mine sites can not be mapped and require special considerations to determine erodibility.

5.5.3. Topography

Topography, especially steepness, affects soil loss. Intense rilling is evidence that steep slopes like road cuts and fills experience intense erosion when bare. Runoff that accumulates on long slopes (overland flow path lengths) is also highly erodible, especially when it flows onto steep slopes. Thus, slope steepness and overland flow path length, to a lesser extent, are major indicators of how topography affects erosion. Slope shape (steepness along the overland flow path), illustrated in Figure 5.2, 5.3, and 5.4, also affects erosion and deposition as evidenced by both erosion and deposition on concave slopes.

5.5.4. Land Use

Erosion occurs when soil is left bare and exposed to raindrop impact and surface runoff. Vegetative cover greatly reduces soil loss. Two types of practices are used to control soil loss. One type is cultural practices like vegetative cover, crop rotations, conservation tillage, and applied mulch. The other type is supporting practices like contouring, strip cropping, and terraces that "support" cultural management practices. Of the factors of climate, soil, topography, and land use, land use is most important. It has the greatest range of effect on soil erosion, and it is the one that can be changed most readily to control soil loss and sediment yield.

A powerful feature of RUSLE2 is that it is land use independent. By using fundamental variables to represent cover-management effects, RUSLE2 can be applied to any land use. These variables include percent canopy cover; fall height; ground cover provided by live vegetation, plant litter, crop residue, and applied materials; surface roughness; soil biomass; degree of soil consolidation, and ridge height. RUSLE2 applies to cropland, rangeland, disturbed forestland, construction sites, reclaimed mined land, landfills, military training sites, and other areas where "mineral" soil is exposed to the forces of raindrop impact and overland flow produced by rainfall in excess of infiltration.

5.6. Computing Soil Loss with RUSLE2

RUSLE2 computes soil loss and other erosion values using inputs for climate, soil, topography, and use practices and conditions. These values stored in the RUSLE2 database under names for locations, which identify climatic variables; soil; cover-management conditions and practices; and supporting practices. The user selects a name from a menu list for each of these factors to compute erosion. RUSLE2 "pulls" the values associated with each input name from the RUSLE2 database. The user changes values of particular variables from those stored in the database as needed to represent site-specific conditions related to topography, yield (production level), rock cover, and type and amount of applied materials like manure and mulch.

In many ways, RUSLE2 is a set of database components that operate like a spreadsheet. Values are stored in each database component for the variables that RUSLE2 uses in its computations. When the user changes a particular value to represent a site-specific condition, RUSLE2 immediately updates its computations, much like a spreadsheet updates its computations when a change is made in a cell.

RUSLE2 is never started from a "blank sheet." It always starts with information already stored in a database component. The user changes the values for particular variables if the values stored in the database are not appropriate for the field conditions where RUSLE2 is being applied.

5.6.1. Computational Database Components

All RUSLE2 database components accept input and make computations. However, three RUSLE2 database components are the primary computational components. These components are the (hillslope) **profile**, **worksheet**, and **plan view** components.

The overland flow path along a hillslope **profile** is the basic computational unit of RUSLE2. Information on the location (climate), soil, cover-management, supporting practices, and topography of a specific overland flow path describes a particular hillslope **profile**. Once this information has been entered in RUSLE2 to describe a particular hillslope profile, the profile can be named and saved in the **profile** component of the RUSLE2 database.

The RUSLE2 **worksheet** component is used to facilitate conservation planning by computing erosion for a set of alternate conservation practices for a **uniform** hillslope profile for a particular location, soil, and topography. The worksheet provides a convenient way to compare alternatives. Another RUSLE2 worksheet is available that can be used to compare hillslope profiles where conditions including location, soil, topography, cover-management, and supporting practice can vary along hillslope profiles and among the profiles.

The RUSLE2 **plan view** component can be used to compute average soil loss and other erosion variables for a spatial area like a field or watershed where profiles vary over the area.

Individual profile, worksheets, and plan views can be named and saved.

5.6.2. RUSLE2 Database Components

The major components of the RUSLE2 database are listed in Table 5.1. With the exception of a few site-specific inputs, RUSLE2 uses values stored in its database to make its computations. Later sections discuss the major variables in each RUSLE2 database component. Information on each variable and how it is used along with information on how to select input values is provided.

Table 5.1. RUSLE2 database components

Components	Comment
Plan view	Computes average erosion for a spatial area like a field or watershed
Worksheet	Computes erosion for alternative management practices and alternative hillslope profiles (overland flow paths)
Profile	Computes soil loss for a single hillslope profile (overland flow path), the basic computational unit in RUSLE2
Climate	Contains data on erosivity, precipitation amount, and temperature
Storm erosivity	Contains data on the distribution of erosivity during the year
Soil	Contains soil data including erodibility, texture, hydrologic soil group, time to consolidation, sediment characteristics, soil erodibility nomographs
Management	Contains descriptions of cover-management systems; includes dates, operations, vegetation, type and amount of applied materials
Operation	Contains data on operations, which are events that affect soil, vegetation, and residue; includes the sequence of processes used to describe each operation; whether an operation places residue in the soil; includes values for flattening, burial, and resurfacing ratios; ridge heights; and initial soil roughness
Vegetation	Contains data on vegetation; includes residue types associated with particular vegetations, yield, amount of aboveground biomass at maximum canopy, senescence, flow retardance, root biomass, canopy cover, fall height, live ground cover
Residue	Contains data that describe the residue description assigned to each vegetation description; includes values for decomposition, mass-cover

	relationship, how residue responds to tillage
Contouring	Contains values for row grade used to describe degree of contouring
Strips/barriers	Contains data that describes filter strips, buffer strips, and rotational strip cropping; includes cover-management in strips, width of strips, number of strips across slope length, whether or not a strip is at the end of the slope; and offset of rotation by strip; includes information on barriers used on construction sites.
Hydraulic system	Identifies the hydraulic elements and their sequence used to describe hydraulic systems of diversions, terraces, and impoundments; includes number across overland flow path length and whether or not a system is at the end of the slope; includes specific locations of practice on the overland flow path length
Hydraulic element	Contains data on grade of named channel for terraces and diversions
Subsurface drainage system	Contains data on the percent of the area covered by optimum drainage

5.6.3. Templates

RUSLE2 uses **control files** known as **templates** and **access/permission files** that control the RUSLE2 computer screen and the variables accessible to the user. **Templates** determine the appearance of the computer screen and the complexity of the problems that can be analyzed. **Templates** can be customized by the user to change the appearance of the screen. Two standard templates, **uniform slope** and **complex slope**, are available for download from the **USDA RUSLE2 Internet site** at http://www.ars.usda.gov/Research/docs.htm?docid=6038. The **uniform slope** template is for application of RUSLE2 to uniform slopes where all conditions are the same along the slope except for regularly spaced strips such as buffer strips and strip cropping. The **uniform slope** template should be used to learn RUSLE2. It is also the template that makes RUSLE2 most comparable to the USLE and RUSLE1 for estimating soil loss. The **complex slope** template can be used to analyze slopes where conditions such as soil, steepness, cover-management conditions, and certain support practices vary along the slope.

RUSLE2 can display information on many more variables than is displayed on the **uniform slope** and **complex slope** templates. Contact your RUSLE2 administrator for information on how to obtain templates that display additional output. Also, you can edit templates yourself to add a display of certain variables to your current templates. The revised template can be saved under an existing name or saved with a new name. **Of course, saving a template under an existing name means that the template as it existed before the change is lost.** Templates can be transferred among users.

5.6.4. Access/Permission Files

RUSLE2 uses **access/permissions** files that can be named and saved. These files determine the variables that are seen and the variables that are seen but cannot be edited. A main benefit of **access/permissions** files is to protect users from making unauthorized changes in a database. Contact your RUSLE2 administrator for information on changing RUSLE2 access control especially if you find that you cannot manipulate key variables because you are apparently locked out of them. In some cases, you can change values and store the information under a new name. Also, don't be surprised to learn that RUSLE2 has many other variables of interest that someone "upstream" has chosen to keep hidden from you.

5.6.5. Computer Program Mechanics

Information on RUSLE2 computer interface mechanics is summarized in documents available on the USDA-ARS (http://www.ars.usda.gov/Research/docs.htm?docid=6010), University of Tennessee (www.rusle2.org), and USDA-NRCS (http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm) Internet sites.

When the RUSLE2 program is first started, the opening screen provides two choices. Select either a **profile** or **worksheet** to perform erosion computations or select one of the other **database components** to work on stored input values such as those for cover-management and support practices, vegetation, operation, residue, and soil properties, and climate inputs. The second choice is to select a **template**. Templates control the appearance of the RUSLE2 interface and determine the complexity of the field problems that can be analyzed. RUSLE2 is easiest to use for a simple uniform slope, which is the **uniform slope** template. As you become familiar with RUSLE2, move to the **complex slope** and other templates to analyze complex slopes. Also, once you learn the program, you can change the program so that the program starts with alternative screens and **default profiles, worksheets, and plan views**.

Input values in the database can be changed during a particular RUSLE2 analysis. However, you may be locked out of certain database elements because of settings in the RUSLE2 **access control file**.

6. CLIMATE DATABASE COMPONENT

This section describes the variables in the **climate database component**, the role of each variable, and how to determine values for key variables. Values on erosivity, precipitation amount, and temperature are the principal information in the climate database component.

Three types of erosivity inputs can be used in RUSLE2. The preferred method is to enter values for **erosivity density**, which is the ratio of monthly erosivity to monthly precipitation. Erosivity density values were recently determined from analysis of modern weather data as a part of the RUSLE2 development. The second method is to enter monthly erosivity values. The third method is to enter an average annual erosivity value along with an erosivity distribution curve for the EI zone containing the site where RUSLE2 is being applied. The third method is the same as that described in AH703 for RUSLE1. However, do not use values from AH703 because those values are based on old data from the 1930's to 1950's period. **Erosivity values determined from the modern data are about 10 percent larger on average than values based on the older data.**[6]

RUSLE2 uses a storm with a 10 year recurrence interval in its runoff computations. **Two types of inputs for this storm can be used in RUSLE2 (see Section 6.5.2).** One option, which is recommended, is to enter a value for the 10 year-24 hour precipitation amount. RUSLE2 computes a corresponding 10 yr EI. The other option is to enter a 10 yr EI value. RUSLE2 computes a corresponding 10 yr-24 hr precipitation amount. Although the two options yield similar results in the eastern US, entering the 10 yr-24 hr precipitation amount yields significantly improved results in the western US.

6.1. Major Climate Variables

Table 6.1 lists the variables in the RUSLE2 **climate database component** for the **preferred erosivity density** approach, which should be used when applying RUSLE2 to locations within the continental US. Table 6.2 lists the erosivity variables for the annual

---

6 This overall 10 percent increase in average annual erosivity should not be attributed necessarily to climate change. The increase could be related to differences in measurement techniques and equipment and analytical procedures used to determine erosivity values from the measured data. Data limitations including temporal and spatial variability, missing data, and errors in weather data do not allow conclusions contribute to the difference. In general, the monthly distributions of erosivity changed less than the overall increase in erosivity. The erosivity values produced by this analysis are superior to previous erosivity values, especially for the Western US, for conservation and erosion control planning using RUSLE2. This 10 percent difference in erosivity values must be interpreted along with RUSLE2's accuracy in the context of the particular RUSLE2 application (see **Section 17**).

R and EI distribution zone approach, which may be convenient when applying RUSLE2 outside of the US.

Table 6.1. Variables in climate database component for **erosivity density** procedure		
Variable	**Symbol**	**Comment**
Monthly erosivity density	α_m	Ratio of monthly erosivity to monthly precipitation; RUSLE2 uses these values and monthly precipitation to compute monthly erosivity
Annual erosivity	R	RUSLE2 sums monthly erosivity values to determine an annual erosivity value (not an input)
Monthly erosivity	R_m	RUSLE2 computes monthly erosivity using monthly values for erosivity density and precipitation (not an input)
Daily erosivity	r_i	RUSLE2 "disaggregates" monthly erosivity values into daily values (not an input)
Monthly precipitation	P_m	Average annual monthly precipitation (rainfall plus snow), used to compute monthly erosivity, the temporal variation of soil erodibility, and decomposition of dead plant materials (litter, residue, roots)
Daily precipitation	p_i	RUSLE2 "disaggregates" monthly precipitation values into daily values (not an input)
Annual precipitation	P_t	RUSLE2 computes annual precipitation from the monthly precipitation values; used to compute time to soil consolidation (not an input)
10 yr 24 hr precipitation	$P_{10y,24h}$	This precipitation, representative of a moderately infrequent erosive rain, is used to compute a storm erosivity and runoff; these variables, in turn, are used to compute transport capacity and deposition for concave slopes, vegetative strips, and channels; reduction of erosion by ponding; effectiveness of contouring; and critical slope length for contouring
EI for 10 yr 24 hr precipitation	$EI_{10y,24h}$	RUSLE2 determines this values from 10 yr 24 hr precipitation and maximum monthly erosivity density value (not an input)
Monthly temperature	T_m	Average annual monthly temperature, used to compute the temporal variation of soil erodibility and decomposition of dead plant materials (litter, residue, roots)
Daily temperature	T_i	RUSLE2 "disaggregates" monthly temperature values into daily temperature values (not an input)
In Req Area?	Yes or no	The Req area is a region in the Northwestern part of the US where the erodibility of certain cropland and other highly disturbed soils is greatly increased during winter months; answer **Yes** to use Req relationships for these land uses

Use Req distribution?	Yes or no	Wintertime adjustment for increased erodibility does not apply to land uses like pasture and rangeland; if answered no, Req relationships will not be used
R equivalent	R_{eq}	The effect of the greatly increased erodibility is accounted for in the Req region by using an equivalent erosivity value based on annual precipitation (not an input)
EI distribution for Req	-	An erosivity distribution that describes the greatly increased erodibility during the winter
Adjust for soil moisture	Yes or no	An adjustment is made for soil moisture when the Req relationship is selected for cropland and other situations of highly disturbed soil, only applies to Req zone
Vary soil erodibility with climate	Yes or no	With the exception of when the Req relationships are used, select **Yes** to vary soil erodibility values through time as a function of monthly precipitation and temperature (may not be available on most templates)
Note: Not all of these Req-type variables are available on some templates. For example, if **No** is the input for **In Req area?,** then RUSLE2 automatically varies soil erodibility with climate.		

Table 6.2. Variables in climate database component for monthly or annual R and EI distribution procedure. Note: Refer to AH703 for information on these variables.

Variable	**Symbol**	**Comment**
Average annual erosivity	R	An erosivity index that indicates how the erosivity of rainfall varies by location
Erosivity distribution	EI zone identifier	Describes how erosivity varies during the year by half-month periods. Not an input when monthly erosivity values are entered.
Monthly erosivity	R_m	RUSLE2 computes monthly erosivity using annual erosivity value and erosivity (EI) distribution by half month period when method of entering annual erosivity is used.
Daily erosivity	r_i	RUSLE2 "disaggregates" half month erosivity values into daily values (not an input)
10 year storm erosivity	EI_{10yr}	This storm represents a moderately infrequent erosive rain; EI_{10yr} value is used to compute runoff, which along with the storm erosivity, is used to compute transport capacity and deposition for concave slopes, vegetative strips, and channels; reduction of erosion by ponding; effectiveness of contouring; critical slope length for contouring

6.2. Basic Principles

RUSLE2 is based on the assumption that net **detachment** caused by a single storm is directly proportional to the product of a storm's **energy E** and its **maximum 30-minute intensity I_{30}**. **The relationship between detachment and storm erosivity EI is linear**, which means that individual **storm EI** values can be summed to determine monthly and annual erosivity values. This linear relationship also means that average annual erosion can be mathematically computed for each day as represented by Equation 5.1 even though erosion does not occur on every day during a year.

The **average annual erosivity value R** is an index of erosivity at a location. For example, R-values in central Mississippi are about 10 times those in Western North Dakota. If all things are equal, erosion in central Mississippi is 10 times that in Western North Dakota. Erosivity reflects the effects of both rainfall amount and rainfall intensity on erosion. Thus, erosivity values can vary significantly among locations having nearly equal rainfall amounts because of difference in rainfall intensity among locations.

6.2.1. Computing Erosivity for Individual Storms

Storm erosivity EI is the product of a storm's total **energy E** and its **maximum 30-minute intensity I_{30}**. A storm's total energy is most related to the total amount of rainfall in a storm. It is also partially related to intensity because the energy content per unit rainfall (**unit energy**) is related to rainfall intensity. Rainfall intensity also has a direct affect on erosion besides its effect on storm energy. The **maximum 30-minute intensity** is a better measure of the intensity effect than either **average intensity** or **peak intensity**. The 30-minute time period over which to average intensity was determined from analysis of empirical erosion data for the continental US. Other time periods such as 15 minutes are better in other places of the world where rainfall characteristics differ from those in the continental US. **The EI product for storm erosivity captures the effects of the two most important rainfall variables that determine erosivity; how much it rains (rainfall amount) and how hard it rains (rainfall intensity).**

Total energy for a storm is computed from:

$$E = \sum_{k=1}^{m} e_k \Delta V_k \qquad \textbf{[6.1]}$$

where: e = unit energy (energy per unit of rainfall), ΔV = rainfall amount for the *kth* period, k = an index for periods during a rain storm where intensity can be considered to be constant, and m = number of periods. Unit energy is computed from:

$$e = 0.29[1 - 0.72\exp(-0.082i)] \quad \textbf{[6.2]}$$

where: unit energy e has units of MJ/(ha·mm) and i = rainfall intensity (mm/h).[7] Table 6.3 illustrates computation of total energy for a storm. The total energy for the example storm is 8.90 MJ/ha.

The next step is to determine the maximum 30-minute intensity I_{30}. Maximum 30-minute intensity is the average intensity for the continuous 30 minutes with the maximum rainfall. (Also, I_{30} = 2·amt of rain in the 30 minutes having the maximum rainfall amt) Plotting cumulative rainfall for the storm as illustrated in Figure 6.1 is helpful for determining maximum 30-minute rainfall. This storm is unimodal (single peak), which means that the 30 minutes with the most rainfall contains the time that the peak intensity occurs. The amount of rainfall is 27.4 mm for the 30 minutes with the most rainfall, which gives an intensity of 57.4 mm/h for I_{30}.

Table 6.3. Sample computation of erosvity EI for an individual storm

Time (hrs:min)	Duration of interval (minutes)	Cumulative rain depth (mm)	Rainfall in interval (mm)	Intensity (mm/h)	Unit energy (MJ/ha* mm)	Energy in interval (MJ/ha)
4:00		0.0				
4:20	20	1.3	1.3	3.8	0.137	0.17
4:27	7	3.0	1.8	15.2	0.230	0.41
4:36	9	8.9	5.8	38.9	0.281	1.64
4:50	14	26.7	17.8	76.2	0.290	5.15
4:53	3	30.5	3.8	76.2	0.290	1.10
5:05	12	31.8	1.3	6.4	0.166	0.21
5:15	10	31.8	0.0	0.0	0.081	0.00
5:30	15	33.0	1.3	5.1	0.152	0.19
Total	90		33			8.88

The erosivity for the storm is the product of 8.90 MJ/ha (storm energy) and 57.4 mm/h (maximum 30-minute intensity) = 512 MJ·mm/(ha·h). **The computation of storm erosivity in US customary units is similar, except that storm erosivity values are divided by 100 to provide convenient working numbers.**

7 Equation 6.2 differs from the corresponding equation used in RUSLE1 (AH703). The 0.082 coefficient in equation 6.2 was 0.05 in AH703. For additional discussion, see McGregor, K.C., R.L. Bingner, A.J. Bowie, and G.R. Foster. 1995. Erosivity index values for northern Mississippi. Transactions of the American Society of Agricultural Engineers. 38(4):1039-1047.

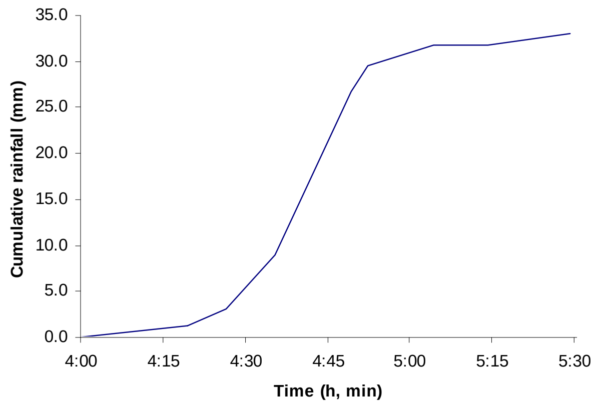

Figure 6.1. Cumulative rainfall for a storm.

Rains less than 0.5 inch (12.5 mm) and separated from other rains by more than 6 hours are not included in the computations unless the maximum 15-minute intensity exceeds 0.5 inch/hour (12.5 mm/h). When erosivity values were first computed in the late 1950's, these small storms were omitted to significantly reduce the amount of rainfall data that must be processed in an era before data could be processed with computers. These storms add little to the total annual erosivity. However, storms less than 0.5 inch (12.5 mm) were also deleted in computing erosivity for RUSLE2 to give some effect of computing reduced erosion at low rainfall amounts and intensities because of little or no runoff.

Average annual erosivity is the sum of the storm erosivities over M number of year as:

$$R = \left[\sum_{m=1}^{M} \sum_{j=1}^{J(m)} (EI_{30})_j \right] \Big/ M \qquad \textbf{[6.3]}$$

where: R = average annual erosivity, EI_{30} = the erosivity of an individual storm, j = an index for each storm, J(m) = number of storms in the *mth* year, and m = an index for year.[8]

6.2.2. Why New Erosivity Values were Computed from Modern Data

A concern has existed for sometime that erosivity values for the eastern US needed to be recomputed based on modern precipitation data. Average annual erosivity values in AH703 for the Eastern US, as well as erosivity values in AH282 and AH537, were based on data collected in the approximate period of 1935 to 1957. This period included two major droughts in large regions of the US. Also, a possible climate change over the last 70 years may have increased rainfall amounts and intensities and caused a corresponding increase in erosivity. To address these concerns, precipitation data from the 1960's through 1999 were analyzed to develop a modern set of erosivity values.[9] **Based on this**

---

[8] The R factor has units. In this guide, the US customary units for R are hundreds of (ft tons in)/(ac yr hr). Metric units in the SI system are (MJ mm)/(ha∗h) for erosivity and (t h)/(MJ mm). See AH703 for additional information.

[9] Precipitation data from 15-minute stations across the US were assembled by the Illinois State Water Survey (ISWS), who computed storm energy and maximum 30-minute intensity for the qualifying

analysis, modern average annual erosivity is about 10% greater over much of the eastern US than that for the1935-1957 period.

Differences in erosivity values derived from the 1930's-1950's data and those derived from the 1960's-1990's data should not be interpreted as having been caused by climate change. Differences in record length, analysis procedures, and interpretation at different points in time and by different people prevent such a direct comparison of values.

Erosivity values described in this RUSLE2 User Reference Guide determined from the modern data should be accepted as representing the best erosivity values currently available for applying RUSLE2 at the local field office level for conservation and erosion control planning—nothing more, nothing less.

6.2.3. Erosivity Density Values

The erosivity density method used to derive erosivity values was developed to maximize the precipitation data that could be used to compute erosivity values and to provide a consistent set of erosivity value for conservation and erosion control planning. **Erosivity density** is the ratio of the monthly erosivity to monthly precipitation. Erosivity density values were computed across the US at about 1610 stations. Statistical analysis showed that erosivity density is independent of elevation, which means that the erosivity density could be smoothed and mapped using GIS techniques for the entire continental US as a spatial unit (See the RUSLE2 Scientific Documentation for additional information). Precipitation data with intensity values needed to compute erosivity are very limited

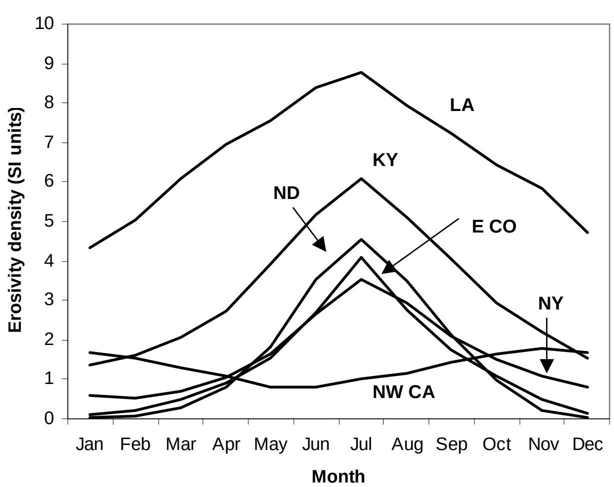

Figure 6.2. Erosivity density at selected locations. LA-Louisiana, KY-Kentucky, ND-North Dakota, E CO-Eastern Colorado, NY-New York, NW CA-Northwestern California

rainstorms. The ISWS and the USDA-NRCS National Water and Climate Center (NWCC) analyzed the data to remove storms with greater than a 50-yr return period, snow events, and invalid data because of equipment failure, a short record length, or other reasons. University of Tennessee personnel performed the spatial analysis of the data.

at higher elevations. The applicability of erosivity density values is limited at elevations higher than about 3,000 m (10,000 ft), especially in the winter months.[10]

Erosivity density is a measure of erosivity content per unit of precipitation. Erosivity density is low during the winter months and high during the summer months with the exception of the western most portion of the US. Erosivity density is greater in the southern part of the US than in the northern part. Erosivity density is more uniform over the year in the southern part of the US than in other parts of the US.

Unsmoothed erosivity density values directly computed from the weather data at individual stations are both spatially and temporally irregular. Trends are sometimes difficult to discern when comparing data among individual weather stations. However, patterns like those in Figure 6.2 emerge when data from several stations are averaged over areas like the quadrants of Indiana.[11] The erosivity density values were spatially smoothed using GIS techniques to provide spatial and temporal consistency required by conservation and erosion control planning applications of RUSLE2. The objective in RUSLE2 is to represent the main geographic trends in the historical data and not the details in historical weather data. Preferably the probability of weather events, both dry and wet, would be the same at all locations in the climate data used by RUSLE2.

Erosivity density values for the continental US are shown in Figure 6.3-6.14. RUSLE2 users can read values from these figures to create entries in their RUSLE2 operational database. However, RUSLE2 users are advised to download values for their RUSLE2 application from the NRCS RUSLE2 National Database rather than to create their own RUSLE2 entries by reading values from these Figures. However, some users may wish to create an entry in their database for a specific site rather than use the NRCS database values. Values for erosivity density can be read from these figures with sufficient accuracy to apply RUSLE2.

The principal application of RUSLE2 is for conservation and erosion control planning. The objective is to capture main effects and consistency so that farmers, contractors, and others impacted by RUSLE2 are treated fairly, especially where costs, benefits, and regulatory impacts are involved. No one should be penalized or rewarded based on unusual events occurring at a location.

---

[10] Erosivity density values are highly variable in the western US. Also, the number of locations is very limited. Because of these data limitations, statistical tests that show that the hypothesis that erosivity density values are not a function of elevation are not robust. Obviously erosivity density values decrease with elevation in the winter because of increasing amounts of snow at higher elevations. Also, erosivity density values probably decrease slightly with elevation in the summer.

11 See RUSLE2 Science Documentation, USDA-Agricultural Research Service.

6.2.4. Monthly Erosivity Values

RUSLE2 computes a monthly erosivity by multiplying monthly erosivity density by monthly precipitation as:

$$R_m = \alpha_m P_m \qquad \textbf{[6.4]}$$

where: R_m = monthly erosivity, α_m = monthly erosivity density, and P_m = monthly precipitation. Annual erosivity is computed as the sum of the monthly erosivity values. Figures 6.15 and 6.16 illustrate average annual R-values for the continental US. The values in these figures are for illustration only. Actual values used in RUSLE2 should be downloaded from the NRCS national RUSLE2 database. Average annual erosivity values for the western US and the mountainous regions of the eastern US are much more variable than indicated in these figures. Nevertheless, these figures can be compared to similar figures in AH282, AH537, and AH703.

6.3. Input Values for Monthly Erosivity Density, Precipitation, and Temperature

6.3.1. Selecting Climate Input Values for Continental US

RUSLE2 requires monthly values for erosivity density, precipitation, and temperature appropriate for the site where RUSLE2 is being applied. A sample set of these values are included with the download of RUSLE2. A complete set of these values can be obtained from the NRCS national RUSLE2 database or by contacting the NRCS state agronomist in your particular state of interest.

The climate values in the NRCS national RUSLE2 database have been assigned by county for those counties in the US where the values can be considered to be uniform over the county. In mountainous areas, the RUSLE2 weather inputs vary over space because of elevation effects. In those regions, NRCS has organized the data by precipitation depth zones that vary with elevation. The precipitation and temperature values in the NRCS national RUSLE2 database are based on 1961-1990 data.

RUSLE2 users in the US should generally use RUSLE2 climate input values from the NRCS national RUSLE2 database. However, in some cases, climate values may be needed for a specific location rather than for the precipitation depth zones used in the NRCS national RUSLE2 database. Erosivity density values at a particular location can be read from Figure 6.3-6.14. Precipitation and temperature values at a specific location can be obtained from the PRISM database available from the USDA-NRCS. PRISM monthly and precipitation values are on a 4 km by 4 km grid throughout the continental US.[12]

Current PRISM values are based on historical data from 1961-1990. The data were not processed to remove unusually dry or wet events. That is, the return periods (probability) of events vary significantly by location, resulting in spatial variability that is inappropriate for conservation and erosion control planning. The PRISM model, considered state-of-the-art, produces precipitation values that can vary greatly over a relatively short distance, which can result in a corresponding wide variation in erosion estimates.

6.3.2. Climate Input Values Outside of Continental US

When RUSLE2 is applied outside of the continental US, input climate data should be assembled using procedures outlined above if possible.[13] However, RUSLE2 is frequently applied where detailed weather data are not available.

Several points should be considered in developing input values for RUSLE2 where weather data are limited. RUSLE2 is a conservation and erosion control planning tool that captures main effects of the variables that affect rill and interrill erosion and general spatial trends. Weather data can be very irregular between locations, especially if the period of record is short. While short records may have to be used out of necessity, the values should be carefully inspected and smoothed based on technical judgment by those knowledgeable of local and regional weather and climate conditions.

Estimating erosivity as outlined above requires precipitation data that include rainfall intensity values. However, these intensity data may not be available. Erosivity can be estimated from monthly and daily precipitation data, provided sufficient data are available to calibrate the procedures.

[12] These PRISM-based values were developed by the NRCS, Oregon State University, and other cooperators using the PRISM model that takes measured precipitation and temperature station (point) data and spatially distributes these values taking into account effects of elevation, proximity to a major water body, atmospheric inversions, and other factors (see Daly, C., G. Taylor, and W. Gibson. 1997. The PRISM approach to mapping precipitation and temperature, 10th Conf. on Applied Climatology, American. Meteorological Society.)

[13] The NRCS National RUSLE2 Database contains values for Alaska, Hawaii, Puerto Rico and US Territories in the Pacific Basin and Virgin Islands.

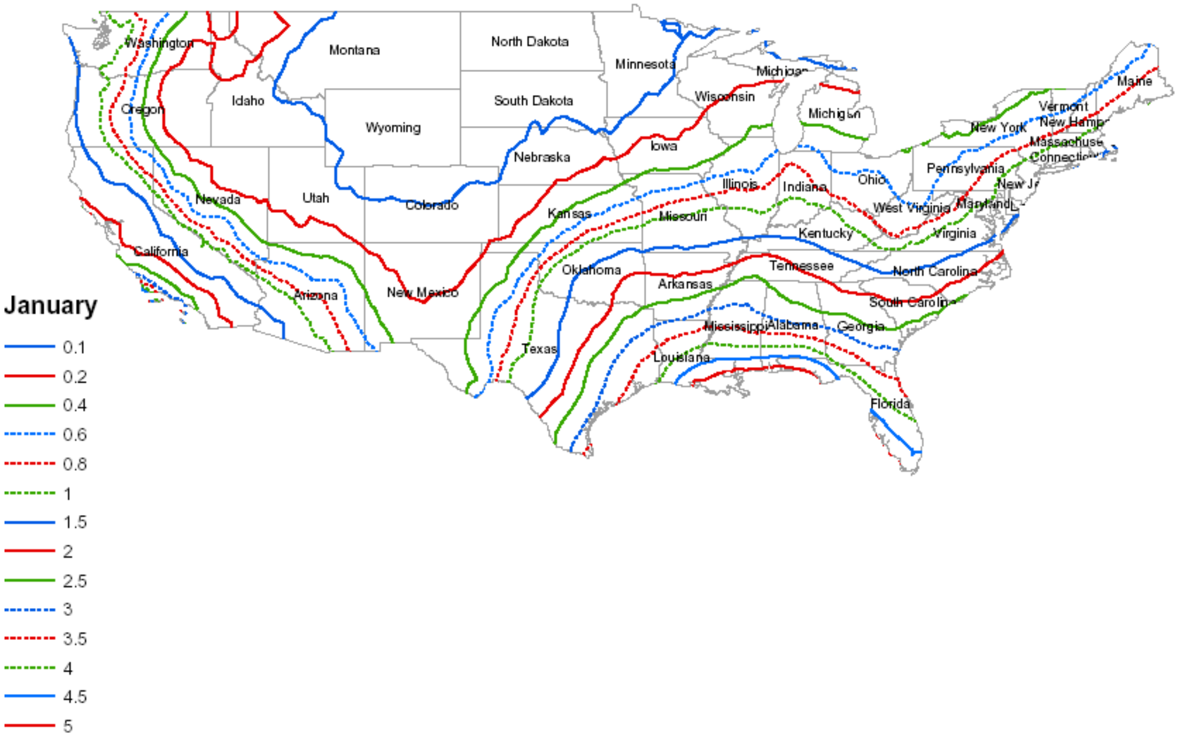

Figure 6.3. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for January.

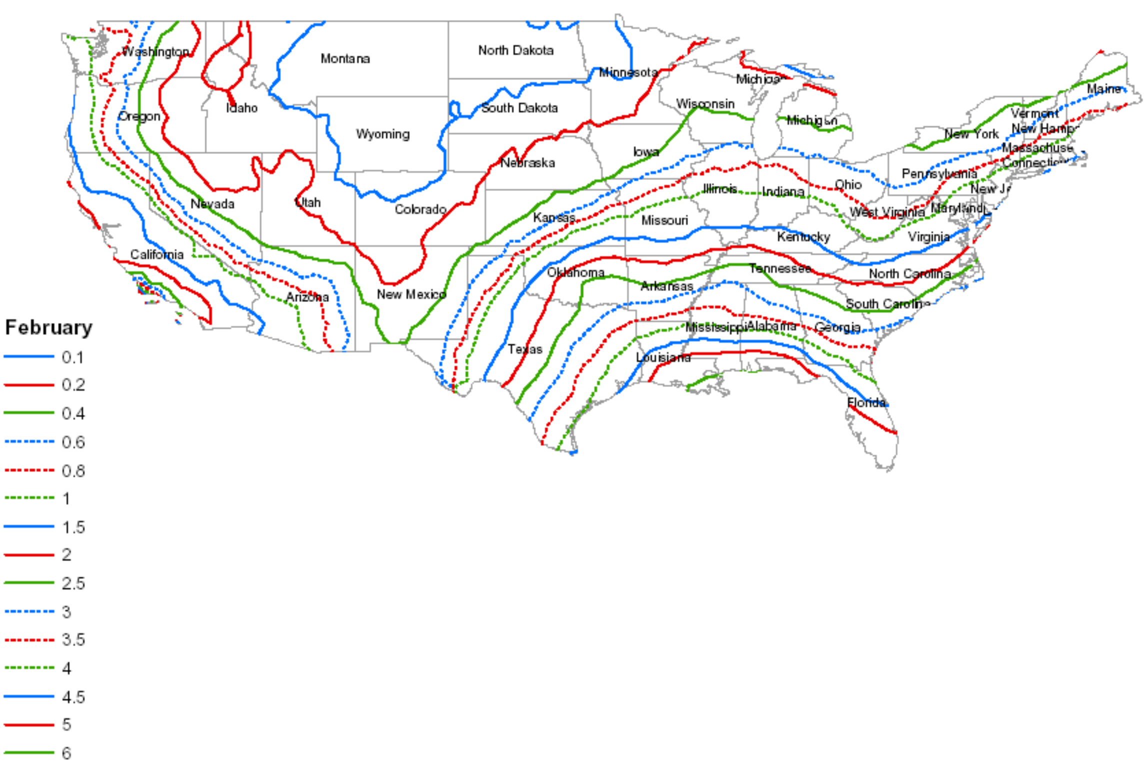

Figure 6.4. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for February.

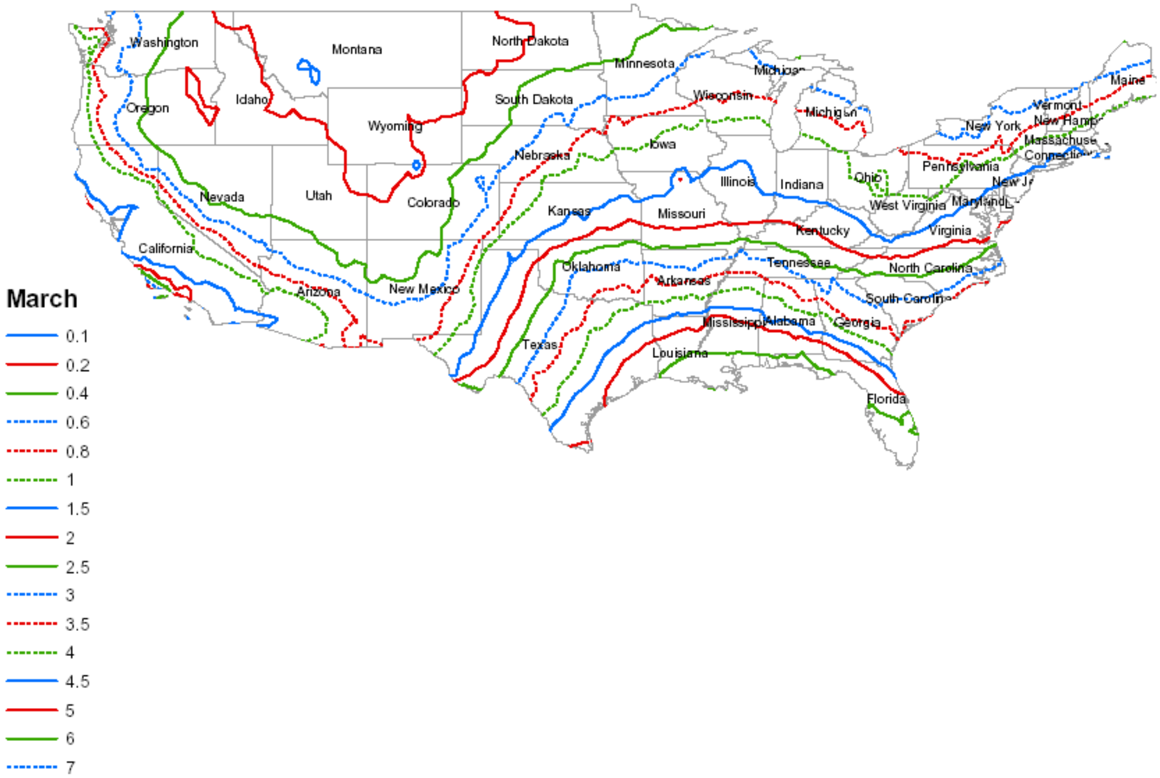

Figure 6.5. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for March.

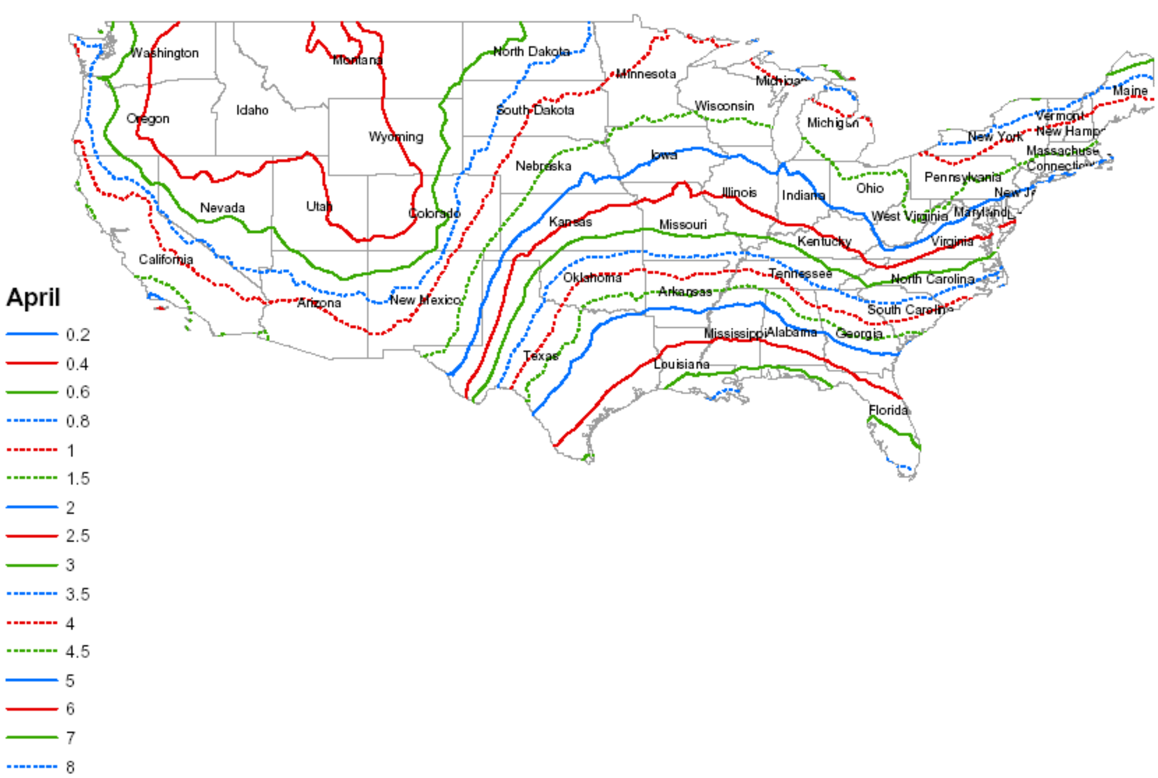

Figure 6.6. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for April.

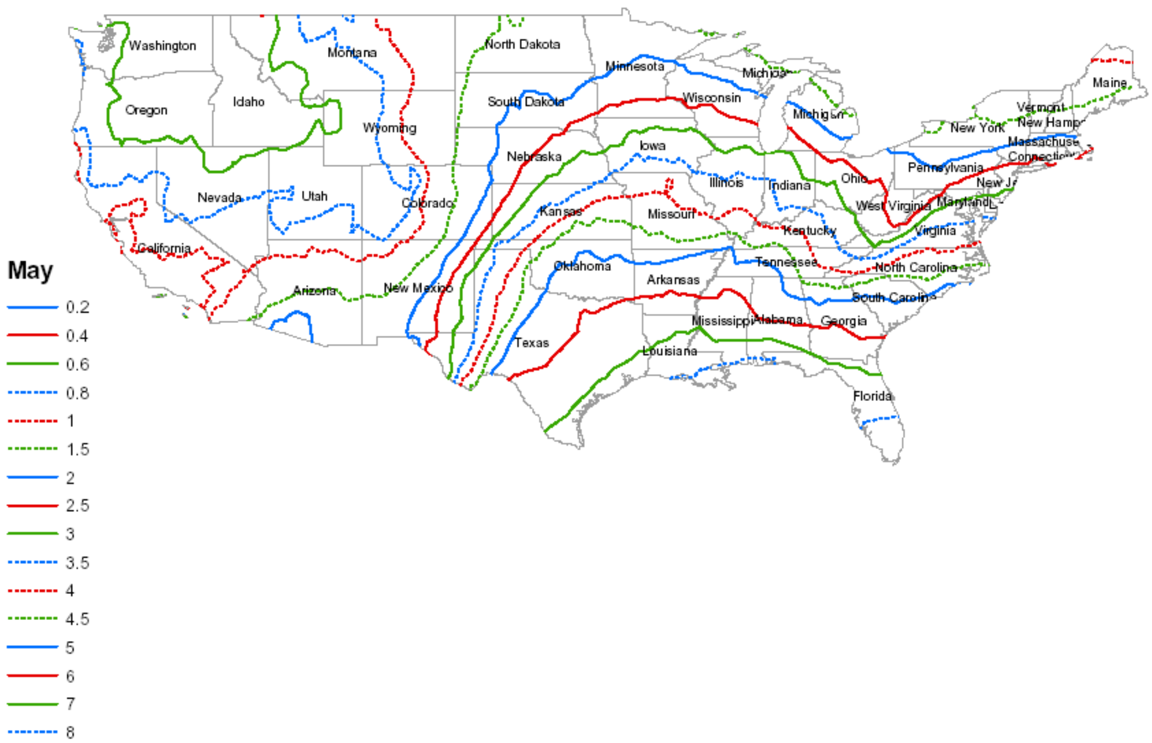

Figure 6.7. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for May.

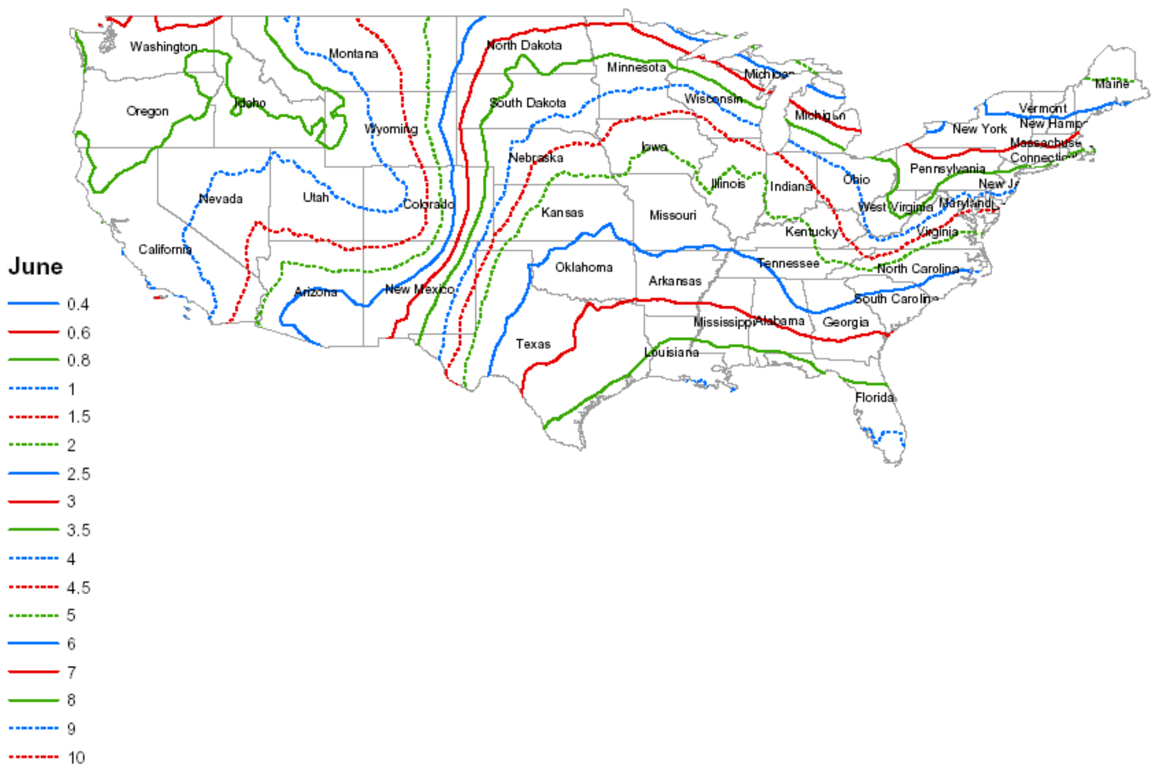

Figure 6.8. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for June.

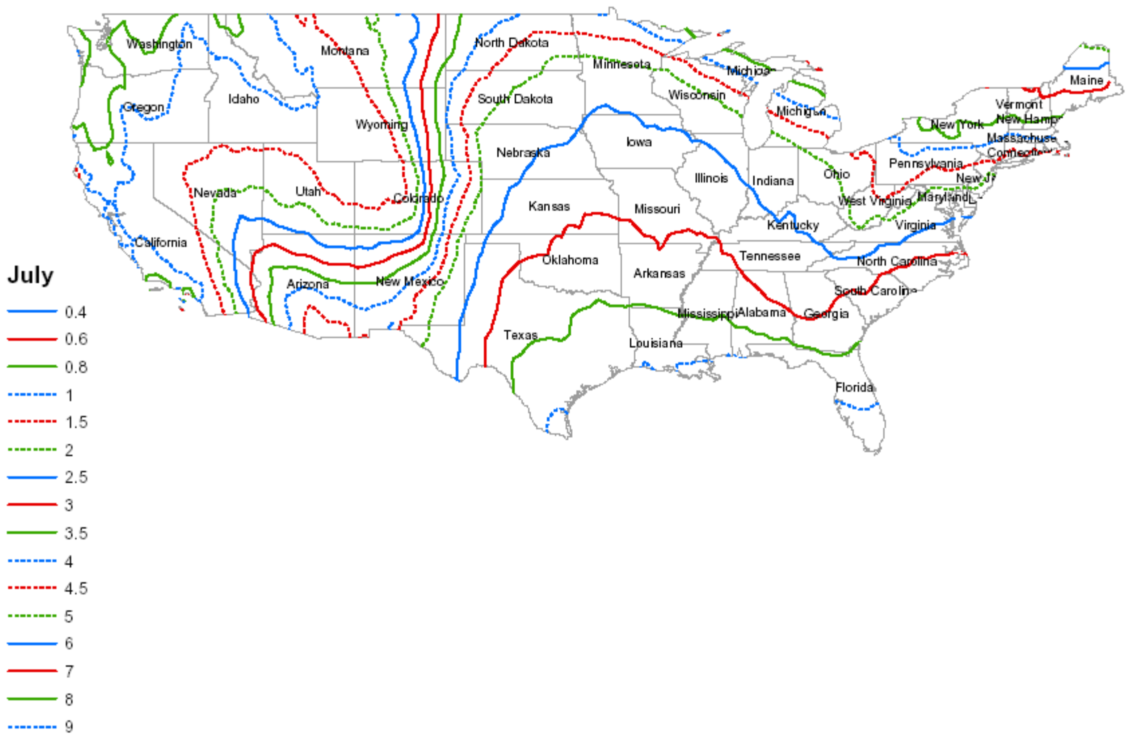

Figure 6.9. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for July.

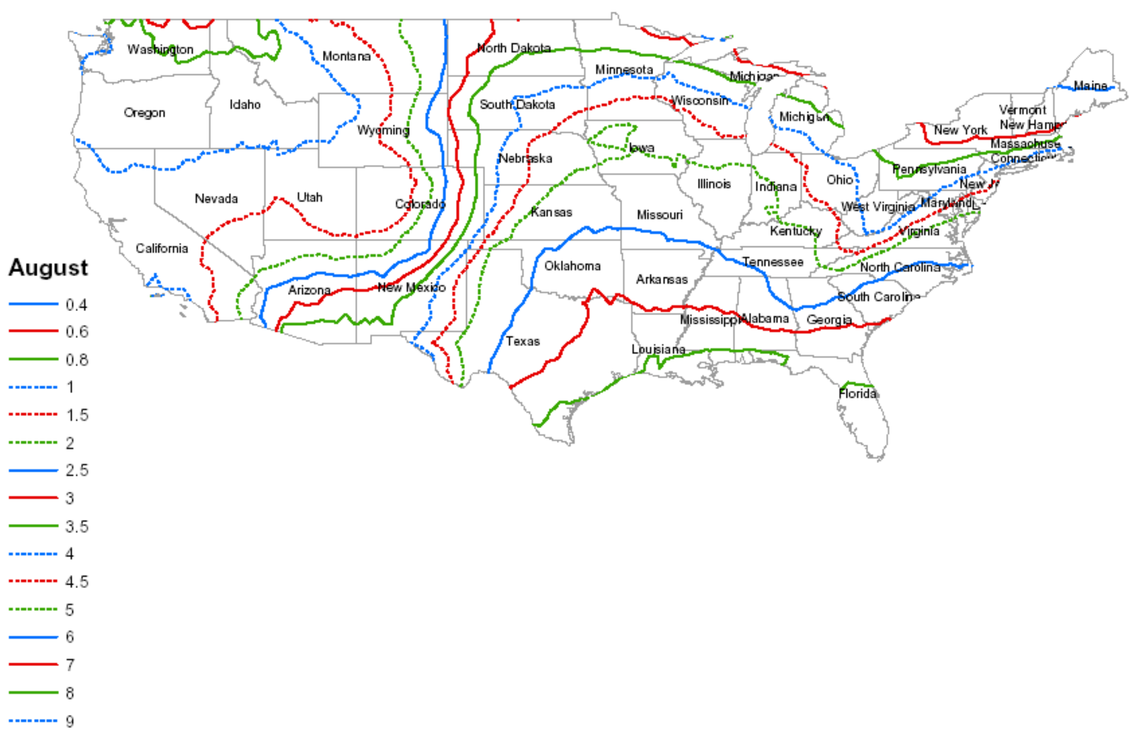

Figure 6.10. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] for August.

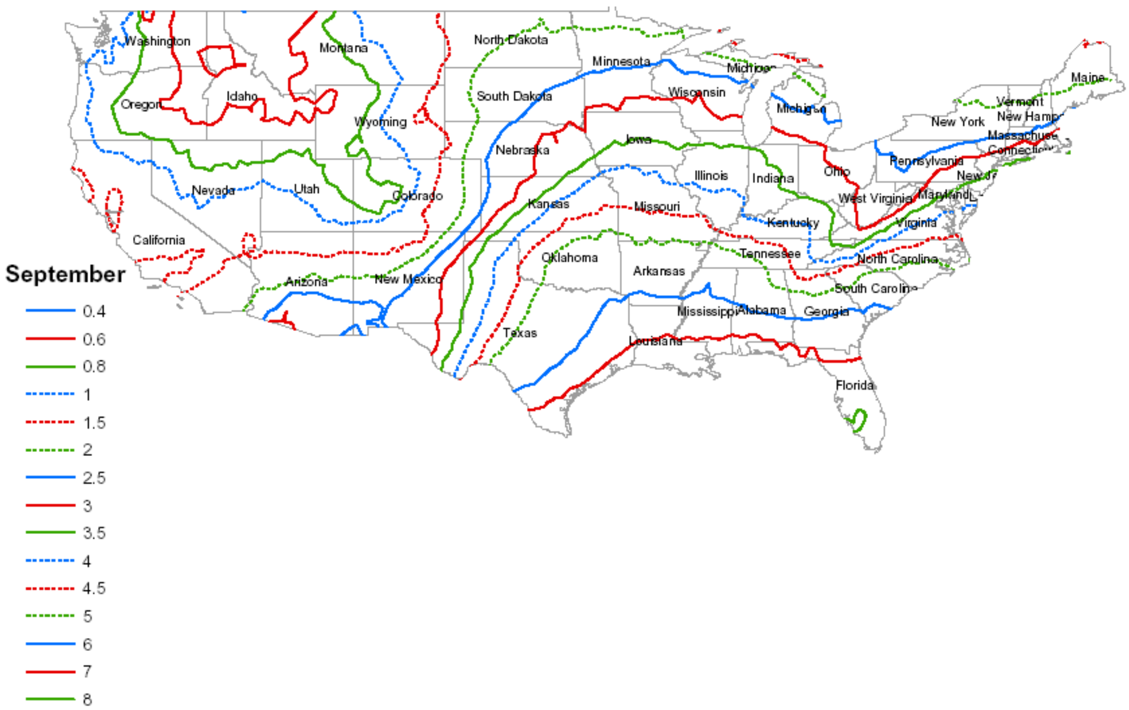

Figure 6.11. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] September.

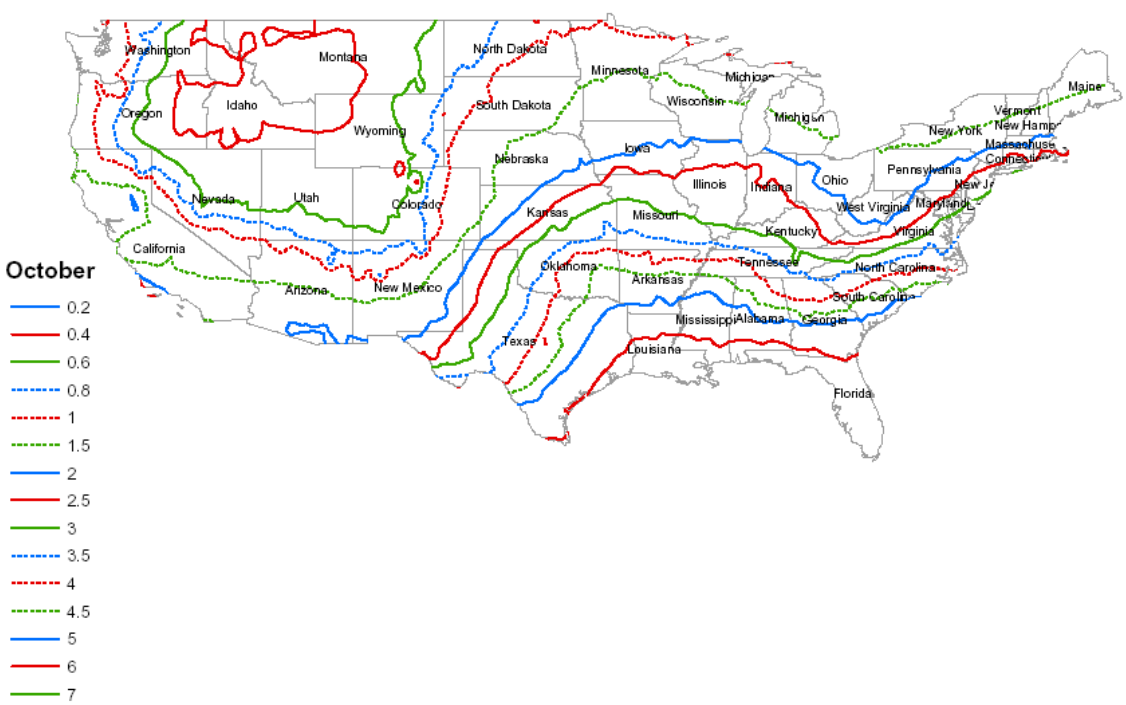

Figure 6.12. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] October.

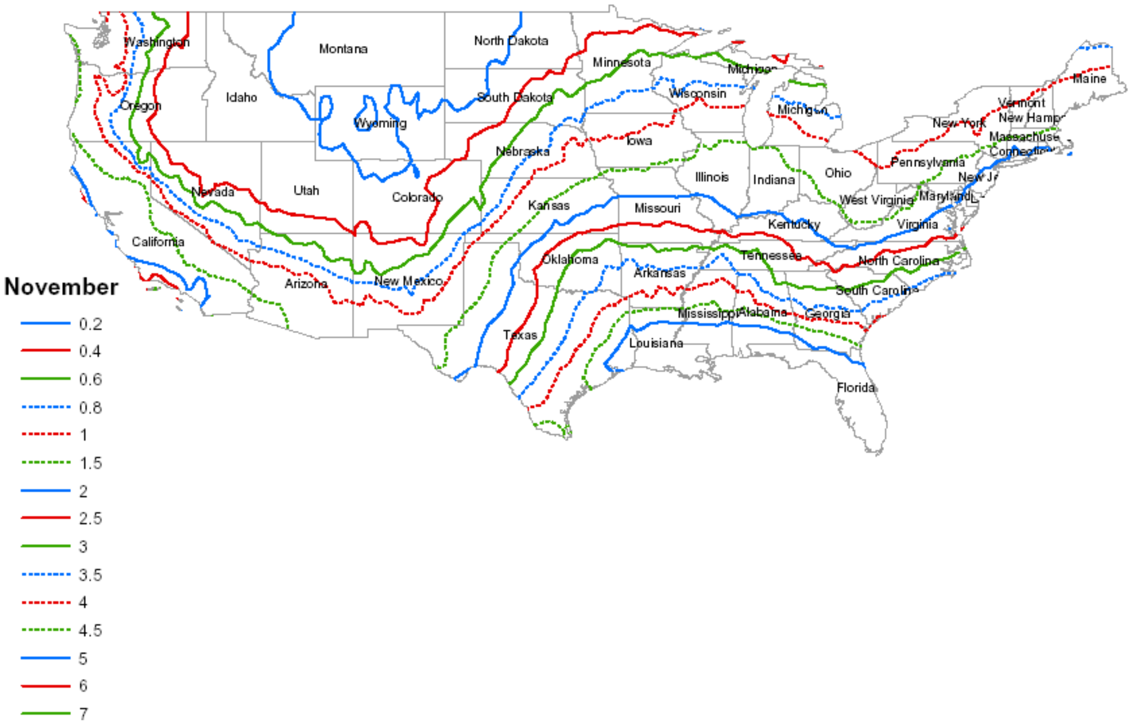

Figure 6.13. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] November.

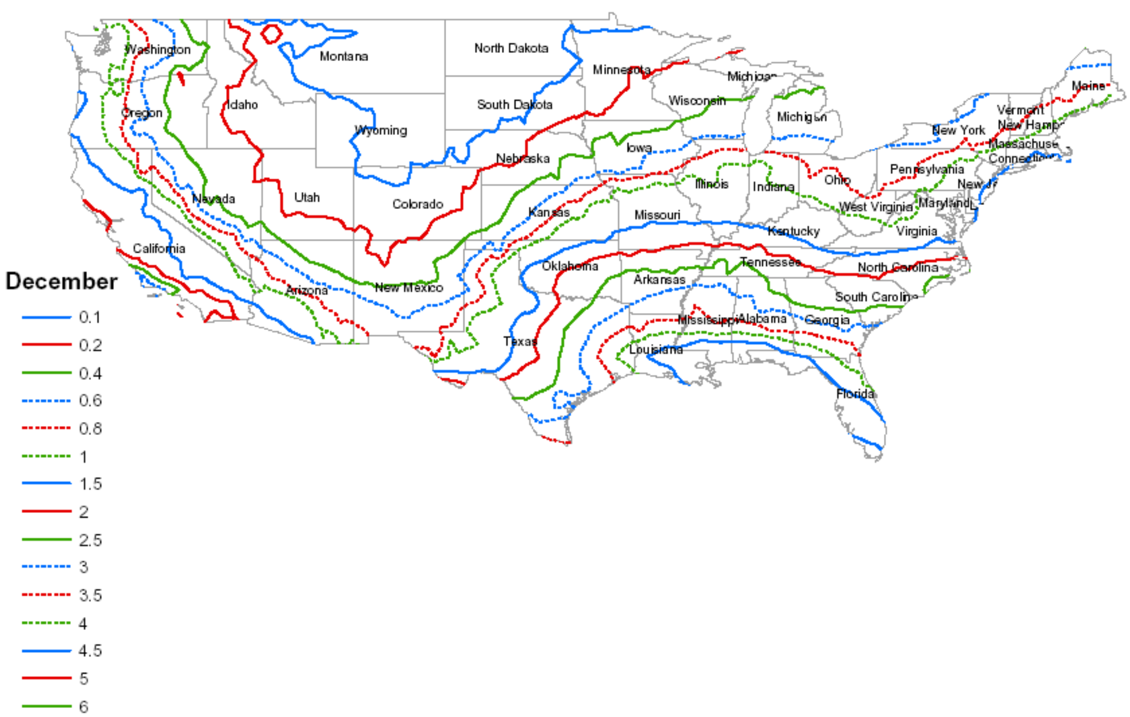

Figure 6.14. Monthly erosivity density [monthly erosivity (SI units)/monthly precip (mm)] December.

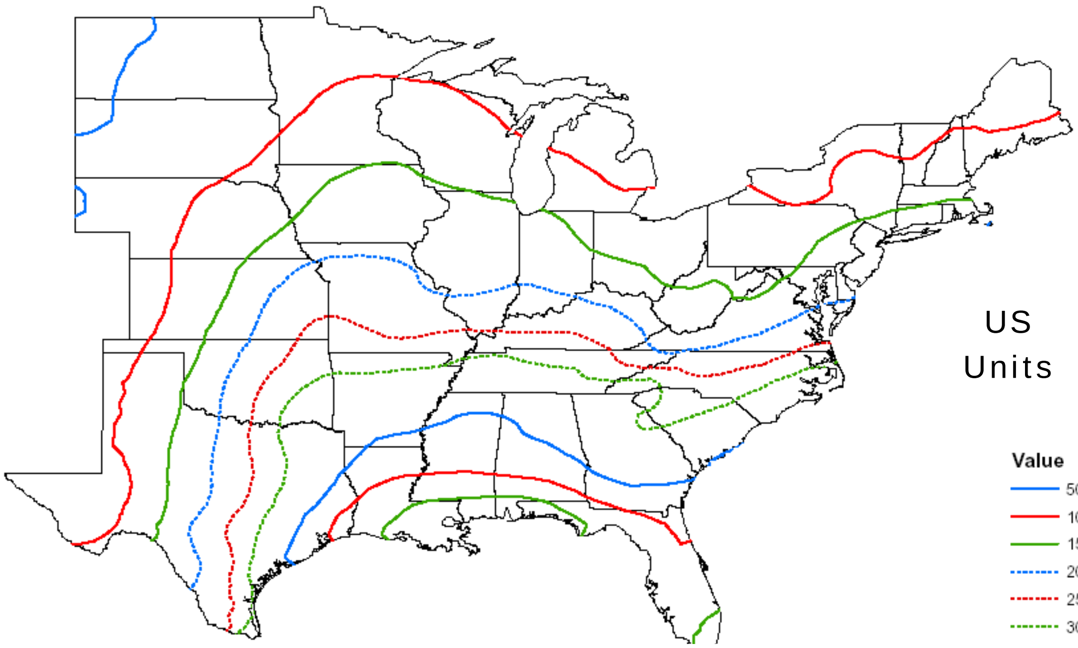

Figure 6.15. Average annual erosivity R-values for the eastern US in customary US units (See Foster, G.R., D.K. McCool, K.G. Renard, and W.C. Moldenhauer. 1981. Conversion of the universal soil loss equation to SI metric units. Journal of Soil and Water Conservation 36(6):355-359.

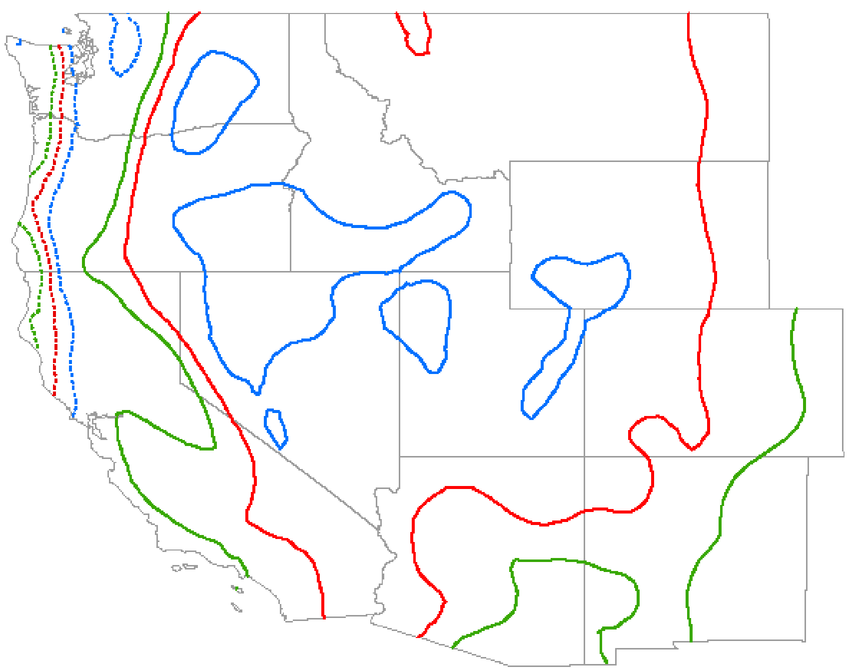

Figure 6.16.Average annual erosivity R values for western US. (For illustration to show broad trends. Local values vary greatly.)

When storm data are used to estimate erosivity, storm erosivity can be computed from storm rainfall amount using the non-linear equations:

$$R_s = aP_s^b \qquad \textbf{[6.5]}$$

where: R_s = storm erosivity, P_s = storm precipitation amount, and values for coefficients **a** and **b** are determined by **nonlinear** analysis of empirical data. A logarithmic transform and linear regression does not return the proper values for the **a** and **b** coefficients in equation 6.5. The coefficient **a** and exponent **b** varies by season of the year and by location as represented by the different shaped curves in Figure 6.2.

Monthly precipitation can also be used to estimate monthly erosivity from empirically derived equations. Equation 6.4 implies a linear relationship between monthly precipitation and monthly erosivity. However, the relationship between monthly erosivity and monthly precipitation is actually non-linear. A linear equation can only be used to estimate monthly erosivity using monthly precipitation when the year is divided into months and having erosivity density values that vary by location and by month in sufficient spatial resolution to stepwise approximate non-linear temporal and spatial variations in erosivity. That is, linear equations can be used in a stepwise fashion to approximate non-linear equations if the temporal and spatial steps have sufficient resolution.

6.3.3. Erosivity Values for High Elevation, Snow Cover, Snow Melt, and Req Zone

Applying RUSLE2 to high elevations, periods when a snow cover is present, and snow melt are discussed below in **Section 6.9** related to applying RUSLE2 in the special **Req** zone.

6.3.4. Erosivity Values for Irrigation

The major types of irrigation are surface applied and sprinkler applied water. RUSLE2 can not be used to estimate erosion from surface irrigation systems because runoff and erosion decrease along the flow path for surface irrigation, whereas RUSLE2 assumes an increase.

Most sprinkler irrigation systems apply water at a sufficiently low intensity that erosion does not occur. Thus, the applied water has little or no erosivity. However, irrigation does affect rill-interrill erosion by increasing soil moisture, and increasing vegetation production (yield) level, which decreases erosion. The increased soil moisture increases runoff and erosion when rainfall occurs during irrigation periods, and the added water increases decomposition of biomass on and in the soil. **Section 14.5** describes how to use RUSLE2 to estimate how irrigation affects rill-interrill erosion caused by rainfall.

6.3.5. Erosivity Values for Subsurface Drainage

Subsurface drainage reduces both soil moisture, which reduces runoff and erosion. RUSLE2 uses a soil erodibility factor value for the drained situation that differs from the soil erodibility value for the undrained condition to compute how subsurface drainage affects erosion. Subsurface drainage also increases vegetation production (yield) level, which reduces erosion. **Section 14.4** describes how to use RUSLE2 to estimate how subsurface drainage affects erosion.

6.4. Disaggregation of Monthly Values into Daily Values

As indicated by Equation 5.1, RUSLE2 uses long term average daily values in its computations. RUSLE2 uses a disaggregation procedure to compute long term average daily weather values from long term daily monthly values. This procedure uses linear equations that interpolate between the monthly values. The RUSLE2 disaggregation equations compute daily values that preserve monthly averages in the input data. The resulting daily values are sometimes not smooth, especially for rainfall values that vary up and down from month to month in comparison to the smooth trends in temperature. Preserving average monthly values was considered to be more important than having a smooth curve. Disaggregation of the monthly erosivity and temperature values for Birmingham, AL is shown in Figure 6.17.

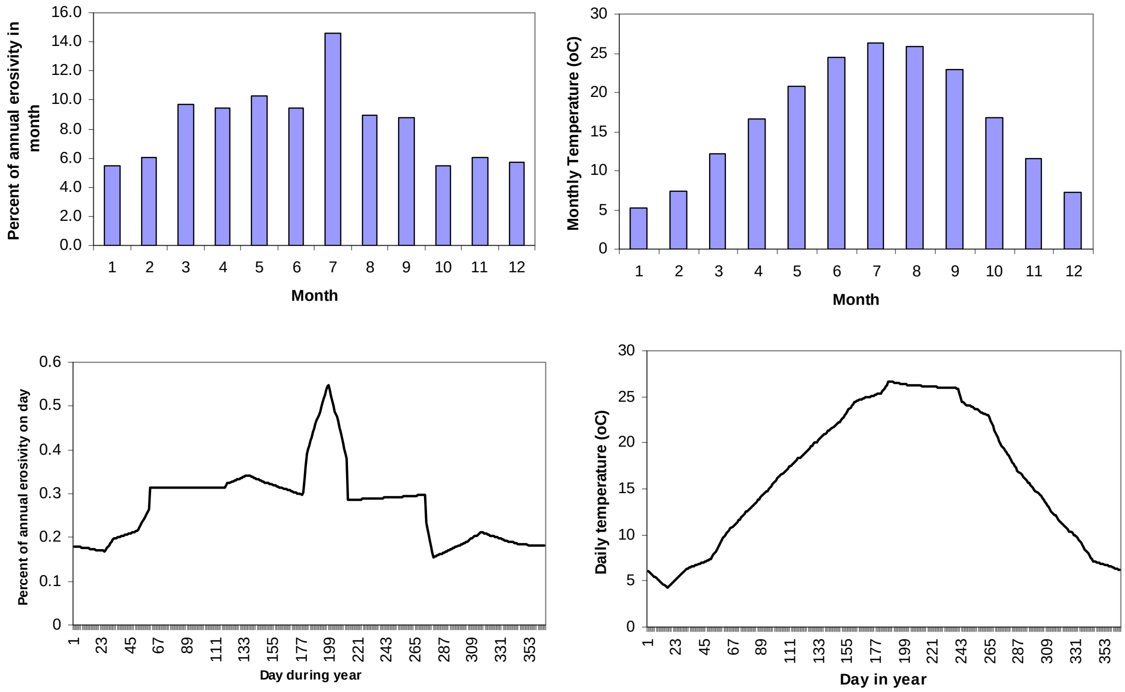

Figure 6.17. Disaggregation of monthly erosivity and temperature into daily values for Birmingham, AL.

6.5. Ten Year Storm

RUSLE2 uses a storm having a 10 year recurrence interval in its runoff computations. Two ways are provided in RUSLE2 for obtaining values for this storm. The strongly recommended way, especially for the eastern US, is to enter values for the 10-year-24 hour precipitation amount. The second way is to enter values for the 10 year EI event like that used in RUSLE1. The 10 year EI event is the storm erosivity that a 10 year recurrence interval.

6.5.1. 10 Year-24 Hour Storm

RUSLE2 uses the 10 year-24 hour (P_{10y24h}) storm to compute storm erosivity and runoff values that are used to compute factor values for contouring, critical slope length for contouring, sediment transport capacity, and the effect of ponding on reducing erosivity. Sediment transport capacity is used to compute deposition by runoff entering slope segments with a concave shape, dense vegetation, high ground cover, or rough soil surface. The 10 year-24 hour precipitation value is the storm amount that occurs in a 24 hour period that has the probability of occurring once every 10 years (a 10-year return period). Values for the 10 year-24 hour precipitation amounts in the NRCS national RUSLE2 database are by county in the eastern US and by precipitation depth zone in the eastern US. Those values were taken from the most recent National Weather Service published values. Values for the 10 yr-24 hour precipitation are illustrated in Figure 6.18 for the eastern US and for New Mexico in Figure 6.19 as an example of the values available for the western US. These figures are taken from older publications (national maps have not been updated) and are for illustration purposes only. More recent data are available that should be used. The modern data are available at http://hdsc.nws.noaa.gov/hdsc/pfds/.

Figure 6.18. (Full illustration only) 10 yr-24 hour precipitation for the US

The P_{10y24h} value is used to compute an erosivity value associated with this precipitation. The procedure used by RUSLE2 computes an EI_{10y24h} value as:

$$EI_{10y24h} = 2\alpha_m P_{10y24h} \qquad \textbf{[6.6]}$$

where: m = the month with the largest erosivity density value.

6.5.2. 10-Year EI Storm

Although use of the 10 year-24 hour storm is the preferred storm input in RUSLE2, the 10-year EI storm has been retained in RUSLE2 as an option. The 10-year EI method gives good results in the eastern US but not in the western US. The 10-year EI value is used to estimate a precipitation amount that is used in the same way that the 10 year-24 hour precipitation amount is used in RUSLE2. The reason that this method does not work well in the western US is that the precipitation amount for this storm is underestimated because the erosivity density (erosivity content per unit precipitation) is much less in the western US than in the eastern US.

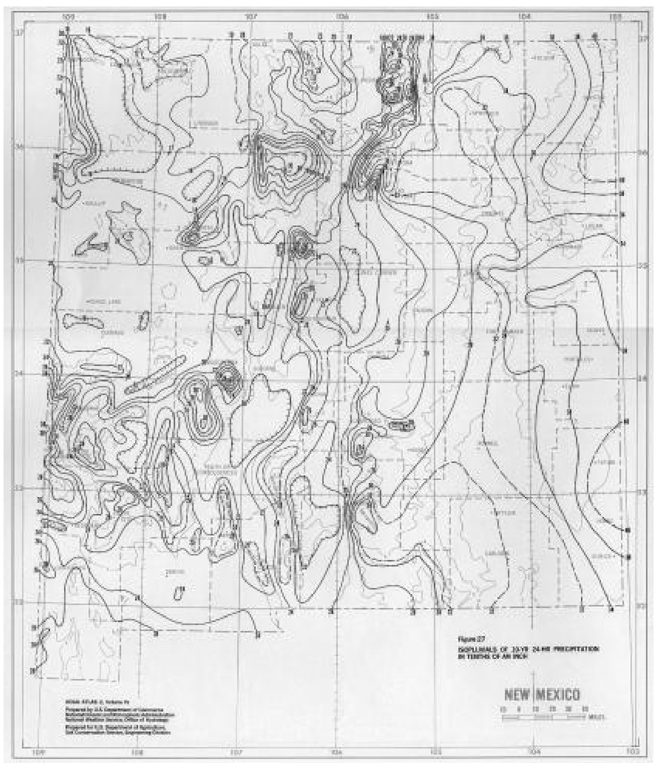

Figure 6.19. (For illustration only) 10 yr 24 hr precipitation for New Mexico.

The map of 10-year EI values has been revised from that in AH703 to greatly smooth the lines to only capture the major trends across the eastern US rather than local variations that reflect unexplained variability in the data rather than "real" differences. The 10-year EI values shown in Figure 6.20 should be used in RUSLE2 and in RUSLE1 rather than the values given in AH703.

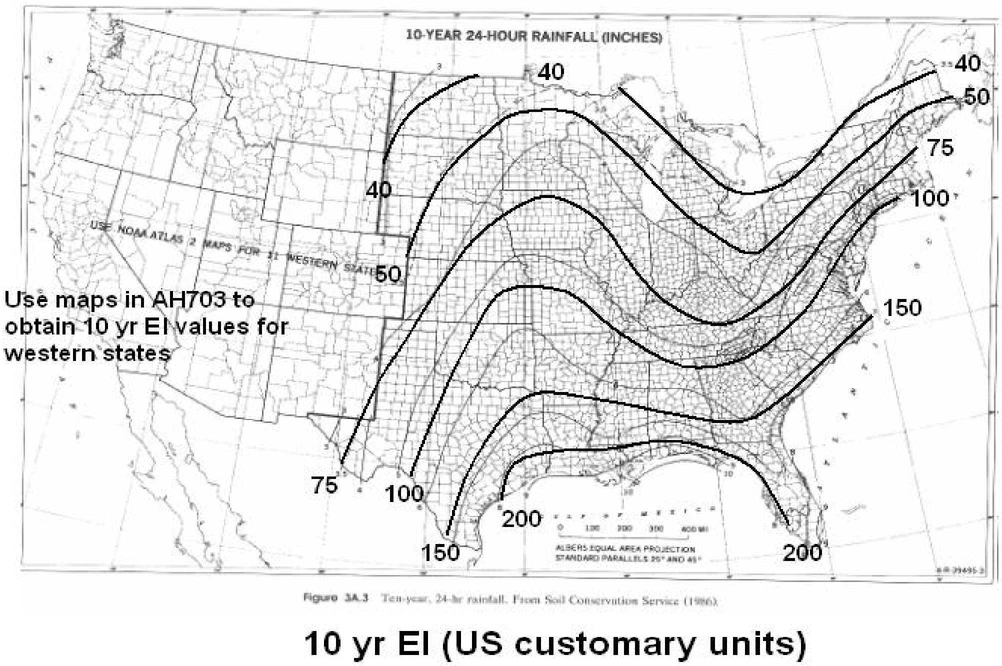

Figure 6.20. 10-year EI values.

6.6. Distribution of Erosivity During the Year

Figure 6.2 illustrates how erosivity density varies temporally by location. Monthly erosivity is computed as the product of erosivity density and precipitation values. Daily erosivity values are computed from the monthly values using the disaggregation procedure discussed in **Section 6.4**. Figure 6.21 illustrates how daily erosivity varies by locations. In central Louisiana, erosivity is nearly the same throughout the year. In contrast, erosivity is very peaked in North Dakota and in eastern Colorado, but the peak occurs at different times of the year. The erosivity density in central Kentucky and New York is similar, but the erosivity tends to be concentrated later in the year in New York than in Kentucky. The climate in northwest California, and other parts of the western continental US, is quite different from that for the eastern US. In this western region of the US, erosivity is highest in the winter months and lowest in the summer months.

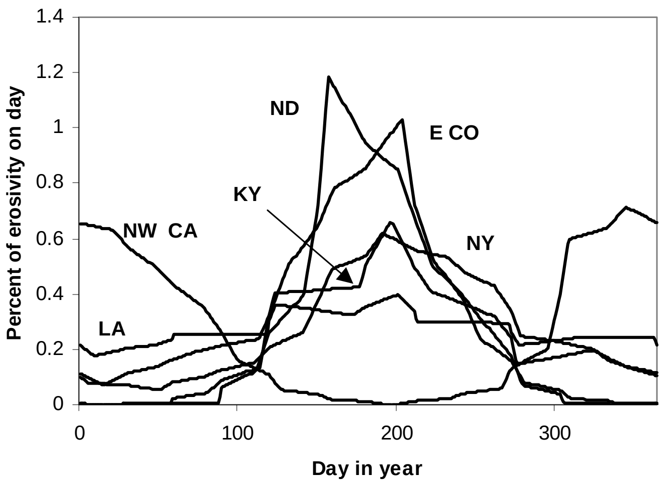

Figure 6.21. Temporal erosivity distribution for several US locations.

The temporal distribution of erosivity significantly affects soil erosion if the soil is exposed during the peak erosivity periods. For example, almost 60% of the annual erosivity in North Dakota occurs in June and July, a period when clean tilled row crops are especially susceptible to erosion because little cover is present. Therefore, on a relative basis, greater erosion occurs with clean tilled crops like corn per unit **annual erosivity R** in North Dakota than in New York because much of the erosivity in New York occurs after a significant canopy cover has developed, leaving the soil less susceptible to erosion. Growing a crop like wheat, rather than corn, that provides the greatest protection during peak erosivity can significantly reduce erosion. Thus, an erosion control practice is to change crops to ones that provide maximum protection during the most erosive period. Similarly, one way to reduce erosion on construction sites is to perform operations that expose the soil at times other than periods of peak erosivity.

6.7. Varying Soil Erodibility with Climate

RUSLE2 varies soil erodibility as a function of monthly precipitation and temperature. This capability is used for all locations and conditions where the standard erosivity relationships are used. However, RUSLE2 does not vary the soil erodibility with climate for the Req zone described in **Section 6.9**. This variation is taken into account in the temporal erosivity distribution used in the Req zone.

6.8. RUSLE2 Reduces Erosivity for Ponding

Intense rainfall on slopes less than about 1 percent steepness causes ponded water that reduces the erosivity of raindrop impact, an effect very important in the Mississippi Delta Region where both precipitation amount and intensity are high. RUSLE2 automatically computes the effect of ponding on erosivity using a cover-management sub-factor (See **Sections 9.1 and 9.2.7**). The reduction is computed as a function of slope steepness and the 10 yr-24 precipitation amount. The 10 yr-24 hr storm captures the effect of a moderately intense and moderately infrequent storm where ponding is most likely to have its greatest effect. In contrast to RUSLE1, RUSLE2 assumes that ponding reduces erosivity on both flat and ridged surfaces. The adjustment for ponding in RUSLE2 cannot be "turned off" as it could in RUSLE1.

6.9. Req Erosivity Relationships

6.9.1. Req Definition, Zones, and Values

The erosion processes in the Northwestern Wheat and Range Region (NWRR),[14] adjacent areas with similar climate, and certain other areas of the western US differ from those in other regions. Erosion from rainfall and/or snowmelt on thawing cropland, construction sites, and other sites of highly disturbed soils in this region is much greater than expected based on standard **R**-values computed according to Equations 6.1 and 6.2. Therefore, equivalent **R**-values, $\mathbf{R_{eq}}$ values, are used to apply **RUSLE2** to these special conditions. In addition, a modified erosivity distribution and special equations for the topographic and cover-managements factors are also used. The Req erosivity distribution is described in this section and the topographic and cover-management relationships are described in **Sections 8 and 9.**

These conditions occur in the Req zones illustrated in Figures 6.22 and 6.23. Northwestern Colorado, southwestern Colorado, southeastern Utah, and northern California are special transitional areas that use different relationships from those in the Req zone. Values for R_{eq} are used instead of standard R-values in the Req zones. Values for Req are computed from annual precipitation as:

$$R_{eq} = 7.86P_a - 50.5 \quad \textbf{[6.7]}$$

---

[14]The Northwest Wheat and Range Region (NWRR) includes about 10 million acres of non-irrigated cropland in parts of eastern Washington, north central Oregon, northern Idaho, southeastern Idaho, southwestern Montana, western Wyoming, northwestern Utah, northern California, and other western US regions. Runoff and erosion processes in this area are dominated by winter events. Many of these events involve rainfall and/or snowmelt on thawing soils. The thawing soils remain quite wet above the frost layer and are highly erodible until the frost layer thaws allowing drainage and soil consolidation. The transient frost layer near the surface limits infiltration and creates a super-saturated moisture condition such that almost all rainfall and snowmelt runs off. This condition occurs most intensively on cropland where the soil has been finely tilled and a well defined interface exists between the tilled soil and the untilled soil. In addition, mechanical soil disturbance (tillage in most cases) has mechanically broken the soil matrix into small soil aggregates. This mechanical soil disturbance breaks bond within the soil and greatly reducing its strength under super-saturated thawing conditions. The effect seems less under cropping management systems like no-till and pasture where little mechanical disturbance has occurred or if mechanical disturbance has not occurred for three or more years. Also, the Req region is characterized by frequent periodic, wide swings in temperature above and below freezing during the winter months. Another important feature is the probability of having rainfall during a thaw of the soil surface when the soil has low strength and is highly vulnerable to erosion.

where: R_{eq} = the equivalent erosivity (US units) and P_a = average annual precipitation (in). Equation 6.7 is an empirical equation developed primarily for the Req zone illustrated in Figure 6.22 across eastern Washington into Idaho. Equation 6.7 should not be applied to situations that give an R_{eq} value greater than 200 US erosivity units. Similarly, an R_{eq} value greater than 200 US erosivity units should not be used in RUSLE2. See **Section 6.10** for guidance on applying RUSLE2 to high elevations where Req > 200 US units.

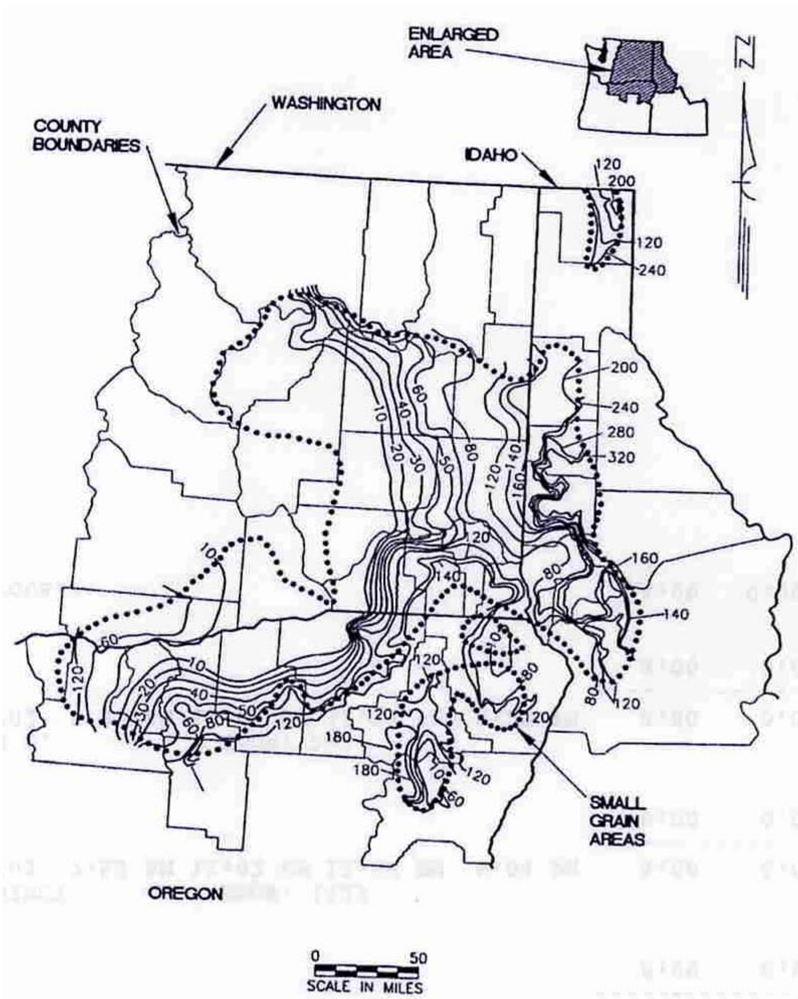

Figure 6.22. Outline of Req zone in Washington, Oregon, and northern Idaho. Only the boundary of area is important. Disregard contour lines.

The Req procedure using equation 6.7 in RUSLE2 can probably be applied to the Req zone illustrated in Figure 6.23. However, the temporal erosivity distribution has to be adjusted to account for differences in temporal precipitation patterns between the Req zones illustrated in Figures 6.22 and 6.23. Also, the Req procedure using equation 6.7 can not be used in the transitional zones in Colorado, Utah, and other areas.

Another consideration in applying the Req approach in the transitional zones is the topographic and cover-management equations. The RUSLE2 equations for the effect of topography and cover-management for the “standard” erosivity regions differs from those for the Req zones.[15] RUSLE2 uses a single set of these equations for the year. That is, RUSLE2 does not apply one set to the winter months when the Req effect occurs and another set to the summer months when the "standard" erosivity effect occurs. This selection of equation is made when the Req choice is made.

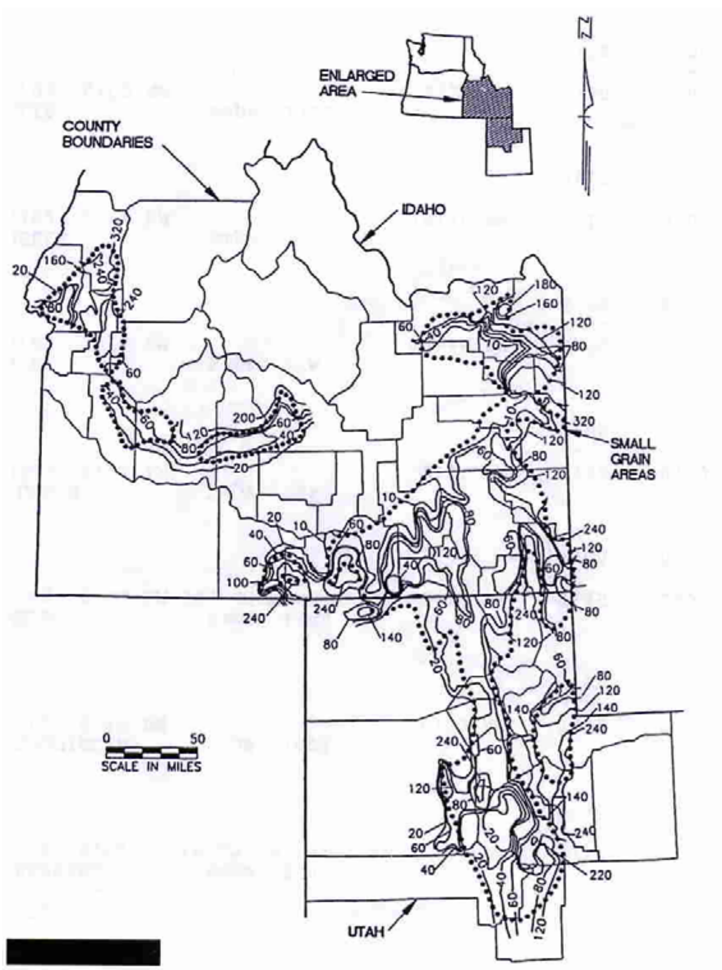

Figure 6.23. Req zone in southern Idaho and northern Utah. Only the boundary of the area is important. Disregard contour lines.

A value for R_{eq} can be entered directly into the RUSLE2 climate database for a particular location, or RUSLE2 can compute it from average annual precipitation using equation 6.7.

At first, the **R_{eq}** effect may appear to apply to areas beyond the Req zones illustrated in Figures 6.22 and 6.23 where frozen soils and runoff from snowmelt occurs, such as the northern tier of states in the U.S. However, that region does not experience the repeated freezing and thawing that is characteristic of the Req zone. Instead, the freezing, thawing, and runoff on thawing soils in those areas is limited to about one month instead of occurring repeatedly throughout the winter months as occurs in the Req zones. Research at Morris, Minnesota showed that only about seven percent of the annual erosion at that location is associated with erosion during the spring thaw. The soil is much more susceptible to erosion during the thawing period. That effect is partially considered in the

[15] Req-type effects occur in many locations of the western US. Also, these effects vary greatly within a local region. The Req procedures in RUSLE2 should be used very carefully when used in regions outside of the Req zone illustrated in Figure 6.22. Consult with ARS or NRCS RUSLE2 support personnel for advice on a recent RUSLE2 version to represent Req-type effect.

temporally varying soil erodibility factor **K** for all areas of the US except for the Req region. The Req value and the Req erosivity distribution account for the temporal variation of soil erodibility.

Rainfall and runoff on thawing soil is common to the upper Mid-South, lower Midwest regions, and similar regions of the US that experience repeated freezing and thawing events and where rainfall routinely occurs during the winter. Even though repeated freezing and thawing is experienced, the soil is not super-saturated by a restricting frost layer several millimeters (a few inches) below the soil surface as in the Req zone. The temporally varying soil erodibility factor **K** partially takes into account the increased erosion during freezing and thawing in the non-Req regions. In contrast to the western US, the increased erosion in late winter and early spring is small relative to the total annual erosion. As mentioned above, erosion during this period at Morris, Minnesota, where annual erosivity is low relative to other parts of the eastern US, is only seven percent of the annual soil loss.

6.9.2. Req distribution

A special erosivity distribution is needed for the Req zone to account for the greatly increased erosion that occurs during the winter months. The Req erosivity distribution is shown in figure 6.24 along with the erosivity distribution based on standard erosivity computations. The distribution shown in Figure 6.24 is for the Pullman, WA area where about 87% of the erosion on the unit plot[16] condition occurs during the winter months. This Req distribution is referred to as an 87-13 Req distribution. This distribution can be used throughout the Req zone illustrated in Figure 6.22. A different distribution should be used in the Req zone illustrated in Figure 6.23 and in the transitional Req zones like north and southwestern Colorado, northern

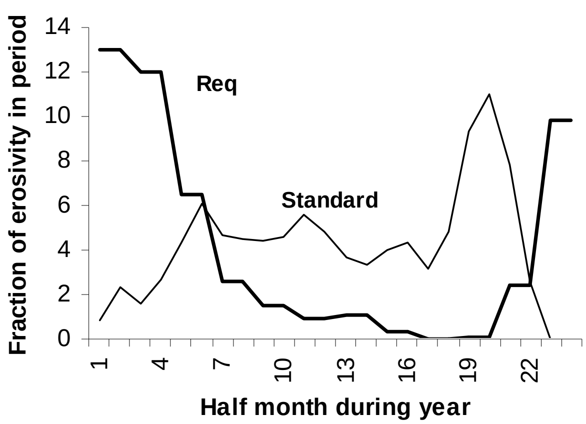

Figure 6.24. 87-13 Req erosivity distribution compared to distribution for standard erosivity at Pullman, WA.

[16] See **Section 7.2** for a definition of unit plot.

California, southeastern Utah, northern Arizona, and northern New Mexico. Less erosivity is concentrated in the winter in these areas. Contact ARS or NRCS personnel for information on Req values and Req erosivity distribution values for these regions.

6.9.3. Should Req Zone be Selected? Yes or No?

Several considerations are necessary in applying RUSLE2 in the Req zone. The first consideration is whether or not to use the Req relationships. Definitely the Req relationships are used for cropland where annual tillage disturbs 100 percent of the soil surface. The Req relationships also apply to certain recently disturbed areas where a well defined soil interface exists just below the soil surface and the upper soil layer is much like a finely tilled cropped soil. However, if the last disturbance occurred more than three years ago, the Req relationships should not be used. Thus, the Req relationships do not apply to undisturbed lands like pasture and rangelands.

Special consideration is required for hay and similar lands where mechanical soil disturbance (cultivation) occurs infrequently. Also, special consideration is required as time elapses after landfill closure or final grading of a reclaimed mine site. Erosion is computed assuming both the Req relationships and the standard erosivity relationships. A soil loss is interpolated between these two values depending on how frequently a mechanical soil disturbance occurs or how much time has elapsed since a disturbance. These same interpolations can be used in the transitional Req zones. RUSLE2 does not make smooth transitions in its computations between Req and standard zones or conditions, which requires professional judgment in applying RUSLE2. These considerations in applying RUSLE2 emphasizes that RUSLE2 is a guide to conservation and erosion control planning.

If the Req relationships, including those for topography and cover, are to be used, answer **Yes** to the question **In Req area?** and **Yes** to the question **Use Req EI distribution**. The standard Req erosivity distribution that is in the RUSLE2 sample database should be used throughout the Req zone illustrated in Figure 6.22. Contact ARS and NRCS personnel regarding Req values and Req distributions for locations outside of the zone illustrated in Figure 6.22.

Answer **Yes** to the question **adjust for soil moisture** when the Req relationships are used in RUSLE2. The amount of moisture in the soil profile during the winter months greatly affects erosion in the Req zone. Certain management practices and crops grown ahead of the winter greatly reduce soil moisture, runoff, and erosion. Answering **Yes** instructs RUSLE to take these effects into account. Answer **No** to the question **Vary soil erodibility with climate** when the Req relationships are used. Answer **Yes** for **varying soil erodibility with climate** when the standard erosivity is used, including all other

The soil moisture relationships are unique to the Req zone and should not be used outside of the Req zone.

areas of the US, including the Western US.

6.10. Applying RUSLE2 at High Elevations in Western US

Special considerations are required when applying RUSLE2 at high elevations in the western continental US. A major consideration involves snow. **If snow is continuously present on the soil surface, RUSLE2 does not apply to those months that the snow cover is present.** RUSLE2 can be applied to the non-winter months by using the standard erosivity relationships and by **turning RUSLE2 off** during the winter period. The way to **turn erosion off** is to use an operation that **adds a non-erodible cover** on the date that the winter period begins and an operation that **removes the non-erodible cover** on the date that the winter period ends. The choice of dates can be based on local observations or long term weather data for snow cover. An alternate approach is to use the date that RUSLE2 computes that the average daily temperature decreases to 1.7 ^{o}C (35 ^{o}F) temperature in late fall or early winter as the beginning date for the non-erdoble winter period. The ending date of the non-erodible winter period date in late winter or early spring is the date that RUSLE2 computes that average daily temperature increases to 7.2 ^{o}C (45 ^{o}F).

Special consideration is required where annual precipitation gives Req values greater than 200 US units. The first factor to consider is whether the Req relationships should be applied to the particular land use. Unless the land use is cropland or a particular type of highly disturbed land condition, the Req relationships probably do not apply. Also, if the precipitation is sufficiently high that a snow cover is present much of the winter and rarely disappears during the winter, the Req relationships do not apply. Even if all of the conditions are met for using the Req relationships but the Req value exceeds 200 US units, RUSLE2 should not be used during the winter months at that location. RUSLE2 is not considered sufficiently accurate to extrapolate it to Req values greater than 200 US units.

A statistical analysis of the erosivity density values showed that erosivity is not a function of elevation. **This statistical result is valid based on the data.** Unexplained variability in the data and the lack of precipitation data at elevations much above 3000 m (10,000 ft) prevent a rigorous testing of the hypothesis that erosivity density does not vary with elevation. This assumption of no elevation effect on erosivity density values is sufficient in the eastern US, but not in the western US during the winter for elevations higher than 3000 m (10,000 ft). The assumption is accepted as valid during the summer months at all locations in the continental US, with the understanding that erosivity is probably being slightly over estimated at elevations above 3000 m (10,000 ft) in the western US.

6.11. Snowmelt Erosivity

RUSLE2 is not designed to estimate erosion caused by snowmelt. The Req relationships do not apply to conditions where snow covers the soil for most of the winter months nor does it estimate the erosion that occurs when the snow melts. RUSLE2 can be **turned off** during the winter period by applying a non-erodible cover at the start of the snow cover and **turned on** after the snowmelt has ended by removing the non-erodible cover using operation descriptions described in **Sections 13.1.9 and 13.1.10.**

However, empirical values that account for snowmelt erosivity can be added to the standard monthly erosivity values to obtain effective monthly erosivity values. These effective monthly erosivity values can be entered in RUSLE2 using the monthly erosivity procedure when the standard topographic and cover-management relationships are being used. An Req value and an appropriate temporal Req erosivity distribution is developed if the Req topographic and cover-management relationships are used. Consult ARS or NRCS personnel for guidance.

7. SOIL DATABASE COMPONENT

This section describes the variables in the **soil database component**, the role of each variable, and how to determine values for key variables. Values for soil erodibility, soil texture, hydrologic soil group, rock cover, and time to soil consolidation are the principal information in the soil database component. These values are available from the local NRCS office in their soil survey database for cropland and similar land uses. These values are also included in the NRCS national RUSLE2 database. Values for most highly disturbed lands like construction sites and reclaimed mined lands must be obtained from on-site determinations.

7.1. Major Soil Variables

The values included in the RUSLE2 **soil database component** are listed in Table 7.1.

Table 7.1. Variables in soil component of RUSLE2 database

Variable	**Symbol**	**Comment**
Soil erodibility factor	K	Obtain from NRCS soil survey for cropland and similar lands; must be determined from on-site measurements for highly disturbed lands; **includes no effect of rock surface cover, but includes effect of rock in soil profile**
Soil texture		USDA soil texture class. If sand, silt, and clay content entered, RUSLE2 assigns appropriate textural class
Sand, silt, clay content		Based on USDA classification; if texture entered, RUSLE2 selects values for sand, silt, and clay % in mid-point of textural class
Hydrologic soil group (undrained)		Index for potential of undrained soil to produce runoff under unit plot conditions; a (lowest runoff potential), B, C, D (highest runoff potential)
Hydrologic soil group (drained)		Index for potential of soil to produce runoff under unit plot conditions with a high performing subsurface drainage system; **hydrologic soil group not automatically an A for drained conditions because soil properties may limit drainage**
Rock cover		Portion of soil surface covered by rock fragments sufficiently large not to be moved by runoff; rock diameter generally must be larger than 10 mm (3/8 inch) to qualify as cover
Calculate time to soil consolidation		Answer **Yes** for RUSLE2 to compute time to soil consolidation
Time to soil		Time for soil erodibility to decrease and level out after a soil

consolidation		mechanical disturbance. Enter a value or have **RUSLE2** compute based on average annual precipitation.
T value	T	Value used as criteria in conservation or erosion control planning; NRCS soil loss tolerance T value is typically used for protecting soil; another value besides T may be used for highly disturbed lands based on local regulatory or other requirements; criteria for sediment yield control depend on off-site conditions affected by sediment delivery

7.2. Basic Principles

Soils vary in their inherent susceptibility to erosion. The soil erodibility **K** factor is a measure of erodibility for the **unit plot** condition. The unit plot is 72.6 ft (22.1 m) long on a 9 percent slope, maintained in continuous fallow, tilled up and down hill periodically to control weeds and break crusts that form on the soil surface. Unit plots are plowed, disked, and harrowed, much like for a clean tilled row crop of corn or soybeans except no crop is grown. The first two to three years of erosion data after a unit plot is established are not used to determine a K value. Time is required for residual effects from previous cover-management to disappear, especially following high production sod, forest conditions with lots of roots and litter, or any condition with high levels of soil biomass. About 10 years of soil loss data are required to obtain an accurate estimate of K. The data record should be sufficiently long to include moderate and large storms.

The K value for a soil is the slope of a straight line passing through the origin for measured erosion data plotted versus storm erosivity as illustrated in Figure 7.1. The equation for this line is:

$$A_u = EI_{30}K \qquad \textbf{[7.1]}$$

where: A_u = the soil loss from the unit plot measured for an individual storm and EI_{30} = the erosivity of the storm that produced the storm soil loss. Data from storms less than 12.5 mm (0.5 inch) are not included in the analysis.

The unit plot procedure determines empirical K values for specific soils where the effect of cover-management on soil erodibility has been removed. Not all soils occur where erosion can be measured under unit plot conditions. The equations used by RUSLE2 for topographic and cover-management can be used to adjust measured erosion data to unit plot conditions. These equations are discussed in later sections.

The soil erodibility factor **K** represents the combined effect of susceptibility of soil to detachment, transportability of the sediment, and the amount and rate of runoff per unit rainfall erosivity for unit plot conditions. Fine textured soils high in clay have low **K** values, about 0.05 to 0.15 tons per US erosivity unit, because they are resistant to detachment.[17] Coarse textured soils, such as sandy soils, have low **K** values, about 0.05 to 0.2 tons per US erosivity unit, because of low runoff even though these soils are easily detached. Medium textured soils, such as silt loam soils, have moderate **K** values, about 0.25 to 0.45 tons per US erosivity unit, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having very high silt content are especially susceptible to erosion and have high **K** values. Sediment is easily detached from these soils, which also tend to crust, produce large amounts and rates of runoff, and produce fine sediment that is easily transported. Values of **K** for these soils typically exceed 0.45 tons/acre per US erosivity unit and can be as large as 0.65 tons per US erosivity unit.

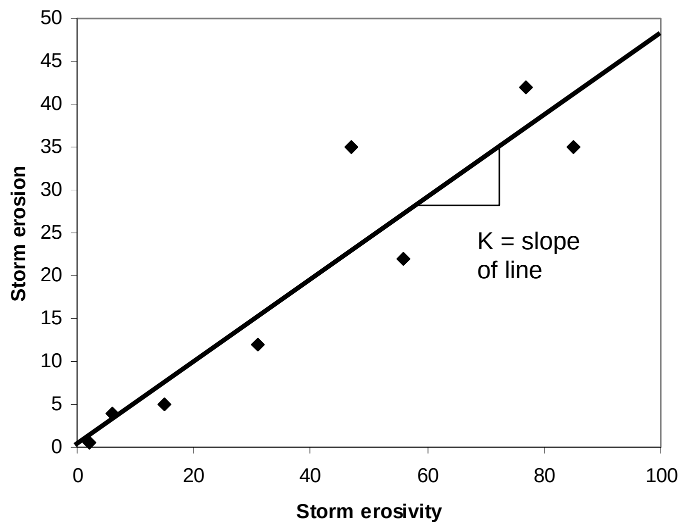

Figure 7.1. Determining a value for the soil erodibility K factor from measured erosion data for unit plot conditions.

The RUSLE2 soil erodibility factor is an **empirical measure** defined by the erosivity variable EI_{30} (product of storm energy and maximum 30 minute intensity) used in RUSLE2. It is not directly related to specific erosion processes, and it is not a soil property like texture. RUSLE2 K values are unique to this definition, and erodibility values based on other erosivity measures, such as runoff, must not be used for K. Values for K are not proportional to erodibility factor values for other erosivity measures. Also, K values may not increase or decrease in the same sequence as other definitions of soil erodibility. For example, the RUSLE2 K value for a sandy soil is low whereas an erodibility factor value based on runoff is high for sand.

---

[17] The R and K factors have units. In this guide, the US customary units for R are hundreds of (ft tons in)/(ac yr hr). The corresponding US customary units on K are tons /[(hundreds of ft tons in)/(ac hr)]. Metric units in the SI system are (MJ mm)/(ha∗h) for erosivity and (t h)/(MJ mm) for erodibility. See AH703 for additional information.

Soil organic matter reduces the K factor value because it produces compounds that bind soil particles and reduce their susceptibility to detachment by raindrop impact and surface runoff. Also, organic matter increases soil aggregation, which increases infiltration and reduces runoff and erosion. Permeability of the soil profile affects **K** because it affects runoff. Soil structure affects **K** because it affects detachment and infiltration. Soil structure refers to the arrangement of soil particles, including primary particles and aggregates, in the soil. Soil mineralogy has a significant effect on **K** for some soils, including subsoils, soils located in the upper Midwest of the US, and volcanic soils in the Tropics.

Many factors affect soil erodibility. Values for the RUSLE2 soil erodibility K factor, which is a measure on inherent soil erodibility, are for unit plot conditions where the effects of management have been removed. These RUSLE2 definitions were also used in the USLE and RUSLE1.

Values for **K** for several "benchmark" soils have been determined from experimental erosion data. Values for **K** can be estimated for other soils by comparing their properties with those of the benchmark soils and assigning K values based on similarities and differences in properties that affect K values. As a part of its soil survey program, the USDA-NRCS has determined K values for cropland and other similar lands where the soil profile has not been disturbed or the soil mixed.[18] RUSLE2 includes two soil erodibility nomographs, discussed in **Section 7.3.2.,** that can be used to estimate K values. See AH703 for additional information on the soil erodibility factor K.[19]

7.3. Selection of Soil Erodibility K Values

7.3.1 From NRCS soil survey

Values for **K** should be selected from the USDA-Natural Resources Conservation Service (NRCS) soil survey for RUSLE2 applications where the soil profile has not been disturbed and mixed. Values for K for both topsoil and subsoil layers are available for most US soils. The greatest detail is for cropland soils and less for rangeland and forestland soils. Values for K are not available for soils on construction sites, landfills, and reclaimed surface mines because of soil mixing and soil-like materials associated

[18] The USDA-NRCS has mapped most US soils on cropland and other land uses where the soil profile has not been disturbed. Soils were mapped as soil map units (names). Descriptions and properties of each soil map unit are published in soil surveys by US county or other survey area. Soils information is available in a computer database and paper form at local USDA-NRCS offices. The soils data required by RUSLE2 have been extracted from the NRCS soil survey database and included in the NRCS national RUSLE2 database.

[19] Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Dept. of Agriculture, Agriculture Handbook 703, 404 pp. Much of the information in AH703 on soil erodibility applies to RUSLE2, except for the part on temporal variability of K.

with surface mining. The RUSLE2 modified soil erodibility nomograph can be used to estimate K values for these soils.

Make sure that K values extracted from the NRCS soil survey are the ones where no adjustment has been made for rock on the soil surface and where the effect of rock in the soil profile has been considered.

Multiple K values for a given soil mapping unit are given in the NRCS soil survey database. Select the K value where no adjustment has been made for rock fragments on the soil surface. Using a K value that has been adjusted for surface rock fragments can cause a major error in RUSLE2 erosion estimates. RUSLE2 uses a single composite ground cover that takes into account overlap of rock by crop residue and plant litter. The RUSLE2 mathematical relationships used to compute the effect of ground cover on erosion are nonlinear. Treating each ground cover individually causes errors because of this nonlinearity.

7.3.2. Estimating K values with the RUSLE2 soil erodibility nomographs

7.3.2.1. Background on nomographs.

RUSLE2 includes two soil erodibility nomographs that can be used to estimate soil erodibility K factor values. One nomograph is the **standard nomograph** described in AH703.[20] This nomograph is used to estimate soil erodibility values for cropland and similar soils where the soil profile has not been disturbed. The other nomograph is the **RUSLE2 modified nomograph**. This nomograph is used to estimate soil erodibility K factor values for highly disturbed lands where the soil profile has been disturbed and the soil mixed.

The difference between the standard and the modified soil erodibility nomographs is in the structure effect. The standard nomograph gives K values that decrease as structure changes from a blocky, platy structure to a granular structure. This trend is inconsistent with accepted science on how erosion varies with soil structure. The standard nomograph was derived from about 55 soils, primarily in Indiana, that were mostly medium textured soils without a wide, uniform sample of soil textures and soil structures. The result is that K values from the standard erodibility nomograph are too high for very high clay soils and too low for very high silt soils. The **standard nomograph** is satisfactory for most cropland soils.

[20] For background information, see Wischmeier, W.H., C.B. Johnson, and B.V. Cross. 1971. A soil erodibility monograph for farmland and construction sites. J. Soil Water Conservation. 26:189-193. However, information provided in this RUSLE2 User Guide determines the RUSLE2 application of the nomograph rather than information from other sources.

The **RUSLE2 modified soil erodibility nomograph** should be used to estimate K factor values for highly disturbed lands like constructions sites, landfills, military training sites, and reclaimed mined land. The RUSLE2 modified nomograph gives more credit to the effect of soil structure than does the standard nomograph. The RUSLE2 modified soil erodibility nomograph is exactly the same as the standard nomograph except that the equation for soil structure has been reversed. The two nomographs give the same K values for a moderate to coarse granular soil structure.

AH703 lists equations for estimating K factor values for special cases. Those equations were not included in RUSLE2 because some input values can not be obtained easily or K values computed by some of the equations seemed questionable. Carefully examine those equations and review original source materials before using values from those equations in RUSLE2.

7.3.2.2. Nomograph inputs.

The inputs for both the **RUSLE2 modified** and the **standard** soil erodibility nomographs are the same. Therefore, the single set of inputs listed in Table 7.2 applies to both nomographs. The definitions and variable descriptions used in the nomograph must be carefully followed.[21]

Table 7.2. Variables used in RUSLE2 soil erodibility nomographs

Variable	**Symbol**	**Comment**
Sand content		Based on mass (weight), proportion of the total for the clay, silt, and sand, 0.050 mm < sand dia ≤ 2.0 mm
Silt+very fine sand content		Based on mass (weight), proportion of the total for the clay, silt, and sand, 0.002 mm < silt dia ≤ 0.050 mm, 0.050 mm < very fine sand dia ≤ 0.10 mm; RUSLE2 can estimate very fine sand content.
Inherent organic matter content		Based on mass (weight), proportion of the total clay, silt, sand, and organic matter; **organic matter content is for unit plot conditions; do not use organic matter content in nomograph to reflect management different from the unit plot conditions.**
Structure class		Arrangement of primary particles and aggregates in soil
Permeability class		Used to indicate runoff potential under unit plot conditions. Represents the entire soil profile, not just soil surface layer. Should not be determined from a pereameter measurement.
Is		Select **Yes** and RUSLE2 assumes that the permeability class

[21] See the USDA-NRCS soil survey manual for a description of the terms used in the soil erodibility nomograph and procedures for determining values for the nomograph variables. This manual is available on the NRCS Internet site www.nrcs.usda.gov.

permeability with coarse fragments present		has been chosen giving consideration to rock in the soil profile. **Strongly recommend selecting permeability based on professional judgment rather than allowing RUSLE2 to adjust for rocks in soil profile.** Select **No** and RUSLE2 will adjust the permeability class for rock in the soil profile. This adjustment does not apply to soils with large rock fragments like mined land.
Coarse fragment content		Based on mass (weight) proportion of total soil made up of rock fragments > 3 in (75 mm) diameter

7.3.2.3. Special nomograph considerations.

Organic matter content is a major variable in the soil erodibility nomographs. **The input value for this variable is the organic matter content of the soil in the unit plot condition after previous land use effects have disappeared.** RUSLE2 has an upper limit of 4% for this organic matter content input. Applying animal manure, plowing under "green" manure, improving residue management, and other management practices that add biomass significantly reduce erosion. **RUSLE2 considers this important effect using equations for cover-management effects rather than the soil erodibility factor.** The soil erodibility factor is for a base condition where the effects of management have been removed.[22]

Adjusting K to account for organic matter as influenced by land use is double accounting and is a misuse of RUSLE2. Similarly, the permeability class in the soil erodibility nomographs is not adjusted to represent how cover-management and support practices affect runoff.

The permeability effect in the nomographs is based on how the **entire soil profile** affects runoff for unit plot conditions. The input permeability code **should not** be based only on the upper 4 inches (100 mm) to 6 inches (150 mm) of soil. Permeability tests on soil samples from this layer should not be the sole basis for determining the permeability input to the nomographs. The input permeability code entered in the nomograph should take into account how restricting layers, such as a rock, fragipan, caliche, or clay layer, below the soil surface affect runoff. The input permeability code should also reflect how

[22] Considering how land use affects organic matter and soil erosion by adjusting the organic matter input in the soil erodibility nomographs to compute K values seems possible because the nomographs include an organic matter variable. However, the erodibility nomographs must not be used for this purpose. RUSLE2 is an empirical equation based on certain definitions that must be carefully followed. Adjusting K to account for the effect of cover and management on organic matter and runoff is inconsistent with RUSLE2 definitions, structure, and equations.

restricting layers, such as a plow pan or a dense compacted layer created by construction traffic, if these layers that are not routinely broken up by ordinary tillage or other soil distributing operations. RUSLE2 takes into account how subsoiling affects erosion by breaking up these layers.

Values computed with the RUSLE2 soil erodibility nomographs apply to a central, base location, which is Columbia, Missouri.[23] Soil erodibility K factor values vary by location even when soil properties are exactly the same between locations. The K factor values are higher (or lower) at those locations where rainfall amount and frequency and other factors caused increased (or decreased) runoff per unit rainfall in relation to climatic conditions at Columbia, Missouri. This effect is taken in account by computing temporal soil erodibility factor values that are referenced to the climate at Columbia, Missouri (see **Section 7.4**)

The K factor values computed by the RUSLE2 nomographs are solely a function of soil properties. Theoretically, these K values should be increased or decreased as the ratio of runoff to rainfall varies by location. Although, this adjustment is seldom made, RUSLE2 takes the effect into account in its computation of temporal soil erodibility values.

The soil erodibility nomograph does not apply to soils of volcanic origin, organic soils such as peat, Oxisols, low activity clay soils, calcareous soils, and soils high in mica. Also, the nomograph is less accurate for subsoils than for topsoils. Professional judgment is used to assign K values for those soils. Contact the NRCS State Soil Scientist in your state for assistance.

7.4. Temporal Variability in K

Soil erodibility K factor values vary during the year. The values tend to be high during and immediately following thawing and other periods when the soil is wet. The values tend to be low when soil moisture and runoff is low because of increased soil evaporation caused by high temperatures. The input K value is a base value that is assumed to represent an average value during the "frost free" period, which is defined as the time that the temperature is above 4.4 ^{o}C (40 ^{o}F). Temporal soil erodibility values computed by RUSLE2 are shown in Figure 7.2 for Columbia, Missouri; St. Paul, Minnesota; Birmingham, Alabama; and Tombstone, Arizona.

---

[23] Columbia, Missouri is used as a base location in both RUSLE1 and RUSLE2. USLE values for slope length and steepness effect, soil loss ratio, and support practice factors are assumed to apply at Columbia, MO. RUSLE2 adjusts its values for these factors about the Columbia, MO base values. The weather at Columbia, Missouri is near the "middle" of the data for the Eastern US.

RUSLE2 computes the ratio of daily **K** values to the base K value as a function of the ratio of daily temperature to the base average frost free temperature at Columbia, Missouri and the ratio of daily precipitation to the base average frost free precipitation at Columbia, Missouri. The ratio of daily K to base K increases as the ratio of daily precipitation to base average frost free precipitation increases. This effect represents the increased runoff per unit precipitation caused by increased soil moisture during high precipitation periods. The ratio of daily K to base K decreases as the ratio of daily temperature to base average frost free temperature increases. This effect represents decreased runoff per unit precipitation because of decreased soil moisture on the unit plot conditions during periods when soil evaporation is high. The relative effect of precipitation is greater than that of temperature in these computations. The effect of cover-management on soil erodibility is computed using equations described in **Sections 7 and 9** for cover-management effects.

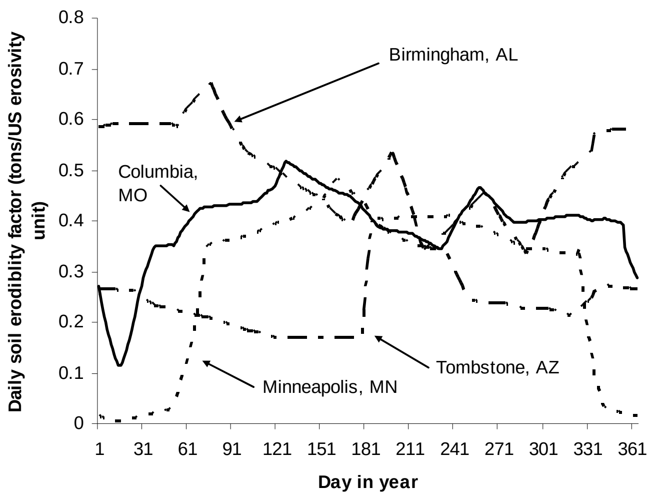

Figure 7.2. Temporal soil erodibility factor values. Base K is 0.42 US units.

When temperature decreases below -1.1 ^{o}C (30 ^{o}F), RUSLE2 reduces K values exponentially as a function of temperature until the K factor value becomes very close to zero at a temperature of -9.4 ^{o}C (15 ^{o}F). The very low K values for Minneapolis, Minnesota during the winter months represent frozen soil that is nonerodible. The same effect is seen for Columbia, Missouri where K values are partially reduced during the winter.

RUSLE2 does not represent increased erodibility during and immediately after the thawing period. The observed data are too few to empirically determine a relationship for this period. Also, the increased erosion during this period is small relative to the total annual erosion for the eastern US. For example, research measurements at Morris, Minnesota showed that erosion during this period was less than 7% of the total annual erosion. This percentage decreases for locations further south. However, the increased erodibility during this period is important in southwestern Colorado, Southeastern Utah, and similar locations in the western US where annual erosivity is low. The relative contribution of the erosion during and immediately after the thawing period is much greater in the western US than in the eastern US. Adjustments can be made in the monthly erosivity values to account for the increased erosion during this period. See **Sections 6.9 and 6.10**.

The peak in erodibility values for Birmingham, AL in March results from increased rainfall, not from the thawing effect. The main influence of temperature on temporally varying K values is in late summer when increased temperature increases soil evaporation and reduces runoff and erosion. The peak erodibility occurs during the summer for Tombstone, AZ because most of the annual rainfall at this location occurs during this period.

As described in Section 7.3.2.3, the RUSLE2 soil erodibility nomographs computes soil erodibility values solely as a function of soil properties. These nomographs do not take into account how soil erodibility factor values are increased in wet locations such as Birmingham, Alabama and are decreased in dry locations such as Tombstone, Arizona. The temporal soil erodibility equations used in RUSLE2 take this effect into account. For example, Figure 7.2 illustrates how the annual average soil erodibility value is much lower at Tombstone than at Birmingham even though the base soil erodibility factor value computed with a RUSLE2 soil erodibility nomograph is the same at both locations.

A constant erodibility value that does not vary during the year can be used in RUSLE2 by answering **No** to the question **Vary erodibility with climate** in the Climate database component. Assuming that soil erodibility varies temporally is recommended for all areas except the Req zones because the Req procedure captures the increased erodibility during the winter in these regions (See **Section 6.9**). The fit of the equation that computes temporal soil erodibility K factor values is weak, and statistically the hypothesis that soil erodibility does not vary with time can not be rejected.[24]

In contrast to RUSLE1 where the time varying soil erodibility relationships were not used in the Western US, the temporally varying erodibility relationships should be used in the Western US for RUSLE2, except in Req applications.

7.5. Soil Texture

Soil texture is the distribution of the primary particles of sand, silt, and clay in the soil. RUSLE2 uses values for sand, silt, and clay fractions to compute soil erodibility, the

[24] A major difference between RUSLE2 and RUSLE1 is in the temporal soil erodibility computations. The differences in erosion between the models can be as large as 25% in the central Midwest and in the New England regions because of the difference in erodibility computations. The RUSLE1 equations (See AH703) were heavily influenced by data from the Morris, MN and Holly Springs, MS locations. While the relationship for temporal erodibility was well defined at these locations, it was not well defined at eight other locations. Given the overall data, a new temporal erodibility relationship was developed for RUSLE2. The current recommendation is that a constant K value be used in RUSLE1.

distribution of the sediment particle classes at the point of detachment, and the diameter of the small and large aggregate particle classes. See **Section 7.5** for a description of the RUSLE2 sediment classes used.

The fractions for soil texture are based on mass (weight) of the total of these three primary particle classes. The sizes of these classes, which are based on the USDA classification, are given in Table 7.3. Refer to the USDA-NRCS soil survey manual for procedures to determine soil texture from soil samples.[25] These procedures involve dispersing a soil sample to breakup soil aggregates into their constituent primary particles. Sieves are typically used to determine the size distribution of the sand classes and the total sand content. Sieves are screens having various sized openings that sort particles by size. A hydrometer or pipette is typically used to determine clay content. This technique is based on fall velocity. Strongly aggregated soils, including some Tropic soils of volcanic origin, may be difficult to disperse and require special procedures. Silt content is 1.0 minus the clay and sand contents.

Table 7.3. Diameter of primary particle classes. Based on USDA classification.

Primary particle class	**Diameter (mm)**
Clay	dia ≤ 0.002
Silt	0.002 < dia ≤ 0.05
Sand	0.05 < dia ≤ 2
Very fine sand	0.05 < dia <0.1
Fine sand	0.1 ≤ dia < 0.5
Coarse sand	0.5 < dia < 1
Very coarse sand	1 ≤ dia < 2

Primary particles are the smallest, discrete mineral soil particles. Obviously, aggregates are larger than the primary particles that form them. The density of aggregates is less than the density of primary particles because of open space within aggregates. This open space can be partially filled with water, and the rate that pore space becomes filled (rate of soil wetting) greatly affects aggregate stability, soil erodibility, and sediment aggregate size. Rapid wetting significantly reduces aggregate stability and increases soil erodibility. Difference in rate of soil wetting is partially why erosion varies greatly between similar storms.

RUSLE2 input values for sand, silt, and clay content (soil texture) are for the upper soil layer susceptible to erosion. This layer is usually assumed to be 4 inches (100 mm) thick depending on the degree and depth of rill erosion. Soil texture values in the NRCS soil survey database can be used as input in RUSLE2 without processing soil samples from the site **provided the soil profile has not been disturbed and soil mixing has not occurred.** The site is located on a soil survey map to identify the soil map unit at the site. Texture values for that soil map unit are given in the NRCS soil survey database.

If the soil profile has been disturbed and the soils mixed, such as at a construction site or reclaimed mine, soil samples from the site must be processed to determine RUSLE2 soil input values.

[25] Soil Survey Manual available on the Internet site www.ftw.nrcs.usda.gov/tech_ref.

RUSLE2 assigns the appropriate textural class when values are entered for sand, silt, and clay content.

If the sand, silt, and clay content is not known, select the soil textural class as the RUSLE2 input if it is known or can be determined by professional judgment such as from feel of the soil. RUSLE2 assigns central values for sand, silt, and clay content for the input textural class based on the textural triangle. The values assigned by RUSLE2 are shown in Table 7.4.

Sometimes the sand, silt, and clay of a soil are known, but the very fine sand content is not known. RUSLE2 can estimate the very fine sand content using the equation:

$$f_{vfsandt} = 0.74 f_{sand} - 0.62 f_{sand}^2 \qquad [7.2]$$

where: $f_{vfsandt}$ = the fraction of the total primary particles (sand+silt+sand) that is composed of very fine sand and f_{sand} = the fraction of the primary particles that is sand. This equation was derived by regression analysis using data in the NRCS soil survey database for Lancaster County in southeastern Nebraska.

7.6. Sediment Characteristics at the Point of Detachment

RUSLE2 uses values for sediment characteristics to compute deposition. Values used to describe sediment can be computed by RUSLE2, which is the recommended approach, or values can be user entered to create a custom sediment distribution.

.

7.6.1. RUSLE2 computes sediment characteristics

Rill and interrill erosion produces sediment that is a mixture of primary particles and aggregates. RUSLE2 uses the five particle classes of primary clay, primary silt, small aggregate, large aggregate, and primary sand to represent sediment. The sediment distribution for many soils has two peaks, one in the silt size range and one in the sand size range. Comparison of sediment size distributions before and after dispersion shows that much of the sediment in these peaks is aggregates. The two aggregate classes represent this sediment. The primary clay, silt, and sand classes represent the sediment that is eroded as primary particles.

RUSLE2 computes the distribution of these five particle classes and the diameters of the small and large aggregate classes at the point of detachment as a function of soil texture.[26]

---

[26] The equations used by RUSLE2 are described by Foster, G.R., R.A. Young, and W.H. Neibling. 1985. Sediment composition for nonpoint source pollution analyses. Trans. ASAE 28(1):133-139, 146.

Cover-management also affects sediment characteristics. Increased soil biomass increases the fraction of the sediment composed of aggregates and the size of the aggregates. However, sufficient experimental data are not available to derive equations to describe how cover-management affects sediment characteristics.

In general, the fractions and diameters for the aggregate classes increase as the soil's clay content increases. Clay is assumed to be a binding agent that increases aggregation. .

Table 7.4. Sand, silt, and clay contents assigned for a textural class. Based on USDA classification.

Textural class	**Sand (%)**	**Silt (%)**	**Clay (%)**
Clay	20	20	60
Clay loam	33	33	34
Loam	41	41	18
Loamy sand	82	12	6
Sand	90	6	4
Sandy clay	51	5	44
Sandy clay loam	60	13	27
Sandy loam	65	25	10
Silt	8	87	5
Silt loam	20	65	15
Silty clay	6	47	47
Silty clay loam	10	56	34

Table 7.5. Characteristics of sediment classes assume

Sediment class	**Density (specific gravity)**	**Diameter (mm)**	
Primary clay	2.6	0.002	Fraction = 0.2
Primary silt	2.65	0.01	Fraction strong
Small aggregate	1.8	0.03 to 0.1	Fraction and d
Large aggregate	1.6	0.3 to 2	Fraction and d
Primary sand	2.65	0.2	Fraction strong

Values assumed by RUSLE2 for each sediment class are listed in Table 7.5. Fall velocity V_f of each sediment class is used in equation 5.2 to represent sediment "depositability." Fall velocity is a function of diameter and density of the sediment particles. RUSLE2 computes fall velocity using Stokes law for the small particle classes and standard drag relationships for the large particle classes assuming that the sediment particles are spheres.

Table 7.6. Sediment characteristics for a silt loam soil (20% sand, 60% silt, 20% clay) at detachment and (0% sand, 56% silt, 44% clay) after deposition by a dense grass strip on the lower 10% of slope length.

Sediment class	Diameter (mm)	% at detachment	% after deposition
Primary clay	0.002	5	43
Primary silt	0.01	24	54
Small aggregate	0.03	36	3
Large aggregate	0.4	28	0
Primary sand	0.2	7	0

Deposition enriches the sediment load in fines, which RUSLE2 computes as illustrated in Table 7.6. Deposition changes the distribution of the sediment classes from that at the point of detachment. RUSLE2 also computes the sand, silt, and clay content in the sediment leaving the RUSLE2 hillslope profile. RUSLE2 computed that the fraction of primary clay sediment class leaving the grass filter strip after deposition is 43% in comparison to 5% at the point of detachment in the example illustrated in Table 7.6. Also, the total clay content in the sediment was 44% versus 20% in soil surface layer.

RUSLE2 assumes that small aggregates are composed of clay and silt primary particles and that large aggregates are composed of clay, silt, and sand primary particles. RUSLE2 computes the distribution of these particles in each aggregate class as a function of soil texture. RUSLE2 also computes an enrichment ratio as specific surface area of the sediment at the lower end of the last RUSLE2 element divided by the specific surface area of the sediment at the point of detachment. The enrichment ratio for the Table 7.6 example is 1.9, which means that the specific surface area of the sediment is almost twice that of the soil. The specific surface areas assumed in RUSLE2 for primary particles are 20 m^2/g for clay, 4 m^2/g for silt, and 0.05 m^2/g for sand. Specific surface area indicates the relative importance of each primary particle class as a binding agent and for transporting soil-absorbed chemicals. The specific surface area of each aggregate class depends on the composition of primary particles.

7.6.2. User entered values.

Although the RUSLE2 names assigned the five sediment classes are arbitrary, the names of the classes and the number of classes can not be changed. However, values for fraction, diameter, and density assigned to each class can be user overwritten to create a custom sediment description. RUSLE2 does not properly compute enrichment if these values are manually overwritten.

7.7. Rock Cover

Rock cover on the soil surface acts as ground cover and reduces erosion much like plant litter, crop residue, and applied mulch, except that rock does not decompose and add biomass to the soil. RUSLE2 combines rock cover with other ground cover to obtain a single composite ground cover value, taking into account the overlap of plant and applied materials on the rock cover. This single ground cover value is used in the equations that compute cover-management effects on erosion (See **Section 9.2.2**.). This overlap of cover is the reason that values for rock cover and other ground cover cannot be added to obtain the total cover. Also, the effects of rock and other ground cover cannot be computed separately and then combined to determine the total ground cover effect because of the nonlinearity in the equation used to compute the ground cover effect on erosion.

The nonlinearity in the equations used to compute the ground cover effect is the reason that a K factor value cannot be used in RUSLE2 where an adjustment has already been made for rock cover.

RUSLE2 handles "rock cover" entered as a soil input differently than ground cover added through a cover-management input. The soil input rock cover remains constant through time, is not buried, and does not decompose. The rock cover variable can also be used to represent mosses, which provide substantial ground cover on rangelands, and other types of ground cover that can be assumed remain constant through time.

See Section 12 for special considerations needed when a mechanical soil disturbance is used to bury rock or other material that does not decompose.

The soil rock cover input is a site-specific entry based on field measurements. The same technique used to measure other ground cover like plant litter and crop residue can be used to measure rock cover.[27] To be counted as ground cover, rock must be sufficiently large not be moved by raindrop impact or surface runoff. The minimum rock size that is measured is site specific, but as a guideline, the minimum rock size is 10 mm (3/8 inch) diameter except on coarse texture rangeland soils where the minimum size is 5 mm (3/16 inch).

---

[27] A typical procedure used to measure ground cover is to lay a line transect, such as a knotted string or measuring tape, across the soil surface diagonal to any cover orientation. An estimate of ground cover is the percentage of knots or markings on a tape that contact ground cover. Another approach is to photograph the surface, lay a grid over the photograph, and count the intersection points that touch ground cover.

Do not use rock cover values or rock content in the soil profile from the NRCS soil survey database to determine rock cover. The definitions of rock cover in that database do not correspond with RUSLE2 definitions.

The appropriate time to measure rock cover is during the 1/4 to 1/3 period of the year or crop rotation when the hillslope is most susceptible to erosion. Measure rock cover on cultivated land after rainfall has exposed the rock so that the rock and its influence can be readily seen.

7.8. Hydrologic Soil Group

Hydrologic soil group is an index of the runoff potential of the soil under unit plot conditions. These designations are A (lowest potential), B, C, and D (highest potential). **RUSLE2** uses the hydrologic soil designation in the NRCS curve number method to compute runoff. Hydrologic soil group designations are available by map unit and component in the NRCS soil survey database. The USDA-NRCS hydrology manual provides information on assigning hydrologic soil group designations for those soils not included in the NRCS soil survey.[28] The soils with the lowest runoff potential, such as deep sandy soils, are assigned an A hydrologic soil group. The soils where almost all of the rainfall becomes runoff are assigned a D hydrologic soil group. Examples of hydrologic group D soils include high clay soils and silt soils that readily crust causing significantly reduced infiltration. Soils having a restrictive layer like a fragipan, rock, plow pan, or traffic pan near the soil surface also are assigned a D hydrologic soil group.

RUSLE2 uses the hydrologic soil group designations for drained and undrained conditions to compute the soil loss reduction caused by tile and other drainage practices. The equation used in the soil erodibility nomographs for the effect of permeability on soil erodibility are used to compute the effect of drainage on erosion. The four hydrologic soil groups are scaled over the six permeability classes so that a hydrologic soil group designation can be converted to a permeability class to use the erodibility nomograph equation.[29]

Two hydrologic soil group designations are entered for a soil. One is for the **undrained** condition and one for the **drained** conditions. Runoff potential can be high because of a perched water table or the soil occupying a low-lying position on the hillslope even though soil properties would indicate a low runoff potential. Artificially draining these

[28] Contact the NRCS Internet site at www.nrcs.usda.gov for additional information

[29] Although hydrologic soil group and the permeability class are directly related, RUSLE2 requires separate inputs for these two variables. Therefore, the user needs to ensure that the inputs for these variables are consistent when one of the nomograph is used to compute a K value.

soil with deep parallel ditches or buried tile lines can greatly increase internal drainage and reduce surface runoff and erosion.

The hydrologic soil group assigned for the drained condition represents runoff potential under drained conditions based on soil properties and assuming a high performance drainage system. A drained soil does not imply that an A hydrologic soil group should be assigned. For example, a drained sandy soil might be assigned an A hydrologic soil group whereas a drained clay soil might be assigned a C hydrologic soil group because the clay limits internal drainage and infiltration.

7.9. Time to Soil Consolidation

RUSLE2 assumes that the soil is 2.2 times as erodible immediately after a mechanical disturbance than after the soil has become "fully consolidated."[30] Erosion decreases with time and "levels out" as illustrated in Figure 7.3. A double exponential decay curve is used to describe this decrease in erodibility. The equation used in RUSLE2 for this curve was derived from erosion data at Zanesville, OH that were collected over time after tillage stopped on a fallow plot. The time required for the erosion rate to "level out" after a mechanical disturbance is the **time to soil consolidation**. Erodibility of a fully "consolidated" soil is 45 percent of that immediately after mechanical disturbance. The time to consolidation is at the time when 95 percent of the decrease in erodibility has occurred.[31]

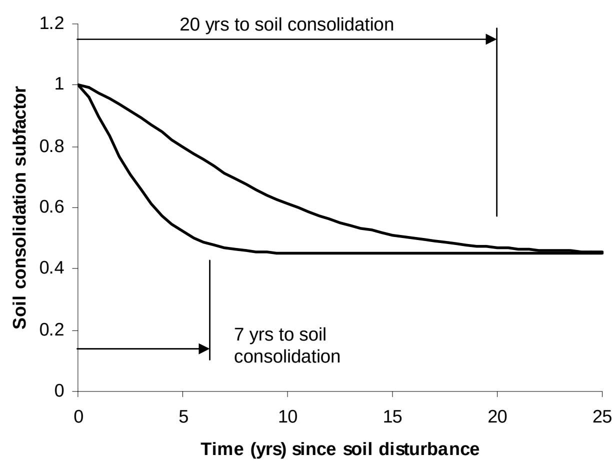

Figure 7.3.Effect of time on decrease in soil erodibility following a mechanical disturbance.

This decrease in erodibility occurs because of soil wetting and drying and biological soil activity. RUSLE2 assumes seven years for the **time to soil consolidation,** but another value can be entered. Also, RUSLE2 can compute the time to soil consolidation based on average annual precipitation as describe below.

---

[30] Soil consolidation does not refer to the physical process of the bulk density of the soil increasing over time. Instead, it refers to a change in erodibility over time.

31 The 95 percent is used rather than 100 percent because the equation from is such that an infinitely long time is required for the computed values to actually reach the fully consolidated condition.

Time to soil consolidation is a function of soil properties. However, insufficient data are available to derive a relationship between soil properties and time to soil consolidation and soil properties and the degree of soil consolidation. The degree of soil consolidation (i.e., the increase in erodibility because of a mechanical disturbance, is less for a high sand soil than for a high clay soil. Also, the relative effect of mechanical disturbance seems to be greater for rill erosion than for interrill erosion.

Answering **Yes** to the question, **Calculate time to consolidation from precipitation**, causes RUSLE2 to compute a **time to soil consolidation** that is a function of average annual precipitation. RUSLE2 assumes seven years for the **time to soil consolidation** where average precipitation exceeds 30 inches (760 mm) and computes a **time to soil consolidation** that increases to 20 years in the driest areas of the Western US, as illustrated in Figure 7.3. The time to soil consolidation increases linearly from 7 years to 20 years between as average annual precipitation decreases from 30 inches (760 mm) to 10 inches (250 mm). A value of 20 years for time to soil consolidation is assumed for average annual precipitation less than 10 inches (250 mm). This increased time to soil consolidation reflects how the effects of a mechanical soil disturbance persist longer in low precipitation areas where reduced water is available and less frequent wetting and drying cycles occurs.

7.10. Soil Loss Tolerance (T)

The objective in conservation and erosion control planning is to control average annual erosion to an acceptable level.

7.10.1. Purpose of "T-value" input

The "T-value" in the RUSLE2 soil database component is the acceptable average annual rill-interrill erosion rate for a particular situation. RUSLE2 is used to identify erosion control practices that give estimated rill-interrill erosion equal to or less than the "T-value" assumed in the particular conservation planning application. In many cases, the T-value used in conservation planning will the NRCS-assigned soil loss tolerance value.

The "T-value" varies with the situation. For example, the "T-value" can be increased from the standard soil loss tolerance T-value for construction sites where the soil is exposed to erosion for a relatively short time. The standard soil loss tolerance T-value is used for cropland where long term productivity must be maintained or landfills where the buried waste must be protected from exposure by erosion over hundreds of years. An especially low "T-value" may be required to control off-site sediment delivery to protect a sensitive downstream resource such as a fish habitat. In many RUSLE2 applications, the "T-value" is determined by applicable government program or regulations.

The "T-value" entered in the RUSLE2 soil database component should be appropriate for the particular application.

Rather than reducing erosion to an absolute "T-value," the erosion control objective in some applications is to reduce erosion by a certain percentage relative to a base condition. Although a "T-value" is not needed in those applications, a nonzero "T-value" must be entered so that RUSLE2 can compute the ratio of segment erosion to the "T-value" adjusted for slope position, as discussed below.

7.10.2. NRCS-assigned soil loss tolerance values

Soil loss tolerance values assigned to each soil map unit by NRCS as a part of its soil survey program are often entered in RUSLE2 as the "T-value." Soil loss tolerance values range from 1 tons/acre (2 t/ha) per year to 5 tons/acre (11 t/ha) per year based primarily on how erosion is judged to harm the soil and to cause other damage. Shallow and fragile soils that can not be easily reclaimed after serious erosion are assigned low soil loss tolerances values. Limiting erosion rate to soil loss tolerance protects the soil as a natural resource and maintains the soil's long term productive capacity. Soil loss tolerance values consider the damages caused by erosion and the benefits of soil conservation. Also, soil loss tolerance values include a socio-economic element by considering the availability of reasonable and profitable erosion control technology.[32]

Although soil loss tolerance values were principally developed for cropland soils, soil loss tolerance values are also used for erosion control planning for reclaimed surface mines, landfills, and military training sites. Applying mulch controls erosion and promotes seed germination and early growth of vegetation. Erosion control facilitates establishing and maintaining vegetation, which is essential to long term site protection and similar to cropland requirements. Reclaimed land regulations require that excessive rill erosion be prevented. A rule of thumb is that rill erosion begins when soil loss for the eroding portion of the overland flow path exceeds about 7 tons/acre (15 t/ha) per year. A major concern on waste disposal sites is that buried waste not be exposed by rill erosion. Controlling soil loss to less than 5 tons/acre (11 t/ha) per year significantly reduces the likelihood of rill erosion. A well designed surface runoff collection system in addition to the rill and interrill erosion control practice is also required to prevent incised gully erosion.

Soil loss tolerance values are primarily for protecting the soil as a natural resource and not for protecting offsite resources from excessive sedimentation or water quality degradation. The criteria for controlling sediment yield from a site should be based on potential off-site sediment damages.

---

[32] The factors considered in assigning soil loss tolerance values are discussed by Toy, T.J., G.R. Foster, and K.G. Renard. 2002. Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley and Son, New York, NY. The definition for soil loss tolerance given in AH537 implies that erosion can occur indefinitely at soil loss tolerance even though soil loss tolerance values exceed soil formation rates by about a factor of ten.

7.10.3. Taking hillslope position into account

A uniform slope for the **eroding portion** of the overland flow path is usually assumed in analyses where soil loss tolerance values are used in erosion control planning. See **Section 5.2** and Figures 5.2 and 5.3 for illustrations of overland flow paths and the eroding portion of an overland flow path. **Soil loss** is computed for this uniform profile and compared to the soil loss tolerance value. A satisfactory erosion control practice is one that reduces soil loss to the "T-value" or less.

However, special considerations should be given to applying soil loss tolerance values where steepness varies along the overland flow path. Average erosion for the profile is underestimated when a uniform profile is assumed for convex shaped profiles and overestimated for concave profiles. This difference is illustrated in Table 7.7 were average erosion is computed for uniform and convex profiles of the same length and average steepness. The average erosion for the convex profile is about 25% greater than the average erosion for the uniform profile. The difference in the erosion between the profiles increases as the degree of curvature of the convex profile increases. The ratio of steepness at the end of the convex slope to average steepness is a measure of curvature. In this example, the steepness at the end of the convex slope is about 1.7 times the average steepness of the profile.

An erosion control approach is to reduce the average erosion for the convex profile to the "T-value," which is illustrated in the two right hand columns of Table 7.7. Average erosion rate does not adequately account for the high erosion rate at the end of convex profiles. The erosion rate on the last segment at the end of the convex profile illustrated in Table 7.7 is more than twice the average erosion rate for the profile. The erosion rate at the very end of the convex profile is higher yet. Therefore, average erosion for the entire profile is not a satisfactory erosion control measure for a convex profile, especially one with significant curvature. Extra protection is needed on the lower end of the convex profile to provide comparable erosion control to that on the uniform profile.

Table 7.7. Soil loss along uniform and convex profiles of same length and average steepness. A = average erosion for entire profile and Adj T = T-value adjusted for position on profile. Assume "T-value" = 5.0.

	Uniform			Convex				
				Same practice as uniform profile			Practice changed to give same A as for uniform profile	
Segment	Steepness (%)	Segment erosion	Erosion/ Adj T	Steepness (%)	Segment erosion	Erosion/ Adj T	Segment erosion	Erosion/ Adj T
1	6	2.50	0.99	2	1.09	0.32	0.88	0.26
2	6	4.22	1.00	4	2.85	0.65	2.29	0.52
3	6	5.29	1.00	6	5.29	1.00	4.26	0.81
4	6	6.12	1.00	8	8.44	1.40	6.81	1.10
5	6	6.84	1.00	10	13.10	1.80	10.50	1.50
		A = 5.0			A = 6.2		A = 5.0	

An erosion control approach for convex profiles could be to reduce erosion rate on the last segment to the "T-value." However, erosion rate for each segment is a function of the segment length. Basing erosion control on segment erosion would make erosion control a function of segment length, which is improper. An alternative approach is to reduce "point" erosion rate to be less than the "T-value," but this approach provides greater protection for the convex profile than is considered necessary for the uniform profile having the same average steepness as the convex profile. Thus, the two profiles are not being compared on an equal basis.

Erosion rate increases along a uniform profile so that the erosion rate at the end of the uniform profile is substantially higher than the "T-value" when average erosion for the profile equals the "T-value." The erosion rate on the last segment on the uniform profile illustrated in Table 7.7 is 6.8, which is about 35% greater than the "T-value." Therefore, a procedure is needed that puts non-uniform profiles on the same basis as uniform profiles when comparing segment erosion to "T-values."

RUSLE2 computes the ratio of segment erosion to T adjusted for position to put erosion on an equal basis when comparing non-uniform shaped profiles.

RUSLE2 computes a **ratio of segment erosion to a "T-value" adjusted for position along the profile** so that erosion on non-uniform shaped profiles can be compared on an equal basis to erosion on uniform profiles when selecting erosion control practices.[33] The reason for having the comparison on an equal basis is that the soil loss tolerance concept is based on a uniform profile. The erosion control objective is that the ratio of segment erosion to "T-value" adjusted for position should be one or less. Note that this ratio is 1

[33] See AH703 for a discussion of this adjustment, including the mathematics used to make the adjustment.

everywhere along the uniform profile illustrated in Table 7.7, which shows that the ratio takes out the position effect along the profile in comparing segment erosion values to "T-values."

The analysis involving the ratio of segment erosion to "T-values" adjusted for position along the profile should be for the eroding portion of the profile and not include depositional portions of concave profiles.

The same level of erosion control is achieved on the convex profile as on the uniform profile when the ratio of segment erosion to "T-value" adjusted for slope position is one or less for all segments. In the example in Table 7.7, the convex profile requires increased erosion control on the last two segments than is required on the uniform profile of the same average steepness as the convex profile because the convex profile accelerates erosion near its end. Similarly, less erosion control is needed on the upper three segments than on the uniform profile because the ratio of segment erosion to "T-value" adjusted for position is less than 1. In this example, the average erosion for the convex profile must be reduced to 3.3 tons/acre to provide the same level of erosion control on the last segment of the convex profile as provided on the last segment of the uniform profile.

8. TOPOGRAPHY

Topographic information is stored in the profile and worksheet components of the RUSLE2 database. Topography is a part the overall description of an **overland flow path** that includes information on cover-management, soil, and steepness along the flow path. This description involves three layers of information, illustrated in Figure 8.1. An overland flow path is also referred to as a RUSLE2 **hillslope profile**.

Segments are created for each layer by specifying the locations where cover-management, soil, or steepness changes along the flow path. Inputs are selected from the RUSLE2 database for each management and soil segment, and values for segment break locations and steepness are user entered. Thus, RUSLE2 computes how change in cover-management, soil, and steepness along the overland flow path affect erosion and deposition. Segment break locations need not coincide among the layers as illustrated in Figure 8.1.

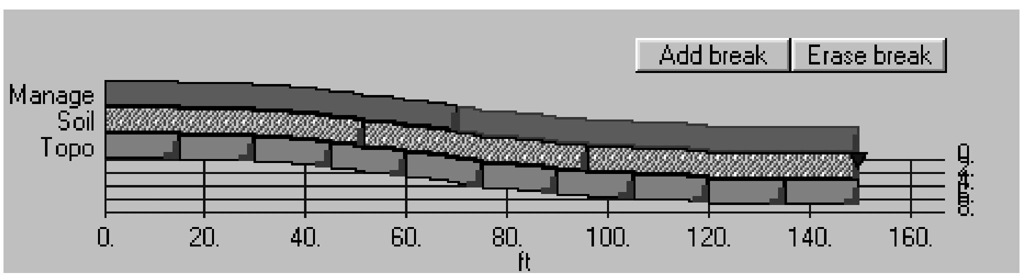

Figure 8.1. Schematic of the three layers that represent an overland flow path (a RUSLE2 hillslope profile).

8.1. Basic Principles

RUSLE2 uses equation 5.4 to compute erosion along an overland flow path. For generality, assume that all RUSLE2 profiles are composed of multiple segments, like Figure 8.1. Each layer (management, soil, topography) has its own segments. RUSLE2 assembles the segments for each layer into a composite set of segments. A composite segment end is located at a change in any one of the three layers.

8.1.1. Detachment

The computations that solve equation 5.4 start at the upper end of the overland flow path and step down slope segment by segment, which "routes" the water and sediment down slope. The sediment load g_{in} entering a particular segment is known from the computation of the sediment load g_{out} leaving the adjacent upslope segment. No sediment enters the first segment because it is at the origin of the overland flow.

The amount, expressed as mass per unit area, of net detached sediment (sediment produced) within the *ith* segment is computed with:

$$D_i = rkScp_c(x_i^{m+1} - x_{i-1}^{m+1}) / \lambda_u^m (x_i - x_{i-1}) \qquad \textbf{[8.1]}$$

where: D_i = net detachment (mass/area), r = erosivity factor, k = soil erodibility factor, S = slope steepness factor, c = cover-management factor, p_c = contouring factor, x_i = distance to lower end of the segment, x_{i-1} = distance to the upper end of the segment, λ_u = length of the unit plot (either 72.6 ft or 22.1 m), and m = slope length exponent. All variables are for a particular day and for the *ith* segment.34 Equation 8.1 is equation 5.1 applied to a segment.

The slope length exponent **m** for the *ith* segment is computed from:

$$m = \beta/(1+\beta) \qquad \textbf{[8.2]}$$

where: β = ratio of rill to interrill erosion for the *ith* segment, which in turn is given by:

$$\beta = \left[\frac{k_r}{k_i}\right]\left[\frac{c_{pr}}{c_{pi}}\right]\left[\frac{\exp(-0.05 f_g)}{\exp(-0.025 f_g)}\right]\left[\frac{(s/0.0896)}{3s^{0.8}+0.56}\right] \qquad \textbf{[8.3]}$$

where: k_r/k_i = the ratio of rill erodibility to interrill erodibility; c_{pr}/c_{pi} = the ratio for below ground effects for rill and interrill erosion, respectively, which is a prior land use type effect; exp(-0.05f_g/exp(-0.025 f_g) = the ratio of the ground cover effect on rill and interrill erosion, respectively; (s/0.0896)/(3$s^{0.8}$+0.56) = the ratio of slope effects for rill and interrill erosion, respectively; s = sine of the overland flow path slope angle; and f_g = percent ground cover.[35] All variables in equation 8.3 are for the *ith* segment. The ratio k_r/k_i is computed as a function of soil texture where the ratio decreases as clay increases because clay makes the soil resistant to rill erosion. The ratio increases as silt increases because silt decreases the resistance of soil to rill erosion. The ratio c_{pr}/c_{pi} represents how rill erosion decreases relative to interrill erosion as both soil consolidation and soil biomass increase. The term exp(-0.05f_g)/exp(-0.025f_g) represents how ground cover has a greater effect on rill erosion than on interrill erosion. The term (s/0.0896)/(3$s^{0.8}$+0.56) represents how slope steepness has a greater effect on rill erosion than on interrill erosion.

[34] See the RUSLE Science Documentation for a complete description of the equations used in RUSLE2. The equations in this RUSLE2 User's Reference Guide are for illustration only and are not the complete equations.

[35] Equation 8.3 replaces the selection of an LS "Table" in RUSLE1.05 and earlier RUSLE1 versions and replaces having to select a land use in RUSLE1.06. RUSLE2, in effect, selects the proper LS relationship based on cover-management conditions.

A constant value of 0.5 is used for m in the Req zone.

The RUSLE2 slope length effect from equation 8.1 is:

$$L_i = (x_i^{m+1} - x_{i-1}^{m+1}) / \lambda_u^m (x_i - x_{i-1}) \qquad \textbf{[8.4]}$$

where: L_i = the slope length factor for the *ith* segment. The slope length effect in RUSLE2 adjusts soil loss from the unit plot up or down depending on whether the ith segment position is located less or greater than the unit-plot length λ_u of 72.6 ft (22.1 m) from the upper end of the overland flow path. Values for the slope length effect are less than 1 when location of the segment is less than the unit plot length and greater than 1 when the location is greater than the unit plot length.

The slope length effect in RUSLE2 is a function of rill erosion relative to interrill erosion except in the Req zone. Interrill erosion is assumed to be caused by raindrop impact and therefore independent of location along the overland flow path, assuming that the variables that affect interrill erosion are constant along the overland flow path. Rill erosion is assumed be caused by surface runoff and to vary linearly along the overland flow path because of runoff accumulation. The slope length exponent **m** in equation 8.2 varies between 0 and 1 and reflects the relative contribution of rill and interrill erosion. The exponent m is near 0 when almost all of the erosion is by interrill erosion, such as on a flat slope, and m is near 1 when almost all of the erosion is from rill erosion, such as on a bare, steep slope. Slope steepness, cover-management, and soil affect RUSLE2's slope length effect because of their different effect on rill erosion relative to interrill erosion. The RUSLE2 slope length effect varies daily as cover-management conditions change. The USLE slope length factor is independent of the other USLE factors, except for slope steepness. The RUSLE1 slope length factor only partially varies with the other RUSLE1 factors.

RUSLE2 spatially integrates equation 5.4 in its computations. A spatial integration of the USLE and RUSLE1 is possible for a limited set of conditions, but the integration must be done manually and is laborious. Few users perform the integration. RUSLE2 performs the integration internally without extra steps required of the user other than to divide the overland flow path into segments and specify the inputs for each segment. Just as RUSLE2 differs from RUSLE1 and the USLE in temporal integration, RUSLE2 also differs from them in spatial integration and interaction among factors. Although RUSLE2 uses fundamentals from the USLE and RUSLE1, RUSLE2 is essentially a new model. These mathematical differences give RUSLE2 much more power than the other equations.[36]

---

[36] The difference in temporal integration can result in as much as 20% differences in erosion estimates between RUSLE2 and the USLE and RUSLE1. The difference in spatial integration between RUSLE2 and RUSLE1 is generally not great provided the proper selections are made in RUSLE1. However, few users

The RUSLE2 slope steepness factor is computed with:

$$S = 10.8s + 0.03 \qquad \text{slope} < 9\% \qquad \textbf{[8.5]}$$

$$S = 16.8s - 0.50 \qquad \text{slope} \geq 9\% \qquad \textbf{[8.6]}$$

for all areas except the Req zone, where equation 8.7 is used.

$$S = (s/0.0896)^{0.6} \qquad \text{slope} \geq 9\% \qquad \textbf{[8.7]}$$

where: slope = slope steepness in percent.[37] The slope steepness factor S has a value of 1 for a 9% slope. Values for the S factor are less than 1 for slope steepness less than 9 percent and greater than 1 for slope steepness greater than 9 percent. The slope steepness factor in RUSLE2 adjusts the soil loss values from the unit plot up or down depending on whether the field slope is steeper or flatter than the 9 percent steepness of the unit plot.

The slope steepness S factor should be a function of the soil and cover-management similar to equation 8.3. However, neither the empirical data nor theory is sufficient for incorporating those effects into RUSLE2.

8.1.2. Runoff

RUSLE2 uses discharge (flow) values for runoff to compute sediment transport capacity, contouring effectiveness, and critical slope length for contouring. Discharge rate at a location is computed from:

$$q = q_{i-1} + \sigma_i (x - x_{i-1}) \qquad \textbf{[8.8]}$$

where: q = discharge rate (volume/width·time) at the location x between the segment ends x_{i-1} and x_i, q_{i-1} = discharge rate at x_{i-1}, and σ_i = excess rainfall rate (rainfall rate - infiltration rate) on the *ith* segment. Excess rainfall rate is computed using the NRCS runoff curve number method that computes runoff depth. RUSLE2 assumes that runoff rate is directly proportional to runoff depth. RUSLE2 computes curve number values, the major parameter in the NRCS curve number method, as a function of hydrologic soil group, soil surface roughness, ground cover, soil biomass, and soil consolidation to represent the effect of cover-management on runoff. In general, RUSLE2 computes reduced runoff as these variables increase, except for soil consolidation that interacts with soil biomass. If soil biomass is very low, soil consolidation increases runoff, typical of a bare construction site. If soil biomass is high, typical of high production pasture, soil

---

properly select inputs for RUSLE1 to achieve this similarity in results.

[37] The slope factor equations are the same in RUSLE2 and RUSLE1.

consolidation decreases runoff.[38] The curve number method is configured within RUSLE2 to compute negative values for rainfall excess (σ) so that RUSLE2 can compute decreasing discharge along a segment having very high infiltration that receives run-on from upslope.

Discharge in RUSLE2 is typically used as a ratio of discharge computed for a given condition to a base runoff computed for moldboard plowed, clean tilled, low yielding corn grown on a silt loam soil in Columbia, MO. RUSLE2 starts with empirical erosion factor values taken from AH537, which is a summary of data collected over a wide range of conditions at many locations. RUSLE2 uses ratios, such as the one involving discharge, in process-based equations to adjust the empirical erosion factor values up or down from a base value. RUSLE2 often computes a departure from a base value rather than an absolute value. Computing departures is more stable and robust than computing absolute values. This approach combines the best of empirically based and process based variables and equations.

Columbia, MO is used as a base because it is centrally located in the US and represents "typical" weather values in the eastern US. The moldboard plowed, clean-tilled, row cultivated corn best represents the condition for contouring and critical slope length values in AH537. These AH537 values are directly related to runoff and serve as calibration data.

8.1.3. Sediment transport capacity

Sediment transport capacity ($T_{c,up}$ and $T_{c,low}$) is computed at both the upper (x_{i-1}) and lower (x_i) ends of each segment using equation 5.3 and the discharge rates and slope steepness of the segment. This approach results in a step change in sediment transport capacity at segment ends, even when steepness varies smoothly in continuous fashion. Slope steepness values for adjacent segments could have been averaged to obtain a smoothly varing transport capacity along the slope. However, such an approach would have increased the difficulty for users to represent sharp changes in steepness, such as the flat top and steep sideslope of a landfill. Transport capacity is also a step function where cover-management conditions, such as at the upper end of a grass strip change as a step function, or slope steepness changes as a step function, such as the change in steepness from the top of a landfill to the sideslope. RUSLE2 computes transport capacity at the lower end of a segment based on conditions for that segment and at the upper end of the adjacent segment using the conditions for that segment to capture step changes. These step changes in transport capacity are illustrated in Figure 8.2.

The product qs in Equation 5.3 represents runoff erosivity. It is proportional to runoff's total shear raised to the 3/2 power. Total shear stress is divided between that acting on the soil (skin friction) and that acting on form roughness elements (form friction). The

[38] Soil consolidation is used as an indicator variable, not as a cause and effect variable.

shear stress acting on the soil is assumed to be responsible for runoff transporting sediment. The coefficient K_T is a measure of the fraction of the flow's total shear stress that acts on the soil to transport sediment. Values for K_T and transport capacity decrease as form hydraulic roughness increases even though total hydraulic roughness increases..

Manning's n is a measure of form and grain (skin) roughness combined. RUSLE2 uses Manning's n values to compute K_T values. In turn, RUSLE2 computes values of Manning's n as a function of standing live and dead vegetation, ground cover, and surface roughness, which are form roughness elements.

The variable K_T is also a calibration coefficient that represents transportability of the sediment. RUSLE2 does not vary K_T as a function of sediment properties, which means that sediment transport capacity is not a function of sediment characteristics. A base value for K_T was determined by calibrating RUSLE2 to a field plot experiment of deposition on a concave slope. The steepness of this concave slope decreased from 18% at the its upper end to 0% at its lower end. Deposition began at the location where steepness was 6%. This condition was assumed to represent moldboard plowed, clean tilled, low yield corn on a silt loam soil at Columbia, MO. The calibration was checked against general field observations and data from laboratory experiments on sediment transport and deposition.

8.1.4. Sediment routing

Several cases must be considered in routing the sediment down slope (i.e., solving equation 5.4 sequentially by segment starting at the upper end of the overland flow path).

8.1.4.1. Case 1: Detachment over the entire segment

Detachment occurs over the entire segment when the transport capacity $T_{c,up}$ at the upper end of the segment is greater than the incoming sediment load g_{in} and the transport capacity $T_{c,low}$ at the lower end of the segment is greater than the maximum possible sediment load at the lower end of the segment. The maximum possible sediment load is the incoming sediment load plus the sediment produced within the segment by detachment. This case occurs on uniform and convex shaped slopes and the upper portion of a concave slope.

Sediment load at the lower end of the segment is given by:

$$g_{out} = g_{in} + D_i(x_i - x_{i-1}) \quad \textbf{[8.9]}$$

where: D_i = net detachment (sediment production) computed with equation 8.1 for the *ith* segment.

Another possibility is that the potential sediment load computed with equation 8.9 exceeds transport capacity at the lower end of the sediment while the potential sediment load based on interrill erosion is less than transport capacity. If this condition exists, RUSLE2 computes a reduced rill erosion so that the sediment load at the end of the segment just fills transport capacity without overfilling it.

RUSLE2 assumes that interrill erosion always occurs at a "capacity" rate. Interrill erosion is computed like net detachment (equation 8.1) except for an interrill erosion slope steepness factor, the slope length factor being 1 (i.e., interrill erosion does not vary by location along the overland flow path), and multiplying by 0.5 based on the assumption that interrill erosion equals rill erosion for unit-plot conditions. The RUSLE2 equation for interrill erosion rate is:

$$D_{ir,i} = 0.5rk(3s^{0.8} + 0.56)cp_c \qquad \textbf{[8.10]}$$

No local deposition occurs for **Case 1** conditions when slope steepness is sufficiently steep.[39] However, at low steepness, interrill erosion can be greater than sediment transport capacity, which causes local deposition. Local deposition occurs where interrill erosion rate exceeds the increase in transport capacity with distance (i.e, $D_{ir} > dT_c/dx$). Equation 8.1 empirically includes local deposition in its computation of net detachment. Local deposition is selective causing coarse particles to be deposited and the sediment load to be enriched in fine particles. RUSLE2 uses the procedure that computes deposition in **Case 2** to compute sediment characteristics and the enrichment ratio for this local deposition (See **Section 7.5**).

The distribution of the sediment added to the sediment load by detachment is the sediment distribution at the point of detachment described in **Section 7.5**. The particle class distribution in the sediment load is the same as that at the point of detachment unless local deposition or remote deposition is computed.

8.1.4.2. Case 2: Deposition over the entire segment

Deposition occurs along an entire segment when the sediment load exceeds transport capacity at both the upper and lower ends of the segment. An example of this case is deposition in a narrow grass strip illustrated in Figure 8.2. Table 7.6 shows values computed by RUSLE2 for an example like this case.

[39] **Local deposition** is deposition very close (few inches, tens of millimeters) to the detachment point. Deposition in the depressions on a rough soil surface is an example of local deposition. **Remote deposition** is deposition a considerable distance (tens of feet, several meters) from the detachment point.

Equation 5.2, which computes deposition, is applied to each particle class. Sediment characteristics used in these computations are described in **Section 7.5.** The transport capacity for each particle class is computed by dividing the total sediment transport capacity computed with equation 5.3 among the particles in proportion to the mass distribution of the sediment classes in the total sediment load. The distribution of sediment transport capacity among the particle classes changes as deposition occurs along the overland flow path because each particle class is deposited at a different rate based on fall velocity

Equation 5.2 has two unknowns, deposition rate and sediment load. Equation 5.2 is combined with the continuity equation to solve for deposition rate and sediment load. The continuity equation for **Case 2** is:[40]

$$\Delta g / \Delta x = D_{ir} + D_p \qquad \textbf{[8.11]}$$

where: $\Delta g/\Delta x$ is the change in sediment load Δg over the distance Δx, D_{ir} = interrill erosion and D_p = deposition rate.

An important assumption involves interrill erosion in equation 8.11. **Does interrill erosion occur simultaneously with deposition?** CREAMS assumes that rill erosion **does not** occur simultaneously with deposition, while RUSLE2 assumes that interrill erosion **does** occur simultaneously with deposition. This assumption is valid for interrill erosion on ridges where deposition occurs in the furrows between the ridges. However, the assumption is not clear-cut where deposition occurs on flat soil surfaces, such as the toe of a concave slope. Deposition is dynamic and spatially varied. Flow depth and transport capacity vary considerably across the slope leaving "exposed" areas where interrill erosion occurs. Deposition and flow patterns change during deposition.[41]

While not a perfect assumption, RUSLE2 assumes that interrill erosion occurs simultaneously with deposition. A consequence of this assumption is that less enrichment of sediment in fines is computed than when no interrill erosion is assumed.

Equations 5.2 and 8.11 and transport capacity being distributed among particles classes based on their distribution in the sediment load creates a very complex and interactive set of equations to be solved. The equations are solved numerically in RUSLE2 because simple, closed form solutions were not found. The RUSLE2 numerical solution divides the portion of the overland flow path where deposition occurs into small sub segments. Decreasing sub segment length increases computational accuracy but noticeably

---

[40] The sign convention is that detachment is positive (increases the sediment load) and deposition is negative (decreases the sediment load).

[41] See Toy et al. (2002) for additional discussion.

increases computational time, which required a compromise between the two. The procedure was carefully designed to minimize differences related to how a user segments the overland flow path. The user will seldom see much effect of segment division on RUSLE2 results. The accuracy of the deposition computation with respect to the numerical solution matching the “true” mathematical solution is well within the overall accuracy of RUSLE2.

RUSLE2 computes deposition rate, total sediment load, and the sediment load of each particle class along each segment. The sediment load g_{out} leaving the segment is the sediment load computed at the end of the segment, which is the sediment load g_{in} entering the next downslope segment. The distribution of the particle classes in the sediment load indicates how deposition enriches the sediment in fines. RUSLE2 computes an enrichment ratio based on specific surface area of the sediment at the end of the last segment on the overland flow path (See **Section 7.5**). The value computed for enrichment ratio is related to the fraction of the sediment load that is deposited. The enrichment ratio increases as the deposition fraction increases.

8.1.4.3. Case 3: Deposition ends within the segment

Deposition ends within a segment when deposition occurs at the upper end of the segment and transport capacity increases within the segment at a rate greater than interrill erosion rate if the segment is sufficiently long as illustrated in Figure 8.3. Sediment load exceeds transport capacity at the upper end of the segment and decreases within the segment while transport capacity increases within the segment. The two become equal within the segment, which is the location x_e that deposition ends. RUSLE2 computes deposition and the sediment load on the upper portion of the segment using the deposition procedure described for **Case 2.**

The same conditions described for **Case 1** exist for the lower portion of the segment beyond the location x_e where deposition ends. Net detachment is computed using equation 8.1 where x_e is substituted for x_{i-1}. Rill erosion is reduced, if necessary, to avoid the sediment load “overfilling” transport capacity. Sediment load at the end of the segment is computed from:

$$g_{out} = g_{xe} + D_{>xe}(x_i - x_e) \qquad \textbf{[8.12]}$$

where: g_{xe} = sediment load at the point where deposition ends and $D_{>xe}$ = net detachment on the lower portion of the segment beyond the location where deposition ends.

8.1.4.4. Case 4: Deposition begins within the segment

Deposition begins within a segment when the transport capacity at the upper end of a segment is greater than sediment load, and transport capacity decreases within the segment to become less than sediment load. This case occurs on a segment where cover-management and/or soil change so that infiltration rate is so high that runoff and transport capacity decrease within the segment. This case is illustrated in Figure 8.4.

Deposition begins at the location where sediment load and transport capacity become equal. RUSLE2 computes the deposition on the lower portion of the segment using the procedure described for **Case 2.**

8.1.5. Computing sediment yield, soil loss from eroding portion, total detachment, conservation planning soil loss, and erosion by segment

RUSLE2 displays several values produced by these computations. These output values are used in conservation and erosion control planning to select erosion control measures appropriate for the site conditions.

8.1.5.1. Sediment yield

Sediment yield is the amount of sediment leaving the overland flow path.[42] It is used in erosion control planning where the objective is to reduce the amount of sediment leaving the site. RUSLE2 computes sediment yield as sediment load at the end of the overland flow path divided by the overland flow path length. That is:

$$SY = g_{out,I} / \lambda_{ofpl} \qquad \textbf{[8.13]}$$

where: SY = sediment yield from the overland flow path length (mass/area), $g_{out,I}$ = the sediment load at the end of the last segment on the overland flow path, I = the index of the last segment, and λ_{ofpl} = the overland flow path length.

8.1.5.2. Soil loss from eroding portion

The eroding portions of an overland flow path are where no deposition occurs, except for local deposition. Figure 5.2 illustrates the eroding portion of a complex shaped profile for an overland flow path. The **soil loss from eroding portion** is used in conservation planning where the objective is to protect eroding areas from excessive erosion to maintain soil productivity, prevent rilling, and reduce sediment yield.

The soil loss for the eroding portion of the overland flow path is computed from:

$$A_{ep} = \sum (g_{out,k} - g_{in,k}) / \sum (x_{out,k} - x_{in,k}) \qquad \textbf{[8.14]}$$

[42] This sediment yield is the sediment yield for the site only if the overland flow path ends at the site boundary.

where: A_{ep} = soil loss (mass/area) for the eroding portions of the overland flow path and the index k refers to each portion of the overland flow path that is an eroding rather than a depositional area. Soil loss for the eroding portions of the overland flow path is the total sediment produced on the eroding portions divided by the total length of the eroding portions.

8.1.5.3. Total Detachment

Total detachment represents the sediment produced for the entire overland flow path, including depositional areas. In contrast, soil loss for the eroding portion of the overland flow path excludes depositional areas.

Total detachment for the overland flow path is the sum of the detachment amount (sediment production) for each segment divided by the overland flow path length. That is:

$$D_T = \sum D_{f,i}(x_i - x_{i-1}) \big/ \lambda_{ofpl} \quad \textbf{[8.15]}$$

where: D_T = the total detachment (mass/area) for the overland flow path length and D_f= the sediment production for each segment. Sediment production for a segment is the value computed by equation 8.1 if rill erosion is not limited as described in **Section 8.1.4.1** or remote deposition does not occur as described in **Sections 8.1.4.2-8.1.4.4.** If rill erosion is limited, the sediment production is the sum of the interrill erosion and the rill erosion required to just fill transport capacity. If remote deposition occurs, sediment production equals interrill erosion.

8.1.5.4. Conservation planning soil loss

Neither **soil loss for the eroding portion** or **total detachment** take any **credit** for **remote deposition** as "**soil saved**," although RUSLE2 gives full credit to **local deposition** as "soil saved" because local deposition is empirically considered in equation 8.1 that computes net detachment. **Giving credit to remote deposition is a matter of judgment.** In the USLE (AH282, AH537), half credit was given to deposition by gradient terraces and full credit was given to deposition by rotational strip cropping.[43] No credit was given to deposition on the toe of concave slopes because this deposition ended the USLE slope length. RUSLE1 gave credit to deposition by terraces based on

---

[43] Gradient terraces are terraces on a uniform grade less than about 1% and may be level for moisture conservation. These terraces reduce overland flow path length and "save" soil by causing deposition uniformly along their length. The deposited sediment is spread by periodic mechanical operations required to maintain flow capacity. Rotational strip cropping is a system of alternating uniform width strips of dense vegetation that deposit sediment and strips where erosion is significantly higher than with the dense vegetative strips. The strips are systematically rotated by position on the hillslope over the crop rotation cycle.

terrace spacing. If the terraces were close together, about half credit was taken, and the credit was reduced to none as terrace spacing increased to 300 ft (100 m). Credit for deposition with narrow permanent vegetative strips (e.g., buffer and filter strips) was not discussed in AH282 or 537. In RUSLE1, the amount of credit given to deposition depended on the location of the deposition. Deposition near the end of the overland flow path was given very little credit. The credit increased to more than 60% for deposition near the origin of the overland flow path.

The **conservation planning soil loss** computed by RUSLE2 gives full credit for deposition with rotational strip cropping, i.e., the **conservation planning soil loss equals sediment yield**. RUSLE2 gives partial credit to deposition that occurs with permanent vegetative strips based on the location of the deposition. Very little credit is given to deposition at the end of the overland flow path, and the credit increases to about 60% for deposition located close to the overland flow origin. The same credit is given to deposition on concave portions of an overland flow path. Very little credit is given for the deposition if it is near the end of the overland flow path like that illustrated in Figure 5.4 and increased credit is given to deposition near the origin of the overland flow path.

The justification of the conservation planning soil loss in RUSLE2 is based on the following principles.

1. Deposition is beneficial. The quality of the soil, hillslope, and landscape is better with the deposition than without it. That is, deposition has a **soil saved** benefit.
2. Deposition that occurs and remains on very small areas relative to the entire hillslope area provides much less benefit that deposition that occurs on and is spread over a significant sized area by mechanical operations such as tillage and terrace maintenance.
3. Deposition that occurs near the end of the overland flow path has almost no value for maintaining the quality of the overall hillslope. Deposition in these locations is essentially “lost” from the hillslope with little chance for recovery.
4. Deposition upslope on the hillslope represents soil that is captured and not “lost” from the hillslope. A benefit can be gained by spreading the deposited sediment using common mechanical operations without having to physically transport the sediment upslope.

In general, the **conservation planning soil loss** is greater than **sediment yield**, except for rotational strip cropping where the conservation planning soil loss equals sediment yield. The conservation planning soil loss is less than the **total detachment** for the slope. The difference between total detachment and the conservation planning soil loss represents the **credit taken for deposition**. **Soil loss on the eroding portion** of the slope is the highest value of the set.

8.1.5.5. Erosion by segment

RUSLE2 computes erosion along the overland flow path. The user can obtain these erosion values by dividing the overland flow path into segments. The average **erosion for a segment** depends on segment length because point erosion varies with distance within the segment.

Point erosion at a can be computed with RUSLE2 using a very short segment such as 1 ft (0.3 m) at the location where the point erosion is desired.

Net erosion for a segment is computed as:

$$a_i = (g_{out,i} - g_{in,i})/(x_i - x_{i-1}) \quad \textbf{[8.16]}$$

where: a_i = erosion for the *ith* segment (mass/area). A positive value means that the segment experiences a net loss of sediment (detachment) and a negative value means that the segment experiences a net gain of sediment (deposition). Even though either net detachment or net deposition occurs overall for a segment, a part of the segment can

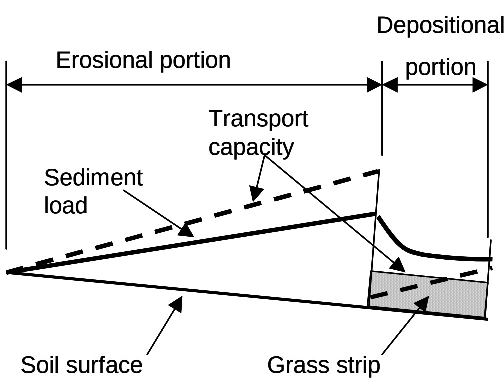

Figure 8.2. Narrow grass where deposition occurs over entire segment

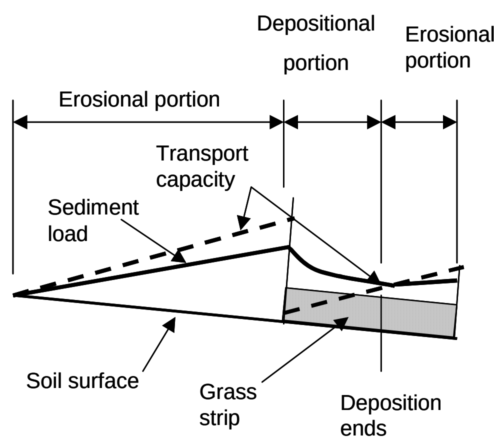

Figure 8.3. Grass strip sufficiently wide that deposition ends within segment and erosion occurs on lower portion of segment

experience net detachment while another part experiences net deposition, such as illustrated in Figures 8.3 and 8.4.

The segment erosion values must be carefully interpreted with respect to the erosion control planning criteria. **Is the erosion control criterion for point erosion or for average erosion for a uniform shaped slope, such as the soil loss tolerance value?**

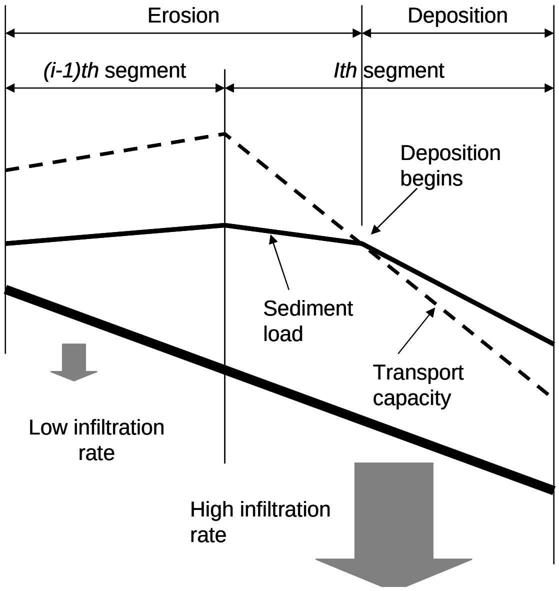

Figure 8.4. Deposition begins within a segment on a segment with a very high infiltration rate

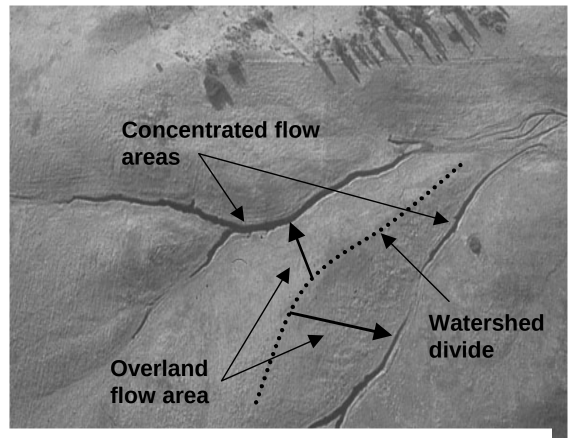

Figure 8.5. A natural landscape with concentrated flow areas and divides where overland flow originates

Comparing a point erosion value computed by RUSLE2 with an erosion control criteria based on average erosion for a uniform slope can produce misleading results and under designed erosion control practices that do not provide sufficient protection or over designed erosion control practices that are too costly. See **Section 7.9** for information on how to interpret RUSLE2 segment erosion values with respect to erosion control criteria based on average erosion for a uniform slope.

8.1.5.6. General comments

RUSLE2 displays a variety of erosion values that can be used in conservation and erosion control planning. Also, RUSLE2 can be applied in variety of ways to a field site. For example, RUSLE2 can be applied in the traditional USLE way by assuming a uniform slope and that deposition ends slope length. The erosion values computed by RUSLE2 can be compared with soil loss tolerance values or other erosion control criteria just as USLE soil loss values were used.

The other option is to apply RUSLE2 to an overland flow path that passes through depositional areas and is terminated by a concentrated flow area. The effect of variability in soil, steepness, and cover-management on erosion along the overland flow path can be analyzed. The RUSLE2 sediment yield estimates are greatly superior to the USLE soil loss estimates for estimating the sediment amount leaving a site. RUSLE2 provides detailed information about how erosion varies along the overland flow path so that a cost effective erosion control practice can be tailored to the specific site conditions better than could be done with the USLE.

Users must understand how to apply RUSLE2 and interpret its computed values. The user must be aware of differences between the USLE, RUSLE1, and RUSLE2 when comparing these models and values from by them. The user must not assume that USLE and RUSLE1 procedures apply automatically to RUSLE2.

8.2. Representing Overland Flow Path Profiles

8.2.1. General considerations

Applying RUSLE2 requires selecting and describing an overland flow path. A hillslope involves an infinite number of overland flow paths. **Section 5.2** describes how to choose overland flow paths for applying RUSLE2 in conservation and erosion control planning.[44]

A point on the hillslope is selected through which the overland flow path passes. The overland flow path is traced from its origin through the point to the concentrated flow area that ends that particular overland flow path as illustrated in Figures 5.1 and 8.5. This flow path is traced perpendicular to the contour lines assuming that the soil surface is flat and ignoring how ridges or micro topographic features affect flow direction.

Overland flow paths are best determined by visiting the site, pacing flow paths, and making measurements directly on the ground. Contour map intervals greater than 2-ft (1-m) should be used cautiously, if at all, to determine overland flow paths. Contour map intervals of 10-ft (3-m) should not be used because concentrated flow areas that end overland flow paths cannot be adequately delineated. Also, these maps do not provide the detail needed to identify depositional areas and the slope steepness with sufficient precision to accurately compute deposition (See **Section 8.2.5**). Overland flow paths are generally much too long when contour intervals greater than 10 ft (3 m) are used to determine them.

Overland flow path lengths on many landscapes generally are less that 250 ft (75 m), and usually do not exceed 400 ft (125 m). Path lengths longer than 1000 ft (300 m) can not be used in **RUSLE2** because the applicability of **RUSLE2** at these long path lengths is questionable. Overland flow often becomes concentrated flow on most landscapes before

[44] See AH703 for additional discussion on identifying, selecting, and describing overland flow paths.

such lengths are reached. The maximum of 1000 ft (300 m) is an extrapolation from the longest plot of about 650 ft (200 m).

RUSLE2 applies to overland flow path lengths as short as zero, which means that RUSLE2 can be applied to ridges and beds like those used in vegetable production as discussed in **Section 8.3.6.2**.

RUSLE2 applies to steepness between flat (0%) and a 100% (1:1) maximum. This maximum of 100% is an extrapolation from 30%, the maximum steepness of the plots used to derive RUSLE2.

Length values like overland flow path segment lengths, distance from the origin of overland flow to lower segment end, overland flow path length, and land area are based on a horizontal measure for internal computations in **RUSLE2**. However, such length values can be input into RUSLE2 based on measuring along the hypotenuse (i.e., parallel to the soil surface). Field measurement parallel to the land surface is easier than measuring horizontally. The difference between horizontal and hypotenuse measurements is insignificant for slope steepness less than 20 percent. Distance and areas measured from maps is a horizontal measure. All references to land areas in RUSLE2 are horizontally based, even if the overland flow path length values were entered on a hypotenuse basis.

Overland flow profiles are segmented to represent differences in steepness, soil, and cover-management along the overland flow path. Topographic segments can be entered in RUSLE2 by distance from the origin of the overland flow path to the lower end of the segment or by segment length. The choice of entry method is based on user preference.

8.2.2. Profile shapes

The profiles for overland flow paths have various shapes as illustrated in Figure 8.6.[45] Simple shapes are uniform, concave, and convex. A uniform shaped profile is one where steepness is the same everywhere along the overland flow path. A convex profile is one where steepness increases everywhere along the overland flow path. RUSLE2 computes net detachment everywhere along uniform and **convex** profiles such that the entire profile is an **eroding portion** (See **Section 5.2**). A **concave** profile is one where steepness decreases everywhere along the overland flow path. If the lower part of a concave profile is sufficiently flat, transport capacity is less than sediment load and deposition occurs. These profiles have an upper **eroding portion** and a lower **depositional portion,** as

[45] Although the terms **hillslope profile** and **overland flow path profile** are often used interchangeably, the two terms are different. A RUSLE2 overland flow path profile does not start at the top of a hill and run to the bottom of the hill. Instead, a RUSLE2 overland flow path profile starts at the origin of overland flow, which is a runoff divide, and perpendicularly crosses contour lines. A RUSLE2 overland flow path is ended by a concentrated flow area.

illustrated in Figure 5.2. However, if the profile does not flatten sufficiently, deposition will not occur and the entire profile is an **eroding portion**.

Deposition does not occur on all concave shaped profiles. A decrease in steepness is not enough by itself to cause deposition.

Simple profile shapes are combined to form complex shaped overland flow profiles. A complex:convex-concave profile is one where the upper part is convex and the lower part is concave. Deposition occurs on the concave portion if steepness flattens sufficiently for transport capacity to become less than sediment load. If deposition occurs, the upper part of the profile is an eroding portion and the depositional area is the depositional portion as illustrated in Figure 5.2. Another complex shaped profile is complex:concave-convex. Deposition occurs on the concave portion if it flattens sufficiently. Runoff can continue as overland flow across the depositional area onto the lower convex portion. If deposition occurs, this profile has both an upper and lower eroding portion separated by the depositional portion. Erosion on the lower eroding portion is directly related to runoff that originates on the upper portion of the overland flow path. Therefore, the path length used to compute erosion on the lower eroding portion of the profile must include the entire path that generates runoff that flows onto the lower eroding portion.

Deposition does not end an overland flow path in RUSLE2.

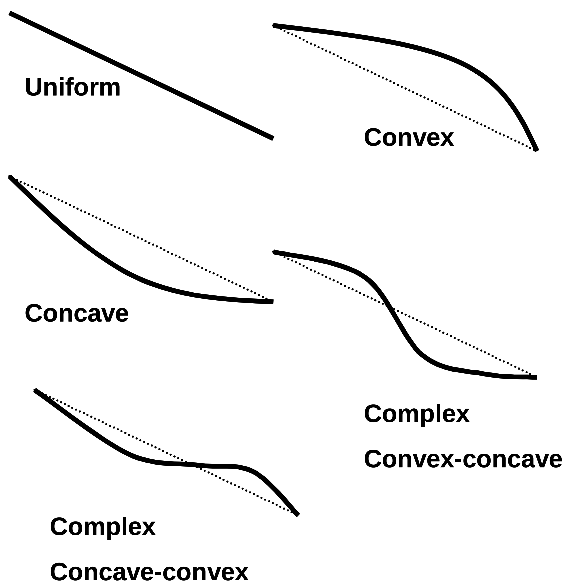

Figure 8.6. Overland flow path profiles

8.2.3. Importance of representing non-uniform profile shapes in RUSLE2

Many conservation and erosion control planners using USLE and RUSLE1 assumed uniform profiles even though procedures were available for applying these models to irregular slopes. This section discusses how profile shape affects RUSLE2 erosion estimates.

The overland flow path profile is a complex:convex-concave shape for many natural landscapes. This profile is illustrated in Table 8.1 along with RUSLE2 computed erosion values. The length of this profile is 250 ft (76 m) and has an average steepness of 4.1%. RUSLE2 computed erosion values are also shown for uniform and convex profiles having the same length and average steepness as the complex profile.

Table 8.1. Computed erosion by segment for three profle shapes, all having the same length and average steepness

			Convex-Concave			Uniform			Convex		
Segment Number	Distance to lower end of segment (ft)	Segment length (ft)	Steepness (%)	Erosion (tons/acre)	Sediment load (lbs/ft width)	Steepness (%)	Erosion (tons/acre)	Sediment load (lbs/ft width)	Steepnes s (%)	Erosion (tons/acre)	Sediment load (lbs/ft width)
1	28	28	2	4	5	4.1	7	8	0.5	1	2
2	64	36	4	10	22	4.1	11	26	1.5	4.2	9
3	107	43	8	28	78	4.1	14	53	2.8	9	27
4	149	42	6	25	125	4.1	16	84	4.2	16	58
5	181	32	4	-1	125	4.1	17	109	5.4	24	94
6	218	37	2	-28	77	4.1	19	141	6.6	34	151
7	250	32	1	-21	46	4.1	20	170	7.7	44	216
Average			4.1	4		4.1	15		4.1	19	

The computed erosion values differ greatly for the three profile shapes. The average erosion on the complex profile is 4 tons/acre (8.8 t/ha) while the average erosion on the uniform profile is 15 tons/acre (33 t/ha). Negative segment erosion values indicate net deposition for the segment. The reason for the large difference is deposition on the complex profile. Although the average erosion for the complex profile is much lower than average erosion for the uniform profile, the maximum segment erosion of 28 tons/acre (62 t/ha) for the complex profile is significantly larger than the maximum segment erosion of 20 tons/acre (44 t/ha) for the uniform profile. Figures 8.7 and 8.8 illustrate the variation in segment erosion and sediment load along the complex profile.

Another comparison is between the convex profile and the uniform profile. As expected, deposition is not computed for either the uniform or the convex profile. However, the average erosion of 19 tons/acre (42 t/ha) for the convex profile is significantly higher than the average erosion of 15 tons/acre (33 t/ha) for the uniform profile. This difference illustrates that uniform profiles underestimate average profile erosion when a uniform profile is assumed to represent a convex profile. The maximum segment erosion on the convex profile is 44 tons/acre (97 t/ha) while the maximum segment erosion is 20 tons/acre (44 t/ha) for the uniform profile. The uniform profile seriously underestimated maximum segment erosion for the convex profile.

Another comparison involves the average erosion for the eroding portion of the profile. The eroding portion of the profile represented in Table 8.1 is between the origin of overland flow and 165 ft (50 m), where deposition begins. The eroding portion of the slope can be approximated with a uniform profile with a length of 165 ft (50 m) on a steepness of 5.2%, which is the average steepness of the eroding portion. The average erosion for the uniform profile is 16 tons/acre (35 t/ha), while the erosion computed with

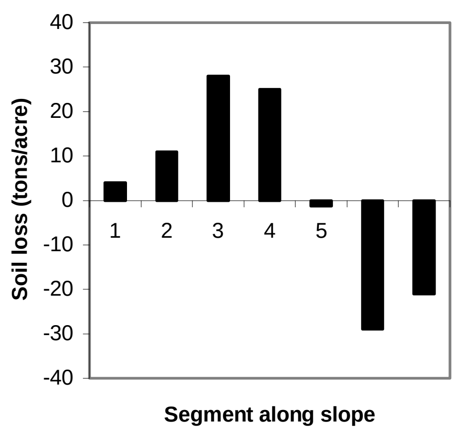

Figure 8.7. Segment erosion along a complex convex-concave hillslope profile

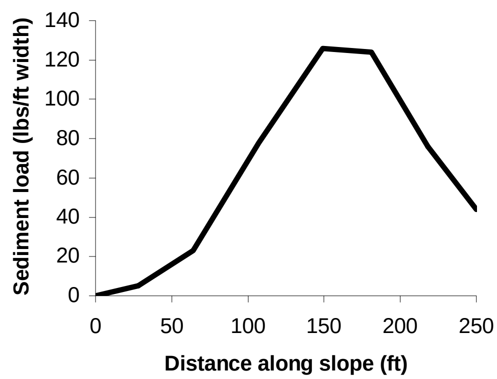

Figure 8.8. Sediment load along a complex convex-concave hillslope profile

the actual non-uniform profile is 18 tons/acre (40 t/ha) for the eroding portion. The average erosion for the eroding portion is about the same with these two methods. However, the maximum segment erosion computed with the non-uniform profile is 28 tons/acre (62 t/ha) while it is 23 tons/acre (51 t/ha) computed with the uniform profile approximation. The uniform profile approximation significantly underestimates the potential for rill erosion on the convex portion of the overland flow path

8.2.4. Implications of using uniform profiles to represent non-uniform profiles for conservation and erosion control planning

Assuming a uniform profile is common when the USLE and RUSLE1 were used in conservation and erosion control planning. A uniform profile is easy to describe, requiring only a length and steepness. The computational procedure for applying the USLE to non-uniform profiles is cumbersome and laborious. The non-uniform slope procedure in RUSLE1 is easy to use, but it only considers the effect of non-uniform steepness. It does not consider variation of soil erodibility or cover-management along the overland flow path.

Interpreting segment erosion values along non-uniform profiles (overland flow paths) is complex where using an erosion control criteria based on average erosion for a uniform profile. RUSLE2 is much more powerful than either the USLE or RUSLE1. RUSLE2 considers the interactive effects of spatial variation in soil and cover-management relative to position along non-uniform profiles. The RUSLE2 inputs are easy to enter, and RUSLE2 provides aids for interpreting segment erosion values (See **Section 7.9)**.

Based on the discussion in **Section 8.2.3**, the implications of using uniform profiles of the same length and average steepness to represent non-uniform profiles are:

1. Uniform profiles underestimate profile (average erosion over the profile length) for convex profiles depending on degree of curvature of the convex profile. The difference can easily be as large as 20%.
2. Uniform profiles seriously underestimate local (segment) erosion for convex profiles and results in inadequate erosion control for rill erosion on the lower end of the convex profile. The difference can easily be as high as a factor of two or more.
3. Uniform profiles overestimate profile erosion for concave profiles. The error can be very large if most of the eroded sediment is deposited on the concave profile. The difference can be large as a factor of five or more.
4. Uniform profiles applied to the eroding portion of concave profiles overestimate profile erosion. The difference can be as large as 20%.
5. Uniform profiles applied to the eroding portion of a concave profile give maximum erosion that is comparable to maximum erosion on the concave profile.
6. Uniform profiles applied to complex:convex-concave profiles overestimate average profile erosion if deposition occurs on the concave portion.
7. Uniform profiles applied to the eroding portion of a complex:convex-concave profile can give about the same average erosion for the eroding portion as representing the non-uniform profile.
8. Uniform profiles applied to the eroding portion of a complex:convex-concave profile can significantly underestimate maximum erosion on the eroding portion of the profile.
9. Deposition does not end the overland flow part on complex:concave-convex profile.
10. Dividing a complex:concave-convex into two separate uniform profiles seriously underestimates erosion on the lower convex portion of the profile.

The strong recommendation is that non-uniform overland flow profiles be represented in RUSLE2, especially convex shaped profiles. Users should recognize that representing a convex profile with a uniform profile will result in erosion control being less than needed (under-designed). Using a uniform profile to represent the eroding portion of a concave profile will result in erosion control being greater than needed (over-designed).

8.2.5. Implications for using RUSLE2 for estimating sediment yield for watersheds

RUSLE2 computes deposition on overland flow areas and the sediment leaving the overland flow path represented in the RUSLE2 computations. For example, RUSLE2 computes a sediment delivery of 4 tons/acre (8.4 t/ha) from the overland flow path as Table 8.1 illustrates. That sediment delivery is the sediment yield for the site only if the overland flow path ends at the site boundary. RUSLE2 overland flow profiles end in concentrated flow areas illustrated in Figures 5.1 and 8.5. These concentrated flow areas are typically within the site boundary. Both erosion (ephemeral gully) and deposition can occur in the concentrated flow areas so that the sediment delivered from site can differ significantly from the RUSLE2 computed sediment delivered from the end of the overland flow profile. That is, sediment leaving the overland flow portion of the site may only be a portion of the site sediment yield because of erosion and/or deposition that occurs in concentrated flow areas.

The USLE is widely used to estimate sediment yield from watersheds by multiplying USLE soil loss estimates by a sediment delivery ratio (SDR).[46] Sediment delivery ratios are typically less than one to account for the deposition that occurs in many watersheds. The sediment mass leaving the watershed is typically less than the sediment produced by rill and interrill erosion. Much of this deposition occurs on the overland flow areas of the watersheds.[47] Although RUSLE2 can compute the deposition on overland flow areas, RUSLE2 should be used to compute erosion on the eroding portion of the overland flow profile because the sediment delivery ratio values already reflect the deposition on overland flow areas as well as deposition by concentrated and channel flow areas.

---

[46] The USLE soil loss has a particular meaning. It is sediment mass delivered to the end of the uniform slope assumed to represent the eroding portion of the overland flow path. The USLE soil loss is expressed as mass delivered to the end of the ULSE slope length per unit width divided by the USLE slope length.
[47] See Toy et al. (2002) for a discussion of this deposition.

Thus, the proper way to use sediment delivery ratio values with USLE soil loss estimates is to use RUSLE2 to compute erosion on the eroding portion of the overland flow profile. That erosion value, which is comparable to the USLE soil loss value, is multiplied by the sediment delivery ratio to obtain a sediment yield for the watershed. For example, assume that the sediment delivery ratio is 0.15 for a particular watershed that contains the representative profile described in Table 8.1. Sediment yield is computed by multiplying the 18 tons/acre (39.6 t/ha) erosion value for the eroding portion of the overland flow path by the sediment delivery ratio of 0.15 to give a sediment yield of 2.7 tons/acre (5.9 t/ha). Multiplying the RUSLE2 computed sediment yield value of 4 tons/acre (8.8 t/ha) for the overland flow path by sediment the delivery ratio value based on a USLE type soil loss value gives a sediment yield that is much too low.

8.2.6. Importance of properly representing steepness at end of concave profiles where deposition occurs

The deposition computed by RUSLE2 is directly related to sediment transport capacity. Accurately computing deposition is very difficult because slight variability in the flow hydraulics on a depositional surface can greatly affect sediment transport capacity. The error in deposition computations is much greater than error in detachment computations.

Even if the computations could be made perfectly, an accurate description of the steepness along the flow path where deposition is needed. For example, the sediment yield from the complex profile illustrated in Table 8.1 is 4.0 tons/acre (8.8 t/ha ac). If the steepness for the last segment, which covers a relatively small portion of the profile, had been estimated at 2%, the estimated sediment yield would have been 7.8 tons/acre (17.2 t/ha). If the steepness had been estimated at 0.5%, the estimated sediment yield would have been 2.6 tons/acre (5.7 t/ha). These differences illustrate the importance of carefully determining the steepness at the end of the overland flow path on concave profiles where deposition occurs.

Deposition estimates are much less accurate than detachment estimates. Also, obtaining accurate deposition estimates requires a more carefully measured steepness than does detachment, especially where deposition occurs at the end of an overland flow profile.

8.3. Applying RUSLE2 to particular profile shapes

This section describes how to apply RUSLE2 to particular overland flow profile shapes commonly encountered in conservation and erosion control planning.

8.3.1. Uniform profile

Uniform profiles (slopes) are often assumed because only a slope steepness and slope length are required to topographically describe them.[48] Uniform slopes are used to represent the eroding portion of overland flow paths, not the entire path (See **Section 5.2**). The **slope steepness** of the uniform slope is set to the average steepness of the eroding portion of the overland flow path.

Slope length, as used in the USLE, is the distance from the origin of overland flow to the upper edge of deposition for concave profiles, illustrated in Figure 5.2, or to concentrated flow areas for convex profiles, illustrated in Figure 5.3. See AH703 for additional illustrations.

The best approach for determining slope length and steepness is to make measurements during a site inspection.

Determining the upper edge of deposition is easy on cropland, construction sites, and other land areas that readily erode. However, deposition may not be apparent where rill erosion does not occur and deposition is low, where heavy vegetative cover obscures the soil surface, or where recent mechanical soil disturbance has mixed deposited sediment with underlying soil.

A rule of thumb is that deposition begins where steepness is one half of the average steepness of the concave portion of the profile.

Two examples illustrate the procedure. The first example is a concave profile that decreases from 18 percent steepness at the upper end to 2 percent steepness at the lower end. The average steepness is 10 percent and one half of the average steepness is 5 percent. Deposition begins at the location where the flow path has flattened to 5 percent steepness as shown in Figure 8.7.

The second example is a concave profile that decreases from 4 percent at the upper end to 2 percent at the lower end. The average steepness is 3 percent and one half of the average steepness is 1.5 percent. Deposition does not occur because the steepness at the lower end of this profile is greater than the steepness where deposition would be expected to occur.

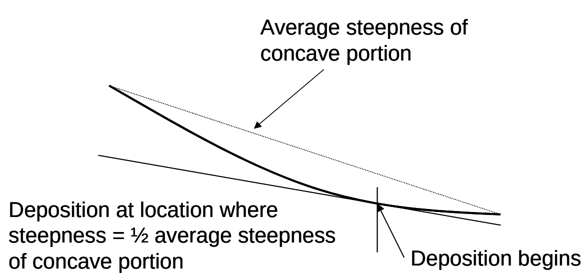

Figure 8.7. Rule of thumb for location of upper edge of deposition on a concave profile

This procedure only captures how degree of profile curvature affects deposition. Other factors also affect deposition. Deposition occurs when

4! Reference Guide. It is the length of the
u overland flow path. Slope steepness
s

sediment load produced by upslope erosion exceeds transport capacity of the runoff. If the sediment load produced by upslope erosion is low relative to transport capacity, deposition begins further downslope than when sediment load is high relative to transport capacity.

RUSLE2 can estimate the location of deposition by segmenting the overland flow profile and entering steepness values for each segment. Negative segment erosion values indicate deposition. RUSLE2 computes erosion for the eroding portion of the overland flow path that can be used in conservation and erosion control planning (See **Section 8.1.5.2**).

Terraces, diversions, grassed waterways, ephemeral gullies, and similar concentrated flow areas are easily identified as ending slope length. Slope length can often be easily determined on cut and fill slopes involved in construction, landfills, and surface mine reclamation. Many landscapes include converging areas where overland flow is collected in defined channels, which are areas where ephemeral gully erosion occurs. These channels are illustrated in Figures 5.1 and 8.5. Slope length ending concentrated flow areas on natural landscapes, such as western rangelands, may not be obvious because the concentrated flow areas are not eroding channels.

The fact that experts can look at the same landscape and choose different slope lengths may seem troubling. Determining slope length involves judgment, and the variability in slope length among RUSLE2 users is a part of the uncertainty in RUSLE2 erosion estimates (See **Section 17.4**). One element in the judgment is how well plots used to derive RUSLE2 represent the specific field site where RUSLE2 is being applied. The data used to determine RUSLE2 were collected from plots that ranged in width from about 6 ft (2 m) to 12 ft (4 m), with some as wide as 75 ft (25 m). Plots lengths were as long as 350 ft (100 m) in two cases, but most plots were about 75 ft (25 m). These plots are illustrated in Figures 5.5 and 5.6. Slope length should not extend beyond the hillslope location where plots of these dimensions and flow conditions would represent erosion.

The depth of an eroded channel on a hillslope does not determine whether RUSLE2 applies. Is this channel parallel to other channels and of comparable size to neighboring channels as illustrated in Figure 5.6? Or is the channel much larger than neighboring channels because runoff has been collected rather than being spread uniformly across the hillslope?

Fortunately RUSLE2 erosion estimates are not sensitive to slope length for slope steepness less than 2 percent. For example, slope length being off by a factor of two for a 0.5 percent steepness has almost no effect on estimated erosion. Estimated erosion is less sensitive to slope length than to slope steepness for steepness between 2 and 20 percent. Above 20 percent steepness, estimated erosion is almost as sensitive to slope length as to slope steepness. Therefore, the uncertainty in estimating slope length does not have a major effect on estimated erosion for steepness less than 10 percent. Much more careful attention should be given to estimating slope steepness than to slope length.

Slope length and steepness values should be determined from field measurements, but site inspections may not be feasible. Problems associated with using contour maps and digital elevation data are discussed in **Section 8.2.1**. In general, those data are seldom satisfactory for determining slope lengths and often are not satisfactory for determining slope steepness because the data do not have sufficient resolution.

Slope length and steepness values have been assigned to soil map units in some cases.[49] These values may be acceptable for large scale regional analyses, but they should not be used for site-specific conservation and erosion control planning. The range in slope steepness across soil map units can give widely different estimated erosion values. For example, the land steepness of a soil map unit can range from 1 percent to 5 percent. The average steepness is 3 percent, which might give an estimated erosion rate of 12 tons/acre (26 t/ha). The estimated erosion values for the extremes of the slope steepness for the soil map unit are 4 tons/acre (9 t/ha) and 22 tons/acre (48 t/ha) for the 1 percent and 5 percent steepness, respectively. The importance of profile shape, especially if the profile is convex, should not be overlooked.

A principle in applying RUSLE2 is that a similar level of precision be used for all inputs for a specific site. Therefore, if a uniform slope is assumed, then a single soil and a single cover-management should be assumed for the slope. Uniform width and uniform spaced cover-management strips can be placed on the uniform slope to represent filter and buffer strip and rotational strip cropping support practices. However, soil and cover-management (e.g., to represent the variation of yield along the slope) should not be varied along a uniform slope that is being used to represent a non-uniform profile, especially a convex profile shape. For example, high soil erodibility at the end of a convex profile can give far higher erosion rates than will be computed assuming a uniform slope.

Not using the same level of precision for all inputs can result in very seriously flawed conservation plans when the planning criteria is to an absolute standard such as soil loss tolerance.[50] This problem is reduced but not eliminated for conservation planning to a relative standard, such as an 80 percent erosion reduction. Profile (overland flow path) averages can be very misleading for both concave and convex profiles because of non-linearity in the RUSLE2 equations. Soil map units sometimes involve multiple soil components where soil erodibility differs significantly among the components.

---

[49] Griffin, M.L., D.B. Beasley, J.J. Fletcher, and G.R. Foster. 1988. Estimating soil loss for topographically nonuniform field and farm units. J. Soil and Water Conservation 43:326-331.

[50] An analogy is using a micrometer to measure the sand grain roughness in a concrete pipe while guessing at the diameter of the pipe and expecting an estimate of discharge rate to be of comparable precision to the sand grain measurements.

Sometimes one of the components is chosen as the dominant component if it occupies more than 50 percent of the soil map unit. An alternative is to take averages. However, a soil component that occupies about 25 percent of the overland flow path with a very high soil erodibility located at the lower end of a convex shaped profile is the dominant soil in terms of the erosion on the profile. The soil component that occupies most of the profile is not necessarily the dominant soil in terms of erosion, although it may be the dominant soil for other processes such as crop production.

If the spatial variation in soil and/or cover-management is sufficient to warrant dividing the overland flow profile into segments, then the variation in steepness along the overland flow path should be entered as well.

The problem is not limited to convex profiles. A uniform profile computes maximum erosion at the end of the profile whereas maximum erosion occurs on a concave profile in the upper part of the profile, not at the end. The positioning of soil components along the profile strongly interacts with profile shape. The result is that erosion computed with uniform slopes and assuming a spatially average soil erodibility or a dominant soil component based on occupying the highest fraction of the profile can produce erosion estimates that greatly differ from those computed using a non-uniform profile shape and the proper placement of the soil and cover-management conditions along the profile.

RUSLE2 users must be aware of the importance of precision in the inputs and the importance of spatial interaction among variables. The same level of precision should be applied to all RUSLE2 inputs. Even though uniform slopes have long been standard practice in conservation planning, most conservation planners have little awareness of the impact of that assumption on the adequacy of the resulting plans.

8.3.2. Complex:convex-concave profile

The profile for overland flow paths on many natural landscapes is complex:convex-concave (See **Section 8.2.2**). The potential for deposition always exists on concave shaped profile sections. The segments used to represent the profile must be carefully chosen to ensure that RUSLE2 correctly make its computations, especially where deposition occurs. The critical choices are number of segments and steepness of the last segment experiencing deposition.

Segments can be long where steepness changes slowly. Segments should be shorter where steepness changes most rapidly. The deposition computations are more sensitive to changes in steepness than are the detachment computations. Therefore, shorter segments are needed in depositional areas than in the detachment areas. The rule of thumb given in **Section 8.3.1** can be used as a first approximation where deposition begins to help in initially choosing segments for the depositional portion of the profile.

A minimum of three, preferably four, segments should be used in the depositional area. If segments are too long in the depositional area, RUSLE2 will incorrectly show no or much too little deposition. A minimum of three segments, preferably four, should be used to describe the eroding portion of the profile. However, each non-uniform profile behaves differently depending on degree of curvature of the convex and concave sections of the profile.

As discussed in **Section 8.2.6,** steepness of the last segment experiencing deposition has a major impact of estimated sediment yield. Make sure that this segment is not too long to help avoid entering a steepness at the end of the profile that is too steep resulting in computed sediment yield being too high. The difference between 1 percent steepness and 2 percent steepness can affect sediment yield by a factor of two.

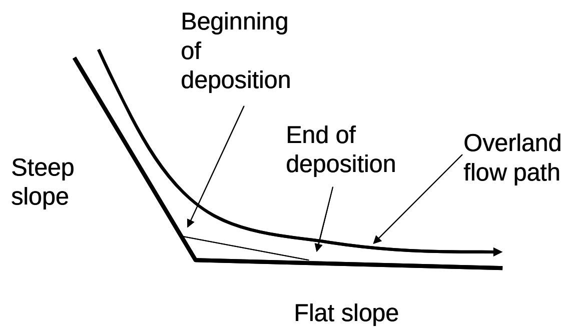

Figure 8.10. Flat uniform slope at toe of uniform steep slope.

Varying segment length is more efficient than using uniform segment lengths for the entire profile. Profile sections of uniform steepness do not need to be divided into segments. A relatively flat slope at the toe of a steep slope is a special case of a concave slope that illustrates that profiles sections of uniform steepness do not need to be divided into segment. This profile is illustrated in Figure 8.10. This profile can be described with two segments, one for the steep slope and one for the flat slope. RUSLE2 computes deposition over a short distance on the upper portion of the flat slope and erosion over the lower portion of the flat slope. RUSLE2 correctly makes these computations without dividing the flat slope into segments.

The most important factor in selecting segments to represent profiles where steepness varies along the profile is that shorter segments are needed where steepness changes most rapidly. Also, shorter segments are needed in depositional than in detachment areas.

8.3.3. Complex:concave-convex profile

Deposition potentially occurs on the lower end of the concave part of the profile provided steepness is sufficiently flat. The guidelines in **Section 8.3.1** can be used to initially estimate whether deposition will occur on the profile and where the depositional area might be as a guide to choosing segments to represent the profile. The same guidelines above for the complex:convex-concave profile (See **Section 8.3.2**) apply for choosing segments to represent a complex:concave-concave profile. An increased number of segments is needed in the depositional area and where steepness is changing most rapidly. An easily made mistake on this profile is to choose segments that are too long in the depositional area. If the segment are too long, RUSLE2 will incorrectly show no deposition when deposition should have been computed.

Deposition on the concave portion of the profile does not end the overland flow path assuming that the flow continues across the depositional area onto the lower part of the slope as overland flow.

The cut-roadway-fill profile illustrated in Figure 8.10 is a special case of a complex: concave-convex profile. Runoff from the cut slope is assumed to flow across the roadway onto the fill slope. If the roadway slopes outward at a sufficient steepness, erosion rather than deposition occurs on an earthen roadway. The overland flow path begins at the top of the cut and extends across the roadway to the bottom of the fill slope assuming that the flow remains as overland flow.

The roadway can be on a sufficiently flat steepness that deposition occurs on the roadway. If the runoff continues across the roadway as overland flow onto the fill slope, the overland flow path begins at the upper end of the cut slope, continues across the roadway, and ends at the bottom of the fill slope. The flow on the fill slope is composed of runoff generated from the cut slope above the roadway so far as runoff produced on the fill slope. The overland flow path length reflects the amount and rate of runoff, which is the reason that it includes the fill slope in this case even though deposition may occur on the roadway. Deposition on the roadway does not end slope length so far as computing soil loss from the fill slope provided the runoff flows across the roadway onto the fill slope as overflow and does not become concentrated flow, perhaps because of a ridge left by a road grader on the outer edge of the road.

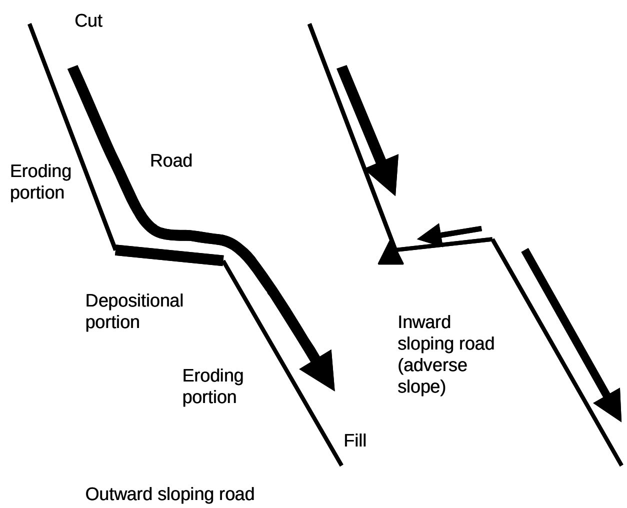

Figure 8.10. Cut-road-fill hillslope illustrating how an inward and outward sloping road section affects overland flow path lengths and that deposition on the outward sloping road does not end overland flow path length

Erosion on the cut slope can be significantly reduced by intercepting and diverting runoff so that the runoff from the cut slope and the roadway do not flow onto the fill slope. A diversion could be placed at the top of the fill slope to intercept the runoff, which is illustrated in **Section 8.3.5**. Placing the diversion at the top of the fill slope reduces erosion on the fill slope, but deposition still occurs on the roadway, which is objectionable.[51]

A better solution is to slope the roadway inward on an adverse steepness back toward the cut slope, as illustrated in Figure 8.10. This profile configuration can be represented very simply in RUSLE2 by entering a negative value for steepness on the roadway to represent an adverse slope. This profile configuration can be described in RUSLE2, as illustrated in Table 8.2, by entering a negative steepness value for the roadway segment. Sloping the road inward creates three overland flow path lengths, one each for the fill slope, roadway, and cut slope segments. RUSLE2 analyzes both profiles illustrated in Figure 8.10 without having to break the analysis into parts. Segments that describe each portion of the profile are entered into RUSLE2, and RUSLE2 automatically determines and handles the overland flow path lengths.

[51] Diversions are considered to be support practices in RUSLE2. Support practices include contouring (ridging), diversions, terraces, vegetative strips, porous barriers, and small sediment basins. See **Section 14** that discusses diversions.

Entering an adverse slope for the roadway causes RUSLE2 to create a channel at the intersection of the cut slope and the roadway. This channel intercepts runoff from the cut slope and collects runoff from the roadway. The sediment yield computed by RUSLE2 is the total sediment yield for the entire profile.

RUSLE2 automatically places a channel where a profile segment with a positive steepness intersects with a profile segment with a negative steepness (an adverse slope). This channel can be described with a grade to compute deposition if the grade is sufficiently flat. RUSLE2 does not compute erosion in channels. This channel ends the overland flow path.

Table 8.2. Erosion on a cut-road-fill slope

Segment #	Distance to lower end of segment (ft)	Segment length (ft)	Segment type	Steep-ness (%)	Soil loss (tons/acre)	Segment type	Steep-ness (%)	Soil loss (tons/acre)
1	75	75	fill	33	162	fill	33	162
2	95	20	outward sloping	2	-493	inward sloping	-2	5.8
3	170	75	cut	33	353	cut	33	162
			Sediment yield = 169 tons/acre			Sediment yield = 143 tons/acre		

8.3.4. Overland flow path with porous barriers (e.g., vegetative strips, fabric fences) and flow interceptors (e.g., diversions, terraces)

RUSLE2 represents two major types of flow barriers. One type is porous barriers where the overland flow is assumed to continue through the barrier onto the portion of the profile downslope of the barrier. Examples of porous barriers include vegetative strips (filter, buffer, stiff grass), fabric fence, gravel bags, and straw bales. The other type of barrier is flow interceptors that cut off the runoff and redirect it around the slope in defined channels. Examples of flow interceptors are diversions and terraces. Diversions and terraces function exactly the same way in terms of intercepting runoff. The difference is that diversions are defined in RUSLE2 as channels that are placed on a sufficiently steep grade that no deposition occurs in them but the grade is not so steep that erosion occurs in the channel. Conversely, terraces are intentionally placed on a sufficiently flat grade that deposition does occur in them. Diversions are placed at critical places on the overland flow profile to intercept runoff and prevent it from flowing onto a steep part of the profile, such as on the landfill example illustrated in Figure 8.12. In contrast, terraces are typically installed as system of uniform spaced channels.

Both diversions and terraces required a runoff disposal system to move the collected runoff down the slope without causing channel erosion. RUSLE2 does not consider the water disposal channel system.

The purpose of porous barriers is to cause substantial deposition. Even though these barriers induce deposition, the overland flow path length does not end at the deposition because the runoff continues through the strip as overland flow. A profile with multiple grass strips that induce deposition has only one overland flow path length as illustrated in figure 8.11b.

Deposition at a grass strip does not end the path length with a new one beginning below the strip. Cover-management segments do not end the overland flow path.

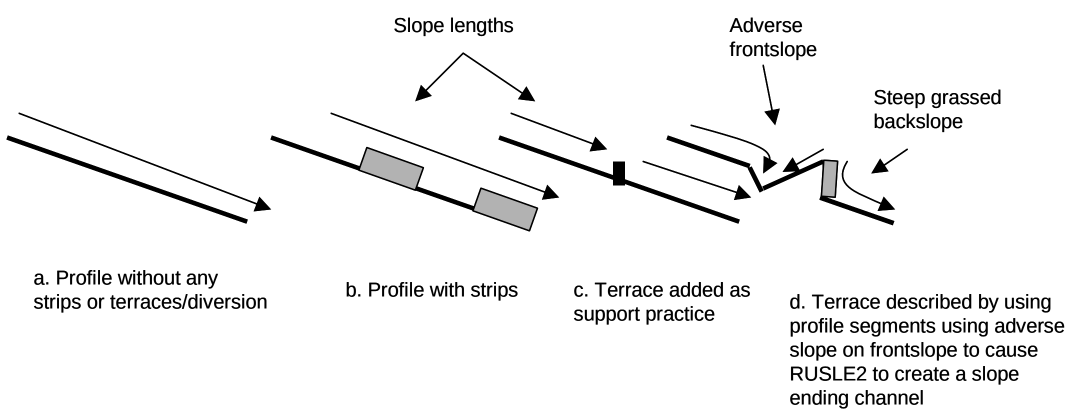

Figure 8.11. How vegetative strips and terraces are described in RUSLE2 and how these practices affect slope lengths assumed by RUSLE2

In contrast, terrace and diversion channels intercept runoff in concentrated flow areas that end the overland flow path. A new overland flow path begins at the terrace/diversion ridge because that is where overland flow originates that flows across the next portion of the profile.

Terraces and diversions can be described in one of two ways in RUSLE2. One approach is used in most conservation planning. RUSLE2 assumes that the terrace/diversion channel and ridge are infinitely thin as illustrated in Figure 8.11c. This approach is used in RUSLE2 where terraces/diversions are represented as a support practice. The other approach is to describe the actual hillslope profile configuration, including the cover-management on each segment such as the grass on a steep backslope of a terrace/diversion.

The overland flow path that is entered in RUSLE2 is the path without the terraces/diversions. The segments are added to create the profile illustrated in Figure 8.11d. RUSLE2 automatically creates a channel where segments with a positive and a negative (adverse) steepness intersect. Such channels end the overland flow path. RUSLE2 determines the appropriate overland flow path lengths without the analysis having to be broken into parts.

8.3.5. Overland flow path for diversions that intercept runoff above steep slopes

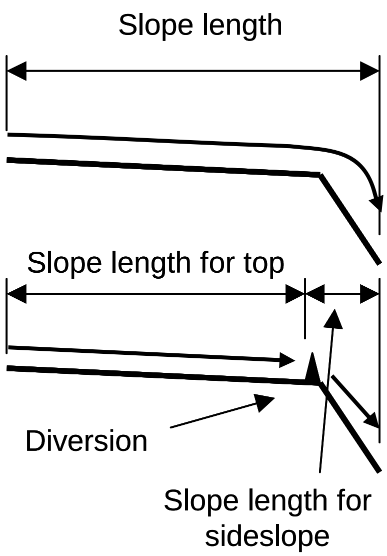

Figure 8.12. Landfill with relatively flat top and steep side slope, with and without a diversion

Table 8.3. Soil loss on a landfill with and without a dversion at the top of the steep sideslope

			Soil loss(tons/acre)	
Segment	Distance to end of segment (ft)	Steep-ness (%)	Without diversion	With diversion
1	250	2	9	9
2	300	33	538	130

Erosion is high at the end of convex shaped hillslope profiles and where runoff from a long slope flows onto a steep slope like the sideslope of a landfill. Placing a diversion at the top of the sideslope as illustrated in Figure 8.12 is an effective practice for reducing erosion on the steep sideslope as shown in Table 8.3. The entire profile description is entered into RUSLE2 and then a diversion is applied at the top of the steep sideslope. RUSLE2 automatically ends the overland flow path for the relatively flat top slope and begins a new overland flow path at the top of the steep sideslope. As expected, the diversion did not reduce erosion on the top of the landfill but significantly reduced erosion on the sideslope.

8.3.6. Overland flow path for contouring (ridging)

The effect of contouring, ridging, and bedding on erosion can be represented in three ways in RUSLE2.[52] The **first method** is that the surface can be represented using a ridge (bed)-furrow description where the overland flow path length is from the top of the ridge (bed) to the furrow that separates the ridges or beds **provided** the ridges and beds are so well defined, so high, and on a sufficiently uniform grade that the runoff flows in the furrows separating the ridges or beds that the flow flows in the furrows along their total length until reaching the end of the furrow or a defined concentrated flow area. The **second method** to describe an overland flow path along the ridges-furrows when the ridges are well defined and flow stays within the ridges as just described.

[52] The effect of contouring on erosion is highly variable and is very difficult to accurately predict. Slight variations can result in wide variations in erosion. For example, under certain conditions, contouring can actually increase erosion, while in other similar conditions, the same contouring can be highly effective. The high variability in effectiveness is partly related to storm severity. The contouring relationships in RUSLE2 represent the main effects that supported by the data. See **Section 14.1** for additional discussion.

The **third method** is to describe an overland flow path assuming a flat soil surface without the ridges and without considering how the ridges affect the flow pattern. This method is used in ordinary cases of ridges like those left in farm fields by tillage equipment such as tandem disks, chisel plows, and field cultivators or those left by ridgers on highly disturbed lands such as reclaimed mine sites.

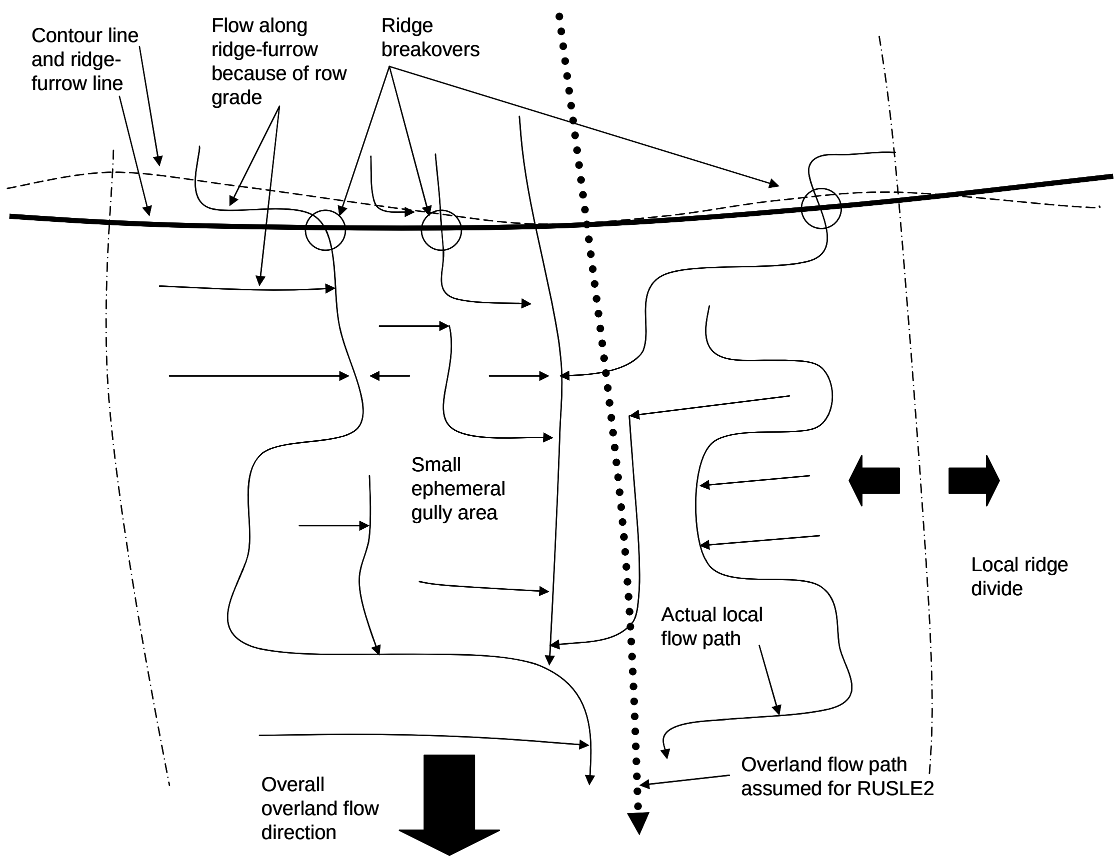

Figure 8.13. Overland flow patterns in a typical field where local runoff flows along ridge-furrows because of a row grade, breaks over in local areas, and accumulates in small local ephemeral gully areas.

These field situations are illustrated in Figure 8.13. Runoff flows along the furrows a distance [a few to several ft (m)] before breaking over one or more ridges before the runoff is intercepted by a sufficiently large ridge to direct runoff along a furrow. The breakovers are located randomly between the major concentrated flow areas. Breakover locations are random and can not be determined after the ridge forming operation in advance of the erosion event because of non-uniform ridge height and non-uniform grade along the furrows. **The first two methods should not be used for the conditions illustrated in Figure 8.13**.

These three methods can give significantly different results, which partially reflects the great difficulty of accurately estimating the effect of contouring (ridging). Use RUSLE2 as a guide to conservation and erosion control planning rather than considering it to provide absolute erosion estimates for any particular site.

8.3.6.1. Overland flow path for ordinary contouring, ridging, and bedding

Contouring, including ridging and bedding, is normally treated as a support practice in RUSLE2. See **Section 14.1** for a description of contouring as a support practice. To treat contouring, ridging, and bedding as a support practice, enter the overland path description in RUSLE2 as the path that the overland flow would follow as if the soil surface is flat and no ridges are present to influence the flow pattern.

8.3.6.2. Overland flow path for a ridge (bed)-furrow description

RUSLE2 can directly compute erosion on ridges and beds and the deposition in the furrows that separate them. RUSLE2 can accommodate overland flow path lengths as short as a zero length. Thus, RUSLE2 can be applied to ridge-furrow and bed systems, like those illustrated in Figure 8.14 for vegetable production.[53] RUSLE2 can also be applied where plastic is added and removed on the beds (See **Section 13.1.9** for a description on how to use RUSLE2 to describe the effect on erosion of adding and removing plastic to beds).

[53] Actually a finite, small number like 0.001 ft (0.5 mm) must be entered, which gives the same result as entering a zero. The erosion rate at a zero overland flow path length is entirely interrill erosion. An erosion rate exists for a zero overland flow path length but the amount of erosion is zero because erosion amount for a uniform profile is the product of average erosion rate for the overland flow path and the overland flow path length.

Representing ridges and beds as the overland flow path and "hillslope profile" is used when the ridges and beds are so high that flow is unquestionably contained in the furrows between the ridges and beds until it reaches a well defined concentrated flow area. RUSLE2 can also compute deposition that occurs in the furrows but not erosion by flow in them.

The overland flow path length is one half of the spacing of the ridges and beds. In this example, 20% is assumed for the steepness of the bed sideslope, and 1% is assumed for the steepness of the top of the beds and 50% is assumed for the steepness of the bed

Table 6.14. Soil loss for ridges and beds

Ridges				Beds			
Segment #	Segment length (ft)	Steepness (%)	Soil loss (tons/acre)	Segment #	Segment length (ft)	Steepness (%)	Soil loss (tons/acre)
1	1.5	20	20	1	0.9	1	3
2	1.5	-20	20	2	0.6	50	27
				3	0.6	-50	3
				4	0.9	-1	27
Soil loss = 20 tons/acre				Soil loss = 13 tons/acre			

sideslope. An adverse steepness (negative values), illustrated in Table 6.14 is used for the segments on either side of the beds. The positive steepness of one sideslope intersecting with the negative (adverse) steepness on the adjacent ridge or bed causes RUSLE2 to create a channel that ends the overland flow path length. The grade that RUSLE2 automatically assumes for the default channel is so steep that no deposition occurs. However, the actual grade can be entered so that RUSLE2 can compute deposition that occurs in the furrows between the ridges or beds.

8.3.6.3. Summary comments

RUSLE2 does not give the same results for all these three approaches for representing ridges-furrows. The approach of explicitly describing the configuration of the ridges and beds works when the ridges contain the flow until a major well-defined concentrated flow area is reached. Although RUSLE2 can estimate deposition in furrows on a relatively flat grade, RUSLE2 can not estimate erosion in the furrows, which RUSLE2 has represented as channels.

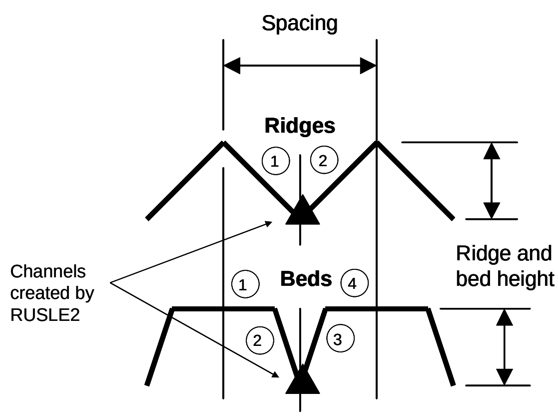

Figure 8.14. Ridge and bed systems.

The approach of representing the overland flow path as if the ridges-furrows are not present works best when the flow pattern is irregular as illustrated in Figure 8.13.

8.4. Influence of Upslope Areas on Overland Flow Path

RUSLE2 is sometimes applied to a field site that is downslope from an area that contributes runoff to the site. The recommended approach is to represent the entire overland flow path even though the upslope area is not a part of the analysis area. The soil loss computed for the downslope area should not be compared to soil loss tolerance, but the procedure described in **Section 7.9.3** where a ratio of soil loss to T value adjusted for position on the slope is computed. A conservation practice should be chosen that reduces this ratio to 1.

RUSLE2 takes into account cover-management conditions on an upslope area for computing transport capacity on downslope segments where cover-management is quite different from the upslope area. However, RUSLE2 does not fully take into account how reduced runoff from the upslope area reduces detachment on the downslope segment. In some applications, **RUSLE2** is applied to a field downslope from an upslope area that is very different from the field. The following approach can be used to take into account how reduced runoff from the upslope segment affects detachment on the downslope segment. If runoff production on the upslope segment is less than that on the downslope segment, the overland flow path length to the upper edge of the downslope segment should be shortened. An example is an undisturbed forest on the upslope area where the overland flow path length begins at the upper edge of the site because no surface runoff is assumed to occur from the undisturbed forest. If the upslope area is pasture and only produces half the runoff that a downslope field produces, the overland flow path length at the upper edge of the field should be one half the distance of the slope length across the pasture area.

Conversely, if the upslope area produces more runoff than does the field, the overland flow path length at the upper edge of the field should be greater than the actual distance in proportion to the differences in runoff potential for the two areas.

9. COVER-MANAGEMENT SUBFACTORS

Cover-management refers to how vegetation, soil condition, and material on and in the soil affect erosion. RUSLE2 describes the effects of cover-management using basic variables applicable to any cover-management system. The basic cover-management variables used in RUSLE2 are canopy (vegetative material not in contact with soil surface), ground (surface) cover (material in contact with soil surface), soil surface roughness, soil ridge height, below ground biomass (live and dead roots and incorporated material), and soil consolidation and antecedent soil moisture in the Req zone (see **Section 6.9**).

RUSLE2 is land use independent, which means that it can be applied to any land use where mineral soil is exposed to raindrop impact and Hortonian overland flow. RUSLE2 can be applied to crop, pasture, hay, range, disturbed forest, mined, reclaimed, construction, landfill, waste disposal, military training, park, wild, and other lands. RUSLE2 does not apply to undisturbed forestlands and lands where no mineral soil is exposed and surface runoff is produced by a mechanism other than rainfall intensity exceeding infiltration rate.

Because RUSLE2 is land use independent, it applies to transitions between land uses. For example, a lightly disturbed military training site may behave much like a pasture or rangeland, a moderately disturbed site may behave like a cropped field, and a highly disturbed site may behave like a very rough construction site. A "fresh" landfill and a recently reclaimed mine site not yet vegetated may behave like a freshly graded construction site but behave like pasture or range land over time. Pasture and rangeland may be periodically converted to and from cropland.

Erosion models based on specific land uses typically do not produce the same erosion values at a common point between land uses resulting in uncertainty between erosion estimates. RUSLE2 does not have this problem.

9.1. Basic Principles

Equation 7.1 estimates soil loss for the unit plot, which is a fallow (no vegetation) condition periodically tilled up and down slope to break the crust and to control weeds. This special condition is used to define and determine soil erodibility factor values (see **Section 7.2**). The daily cover-management factor **c** in equations 5.1 and 8.1 "adjusts" the unit-plot erosion to site-specific field conditions as affected by cover-management.

The cover-management factor c describes how cover-management affects both erosivity and erodibility. For example, vegetation and ground cover affect erosivity by reducing the erosive forces applied to the soil by raindrop impact and surface runoff. Both live and dead roots and organic material in the soil increase infiltration, which reduces erosivity by reducing runoff. These materials reduce erodibility by decomposing in the soil to produce chemical bonding agents that increase the soil's resistance to detachment. Soil mechanical disturbance, which creates a very rough soil surface that ponds water, reduces the erosivity of both raindrop impact and surface runoff. Large soil clods that form the roughness peaks reduce erodibility by being resistant to detachment in comparison to a mechanical disturbance that finely pulverizes the soil. Thus, the effects of both erosivity and erodibility are included in other RUSLE2 factors besides just the erosivity and erodibility factors in equation 8.1.

RUSLE2 uses an index-based method to estimate soil loss without mimicking (explicitly modeling) erosion processes. RUSLE2 involves specific definitions and rules that must be followed, even when logic suggests something different.

A subfactor method used in RUSLE2 to compute values for the cover-management factor c gives RUSLE2 its land use independence.[54] This method uses subfactors that are universally important in how any cover-management system affects rill and interrill erosion. The RUSLE2 subfactors, listed in Table 9.1, are canopy, ground cover, soil roughness, ridge height, soil biomass, soil consolidation,[55] and antecedent soil moisture used in the Req zone. RUSLE2 computes a value for each subfactors for each day and uses equation 9.1 to compute a daily c factor value in equation 8.1.

$$c = c_c g_c s_r r_h s_b s_c p_p a_m \qquad [9.1]$$

where: c_c = canopy subfactor, g_c = ground cover subfactor, s_r = soil surface roughness subfactor, r_h = ridge height subfactor, s_b = soil biomass subfactor, s_c = soil consolidation subfactor, p_p ponding effect subfactor, and a_m = antecedent soil moisture subfactor.

Cover-management variables also affect the RUSLE2 topographic and support practice factors. Thus, the topographic, cover-management, and support practice factors must be examined to see the entire effect of land use and management on RUSLE2 erosion estimates.

---

[54] The RUSLE2 daily cover-management factor c is comparable to the soil loss ratio used in the USLE and RUSLE1. Soil loss ratios in the USLE applied to a crop stage period and to a 15-day period in RUSLE1. The C factor in the USLE and RUSLE1 is an average soil loss ratio value weighted by the temporal distribution of erosivity (EI distribution). Although RUSLE2 can compute a C factor value, RUSLE2 does not use a C factor value and a C factor value from another source can not be entered into RUSLE2 to compute erosion. The RUSLE2 subfactor method involves more variables and a different set of equations than used in the USLE or RUSLE1.

[55] Soil consolidation refers to how erosion decreases with time after a mechanical soil disturbance. Soil consolidation includes how the increase in soil bulk density after a mechanical soil disturbance affects erosion, but the major effect is how wetting and drying and other processes cement soil particles.

Table 9.1. Cover-management subfactors used in RUSLE2.		
Subfactor	Symbol	Comment
Canopy cover	c_c	Influence of above-ground vegetative material not in contact with soil surface; includes both live and dead vegetation
Ground cover	g_c	Material in contact with soil surface; includes both live and dead plant material and other material like manure, mulch, and "roll" erosion control materials applied to the soil surface
Soil (surface) roughness	s_r	Random roughness created by a mechanical soil disturbance; includes peaks and depressions that are randomly shaped and located without an orientation to runoff direction
Ridge height	r_h	Ridges formed by a mechanical soil disturbance; ridges and furrows between ridges redirect flow if not oriented up and down hill
Soil biomass	s_b	Includes plant and other organic material in the soil that has been incorporated by a mechanical soil disturbance, grown there as live roots that become dead roots, or moved into the soil by worms or other organisms
Soil consolidation	s_c	Refers to how a mechanical soil disturbance loosens the soil to increase erosion and the degree to which erosion has decreased following a mechanical soil disturbance
Antecedent soil moisture	a_m	Used in the Req zone; refers to how previous vegetation reduces soil moisture so that subsequent runoff and erosion is decreased

9.2. Cover-Management Subfactors

This section describes each cover-management subfactor and how RUSLE2 computes a value for each subfactor.

9.2.1. Canopy

Canopy is live and dead vegetative cover above the soil surface that **intercepts raindrops** but does not contact the **surface runoff**. The portion of the **above ground plant biomass** touching the soil surface is treated as **live ground cover**.

9.2.1.1. Canopy effects

Canopy intercepts raindrops. Some of the intercepted rainfall reforms as waterdrops that fall from the canopy. The erosivity of these drops is directly related to their impact energy. The impact energy of a waterdrop is one half of the product of mass (determined by drop diameter) and the square of impact velocity (determined by fall height). In contrast to raindrops that vary over a wide size range, all water drops falling from canopy are nearly of an equal size (about 3 mm) that is significantly larger than the median raindrop size (about 1.5 mm). Even though the mass of each waterdrop falling from canopy is greater than the mass of most raindrops, the impact velocity of waterdrops falling from canopy is generally much lower than the impact velocity of raindrops because of the low fall heights from plant canopy. However, if the bottom of the canopy is greater than about 30 ft (10 m), the erosivity of waterdrops falling from canopy is greater than that of raindrops because of the increased mass of the drops falling from canopy.

Some of the rainwater intercepted by canopy flows along plant stems to the soil surface. While this water has no erosivity to detach soil particles by waterdrop impact, it provides water for runoff, but the delay caused by the water flowing along the stems to the soil surface reduces peak runoff rate, which in turn reduces runoff erosivity. Dense canopies retain a significant amount of water that never reaches the ground because it is evaporated after the storm. While this water is not significant for large storms, it can significantly reduce runoff for small storms.

The equation used to compute a value for the canopy subfactor is:

$$c_c = 1 - f_c \exp(-0.1 h_f) \qquad [9.2]$$

where: f_c = canopy cover (fraction) and h_f = effective fall height (ft). The two canopy variables of **canopy cover** and effective **fall height** are used to describe the effect of canopy on erosion.

9.2.1.2. Canopy cover (f_c)

Canopy cover is the portion of the soil surface covered by canopy in a horizontal plan view. The fraction of the soil surface covered by canopy is 1 minus the fraction of open space, which is the space through which a raindrop can fall to the soil surface without being intercepted by the plant canopy. Open space can be seen by looking down on the canopy from above and identifying the open space between the outer perimeter of the individual plant canopies and the open space within the outer perimeter of individual plant canopies. The

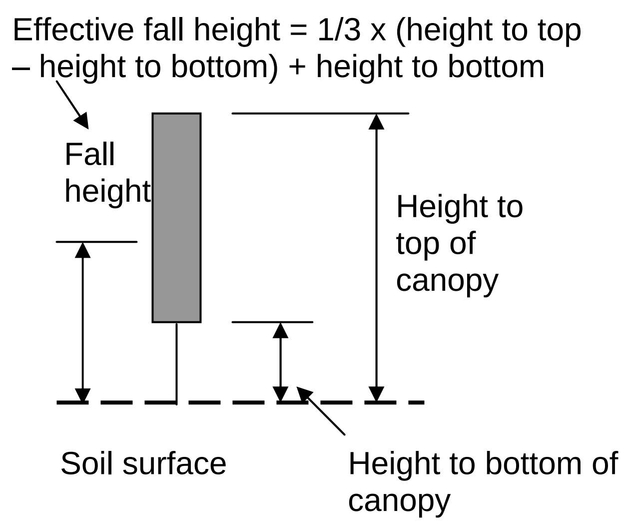

Figure 9.1. Effective fall height for a cylindrical shaped canopy of uniform density

effect on wind on the erosivity of raindrops or on how canopy intercepts raindrops is not considered in RUSLE2.

9.2.1.3. Effective fall height (h_f)

Waterdrops fall from various heights within the plant canopy, and some of the drops are intercepted by lower canopy. The total impact energy of these waterdrops is the sum of the impact energy of each drop on the soil surface. Effective fall height is the single fall height that gives the total energy if all drops fell from a single height. Effective fall height varies with plant maturity and shape, density gradient within the canopy, and heights to the top and bottom of the canopy. If the canopy shape is cylindrical and canopy density is uniform with height, the fall height is assumed to be one third of the way up from the bottom of the canopy as illustrated in Figure 9.1. The lower than average height reflects the likelihood that waterdrops falling from higher in the canopy are intercepted by lower canopy.

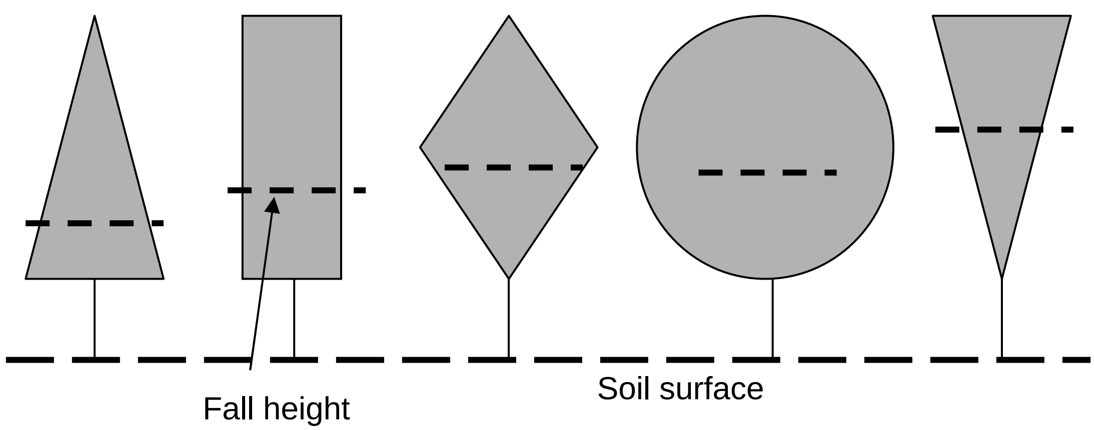

Figure 9.2. Effect of canopy shape on fall height

Canopy shape and density gradient of the canopy material with height influence effective fall height because lower canopy can intercept waterdrops that fall from higher in the canopy. Effective fall height is low when the canopy material is concentrated low in the canopy because of shape and density gradient as illustrated in Figures 9.2 and 9.3. If most of the leaves and branches of the plant are concentrated in the upper portion of the canopy, the effective fall height is one half to two thirds of the distance from the bottom to the top of the canopy. RUSLE2 includes a procedure that uses graphical shapes of these figures to assist in assigning effective fall height values for any particular vegetation throughout its growth.

Fall height assigned to a vegetation (plant community) should be assigned based on how the canopy of the particular plant community affects erosion relative to other plant communities. Fall height must be consistent among vegetations in the RUSLE2 database and consistent with fall heights in the Core Database.

Because the effect of fall height in equation 9.2 is nonlinear, the heights cannot be averaged to determine an effective fall height.

Fall height can be measured at regular intervals along a transect where a rod is lowered through the canopy to the ground. The height to the lowest part of the canopy touching the rod is measured. Rather than averaging these values, the proper approach is to compute a canopy subfactor value by using equation 9.2 for each height and assuming that $f_c = 1$. These subfactor values are averaged and the effective fall height is computed from:

$$h_{fe} = -\ln(1 - c_{ca})/0.1 \qquad [9.3]$$

where: h_{fe} = effective fall height (ft) and C_{ca} = average canopy subfactor.

9.2.1.4. Understory

RUSLE2 uses a single vegetation description at any point in time. The values in this description are for the composite of the plant community that exists at the given point in time. RUSLE2 cannot take components of a plant community and aggregate values for each component into a composite value. The user directly assigns and enters a composite value for each RUSLE2 variable used to describe a particular vegetation.

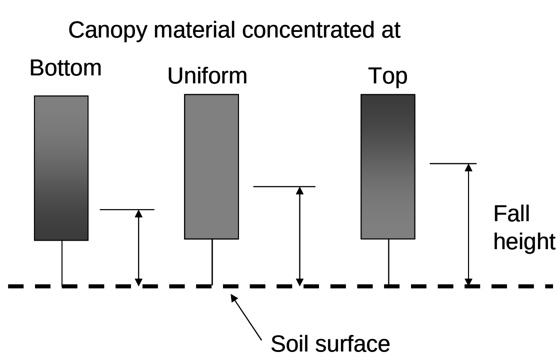

Figure 9.3. Effect of canopy density distribution on fall height

Some plant communities have distinct canopy components of over and understories. Examples include grass under shrubs on a rangeland, grass under vines on a vineyard, a legume interseeded in a small grain, a rye cover crop interseeded in corn, and volunteer weeds that begin to grow as crops approach maturity. Consideration must be given to overlapping canopies in determining an effective fall height. **The understory is often dominant in determining fall height especially if the understory is dense.**

9.2.1.5. Interaction with ground cover

Canopy that is directly above ground cover is assumed not to affect erosion. Thus, the effective canopy cover is computed from:

$$f_{ce} = f_c(1 - f_g) \qquad [9.4]$$

where: f_{ce} = effective canopy cover (fraction) and f_g = portion of soil surface cover by ground cover (fraction).[56] Also, RUSLE2 compares the canopy subfactor value with the ground cover subfactor value computed with the canopy cover value. RUSLE2 does not allow the canopy subfactor value to be less than this ground cover subfactor value. The effect of this comparison is that canopy cover behaves as ground cover as fall height approaches zero.

9.2.1.6. Effect of production level (yield)

RUSLE2 does not "grow" vegetation like a plant model "grows" vegetation. The user describes vegetative growth by entering values for retardance and above-ground biomass at maximum canopy, and values for root biomass, canopy cover, fall height, and live ground cover that vary through time. These values are entered in the vegetation component of the RUSLE2 database to describe a particular vegetation.

Variables used in RUSLE2 to describe vegetation are a function of production level (yield). **RUSLE2** can vary these values for these variables as a function of yield so that a vegetation description does not have to be created for each production (yield) level. A single vegetation description is created for a base yield, which RUSLE2 adjusts to the site specific yield.[57]

The purpose of entering a site-specific production (level) yield is so that RUSLE2 can determine values for biomass on and in the soil. Sources of biomass are **above-ground biomass** and **root biomass** from the vegetation grown on site and from **external residue**

---

[56]The RUSLE2 interaction between canopy and ground cover is similar to the one assumed in the USLE (AH537). No interaction between canopy cover and ground cover was assumed in RUSLE1 (AH703). As a result, the effect of canopy at low fall heights was too great in RUSLE1. In fact, RUSLE1erroneously computed a zero erosion for a 100% percent canopy cover when fall height was zero, rather than erosion for 100% ground cover. The RUSLE1 technique of using a zero fall height to shut off erosion for special purposes such as plastic mulch can not be used in RUSLE2. The **add** and **remove nonerodible cover processes** used to describe **operations** serves this purpose in RUSLE2.

[57] RUSLE2 differs from RUSLE1 in this regard. Different yields could only be accommodated In RUSLE1 by creating a vegetation description for each yield. A single base vegetation description is created In RUSLE2 for a base yield. RUSLE2 adjusts the base vegetation description to fit the specific site yield entered. However, a vegetation description for specific yields can be used in RUSLE2 just as in RUSLE1.

applied to the soil surface and/or incorporated into the soil. External residue includes straw, wood fiber, wood chips, organic-based roll erosion control materials, compost, leaves and forest debris, manure, and other similar materials that are typically applied to control erosion.[58]

Biomass values must be on a dry weight basis. The dry weight of external residue is known at the time of application from the user input value. The dry weight values for the above-ground and root biomass is determined from the production (yield) level entered by the user to represent a particular field site. RUSLE2 adjusts the aboveground biomass value at maximum canopy as a function of yield according to:

$$M_a = M_0 + b_a Y \qquad [9.5]$$

where: M_a = dry weight aboveground biomass at maximum canopy for the site specific yield, M_0 = the aboveground biomass at maximum canopy for a zero yield, and Y = yield in units chosen by the user. RUSLE2 determines values for M_0 and the slope term b_a from values entered by the user for two different yields. RUSLE2 uses a similar relationship to vary retardance with yield (see **Section 11.1.4**).

Dry weight values for root biomass are entered in RUSLE2 for a vegetation description at the base yield. RUSLE2 assumes that dry weight root biomass varies directly with yield, that canopy and live ground cover vary with the square root of yield, and that effective fall height varies with yield to the 0.2 power.

The base vegetation used to create vegetation descriptions at a new yield should be for a base yield where maximum canopy cover is less than 100 percent. The base maximum canopy cover must be less than 100 percent for the RUSLE2 yield adjust function to fully work. If the maximum canopy cover is 100 percent, RUSLE2 can adjust only for yield values greater than the base yield. RUSLE2 does not directly adjust vegetation values as a function of seeding rate, population, or row spacing. RUSLE2 can indirectly adjust for seeding rate and population by assuming a relationship between yield and these variables. Row spacing can only be considered in RUSLE2 by having a vegetation description for each row spacing. If canopy characteristics vary significantly between crop varieties, plant communities, or management practices, a vegetation description must be constructed to reflect each significant difference.

RUSLE2 computes the variation of above-ground biomass through time by assuming that above-ground biomass varies with the 1.5 power (see **Section 11.1.3.1**) of canopy cover.[59] RUSLE2 calibrates this relationship using the user entered values for above-

---

[58] External residue also includes inorganic materials such as rock and roll erosion control materials applied to the soil surface. These materials require special consideration. See **Section 12**.

[59] RUSLE2 tracks aboveground biomass through time, which is different from RUSLE1. A biomass value entered in RUSLE1 had to correspond to the date of an operation that affected aboveground biomass.

ground biomass at maximum canopy and the amount of above-ground biomass remaining after full senescence has occurred. This approach allows an operation to be entered at any date during a cover-management system without the user having to explicitly enter the biomass at that point in time. In some cases, the assumed relationship between canopy and aboveground biomass may not give the proper value for the aboveground biomass when an operation with a **kill** vegetation process occurs before the vegetation reaches maturity.[60] A vegetation description can be created where the above-ground biomass at maximum canopy is the aboveground biomass at the time that the vegetation is killed rather than the above-ground biomass at maximum canopy as the vegetation approaches maturity.

The yield entered in RUSLE2 for the vegetation at a particular field site must be consistent with the site climatic, soil, and management conditions. **RUSLE2 assumes that the user has selected a vegetation description and yield appropriate for the site.** Because RUSLE2 does not model vegetation growth, it can not determine the appropriateness of a vegetation description for a particular site nor does RUSLE make adjustments based on climatic, soil, or management conditions. For example, an operation description must be used to tell RUSLE2 to represent frost killing vegetation.

In RUSLE2, the users define production (yield) level in any terms that they choose, although customary usage is recommended. For example, yield can be expressed in terms of a "fresh" weight or a "dry" weight. Equation 9.5 converts the specified yield, which might be in fresh weight units, to the dry weight values that RUSLE2 needs for biomass.

Accounting for all of the biomass involved in a particular cover-management system is not necessary. **The amount of biomass left in the field to affect erosion is the critical variable.** The amount of biomass that leaves a field is unimportant.

RUSLE2 does not have this requirement. The biomass values are entered at maximum canopy and RUSLE2 tracks biomass through time. An operation can be entered in RUSLE2 at any time in a cover-management system without having to specify (enter) a biomass value in the vegetation description on the date of the operation.

[60] **Kill vegetation** has a particular definition in RUSLE2. Kill vegetation is one of several processes used to describe an operation. Killing vegetation converts live vegetation to dead vegetation. See **Section 13** for the RUSLE2 rules regarding manipulation of vegetation. A **kill vegetation process** must be used in an operation description to tell RUSLE2 that vegetation has died by maturity or has been killed by frost.

RUSLE2 uses a description of site specific conditions to compute erosion. The user carefully follows the RUSLE2 definitions and procedures to create this description. Multiple approaches can often be used to create a description. In general, RUSLE2 was designed so that vegetation descriptions can be created independently of the operations used to manipulate vegetation. For example, this approach allows RUSLE2 to use a single description for corn grown for grain and corn grown for silage. However, some cases may occur where a vegetation description is created to reflect the manipulations of an operation that can not be conveniently created using an operation. The important consideration is that RUSLE2 gets the values that it needs for its computations.

9.2.1.7. Senescence and other canopy losses

Canopy cover increases during the growth period when plants accumulate aboveground biomass. As plants become maturity, some vegetation, such as soybeans and perennial grasses, lose canopy cover by senescence. Other plants, such as cotton, lose canopy cover by being defoliated with chemicals. This loss of canopy cover transfers biomass from standing vegetation to plant litter (residue) on the soil surface. Once canopy material falls to the soil surface, RUSLE2 begins to compute its decomposition. Some plants, like corn, lose canopy cover by leaves drooping without falling to the soil surface, which RUSLE2 also considers (see **Section 11.2.4**).

Plants such as hay and pasture crops and permanent vegetation on rangeland, closed landfills, and other undisturbed areas experience a simultaneous birth and death of aboveground biomass during the growth period while cover is increasing. The death of live aboveground biomass adds a substantial amount of biomass to the surface litter (residue) pool. The daily death of live aboveground biomass is approximately one percent of the live aboveground biomass on that day.

The other way that canopy is lost is by **operations** that **remove live biomass**. Harvest, shredding, mowing, grazing, and burning are typical operations that reduce canopy cover (see **Section 13.1**).

9.2.1.8. Assigning values for canopy

Canopy values assigned to represent a particular vegetation must be consistent with those in the **RUSLE2 Core Database** and with values for other plant communities in the **vegetation component** of the RUSLE2 database. Core values are used to guide assigning values to new vegetation descriptions entered in the RUSLE2 vegetation database. Using consistent values with those in the Core Database helps ensure that RUSLE2 gives the expected erosion estimate and that erosion estimates are consistent between plant communities.

9.2.2. Ground Cover

Ground cover, which is material in contact with the soil surface, slows surface runoff and intercepts raindrops and waterdrops falling from canopy. Ground cover includes all material that touches the soil surface. Examples are rock fragments, portions of live vegetation including basal area and plant leaves that touch the soil, cryptogams (mosses), crop residue, plant litter, and applied materials including manure, mulch, and roll erosion control materials. Ground cover is probably the single most important variable in RUSLE2 because it has more effect on erosion than almost any other variable, and applying ground cover is the simplest, easiest, and most universal way of controlling erosion.

To be counted as ground cover, the material must remain in place and not be moved downslope by surface runoff during a rainstorm. Also, the material must contact the soil surface so that runoff does not flow between the material and the soil to cause erosion.

Operations in RUSLE2 do not affect rock cover entered in the soil component of the RUSLE2 database. Rock fragments added as an external residue are manipulated just like any other "residue" by operations in RUSLE2. See *Section 12* for special consideration regarding treating rock as an external residue

Rock fragments on the soil surface require special consideration. Generally rock fragments must be larger than 5 mm on coarse textured soils in arid and semi-arid regions where runoff is low and larger than 10 mm in other regions to be counted as ground cover. Rock fragments on the soil surface can be treated in one of two ways. They can be considered to be a part of the soil where a rock cover value is entered in the **soil component** of the RUSLE2 database (see Section 7.6). Rock fragments can also be "applied" as an **external residue**.[61]

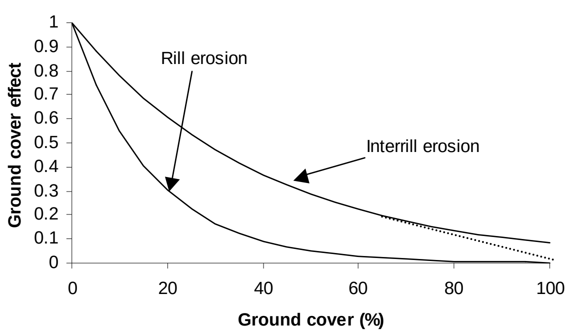

Figure 9.4. Effect of ground cover on rill and interrill erosion

9.2.2.1. Ground cover effect

Ground cover reduces erosion by protecting the soil surface from direct raindrop impact, which reduces **interrill erosion**. Ground cover also slows surface runoff and reduces its detachment and transport capacity, which reduces **rill erosion**. If

[61] **External residue** is RUSLE2 nomenclature that refers to any material added to the soil surface or placed in the soil from a source other than vegetation grown on site.

ground cover is low (less than about 15%) and ground cover pieces are long and oriented across slope, ground cover reduces soil loss by causing deposition in small ponds above ground cover pieces. As ground cover increases, deposition ends and ground cover reduces runoff detachment capacity, which reduces rill erosion. The ground cover effect for both interrill and rill erosion is illustrated in Figure 9.4.

Ground cover reduces rill erosion more than interrill erosion. That is, the ground cover subfactor is less for rill erosion than for interrill erosion for a given ground cover percent as illustrated in Figure 9.4. The net or overall effectiveness of ground cover depends on the relative contributions of rill and interrill erosion. The ground cover subfactor value is less when rill erosion makes the greater contribution to total erosion than when interrill erosion makes the greater contribution.

Factors that affect the relative contributions of rill and interrill erosion affect the ground cover subfactor. These variables include ratio of soil erodibility for rill erosion to soil erodibility for interrill erosion, soil biomass, soil consolidation, ground cover type, and the anchoring and bonding of ground cover to the soil. Obviously ground cover provides the greatest erosion control when it is well anchored and bonded to the soil. Conversely, ground cover is least effective where mulch pieces bridge across soil roughness so that runoff flows under the ground cover and where runoff moves poorly anchored ground cover. RUSLE2 partially represents these effects by reducing erosion for a given amount of ground cover when increased soil biomass is present.

These mechanical effects reduce the forces applied to the soil by waterdrop impact and surface runoff. An indirect effect is ground cover's effect on infiltration and runoff. Infiltration rate can be very high and runoff low on a freshly tilled soil without a surface seal.[62] If ground cover is placed on the soil before a crust is formed, the ground cover will reduce seal formation and help maintain high infiltration and low runoff. Therefore, ground cover has a lesser effect on reducing erosion when placed on a soil after it becomes crusted or placed on a soil where internal soil properties, such as a high clay content or high bulk density, reduce infiltration. A given amount of ground cover reduces erosion more for cover-management systems, such as no-till cropping, that maintain high soil biomass, improve soil quality, and reduce crusting because of increased infiltration. An interaction between soil biomass and soil consolidation is a major variable used by RUSLE2 to compute values for the ground cover subfactor.

Size and shape of ground cover material vary widely. Sizes and shapes include round rock fragments; thin, flat leaves; long slender pieces of unchopped wheat reside; long and increased diameter unchopped corn stalks; large pieces of woody debris left by logging operations; and continuous roll erosion control blankets. The portion of the soil surface

---

[62] A surface seal is a thin, dense layer of soil particles at the soil surface caused by soil particle dispersion associated with raindrop impact and other processes. This thin layer, which reduces infiltration, is known as a surface **seal** when wet and a **crust** when dry.

covered is used as a single variable to describe the effect of ground cover on erosion. Even though the geometry of individual ground cover pieces can vary greatly, even for the same type of ground cover, the portion of the soil surface covered integrates the effects of varying geometry of ground cover pieces on erosion, as illustrated in Figure 9.4. Ground cover (crop residue) provided by above-ground biomass from a typical agricultural crop includes leaves, pods, hulls, cobs, stems, and stalks and fine and coarse roots for below-ground biomass. Ground cover (slash) on a disturbed forest ranges from leaves and needles to broken tree limbs. Furthermore, certain operations, especially harvest operations, frequently reduce size of biomass pieces that becomes ground cover. Even though size and shape of residue pieces vary over a wide range for a particular residue, a single **residue type** is selected to represent the residue. **Residue type** is an entry in the **residue component** of the RUSLE2 database that is selected based on size and toughness of the residue.

Several types of ground cover may occur at a specific site and overlap each other. Examples include rock fragments, live ground cover (basal area and plant leaves), and plant litter. RUSLE2 assumes that ground cover produced by vegetative biomass and ground cover from external residue overlap rock cover represented in the soil description. RUSLE2 also assumes that live ground cover overlaps all other types of ground cover. RUSLE2 assumes that the last ground cover that arrives on the soil surface overlaps existing ground cover, except for live ground cover. RUSLE2 accounts for the overlap of individual ground cover pieces instead of adding the cover provided by each ground cover type.

The important consideration is the net effect of the composite ground cover, not how the individual ground cover materials affect erosion. RUSLE2 uses the net ground cover to compute a value for the ground cover subfactor. The best way to visualize the net ground cover is to determine the fraction of bare, exposed soil and subtract that value from one.

RUSLE2 accounts for ground cover on a mass per unit area basis (e.g., tons/acre, t/ha). RUSLE2 converts mass (weight) values to a percent (fraction) of the soil surface covered (see **Section 12**), accounts for overlap, and uses a net (effective) ground cover value to compute a value for the ground cover subfactor.

Although RUSLE2 tracks ground cover by mass, RUSLE2 displays ground cover in percent (fraction) to aid conservation planning that if often based on maintaining a certain ground cover percent.

9.2.2.2. Equation for ground cover subfactor

The main equation used in RUSLE2 to compute a value for the ground cover subfactor is:

$$g_c = \exp(-bf_g) \qquad [9.6]$$

where: **b** = a coefficient that describes the relative effectiveness of ground cover and f_g = ground cover (percent). The effectiveness of ground cover varies with the site-specific condition. For example, a 50% ground cover can reduce soil loss by 95% under some conditions while only reducing soil loss by 65% under other conditions. Values for **b** in RUSLE2 range from about 0.025 for the interrill erosion ground cover effect to 0.06 for the rill erosion ground cover effect, illustrated in Figure 9.4, to represent this variation in ground cover effectiveness.

Therefore, the net **b** value depends how interrill erosion varies relative to rill erosion. Consequently, the **b** value used by RUSLE2 in equation 9.6 varies daily with the ratio of rill to interrill erosion. RUSLE2 computes a net **b** value using equations based on rill and interrill erosion as:

$$a_t = a_r \exp(-0.06 f_g) + a_i \exp(-0.025 f_g) \qquad [9.7]$$

$$b = -\ln[(a_t /(a_i + a_r)] / f_g \qquad [9.8]$$

where: a_t = total relative erosion with ground cover, a_r =relative rill erosion on the same bare soil with all other conditions the same as when ground cover is present, and a_i = relative interrill erosion on a bare soil with all other conditions the same as when cover is present. Values for relative interrill and rill erosion in equations 9.7 and 9.8 are computed using the variables in equation 8.3. These equations compute daily **b** values daily that capture the main effects of how the net effectiveness of ground cover on rill-interrill erosion is affected by soil, cover-management, and by slope steepness. These effects are described in **Section 9.2.2.1**.[63]

In Req applications, a constant **b** value of 0.046 is used because the majority of the erosion is assumed to occur from rill erosion. The 0.046 value is based on analysis of plot data.

[63] RUSLE2 eliminates the need to choose a **b** value for the effectiveness of ground cover required in RUSLE1.05 or the choice of a land use required in RUSLE1.06. RUSLE2 automates a manual selection of **b** required in RUSLE1. RUSLE2 computes **b** values as cover-management conditions vary through time that RUSLE1 did not compute.

RUSLE2 does not compute a composite ground cover subfactor value by computing a subfactor value for each ground cover type and then multiplying those values. That procedure would be an improper mathematical operation. Therefore, rock fragment cover must be combined with other ground cover considering overlap rather than using a soil erodibility factor value already adjusted for rock cover.

RUSLE2 reduces the effect of ground cover on steep slopes with little soil biomass. This feature represents how mulch is less effective on steep construction sites than crop residue and plant litter on crop, range, pasture, and disturbed forestland. RUSLE2 takes into account how small ground cover pieces that conform closely to the soil surface reduce erosion more than long pieces of ground cover that bridge across roughness elements like soil clods. This effect is greatest on steep, construction-like soil and slope conditions.

RUSLE2 assumes an interaction between soil surface roughness and ground cover such that the effectiveness of ground cover is reduced as surface roughness increases. For example, ground cover in the bottom of a depression filled with ponded water does not reduce erosion as much as does the same ground cover on a flat soil surface.
RUSLE2 computes a low **b** value for flat slopes where interrill erosion dominates, a high **b** value on steep slopes where rill erosion dominates, and an increased **b** value on no-till and other soils conditions where ground cover increases infiltration. The interaction of soil consolidation and soil biomass is used to indicate conditions where ground cover increases infiltration. RUSLE2 also compute increased **b** values for soils susceptible to rill erosion based on soil texture and decreased **b** values for increased soil consolidation that is assumed to reduce rill erosion more than interrill erosion.

RUSLE2 b values are not always comparable to b values reported in scientific literature. In many cases, literature b values are based on plotting soil loss versus percent ground cover without considering other variables such as soil surface roughness, soil biomass, and soil consolidation. Values determined on that basis cannot be compared with RUSLE2 b values because RUSLE2 represents those effects in other variables. Also, reported b values are as large as 0.1, which are larger than can be obtained by RUSLE2. These high b values represent extremes rather than the typical condition represented by RUSLE2.

RUSLE2 biomass residue pools:
1. Standing (canopy cover)
2. Flat (ground cover)
3. Buried

9.2.2.3. How ground cover is added to and removed from the soil surface

Ground cover is added to the soil surface by live vegetation (live ground cover), senescence causing canopy material to fall to the soil surface, natural processes causing standing residue to fall over, an operation (e.g., harvest)[64] flattening standing residue, an operation (e.g., tillage) resurfacing previously buried residue, or an operation applying **external residue** (e.g., mulch, manure, roll erosion control product) to the soil surface. Ground cover is removed when plant growth reduces leaves or other live plant parts from touching the soil surface, an operation (e.g., tillage) buries ground cover, or an operation (e.g., straw baling, burning) removes ground cover.

Live ground cover values are entered in the **vegetation descriptions** in the **vegetation component** of the RUSLE2 database (see **Section 11**). Live ground cover is controlled entirely by these values, and live ground cover does not decompose. **The mass of live ground cover is accounted for in the above-ground biomass of the live vegetation.** Senescence transfers material from the live above-ground biomass (canopy) to the soil surface where it is treated as ground cover (flat residue). Once on the soil surface, this residue decomposes as a function of daily rainfall, daily temperature, and decomposition half life (coefficient) assigned in the **residue description** entered in the **residue component** of the RUSLE2 database (see **Section 12**).
.
When live vegetation is **killed**, it becomes **standing residue**. Over time this residue falls over because of natural processes and becomes ground cover (i.e., becomes surface residue). The rate that standing residue "falls" (i.e., mass is converted from standing residue to surface residue) is proportional to the decomposition rate at the base of the dead standing residue. The base of the standing residue is assumed to decompose at the same rate as the **flat (surface) residue**.

Standing residue, which is not in contact with the soil surface, decomposes at a much slower rate than flat or buried residue because of no soil contact to provide moisture to accelerate decomposition.[65] Standing residue can also be converted to ground cover (flat residue) by an **operation** that includes a **flattening process**. **Flat residue** is lost by decomposition and burial by operations. **Buried residue** is also reduced by decomposition at the same rate as flat residue, and buried residue can be resurfaced by an operation that includes a **(mechanically) disturb soil process**, which adds material to ground cover. **External residue** can also be added to the soil surface by an operation that includes an **add other cover process**. External residue decomposes at the rate determined by the decomposition half life (coefficient) entered for the **residue description** in the **reside component** of the RUSLE2 database**.** See **Section 13** for a description of how operations manipulate ground cover.

---

[64] An operation is an event that mechanically disturbs the soil, changes the vegetation, or changes the residue.

[65] RUSLE2 assumes that flat residue, buried residue, and dead roots all decompose at the same rate. Standing residue is assumed to decompose at a much slower rate than residue in the other pools. Decomposition rate at the base of standing residue, which determines the rate that standing residue falls, is the same as the decomposition rate for flat residue.

The information in each RUSLE2 database component and the rules for manipulating RUSLE2 variables are a "language" and procedure used to describe field conditions through time. The objective in RUSLE2 is to describe field conditions as they exist, not to model processes as a way to describe field conditions. A check should always be made before making a RUSLE2 computation to verify that the user created description matches the actual field situation. RUSLE2 uses your field description to estimate erosion.

Nonerodible cover can be added to the soil surface to represent adding a plastic mulch used in vegetable production, a water layer used in rice production, a snow cover in winter months, and to shut off erosion for particular computational reasons. Nonerodible cover acts like other kinds of ground cover except that it completely shuts off erosion for the portion of the soil surface that it occupies. Half life and permeability are parameters used to describe nonerodible cover (see **Section 13.1.9**).

Most types of ground cover can be removed from the soil surface. Live ground cover is removed controlled by the values assigned through time in the **vegetation description**. Rock cover assigned in the **soil description** can not be removed. Other forms of ground cover can be removed by using an **operation** that has a **remove residue/cover process.** Buried residue biomass in the soil can be removed by using an operation to **resurface** the residue to become ground cover and then using another operation that removes this ground cover. Neither live nor dead roots can be removed from the soil. **RUSLE2**

RUSLE2 rules for transfer of residue among pools:

1. Residue is added to the soil surface by senescence, standing residue falls over by natural processes, standing residue that is flattened by an operation, or application of external residue

2. Senescence transfers biomass from live canopy to the soil surface, adding ground cover (flat residue)

3. Live vegetation cannot be flattened or buried

4. Killing live vegetation creates standing residue (dead plant material)

5. Standing residue becomes flat residue by falling over from natural processes or by being flattened by an operation

6. Only flat residue can be buried (standing residue must first be flattened by natural processes or by an operation before it can be buried)

7. Flat residue can only be buried by an operation that mechanically disturbs the soil

8. Twenty five percent of the daily decomposed flat (ground cover) residue becomes buried residue in the upper 2 inch (50 mm) soil layer where it decomposes again

9. Only buried residue can be resurfaced; roots can not be resurfaced

10. Buried residue can only be resurfaced by an operation mechanically disturbs the soil

assumes that a decrease in the live root biomass in the vegetation description represents root sloughing that becomes a part of the dead root biomass pool (see **Section 11.2.6.3**). **Also, RUSLE2 can represent daily additions to the dead root pool by root death during growth periods (i.e., when live root biomass is increasing).**

9.2.2.4. Conversion of residue mass to portion of soil surface that is covered

RUSLE2 uses the following equation to convert ground cover (residue) mass to portion of the soil surface that is covered:

$$f_g = 1 - \exp(-\alpha M_g) \qquad [9.9]$$

where: α = a coefficient that is a function of residue characteristics (units depend on the units of M_g) and M_g = residue mass per unit area (e.g., lbs/acre, kg/ha) expressed on a dry matter (weight) basis. Figure 9.5 shows a plot of equation 9.9 for four residue types.

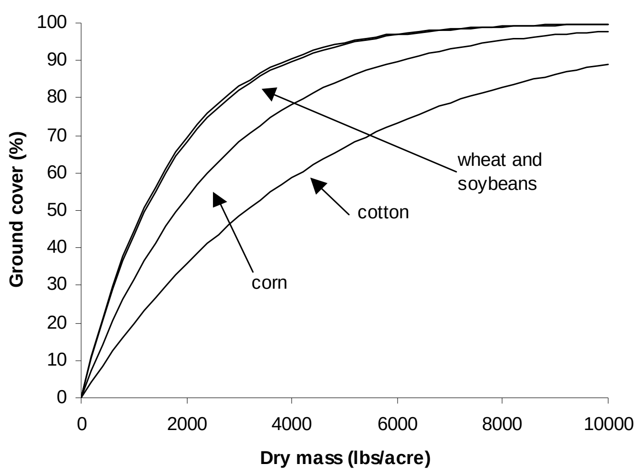

Figure 9.5. Relationship of ground cover to dry mass for four types of residue.

RUSLE2 uses data points entered in the **residue description** in the **residue component** of the RUSLE2 database to determine a value for α in equation 9.9 for each residue description in the residue component of the RUSLE2 database (see **Section 12.3**).

Figure 9.5 illustrates differences in residue types. Cotton residue is mainly composed of very coarse, woody stems, which requires a large mass of these residue pieces to produce a given ground cover. The other extreme is soybean residue, which is a mixture of several plant components including leaves, stems, and seed pods. The curve for wheat residue is similar to the one for soybean residue, but in this case, not a particularly large mass of hollow wheat stems is required to provide significant ground cover. Also, a significant amount of wheat residue is composed of leaves. Corn residue is intermediate. Much of the corn residue is large stalks that are solid but less dense than cotton stems. Also, much of the corn residue is composed of leaves.

The portion of the soil surfaced covered by residue does not change greatly as residue mass (weight per unit area) changes at high amounts of ground cover. For example, reducing the mass of the ground cover material by 50% has little effect on ground cover if mass of material on the soil surface is very large. In contrast, a slight change in mass per unit area at low mass values can significantly change ground cover. The small change in ground cover at large mass values is a major reason that RUSLE2 computes burial and resurfacing of material based on mass rather than on percent cover.

The best approach for selecting values for a residue description in the RUSLE2 database is to choose values based on information in the **core database** rather than making site specific field measurements. Field data are highly variable and should be avoided unless a large mass of data collected under research conditions are available (see **Section 9.2.2.6**).

Be cautious in developing residue descriptions for different crop varieties. Differences reported in scientific literature often represent unexplained variability rather than real differences.

RUSLE2 uses a single composite residue description for a particular residue although crop residue and plant litter are composed of a wide variety of plant components of different sizes. This approach is a compromise. A small mass of leaves gives a much greater percent ground cover than does the same mass of stems. Therefore, the relationship between cover and mass depends on the relative proportion of leaves and stems, or other plant components. This relationship changes through time because the residue components decompose at different rates. For example, leaves decompose much more rapidly than do stems. Consequently the mass-cover relationship is very different immediately after harvest when many leaves are present than later after the leaves have decomposed with only stems remaining. Also, the mass-cover relationship for a residue type can appear to differ by location for a particular plant community, when in reality the mass-cover relationship is reflecting how the proportion of leaves to stems varies by time and location.

The mass-cover values for the residue descriptions in the RUSLE2 core database were primarily chosen so that RUSLE2 computes erosion estimates that compare well with measured erosion values in research studies.[66] Also, the core database residue descriptions were chosen to represent the overall mass-ground cover relationship for the first year after harvest rather than fitting ground cover values at a specific point in time, such as one year after harvest. The result is that RUSLE2 may underestimate cover

[66] The major reason for having and using a RUSLE2 **core database** is to help ensure consistency in RUSLE2 estimates, especially by cover-management system and by location. Consistency is a major requirement when RUSLE2 is used to implement cost sharing and regulatory type programs so that all clients are treated fairly.

beyond about 12 months. The core database values were chosen to compute average annual erosion as a function of main effects rather than secondary effects associated with residue components decomposing at different rates. Fitting secondary effects, especially with limited data, is often fitting unexplained variability. The core database values represent several data sets rather than focusing on a single data set.

9.2.2.5. Spatially non-uniform ground cover

This section describes how to apply RUSLE2 where ground cover is concentrated in strips and patches. Examples of non-uniform ground cover are narrow strips mechanically disturbed by tillage and planting equipment, residue strips left by harvest operations, natural processes that cause residue to collect in strips, “patches” of highly disturbed soil left by logging and military training operations, and grass/shrub “clumps” on rangeland.

RUSLE2 uses different **cover-management descriptions** along the overland flow path to compute erosion for these conditions. Segments are created in the **management layer** illustrated in Figure 8.1. Cover-management descriptions are assigned to segments to represent non-uniform ground cover and disturbed soil along the flow path.

RUSLE2 assumes that ground cover is uniformly distributed for a particular cover-management description. RUSLE2 values for flattening, burial, and resurfacing ratios used to describe the manipulation of residue by operations are based on the entire area, not the local area where the residue is manipulated, such as in a tilled strip where seeds are planted.

The first example is the patchiness common to disturbed forest lands and military training sites where ground cover and soil disturbance vary randomly. The boundaries between the patches are the location of segment breaks. Cover-management descriptions are applied to each segment to represent each cover-management condition along the flow path.

A second example is landfills where vegetation and ground cover vary along the flow path because of soil differences. Segments are created in both the soil layer and the management layer in Figure 8.1. Appropriate soil and cover-management descriptions are assigned to each segment.

A third example is residue strips left by a combine without a straw spreader. Two cover-management descriptions are used to represent this condition. One description is for the strip that has standing residue with no flat residue from the vegetation just harvested. An operation with a **remove residue/cover process** is used to remove the flat residue that RUSLE2 assumes to be uniformly distributed. The cover-management description for the other strip is the same except it **applies external residue** to add the residue removed in the first cover-management description. The management layer in Figure 8.1 is divided into segments based on the width of each cover-management strip and the appropriate cover-management description is applied to each strip.

A fourth example is for mechanically disturbed strips, such as in vineyard or orchard where clean tilled strips are maintained within a relatively undisturbed area. A cover-management description is created for each strip and the management layer in Figure 8.1 is divided into segments to represent each of these strips along the overland flow path. If the strips are uniform along the flow path, the **strip/barrier descriptions** can be used to facilitate dividing the flow path into segments (see **Section 8**). Dividing the profile illustrated in Figure 8.1 into many segments can be tedious and laborious. The important variable is the ratio of the sum of the segment lengths of one strip type to the entire overland flow path length. This variable is more important than the actual number of strips along the flow path provided the number of strips exceeds a total of about 20 for the combination of strips (10 of one strip type and 10 of the other strip type). The inputs for number of strips and width of strips must be coordinated to ensure that the relative portion of the flow path occupied by each strip type is maintained.

A RUSLE2 template that includes the profile schematic illustrated in Figure 8.1 must be used to apply this procedure. This template allows non-uniform segment lengths. Also, strips are not constrained to be on the contour.

HOWEVER, CARE SHOULD BE TAKEN IN APPLYING RUSLE2 TO STRIPS. THE POSSIBILITY OF RUNOFF RUNNING ALONG THE UPPER EDGE OF HIGH RETARDANCE STRIPS BELOW ERODIBLE AREAS MUST BE CONSIDERED.

9.2.2.6. What to do when RUSLE2 computes a ground cover value that is not the expected value

Ground cover is a key variable used in conservation and erosion control planning and in determining whether a conservation or erosion control plan has been properly implemented. Residue ground cover immediately after planting is often the key value for conservation planning on cropland. RUSLE2 is expected to provide a good estimate of this ground cover value. The acceptability of RUSLE2 is sometimes judged on the basis of this value. Comparisons are made between the RUSLE2 estimated residue cover values with research data, site-specific field measurements, and professional judgment. This section provides guidance on making these comparisons and how to adjust RUSLE2 inputs if ground cover estimates do not meet expectations.

Several factors must be considered in comparing RUSLE2 residue ground cover values with field observations. RUSLE2 computes “typical,” average annual daily residue cover values rather than residue cover at any specific time. Residue cover values measured at a particular site vary greatly from year to year, requiring at least three years of data where a range of production (yield) levels and weather conditions occurred to obtain measured values comparable to RUSLE2 estimates. Also, residue cover varies greatly from location to location within a field site requiring numerous measurements at a site depending on the measurement procedure (e.g., a beaded string versus photographs of a meter (yard) square area).

Great care must be taken in measuring residue cover when the cover is spatially non-uniform in strips and patches to ensure that the sample density is sufficient when measuring residue cover using the bead-string or similar method, especially if the strips are narrow and residue cover is heavy in one strip type. In fact, the best way to measure residue cover for this condition is to use transects within each strip type rather than diagonally across strips and weight the values based on area represented by each strip type.

The RUSLE2 mass-cover and erosion equations are highly nonlinear. As a consequence, using residue cover averaged over the entire area to estimate erosion with RUSLE2 likely will not give the same result as that obtained when the spatially non-uniform cover is analyzed using segments as described in **Section 9.2.2.5**. Remember, the purpose of RUSLE2 is to serve as a tool to guide conservation and erosion control planning rather than being a scientific tool.

The error in residue cover measurements can be large for residue cover less than about 20 percent. Sometimes residue mass is estimated based on field measurements of residue cover percent converted to a mass using curves like those in Figure 9.5. The error in mass can be large, sometimes by as much as a factor of two, for residue cover values greater than 75 percent. The residue mass can change by a large amount with only a small change in ground cover because of the flatness of the mass-cover curve at high cover values. Also, the data used to develop curves like those in Figure 9.5 are highly variable based on the relative portion of leaves to stems and other factors.

Very carefully compare the values determined from site-specific field measurements with values in the **core database** and values reported in the literature. Ask the question, “Are the field measured values consistent with commonly accepted values and reasonable when the data as a whole are considered? If the measured values differ significantly from other values, can the differences be reasonably explained?”

Getting a good comparison between the RUSLE2 residue cover estimate and a measured value at a particular point in time, such as immediately before harvest, does not ensure a good average annual erosion estimate. The best average annual erosion is obtained from a good estimate of residue cover over the two to three month period during the most erodible part of the year. The most erodible period is determined by a combination of peak erosivity and peak susceptibility of the field condition to erosion. RUSLE2 templates that display erosion through time can be used to identify the most erodible period.

RUSLE2 was constructed and calibrated, and values in the core database were carefully chosen to ensure that RUSLE2 produces average annual erosion estimates consistent with commonly accepted erosion scientific knowledge and the uncertainty in the research erosion measurements (see **Section 17** for a discussion of the uncertainty in erosion data and RUSLE2 erosion estimates). RUSLE2 was developed to capture main effects rather than secondary variability, which often reflects statistically unexplained viability. Thus, fitting RUSLE2 to data from a specific research study or measurements made at a specific field site often does not improve RUSLE2 estimates and in fact may degrade the quality of estimates. Residue cover can vary greatly from year to year as yield and weather vary.

Don't make changes just to get a better fit to local conditions. Always compare against a broad data set. Look at RUSLE2 estimates as representing main effects and typical conditions in a conservation planning context, not in a research context. Make sure that data being fitted are high quality, and collect as much supplemental data as possible, including yield, residue mass, and how residue cover varies during the year.

ALWAYS CHECK RUSLE2'S ESTIMATED EROSION. CHANGING INPUTS THAT AFFECT RESIDUE COVER ALSO AFECTS OTHER RUSLE2 COMPUTATIONS. DO NOT AUTOMATICALLY ASSUME THAT A RESIDUE COVER VALUE AT A PARTICULARLY TIME, SUCH AS IMMEDIATELY AFTER PLANTING OR BEFORE HARVEST, CORRECTLY COMPUTED BY RUSLE2 ENSURES A CORRECT AVERAGE ANNUAL EROSION ESTIMATE.

If one concludes that RUSLE2 is not computing the desired residue cover values, how does one change input values to obtain the desired residue cover values? The main factors that affect residue cover must be considered in a systematic, stepwise manner. The factors that affect residue cover affect many other RUSLE2 computations. Adjusting a particular RUSLE2 input may give the expected residue cover but adversely affect the RUSLE2 erosion estimate because other RUSLE2 computations were affected. The main variables to consider and the order to consider them are: (1) the amount of residue at harvest, (2) the distribution between standing and flat residue at harvest, (3) the mass-ground cover relationship, (4) values for the burial and resurfacing ratios of the operations, and (5) the decomposition half life (coefficient) value. Estimated residue cover and erosion values should be checked at each step. Sometimes changing a particular variable gives unexpected results. For example, changing the value for the decomposition half life affects not only ground cover, but standing residue, buried residue, and dead roots as well.

9.2.3. Soil (Surface) Roughness

Soil (surface) roughness, illustrated in Figure 9.6, refers to the random peaks and depressions left by soil disturbing operations. This random roughness does not affect general overland flow direction in contrast to oriented roughness (ridges and furrows) that redirects runoff. Roughness characteristics at the time that the roughness is created depend on soil disturbing operation that creates the roughness, soil properties including texture and soil moisture, live vegetation, standing and flat residue, and soil biomass. Different types of soil disturbing operations produce widely differing distributions of aggregates and clod sizes depending on soil conditions, which affect roughness. Surface roughness decays over time to a smooth surface, except for a few persistent clods on some soils.

Figure 9.6. Soil surface with a 1.0 inch roughness just created by a mechanical disturbance.

9.2.3.1. Soil (surface) roughness effect

Soil surface roughness affects erosion in several ways. The depressions formed by surface roughness pond water and slow runoff, which reduce the erosivity of raindrops, waterdrops falling from vegetation, and surface runoff. Runoff's transport capacity through the depressions is very low, which causes local deposition. Soil surface roughness decays over time as deposition fills the depressions with sediment, interrill erosion wears away the roughness peaks, and the presence of water and weathering cause the soil to subside.

Soil clods resistant to detachment primarily form the roughness illustrated in Figure 9.6. Surface roughness is a partial measure of clodiness left by a soil disturbance. Large clods also produce deep depressions. Fine soil particles produced during the creation of the roughness are often left in the depressions where they are protected from erosion. Thus, erodibility of a rough soil surface is less than that of a smooth, finely pulverized soil surface. The degree that a soil forms clods depends on soil texture and soil moisture at the time of the soil disturbance. RUSLE2 does not consider the effect of soil moisture on soil roughness, mainly because RUSLE2 is an average annual model. Clods are smaller and less stable for coarse textured soils than for fine textured soils (see **Section 7.4**).

Soil surface roughness increases infiltration, which reduces runoff. Also, cloddy, rough soils resist sealing and crusting in comparison to finely pulverized soils that readily seal and crust, especially if soil biomass is low. Thus, rough soils reduce erosion because of decreased runoff.

RUSLE2 considers a **short term roughness** and a **long term roughness**. Short term roughness is created by tillage equipment, earth moving machines, and similar operations that mechanically disturb the soil. Long term roughness evolves over time after the last mechanical soil disturbance on pasture, range, landfills, and reclaimed land. Long term roughness is related to vegetation type (bunch versus sod forming), plant roots near the soil surface, local erosion and deposition by both water and wind, and animal traffic. RUSLE2 simultaneously keeps track of the decay of short term roughness and the natural development of long term roughness over the **time to soil consolidation** (see **Section 7.8**). Daily short term roughness decay is computed as a function of daily precipitation and daily interrill erosion. The effect of soil conditions at any point in time is captured by the effect of soil conditions on the initial roughness discussed in Section 9.2.3.3. Long term roughness is computed as a function of time and the final roughness roughness value that is a user input.

9.2.3.2. Roughness measure

RUSLE2 uses a roughness index that is the standard deviation of the micro-surface elevations about the mean elevation as a measure of soil surface roughness. Machines like scarifiers, moldboard plows, and heavy offset disks create rough soil surfaces [e.g., R_m > 1.5 inch (35 mm), R_m = field measured roughness value] while machines like rotary tillers pulverize the soil and leave a smooth soil surface [e.g., R_m < 0.2 in (5 mm)]. Machines, like bulldozers and road graders having blades that cut the soil also leave a smooth surface with a low roughness value.

The method of laying a roller chain on the soil surface and estimating roughness by how much the horizontal measurement between the ends of the chain is shorter than the chain length should not be used to measure roughness for RUSLE2. This procedure does not capture all roughness features important in RUSLE2.

Micro-relief meters are used in research to measure surface roughness. These meters measure micro-surface elevations over a grid by lowering pins to the soil surface or by using a laser system.[67] Because roughness index values depend on grid spacing, a standard spacing of 1 inch (25 mm) should be used to determine roughness index values for RUSLE2. Also, a plane should be fitted to the elevation data, and deviations taken

[67] Toy, T.J., G.R. Foster, and K.G. Renard. 2002. Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley and Son, New York, NY.

with respect to the plane to remove the effects of land slope. Also, the effect of ridges (oriented roughness) should be avoided or taken out of the data by analysis as well.

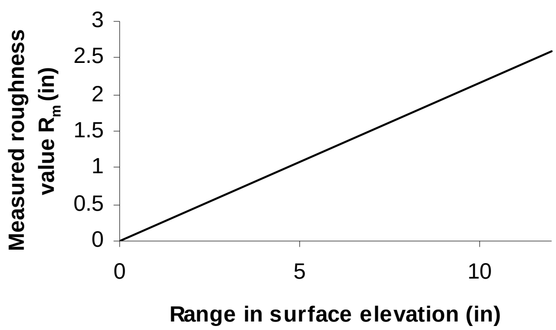

Figure 9.7. Relation of measured surface roughness value to range in elevation from highest roughness peak to deepest depression

Figure 9.7 provides an approximate estimate of surface roughness if a micro-relief meter is not available. The range in surface elevation from the highest roughness peak to the bottom of the deepest depression is measured by laying a 6 ft (2 m) straight edge across the roughness peaks.[68] A third approach for estimating surface roughness is to compare the appearance of the soil surface with photographs for soil surfaces having measured roughness values.[69]

Roughness values used in *operation descriptions* in the *operation component* of the RUSLE2 database are selected from the core database, not from field measurements at the site where RUSLE2 is being applied.

9.2.3.3. Soil surface roughness subfactor

Values for the RUSLE2 soil surface roughness subfactor are computed from:

$$s_r = \exp[-0.66(R_a - 0.24)] \qquad [9.10]$$

where: R_a = adjusted roughness value (inches) and 0.24 inches (6 mm) = the adjusted roughness value assigned to unit plot conditions (see **Section 7.2** for a description of unit plot conditions). The value for the roughness subfactor for the unit plot conditions is 1 by definition. Roughness subfactor values are less than 1 when the surface roughness effect of the site-specific condition is greater than on the unit plot and greater than 1 when the site-specific surface roughness effect is less than on the unit plot. An example of a soil surface that is smoother than the unit plot is a soil finely tilled with a rotary tiller for vegetable seeding. A soil surface with an adjusted roughness greater than the 0.24 in (6 mm) of the unit has roughness subfactor values less than 1. Roughness subfactor

[68] See Figure C-10, AH703 for details.
[69] See AH703.

values can range from almost 1.2 for a perfectly smooth surface to lower than 0.3 for an exceptionally rough surface as illustrated in Figure 9.8.

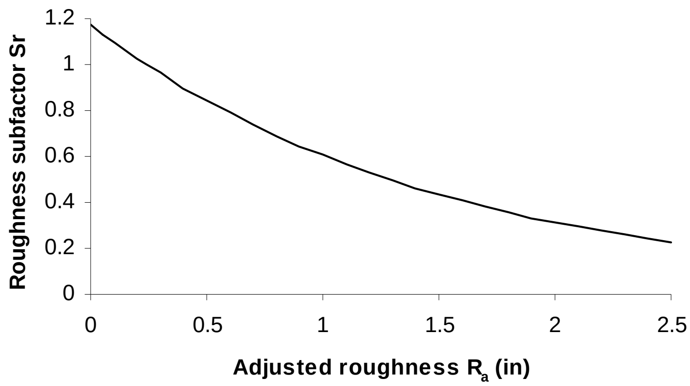

Figure 9.8. Relation of roughness subfactor to adjusted roughness

Computation of the adjusted roughness R_a starts with the initial base R_{ib} roughness assigned to **operation descriptions** having a **disturb soil process** in the **operations component** of the RUSLE2 database. The **initial base roughness** is assigned according to the roughness that the operation would produce for a smooth silt loam soil having a high soil biomass similar to a soil with a dense sod grass cover.

The input roughness value assigned to an operation is the roughness that the operation would create on a silt loam soil where the soil biomass is very high.

The first step in computing an adjusted roughness value to use in equation 9.10 is to adjust the initial roughness value R_{ib} for the effect of soil texture by multiplying by a soil texture adjustment factor. Soil texture adjustment factor values computed with the RUSLE2 equations for the midpoint of the soil texture classes are shown in Table 9.2.

The roughness adjustment factor is greater for high clay soils than for high sand soils. Consequently, RUSLE2 uses a higher roughness value for high clay soils than for high sand soils for a given initial (input) base roughness values, which means that soil surface roughness reduces erosion more on high clay soils than on high sand soils for a given operation. The adjustment factor for a silt loam soil is 1.0 because it is the base condition.[70]

The next adjustment is for soil biomass computed with:

$$R_a = 0.24 + (R_{it} - 0.24)\{0.8[1 - \exp(-0.0015B_{ta})] + 0.2\} \qquad [9.11]$$

70 The difference between 1.0 and the 1.02 value in Table 9.1 results from rounding and not being able to fit the equation to exactly 1.0 for the mid-point of the silt loam texture.

where: R_{it} (inches) = the initial (input) roughness adjusted for soil texture and B_{ta} = the total mass (dry weight basis) of buried residue and dead roots averaged over the soil disturbance depth after the operation (lbs/acre per inch depth). Figure 9.9 illustrates how the input roughness value is adjusted for soil biomass for a range of input roughness values.

Table 9.2. Factor to adjust input roughness as a function of soil texture

Soil texture class	Adjustment factor
clay	1.39
clay loam	1.22
loam	1.05
loamy sand	0.78
sand	0.69
sandy clay	1.25
sandy clay loam	1.13
sandy loam	0.90
silt	0.81
silt loam	1.02
silty clay	1.33
silty clay loam	1.23

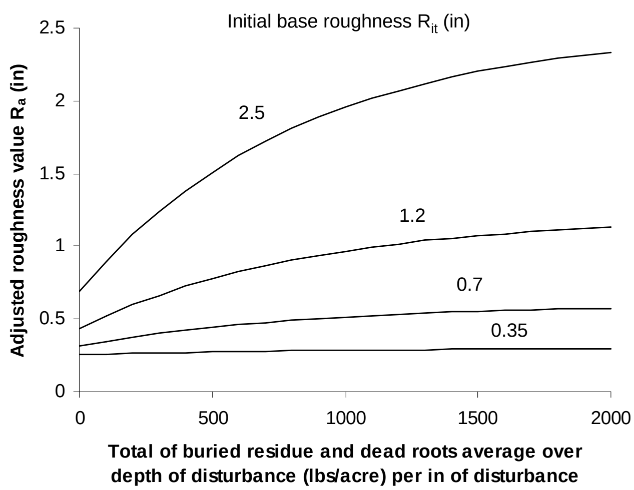

Figure 9.9. Roughness value adjusted from input value for soil biomass effect.

The effect of soil biomass on roughness can be observed in the field by comparing roughness after sod field is plowed with the roughness after a field in continuous low residue vegetable cropping is plowed. The difference in roughness can also be observed when a permanent grass strip beside a continuously cropped field is plowed. Soil surface roughness is much larger on the sod field and grass strip than on the continuously cropped fields having much lower biomass than the sod and grass conditions. The soil plowed out of sod turns up in "chunks" as if it is held together by roots. A similar effect occurs in chisel plowed wheat stubble fields.

The effect of roughness in a sod, meadow, and hay fields on erosion is very significant. According to Table 5-D, AH537[71] erosion immediately after moldboard plowing a high biomass condition is one fourth of that immediately after moldboard plowing a continuous row cropped field where biomass is reduced. The biomass effect on erosion depends on the sod, meadow, or hay production (yield) level, which determines the biomass of roots and buried residue. The roughness effect for moldboard plowing in a continuous cropped corn is also a function of yield as illustrated in Table 5, AH537. For example, the roughness subfactor value is about 0.55 for a 110 bu/ac yield and about 0.75 for a 50 bu/ac yield. A roughness related to biomass effect is also illustrated in Table 5,

[71] Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall-erosion losses: A guide to conservation planning. U.S. Dept. of Agriculture, Agriculture Handbook # 537.

AH537 where the residue is removed, which reduces soil biomass. For example, the soil surface roughness subfactor is about 0.90 where the residue is removed for a 110 bu/acre corn yield while it is about 0.55 where the residue is not removed. The values in Tables 5 and 5-D, AH537 are based on measured soil loss data. Another illustration of how soil biomass affects the soil surface roughness is that a soil surface is noticeably smoother after tillage following soybeans than tillage following corn.

When roughness data from field research are analyzed to develop input roughness values for RUSLE2, field measured roughness R_m values must be adjusted for soil texture using Table 9.2 and for soil biomass using Figure 9.10. The best approach is to make roughness measurements under high soil biomass conditions to minimize the amount of adjustment required for biomass. As illustrated in Figure 9.10, biomass does not have much effect on the soil surface roughness value for soil biomass values (buried residue plus dead roots) greater than about 1000 lbs/acre per inch depth of disturbance.

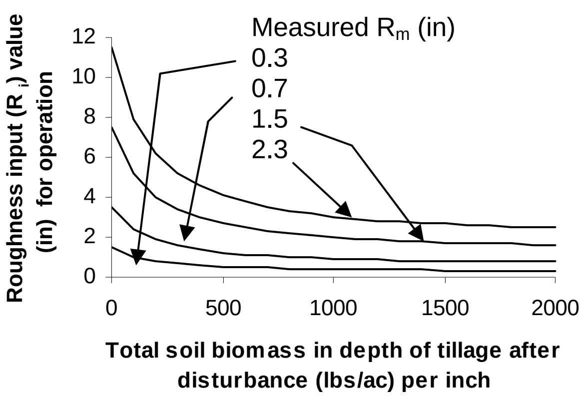

Figure 9.10. Conversion of a measured roughness value (R_m) to a roughness input value (R_i) (silt loam soil)

Roughness measurements made with yields of 200 bu/acre corn, 70 bu/acre wheat, and 4 tons/acre on hay or pasture land are conditions where measured roughness values need little if any adjustment for soil biomass.

The following example illustrates how to use Figure 9.10 to adjust a measured roughness value for biomass. Assume that the measured roughness is 1.5 inches (40 mm) and the average soil biomass is 500 lb/ac per inch depth of disturbance after the operation. A value of about 3.2 in (80 mm) is read from Figure 9.10, which would be the input roughness value for the operation that produced this roughness on a silt loam soil.

The input roughness values in the **operation descriptions** in the **operation component** of the RUSLE2 database are greater than are typically measured in the field because of the biomass effect. Roughness values computed by RUSLE2, rather than input values, should be compared to measured roughness values. Even then, field measured roughness values may not match those computed by RUSLE2. As described in **Section 9.2.3.1,** the RUSLE2 soil surface roughness subfactor captures more than just the physical effect of roughness geometry on soil loss. It also captures the effect of soil management as represented by soil biomass on aggregate size distribution and stability and their effect on infiltration and erodibility. The roughness input value and the roughness subfactor have been developed together to reflect these effects. Priority is given to capturing these effects rather than reproducing roughness values that can be measured in the field.

Perhaps more than any other RUSLE2 variable, roughness values from the *core database* should be used rather than using roughness values measured at the specific site specific for input into RUSLE2.

9.2.3.4. Effect of existing roughness (tillage intensity effect)

The input roughness values represent the roughness that a particular operation creates when used on a smooth soil surface of silt loam texture and having high soil biomass as discussed in **Section 9.2.3.3.** The field roughness left by an operation depends on the roughness existing at the time of the operation. For example, the roughness left by a spike tooth harrow following a moldboard plow is much greater than the roughness left by the spike tooth harrow following a tandem disk. The spike tooth harrow has relatively little effect on roughness such that the roughness left by the harrow strongly depends on the existing roughness at the time of the operation. The roughness is only slightly greater when a tandem disk follows a moldboard plow than when it follows another tandem disk. The roughness following a moldboard plow is independent of existing roughness.

The influence of existing roughness is represented by the **tillage intensity** variable in RUSLE2. A soil disturbing operation where existing roughness has no effect on the roughness created by the operation is assigned a tillage intensity of 1. That is, the operation "wipes" out all effects of the existing roughness. Operations are assigned a tillage intensity less than 1 based on the degree that the roughness left by an operation is influenced by existing roughness at the time of the operation. For example, tillage intensity values of 0.4, 0.75, and 1 are assigned to spike harrows, tandem disks, and moldboard plows, respectively.[72]

A tillage intensity of 0.4 means that the operation converts 40 percent of the existing roughness to the operation's assigned roughness and leaves 60 percent of the existing roughness. A tillage intensity of 1 means that that 100 percent of the existing roughness

[72] RUSLE1 does not use a tillage intensity effect. RUSLE1 uses an absolute concept where an operation is assumed to create a particular roughness regardless of the existing roughness. That is, the roughness following a spike tooth harrow in RUSLE1 is the same regardless of whether the harrow follows a moldboard plow or a tandem disk. Input roughness values are the same for RUSLE1 and RUSLE2 for operations where the tillage intensity is 1. However, input roughness values for operations where tillage intensity is less than 1 are smaller in RUSLE2 than in RUSLE1 to achieve comparable roughness values in both models. However, the two models can not compute the same roughness values for all situations because of the tillage intensity factor effect.

is "wiped out," and the resulting roughness is 100 percent of the operation's assigned roughness.

Tillage intensity does not indicate the roughness left by an operation performed on a smooth surface. Soil disturbing operations like moldboard plows and heavy offset disks are assigned 1 for tillage intensity and leave a very rough surface. In contrast, a rotary tiller is also assigned 1 for tillage intensity value but leaves a very smooth surface. The key factor in both cases is that existing roughness has no effect on the resulting roughness, which is the basis for assigning a tillage intensity value of 1, not the roughness left by the operation.

If existing roughness is less than that created by an operation on a smooth soil surface, the surface roughness computed by RUSLE2 is not affected by the tillage intensity factor.

9.2.3.5. How RUSLE2 handles roughness when soil disturbance is in strips

Some operations like strip tillage, manure injection, and planting only disturb a portion of the soil surface. **The input roughness base value for these operations applies only to the portion of the soil surface that is disturbed.** RUSLE2 does not average the roughness values for the disturbed and undisturbed portions to determine an average roughness value because of non-linearity in equation 9.10 used to compute the roughness subfactor value. Instead RUSLE2 computes a roughness subfactor value using equation 9.10 for each strip (disturbed and undisturbed) and computes a composite roughness subfactor value based on the portion of the surface disturbed by the operation. This composite roughness subfactor value is used in a rearrangement of equation 9.10 to compute an effective roughness value for the entire surface. This effective roughness is then decayed based on rainfall amount and interrill erosion as described in **Section 9.2.3.7.**

The approach used to handle roughness with strips differs from the way that ground cover in strips is handled. Input roughness values only apply to the portion disturbed whereas input values for flattening, burial, and resurfacing ratios apply to the entire area.

9.2.3.6. Assigning roughness values

Input roughness base values for soil disturbing operations are assigned by selecting a value from the RUSLE2 "core database" by comparing characteristics of an operation with characteristics of operations in the "core database." Basing input values on the "core database" values helps ensure consistency between RUSLE2 applications. Consult the research literature if no operations are in the "core database" that are sufficiently close to your operation,. Use the largest possible database to estimate input roughness values and apply the adjustment procedures described in **Section 9.2.3.3.** Make sure that field measurements were carefully made and that sufficient measurements were taken to deal with spatial and temporal variability.

Field measurements should not be made at the specific site where RUSLE2 is being applied to determine an input roughness value for RUSLE2. Rather, values based on the RUSLE2 core database should be used.

9.2.3.7. Roughness decay

RUSLE2 decays the adjusted roughness, R_a in equation 9.10, each day based on daily precipitation and interrill erosion. About 40 percent of the roughness decay is by rapid subsidence and the remainder is by interrill erosion. Precipitation amount is used to compute the rapid subsidence of roughness that is assumed to be caused by soil wetting. Roughness decay by interrill erosion represents impacting waterdrops wearing away soil peaks and filling depressions with sediment. Interrill erosion is computed using the terms in the denominator of equation 8.3. The result is that roughness persists longer in dry climates than in wet climates and longer when the soil is protected from interrill erosion than when the soil is exposed to raindrop impact.

Roughness decays over time to a "final" roughness that is entered as an input for each **operation description** having a **disturb soil process** (see **Section 13.1.5**). A value of 0.24 inches (6 mm) is typically used for **final roughness** to represent the long term persistence of a few exceptionally stable soil clods. Although the final roughness value would seem to be a function of soil texture, a value of 0.24 inches (6 mm) is used for all soils. The reason for applying the 0.24 in (6 mm) value to all soils is to compute a surface roughness subfactor value of 1 for the unit plot condition for all soils when all roughness has decayed.

The expectation is that the final roughness value should be higher for high clay soils where clods persist than for sand soils that have no clods. However, such an adjustment should not be made because that effect is empirically considered in the K factor value.

However, an input final roughness other than 0.24 inches (6 mm) is used in RUSLE2 to represent conditions where an operation leaves the soil smoother than the unit plot condition. For example, rotary tiller and blading operations leave a smoother soil surface than exists for unit plot conditions. When a **final roughness** value less than 0.24 in (6 mm) is entered, an **initial roughness** value equal to the **final roughness** value must be entered. RUSLE2 does not compute a change in roughness when the final roughness value is less than 0.24 inches (6 mm). Also, if the input initial roughness is greater than 0.24 inches (6 mm) and the input final roughness is less than 0.24 inches (6 mm), RUSLE2 will not decay the roughness to less than 0.24 inches (6 mm).

The rate of roughness decay is not a function of soil conditions in RUSLE2. RUSLE2 captures the effect of soil conditions on roughness at any time by making the initial roughness a function of soil conditions.

9.2.3.8. Long term roughness

As described in **Section 9.2.3.1**, RUSLE2 computes a long term development of soil roughness to an input natural roughness value. The development of long term roughness is assumed to be directly proportional to the soil consolidation subfactor value. The starting point for the development of long term roughness is 0.24 inches (6 mm). Long term roughness is reset to this value each time a soil disturbing operation occurs. If only a portion of the soil surface is disturbed, a weighted value for the long term roughness is computed as described in **Section 9.2.3.5.**

9.2.3.9. Overriding RUSLE2 roughness values

Sometimes the way that RUSLE2 computes roughness needs to be overridden for research purposes. Set the initial and final input roughness values to the same value and RUSLE2 will use this roughness value in equation 9.10 to compute roughness subfactor values. This procedure can be used in RUSLE2 so that RUSLE2 can use measured roughness values directly in its computations. However, RUSLE2 does not compute roughness decay when this procedure is used.

The adjustments that RUSLE2 makes for soil texture and soil biomass can not be easily overridden while retaining the RUSLE2 procedure for computing roughness decay. The only approach that can be used is to adjust RUSLE2 input values until RUSLE2 computes adjusted roughness values that correspond to the measured field values. A special template must be obtained to display the adjusted roughness values.

The proper approach for applying RUSLE2 in conservation and erosion control planning is to use roughness values from the core database and allow RUSLE2 to make its adjustments for soil texture and soil biomass rather than attempt to use field measured roughness values.

9.2.4. Ridges

Ridges affect soil erosion in two ways. One effect is on sediment production, which is discussed in this section, and the other effect is runoff flow direction, which is discussed in **Section 14.1**. Ridges, and the furrows that separate them, are referred to as oriented roughness because they redirect runoff from a direct, downslope direction (perpendicular to the contour) when the ridges are oriented in direction besides directly up and down slope. Orienting ridges parallel with the contour is an important conservation (support) practice known as contouring that can significantly reduce soil loss if the ridges are sufficiently high.

9.2.4.1. Ridge subfactor effect

The ridge subfactor describes how ridges affect sediment production by increased interrill erosion on steep ridge sideslopes. Erosion can be as much as twice that from a level soil surface for land slopes up to 6 percent.[73] The increase in soil loss caused by ridges is related to ridge sideslope steepness where interrill erosion increases according to $3s^{0.8}+0.56$ where s_i = sine of the ridge sideslope angle. This equation computes interrill erosion from a 30 percent steep ridge sideslope that is about three times the interrill erosion from a flat, level soil surface. Even when land slope is flat, the local ridge sideslope can be very steep, such as 30 percent so that interrill erosion is very high on the ridge sideslope.[74]

Figure 9.11. Ridge subfactor values as a function of ridge height for land slopes less

Figure 9.11 shows RUSLE2 ridge subfactor values as a function of ridge height when the land slope is less than 6 percent and the ridges are oriented up and down hill. Ridge height is used to represent ridge sideslope steepness because ridge height values can be easily visualized and measured for ridge forming operations. Using ridge sideslope steepness in RUSLE2 would require that a value for ridge spacing be entered, which is not always available, in addition to a ridge height value. Also, more ridges are often present than is often recognized. For example, the ridge spacing assumed for row crops is often the spacing of the rows. However, the planter may leave several small, but very important ridges besides the ridges directly associated with the

[73] Young, R.A. and C. K. Mutchler. 1969. Soil and water movement in small tillage channels. Trans. ASAE. 12(4):543-545. Also, personal communication with K.C. McGregor and C.K. Mutchler, USDA-Agricultural Research Service, National Sedimentation Laboratory, Oxford, MS.

[74] RUSLE1 does not include a ridge sufactor. RUSLE2 can compute up to twice the erosion for high ridges on slope less than six percent than that computed by RUSLE1.

plants. Determining ridge height is much easier for construction machines like scarifiers and bulldozer treads than determining ridge spacing.

A value of 1 corresponds to the ridge subfactor value for a unit plot. The unit plot condition based on being tilled up and down slope with a harrow is assumed to have a 1 inch (25 mm) ridge height. Thus, values for the ridge height subfactor as less than 1 for ridge heights less than 1 inch (25 mm) because of the unit plot condition being the reference in RUSLE2 and the unit plot having a 1 inch (25 mm) ridge.

The effect of ridges on sediment production diminishes in RUSLE2 as land slope steepness increases above 6 percent because the local steepness of the ridges becomes almost equal to the land slope at steepness above 30 percent. For example, the local steepness of the ridge sideslopes is 42 percent when the ridge sideslope is 30 percent and the land slope is 30 percent. Figure 9.12 shows ridge subfactor values as landslope increases above six percent. As illustrated, ridge subfactor values converge to 1 at steep land slopes. The values in Figure 9.11 were derived from experimental data while the values in Figure 9.12 were derived from a simple rill-interrill erosion model where rill erosion varies linearly with land slope steepness and interrill erosion with $3s^{0.8}+0.56$.

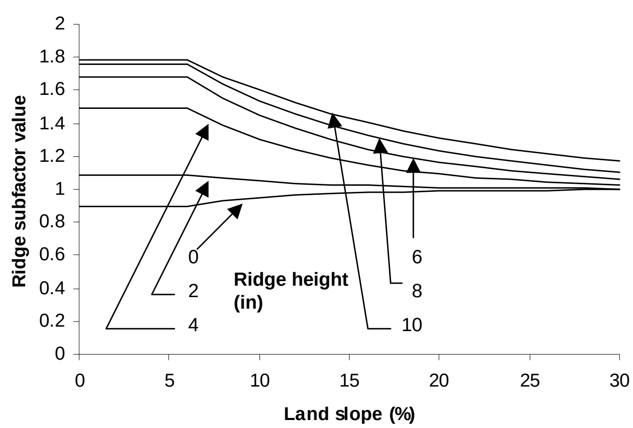

Figure 9.12. Ridge subfactor values as a function of ridge height and land slope steepness

9.2.4.2. Effect of ridge orientation on ridge subfactor

The ridge subfactor values in Figures 9.11 and 9.12 apply when ridges are oriented up and down slope. When the ridges are oriented on a direction different from up and down slope, ridge subfactor values decrease to 1 as ridge orientation approaches the contour. The relationship used to adjust ridge subfactor values as a function of ridge orientation (row grade) is shown in Figure 9.13. This relationship is a mirror image of Figure 14.3, the one used to adjust contouring factor values for ridge orientation, which is discussed in **Section 14.1**. The net effect of ridges is a composite of Figure 9.13 and Figure 14.3.

The need for Figure 9.13 seems questionable. Why does ridge orientation with respect the land slope affect sediment production? It doesn't. The reason for these adjustments is related to the empirical structure of RUSLE2 and constructing RUSLE2 so that it gives the expected erosion values with contouring.

9.2.4.3. Ridge formation and decay

Ridges are described in RUSLE2 by using a **soil disturbing operation**. An input ridge height value is entered in the **operation** component of the **RUSLE2 database** for each soil disturbing operation. This input value is the "typical" (representative) ridge height created by the operation. A "typical" ridge height is used because ridge height can vary with soil and cover-management condition, factors not considered in RUSLE2 in contrast to random roughness that RUSLE2 computes as a function of soil texture and soil biomass. The assumption is that ridge height is far more controlled by the physical mechanics of the operation than by soil conditions. Operations having different ridge heights for different soil conditions can be created for RUSLE2 to compute how ridge height affected by soil condition affects erosion.

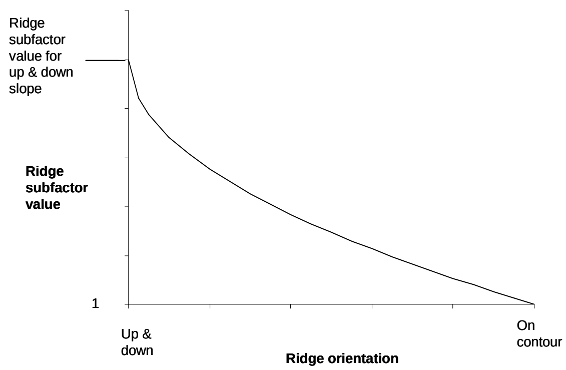

Figure 9.13. Effect of ridge orientation (row grade) on ridge subfactor

RUSLE2 computes a daily decay of ridge height as a function of daily precipitation and interrill erosion. The decay in ridge height by precipitation is independent of soil and cover-management conditions. The decay of ridge height by interrill erosion depends on rainfall erosivity, canopy cover, and ground cover. About 40 percent of the ridge height decay is from precipitation, which represents how the presence of water causes soil settlement. The remainder is from interrill erosion, which represents the wearing away of the ridge by raindrop impact.

The only way that ridges exist in RUSLE2 is to create them with a soil disturbing operation.

9.2.4.4 Assignment of input ridge height values

RUSLE2 input values for ridge height for an operation should be selected by comparing the characteristic of the operation with operations having ridge height values assigned in the RUSLE2 "core database." Ridge heights should not be selected based on field measurements. Ridge heights should be assigned very carefully to ensure consistency. Keep in mind that ridge heights affect both sediment production and contouring on erosion. Ridge height values in the RUSLE2 **core database** were selected very carefully to ensure that RUSLE2 computes the proper contouring effect. The tendency is to assign ridge height values that are too low and then be surprised that RUSLE2 computes too little contouring effect. Although RUSLE2 has been constructed to use easily measured field values, ridge heights is a situation where assigning values based on the **core database** gives far better results than can be obtained by entering field measurements of ridge height.

The effectiveness of contouring in RUSLE2 depends on ridge height: no ridge height, no contouring effect. To have a contouring effect, ridges must be present.

9.2.5. Soil biomass

Soil biomass in RUSLE2 includes live and dead roots, buried plant litter and crop residue from vegetation "grown" on-site, and added materials (external residue) that were buried or directly placed in the soil. These materials, including rock added as an "external residue," are assumed to be organic materials that decompose and reduce soil erodibility.

Buried inorganic materials including rock require special consideration. An extremely low value is entered for the decomposition coefficient for materials, such as rock, that do not decompose so that essentially no mass is lost by decomposition. RUSLE2 assumes buried inorganic material has the same effect as buried organic material, which may be too much effect.[75] For example, non-organic materials do not produce compounds that reduce soil erodibility. This problem can be accounted for in RUSLE2 by reducing the amount of inorganic material that is entered as having been added to an amount that has the expected effect on erosion. However, if this adjustment is made, the mass-cover relationships for the inorganic material must be adjusted so that RUSLE2 uses the proper ground cover percent in computing how a surface application of this material would affect erosion.

9.2.5.1. Soil biomass effect

[75] Rock cover entered in the **soil descriptions** in the **soil component** of the RUSLE2 database remains constant and is not subject to burial or decomposition. This rock cover is unaffected by operations in contrast to rock added as an external residue that is manipulated by operations.

Live roots affect soil loss by mechanically holding the soil in place, resisting erosive forces if the roots are exposed, and producing exudates that reduce soil erodibility. Also, live roots are a measure of plant transpiration that reduces soil moisture, which in turn increases infiltration and reduces runoff and soil loss.

When vegetation is "killed" in RUSLE2 by an operation that has a **kill process**, live roots becomes **dead roots** and begin to decompose. The physical presence of dead roots reduces erosion by reducing runoff erosivity if the dead roots are exposed, and dead roots also seem to hold the soil in "clumps" when the soil is mechanically disturbed.[76] Also, dead roots decompose to produce organic compounds that reduce soil erodibility and increase infiltration and reduce runoff.

Exposed **buried residue**[77] acts similar to exposed dead roots by physically reducing runoff's erosive forces applied to the soil, but buried residue does not mechanically hold the soil like roots hold the soil. Residue decomposes and produces organic compounds that reduce soil erodibility and increase infiltration and decrease runoff and erosion. Overall, buried residue is less effective than roots on reducing erosion because buried residue does not mechanically hold the soil in place, and buried residue is not associated with plant transpiration like roots.

Although buried residue occurs in a wide range of sizes and types of vegetative and organic material, the effect of all buried residue is treated the same based on experimental research that compared how crop residue, "green" manure, compost, animal manure, hardwood litter, and pine needles affected erosion.[78] However, preference is given to fine roots instead of coarse roots when root biomass values are entered in a **vegetation description** in the **vegetation component** of the **RUSLE2 database**. Fine roots have greater surface area per unit mass than coarse roots and often are very close to the soil surface where they have a greater effect on runoff and erosion than coarse roots. Fine roots readily slough and become a part of the soil organic matter pool. Not much of

---

[76] Some of the effect may well be roots mechanically holding the soil together. Another effect is that roots produce compounds that have caused a local increased in soil strength. Another effect is that the soil fractures along lines that expose the roots as if they are holding the soil in place. The fact is clearly obvious that soil roughness is increased with high levels of soil biomass when soil is disturbed.

[77] Buried residue is RUSLE2 nomenclature for organic material in the soil that affects soil loss that has been buried or placed in the soil by an operation. Buried residue also includes non-organic material in the soil, but this material requires special considerations.

[78] Browning, F.M., R.A. Norton, A.G. McCall, and F.G. Bell. 1948. Investigations in erosion control and reclamation of eroded land at the Missouri Valley Loess Conservation Experiment Station, Clarinda, Iowa, 1931-42. USDA Technical Bulletin 959.

Copley, T.L., L.A. Forrest, A.G. McCall, and F.G. Bell. 1944. Investigations in erosion control and reclamation of eroded land at the Central Piedmont Conservation Experiment Station, Statesville, North Carolina, 1930-40. USDA Technical Bulletin 873.

Hays, O.E., A.G. McCall, and F.G. Bell. 1949. Investigations in erosion control and reclamation of eroded land at the Upper Mississippi Valley Conservation Experiment Station near LaCrosse, Wisconsin, 1933-43. USDA-Technical Bulletin 973.

the mass of coarse roots is entered for root biomass because coarse roots are assumed to have relatively little effect on erosion.

9.2.5.2. Soil biomass subfactor

Equation 9.12 is used in RUSLE2 to compute values for the soil biomass subfactor.

$$s_b = c_b \exp(-0.0026 B_{rt} - 0.00066 B_{rs} / s_c^{0.5}) \qquad [9.12]$$

where: s_b = soil biomass subfactor, c_b = 0.951,[79] B_{rt} = the sum of the live and dead root biomass averaged over a 10 inch (250 mm) depth (lbs/acre per inch of depth), B_{rs} = the amount of buried residue averaged over a depth that linearly ranges from 3 inches (75 mm) if the soil is not consolidated (i.e., c_s = 1) to 1 inch (25 mm) if the soil is fully consolidated (i.e., s_c = 0.45), and s_c = the soil consolidation subfactor (see **Sections 7.8 and 9.2.6** for discussion of the soil consolidation subfactor). The coefficients 0.0026 for root biomass B_{rt} and 0.00066 for buried residue B_{rs} are multiplied by 1.65 for Req applications. Most of the erosion in Req situations is assumed to be caused by rill erosion. Soil biomass has a much greater effect on rill erosion than on interrill erosion.

All soil biomass variables are on a dry weight basis.

Equation 9.12 was empirically derived by fitting it to soil loss ratio values for the seedbed crop stage period[80] in Table 5 and accompanying tables in AH537.[81] These soil loss ratio values were for a wide range of soil biomass and soil consolidation conditions, including pasture and hay lands; no-till and reduced-till forms of conservation tillage for corn grain; and conventional clean-till corn grain, corn silage, soybean, and wheat cropping over a range of yields. Also, soil loss data on the effect of incorporation of green manure, animal manure, compost, hardwood litter, and pine needles into the soil were analyzed. Erosion data from rainfall simulator studies were used to determine values for effective root biomass for rangeland (see **Section 17.4.1.4**).

---

79 Equation 9.12 also has a second part for very low soil biomass where c_b increases from 0.95 to 1 so that the soil biomass subfactor equals 1 when no soil biomass is present.

80 Soil loss ratio values in AH537 are the ratio of soil loss with a given cover-management system at a particular crop stage period to soil loss from the unit plot for the same crop stage. The seedbed crop stage period is when the soil has been tilled to prepare a relatively smooth surface for seeding a crop so that the major effect is from soil biomass.

81 The soil loss ratio values in AH537, except for conservation tillage and "undisturbed" land, are a summary of field measured soil loss for more than 10,000 plot-years of data. Erosion data are quite variable for unexplained reasons. Also, the length of record often varied between studies and locations, and the number of treatments and replications and other variables differed between locations, which prevents the data from being analyzed by common statistical procedures. Instead, the data must be analyzed and interpreted for main effects, which was expertly done by W.H. Wischmeier and D.D. Smith in AH537. The soil loss ratio values in AH537 are the most comprehensive available by far for calibrating RUSLE2 and are much better for calibrating and validating RUSLE2 than the original soil loss data.

The 10-inch (250 mm) depth over which root biomass is averaged was the best of several depths analyzed. A 3-inch (75 mm) depth over which buried residue is averaged also was the best of several depths analyzed. This 3 inches (75 mm) depth is linearly reduced in RUSLE2 to 1 inch (25 mm) as the soil consolidation subfactor c_s decreases from 1 to 0.45 to give increased credit to buried residue B_{rs} in the upper soil layer with no-till cropping and other cover-management systems that leave residue at the soil surface and do not disturb the entire soil surface. A similar feature is the division of the variable buried residue B_{rs} by the square root of the soil consolidation subfactor c_s, which also gives increased credit to buried residue as the soil consolidates. A major advantage of no-till cropping is the accumulation of organic matter in the upper two inches (50 mm) of soil. This layer promotes earthworm burrowing and other processes that decrease runoff and soil erodibility. Tillage and other mechanical soil disturbances disrupt this layer and cause an immediate increase in soil erosion. This zone requires about 5 years to develop in the eastern US, which is consistent with using 7 years for the time to soil consolidation to represent this time.

Soil consolidation refers to lack of soil disturbance and the soil becoming less erodible over time after a soil disturbance rather than the soil necessarily becoming dense.

Table 9.3. Effect of corn yield and tillage system on the soil biomass subfactor at Columbia, MO

	Soil biomass subfactor		
	Type tillage system		
Yield (bu/acre)	Clean till	Reduced till	No till
50	0.78	0.74	0.57
100	0.66	0.60	0.38
200	0.48	0.40	0.16

Table 9.4. Effect of production level of a grass on the soil biomass subfactor

	Soil biomass subfactor		
Yield (lbs/acre)	St. Paul, MN	Columbia, MO	Baton Rouge, LA
1000	0.47	0.51	0.56
2000	0.22	0.27	0.33
4000	0.05	0.08	0.11

Tables 9.3 and 9.4 illustrate values for the soil biomass subfactor for the three corn tillage systems at different yield levels and grass at three production levels. The values for the soil biomass subfactor computed by equation 9.12 decrease as yield increases as illustrated in Table 9.3 because of increased buried residue and live and dead roots. The difference between the clean-till and reduced-till systems is that the reduced-till system leaves additional residue near the soil surface where it has greater effect than residue buried more deeply by the moldboard plow in the clean-till system. The major difference in the no-till system from the other systems is from additional residue near the soil surface and the additional credit given in equation 9.12 for buried residue B_{rs} because of a reduced soil consolidation subfactor c_s. The reduced soil consolidation subfactor has even greater effect in the grass system that has no soil disturbance than in the no-till system where narrow strips are disturbed to plant the seeds. Another factor that reduces the soil

biomass subfactor s_b in the grass system is greater live and dead root biomass at the high grass production level than for the high corn yield. More dead root biomass is produced by root sloughing (death) with the grass than is left after the corn harvest.

The soil biomass subfactor is a function of location as illustrated in Table 9.4 because decomposition of buried residue and dead roots is related to monthly precipitation and temperature, which vary by location. For example, the soil biomass subfactor for the 2000 lbs/acre grass production level is 0.22, 0.27, and 0.33 at St. Paul, MN; Columbia, MO; and Baton Rouge, LA, respectively. Decomposition is much higher at Baton Rouge, LA than at St. Paul, MN because of increased temperature and precipitation, especially during winter at Baton Rouge, LA where temperatures are sufficiently high for significant decomposition to occur. The relative effect of location increases as production level (i.e., biomass level) increases.

Values for the soil biomass subfactor are significant and comparable in magnitude to values for other subfactors. Although ground cover is frequently considered to be the single most important variable in RUSLE2, the soil biomass subfactor can be equally important. Perhaps most important is the total amount of biomass in a cover-management system and how that biomass is distributed between the biomass pools.

All features of cover-management systems should be considered rather than focusing on a single variable such as ground cover as a measure of erosion control effectiveness.

9.2.5.3. How biomass is added to and removed from the soil

9.2.5.3.1. Live root biomass. RUSLE2 obtains values for live root biomass from the **vegetation description** in the **vegetation component** of the RUSLE2 database for the **current vegetation**. A name for a vegetation description is entered for each operation with a **begin growth process** in each **cover-management description** in the RUSLE2 database. RUSLE2 begins to use values for this vegetation description on the date of the operation that contains the begin growth process.

The live root biomass values in a vegetation description are for the upper 4 inches (100 mm), whereas equation 9.12 uses live root biomass values for the upper 10 inches (250 mm). RUSLE2 uses the live root distribution illustrated in Figure 9.14 to compute live root biomass in the upper 10-inch (200 mm) depth from the input values for the 4 in (100 mm) depth.[82] The distribution in Figure 9.14 is used for all vegetations[83] and all time.

[82] RUSLE2 divides the soil into 1-inch (25 mm) layers to account for soil biomass. Depths of disturbance are rounded to the nearest 1-inch (25 mm) so that the depth of disturbance corresponds with the bottom of a soil layer. The number of layers considered in an operation depends on the number of 1-inch (25 mm) in the depth of disturbance. Thus, an operation with a 2-inch disturbance depth only involves two layers. The

Figure 9.14 shows that most of the live root biomass is in the upper 4 inches (100 mm) of soil, which is a major reason for the 4-inch (100 mm) depth used for the root biomass input values in the RUSLE2 database.[84]

An input for rooting depth is not required by RUSLE2, which does not consider how rooting depth varies with vegetation or plant maturity.

9.2.5.3.2. Dead root biomass. Live roots become dead roots in one of three ways. One way is by including an operation in the **cover-management description** that has a **kill process**. The live root biomass for the **current vegetation** on the date of this operation is added to the dead root biomass pool and the live root biomass becomes zero.

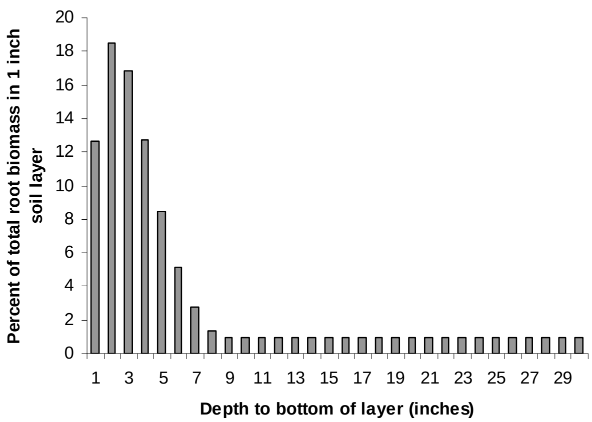

Figure 9.14. Distribution of live root biomass assumed for RUSLE2.

The second way that live root biomass becomes dead root biomass is by root sloughing and root death during growth periods, similar to canopy senescence (and live aboveground death during growth periods). Root death and sloughing is an important source of dead root biomass for perennial and similar types of vegetation to create a soil organic pool. The amount of root sloughing in a year ranges from about 25 to 40 percent of the root biomass.[85]

---

minimum depth that RUSLE2 recognizes is 1 inch (25 mm).

[83] Data from several literature sources for major agricultural crops of corn, soybeans, wheat, and cotton, several hay and pasture crops, and for selected vegetable crops were reviewed to determine the distribution in Figure 9.14 at plant maturity. The relative shape of the root distribution was very nearly the same for all crops. The rooting depth for the fine roots judged to have the most effect on soil loss did not vary among crops, except that the rooting depths for field and pasture crops was about twice that for vegetable crops. Even though rooting depth differs among plant types and with plant development, RUSLE2 empirically captures the main effect of roots on soil loss.

[84] The root distribution in RUSLE2 differs between from the one used in RUSLE1. RUSLE1 assumes that the root biomass in the second 4 inch (100 mm) soil layer is 75 percent of that in the top 4 inch (100 mm) layer and that no roots occur below 8 inches (200 mm). Based on Figure 9.14, RUSLE1 assumed significantly too much root biomass below the 4 inch (100 mm) soil layer below the upper 4 inches (100 mm) of soil.

[85] For additional information, see Reeder, J.D., C.D. Franks, and D.G. Michunas. 2001. Root biomass and microbial processes. In: The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect. R.K. Follett, J.M. Kimble, and R. Lal (eds). Lewis Publisher, Boca Raton, FL.

RUSLE2 represents daily root death during growth periods by multiplying daily live root biomass by a fraction. RUSLE2 represents root sloughing by a decrease in the root biomass during the year, much like RUSLE2 determines senescence by a reduction in canopy. Input values for root biomass increase when growth occurs and decrease after plant maturity when live root biomass is being lost by root sloughing.[86] Roots develop more rapidly than does canopy and reach maturity while the canopy is still adding biomass. Root sloughing can be assumed to either precede or parallel canopy senescence. Values for the temporal distribution of root biomass can be manually developed and entered for vegetations in the RUSLE2 database. Also, RUSLE2 includes an easy-to-use procedure that can be used to construct temporally varying root biomass values based on dates of maximum and minimum root biomass and root biomass values at those dates. RUSLE2 also has a procedure that estimates root biomass using built-in values for the ratio of root biomass to aboveground biomass production for selected plant communities. See **Section 11** that describes the vegetation component of the RUSLE2 database for additional information.

RUSLE2 determines the amount of root sloughing on each day by comparing the live root biomass values on a given day with the live root biomass on the previous day. RUSLE2 assumes that a decrease in live root biomass from one day to the next is caused by root sloughing and adds the decrease to the dead root biomass pool. RUSLE2 computes daily root biomass death by multiply daily root live biomass by a fraction. Daily root death biomass is added to the dead root biomass pool.

Using a single root biomass for the entire year for perennial type plants, including pasture and hay crops grown for several years, causes RUSLE2 to over estimate erosion because the dead root biomass pool that accumulates from root sloughing is not represented.

The third way that live root biomass becomes dead root biomass is when the live root biomass on the first day of a new **vegetation description** is less than the live root biomass on the last day when the current vegetation is used. The difference in live root biomass is added to the dead root biomass. This procedure is used when only a portion of the live root biomass is to be transferred to the dead root biomass pool because the **kill process** in an operation transfers the entire live root biomass to dead root biomass.

---

[86] The time invariant C factor in RUSLE1 uses a single representative value for root biomass for the entire year and does not consider root sloughing and the accumulation of a dead root biomass pool that can significantly reduce soil loss. Also, the time invariant C factor in RUSLE1 does not consider the accumulation of a buried residue biomass pool that can significantly reduce soil loss. Although the time invariant C factor in RUSLE1 was easy to use, it could seriously over estimate soil loss by not considering these important soil biomass pools. Thus, RUSLE2 does not include a time invariant cover-management computation, but it does include many of the easy to use features of the RUSLE1 time invariant C factor so that root sloughing can be easily considered using simple inputs that mimic RUSLE1 inputs. RUSLE1 can consider these soil biomass pools by using its time variant C factor with temporally varying canopy and root biomass values.

This procedure is used to apply RUSLE2 to intercropping type situations. Intercropping involves growing multiple crops at the same time where they typically have different seeding and harvest dates. Examples include planting a cover crop before silage harvest, planting a legume in small grain where the legume is harvest for hay after the grain is harvested, and weeds that develop before a crop is harvested. The procedure is illustrated where a cover crop is seeded before a silage corn crop is harvested. The cover crop provides vegetative cover to control erosion after the silage crop is removed by harvest. Values for live root biomass for this cover-management description are given in Table 9.5.

This **cover-management description** involves three **vegetation descriptions**. The first one is for the silage corn. The second one is for the composite of the rye, which is seeded on June 8, and the silage corn growing together. The third vegetation description is for the rye after the silage corn is harvested on August 8.

RUSLE2 detects that the live root biomass for the new vegetation, which is the rye after the silage has been harvested on August 8, is less than the live root biomass of the current vegetation, which is the composite of the corn and rye, on August 8. The difference of 950 lbs/acre in the upper 4 inches between the 1380 lbs/acre on August 8 for the current vegetation and the 430 lbs/acre for the new vegetation is the amount of live root biomass that is put in the dead root biomass. This 950 value represents the live root biomass of the silage corn on the date that it was harvested and killed. The live root biomass value for the rye vegetation immediately after the silage harvest represents conditions on the first day that this particular **vegetation description** is used, not the date that the vegetation was seeded.

Root biomass and other values used in the vegetation description can start at any time as required to describe the vegetative conditions for a cover-management system. The values for day zero and beyond describe conditions on the day that RUSLE2 is to begin using that vegetation description.

The **silage harvest operation** does not include a **kill process** to kill the corn. If a kill process had been included in the operation, the entire live root biomass would have been transferred to the dead root biomass. Only the corn live root biomass is to be transferred to the dead root biomass. The difference of 950 lbs/acre in the upper 4 inches represents the change in live root biomass from "killing" the corn and allowing the rye to continue "growing." RUSLE2 adds this difference to the dead root biomass pool.

Dead root biomass is lost by decomposition, which is a function of daily precipitation and temperature, and the decomposition half life for the roots. RUSLE2 uses the same decomposition half life for the dead roots as for aboveground biomass. RUSLE2 maintains a biomass pool for dead roots, much like a litter layer on the soil surface. The amount of biomass that RUSLE2 computes is a function of location. The biomass in these pools is greater at locations where decomposition is less because of reduced temperature and rainfall, such as the Northern US in comparison to the Southern US. The accumulation of biomass in the dead root biomass pool can significantly reduce erosion as computed by equation 9.12.

Although operations that include a disturb soil process resurface buried residue, these operations do not resurface dead roots. The dead roots that are most important for influencing rill and interrill erosion are fine roots that are assumed to be tightly bound to the soil so that they are not resurfaced.

Table 9.5. Values for two vegetations: silage corn interseeded with rye to provide cover after the silage is harvested

Calendar date	Days since begin growth	Root biomass (lbs/acre in top 4 inches)	Comment
10-Mar	0	0	Operation with begin growth process that uses silage corn vegetation description
25-Mar	15	40	
9-Apr	30	160	
24-Apr	45	320	
9-May	60	480	
24-May	75	760	
8-Jun	0	950	Operation with begin growth process that uses a vegetation description for the composite of the silage and rye; rye seeded on this day
23-Jun	15	980	
8-Jul	30	1080	
23-Jul	45	1280	
8-Aug	60	1380	Silage harest operation, silage corn harvested which removes the corn vegetative cover, kills corn roots, rye continues to grow
8-Aug	0	430	Silage harvest operation contains a begin growth process as last process in list of processes used to describe that operation. This begin growth process begins to use the rye vegettion description having values on day 0 appropriate for the date of the silage harvest
22-Aug	15	530	
7-Sep	30	610	

actual vegetation description includes additional dates to complete growth of the rye

9.2.5.3.3. Buried residue. Buried residue is added to the soil in three ways: (1) a fraction of the decomposed ground cover biomass is added, (2) a fraction of the ground cover biomass is buried by certain operations, and (3) biomass is placed directly into the soil with certain operations.

Each day, RUSLE2 arbitrarily adds a fraction of the surface (flat) layer of biomass (i.e., crop residue, plant litter) that decomposes on that day to the upper 2 inch (50 mm) soil layer. The fraction varies from zero if the soil has been recently mechanically disturbed to 0.25 if the soil is fully consolidated as a function of the soil consolidation subfactor s_c. RUSLE2 uses this procedure to accumulate organic matter at the soil surface on pastureland, rangeland, no-till cropland, and other lands not regularly tilled or mechanically disturbed.

Operations with a **disturb soil process** transfer (bury) a portion of the surface (flat) layer of biomass to the buried residue pool. The amount of residue that is buried is the product of the surface residue mass and a **burial ratio**. Values for the burial ratio are entered for each **operation description** having a disturb soil process in the **operation component** of the RUSLE2 database. RUSLE2 distributes the residue that it buries according to one of **three mixing distributions** illustrated in Figure 9.15. A distribution is selected when a **tillage type** is selected to describe an operation having a disturb soil process. The distributions **inversion with some mixing** is for operations like a moldboard plow that invert the soil. Most of the buried residue is placed in the lower half of the depth of disturbance. The distribution **mixing with some inversion** is for operations like a tandem disk, chisel plow, and field cultivator that place most of the residue in the upper half of the depth of disturbance. These operations bury residue primarily by mixing but involve some burial by inversion. The distribution **mixing only** applies where almost all of the burial is by mixing with very little burial by inversion for operations like rotary tillers, subsoilers, and manure and fertilizer injectors that place most of the residue in the upper one third of the depth of disturbance. One of these three mixing distributions is assigned to each operation with a **disturb soil** process when data for the operation are entered into the RUSLE2 database. The placement distribution for the **lifting and fracturing** and **compression** tillage types place the buried residue using the **mixing only** distribution.

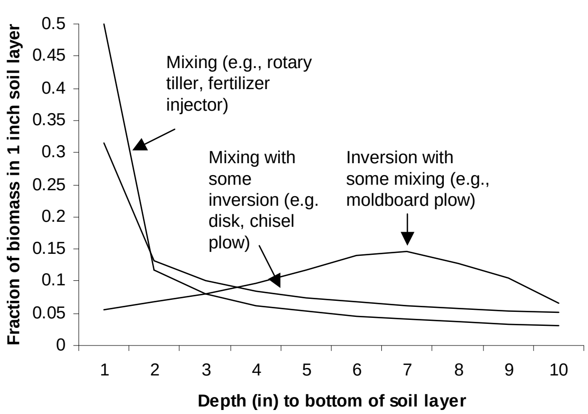

Figure 9.15. The initial distribution when residue is buried by an operation.

Buried residue can also be added to the soil in RUSLE2 by placing **external residue** in the soil with an operation that includes an **add residue process**. A disturb soil process must be included in the operation description to place external residue in the soil because the assumption is that the soil must be disturbed to place material in it. External residue is placed in the lower half of the disturbance depth as illustrated in Figure 9.16.

Buried residue is lost from the soil by being resurfaced by an operation that includes a **disturb soil process** and by decomposition. Buried residue is removed from the soil by being resurfaced and transferred to the surface (flat residue) pool by soil disturbing operations. The amount of **resurfaced residue** is the product of the amount of buried residue in the depth of disturbance at the time of the operation and a **resurfacing ratio** value assigned to the operation description in the RUSLE2 database. The resurfaced residue is extracted layer by layer by first taking out the entire buried residue in the layer, if necessary, from the top soil layer and then moving to the next and succeeding layers until the total mass of resurfaced residue is obtained. In many cases, only a portion of the buried residue in the top 1-inch (25 mm) layer is extracted. Extraction seldom extends beyond the second layer. RUSLE2 does not resurface dead roots as discussed in **Section 9.2.5.3.2.**

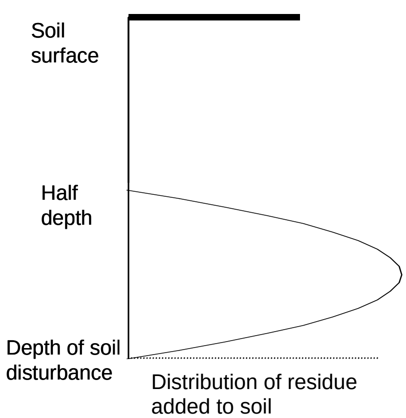

Figure 9.16. Distribution of residue placed in by an operation that has an "add residue" process.

Buried residue lost by decomposition as function of daily precipitation and temperature and the decomposition half life of the buried residue. RUSLE2 assumes that the decomposition half life is the same for buried residue as for the surface, flat residue. RUSLE2 maintains biomass pools for buried residue like it does for dead roots and a litter layer on the soil surface that is a function of location. The biomass in these pools is greater at locations where decomposition is less because of reduced temperature and rainfall, such as the Northern US in comparison to the Southern US. The accumulation of biomass in the buried residue pool can significantly reduce erosion as computed by equation 9.12.

Table 9.6. Retention coefficient values for redistributing residue among soil layers

	Mixing distribution		
Layer	Inversion w/mixing	Mixing w/inversion	Mixing
1 (top)	0.40	0.32	0.50
2	0.40	0.39	0.56
3	0.40	0.47	0.61
4	0.40	0.54	0.67
5	0.40	0.62	0.72
6	0.40	0.69	0.78
7	0.40	0.77	0.83
8	0.40	0.84	0.89
9	0.50	0.92	0.94
10	1.00	1.00	1.00

9.2.5.4. Redistribution of dead roots and buried residue in soil by soil disturbing operations

Operations with a **disturb soil process** redistribute buried residue and dead roots according to the **mixing distribution** assigned to that operation. When a soil disturbing operation occurs, RUSLE2 first redistributes the buried residue and dead roots and then buries the residue. Two steps are involved for an operation that has an **inversion with some mixing** distribution. The first step is to invert the soil layers with their buried residue and dead roots by layer so that the biomass in the bottom layer becomes the biomass in the top layer, the biomass in the next to bottom layer becomes the biomass in the next to the top layer, and so forth. The second step transfers biomass between soil layers. A **filtering** concept is used in RUSLE2 where each soil layer is **sifted** so that some of the biomass in each layer is retained in the layer and the remainder of the biomass moves down to the next layer. The amount retained is the product of the biomass in the layer and a retention coefficient having values shown in Table 9.6.[87] The retention values for the **inversion with some mixing** distribution are all equal except for the values for the bottom two layers. The value for the bottom layer must be 1 so that no biomass passes through the bottom layer and the slightly higher value for the next to bottom layer was empirically determined to give a good fit between experimental data and computed values. The equal retention values imply that the biomass is equally likely to move downward in the lower part of the disturbance depth as in the upper part. In effect, the soil is uniformly "stirred, mixed, and sifted" over the disturbance depth.

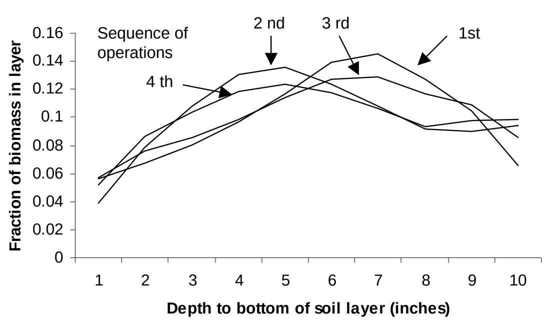

Figure 9.17. Initial burial and redistribution of residue by repeated operations with an inversion mixing distribution (e.g., moldboard plow)

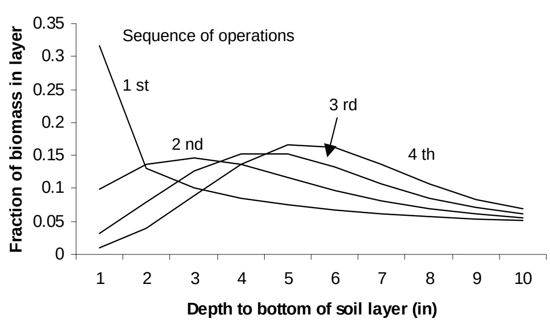

Figure 9.18. Initial burial and redistribution of residue by repeated operations with a mixing and some inversion mixing distribution (e.g., tandem disk)

Only one step is involved in redistributing biomass with the two mixing distributions that minimally involve inversion. The retention coefficient for the top layer is assumed to be same as the fraction of residue placed in the top layer by burial. The values for the retention coefficients for the remaining layers are linearly increased with depth to a value of 1 as shown in Table 9.6. The value of 1 for the last layer prevents biomass from passing through the bottom layer. The increase in retention values with depth means that biomass is more likely to move down in the upper part of the disturbance depth than in the bottom part and that stirring and mixing decrease with depth.

Figure 9.17 shows the buried residue distributions after each of four repeated

dure used to distribute buried residue in the soil
ots is described in **Section 13**. The RUSLE2
where material becomes uniformly distributed in
RUSLE1 assumes that the material is uniformly

operations for a moldboard plow that has an **inversion with some mixing** distribution where no additional residue is buried after the first operation. The buried residue distribution gradually becomes more uniform with each operation. Figure 9.18 shows buried residue distribution with repeated operations with a tandem disk where residue burial is mainly by mixing. After repeated operations, a bulge of biomass develops that moves downward in the soil. The bulge becomes increasingly concentrated with each operation and moves downward less with each operation. Thus rather than the distribution becoming increasingly uniform as assumed in some models, RUSLE2 computes an increasingly non-uniform distribution for the mixing type distributions. Implements like tandem disks and rotary tillers are assumed to bury residue uniformly in the soil, but in fact they only bury residue uniformly under certain conditions, which occurs with about two passes as can be seen from Figure 9.18.

9.2.5.5. Spatial non-uniformity of soil biomass

The soil biomass for live and dead roots and buried residue is spatially non-uniform for row crops, widely disperse plants like clumps of shrubs and grass on rangelands, and tree seedlings in a forest. However, RUSLE2 assumes that all soil biomass is uniformly distributed, even when the operation only disturbs a portion of the soil surface.

9.2.5.6. Assigning input values that determine soil biomass

The amount of soil biomass is a critical variable in determining how a cover-management system affects erosion. The three principal sources of soil biomass are from live root biomass, plant litter and crop residue, and externally added residue. The mass of external residue is based on dry matter basis and is known. Root biomass values for a **vegetation description** should be selected by comparing the vegetation's characteristics with those of vegetation descriptions in the RUSLE2 **core database**. When selecting root biomass values for a particular vegetation description, the role of fine roots versus coarse roots must be considered. For example, even though carrots and potatoes make up root biomass, their mass is not considered in assigning root biomass values because those "coarse roots" have little effect on erosion. In cases where some credit is to be taken for coarse roots, some, but not all, of their biomass is entered along with the biomass of the fine roots.

> **A key factor in selecting input root biomass values is to account for the temporal variation in root biomass so that the effect of root sloughing is captured by RUSLE2.**

Do not make field measurements of root biomass values to determine input values for RUSLE2. Measuring root biomass is very difficult, tedious, and tiresome and should only be done in a research setting. Large errors are common unless extreme care is taken and even then the results may show much variability. The ratio values in the RUSLE2

core database used to determine root biomass values for rangeland plant communities have been chosen based on measured soil loss values obtained during rainfall simulator experiments.[88] Other root biomass values in the RUSLE2 **core database** have been selected from the scientific literature and these values were used when equation 9.12 was fitted to erosion data.

Use of root biomass values that have not been checked for consistency with values in the RUSLE2 *core database* can cause serious errors in RUSLE2.

The other major source of soil biomass is from decomposition of plant litter and crop residue on the soil surface and from the incorporation of crop residue into the soil. The amount of plant litter is determined by senescence of the plant canopy and the amount of biomass associated with that loss of canopy. The amount of residue produced by a crop is determined by the residue to yield relationships defined for the crop and is entered in the vegetation component of the RUSLE2 database. The other important factor that determines the amount of buried residue is the flattening, burial, and resurfacing ratios used to describe operations in the operation component of the RUSLE2 database.

Even though a plant community may be a mixture of species, RUSLE2 represents the plant community as a single vegetation description where input values are selected to describe the composite effects of the vegetation. RUSLE2 "grows" only one vegetation at a time. RUSLE2 cannot take data from two vegetation descriptions, such as corn and rye, and combine them into a single composite vegetation.

9.2.5.7. Comments

RUSLE2 does not consider how soil texture or other soil properties affect the distribution of residue and roots in the soil. Although RUSLE2 adjusts amount of biomass buried by a soil disturbing operations as a function of speed and depth, RUSLE2 does not adjust the distribution of the residue as a function of operation speed or depth.

9.2.6. Soil consolidation[89]

A mechanical disturbance loosens soil and increases its erodibility, which in turn increases erosion. After a mechanical soil disturbance, soil erodibility decreases as soil

---

[88] The data used to calibrate RUSLE2 to rangelands were collected as a part of the Water Erosion Prediction Project (WEPP) by R. Simantion and others, USDA-ARS, Tucson, AZ. See Table 5-4 in AH703.

[89] A prior land use (PLU) subfactor was used in RUSLE1. This subfactor was the product of the soil consolidation subfactor and the soil biomass subfactor. This same product is used to display RUSLE2 subfactor values in some of the templates.

primary particles and aggregates become cemented together by wetting and drying and

Soil consolidation in RUSLE2 refers to the decrease in soil erodibility following a mechanical soil disturbance rather than an increase in bulk density.

other soil processes, which is the main soil consolidation effect. A mechanical soil disturbance decreases the bulk density of soil. Increases in soil bulk density do not greatly reduce soil erodibility, except when compaction is extreme.

9.2.6.1. Soil consolidation effect

Figure 7.3 is a plot of the soil consolidation subfactor s_c as it decreases with time after a mechanical soil disturbance. The soil is assumed to be 0.45 times as erodible at full consolidation as it is immediately after a disturbance. A soil disturbance resets the soil consolidation subfactor to 1 and it begins to decrease again with time. Seven (7) years is normally assumed for the time for the soil to become fully consolidated after a mechanical disturbance in the Eastern US where rainfall events are sufficiently frequent for the soil to experience repeated wetting and drying cycles required for the cementing process (See **Section 7.8**). RUSLE2 computes an increased **time to soil consolidation** up to 20 years as annual precipitation decreases from 30 inches (760 mm) to 10 inches (250 mm). A constant 20 years for time to soil consolidation is used where annual precipitation is less than 10 inches (250 mm). This increased time to soil consolidation reflects how the effects of a mechanical soil disturbance persist longer in low precipitation areas where reduced water is available and less frequent wetting and drying cycles occur.

The soil consolidation effect is greatest for those soils that have the greatest and most active cementing agents. These agents are most closely related to clay and organic matter particles because of their high specific surface area. Thus, the soil consolidation effect is greatest for soils having a high organic matter content, characteristic of cover-management systems involving a high level of soil biomass. The effect of organic matter content as affected by cover-management system is captured in the soil biomass subfactor s_b computed with equation 9.12.

The soil consolidation effect is also a function of soil texture because of the role of clay in cementing soil particles. The soil consolidation effect is greatest for fine textured soils with a high clay content and least for coarse textured soils with a low clay content. However, RUSLE2 does not consider the effect of soil texture on the soil consolidation subfactor.[90]

---

[90] The soil consolidation subfactor in RUSLE2 is one of the variables least well defined by scientific research. Its effect varies with many factors, but the research data are not sufficient to derive an empirical equation for the effect of soil conditions on the time to soil consolidation. Although, the soil consolidation

9.2.6.2. Importance of soil consolidation subfactor to other variables

The soil consolidation subfactor has indirect effects in RUSLE2 by being a variable in equations used to compute values for other cover-management subfactors. For example, the consolidation subfactor s_c is used in equation 9.12 to compute values for the soil biomass subfactor s_b. The soil consolidation subfactor is used to compute the rill-to-interrill erosion ratio in equation 8.3 where soil consolidation is assumed to reduce rill erosion much more than interrill erosion. The ratio of rill-to-interrill erosion affects the slope length effect and the ground cover subfactor g_c. Mulch is assumed to have reduced effectiveness on steep, cut construction slopes, which are detected in RUSLE2 by a low soil consolidation subfactor and low soil biomass values.

The soil consolidation subfactor is also a variable in RUSLE2 equations used to compute runoff index values (curve numbers) and runoff, which is used to compute how support practices affect soil loss (see **Section 14**). For example, when the soil is consolidated (i.e., s_c values near 0.45), infiltration is assumed to be low and runoff high if no soil biomass is present. A construction site where a surface soil layer was cut away without disturbing the underlying soil represents this condition. However, if the soil is undisturbed, which is indicated by a low s_c value, and contains a high level of soil biomass, infiltration is assumed to be high and runoff low. A high production permanent pasture represents this condition.

An undisturbed soil is required for a layer of high organic matter to develop at the soil surface on range, pasture, and no-till cropland. The soil consolidation subfactor is used as an indicator of the potential for this layer to develop. This effect is captured in equation 9.12 for the soil biomass subfactor s_b.

The portion of the soil surface that is mechanically disturbed during a cover-management system determines the overall effect of soil consolidation. The effects of the portion of the soil surface disturbed and the soil consolidation subfactor are illustrated in Figure 9.19 for a no-till corn cropping system at Columbia, MO.[91] One of the curves in Figure 9.19 is where the only soil disturbance is by a no-till planter that disturbs the soil in strips for a place to plant the seeds. The portion of the soil surface disturbed by the planter was varied from none to full width disturbance. No other variable such as burial ratio that would normally vary with the portion of the soil surface disturbed was changed. Thus the only effect represented is the effect of soil consolidation as reflected by portion of the soil surface disturbed. The other curve is where a fertilizer injector that disturbs 50

---

subfactor equation was primarily derived from soil loss measured at the single location Zanesville, OH, limited data from other locations indicate that the equation is valid in general.

[91] The effects computed for the soil consolidation subfactor differ between the non-Req and Req applications. The Req applications give increased credit for soil biomass, which is affected by the soil consolidation subfactor, but the Req applications do not adjust the slope length factor and the ground cover subfactor values as a function of the rill-to-interrill ratio that are used in non-Req applications.

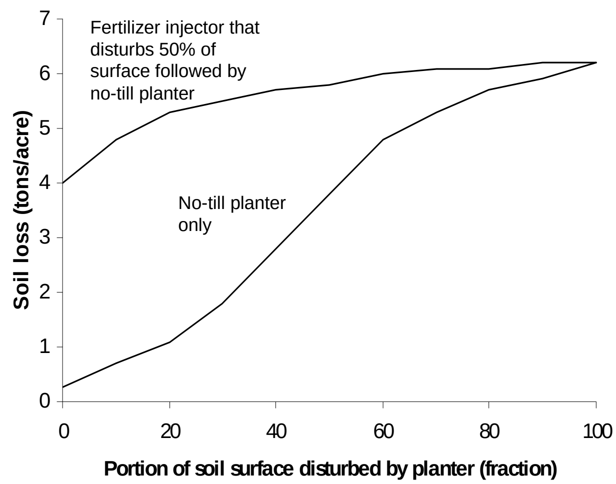

Figure 9.19. Effect of portion of soil disturbed on soil loss at Columbia, MO for no-till corn at 110 bu/acre. Fertilizer injector does not bury or resurface residue.

percent of the soil surface precedes the planter. Portions of the soil surface disturbed by the planter were varied while the 50 percent portion disturbed by the fertilizer injector was fixed.

The ratio of soil loss for the no-till planter with no disturbance and without the fertilizer injector to soil loss with full disturbance in Figure 9.19 is 0.04, which is much more effect than the 0.45 value for the full soil consolidation subfactor for no disturbance. Several variables cause additional effects beyond the 0.45 value directly associated with the soil consolidation subfactor. The soil consolidation affects the soil biomass subfactor as computed with equation 9.12. Another variable is the soil depth over which buried residue mass is averaged for equation 9.12 is reduced as the soil consolidation subfactor decreases. Another variable is the reduced slope length effect that is computed as a function of the rill to interrill erosion ratio that RUSLE2 computes as the soil consolidation subfactor decreases (see **Section 8.1.1**). Another variable is a decreased ground cover subfactor that is computed as a function of the rill-interrill erosion ratio that is a function of the soil consolidation subfactor (see **Section 9.2.2**).

The second curve in Figure 9.19 where a fertilizer injector precedes the no-till planter illustrates the importance of considering all soil disturbing operations in a cover-management system instead of giving attention solely to a single operation like a planter or drill. Varying the portion of the soil surface disturbed by the planter when it follows the fertilizer injection that disturbs a relative large portion of the soil surface had relatively little effect on erosion. The fertilizer injector is the dominant operation in terms of the soil consolidation subfactor effect. Most of the benefits of no-till cropping are lost by the fertilizer injector. The fertilizer injector disturbs the soil more than the no-till planter that follows the fertilizer injector. Consequently, adjusting the portion of the soil surface disturbed by the planter had little effect on the RUSLE2-computed soil loss..

9.2.6.3. Definition of mechanical soil disturbance

Soil disturbance, as used in RUSLE2, occurs when an operation fractures and loosens the soil, displaces soil, mixes soil and surface residue so that the interface between the residue and the surface soil is no longer distinct, and disrupts a high organic matter layer at the soil surface.

Operations that seed crops like corn, soybeans, and wheat in rows and that inject fertilizer and manure with thin shanks disturb only strips of soil and not the entire soil surface. An important input value, as illustrated in Figure 9.19, is the portion of the soil surface disturbed by each operation. A definition of mechanical soil disturbance is required to assign values for the portion of the soil surface that is disturbed by an operation.

A lower limit of 15% for portion of the soil surface disturbed should be used for no-till implements. This limit is related to the computational accuracy of RUSLE2; it is not related to definitions of no-till as used by NRCS or others.

When an operation displaces soil, the source area of the soil is included in the soil surface disturbed and the receiving area is included under certain conditions. The receiving area **is not** included in the area disturbed if the resulting soil depth from the displaced soil is so thin, less than 0.5 inch (10 mm) as a guide, that it has little effect on detachment by raindrop impact (interrill erosion) or detachment by runoff (rill erosion). The soil surface should be essentially level after an operation to assign a low value to the portion of the soil surface disturbed. The receiving area **is** included in the disturbed area if the surface residue and soil were mixed by the operation or any high organic matter soil layer at the soil surface was disrupted. The receiving area **is** included in the area disturbed, even though the surface residue has not been mixed with soil or high organic matter layer at the soil surface has not been disrupted, if displaced soil is deeper than about 0.5 inches (10 mm) such that significant amounts of interrill and rill erosion occurs because of exposed bare soil. Ridges and furrows are an indication of a high portion of the soil surface disturbed, especially where soil thrown from either side meets to form the ridge. Machines and implements, like scarifiers and hoe drills that involve shanks and shovels typically disturb a greater portion of the soil surface than implements that involve straight coulters. However, concave coulters and disks can throw large amounts of soil, resulting in almost the entire surface being disturbed.

New input values for portion of soil disturbed by an operation should be carefully examined for consistency and guidelines established so that input values are consistently assigned for other new operations.

9.2.6.4. How RUSLE2 handles strips

RUSLE2 does not keep track of individual strips of disturbed areas through time. RUSLE2 computes only a single composite soil consolidation subfactor value at any time. When an operation occurs that disturbs only a portion of the soil surface, RUSLE2 computes a composite soil consolidation subfactor value based on the portion of the soil surface that is disturbed by using a subfactor value of one (1) for the portion of the soil surface disturbed and the subfactor value at the time for the undisturbed portion at the time of the operation. This composite soil consolidation subfactor value is used in the RUSLE2 soil consolidation subfactor equation, represented by Figure 7.3, to compute an effective time after last soil disturbance. RUSLE2 accounts for time after a soil disturbance by starting with this effective time after last disturbance and proceeds.

9.2.6.5. Assigning values for portion of soil disturbed

A value of one (1) is assigned to the portion of the soil surface disturbed for most full width operations like scarifiers, moldboard plows, offset disks, tandem disks, chisel plows, and field cultivators. The portion of the soil surface disturbed by implements like row cultivators, planter, drills, and fertilizer and manure injectors that disturb strips of soil may be, but are not necessarily, less than one (1). Values for the portion of the soil surface disturbed selected for these operations should be consistent with values assigned to comparable operations in the RUSLE2 **core database**, which should be consulted first before values are assigned to new operations being put in the operation component of the RUSLE2 database. However, the portion disturbed can depend on local conditions, specific machines, and individual operators. Thus, input values may need to be adjusted from the **core values** based on the guidelines in **Section 9.2.6.3.**

Blading and grading used in construction operations must be carefully considered when a value for the portion of the soil disturbed is assigned to these operations. A grading operation for fill material should include a **disturb soil** process that uses a value of one (1) for the portion of the soil surface disturbed, even if the soil has been compacted with a roller or other compaction device. Compaction of the soil does not greatly reduce soil erodibility. Repeated wetting and drying and related soil processes must occur to cement the soil particles for the soil to be **consolidated**. A zero (0) is assigned to portion of the soil surface disturbed for a grading operation that cuts and removes a soil layer and leaves the underlying soil undisturbed. Thus, RUSLE2 assigns a value of one (1) for the soil consolidation subfactor for a fill slope and a value of 0.45 to a cut slope. However, if the cut slope has been ripped with a scarifier, disked for a seedbed, or mulch crimped in, a value is assigned to the portion of the soil disturbed according to the guidelines in **Section 9.2.6.3.**

Important RUSLE2 rules:
Surface material cannot be buried without using an operation with a *disturb soil* process
Material cannot be placed in the soil (e.g., manure injection) without an operation with a *disturb soil* process
Roughness cannot be created without an operation with a *disturb soil* process
Select values for portion of soil surface disturbed based on guidelines in section 9.2.6.3.

9.2.7. Ponding effect

Water ponds on flat lands during intense rainfall. The ponded water depth reduces rainfall erosivity. The effect is greatest along the Gulf Coast and the lower Atlantic Coast of the US. For example, RUSLE2 computes that the ponding effect reduces erosion by 46 percent at New Orleans, Louisiana on a 0.5 percent slope.

RUSLE2 computes values for the ponding sub-factor as a function of the 10 yr-24 hr precipitation amount and land steepness. The ponding effect sub-factor decreases as the 10 yr-24 hr precipitation amount increases, which is indicative of increased rainfall intensity. The ponding effect sub-factor increases as land steepness increases. For example, RUSLE2 computes only a 6 percent reduction in erosion because of the ponding effect for a 5-percent land steepness at New Orleans.

The RUSLE2 assumption is that the ponding effect is not affected by soil-surface roughness or soil ridges.

9.2.8. Antecedent soil moisture

The level of soil moisture affects infiltration and runoff to some degree at all locations. However, the effect is least where large amounts of rainfall frequently occur such as in the humid Southeastern US. The effect is more pronounced in the Western portion of the Great Plains in the US. Soil moisture is removed by growing crops depending on the type of crop and its production level. Soil loss is less following a crop that extracted much of the soil moisture in a low rainfall area. This effect is especially pronounced in the NWRR where rainfall is relatively low and environmental conditions associated with timing of rainfall and the freezing and thawing of soil under either high or low soil moisture content. A soil moisture subfactor is needed in the NWRR for Req applications to account for these special effects.

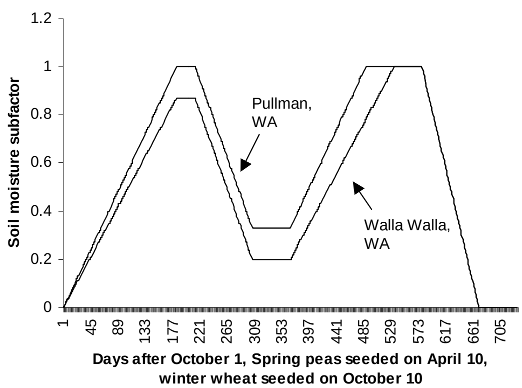

Figure 9.20. Antecedent soil moisture subfactor values for two locations in Washington for a winter wheat-spring pea rotation. The first peak is the effect of the winter wheat and the second one is the effect of spring peas.

9.2.8.1. Antecedent soil moisture subfactor effect

Values for the antecedent soil moisture subfactor s_m are illustrated in Figure 9.20. Subfactor values are 1 when the soil profile is "filled" relative to the unit plot and less than 1 when the soil profile is depleted of moisture relative to the unit plot.

As Figure 9.20 illustrates, the effect is a function of both location and type of crop. Antecedent soil moisture subfactor values are lower at Walla Walla, WA than at Pullman, WA because of less precipitation. Also, the values are lower following wheat than following spring peas because of the water usage difference between the two crops. As always, the values for the antecedent soil moisture subfactor are one (1) for unit plot conditions.

9.2.8.2. Assigning input values

An input value is assigned to each **vegetation description** in the **vegetation component** of the RUSLE2 database. Values are listed in **Section 11.1.6** and in the RUSLE2 **core database** that can be used as a guide for assigning input values used in the antecedent soil moisture subfactor.

The antecedent soil moisture subfactor must only be used in the NWRR for Req applications.

10. COVER-MANAGEMENT DATABASE COMPONENT

The **cover-management component** of the RUSLE2 database contains the **cover-management descriptions** that RUSLE2 uses to compute how cultural practices such as tillage systems for cropped fields, temporary erosion control practices for construction sites, and long term vegetation on a reclaimed mine sites affect erosion.

A **RUSLE2** cover-management description is primarily a list of operations and the dates on which each operation occurs. An **operation** is an event that changes the vegetation, residue, and/or soil in some way. Examples of operations are given in Table 10.1.

Table 10.1. Examples of operations

Operation	Effects	Comment
Moldboard plow	Kills vegetation, disturbs soil, buries residues, redistributions biomass in soil	Primary tillage, first step in growing a crop
Planting	Disturbs a strip of soil, seeds a crop	Includes a **begin growth** process. The name for the appropriate vegetation description is entered to represent the crop being grown
Broadcast seeding	Seeds a particular vegetation. This seeding operation does not disturb the soil.	Includes a **begin growth** process. The name for the appropriate vegetation description is entered to represent the vegetation that is seeded.
Volunteer weeds	Starts growth of volunteer weeds	Includes a **begin growth** process. The name for the appropriate vegetation description is entered to represent the volunteer weeds
Harvest	Kills vegetation and flattens some of the standing residue	Typical operation for crops like corn, soybeans, and wheat
Baling straw	Removes residue, flattens standing residue	Removes residue and flattens remaining standing residue
Silage harvest	Removes live biomass, kills vegetation	Leaves a portion of the live biomass in the field to represent harvest losses
Mowing	Removes live biomass, add cut material back as external residue, regrow vegetation	Cuts the live biomass but leaves it in the field. Does not kill vegetation. **Begin growth** process calls vegetation description that regrows vegetation after mowing
Baling hay	Remove live biomass,	**Begin growth** process calls vegetation

	regrows hay	description for vegetation that regrows after the hay harvest
Frost kills vegetation	Uses a **kill vegetation** process	RUSLE2 does not model plant growth. Must tell RUSLE2 when vegetation is killed, even if it occurs naturally
Fire	Remove residue/cover	RUSLE2 can not remove dead roots from the soil
Apply mulch	Add other residue/cover	Use to apply mulch to represent construction sites
Apply plastic mulch in a vegetable field, water in a rice field, or deep snow at a construction site in mountains	Apply non-erodible cover	Shuts off erosion for period that non-erodible cover is present. Use a **remove non-erodible cover** process to remove cover and to restart erosion.

The cover-management description includes the names of vegetation and residue descriptions needed by certain operations. An operation that includes a **begin growth** process requires that a vegetation description be specified for that operation. The **begin growth** process signals RUSLE2 to begin using information from the specified vegetation description on the operation's date. Similarly, operations with an **add other residue/cover** process require specifying a residue description and the amount of the material being added for the operation. RUSLE2 adds the cover at the specified amount on the date of the operation.

Additional non-event based information is also entered as a part of the cover-management description. For example, the user specifies whether the list of operations is repeated in a cycle (rotation) with a particular frequency or whether RUSLE2 is to compute erosion based on a single occurrence of each operation.

The variables in a cover-management description associated with the list of operations are listed in Table 10.2. The non-event variables that apply to a cover-management description are listed in Table 10.3.

Table 10.2. Variables in a cover-management description

Variable	Comment
List of dates	List of dates for the operations used to describe the cover-management condition (practice)
List of operations	Name of operation description in operation component of the RUSLE2 database containing values that RUSLE2 uses to

	describe the effect of the operation on erosion. Operations are events that change vegetation, residue, and/or soil. The list of operations is the main part of a cover-management description, which represent how cultural practices affect erosion.
List of vegetation descriptions	Name of vegetation description in the vegetation component of the RUSLE2 database containing values used by RUSLE2 to represent the effect of vegetation on erosion. Only one vegetation description is used at a time by RUSLE2. That is, RUSLE2 can not combine multiple vegetation descriptions into a single description.
Yield	Identifies production (yield) level in user defined units
Operation depth	Specifies the disturbance depth of operations that disturbs the soil. Default value is "recommended" value in operation description in operation component of RUSLE2 database. RUSLE2 will adjust for a depth value different from the default value.
Operation speed	Specifies the speed of operations that disturbs the soil. Default value is "recommended" value in operation description in operation component of RUSLE2 database. RUSLE2 will adjust for a speed value different from the default value.
External residue	Name of material (residue description in residue component of RUSLE2 database) added to soil surface and/or placed in soil. RUSLE2 uses values in residue description to compute how material affects erosion. Vegetation produces plant litter and crop residue. That material is considered by operations that manipulate vegetation and its biomass. External residue is material other than that associated with the vegetation descriptions in the cover-management description. Typical external residue includes manure and mulch (applied erosion control materials),
Residue added/removed	User entered mass value (dry weight basis) for material added when external residue is applied. Value shown is for the amount of plant material added from the "current" vegetation is computed by RUSLE2.
Cover from residue addition	Portion of soil surface covered by the added external or vegetation material. Value is computed by RUSLE2. This value is only for the added material and does not include existing surface (flat) cover.
Vegetative retardance	Refers to the degree that the vegetation slows surface runoff. RUSLE2 computes value based on user enter information in the vegetation description.

Table 10.3. Non-event variables used in a cover-management description

Rotation and duration	Is RUSLE2 to process the list operations multiple times in a cycle (rotation) with a certain frequency to represent steady state conditions for the cycle? Duration is the time for the cycle to be repeated. Crops are frequently grown in a crop rotation. The same crop grown each year (e.g., continuous corn) has a one-year rotation. Constructions sites are typically analyzed as a no-rotation. That is, the list of operations in the cover-management description are processed as a single pass through them.
Long term roughness	The soil surface roughness index value that evolves over time after the last soil disturbance.
Build new rotation with this management	Use this procedure to combine existing cover-management descriptions to create a new cover-management description.
Relative row grade	Can be used to specify cover-management description used as a part of a contouring system
Management alignment offset	Specifies the timing of operations when the same cover-management description is used on multiple segments along the overland flow profile.

10.1 Creating a cover-management description

The cover-management description provides information that RUSLE2 uses to compute values for the cover-management subfactors described in **Section 9**.[92] Table 10.4 illustrates a cover-management description for a corn-soybean-wheat rotation while Table 10.5 illustrates a cover-management description for a construction site where mulch is applied, a temporary cover crop is seeded, and permanent vegetation is seeded.

Table 10.4. List of operations for a corn-soybean-wheat 3-yr rotation

Date	Operation	Vegetation	Yield
4/15/1	Twisted shovel chisel plow		
5/1/1	Tandem disk		
5/5/1	Field cultivator		
5/10/1	Planter	Corn 112 bu/ac base yield	150 bu/ac
6/10/1	Row cultivator		
10/15/1	Harvest		
4/15/2	Moldboard plow		
5/1/2	Tandem disk		
5/5/2	Field cultivator		

[92] See Section 17.4.1.4 for information on creating a cover-management description for range, pasture, idle, undisturbed, and similar lands using a time invariant approach.

5/10/2	Planter	Soybeans 25 bu/acre base yield	35 bu/ac
9/10/2	Harvest		
9/15/2	Tandem disk		
9/20/2	Double disk drill	Wheat 35 bu/acre base yield	50 bu/ac
7/1/3	Harvest		
Non-event variable	Long term roughness	0.24 inches (6 mm)	
Non-event variable	Rotation	Yes	
Non-event variable	Duration	3 years	
Non-event variable	Management alignment	Not applicable	
Non-event variable	Relative row grade	10 percent	

Table 10.5. Cover-management description for applying straw mulch, seeding spring barley as temporary vegetation, and seeding a local native grass for permanent cover at a construction site

Date	Operation	Vegetation	Yield	External residue	Amount external residue added/removed
4/1/1	Blade fill material				
4/2/1	Broadcast seed	Spring barley 35 bu/ac base yield	25 bu/ac		
4/3/1	Apply mulch			Wheat straw	4000 lbs/ac
9/15/1	Killing frost				
9/16/1	Shred standing vegetation				
9/17/1	Double disk drill	Local native grass	1000 lbs/ac		
Non-event variable	Long term roughness	0.6 inches (15 mm)			

Non-event variable	Rotation	No			
Non-event variable	Duration	10 years			
Non-event variable	Management alignment	Not applicable			
Non-event variable	Relative row grade	Not applicable			

The first step in creating a RUSLE2 **cover-management description** is to list the dates and events that affect the soil, vegetation, and/or residue. A RUSLE2 **operation description** is selected from the **operation component** (see **Section 13**) of the RUSLE2 database to describe each of these events, even if the event is a natural occurrence such as frost killing vegetation. In general, the list of operations mimics actual events. However, only events that affect erosion are included in the list. For example, an aerial pesticide application would not be included. Be careful not to overlook an important natural event, such as a killing frost. The second step is to add supporting information such as the names for required **vegetation and external residue descriptions** and **application rates** for external residue. RUSLE2 procedures and definitions must be followed in creating a cover-management description to describe a field situation, keeping mind that RUSLE2 is not a simulation model. The input is a description for the field conditions that affect erosion.

A cover-management description can involve as many operations and vegetation descriptions as required. A field description can often be created in multiple ways. An example is the development of permanent, perennial vegetation from seeding to maturity after erosion has stabilized. The **duration** of the cover-management description is longer than the time for the vegetation to reach maturity to allow time for a stable litter layer and soil biomass pool to develop. Assume that three years is required for the vegetation to reach maturity and that an additional three years is needed for the litter layer and soil biomass pool to fully develop. The additional time for the litter layer and soil biomass pool to fully develop depends on temperature and precipitation at the location. The duration of the cover-management description is six years to include time for RUSLE2 to compute the effect on erosion of a fully developed litter layer and soil biomass pools.

The vegetation for this condition can be described with a single vegetation description that covers the entire six year period where the last four years involve duplicate values. A second way to apply RUSLE2 is to create three vegetation descriptions, one for the first year, one for the second year, and one for the third and subsequence year. Each of the six years represented in the cover-management description includes an operation description with a **begin growth** process where the appropriate vegetation description is assigned to the particular year.

RUSLE2 is often used to evaluate erosion for the maturity period alone without concern for erosion during establishment of the permanent vegetation. Examples include estimating erosion on pasture, range, reclamined mine, and waste disposal lands. In this case, a vegetation description of one year is created to represent the vegetation at maturity. Values at the end of the year equal those at the beginning of the year to represent a complete annual cycle. The cover-management description is a 1-year rotation. RUSLE2 cycles through the annual vegetation description a sufficient number of times so that RUSLE2 computes a stable litter layer and soil biomass pool and thus computes a stable erosion rate representative of condition where the permanent vegetation is fully established.

The same agricultural crop such as corn, soybeans, or wheat can be grown year after year (continuous cropping). The same crops can also be grown in a rotation such as a corn-soybean rotation. A cover-management description can be created for each possible combination, although the number of cover-management descriptions becomes large and difficult to manage.

An alternative is to use the **rotation builder** in RUSLE2. The rotation builder is used to combine multiple cover-management descriptions into a single cover-management description. The rotation builder most often is used to combine annual cover-management descriptions to create multiple year cover-management descriptions. The rotation builder can also be used to combine partial year cover-management descriptions for a single crop to create a single year cover-management description such as for vegetable cropping. Another example is using the rotation builder to combine a one-year wheat cover-management description with a two-year corn-soybean cover-management description to create a three-year corn-soybean-wheat cover-management description. In general, the rotation builder can also be used to combine cover-management descriptions of any duration.

The RUSLE2 rules must be carefully followed.

10.2. Discussion of variables used in a RUSLE2 cover-management description[93]

10.2.1. Dates

10.2.1.1. Operations as discrete events and representing continuous activity

Operations are discrete events that occur on a particular day. More than one operation can occur on a given day. Having each operation occur on individual days in RUSLE2

[93] The variables displayed in RUSLE2 depend on the template used to configure the RUSLE2 computer screen. Variables are discussed that you may not see displayed in RUSLE2 depending on the template you are using.

rather than on the same day is sometimes useful for seeing the effect of individual operations and for locating errors in cover-management descriptions. **However, this procedure can cause very serious errors in certain situations.** An example is creating ridges and applying mulch on a construction site. These two operations should be on the same day to avoid erroneous critical slope length values (see **Section 14.1.2.5**).

Representing continuous activity like grazing requires applying an operation multiple times over the period that the activity occurs. For example, a grazing operation description might be used once a week for each week that the grazing occurs. A sensitivity analysis should be conducted to determine how best to represent a continuous activity with a set of discrete events. In many cases, such as grazing, the best way to represent a continuous activity is to create vegetation descriptions that include the effect of the activity rather than using multiple operations.

Keep in mind that RUSLE2 uses descriptions to compute erosion. In many cases, the desired description can be created in multiple ways.

10.2.1.2. Representing the year in dates

The year of the operation can be any integer provided the years are in sequential order (e.g., 1, 2, 3, …; 2004, 2005, 2006, …; 75, 76, 77). The years 1, 2, 3 were used in Tables 10.4 and 10.5 to represent the calendar year of the rotation.

10.2.1.3. Tracking time in RUSLE2

RUSLE2 begins tracking time on the date of the first operation in the cover-management description. RUSLE2 computes average annual erosion based on the date of the first operation. Sometimes annual erosion estimates are needed on a calendar year basis or time needs to start at the same point when erosion estimates from alternative cover-management descriptions are being compared. A **no operation** operation description, which is described with a single **no effect process**, is used as the first operation in each cover-management description. A no operation only marks time and has no effect on the RUSLE2 computations. The date of a no operation is set to **January 1, 1** so that RUSLE2 will display erosion estimate on an actual calendar year basis. The no operation can also be placed on another date such as September 1 as the starting point for annual erosion accounting.

10.2.1.5. Allowing RUSLE2 to set duration

RUSLE2 scans the dates in the list of operations to determine the **duration** of the cover-management description. Using a no operation in the last year of the duration ensures that RUSLE2 makes the correct determination of duration. See **Section 10.2.8** for a discussion of rotation and duration.

> **A value for the duration can be entered in the cover-management description. RUSLE2 may over ride this duration based on the dates in the list of operations. An inadvertent error can occur that will not be noticed. To avoid this error, include a *no operation* in the list of operations to ensure that RUSLE2 determines the proper duration from the dates for the list of operations.**

10.2.1.6. Initial conditions

The operations must always be in the proper sequence. The starting operation is unimportant for a rotation because RUSLE2 loops through the list of operations until the erosion computations become stable. Because of this computational feature, values for initial conditions for RUSLE2 are not required for rotations.

However, initial conditions are needed where the cover-management description is a **no rotation** such as applying RUSLE2 to a construction site. In this case, initial conditions must be set in RUSLE2. The first set of operations in the cover-management description are selected to create the desired initial condition. The default initial condition assumed by RUSLE2 is that the soil is bare, fully consolidated, and has no soil biomass. This condition is like that created by a blade and cutting away the surface layer of soil below the root zone without disturbing the underlying soil. If this situation is applicable to the actual field situation, no operations are needed to set initial conditions. Start with the first operation, which might be an application of mulch on a construction site. A common condition on construction sites is placing mulch on a freshly graded fill. An operation description named **blade fill material** can be used as the first operation description in the list of operations. This operation includes a **disturb soil** process with the result that the soil is not consolidated in contrast to the cut, default condition. Erosion on the fill slope will be twice that on the cut slope because of the soil consolidation effect. An initial condition of a rough soil can be created by using an operation description to create a rough surface keeping in mind that a disturb soil process is required in the operation to create the roughness that also eliminates soil consolidation at the time of the operation.

The initial condition may also involve soil biomass, a litter cover, and growing vegetation. The appropriate initial conditions are created by using an initial set of operations that create the desired description. A **no operation** can be used before and after the initial set of operations used to create the initial conditions to mark time so that RUSLE2 displays erosion on the desired date. Be sure to set up operations so that RUSLE2 displays average annual erosion starting on the desired date. Keep in mind that the average annual erosion displayed by RUSLE2 is for the entire cover-management description including the operation descriptions used to establish initial conditions.

RUSLE2 displays average annual erosion for each year that provides the erosion values that can be used to compute average annual erosion for any period during the entire duration of the cover-management description.

10.2.2. Operations

Operations are events that affect soil, vegetation, and/or residue. RUSLE2 uses the information in **operation descriptions** to compute how operations effect erosion.

Many RUSLE2 operations are created and named to represent actual events such as tilling, seeding, harvesting, burning, frost, grading, and applying mulch. A single operation description can often be created to represent an event such as tillage. However, cases arise where multiple RUSLE2 operations are used to represent a single actual field event. An example is a harrow drawn behind a tandem disk through the field as a single unit. A more accurate representation of how the composite implement buries residue can be obtained in RUSLE2 by representing the effects of tandem disk separate from the effects of the harrow. Thus, two operation descriptions are used on the same day, one to represent the tandem disk and one to represent the harrow, to represent a single actual field event. The operation descriptions can be put on two consecutive dates so that the effects of the tandem disk can be seen separate from the effects of the harrow in a test computation, but the two operations should be on the same day for the erosion control planning computation..

Having the operations in the proper sequence is an absolute necessity.

Operations represent discrete events. Representing a continuous activity like grazing is discussed in **Section 10.2.1.1**.

See **Section 13** for a complete discussion of operation descriptions.

10.2.3. Vegetation

RUSLE2 uses the information in a **vegetation description** in the **vegetation component** of the RUSLE2 database to compute erosion when vegetation is present. **Operation descriptions** with a **begin growth** process in a **cover-management description** instruct RUSLE2 to begin using data from a particular vegetation description in its computations. Thus, the name of a vegetation description must be entered for each operation that includes a **begin growth** process. RUSLE2 begins using data from the selected vegetation description on the date of the operation and references the first date, day zero, in the vegetation description to this date.

Various approaches are used in RUSLE2 to create cover-management descriptions involving vegetation. In the case of annual crops, a vegetation description for each crop is used, which requires an operation description with a **begin growth** process to call a vegetation description for the appropriate crop in a **rotation** like a corn-soybeans-wheat rotation. The vegetation descriptions for annual crops like corn, soybeans, and wheat represent a year or less.

Multiple vegetation descriptions can also be used during a year. An example is using multiple vegetation descriptions to represent sequential planting and harvesting of two or more vegetable crops during the year.

A particular plant community can be divided into multiple vegetation descriptions. For example, the following sequence of vegetation descriptions can be used to represent a hay crop. The first vegetation description is for the period from fall seeding of alfalfa and through early growth, senescence, dormancy through the winter, and spring growth to the first harvest in the first harvest year. The second vegetation description describes the regrowth following the first and second harvests in the first harvest year. The third vegetation description describes the regrowth after the last harvest in the first harvest year, senescence, winter dormancy, and spring regrowth to first harvest in the second harvest year. The fourth vegetation description describes regrowth after the first and second harvests in the second harvest year. Additional vegetation descriptions are used as required to complete the rotation. Each vegetation description should represent the progression of growth in terms of **yield**, **canopy**, **live ground cover**, and **live root biomass**. For example, yield typically increases in the early years of a hay rotation while it may decrease in latter years.

Another example of using multiple vegetation descriptions is when RUSLE2 is applied to **intercropping**. Intercropping is when two crops grow together at the same time. An example is planting a legume crop in late winter in a small grain crop. The small grain is harvested in early summer. The legume crop continues to grow after the small grain is harvested until the legume is harvested for hay in late summer. Another example is planting a rye cover crop in corn before it is harvested for silage so that vegetative cover will be present after the vegetative cover is removed when the corn is harvested for silage. Another example of intercropping is ally-way cropping in commercial tree production and grass growing in the alley ways in vineyards and orchards. Another example is volunteer weeds that grow in crops like corn, soybeans, or cotton, especially in the southern US, as the canopy cover decreases after the crop matures. The weeds continue to grow after the crop is harvested.

The small grain-legume cropping system illustrates use of multiple vegetation descriptions. The cover-management description starts in the fall with primary tillage followed by secondary tillage and seeding of the small grain. The first vegetation description is for the period between the time that the small grain is seeded and the time that the legume is seeded. The second vegetation description is for the period between the time that the legume is seeded and the small grain is harvested when the combined growth of both the small grain and legume is represented. The values for canopy, live ground cover, and live root biomass on day zero in this vegetation description should be the same as the same as the corresponding values on the last day that the previous vegetation description is used. The third vegetation description used in this 1-year rotation is for the period between the small grain harvest and the harvest of the legume. The values for canopy, live ground cover, and live root biomass on day zero in this vegetation description are less than corresponding values on the last day that the previous vegetation description was used to reflect the dead above ground and root biomass that was created with the harvest of the small grain.

RUSLE2 is often used to estimate erosion for a perennial plant community like that on a range, pasture, landfill, or reclaimed mine lands. The cover-management description to represent this condition is a 1-year rotation involving a single vegetation description. The **vegetation description** describes the vegetation over an entire year.

Another important application of RUSLE2 is to estimate erosion during the period immediately following grading of a construction site, landfill, or reclaimed mine to when the permanent vegetation becomes fully established. Temporary vegetation is seeded in the spring followed by seeding of the permanent vegetation in the fall. The vegetation description for this **no-rotation** cover-management description can be represented in two ways.

The first approach uses two **vegetation descriptions**. The first **vegetation description** represents the period between when the temporary vegetation is seeded and the permanent vegetation is seeded. The second vegetation description is for the period after the permanent vegetation is seeded until a stable litter layer and soil biomass pool has developed. The values for each year over the last few years of the description are repeats where the vegetation has matured and become stable on an annual cycle. The **long-term vegetation tool** discussed in **Section 11.2.6** can be used to create these vegetation descriptions.

The second approach uses multiple **vegetation descriptions** of the permanent vegetation. The first **vegetation description** is for the temporary vegetation. The second **vegetation description** is for the first year of the permanent vegetation. The third **vegetation description** is for the second year of the permanent vegetation. The fourth **vegetation description** is for the third year of the permanent vegetation, which represents maturity for this particular vegetation. The third year **vegetation description** is used as many years as necessary for the litter layer and soil biomass to become stable.

The RUSLE2 rules related to **vegetation descriptions** must be carefully observed. In particular RUSLE2 only uses a single **vegetation description** at a time, which is referred to as the **current** vegetation description. An **operation description** with a **begin growth** process is required to tell RUSLE2 when to begin using data from a particular vegetation description. A vegetation description can start at anytime during the growth cycle of the vegetation. A vegetation description is simply that, a description of the vegetation at a given time. The first date in the vegetation description is day zero, which is referenced to the date that an operation calls that vegetation description. Decreases in **live root biomass** are assumed to become dead biomass that are put in the **dead root biomass** pools, respectively. Thus, the ending values of one vegetation description must properly match those of the next vegetation description used in a cover-management description. For example, the **canopy**, **live ground cover**, and **live root biomass** values at the end of a vegetation description used to represent a mature perennial plant community should be the same as corresponding values at the beginning (day zero) of that vegetation description.

Important RUSLE2 rules related to vegetation

1. **RUSLE2 uses only one vegetation description at a time. This vegetation description is referred to as the *current* vegetation.**
2. **A vegetation description describes the *composite* of plants present at a given time.**
3. **The length of time in a vegetation description should be as long as that vegetation description is used in a cover-management description. If the length of the vegetation description is too short, RUSLE2 uses the values on the last date in the vegetation description until a new current vegetation description is established.**
4. **A new, current vegetation is established by using an operation having a *begin growth* process.**
5. **A *decrease* in *live root biomass* between the first day (day zero in the vegetation description) of the new current vegetation description and the last day that the previous vegetation was used is considered to be dead roots and is added to the *dead root biomass* pool.**

The vegetation descriptions selected in a cover-management description must be consistent with site conditions. RUSLE2 does not check appropriateness of a vegetation description based on environmental conditions or other factors. RUSLE2 simply uses the values in the selected vegetation description. For example, RUSLE2 uses the same values for non-irrigated corn grown in a humid area as in a desert area.

Must be sure that the selected vegetation description is appropriate for the cover-management description and for the site specific environmental conditions.

See **Section 11** for a complete discussion of vegetation descriptions.

10.2.4. Yield

Each **vegetation description** is created for a particular **yield**. Multiple vegetation descriptions can be created for various yield values. A vegetation description having the desired yield can be selected when creating a **cover-management description**. RUSLE2 does not adjust yield based on environmental, management, or other factors. The input yield value must be consistent with site specific conditions, including precipitation, irrigation, temperature, soil, fertility, pest control, plant variety, and management, where RUSLE2 is being applied,.

Instead of selecting a vegetation description created for the desired yield, a vegetation description at a base yield can be selected. RUSLE2 assumes the base yield as the default yield, which the user can change to a value appropriate for the specific RUSLE2 application. RUSLE2 will adjust values in the base vegetation description to the input yield value. The base vegetation should be chosen so that maximum yield is less than 100 percent cover. The RUSLE2 yield adjusting equations, described in **Section 11.2.1**, can not adjust to yield values less than the base yield if maximum canopy of the base vegetation description is 100 percent. However, RUSLE2 can adjust to yield values greater than the base yield when maximum canopy is 100 percent.

The input yield value is in the user defined units for that particular vegetation description. Vegetation descriptions are typically created to use customary units. However, units vary among users applying RUSLE2 to various land uses. Open the vegetation description to determine how yield is defined for a particular vegetation description. If the units defined for that particular vegetation description are not the preferred units, create a new yield unit definition. The input yield units can be wet weight, dry volume, or number of items per unit area, for example. Also, the units can be non-customary and even original units created specifically for a particular RUSLE2 application. When defining units, the user enters values that RUSLE2 uses to convert input units values to dry mass values needed to compute subfactor values in equation 9.1 and related equations.

The input yield value must match site specific conditions.

10.2.5. Operation depth and speed

Operation **depth** refers to the **depth of disturbance** for those **operation descriptions** that include a **disturb soil** process. The default depth of disturbance is the recommended depth entered in the operation description. Similarly, operation **speed** refers to the speed of operation descriptions that include a disturb soil process. The default speed is the recommended speed entered in the operation description.

The amount of surface (flat) cover, crop residue in cropping-management systems, that is buried depends on machine depth of disturbance and speed. In general, **recommended** depth and speed values should be accepted and used in RUSLE2 computations. However, varying input values for depth and speed provides an indication of how residue cover can be affected by depth and speed of soil disturbing implements. Input values must fall within **limits** entered in the operation description.

A common assumption is that residue cover, especially in conservation tillage systems, can be easily manipulated by how tillage implements are operated. The two variables easiest to vary are depth and speed. The RUSLE2 relationships for the effect of these variables on residue burial are based on a very careful study of the research data. If RUSLE2 does not produce the desired residue ground cover value over the range of depths and speeds that are possible in the RUSLE2 inputs, then a particular ground cover can not be reasonably achieved by changing depth and/or speed.

The adjustments that RUSLE2 makes for operation depth and speed are discussed in **Section 13.1.5.3**.

Be very careful in assuming that practically any residue cover can be achieved with any implement based on changes in depth and speed. The RUSLE2 values are based on sound research. Assumptions for varying residue cover by adjusting implement depth and speed that are inconsistent with RUSLE2 computations should be rejected.

10.2.6. External residue and amount added

External residue refers to material added to the soil surface or placed in the soil. This material is usually organic material such as straw mulch, certain erosion control roll products, manure, and compost. In general, RUSLE2 assumes that external residue is organic material that produces organic compounds that reduce soil erodibility when the external residue decomposes. Some materials like rock such as gravel mulch do not decompose. Other materials, such as some roll erosion control products, deteriorate by a different process than the one assumed in RUSLE2. See **Section 12** for a discussion on how to handle these situations.

External residue can be placed entirely on the soil surface, entirely in the soil, or divided between the two. An **operation description** that includes an **add other cover** process tells RUSLE2 that external residue is being added. When an operation description having this process is in the list of operation descriptions in a **cover-management description**, a **residue description** from the **residue component** (see **Section 12**) of the RUSLE2 database is selected to identify the external residue being added. RUSLE2 uses the information in the selected residue description to compute how that external residue affects erosion. Important residue variables include residue type that affects how soil disturbing operations bury the residue and the degree that the residue conforms to the micro-topography of the soil surface, the portion of the soil surface covered by a given residue mass, and a decomposition coefficient that determines how rapidly that the material decomposes as a function of daily precipitation and temperature at the location.

When external residue is placed in the soil, a **disturb soil** process must follow the **add other cover** process in the operation description used to apply the external residue. The information for this process determines the depth in the soil that the external residue is placed. RUSLE2 assumes that external residue placed in the soil is placed in the lower half of the disturbance depth with most of the residue concentrated near the three fourths disturbance depth as illustrated in Figure 9.16.

The value entered for amount of external residue added must be a mass value based on dry weight. Also, the value must be consistent with the mass values used in the residue description to describe the relationship for portion of the soil surface covered by a given residue mass.

Residue, including residue from vegetative growth and applied external residue, can be removed from the soil surface by using an operation description that includes a **remove residue/cove**r process. This process removes standing and flat residue but not buried residue. Operation descriptions use this process to represent burning and straw baling for example. **Buried residue** in the soil can be removed, by burning for example, by using an operation description that includes two steps. The first step is to resurface the desired amount of buried residue with a **disturb soil** process and then remove the resurfaced residue from the soil surface with a **remove residue/cover** process. The **resurfacing coefficient** in the disturb soil process is set so that the desired amount of buried residue is resurfaced. The value for the **portion of the soil surface disturbed** for this soil disturb process is usually set to 100 percent, which sets the **soil consolidation** subfactor to 1 (a fully disturbed soil) because RUSLE2 assumes that buried residue can not be removed from the soil without disturbing the soil. However, resetting the soil consolidation effect can be eliminated by setting the portion of the soil surface disturbed in the disturb soil process disturbed to 1 percent.

RUSLE2 does not resurface dead roots in the soil because the fine roots, which are the most important roots in affecting erosion, are assumed to be so tightly bound to the soil that a mechanical disturbance can not resurface them.

See **Section 12** for a detailed discussion of residue descriptions.

10.2.7. Long term soil surface roughness

Long term soil surface roughness is the roughness that develops over time by natural processes such as local erosion and deposition by both wind and water erosion (See

Section 9.2.3.1.) Long term soil surface roughness is also a function of vegetation characteristics such as grasses being bunch or sod forming grasses and the density of the vegetation.

Long term soil surface roughness begins to develop after the last soil disturbing operation. The time over which this roughness is assumed to develop is the **time to soil consolidation** (See **Section 7.8**.).

Entering an appropriate value for long term soil surface roughness is most important for range, pasture, reclaimed mine, and landfills lands where permanent vegetation exists. Recommended values for long term soil surface roughness are given in Table 10.6. Long term soil surface roughness is generally set to 0.24 inch (6 mm) for cropping-management systems.

Table 10.6. Long term roughness values for range and similar lands. (Source: AH703)

Condition	Long term soil surface roughness	
	(inches)	(mm)
California annual grassland	0.25	6
Tallgrass prairie	0.30	8
Shortgrass, desert	0.80	20
Mixed grass, prairie	1.00	25
Natural shrub	0.80	20
Pinyon/Juniper interspace	0.60	15
Sagebrush	1.10	28
Bare with rock fragments	0.6	15
Moderate pitted	1.10	28
Deep pitted	2.00	50
Root plowed	1.30	32

10.2.8. Rotation and duration

Rotation in RUSLE2 refers to whether or not the list of operations in the **cover-management description** is to be repeated as a cycle (rotation). The length of the cycle is the **duration** of the rotation.

Designating a cover-management description as a rotation causes RUSLE2 to cycle through the list of operations until average annual erosion for the cycle (rotation) becomes stable. Most RUSLE2 cropland applications involve cover-management descriptions that are rotations. The value entered for duration for a rotation-type cover-management description is the number of years from the first operation in the list of operation descriptions until that operation is repeated in the next cycle. Continuous cropping, such as for corn, has a 1-year duration. Also, a rotation-type cover-management description for three vegetable crops grown in the same year has a 1-year duration. A 1-year duration is used to apply RUSLE2 to permanent vegetation on range, pasture, reclaimed mine, landfill, and similar lands. A 2-year rotation applies to corn and soybeans grown in subsequent years. A corn-soybean-wheat rotation is an example of a 3-year rotation. Three years elapses from the date of the first operation in the rotation until that operation is repeated in the next cycle.

Duration is not the same as the number of calendar years over which the operations occur. For example, operations for the corn-soybean-wheat rotation occur in four calendar years while 3 years is the duration for the rotation.

An actual field event need not occur in each year of a rotation. For example, corn could be grown in a 2-year corn-fallow rotation where no operations occur in the fallow year. This rotation is a 2-year duration because two years elapses between an occurrence of the first operation in the list of operations until its occurrence when the cycle is next repeated.

The listing of operation descriptions in a rotation can begin with any operation in the list. RUSLE2 cycles through the list until the average annual erosion rate becomes stable. Specifying initial conditions for rotations is not required because of this feature.

A **no-rotation** designation for a cover-management description instructs RUSLE2 to start its computations with the first operation in the list of operation descriptions and proceed through the list. The time period over which RUSLE2 computes erosion begins on the date of the first operation and continues through the number of years specified for duration. Cover-management descriptions for construction sites, establishment periods for vegetation on reclaimed mine and landfills, and recovery from disturbances on range, pasture and disturbed forest land are typically designated as no-rotations. RUSLE2 computes an average annual erosion for the duration, as well as average annual erosion for each year of the duration. See **Section 10.2.1.3** for guidance on how to use an operation description with a **no effect** process to set RUSLE2's starting point in its computations and to display output at desired times.

In a no-rotation cover-management description, the first few operations are used to establish initial conditions, which is discussed in **Section 10.2.1.6.**

RUSLE2 scan the dates in the list of operation descriptions to determine the duration of the cover-management description. In several cases, this computation needs to be over ridden by the user entering a different value for duration. An example is the corn-fallow rotation mentioned above where operations only occur in the first year of the rotation but the actual duration is two years. Another example is a construction site where mulch is applied and the site is temporarily seeded. An average annual erosion estimate is needed over the next two years before the final grading and seeding occur. In these examples, RUSLE2 sets the duration to 1 year when the proper value is 2 years.

Even when proper values are entered for duration, RUSLE2 can unexpectedly change the duration, which causes serious errors. To prevent such errors, enter a *no-operation* operation description (an operation using a single *no effect* process) in each year (*not each calendar year*) of the duration for the cover-management description.

10.2.9. Build new rotation with this management

The **rotation builder** is a RUSLE2 tool that can be used to combine individual cover-management descriptions, including both rotation and no-rotation type cover-management descriptions, into a single cover-management description. The combined cover-management description can be named, saved, and used later in a RUSLE2 erosion computation. Also, the combined cover-management description can be used directly in a RUSLE2 erosion computation without naming and saving it. This tool is most often used in RUSLE2 cropland applications where the combination of single year cover-management descriptions into multi-year rotations is almost limitless. Having a cover-management description for each combination results in a large and cumbersome set of cover-management descriptions in the RUSLE2 database.

RUSLE2 has editing capability for copying and pasting between cover-management descriptions, which can be used to combine cover-management descriptions. The disadvantage of this approach is that the year in the dates must be changed for each individual cover-management description except for the first one. The rotation builder greatly facilitates the manipulation of these dates.

Refer to the RUSLE2 Summary User Manual at http://www.ars.usda.gov/SP2UserFiles/Place/64080530/RUSLE/RUSLE2_User_Manual.exe for information on the mechanics of using the rotation builder.

10.2.10. Relative row grade

Contouring is a support practice used in conjunction with cover-management practices to reduce erosion, especially on cropland. **Ridging** is a comparable practice used on reclaimed mined land and similar lands. The effectiveness of contouring (ridging) depends on ridge height and row grade, two major variables directly related to the cover-management practice. Ridge height is determined by values entered in **operation descriptions** that include a **disturb soil** process (soil disturbing operations). See **Section 13.1.5.4** for information on specifying ridge heights. Thus, one of the most important variables that determines effectiveness of contouring is actually specified in the **cover-management descriptions** rather than in a **support practice description**.

Row grade is the grade along the ridge-furrows created by soil disturbing operations. Contouring is most effective when row grade is perfectly level, but level row grades are seldom obtained in actual field contouring. The effectiveness of contouring decreases as row grade increases.

The recommended row grade input in RUSLE2 is **relative row grade**, which is the ratio of row grade to land steepness along the overland flow path assuming that the soil surface is flat (no ridges to redirect flow) so that runoff flows perpendicular to the topographic contours. Inputting relative row grade according to the guidelines in **Section 14.1.5** provides a more accurate RUSLE2 estimate of how contouring affects erosion than inputting absolute row grade. A major advantage of inputting relative row grade in a cover-management description is that the contouring effectiveness of a cover-management practice can be represented within a cover-management description. A cover-management description using relative row grade can be applied to any overland flow path without considering site-specific topography. This capability is advantageous for applying RUSLE2 in erosion inventories.

See **Section 14.1.5** for information on how to specify relative row grade to represent various conditions.

10.2.11. Management alignment offset

Rotational contour strip cropping is a support practice that uses a rotation cover-management practice having a combination of erodible and dense vegetation conditions. The hillslope is divided into a series of contour strips where the same rotation cover-management practice is applied to each strip. However, the rotation is sequenced differently among the strips along the overland flow path so that dense vegetation strips are alternated with erodible strips. The dense vegetation strips induce deposition to reduce net erosion.

The **management alignment offset** is the years that the rotation cover-management description is offset (delayed) relative the starting date in the cover-management description on the base strip, which is typically the uppermost strip but can be any of the strips. RUSLE2 applies the offset assigned to each strip to achieve the alternating pattern of erodible-dense vegetation strips along the overland flow path.

See **Section 14.2** for detail discussion of rotational contour strip cropping.

11. VEGETATION DATABASE COMPONENT

The **vegetation descriptions** in the **vegetation component** of the RUSLE2 database provide RUSLE2 with the information that it uses to compute how vegetation affects rill-interrill erosion. The RUSLE2 descriptions do not contain all of the information commonly used to describe vegetation. For example, RUSLE2 assumes the same rooting depth for all growth stages, plant types, and soil profiles. Even though rooting depth may affect erosion, the empirical erosion data used to develop RUSLE2 are not adequate for determining how rooting depth affects erosion. The main rooting effect captured in the data is the effect of root biomass.

RUSLE2 does not model vegetation growth. Instead, the RUSLE2 user explicitly describes the vegetation at the site where RUSLE2 is being applied. RUSLE2 does not compute how climate, soil, or management affects production (yield) level, canopy cover, height, or any other vegetative property that affect erosion.

When RUSLE2 users create vegetation, residue, operation, and cover-management descriptions, they should choose input values that ensure that RUSLE2 is using expected values for the variables that affect rill-interrill erosion. These variables include canopy cover, effective fall height, live ground cover, live root biomass, surface residue added by litter fall, standing and surface residue created at harvest, and dead roots created by root sloughing (death) and harvest.

Accounting for all of the biomass produced by the vegetation is not important in RUSLE2. The important biomass is the biomass that affects erosion. For example, the biomass left in the field after a hay harvest is a critical variable, not how much biomass left the field. Yield is only important as it is used to determine values for the biomass variables used in its computations.

RUSLE2 users create vegetation descriptions using RUSLE2 rules and procedures. These descriptions contain values for the variables that RUSLE2 uses to compute erosion. RUSLE2 vegetation descriptions are created with the focus on the information needed by RUSLE2 to compute erosion. The focus is not on accounting for biomass that leaves the site and has economic value.

Thee variables in a RUSLE2 vegetation description are listed in Table 11.1. The RUSLE2 vegetation descriptions also include **tools** listed in Table 11.2 used to develop input values for some of the variables listed in Table 11.2.

Table 11.1. Variables in a RUSLE2 vegetation description

Variable	Comment
Base production (yield) level	Production (yield) level for which a particular vegetation description applies. Value units defined by user.

Production (yield) level definition	User provided information that defines units for production (yield) level.
Amount of biomass at maximum canopy	RUSLE2 uses this information to determine amount of aboveground biomass based on canopy percent over the time represented in the growth chart. Value important in determining the amount of crop residue available at harvest and the amount of senescence (litter) fall. Values are on a dry weight basis.
Retardance	Indicates degree that vegetation retards (slows) runoff to affect critical slope length and transport capacity.
Residue	Name for residue description that applies to this vegetation description.
Relative moisture depletion rate	**Used only for Req applications.** Describes the degree that the vegetation extracts moistures during growth that affects erosion after the vegetation.
Growth chart involves the following variables	
Age (days)	Points through time used to describe temporal variation of vegetation. Starts at zero. RUSLE2 references day zero to the calendar date of the operation containing the begin growth process that tells RUSLE2 to begin using this vegetation description.
Root biomass	Mass (dry weight basis) of roots in upper 4 inch (100 mm) of soil.
Canopy cover	Portion of soil surface covered by canopy that intercept raindrops falling vertically.
Fall height	Effective height from which water drops fall where canopy has intercepted rainfall.
Live surface cover	Portion of the soil surface covered by live plant parts that touch the soil surface and affect erosion.

Table 11.2. Tools used to input values in vegetation description.	
Tool	Comment
Develop growth chart for a production (yield) level other than base level	Used to create a growth chart for a new production (yield) level that can be used in a vegetation description.
Estimate fall height	A graphical tool that estimates fall height values based on heights to the top and bottom of canopy and a graphical description of canopy.
Develops the relationship between aboveground biomass and production (yield) level	User inputs aboveground biomass values at two yield values so that RUSLE2 can develop a relationship between aboveground biomass and production (yield) level.
Develops the relationship for senescence	User inputs canopy values that RUSLE2 uses to develop a relationship between canopy cover and aboveground biomass that is used to compute the mass of plant material

	that falls to the soil during senescence.
Develops a relationship between retardance and production (yield) level	User inputs retardance values at two production (yield) levels that RUSLE2 uses to determine a relationship for retardance as a function of production (yield) level.
Develops a growth chart for long term vegetation	Used to develop temporal values for perennial and permanent vegetation on range, pasture, reclaimed mine, wastes disposal, and similar lands.

11.1. Variables in a RUSLE2 vegetation description

11.1.1. Base production (yield) level

The RUSLE2 vegetation variables are a function of production (yield) level. Therefore, each **vegetation description** in the **vegetation component** of the RUSLE2 database is for a particular **production (yield) level**. When RUSLE2 is applied to a particular site, the vegetation's production (yield) level must match site-specific conditions. The vegetation and its production (yield) level must be consistent with the location's climate, irrigation, soil, fertility, pest control, and other management conditions. Because RUSLE2 is not a plant growth model, it does not adjust vegetation variables to match site-specific conditions. Production (yield) level is a user site-specific input that reflects long-term production levels rather than production in any specific year. Although RUSLE2 can indicate how erosion varies between dry and wet years, it is not intended for such applications.

The RUSLE2 production (yield) level input can be handled in one of two ways. One way is to create a vegetation description for a set of production (yield) levels where the user selects a vegetation description for the production (yield) level that is appropriate for the site. The second way is for the user to select a vegetation description at a base production (yield) level and input the site production (yield) level value. RUSLE2 will then adjust values in the base vegetation description to ones appropriate for the input production (yield) level value.

RUSLE2 can adjust to a production (yield) level value that is higher than the production (yield) level of the base vegetation description. However, the maximum canopy cover in the base vegetation must be less than 100 percent for RUSLE2 to adjust to a production (yield) level lower than the base production (yield) level. This restriction is related to the RUSLE2 equations used to adjust for production (yield) level. The user can alternately create a new vegetation description for a new production (yield) level if the RUSLE2 adjustments are not satisfactory.

The units for the production (yield) level are user defined (see **Section 11.1.2)** and can be almost any units that a user prefers.

Yield is important in RUSLE2 only to indicate the yield to which a particular vegetation description applies or as a variable that can be used to adjust values in a given vegetation description to the desired yield. The biomass associated with a harvestable part of vegetation and its yield are important only if that biomass in the harvestable part directly affects erosion and is represented by a RUSLE2 vegetation variables. For example, accounting for the biomass in the harvestable corn grain is not important. Accounting for the biomass in a harvestable hay crop is only important until the hay is harvested. The biomass in watermelons before harvest is not important, but the ground cover provided by watermelons may be important. The biomass left behind in the field after harvest is important, not the biomass taken from the field. RUSLE2 procedures are used to create a field description of the variables that affect erosion, not to account for vegetation in its entirety.

11.1.2. User definition of production (yield) level units

Almost any user preferred units can be created for inputting values for **production (yield) level** in RUSLE2. These units can be on any basis including dry or wet, mass (weight), volume, standard moisture such as 14 percent for corn grain, number such as bales of hay or straw, or even an original user created basis. The production (yield) level input must be on a per unit area basis. These units should be common usage for intended RUSLE2 users, convenient, and a reliable indicator of how values for RUSLE2 vegetation variables change with production (yield) level.

Two inputs are used to define the production (yield) level units. The first input is the displayed yield unit, typically a common unit such as bushels per acre (liters/ha), lbs per acre (kg/ha), tons per acre, or hundred weight per acre.

The second input is a **conversion factor.** RUSLE2 multiplies the user production (yield) level input value by this conversion factor to convert the input value, which may be a mass, volume, or number per unit area value, to a mass value. Converting the production (yield) level input to a mass value facilitates using rules of thumb for estimating crop residue at harvest. The production (yield) level value expressed as a mass is multiplied by a residue:yield ratio to estimate residue at harvest.

To illustrate, the conversion factor for corn is 56 lbs/bushel at the standard 14 percent moisture content. Multiplying a 100 bu/acre corn yield by this conversion factor gives a corn grain yield of 5600 lbs/acre in terms of mass. Multiplying this mass value by the 1:1 to the residue:yield rule of thumb gives an estimate of 5600 lbs/acre of corn residue at harvest. A linear equation, discussed in **Section 9.2.1.6** is used in RUSLE2 to estimate residue at harvest rather than a simple residue:yield ratio because the residue:yield ratio varies with yield. The input data needed for this equation are discussed in **Section**

11.2.1.

The conversion factor value for converting production (yield) level inputs to a mass value is plant specific. The conversion factor for corn is 56 lbs/bushel while it is 32 lbs/bushel for oats. The input units for some plants, such as hay, are already a mass value. The conversion factor for those plants can be one (1) or it may be different from 1 if a conversion from a wet to dry basis is involved. A conversion of dry basis can either be made in this conversion factor on in the computation of aboveground biomass as a function of production (yield) level.

RUSLE2 uses the production (yield) level input to compute aboveground biomass values. This computation involves two steps. One is to multiply the input production (yield) level value by a conversion factor to obtain a mass value and the second is to convert the production (yield) level value to aboveground plant biomass values on a dry basis. The user arranges these two steps as desired to end up with the appropriate aboveground biomass values. For example, a wet to dry basis conversion can be made in the first step or the second step. The input and conversion values must be consistent so that the final result is a mass on a dry basis.

11.1.3. Live Aboveground biomass at maximum canopy cover

RUSLE2 computes daily values for live aboveground biomass as a function of daily canopy cover. Coefficient values in the equation for this computation value are determined from user input values for **live aboveground biomass at maximum canopy cover** and the value for **live above ground biomass at minimum canopy cover.**

11.1.3.1. Basic principles

The input values entered in a **vegetation description** are selected to provide RUSLE2 with the values that it needs to compute erosion. Consequently, not all of a plant's aboveground biomass is necessarily included in the input for **aboveground biomass at maximum canopy cover**. Only that plant material that becomes litter fall or that will become standing, surface, or incorporated residue is included in the input. For example, harvestable grain is not included in this input because the grain is removed from the field without affecting erosion. If a harvestable product is left in the field to provide standing or surface (flat) residue or is incorporated into the soil to provide soil biomass, it should be included in the aboveground biomass input.

RUSLE2 uses the input for aboveground biomass at maximum canopy cover to estimate daily live aboveground biomass during the time period represented by a vegetation description. Three stages of vegetation growth are represented in RUSLE2. These stages are: (1) new growth, (2) senescence/regrowth, and (3) stem growth, which are illustrated in Figure 11.1.

The general equation for all three stages is:

$$B = B_0 + \alpha(C - C_0)^{1.5} \qquad [11.1]$$

where: B = live aboveground biomass (mass/area), B_0 = live aboveground biomass at the canopy cover C_0, C = canopy cover (percent), and α = a coefficient. Figure 11.1 represents these growth stages for a plant community that reaches is already or reaches maturity in a single growth cycle. RUSLE2 determines values for B_0, C_0, and α from user input values.

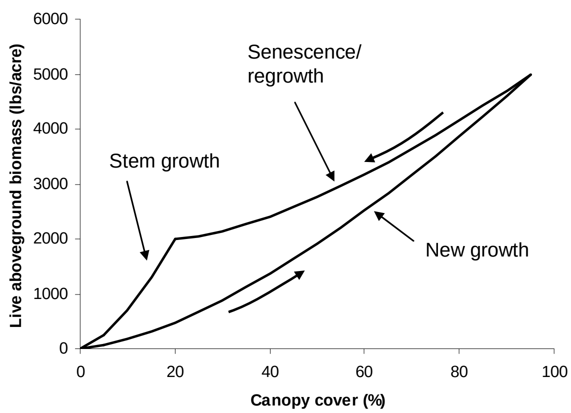

Figure 11.1. Canopy cover-live aboveground biomass relationship for a plant community that reaches maturity in a single growth cycle.

Equation 11.1 works best where maximum canopy cover is less than 100 percent. It works less well for conditions where aboveground biomass increases significantly after canopy cover reaches 100 percent. Equation 11.1 was chosen for its simplicity, robustness, and ability to be calibrated with minimal user inputs after an evaluation of alternate equation forms, including exponential forms.

A plant community well represented by Figure 11.1 is soybeans. The new growth period represents the relation between canopy cover and live aboveground biomass from plant emergence after seeding until full maturity and senescence begins. Equation 11.1 for the new growth period is:

$$B_n = \alpha_n C_n^{1.5} \qquad [11.2]$$

where: B_n = live aboveground biomass and C_n = canopy cover during the new growth stage. RUSLE2 computes a value for α_n using:

$$\alpha_n = B_{mx} / C_{mx}^{1.5} \qquad [11.3]$$

where: B_{mx} = the user entered value for live aboveground biomass at maximum canopy cover C_{mx}.

Senescence occurs during the period of decreasing canopy after the plant community has reached maturity. Equation 11.1 during the senescence stage is:

$$B_r = B_{mn} + \alpha_r (C_r - C_{mn})^{1.5} \qquad [11.4]$$

where: B_r = live aboveground biomass and C_r = canopy cover during the senescence period and B_{mn} = the user entered value for live aboveground biomass at minimum canopy cover C_{mn}.

RUSLE2 computes a value for α_r using:

$$\alpha_r = (B_{mx} - B_{mn})/(C_{mx} - C_{mn})^{1.5} \qquad [11.5]$$

In general, RUSLE2 assumes that any decrease in canopy cover within a vegetation description represents senescence, except for special plants like corn. Leaves droop on those plants that reduce canopy cover but do not fall to the soil surface. A user input tells RUSLE2 to not apply equation 11.4 to those plant communities.

The stem growth stage represents conditions when canopy cover is less than the minimum canopy cover that results after senescence is completed. This growth stage is important, for example, when a plant community is mowed or hay is harvested, which leaves a canopy cover that is less than the minimum canopy cover after full senescence. Equation 11.1 for the stem growth stage is:

$$B_s = \alpha_s C_s^{1.5} \qquad [11.6]$$

where: B_s = the live aboveground biomass and C_s = the canopy cover during the stem growth stage. RUSLE2 computes a value for the coefficient α_s using:

$$\alpha_s = B_{mn} / C_{mn}^{1.5} \qquad [11.7]$$

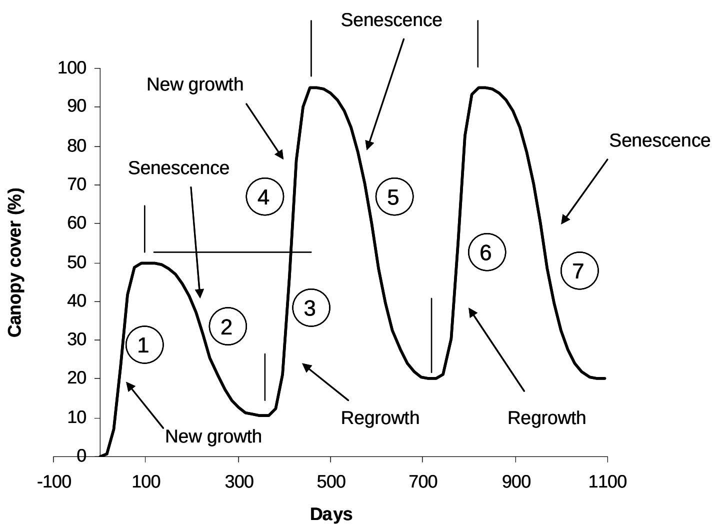

Figure 11.2 illustrates canopy cover for a plant community that takes two growth cycles to reach maturity. The third growth cycle in Figure 11.2 represents full maturity. The plant community can be described in RUSLE2 by

Figure 11.2. Canopy cover for a plant community that requires two cycles to reach maturity

using the **long-term vegetation tool** or by creating a vegetation description for each growth cycle. The principles that are used in the long-term vegetation tool should be used in creating individual vegetation descriptions for plant communities like those represented in Figure 11.2.

Period 1 is new growth that begins on day zero and continues to the date of the maximum canopy cover in the first growth cycle. Period 2 is senescence that begins at maximum canopy cover in the first growth cycle and continues until minimum canopy cover at the end of the first growth cycle. Period 3 is regrowth that begins at the minimum canopy cover at the beginning of the second growth cycle and ends on the date that the canopy cover in the second growth cycle reaches the maximum canopy cover in the first growth cycle. Period 4 is new growth that begins at the date that canopy cover in the second growth cycle reaches maximum canopy cover in the first growth cycle and continues until maximum canopy cover in the second growth cycle. Period 5 is senescence that begins at maximum canopy cover in the second growth cycle and continues until minimum canopy cover at the end of the second growth cycle. Period 6 is regrowth that begins at minimum canopy cover at the beginning of the third growth cycle, which is the first full mature growth cycle. The regrowth period 6 continue until the maximum canopy cover of the third growth cycle. Period 7 is senescence that begins at maximum canopy cover in the third growth cycle and continues until the minimum canopy cover at the end of the third growth cycle. A growth cycle that represents full maturity does not contain any new growth periods.

Figure 11.3 shows the canopy cover-live aboveground biomass relationships for the plant community illustrated in Figure 11.2. Period 1 represents the new growth period in the first growth cycle. Period 2 represents senescence in the first growth cycle. Period 3 represents regrowth in the second growth cycle. Plant regrowth stage is assumed to retrace canopy loss during the previous senescence. Consequently, the same equation is used for the regrowth stage that follows the immediately previous senescence stage. That is, the same equation is used to describe both periods 2 and 3. Another equation is used to describe both periods 5 and 6.

Once canopy cover reaches the maximum canopy cover in the previous growth cycle, plant growth shifts from regrowth to new growth. Plant growth "rejoins" the previous new growth. The same equation is used for new growth in all growth cycles. Plant communities that have three or more growth cycles to reach maturity are represented using these same principles. These principles are repeatedly applied to each growth cycle until maturity is reached. New growth stages are not involved in the growth cycle that represents plant maturity.

The user inputs in the RUSLE2 **long-term vegetation tool** are **live above ground biomass for maximum canopy cover at maturity** and **live above ground biomass at minimum canopy cover at maturity**. RUSLE2 uses these inputs and the canopy cover

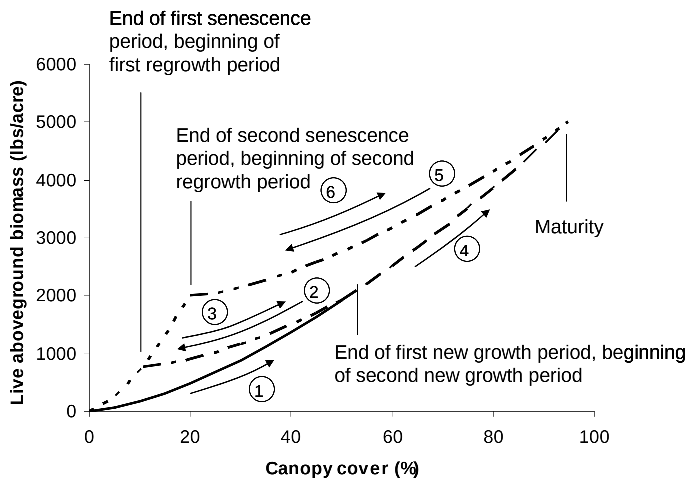

Figure 11.3. Canopy cover-live aboveground biomass relationship for a plant community that reaches maturity in two growth cycles.

values entered by the user to determine similar values for local maxima and minima canopy covers for growth cycles before plant maturity. A RUSLE2 assumption is that canopy cover for the local minimum canopy cover at the end of a growth cycle equals the product of minimum canopy cover at maturity and the ratio of local maximum canopy cover for the growth cycle to the maximum canopy cover at maturity. Another RUSLE2 assumption is that the live aboveground biomass, minimum canopy cover data point for each growth cycle must lay on the stem growth curve given by equations 11.6 and 11.7.

The other RUSLE2 option for describing plant communities having multiple growth cycles is to create a vegetation description for each growth cycle. The assumptions used in the RUSLE2 **long-term vegetation tool** should be used in creating these vegetation descriptions to ensure continuity between the individual vegetation descriptions.

Maintaining continuity between vegetation descriptions in a cover-management description is very important.

Equation 11.1 allows RUSLE2 to use the same **vegetation description** in different **cover-management descriptions** where the vegetation is killed on different dates.[94] For example, a wheat cover crop used to provide winter erosion control is killed on different spring dates depending on the main crop (e.g., corn versus cotton) and early or late planting. RUSLE2 needs an aboveground biomass estimate on the date that the wheat crop is killed and the main crop is planted. RUSLE2 estimates a value for that biomass by substituting the canopy cover value in the vegetation description on the date that the

[94] RUSLE1 differs from RUSLE2 regarding the input value for biomass when the vegetation is killed. The RUSLE1 vegetation descriptions contain the values for residue mass at the time that the vegetation is killed. Separate RUSLE1 vegetation descriptions are required for each date that the vegetation is killed. Also, two separate RUSLE1 vegetation descriptions are required for silage corn and grain corn. In RUSLE2, the same vegetation description can be used for both silage and grain corn, and the same vegetation description can be used when the vegetation is killed on different dates.

wheat is killed into equation 11.1. Without equation 11.1, RUSLE2 would require a vegetation description for each date that the wheat is killed in alternative cover-management descriptions.

RUSLE2 can also use vegetation descriptions that end on the date that the vegetation is killed where the input for aboveground biomass is for the maximum canopy cover on that day. This input technique can be used to ensure that RUSLE2 uses a particular value for aboveground biomass on the date that the vegetation is killed rather than the one computed with equation 11.1. This procedure can be used when equation 11.1 is considered to be a poor representation of the canopy cover-live aboveground biomass.

Perennial vegetation including hay and pasture crops and plant communities on rangelands, closed landfills, and other undisturbed areas exhibit a simultaneous birth and death of live aboveground biomass during new and regrowth periods. RUSLE2 computes a daily death amount of aboveground biomass as a fraction, approximately 0.01, of the live aboveground biomass on that day (see **Section 11.2.6**). This daily biomass amount is added to the surface litter (residue) biomass on that day.

RUSLE2 also considers a daily "mechanical" loss of live aboveground biomass that is added to surface litter. This daily addition is a fraction of the daily live aboveground biomass. This computation represents the loss of live aboveground biomass by mechanical processes such as animal traffic or by vehicular traffic (see **Section 11.2.6**).

11.1.3.2. Consistency between inputs for aboveground biomass at maximum canopy cover with processes in operation descriptions

RUSLE2 inputs for cover-management, vegetation, residue, and operation are descriptions based specifically on RUSLE2 rules and procedures. A particular field condition can often be described in multiple ways. However, the individual vegetation, residue, and operation descriptions used to create a cover-management description must be consistent with each other. A key element in this consistency is ensuring that the input value for aboveground biomass at maximum canopy cover in the vegetation description is consistent with the operation descriptions.

The value entered in a *vegetation description* for *aboveground biomass at maximum canopy cover* must be consistent with the *processes* in the *operation descriptions* in the *cover-management description* to ensure that RUSLE2 has the proper biomass values for standing residue, flat residue, and soil biomass for its computations.

Four examples are used to illustrate selecting values for aboveground biomass that are consistent with operation descriptions.

Example 1. Corn
Corn is grown for grain or silage. When corn is grown for harvestable grain, all of the aboveground biomass, except for the grain, is left in the field as standing and flat residue. When corn is grown for silage, almost all of the aboveground biomass is removed from the field as a harvestable product. Only a small amount of plant material is left in the field as standing and flat residue.

Table 11.3 lists **processes** that would be used in a **harvest operation description** for alternative input values for aboveground biomass at maximum canopy cover. Alternative 1 for corn grain is where the input value for aboveground biomass at maximum canopy cover is the amount of biomass that will be left in the field after the actual harvest removes the harvestable grain from the field. Alternative 2 is where the input value for aboveground biomass includes the entire aboveground plant material (i.e., fodder and grain). The harvest operation description for this vegetation description must include either a **remove live biomass process** before the **kill process** or a **remover residue/cover process** after the **kill process** to remove the grain. These processes are not required in Alternative 1 because the biomass for the grain is not included in the accounting. If the grain is not removed in Alternative 2, the amount of residue assumed by RUSLE2 after the harvest will be too high. Alternative 1 is the recommended procedure for corn grain.

The RUSLE2 objective is not to fully account for all of the biomass, but to describe only the biomass that affects erosion.

The alternatives for corn silage are similar to those for corn grain. Alternative 1 is where the aboveground biomass includes only the fodder without the grain, which is the same vegetation description as Alternative 1 for the corn grain. The harvest operation for this alternative includes a remove live biomass process before the kill process. Just as in Alternative 2 for the corn grain, a remove residue/cover process can be used after a kill process. In any case, plant material must be removed so that RUSLE2 has the proper value for the residue left in the field after the actual field operation. Alternative 2 for the corn silage is where the input value for aboveground biomass value at maximum canopy cover is the amount of residue that exists in the field after the actual field harvest operation.

Table 11.3. Harvest operation descriptions for corn grain and corn silage production			
Grain		Silage	
Alternative 1		Alternative 1	
Process	Comment	Process	Comment
Alternative 1 Aboveground biomass at max canopy does not include grain		Alternative 1 Aboveground biomass at max canopy includes all of the aboveground plant material except the grain	
Kill vegetation	Converts live aboveground biomass to standing residue, amount of standing residue directly related to input for aboveground biomass at maximum canopy	Remove live biomass	Removes most of live aboveground biomass from RUSLE2's accounting of aboveground biomass but leaves behind a small portion as flat residue
Flatten standing residue	Converts a portion of the standing residue to flat residue	Kill vegetation	Converts the remaining live aboveground biomass to standing residue
		Flatten standing residue	Converts a portion of the standing residue to flat residue
Alternative 2 Aboveground biomass at max canopy includes grain		Alternative 2 Aboveground biomass at max canopy is only the residue that will be left after the harvest operation	
Remove live biomass	This process removes the grain and leave the remaining as material that will become residue	Kill vegetation	Converts live aboveground biomass to standing residue
Kill vegetation	Converts live aboveground biomass to standing residue	Flatten standing residue	Flatten the portion of the standing residue that is to be left as flat residue
Flatten standing residue	Flatten the portion of the standing residue that is to be left as flat residue		

Example 2. Harvesting hay and mowing permanent vegetation.
Forage crops such as alfalfa regrow after each hay harvest. Similarly, permanent vegetation such as that on a landfill regrows after it is mowed. The objective is to provide RUSLE2 with inputs so that it can determine the amount of surface residue added by a hay harvest or mowing operation. Two alternatives, illustrated in Table 11.4, can be used for the hay harvest/mowing operation descriptions. In Alternative 1, the input value for the aboveground biomass at maximum canopy cover includes all of the aboveground plant material. RUSLE2 uses equation 11.1 to compute the aboveground biomass on each day, including the date of the hay harvest/mowing. Given a particular aboveground biomass on the date of the hay harvest or mowing, what is the amount of

this biomass that is added to the surface residue? The two processes of **remove live biomass process** and a **begin growth process** are used in both the hay harvest and mowing operation descriptions. The begin growth process identifies the vegetation description that RUSLE2 is to use immediately after the hay harvest/mowing operation. In addition to the input for aboveground biomass at maximum canopy cover, the other key inputs are the **portion of the aboveground biomass that is affected** and the **portion of the affect biomass that is left as surface residue** for the remove live biomass process.

To illustrate, assume that the aboveground biomass on the date of the hay harvest is 3600 lbs/acre. The input for the portion affected in the remove live biomass process in the hay harvest operation is 98 percent, which means that 3528 lbs/acre of biomass is affected. The input for the portion of the affected biomass that is left is 5 percent, which means that 176 lbs/acre is added to surface residue as a result of the hay harvest operation.

The inputs used to describe mowing a short grass permanent vegetation are similar to those used to describe the hay harvest. Assume that the amount of aboveground biomass on the date of the mowing is also 3600 lbs/acre. The input value is assumed to be 50 percent for the portion of the aboveground biomass affected by the mowing, which is 1800 lbs/acre. The input value for the portion of the affected biomass that is left as added surface residue is 100 percent, which means that 1800 lbs/acre is added to the surface residue as a result of the mowing.

The input values for these operation descriptions are both machine and vegetation specific. For example, assume that the permanent vegetation is a tall grass at the same production 3600 lbs/acre level as the short grass. Assume that 75 percent of the aboveground biomass is affected by the mowing with the tall grass in comparison with the short grass because of differences in vegetation characteristics even though the mower is operated at the same height with both vegetations. The amount of affected aboveground biomass is 2700 lbs/acre. The portion of the affected biomass that is added to the surface residue is still 100 percent, which means that 2700 lbs/acre of biomass is added to the surface residue for the tall grass mowed at the same height as the short grass where aboveground biomass was the same for both grasses. The portion of the aboveground biomass that is affected depends on the vegetation, the machine, and its cutting height.

These inputs, which can be cumbersome and confusing, must be handled very carefully according the RUSLE2 rules and procedures to avoid errors. The intent in RUSLE2 is not to mimic machines, their operations, and settings, but to provide a way to enter information that RUSLE2 needs to determine the surface residue cover and the vegetation conditions after the operation. The operation and vegetation descriptions must be consistent and considered together to ensure that RUSLE2 has the desired values for its computations.[95]

Alternative 2 applies when RUSLE2 is to use a user-entered value for the surface residue added by a hay harvest or mowing operation. The input value for aboveground biomass at maximum canopy is only important in determining the litter fall and the aboveground biomass on the date that the vegetation is killed. In contrast to Alternative 1, it plays no role in determining the surface residue added by the hay harvest/mowing operation. The **processes** in the hay harvest/mowing operation descriptions are **remove live biomass**, **add external residue/cover**, and **begin growth**. The input values for the **remove live biomass process** are 100 percent for the portion of the aboveground biomass affected and 0 percent for the portion of the affected biomass that is left behind as added surface residue. This process removes all of the aboveground biomass on the date of the hay harvest/mowing operation. The **add external residue/cover process** is used to add a specific user entered value for the biomass added to the surface residue by the hay harvest/mowing operation. The inputs for the **add external residue process** are a residue description for the material that is to be added to the soil surface by the operation and the amount of the material that is added. In the mowing example, the value entered for amount of external residue added might be 2000 lbs/acre.

An advantage of this approach is that the effect of cutting height can be quickly and easily evaluated by changing the input value for amount of external residue added. A disadvantage of Alternative 2 is that RUSLE2 does not automatically change this input value as production (yield) level changes because the effect of yield can only be accommodated by manually entering different values for the amount of external residue added. The value for surface residue added that RUSLE2 computes in Alternative 1 does vary with yield as expected.

Table 11.4. Alternative descriptions for hay harvest/mowing operations.			
Alternative 1. Operation description uses aboveground biomass to estimate surface residue added by operation		Alternative 2. Operation description assigns surface residue added by a direct input	
Process	Comment	Process	Comment
Remove live biomass	Removes a portion of the live aboveground biomass at the time of harvest and leaves a part of it in the field as surface residue added	Remove live biomass	Removes all of the live aboveground biomass from the system

[95] RUSLE2 was not designed to use absolute cutting height for hay harvest and mowing operations so that user-entered information is not required on the vertical biomass distribution for each vegetation description and how that changes through time. Such inputs for describing vegetation are not readily available. A major advantage of the RUSLE2 approach, which may seem crude, is that practically any situation can be represented with simple, easy-to-understand inputs.

Begin growth	Identifies the vegetation description that RUSLE2 to use after the hay harvest/mowing operation	Add other cover	Adds external residue in a user entered amount to represent the surface residue added by the operation
		Begin growth	Identifies the vegetation description that RUSLE2 is to use after the hay harvest/mowing operation
Note: A kill vegetation process was not used. A kill vegetation process transfers the live root biomass into the dead root biomass pool, which does not occur in a hay harvest or mowing operation for vegetation that regrows following the operation.			

Example 3. Cover crop.
Vegetation such as rye can be used as a cover crop to reduce erosion over the winter after harvest of the main crop until it is replanted in the spring. A **vegetation description** for a cover crop can be created in either of two ways.

The preferred approach is to develop a vegetation description that extends beyond the last possible date when the cover crop would be killed. The input value for above-ground biomass at maximum canopy cover is for the day in the vegetation description having the maximum canopy cover. This vegetation description can be used in **cover-management descriptions** where the date of the **operation description** that kills the cover crop can vary from day zero until the last day in the vegetation description. RUSLE2 uses equation 11.1 to estimate aboveground biomass on the date on the cover crop killing operation description.

Another approach is to describe the cover crop from its seeding date to the date that the cover crop is killed. The input value for the aboveground biomass at maximum canopy is the amount of aboveground biomass on the date that the cover crop is killed, assuming that the cover crop has not reached maturity and canopy cover is still increasing. The ending date of this vegetation description should coincide with or be within a few days of the date for the cover crop killing operation description. A disadvantage of this approach is that getting these dates to coincide is cumbersome and inconvenient. Another disadvantage is that a separate vegetation description is needed for each date that the cover crop might be killed, which varies according to main vegetation (e.g., cotton is planted later than corn) and early or late planting. The advantage of this approach is that the user can control the amount of biomass at the time that the vegetation is killed instead of letting RUSLE2 use equation 11.1 to estimate aboveground biomass at the date that the cover crop is killed. If the cover crop killing date occurs before the last date in the vegetation description, RUSLE2 will still use equation 11. 1 or 11.2 to estimate aboveground biomass on the date that the cover crop is killed. A few days difference in the killing date and the last date in the vegetation description has only a minimal effect on the results. If the date of the cover crop killing operation occurs after the last day in the vegetation description, RUSLE2 assumes the value on the last day of the vegetation description for all later days. Make a careful check to avoid this condition.

Example 4. Green beans.
Green beans can be cropped in several ways. Mechanically harvested green beans often involve a single harvest that kills the green beans. A vegetation description for green beans can be developed specifically for this cover-management description where the last date in the vegetation description corresponds with the mechanical harvest date. The input value for the above-ground biomass at maximum canopy cover would be for the harvest date, assuming that plant maturity and maximum canopy cover are not reached before the harvest.

A second way of cropping green beans is to hand pick them multiple times before the green beans are mechanically killed by tillage or chemically killed to plant the vegetable crop that follows the green beans. A vegetation description for the green beans is constructed that ends on the date of the operation description that kills the green beans. The input for above-ground biomass at maximum canopy cover would differ in this vegetation description from corresponding input in the vegetation description for the mechanically harvest green beans because the green beans would be killed later than with the single mechanical harvest green beans.

A third way that green beans can be grown is to hand pick the green beans multiple times and let the green beans grow until they die naturally. A vegetation description for this cropping method describes the green beans from seeding until the date that the green beans are assumed to die naturally. An operation description with a kill vegetation process must be included in the cover-management description on the date that the green beans are assumed to die naturally. This operation is needed to convert the live aboveground biomass and live roots to standing residue and dead root biomass.

The input for aboveground biomass at the natural maximum canopy cover is the aboveground biomass amount just before senescence begins. This vegetation description can also be used for the other two types of green bean production methods. This vegetation description has the advantage of not requiring a vegetation description for each production method and also has the advantage of not requiring the cumbersome process of matching the last date in the vegetation description with the date in the cover-management description for the operation description that kills the green beans. The advantage of ending the vegetation description on the date that the green beans are killed is that the user can control the value that RUSLE2 uses for aboveground biomass on the date that the green beans are killed rather than relying on RUSLE2 to use equation 11.1 to estimate the live aboveground biomass value on that date.

11.1.3.3. Residue:yield ratio

The value for aboveground biomass at maximum canopy cover can be entered in one of two ways. The recommended way is to directly enter a value for biomass in terms of dry biomass per unit area. The alternative is to enter a value for residue:yield ratio. RUSLE2 multiplies the value for this ratio by the input yield value and the conversion factor that computes a yield mass (see **Section 11.1.2**) to compute a value for aboveground biomass at maximum canopy cover. See Section **11.2.1** for a discussion on how RUSLE2 adjusts aboveground biomass as a function of production (yield) level.

Make sure that when the residue:yield ratio, yield, and conversion factor are all combined, the resulting aboveground biomass value is on a dry basis.

Residue:yield ratios are primarily rules of thumb, which are useful if values for aboveground biomass are not available. Residue:yield ratio values are a function of yield. Assuming a constant residue:yield ratio value over a working range is acceptable for several crops, but residue yield ratio values can be significantly larger at low yield than at high yields.

The residue:yield ratio values can vary by crop variety. Some of the common rule of thumb residue:yield ratio values were developed 40 or more years ago. Make sure that those values, although widely used, apply in your situation.

Be slow in having different residue:yield ratios in an attempt to compute how crop variety affects erosion. RUSLE2 is not sufficiently accurate for basing conservation planning on such differences. The main intent of RUSLE2 is to represent how main plant types, such as wheat, affect erosion in relation to another crop type, such as corn. The same is true for capturing the differences between plant community types for permanent vegetation on pasture, range, reclaimed mine, and landfills.

11.1.3.4. Selecting input value for aboveground biomass at maximum canopy cover

The input for aboveground biomass at maximum canopy is one of the most important inputs in RUSLE2 because this value determines the amount of litter fall and crop residue that ends up on the soil surface as ground cover to affect erosion. In most situations involving disturbed land, ground cover has more effect on erosion than any other variable. The input value for this aboveground biomass should be chosen very carefully and must be consistent with the values in the **RUSLE2 core database**. The values shown in the RUSLE2 core database were used to calibrate RUSLE2. If a user assumes different values for the RUSLE2 core database conditions than were used by the RUSLE2 developers in their calibration of RUSLE2, then RUSLE2 will give erroneous results.

Consistency between inputs and the RUSLE2 core database must be followed.

Scientific literature is a source of data for values for aboveground biomass at maximum canopy cover. These data can be quite variable. Assemble as much data as possible and review the data as a whole. Select input values that represent the data as a whole rather than trying to capture the effects of individual studies. Some or even most of the differences between individual studies can be unexplained by variability that occurs between particular years and locations.

11.1.4. Vegetative retardance

Vegetative retardance refers to the degree that vegetation slows runoff to reduce its erosivity and transport capacity. Vegetative retardance depends on type, growth stage, and density of the vegetation. For example, the retardance of dense, sod forming grasses is much greater than that of vines in a vineyard. The retardance of sod forming grasses is greater than that for bunch grasses. The retardance of a sod forming grass is very low if its production (yield) level is very low. Retardance increases during the growing season as plant material develops. Plant material must be in contact with the soil surface and slow the runoff to affect vegetation retardance. Additional factors such as soil surface roughness, surface residue cover, and live ground cover are considered by RUSLE2 to determine the overall retardance as it varies through time in a RUSLE2 computation.

Eight retardance classes ranging from none to the greatest, which is for a dense sod forming grass, are used to represent the vegetation retardance at maximum canopy cover at the base yield. RUSLE2 adjusts the class selected to represent the vegetation description as canopy cover changes during the time and as yield varies from the base yield represented by the vegetation description.

The input for retardance class for a **vegetation description** is discussed in **Section 11.2.5**. The retardance class that RUSLE2 assigns to the vegetation description at the input yield value is displayed in the **cover-management description** window of the RUSLE2 computer program for certain **user template** RUSLE2 program configurations. The purpose for giving the user access to vegetation retardance class during a RUSLE2 computation is to allow the user to manually override RUSLE2's selection of the retardance class for the input yield, if desired.

11.1.5. Residue

As described in **Section 11.1.3,** aboveground plant material can reach the soil surface as litter fall or by mechanical operations such as mowing and harvesting. RUSLE2 uses data on plant material properties to compute how this material, referred to as **residue** in RUSLE2 terminology, affects erosion. These properties include how well the material conforms to the soil surface, resists breaking into smaller pieces when the soil surface is mechanically disturbed (fragility), the portion of the soil surface cover by a given mass of material, and the rate that the material decomposes under a standard environmental condition.

Data for these properties are input for **residue descriptions** contained in the **residue component** in the RUSLE2 database. A residue description is selected and assigned to each **vegetation description** depending on how a vegetation description is used in a **cover-management description**. Plant litter (residue) is typically composed of several plant components including leaves, seed pods, chaff, and fine and coarse stems that vary greatly in their properties. A residue description represents a composite of all plant components present in the residue at the time that residue description is being used in RUSLE2. Assigning a residue description to a vegetation description is almost always a compromise. For example, immediately after harvest, the leaves in soybean residue provide a high degree of soil cover, but these leaves decompose very rapidly so that the residue becomes composed primarily of stems. The stems cover a far smaller area than do the leaves for a given mass, and the stems decompose far more slowly than do the leaves. Thus, the net properties of the soybean residue change greatly through time as the relative mass of the residue components change through time.

RUSLE2 does not consider how the properties of a residue description change through time.

Select a residue description to obtain the best overall results, which is usually an estimate of average erosion rather than erosion for a particular period. Values for residue and other variables in the RUSLE2 core database were chosen to give good estimates for average annual erosion.

However, cases arise where a different residue description should be selected for a particular plant community, such as wheat, depending on how the vegetation description is used in a cover-management description. Mature wheat straw decomposes much more slowly than does wheat residue when the wheat is killed in its early growth stage. Thus, two wheat residue descriptions should be developed, one for wheat grown to maturity where the grain is harvested and wheat straw remains and one for wheat grown as a cover crop that is killed before the wheat reaches maturity. Thus, the residue assigned to wheat depends on whether the wheat vegetation description is used in a cover-management description for grain or in a cover-management description where the wheat is used as a cover crop that is killed before reaching maturity.

The same residue description can be used for multiple vegetation descriptions. For example, several vegetation descriptions can be developed for corn based on days to maturity. The same residue description can be used for all of these corn descriptions.

11.1.6. Relative moisture depletion

A value for the variable **relative moisture depletion** is entered in vegetative descriptions used when RUSLE2 is applied to Req zones (see **Section 6.9**). This variable describes how a previous crops depletes soil moisture, which reduces runoff and erosion in subsequent periods in a crop rotation.[96] Recommended values for relative moisture depletion are given in Table 11.5.

A value of 0.00 for relative moisture depletion means that the vegetation (crop) does not remove sufficient water to significantly affect erosion. In comparison, a crop such as winter wheat is assigned the maximum value of 1.00. See **Section 9.2.7** for discussion on how this variable affects erosion computed by RUSLE2.

Table 11.5. Recommended value for relative moisture depletion for vegetation description used in applying RUSLE2 to Req zones. (Source: AH703)

Crop	Relative moisture depletion input value
Winter wheat and other deep rooted crops	1.00
Spring wheat and barley	0.75
Spring peas and lentils	0.67
Shallow-rooted crops	0.50
Summer fallow	0.00

11.1.7. Growth chart variables

A **vegetation description** includes arrays of input values for the **temporal variables** of age (time), live root biomass, canopy cover, effective fall height, and live surface (ground) cover. The collection of these values is referred to as the **growth chart** for a vegetation description. A value for each variable is entered for each **time** in the growth chart. Each entered value is the value for a variable on that day, not an average or representative value over a time interval.

RUSLE2 uses a descriptive procedure to input values for vegetation variables that affect erosion rather than using a plant model to compute values for those variables. The focus in creating and using vegetation descriptions is to describe, not to model. This RUSLE2 feature gives RUSLE2 great power and flexibility.

A vegetation description is just that, a description of the vegetation condition over the time represented in the growth chart. This description is for the composite field condition on each day. RUSLE2 can not combine vegetation descriptions from multiple

[96] Contact Donald K. McCool, USDA-Agricultural Research Service, Pullman, WA for additional information.

plant communities into a new vegetation description for a plant community composed of multiple components. That is, a single set of vegetation values are used to describe intercropping, where two or more plant types are growing at the same time, rather than combine values for the component parts. For example, the input values for canopy cover and fall height are the values that you want RUSLE2 to use to represent the composite field condition on each day. See **Section 10.2.3.**

11.1.7.1. Age

Age in days is the time variable used in the growth chart. The first entry in a growth chart is always for **day zero (0),** which represents conditions on the date that this **vegetation description** begins to apply. RUSLE2 references day 0 to the date in the **cover-management description** for the **operation description** with a **begin growth process** that instructs RUSLE2 to begin using this particular vegetation description. A set of time (age) values are chosen to describe the temporal variables in the vegetation description. RUSLE2 assumes that variables are linear between each time value. Only a time at the beginning and a time at the end of a period are entered if values for all of the temporal variables do not change over the time period. Similarly, only times at the beginning and end of a period are entered if the temporal variables vary linearly over the time period. Additionally, closely spaced times are used to represent periods when one or more of the temporal variables change non-linearly. A sensitivity analysis (see **Section 17.3**) may be needed to determine the spacing of the times in these non-linear periods.

The growth chart for a RUSLE2 vegetation description often uses days on a 10-day or 15-day internal for convenience. [97]

The days in the growth chart for a vegetation description need not be on a fixed interval.

Day zero in a vegetation description is not necessarily the date that the vegetation is seeded. The values on day 0 describe conditions that exist on the day that RUSLE2 begins to use this vegetation description. Value for day 0 should be entered very carefully. RUSLE2 compares the root biomass and canopy cover values on day 0 with corresponding values for the last day that the previous vegetation description is used. RUSLE2 assumes that a decrease in live root biomass between two vegetation descriptions represents an event where the decrease in live root biomass should be added to the dead root biomass pool. An example is the wheat-legume intercropping cover-management description discussed in **Section 10.2.3.** The live root biomass on day 0 for

[97] Vegetation descriptions in RUSLE1 must be on a 15-day time interval. Although that 15-day time interval is often retained where RUSLE1 data files are imported into RUSLE2, day values in RUSLE2 can be on any interval and the interval can vary throughout a RUSLE2 vegetation description.

the legume vegetation description that represents conditions after the wheat harvest is less than the live root biomass of the combined wheat-legume vegetation on the day of wheat harvest. The effect represented by this decrease is that the wheat harvest killed the wheat and transferred the wheat's live root biomass to the dead root biomass pool. A harvest operation with a **kill vegetation process** is not used in this cover-management description because that process would have transferred the entire live root biomass, not just the wheat live root biomass, to the dead root biomass pool.

The last day in the vegetation description should be carefully selected as discussed in **Section 11.1.3.2.** The last day in the vegetation description should be later than the date in the cover-management description for the operation description that kills the vegetation. In special cases, the last day in the vegetation description and date of the kill vegetation operation should be the same or nearly the same to ensure that RUSLE2 uses a particular value for aboveground biomass at maximum canopy cover. However, if the last day in the vegetation description is less than the date of the kill vegetation operation, RUSLE2 uses values for the last day in the vegetation description until RUSLE2 begins to use the next vegetation description.

No time limit exists for the last day in a vegetation description. Many vegetation descriptions are for a year or less.[98] For example, the duration of vegetation descriptions vary from 60 days for spring broccoli, 120 days for corn grain, 255 days for winter wheat, and 365 days for a mature pasture. In RUSLE2, the time can be as long as desired to represent the full duration of the vegetation, which can be multiple years. For example, the vegetation description for seeding and establishment of permanent vegetation on a landfill or reclaimed mine may be 10 years that includes the initial three-year establishment period and an addition seven years required for a stable litter and soil biomass pool to develop. The RUSLE2 long term vegetation tool described in **Section 11.2.6** can be used to construct these multi-year vegetation descriptions. A set of three vegetation descriptions can be used in this example rather than using one long 10-year vegetation description. Three 1-year vegetation descriptions would be used, one for the first year starting at seeding, one for development during the second year, and one for the third year and every year thereafter, which represents maturity. An operation with a begin growth process is used each year to tell RUSLE2 which vegetation description to use for that year.

Another example where multiple vegetation descriptions are used is to represent mowing permanent vegetation and hay harvests (see **Section 11.1. 3.2**). The main use of the multiple vegetation description is to represent regrowth of the vegetation following mowing or hay harvest. Simultaneous with the representation of mowing and harvest, multiple vegetation descriptions can be used to represent both the increase and decrease of vegetative production between renovations of the vegetation. See **Section 10.2.3** for a

[98] The duration of a vegetation description in RUSLE1 is limited to 1 year. Vegetation descriptions in RUSLE2 can be of any duration.

discussion of an alfalfa cover-management description where multiple vegetation descriptions are used.

11.1.7.2. Live root biomass

Live roots reduce erosion by mechanically protecting and holding soil in place, producing exudates that reduce soil erodibility, becoming a part of the soil dead root biomass by root sloughing (death) or the vegetation being killed, and indirectly representing increased infiltration, reduced runoff, and reduced erosion (see **Section 9.2.5**). The most important roots are the fine ones very near the soil surface. Coarse roots, especially tap roots, have much less effect on erosion than the fine roots. A value for **live root biomass per unit area in the upper four inches (100 mm) of soil** is entered for each time in the **growth chart**. RUSLE2 uses each value in the array to estimate live root biomass values for the entire rooting depth according to the distribution illustrated in Figure 9.14.

Live root biomass values for annually seeded plants, such as the corn and winter wheat illustrated in Figure 11.4, start from zero on day zero (0) in the growth chart and increase through time to a maximum value. In the case of spring planted corn, the values increase as an S-shaped curve and level off at a maximum. The pattern for fall planted winter wheat differs from that for the spring planted corn. The winter wheat experiences early growth during the fall and dormancy during the winter, reflected by the plateau from about day 50 to day 170 in Figure 11.4. The degree of fall growth for the winter wheat and the length of dormancy is climate dependent. RUSLE2 does not adjust vegetation descriptions to account for those climatic differences. Instead, users create multiple vegetations by climatic regions, such as cropping zones. Figure 11.4 illustrates vegetation descriptions for annually seeded crops. Figure 11.5 illustrates vegetation descriptions for permanent vegetation. Two types of erosion analysis are made for permanent vegetation. One analysis is to compute erosion from the date of seeding until the vegetation becomes mature, fully established along with a fully developed litter layer and soil biomass pool. The other analysis is to estimate erosion for a fully established permanent vegetation (see **Section 10.2.8**).

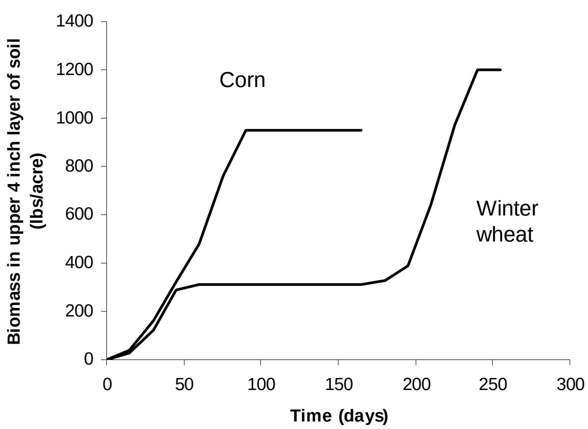

Figure 11.4. Live root biomass values for corn and winter wheat.

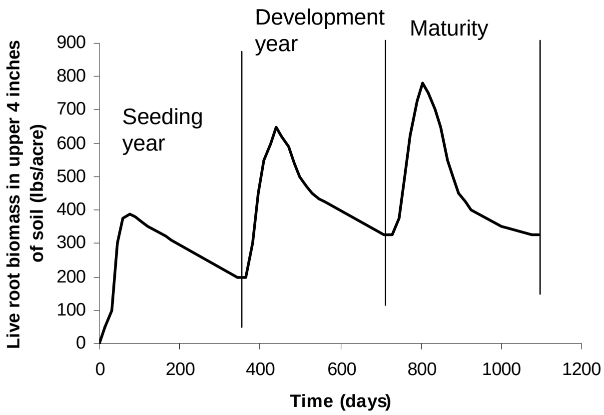

Figure 11.5. Live root biomass for three vegetation descriptions used in series to represent the establishment of permanent vegetation

A single **vegetation description** can be created to describe the vegetation from seeding through complete establishment. The vegetation can also be described with a set of three vegetation descriptions as illustrated in Figure 11.5. The time period for each vegetation description is an entire year. The ending live root biomass for one vegetation description matches the live root biomass at the beginning of the next vegetation description. In the mature year, the beginning live root biomass matches the ending live root biomass. The vegetation description for the mature year is repeated for as many years as necessary for RUSLE2 to compute a stable litter layer and soil biomass pool. This **cover-management description** is a **no-rotation** with a **duration** sufficiently long for fully established conditions to be represented.

Only the vegetation description for the mature year is used to compute erosion for a vegetation completely established. This cover-management description is a **rotation** with a 1-year **duration**. RUSLE2 automatically repeats the computations for as many years as necessary to compute the development of a stable litter layer and soil biomass pool.

The value for live root biomass on day 0 begins at zero for plants started from seed. However, live root biomass on day 0 begins at a value greater than zero when describing vegetable transplants, for example, to reflect the presence of live root biomass is when RUSLE2 begins to use this vegetation description.

Live root biomass is the source of the dead root biomass pool represented by RUSLE2. An **operation description** with a **kill vegetation process** transfers the entire live root biomass that exists on the date of the kill vegetation operation description to the dead root biomass pool. Live root biomass becomes zero on that day and the dead root biomass pool is increased by this amount of live root biomass.

A kill vegetation process in an operation description transfers the entire live root biomass to the dead root biomass pool. Sequential vegetation descriptions without a kill vegetation operation description are used to transfer only a portion of an existing live root biomass pool to the dead root biomass pool.

Root sloughing (death) is also a major source of dead root biomass for permanent vegetation on range, pasture, landfills, and reclaimed mine lands. Up to 40 percent of the annual root biomass can be sloughed (see **Sections 9.2.5.1 and 9.2.5.3.2**). RUSLE2 assumes that a decrease in live root biomass, as illustrated in Figure 11.5, during the time represented by a vegetation description is root sloughing. RUSLE2 can also compute death of root biomass during growth periods by assuming that daily root biomass death is a fraction of the daily live root biomass. The decrease in live root biomass between days is added each day to the dead root biomass pool. Using a constant live root biomass in a permanent vegetation description prevents RUSLE2 from computing an accumulation of dead root biomass, which can result in a serious overestimate of erosion.[99]

Time varying root biomass values should be used in vegetation descriptions for permanent, multiple year forage crops, and similar vegetation.

Situations, such as intercropping, exist where only a portion of an existing live root biomass pool should be transferred to the dead root biomass pool. An example is the small grain-legume **cover-management description** discussed in **Section 10.2.3.** A similar situation is winter weed growth in southern US regions. The canopy of crops like corn, soybeans, and cotton decrease before harvest so that volunteer weeds begin to grow and continue to grow after crop harvest. These weeds provide vegetative cover during the winter to significantly reduce erosion, which is especially important because of the high erosivity during winter months in this region.

Sequential vegetation descriptions are used in RUSLE2, such in these cover-management descriptions, when only a portion of an existing live root biomass pool is to be transferred to the dead root pool. Three vegetation descriptions are used: (1) the wheat only period from seeding until the legume is seeded (corn only), (2) the period when the wheat and legume grow together until wheat harvest (corn and weeds together), and (3) the period after wheat harvest where the legume continues to grow (also, weeds after corn harvest). RUSLE2 makes no change to the dead root biomass pool between periods 1 and 2 because the live biomass values at the end of period 1 equals the live root biomass at the beginning of periods. RUSLE2 adds to the dead root biomass pool between periods 2 and 3 because the live root biomass decreases from that at the end of period 2 to the live biomass at the beginning of period 3. The addition to be dead root biomass pool is the amount of the decrease in the live root biomass. This procedure represents harvest

[99] The time-invariant C-factor procedure in RUSLE1 does not directly account for the effect of dead root biomass on erosion.

killing one vegetation while allowing growth of another vegetation to continue.

Figure 11.5 illustrates a situation where no live root biomass should be transferred to the dead root biomass when RUSLE2 switches vegetation descriptions in the cover-management description. The vegetation descriptions for Figure 11.5 were constructed with the biomass value at the end of one vegetation description matching the live root biomass value at the beginning of the next vegetation description in the sequence so that a smooth continuous condition in live root biomass is represent between vegetation descriptions.

Hay harvest of forage crops that regrow after harvest and permanent vegetation that regrows after mowing are cover-management descriptions where an event causes a major change to occur in the aboveground biomass but no change in the live root or dead root biomass pools. Principally two vegetation descriptions are used, one to represent conditions through the day of the hay harvest/mowing and one to represent regrowth conditions after hay harvest/mowing. The live root biomass value at the end of the first vegetation description matches the live root biomass value at the beginning of the second vegetation description. The two live root biomass values should be equal on the day of harvest and the day after harvest so that no change in the dead root biomass occurs. Multiple vegetation descriptions can be created to shows a progression of live root biomass over time where a hay (pasture) crop reaches maximum production and then declines until the hay (pasture) crop is renovated.

RUSLE2 makes no change in the dead root biomass when the live root biomass increases either within a vegetation description or between vegetation descriptions.

Inspect the vegetation descriptions used in a cover-management description to avoid an unintended decrease in live root biomass and addition to dead root biomass between vegetation descriptions.

The recommended approach for selecting input values for live root biomass is to use the values listed in the **RUSLE2 core database** as a guide. Start by selecting a vegetation description in the RUSLE2 core database that is similar to the plant community for which you are selecting input live root biomass values. Modify the live root biomass values for the selected core database plant community based on how you think differences between the two plant communities would affect live root biomass. This approach for selecting live root biomass values is far better than making field measurements of live root biomass values. Measuring root biomass is very difficult and time consuming, which is evident by the huge range of values given in the literature for wildland type plant communities (see **AH703**). The variability is much less for agricultural and pasture land crops, but is still significant. If input values for live root biomass are to be selected based on field measurements, make many measurements, being careful to measure the fine roots, which have the greatest effect on erosion.

The research literature is a source of live root biomass values that are reliable for vegetable and field crops but not for wildland plant communities. Be very careful in selecting live root biomass values based on literature sources. Many data sources should to be reviewed to determine overall main effects. The best way to select live root biomass values for wildland plant communities is to use the ratio of effective root biomass to average annual aboveground biomass production listed in **Section 17.4.1.4**. These values were obtained by using measured erosion data to back calculate effective live root biomass values using the subfactor equations described in **Section 9**.

A major problem with using measured root biomass values for wildland type plant communities is knowing the credit to give to fine roots versus the credit to give to coarse roots. The input values for live root biomass should be based primarily on the annual production of fine roots. However, erosion and root research has not provided definitive information on how to measure root biomass for use in RUSLE2, which was overcome in the RUSLE2 approach that back calculates effective live root biomass values from measured erosion data.

A major requirement is that input values for live root biomass values are consistent with values in the RUSLE2 core database to ensure that RUSLE2 computes the expected erosion values. RUSLE2 was calibrated with the values given in the RUSLE2 core database to give expected average annual erosion estimates. If input values are not consistent with the core values used to calibrate RUSLE2, then RUSLE2 may give erroneous results. Do not use live root biomass values without checking them for consistency with RUSLE2 core values.

11.1.7.3. Canopy cover

Canopy cover is the portion of the soil surface covered by plant material that is above the soil surface. Canopy cover intercepts raindrops but has no effect on surface runoff, (see **Section 9.2.1**). Canopy cover is a major variable in the canopy subfactor, and it is also used by RUSLE2 to estimate live aboveground biomass during the time represented by a **vegetation description** (see **Section 11.1.3.1**).

Canopy cover values are entered for each time value in the **growth chart**. RUSLE2 interprets an increase in canopy cover as plant growth adding aboveground biomass. Conversely, RUSLE2 interprets a decrease in canopy cover as a transfer of live aboveground biomass to the soil surface. Senescence and litter fall are natural processes where leaves fall from mature plants to the soil surface and become surface (flat) cover. Most permanent vegetation and some agricultural crops like soybeans experience senescence. Also, a senescence type process is chemically induced in cotton just before harvest. Not all decreases in canopy cover represent a transfer of biomass from the live aboveground biomass to surface residue. For example, mature corn leaves droop without falling to the soil surface. RUSLE2 uses data are entered in the **senescence tool** in the vegetation description to calibrate equation 11.2 that computes values for live aboveground biomass as a function of canopy cover.

A decrease in canopy cover between the last day of the previous vegetation description and the canopy cover on day zero of the next vegetation description has no significance to RUSLE2. RUSLE2 makes no changes in residue cover when canopy cover changes between vegetation descriptions. In contrast, RUSLE2 assumes that a decrease in live root biomass between vegetation descriptions is dead root biomass that is added to the dead root biomass pool. **Operation processes**, such as **kill vegetation**, in **operation descriptions** to explicitly describe changes in standing and surface residue between vegetation descriptions.

A **kill vegetation process** in an **operation description** converts the entire live aboveground biomass to standing reside rather than just a part. **Understanding this feature is important** for describing intercropping represented in the wheat-legume cover-management description discussed in **Section 10.2.3**. The wheat harvest creates a large pool of standing and flat wheat straw residue. However, the live aboveground biomass for the legume should remain unchanged after the wheat harvest.

A similar situation is hay crops that regrow after hay harvest and permanent vegetation that regrows after mowing. These **cover-management descriptions** typically involve a harvest operation description that includes a **remove live biomass process** to manipulate the live aboveground biomass amounts to add the desired amount of surface (flat) residue and a **begin growth process** to identify the vegetation description that RUSLE2 is to use immediately after harvest. **The value that RUSLE2 uses for standing residue needs to be checked to ensure that RUSLE2 is leaving the proper amount of standing residue. This check is critically important in cover-management descriptions like wheat-legume intercropping because of the large mass of residue left by the wheat harvest.**

Input values for canopy cover should be selected by comparing your vegetation description with vegetation descriptions contained in the **RUSLE2 core database**. Select canopy cover values by adjusting core database values based on differences in characteristics between your vegetation and the core database description being used as a guide.

The literature is a source of canopy cover values. However, make especially sure that the canopy cover values reported in the literature are consistent with **RUSLE2 definitions**. For example, literature values often includes leaves touching the ground as **canopy cover** that the RUSLE2 definitions require counting as **live ground cover** (see **Sections 9.2.2.1 and 11.1.7.5**). Review as many data sources as possible because of data variability. The data should be reviewed to determine overall main effects rather than focusing on the data for a single location.

In some cases, field measurements may be necessary. One way to estimate canopy cover is to sum the open space between plants and open space within the perimeter of the plant canopy and subtract this sum expressed as a percent of the total area from 100. Canopy cover can be estimated from plan view photographs for certain plant communities like corn where live vegetation does not touch the soil surface. A better approach for measuring canopy cover of permanent vegetation on range, pasture, landfills, and reclaimed mine land where some of the live vegetation touches the ground is to lay a transect across the field slope, lower a pointed rod vertically to the soil surface, and count the number of hits for canopy cover, surface (flat) residue (litter), and live parts of the vegetation touching the soil surface (live ground cover). Make sure that a large number of measurements are taken to properly deal with spatial and temporal variability, such as that associated with hillslope position.

11.1.7.4. Canopy Fall Height

Canopy fall height is the effective height from which intercepted rainwater forms drops that fall from the plant canopy (see **Section 9.2.1.1**). **Effective fall height** is less than the canopy height but greater than the height to the canopy bottom. Effective fall height is also a function of canopy shape and the vertical density distribution within the canopy. Some plant communities like grass growing under shrubs on rangelands have two distinct canopies. The understory is the main determinant of effective fall height if the understory is dense. Enter an effective fall height value for each time in the **growth chart**.

Several procedures are available for selecting effective fall height values. One approach is to compare characteristics of your vegetation with **vegetation descriptions** in the **RUSLE2 core database** and assign effective fall height values based on that comparison. Another approach is to inspect plants in the field or in photographs and assign effective fall height values. Another approach is to measure the height to the lowest part of the canopy at locations along a transect. Effective fall height is the average of those values. A fourth approach is to use the **fall height tool** in a RUSLE2 vegetation description to estimate effective fall height. This procedure uses height values to the top and bottom of the canopy, canopy shape, and the density gradient within the plant canopy to estimate effective fall height (see **Section 9.2.1.3**).

Review effective fall height values to ensure consistency among vegetation descriptions so that RUSLE2 computes expected differences in erosion among plant communities.

11.1.7.5. Live ground cover

Live ground cover is live vegetation that touches the soil surface to affect raindrop impact and surface runoff as does other ground cover (see **Section 9.2.2.1**). Live ground cover is one form of ground cover along with crop residue, plant litter, and rock fragments. The portion of the soil surface covered by live ground cover can be very high in early plant growth when the vegetation is composed almost entirely of very low leaves. As the vegetation grows and stems develop, live ground cover can decrease, even to the point that no part of the plant, other than the stems, touches the soil surface to provide live ground cover. Live ground cover inputs also include basal area of the vegetation. A value for live ground cover is entered for each time value in the **growth chart**.

The best way to select live ground cover input values for a vegetation description is to make comparisons with **vegetation descriptions** in the **RUSLE2 core database**. Field measurements can also be made. Many measurements are needed to deal with both temporal and spatial variability. Field measurements can be made using points along a transect. Live ground cover is measured even if it lies on top of plant litter, crop residue, rock, or other types of ground cover. RUSLE2 accounts for overlap of ground cover from different sources. Input values for live ground cover should be reviewed for consistency among the vegetation descriptions in the RUSLE2 database. Also, field inspections of plant communities are helpful, especially if field measurements of live ground cover are not made.

The mass in live ground cover is included in the live aboveground biomass inputs. RUSLE2 does use a relationship between cover and mass for live ground cover as it does for crop residue, plant litter, or applied residue.

11.2. Tools used to develop input values for vegetation descriptions

11.2.1. Develop growth chart for a new production (yield) level

Each **vegetation description** in the RUSLE2 database is for a particular **production (yield) level**. Adjustments are required in a vegetation description to apply RUSLE2 to other production (yield) levels (see **Section 9.2.1.6**). Two options are available to make the adjustments.

One option is to enter the desired production (yield) level value in the **cover-management description** where the vegetation descriptions are selected. RUSLE2 can adjust any vegetation description to a production (yield) level greater than the assigned value for the selected vegetation description. However, the maximum canopy cover must be less than 100 percent in the selected vegetation description for RUSLE2 to adjust to a production (yield) level less than the assigned value for the selected vegetation description. RUSLE2 adjusts values for aboveground biomass at maximum canopy; live root biomass, canopy cover, effective fall height, and live ground cover in the growth chart; and retardance index values to represent the new value entered for production (yield) level. Live aboveground biomass at maximum canopy is assumed to vary with yield according to equation 9.5. RUSLE2 assumes that live root biomass varies linearly with aboveground biomass at maximum canopy cover; canopy and live ground cover vary with the square root of live aboveground biomass at maximum canopy cover; and effective fall height varies with the 0.2 power of live aboveground biomass at maximum canopy. RUSLE2 varies the retardance index as a linear function (retardance index = a + b·yield) (see **Section 11.2.5**).

The second option is to use the RUSLE2 tool **develop growth chart for new production (yield) level** to create a new vegetation description for the desired production (yield) level. This RUSLE2 tool starts with the selection of a base vegetation description at its assigned production (yield) level. A value is entered for the new production (yield) level and RUSLE2 creates a new vegetation description for the new production (yield) level. This new vegetation can be saved in the RUSLE2 database and used in other RUSLE2 computations. The same requirements and equations discussed above for entering a new production (yield) level in a cover-management description apply in the **develop new growth chart tool**. The advantage of using the develop new growth chart tool is that the adjustments do have to be made by hand and manually entered in a new vegetation description in the RUSLE2 database.

11.2.2. Estimate effective fall height based on canopy characteristics

As discussed in **Section 9.2.1.2, effective fall height** varies with heights to the top and bottom of the canopy, canopy shape, and the vertical density gradient of plant material within the canopy that affects fall height. The RUSLE2 tool that estimates **effective fall heights as a function based on canopy characteristics** can be useful in assigning effective fall height values and improves consistency among users assigning effective fall height values.

Effective fall height varies temporally during plant growth and senescence. Input values for canopy characteristics are entered into the fall height tool at selected times during the period represented by a **vegetation description**. These inputs include values for heights to the top and bottom of the canopy, selection of a canopy shape from those illustrated in Figure 9.2, and selection of a canopy density gradient. The canopy density gradient refers to whether canopy material affecting fall height is uniformly distributed with height in the canopy, concentrated near the bottom of the canopy, or concentrated near the top of the canopy. The base condition is for a uniform canopy density gradient where effective fall height is one third of the difference in heights between the top and bottom of the canopy plus the height to the bottom of the canopy as illustrated in Figure 9.1. The effective fall height is adjusted up or down with respect to canopy shape as illustrated in Figure 9.1 and adjusted up if the plant material affecting fall height is concentrated near the top of the canopy or down if the material is concentrated near the bottom of the canopy.

RUSLE2 computes an effective fall height at each of the times where values are entered for canopy characteristics. RUSLE2 then linearly interpolates between these effective fall height values to assign effective fall height values for each time value in the **growth chart**.

11.2.3. Live aboveground biomass at maximum canopy as a function of production (yield) level

The input for **live aboveground biomass at maximum canopy cover** determines the mass of vegetative material that becomes standing and surface (flat) residue, both of which have a major effect on erosion (see **Sections 9.2.2, 9.2.5, and 11.1.3**). The amount of live aboveground biomass varies with production (yield) level as illustrated in Figure 11.6. RUSLE2 uses equation 9.5, represented by the fitted line in Figure 11.6, to estimate live aboveground biomass at maximum canopy cover as a function of **production (yield) level** (see **Section 9.2.1.6**).

The **biomass-yield tool** [live aboveground biomass at maximum canopy as a function of production (yield) level] is used to input values that define the fitted line illustrated in Figure 11.6 for a particular vegetation description. The procedure is to plot observed data for live aboveground biomass at maximum canopy as a function of production (yield) level and fit a straight line to the data. The production (yield) level units in this relationship are the ones created for this particular **vegetation description** (see **Section 11.1.2**).

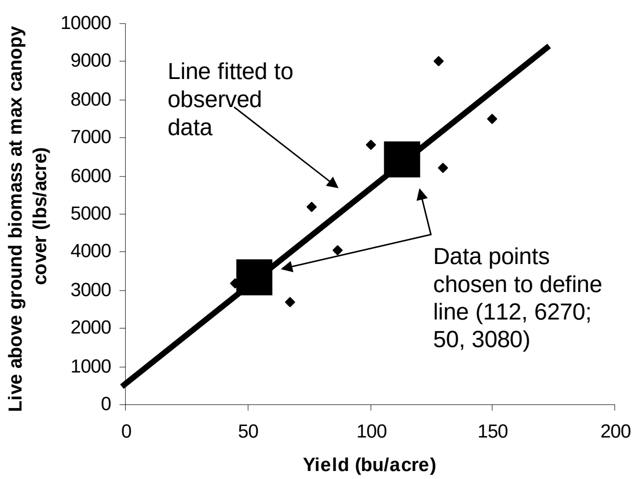

Figure 11.6. Fitting line to aboveground biomass data as a function of yield.

Values for two data points on the line are chosen and entered in the biomass-yield tool. RUSLE2 uses these two data points to compute values for the coefficients M_0 and b_a in equation 9.5. The data point for the higher production (yield) level is the production (yield) level for which the vegetation description applies and the second data point is at a lower production (yield) level. If the same values are entered for both data points, RUSLE2 assumes that the value for the intercept M_0 is zero (0) and that the slope b_a equals the value entered for live aboveground biomass live divided by the production (yield) level. This procedure can be used to describe forage crops and permanent vegetation. Otherwise, this procedure should only be used within a limited production (yield) range. See the discussion later in this section related to the variation of the ratio of live aboveground biomass to production (yield) level.

The value for the intercept (coefficient M_0) represents the live aboveground biomass at maximum canopy at zero production (yield) level. The intercept value is greater than zero for grain and vegetable crops like corn, soybeans, wheat, green beans, and cucumbers, while the intercept value is zero for the typical production (yield) level definitions used for forage crops and permanent vegetation. The value for the coefficient b_a is the slope of the line fitted to the data illustrated in Figure 11.6. It represents the increase in the live aboveground biomass at maximum canopy for a unit increase in production (yield) level.

The input values for live aboveground biomass at maximum canopy must be on a dry basis. The input values are for the live aboveground biomass at maximum canopy cover, not the live aboveground biomass at harvest. RUSLE2 accounts for loss of live aboveground biomass by senescence using the live aboveground biomass at maximum canopy cover as its starting point. Input values used by RUSLE2 to calibrate equation 11.4 to compute loss of live aboveground biomass by litter fall and senescence tool are entered in the senescence tool (see **Section 11.2.4**).

The two input values for live aboveground biomass provide RUSLE2 with the information it uses to compute the mass of above ground plant material that influences erosion. The objective is not to account for all of the biomass in the system but only that biomass that affects erosion. For example, harvested soybean grain does not end up on the soil surface to affect erosion, but pods around the grain do and should be counted in the live aboveground biomass input. Another example is woody-type vegetation such as shrubs on rangelands. The amount of aboveground biomass that becomes litter fall is the only important biomass under most permanent vegetation conditions. However, if the woody-type material becomes surface residue, perhaps as a part of rangeland renovation, then the woody-type biomass must be accounted for in the vegetation description and in the **residue description** selected for the vegetation description.

The values entered for live aboveground biomass at maximum canopy must be consistent with values entered in the senescence tool in a vegetation description.

Input values for the biomass-yield tool can be obtained in several ways. One way is to compare your vegetation with vegetation descriptions in the **RUSLE2 core database** and select input values based on this comparison. A data source is residue-yield research data published by agricultural experiment stations to which you can use to fit equation 9.5. Ensure that yield definitions used in these data are consistent with the RUSLE2 yield definition used in the vegetation description. Also, adjustments may be needed in crop residue data measured at harvest where senescence has occurred. The input values used by RUSLE2 are for the live aboveground biomass at maximum canopy, which is different from the aboveground biomass at harvest after senescence has occurred and surface residue has been lost by decomposition.

Research data vary greatly from study to study. Assemble as much data as possible and choose values that best represent the data as a whole rather than focusing on data from a single location or localized region. Also, be careful about attempting to represent differences between crop varieties. RUSLE2 was calibrated to represent main effect differences between plant communities such as between corn and wheat and not differences between crop varieties.

Rule of thumb values for residue:yield ratios can be used to estimate values for the two input data points in the RUSLE2 biomass-yield tool (see **Section 11.1.3.3**). Values for residue:yield ratios are given in Appendix D of Agriculture Handbook (AH) 703 for particular crops for a range of yields. Assume that the residue:yield ratio value applies to the middle of the yield range. Enter the yield value for the midpoint of the yield range and the residue:yield ratio for the first residue-yield data point. For the second data point, enter the yield for the lower end of the yield range in AH703 and the residue:yield ratio times 1.1. For example, the value for the residue:yield ratio value for corn in AH703 is 1.0. The residue to yield ratio value that would be entered for a 50 bu/ac yield, the lower end of the yield range in AH703, would be 1.0·1.1=1.1.

The assumption of a constant residue:yield ratio only applies over an upper range of yield values for vegetation descriptions where the intercept M_0 value is greater than zero. The equation for residue:yield ratio derived from equation 9.5 is:

$$M_a / Y = M_0 / Y + b_a \qquad [11.8]$$

where: M_a/Y = the ratio of live aboveground biomass at maximum canopy to production (yield) level, which is equivalent to residue:yield ratio after proper consideration for senescence. Residue:yield ratio values for the data illustrated in Figure 11.6 are shown in Figure 11.7. Note that residue:yield ratio values approach infinity at a zero yield and decrease to almost a constant value for yield greater than 50 bu/acre. The change in residue:yield ratio for these data is sufficiently small that a constant residue:yield ratio value could be assumed for yields greater than 50 bu/acre. A constant residue:yield ratio can be used in vegetation descriptions provided the production (yield) level does not vary too widely. However, the best approach is to enter values for live aboveground biomass at maximum canopy at two production (yield) levels rather than residue:yield ratio values. If the intercept M_0 for equation 9.5 is zero, the ratio of live aboveground biomass at maximum canopy to production (yield) level is constant and equal to the b_a coefficient in equation 9.5, which is appropriate for forage crops and permanent vegetation.

Crop residue cover immediately after planting is used as an indicator of the level of erosion control provided by conservation tillage systems. If RUSLE2 does not compute expected residue cover values, users can make changes in RUSLE2 inputs so that RUSLE2 computes the expected cover values. These changes should be made very carefully to avoid unexpected consequences. For example, change the live aboveground biomass at maximum canopy cover does affect the residue cover after planting computed by RUSLE2. Changing this value also affects the amount of belowground biomass computed by RUSLE2, which can have a significant effect on RUSLE2's erosion computations. Consider the following variables, their interactive effects, and their effects on other variables that affect erosion estimates in making changes to RUSLE2 inputs related residue cover after planting:

1. **Amount of live aboveground biomass at maximum canopy cover**
2. **Relationship between portion of soil surface covered for a given residue mass (mass-cover relationship in residue description)**
3. **Decomposition coefficient (half life) value in the residue description selected for the vegetation description**
4. **Flattening, burial, and resurfacing ratio values entered for the operation descriptions used in the cover-management description**

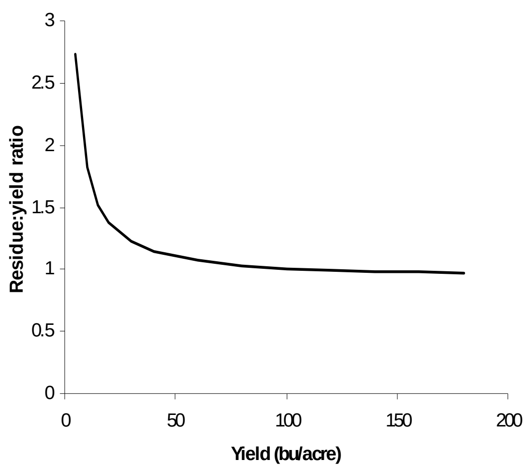

Figure 11.7. Residue:yield ratio for data illustrated in Figure 11.6.

11.2.4. Senescence

Values are entered in the **senescence tool** that RUSLE2 uses to calibrate equation 11.4 to represent senescence and litter fall as a transfer of live aboveground biomass to the surface (flat) residue pool. RUSLE2 computes senescence and litter fall as a function of a decrease in canopy cover (see **Section 11.1.3.1**). The two inputs entered in the senescence tool are portion of the live aboveground biomass at maximum canopy that is subject to senescence (litter fall) and canopy cover after complete senescence has occurred.

As permanent vegetation and agricultural crops like soybeans approach maturity, leaves fall from the plant canopy to the ground, which is senescence and litter fall. The decrease in live aboveground biomass results in a corresponding increase in biomass in the surface (flat) residue pool. In most cases, the entire live aboveground biomass is not subject to senescence. The value entered for portion of the live aboveground biomass subject to senescence is greater than the actual amount that falls to account for the fact that most of this plant material is leaves. A value of 0.6 for the ratio of biomass that falls during senescence to the aboveground biomass at maximum canopy seems to work well for crops like soybeans and cotton. A high value, perhaps up to 0.9, is appropriate for some grass-type vegetation. RUSLE2 multiplies this fraction by the live aboveground biomass at maximum canopy cover to estimate the potential biomass that will be transferred to the soil surface. RUSLE2 distributes the transfer over time using equation 11.2 and the decrease in canopy cover values entered in the **growth chart** of the **vegetation description**. The input in the senescence tool for canopy cover after complete senescence should be less than the minimum canopy cover that occurs after maximum canopy cover in the growth chart.

The standard assumption in RUSLE2 is that senescence occurs during the period of decreasing canopy cover. However, litter fall can also occur during growth periods when canopy cover is increasing, especially for perennial vegetation. RUSLE2 computes the daily litter fall by death during growth periods by multiply the live aboveground biomass on each day by a fraction that is typically 0.01, unless more specific information is available. If RUSLE2 is not to compute litter fall during growth periods, a zero (0) is entered for the death coefficient. Similarly RUSLE2 can compute death of the live root biomass during growth periods entering a non-zero (0) value for the death coefficient for live roots. Generally the same value (0.01) should be used for both live aboveground and root biomass.

Some plants lose canopy cover without aboveground biomass falling to the soil surface. An example is corn where the leaves droop as the plant approaches maturity. For this and similar types of vegetation that lose canopy cover without losing canopy mass, enter a zero for the portion of the aboveground biomass that experiences senescence. This entry prevents RUSLE2 from computing a decrease in aboveground biomass along with an increase in surface (flat) residue when canopy cover decreases.[100]

The objective is to account for the dead biomass that reaches the soil surface in association with a decrease in canopy cover rather than perfectly model senescence as a process.

The reason that a high value is entered for the portion of the live aboveground biomass subject to senescence is related to RUSLE2 using a single **residue description** to represent a composite of plant components that vary greatly in their properties. Above ground plant material is composed of leaves, stems, seed pods, chaff, and other

[100] This input in RUSLE2 is comparable to the input in RUSLE1 for no senescence in the table where operations are entered for each vegetation in the time variant C factor.

components. Leaves cover a much greater portion of the soil surface per unit mass than do stems. Leaves decompose much more rapidly than do stems. The value for a property in a residue description depends on the relative mass of the plant components in the residue. This distribution changes through time because the components decompose at greatly different rates, which means that residue properties change through time even though RUSLE2 assumes constant residue properties.

Consequently, the input for the portion of the live aboveground biomass subject to senescence is a compromise. The values entered in the residue description for the mass-cover relationship often gives priority to stems because the stems remain long after the leaves have disappeared. Entering a value for the actual amount of fallen plant material significantly underestimates the ground cover provided by senescence and litter fall because most of this material is leaves that provides high ground cover for their mass. To offset the underestimation in ground cover, an artificially high value is entered for the portion of live aboveground biomass subject to senescence to give ground cover values that more closely match actual field ground cover values during the senescence period. This approach works satisfactorily for agricultural and vegetable crops like soybeans, cotton, and green beans because of the importance in the portion of the soil surface covered in the erosion computations and the relatively short time between the beginning of senescence and harvest that converts live aboveground biomass to standing and flat residue.

Both the portion of the soil covered by plant material transferred by senescence and litter fall and the biomass amount must be considered when selecting inputs for permanent vegetation. The residue description for permanent vegetation should represent the composite of plant material that reaches the soil surface during an annual growth cycle. Similarly, the input values for live aboveground biomass at maximum canopy and the portion of this biomass that reaches the soil by senescence and litter fall should represent the actual biomass transfer rather than the artificially high values used for agricultural and vegetable crops discussed above. The residue description for permanent vegetation that is never mowed can be different from the residue description for permanent vegetation that is periodically mowed. The decomposition rate for biomass reaching the soil surface by mowing could be greater than the biomass from the same vegetation that reaches the soil surface by litter fall after plant maturity because of differences in decomposition properties of plant material at different growth stages. These residue descriptions are similar to having a residue description for wheat grown a cover crop that is killed well before maturity and different from the residue description for wheat grown to maturity and harvested for grain.

An approach that sometimes can be used to better represent differences among residue properties at certain times is to use multiple vegetation and residue descriptions for the same vegetation. For example, the residue description assigned in the vegetation description that applies to the senescence period reflects residue being mostly composed of the leaves that fall during senescence. The residue description assigned to the vegetation description for the period that begins immediately after the end of senescence reflects a high proportion of coarse plant parts like stems.

The best guidance for selecting input values to describe senescence and litter fall is to compare your vegetation with the vegetation descriptions in the **RUSLE2 core database**. Consistency between your values for a particular vegetation description and values in the RUSLE2 core database and values for other vegetation descriptions in your database is very important to ensure that RUSLE2 computes expected erosion values. Assigning these input values involves judgments that may seem counter intuitive.

11.2.5. Retardance

Retardance describes the degree that vegetation slows overland flow. RUSLE2 uses information on vegetation retardance, along with information on ground cover and soil surface roughness, to compute values for Manning's n, a hydraulic roughness index. The retardance index and Manning's n are used to compute the contouring effectiveness of rows of closely spaced vegetation, transport capacity used to compute deposition caused by dense vegetation strips, and critical slope length associated with contouring (see **Section 14**). Retardance depends primarily on the type, stiffness, and density of vegetation parts that touch the soil surface to slow surface runoff. Retardance is two dimensional, having a value for vegetation grown in strips on the contour perpendicular to the overland flow and a value for the same vegetation grown in rows up and down slope parallel to the overland flow direction.

Retardance for vegetation in contour strips is specified using one of eight classes listed in Table 11.6. These eight retardance classes represent the entire range in retardance from no retardance where the vegetation hardly slows the runoff to maximum retardance produced by a dense, sod forming grass. **The eighth class, retardance index 7, is a special case used to represent exceptionally dense, erect, stiff grass strips, fabric (silt) fences, gravel dams, straw bales, and similar erosion control measured used on overland flow areas.**

A retardance class is selected for a vegetation description along this scale based on the degree that the vegetation is judged to slow runoff considering vegetation type, stiffness, and density. Crops at typical yields are listed with each retardance class to guide the selection of a retardance class.

Table 11.6. RUSLE2 retardance classes for overland flow through vegetation in strips on the contour.

Retardance class at maximum canopy cover	Class index value	Comment

No retardance	0	Vegetation has no appreciable effect on slowing runoff
Low retardance	1	Slightly slows runoff, much like corn at 125 bu/acre
Moderate low retardance	2	Slows runoff somewhat, much like soybeans at 35 bu/acre, cotton at 1 ½ bales/ac, corn at 200 bu/acre
Moderate retardance	3	Slows runoff moderately, much like wheat at 45 bu/acre
Moderately high retardance	4	Slows runoff significantly, much like a moderate yield (3 tons/acre) legume hay before mowing
High retardance	5	Slows runoff very significantly, much like moderate yield (3 tons/acre) legume-grass hay before mowing, dense bunch grass
Very high retardance	6	Slows runoff almost to the maximum degree, like a dense, sod forming grass
Extreme retardance	7	Used as a special class to represent the retardance of stiff, erect, very dense grass strips (hedges), fabric (silt) fences, gravel dams, and straws bales used on overland flow areas

Retardance is also a function of plant growth stage and production (yield) level. The **retardance tool** is used to enter retardance classes at two production (yield) levels for a vegetation description at maximum canopy cover. RUSLE2 uses these inputs to calibrate a linear equation that computes retardance as a function of production (yield) level as illustrated in Figure 11.8. RUSLE2 internally treats the retardance as a continuous variable rather than an integer that changes stepwise. Thus, computed erosion values affected by retardance vary in a continuous fashion rather than in a stepwise fashion between retardance classes. RUSLE2 computes a base hydraulic roughness index value as a function of retardance at maximum canopy cover. RUSLE2 uses this base values to compute a daily hydraulic roughness index that varies with the 0.3 power of daily effective fall height.

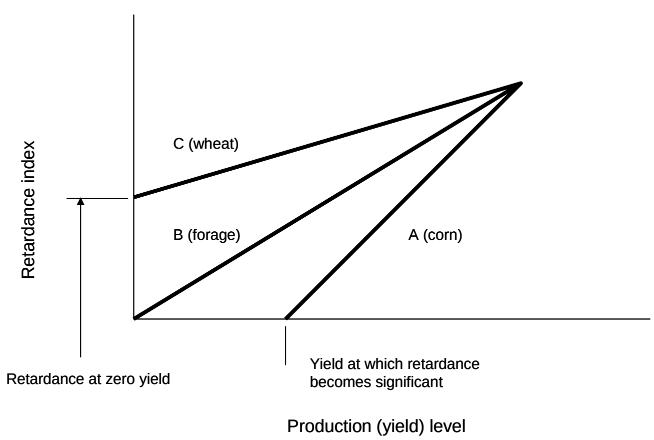

Figure 11.8. Retardance index relationships for different vegetation types

Figure 11.8 shows retardance index-yield relationships for three types of vegetation. Type A vegetation is where plant population must increase to a significant level before retardance becomes significant. For example, corn yield must exceed 100 bu/acre before retardance becomes significant. The entry for this condition in the retardance tool is **Yes** for **Does no retardance apply for a yield greater than zero?** and the second entry is the **Maximum yield at which no retardance applies**, which is 100 bu/acre in this example. RUSLE2 assumes that corn provides no retardance for yields less than 100 bu/acre and that retardance increases linearly for yields greater than 100 bu/acre as illustrated in Figure 11.8

The question **Does no retardance apply to a yield greater than zero?** is answered **No** for vegetation types B and C. RUSLE2 then asks that a retardance class be selected for a zero yield. Type B vegetation is forage-type vegetation grown on hay, pasture, landfills, and reclaimed mine lands. This vegetation is sufficiently dense and stiff to provided retardance that begins to develop at a zero yield. The **no retardance** class is selected for a zero yield, even for a dense sod forming grass that provides maximum retardance at a high yield. Type C vegetation is vegetation like wheat that provides significant retardance at zero yield. The retardance selection for Type C vegetation at zero yield depends on the stiffness and density of the vegetation at zero yield. The type of vegetation and the retardance entries at zero yield are related to the yield definition used in the vegetation description.

Information on retardance at a high yield is entered in the retardance tool for a second data point. The input for this data point along with the entry for the first data point discussed above are used by RUSLE2 to determine values for the coefficients that define the linear equations depicted in Figure 11.8. This second yield point need not correspond with the yield for which the vegetation description applies. In fact, the best yield for the second data point is the highest yield for which this vegetation description might possibly be applied.

Vegetation type in relation to retardance and the entries used to describe the retardance-yield relationship depend on the yield definition used in the vegetation description. For example, a woody-type vegetation could have a significance retardance index for a zero yield where the yield definition is based on annual production rather than the accumulation of biomass over several years.

The second major input in the retardance tool is used by RUSLE2 to define retardance when the vegetation is grown in rows parallel with the assumed flow direction (up and down slope). Row spacing is used as an indicator of this retardance. The retardance for up and down hill rows ranges from no retardance for widely spaced rows and for vegetation grown on ridges where the vegetation does not contact the down slope overland flow to maximum retardance when the vegetation is in a random pattern. The retardance for the random pattern (i.e., no orientation effect) is assumed to be the same as the retardance for the vegetation grown in a contour strip perpendicular to the overland flow. A retardance class for a particular vegetation description is selected from the six classes listed in Table 11.7 between these extremes using row spacing as an indicator.

Although row spacing is used as an indicator, the selection is actually the degree that the vegetation affects retardance at maximum canopy when rows of the vegetation are oriented in an up and down hill direction.

Table 11.7. Row spacing classes used to indicate retardance for vegetation at maximum canopy cover in rows oriented up and down slope.

Row spacing class	Comment
Wide row	Vegetation provides no retardance to overland flow. Row spacing for typical agricultural crops would be 30 inches or wider.
Vegetation on ridges	Vegetation is on ridges sufficiently high that vegetation does not come in contact with overland flow and provides no retardance to the flow. Actual spacing is unimportant.
Moderate	Rows of vegetation and vegetation characteristics such that the vegetation provides a slight but significant retardance relative to the same vegetation in a random pattern. Row spacing for typical agricultural crops would be 15 inches.
Narrow	Rows of vegetation and vegetation characteristics provide moderate retardance relative to the same vegetation in a random pattern. Row spacing for typical agricultural crops would be 7 inches.
Very narrow	Rows of vegetation and vegetation characteristics provide major retardance so that retardance in the down slope direction is almost as great as retardance when the vegetation is in a random pattern. Row spacing for typical agricultural crops would be 3 inches.
No rows, random, broadcast	Characteristics of the vegetation are such that orientation has no effect on retardance because the vegetation is grown in a random pattern.

RUSLE2 adjusts retardance between the value for vegetation grown in rows up and down slope and retardance for contour vegetation strips based on relative row grade to take into account row orientation of the vegetation. For example, if row grade is up and down slope and the vegetation has been assigned a wide row spacing, RUSLE2 will compute no retardance for the vegetation and no deposition will be computed if the vegetation in grown in strips with an up and down hill row orientation.

The best approach for selecting input values for retardance is to use values in the **RUSLE2 core database** as a guide. Maintaining consistency with the RUSLE2 core database is critically important because RUSLE2 was calibrated and validated against values in the RUSLE2 core database.

11.2.6. Long-term vegetation

The **long-term vegetation tool** is useful for creating multiple year duration **vegetation**

descriptions for permanent vegetation. In many cases, the long term vegetation tool can create a vegetation description that can be used without manual adjustments. Even when manual adjustments are required, the long term vegetation tool greatly facilitates the creation of long duration vegetation descriptions. A graph of canopy cover in a vegetation description created with the long term vegetation tool is illustrated in Figure 11.9. This 10-year vegetation description covers the time from seeding, through development, and into full maturity. The long term vegetation tool is most useful for creating vegetation descriptions for permanent vegetation like that on pasture, range, landfills, reclaimed mine, and similar lands.

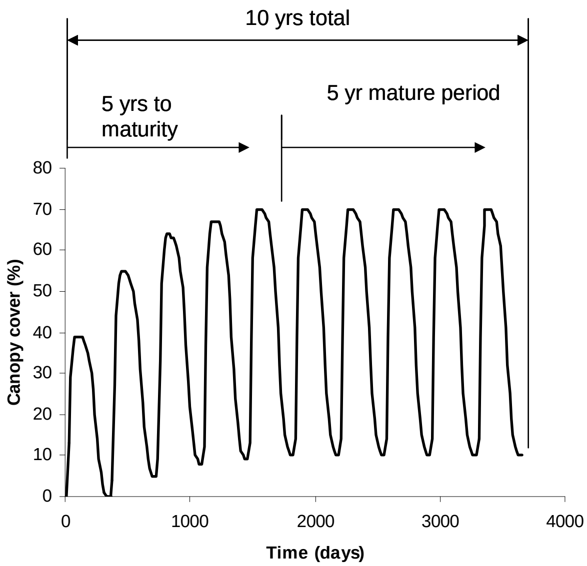

Figure 11.9. 10-year long term vegetation description created with long term vegetation tool.

The inputs entered in the long term vegetation tool are listed in Table 11.8. RUSLE2 uses spline-type equations to temporally distribute values between those entered for the minima and maxima of the variables in the **growth chart** of a vegetation description based on duration and annual timing inputs.

11.2.6.1. Duration inputs

The first set of inputs in the long term vegetation tool is related to **duration** of the vegetation description. The duration of a vegetation description is one year when RUSLE2 is used to estimate erosion for mature vegetation (see **Section 10.2.8**). The **yes-no** input for **rotation** in the **cover-management description** is set to **Yes** with a **1-year duration**. A value of **0** is entered for the **number of years to maturity** and a value of **1 year** is entered for the duration of the vegetation description **(# of years to include in growth pattern**) in the long term vegetation tool to create a vegetation description for mature vegetation.

The long term vegetation tool can also be used to create a vegetation description that starts on the seeding date and continues through the development phase and into the completely mature phase, like the vegetation description illustrated in Figure 11.9. This vegetation description can be used in RUSLE2 to analyze erosion during the establishment period for permanent vegetation on landfills, construction sites, and reclaimed mine lands. The duration of this vegetation description includes a mature period sufficiently long for RUSLE2 to compute a stable litter layer and soil biomass pool.[101] In the example illustrated in Figure 11.9, the development period is five years (time to maturity), and the mature period is five years. A value of **5 years** is entered for the time required for the vegetation to reach maturity (the development phase) and a value of **10 years** is entered for the entire duration.

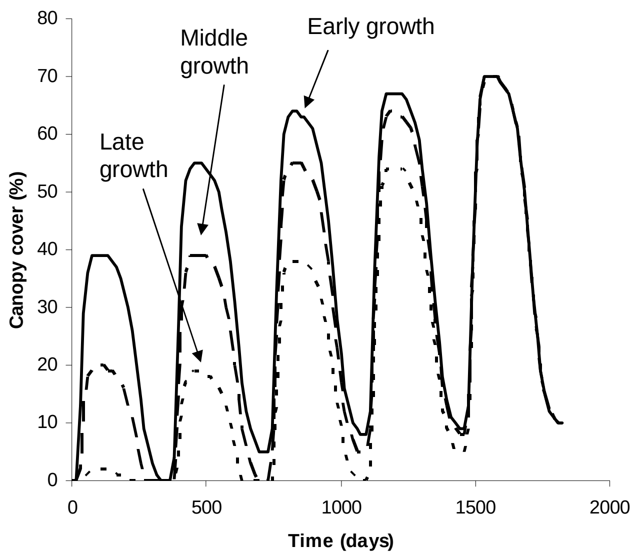

Figure 11.10. Fast growth in the early, middle, or late part of development stage.

The next input is a selection for the period when overall growth is most rapid during the development phase. The choices of **early**, **middle**, and **late** are illustrated in Figure 11.10. Values for all three choices converge in the mature year. Choose the entry appropriate for your vegetation considering seeding date and environmental conditions related to climate, soil, and management at the location where RUSLE2 is being applied. An input of **early** was selected for the vegetation description illustrated in Figure 11.9.

11.2.6.2. Annual timing inputs

The next set of inputs are the **annual timing inputs** related to dates of annual maximum and minimum live aboveground biomass and when most rapid growth and decline occur during the year.

The first timing input is the date of the annual maximum live aboveground biomass, which is also the date when all other temporal variables, including live ground cover, are at a maximum. This date for the example illustrated in Figure 11.9 is July 1. The maximum values occur on this date for every year in the vegetation description created with the long term vegetation tool.

The second timing input is the date that live annual aboveground biomass is minimal, which is also the date that the values for all temporal variables are minimal. RUSLE2 assumes this date for day zero for the vegetation description. The values for all temporal variables are zero on day zero unless the vegetation description has been created for

[101] Stability is defined in terms of litter and soil biomass daily values repeating each year.

mature vegetation.[102] In the example illustrated in Figure 11.9, the date of annual minimum live aboveground biomass is April 1. The date of the **operation description** in the **cover-management description** that uses this vegetation description should be April 1.

Inspect the main vegetation description, including all of the support tools discussed in Section 11.2, to ensure that the proper values are entered and displayed. The long-term vegetation does not transfer all required information into the main vegetation description and the supporting tools.

The time between the dates for maximum and minimum biomass can be any value. Six months between these dates gives a symmetrical distribution during the year. The long term vegetation tool creates non-symmetrical distributions when dates are more or less than six months apart as illustrated in Figure 11.9.

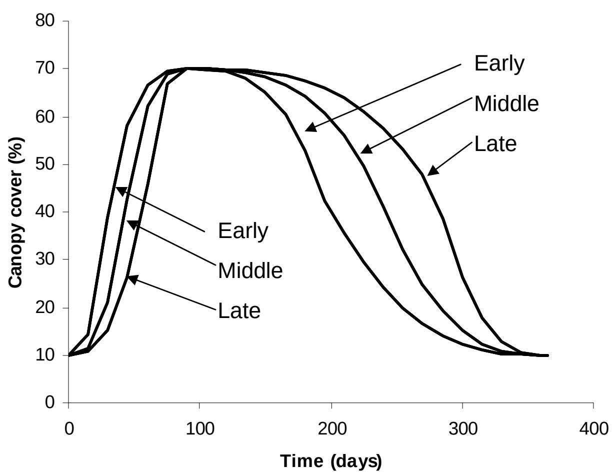

Figure 11.11. Timing of rapid growth and senescence during year.

An important consideration is whether the date of minimum live aboveground biomass corresponds with the seeding date. In the example illustrated in Figure 11.9, the seeding date and date of minimum biomass are the same. However, that assumption is not true for fall seeding when the annual minimum live aboveground biomass occurs in the spring. The long term vegetation tool has no provision for dealing with situations where seeding date and date of minimum live above ground do not correspond. However, the long term vegetation tool is still useful for developing a vegetation description even though manual adjustments are required for these situations. For example, assume that the seeding date is September 1 rather than April 1. The same input values would be used as in the example illustrated in Figure 11.9, but with a change in the selection for the **time that most rapid growth occurs during the development period** and **the time to maturity**. Rather than entering **early,** as in the example, a **middle** selection is made. The time to maturity would be six rather than five years. The

102 This statement applies to vegetation descriptions created with the **long-term vegetation tool**. RUSLE2 can also use multiple annual vegetation descriptions. The temporal values would not be zero on day zero for these vegetation descriptions. However, such annual vegetation descriptions can not be created with the **long-term vegetation tool**.

user manually make changes to values in the vegetation description **growth chart** to correspond to a September 1 seeding date. The manually adjusted values are blended into the values created by the long term vegetation tool. Manual entry of the entire vegetation description is not required.

The third and fourth timing inputs are the times during the year when most rapid growth (gain in live aboveground biomass) and senescence (litter fall, decline in live aboveground biomass) occur. The choices are **early**, **middle**, and **late**. These choices are illustrated in Figure 11.11. One selection can be made for the growth period, such as **early** in the example illustrated in Figure 11.9, and another selection can be made for the senescence period, such as **middle** for the example illustrated in Figure 11.9.

11.2.6.3. Biomass inputs

The **biomass inputs**, which must be on a dry basis, in the **long term vegetation tool** are the same as those in the main part of the **vegetation description** and the **growth chart** discussed in **Section 11.1**. However, a few of the inputs are in a different form. The values entered for **maximum annual live ground biomass** and the corresponding **canopy cover** are for the date of annual maximum canopy cover after the vegetation has reached maturity, which is the date entered in the **annual timing inputs** for maximum biomass. The values entered for **minimum annual live ground biomass** and the corresponding **canopy cover** are for the date of annual minimum canopy cover after the vegetation has reached maturity, which is the date entered in the **annual timing inputs** for minimum biomass.

The input value for annual minimum live aboveground biomass is similar to, but different from, the inputs entered in the senescence tool (see **Section 11.2.4**). The input entered in the long term vegetation tool for annual minimum live aboveground biomass is the ratio f_{mx} of annual minimum live aboveground biomass to annual maximum live aboveground biomass after the vegetation has reached maturity. The value for annual minimum live aboveground biomass is given by:

$$B_{amn} = f_{mx} B_{amx} \quad [11.9]$$

where: B_{amn} = annual minimum live aboveground biomass at maturity, B_{amx} = annual maximum live aboveground biomass at maturity, and f_{mx} = the ratio of the annual minimum live aboveground biomass at maturity to annual maximum live aboveground biomass at maturity. Essentially the same information must be entered in the **senescence tool**, and it must correspond to the information entered in the long term vegetation tool. The entry in the senescence tool related to biomass is the portion f_s of the annual maximum live aboveground biomass that is available for senescence. The annual minimum live aboveground biomass computed with f_s is given by:

$$B_{amn} = B_{amx} - f_s B_{amx} \quad [11.10]$$

$$B_{amn} = B_{amx}(1 - f_s) \quad [11.11]$$

Combining equations 11.9 and 11.11 shows that the fraction of maximum live aboveground biomass available for senescence that is entered in the senescence tool is related to the ratio of annual minimum live aboveground biomass to annual maximum live aboveground biomass as:

$$f_s = 1 - f_{mx} \quad [11.12]$$

That is, the value entered in the senescence tool equals one minus the ratio of annual minimum live aboveground biomass to annual maximum live aboveground biomass, which is the value entered in the long term vegetation tool for minimum annual live aboveground biomass.

The value entered for canopy cover after full senescence in the senescence tool should be the same as the canopy cover value entered in the long-term vegetation tool for canopy cover for annual minimum live aboveground biomass at maturity.

A value of zero (0) for the **death rate coefficient** for the death of live aboveground is entered biomass when the process of litter fall during the growth period is not be represented. Enter a value of approximately 0.01 when this process is to be represented. A value of 0.01 seems appropriate for a wide range of plant communities.103

The production (yield) level definition, value for production (yield) level and the biomass-yield relationship inputs should be entered in the vegetation description. These values should be carefully checked to ensure that the live aboveground biomass value displayed in the vegetation description is the maximum live aboveground biomass intended from the inputs made in the long term vegetation tool.

.

[103] Dubeux, Jr., J. C. B.; L. E. Sollenberger, J. M. B. Vendramini, R. L. Stewart, Jr. and S. M. Interrante. (2006). Litter Mass, Deposition Rate, and Chemical Composition in Bahiagrass Pastures Managed at Different Intensities. 46:1299-1304.

Thomas, R.J. and N.M. Asakawa. 1993. Decomposition of leaf litter from tropical forage grasses and legumes. Soil Biology and Biochemistry. 25:1351-1361.

Enter the value for **effective fall height** for the annual maximum live aboveground biomass at maturity. See **Sections 9.2.2.2 and 11.1.7.4** for guidelines for selecting effective fall height values as a function of heights to top and bottom of the canopy, canopy shape, and density gradient within the canopy. Also, the **effective fall height tool** discussed in **Section 11.2.2** can be used to adjust the temporal effective fall height values created by the long term vegetation tool.

Values for **live ground cover** should be entered for most permanent vegetation on range, pasture, landfills, reclaimed mine and similar lands. Enter values to represent live (green) leaves, the basal area, and other live vegetative parts that slow runoff during a rainfall event. The temporal pattern of the live ground cover values created by the long term vegetation tool is exactly the same as the temporal pattern for canopy cover values. This pattern may not be appropriate for live ground cover. For example, live ground cover may develop early in the annual growth period ahead of canopy cover and then decrease while canopy cover is still developing. The values created by the long term vegetation tool can be manually adjusted in the vegetation description as desired.

The long-term vegetation tool multiples the input value for the **ratio of live root biomass to live aboveground biomass** by the value for live aboveground biomass to create values for live root biomass. This ratio is for the biomass (dry basis) of predominantly fine roots in the upper 4 inches (100 mm) of soil to the average annual production of aboveground biomass. RUSLE2 assumes that the ratio of live root biomass to live aboveground biomass is constant over time, which means that live root biomass values follow exactly the same pattern as the live aboveground biomass values. In the field, annual live root development usually precedes development of the live aboveground biomass and root sloughing usually precede senescence and litter fall. The RUSLE2 assumption that the two are the same is considered adequate for erosion estimates used in conservation and erosion control planning. RUSLE2 is designed to be an easy-to-use tool for conservation and erosion control planning rather than a model of actual processes. However, RUSLE2 is quite flexible. The live root biomass values can be manually adjusted in the growth chart to represent any desired pattern.

Obtaining reliable information on live root biomass values is very difficult as discussed in **Section 11.1.7.2**. The recommendation is that the ratio values previously stored in RUSLE2 by plant community be used rather than selecting values from the literature or making field measurements. Selecting a plant community in the long term vegetation tool selects the ratio value stored in RUSLE2 for that plant community. A RUSLE2 previously stored plant community ratio value can be overridden by entering another value. The values for ratio of live root biomass to live aboveground biomass stored in RUSLE2 by plant community types are based on field simulated rainfall erosion experiments where values for these ratios were back calculated using RUSLE2 subfactor equations and measured erosion values. Values for these ratios are given in **Section**

17.4.1.4.[104]

RUSLE2 assumes that a daily decrease in live root biomass represents root sloughing where this decrease represents live roots that become dead roots that is added to the dead root pool. RUSLE2 can also compute root death during the growth period when live root biomass is increasing. If this root death process is not to be represented enter a zero (0) for the daily fraction of live root biomass that becomes dead roots during the growth period. If this process is to be represented, enter a value of 0.01, which is the daily fraction of the live root biomass that becomes dead roots during the growth period. In general, the value selected for this fraction should the same as the value for the comparable fraction of daily live aboveground biomass that becomes surface litter.

Table 11.8. Inputs in the long-term vegetation tool used to create vegetation descriptions for permanent vegetation on pasture, range, landfills, reclaimed mine, and similar lands.

Input	Comment
Duration inputs	
Number of years to maturity (development phase)	If a vegetation description for mature vegetation is being created, enter 0; otherwise, enter the number of years required for the vegetation to reach a stable annual pattern (5 yrs for example in Figure 11.9)
Total number of years in the vegetation description (duration)	Enter total number of years in the vegetation description; should include enough years after maturity for a stable litter layer and soil biomass pool to develop at the location where vegetation description is being used; (10 yrs for example in Figure 11.9)
Fastest growth in development period occurs when? (early, middle, late)	Select the time period during the development phase when most rapid development occurs; (Early for example in Figure 11.9); see Figure 11.10 for illustrations of each period.)
Annual timing inputs	
Annual day of maximum live aboveground biomass at maturity (month/day)	Select date of annual maximum canopy cover, which is also the date of annual maximum live aboveground biomass; maximum of all temporal variables is assumed to occur same date; same date assumed for all years in vegetation description; (7/1 for example in Figure 11.9)

[104] The time invariant C factor procedure in RUSLE1 is frequently used to estimate erosion for permanent vegetation. Single values that represent temporal conditions over the year are used as input rather than the temporal values used in RUSLE2. Also, this RUSLE1 procedure does not include the accumulation of a soil biomass pool or the effect of decomposition of the litter layer at the soil surface. Both RUSLE1 and RUSLE2 can give comparable results if the recommended procedures for each model are carefully followed.

Annual day of minimum annual biomass (month/day)	Select date of annual minimum canopy cover, which is also the date of annual minimum live aboveground biomass; minimum of all temporal variables is assumed to occur on same date; same date assumed for all years in vegetation description; (4/1 for example in Figure 11.9)
Fastest growth occurs when during year? (early, middle, late)	Select early to describe vegetation where most rapid growth occurs early in annual cycle; select late to describe vegetation where early development is slow and most rapid development occurs just before maximum live aboveground biomass is reached; (early for example in Figure 11.9); see Figure 11.11 for illustration.
Fastest decline in growth occurs when during year? (early, middle, late)	Select early to describe vegetation where most canopy is lost immediately after senescence (litter fall) begins in annual cycle; select late to describe vegetation where loss of canopy mass is very slow after maximum aboveground biomass is reached and is very high just before the end of senescence; (middle for example in Figure 11.9); see Figure 11.11 for illustration.
Biomass inputs	
Maximum annual live aboveground biomass at maturity (dry basis)	Enter the live aboveground biomass at maximum canopy for the vegetation when it is mature; in general, annual biomass production rather than long term accumulation of biomass is used for this input; the yield value in main vegetation description where yield is defined must correspond with this value; (1000 lbs/acre for example in Figure 11.9)
Canopy cover at maximum biomass (maximum canopy) at maturity	Enter the canopy cover at annual maximum live aboveground biomass at maturity; (70% for example in Figure 11.9)
Effective fall height at maximum canopy cover at maturity	Enter the effective fall height value at annual maximum canopy cover at maturity; (0.3 ft for example in Figure 11.9)
Live ground cover at annual maximum live aboveground biomass at maturity	Enter the live ground cover at annual maximum live ground cover; check live ground cover computed by tool; values may need adjustment so that live ground cover develops earlier than canopy cover; (15% for example in Figure 11.9)
Ratio of annual minimum live aboveground biomass at maturity to annual maximum live aboveground biomass at maturity (dry basis)	The amount for the annual minimum live aboveground biomass is the product of the ratio entered and the annual maximum live aboveground biomass; this value must correspond to the value entered in the senescence tool for amount of annual live aboveground biomass that is available for senescence; (20 % for example in Figure 11.9)
Canopy cover at minim live	Enter the minimum canopy cover provided the annual

aboveground biomass	minimum live aboveground biomass; value must correspond with value entered in senescence tool; (10% for example in Figure 11.9)
Death fraction for live above ground biomass	Enter the fraction of live aboveground biomass that becomes daily surface litter by death during the growth period when canopy cover is increasing (use 0.01 unless other information is available)
Mechanical loss coefficient	Fraction of live aboveground that is added daily to the surface litter biomass; represents mechanical processes such as animal trampling and vehicular traffic
Plant community	Select the plant community that this vegetation description represents; selection of a plant community causes RUSLE2 to select a ratio of live root biomass to live aboveground biomass; select **Enter root mass/live aboveground biomass** if your plant community is not in the list so that you can enter your own value for this ratio; (southern grasses selected for example in Figure 11.9)
Ratio for live root biomass in upper 4 inches (100 mm) of soil/live aboveground biomass ratio (dry basis)	Selection of a plant community causes RUSLE2 to use the ratio value assigned and stored in RUSLE2 for this plant community; user can override value by entering a new value; (4.5 is stored in RUSLE2 for plant community in the example in Figure 11.9)
Death fraction for live root biomass	Enter the fraction of live root biomass that becomes daily dead root biomass by death during the growth period when live root biomass is increasing (use 0.01 unless other information is available, value should generally be the same as that used for comparable fraction for live aboveground biomass)
Grazing/haying/mowing inputs	
Dates	Enter dates that operations begin
Duration	Enter duration (days) of operation
Regrowth period	Enter days in regrowth period
Fraction live aboveground biomass remaining after operation	Enter the fraction of the live aboveground biomass that remains at the end of the operation; fraction is based on live aboveground biomass that exists on day that operation begins

12. RESIDUE DATABASE COMPONENT

Residue descriptions in the **residue component** of the RUSLE2 database contain values that RUSLE2 uses to compute how residue affects erosion. A residue description is assigned to each **vegetation description** and to **external residue**. A residue description assigned to a vegetation description describes the material that remains after the vegetation is killed with an **operation description** having a **kill vegetation process**. A residue description represents a composite of all plant components including leaves, stems, seed pod, and roots present in a sufficient amount to affect erosion. Thus, the values in a residue description for vegetation depend on the relative mass of each plant component in the residue.

The **residue description** selected for an **operation description** that adds **external residue** is used to describe materials added to the soil surface or placed in the soil that affect erosion. External residue includes applied mulch (e.g., straw), manure, gravel, compost, papermill waste, pine needles, roll erosion control products, and other similar materials. The materials represented by residue descriptions are assumed to be organic and decompose much like natural plant materials. Non-organic materials require special considerations that are described in this section.

The variables used to describe residue are listed in Table 12.1.

Table 12.1. Variables used to describe residue

Variable	Comment
How residue responds to mechanical disturbance (residue type)	Describes fragility (how easily material fractures into smaller pieces) to mechanical disturbance and the size and stiffness of the residue pieces in relation to how well the residue conforms to the soil surface to affect erosion
Decomposition coefficient	A variables that determines the rate that residue decomposes under the standard condition of non-limiting moisture and a temperature of 90 ^oF (32.2 ^oC)
Decomposition half life (days)	Time required for one half of the residue mass to decompose under the standard conditions of non-limiting moisture and a temperature of 90 ^oF (32.2 ^oC)
Mass-cover relationship	Portion of the soil surface covered by a given mass on a dry weight basis

12.1. How residue responds to mechanical soil disturbance (residue type)

RUSLE2 includes five predefined residue types listed in Table 12.2. Residue type represents two important residue properties that are related. One is the fragility and size of residue pieces that determine how much residue is flattened, buried, and resurfaced by an operation and the size and stiffness of residue pieces that determine how closely the residue conforms to the soil surface. Assigning a residue type to a residue description requires consideration of both properties.

Table 12.2. RUSLE2 predefined residue types.

Residue type	Comment
Fragile-very small	Small pieces (about 1 inch, 25 mm), easily broken into smaller pieces, moderate conformity to soil surface, similar to soybean residue
Moderately tough-short	Short to moderate pieces (1 to 5 inch, 25-125 mm), moderately tough (resistant) to being broken into smaller pieces, moderate conformity to soil surface, similar to wheat residue run through a straw chopper
Non fragile-medium	Moderate length pieces (3 to 10 inch, 75- 250 mm), non fragile, not easily broken into smaller pieces, low conformity to soil surface, similar to corn residue run through a combine
Woody-large	Long pieces (> 10 inch, 250 mm), very tough, only breaks into smaller pieces with a very aggressive machine, low conformity to soil surface, similar to woody debris left on disturbed forest land by logging, debris left by aggressive mechanical renovation of shrub dominated rangelands
Gravel	Small to moderate sized pieces with gradation of sizes to fill voids, pieces are not reduced in size by mechanical operations, high conformity to soil surface, similar to gravel and crushed stone about ¾ inch (20 mm) used on driveways.
Note: Woven and netting type erosion control products like erosion control blankets are assigned a residue type based primarily on their conformity to the soil surface micro-topography.	

Mechanical soil disturbance by tillage, construction, logging, and similar equipment break residue into smaller pieces. The susceptibility to residue being broken into smaller pieces is referred to as residue fragility. Conversely, the resistance of residue to size reduction is referred to as residue toughness. The size, length, and fragility of residue pieces affect residue flattening, burial, and resurfacing by operations. Consequently, the ratio values for these processes assigned in operation descriptions (see **Section 13.1**) vary with residue properties represented by the five residue types. Fragile residue like soybeans is more easily buried and conforms more to the soil surface than tough residue like woody debris. Long, stiff, and tough residue is not easily buried and does not conform to the soil surface. Gravel and rock fragments conform very closely to the soil surface.

The residue type assigned to roll erosion control products like blankets that are woven or bound together with netting is determined by their conformity to the soil surface. Similarly, a residue type is assigned to spray products used to control erosion on construction sites. The mechanical fragility of these erosion control products is not important unless mechanical operations are performed on the soil after these materials are placed that affects their coverage of the soil surface. The size and nature of residue pieces is not important in assigning a residue type to these products. For example, a gravel residue type can be assigned to these products where the material conforms very closely to the soil surface and perfect contact with the soil exists.

The degree that residue conforms to the soil surface is the other factor considered in selecting a residue type for a residue description. Small, flexible, stable residue pieces that closely conform to the soil surface provide greater erosion control than do long, stiff residue pieces that bridge soil clods. Runoff can partially or completely flow under the residue pieces with greater erosivity than when residue fully contacts the soil surface.

Selection of a residue type assigns one of three conformity index classes to the residue description to describe how the residue conforms to and is in contact with the soil surface. The three residue conformity index classes are low, moderate, and high. The **gravel** residue type listed in Table 12.2 are assumed to provide high conformity (contact with the soil surface), **fragile-very small** (e.g, chopped soybean residue) and **moderately tough-short** (e.g., chopped wheat straw) residue types are assumed to provide moderate conformity, and **non fragile-medium** (e.g., not-chopped corn stalks) and **woody** (e.g., slash on a logged site) residue type is assume to provide low conformity. The conformity class associated with each residue type is internal in RUSLE2 and can not be changed by the user.

The residue conformity index is most important when applying RUSLE2 to steep (greater than 33%), bare construction-type slopes. For example, the residue conformity index makes only about 14 percent difference in RUSLE2 erosion estimates between the low and high residue conformity class for corn residue in a no-till **cover-management description** applied to a 6 percent steep slope. The effect of residue conformity decreases as soil biomass increases. In contrast, the residue conformity makes about 110 percent difference in RUSLE2 estimated erosion between a residue type with low conformity and one with high conformity for a fully consolidated, cut slope with no soil biomass on 33 percent steepness. The difference in RUSLE2 estimated erosion between residue types with low and high conformity class is 40 percent for recently graded fill material on a 33 percent steep slope. RUSLE2 assumes better contact between soil and residue on recently graded fill material than on hard, fully consolidated soil.

The relative effectiveness of residue for controlling erosion decreases as slope steepness increases above about 33%. The loss of erosion control effectiveness is greater for residue types that provide low conformity than for those residue types that provide high conformity.

Residue types in terms of fragility (toughness) are defined only by the values entered for flattening, burial, and resurfacing ratios in the operation descriptions. However, conformity classes for each residue type are internally assigned in RUSLE2 and can not be changed by the user.

12.2. Decomposition coefficient (decomposition half life)

The decomposition rate of organic residue depends on the organic properties of the material, area and thickness of residue pieces, mechanical fracturing (e.g., fine chopping) of residue pieces to expose easily decomposed material inside a decomposition-resistant outer shell (e.g., corn stalks), and the relative composition of plant parts including leaves, seed pods, chaff, stems, and coarse and fine roots. Residue decomposition rate changes through time as these characteristics change through time. For example, leaves decompose at a much faster rate than stems, which leaves residue main composed of stems that slowly decompose.

The decomposition coefficient value assigned to each residue description is used by RUSLE2 to compute residue loss as a function of daily precipitation and temperature at the location where RUSLE2 is being applied. The decomposition coefficient ϕ value for a residue description is determined by fitting the RUSLE2 decomposition equations to empirical field data. A residue with a large decomposition coefficient ϕ value decomposes more rapidly than does a residue with a low decomposition ϕ value for particular environmental conditions.

Decomposition half-life is another way to express the decomposition coefficient ϕ. Half-life is the time required for half of the residue to be lost under the standard condition of 90 ^{o}F (32.2 ^{o}C) temperature with plentiful, non-limiting moisture. A residue with a long half-life is lost more slowly than residue with a short half-life. The relationship between half-life and the decomposition coefficient is an inverse one where half-life values increase as the decomposition coefficient values decrease. The mathematical relationship between the two is give by:

$$d_{1/2} = 0.693 / \phi \qquad [12.1]$$

where: $d_{1/2}$ = residue decomposition half-life (days) and ϕ = residue decomposition coefficient (days^{-1}).

Decomposition computations are based on residue mass. Residue cover is computed using the mass-cover relationship assigned to the residue description. Half-life refers to residue decomposition under the standard condition of 90 ^{o}F (32.2 ^{o}C) and plentiful moisture, which differs from residue decomposition under actual field conditions.

Figure 12.1 illustrates how RUSLE2 computes residue decomposition as a function of location and residue half-life. Decomposition occurs more rapidly in central Mississippi than in central Missouri because of increased precipitation and temperature, especially in the fall and winter. The 43 day half-life residue decomposes much more rapidly than does the 86 day half life residue. Field decomposition rates are slower than the optimum decomposition conditions used to express half-life values.

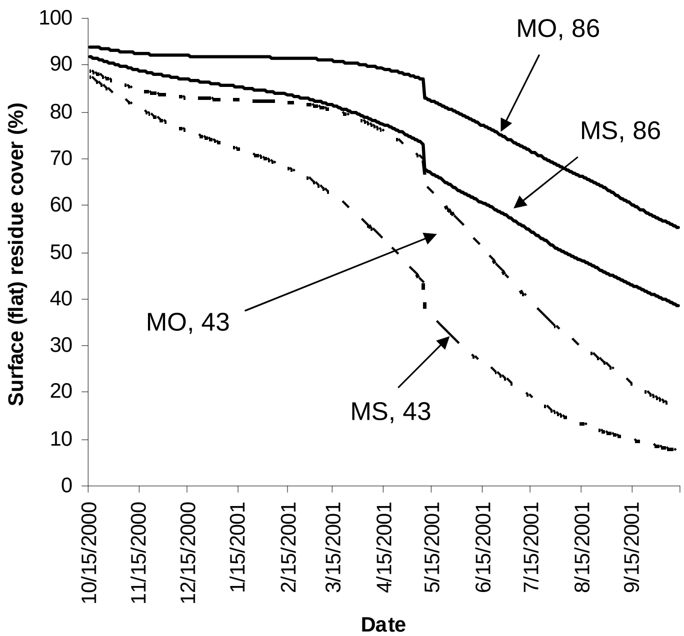

Figure 12.1. Effect of location (Columbia, MO, Jackson, MS) and decomposition half life (43, 86 days) on decomposition of corn residue in a no-till cover-management description.

The intent in RUSLE2 as an erosion control and conservation planning tool is to reflect the main effects of the material (as represented by the decomposition coefficient) and location (represented by precipitation amount and temperature that varies with location) on decomposition. By intent, RUSLE2 does not capture everything that affects decomposition. The following comments discuss particular areas where RUSLE2 represents a compromise and adjustments that users might make to partially overcome the RUSLE2 limitations while retaining RUSLE2's utility.

12.2.1. Soil Moisture

RUSLE2 does not directly consider the effect of soil moisture on decomposition other than how soil moisture is empirically related to precipitation in the decomposition data used to determine RUSLE2 decomposition coefficient ϕ values. Soil moisture is influenced by both cover-management and soil texture. Decomposition coefficient ϕ values can be increased for soil and cover-management conditions that retain water because soil moisture increases decomposition when moisture, rather than temperature, limits decomposition. Thus, the effect of soil texture and cover-management on soil moisture affecting residue decomposition can be partially captured in RUSLE2 by adjusting decomposition coefficient ϕ values. Decomposition coefficient ϕ values are assigned to residue descriptions based on how soil texture and soil moisture are assumed to affect decomposition at that location. A residue description having a decomposition coefficient ϕ value that reflects site-specific field conditions is chosen. However, based on comparisons with the WEPS and WEPP models, the effect of soil moisture as influenced by soil texture and cover-management is so small that the effect is best ignored in RUSLE2. Therefore, the same decomposition coefficient ϕ value is used for soil, cover-management, and climatic conditions except in the Northwestern US (Req region).

12.2.2. Above ground and below ground biomass decomposition

Buried residue is expected to decompose more rapidly than flat residue on the soil surface. However, research data used to derive decomposition coefficient ϕ values for RUSLE2 were inconclusive regarding this expected difference, especially when adjustments are taken into account for how residue confined in mesh bags used in decomposition measurements decomposes at a different rate than unconfined residue typical of field conditions. Therefore, RUSLE2 uses the same decomposition coefficient ϕ value for residue lying flat on the soil surface and residue buried in the soil. Most error, if any) that exists because RUSLE2 uses the same decomposition coefficient ϕ value for buried residue as surface residue is minimized because the RUSLE2 equation for the soil biomass subfactor (equation 9.12) is calibrated using RUSLE2 computed soil biomass values, not measured values (see the **RUSLE Science Documentation**).

RUSLE2 computes decomposition at the base of standing residue at the same rate as residue lying on the soil surface. RUSLE2 uses decomposition rate at the base of standing residue to compute the rate that standing residue is flattened by natural processes (see **Section 9.2.2.3**). However, RUSLE2 assumes that the decomposition coefficient value for standing residue is three tenth of the decomposition coefficient value for surface (flat) residue. Standing residue is assumed to decompose much more slowly than surface residue because of the lack of moisture that soil contact provides to surface residue.

The RUSLE2 user can not change decomposition coefficient values to reflect decomposition differences between surface and buried residue or between above ground plant components and roots. Also, the user can not change the ratio of the decomposition coefficient for standing residue to the decomposition coefficient for surface residue. Decomposition coefficient values can not be entered for individual plant components.

12.2.3. Differences in decomposition among plant components

Individual plant components of leaves, pods, stems, stalks, coarse roots, and fine roots decompose at different rates. For example, leaves decompose much more rapidly than stems, and finely chopped stems decompose more rapidly than intact stems. RUSLE2 uses a single residue description with a single decomposition coefficient ϕ value to represent a composite of plant components. The single, constant decomposition coefficient ϕ value for a residue description causes RUSLE2 to compute decomposition rates that are too low immediately after harvest before the leaves decompose and too high after most of the residue has decomposed. Residue decomposition slows over time as the residue becomes increasingly composed of decomposition-resistant plant parts, which RUSLE2 does not take into account with its constant decomposition coefficient value. Differences between computed and observed residue mass are illustrated in Figure 12.2.[105]

The RUSLE2 composite residue structure and its equations for computing decomposition are a compromise. Separately tracking individual plant components such as leaves and stems with their own decomposition coefficient value would be better scientifically than the RUSLE2 composite approach. However, the RUSLE2 developers' judged that data were not available to derive the decomposition coefficient values for individual plant components for the wide range of residue descriptions needed by RUSLE2 when used as a conservation and erosion control planning tool.

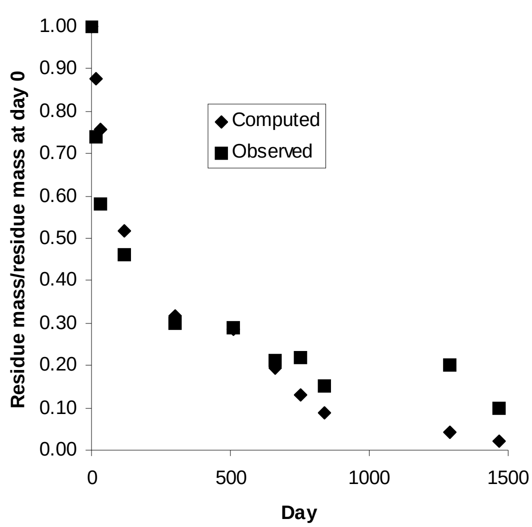

Figure 12.2. Comparison of computed residue mass with observed residue mass for corn in Missouri. (Parker, 1962)

The RUSLE2 composite residue structure must be considered when evaluating residue cover values computed by RUSLE2. Decomposition coefficient values were determined by empirically fitting the RUSLE2 decomposition equations to field residue data to give the best overall fit during the first year after harvest. In many agricultural cropping systems, the annual harvest residue input is much larger than the residue mass immediately before harvest. Errors in residue mass immediately before harvest has little effect on the overall residue mass. Also, errors in residue cover immediately before harvest are often not significant because of low erosion rates at that time. Residue cover should be accurately estimated during the most erosive period,

---

105 Parker, D.T. 1962. Decomposition in the field of buried and surface-applied cornstalk residue. Soil Science Society of America Proceedings. 26:559-562.

which is the late spring and early summer before complete canopy develops for most US row crops. The most important RUSLE2 residue cover estimates at a point in time are those immediately after planting. The RUSLE2 residue decomposition may be too high for times longer than a year for agricultural crops where harvest does not provide a large residue mass input. Overall decomposition coefficient values are chosen to give good residue cover estimates during the most erosive period rather than residue cover values at particular points in time, especially if residue cover errors at those times have little effect on estimated erosion.

These concerns with estimating residue mass over time are much less significant for construction sites where mulch and erosion control products are much more uniform than the residue pieces associated with agricultural crops. However, the problem can be very significant on disturbed forest land where residue ranges from leaves to fine branches to coarse limbs.

Decomposition coefficient ϕ values for a particular residue are preferably location independent, but that objective is not always achieved. For example, the decomposition half-life is 28 days for soybeans grown in the Midwestern US while it is 53 days for soybeans grown in the Southern US. Differences in the vegetative properties of soybeans grown in the two regions partly contribute to the difference in decomposition half-life. The other contributor is climatic differences. The climate in the Southern US is warm and wet during the winter so that the leaves decompose very rapidly after harvest leaving residue in the spring that is primarily composed of stems that decay much more slowly than leaves. In contrast, the climate in the Midwestern US is cold so that little decomposition occurs after harvest during the winter, as illustrated in Figure 12.1. Thus, soybean residue has a higher ratio of leaves to stems in the spring in the Midwestern US than in the Southern US, which gives an apparent higher decomposition coefficient.

Another example where decomposition coefficient ϕ values differ between regions is for wheat residue. The decomposition half-life for wheat grown in the Northwest Wheat and Range Region (NWRR) is 40 days while it is 87 days for wheat grown in other parts of the US. Wheat residue seems to decompose much more rapidly in the NWRR than in other regions.[106] A contributing factor is the difference in climate between the NWRR where precipitation is very low immediately after harvest in comparison to the central Midwestern US. Although the reasons for this difference are not fully understood, the empirical data are more than sufficient to substantiate the difference.

The objective is to obtain the best average annual erosion estimate for conservation and erosion control planning.

---

[106] The NWWR is a major portion of the region where the Req RUSLE2 relationships are used. **See Section 6.9.**

12.2.4. Decomposition coefficient ϕ values based on stage of growth

The organic properties that affect decomposition of plant materials vary with stage of growth. For example, the residue from a wheat cover crop killed well before maturity decomposes at a much faster rate than does the residue from a wheat crop harvested for grain. The decomposition half-life for wheat cover crop residue is 41 days while it is 87 days for residue from wheat harvested for grain. Therefore, two residue descriptions are created for wheat, one for wheat used as a cover crop that is killed well before maturity and one for wheat harvested for grain. The data inputs into RUSLE2 are always to create a description rather than to model a process. The residue description that best fits the situation is assigned to the vegetation description or selected for external residue.

12.2.5. Decomposition coefficient ϕ values for manure

Manure ranges widely from being almost entirely composed of straw used for bedding to liquid slurry. The important properties of manure include its dry matter biomass content and its decomposition properties. The residue descriptions for manure represent a composite of straw, wood shavings, manure, and other materials that may be present. The decomposition half-life assigned to a particular manure depends on the relative mass of individual components and the decomposition properties of each component, including the type of manure. Four classes of manure are recommended for use in RUSLE2. These classes are listed in Table 12.3.

Table 12.3. Recommended classes for residue descriptions for manure.

Class	Decomposition half-life (days)	Comment
Slow decomposition	87	Manure with high content of straw bedding
Moderately slow decomposition	41	Manure from open lots
Moderately rapid decomposition	23	Manure stored in settling basins
Rapid decomposition	14	Poultry litter

12.2.6. Decomposition coefficient ϕ values for erosion control products used on construction sites

Straw mulch is widely used on construction sites to control erosion. A decomposition half-life of 87 days is recommended for straw mulch. The decomposition half life for other erosion control materials used on construction sites can be determined by comparing their longevity with the longevity of wheat straw and adjusting the decomposition half life accordingly. For example, the decomposition half-life for native hay would be shorter than for wheat because of the greater proportion of leaves and fines in the native hay than in the wheat straw. Manufacturers' literature for roll products often includes information that can be used to estimate a decomposition half-life relative to that for wheat straw.

12.3. Mass-cover relationship

Although RUSLE2 tracks residue by mass, RUSLE2 computes the effect of surface (flat) residue on erosion using portion of the soil surface that the residue covers (see equation 9.6). RUSLE2 uses equation 9.9 to convert surface (flat) residue mass to portion of the soil surface cover by residue. User entered values in the residue description for data points (residue mass, cover) are used by RUSLE2 to determine values for the coefficient α in equation 9.9. These data points are the mass of residue that provides 30, 60, and 90 percent ground cover, respectively. RUSLE2 will use a single data point or an average of multiple data points to compute a value for α based on the data points for which values have been entered. Enter a mass value for 60 percent cover if only a single value is entered. The next best choice is a mass value for 30 percent cover. A single data point for 90 percent should be avoided because the mass-cover curve is very flat at high cover for many residue types, as Figure 9.5 illustrates. The best combination of two data points is 30 and 60 percent cover, and the poorest combination is one that involves a data point for 90 percent ground cover. Cover is very insensitive to a change in mass at high cover values where the curve is nearly flat. A value at this high cover is very poor for computing a value for α in equation 9.9 because residue mass value can vary over a wide range without affecting cover, which can result in great error when extrapolated to small cover values.

A RUSLE2 residue description is a composite that represents the net cover provided by the combined mass of the individual plant components of stems, leaves, pods and other plant parts. Leaves cover much more of the soil surface for a given mass per unit area than do stems, as illustrated in Figure 12.3. Thus, the mass-cover relationship for the composite residue depends on the relative mass of each plant component in the residue. A given residue mass covers much more of the soil surface immediately after harvest before the leaves decompose than later after the leaves have decomposed and only stems remain. For example, leaves decompose very rapidly and only stems are left soon after harvest for soybeans in the Southeastern US where fall and winter temperature and precipitation are high. In contrast, soybean leaves persist longer in the upper Midwestern US, and thus the leaves should be given greater consideration in selecting input values for the residue mass-cover relationship in the upper Midwestern US than in the Southeastern US.

RUSLE2 underestimates percent cover for a given mass per unit area immediately after harvest and overestimates percent cover late in the first year and beyond, as illustrated in

Figure 12.2. Refer to **Section 12.2.3** for information on how to best represent cover-mass for time periods that extend beyond one year after residue is added to the soil surface.
.

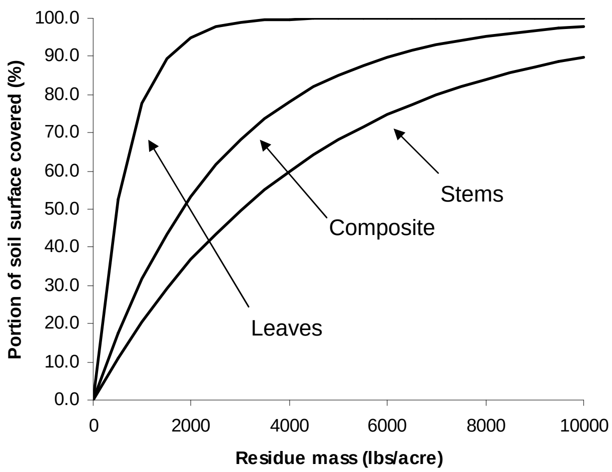

Figure 12.3. The relationship of cover to mass for leaves, stems, and the composite.

12.4. Non-organic residue

Non-organic materials, including stone, are used as mulch applied to the soil or incorporated into the soil. These materials are treated as **external residue** in RUSLE2. Input values in the residue descriptions for these materials must be carefully selected, especially if the materials are manipulated by operations.

12.4.1. Stones (rock fragments, gravel)

Stone, rock fragments, and gravel on the soil surface act as ground cover to reduce erosion (see **Sections 7.6, 9.2.2.1**). Values for rock cover can be entered in the **soil descriptions** in the **soil component** of the RUSLE2 database. RUSLE2 treats the rock cover value entered in a soil description as a constant that is not changed by operations.

Rock cover can also be added to the soil surface as an **external residue** by using an **operation description** that includes an **add other cover process** in a **cover-management description.** Rock cover added as an external residue is affected by soil disturbing operations (operation descriptions that include a **disturb soil process**). RUSLE2 treats rock added as an external residue as biomass that has the same effect on erosion as soil biomass described in **Section 9.2.2.1**. Adjustments should be made in the residue descriptions for rock added as external residue to prevent RUSLE2 from computing a soil biomass effect for rock.

Two special considerations are required to represent rock as external residue. The first step is to assign zero (0) for the decomposition coefficient value.[107] If the rock is not incorporated (buried) in the soil by a soil disturbing operation, no further adjustments are needed.

A second step is required if the rock is incorporated into the soil with a soil disturbing

---

[107] A very small value like 0.00001 should be entered rather than 0 to avoid a mathematical error in RUSLE2.

operation so that RUSLE2 does not treat rock as soil biomass. An index that has values less than 1 is used to represent the mass of the applied rock. For example, an index value of 0.2 could be used to represent 200,000 lbs/acre of applied rock cover. Values entered in the residue description to define the mass-cover relationship would be based on this index. The biomass subfactor equation (equation 9.12) in **Section 9.2.5.2** will use the index value as if the rock is biomass, but the equation will compute essentially no effect because the index indicates a very small biomass. Should you wish for RUSLE2 to compute an erosion reduction caused by rock incorporated into the soil, adjust the rock mass index until RUSLE2 computes the desired effect.

Be very careful in making these adjustments. See *Section 7.6.* The effect of rock in the soil on erosion is not well understood.

12.4.2. Non-organic erosion control materials that decay

Non-organic materials that decay by ultra-violet radiation are sometimes used at construction sites to control erosion. This decay process differs from the decomposition process assumed for **external residue**. Several special steps are required to develop **residue descriptions** for these materials.

Step 1 involves determining a decomposition coefficient value. RUSLE2 computes decomposition as a function of temperature and precipitation, whereas the decay of these materials is related to ultra-violent (u-v) radiation. Decomposition coefficient values must be determined by location or climatic region because the decomposition of these materials varies by location as u-v radiation, temperature and precipitation conditions that vary by location but are not internally represented in RUSLE2. Decomposition coefficient values are selected by running RUSLE2 and changing decomposition coefficient values until a value is determined that gives the desired loss of erosion control material over time.

Step 2 involves making adjustments for the fact that RUSLE2 adds a portion of the computed decomposed mass to the upper two inches of the soil (see **Section 9.2.5.3**). The decay products of these materials are assumed to have no effect on erosion. The adjustment for these non-organic materials that decay is like the one used for rock. An index is chosen for the erosion control product mass that numerically has values less than 1. The value entered in the **cover-management description** for the mass of the applied materials must be based on this index, and the values entered in the **residue description** for the cover-mass relationship must be consistent with the index definition.

Some erosion control materials are a combination of organic material and non-organic materials, such as compressed straw mulch between a plastic netting. The input values in the residue description should represent a composite of the material, much like residue with multiple plant components is represented as a composite. For example, the mass of the netting could be entirely ignored.

12.5. Selecting input values

The recommended approach for selecting input values for **residue descriptions** is to compare characteristics of the given residue with those in the residue descriptions in the RUSLE2 **core database.** The values in the core database are based on research data and have been evaluated to ensure that RUSLE2 computes erosion estimates appropriate for conservation and erosion control planning.

If the input values can not be selected based on a comparison with residue descriptions in the RUSLE2 core database, research literature may be a data source that can be used to derive RUSLE2 input values for residue descriptions. Otherwise field measurements may be required. Data used to determine RUSLE2 input values should meet certain conditions regardless of source. Data from multiple data sets, sources, locations, and measurements at a location are needed to deal with both spatial and temporal variability. Residue data, especially mass-cover values, are highly variable. The measurements should be made over at least a three year period at various times during the year. The objective is to capture main effects and trends rather than the details or differences between individual measurements. Differences often represent unexplained variability rather than characteristics of a particular residue.

The best measurements are from actual field conditions rather than from laboratory or specialized field experiments. This empirical approach also captures residue loss by other means besides decomposition such as by wind and worms. The purpose of RUSLE2 is not to be an accurate representation of processes but to be an easy-to-use conservation planning tool. Input values determined from measured data for residue descriptions should be compared among themselves and with those in the RUSLE2 core database for consistency. Such consistency is especially important for agencies implementing RUSLE2 on a national basis where fairness is an important requirement for those impacted by RUSLE2 estimates.

The input values in residue descriptions should reflect the most erosive period for the conditions where RUSLE2 is being applied. The values listed in the RUSLE2 core database were chosen to best fit the first year of the data, which is most important for agricultural cropping systems where annual harvest provides a relatively large biomass input. RUSLE2 tends to overestimate residue cover immediately after harvest and underestimate residue cover for periods longer than a year. Fitting the first year of data overall was considered more important than fitting the residue cover at end of the first year or fitting residue cover values beyond the first year. However, certain conditions exist where fitting over a longer period is important. Non-uniformity in the residue such as plant components that range from leaves to stems contributes significantly to RUSLE2 not fitting residue values beyond one year as well as during the first year. RUSLE2 fits residue data much better when residue pieces are uniform.

Surface residue cover values estimated by RUSLE2 are frequently used to judge the adequacy of RUSLE2. The first requirement in making these judgments is to ensure that the residue cover values being used to evaluate RUSLE2 values meet the requirements discussed above.

If RUSLE2 computed surface residue cover values do not match field measurements sufficiently well, do not immediately conclude that the residue decomposition coefficient value (half-life) should be modified. Numerous factors affect the surface residue cover values computed by RUSLE2. Changing the value for a single variable like the decomposition coefficient ϕ can have unexpected consequences that result in seriously erroneous erosion estimates even if the expected surface residue cover values are computed. That is, numerous other factors besides residue (ground) cover affect erosion. For example, changing the decomposition coefficient ϕ value, which affects residue cover, also affects buried residue and dead roots, which can significant affect computed erosion, especially for high yield, no-till corn cropping systems.

Several factors in addition to decomposition affect surface residue cover. These factors include the residue mass at harvest, the distribution between standing residue at harvest and surface (flat) residue, the rate that standing stubble falls, the relationship between residue cover to mass, and flattening, burial, and resurfacing of residue by operations. All of these factors should be systematically considered in correcting a surface residue cover problem.

13. OPERATION DATABASE COMPONENT

The **operation descriptions** in the **operation component** of the RUSLE2 database contain the information that RUSLE2 uses to compute how operations affect erosion. An **operation** is an event that affects the **soil**, **vegetation**, and/or **residue**. Operations play a major role in determining the values for variables used in the subfactor equations described in **Section 9**.

The variables used to describe an operation are given in Table 13.1. Speed of the operation is one of the variables used to describe an operation. Speed affects residue burial, much like disturbance depth. These two variables are discussed together in **Section 13.1.5.3**.

Table 13.1. Variables used to describe an operation

Variable	Comment
Recommended speed	The speed for which values in the operation description apply. The usual input value is the speed recommended by the manufacturer if the operation represents a machine
Minimum speed	RUSLE2 can adjust values in the operation description if the operation occurs at a speed that differs from the recommended speed. The minimum speed is the slowest speed that RUSLE2 will allow for the adjustment
Maximum speed	RUSLE2 can adjust values in the operation description if the operation occurs at a speed that differs from the recommended speed. The maximum speed is the fastest speed that RUSLE2 will allow for the adjustment
Sequence of processes	A set of processes is used to describe the operation. The processes must be listed in the proper order to have the desired effect. The variables used to describe processes are listed in Table 13.2.
List of processes that can be used to describe an operation	
No effect	Process has no effect. Typically used to cause RUSLE2 to display information on particular dates
Begin growth	Identifies the vegetation description that RUSLE2 is to begin using on the date of the operation description in the cover-management description. RUSLE2 references day zero in the vegetation description to the date of the operation
Kill vegetation	Converts live aboveground biomass and live root biomass to dead biomass that decomposes
Flatten standing residue	Transfer biomass from the standing residue pool to the surface (flat) residue pool. Does not affect live biomass
Disturb soil	Represents a mechanical disturbance of the soil. Creates roughness and ridges. Buries and resurfaces buried residue. Redistributes buried

	residue and dead roots in the soil. Does not affect live roots.
Live biomass removed	Takes a portion of above ground live biomass from the site. The removed biomass is no longer involved in RUSLE2's biomass accounting
Remove residue/cover	Removes residue (dead biomass) and other material from the soil surface.
Add other (external) cover	Adds external residue (e.g., mulch, manure, rolled erosion control materials) to soil surface. Also used to place materials like manure in the soil, which must be accompanied by a disturbed soil process in the operation description
Add non-erodible cover	Adds non-erodible cover including plastic used in vegetation production, water used to flood rice fields, and snow cover. RUSLE2 computes no erosion for portion of soil surface covered by non-erodible cover
Remove non-erodible cover	Removes non-erodible cover.

Some processes like **disturb soil** use additional variables to describe them. Those processes and variables and the variables used to describe them are listed in Tables 13.2.

Table 13.2. Variables used to describe particular operation processes

Process	Variables	Comment
Flatten standing residue	Flattening ratio	Portion of the standing residue mass (dry basis) that is flattened by the operation. Value entered for each residue type
Disturb soil	Tillage type	Describes where operation places buried material in soil and how it redistributes buried residue and dead roots in the soil
	Tillage intensity	Describes the degree that operation obliterates existing roughness
	Recommended depth	Typical depth of disturbance. Use value recommended by manufacturer if operation represents a machine
	Minimum disturbance depth	RUSLE2 adjusts values in operation description if disturbance depth differs from recommended depth. Minimum depth is the shallowest depth that RUSLE2 will use to make an adjustment.
	Maximum disturbance depth	RUSLE2 adjusts values in operation description if disturbance depth differs from recommended depth. Maximum depth is the deepest depth that RUSLE2 will make an adjustment.
	Ridge height	Height of ridges created by operation

	Initial roughness	Roughness left by operation when used on a smooth, silt loam soil when surface and soil biomass are very great
	Final roughness	Roughness after roughness has fully decayed
	Portion of surface area disturbed	Portion of the surface disturbed when disturbance occurs in strips.
	Burial ratios	Portion of surface (flat) residue (dry basis) that is buried. Value entered for each residue type
	Resurfacing ratios	Portion of buried residue in the disturbance depth brought to the soil surface and added to surface (flat) residue pool. Value entered for each residue type
Live biomass removed	Biomass affected	Portion of live aboveground biomass (dry basis) affected by operation
	Amount left on surface	Portion of the affected live biomass (dry basis) added to the surface (flat) residue pool by operation
	Amount left as standing residue	Portion of the affected live biomass (dry basis) added to the standing residue pool by operation
Remove residue/cover	All residue affected	Determines whether operation applies to all residue that is present or to the last residue added
	Flat residue removed	Portion of surface (flat) residue (dry basis) removed by operation
	Standing residue removed	Portion of standing residue (dry basis) that is removed by operation
Add other cover	Portion of external residue added to soil surface	Distributes added external residue between soil surface and placement in the soil over lower half of soil disturbance depth
Add non-erodible cover	Cover added	Portion of soil surface receiving non-erodible cover. Erosion is zero on the portion of the soil surface covered by the non-erodible cover
	Cover half life (days)	Time in days that half of the cover disappears by any process. Value entered must be appropriate for location because RUSLE2 does not consider environmental variables in computing loss of non-erodible cover.
	Cover permeability	Determines the degree that the non-erodible cover affects infiltration and runoff. 100% permeability means that the cover has no effect on infiltration. 0% permeability means that all precipitation on the non-

		erodible cover portion runs off
Remove non-erodible cover	Portion of non-erodible cover removed	Portion of current non-erodible cover removed by the operation.

13.1. Processes Used to Describe Operations

Operations are **discrete events** that change properties of **vegetation**, **residue**, and/or the **soil** that affect erosion. Examples of operations include tilling, planting, harvesting, grazing, burning, frost, ripping, blading, and applying mulch. Operations are described using a **sequence of processes**. Both the processes themselves and their sequence determine an operation's effect. Additional variables are used to describe some processes.

13.1.1. No Effect

The **no effect process** has no effect on RUSLE2 computations. It's main use is in a ***no operation*** **operation-description** to cause RUSLE2 to display output information on certain dates and for certain periods. **Section 10.2.1.3** discusses how to use a *no operation* operation-description to set the starting point for RUSLE2's tracking of time in an erosion computation. Also, users will sometimes place *no operation* operation-descriptions in a **cover-management description** where other users will later substitute other operation descriptions.

13.1.2. Begin growth

The **begin growth process** is used in an **operation description** to identify the **vegetation description** that RUSLE2 is to begin using on the date of the operation description in a **cover-management description**. RUSLE2 references day zero in the vegetation description to the date of the operation description containing the **begin growth process**. **Section 10.2.3** describes how a **begin growth process** is used in RUSLE2.

RUSLE2 uses only a single vegetation description at any time during its computations (i.e., only one vegetation description is **current** and being used at any time). RUSLE2 begins using a new vegetation description at each occurrence of an operation description with a **begin growth** process in a cover-management description. RUSLE2 does not combine information from multiple vegetation descriptions.

RUSLE2 uses certain rules regarding the **begin growth process** when an operation description with a begin growth process occurs where the previous vegetation description was not ended with a **kill vegetation process**. RUSLE2 adds the decrease between live root biomass on the last day the previous vegetation description was used and the live root biomass on day zero of the new vegetation description to the dead root biomass pool. RUSLE2 makes no change in the dead root biomass pool if live root biomass increases between vegetation descriptions.

RUSLE2 does not adjust residue pools as a result of differences in canopy cover or live aboveground biomass between vegetation descriptions. Any changes to these biomass pools must be explicitly represented using processes in operation descriptions. However, RUSLE2 DOES adjust the dead root biomass pool between vegetation descriptions. RUSLE2 assumes that a decrease in live root biomass between two vegetation descriptions is dead root biomass that is added to the dead root biomass pool on the date that the change in vegetation description occurs.

13.1.3. Kill vegetation

The **kill vegetation process** converts live aboveground biomass to standing residue and live roots to dead roots and sets values for live root biomass and live ground cover to zero. This process is used in most tillage and harvest **operation descriptions** that end vegetative growth. It is also used in frost killing operation descriptions and in burning operation descriptions if burning entirely kills the vegetation. If an operation such as burning or harvest kills only a portion of the vegetation, the procedure described below is used (see **Section 11.1.3.2**).

Because RUSLE2 uses a descriptive approach and is not a process model, an *operation description* using the *kill vegetation process* must be used to end vegetation growth.

The **kill vegetation process** “kills” all vegetation represented by the current vegetation description. A **kill vegetation process** also ends RUSLE2’s use of information from the current vegetation description. If RUSLE2 computations extend beyond the last date represented in a vegetation description, RUSLE2 uses the values on the last date in the vegetation description until an operation description with either a **kill vegetation process** or a **begin growth process** occurs in the **cover-management description**.

Two processes are used in an operation description to represent a partial kill of vegetation. These processes transfer only a portion of the live aboveground biomass to the standing and surface (flat) residue pools and a portion of the live root biomass to the dead root biomass pool. The **first process** is **remove live biomass**, which determines how much of the live aboveground biomass that is affected by the operation and the portion of the affected biomass that is transferred to the standing and surface (flat) residue pools. The **next process** in this operation description is a **begin growth process** that identifies the vegetation description that follows the current vegetation description. RUSLE2 compares the live root biomass on day zero in the new vegetation description with the live root biomass in the current vegetation description on the transfer date. RUSLE2 transfers a **decrease** in live root biomass between the vegetation descriptions to the dead root biomass pool. An increase does not change the dead root biomass pool.

A *kill vegetation process* transfers all live aboveground biomass for the current vegetation to the standing residue pool and all live root biomass to the dead root biomass pool. Use *remove live biomass* and *begin growth processes* to transfer only a portion of live biomass to dead biomass.

13.1.4. Flatten standing residue

Biomass is transferred from the standing residue pool to the surface (flat) residue pool by natural and mechanical processes that flatten the standing residue (see **Section 9.2.2.3**).[108] Flattening of standing residue by natural processes is represented internally in RUSLE2 based on decomposition at the standing residue base. The **flatten standing residue process** is used in **operation descriptions** to represent mechanical flattening of standing residue. For example, this process is used in operation descriptions that describe flattening of standing residue by foot or vehicular traffic. Also, this process is used in operation descriptions for tillage operations that bury crop residue because standing residue must first be flattened before it can be buried according to RUSLE2 rules. This process is also used in harvest operation descriptions to describe the distribution between standing and flat residue after harvest. For example, about 50 percent of wheat residue is left standing after harvest, while only 5 percent of soybean residue is left standing. The difference is primarily related to combine cutter bar height. The amount of residue left standing for corn harvest can range from about 15 to 85 percent depending on combine snapper height or whether the corn was harvested by combine, picker, grazing, or hand. This process can be used in operation descriptions to represent wind flattening standing residue where the RUSLE2 internal procedures for natural processes do not compute sufficient fattening. To flatten live vegetation, a **begin growth process** is used to call a new vegetation description to describe characteristics of the live vegetation after flattening. **A flatten standing residue process** can not be used to descrbe flattening of live vegetation because a RUSLE2 rule is that only standing residue can be flattened..

Two rules apply in using the **flatten standing residue process** in an operation description. The **first rule** is only standing residue can be flattened. Live vegetation must first be converted to standing residue using a **kill vegetation process** or a **remove live biomass process** in an operation description. The **flatten standing residue process** has no effect on live vegetation. Live vegetation can be flattened and continue to live

[108] The companion values for burial and resurfacing ratios are entered in the **disturb soil process**.

(e.g., wheat blown over by wind before maturity). An operation description that includes a **begin growth process** and associated vegetation description that represents flattened live vegetation is used to describe this condition. The **second rule** is that standing residue can not be buried by an operation until the standing residue has been converted from standing residue to surface (flat) residue. Therefore, a tillage operation description that buries standing residue must include a **flatten standing residue process** before a **disturb soil process**. Sequence of processes is important.

Flattening ratio is the input used to describe the **flatten standing residue process**. This ratio is defined as the portion of mass (dry basis) of standing residue that is flattened to the mass (dry basis) of standing residue before flattening. A flattening ratio of 0 means that no standing residue was flattened, and a value of 1 means that the entire standing residue was flattened. The portion of standing residue flattened by a mechanical process depends on both residue type (e.g., the standing residue of some vegetation types resists flattening), type of mechanical process (e.g., vehicular traffic versus harvest, corn combine versus corn picker), and properties of the process (e.g., cutter bar height). A value for the flattening ratio in an operation description is entered for each residue type (see **Section 12.1**). The values must also represent the particular process (e.g., type of machine) and the properties of the process (e.g., how the machine is operated). Multiple operations are required for a particular machine operated in different ways (e.g., cutter bar set at different heights). Values for the flattening ratio are largest for residue types most easily flattened by mechanical action and cutter bar height close to the ground, such as for soybeans.

Values entered for flattening ratio in an operation description should be based on a comparison with operation descriptions in the RUSLE2 **core database**. If a selection can not be made on that basis, research literature may provide data that can be used to determine flattening ratio values. The third possibility is to make field measurements. Data used to determine flattening ratio values should be sufficient to deal with variability, and the emphasis should be on capturing main effects rather than details that may well be unexplained variability. Values determined from the literature or from actual measurements should be checked for consistency with values in the RUSLE2 core database.

13.1.5. Disturb Surface (Soil)

The **disturb surface (soil) process** represents a mechanical disturbance of the soil that, with one exception, resets the soil consolidation subfactor to 1 for the portion of the soil surface that is disturbed (see **Section 9.2.6**). RUSLE2 assumes that the soil must be disturbed to bury surface (flat) residue, to create soil surface roughness and ridges, to mechanically smooth the soil, and to place material in the soil. The exception is the compression tillage type that buries residue without loosening the soil (see **Table 13.3**).

Also, RUSLE2 assumes that a infinitely thin surface layer of soil can be cut away without disturbing the underlying soil. The **operation description** that describes this action would **not** include a **disturb soil process** but would include a **Remove residue/cover process** that removes all above ground and surface vegetation and cover. This operation description does not affect any soil biomass.

Input values for the variables listed in Table 13.2 are required to described the **disturb soil process** for a particular **operation description**.

13.1.5.1. Tillage type

Assigning a **tillage type** from the list in Table 13.3 for an **operation description** provides information to RUSLE2 how a **soil disturbing** operation vertically distributes surface residue when it is buried. This input also provides information on how the operation vertically redistributes existing buried residue and dead roots. The **disturb soil process** has no effect on the distributions of live roots. Live root biomass must be transferred to the dead root biomass pool before root biomass can be redistributed in the soil by a soil disturbing operation. The distribution and redistribution functions represented by the tillage types are described in **Sections 9.2.5.3.3 and 9.2.5.3.4.**

The **inversion+some mixing** tillage type is used to describe machines like moldboard plows and manual operations that bury residue by inverting the soil. These operations bury most of the residue in the lower one half of the disturbance depth as illustrated in Figure 9.15. One way to represent how a soil disturbing operation redistributes buried residue and dead roots is to describe the pattern that results after the operation is applied repeatedly. Repeated applications of the inversion+some mixing tillage type operation results in buried residue and dead roots being nearly uniformly distributed as illustrated in Figure 9.17.

The **mixing with some inversion** tillage type is used to describe machines like heavy offset disks, tandem disks, chisel plows, and field cultivators and manual operations that primarily bury residue by mixing but also bury some residue by soil inversion. These operations bury most of the residue in the upper one half of the disturbance depth as illustrated in Figure 9.15. The second application of an operation of this tillage type mixes the residue fairly uniformly in the upper one half of the disturbance depth as illustrated in Figure 9.18. Subsequence applications result in a moderate bulge of material that moves downward in the soil.

The **mixing only** tillage type is used to describe machines like rotary powered tillers and manual operations that incorporate residue by mixing with hardly any soil inversion. These operations tend to bury residue in the upper one third of the soil depth as illustrated in Figure 9.15 rather than uniformly over the disturbance depth as commonly assumed. Repeated applications of this tillage types results in a well defined bulge of material that moves downward in the soil.

The **lifting, fracturing** tillage type is used to describe machines like fertilizer and manure injectors, subsoilers, and sacrifiers and manual operations that have a similar effect on the soil and residue. This tillage type assumes almost no mixing or inversion, and an operation of this tillage type buries residue in the upper one third of the disturbance depth. The residue distribution and redistribution relationships for **mixing only** are used to describe this tillage type.

An **add other residue/cover process** is used to place external residue in the soil. This process must be followed by a **disturb soil process** in the **operation description**. The lifting, fracturing tillage type is selected for the operation. RUSLE2 places the inserted material in the lower one half of the disturbance depth as illustrated in Figure 9.16. This procedure assumes that the material is placed in the soil by injection. Material can be also placed in the soil by applying it to the soil surface and incorporating it using machines like disks, chisel plows, field cultivators, or rotary powered tillers or manual implements. The operation description for this method of incorporation includes an **add other residue/cover process** followed by a **disturb soil process**.

Table 13.3. Tillage types used in RUSLE2			
Tillage type	Burial pattern	Redistribution characteristics with repeated applications	Comment
Inversion + some mixing	Most of material is placed in lower 1/2 of disturbance depth	Material is nearly uniformly distributed	Used to represent soil disturbing machines like moldboard plows that invert soil
Mixing with some inversion	Most of material is placed in upper 1/2 of disturbance depth	2nd application results in a fairly uniform pattern in the upper ½ of soil disturbance depth after which a moderate bulge develops that moves downward in soil	Used to represent soil disturbing machines like chisel plows, field cultivators, and disks
Mixing only	Most of material placed in upper 1/3 of disturbance depth	A well defined bulge rapidly develops that moves downward in soil	Used to represent powered rotary tillers
Lifting, fracturing	Most of material placed in upper 1/3 of disturbance depth	A well defined bulge rapidly develops that moves downward in soil	Used to represent fertilizer injectors, manure injectors, subsoilers, and sacrifiers
Compression	Most of material placed in upper 1/3 of disturbance depth	No redistribution	Used to represent sheep's foot roller and animal traffic that presses residue into the soil. The soil consolidation subfactor is not reset to 1
Note: When external residue is placed in the soil, the **add other residue/cover process** must be followed with a **disturb soil process** in the operation description, which places the inserted material in the lower one half of the disturbance depth			

The **compression** tillage type is used to describe cattle trampling, a sheep foot's roller, and similar operations pressing residue into the soil without loosening the soil. The **mixing only** distribution relationship is used to vertically distribute the buried residue. Operations of this tillage type are assumed to not redistribute buried residue or dead roots. **An important difference between this tillage type and the other tillage types is that the soil consolidation subfactor is not reset to 1.**

The best way by far for assigning tillage types to soil disturbing operations is to base the selection on Table 13.3 in conjunction with comparisons with tillage types assigned in the RUSLE2 **core database**. Consistency between the assigned tillage type and those in the core database is essential.

A very important feature of the soil mixing relationships used in RUSLE2 is that material does not become uniformly mixed in the soil with repeated applications of the operation except for the *inversion+some mixing* tillage type. The distribution becomes more non-uniform with repeated applications of operations described with the other tillage types.

13.1.5.2. Tillage intensity

Tillage intensity refers to the degree that a soil disturbing operation obliterates existing roughness. Tillage intensity relates to the aggressiveness of the soil disturbance. A tillage intensity value of 1 means that existing soil roughness has no effect on the roughness created by the operation. A tillage intensity value of 0 means that roughness after the operation is the same as before the operation, unless the existing roughness is smoother than the roughness created by the operation on a smooth soil.

A moldboard plow and a rotary powered tiller are both assigned tillage intensity values of 1 because these aggressive machines totally eliminate any signs of existing roughness. In contrast, a spike tooth harrow, which is non-aggressive, is assigned a tillage intensity of 0.4 because the harrow hardly changes existing roughness. For example, soil surface roughness is greater when the harrow follows a moldboard plow than when it follows a tandem disk because of differences in existing roughness and the minimal effect that the harrow has on roughness. The harrow does some smoothing but does not totally work the soil to eliminate all existing soil surface roughness to create a totally new soil surface roughness. Tillage intensity values range from 0.5 to 0.9 machines like field cultivators, tandem disks, and chisel plows depending on the machine's "aggressiveness."

When the roughness immediately before an operation is smoother than the roughness created by the operation on a smooth soil, the tillage intensity variable has no effect on the roughness value estimated by RUSLE2. The roughness value for the operation is set to the **input (initial) roughness value** for the operation, adjusted for soil texture and soil biomass (see **Section 9.2.3**).

Tillage intensity is not necessarily related to the initial roughness created by an operation. For example, both a moldboard plow and a rotary powered tiller are assigned 1 for tillage intensity but the soil surface roughness left by the two machines is very different. The moldboard plow leaves a very rough surface and the powered rotary tiller leaves a very smooth surface. Both machines are very aggressive and completely disturb the soil. Machines that have low tillage intensity values also tend to leave a relatively smooth surface when used on a smooth soil.

Tillage intensity values should be assigned using values in the RUSLE2 **core database** as a guide. The selection is the operation's aggressiveness for obliterating signs of existing soil surface roughness, not the soil surface roughness left by the operation. The RUSLE2 assumption is that tillage intensity is not a function of soil properties. However, different intensity values can be assigned based on soil properties. The RUSLE2 user then chooses the operation description having the tillage intensity values most appropriate for the site-specific condition.

13.1.5.3. Recommended, minimum, and maximum speed and disturbance (tillage) depths

The portion of the surface (flat) residue mass buried by a **soil disturbing operation** (e.g., tillage) increases as disturbance depth and speed increase as illustrated in Figures 13.1 and 13.2. These relationships were derived from analysis of research data. The manufacturer of tillage implements and soil disturbing machines often specify a recommended disturbance depth and speed along with working ranges where the machine operates satisfactorily. The input burial ratio values are for the **recommended disturbance depth and speed**.[109] No other variable, including residue resurfacing, is affected by disturbance depth and speed in RUSLE2.

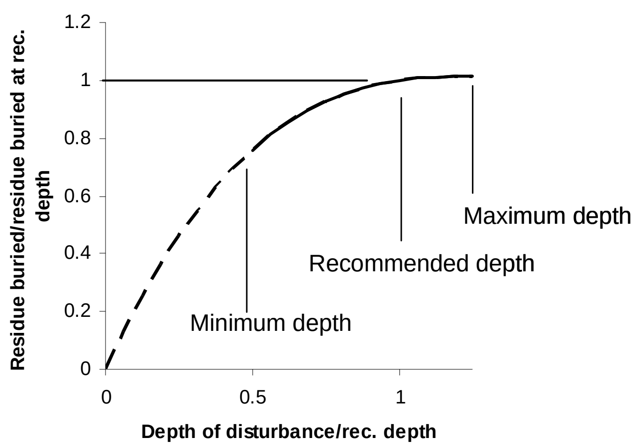

Figure 13.1. Effect of disturbance depth on residue burial (mass basis).

Increasing disturbance depth at shallow depths significantly increases residue burial, but increasing disturbance depth to depths deeper than the recommended depth does not greatly increase residue burial. Increasing speed does not significantly increase residue burial. The effect of speed on residue burial is generally less than the effect of disturbance depth.

---

[109] Disturbance depth in RUSLE2 is for the entire disturbance (tillage) depth, which differs from the incorporation depth used in RUSLE1. The RUSLE1 incorporation depth is the effective depth of residue burial assuming that residue is buried uniformly with depth. The RUSLE1 incorporation depth is shallower than the RUSLE2 disturbance depth.

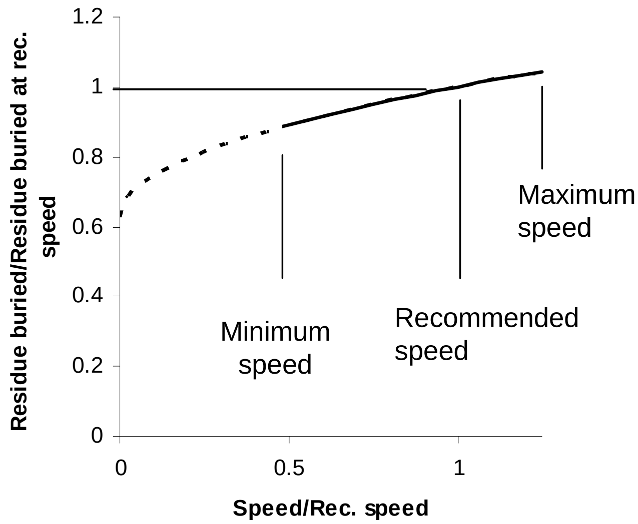

Figure 13.2. Effect of speed on residue burial (mass basis)

In most RUSLE2 applications, the recommended disturbance (tillage) depth and speed are accepted as default values.[110] Input values for disturbance depth and speed entered in **cover-management descriptions** must be within the minimum and maximum values entered in each **operation description.**

The common belief is that practically any surface residue cover can be achieved by varying how a machine is operated. Disturbance depth and speed are the two machine variables that can be changed easily. The assumption that a particular residue cover can be achieved by varying machine operation should be checked. The range in residue cover that can be achieved by varying disturbance depth and speed is determined by making RUSLE2 computations at the minimum and maximum disturbance depth and speed values. If RUSLE2 shows that the desired residue cover is not obtained by varying disturbance depth or speed, another change in the machine such as changing shovel type is required.

Input values for disturbance depth and speed can often be obtained from manufacturer's literature. Also, values given in the RUSLE2 **core database** can be used as a guide to selecting input values. The preferred approach is to select a tillage depth based on the implement type rather than selecting value specific to an individual machine or operator. The disturbance depth and speed values shown in the RUSLE2 core database were chosen to give the desired differentiation between implement types. Input values should be reviewed for consistency among themselves and with values in the RUSLE2 core database.

Input values for disturbance depth and speed should not deviate significantly from those in the RUSLE2 core database for a particular type of machine.

[110] Depth and speed of operations in a **cover-management description** may not be displayed by the RUSLE2 template used to configure your RUSLE2 screen. Choose an alternate RUSLE2 template that displays additional variables so that disturbance depth and speed can be entered for each operation in a **cover-management description**.

13.1.5.4. Ridge height

Ridge height has two effects in RUSLE2. One effect is that increased ridge height increases erosion when the ridges are oriented up and down hill perpendicular to the contour. This ridge effect is considered in the subfactors used to compute **cover-management** effects (see **Section 9.2.4**). The other effect is that increased ridge height decreases erosion when the ridges are on the contour (parallel to the contour). This ridge effect is considered in **support practice** relationships used to compute the **contouring** effect (see **Section 14.1**). The overall ridge height effect, which is the net between these effects, also varies with row grade (grade along the furrows between the ridges).

Operation descriptions that include a **disturb soil process** must be used in a **cover-management description** to create ridges for RUSLE2 to compute a contouring support practice effect. RUSLE2 assumes that ridges can not be created without disturbing the soil, which resets the soil consolidation subfactor to 1 for the portion of the soil surface that is disturbed by the operation that creates the ridges.

Input values for initial ridge height are entered in operation descriptions that include a **disturb soil process**. Ridge height created by an operation is not affected by ridge height that existed before the operation. In effect, an operation obliterates any ridge height that existed prior to the operation even when the operation minimally disturbs the soil. The ridge height entered for an operation should reflect the ridge height that exists when the operation is used in combination with other operations. RUSLE2 computes loss of ridge height over time as a function of precipitation amount and interrill erosion.

The best way, by far, to assign ridge height values is to use the values in the RUSLE2 **core database** as a guide. RUSLE2's estimate of the contouring effect on erosion is RUSLE2's most uncertain estimate. Too frequently, initial ridge height values are entered that are too low, which results in RUSLE2 not computing the expected contouring effect (see **Section 14.1**). Field measured ridge height values may be lower than the corresponding values in the RUSLE2 core database. Also, important ridges are also overlooked when field measurements are made.

If RUSLE2 is not computing as much contouring effect as expected, initial ridge height values in key operation descriptions may need to be increased.

13.1.5.5. Initial roughness

As described in **Section 9.2.3**, RUSLE2 computes decreased sediment production (i.e., detachment, see equations 5.4, 8.1, 9.1, 9.10) as soil surface roughness increases. RUSLE2 also computes decreased runoff rates as soil surface roughness increases (see **Section 5.4**). RUSLE2 uses runoff rate to compute how contouring affects erosion (see **Section 14.1**) and to compute sediment transport capacity (see equation 5.3). RUSLE2 uses sediment transport capacity to compute deposition, sediment yield, and enrichment of the sediment in fines on rough surfaces; on concave shaped slopes; upslope of strips of dense vegetation, rough soil surfaces, and heavy ground cover; and in low grade terrace/diversion channels (see **Section 14**).

RUSLE2 assumes that the soil must be disturbed to create roughness, which resets the soil consolidation subfactor to 1 for the disturbed portion of the soil surface, with one exception. The exception is a **compression tillage type** that creates soil surface roughness but does not reset the soil consolidation subfactor to 1 (see **Section 13.1.5.1**). Therefore, **operation descriptions** that include a **disturb (soil) surface process** must be included in **cover-management descriptions** to describe surface roughness. The input value for **initial roughness** in the disturb soil process in an operation description is an index for the roughness that the operation creates for a standard condition. **This standard condition is a smooth, silt loam soil, where the amount of soil biomass from buried residue and dead roots is very high in the soil disturbance depth after the operation** (see **Section 9.2.3.3**). RUSLE2 adjusts the input initial roughness value to obtain an **adjusted roughness** value for its erosion computations.

These adjustments are for:
soil texture (increased roughness for fine textured soils, decreased for coarse textured soils),

soil biomass in disturbance depth after operation (decreased roughness with decreased soil biomass), and

tillage intensity if the existing roughness is greater than the roughness created by operation on a smooth soil (resulting roughness is least affected by existing roughness as tillage intensity increases).

The initial roughness input value applies only to the **portion of the soil surface disturbed** and not to the entire soil surface. **The input value is not a net for the entire surface.**[111] RUSLE2 does not arithmetically average the roughness values for the disturbed and undisturbed portions of the soil surface. Instead, RUSLE2 computes a roughness subfactor value (see equation 9.10) for both the disturbed and undisturbed portions. These subfactor values are averaged based on the portion of the soil surface disturbed. This average roughness subfactor value is used to compute an **equivalent roughness** value for the entire surface that gives the proper net erosion for the entire surface.[112] This equivalent roughness value is decayed over time by precipitation amount and interrill erosion.

---

[111] The roughness input is different from the inputs for residue burial and resurfacing in the **disturb (soil) surface process** description. Burial and resurfacing input values are net for the entire soil surface.
112 Proper erosion is the net erosion that is computed to occur based on the undisturbed and disturbed surfaces. An equivalent roughness is determined that gives this net erosion.

The best approach for selecting input values for initial roughness is to base them on values in the RUSLE2 **core database**. Like other variables, the values in the RUSLE2 core database were selected to represent operation classes and types to ensure that RUSLE2 computes main effect erosion differences among operations based on research data and professional judgment. User selected initial roughness input values should be reviewed for consistency among implements, machines, and manual types of soil disturbance and for consistency with RUSLE2 core database values. The requirement is that RUSLE2 estimate expected erosion rather than exactly reproducing a field roughness measurement.

The scientific literature is a source of initial roughness input values, but literature values require modification using equations in **Section 9.2.3.3** before using them in RUSLE2. For example, the RUSLE2 initial roughness input values are often higher than comparable values used in other erosion models because of the standard condition used to define RUSLE2 initial roughness. The internal RUSLE2 adjusted roughness values are often similar to input values used in other models.

The RUSLE2 standard condition used to define initial roughness is the same as the one used in RUSLE1 (AH703). However, the RUSLE2 initial roughness input values differ from the RUSLE1 values because of the RUSLE2 tillage intensity effect that is not used in RUSLE1. RUSLE2 initial roughness values are less than comparable RUSLE1 values where tillage intensity is less than 1.

RUSLE1 initial roughness values can not be used directly in RUSLE2 without adjusting for the tillage intensity effect

Field measurements can be made to determine RUSLE2 input initial roughness subfactor values (see **Section 9.2.3.2**). The measurements are on a 1 inch (25 mm) grid using pins lowered to the soil surface or elevations determined using a non-contact method. The chain method should not be used to determine roughness values for RUSLE2. Elevations related to ridges should be removed, and a plane should be fitted to the data to remove land slope effects. The roughness measure used in RUSLE2 is the standard deviation of elevations about this plane. Equations described in **Section 9.2.3.3** must be used to adjust measured values for a particular field condition to the RUSLE2 standard condition for initial roughness. Sufficient measurements are made to account for both temporal and spatial variability. The intent is to characterize main effects of roughness using a diverse data set rather than representing a single, specific site condition.

13.1.5.6. Final roughness

The RUSLE2 subfactors described in **Section 9**, including the roughness discussed in **Section 9.2.3**, are relative to the unit plot conditions used to determine soil erodibility factor values (see **Section 7.2**). The value for each subfactor is 1 for unit plot conditions. A roughness value of 0.24 inches (6 mm) is assumed to represent unit plot roughness. This roughness is similar to the roughness at harvest of a row crop where a moldboard plow, tandem disk, field cultivator, and row cultivator were used to till the soil. A 0.24-inch (6 mm) roughness is nearly but not completely smooth. A perfectly smooth soil surface has a roughness value of 0 inches (0 mm).

The 0.24-inch (6 mm) roughness represents the effect of a few erosion resistance clods on erosion. Even though **final roughness** represents the effect of a few erosion resistant clods, the input value for final roughness is not a function of soil texture. The effect of soil texture on final roughness is empirically represented in the soil erodibility factor values derived from unit plot conditions.

This empirical effect of soil texture on final roughness being included in the soil erodibility factor is but one reason why RUSLE2 definitions must be understood and followed.

A final roughness value of 0.24 inches (6 mm) is typically used in RUSLE2 for operation descriptions that create a roughness greater than 0.24 inches (6 mm) on a smooth soil. However, some operations leave a smoother surface than 0.24 inches (6 mm). A rotary powered tiller used to prepare a very fine seedbed is an example. This tiller creates almost uniform, small-sized soil aggregates (clods) and leaves almost no large clods in comparison to a moldboard plow, heavy offset disk, or chisel plow. Another example is a bulldozer or a road grader that cuts away soil leaving a very smooth surface. A 0.15-inch value is used for final roughness for these operations.

If the input value for final roughness is greater than or equal to 0.24 inches (6 mm), RUSLE2 decays roughness from a starting value to the final roughness value based on daily precipitation and daily erosion. If the input value for final roughness is less than 0.24 inches (6 mm), the input value for initial roughness should be the same as the input value for final roughness. RUSLE2 does not decay this roughness value.

Similarly, RUSLE2 does not decay roughness when the input values for both initial and final roughness are the same, even when the input value for final roughness is greater than 0.24 inches (6 mm). These inputs cause RUSLE2 to use a specific roughness value. An example of this application is representing roughness created by animal traffic, which also involves selecting compression for tillage type (see **Section 13.1.5.1**).

***Long term natural roughness*, discussed in *Section 10.2.7*, is the soil surface roughness that develops over time to soil consolidation after a soil disturbance. Final roughness and long term roughness are not the same, and the values entered for the two variables are not the same.**

13.1.5.7. Surface area disturbed

Some operations like planters disturb only a portion of the soil surface. The variable **portion of soil surface disturbed** directly affects the soil consolidation and soil surface roughness subfactors and indirectly affects the soil biomass subfactor, the effect of distance along an overland flow path on erosion, the effect of surface cover on erosion, and runoff (see **Section 9.2.6**).

Selecting proper values for the portion of the soil disturbed requires an understanding of the definition of soil disturbance, knowing the effect of soil disturbance on erosion, and recognizing indicators of soil disturbance. The definition of soil disturbance is given in **Section 9.2.6.3.**

Soil disturbance, as used in RUSLE2, occurs when an operation fractures and loosens the soil, displaces soil, mixes soil and surface residue so that the interface between the residue and the surface soil is no longer distinct, and disrupts a high organic matter layer at the soil surface.

The portion of the soil surface disturbed includes a **soil source area** and the **soil receiving area** that collects soil displaced from the soil source area. The soil source area is mechanically disturbed (disrupted) where the soil disturbing tool (e.g., disk blade, shank, or shovel) fractures, loosens, and displaces soil. This area is considered disturbed if the tool action penetrates below the residue (litter)-soil interface to mix underlying soil and residue (litter) and expose and displace mineral soil. The area disrupted by the tool should be considered to be disturbed if the disturbance depth exceeds an inch (25 mm) or two (50 mm).

Some tools run beneath the residue (litter)-soil interface and do little more than fracture and loosen the soil. This action is also soil disturbing even though mineral soil may not be exposed. However, the input value for the portion of the soil surface disturbed may be less that the actual field width of disturbance for conditions where the residue (litter)-soil interface remains largely intact and undisturbed. Selecting an input value for portion of the soil surface disturbed by undercutting involves comparing the surface high organic soil layer left after undercutting with this layer where no disturbance occurs.

The soil receiving area receives mineral soil displaced from the soil source area. The soil receiving area is considered disturbed if the residue (litter)-soil interface is disturbed and

Assigning input values for portion of the soil surface disturbed requires judgment. The effect being represented in RUSLE2 needs to be understood. A set of rules is highly useful to ensure that consistency is achieved in assigning input values among types of soil disturbances.

soil and residue (litter) are mixed. If the displaced soil is sufficiently deep that rill erosion does not penetrate the displaced soil layer, the buried residue (litter) has little direct effect on erosion and the entire receiving area should be considered disturbed. In this case, the portion of the soil surface disturbed includes the soil source area and all of the soil receiving area. A displaced soil depth of ½ inch (12 mm) or more is used as a guide in making this determination. The input value for the portion of the soil surface disturbed is reduced where rill erosion erodes through the displaced soil layer to the underlying intact reside (litter). The residue (litter) reduces erosion only after it becomes exposed.

Ridges are evidence of soil disturbance. Ridge creation requires a soil source area, and the receiving (ridge) area is soil of sufficient depth that erosion is unaffected by the underlying residue (litter). Ridges higher than ½ to 1 inch (12 to 50 mm) are considered to be disturbed areas.

The degree of soil disturbance is highly important considerations in determining the effectiveness of no-till cropping systems for controlling erosion. The two characteristics of these systems most responsible for their high erosion control effectiveness are the continuous presence of surface residue and a surface soil layer of high organic matter content, both of which are reduced by soil disturbance. **Both conditions must be present; high residue cover alone is not sufficient for the full no-till effect.** RUSLE2 uses **portion of the soil surface disturbed** along with the **soil consolidation subfactor** and **soil biomass** in the upper 2-inch (50 mm) soil layer to compute the effect of the upper high organic matter soil layer on erosion (see **Section 9.2.6**).

Portion of the soil surface disturbed by an operation and the **time since the last mechanical disturbance** are key variables. According to RUSLE2, surface residue cover is restored quickly in three years or less for much of the Eastern US after a single major disturbance such as moldboard plowing that buries almost the entire surface residue. About three to five years are required in much of the Eastern US to restore soil biomass in the upper 2-inch layer based on decomposition. This determination can be made by setting the **time to soil consolidation** to 1 year, which eliminates the effect of soil consolidation on the accumulation of soil biomass.

The accumulation of soil biomass in the upper 2-inch (50 mm) layer and the effect of this soil biomass on erosion are functions of the soil consolidation subfactor. Consequently, the total time for the no-till effect to be fully regained after a soil disturbance is about the same as the time entered in the **soil description** for the **time to soil consolidation**. The standard assumption for **time to soil consolidation** is seven years in most of the Eastern

US. RUSLE2 computes that most of the no-till effect is regained in about five years, as Table 13.4 illustrates for no-till 112 bu/ac corn **cover-management description** for Columbia, MO. This RUSLE2 estimate is consistent with the rule of thumb that five years is required for the full effect a no-till cropping system to be realized.

RUSLE2 computes a loss of the no-till effect that is almost as great with undercutting blade, chisel plow, field cultivator, and disk-type implements that disturb 100 percent of the soil as with soil inversion implements like moldboard plows. About one half of the no-till effect is lost directly through changes in the soil consolidation subfactor and the other half is lost through the effect of the soil consolidation subfactor being used as a variable in the soil biomass subfactor (see Figure 7.3 and equation 9.12).

Table 13.4. No-till effect after long term no-till is moldboard plowed in one year

Time (years) in no-till after moldboard year	Annual no-till effect (soil consolidation subfactor·soil biomass subfactor) weighted by erosivity distribution
1	0.61
2	0.49
3	0.39
4	0.32
5	0.28
6	0.25
7	0.24
8	0.23

All operations in a **cover-management description** are important in determining the degree of the no-till (lack of soil disturbance) effect. A single operation, such as a fertilizer/manure injector that disturbs as much as 50 percent of the soil surface causes RUSLE2 to compute a significantly reduced no-till effect (i.e., values closer to 1 for the product of the soil consolidation and soil biomass subfactors means a reduced no-till effect). The no-till effect is 0.54 where an injector that disturbs 50 percent of the surface is used with a planter that disturbs 15 percent of the surface for no-till 112 bu/acre corn at Columbia, MO. The no-till effect is 0.22 if the injector is not used for.

Multiple occurrences of an operation that minimally disturbs the soil surface in a cover-management description reduce the no-till effect. For example, the no-till effect is 0.22, 0.32, and 0.40 for one, two, and three occurrences, respectively, of a no-till planter on the same day in the Columbia, MO no-till corn example. **Section 9.2.6.4** describes the mathematical procedure that RUSLE2 uses where only a portion of the soil surface is disturbed by an operation. The net effect is similar to RUSLE2 assuming that most, but not all, of the soil disturbance is in an undisturbed area. RUSLE2 does not assume that a planter runs in the same place each year. However, the overlap effect was empirically considered by fitting RUSLE2 to no-till field data so that the expected erosion estimate is computed.

The large effect of the portion of the soil surface disturbed on estimated erosion is illustrated in Figure 9.19. This difference is significant when using RUSLE2 to estimate erosion for wide row (e.g., 30-inch width) no-till planters and narrow row no-till drills (e.g., 7-inch width). The no-till effect is 0.22, 0.30, 0.57, and 0.62 for 15, 25, 65, and 85 percent for portion of the soil surface disturbed, respectively, for a no-till 112/bu/acre corn cropping system at Columbia, MO. These values illustrated that a small change in portion of the soil surface disturbed has a greater effect on estimated erosion when little of the soil surface is disturbed in comparison to when most of the soil surface is disturbed. The soil disturbance characteristics for both wide row and narrow row seeding implements should be very carefully considered in assigning values for **portion of the soil surface disturbed**. The tendency is to assign values that are too low for wide row implements and values that are too high for narrow row implements.

The effect of no-till cropping on soil erosion was analyzed in depth during the development of RUSLE2. To achieve maximum benefits from no-till cropping, the portion of the soil surface disturbed must be minimized.

13.1.5.8. Burial and resurfacing ratios

RUSLE2 assumes that an **operation description** with a **disturb soil process** buries **surface residue** and resurfaces **buried residue** as described in **Sections 9.2.5.3.3 - 9.2.5.5**. RUSLE2 only buries surface residue because standing residue must be flattened before it can be buried. Therefore, if an operation is being used to bury **standing residue**, the operation description must include a **flatten standing residue process** followed by a **disturb soil process**. RUSLE2 only resurfaces buried residue; it does not resurface **live** or **dead roots**.

The processes in an operation description must be entered in the proper sequence. To bury standing residue, proper sequence is flatten standing residue and disturb soil. A reverse order of these processes in an operation description will give a very different result.

The residue mass left on the soil surface after a soil disturbing operation is the **net** between the residue that is buried and the residue that is resurfaced. Having both residue burial and resurfacing components allows RUSLE2 to compute an increase in surface residue after an operation in certain conditions. An example is a field cultivator following a tandem disk and a moldboard plow in a high yield corn **cover-management description**.[113]

Input values for burial and flattening ratios are on a **mass basis** rather than on the

[113] RUSLE1 does not include a resurfacing component in its residue equations. Consequently, RUSLE1 can not compute an increase in residue cover following an operation like a field cultivator. RUSLE1 can not duplicate the residue burial values computed by RUSLE2. The residue burial ratio values used in RUSLE2 differ from those used in RUSLE1 because of the resurfacing component in RUSLE2.

portion of the soil surface covered even though RUSLE2 uses portion of soil surface covered to estimate erosion. RUSLE2 displays values for portion of the soil surface covered (e.g., percent cover) that are useful in conservation and erosion control planning.

The best information for selecting input values for burial and resurfacing ratios is the RUSLE2 **core database**. The values in the RUSLE2 core database have been carefully selected based on research data and the validation of RUSLE2 to ensure that it computes good estimates of surface residue cover immediately after planting and that it computes good estimates of average annual erosion.

Values for net residue burial ratio are widely available in the technical literature. Unfortunately, much of this literature fails to specify whether the values are based on residue mass or portion of the soil surface covered by residue. In many cases, a mixture of the two was unknowingly included because original sources failed to describe the basis for the values. Consequently, many of the widely available and accepted burial ratio values are not appropriate for RUSLE2 use.

Residue burial values based on mass are very different from those based on percent cover because of the strong non-linear relationship between residue mass and the portion of the soil surface covered by a given residue mass.

Residue burial ratio values in the technical literature almost always represent net burial (net effect of burial and resurfacing combined) rather than burial alone as required by RUSLE2. Consequently, RUSLE2 residue burial ratio values are higher than the common values in technical literature.

The net residue burial ratio computed by RUSLE2 for an operation depends on the operations and their sequence in the cover-management description and the soil biomass in the operation's disturbance depth. For example, RUSLE2 computes 17 percent for the net burial ratio for a tandem disk for a 150 bu/acre corn cover-management description where the tandem disk follows a moldboard plow. In contrast, RUSLE2 computes 53 percent for the net burial ratio for the same tandem disk following a chisel plow with straight points. This illustrates a reason for variability in field observed residue net burial ratio values.

Residue burial and resurfacing ratio values must be assigned to operation descriptions not in the RUSLE2 core database. Sometimes adjustments to the values in the RUSLE2 core database may be desired. The value RUSLE2 computes for surface residue mass after a soil disturbing operation is very sensitive to the resurfacing ratio value. Unfortunately, very little research data are available for determining values for the resurfacing ratio. **The best approach is to accept the resurfacing ratio values in the RUSLE2 core database without adjustments.** Residue burial ratio values are adjusted until RUSLE2 computes the desired residue cover following a particular operation.

The proper field data required to determine RUSLE2 residue burial and resurfacing ratio values are where as operation has been repeated three or more times in the same area.[114] A value for the resurfacing ratio can not be determined from a single occurrence of an operation. Repeated occurrences of an operation establish the equilibrium surface residue mass as illustrated in Figure 13.3. The first occurrence of the operation can be used to estimate a residue burial ratio value provided soil biomass is insignificantly low in the operation's disturbance depth.

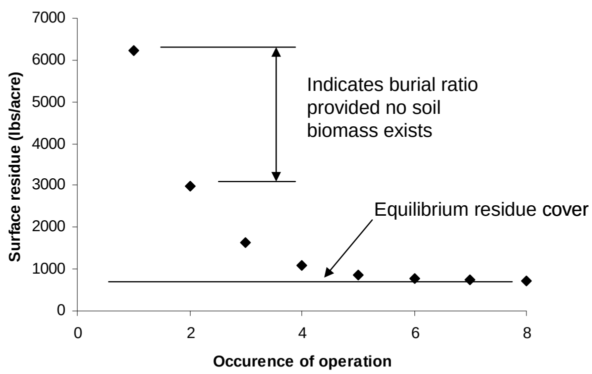

Figure 13.3. Residue burial by repeated occurrences of a field cultivator.

This residue burial ratio value along with the equilibrium surface residue mass can be used to estimate a resurfacing ratio value. The proper procedure for determining values for residue burial and resurfacing ratios is to fit RUSLE2's complete set of residue equations to field data.

Both residue burial and resurfacing ratios are a function of residue type discussed in **Section 12.1**. In general, residue burial ratio values are larger for residue that is in small, fragile pieces that break easily from the forces of a soil disturbing operation. Conversely, resurfacing ratio values are typically larger for residue composed of long, tough pieces. Therefore, size, shape, and fragility (inverse of toughness) all must be considered in selecting both burial and resurfacing ratio values. Rock/gravel is a special case where size and shape is a major factor.

The values in the RUSLE2 core database have been selected to represent the main classes of implements and machines that bury and resurface residue rather than describing specific machines operated in a specific way. The intent with RUSLE2 is to capture main effects within the overall accuracy of RUSLE2. The assigned burial and resurfacing ratio values, regardless of how they were obtained, should be consistent with values in the RUSLE2 core database and with values in the user's working database so that RUSLE2 computes the expected relative effects of the operation on erosion.

[114] Two excellent examples of the type of data needed to determine burial and resurfacing ratio values are:
Brown, L.C., R.K. Wood, and J.M. Smith. 1992. Residue management, demonstration, and evaluation. Applied Engineering in Agriculture. 8:333-339.
Wagner, L.E. and R.G. Nelson. 1995. Mass reduction of standing and flat crop residues by selected tillage implements. Transactions of the ASAE. 38:419-427.

The common assumption is that machines can be adjusted to produce almost any desired residue cover. This assumption is often erroneous. RUSLE2 includes relationships discussed in **Section 13.1.5.3** that describe how speed and disturbance depth affect residue burial based on research data. **Input residue burial ratio values outside of the range computed by RUSLE2 on the basis of varying disturbance depth or speed are highly questionable.**

13.1.6. Live biomass removed

The **remove live biomass process** removes live aboveground biomass without **killing** the current vegetation. This process is used in **operation descriptions** used to represent such operations as silage harvest, hay harvest, and mowing permanent vegetation. It's most important use is where a portion, but not all, of the live aboveground biomass is converted to standing and/or surface (flat) residue without killing the current vegetation. Examples include intercropping where one crop is harvested and a second crop continues to grow, volunteer weeds and cover crops that continue to grow after a main crop is harvested, and vegetation that regrows after a mowing or hay harvest. In these cases, some or all of the live root biomass remains, and some or all of the live aboveground biomass remains. The **kill vegetation process** can not be used in **cover-management descriptions** for these vegetation systems because this process converts **all** live aboveground biomass to standing residue and **all** live roots to dead roots, rather than portions of these biomass pools.

RUSLE2 assumes that live aboveground biomass can not be removed without substantially affecting the vegetation. Therefore, RUSLE2 requires that a **begin growth process** or a **kill vegetation process** follow the **remove live biomass process** in an **operation description**. The **begin growth process** identifies the **vegetation description** that RUSLE2 is to use immediately after the operation. If the live root biomass on day zero of the new vegetation description is less than the live root biomass on the last day that the previous vegetation description was used, **the difference is added to the dead root biomass pool because the operation is assumed to have killed a portion, but not all, of the current vegetation.**

Changes in aboveground biomass caused by the operation are described using the input values for the variables that describe the remove live biomass process. These variables are portion of live aboveground biomass **affected** by the operation, portion of the affected biomass left as **surface (flat) residue**, and portion of the affected biomass left as **standing residue**. Although the biomass removed from the local area (field, site) is not important to RUSLE2, this variable is used for user input convenience. RUSLE2 needs a description of the biomass at the site at any particular time to compute erosion. Thus, the biomass left behind either as remaining live biomass and residue after the operation are key variables. The values in the vegetation description identified by the **begin growth process** in the operation description describe the vegetation variables that affect erosion after the operation. Therefore, the remove live biomass process tells RUSLE2 how much residue is left behind for an operation that affects the current vegetation but does not kill it.

Table 13.5 illustrates the input values for three typical operation descriptions where the **remove live aboveground biomass process** is used. The first example is mowing permanent vegetation where the biomass above the cutting height is left as surface residue and the vegetation regrows after the mowing. The amount of live biomass affected is the biomass above the cutting height. The affected biomass is assumed to be 50 percent of the total live aboveground biomass at the time of the mowing. All of the cut (affected) biomass is assumed to become surface residue. Thus, the input for portion of the affected biomass that becomes surface residue is 100 percent. The input is zero for the portion of affected biomass that is left as standing residue because the operation creates no standing residue. A **begin growth process** follows the **remove live biomass process** in the operation description to identify the vegetation description that RUSLE2 uses immediately after mowing. The canopy cover is reduced to reflect the mowing but the live root biomass remains the same between the current vegetation description and the new one.

Table 13.5. Input values for three operation descriptions that use the remove live aboveground biomass process (values on a dry matter basis)

Operation	Live aboveground biomass at time of operation (lbs/ac)	Live aboveground biomass affected (%)		Surface residue left by operation		Standing residue left by operation	
		Portion (%)	Mass (lbs/ac)	Portion (%)	Mass (lbs/ac)	Portion (%)	Mass (lbs/ac)
Mowing permanent vegetation that regrows	3,000	50	1,500	100	1,500	0	0
Legume hay harvest, hay regrows	2,000	95	1,900	5	95	0	0
Harvest small grain in a small grain-legume hay intercropping system	5,000	80	4,000	50	2,000	50	2,000

Note: Values for Portion are user entered input values. Mass values are computed by RUSLE2.

The second example is a legume hay harvest that removes live aboveground biomass and where the legume hay crop regrows after the hay harvest. In this example, 95 percent of the live aboveground biomass on the day of the operation is assumed to be affected. Only a small amount of stubble is left unaffected. The amount of the live aboveground biomass that is affected is 1,900 lbs/acre (= 2,000·95/100). All of the affected biomass is removed from the field except for five percent, which is 95 lbs/acre (= 1,900·5/100), that remains as surface residue. None of the affected biomass is left as standing residue. The surface residue left in the field is from leaf shatter and inefficiencies of the harvesting machines. The operation description includes a **begin growth process** immediately after the **remove live biomass process**. The **begin growth process** identifies the vegetation description that RUSLE2 is to use after the hay harvest. The canopy cover on day zero will be very low because the harvest left nothing but very short stubble. The root biomass does not change between the two vegetation descriptions because the hay harvest has no effect on live root biomass.

The third example is for an intercrop of small grain and legume hay. The small grain is seeded in the fall and the legume hay is seeded in late winter. The small grain is harvested in late spring, which kills that portion of the vegetation. The legume continues to grow after the small grain harvest to be killed by a hay harvest in late summer. The small grain harvest is represented with an operation description that includes a remove live biomass process followed by a **begin growth process**. The total live aboveground biomass at the time of the small grain harvest is 5,000 lbs/acre. Eighty percent (= 5,000·80/100 lbs/acre) of the total live aboveground biomass is affected by the small grain harvest. Half (50 percent) of the affected biomass is left as surface residue, which represents the straw discharged by the combine that harvested the small grain. The other half (50 percent) of the affected biomass is left as standing residue, which represents the standing small grain stubble left by the harvest. The **begin growth process** identifies the vegetation description that applies after the small grain harvest. Both the canopy cover and effective fall height values on day zero in the new vegetation description are reduced slightly from the values on the last day that the previous vegetation description was used. The legume already has a sufficient understory by the time of the small grain harvest that the legume is the major determinant of canopy cover and effective fall height (see **Section 9.2.1**). The live root biomass on day zero in the new vegetation description is significantly reduced from that on the last day for the previous vegetation description, which represents the combined small grain-legume hay vegetation. RUSLE2 assumes this difference to be dead root biomass created by the small grain harvest.

Relative (fractions, percents) rather than absolute variables are used to describe the remove live biomass process. Using an absolute variable like height above which the biomass is removed (e.g., cutting height) could be used for common machine operations like mowing and hay harvest. However, using an absolute height as an input variable also requires user entered values for vegetation height and user entered values or user selected relationships that describe the distribution of the vegetation's biomass within the plant height. The judgment of the RUSLE2 developers was that users could more easily estimate the portion of total plant biomass involved in a remove live aboveground biomass process than users could determine the distribution of biomass within the plant height. Furthermore, relative variables generalize RUSLE2, which gives RUSLE2 additional power and broadens its applicability. For example, RUSLE2 can be used to evaluate operations like hand picking of leaves over the entire canopy, which can not be described using an absolute height approach where all biomass above a given height is affected. Also, this approach gives the user direct control of aboveground biomass values that RUSLE2 uses in its computations.

Unfortunately the relative variable approach means that input values that describe the remove live biomass process are functions of the height above which the biomass is removed, vegetation type, and stage of growth. For example, a particular mower is operated at the same height regardless of the vegetation and its stage of growth. The portion of the biomass affected might be 90 percent for mature, tall weeds but less than 50 percent for early growth weeds and some grasses. Users should develop typical operations that use the remove live biomass process for several vegetation types and conditions.

Values in the RUSLE2 **core database** can be used as a guide for selecting input values for the remove live biomass process. Input values should be checked by making RUSLE2 computations to ensure that the values give expected standing and surface residue amounts. Input values should also be checked for consistency with values in the RUSLE2 core database and values in the user's working database.

Input values for the remove live biomass process are selected considering that the RUSLE2 objective is to describe a field condition rather than to model (simulate) the condition.

13.1.7. Remove residue/cover

The **remove residue/cover process** removes standing and surface (flat) residue. This process is used in **operation descriptions** such as burning and baling straw where a preceding operation description has created standing and/or surface (flat) residue. This process is also used in operation descriptions to represent silage and hay harvests where the current vegetation is live at the time of the operation. A **kill vegetation process** must precede the **remove residue/cover process** in a silage or hay harvest operation description to convert the live aboveground biomass to standing residue and/or surface (flat) residue. **The remove residue/cover process only removes standing and surface (flat) residue**; it does not remove live aboveground biomass. See **Section 13.1.6** for information on how to remove live aboveground biomass.

The three variables used to describe the remove residue cover process are: (1) are all residues affected, (2) portion of surface (flat) residue removed, and (3) portion of standing residue removed.

The first variable is related to how many residue applications on the surface that are to be removed. A **cover-management description** may involve several **residue descriptions** when multiple vegetation descriptions are involved. (e.g., corn, soybean, wheat). Multiple residue descriptions may also be involved when residue is added with the **add other cover process** (see **Section 13.1.8**). Added residues include manure spread on the soil surface and surface applied mulch, such as wheat straw, woodchips, erosion control blankets, and rock.

The input **yes** for the variable **are all residues affected** tells RUSLE2 to remove the same portion of all residues regardless of source, age, or how the residue was placed on the soil surface. An example operation description for this **yes** input is a burning operation that removes some of all residues that are present at the time of the operation.

An example of a **no** input is for a baling straw operation description in a cover-management description for a corn-soybean-wheat crop rotation. The baling straw operation description follows a wheat harvest operation description that kills the wheat to create standing and surface (flat) residue.[115] The **no** input tells RUSLE2 to only remove a portion of the wheat residue, which is the **last** residue description considered by RUSLE2 before the baling straw operation. Residue from previous crops of corn, soybeans, and wheat would not be removed. That is, the **no** input causes only the most recent residue application to be affected.

Inputs for the second and third variables are for the portions of the surface (flat) and standing residue that are removed by the remove residue/cover process. **These variables are on a dry mass basis**. In the baling straw operation description, a zero (0) is entered for the portion of the standing stubble removed because the baling operation has no effect on the standing straw stubble left after the wheat harvest other than to flatten it. If the **flatten standing residue process** occurs in the operation description before the remove residue/cover process, RUSLE2 will remove a portion of the surface (flat) residue created by the **flatten standing residue process** along with the same portion of the other surface (flat) residue.

In the burning operation description, a value of 90 percent is entered for the portion of the standing stubble removed by burning and 25 percent is entered for the portion of the

---

[115] The processes that describe the wheat harvest and the baling straw operations could be combined into a single operation description provided the harvest and straw baling operations occurred within a few days of each other before residue biomass decreases significantly by decomposition.

surface (flat) residue removed. The reason for the different input values is that the standing residue is assumed to be dry and to burn much more completely than the surface residue that is in contact with soil.

RUSLE2 can remove **buried residue**, but the residue must first be resurfaced with an operation description that includes a **disturb soil process** (see **Section 10.26**). Once the buried residue has been resurfaced as surface (flat) residue, it can be removed with an operation description that includes a remove residue/cover process. Dead roots can not be removed because RUSLE2 has no direct way to remove dead roots and dead roots can not be brought to the surface with a disturb soil process.

Values in the RUSLE2 **core database** can be used to guide the selection of input values for the remove residue/cover process. RUSLE2 computations should be made with the selected input values to ensure that RUSLE2 computes the expected residue cover left by the operation with a remove residue/cover process. Also, input values for the process should be checked for consistency with comparable values in the RUSLE2 core database and the user's working database.

13.1.8. Add other cover

The **add other cover process** is used in **operation descriptions** to place material that affects erosion on the soil surface and in the soil.[116] Typical operations descriptions using this process describe applying mulch on construction sites and in strawberry fields and manure and organic municipal and industrial waste (e.g., papermill waste) to crop and other lands.

The **add other cover process** involves three variables. Two variables are the description of the material added and the amount (dry mass basis) of the material added. These inputs are entered in the **cover-management description** that contains the operation description that uses the add other cover process (see **Section 10.6**). The entry for the type of material added, referred to as **external residue**, is selected from the list of **residue descriptions** in the **residue component** in the RUSLE2 database (see **Section 12**). The material added by this process has sufficient size to reduce the erosive forces of raindrop impact and runoff. Also, the material is generally assumed to be organic (biomass) that decomposes and affects erosion similarly to the decomposition of crop residue and plant litter. The procedure for handling non-organic material such as rock and synthetic erosion control blankets applied to the soil surface to control erosion is described in **Section 12.4**.

The third input, which describes the **add other cover process** itself, is the portion (dry

---

[116] This process is **not** used to add irrigation water (e.g., see **Sections 6.3.4, 10.2.4**). Also, this process is **not** used to represent the addition of chemical compounds that affect soil erodibility. That effect must be represented by adjusting soil erodibility factor values (see **Section 7.3**)

mass basis) of the material that is added to the soil surface. RUSLE2 places the remainder of the added material in the soil. A 100 percent value is used to represent applying straw mulch at a construction site, for example, where none of the material is incorporated into the soil. A value less than 100 percent instructs RUSLE2 to place some of the material in the soil. A zero (0) value places all of the added material in the soil.

If the **add other cover process** places some of the added material within the soil, a companion **disturb soil process** must immediately follow the **add other cover process** in the operation description. RUSLE2 assumes that the soil must be disturbed for material to be placed in the soil, which resets the soil consolidation subfactor to 1 for the portion of the soil surface disturbed except when a **compression tillage type** is assumed.[117] Material placed in the soil using the **add other cover process** is placed in the lower one half of the disturbance depth as illustrated in Figure 9.16. The value for disturbance depth is entered in the **disturb soil process** that follows the **add other cover process** in the operation description.

13.1.9. Add non-erodible cover

RUSLE2 describes the effect of both erodible cover and non-erodible cover. **Erodible cover** is surface cover provided by residue and live ground cover. Residue includes material left by vegetation growth, applied mulch, erosion control blankets, and rock. These materials are referred to as erodible covers because RUSLE2 computes erosion even when these materials completely cover (100 percent cover) the soil surface.

The *add non-erodible cover process* can not be used to represent the application of erosion control blankets and similar materials. That effect is represented using the *add other cover process*.

In contrast, RUSLE2 computes no erosion for **non-erodible cover** for the portion of the soil surface covered by these materials. Consequently, RUSLE2 computes no erosion when these materials completely cover the soil surface. Examples of non-erodible cover include plastic sheeting used in vegetable production, a water depth produced by flooding rice fields, and deep snow.

RUSLE2 assumes a linear relationship between erosion and non-erodible cover, in contrast to the non-linear relationship illustrated in Figure 9.4 for surface residue. Therefore, erosion varies linearly with non-erodible cover as it disappears over time.

[117] An exception is that a **compression tillage type** can be selected in the **disturb soil process** to place material in the soil without resetting the soil consolidation subfactor value to 1. However, this tillage type is specifically meant to describe the effects of animal traffic, sheep's foot soil compaction machines, and similar operations and not meant to describe injection of manure and fertilizer by typical machines used in these operations.

A non-erodible cover is also used to "shut off" RUSLE2's erosion computations for certain periods. An example is turning off erosion computations during winter periods during frozen soils and/or snow cover. Another example is turning off erosion computations for periods when the RUSLE2 annual computational period does not correspond with the erosion control planning period. Some erosion control regulations for constructions sites require a certain level of erosion control between the date of final grading and the date that vegetation reaches a particular canopy cover. The assumption is that erosion control is adequate once the vegetation reaches a certain canopy cover. Thus, erosion computations are turned off for dates beyond the end date based on canopy cover.

13.1.9.1. Applications of add non-erodible cover process

The **add non-erodible cover process** is used in **operation descriptions** to cause RUSLE2 to compute no (zero) erosion for the portion of the soil surface covered by the non-erodible cover. Example applications include applying strips of plastic mulch in vegetable production, applying ponded water in rice production, representing no erosion during snow cover, and setting computed erosion to zero for computational purposes.[118] An operation description with a **remove non-erodible process** is used to remove non-erodible cover when the period of no erosion ends.

An example of using the **add non-erodible cover process** for computational purposes is a construction site where the overland flow path changes during construction and reclamation. The first analysis period represents the exposed hillslope from clearing and scalping until the topography is reshaped. The second analysis period represents the time after the hillslope is reshaped and erosion control practices are applied before permanent vegetation becomes established. The third analysis period is for mature, fully established vegetation.

Reshaping the hillslope creates a new overland flow path, which requires multiple sets of RUSLE2 computations because RUSLE2 can not change overland flow paths during a **cover-management description**. In this example, a cover-management description is created for each analysis period, and a RUSLE2 computation is made for each overland flow path using the corresponding **soil**, **cover-management**, and **support practice descriptions**. Table 13.6 outlines the three RUSLE2 computations for this example.

The date that RUSLE2 starts its computations must be set first. RUSLE2 operates and accounts for erosion on an annual basis. In this example, the 9/1/0 start date is set one year before the day that the hillslope is reshaped that creates a new overland flow path. The date that the hillslope is reshaped is the reference date in this example. **Section**

---

[118] This procedure is used in RUSLE2 to set erosion to zero. The comparable procedure used in RUSLE1 to set erosion to zero was to enter a 100 percent canopy cover at a zero fall height. This RUSLE1 technique can not be used in RUSLE2 (see **Section 9.2.1**).

10.2.1.3 describes procedures that can be used to cause RUSLE2 to start tracking time on a particular date.

The first RUSLE2 computation must end on the day before the new overland flow path is created. The erosion that RUSLE2 computes between 9/1/0 and 4/15/1 must be excluded from RUSLE2's accounting of erosion. This erosion is excluded by using an operation description that adds non-erodible cover on 9/1/0 and an operation description that removes the non-erodible cover on 4/15/1. The non-erodible cover causes RUSLE2 to set erosion to zero during this preliminary period. This approach starts RUSLE2's erosion accounting on 4/15/1 with the clearing and scalping of the hillslope.

Table 13.6. RUSLE2 computations for a construction site example where the overland flow path changes during construction and reclamation

RUSLE2 computation	Date	Event	Overland flow path	Cover-management description	Soil description
1	9/1/0	RUSLE2 starts tracking time	Natural topography	Non-erodible cover	Natural soil profile
	4/15/1	Cleared and scalped		Bare soil, freshly disturbed	
2	9/1/1	Reshaped, temporary erosion control, permanent vegetation seeded	Reshaped topography	Graded, temporary erosion control applied, permanent vegetation seeded	Highly disturbed
3	9/1/4	Permanent vegetation becomes established		Mature vegetation conditions	

Notes:

1. The first date is set so that RUSLE2's annual erosion accounting for the first period ends on the last day before the topography is reshaped that creates a new overland flow path.
2. NRCS soil survey data applies to the natural topography. Soil conditions after reshaping are highly disturbed, which requires use of the RUSLE2 modified soil erodibility nomograph.
3. Cover-management conditions after reshaping could be described with a single cover-management description rather than two as illustrated.

The second analysis period begins on the date (9/1/1) that the hillslope is reshaped and a new overland flow path is established. The third analysis period begins when the vegetation has become mature and fully established (see **Section 11.2.6**). The last two analysis periods can also be combined into a single period using a single cover-management description.

An alternative approach is to start RUSLE2's tracking time on the clearing and scalping date (4/15/1). However, because of RUSLE2's annual accounting, it will include erosion computed from 4/15/1 through 4/14/2 using the first overland flow path. The computed erosion from 9/1/1 through 4/14/2 must be excluded in RUSLE2's erosion accounting to obtain an erosion estimate for just the 4/15 to 9/1 period. This erosion can be excluded by using an operation description that adds non-erodible cover on 9/1/1.

The accounting date in RUSLE2 computations for the second analysis period can start on 9/1 by having the first date in the cover-management description be on 9/1 or it can start on 4/15 if an erosion estimate is needed for each year starting on 4/15. To start RUSLE2's accounting on 4/15/1 for the second analysis period, use an operation description that adds non-erodible cover on 4/15/1 and an operation description that removes the non-erodible cover on 9/1/1. RUSLE2 will set erosion to zero during this period when non-erodible cover is present. The estimated erosion for the period 4/15/1 to 4/14/2 can be obtained by adding the annual erosion from these two RUSLE2 computations.

13.1.9.2. Variables used to describe add non-erodible process

The variables used to describe the **add non-erodible cover process** are the portion of the soil surface covered by the non-erodible cover, half-life of the cover, and permeability of the cover. The value entered for the **portion of the soil surface covered** is the portion of the total area having zero erosion because of the non-erodible cover. This value is 100 percent for applying ponded water on rice fields or for the computational purpose described above where erosion is to set to zero for the entire area. Erosion is set to zero on the entire area. The value is less than 100 percent when strips of plastic are applied in a vegetable field resulting erosion being set to zero for only a portion of the total area.

Half-life is the time required for half of the non-erodible cover to disappear based on a simple exponential relationship involving time. RUSLE2 does not compute the loss of non-erodible material as a function of environmental conditions as it does for residue. The value entered for half-life must represent how local site conditions, such as ultraviolet radiation, temperature, or precipitation, affect loss of the non-erodible cover. Thus, input values for half-life for non-erodible cover can vary with location.

The loss of non-erodible cover is computed solely on an area basis, although mass per unit should be considered in assigning half-life input values. RUSLE2 does not use a mass-cover relationship for non-erodible cover like it does in residue descriptions.

A very large value, such as 1,000,000 days is input for half-life where non-erodible cover does not disappear over time. Refer to manufacture's literature for selecting input values for plastic and similar products. A half-life value can be used to approximate the loss of snow cover, but using RUSLE2 to compute erosion by snowmelt is questionable (see **Sections 6.9.1 and 6.11**). Selected input half-life values should be checked by making RUSLE2 computations to ensure that RUSLE2 computes the expected non-erodible cover over time for the conditions where RUSLE2 will be applied.

Although RUSLE2 computes no erosion for the portion of the soil surface covered by the non-erodible cover, RUSLE2 needs information on how non-erodible cover affects runoff. Deposition computed by RUSLE2 on concave-shaped overland flow paths, behind dense strips of vegetation, and in terrace channels is a function of runoff. If non-erodible cover significantly increases runoff, the computed deposition amount may be significantly reduced. RUSLE2 uses the value entered for non-erodible cover permeability and portion of the soil surface covered by the non-erodible cover to compute runoff.

The input value entered for **non-erodible cover permeability** is the portion of the precipitation that passes through the cover. Many non-erodible covers, such as plastic used in vegetable production and ponded water in rice fields, are impermeable. A value of zero (0) is entered for those materials. If all of the precipitation passes through the cover, 100 percent is entered. An input value less than 100 percent is entered when some but not all of the precipitation passes through the non-erodible cover. For example, 50 percent is entered if half of the precipitation passes through the non-erodible cover and the other half runs off the cover onto the soil surface.

Non-erodible cover such as plastic on the top of beds in vegetable fields completely eliminates both interrill and rill erosion. However, significant rill erosion can occur where runoff accumulates and flows onto the portion of the soil surface not covered. Also, runoff can accumulate under non-erodible cover to cause erosion. Therefore, the presence of non-erodible is not sufficient *alone* to completely eliminate erosion in all situations.

13.1.10. Remove non-erodible cover

The **remove non-erodible cover process** is used in **operation descriptions** to remove part or all existing non-erodible cover. The single variable used to describe this process is the portion of the non-erodible cover that is removed by the process. An input value of 100 percent completely removes non-erodible cover. An input value less than 100 percent removes that portion of the non-erodible cover. For example, assume that non-erodible cover is 62 percent and 50 percent is the input value for portion removed. The non-erodible cover after the removal operation will be 62% ·50%/100 = 31%. The non-erodible cover may have covered 100 percent of the soil surface when it was initially applied, but it only covers 62 percent of the soil surface on the removal date because of loss by ultraviolet radiation or other processes.

14. SUPPORT PRACTICES DATABASE COMPONENTS

Support practices include contouring (ridges around the hillslope), filter and buffer strips (strips of dense vegetation on the contour), rotational strip cropping (a system of equal width cropping strips that are annually rotated with position along the overland flow path), terraces and diversions (ridges and channels that divide the overland flow path, collect runoff, and redirect it around the hillslope), and small impoundments (impoundment terraces and sediment traps). These practices are referred to as support practices because they are used to support primary cultural erosion control practices based on vegetation, crop residue, plant litter, and applied mulch. The effect of cultural erosion practices on erosion is described with the cover-management variables (see **Section 10**). Most support practices affect rill and interrill erosion and sediment delivery by reducing runoff's erosivity and transport capacity by redirecting the runoff around the hillslope; dividing the overland flow path that reduces the accumulation of runoff; slowing the runoff with strips of rough soil surface, heavy surface residue, or dense vegetation; and capturing and ponding runoff.

RUSLE2 computes how support practices affect **interrill** and **rill erosion** and **sediment yield** at the end of the flow path represented in a RUSLE2 computation (see **Sections 5.1, 5.3.1, 8.2.5**). Most properly designed, installed, and maintained support practices also reduce ephemeral gully erosion. However, RUSLE2 is not a conservation or erosion control planning tool for ephemeral gully erosion because RUSLE2 does not estimate ephemeral gully erosion.[119] RUSLE2 gives partial, indirect credit for reduction of ephemeral gully erosion by contouring and rotational strip cropping. Some of the data used to empirically derive RUSLE2's contouring relationships were measured on small watersheds, less than about 5 ac in size, where ephemeral gully erosion occurred on the non-contoured experimental watershed.

The benefits of support practices for controlling ephemeral gully can only be considered using a procedure other than RUSLE2.

Each support practice affects erosion and sediment delivery in a unique way. Therefore, each major support practice is discussed individually.

14.1. Contouring (ridge orientation relative to overland flow path)

14.1.1. Description of practice

[119] Conservation planners sometimes assume that the USLE and RUSLE1 describe all erosion that occurs within farm fields, which is not the case with these prediction technologies or with RUSLE2. Ephemeral gully erosion is not estimated with any of these technologies and can amount to one half or more of the total sediment production that occurs within field sized areas.

Contouring is the creation of ridges and furrows by tillage equipment, earth moving machines, and other soil disturbing operations to redirect runoff from a path directly downslope to a path around the hillslope.[120] Grade along the furrows is zero when contouring is "perfectly on the contour," which results in runoff spilling uniformly over the ridges along their length. If furrow grade is not level, runoff flows along the furrows until it reaches low ridge heights or local low areas on the hillslope. The runoff break over ridges in these locations as illustrated in Figure 8.13.

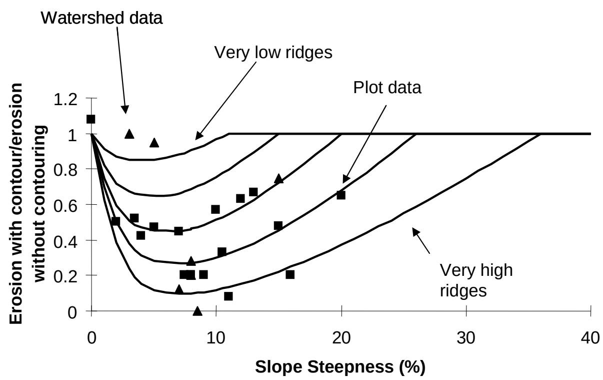

Figure 14.1. Experimental data on how contouring affects erosion.

Section 8.3.6 describes the three RUSLE2 methods that can be used to estimate how contouring affect erosion. The first two methods apply where the ridges are so high, well defined, and on a sufficiently uniform grade that runoff flows to major concentrated flow areas on a hillslope before overtopping the ridges. Application of these two methods is based on a detailed overland flow path description. The **third method** is for typical ridges left in farm fields by tillage equipment like tandem disks, chisel plows, and field cultivators and on reclaimed mined land and other highly disturbed lands by ridgers. This method uses the RUSLE2 relationships that describe contouring (ridging) as a support practice and a overland flow path description based on a flat soil surface.

14.1.2. Basic principles

RUSLE2 uses a daily value for the contouring factor p_c in equation 8.1 to compute the effect of contouring. This subfactor is the ratio of erosion with contouring to erosion without contouring. A value of 1 means that contouring has no effect on erosion. The value for the contouring subfactor is lowest when contouring has its greatest effect on erosion.

The effect of contouring on erosion that was measured on research plots and watersheds is illustrated in Figure 14.1. The effect of contouring varied greatly among the studies.

---

[120] Contouring in RUSLE2 refers to how orientation of ridges with respect to the overland flow path affects erosion. Standards for erosion control practices published by organizations like the USDA-Natural Resources Conservation Service require that ridging meet certain specifications to be considered the specific erosion control practice of contouring.

For example, contouring reduced erosion as much as 90 percent in one study but did not reduce erosion in another study also conducted on a 6 percent slope steepness.

Information from the research studies represented in Figure 14.1 and from other research studies was not sufficient to empirically derive RUSLE2 contouring relationships. The data were sufficient, however, to identify the main variables that determine how contouring affects erosion. That basic information, along with accepted erosion scientific knowledge and scientific and technical judgment were used to develop the mathematical relationships used in RUSLE2 to compute how contouring affects rill and interrill erosion.

14.1.2.1. Steepness

The first variable considered in developing the equations used to describe the contouring effect illustrated in Figure 14.1 was slope steepness. Contouring does not affect erosion at a flat slope because no preferred runoff path exists. Contouring also has no effect at very steep slopes because the ridge top is at a lower elevation than the ridge base (furrow) on the upper side of the ridge as illustrated in Figure 14.2. The ridge top elevation relative to the elevation of the upslope furrow is a function of both slope steepness and ridge height, which determine the slope steepness that contouring loses its effectiveness.

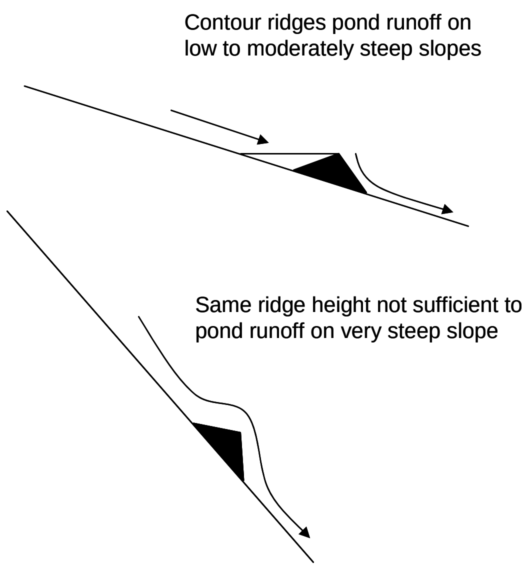

Figure 14.2.Effect of slope steepness and ridge height on contour ridges ponding runoff.

The general shape of the RUSLE2 relationship for contouring's effect on erosion is illustrated in Figure 14.1. The curve decreases from a value of 1, which means that contouring has no effect on erosion, for a flat slope (zero steepness) to a minimum value at a moderate slope steepness, which is the slope steepness that contouring has its greatest reduction on erosion. The curve increases from the minimum value to 1 (no effect) at a steep slope based on the concept that the steepness is so great that no runoff is ponded as illustrated in Figure 14.2 (see AH537, AH703). [121]

14.1.2.2. Ridge height

[121] The relative effect of slope steepness on contouring in RUSLE2 is the same as that in the USLE. The middle curve in Figure 14.1 is very similar to the contouring-slope steepness effect in the USLE (AH537).

The second variable considered was ridge height. The basic concept is that contouring's effect on runoff and erosion is a function of ridge height. Figure 14.2 illustrates the concept for steep slopes. Field data from research plots also showed that erosion decreased as ridge height increased. The ridges on these plots were perfectly on the contour on a moderate slope steepness. The overall variability illustrated in Figure 14.1 for the effect of contouring on erosion was interpreted as being caused by a variation in ridge height.

Contouring is assumed to lose its effectiveness over time as ridge height decays. In RUSLE2, ridge height decays after it is created because water from precipitation causes the soil to subside and as interrill erosion erodes the ridges (see **Section 9.2.4.3**).

Experimental data involving wheat and soybeans showed that closely spaced stems in rows on the contour affect erosion much like soil ridges on the contour. Therefore, RUSLE2 adds an effective vegetative ridge height to the soil ridge height to give an overall ridge height that is used by RUSLE2 to compute the effect of contouring on erosion. The effective vegetative ridge height increases as vegetative retardance increases, which is a function of the retardance class assigned in the vegetation description (see **Section 11.1.4**), yield (production) level, and growth stage.

14.1.2.3. Storm severity and runoff

Experimental plot data showed that contouring's effectiveness (p_c) is greater for small storms than for large storms (i.e., p_c values are less for small storms than for large storms). One reason for this difference in effectiveness is that a higher percentage of the excess rainfall (rainfall in excess of infiltration) is stored in ponded runoff behind the ridges for small storms than for large storms. Similarly, contouring reduces erosion more for low runoff amounts than for high runoff amounts. Therefore, RUSLE2 computes values for the contouring subfactor p_c that decrease as runoff depth decreases.

The minimum contouring factor value at the low point of each curve illustrated in Figure 14.1 is reduced linearly with runoff depth. Also, the slope steepness above which contouring has no effect on erosion is computed as a function of runoff depth raised to the 0.857 power. This power is based on the assumption that the maximum slope steepness at which contouring is effective for a given ridge height is a function of the shear stress that the runoff applies to the soil. The runoff variable used by RUSLE2 to compute contouring subfactor values is the ratio of runoff computed for the site specific condition to runoff computed for the base condition of a moldboard plowed, clean tilled, low yielding corn grown on a silt loam soil in Columbia, MO (see **Section 8.1.2**).

Field data from contouring on small watersheds (less than five acres) in the south central US showed that the effectiveness of contouring is related to storm severity. The data showed that erosion with contouring can be greater for very intense storms than for a comparable non-contoured situation. The intense storms caused much ridge breakovers, concentration of overland flow in a few rills which causes increased rill erosion, and a cascading effect similar to dam failures releasing water. These effects partially accounts for contouring subfactor values being greater than 1 in Figure 14.1. Also, moderate and large storms cause most of the erosion. The 24-hour precipitation amount with a 10-year return period rather than a precipitation amount based on an average annual return period is used in RUSLE2 to compute runoff depth. The 10-year return period captures how a more severe than average annual storm has a dominant effect on how much contouring reduces erosion.

The RUSLE2 computed contouring subfactor values vary daily as cover-management conditions change. The runoff curve number is a key variable in the NRCS runoff curve number method. RUSLE2 computes values for the curve number as a function of surface roughness, ground cover, soil biomass, and soil consolidation, which in turn means that runoff and contouring subfactor values vary daily in RUSLE2.

14.1.2.4. Relative row grade (ridge-furrow orientation relative to overland flow path)

In this RUSLE2 procedure for computing how contouring affects erosion, the overland flow path is determined assuming a flat soil surface without ridges. The contouring subfactor p_c value is 1 by definition for a ridge-furrow orientation directly **up and down hill** (parallel to the overland flow path). Contouring subfactor values are less than 1 when the ridge-furrow orientation is **perfectly on the contour** (perpendicular to the overland flow path).[122] **Relative row grade**, which is the ratio of absolute row (furrow) grade to the overland flow path steepness, is RUSLE2's measure of ridge-furrow orientation to the overland flow path.[123] A relative row grade of 1 means that the ridge-furrow orientation is up and down hill parallel to the overland flow path, and a relative row grade of zero (0) means that the ridge-furrow orientation is perfectly on the contour and perpendicular to the overland flow path. A 0.1 relative row grade means that the ridge-furrow orientation is slightly off contour, and a 0.5 relative row grade means that the ridge-furrow orientation is half way between being perfectly on the contour and up and down hill.

---

[122] The **cover-management description** must include a **soil disturbing operation description** that creates ridges with a greater than zero height for RUSLE2 to compute a contouring subfactor value less than 1. That is, ridges with a height greater than zero must be present for RUSLE2 to compute a contouring effect.

[123] Even though absolute row grade can be entered into RUSLE2, RUSLE2 uses relative row grade to compute how ridge-furrow orientation to the overland flow path affects erosion.

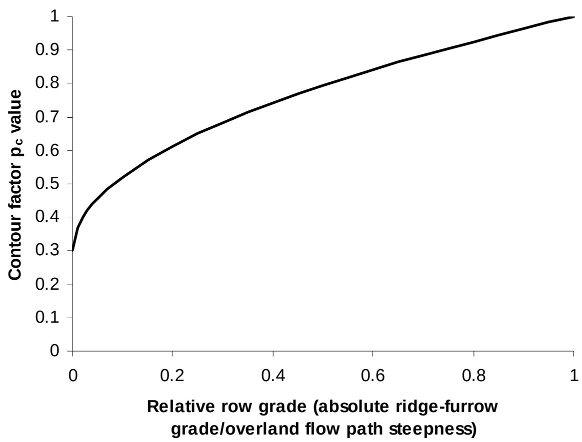

Figure 14.3. Effect of relative row grade on the contouring subfactor p_c.

RUSLE uses the empirical relationship illustrated in Figure 14.3 to compute contouring subfactor p_c values for ridge-furrow orientations between these two extremes. The assumption implicit in Figure 14.3 is that contouring rapidly loses effectiveness as ridge-furrow orientation deviates from being perfectly on the contour (i.e., as relative row grade increases from zero). This assumption is supported by the limited research data available for validation.

14.1.2.5. Contouring failure (critical slope length)

Contouring fails and totally loses its effectiveness when the combination of runoff rate and steepness along the overland flow path becomes too great for the given cover-management condition. The high contouring subfactor values in Figure 14.1 represent such failure based on the description of the field conditions in the research report. On simple uniform overland flow paths where soil, steepness, and cover-management do not vary spatially, a **critical slope length** is defined as the location along the path where contouring fails from that location through the end of the overland flow path. The contouring subfactor value for the upper portion of the overland flow path from its origin to the critical slope length location is the RUSLE2 computed values for contouring (i.e., contouring is fully effective). The contouring factor value is set to 1 for the portion of the overland flow path from the critical slope length location to the end of the path (i.e., contouring has completely failed). The contouring subfactor makes a step increase, rather than a gradual increase, at the critical slope length location as illustrated in Figure 14.4. Contouring subfactor values do not vary with distance along the overland flow path because RUSLE2 contouring subfactor values are based on runoff depth, not runoff rate.

RUSLE2 does not compute contouring failure and a critical slope length if the overland flow path length is sufficiently short. ***Also, contouring failure and critical slope length are not a function of ridge height or soil erodibility properties.***

RUSLE2 assumes contouring failure when the runoff applies a shear stress to the soil in the ridges that exceeds a critical shear stress related to ridge stability.[124] The shear stress

[124] Shear stress applied to the soil is a frictional type force per unit area much like the frictional force felt

applied to the soil by runoff **increases** as runoff rate and steepness of the overland flow path increase and **decreases** as total hydraulic roughness provided by cover-management increases.[125] Runoff rate is a function of both runoff depth and location along the overland flow path (see **Section 8.1.2**). Shear stress applied to the soil decreases as cover-management intensity increases because of the effect of cover-management on both runoff depth (hence, runoff rate) and the total hydraulic roughness (see **Section 14.2.3**).[126] Contouring failure increases and critical slope length decreases for a given cover-management condition as steepness of the overland flow path increases. Contouring failure increases with a change in location where storm erosivity represented by the 10-year, 24 hour precipitation amount increases. Conversely, contouring failure is reduced by increased soil surface cover, soil-surface roughness, and vegetation retardance and cover-management practices that reduce runoff, all of which reduce runoff's shear stress that causes contouring failure. Contouring failure on long overland flow paths is reduced by changing cover-management conditions that reduce runoff's shear stress and/or by dividing the overland flow path with terraces/diversions.

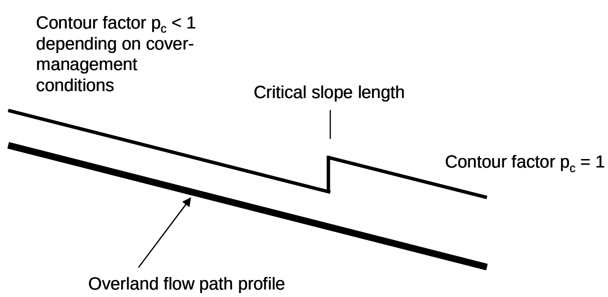

Figure 14.4. Illustration of critical slope length and contouring subfactor values for a uniform overland flow path.

Depending on conditions, RUSLE2 computes zones of contour failure along complex overland flow paths, like that illustrated in Figure14.5. Contouring failed in the mid-portion of the overland flow path because of the combination of runoff rate (represented by distance from the path origin) and steepness. Runoff's shear stress acting on the soil exceeds the soil's critical shear stress in this zone. Contouring does not fail on the upper portion of the overland flow path. The combination of runoff rate and steepness is low because distance is short even though steepness becomes large. Contouring failure ends on the lower portion of the overland flow path because the combination of runoff rate and steepness decrease so that the runoff's shear stress acting on the soil decreases below the soil's critical shear stress even though distance is large.

---

when your hand is rubbed by sandpaper.

[125] Total hydraulic roughness is composed of two parts, the part related to the shear stress that the flow exerts on the soil particles (referred in channel hydraulics as grain roughness) that causes erosion and sediment transport and the part related to the shear stress applied to hydraulic elements (referred to as form roughness) including soil surface roughness (e.g., clods), ground cover (e.g., surface residue and live ground cover), and plant stems.

[126] An increase in cover-management intensity refers to an overall increase in soil surface roughness, surface residue cover, aboveground biomass, soil biomass, vegetative retardance, and soil consolidation.

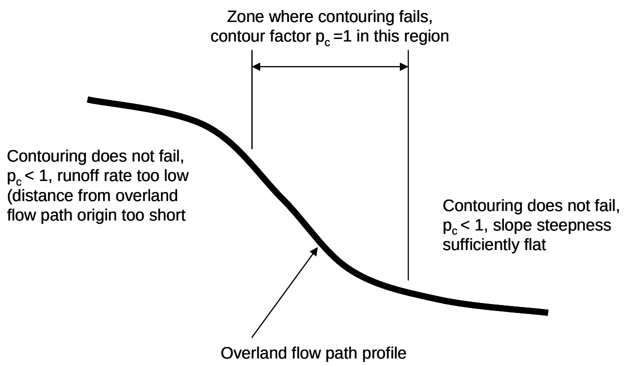

Figure 14.5. Zone on a complex shaped overland flow path where contouring fails because the combination of distance and steepness.

Figure 14.6 illustrates how RUSLE2 handles an overland flow path with an intense cover-management strip upslope from the end of the overland flow path. Several zones are identified in Figure 14.6. Contouring does not fail and the contouring subfactor value is less than 1 in Zone 1 because the combination of runoff rate (represented by distance from the path origin) and steepness is not sufficient for runoff's shear stress applied to the soil to exceed the soil's critical shear stress for the given cover-management condition. The applied shear stress equals the critical shear stress at the boundary between Zones 1 and 2 and exceeds the critical shear stress in Zone 2. Contouring fails and the contouring subfactor value equals 1 in Zone 2. The intense cover-management in Zone 3 greatly reduces the runoff's shear stress applied to the soil to less than the soil's critical shear stress. Contouring does not fail and contouring subfactor values are less than 1 in Zone 3.

Zone 4 is a special situation. The cover-management condition in Zone 4 is the same as in Zones 1, 2, and 5. Because contouring failed in Zone 2, the expectation is that contouring also fails in Zone 4 based on runoff rate, steepness, and cover-management condition. However, the difference is that the intense cover-management strip in Zone 3 is assumed to spread the runoff so that it leaves the strip in a very thin flow. The flow's shear stress applied to the soil is less than soil's critical shear stress in Zone 4. RUSLE2 assumes that the shear stress applied to the soil at the upper end of Zone 4 equals the shear stress applied to the soil at the lower end of Zone 3. The runoff's shear stress increases over Zone 4 and becomes equal to the soil's critical shear stress at the boundary between Zones 4 and 5. Contouring does not fail and the contouring subfactor value is less than 1 in Zone 4.

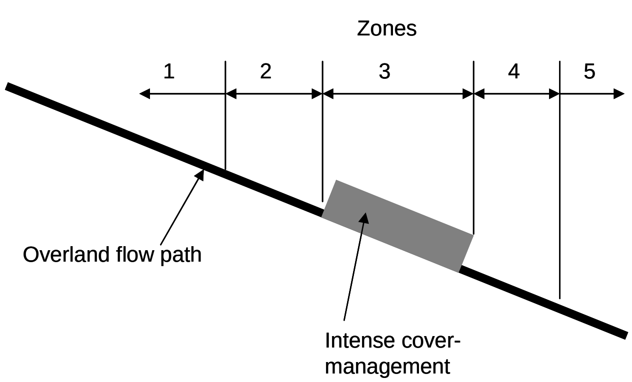

Figure 14.6. Zones along an overland flow part with an intense cover-management strip.

Runoff leaves the intense cover-management strip spread in a thin flow across the slope. The runoff becomes concentrated again in rill flow with distance in Zone 4.

This flow concentration increases the shear stress that the runoff applies to the soil and equals the soil's critical shear stress at the boundary between Zones 4 and 5. Contouring fails in Zone 5 because the runoff's shear stress applied to the soil exceeds the soil's critical shear stress and the contouring subfactor value equals 1 in Zone 5.[127]

14.1.2.6. Temporal changes in contouring subfactor values and contouring failure

RUSLE2 computes a daily value for the contouring subfactor p_c. The value changes daily because the soil ridge height decays daily and the effective vegetation ridge height changes as vegetative retardance changes daily. Cover-management conditions change daily to influence runoff depth that RUSLE2 uses to compute daily contouring subfactor p_c values. The daily contouring subfactor p_c value also changes on days that soil disturbing operations occur that creates ridges with a new height.

Runoff rate and shear stress applied to the soil by runoff change daily as cover-management conditions change. Runoff rate also changes as daily erosivity changes, which captures the likelihood of an intense storm occurring when the cover-management condition is vulnerable to contouring failure. The daily erosive precipitation amount used to compute runoff rate is the product of the 10 year, 24 hour precipitation amount and the ratio of daily erosivity to the maximum daily erosivity.[128]

This effect of combining a vulnerable cover-management condition for contouring failure with the likelihood of an intense storm is illustrated in Figure 14.7 for a conventionally tilled corn **cover-management description** at Lincoln, NE. This example is for a uniform overland flow path where the contouring fails beyond the critical slope length on the lower portion of the overland flow path. The most vulnerable period to contouring failure is from the first secondary tillage operation (tandem disk) on May 1 until harvest on October 15 because the soil surface is smooth with very little surface residue and the vegetation provides little retardance, even at maturity.

---

[127] Equation 8.1 is used to compute detachment in each zone in Figure 14.6. The contouring subfactor p_c value for Zone 4 is computed based on runoff depth, steepness, cover-management condition, and relative row grade assuming no contouring failure. Even though runoff is spread in a thin sheet flow that has reduced erosivity, the values of no other factor are changed in equation 8.1 because the intense cover-management strip spreads runoff. That is, the only erosion reduction computed by RUSLE2 for Zone 4 is from the contouring subfactor value being less than 1 for Zone 4 because the intense cover-management strip spreads the runoff. The contouring subfactor value would equal 1 because of contouring failure if the intense cover-management was not on Zone 3.

[128] The daily erosive precipitation amount used to compute runoff rate is not the same as the daily precipitation amount determined by disaggreagtion of the monthly precipitation amounts in a location's **climate description**.

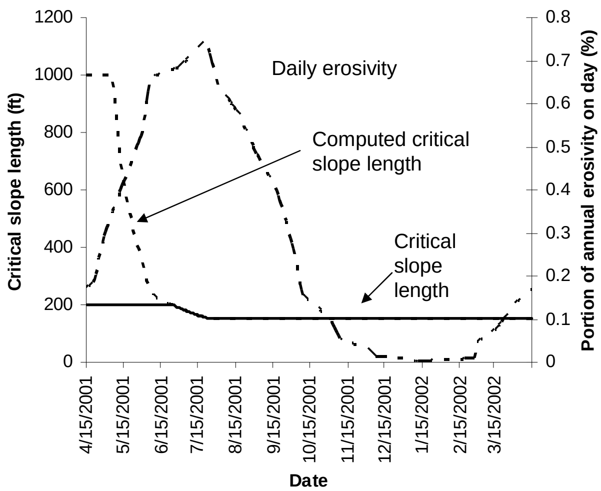

Figure 14.7. Daily critical slope length.

The critical slope length shown in Figure 14.7 is 200 ft, which is the overland flow path length, from April 15 to June 25.[129] A RUSLE2 displayed critical slope length that equals the overland flow path length means that the computed critical slope length is longer than the overland flow path length. A computed critical slope length longer than the overland path length has no consequence because contouring does not fail within the actual overland flow path length. The RUSLE2 computed critical slope length starts at 1000 ft, which is the longest overland flow path that RUSLE2 considers. The computed critical slope length becomes less than 1000 ft on May 7 and steadily decreases to 200 ft on June 25. The reason for the decrease is the increase in the daily erosive precipitation amount used to compute shear stress, which is indicated by the increase in the daily erosivity to July 22 in Figure 14.7. The vulnerability of the cover-management condition to contouring failure in this example does not change significantly during this period. However, in other cases, vulnerability to contouring failure can increase significantly over time as roughness and surface residue decay.

After June 25, the computed critical slope length decreases to a value less than 200 ft, which means that RUSLE2 has computed contouring failure and has set the contouring subfactor p_c value to 1 on the lower portion of the overland flow path. The critical slope length ultimately decreases to a minimum of 154 ft on July 22, the date of peak erosivity. Even though the site condition was slightly more vulnerable to contouring failure earlier, the shortest critical slope length did not occur until later when the combination of cover-management vulnerability and daily erosive precipitation was maximal.

The potential for contouring failure decreased significantly after July 22 because the daily erosivity decreased as illustrated in Figure 14.7. However, the critical slope length did not increase. Similarly, harvest on October 15 added a very heavy surface residue cover that greatly reduced the vulnerability for contouring failure, but the critical slope length did not increase at harvest. Once contouring fails, contouring effectiveness is not

[129] The actual critical slope length before June 25 is longer than 200 ft, but RUSLE2 does not display critical slope length value longer than the overland flow path length. The computed critical slope length can be seen by entering 1000 ft for the overland flow path length, which is the longest value that can be entered in RUSLE2.

restored until the next **operation description** that includes a **disturb soil process** to create new ridges. In RUSLE2, contouring failure is assumed to occur by runoff breaking through ridges; consequently ridges must be recreated to restore contouring effectiveness. Critical slope length is reset when new ridges are created. See **Section 14.1.2.5** for discussion on the importance of critical slope length in conservation planning.

In this example, the first soil disturbing operation after the critical slope length reached its minimum on July 22 is a moldboard plowing operation on April 15. This operation resets computed critical slope length, which is the reason for the increase in critical slope from 154 ft on April 14 to 1000 ft on April 15. The contouring subfactor p_c value remains at 1 for the portion of the slope beyond the critical slope length until new ridges are created to restore contouring effectiveness.

This example is for a uniform overland flow path. The same concepts apply to a non-uniform overland path. Contouring fails on portions of the overland flow path where runoff's shear stress applied to the soil exceeds the soil's critical shear stress for contour failure. That area expands as the combination of vulnerable cover-management and erosive conditions increase. Once contouring fails on an area, RUSLE2 sets the contouring subfactor value to 1, and contouring effectiveness is not restored until a soil disturbing operation occurs that creates new ridges.

***Dates* for *operation descriptions* must be carefully selected for *no rotation cover-management descriptions* where critical slope length is important. Operations that occur together to create a particular field condition should be combined into a single operation, or the same date should be used for the operation descriptions. An example is creating ridging and applying mulch that occur together on a construction site. These two operation descriptions should either be combined into a single operation description or occur on the same date to prevent RUSLE2 from computing erroneous contouring failure (critical slope length) values.**

14.1.2.7. Use of critical slope length information in conservation planning

The usual conservation and erosion control planning objective is to avoid contouring failure anywhere along the overland flow path. In the case of uniform overland flow paths, this objective corresponds to the critical slope length not being less than the overland flow path length.

If contouring failure occurs, the two frequently used corrective measures are to change the cover-management practice or add terraces/diversions along the overland flow path. Reducing land steepness is a possible alternative on landfills, construction sites, reclaimed mine, and other similar highly disturbed lands where topography can be modified. An average erosion rate for the erodible portion of the overland flow path less than the planning criteria, such as soil loss tolerance, is usually not sufficient for adequate erosion control when contouring fails. Local erosion can be too high where contouring fails on an overland flow path even though the average erosion for the erodible portion of the overland flow path is sufficiently low.

14.1.3. Calibration

RUSLE2's contouring equations, which capture these contouring principles, were calibrated to the experimental field data illustrated in Figure 14.1.[130] The middle curve in Figure 14.1 was assumed to represent the overall, main effect of contouring on erosion. This curve is comparable to the contouring subfactor values in AH537. The calibration procedure required assuming a base condition to represent this overall, main effect curve in Figure 14.1.

Most of the experimental data illustrated in Figure 14.1, which includes the data that were the basis for the AH537 contouring subfactor values, are from research studies conducted from the early 1930's to the mid 1950's.[131] The base condition used in the RUSLE2 contouring calibration represented those conditions rather than modern conditions.[132] The assumed base condition was a conventionally tilled, low yield (60 bu/ac) corn cover-management description at Columbia, MO (see **Footnote 23**). The operations in this cover-management description included a moldboard plow in the spring for primary tillage, two secondary tillage operations to prepare the seedbed, row planter to seed the crop, row cultivation to control weeds, and harvest .

A second cover-management description used in the calibration was conventionally tilled soybeans and wheat added to the base corn cover-management description. This cover-

[130] The data sources are listed in Tables 6-1 and 6-2, AH703.

[131] Using modern data to calibrate RUSLE2 contouring computations was preferred, but unfortunately adequate modern data do not exist. The important output from RUSLE2 for most conservation and erosion control planning is average annual erosion rather than erosion for individual storms. Also, erosion is highly variable and data over several years are needed to obtain good average annual erosion estimates. This requirement is especially important for calibrating RUSLE2 for contouring because the effectiveness of contouring is strongly related to major storms that occur at vulnerable times. The best data for calibrating RUSLE2 are from natural runoff events on small watersheds (less than 5 ac). Natural runoff plot data supplement these data. Rainfall simulator plot data are not especially useful for calibrating RUSLE2, although these data are extremely important for developing principles, concepts, and basic equations.

The calibration data should be from a wide range of climatic, soil, topographic, and cover-management conditions to capture main effects and to deal with the extreme variability in contouring data. Unfortunately, by the end of the 1970's, many studies involving natural runoff plots were discontinued and the emphasis shifted to rainfall simulator studies. Similarly the number of small watershed studies decreased and remaining studies did not have common study conditions needed to calibrate RUSLE2.

[132] The common assumption is that AH537 contouring subfactor values from the 1930's to 1950's data apply to modern cropping practices. That assumption is highly questionable, if not invalid, because of differences in cropping practices in the two eras. For example, row cultivation is used much less in modern practices than in older practices and yields for most crops have increased significantly since the 1930's.

management description was used to calibrate RUSLE2's effective vegetative ridge height. Research data from a location in Illinois and a location in Oklahoma were used in the calibration. Another important study in the RUSLE2 contouring calibration was a 1960's field study in Northern Mississippi on the effect of relative row grade.

Two very important calibration inputs were ridge height and relative row grade (ratio of row grade along furrows to average steepness of overland flow path). The calibration input values for these variables must be followed when RUSLE2 input values are selected for conservation and erosion control planning. A 3 inches (75 mm) ridge height was input for the row cultivation operation, which had the greatest contouring effect among the operation in the base cover-management description. The second important input was the 10 percent relative row grade used to represent contouring on the small research watersheds and farm fields, which is in contrast to a zero (0) relative row grade used to represent contouring on research plots.

Ridge heights assigned to operation descriptions must be consistent with the 3-inch (75 mm) ridge height assigned to the row cultivation used in the RUSLE2 contouring calibration.

The second major calibration of the RUSLE2 contouring computations was for critical slope length on uniform overland flow paths and contouring failure in general on complex overland flow paths. RUSLE2 was calibrated to AH537 critical slope length values for contouring alone without strip cropping using the base condition described above.[133] AH537 critical slope lengths values for strip cropping were doubled from those for contouring alone. Instead, RUSLE2 computes contouring failure as a function of cover-management conditions along the overland flow path rather than using a multiple of critical slope length values for contouring alone.[134] A cover-management description involving a conventionally tilled corn, alfalfa-timothy hay rotational strip cropping system was used to calibrate RUSLE2's computation of contouring failure, especially as it relates to a hydraulically rough strip spreading runoff. Research strip cropping data from the 1930's to mid 1950's for LaCrosse, Wisconsin were used to partially validate these RUSLE2 computations. The validation was based on the ratio of average sediment yield from the strip cropping system to sediment yield from the same rotational cropping system not in strips. Measured values for this ratio were compared to RUSLE2 computed values.

[133] No explicit research data exist for critical slope length. Contouring failure has been observed and described in research reports, especially at locations in Arkansas and Texas, where severe runoff events occurred. Critical slope length values given in AH282 and AH537 were based on these and other visual field evidence of contouring failure from the early 1930's to mid 1950's. The critical slope length concept and the assigned values based on scientific and technical judgments continue to be accepted by conservation and erosion control planners and were, therefore, used in the RUSLE2 calibration.

[134] RUSLE1 assumes that strip cropping and buffer strips have critical slope lengths that are 1 ½ times those for contouring alone.

14.1.4. Interpretation of RUSLE2 contouring relationships

Of all the variables that affect erosion, contouring is easily the most difficult one to accurately represent, especially at a specific site. Slight, non-obvious differences seem to greatly affect how contouring affects erosion. Consequently, RUSLE2 erosion estimates affected by contouring are more uncertain than erosion estimates influenced by any other RUSLE2 factor. **Therefore, special care should be exercised in interpreting RUSLE2 erosion estimates in relation to contouring.**

RUSLE2 describes the established main effects of contouring in relation to major variables. These effects are valid in general, but an effect at a specific site may be quite different from the general effect. For example, the statement that contouring reduces erosion by 50 percent for a given condition is true in general, but the reduction may be 10 percent at one site and 90 percent at another site. Contouring is a good conservation practice but its effectiveness at a specific site is more uncertain than for other erosion control practices. RUSLE2 is designed to capture broad trends related to contouring. For example, use of the 10 -year, 24-hour precipitation amount is intended to capture differences in general contouring effectiveness by geographic region. Similarly, the relationship of contouring to runoff is meant to capture general trends of how cover-management conditions affect runoff that in turn affect how contouring affects erosion. These RUSLE2 estimates are not meant to explicitly describe how cover-management affect runoff and contouring's effectiveness at a specific site. RUSLE2 is a tool to assist conservation and erosion control planning.

Although, research data are sufficient to identify the main variables that affect contouring, the amount and quality of the data are insufficient to empirically derive and calibrate mathematical relationships for the effect of contouring on erosion except in the general sense. In addition, the contouring data used to develop RUSLE2 do not represent modern agronomic conditions. The RUSLE2 developers significantly extended contouring relationships beyond the main effect of slope steepness normally represented in contouring subfactor values (see AH537). Because research data are not available to validate these extensions, RUSLE2 computations were very carefully examined to ensure that computed values reflect the current scientific knowledge, are acceptable based on modern scientific and technical judgment, and are reasonable for use in conservation and erosion control planning.

14.1.5. Contouring inputs

The **contour systems description** in the RUSLE2 database involves the two inputs of **how row grade is specified** and the **input value for row grade**. The other important input for contouring is the **ridge heights** for the **operation descriptions** in the **cover-management description.**

14.1.5.1. Method of specifying row grade

Row grade can be entered in a **contour system description** using the methods listed in Table 14.1. When a contour system description is used to represent to represent contouring, the assumption is that the overland flow path input represents the flow path perpendicular to contour lines, not a flow path along the ridges and furrows.

The first method of **up and down slope** represents a no-contouring effect. RUSLE2 gives the same result obtained with the other three methods by inputting an **absolute row grade** that equals the overland flow path steepness or inputting 1 for **relative row grade**. This selection tells RUSLE2 to compute erosion without considering any contouring effect.

The method **set absolute row grade** is where a value for the actual furrow (row) grade at the site is entered. This method should be used only where ridges and furrows are well defined and runoff flows to major concentrated flow areas before breaking over the ridges.

Using the *set absolute row grade* input method for ordinary contouring provided by most typical agricultural implements is a *misuse* of RUSLE2.

Table 14.1. Ways to specify row grade.

Row grade specification method	Comment
Up and down slope	Specifically sets relative row grade to 1, i.e., absolute row grade equals overland flow path steepness
Set absolute row grade	Value entered for absolute row grade as measured in the field. **Should only be used in special cases**.
Set relative row grade	Relative row grade is the ratio of the absolute row grade to steepness of overland flow path. Should be used to represent most ordinary contouring situations.
Use management relative row grade	RUSLE2 uses relative row grade input in the cover-management description used in the particular RUSLE2 application.

The **set relative row grade** is the appropriate way to enter row grade for ordinary contouring that affects runoff as illustrated in Figure 8.13 (see **Section 8.3.6**). Relative row grade is the ratio of absolute row grade to overland flow path steepness. As discussed in **Section 14.1.4**, RUSLE2's estimates of how contouring affect erosion are more uncertain than for any other variable. **Contouring system descriptions** based on relative row grade can be developed, stored in the RUSLE2 database, and used so that

RUSLE2 computes the proper relative differences in erosion in relation to contouring. The proper relative difference related to contouring between field situations is not achieved when the absolute row grade entry method is used. Contouring effectiveness is related to how closely the ridge forming operation follows the actual field contours. Equal values for relative row grade imply the same contouring quality in relation to following field contours regardless of land steepness.[135]

The following example illustrates how inputting absolute row grade gives too much credit for contouring on steep land. Assume that an absolute row grade of 1 percent is entered for both a 6% and a 30% overland flow path (land) steepness. The relative row grade is 1/6 = 0.17 for the 6% slope, which gives a contouring subfactor value of 0.70 if the contouring subfactor value is 0.50 for perfect contouring. The relative row grade is 0.033 for the 30% slope, which gives a contouring subfactor value of 0.59 if the contouring subfactor value for perfect contouring is also 0.50. Assuming the same row grade regardless of land steepness computes a much greater relative benefit for contouring on steep slopes than on moderately steep slopes. Achieving this increased contouring benefit requires extra care, which is unlikely, with the ridge forming operation to maintain the 1 percent row grade on steep slopes. Furthermore, such precision implied by varying absolute row grade on steep slopes is unwarranted given RUSLE2's accuracy and quality of the contouring data used to calibrate RUSLE2.

The entry method **use management relative row grade** requires the same inputs as the set relative row grade selection. When this selection is made, RUSLE2 uses the relative row grade entered in the **cover-management description** (see **Section 10.2.10**). The advantage of this method is that contouring and cultural erosion control can be combined into a single erosion control practice described by a cover-management description, which is useful in erosion inventory analysis. The relative row grade should be set to 10% in the cover-management description for ordinary contouring.

14.1.5.2. Row grade

The **set absolute row grade** entry method requires that the **absolute row grade** along the ridges-furrows be entered. As discussed in **Section 14.1.5.1**, this entry method should only be used where the ridges-furrows are so well defined that runoff travels in the furrows to major concentrated flow areas before breaking over the ridges. An alternative method for applying RUSLE2 to this condition is discussed in **Section 8.3.6.**

Absolute row grade is the value that is determined by measuring a decrease in elevation over distance along the furrows (rise/run). In many cases row grade varies along the ridges-furrows, particular on either side of concentrated flow areas to reduce sharp bends in the ridges and to facilitate the ridge forming operation. A representative row grade

[135] Regardless of input method, RUSLE2 uses relative row in its computations.

must be selected because non-uniform row grades along the ridges-furrows can not be entered into RUSLE2.

Relative row grade is the ratio of row grade to overland flow path steepness. However, a more appropriate way to consider relative row grade is that values for relative row grade represent contouring classes, which are actually classes for ridge-furrow orientation with respect to the overland flow path. Five classes are listed in Table 14.2.[136] Additional classes are not warranted given RUSLE2's accuracy. The classes in Table 14.2 are **contour system descriptions** that have been created and placed in a RUSLE2 database.

Perfect contouring is where the ridges-furrows are oriented parallel to the contour. The row grade is perfectly flat and the ridge tops are level so that runoff spills over the ridge uniformly along the ridge. This condition is obtained in the field when a surveying instrument is used to lay out contour lines. This contouring class is used with high quality rotational strip cropping where row grade is level across concentrated flow areas. Strip cropping in the LaCrosse, Wisconsin area with its smooth sweeping curves with no evidence of ephemeral gully erosion is an example of perfect contouring.

Sometimes row grade associated with rotational strip cropping and buffer strips (see **Section 14.2**) is increased in the vicinity of concentrated flow areas to avoid sharp bends that hinder farming operations.[137] **Contouring with strips** (5% relative row grade) or **standard contouring** (10% relative row grade) should be selected for this situation. If the contouring subfactor value is 0.50 with perfect contouring, a 5% relative row grade gives a contouring subfactor value of 0.61.

Standard contouring (10% relative row grade) should be selected for contouring where no vegetative strips are present to guide ridge forming operations. Unless the topography is quite uniform, creating ridges and furrows perfectly on the contour is practically impossible. Also, row grade is often increased on either side of concentrated flow areas to facilitate ridge forming operations. If the contouring subfactor value is 0.5 with perfect contouring, a 10% relative row grade gives a contouring subfactor value of 0.66.

---

[136] The classes listed in Table 14.2 are names used for **contour system descriptions** in the RUSLE2 database that is downloaded from the RUSLE2 Internet site at the USDA-Agricultural Research Service-National Sedimentation Laboratory, Oxford, MS (http://msa.ars.usda.gov/ms/oxford/nsl/rusle/index.html) ARS reviewer, check this). The values for relative row grades in Table 14.2 are the important information. Users may change the names of the contour system descriptions to other names for convenience.

[137] Row grade should remain level across concentrated flow areas. Increasing row grade from level on either side of concentrated flow areas ensures that concentrated areas will persist and may require a grassed waterway to control ephemeral gully erosion. Contour strip cropping that does not have level row grades across concentrated flow areas will not eliminate concentrated flow areas and ephemeral areas as occurred so effectively with level grade contour strip cropping in the LaCrosse, WI area.

RUSLE2 has two contouring (ridge-furrow orientation) classes to represent “cross slope” ridging. The two classes are **moderately off contour**, which is a relatively row grade of 25%, and **half off contour**, which is a relative row grade of 50%. If the contouring subfactor value is 0.50 for perfect contouring, the contouring subfactor values are 0.75 and 0.93, respectively, for these two ridge-furrow orientations.

The last class is **up and down slope** (hill) where the ridge-furrow orientation is parallel to the land slope. The relative row grade is 100% and the contouring subfactor value is 1 for this class.

Table 14.2. Classes of relative row grades to represent contouring (ridge-furrow orientation to land slope)

Contouring (ridge-furrow orientation) class	Relative row grade	Comment
Perfect contouring	0	Ridges-furrows are exactly on the contour (orientation is parallel to contour), use with strips that exactly follow the contour laid out with surveying instruments
Contouring with strips	5%	Use with strips laid out on the contour with survey instruments but with row grade adjustments when approaching concentrated flow areas
Standard contouring	10%	Typical contouring that was initially laid out with survey instruments. Row grade adjustments are made when approaching concentrated flow areas
Cross slope-moderately off contour	25%	Ridge-furrow orientation ¼ off contour. Sufficiently close to the contour to merit significant credit for reducing rill-interrill erosion
Cross slope-half off contour	50%	Ridge-furrow orientation is ½ off contour (half way between on-the-contour and up and down slope). Merits some but not much credit for reducing rill-interrill erosion
Up and down slope	100%	Ridge-furrow orientation is parallel to land steepness. Merits no credit for reducing rill-interrill erosion

Note: The effect of ridge-furrow orientation on ephemeral gully erosion, which RUSLE2 does not estimate, should be considered in developing a complete erosion control plan.

Being able to enter a non-zero row grade in RUSLE2 does not imply that use of such row grades is encouraged or even acceptable. It is recognition that contouring can not be perfect in most field situations and that some credit should be given for rill-interrill erosion reduction for ridge-furrow orientations that are not directly up and down hill. Ridge-furrow grades greater than flat (zero) should be avoided so runoff does not flow along the furrows to concentrated flow areas on the landscape, which promotes ephemeral gully erosion. In fact, a slight row grade may cause more ephemeral gully erosion because the ridges and furrows discharge runoff in a concentrated flow area much further upslope than with a steep relative row grade. RUSLE2 does not consider ephemeral gully erosion; RUSLE2 only deals with rill-interrill erosion.

Conversely, effective erosion control is to place ridges-furrows on a continuous grade with a sufficiently high ridge to ensure that runoff flows to a concentrated flow area protected by a grassed waterway.

A complete erosion control plan includes consideration of both rill-interrill and ephemeral gully erosion.

14.1.5.3. Input ridge heights in relation to contouring

At least one **operation description** that includes a **disturb soil process** to create ridges must be in the **cover-management** description for RUSLE2 to compute a contouring effect (see **Section 9.2.4**). The RUSLE2 assumption is that ridges oriented at an angle to the overland flow path must be present for a contouring effect on erosion. The degree that contouring (ridging) reduces rill-interrill erosion depends on ridge height and row grade.[138] Input ridge height values are entered in the operation descriptions (see **Section 13.1.5.4**).

Ridge height (along with row grade) is the single most important variable that determines the effectiveness of contouring (ridge-furrow orientation to the overland flow path) in RUSLE2. If RUSLE2 computes less contouring effect than expected, ridge heights may be too low.

Ridge height after an operation is totally determined by the operation description, and the ridge height that existed before the operation has no effect on ridge height left by an operation, even when the operation minimally disturbs the soil. The ridge height input in a particular operation description should reflect the ridge height that exists when that operation is used in combination with other operations.

---

[138] The total effect of ridges on rill-interrill involves two parts. One part is the contouring effect which is related to the orientation of the ridge-furrows with respect to the overland flow path and the other part is the increased detachment caused by increased ridge height as described in **Section 9.2.4**.

After an operation description creates a ridge, ridge heights decay with precipitation amount and interrill erosion. RUSLE2 does not consider the loss of ridge height caused by deposition in the furrows. Daily ridge height used by RUSLE2 to compute the contouring effect can be much less than the input ridge height value.[139]

Ridge height values input in an operation description must be referenced to the initial 3-inch (75 mm) ridge height assigned to row cultivation used to calibrate the RUSLE2 contouring relationships for Columbia, MO (see **Section 14.1.3**). In assigning a ridge height to an operation description, ask the question of how the operation affects contouring in relation to row cultivation used for corn from the early 1930's to the mid 1950's? Measured ridge heights are a guide because RUSLE2 has been calibrated as much as possible to use ridge heights that are measured in the field. However, measured ridge heights may not always capture how RUSLE2 should compute contouring effectiveness for a particular operation description or for a cover-management description overall. Input ridge height values must be consistent with the ridge height values in the RUSLE2 **core database** because those values were selected to ensure that RUSLE2 computes the desired contouring effect.

Consequently, the best approach by far is to use ridge height values in the RUSLE2 **core database** as a guide in selecting an input value for an operation description. Consistency of ridge height values among operation descriptions is critically important so that RUSLE2 computes the expected relative erosion differences among contouring conditions. This requirement is especially important given the high variability and uncertainty in the research data used to develop RUSLE2 and the high variability in site specific contouring performance.

14.2. Porous Barriers

14.2.1. Description of practices

Porous barriers are support practices that do not terminate the overland flow path because runoff flows through these barriers. These practices must be placed on the contour or else their effectiveness is greatly reduced because runoff flows along them rather than through them. Examples include filter strips (dense vegetation strips at the end of overland flow paths), buffer strips (multiple narrow strips of dense permanent vegetation along the overland flow path), rotational strip cropping (equal width strips including some dense vegetation strips grown in a rotating and alternating fashion in time and space along the overland flow path), and fabric fences, gravel dams, and straw bales used on construction sites and similar lands.

---

[139] The ridge height values used in RUSLE2's contouring computations do not correspond with those in RUSLE1 because ridge heights change daily in RUSLE2. The RUSLE2 input values for ridge height are similar to the ridge height values used in RUSLE1 computations.

14.2.2. Basic principles

The high flow retardance of the most effective porous barriers slows runoff and ponds water on the upper side of the barrier. Runoff leaves the barrier spread across the slope in a uniform thin depth, which significantly reduces the potential for contouring failure immediately downslope of the barrier (see **Section14.1.2.5**).

14.2.2.1. Description of actual processes

Ponding (**backwater**) immediately upslope of a barrier reduces runoff's transport capacity, which can cause deposition. As much as 90 percent of the incoming sediment load can be deposited in the backwater until deposited sediment accumulates so much that the lower edge of the sediment wedge reaches the upper edge of the barrier as illustrated in Figure 14.8. Narrow width, dense, high retardance barriers less than 18 inches (500 mm) wide produce wide backwater that causes much deposition. **However, vegetation type barriers must be sufficiently wide to protect against localized failure and short circuiting of the runoff through the barrier that are caused by poor non-uniform plant stands, for example.**

As deposited sediment accumulates during runoff events, the upper edge of the backwater and deposited sediment combined advance upslope as illustrated in Figure 14.8. The upslope advancement of the deposited sediment increases transport capacity in the backwater and fills the ponded area with sediment. Sediment is transported into the barrier itself where sediment is deposited because the barrier's high flow retardance greatly reduces runoff's sediment transport capacity. Eventually both the backwater and barrier, such as a grass strip, become filled with sediment. The barrier becomes almost ineffective because it no longer causes deposition and does little to reduce sediment load. Vegetation strips regain flow retardance during reduced erosion periods if vegetation growth is not overly hindered by sediment.

14.2.2.2. RUSLE2 description

RUSLE2's representation of these very complex processes is simplified as illustrated in Figure 14.9. **RUSLE2 bases its computations solely on the hydraulics within the effective width of the barrier itself.** RUSLE2 does not compute backwater hydraulics and deposition in the backwater. Instead RUSLE2 represents the backwater by computing an additional width that is added to the actual width to create a total effective width for the strip/barrier. **Temporal changes in the backwater effect are not considered. Section 8.1.4** describes the RUSLE2 computational procedures for porous barriers.

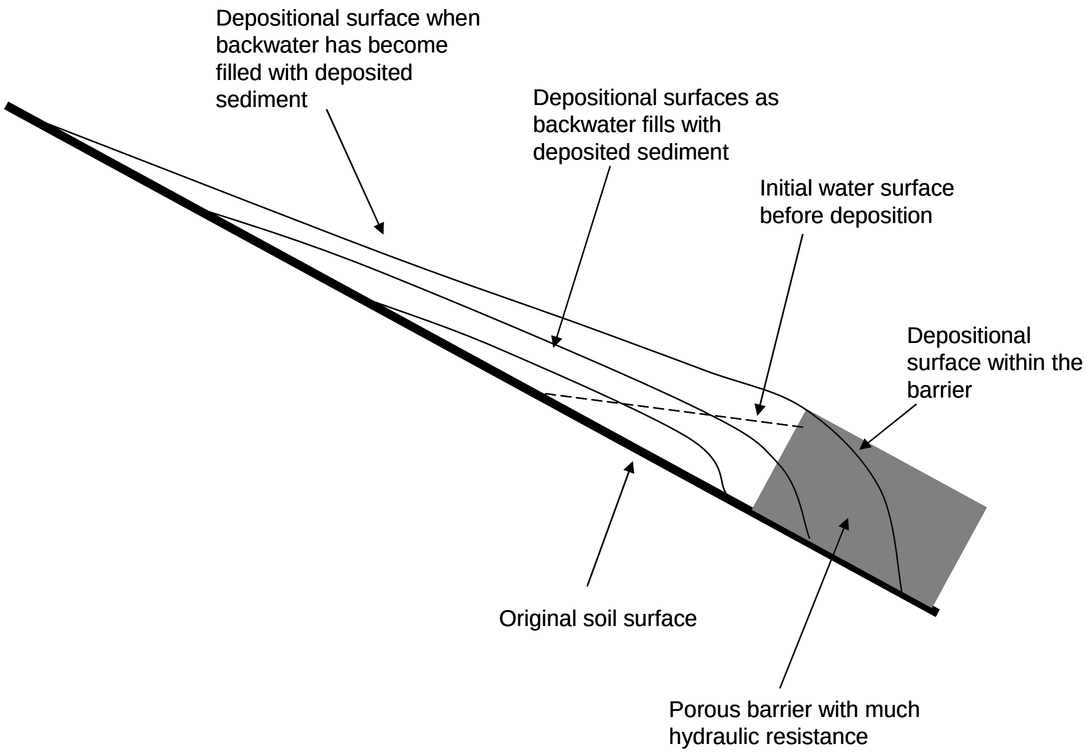

Figure 14.8. Deposition in backwater upslope of a porous barrier as deposition develops over time.

Neglecting deposition in the backwater and temporal changes is insignificant in most cases where barrier are wide such as with most grass buffer and filter strips.

The porous barrier's flow retardance must reduce runoff's sediment transport capacity to less than the incoming sediment load for RUSLE2 to compute deposition. If a barrier's retardance is low, the barrier will hardly slow runoff and transport capacity will not be sufficiently reduced at the barrier's upper edge for RUSLE2 to compute deposition. Also, RUSLE2 will not compute deposition by a barrier if the incoming sediment load is less than the transport capacity at the barrier's upper edge.

Deposition caused by a barrier reduces sediment load along the overland flow path, especially if a high retardance barrier is located at the end of the overland flow path. Detachment (sediment production) is typically low within high retardance barriers, but sediment production will not be greatly reduced if barriers are narrow with respect to the overland flow path length.

RUSLE2 computes deposition ending within a barrier as illustrated in Figure 14.9 where runoff's sediment transport capacity increases within the barrier, which is the usual case, and the barrier (e.g., grass buffer strip) is sufficiently wide. Increasing barrier width when RUSLE2 computes that deposition ends within a barrier does not significantly increase the fraction of the incoming sediment load that is trapped by the barrier. The decrease in sediment yield from the overland flow path that occurs as barrier width is increased results from the barrier occupying an increased portion of the overland flow path. Increasing barrier width reduces sediment yield more because of very low detachment (sediment production) within the barrier than sediment yield is reduced by increased sediment trapping.

However, increasing barrier width increases sediment trapping if RUSLE2 computes deposition over the entire barrier width (i.e., deposition does not end within the barrier). RUSLE2 computes reduced sediment yield because of both increased deposition and reduced sediment production in this case.

Figure 14.9 illustrates the usual case where transport capacity increases within the barrier after a step decrease at the upper edge of a barrier. This increase in transport capacity occurs where runoff rate increases within the barrier because rainfall rate exceeds infiltration rate (see **Sections 8.12 and 8.1.3**). Runoff rate and transport capacity decrease within a barrier where infiltration rate is greater than rainfall rate. RUSLE2 does not compute deposition ending within a barrier when transport capacity decreases within the barrier. Runoff ends within a barrier when infiltration rate exceeds rainfall rate if the barrier is sufficiently wide.

The width required for runoff to end within a barrier depends on discharge rate of the upslope runoff where it enters the barrier as well as rainfall rate and infiltration rate within the barrier. If runoff ends within a barrier, runoff begins at the next location on the overland flow path where infiltration rate is less than rainfall rate, which is often at the upper edge of the strip immediately downslope of the barrier as illustrated in Figure 14.10. An example of runoff ending within a barrier is a high residue strip, left rough by a moldboard plow throwing soil upslope in the Northwest Wheat and Range Region (NWRR, see **Section 6.9.1**). The rainfall rate and flow rate of upslope runoff entering the strip is very low, about 0.25 in/hr (6 mm/h) and infiltration rate in the strip is relatively high.

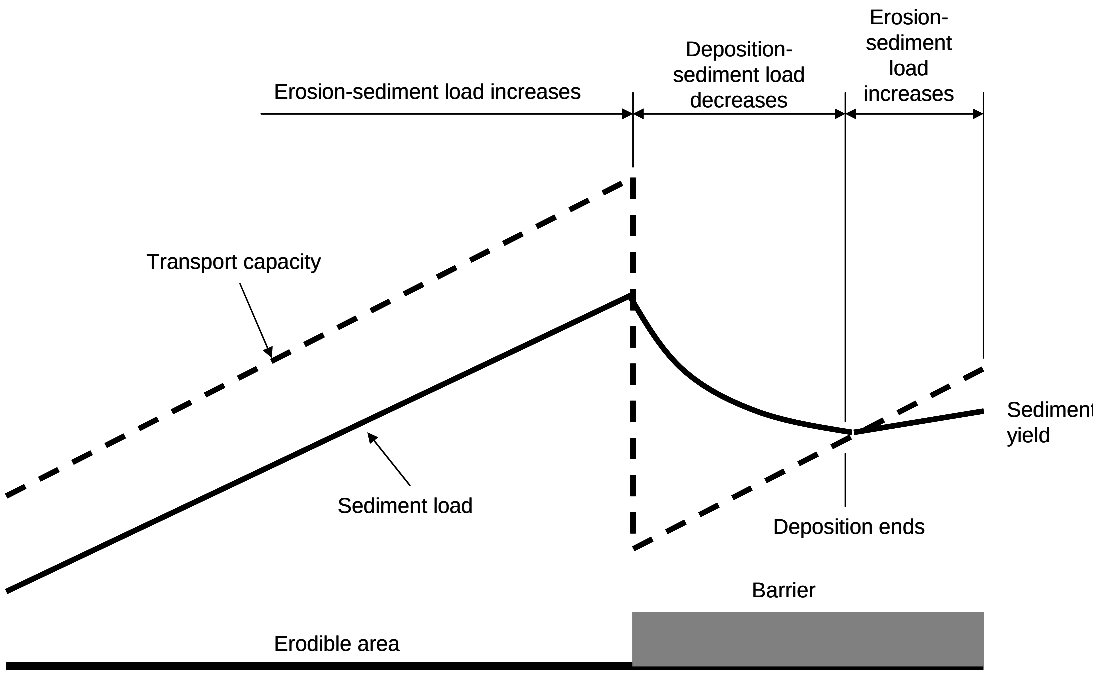

Figure 14.9. RUSLE2 hydraulic representation of a porous barrier.

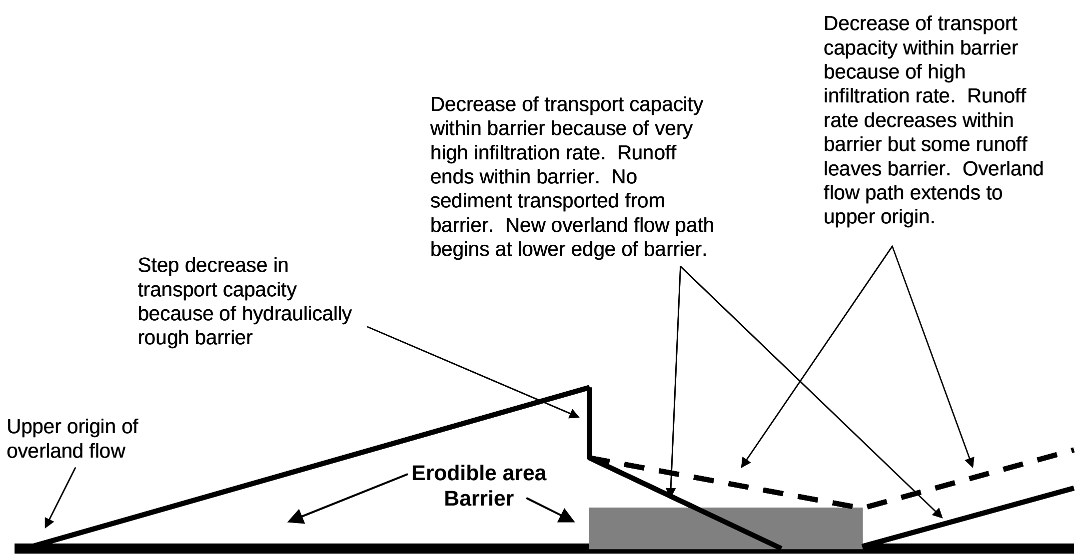

Figure 14.10. Effect of high infiltration rate within barrier that causes runoff date to decrease within barrier.

Most of the deposition caused by a porous barrier occurs in the backwater on the upper side of a strip/barrier. The length of this depositional area must be included with the actual physical width of the strip. Otherwise, RUSLE2 will overestimate sediment yield, especially if the strip is very narrow like a silt fence. RUSLE2 estimates a backwater width based on runoff rate and flow retardance of the strip. RUSLE2 computes the backwater/depositional length along the overland flow path and add this length to the input value for actual strip/barrier width. To simplify the computations, RUSLE2 adds the backwater/depositional width to the lower edge of the barrier/strip, which increases the overland flow path length by the same amount. RUSLE2 computes the backwater/depositional length by first computing flow depth at the upper edge of the strip/barrier using the total Manning's n for the barrier, discharge rate at the upper edge of the barrier, and steepness of the barrier segment. This computation was calibrated based on erosion plot studies involving 1.5 ft wide (0.46 m) stiff grass hedges at Holly Springs, Mississippi. The backwater/depositional length is computed from this flow depth and the steepness of the segment immediately upslope of the barrier assuming a level water surface.

RUSLE2 uses the retardance classes assigned to **vegetation descriptions** to compute the flow depth at the upper edge of the strip/barrier.[140] The maximum width that RUSLE2 adds for any retardance and hydraulic resistance is 15 ft (5.0 m). RUSLE2 only sets a minimum for the retardance class 7 condition, where the minimum backwater/deposition width that is added is 3 ft (1.0 m). Retardance class 7 represents stiff grass hedge, silt fence, or similar porous barrier that have an especially high retardance (see **Section 11.2.5**). If the retardance of these barriers is similar to the retardance of vegetation, an appropriate vegetation retardance class is assigned. The width added for the other retardance classes is computed value, except that it can not exceed 15 ft (5.0 m).

The backwater/depositional length increases as the hydraulic resistance (retardance, ground cover, surface roughness) of the strip/barrier increases. Also, the backwater/depositional length increases as discharge rate increases. RUSLE2 uses the same temporally varied discharge rate to compute backwater/depositional length that it uses to compute contouring failure (critical slope length). The backwater/depositional width decreases as steepness upslope of the strip/barrier and slope steepness of the segment that contains the barrier increases.

The RUSLE2 overland flow path begins at the origin of overland flow assuming that rainfall rate exceeds infiltration rate everywhere along the possible overland flow path based on topography. This choice of an overland flow path includes situations where discharge rate decreases within a barrier placed along the overland flow path, including situations where runoff ends within the barrier. RUSLE2 properly takes into account variations in infiltration and runoff along the overland flow path because of barriers and other changes in cover-management along the overland flow path. However, if the cover-management upslope of an erodible area is known not to produce runoff, the overland flow path can be started at the upper edge of the erodible area where runoff

---

[140] A **vegetation description** is used to describe the retardance of mechanical porous barriers. The canopy cover should be 100 percent and the effective fall height should be set to 0 to minimize the detachment computed over the effective width for the strip/barrier. See **Section 14.2.5.1**.

begins. **Section 8.3.4** describes selecting RUSLE2 overland flow paths for porous barriers.

Barriers most effectively induce deposition and reduce sediment load when perfectly on the contour. Runoff may flow along but not through a barrier when the barrier's upper edge is on a grade. Runoff flows along the barrier until the runoff reaches a concentrated flow area where the runoff flows through and over the barrier. Porous barriers designed for overland flow generally perform very poorly in concentrated flow areas. The sediment trapping capacity of a barrier such as a grass strip is rapidly lost by becoming inundated with deposited sediment, or a barrier such as a fabric fence loses its sediment trapping capacity by structural failure. A ridge of soil can develop on the upper side of a barrier because of the combination of high rates of deposition and vegetation re-growing on top of the deposited sediment. Also, tillage in cropped fields and other soil disturbing operations can leave a ridge of soil at the upper edge of a barrier that causes runoff to flow along the barrier rather than entering it. Runoff may not reach a barrier when row grade is steep and ridges high on the inter-barrier area. The runoff flows along the ridges and furrows to concentrated flow area, where the concentrated flow causes the barriers to rapidly fail. [141]

Porous barriers should be analyzed as flow interceptors (e.g., terraces or diversions) when runoff flows along the upper edge of the barrier without entering the barrier.

When porous barriers are selected from the *strips-barriers component* of the *RUSLE2 database*, RUSLE2 requires that relative row grade (see *Section 14.1.5.2*) be 10 percent or less.

Sediment delivery ratio, which is the ratio of sediment leaving the overland path having porous barriers to sediment leaving the overland flow path without barriers is a measure of the degree that the barriers cause deposition. Values for the sediment delivery ratio determined from the RUSLE2 computed sediment yield values depend on the sediment load reaching a porous barrier relative to runoff's transport capacity within the barrier. That is, the sediment delivery ratio is near one, which means little deposition, when the incoming sediment load is only slightly greater than the transport capacity within the porous barrier. In contrast, deposition is much greater and the sediment delivery is much less than 1 when the incoming sediment load is much greater than the transport capacity

[141] RUSLE2 requires that a relative row grade of 10 percent or less be used when porous barriers are selected from the **strips-barriers RUSLE2 database component**. However, this restriction can be bypassed by selecting a **RUSLE2 template** that displays the three layer profile schematic (see **Section 8**), dividing the cover-management layer of the overland flow into segments, and selecting appropriate **cover-management descriptions** for each segment.

within the barrier. Therefore, the RUSLE2 sediment delivery ratio for a particular porous barrier depends on the erosion environment in which the porous barrier is placed as well as characteristics of the barrier itself.

The sediment delivery ratio based on RUSLE2 computations is not constant in general. For example, the sediment delivery ratio for a vegetation strip of moderate retardance is larger for no-till than for clean-till cropping on the inter-barrier area. The vegetation strip traps a smaller portion of the incoming sediment load from the no-till area than from the clean-till area because the incoming sediment load from the no-till area is only slightly higher than the transport capacity within the strip. Detachment and sediment production, which determine the incoming sediment load, is low with no-till cropping in comparison with clean-till cropping. Even though the sediment delivery ratio is higher for the clean-till cropping, overall erosion is less with the no-till cropping.

The RUSLE2 computed sediment delivery ratio for a porous barrier depends on the characteristics of the sediment that reaches the barrier. Sediment characteristics are determined by the properties of soil from which the sediment is eroded (see **Section 7.5**) and upslope deposition. For example, a high portion of sediment eroded from sandy soils is large, easily deposited particles. The RUSLE2 sediment delivery ratio for this sediment is much lower than for sediment eroded from high silt soils that produce a high portion of small, not easily deposited particles. A high portion of the sediment eroded from high clay soils is large, easily deposited aggregates. Clay is a bonding agent that contributes to sediment being eroded as aggregates. The RUSLE2 computed sediment delivery ratio is lower than is commonly assumed for sediment eroded from clay soils because of the high portion of large aggregates in the sediment eroded from these soils.

The RUSLE2 computed sediment delivery ratio for a porous barrier is high where much upslope deposition occurs. An example is a grass strip at the end of a concave-shaped overland flow path where much deposition occurred because of reduced steepness. This deposition removes a high portion of the coarse, easily deposited particles from the sediment load so that the sediment reaching the barrier is largely composed of fine, not easily deposited particles.

Sediment delivery ratio values for porous barriers do not depend very much on the erosion environment, except for sediment characteristics, where runoff's sediment transport capacity is near zero within the barriers. Dense grass strips are an example of this porous barrier.

Deposition is a selective process that enriches the sediment in fines because coarse, dense sediment like sand and large aggregates are more easily deposited than is fine sediment like clay, silt, and small aggregates (see **Sections 5.4 and 7.5**). RUSLE2 computes an **enrichment ratio** that is a measure of the degree that deposition enriches the sediment in fines. The enrichment ratio is the ratio of the specific surface area of the sediment leaving the RUSLE2 overland flow path to the specific surface area of the soil subject to erosion. The enrichment ratio for a porous barrier increases as portion of the incoming sediment load that is deposited increases. That is, enrichment ratio values increase as values for the sediment delivery ratio decrease.

A major question is the credit given to sediment deposited by porous barriers as **soil saved**. This deposition is referred to as **remote deposition** where the deposition is localized in contrast to **local deposition** that occurs over most of the overland flow area. As discussed in **Section 8.1.5.4**, the credit given to remote deposition as soil saved is a matter of scientific and technical judgment. Keeping the sediment on the overland flow path is clearly preferred to the sediment leaving the overland flow path. Furthermore, sediment deposited upslope is preferred to the sediment deposited near the end of the overland flow path. Also, sediment deposited in localized, semi-permanent locations, such as above grass buffer strips, is less desirable than sediment deposited where soil disturbing operations, such as tillage operations associated with rotational strip cropping, routinely spread the deposited sediment. An increased portion of the overland flow path (i.e., hillslope) benefits when the deposited sediment is spread.

The **conservation planning soil loss** discussed in **Section 8.1.5** gives partial credit for the deposition that occurs with porous barriers as soil saved that benefits the landscape. The credit taken for deposition reduces the soil loss used in conservation planning. The credit taken for this deposition depends on both the location and amount of deposition. For example, RUSLE2 takes little credit for deposition that occurs near the end of the overland flow path, but can take more than 80 percent credit for deposition that occurs on the upper one third of the overland flow path. Rotation strip cropping (see **Section 14.2**) is a special case where full credit is taken for deposition.[142]

Erosion on the inter-barrier area is not greatly affected by the barrier, except for the immediate area downslope of the barrier where erosion may be reduced. Even though the infiltration rate within a porous barrier may be substantially higher than on the inter-barrier area, RUSLE2 does not consider how erosion below a barrier is affected by reduced runoff exiting the barrier. RUSLE2 does compute how reduced runoff affects contouring failure and sediment transport capacity downslope of a porous barrer. High retardance porous barriers spread the exiting runoff so that rill erosion is reduced for a distance downslope before the runoff becomes concentrated once again in rills. This distance has not been defined in research studies. Based on field observations, rill erosion and runoff concentrated in rills occurs immediately downslope of the barrier if the soil is highly susceptible to rill erosion. In other cases, rill erosion and runoff

[142] A rotational strip cropping support practice must be selected through the **strips/barriers component** of the RUSLE2 database in order for RUSLE2 to give full credit (i.e., set **conservation planning soil loss** value to the **sediment yield** value) for deposition associated with rotational strip cropping. Rotational strip cropping can be represented in RUSLE2 by dividing the **management layer** of the **overland flow path schematic** (see **Section 8**), but this procedure takes only partial credit for deposition.

concentrated in rills has been observed not to occur until beyond 3 ft (1 m) on soils moderately resistant to rill erosion. A 10 ft (3m) and greater distance is required for visible evidence of rill erosion downslope of porous barriers on soils highly resistant to rill erosion. Runoff exiting a porous barrier has a very low sediment load and, therefore, has increased erosivity, which increases rill erosion. The RUSLE2 assumption is that these effects offset each other. Consequently, RUSLE2 computes the same erosion rate below a barrier regardless of the presence or absent of the barrier, except for conditions where RUSLE2 computes no contouring failure immediately downslope of a barrier as discussed in **Section 14.1.2.5**.

14.2.3. Calibration

Calibrating RUSLE2 for porous barriers required determining mathematical relationships and numerical values for the K_T coefficient in equation 5.3, which is RUSLE2's equation for runoff's sediment transport capacity (see **Section 8.1.3**). . Equation 5.3 is based on the concept that total overland flow shear stress is divided into the two components of shear stress applied to soil and sediment particles (grain roughness) and shear stress applied to ground cover, soil surface roughness, and standing vegetation (form roughness) (see **Section 14.1.2.5**). The shear stress applied to the soil and sediment particles is used to compute runoff's sediment transport capacity. The shear stress applied to the soil and sediment particles is related to the ratio of the hydraulic resistance of a smooth soil to total hydraulic resistance.

The K_T coefficient involves two parts. One part represents the combined effects of sediment transportability with the hydraulic resistance (grain roughness) of a smooth soil surface and the second part represents the effect of total hydraulic roughness (resistance). Although sediment transportability is related to diameter and density of sediment particles, RUSLE2 uses the same transportability value for all soils even though sediment characteristics vary. **However, RUSLE2 captures the main effects of sediment characteristics on deposition by using equation 5.2, which involves sediment fall velocity that is a function of sediment particle diameter and density (see Section 7.5).** A single Manning's n value is used for all smooth soil; it does not vary as a function of soil particle diameter.

The RUSLE2 developers judged that using constant representative values for sediment transportability and grain resistance improved RUSLE2's robustness as a conservation and erosion planning tool.

A combined base value for grain roughness (resistance) of a smooth soil and sediment's transportability was determined by calibrating RUSLE2 to measured sediment load on a concave overland flow path profile. The RUSLE2 assumption is that sediment transport capacity equals sediment load at the location where deposition begins on a concave profile. The calibration data were from a simulated rainfall field study on a concave plot

35 ft (10.7 m) long where slope steepness decreased continuously from 18 percent at the upper end to 0 percent at the lower end. The bare silt loam soil was smooth so that the only hydraulic resistance was grain roughness. The slope profile was cut from a deep soil profile so that soil characteristics were uniform along the overland flow path. Deposition began at the location where steepness equaled 6 percent. A base value for the K_T coefficient for grain roughness only was determined by adjusting its value until RUSLE2's sediment transport capacity equaled measured sediment load at the 6 percent steepness location. Additional evaluations of the calibrated K_T value were made by comparing RUSLE2 estimates with measured values in laboratory deposition studies, visual field evidence of deposition, and scientific and technical judgments.[143]

The second part of the K_T variable involves the mathematical equation that computes K_T values as a function of the ratio of grain hydraulic resistance to total hydraulic resistance. This equation was derived from sediment transport theory. The Manning's n, which is widely used in hydraulic analyses, is used in RUSLE2 as the measure of total hydraulic resistance. A RUSLE2 total Manning's n value is the sum of the Manning's n values for ground cover, soil surface roughness, and standing vegetation. Values for Manning's n for ground cover and surface roughness were developed from field overland flow velocity measurements.[144]

Manning's n for standing vegetation is based on a retardance concept where seven retardance classes are used to describe the hydraulic resistance provided by standing vegetation (see **Section 11.1.4**). RUSLE2 uses an equation that converts retardance values to Manning's n values. The retardance classes and the empirical equation that computes Manning's n as a function of retardance class were based on both field velocity measurements and scientific judgment of how standing vegetation affects overland flow velocity and hydraulic resistance.

---

[143] Foster, G.R., W.H. Neibling, S.S. Davis, and E.E. Alberts. 1980. Modeling particle segregation during deposition by overland flow. *In:* Proceedings of Hydrologic Transport Modeling Symposium. American Society of Agricultural Engineers. St. Joseph, MI. pp. 184-195.

[144] e.g.,

Foster, G.R. and L.D. Meyer. 1975. Mathematical simulation of upland erosion by fundamental erosion mechanics. *In:* Present and Prospective Technology for Predicting Sediment Yields and Sources. ARS-S-40 USDA-Science and Education Administration. pp. 190-204.

Foster, G.R., L.J. Lane, and J.D. Nowlin. 1980. A model to estimate sediment yield from field sized areas: Selection of parameter values. *In:* CREAMS - a field scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. Vol. II: User Manual. USDA-Conservation Research Report No. 26. USDA-Science and Education Administration. pp. 193-281.

Foster, G.R. 1982. Modeling the erosion process. Chapter 8. *In:* Hydrologic Modeling of Small Watersheds. C.T. Haan, H.P. Johnson, D.L. Brakensiek, eds. American Society of Agricultural Engineers. St. Joseph, MI. pp. 297-382.

The next step was to calibrate the equations used to compute sediment characteristics as a function of deposition. The coefficient value involved in these equations was calibrated by comparing RUSLE2 computation of sediment yield and sediment class distributions for very dense grass strips of 3, 6, and 9 feet (0.9, 1.8, and 2.6 m) widths where sediment transport capacity within the grass strips can be considered to be zero (0).

The final step in the calibration was to validate the equations as a complete set. These equations involve complex interactions, which prevents calibration of coefficient values except for very special conditions. The equations and coefficient values, therefore, had to be validated as a set over the conditions where RUSLE2 would likely be applied in conservation and erosion control planning. RUSLE2 computed values for sediment load and sediment particle distributions along and at the end of concave shaped overland flow paths were compared to measured values for both field and laboratory studies. Similar comparisons were made for sediment yield from the end of slopes involving mulch strips of different hydraulic resistance and placement along the overland flow path and contour strip cropping at several locations.[145] In all cases, evaluations were made to ensure that RUSLE2 computed values for sediment load and sediment class distribution are reasonable and consistent with accepted scientific knowledge and available data.

14.2.4. Interpretation

RUSLE2's erosion, deposition, and sediment load computations for porous barriers are for conservation and erosion control planning purposes. Numerous assumptions were made in that context to derive simple, robust RUSLE2 equations that give reasonable values consistent with research data and accepted scientific and erosion control principles. With the possible exception of contouring, porous barrier erosion control varies more with site-specific condition than any other factor. For example, a barrier not perfectly on the contour can result in runoff flowing along the barrier, collecting in a concentrated flow area, breaking over the barrier, and causing the barrier to fail and trap almost no sediment. The effectiveness of vegetative strips depends on a ridge of soil not accumulating along the barrier's upper edge that prevents runoff from entering the barrier. Also, vegetation uniformity and a high quality and dense plant stand must be maintained for vegetative barriers to be fully effective. Installation and maintenance of fabric fences is more important than any other factor in determining their effectiveness.

---

[145] e.g,

Foster, G.R., W.H. Neibling, S.S. Davis, and E.E. Alberts. 1980. Modeling particle segregation during deposition by overland flow. *In:* Proceedings of Hydrologic Transport Modeling Symposium. American Society of Agricultural Engineers. St. Joseph, MI. pp. 184-195.

Neibling, W.H. and G.R. Foster. 1983. Transport and deposition of soil particles by shallow flow. *In:* Proceedings of the D.G. Simons Symposium on Erosion and Sedimentation. Colorado State University, Ft. Collins. pp. 9.43-9.64.

Having and enforcing a good set of installation and maintenance specifications and standards is essential.

RUSLE2 **core database** values for porous barriers represent values that should be used in RUSLE2 applications in the judgment of RUSLE2 developers. RUSLE2 represents the general, overall main effects of these practices as they are judged to be commonly installed in the field. The effectiveness of porous barriers under ideal laboratory conditions is almost always much better than under typical field conditions. RUSLE2 input values for porous barriers values should reflect local conditions and the judgment of designers and regulatory officials for fabric fences, gravel dams, straw bales, and similar porous barriers typical of those used on construction sites.

14.2.5. Inputs

The inputs used to represent porous barriers in RUSLE2 include overland flow path description, a contouring description, and the specific inputs for the strip/barrier system. Porous barriers do not affect the overland flow path description because overland flow is assumed to pass through porous barriers. RUSLE2 accounts for infiltration variations along the overland flow path, including strips where infiltration is so high that runoff ends within the strip, to compute sediment transport capacity and contouring failure (critical slope length). The overland flow path length is selected as if runoff is produced along the entire overland flow path.

The upper edge of a strip/barrier system should be as close as possible to perfectly on the contour (zero row grade) for maximum effectiveness. Figures 14.11 and 14.12 illustrate the importance of a strip/barrier's upper edge being on the contour. If the upper edge is placed parallel to the site boundary as illustrated in Figure 14.11, a grade exists along the upper edge. This grade results in overland flow collecting and running along the upper edge of the strip/barrier to a concentrated flow area, where the flow can overwhelm the barrier. A much better layout is where the upper edge is on the contour as illustrated in Figure 14.12. Runoff enters the barrier uniformly along its length, and the barrier is much less likely to fail in concentrated flow areas. An advantage of having the upper edge of strips/barriers on the contour on cropland is that concentrated flow and ephemeral gully erosion can be greatly reduced.

Selecting a **strip/barrier description** from the RUSLE2 **strip/barrier database component** requires that relative row grade be 10 percent or less except for up and down slope (100 percent relative row grade) where runoff flows perpendicular into the strip/barrier. This restriction can be circumvented by using a RUSLE2 screen **template** that displays the three-layer profile schematic (see **Section 8**). In both input approaches, RUSLE2 assumes that the runoff flows into the porous barrier and that the only effect of the barrier being off grade is in the contouring effect described in **Section**

14.1. See **Section 14.1.5** for additional guidance on selecting contouring inputs for porous barriers.

Inputs specific to a strip/barrier system can be entered in one of two ways. Selecting a **strip/barrier description** from the RUSLE2 database is the intended approach for routine conservation planning. These descriptions involve simplifying assumptions such as uniform strip/barrier widths for convenience and consistency with RUSLE2's accuracy. However, the **three layer profile schematic** can be used to circumvent the 10 percent relative row grade rule when flexibility is needed to represent a complex field situation. The **management layer** in the profile schematic is divided into segments and **cover-management descriptions** are selected for each segment to represent the strips and barriers along the overland flow path.

The inputs for strip/barrier descriptions in the strip/barrier component of the RUSLE2 database are listed in Table 14.3.

Table 14.3. Input variables for strip/barrier descriptions

Input variable	Comment
Strip barrier type	Type refers to filter strip/barrier, buffer strip/barrier, or rotation strip cropping. A filter strip/barrier is permanent at end of overland flow path. Buffer strip/barrier type involves multiple permanent barriers along overland flow path. Rotational strip cropping involves multiple, equal width strips that alternate in time along the overland flow path
Number of strips/barriers crossing overland flow path	Assumption is that strips/barriers are equally spaced along overland flow path
How strip/barrier width is specified	Width can be specified in absolute units or as the portion of the overland flow path length
Absolute strip width	Strip/barrier width if input for width is specified in absolute units
Strip/barrier width relative to overland flow path length	Strip/barrier width if input for width is specified as the portion of the overland flow path length
Strip/barrier cover-management description	Select the cover-management description for the filter and buffer strip/barrier system. Cover-management description selected for profile is cover-management input for non-strip portion of the overland flow path. The cover-management description selected for the profile is the cover-management description that RUSLE2 uses for rotational strip cropping.
Strip/barrier at bottom of overland flow path	Selecting **yes** places a strip/barrier at the end of the overland flow path. Remaining strips are uniformly spaced along the overland flow path. Selecting **no** places the last strip/barrier

	the same distance above the end of the overland flow path that strips/barriers are spaced along the overland flow path.
Is strip/barrier used for water quality	For USDA-NRCS conservation planning. NRCS specifies require that last strip width be twice as wide as the other strips when explicit purpose is to improve water quality.

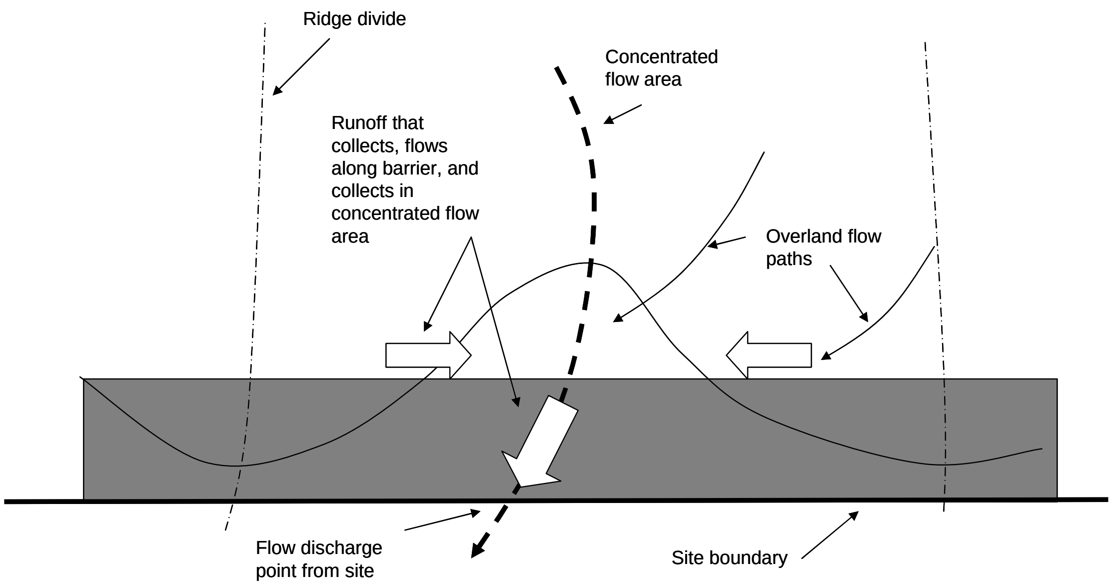

Figure 14.11. A strip where upper edge is parallel to site boundary.

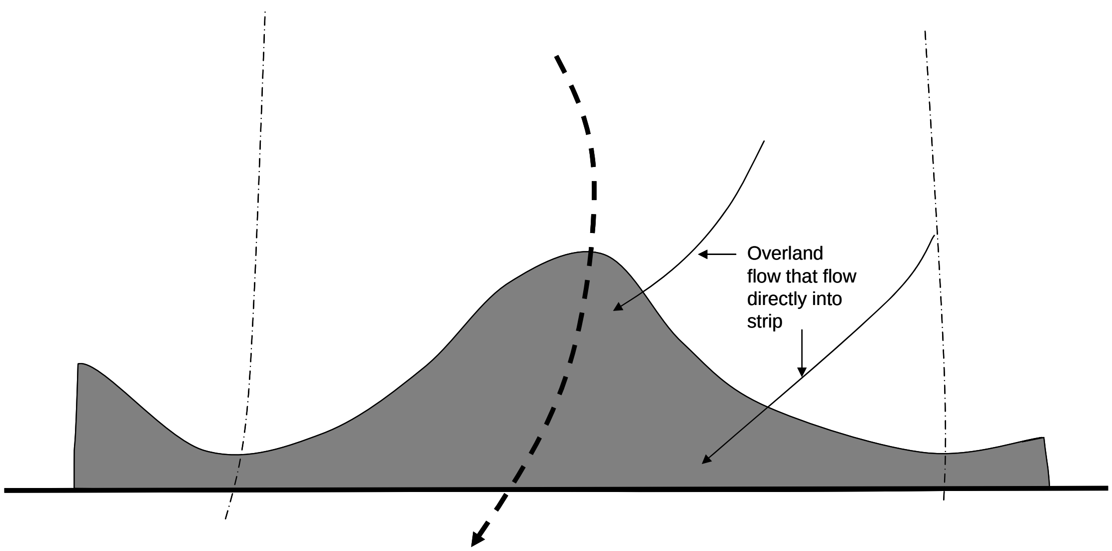

Figure 14.12. A strip where upper edge is perfectly on the contour.

14.2.5.1. Inputs for filter strip/barrier

A filter strip porous barrier is a single barrier at the end of the overland flow path. Four examples of a filter strip porous barrier are a wide strip of dense vegetation (e.g., grass strip) on cropland, a narrow strip of erect, stiff, dense grass (stiff grass hedge) on cropland, an undisturbed strip left along concentrated flow areas on disturbed forestland, and a fabric (silt) fence on a construction site. The specific inputs for a filter strip-type porous barrier are: strip/barrier type (select **filter strip**), how strip/barrier width is specified, strip/barrier width, and cover-management description for strip/barrier.

The general recommendation for conservation and erosion planning is to specify **strip/barrier width** as the portion of the overland flow path length. A strip width of 10 percent of the overland flow path length is commonly assumed for general conservation and erosion control planning. An alternate is to specify the actual widths in absolute units instead of a portion of the overland flow path length.

Figure 14.12 illustrates that the portion of the overland flow path occupied by a filter strip/barrier of a fixed width varies by overland flow path. This variation means that the relative filter strip/barrier width depends on the overland flow path assumed in applying RUSLE2 to a particular site. The recommended approach is to choose an overland flow path and a representative filter strip/barrier width that are consistent with the conservation and erosion control planning objectives for the site. For example, a typical RUSLE2 application is to protect the eroding portion of the hillslope from excessive erosion so that the soil resource is protected. The one third portion of the hillslope having the highest erosion potential is typically selected as the area where RUSLE2 will be applied when conservation planning objective is to protect the soil resource. An overland flow path is assumed through this hillslope area, and the filter strip/barrier width for that overland flow path is used as the input width. However, if this width is not representative of the filter strip/barrier as a whole, use a representative filter strip width even if it does not match the actual width for the selected overland flow path.[146]

Filter strips/barriers are often used to reduce sediment yield from a site. RUSLE2 computes sediment yield from the area represented in a RUSLE2 computation. This area can include the entire overland flow area, diversions/terrace channels having deposition, and small impoundments, but it does not include concentrated flow areas where additional deposition and ephemeral gully erosion can occur (see **Sections 5.1 and 5.2**).

RUSLE2 computations should be made for a collection of overland flow paths when computing sediment yield where conditions vary over the area of interest. The sediment yield value for each overland flow path is weighted by the area represented by that path to obtain a sediment yield estimate for the entire area represented by the RUSLE2 computations. The **plan component** of the **RUSLE2 database** can assist in this computation where the sediment yield values are weighted by the sub-area that each overland flow path represents relative to the total area.

---

[146] RUSLE2 computes erosion and deposition values for porous barriers that are consistent with erosion science and research data. RUSLE2 is not meant to displace erosion control practice standards and specifications issued by agencies like the USDA-Natural Resources Conservation Service. However, such standards sometimes compromise erosion control performance for convenience of certain farming operations. RUSLE2 does not consider all factors important in conservation and erosion control planning. Use RUSLE2 values to guide developing an appropriate site-specific plan.

RUSLE2 only computes sediment yield from the overland flow area, diversion/terrace channels where deposition occurs, and small impoundments. RUSLE2 does not compute sediment yield from the site unless the flow paths represented by RUSLE2 end at the site boundary (see *Sections 5.1 and 5.2*).

RUSLE2 computes a backwater/deposition width and adds that value to the input width for the strip/barrier. This approach takes into account type and porosity of the barrier based on the retardance value assigned in the **vegetation description** used to represent the barrier (see **Sections 11.1.4 and 11.2.5**). This approach also takes into account how location, soil, and cover-management affect runoff and backwater/deposition width.

A **cover-management description** is selected to describe the filter strip/barrier, even for mechanical barriers like silt fences. The cover-management description for permanent vegetation strips should be a **no-rotation** type cover-management description (see **Section 10.2.8**). If the cover-management description on the upslope portion of the overland flow path is also a no-rotation type cover-management description, then consistency of the dates between the cover-management descriptions is not required. Similarly, consistency of dates between the cover-management descriptions is not important when cover-management description is a rotation type for the strip/barrier even though the upslope cover-management description is a no-rotation type. **However, if the cover-management descriptions are a no-rotation type for both the upslope area and the strip/barrier, then the dates in the two cover-management descriptions must be consistent.**

Strips/barriers can be added and removed at particular times over the computational period using operations in the cover-management description for the strip/barrier.[147] This RUSLE2 capability allows the use of a single cover-management description to describe a strip/barrier to compute erosion over the pre-construction, construction, and post construction phases.

A **vegetation description** is used to describe mechanical barriers such as fabric fences, gravel dams, straw bales, berms, and similar erosion control porous barriers used on construction sites. A selection is made from the **retardance classes** defined for vegetation plus the additional retardance class for silt fences and stiff grass hedges to describe the porosity of the barrier (see **Section 11.2.5**). Retardance class 7 for stiff grass hedges and silt fences is selected if the material provides extremely high retardance. Another retardance classes is used for more porous barriers. Also, the **production**

[147] A **begin growth process** in an **operation description** is used to install (put in place) a mechanical barrier (e.g., silt fence) because a vegetation description is used to represent the barrier. A **kill vegetation** and a **remove residue processes** are used in an operation description to remove a mechanical barrier.

(yield) level can be changed to alter the retardance (porosity) of the strip/barrier unless the **extremely high retardance class** is selected for the strip/barrier.

The canopy cover should be set to 100 percent and the effective fall height should be set to zero in the vegetation description used to describe a mechanical barrier to minimize detachment that RUSLE2 computes for the portion of the overland flow path occupied by the barrier.

High quality filter strips/barriers can greatly reduce sediment yield, but they do not significantly reduce the conservation planning soil loss (see **Section 8.1.5.4**). The deposition caused by the strip/barrier is near the end of the overland flow path unless the strip is very wide such as a strip that occupyies more than 40 percent of the overland flow path.

Porous barriers must be perfectly on the contour for effective performance. RUSLE2 assumes well designed, installed, and maintained barriers.

14.2.5.2. Inputs for buffer strips/barriers

A **buffer strip/barrier** type porous barrier is a set of equal width strips/barriers spaced uniformly along the overland flow path and having the same cover-management description and width. The same base **cover-management description** applies to all of the inter-strip/barrier areas. Examples include permanent grass strips on cropland and silt fences on a construction site.

The specific inputs for a buffer strip type porous barrier are:

barrier type (select **buffer strip**),
number of strips/barriers crossing the overland flow path,
how strip/barrier width is specified,
strip/barrier width,
cover-management description for strip/barrier,
whether a strip/barrier is at the end of the overland flow path, and
is the buffer strip system for water quality.

The **buffer strip/barrier description** in the **strip/barrier component** of the RUSLE2 database is for routine conservation and erosion control planning. A RUSLE2 template (see **Section 8**) that displays the three layer profile schematic can be used to apply RUSLE2 to complex, non-uniform conditions.

Several inputs for a buffer strip/barrier system are the same as for a filter strip barrier description. See **Section 14.2.5.1** for a description of the common inputs. Only the additional inputs required to describe a buffer strip/barrier system are discussed in this section.

The number of strips/barriers is not the number of strips/barriers on the hillslope or in the field, but the number of strips/barriers that cross the overland flow path used in the RUSLE2 computation.

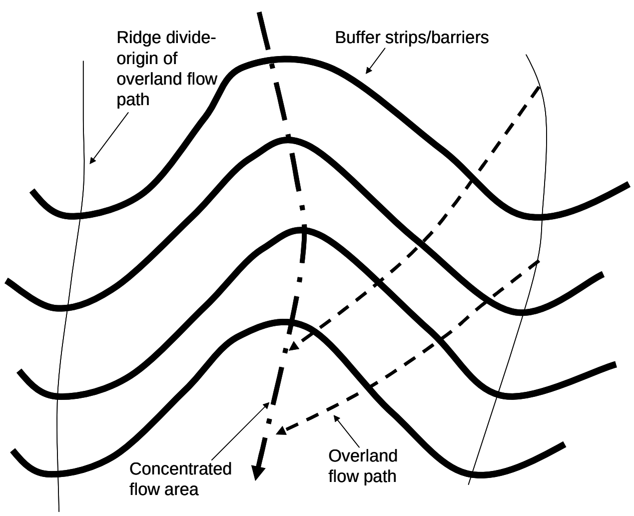

Figure 14.13. A buffer strip/barrier system on a typical hillslope illustrating various overland flow paths.

Enter a representative value for the number of strips/barriers that cross the overland flow path. The number will vary depending on the overland flow path that is chosen for the RUSLE2 computation as illustrated in Figure 14.13. Apply the guidelines described in **Section 14.2.5.1** regarding filter strip width for selecting a value for the number of strips/barriers that cross the overland flow path.

If a strip/barrier is placed at the end of the overland flow path, select **yes** for the input of **strip/barrier at the end of the overland flow path**. RUSLE2 divides the overland flow path into a number of barrier-interbarrier intervals equal to the number of strips/barriers crossing the overland flow path. This arrangement is illustrated in Figure 14.14.

The strip/barrier arrangement where a strip/barrier is not at the end of the overland flow path is also illustrated in Figure 14.14. In this case, the number of inter-strip/barrier intervals along the overland flow path is one greater than the number of strips/barriers. Consequently, the strips/barriers are more closely spaced than when a strip/barrier is at the end of the overland flow path. Sediment yield is increased when a strip/barrier is not at the end of the overland flow path to trap the sediment eroded on the last inter-strip/barrier area. Although sediment yield is reduced when a strip/barrier is at the end of the overland flow path, the conservation planning soil loss (see **Section 8.1.5.4**) may not differ greatly with strip/barrier placements.

As Figure 14.13 illustrates, the relationship of the last strip/barrier to the end of the overland flow path varies. Either chose the input that best represents the overall field situation or make RUSLE2 computations for both strip/barrier placements. The conservation or erosion control plan could be based on an average of the two computations or on the one where the erosion and sediment yield potential is greater.

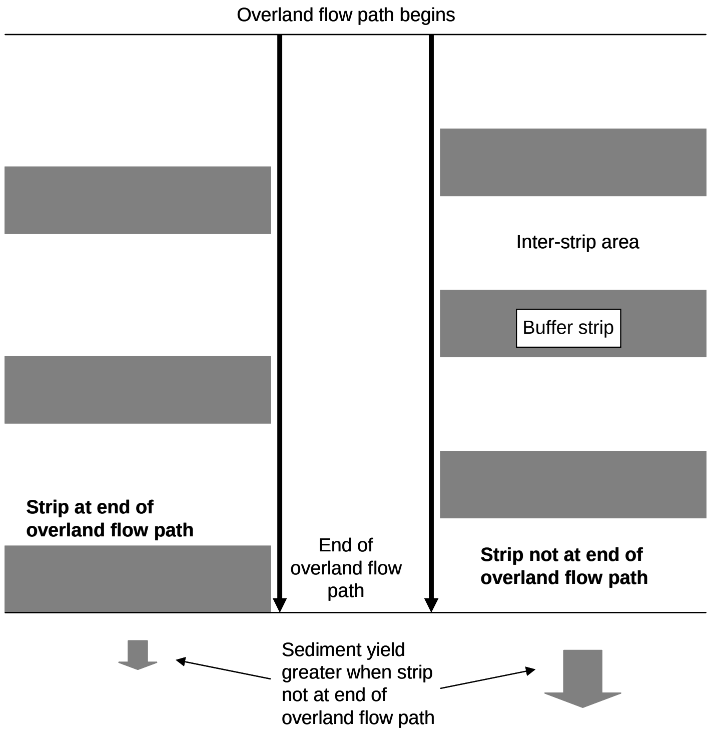

Figure 14.14. Illustration of a buffer strip systems where strip is at end of overland flow path and one where strip is not at end of overland flow path.

Select **yes** for the input **used for water quality** if the buffer strip/barrier description is being used for water quality purposes according to USDA-NRCS standards. Also, select **yes** for the input **to place a strip/barrier at the end of the overland flow path**. These selections cause the width of the strip at the end of the overland flow path to be twice the width of the other strips.

14.2.5.3. Inputs for rotational strip cropping

A rotational strip cropping system is a set of equal width strips that are annually rotated on the overland flow path in a sequence determined by a **cover-management description**. The cover-management description includes erodible periods and dense vegetations periods. Rotational strip cropping's effectiveness is from the deposition caused by the dense vegetation strips. The specific inputs for a rotational strip cropping type porous barrier are barrier type (select **rotational strip cropping**), number of strips/barriers crossing the overland flow path, the cover-management description, and the sequencing of the strips along the overland flow path.

Select a representative value for the number of strips that cross the overland flow path. The number of strips that cross the overland flow path varies with the overland flow path as described in **Section 14.2.5.2** for buffer strip systems. Also, the field overland flow path does not always begin and end on a strip boundary as assumed by RUSLE2. The idea is to a chose a number that best represents the overall field situation where RUSLE2 is being used as a conservation and erosion control planning tool. A RUSLE2 **template** that displays the three layer profile schematic can be used to estimate erosion on more complex situations that can be represented with the **rotation strip cropping description** in the **strip/barrier component** of the RUSLE2 database.[148] For example, this template

[148] If a RUSLE2 template with the three layer profile schematic is used to represent rotational strip cropping

is required to compute erosion for a rotational strip cropping system combined with a filter strip system because a filter strip description and a rotational strip cropping description from the RUSLE2 strip/barrier database component can not be combined.

The number of strips is not the number of strips on the hillslope or in the field, but the number of strips that cross the overland flow path used in the RUSLE2 computation.

Select a cover-management description that includes periods of dense vegetation that provide substantial flow retardance to cause deposition. The cover-management description, which is applied to all strips along the overland flow path, must include dense vegetation or other high hydraulic resistance conditions to cause deposition. The effectiveness of rotational strip cropping is achieved by having alternating strips of dense vegetation that cause deposition.

These alternating strips of dense vegetation are described by sequencing the cover-management description among the strips. The sequencing procedure used in RUSLE2 is to **offset** the starting date of the cover-management description by a particular number of years for each strip.

The following examples illustrate how to offset a cover-management description, which must be a rotation, to describe a rotational strip cropping system in RUSLE2. Assume a simple cover-management description of two years of corn followed by three years of hay represented by corn 1 - corn 2 - hay 1 – hay 2 – hay 3. Multiple years of each crop are grown together for convenience. Assume four strips along the overland flow path. The number of strips along an overland flow path need not match the years in the rotation as illustrated in this example. The number of strips will often be less than the number of years in the rotation.

Table 14.4 illustrates a rotation strip cropping description where the cover-management description is not offset for any strip. The result is that the same cover-management condition exists on all strips in any year. This system only reduces the conservation planning soil loss by reducing erosion that results from the three years of hay being much less erodible than is the corn. No deposition occurs among the strips because the hydraulic resistance does not increase between any two adjacent strips. This system is not rotational strip cropping because the dense vegetation (i.e., hay) are not alternated among the erodible (i.e., corn) strips.

Table 14.4. Example of no offset for a corn-corn-hay-hay-hay cropping rotation.

Strip	Years of	Year 1	Year 2	Year 3	Year 4	Year 5

and similar strip conditions where the strips must be sequenced along the overland flow path, the inputs to describe strip sequencing are entered in the **cover-management tab**.

Number	Offset					
1 (upper end of overland flow path	0	corn 1	corn 2	hay 1	hay 2	hay 3
2	0	corn 1	corn 2	hay 1	hay 2	hay 3
3	0	corn 1	corn 2	hay 1	hay 2	hay 3
4	0	corn 1	corn 2	hay 1	hay 2	hay 3

To achieve strip cropping, the cover-management description on some of the strips needs to be offset as illustrated in Table 14.5. The 2-year offset on strips 2 and 4 shifted the cover-management description by two years so that runoff from at least one corn strip runs through at least one hay strip. Sediment yield is reduced in the first two years because of a hay strip at the end of the overland flow path. However, sediment yield is increased in years 4 and 5 because the erodible corn strip is the last strip on the overland flow path. Both erosion and sediment yield are low in year 3 because the entire overland flow path is in the low erodible hay condition and only slight deposition occurs in this year.

Table 14.5. Example of a rotational strip cropping system where cover-management conditions are alternated by strip along the overland flow path.

Strip Number	Years of Offset	Year 1	Year 2	Year 3	Year 4	Year 5
1	0	corn 1	corn 2	hay 1	hay 2	hay 3
2	2	hay 1	hay 2	hay 3	corn 1	corn 2
3	0	corn 1	corn 2	hay 1	hay 2	hay 3
4	2	hay 1	hay 2	hay 3	corn 1	corn 2

Table 14.6 illustrates another possible strip cropping system described with a different set of offset years from the set illustrated in Table 14.5. The system illustrated in Table 14.6 is not as effective as the one illustrated in Table 14.5. In an example computation for Columbia, MO, the conservation planning soil loss for the system illustrated in Table 14.4 is 5.8 tons/acre. The conservation planning soil loss for the system illustrated in Table 14.5 is 2.6 ton/acre while it is 3.9 tons/acre for the system illustrated in Table 14.6. The major deficiency of the system illustrated in Table 14.6 is that it has fewer alternating strips of hay among corn strips than in the system illustrated in Table 14.5.

Table 14.6. Example of a rotational strip cropping system where the rotation is delayed a year on each subsequent strip.

Strip Number	Years of Offset	Year 1	Year 2	Year 3	Year 4	Year 5
1	0	corn 1	corn 2	hay 1	hay 2	hay 3
2	1	hay 3	corn 1	corn 2	hay 1	hay 2

3	2	hay 2	hay 3	corn 1	corn 2	hay 1
4	3	corn 2	hay 1	hay 2	hay 3	corn 1

RUSLE2 gives full credit to all deposition in the conservation planning soil loss for rotational strip cropping in contrast to the partial credit given for deposition caused by filter and buffer strip/barrier systems.

14.3. Flow Interceptors (diversions/terraces, sediment basins)

The conservation planning soil loss for rotational strip cropping is the same as the sediment yield when the *rotation strip cropping description* in the *strip/barrier component* of the RUSLE2 database is used. The two are not equal when the three layer profile schematic is used to represent rotational strip cropping by directing the overland flow path into segments.

14.3.1. Description of practices

Flow interceptors are topographic features that end the overland flow path (see **Sections 8.2 and 8.3**). Flow interceptors include diversions, terraces, and sediment basins. Diversions and terraces are constructed specifically to intercept overland flow and redirect the runoff around the hillslope in a low gradient channel. Terraces are constructed on a sufficiently low grade to cause deposition and even on a level grade with a closed outlet to conserve soil moisture in dry climates. Diversions are constructed on a sufficiently steep grade so that deposition does not occur but on a sufficiently flat grade so that erosion does not occur. Constructed terraces and diversions typically involve ridges and accompanying channels that convey the runoff to a protected open channel or an underground pipe that conveys the runoff downslope to a safe outlet. Disposal channels must be lined with vegetation, stone, or other material to prevent erosion because flow erosivity can be quite high in these channels.

The two major terrace types used on cropland are gradient and parallel tile outlet (PTO). Grade along a gradient terrace is nearly uniform, which requires plan curvature to fit the hillslope as illustrated in Figure 14.15. This curvature and the resulting non-uniform spacing between terraces along their length inconvenience farming operations. Gradient terraces generally divide the overland flow path length in shorter nearly uniform length overland flow paths between the terraces.

Parallel tile outlet terraces are relatively straight and are nearly uniformly spaced along their length. The terraces create small impoundments where they cross concentrated flow areas as illustrated in Figure 14.15. Impounded runoff drains through a vertical riser connected to an underground tile line (pipe). Grade along parallel terraces is typically non-uniform requiring that the grade be limited to prevent erosion. A variety of overland

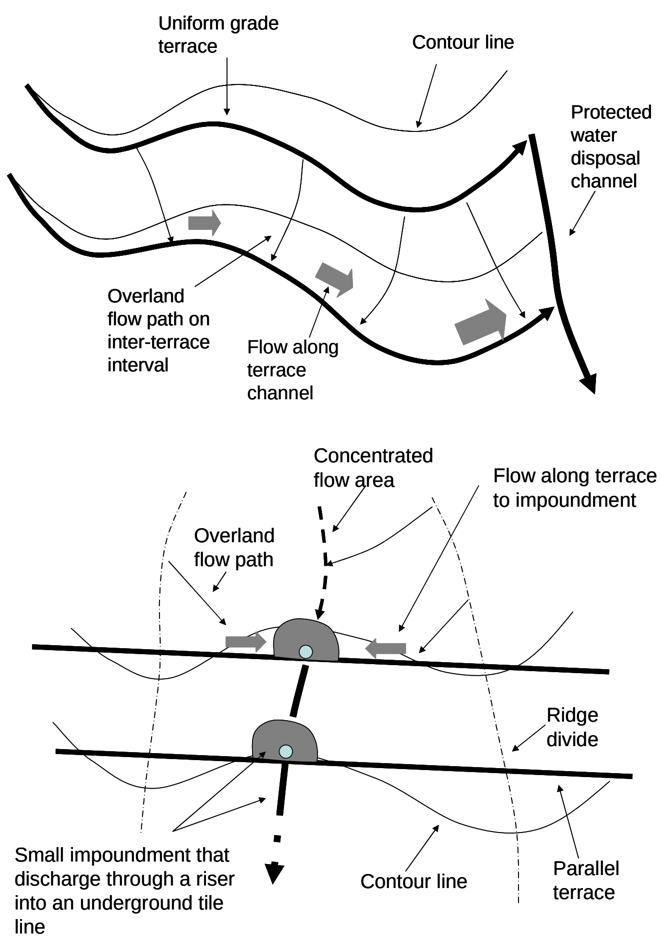

Figure 14.15. Illustration of a gradient terrace (top sketch) and parallel tile outlet (PTO) terrace systems (bottom sketch) and associated flow paths.

flow path lengths exist between parallel terraces. In contrast, to gradient terraces that almost always divide the overland flow path length, the longest overland flow path between parallel terraces may not be affected if the terraces are widely spaced. Sediment yield is low because of deposition in the small impoundment (sediment basin) in the concentrated flow areas.

Diversions, terraces, and sediment basins are also used on construction sites, reclaimed mine land, landfills, and other highly disturbed lands to shorten the overland flow path as illustrated in Figure 8.12 and reduce sediment yield, especially during periods when cover-management erosion control methods can not be used during soil disturbing operations.

Other features, including windrowed forest debris on disturbed forest land following site preparation for reseeding, act as diversion/terraces. Another example is a ridge of soil left by grading operations at the top of a cut or embankment on a construction site (see **Section 8.3.3**). Another example is an off-contour stiff grass hedge where tillage leaves a ridge of soil along the hedge that diverts the runoff rather than allowing it to flow through the hedge. A similar example is an off-contour silt fence on a construction site.

14.3.2. Basic principles

Flow interceptors involve two basic **hydraulic elements**, which are a **channel** and an **impoundment**. Diversions/terraces reduce rill and interrill erosion by shortening the overland flow path length, which is considered in the **topographic description** of the overland flow path (see **Section 8**).

Terraces also reduce sediment yield by causing deposition in the terrace channel. The basic principles described in **Section 5.4** for computing deposition on overland flow areas are used to compute deposition in diversion/terrace channels. The basic concept is that deposition occurs when the sediment load delivered to the diversion/terrace channel by overland flow on the inter-terrace interval exceeds transport capacity in the terrace channel. Deposition is computed with:

$$D = [\phi/(1+\phi)](dT_c / dx - D_o) \qquad [14.1]$$

where: D = deposition rate (mass/time·unit channel width), T_c = transport capacity in the diversion/terrace channel (mass/time), x = distance along the channel, dT_c/dx = change of transport capacity along the channel (mass/time·distance), and D_o = sediment delivered to the channel from the overland flow area (mass/time·unit distance along channel). The variable φ is given by:

$$\phi = aV_f / q_c \qquad [14.2]$$

where: α = a coefficient to be determined by calibration, V_f = fall velocity of the sediment particles, and q_c = discharge rate in channel per unit channel width, which is the discharge rate from the overland flow path that ends at the diversion/terrace channel. Transport capacity in the channel is computed by:

$$T_c = K_{Tc} Q_c s \qquad [14.3]$$

where: K_{Tc} = a coefficient to be determined by calibration, $Q_c = q_c x$ = discharge rate in the channel, and s = sine of the grade angle of the channel.

Simplifying assumptions consistent with RUSLE2's purpose to serve as a guide for conservation and erosion control planning were made in solving these equations. The equations are applied to each sediment particle class assuming no interaction among the particle classes. Grade along the channel is assumed to be uniform, which gives the mathematical result that deposition is uniform along the channel. Consequently, channel length is not a factor in the computations and, therefore, is not an input.

Transport capacity for a sediment particle class is assumed to be proportional to its portion in the sediment load that reaches the channel. Deposition among the particle classes varies according to the particle class's fall velocity. RUSLE2 computes the particle class distribution and the sediment load leaving the channel. RUSLE2 computes an enrichment ratio that is a measure of how deposition enriches the sediment load in fines (see **Section 7.5.1**). The enrichment ratio increases as deposition increases (i.e., as the sediment delivery ratio decreases).

RUSLE2 also assumes a smooth, bare soil surface in a diversion/terrace channel. Deposition in these channels is highly localized, typically along the channel edge where overland flow enters the channel flow. Deposition covers most soil surface roughness and crop residue to leave a bare, smooth soil surface. RUSLE2 does not accurately compute deposition where vegetation in the channel retards the flow to cause deposition. This limitation is not especially important because most erosion and deposition occur during the cropping season before vegetation develops.

RUSLE2 does not consider channel cross section shape in its computations.

Sediment delivery ratio is a measure of deposition. In RUSLE2, the sediment delivery ratio for a given diversion/terrace channel varies with several factors including channel grade and runoff, sediment load, and sediment characteristics entering the channel from the inter-diversion/terrace area. For example, very little or no deposition occurs when the channel grade is steep because transport capacity is high. Very little deposition occurs when sediment delivery is low and runoff is high from the overland flow area. Deposition is reduced when incoming sediment is mostly fine particles caused by the source soil properties or deposition on the overland flow path, particularly near its end (e.g., deposition by a grass strip or a flat concave overland flow path segment at the channel edge). Consequently, the sediment delivery ratio computed by RUSLE2 for a diversion/terrace is not constant for a particular channel grade, but depends on the conditions on the inter-diversion/terrace area as well.[149]

RUSLE2 computes deposition in a small impoundment (sediment basin) using:

$$g_{out} = g_{in} \exp(-\beta V_f) \qquad [14.4]$$

where: g_{in} = sediment load coming into the sediment basin, g_{out} = sediment load leaving the sediment basin, and α = a coefficient determined by calibration. This equation is fundamentally for a simple settling tank where transport capacity is assumed to be zero and the effective length is determined by calibration. RUSLE2 computed deposition depends only on the characteristics of the incoming sediment. RUSLE2 typically computes large deposition amounts and fine sediment leaving the basin. RUSLE2 computes reduced deposition if the incoming sediment is fine, which is why RUSLE2 computes significantly less deposition by a second sediment basin than by the first basin in a series. RUSLE2 computes an enrichment ratio, which is a measure of deposition enriching the sediment in fines, for the outgoing sediment (see **Section 7.5.1)**.

---

[149] The RUSLE1.06 computes deposition by diversions/terraces similar to RUSLE2. However, RUSLE1.05 computes sediment delivery ratio solely as a function of diversion/terrace grade.

RUSLE2 computed deposition is not a function of basin geometry, hydraulics, or remaining basin capacity. That is, RUSLE2 does not consider design or maintenance in its impoundment (sediment basin) computations.

RUSLE2 takes partial credit for the deposition caused by terraces and impoundments as soil saved in protecting the soil resource. The amount of deposition credited as soil saved in computing the conservation planning soil loss depends on diversion/terrace spacing and location of the diversion/terrace along the overland flow path. Deposition in a terrace located near the end of the overland flow path gets very little credit as soil saved. Deposition in a terrace located about half way along the overland flow path gets approximately half credit as soil saved when diversion/terrace spacing is less than 90 ft (30 m). The credit decreases as spacing increases beyond 90 ft (30 m) to essentially no credit for spacing greater than 300 ft (100 m).

RUSLE2 is a conservation and erosion control planning tool. It is not a hydraulic design tool. See *Haan et al. 1994. Design Hydrology and Sedimentology for Small Catchments. Academic Press* for a description of procedures that can be used to design channels and impoundments. Also, RUSLE2 is not meant to displace standards used by agencies such as the USDA-NRCS, although those standards sometime compromise practice performance for farming convenience and other reasons not considered by RUSLE2.

14.3.3. Calibration

Calibrating RUSLE2 for flow interceptors involves two sets of calibration, one for deposition in terrace channels and one for deposition in small impoundments (sediment basins). The erosion component of the CREAMS and the RUSLE1.05 equation that computes sediment delivery as a function of terrace grade were major tools used in this RUSLE2 calibration.[150] The CREAMS erosion component represents experimental field data involving gradient terraces on a range of grades at numerous locations, which were also used to derive the RUSLE1.05 equation. Another data set used in the RUSLE2 calibration was from a study of deposition in a ridge-furrow system.[151] The first step in

[150] See:
AH703

Foster, G. R., L. J. Lane, J. D. Nowlin, J. M. Laflen, and R. A. Young. 1980. A model to estimate sediment yield from field sized areas: Development of model. *In:* CREAMS - a field scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. Vol. I: Model Documentation. Conservation Research Report No. 26. USDA-Science and Education Administration. pp. 36-64.

Foster, G. R. and R. E. Highfill. 1983. Effect of terraces on soil loss: USLE P factor values for terraces. Journal of Soil and Water Conservation 38:48-51.
[151] Meyer, L.D. and W. C. Harmon. 1985. Sediment losses from cropland furrows of different gradients. Trans. ASAE. 28: 448-453, 461.

the calibration was to determine a value for the $\mathbf{K_{TC}}$ coefficient in the sediment transport capacity equation, equation 14.3, for a terrace channel. The value for this coefficient was adjusted until sediment transport capacity matched sediment load at the point that deposition was judged to begin based on field data as channel grade was reduced. Sediment transport capacity equals sediment load at the point that deposition begins according to RUSLE2 theory. The next step in the calibration was to determine a value for the coefficient $\boldsymbol{\beta}$ in equation 14.2. This equation determines the RUSLE2 computed particle class distribution in the sediment leaving the channel and determines deposition amount to a much lesser extent. Both the experimental field data and computed values from the CREAMS erosion component were used in this calibration.

The second set of calibrations was to determine a value for the coefficient **a** in equation 14.4 that RUSLE2 uses to compute deposition by particle class for a small impoundment. Once again, the CREAMS erosion component was used in the calibration because it had been calibrated using data from several field studies of impoundment, tile outlet terraces in Iowa. The primary calibration was to adjust values for the coefficient $\boldsymbol{\beta}$ until the RUSLE2 computed sediment delivery ratio matched experimental values. Also, the RUSLE2 computed values were evaluated against experimental values determined from sediment basins used on construction sites and mined land. The RUSLE2 computed sediment delivery ratio values matched the experimental values for sediment basins on highly disturbed land where the basins were well designed and constructed and were clear of sediment, i.e., functioning at optimum performance.[152]

14.3.4. Interpretation

RUSLE2 computations for **hydraulic elements** are for conservation and erosion control planning, **not for design**. RUSLE2 computes deposition in channels typical of diversions, terraces, and similar channels that intercept overland flow. RUSLE2 does not consider channel shape or hydraulic resistance in its computations. Although RUSLE2 computes average annual deposition, the computations represent an approximate 10 year return period. The channels are assumed to be in an environment, typically cropland and construction sites, where failure does not cause major damage and routine maintenance and repair are readily available.

---

[152] See:

Foster, G. R., L. J. Lane, J. D. Nowlin, J. M. Laflen, and R. A. Young. 1980. A model to estimate sediment yield from field sized areas: Development of model. *In:* CREAMS - a field scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. Vol. I: Model Documentation. Conservation Research Report No. 26. USDA-Science and Education Administration. pp. 36-64.

Toy, T.J. and G.R. Foster (coeditors). 1998. Guidelines for the use of the Revised Universal Soil Loss equation (RUSLE1.06) on mined lands, construction sites, and reclaimed lands. USDI-Office of Surface Mining. Denver, CO.

However, a different environment exists in other RUSLE2 applications where a diversion failure causes major problems. Diversions are sometimes used on the steep side slopes of landfills and hazardous waste sites to reduce rill erosion. Deposition in the diversions should be avoided because it reduces flow capacity, which can cause overtopping, very serious gully erosion, and major failure of the diversion. Maintaining a uniform grade and avoiding adverse grades along these diversions is especially important to prevent overtopping. Also, differential settling on the overland flow area between diversions can cause overland flow to become concentrated flow that causes serious gully erosion and overwhelms downslope diversions. RUSLE2 provides no information on such localized failures.

Similarly, RUSLE2 computes average annual deposition by small impoundments (sediment basins) assuming optimum performance without considering basin geometry, hydraulics, or water and sediment chemistry. RUSLE2 computed values apply to small sediment basins similar in size and hydraulic performance to the impoundments created by parallel tile outlet terraces where impounded water is drained by a perforated riser pipe that discharges into an underground pipe. Retention time in these basins is about 24 hours and the maximum water depth is about 4 to 6 ft (1 to 2 m).

These sediment basins often have a life expectancy less than five years, which means that the probability of an extreme event occurring while they are in place is low. Therefore, RUSLE2's estimate of average annual deposition is reasonable for conservation and erosion control planning. Damages are likely to be minor if failure occurs. Construction cost is low and maintenance and repair are readily available. Cleaning the basin after major storms may be more cost effective than building a large basin based on an extreme event.

All hydraulic structures including channels and impoundments should be based on proper engineering design. *RUSLE2 IS NOT AN ENGINEERING DESIGN TOOL.* Good professional judgment should always be used in making final decisions rather than relying solely on RUSLE2. RUSLE2 is to be used as a guide to supplement other information.

14.3.5. Inputs

The **hydraulic element (open channel-impoundment) systems component** of the RUSLE2 database is used in routine conservation and erosion control planning to evaluate the effect of diversions/terraces and small impoundments (sediment basins) on erosion and sediment yield from the flow path represented in the RUSLE2 computation. The hydraulic element systems database component contains **diversions/terraces and sediment basin systems descriptions** that are applied to the overland flow path without the hydraulic elements in place. Each hydraulic element system description involves a **hydraulic element (channel/impoundment) flow path description** that is applied at one or more equally spaced intervals along the overland flow path. A channel/impoundment flow path description lists the **hydraulic elements** (i.e., channels, impoundments) in the channel/impoundment flow path. Each diversion/terrace and sediment basin is assumed to be thin and to take up no space on the hillslope. This approach does not take into account how back and front slope characteristics of a diversion/terrace or sediment basin affect erosion.

A RUSLE2 **template** having the **three layer profile schematic** should be used (1) for complex conditions where the channel/impoundment flow paths are not equally spaced along the overland flow path, (2) where the individual channel/impoundment flow path differ, (3) where the soil, topography, and cover-management conditions of the embankment/channel should be described because of their effect on erosion, and (4) where soil, steepness, or cover-management vary along the overland flow path.

An example where the hydraulic element flow paths are non-uniformly spaced along the overland flow path is illustrated in Figure 8.12 where a diversion is placed at the top of a landfill sideslope. Figure 8.11 illustrates a detailed description of embankment/channel topography. Grass is often used on steep backslope terraces to prevent excessive erosion. The detailed soil, topography, and cover-management of such embankment/channels can be represented as described in **Sections 8.3.3 and 8.3.4**.

14.3.5.1. Inputs for a hydraulic element (channel/impoundment) system description

The inputs for a **hydraulic element (channel/impoundment) system description** are (1) number of hydraulic element (channel/impoundment) flow paths that cross the overland flow path, (2) whether a channel/impoundment flow path is located at the end of the overland flow path, and (3) the **hydraulic element (channel/impoundment) flow path description**.

When a hydraulic element (channel/impoundment) system description is used in RUSLE2, the overland flow path length is described without the hydraulic elements present. RUSLE2 uses the input for number of channel/impoundment flow paths that cross the overland flow path to determine the overland flow path length between the hydraulic element flow paths. This overland flow path length is the overall overland flow path length divided by number of channel/impoundment flow paths (diversion/terraces) if a channel/impoundment path is located at the end of the overland flow path. If a channel impoundment path is not located at the end of the overland flow path, the overland flow path length between channel/impoundment paths is computed as the overall overland flow path length divided by the number of channel/impoundment paths plus one.

The number of channel/impoundment flow paths that cross the overall overland flow path varies with the overland flow path chosen for the RUSLE2 computation. A representative number should be chosen based on the conservation and erosion control planning objective, which is similar to choosing the number of porous barriers that cross the overland flow path (see **Sections 14.2.5.1 and 14.2.5.2**).

Extra consideration should be given to selecting the number of channel/impoundment flow paths that cross the overall overland flow path when representing parallel impoundment terraces. The overland flow path length between parallel impoundment terraces varies greatly as illustrated in Figure 14.15. The RUSLE2 computed overland flow path length should be checked to determine if this overland flow path length is appropriate. The RUSLE2 computed overland flow path length can sometimes be too short. An improvement in the erosion computation can be made by decreasing the number of channel/impoundment flow paths that cross the overall overland flow path. Also, the overall overland flow path can be lengthened for the hydraulic element computation but not for the computation when the hydraulic elements are not present. Another alternative is to apply RUSLE2 to a single inter-terrace interval.

The number of channel/impoundment paths is not the total number on the hillslope but the number that cross the selected overland flow path used in the RUSLE2 computation.

The input of whether a channel/impoundment (diversion/terrace) flow path is at the end of the overland flow path significantly affects computed sediment yield. A diversion/terrace at the end of the overland flow path is unnecessary when the sole purpose of the diversion/terrace system is to control rill-interrill erosion. In that case, a **no** input is selected for whether a channel/impoundment flow path is located at the end of the overland flow path. When **no** is selected, the sediment eroded on the last overland flow path interval leaves the RUSLE2 overall overland flow path without passing through the selected channel/impoundment flow path. If a channel/impoundment flow path is placed at the end of the overland flow path to trap sediment and control sediment yield from the site, select **yes** for whether a channel/impoundment flow path is located at the end of the overland flow path. This selection causes RUSLE2 to compute that sediment eroded on all overland flow path intervals passes through the selected channel/impoundment flow path.

The last input is to select a **hydraulic element (channel/impoundment) flow path description** from previously created entries in the RUSLE2 database.

14.3.5.2. Inputs for a hydraulic element (channel/impoundment) flow path description

A **hydraulic element (channel/impoundment) flow path description** gives the sequence of hydraulic elements (i.e., channel and impoundment) along the flow path.

Table 14.7 lists the possible sequences that can be used in RUSLE2.[153]

DO NOT ENTER SEQUENCES OTHER THAN THOSE LISTED IN TABLE 14.8.

Table 14.7. Possible sequences of channel and impoundment hydraulic elements used to represent hydraulic element (channel/impoundment) flow paths.

Sequence	Comment
Impoundment	Overland flow drains directly into impoundment. Typical application is a sediment basin on a construction site.
Impoundment-impoundment	Overland flow drains directly into the first impoundment, which in turn drains directly into the second impoundment. Typical application is two sediment basins in series on a construction site where sediment yield leaving the site must be very low.
Channel	Overland flow drains uniformly into channel along its length. No inflow at upper end of the channel can occur. Typical application are gradient terraces on an agricultural field or a diversion on a construction site or landfill.
Channel-impoundment	Overland flow area drains uniformly into channel along its length. No inflow at upper end of the channel can occur. Discharge from channel flows directly into impoundment. Typical applications are impoundment parallel terraces on an agricultural field and a diversion used to divert overland flow into a sediment basin on a construction site.
Channel-impoundment-impoundment	Same as a channel-impoundment sequence except that discharge from the first impoundment flows directly into the second impoundment. An example application is a diversion channel discharging overland flow into a series of two sediment basins on a construction site.
Note: When a segment on the overland flow path is adjacent to a segment with an adverse (negative) steepness, RUSLE2 assumes a channel hydraulic element at the intersection of the segments (see **Section 8.3.3**). The default channel assumed by RUSLE2 is steep so that no deposition occurs. A hydraulic element (channel/impoundment) flow path description from the RUSLE2 database can be substituted for the default channel, which allows RUSLE2 to compute deposition in channels at the intersection of the backslope and frontslope of a bench terrace system (see Figure 14.16) and in furrows separating ridges (see Figure 8.14), for example.	

An impoundment element can be the single element in the sequence, which represents overland flow discharging directly into an impoundment without first flowing through a channel. This sequence represents a sediment basin on a construction site.

[153] Other sequences besides those listed in Table 14.8 can be entered, but RUSLE2 does not properly compute deposition for other sequences.

Outflow from an impoundment is assumed to be a point discharge that can only flow into another impoundment. It can not discharge into a channel because a channel can not accept inflow at its upper end. Two or more impoundments can be placed in series to represent sediment basins in series.

A RUSLE2 channel hydraulic element is a channel of uniform grade that receives runoff uniformly along its length from the adjacent overland flow area. No inflow occurs at the upper end of the channel (i.e., discharge is zero at the upper end of the channel). **Only a single channel can be in the sequence of hydraulic elements used to describe a hydraulic element (channel/impoundment) flow path. If a channel is in the sequence, it must be the first hydraulic element in the sequence.**

RUSLE2 does not compute erosion in a channel. Ensure that the channel's lining is sufficient to prevent erosion for the channel's field grade.

A single channel is used to represent gradient terraces, illustrated in Figure 14.15, on an agricultural field, a diversion on a construction site, and a diversion at the top of the landfill sideslope illustrated in Figure 8.12. The discharge from a channel is a point discharge that can only flow into an impoundment element because of the no inflow requirement for a channel. A channel-impoundment sequence is used to represent parallel impoundment terraces illustrated in Figure 14.15.

The no inflow requirement for channels means that a sequence of channels can not be used to describe a variable grade diversion or terrace system, for example. A single grade must be entered to represent a variable grade channel. If the profile along the channel is concave, enter the grade over the last one fourth to one third of the channel. If the profile along the channel is convex, enter the grade over the first one third to one half of the channel.

Notes:
Grade along a RUSLE2 channel is uniform.
No inflow can occur at the upper end of a RUSLE2 channel, i.e., channels can not be in series to represent non-uniform grade channels.
RUSLE2 does not compute erosion in channels.
RUSLE2 is not a hydraulic design procedure. Proper hydraulic procedures should be used to design channels and impoundments.
The impoundments considered by RUSLE2 are small impoundments like sediment basins and impoundments associated with parallel tile outlet terraces.
RUSLE2 does not consider the disposal channel system associated with diversions and gradient terraces.

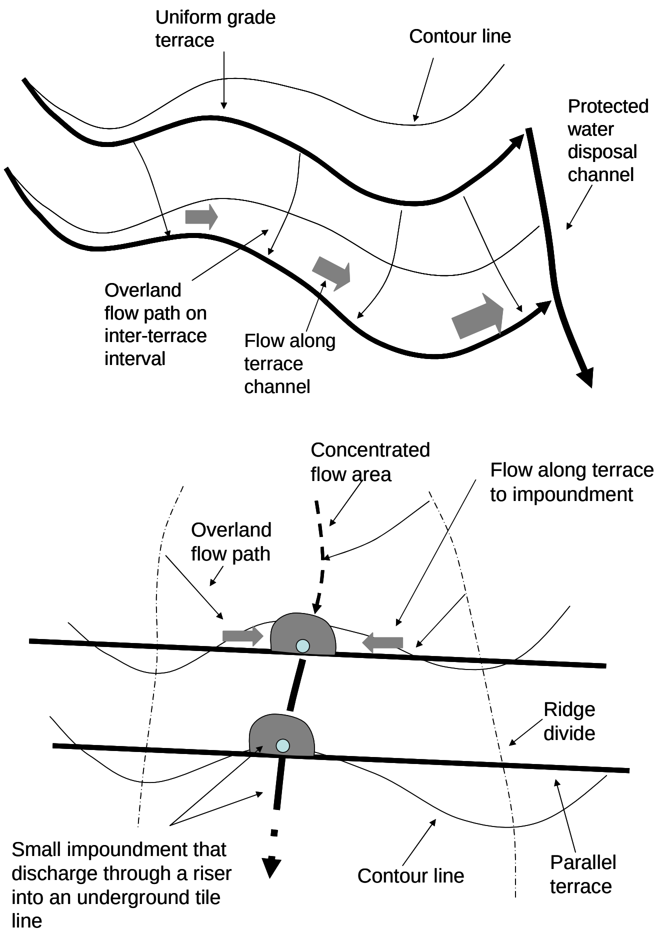

Figure 14.15. Illustration of a gradient terrace (top sketch) and parallel tile outlet (PTO) terrace systems (bottom sketch) and associated flow paths.

No inputs are required to describe an impoundment hydraulic element. Grade is the single input used to describe a channel hydraulic element. A typical RUSLE2 database contains channel descriptions over a range of grades from which selections can be made in describing channel/impoundment flow path systems.

RUSLE2 makes no distinction between a diversion or a terrace channel. Both are represented by the same channel hydraulic element. If a channel is intended to behave as a diversion where no deposition is expected, the RUSLE2 output should be reviewed for deposition. If deposition is computed in the diversion channel, a channel with an increased grade should be selected.

14.3.5.3. Inputs for the RUSLE2 default channel description

RUSLE2 automatically inserts a **default channel** when an overland flow path segment intersects with an overland flow path segment having an adverse (negative) steepness (see **Section 8.3.3**). Also, RUSLE2 may automatically assign a default channel at the end of the overland flow path. The grade of this default channel is already entered in the RUSLE2 database, and it can be changed. The grade is usually set at a very high steepness (e.g., 100 percent) so that RUSLE2 does not compute deposition in the default channel. Another channel that represents the field condition can be selected to replace the default channel in a particular RUSLE2 computation by selecting a channel/impoundment flow path description from the RUSLE2 database. By making this substitution, RUSLE2 can compute deposition in the channels that RUSLE2 assigns for inward sloping bench terraces illustrated in Figure 14.16, in the furrows between ridges illustrated in Figure 8.14, and in a concentrated flow areas that separates two overland flow areas, which are created by dividing an overland flow path into two segments and entering a negative steepness for the second segment.

14.3.5.4. Inputs for bench terraces

Figure 14.16 illustrates bench terraces that can be represented by RUSLE2. The hydraulic element system component of the RUSLE2 database is not used in this RUSLE2 application. A RUSLE2 template having the three layer profile schematic is used to describe bench terraces.

The first bench terrace system is an outward sloping bench terrace where the benches slope outward away from the hillslope. The overland flow path is divided into segments where steepness values are entered into appropriate segments to represent the steep backslope and the relative flat bench. Runoff as overland flow is assumed from the top of the benches across each bench through the last bench. Different cover-management descriptions are selected for the backslope and bench segments.

The same procedure is used to describe inward sloping bench terraces where the benches slope inward to the hillslope. A negative steepness is entered for the inward sloping bench segments. Using this information, RUSLE2 determines the overland flow path lengths for each segment. RUSLE2 treats each backslope-bench combination as a separate catchment. RUSLE2 also assigns a default channel at the intersection of the backslope and bench. A channel on a low grade can be selected from the RUSLE2 database to replace the default channel so that RUSLE2 can compute deposition in the runoff that flows around the hillslope at the base of each backslope. Appropriate cover-management descriptions are selected for the backslope and bench segments.

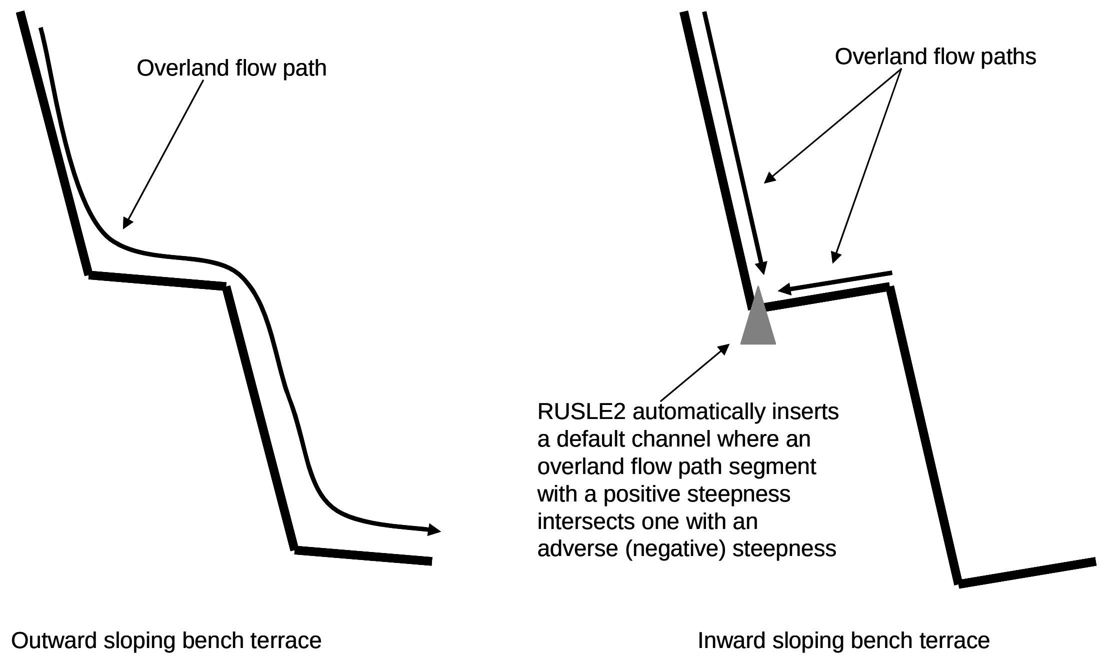

Figure 14.16. Overland flow paths for outward and inward sloping bench terraces.

14.4. Subsurface Drainage

14.4.1. Description of practice

Subsurface drainage is where lateral ditches or perforated pipe (tile line) placed about 2 to 3 ft (0.5 to 1 m) below the soil surface are used to reduce soil wetness to facilitate farming operations and improve crop yield. Subsurface drainage is most often used on relative flat slopes, less than 3 percent steepness, where the water table is near the soil surface over most of the site. Subsurface drainage lowers the water table and reduces soil water content, which in turn reduces runoff and erosion. Localized areas can also be subsurface drained. Examples include where a restricting layer causes a perched water table or in swales where the water table is high at the toe of hillslopes.

Installing tile drainage can be expensive, and therefore, a tile drainage system should be well designed based on site-specific conditions. The two major variables in a subsurface drainage system are depth and spacing of the tile lines and drainage ditches. Increasing depth and decreasing spacing improves subsurface drainage performance but also increases costs. Therefore, most subsurface drainage systems represent a balance between benefits and costs.

14.4.2. Basic principles

Subsurface drainage reduces rill-interrill erosion because it reduces surface runoff and increases vegetation production (crop yield) level. RUSLE2 uses the permeability subfactor equation in its soil erodibility nomographs to estimate how runoff potential reduced by subsurface drainage affects soil erodibility. The effect of increased production (yield) level is considered by inputting a production (yield) level value appropriate for the drained condition.

The two RUSLE2 soil erodibility nomographs include a permeability subfactor that adjusts soil erodibility based on the soil's runoff potential. The six permeability classes used in the nomographs describe runoff potential. Choice of a soil erodibility nomograph permeability class is based on texture and other surface soil properties, soil profile characteristics, presence of a naturally occurring restrictive layer, landscape position, location, and other factors that affect runoff potential under the unit plot condition (see **Sections 7.2 and 7.3.2**). Soil erodibility factor values increases as runoff potential increases.

Each **soil description** in the RUSLE2 database includes a hydrologic soil group designation, which is an index of runoff potential, for the undrained and drained conditions (see **Section 7.7**). RUSLE2 uses this index in the NRCS curve number method to estimate runoff (see **Section 8.1.2**).[154] A **D** hydrologic soil group represents the highest runoff potential while an **A** hydrologic soil group represents the lowest runoff potential. The same factors that determine a permeability class in a RUSLE2 soil erodibility nomograph also determine a hydrologic soil group.

The degree that subsurface drainage changes the hydrologic soil group depends on site specific conditions. A very fine texture undrained soil may be assigned a **D** hydrologic soil group. Subsurface drainage will decrease the soil's runoff potential, but not greatly, resulting in a change of hydrologic soil group from **D** to **C** or **B**. Soil texture is a limiting factor in being able to economically drain this soil.

A coarse texture soil may be assigned a **D** hydrologic soil group because of a restrictive subsoil layer or being in a low position on the landscape. Subsurface drainage can greatly improve internal drainage of this soil resulting in the hydrologic soil group changing from a **D** to an **A**. A coarse soil texture does not limit internal drainage nearly as much as does a fine texture.

Subsurface drainage does not always change the hydrologic soil group designation to an A hydrologic soil group. Internal soil properties, especially texture, also affect the assigned hydrologic soil group for the drained condition.

RUSLE2 uses the permeability subfactor in its soil erodibility nomographs to compute how subsurface drainage affects erosion. RUSLE2 computes permeability subfactor values for the soil erodibility factor based on the hydrologic soil group assigned for the undrained and the drained conditions. RUSLE2 uses the permeability subfactor values and the soil erodibility factor for the undrained condition to compute an **effective soil erodibility factor** value for the drained condition. The four hydrologic soil group classes are scaled to match the six permeability classes used in the permeability subfactor so that a hydrologic soil group can be converted to a soil erodibility nomograph permeability class. RUSLE2 computed values for the effect of subsurface drainage on rill-interrill erosion are illustrated in Table 14.8.

RUSLE2 computes the greatest effect of subsurface drainage when soil erodibility factor (K) values are low. For example, RUSLE2 computes a 60 percent reduction in erosion for subsurface drainage that reduces runoff potential from a **D** to **A** hydrologic soil group for a silty clay soil with a 0.20 US units soil erodibility factor (**K**) value. This runoff potential reduction is too high for a fine textured soil. A more likely runoff reduction potential would be either from a **D** to **C** or **B** hydrologic soil group. RUSLE2 computes

[154] The permeability classes used in the RUSLE2 soil erodibility nomographs are essentially a runoff potential index in much way that the hydrologic soil group is a potential runoff index. The permeability class index is used in RUSLE2's soil erodibility nomograph to compute soil erodibility values and the hydrologic soil group index is used in RUSLE2 in the NRCS curve number runoff estimation method to estimate runoff in RUSLE2.

about a 20 percent reduction in erosion for this silty clay soil when runoff potential decreased from a **D** to **C** hydrologic soil group. RUSLE2 computes about a 25 percent reduction in erosion when the runoff potential decreases from **D** to **A** hydrologic soil group for a silt soil having a **K** value of 0.55 US units. These computations are based on the same crop yield for all cases.

The additive, rather than multiplicity, mathematical structure of the soil erodibility nomograph accounts for the much greater relative reduction in erosion by subsurface drainage at low soil erodibility factor values than at high soil erodibility factor values.

A lower limit of 0.2 is set in RUSLE2 for the ratio of erosion with subsurface drainage to erosion without subsurface drainage to prevent RUSLE2 from computing unreasonably low erosion estimates with subsurface drainage.

The RUSLE2 computed values for the effect of subsurface drainage on erosion is essentially not a function of location as illustrated in Table 14.8. Subsurface drainage should affect erosion more at a low precipitation location that at a high precipitation location, especially for coarse texture soils. Values for the hydrologic soil group for the drained condition entered in the **soil descriptions** in the RUSLE2 database can be selected to take this effect into account (see **Section 14.4.5**).

The runoff reduction provided by subsurface drainage depends on drain depth and spacing. This effect can be considered by the values entered in the soil descriptions for the drained condition (see **Section 14.4.5**).

Cover-management condition interacts with surface drainage to affect runoff. That effect is considered by the production (yield) level value for the drained condition entered in the **cover-management descriptions** in the RUSLE2 database (see **Section 10.2.4**). The production (yield) value in a RUSLE2 computation should be appropriate for the subsurface drainage condition.

The other effect of subsurface drainage that RUSLE2 considers is how reduced runoff affect contouring, contouring failure (critical slope length), and sediment transport capacity and deposition. A reduced runoff, which is used in these computations, is computed because of the reduced hydrologic soil group for subsurface drainage. Therefore, because of this reduced runoff, RUSLE2 computes less erosion and sediment yield for situations where contouring and deposition is involved.

If a subsurface drainage support practice is selected, the production (yield) level value should be changed accordingly from the undrained condition.

14.4.3. Calibration/validation

A rule of thumb is that tile drainage reduces rill-interrill erosion by about 40 percent.[155] RUSLE2 computations based on the principles described in **Section 14.2** were made for a wide range of soil textures and drainage intensities to ensure that RUSLE2 gives this result overall. Based on a review of the values listed in Table 14.8 and other values, RUSLE2 was judged to adequately capture the main effects of subsurface drainage on rill-interrill erosion for conservation and erosion control planning. The values shown in Table 14.8 do not consider how subsurface drainage affects yield and its consequent effect on erosion, which is an additional subsurface drainage effect.

14.4.4. Interpretation

Just as for other support practices, RUSLE2 erosion estimates for subsurface drainage represent broad, general effects more than site specific effects. RUSLE2 captures how factors related to site location, vegetation production (yield) level, soil properties, soil position on the landscape, and characteristics of the drainage system affect erosion. RUSLE2 results are much better than the rule of thumb that subsurface drainage reduces erosion by 40 percent. The accuracy of RUSLE2 erosion estimates for subsurface drainage is similar to that for other support practices, including contouring.

Sometimes subsurface drainage is given little consideration as an erosion control practice. It is seldom installed solely for erosion control because of its expense. However, research clearly shows that subsurface drainage significantly reduces erosion in certain conditions, and, therefore, erosion reduction should be recognized as an important benefit of subsurface drainage. Sometimes subsurface drainage is considered to be environmentally detrimental because it is used to drain wetlands, for example.

---

[155] See:
AH703

Bengston, R.I. and G. Sabbage. 1988. USLE P-factor for subsurface drainage in a hot, humid climate. ASAE Paper 88-2122. American Society of Agricultural Engineers. St. Joseph, MI.

Formanek, G.E, E. Ross, and J. Istok. 1987. Subsurface drainage for erosion reduction on croplands of northwestern Oregon. In: Irrigation Systems of the 21st Century. Proceeding Irrigation and Drainage Division Specialty Conference. American Society of Civil Engineers. New York, NY. pp. 25-31.

Schwab, G.O. 1976. Tile or surface drainage for Ohio's heavy soils? Ohio Report. March-April. Ohio Agricultural Experiment Station. Columbus, OH.

Schwab, G.O. and J.L. Fouss. 1967. Tile flow and surface runoff from drainage systems with corn and grass cover. Transactions ASAE 10:492-493, 496.

Skaggs, R.W., A Nassehzadeh-Tabrizi, and G.R. Foster. 1982. Subsurface drainage effects on erosion. Journal of Soil and Water Conservation 37:167-172.

Table 14.8. RUSLE2 computed effect of subsurface drainage on erosion as a function of soil erodibility factor value (K) ad hydrologic soil group at three locations (does not consider any change in yield)

	Erosion drained/erosion undrained
silty clay soil (K = 0.20 US units), change in hydrologic soil group from D to A	
Ft Wayne, IN	0.38
Raleigh, NC	0.38
Jackson, MS	0.38
silty clay soil (K=0.20), hydrologic soil group D to C	
Ft Wayne, IN	0.83
Raleigh, NC	0.78
Jackson, MS	0.75
sandy loam soil (K = 0.30), hydrologic soil group D to A	
Ft Wayne, IN	0.58
Raleigh, NC	0.57
Jackson, MS	0.60
silt soil (K = 0.55), hydrologic soil group from D to A	
Ft Wayne, IN	0.77
Raleigh, NC	0.76
Jackson, MS	0.77

However, subsurface drainage should be recognized for its merits in appropriate situations.

Perhaps more than any other practice, the subsurface drainage component in RUSLE2 is subject to misuse. For example, subsurface drainage is most effective on relatively flat hillslope areas less than 3 percent steep and in localized areas of wet soils. RUSLE2 does not identify where subsurface drainage should not be used. Technical standards should be consulted for information on subsurface drainage applications.

14.4.5. Input

The **deep (subsurface) soil drainage system descriptions** in the RUSLE2 database have a single input of **portion of the hillslope that is well drained.** The other RUSLE2 inputs to represent subsurface drainage are the hydrologic soil groups in the **soil description** for the undrained and drained conditions (see **Section 7.7**) and the production (yield) level input in the **cover-management description**s used for the drained and undrained conditions (see **Section 10.2.4**).

The hydrologic soil group input represents the degree that subsurface drainage reduces runoff potential of the soil under the unit plot condition given the site location, the soil's position on the landscape, soil profile properties, naturally occurring soil restrictive layers, and subsurface drain depth and spacing. Multiple **soil descriptions** for the same soil profile can be created for various drain depths and spacings. The input for the hydrologic soil group for the drained condition should reflect the site's location. For example, subsurface drainage may have a greater effect on the reduction of runoff potential on a coarse texture soil at a low precipitation location when compared to a high precipitation location. The input for hydrologic soil group for the undrained and drained conditions reflects soil profile properties, especially texture. As discussed in **Section 14.2**, subsurface drainage does not automatically reduce the hydrologic soil group to **A** for all soils, especially fine textured soils.

The NRCS soil survey database and the NRCS RUSLE2 database may have a hydrologic soil group assigned for drained conditions. Check the criteria that NRCS used to select hydrologic soil groups to ensure consistency with RUSLE2 criteria.

Vegetation production (yield) level is usually increased by subsurface drainage because increasing crop production is the major reason for subsurface drainage. Use appropriate yield values for both the undrained and drained conditions.

Subsurface drainage was installed decades ago in many farm fields. When applying RUSLE2 to these fields, the easiest approach is to ignore subsurface drainage if no assessment is being made on how subsurface drainage affects erosion. Make sure that the hydrologic soil group input for the undrained condition and the input for vegetation production (yield) level represents the current field condition. RUSLE2 computes a subsurface drainage effect only if the hydrologic soil group input for the drained condition differs from the corresponding input for the undrained condition, and different vegetation production (yield) level inputs are not entered for the drained and undrained conditions.

The input for **portion of the hillslope that is well drained** is used to compute erosion for an overland flow path where only a portion of it is subsurface drained. An overland flow path having a complex:convex-concave profile is an example. The lower concave portion of this profile can have high soil wetness because of a low landscape position. Localized subsurface drainage is used to eliminate this soil wetness. Soil wetness is not a problem on the upper part of the overland flow path. An input value less than 100 percent for **portion of the hillslope that is well drained** represents this situation. RUSLE2 uses this input to weight its detachment (sediment production) computations and the curve numbers it uses to computes runoff for the undrained and drained conditions.

Also, this input can be used to reduce the effect that RUSLE2 computes for subsurface drainage. For example, if RUSLE2 is judged to compute too much erosion reduction, a value less than 100 percent can be input to reduce the subsurface drainage effect computed by RUSLE2. If the trivial input of zero (0) is entered, RUSLE2 computes no subsurface drainage effect on erosion, unless different yield values are used for the undrained and drained conditions.

RUSLE2 does not notify the user when it computes questionable erosion estimates for subsurface drainage. The RUSLE2 user must know where and how subsurface drainage is used and must make the proper inputs.

14.5. Irrigation

14.5.1. Description of practice

Irrigation adds water to the soil to increase vegetation (crop) production or to dispose of waste. The principal irrigation types are surface, sprinkler, and subsurface applied water. Surface irrigation discharges water in a line source at an upslope field edge and water infiltrates along the flow path, which results in discharge rate decreasing with downslope distance.[156] Although surface irrigation can cause high erosion, RUSLE2 does not estimate this erosion because RUSLE2 assumes an increasing discharge rate along its flow path.

RUSLE2 can not be used to estimate erosion directly caused by irrigation.

Sprinkler irrigation applies water through a system of pipes and overhead spray nozzles. Water is applied to only a portion of the area at a time. The water application is moved through time to cover the entire area. A two week cycle might be used, for example, to cover the entire area with multiple applications over a crop production season. Water is applied at a sufficiently low rate so that no runoff, and thus no erosion, occurs.

Subsurface (drip) irrigation applies water through a system of underground pipes and emitters. This type of irrigation does not cause rill-interrill erosion.

Although RUSLE2 is not used to estimate rill-interrill erosion caused by any type of irrigation, it can be used to estimate erosion caused by rainfall to reflect how irrigation changes the field conditions that affect rill-interrill erosion.

14.5.2. Basic principles

A main effect of irrigation captured by RUSLE2 is increased soil moisture that increases soil erodibility, increases biomass decomposition, and decreases soil surface roughness and soil ridge height. The main inputs to represent irrigation in RUSLE2 are the vegetation production (yield) level appropriate for the irrigation management, amount of water added by irrigation, and amount of biomass added in the irrigation water.

[156] The erosion mechanics of surface irrigation are described by Toy, T.J., G.R. Foster, and K.G. Renard. 2002. Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley and Son, New York, NY.
.

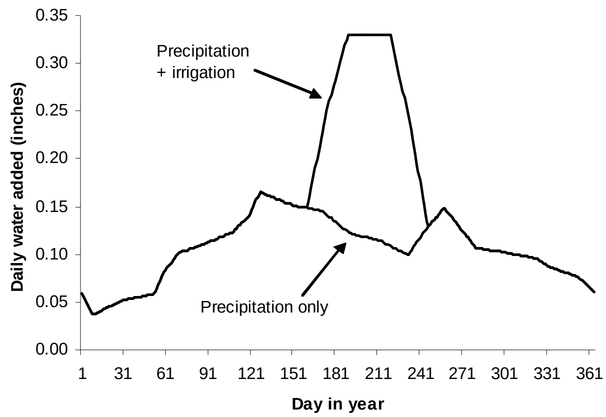

Figure 4.17. Precipitation and water added by irrigation for a 112 bu/ac corn crop at Columbia, Missouri.

RUSLE2 computations for the effect of irrigation were made for a 112 bu/ac conventionally tilled and a 112 bu/ac no-till corn crop at Columbia, Missouri. The results are summarized in Figure 14.17-14.20. In this example, irrigation water was added at the rate to just meet daily consumptive use, which is illustrated in Figure 14.17. The daily water added by irrigation is summed with daily precipitation, which is used to compute daily soil erodibility, daily decomposition, and daily loss of soil surface roughness and ridge height.

A major effect of irrigation computed by RUSLE2 is the increased soil erodibility during the irrigation period, which is illustrated in Figure 14.18. An upper limit is placed on how much added irrigation water can increase soil erodibility. No daily soil erodibility value can be greater than twice the soil erodibility value computed by a RUSLE2 nomograph.

The other major effect of irrigation is that it increases residue decomposition. Figure 10.19 shows the increase in decomposition computed by RUSLE2 for the 112 bu/ac no-till corn at Columbia, Missouri. The increase in decomposition was not great. The relative increase will be significantly greater in dry regions, such as Scotts Bluff, Nebraska. Very little of the decomposition effect continues beyond harvest because of the large amount of residue added by harvest.

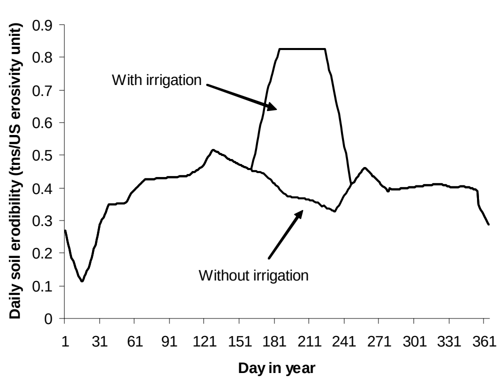

Figure 14.18. Effect of irrigation on daily soil erodibility at Columbia, Missouri.

Most of the effect of irrigation on erosion is during the irrigated period, as shown in Figure 10.20 by daily erosion rates computed for the 112 bu/ac conventionally tilled corn. The computed annual increase in erosion was from 24 to 30 tons/acre·year and 1.5 to 2.4 tons/acre·year, for the conventionally tilled and no-till crops, respectively. This difference in erosion is for the same yield. These computations illustrate how irrigation affects RUSLE2 computed erosion if nothing changes other than adding irrigation. The proper calculation would have been to input a yield value appropriate for the irrigated conditions. The RUSLE2 computed erosion is 26 tons/acre·year if the irrigation is assumed to increase yield from 112 bu/ac to 150 bu/ac. Further erosion reduction would have occurred if the applied irrigation had a significant content of bio-solids.

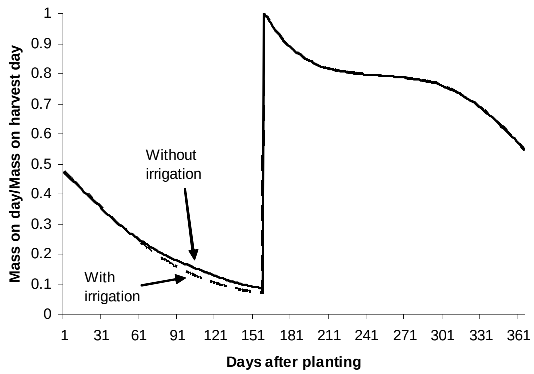

Figure 14.19. RUSLE2 computed decomposition for no-till corn at Columbia, Missouri.

14.5.3. Calibration

The RUSLE2 procedure that describes how irrigation affects erosion caused by natural precipitation (rainfall) and its associated runoff was not calibrated. Computed erosion values were not compared to measured values. However, erosion values were computed for a range of conditions and reviewed to ensure that RUSLE2 gives values acceptable for conservation planning.

14.5.5. Inputs

The input yield values should be appropriate for the irrigated management system (see **Section 10.2.4**). The effect of the increased yield that reduces erosion is just as important as the increased soil moisture that increases erosion. The best way to input yield values for irrigation is to create vegetation descriptions specifically for irrigated conditions. These vegetation descriptions include consumptive use values. A vegetation description is selected that is appropriate for the region, soil, and irrigation management system. Yield values in the cover-management descriptions using these vegetation descriptions can be varied to accommodate site-specific conditions. The RUSLE2 yield adjustment procedure for vegetation descriptions adjusts consumptive use values along with the other values.

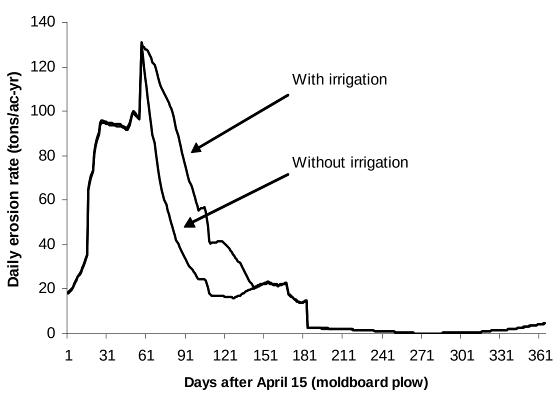

Figure 14.20. RUSLE2 computed effect of irrigation on daily erosion rate for 112 bu/ac conventionally corn at Columbia, Missouri.

The amount of water added by irrigation can be input using either of: (1) consumptive use through time, (2) dates and application rates on those dates, and (3) and period application depths. Irrigation systems are typically designed to supply water at the daily consumptive use of the crop being grown. Therefore, the consumptive use input method is preferred for inputting irrigation amount values in RUSLE2. Daily consumptive use values are entered in the vegetation description for the irrigated system, soil, and region. Consumptive use values depend on the crop and its yield, location, soil, and perhaps other factors.[157] If consumptive use is less than natural precipitation, such as for supplemental irrigation in the southeastern US, one of the other two input methods can be used to input irrigation amounts.

The other two input methods for irrigation amount are to enter application rates on particular days or to enter irrigation amounts (depths) by period. These periods are at the user's choice, which can be monthly, biweekly, or arbitrary non-uniform periods. Consideration should be given to reducing added water amounts for irrigation systems, such as drip irrigation, that do wet the surface soil.

The effect of added biomass that is applied by irrigation (e.g., for example waste disposal of bio-solids) is represented by including an **operation** that **adds external residue** in cover-management descriptions (see **Section 10.2.6**). Biomass added by irrigation is represented in a cover-management description having an **operation description** that applies **external residue** (see **Section 10.2.6**). This cover-management description involves the date of the operation that applies the biomass, biomass amount (dry matter basis) added by the operation (not the average annual mass applied), and the selection of a **residue description** that represents the applied biomass (see **Section 12**). RUSLE2 applies external residue by event rather than on a continuous daily rate. If biomass is applied by an irrigation system that operates on a cycle, the dates of the **add biomass** operation should be on the same frequency as the irrigation cycle. If the biomass is applied daily, the application can be approximated by applying a two week biomass amount once every two weeks. A sensitivity analysis (see **Section 17.3**) can be conducted to determine if the biomass can be applied in monthly intervals rather than in biweekly or other intervals. Decomposition characteristics of the biomass mainly determine the frequency of the biomass applications when approximating daily applications.

14.5.4. Interpretation

[157] Values for consumptive use and other information related to irrigation application rates can be obtained from local offices of the USDA-NRCS and Extension Service affiliated with Land Grant Universities in each state.

The RUSLE2 intent is to capture broad, main effects of increased soil moisture caused by the addition of water by irrigation. RUSLE2 does not capture hydrologic and hydraulic detail. The purpose of RSULE2 is to provide information useful for conservation and erosion control planning, not for irrigation system design. RUSLE2 estimated erosion for the effect of irrigation is comparable in accuracy to RUSLE2 computed values for other support practices, including contouring. Using RUSLE2 to evaluate the effect of irrigation on rill-interrill erosion by rainfall is much better than disregarding the effect.

15. APPLICATION OF RUSLE2 TO PARTICULAR LAND USES

RUSLE2 is **land use independent**, which means that RUSLE2 estimates rill-interrill erosion caused by rainfall and its associated Hortonian-type overland flow any where mineral soil is exposed (see **Section 5**). This capability is a major advantage when applying RUSLE2 to reclaimed mined land, waste disposal sites, disturbed forest land and mechanically disturbed military lands, and other lands where climate, soil, topography, and cover-management variables that affect erosion traverse the spectrum of conditions on common land use classifications such as cropland, rangelands, grazing lands, pasture lands, and disturbed forest lands. Erosion conditions on a common land use like cropland vary from a bare, highly erodible soil to a highly erosion resistant, well maintained pasture. Similarly, erosion conditions on rangeland vary from a highly erodible, recent mechanically disturbed pipeline construction site to a site never mechanically disturbed other than by wild animal presence. Well designed erosion prediction technology like RUSLE2 is based on a description of the fundamental variables that are land use independent. Erosion is a mechanical process where soil particles are detached and transported when the forces on them from raindrop impact and surface runoff become sufficiently strong.

Erosion prediction technologies designed for specific land uses like rangelands are much more limited than is RUSLE2, even when applied to that land use. RUSLE2's land-use independence allows it to be applied anywhere mineral soil is exposed to the erosive forces of raindrop impact and surface runoff produced by Hortonian overland flow.

However, many RUSLE2 users' applications will be limited to specific land uses such as construction sites. Easy-to-use RUSLE2 user guides targeted to specific land uses are needed. This RUSLE2 User's Reference Guide provides reference information on which to base user guides for specific land uses. Such RUSLE2 user guides will include input data and other land use specific information not available in this RUSLE2 User's Reference Guide. Also, user guides are needed that describe RUSLE2 computer program mechanics and operations for specific land uses.

An example of user guides for a specific land use includes a workbook and a user manual for construction sites and other highly disturbed lands. These documents are available from the International Erosion Control Association.

A primary source of RUSLE2 information is the USDA-ARS RUSLE2 Internet site http://www.ars.usda.gov/Research/docs.htm?docid=6010. The University of Tennessee and the USDA-Natural Resources Conservation Service, both of whom participated in the RUSLE2 development, also maintain RUSLE2 Internet sites.

Several RUSLE2 related documents are helpful for developing land use specific RUSLE2 user guides. Not all information in these and other RUSLE2 related documents applies to RUSLE2. Always check information from other sources to ensure that it is consistent with the RUSLE2 User's Reference Guide before using it in RUSLE2 applications.

15.1. Additional RUSLE2 Related Documents[158]

Dissmeyer, G.E. and G.R. Foster. 1980. A guide for predicting sheet and rill erosion on forest land. Technical Publication SA-TP-11. USDA-Forest Service-State and Private Forestry-Southeastern Area. 40 pp.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Dept. of Agriculture, Agricultural Handbook 703, U.S. Govt Printing Office, Washington, D.C.

Toy, T.J. and G.R. Foster (coeditors). 1998. Guidelines for the use of the Revised Universal Soil Loss equation (RUSLE1.06) on mined lands, construction sites, and reclaimed lands. USDI-Office of Surface Mining. Denver. CO.

Wischmeier, W.H. and D.D. Smith. 1965. Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains: A guide to conservation planning. U.S. Dept. of Agriculture, Agriculture Handbook No. 282. U.S. Govt Printing Office, Washington, D.C.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting Rainfall-Erosion Losses: A guide to conservation planning. U.S. Dept. of Agriculture, Agriculture Handbook No. 537. U.S. Govt Printing Office, Washington, D.C.

[158] See the USDA-ARS RUSLE2 Internet Site at http://msa.ars.usda.gov/ms/oxford/nsl/rusle/index.html (ARS reveiwer, check this) for information on how to obtain copies of these and other RUSLE2 related documents.

16. CORE DATABASE

A core database was used to develop, verify, and validate RUSLE2 for a base set of conditions. Values selected for new entries in a user's RUSLE2 working database should be selected based on information in this **RUSLE2 User's Reference Guide** and values in the **RUSLE2 core database**. Values for new entries must follow RUSLE2 definitions and be consistent with RUSLE2 core database values. Also, the **RUSLE2 core database** values must be used when RUSLE2 is being evaluated against the USLE, RUSLE1, and other erosion prediction technologies, against research data, and other analyses.

The **RUSLE2 core database** can be obtained from the official USDA-Agricultural Research Service Internet site http://www.ars.usda.gov/Research/docs.htm?docid=6010 maintained at the National Sedimentation Laboratory in Oxford, Mississippi. The **RUSLE2 core database** is named **RUSLE2 core data**.

17. EVALUATION OF RUSLE2

17.1. Verification/Validation

Verification is the process of ensuring that RUSLE2 makes its calculations as intended. Verification ensures that the equations, parameter values, and logic that links the equations have been programmed as designed and give the expected results. Verification involves running the model for the range of: research data used to derive the model, the RUSLE2 core database, and field conditions for which RUSLE2 might be used. Also, verification involves running the model for special conditions to make sure that every equation and every logic step in the model is exercised. The objective is to test every element of the model to find and fix all errors.[159] This verification process was extensively and fully followed in developing RUSLE2.

No guarantee is made that RUSLE2 contains no computational errors, only that an aggressive effort was made to find and fix errors.

Validation is the process of ensuring that RUSLE2 serves its intended purpose as described…"[160]

The stated purpose of RUSLE2 is to guide conservation and erosion control planning by users at the field office level, such as the field offices of the USDA-Natural Resources Conservation Service (NRCS). RUSLE2 was designed to be land use independent and is to apply to all conditions where rainfall and its associated Hortonian overland flow cause rill-interrill erosion of exposed mineral soil (see **Section 5**). RUSLE2 does not apply to erosion caused by runoff during irrigation (see **Section 14.5**) or snow melt (see **Section 6.3.3**). RUSLE2 is not a process representation of erosion, and RUSLE2 is not a tool for discovering new, original scientific knowledge about erosion. RUSLE2 represents its developers' interpretation of research data, accepted scientific and technical information, and judgments about use of erosion prediction technology in conservation and erosion control planning (see **Section 17.2**).

The most important part of RUSLE2's validation is whether RUSLE2 leads to the desired erosion control decision, not how well RUSLE2 estimates compare to measured data. Validation certainly involves evaluating RUSLE2's accuracy, but many other considerations are also important in judging how well RUSLE2 serves its stated purpose. For example, a model could perfectly compute erosion, but if the resources required to use the model exceed available resources, the model is invalid, (i.e., it does not serve its intended purpose).

---

[159] Essentially a quote from Toy, T.J., G.R. Foster, and K.G. Renard. 2002. Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley and Son, New York, NY. p. 146.
[160] Essentially a quote from Toy et al., 2002. p. 146. Also, see pp. 146-149 regarding model validation.

RUSLE2 should be easy and convenient to use, including when it is used infrequently. RUSLE2 must not require excessive resources including: time required to learn the model; time to actually run the model in developing a conservation or erosion control plan; acquisition, assembly, and entry of input data; computer skills; and technical expertise required to run RUSLE2. Support documents, training, and assistance when problems arise must be available.

Are the benefits gained from using RUSLE2 worth its costs, especially in comparison to using alternative methods to develop conservation and erosion control plans? How does the quality of conservation and erosion control plans developed with RUSLE2 compare with those developed from use of other erosion prediction technologies? If two erosion prediction technologies result in the same conservation and erosion control plan, each technology performs equally well. The choice of a specific erosion prediction technology is, therefore, determined by preferences and resources required to use each technology.

RUSLE2 must accurately represents scientifically accepted trends of how major variables such as precipitation amount and intensity, soil texture, overland flow path length and steepness, ground cover, soil biomass, and contouring affect erosion. Research data available to develop erosion prediction technology are unavoidably incomplete and biased. The data do not represent all of the conditions where RUSLE2 will be applied, and consequently, numerous RUSLE2 applications will be extrapolations beyond the data used to derive RUSLE2. Therefore, whether RUSLE2 accurately represents scientifically accepted trends is a key factor in how well RUSLE2 performs when extrapolated. RUSLE2 was also developed to be robust so that extrapolations are conservative and conform to obvious, defined limits, (i.e., if RUSLE2 estimates are erroneous, the estimates will not be unreasonable).

Erosion data have a high degree of explained variability and bias. For example, regression fitting of an equation to a particular experimental data set gives the nonsensical results that the fitted equation computes increased erosion with increased ground cover. The data are obviously flawed or biased by incompleteness, measurements not based on RUSLE2 definitions, or measurement error. RUSLE2 describes accepted scientific trends even though the fit to particular observed data may be compromised.

RUSLE2 developers envisioned themselves in the position of land users impacted by RUSLE2. Given their knowledge of both erosion science and RUSLE2's representation of that science, RUSLE2 developers asked themselves the question, do they have sufficient confidence in RUSLE2 erosion estimates in particular situations to be willing to implement RUSLE2 based erosion control practices?

Users should assure for themselves the validity of RUSLE2. This RUSLE2 User's Reference Guide describes in detail how RUSLE2 was derived, what it represents, and how RUSLE2 represents accepted scientific and technical information.

17.2. Interpretations in the context of conservation and erosion control planning

The RUSLE2 developers followed several fundamental principles to interpret research data used to empirically derive and calibrate RUSLE2 equations and to validate RUSLE2. Whether or not RUSLE2 is considered valid depends on the acceptance of these principles.

17.2.1. Principle 1: Fit main effects

The first step in applying the **main effects principle** is to assemble the largest possible dataset for the erosion control practice or other condition being analyzed. These datasets are seldom ideal because of incomplete, non-uniform, and biased coverage, and much unexplained variability.[161] The second step is to identify the variables and equation form based on erosion theory and fundamental erosion process studies that will be used to describe the main effects. Analyzing erosion data for no-till cropping provides a case study for illustrating the main effects principle.

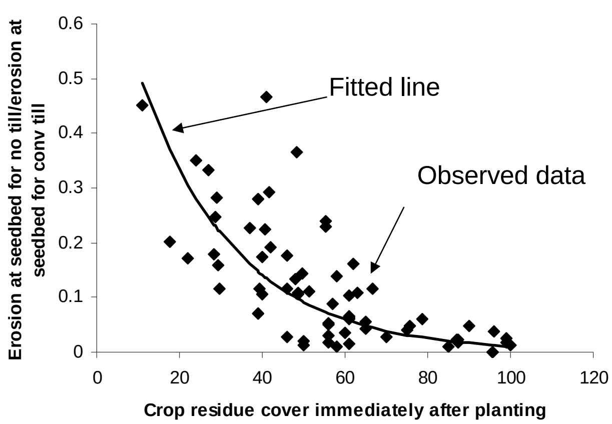

Figure 17.1. Relation of erosion with no-till cropping to erosion with conventional tillage for seedbed period.

Conservation tillage, including no-till, is widely used to control erosion on cropland. Experimental erosion data for no-till cropping are plotted in Figure 17.1 where the dependent variable is ratio of erosion with no-till to erosion with conventional till for the seedbed period. Results from many fundamental erosion studies involving applied mulch show that erosion decreases rapidly as ground cover increases as represented by Equation 9.6.[162]

[161] Nearing, M.A., G. Govers and L.D. Norton. 1999. Variability in soil erosion data from replicated plots. Soil Sci. Soc. Amer. J. 63: 1829-1835.

[162] See, for example,

Manering, J.V. and L.D. Meyer. 1963. Effects of various rates of surface mulches on infiltration and erosion. Soil Science Society of America Proceedings 27:84-86.

Therefore, ground cover is assumed to be a main effect variable for no-till's effect on erosion.

The deviation in erosion from the main effect is large in Figure 17.1. For example, the fitted value at 50 percent ground cover (crop residue cover) is 0.1 while the experimental values ranged from about 0.02 to 0.4. Other variables have a significant effect, which is captured in RUSLE2 by varying the coefficient **b** in equation 9.6.

Erosion theory and fundamental experimental erosion studies show that the coefficient **b** varies with the rill to interrill erosion ratio because of difference between rill erosion and interrill erosion mechanics. Ground cover reduces rill erosion more than it reduces interrill erosion.[163] Values for **b** are larger where rill erosion is dominant on bare soils, such as on relatively steep overland flow paths (greater than 12 %), than where interrill erosion is dominant, such as on relatively flat overland flow paths (less than 3%).

Fundamental erosion studies show that **b** values are increased when added ground cover increases infiltration, which in turn reduces runoff and rill erosion. Increased biomass in the upper soil layer accompanies increased ground cover in long term no-till cropping but not in short term no-till cropping or in mulch applied to freshly graded construction sites. Consequently, **b** values are a function of land use. Rather than making **b** values a function of land use classification, RUSLE2 computes **b** values as a function of cover-management variables.[164] For example, RUSLE2 detects the difference between a construction site and a no-till cropped field using the soil consolidation factor and the amount of soil biomass in the upper soil layer.

This approach of using equations to represent main effects of major universal climate, soil, topographic, and cover-management variables rather associating equations and coefficient values with a land use classification gives RUSLE2 its land use independence.

The concept in RUSLE2 is to describe the main effect that major variables have on erosion and then compute deviations about the main effect using secondary variables. RUSLE2 properly represents trends apparent from an overall analysis of the experimental data and erosion science even though RUSLE2 may not faithfully reproduce individual

---

Meyer, L.D., W.H. Wischmeier, and G.R. Foster. 1970. Mulch rates required for erosion control on steep slopes. Soil Science Society of American Proceedings 34:928-931.

[163] Foster, G.R. and L.D. Meyer. 1975. Mathematical simulation of upland erosion by fundamental erosion mechanics. *In:* Present and Prospective Technology for Predicting Sediment Yields and Sources. ARS-S-40 USDA-Science and Education Administration. pp. 190-204.
[164] RUSLE1.06 assigns **b** values as a function of land use classification. RUSLE1.05 assigns b_g values according to a user selected classification for rill to interrill erosion ratio.

data values in an experimental dataset. The RUSLE2 approach increases robustness, which means that RUSLE2 can be more confidently extrapolated beyond the data used to derive it than can regression equations involving a large set of variables fitted to the data.

Selecting equations and coefficient values based on best statistical fits to experimental field data can produce very flawed results for conservation and erosion control planning. The results can be especially flawed if the experimental data have a high degree of unexplained variability and are non-uniform in coverage, incomplete, and biased, problems impossible to avoid in erosion data. For example, the regression approach can result in nonsensical results where erosion is computed to increase as ground cover increases. RUSLE2 faithfully reproduces trends proven by erosion science rather than simply providing the best fit to experimental data that are almost always flawed.

17.2.2. Principle 2: Don't custom fit to local data or to specific data

Some users adjust RUSLE2 parameter and input values to fit a particular data point because that data point is considered more valid that other data points. Increased value is placed on that data point because the data came from a particular locale or because of familiarity with the investigator who collected the data. RUSLE2 adjustments and evaluations based on how well RUSLE2 fits a single data point are generally improper.

RUSLE2 is designed to fit main effects as described in **Section 17.2.1**. Erosion data are highly variable and have a high degree of uncertainty for unknown reasons, especially if the measured erosion rates are low (less than 1 ton/acre per year). The validity of any single data point is, therefore, highly questionable. The validity of a single data point must be judged against the dataset as a whole.

If a particular data point is judged to be valid, fitting RUSLE2 to the single data point should still be avoided. Calibrating RUSLE2 to a data point could well result in RUSLE2 estimates that are seriously erroneous because RUSLE2 no longer will fit the main effect. Either RUSLE2's fit of this single data point should be considered in a particular RUSLE2 application, or another erosion prediction procedure should be used instead of RUSLE2.

17.2.3. Principle 3: Follow RUSLE2 definitions, rules, procedures, guidelines, and core database values

RUSLE2 uses specific definitions, rules, procedures, and core database values that must be followed. RUSLE2 definitions, rules, and procedures were chosen for specific reasons that are sometimes not obvious. For example, adjusting RUSLE2 soil erodibility K factor values to account for increased organic matter resulting from organic farming or applying manure is improper and gives erroneous results. Similarly, soil erodibility factor values adjusted for surface rock fragments should not be used. RUSLE2 considers the effect of rock cover and increased soil biomass in its cover-management computations. The soil erodibility factor applies specifically and only to unit plot conditions.

Similarly, RUSLE2 core database values must be followed because RUSLE2 was calibrated based on those values. The core database values were selected to represent main effects adequately supported by research data and erosion science. The values were selected to be consistent with accuracy of RUSLE2 and the data used to derive RUSLE2. Input values for database entries not represented in the RUSLE2 core database must be consistent with core database values for similar conditions.

While you as a user may not agree with the RUSLE2 definitions, rules, procedures, and core database values, they must be observed. Do not assume that USLE and RUSLE1 definitions, rules, procedures, and input values apply to RUSLE2, because many do not.

17.2.4. Principle 4: Don't evaluate RUSLE2 based on how well it fits secondary variables

RUSLE2 was developed, calibrated, and validated to ensure that it gives good average annual erosion estimates, even if the fit of RUSLE2 computed values for secondary variables (e.g., crop residue) is less than expected. For example, RUSLE2 typically under estimates residue cover for periods longer than about 1 year, but this underestimate does not mean that the average annual erosion estimate is erroneous, especially in rotation-type cover-management descriptions where a large amount of residue is added annually. The adequacy of RUSLE2 computed values for secondary variables is based on RUSLE2 computing the expected erosion estimate, not on how RUSLE2 computed values for secondary variables are used for non-RUSLE2 purposes.

RUSLE2 estimates of crop residue cover immediately after planting can be used in routine conservation planning and compliance activities.

However, situations arise where the RUSLE2 accuracy of a secondary variable is insufficient in a particular RUSLE2 application. An example is applying RUSLE2 to a construction site two or more years after only a single mulch application. Separate RUSLE2 computations using different input residue values for each year may be required to accurately compute erosion in particular years.

Users should use this RUSLE2 User's Reference Guide to determine where RUSLE2 erosion estimates may need special interpretations or RUSLE2 inputs may need adjustment.

17.2.5. Principle 5: Avoid fine tuning parameter and input values

If you must adjust parameter and input values, be sure that you understand the variable being adjusted and how it is used in RUSLE2. Carefully read and follow this RUSLE2 User's Reference Guide to avoid unintended consequences.

Adjusting input values so that RUSLE2 computes an expected residue cover is an example where adjustments are sometimes made. Because RUSLE2 has many interacting variables, changing the value for a single variable may affect several computations. For example, changing the value for the residue decomposition coefficient affects surface residue cover and soil biomass as well. Soil biomass affects computed values for the soil biomass subfactor, surface roughness, and runoff. If the change is only to affect surface residue cover, the residue decomposition coefficient value is not the input variable that should be changed.

Another example where changing the value of a single variable can have unexpected results is the width of soil disturbance. Changing the value for this variable affects more than the soil consolidation subfactor value because several RUSLE2 computations are a function of the soil consolidation subfactor.

Section 12.5 describes a procedure for adjusting input values to obtain an expected residue cover. This procedure is a guide for changing input values for other variables to achieve a particular result.

Make sure that the proper variables are being changed to achieve the desired result.

17.2.6. Principle 6: Make sufficient temporal and spatial field measurements according to RUSLE2 requirements

Canopy, surface cover, surface roughness, and yield are variables that are sometimes field measured as a part of evaluating RUSLE2 and collecting field data for RUSLE2 input. Measuring root biomass should not be attempted except in a very carefully managed research environment, and even then the results are questionable. Soil biomass as used in RUSLE2 should be back calculated from other variables because it is almost impossible to measure.

Field measured values vary randomly and systematically (e.g., a combine leaving residue in strips) in both space and time. Field measurements must be proper and in sufficient number to account for variability keeping in mind that RUSLE2 is designed to represent main effects. Canopy cover, surface cover, fall height, and other RUSLE2 variables must be measured based on RUSLE2 definitions, rules, and procedures to accurately evaluate

RUSLE2 and properly selected input values. Also, many RUSLE2 relationships are nonlinear, which affects how field measurements are made, analyzed, and interpreted. Follow this RUSLE2 User's Reference Guide closely in making field measurements.

Field measurements of residue surface cover are often made and used in the conservation planning and compliance determination on cropland. Given the importance of residue surface cover, special precautions should be observed in making residue cover

Field measurements must be made in accordance with RUSLE2 definitions, rules, and procedures.

measurements.

Both high residue and low residue cover is difficult to measure and convert to residue mass values, partly because of the non-linear residue mass-cover relationship (see **Section 12.3**). Residue samples must be carefully collected and processed (e.g., soil particles carefully removed). The residue mass to cover relationship varies within the field and during the year as the relative composition of plant parts (leaves, stems, and other components) vary in the residue. The relationship also varies from year to year as weather, yield, and field operations vary. Residue measurements should be made over a minimum of three years to obtain values that can be compared to RUSLE2 estimates. Experience also shows that when residue surface cover is accurately measured, cover is often less than assumed based on visual observations.

Soil surface roughness values used in RUSLE2 computations are not the input values because RUSLE2 adjusts the input values for soil texture and soil biomass (see **Section 9.2.3.2**). Also, field measured values for soil surface roughness only match input values when roughness is measured for the base condition used to define RUSLE2 soil surface roughness input values.

The terminology and definitions of plant cover used in vegetation surveys may be quite different from the very specific definitions of canopy cover, ground cover, live ground cover, and fall height used in RUSLE2. Also, the definitions of vegetation production (yield) level may be quite difference from RUSLE2 definitions and input values in the RUSLE2 core database.

Before using information from vegetation surveys, ensure that the values taken from these survey are proper when using them for RUSLE2 input.

17.2.7. Principle 7. Avoid too much detail

Difference between RUSLE2 computed erosion estimates may not be significant. Significance in this context is not the same as statistical significance discussed in **Section 17.4**. In this context, significance refers to a sufficient difference resulting in a conservation planning or compliance decision being altered.

The general guideline is that difference in estimated erosion values should exceed 10 percent because the difference is considered practically significant.

RUSLE2 is not designed to capture the difference between machine adjustments on particular tillage machines, unless the effect of the adjustment is sufficiently great. RUSLE2 is designed to distinguish between machine classes such as straight, sweep, and twisted shovel type chisel plows. Some of the differences in residue burial that are often claimed to be achievable by machine adjustment are questionable (see **Section 13.1.5.3**). Input values should be for machine classes and not varied to reflect individual machine configuration or operation.

Similarly, RUSLE2 is not designed to capture differences between crop varieties other than major differences such as between popcorn and field corn, for example. When differences between crop varieties grown in different regions are sufficiently great to give erosion estimates that differ by more that 10 percent (i.e., the 10 percent rule), differences in crop varieties should be represented. Likewise, dates in cover-management descriptions should be selected to represent major differences such as early, mid, and late season planting and/or harvest, not to represent operations on particular dates. Also, RUSLE2 is not intended to capture how annual variation in operation dates within a cover-management description affects erosion.

RUSLE2 users, especially those who prepare RUSLE2 databases, have the responsibility of determining when difference are sufficiently great to warrant creating new entries in the RUSLE2 database with different input values. Differences in erosion estimates because of difference in inputs values for similar conditions are a partial measure of uncertainty and precision in RUSLE2 erosion estimates.

17.2.8. Principle 8. Computing erosion with RUSLE2 for historical events and individual storm events is an advanced application

RUSLE2 is a conservation planning tool, not a model that reproduces historical erosion events. RUSLE2 is not designed to be evaluated or calibrated by inputting historical data to compute erosion values that are compared to values measured at a particular site. Also, RUSLE2 is not designed to evaluate how historical events such as an unusually dry or wet season or year affected erosion. The uncertainty in RUSLE2 erosion estimates for these applications is much greater than in average annual erosion estimates.

RUSLE2 is not structured to readily accommodate input of historical data, especially weather data for multiple years. Also, RUSLE2 does not represent temporal variations in soil moisture that can greatly affect runoff from individual storm events. RUSLE2 does not conveniently represent residual effects from a previous year, although expert RUSLE2 users can capture much of the effects of these initial conditions. RUSLE2 does not model how vegetation responds to environmental conditions, but values that represent the vegetation and operations for a specific historical period can be input into RUSLE2.

The adequacy of the historical experimental data against which RUSLE2 is being evaluated must be considered. Are the historical, experimental data comparable to the data used to develop RUSLE2 parameter and input values? If not, RUSLE2 computed erosion may not compare well with the measured erosion. A poor fit does not necessarily indicate that RUSLE2 performs poorly, but that the historical experimental data are not representative of the main effects represented by RUSLE2.

A short record, such as three years, often produces data that differ significantly from average annual erosion values measured over an extended period or estimated by RUSLE2. The cover-management data used to develop RUSLE2 were analyzed to compute ratios of erosion values for a given cover-management condition to erosion values for a base condition. The advantage of the RUSLE2 approach is that these ratio values varied much less year to year than did absolute erosion values. RUSLE2 does not reflect how year to year variation in soil moisture, runoff, plant yield, and other variables affects erosion.

RUSLE2 has similar limitations when used to estimate how an especially dry or wet season or year affects erosion. In these extremes, the ratio of runoff to precipitation usually differs significantly from average annual values. Extreme storm events sometimes occur in dry years. Although annual rainfall may be quite low in a dry year, a few very intense rainfall events can cause exceedingly high erosion per unit precipitation. Conversely, a wet year can involve many relatively low intensity storms that cause reduced erosion per unit precipitation. Although RUSLE2 captures some but not all of these effects, RUSLE2 is limited because it does not compute runoff by individual storm event.

Input data for the climate, operation, vegetation, residue, and cover-management descriptions can be entered to represent a particular year. RUSLE2 computes erosion estimates that partially reflect how departure of these input values from average annual conditions affects erosion. Also, expert users can set up RUSLE2 to capture most residual effects from a previous year where conditions differed greatly from those for the year being analyzed. The RUSLE2 computed erosion is likely to be less than it should be for a wet year and greater than it should be for a dry year.

RUSLE2 can be configured to estimate erosion for a single storm by inputting values to represent conditions on the day of the storm. However, RUSLE2 does not estimate soil moisture and how runoff is affected by soil moisture on the day of the rainfall event. Thus, RUSLE2 erosion estimates will be low or high depending on how soil moisture departs from its average annual value for the particular event. Although RUSLE2 is not intended to estimate erosion from individual storms, its accuracy for individual storm event erosion estimates may be comparable to estimates from complex, process-based models.[165] **RUSLE2 is better for estimating individual event erosion than is commonly assumed.**

These RUSLE2 applications are quite advanced. Proper procedures must be followed. For example, no-rotation type cover-management descriptions should be used in most cases rather than using standard rotation-type cover-management descriptions, even when representing crop rotations. This RUSLE2 User's Reference Guide should be carefully studied and followed in applying RUSLE2 in these special applications.

If users understand how RUSLE2 works regarding individual storms and representing historical events and they have the expertise and other resources to apply RUSLE2, then RUSLE2 is valid in these applications if these RUSLE2 users consider RUSLE2 estimates to be useful.

17.2.9. Principle 9. Always evaluate the adequacy of the data

17.2.9.1. An ideal dataset

All measured erosion data available for developing and evaluating RUSLE2 are questionable in some way.[166] An ideal dataset represents modern climatic and land use conditions, soils and topography as they occur on actual hillslopes, and the full range of conditions where RUSLE2 is applied. Record length is sufficient to provide accurate average annual estimates and probability distributions. The dataset is complete, un-biased, and without measurement error. Replications and treatments are sufficient to define RUSLE2 relationships with a high degree of statistical accuracy. Measurements must be made according to RUSLE2 definitions, rules, and procedures.

17.2.9.2. Natural rainfall versus simulated rainfall

---

[165] Although RUSLE2 is not intended for estimating erosion for specific storm events, RUSLE2 is fundamentally an event-based procedure. The linearity between storm erosivity and storm erosion simplifies the RUSLE2 mathematical integration for estimating average annual erosion. See **Sections 5.4 and 7.2**.

[166] Toy, T.J., G.R. Foster, and K.G. Renard. 2002. Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley and Son, New York, NY.

Data from natural rainfall events are much preferred over data from simulated rainfall because simulated rainfall does not perfectly match natural rainfall. Most erosion data collected with rainfall simulators are for standard, uniform intensity storms in comparison with natural rainstorms having greatly varying intensities and amounts. Measured infiltration, runoff, and erosion are functions of temporal rainfall intensity pattern and its interaction with spatially varied soil conditions.[167] Energy for some rainfall simulators is much less than that of natural rainfall. **Data were not used in the development of RUSLE2 that were collected using simulated rainfall where energy was less than about 75 percent of that in natural rainfall.** Rainfall simulators having energies approaching natural rainfall typically apply water intermittently on a cycle ranging from about 5 seconds to 30 seconds, which affects infiltration, runoff, erosion, sediment transport, deposition, and sediment characteristics.

The standard storm set is typically applied only at a few times during the year, usually when the study condition is most vulnerable to erosion condition. In some erosion studies on rangelands involving rainfall simulators, the applied erosivity was much greater than typical annual rainfall erosivity at some locations.[168]

These differences between natural and simulated rainfall raise questions about the advisability of using simulated rainfall erosion data to develop and evaluate RUSLE2. The RUSLE2 developers judged that these data were useful in the context of RUSLE2 being a conservation and erosion control planning tool. Erosion data from simulated rainfall would be interpreted against erosion data from natural rainfall. Erosion data from simulated rainfall were primarily analyzed, except for the soil erodibility nomographs, by forming ratios of erosion for a given condition to erosion for a base condition, realizing that these ratios vary with storm characteristics and other factors (see Figure 17.1).

17.2.9.3. Measurement area size

Erosion plots that are either 35 ft long or 72.6 ft long and 6, 10, or 12 ft wide were widely used to measure the effect of climate, soil, land steepness, and cover-management on erosion. Plots of about 36, 72.6, and 150 ft long (plots as long as 370 ft were used in one study and 650 ft in another study) were used in multiple studies to determine the effect of overland flow path length on erosion. Small watersheds ranging in size from about 2 ac to 5 ac were used to measure the effect of contouring, rotational strip cropping, and terracing on erosion.

---

[167] Flanagan, D.C., G.R. Foster, and W.C. Moldenhauer. 1988. Storm pattern effect on infiltration, runoff, and erosion. Trans. ASAE 31:414-420.

[168] See:
Simanton, J.R., L.T. West, M.A. Weltz, and G.D. Wingate. 1987. Rangeland experiments for Water Erosion Prediction Project. Paper No. 87-2545. American Society of Agricultural Engineers. St. Joseph, MI.
Spaeth, Jr., K.E., F.B. Pierson, M.A. Weltz, and W.H. Blackburn. 2003. Evaluation of USLE and RUSLE estimated soil loss on rangelands. J. Range Management 56:234-246.

Do these erosion plots tilled manually or with small equipment adequately represent typical land use practices and non-uniform overland flow paths having lengths that range from 1 ft to 1,000 ft.? Do these small watersheds with their spatial variability of soil, topography, and cover-management conditions provide data suitable for developing RUSLE2?

Even though these and other questions can be raised about these measurement areas, the RUSLE2 developers judged that these measurement areas were appropriate for developing RUSLE2 as a conservation and erosion control planning tool. RUSLE2 users must interpret RUSLE2 erosion estimates in terms of how well these plots and small watersheds represent erosion on the field area where RUSLE2 is being applied (see **Sections 5.1, 5.2, and 5.3**). RUSLE2 developers judged that erosion data from small measurement areas about 3 ft by 3 ft (1 m by 1m) where essentially only interrill erosion occurs are not suitable for developing RUSLE2 or evaluating its estimates of rill and interrill erosion combined for typical overland flow paths.[169] This small measurement area is not suitable for determining RUSLE2 soil erodibility factor values or making relative comparisons of soil erodibility and erosion control practices. Erosion data from plots shorter than 35 ft were not used in the development of RUSLE2 where both interrill and rill erosion were being considered. However, data from interrill erosion type areas were used to develop RUSLE2 interrill erosion relationships.

Finding a suitable area on a natural hillslope for a set of erosion plots having uniform soil and steepness is difficult. A minimum of three replications along with a base treatment, and three treatments are needed, for example, in a simple study to evaluate mulch application rate for a particular mulch type. A set of 12 rainfall simulator plots are needed for this study, which requires a total width of about 220 ft. Finding a uniform area that wide is difficult on natural landscapes. The problem is especially acute on rangelands where erosion rates are low and spatial variability is great. The scale of the variability is on the order of the plot width and length. A slight shift in the placement of a plot can result in significantly different measured erosion rates.

17.2.9.4. Modern data

Modern data representative of current land use practices and climate conditions should be used to develop and evaluate RUSLE2. Modern climate data were used to develop RUSLE2 input erosivity, precipitation, and temperature values. However, the underlying natural rainfall erosion data used to calibrate the soil biomass subfactor equation (equation 9.12) were from the mid 1930's to the mid 1950's. Few natural rainfall erosion

---

[169] Foster, G.R., J.R. Simanton, K.G. Renard, L.J. Lane, and H.B. Osborn. 1981. Discussion of "Application of the Universal Soil Loss Equation to Rangelands on a Pre-Storm Basis." Journal of Range Management 34:161-165.

plot data were collected after the 1970's. Most modern erosion data were collected using simulated rainfall.

Therefore, a question is how well does RUSLE2 estimate erosion for modern conditions? Applying RUSLE2 to modern conditions represents an extrapolation from conditions quite different from current ones. RUSLE2 developers addressed this question and judged that RUSLE2 performs satisfactorily for modern conditions. They also judged that the cover-management subfactor procedure allows RUSLE2 to be extrapolated to conditions significantly beyond those represented in the underlying data.

17.2.9.5. Data record length

About 10 years are usually required to obtain representative average annual values for erosion data measured from natural rainfall for one- and two-year crop rotations. Erosion data for cropped conditions are available from only two locations where the record length exceeded a decade. However, interpretation of a long term data is difficult because of temporal weather variability and changes in farming practices over time. None of the data available for analyzing rotational strip cropping involving five-year and longer crop rotations are fully adequate because of short record length even though record length is about 10 years. A five-year rotation requires 20 or more years to obtain reasonable average annual data and even longer when the crop rotation is used in strip cropping. Collecting such data is often not feasible, which is the reason that these data do not exist.

Data having record lengths as short as three years for natural rainfall events were used in the development of RUSLE2. These data were primarily analyzed to determine ratios, which vary less temporally than do absolute values (see Figure 17.1). Data having a short record length are more susceptible to interpretation problems caused by extreme events occurring during the measurement period and to measurement equipment failure than data having a long record length.

Missing data can be a serious problem. An example is the high erosion rates that can occur during late winter and early spring thaws when soil erodibility is significantly increased. Too few events were measured to adequately represent them in the temporal erodibility equation (see **Section 7.3**). Few locations were adequately equipped to measure runoff and erosion in these environmental conditions, and the need to make those measurements was probably not recognized at the time.

17.2.9.6. Dividing the data into development and evaluation parts

Developers of models sometimes divide data into two parts, one part is used to develop the model and the other part is used to evaluate the model. The entire dataset was used to develop RUSLE2 rather than dividing the data. The best approach is to use the largest dataset possible to develop erosion models given the variability, incompleteness, bias, and other shortcomings in erosion data.

Reports are sometimes published where measured data at a single location for a small, specific set of conditions are compared with RUSLE2 estimates. Such data should first be evaluated to determine how they fit with the RUSLE2 dataset as a whole to ensure that the specific study data are not outliers. Given the unexplained variability in erosion data (e.g., see Figure 17.1), either a good or poor fit of RUSLE2 to a single data point is by chance. Evaluations involving essentially a single data point usually provide very little information about RUSLE2's adequacy.

A main criterion in developing RUSLE2 is that it describes well established main effects. Fitting an erosion prediction equation to incomplete and biased data can produce nonsensical results such as erosion increasing as ground cover increases. The fit of RUSLE2 to experimental data as determined by statistical goodness of fit measures was sometimes compromised so that RUSLE2 accurately represents established main effects. Getting the best statistical fit to reduced quality data may not produce the best result for conservation and erosion control planning.

17.2.9.7. Users must make their own judgments

All developers of erosion prediction technology make judgments about erosion data used to derive equations, parameter values, and input values. Different people reach different conclusions when evaluating a particular dataset and in evaluating RUSLE2's adequacy relative to the dataset. The RUSLE2 developers' judgments are described in this RUSLE2 User's Reference Guide.

Users must make their own judgments about RUSLE2. Users should only use RUSLE2 when they are satisfied that RUSLE2 is suitable for their purposes.

17.2.10. Principle 10. Make sure that the inputs are proper

When RUSLE2 users obtain poor results, they often suspect a problem with RUSLE2, while RUSLE2 developers often suspect improper inputs. Always double check input values when evaluating and applying RUSLE2, and especially ensure that input values are consistent with the core database values. Do not use input values from other erosion models. RUSLE2 input values sometimes differ from values used for similar variables in other erosion prediction technologies, including the USLE and RUSLE1.

Ensure that RUSLE2 rules and procedures are followed. Errors in the sequence of processes used in an **operation description** can easily occur, for example. If a **flatten standing residue process** is used in a soil disturbing operation description, the results will differ significantly depending on whether the flattening process is placed in the operation description before or after the **disturb soil process**. Another example of an input error is where the live root biomass value on day zero in a **vegetation description** is much less than the live root biomass on the last day in this vegetation description when it is used to represent mature vegetation. RUSLE2 adds the difference in the live root biomass between the ending and beginning dates to the dead root biomass pool when none should be added in this situation.

RUSLE2 results can be no better than the inputs.

17.2.11. Principle 11. Be alert for RUSLE2 users who believe RUSLE2

RUSLE2 estimates contain error and uncertainty. All RUSLE2 estimates should be examined, interpreted, and carefully considered before using them. Conservation and erosion control planners should always make planning decisions using RUSLE2 estimates as a guide.

17.2.12. Principle 12. RUSLE2 is only in error when it leads to a poor conservation or erosion control plan

RUSLE2's accuracy (see **Section 17.4**) should be evaluated in the context of conservation and erosion control planning.[170] Does RUSLE2 result in the desired conservation and erosion control planning decision? For example, RUSLE2 could compute annual erosion estimates of 50, 200, and 400 tons/acre for a particular highly erodible site given the uncertainty in RUSLE2 estimates. The range in these values represents significant numerical error. However, RUSLE2 leads to the correct conservation decision with each estimate; that is; erosion is excessive and needs to be significantly reduced. In fact, RUSLE2 probably is not needed in this situation because the erosion hazard is easily recognized from general erosion knowledge.

Similarly, RUSLE2 could compute an annual erosion estimate between 0.001 and 0.1 tons/acre for a rangeland site given the uncertainty in RUSLE2 estimates. Nevertheless, RUSLE2 leads to the desired conservation planning decision; erosion is low. Making erosion measures using plots that are 35 ft long and 12 ft wide to determine the "correct" value is difficult for low erosion rates, especially on rangelands. The 0.001 tons/acre value could have been 0.05 tons/acre if a gopher hole had been near the plot end or the soil had been slightly disturbed and exposed when placing a plot border or installing a plot end. The 0.1 tons/acre value could have been 0.01 tons/acre had the plot had been located differently because of non-uniform spatial variability within the plot and on the hillslope.

---

[170] For additional discussion, see Toy, T.J., G.R. Foster, and K.G. Renard. 2002. Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley and Son, New York, NY.

RUSLE2's accuracy is most important when erosion estimates are sufficiently close to the erosion control criteria such that errors result in substantial expense to apply unnecessary erosion control. RUSLE2 is typically used in conservation planning to compute a soil loss value that is compared against a soil loss tolerance value **T** or another erosion control criteria value. If the computed soil loss value is less than the erosion control criteria, erosion control is assumed to be adequate.

Assume that the erosion control criterion is an annual 5 tons/acre. If the RUSLE2 annual erosion estimate is 10 tons/acre, the RUSLE2 based conservation planning decision is that erosion is excessive and additional erosion control is needed. However, if the "correct" erosion estimate is an annual 5 tons/acre, the proper conservation planning decision is that erosion control is acceptable and no further erosion reduction is needed. The significance of the error is determined by the expense of additional erosion control when none was needed.

Fortunately RUSLE2 is most accurate in the critical range of annual estimates between about 2 to 20 tons/acre. Annual erosion greater than 20 tons/acre is usually considered excessive and annual erosion less than 1 ton/acre is generally considered to be acceptable. If RUSLE2 computes an annual erosion of 10 tons/acre with one practice and 20 tons/acre with a second practice, the erosion control planner can be confident that erosion with the first practice will be substantially less than with the second practice. However, if RUSLE2 computes 1 and 2 tons/acre annual erosion estimates for two practices, especially on pasture land, the difference between the two practices is not great, and the most that can be said is that erosion will likely be less with one practice than with the other practice and that erosion will be low with both practices.

RUSLE2 erosion estimates for support erosion control practices, especially contouring, are much more uncertain than those for cultural erosion control practices based on cover-management variables. RUSLE2 accurately represents the global effects of support practices but not their performance on specific sites. The uncertainty in the estimated erosion reduction by support practices on a specific site is much greater than the uncertainty in estimated erosion reduction by cultural erosion control practices.

17.3. Sensitivity analysis

A RUSLE2 sensitivity analysis is very helpful in understanding how RUSLE2 computes erosion, determining how a particular practice or condition affects erosion, determining the effect of a particular variable on erosion, and detecting input errors. The general procedure for conducting a sensitivity analysis is to change a single input while holding other inputs constant. For example, a sensitivity analysis can be conducted on how location affects erosion by making RUSLE2 computations for a set of locations using a single set of inputs for soil, topography, cover-management, and support practices. Likewise, a sensitivity analysis can be conducted on cover-management practices by making erosion computations for a set of practices for a given location, soil, topography, and support practices.

A sensitivity analysis can also be conducted on a single variable such as overland flow path length. Changing input values from 10 to 1000 ft for the overland flow path length has little effect on RUSLE2 computed erosion where steepness is 1 percent or less. Therefore, carefully selecting a precise input value for overland flow path length on very flat slopes is not critical.

A sensitivity analysis for the single variable overland flow path length can be easily conducted by changing input values on the main RUSLE2 **profile** screen. Sensitivity analyses conducted on other individual variables usually requires changing values in the **RUSLE2 database description** that contains the values for that variable. For example, conducting a sensitivity analysis on canopy cover requires changing values in a **vegetation description**.

The effect of a single variable or a set of variables, such as those in cover-management descriptions, on erosion varies with the situation. For example, overland flow path length has little effect on erosion on very flat slopes. However, it has a moderate effect on steep slopes. Therefore, more care is needed in selecting input values for overland flow path lengths on moderate and steep slopes than on very flat slopes. Furthermore, the effect of overland flow path length also depends on soil and cover-management conditions. Similarly, the effect of a particular cover-management practice depends on location, soil, and topography.

Some variables are used in multiple RUSLE2 equations, which results in complex interactions that complicate sensitivity analyses. Surface biomass, soil biomass and the soil consolidation subfactor are examples of such variables. Each variable has a primary effect and several secondary effects. Surface (flat) cover is often assumed to be the most important RUSLE2 variable, which is true for many but not all conditions. Soil biomass can have a much greater effect on erosion than surface biomass in certain conditions. Surface biomass, soil biomass, and soil consolidation strongly interact so that the combined effect is more than expected based on the primary effect of each variable. Special inputs must be used in sensitivity analyses to isolate the primary effect of individual variables separate from their interactive effects.

Be very careful about generalizing results from a sensitivity analysis. Sensitivity analyses should be conducted over a wide range of conditions before drawing conclusions about the effect of a particular variable on erosion.

Inputs must be changed carefully to conduct sensitivity analyses on surface (flat) cover, which is an important variable in conservation planning on cropland. An input must be selected to change surface cover to conduct a sensitivity analysis on surface cover. An obvious input is vegetation production (yield) level. Changing yield does change surface biomass, but it also changes soil biomass and canopy values. Changing yield is an important sensitivity analysis but not for conducting a sensitivity analysis on surface cover. Is the surface cover analysis to study the effect of surface biomass or is it to study the effect of the portion of the soil surface covered? If the purpose of the sensitivity analysis is to study the effect of surface biomass, inputs for the relationship of aboveground biomass to yield in a vegetation description can be changed. If the sensitivity analysis is to study the effect of how the portion of the soil covered affects erosion, inputs in a **residue description** that relate portion of the soil surface covered to the surface biomass can be changed.

An important sensitivity analysis is the effect of soil disturbance width on erosion (see **Section 9.2.6**). The soil disturbance width effect of a particular soil disturbing operation depends greatly on whether the operation is the only soil disturbing operation in the **cover-management description**. The soil disturbance width effect can be great if only one **soil disturbing operation** is in a cover-management description. The soil disturbance width effect for a particular operation is much less if other soil disturbing operations, especially ones that disturb the full soil width, are included in the cover-management description.

Although soil disturbance width has a minor effect on surface roughness, its major effect is on the soil consolidation subfactor and its secondary effects. The soil consolidation primary effect is illustrated in Figure 7.3. Its secondary effects are from being a variable in several other computations including the soil biomass subfactor, decomposition's transfer of surface biomass to soil biomass, runoff, and the rill-interrill erosion ratio that affects the slope length exponent in equation 8.1 and **b** value in equation 9.6 used to compute ground cover effect. A sensitivity analysis on soil disturbance width and on the soil consolidation effect requires sorting through an array of complex, interacting variables.

Care must also be taken in sensitivity analyses to ensure that the effect of a variable being studied is not being masked by another variable. An example is disturbance depth of secondary tillage. A primary tillage operation with a deep disturbance depth typically precedes secondary tillage operations in many cropland cover-management descriptions. Disturbance depth of secondary tillage operations has very little effect on erosion because primary tillage buries most of the residue below the disturbance depth of the secondary tillage operation. The effect of disturbance depth of the same secondary tillage operation can be significant when no primary tillage operations are in the cover-management description.

RUSLE2 uses a description of field conditions to compute erosion. Most variables in a RUSLE2 description are not automatically changed when input values for key variables are changed. For example, RUSLE2 does not change vegetation production (yield) level when a new location (which changes precipitation and temperature), soil, or management is selected that affects yield. Therefore, a sensitivity analysis that involves changes in variables that affect yield requires changing the yield input value in the cover-management descriptions used in the analysis.

The value entered for yield must be consistent with the selected location's climatic, soil, and management.

17.4. RUSLE2 Accuracy

The assumption in developing RUSLE2 was that the widely accepted and used USLE and RUSLE1 were valid models for conservation and erosion control planning. RUSLE2 was developed to improve these technologies by significantly extending their applicability to practically every field situation where rill and interrill erosion occurs, increasing their power, and improving their underlying supporting science. Therefore, one assessment of RUSLE2's accuracy is to compare RUSLE2 and USLE computed erosion values. A second assessment is the fit of the USLE, and thus RUSLE2, to the research data from which the USLE was derived. A third assessment is identifying where RUSLE2 is most, (and least) accurate.

17.4.1. Comparison of RUSLE2 erosion estimates with USLE erosion estimates

Determining the accuracy of RUSLE2 for estimating how cover-management affects erosion is perhaps the most important assessment of RUSLE2 because of the major role of cover-management in conservation and erosion control planning. The soil loss ratio values in Table 5, AH537 represent measured values.[171] These values are a summary of a large mass of research data, 10,000 plot-years, as analyzed and interpreted by Wischmeier and Smith (AH537). The fully empirical USLE directly uses measured values to compute cover-management's effect on erosion. In contrast, RUSLE2 uses a set of equations that were fitted to the soil loss ratio values in Table 5, AH537 and other data (see **Section 9**). Therefore, one part of the assessment is how well the RUSLE2 subfactor equations fit measured soil loss ratio values.

17.4.1.1. Average annual erosion values for cropland

Table 17.1 shows erosion values computed with the USLE and RUSLE2 for a wide range of cover-management practices for Columbia, MO and for two cotton cover-management practices for Holly Springs, MS.[172] The values in AH537 represent a summary of

[171] Soil loss ratio values in AH537 are the ratio of soil loss with a given cover-management condition at a particular crop stage period to soil loss from the unit plot for the same crop stage.
[172] Columbia, MO is used as a base location in RUSLE2. AH537 values for slope length and steepness, soil loss ratio, and support practice factors are assumed to apply at Columbia, MO. RUSLE2 adjusts its values for these factors about the Columbia, MO base values. The weather at Columbia, MO is near the "middle"

measured values for the eastern US. Measured soil loss ratio values varied greatly among

Table 17.1. Estimated average annual erosion values (tons/acre) for the USLE and RUSLE2 (overland flow path length = 150 ft, steepness = 6%)

Management	USLE	RUSLE2
conv. cont corn, 112 bu/ac spring plow	16	17
conv. cont corn, 112 bu/ac fall plow	19	19
conv. cont. corn 50 bu/ac spring plow	23	28
conv. cont. corn 50 bu/ac fall plow	27	31
conv cont corn silage 112 bu/ac spring plow	28	28
conv cont corn silage 112 bu/ac fall plow	31	29
conv cont corn silage 50 bu/ac spring plow	34	37
conv cont corn silage 50 bu/ac fall plow	37	38
conv 112 bu/ac corn-25 bu/ac soybeans	20	22
conv 112 bu/ac **corn**-25 bu/ac soybeans	21	23
conv 112 bu/ac corn-25 bu/ac **soybeans**	18	21
conv 112 bu/ac corn-25 bu/ac soybeans fall plow	22	25
conv 112 bu/ac **corn**-25 bu/ac soybeans fall plow	23	25
conv 112 bu/ac corn-25 bu/ac **soybeans** fall plow	22	27
conv cont soybeans 25 bu/ac		27
conv cont winter wheat 30 bu/ac	9.4	13
conv 112 bu/ac corn - 25 bu/ac soybeans-30 bu/ac winter wheat	14	19
no till 112 bu/ac corn		1
mulch till 112 bu/ac corn		10
ridge till 112 bu/ac corn		10
conv. cont corn, 112 bu/ac spring plow manure 8000 lbs/ac (dry basis)		9
corn-corn-meadow-meadow-meadow (high production)	7	6
corn-**corn**-meadow-meadow-meadow (high production)	14	17
established meadow, 4 tons/acre	0.2	0.2
established alfalfa	1.1	0.9
conv cotton "flat" planted	32	37
cotton hipped	44	47

Notes:
1. conv - conventional
2. cont - continuous
3. erosion value is erosion in year for crop in bold
4. erosion values computed for Columbia, MO except for two cotton management where values are for Holly Springs, MS
5. meadow refers to hay production
6. Same R value and K value used in USLE and RUSLE2 comptuations
7. LS = 0.824 for USLE while "net" LS value for RUSLE2 varied from 0.73 for no-till corn to 1.01 for conv cont 50 bu/ac silage corn

locations. For example, the soil loss ratio value for the seedbed crop stage for conventionally tilled corn varied from about 0.2 to 0.8 in data collected in the 1970's at several locations.[173] The reasons for this variation could not be empirically determined

---

of the data for the Eastern US. Holly Springs, MS was used in RUSLE2 as the base location for cotton cover-management because research at that location and other nearby locations provided most of the data used to derive AH537soil loss ratio values for cotton.

[173] The seedbed crop stage is when the soil is finely tilled in preparation for crop seeding. No vegetation

because of unexplained variability in the data. However, fundamental research conclusively shows that erosion decreases as soil biomass increases. Therefore, the seedbed soil loss ratio value for conventionally tilled continuous corn at a particular yield should be higher in the southern US than in the northern US because increased precipitation and temperature significantly increase decomposition, which reduces soil biomass. RUSLE2 captures this and other effects in its cover-management subfactor equations that are not captured by the USLE.

The soil loss ratio values computed by RUSLE2 vary by location, soil, and topography in contrast to the USLE soil loss ratio values that do not vary with these factors. Therefore, a comparison between RUSLE2 and USLE estimated erosion values must be for a representative condition. Columbia, MO (a central location), a silt loam soil, and a uniform overland flow path 150 ft (50 m) long, 6 percent steep were chosen to compute the estimates shown in Table 17.1. Differences in RUSLE2 and USLE erosion estimates vary with location, generally becoming greater with distance from Columbia, MO as climatic conditions differ from those at Columbia, MO.

Even at Columbia, MO, RUSLE2 and the USLE do not compute the same erosion estimates because of differences in equation structure. The daily topographic length factor in RUSLE2 varies with cover-management, while the corresponding USLE L factor does not vary. RUSLE2 computes a "net" LS value that is a temporal integration of daily values weighted by the temporal distribution of erosivity. Values for the RUSLE2 "net" LS factor vary from a low of 0.73 for the 112 bu/ac no-till corn to 1.01 for the 50 bu/ac corn silage whereas the USLE LS value is 0.82 for all conditions in Table 17.1.

Even when the RUSLE2 "net" LS value is the same as the USLE LS factor value, RUSLE2 and the USLE likely will not compute the same erosion values because of differences in temporal integration. RUSLE2 multiplies its daily factors values to determine a daily erosion estimate and sums these values for an annual erosion estimate. The only temporal integration in the USLE is by crop stage period where the soil loss ratio values are weighted by the temporal erosivity distribution to compute a cover-management factor value, which is multiplied by the other factor values to determine an annual erosion estimate.

RUSLE2 does not use "net" factor values to compute annual erosion. These values are only for comparison with USLE factor values and for use in the USLE for conditions where empirical erosion data are not available to determine USLE factor values. **Multiplication of the RUSLE2 computed "net" factor values according to the USLE equation structure does not compute the same erosion estimate as that computed by RUSLE2 (see *Section 5.4*)**.

---

and very little surface residue cover are present in conventional moldboard plowed cropping systems that bury almost the entire residue from the previous year's crop.

An assessment of RUSLE2 based on a comparison of estimated erosion values with USLE estimates must consider differences in equation structure and the additional effects represented by RUSLE2 (see *Section 17.2*).

As illustrated in Table 17.1, RUSLE2 computed erosion values compare well with USLE values. Biomass is the principal factor that affects erosion for the conditions listed in Table 17.1. Biomass differences primarily account for the difference in erosion values from the high biomass meadow (hay) to the low biomass in 50 bu/ac corn silage. Biomass differences also principally account for the differences in erosion between the 50 and 112 bu/ac corn practices. A land use residual effect results from soil biomass loss over time after large amounts of biomass are buried in the soil and a large amount of roots are killed. Erosion increases over two years of corn following a high production meadow (hay) as soil biomass is lost.

Vegetation characteristics and vegetation management affect erosion (e.g., corn, wheat, and hay and hay versus grain production). As the values in Table 17.1 show, RUSLE2 captures the effect of these variables on erosion.

Other factors besides cover-management must be considered when evaluating the RUSLE2 values in Table 17.1. The topographic length factor discussed above is one of those factors. RUSLE2 does not vary the topographic steepness factor; it is constant just as in the USLE. However, the RUSLE2 topographic steepness factor differs from the USLE one. The RUSLE2 steepness factor value for a 6 percent steepness is 18 percent greater than the corresponding USLE value. Consequently, all RUSLE2 erosion estimates in Table 17.1 are systematically increased by 18 percent larger relative to the corresponding USLE values. The difference between the RUSLE2 and USLE steepness factors decreases for steepness less than 6 percent except for very flat steepness where the RUSLE2 values are greater than the USLE values. The RUSLE2 and USLE steepness factor values are equal at 9 percent steepness. Above 9 percent, the USLE values become progressively greater than the RUSLE2 values.[174]

Even when the RUSLE2 "net" soil erodibility value equals the USLE soil erodibility factor value and all other factors are the same, the erosion estimates computed by RUSLE2 and the USLE can differ. The daily RUSLE2 soil erodibility values temporally vary, which affects estimated erosion, especially when comparisons are made for

[174] See:
AH703

McCool, D.K., L.C. Brown, G.R. Foster, C.K. Mutchler, and L.D. Meyer. 1987. Revised slope steepness factor for the Universal Soil Loss Equation. Transactions of American Society of Agricultural Engineers 30:1387-1396.

multiple locations and soils. Also, the rill erodibility to interrill soil erodibility ratio

Therefore, differences in RUSLE2 and USLE erosion estimates can not be generalized on the basis of computations for a single location, soil, or topography.

varies among soils, which also affects results.

Conservation tillage, including no-till, mulch till, and ridge till, is a major erosion control practice used on cropland. However, no USLE erosion estimates are given in Table 17.1 for conservation tillage because AH537 soil loss ratio values for conservation tillage are considered unreliable. The AH537 values were based on research conducted early when conservation tillage was beginning to be adopted and do not represent modern conservation tillage. Other data on conservation tillage besides the AH537 values were used to develop the RUSLE2 cover-management subfactor equations. Data from a large number of references were reviewed and analyzed to give special attention to no-till because the USLE and RUSLE1 were highly criticized for not accurately computing erosion for no-till. As Figure 17.1 shows, the effectiveness of no-till varies greatly, even more than erosion with conventional tillage. A very detailed analysis of the empirical data did not provide the information required to describe the variability in the no-till data. RUSLE2 captures the main effect illustrated in Figure 17.1 and computes values about this line as a function of location, slope steepness, soil, crop, and yield.

The cover-management subfactor approach used in RUSLE2 computes erosion values that compare well with values computed by the USLE and, therefore, with the experimental data on which the USLE is based.

17.4.1.2. Soil loss values by crop stage for cropland

An additional assessment of RUSLE2's accuracy is how well it reproduces the soil loss ratio values in Table 5, AH537 for crop stage periods.[175] Tables 17.2, 17.3, and 17.4 show RUSLE2 computed soil loss ratio values for corn and cotton. The soil loss ratio values for the fallow crop stage period shows that RUSLE2 captures the effects of surface roughness and the values for crop stages 1, 2, and 3 shows that RUSLE2 captures the effect of a developing and mature crop. Differences between values in Tables 17.3 and 17.4 confirm that RUSLE2 captures the effect of ridges where repeated tillage operations bury almost the entire residue for a low residue cotton crop.

Comparisons for soil loss ratios were made for the other cover-management conditions listed in Table 17.1. The values in Tables 17.2, 17.3, and 17.4 and from the other comparison between RUSLE2 soil loss ratio estimates and the AH537 values indicate that RUSLE2 accurately computes the temporal variation in soil loss ratio values.

RUSLE2 is judged to accurately compute temporal cover-management effects during the year.

Table 17.2. Soil loss ratios for 112 bu/ac conv cont corn from AH537 and values computed with RUSLE2

Crop stage (defined in AH537)	AH537 Soil loss ratio	RUSLE2 Soil loss ratio
Fallow	31	28
Seedbed	55	54
1 -- 10% < canopy < 50%	48	52
2 – 50% < canopy < 75%	38	30
3 – to maturity	23	18
4 after harvest (stalks spread)	6	6

Table 17.3. Soil loss ratio values for 750 lbs/acre cotton flat planted at Holly Springs, MS. Values from AH537 and computed by RUSLE2

Crop stage (defined in AH537)	AH537 Soil loss ratio	RUSLE2 Soil loss ratio
Fallow	0.39	0.54
Seedbed	0.64	0.74
1--10% canopy < 35%	0.59	0.74
2--35% < canopy < 60%	0.46	0.49
3--to maturity	0.32	0.23
Defoliation to Dec 31	0.26	0.24
Jan 1 to Feb. tillage	0.32	0.32

Table 17.4. Soil loss ratio values for 750 lbs/acre cotton hipped (ridged) at Holly Springs, MS. Values from AH537 and computed by RUSLE2

Crop stage (defined in AH537)	AH537 Soil loss ratio	RUSLE2 Soil loss ratio
1st hip, no prior tillage	84	88
Split ridges with a “do-all”	54	52
Hip after 2 prior tillages	108	101
Split ridges with a “do all”	62	58
Hip after 3 or more tillages	110	112
Split ridges with a “do all”	64	64
Seedbed	64	64
1--10% canopy < 35%	59	64
2--35% < canopy < 60%	46	45
3--to maturity	32	21
Defoliation to Dec 31	22	23
Jan 1 to Feb. tillage	32	27

17.4.1.3. Crop residue cover immediately after planting

Crop residue cover immediately after planting is an important variable used in conservation planning and compliance determination on cropland. RUSLE2 is expected to accurately estimate this cover, which it does as illustrated in Table 17.5 for a wide range of conservation tillage systems and the major crops of corn and soybeans.

RUSLE2 accurately estimates crop residue cover immediately after planting for a wide range of tillage systems.

17.4.1.4. Erosion values for range, pasture, and similar lands

Both RUSLE1 and RUSLE2 apply to range and similar lands, although the USLE poorly estimates erosion for these lands.[176] The major problem is with Table 10, AH537, entitled "Factor C for permanent pasture, range, and idle land" used to apply the USLE to these lands. This table does not include a soil surface roughness effect, and it improperly links below ground biomass to ground cover. Table 10, AH537 does not allow rock cover to be considered separately from biomass ground cover, it does not properly account for production (yield) level, and the **b** value in equation 9.6 for the ground cover effect is about 0.026 rather than a much more preferred value of 0.035. Also, values for the USLE slope steepness are too large for steepness greater than 25 percent.

Differences between the RUSLE2 and RUSLE1.06 soil biomass subfactor equations required that new RUSLE2 values for the ratio of effective root biomass to annual above ground production be developed. Two major datasets known as the WEPP rangeland data[177] and the USDA Rangeland Study Team data[178] are available for determining these RUSLE2 ratio values and evaluating RUSLE2 for rangelands.

Only the WEPP data set was used because of problems with the USDA Range Study Team data. The USDA Range Study Team dataset was carefully analyzed to compute effective root biomass values or to evaluate RUSLE2. When the data were divided into plant type categories of sagebrush, bunch, sod, and tall grass, the relationship between surface cover and erosion empirically derived from the data showed that erosion increased as surface cover increased for some of the

[176] Spaeth, Jr., K.E., F.B. Pierson, M.A. Weltz, and W.H. Blackburn. 2003. Evaluation of USLE and RUSLE estimated soil loss on rangelands. J. Range Management 56:234-246.
[177] Simanton, J.R., L.T. West, M.A. Weltz, and G.D. Wingate. 1987. Rangeland experiments for Water Erosion Prediction Project. Paper No. 87-2545. American Society of Agricultural Engineers. St. Joseph, MI.
[178] Spaeth, Jr., K.E., F.B. Pierson, M.A. Weltz, and W.H. Blackburn. 2003. Evaluation of USLE and RUSLE estimated soil loss on rangelands. J. Range Management 56:234-246.

Table 17.5. Measured and RUSLE2 estimated residue cover (percent) immediately after planting

Crop	Tillage system	Observed cover	Estimated cover	Reference
corn	spring disk	15	21	1
corn	fall chisel, spring disk	13	12	1
corn	spring disk, spring disk	27	18	2
corn	spring chisel, spring disk	22	11	2
corn	spring disk	15	21	2
corn	fall chisel, spring disk	13	12	2
soybeans	spring disk, spring disk	27	18	2
soybeans	spring chisel, spring disk	22	11	2
corn	spring disk	8	20	2
corn	spring disk, spring disk	5	7	2
corn	spring chisel, spring disk	7	3	2
corn	field cultivator	24	20	2
soybeans	spring disk, spring disk	11	8	2
soybeans	spring disk	15	22	2
soybeans	spring chisel, spring disk	11	4	2
corn	fall chisel, spring disk	33	26	3
corn	spring chisel, spring disk	19	19	4
corn	spring disk, spring disk	30	27	4
corn	fall chisel, spring disk, spring field cultivator	9	14	5
soybeans	fall chisel, spring field cultivator, spring field cultivator	9	5	5
corn	fall chisel, spring disk, spring field cultivator	16	14	6
soybeans	fall chisel, spring field cultivator, spring field cultivator	3	5	6
soybeans	spring disk, spring disk	9	7	7
soybeans	spring disk, spring disk	9	7	8
soybeans	spring disk	13	18	8

Table 17.5 (continued). Measured and RUSLE2 estimated residue cover (percent) immediately after planting			
References:			
1. Siemens, J. C., W. R. Oschwald.1976. Erosion from corn tillage systems. Trans. ASAE 19:69-72.			
2. Dickey, E. C., D. P. Shelton, P. J. Jasa, T. R. Peterson. 1985. Soil erosion from tillage systems used in soybeans and corn resides. Trans. ASAE 28:1124-1129, 1140.			
3. Lindstrom, M. J. and C. A. Onstad. 1984. Influence of tillage systems on soil physical parameters and infiltration after planting. J. of Soil and Water Cons. 39:149-152.			
4. Laflen, J. M., J. L. Baker, R. O. Hartwig, W. F. Buchele, and H. P. Johnson. 1978. Soil and water losses from conservation tillage systems. Trans. ASAE 21:881-885.			
5. McIsacc, G. F., J. K. Mitchell, and M. C. Hirschi. 1990. Contour and conservation tillage for corn and soybeans in the Tama Silt Loam Soil:hydraulics and sediment concentration.Trans. ASAE 33:1541-1550.			
6. McIsaac, G. F., J. K. Mitchell, M. C. Hirschi, and L. K. Ewing. 1991. Conservation and contour tillage for corn and soybeans in the Tama silt loam soil:the hydrologic response. Soil and Tillage Research 19:29-46.			
7. Shelton, D. P., P. J. Jasa, and E. C. Dickey. 1986. Soil erosion from tillage and planting systems used in soybean residue:Part I-influences of row spacing. Trans. ASAE 29:756-760.			
8. Jasa, P. J., E. C. Dickey, and D. P. Shelton. 1986. Soil erosion from tillage and planting systems used in soybean residue:Part II-influences of row direction. Trans. ASAE 29:761-766.			

plant types, which is unacceptable based on well accepted fundamental research. Measurements were taken at too few sites for the number of variables affecting erosion, and perhaps measurements of input variables were not made according to RUSLE definitions. In several cases, the plant litter cover was inconsistent with the production level (e.g., far too much litter cover for the annual production). Also, in the few cases when experimental sites for the WEPP and Range Study Team studies coincided or were close together much of the data for the basic cover-management variables from these common sites values did not agree. Some of these differences may have been caused by temporal differences because the experiments were conducted in different years.

The first step in determining these ratio values was to classify the WEPP data by plant community. The standard RUSLE2 soil erodibility, topographic, canopy, ground cover, surface roughness, and soil consolidation factor values were assumed to apply to these data, which reflects RUSLE2 land use independence. Measured erosion values were divided by the product of these factor values to compute a soil biomass subfactor value for each experimental site. A value for effective root biomass was next obtained by substituting the soil biomass subfactor value computed from the experimental data in equation 9.12, where a zero buried residue biomass was assumed. The effective root biomass value computed by solving equation 9.12 was divided by the annual aboveground biomass production (yield) level to determine a value for the ratio of effective root biomass in the upper 4 inch (100 mm) soil depth to annual aboveground production. A non-linear procedure that fitted predicted erosion to measured (observed) erosion was used to determine ratio values for plant communities that occurred at multiple sites. The resulting values are shown in Table 17.6.

Table 17.6. Values for ratio of effective root biomass to annual above ground biomass production for vegetation typical of range, pasture, and similar lands.

Plant community	ratio effective root biomass in upper 4 inches (100 mm)/annual above ground production
N mixgrass	2.5
S mixgrass	3.1
tallgrass prairie	1.0
shortgrass prairie	3.0
desert grassland	6.1
southern grasses	6.4
CA annual grass	2.6
cold desert shrub	5.9
southern desert shrub	6.6
shinnery oak w/herb interspace	2.6
chaparral	1.3
pasture, sod grasses	6.0
pasture, bunchgrasses	3.7
pasture, weeds	2.3

The values shown in Table 17.6 may not be consistent with known rooting and other characteristics of these plant communities. One reason for the lack of expected trends is variability in the measured data, too few measurement sites for each plant community, and too few replications. A sufficient number of sites to obtain a reasonably accurate overall effective root biomass ratio value for a plant community were available for only the southern desert shrub and southern mixed grass prairie plant communities. With these two exceptions, the Table 17.6 values for each plant community were derived from data for a single site. The Table 17.6 value for a plant community could differ from the expected value by a factor of two based on data for the two plant communities that occurred at multiple sites.

The Table 17.6 values are also affected by applying the standard RUSLE2 soil erodibility factor and the soil consolidation factor values to rangeland conditions. Tilling coarse texture rangeland soils in the southwestern US to create unit plot conditions greatly increases infiltration and reduces runoff and erosion (see **Section 7.2**). The low erosion immediately after tillage is related to land use residual effects (see **Section 9.2.5**). For example, soil plowed out of high production meadow is only one fourth as erodible immediately after tillage as it is after two years of tillage for row crop production (AH537). This land use residual effect disappears over time as a soil is continuously maintained in a unit plot condition. Research on these southwestern US rangeland soils showed that erosion increased over about three years after an initial tillage but no subsequent tillage, which indicates a strong land use residual effect in these soils.[179] The RUSLE2 assumption that standard erodibility values apply to rangeland conditions seem reasonable.

The soil consolidation effect assumes that tillage increases erosion by about 55 percent (see **Section 7.8**). This effect seems to have been masked in the land use residual effect in the research described above. The soil consolidation effect surely varies with soil properties and climate. However, research has not defined the relationship between the soil consolidation effect with these variables, even for cropland conditions and certainly not for rangeland conditions. The RUSLE2 soil consolidation relationship was empirically derived from data collected on a single soil at Zanesville, Ohio.

In any case, discrepancies between RUSLE2 soil erodibility and soil consolidation relationships and those for rangeland conditions were empirically incorporated in the Table 17.6 values. These soil and climate effects, along with data variability, account for any inconsistency in Table 17.6 values with vegetation characteristics.

Until research provides improved information, the values in Table 17.6 should be used even if they do not seem consistent with vegetation characteristics.

The Table 17.6 values were derived assuming the time invariant cover-management (C factor) procedure (AH703). Therefore, these values represent buried residue and dead roots as well as live roots. Vegetation, residue, and cover-management descriptions can be created so that RUSLE2 computes erosion using a time invariant C factor procedure similar to that in RUSLE1.06c. The **vegetation description** has a single entry in the **growth chart** on day zero. The entered value for live root biomass is the product of the site average annual production level and the ratio value in Table 17.6 for the plant community. Entered values for canopy cover, effective fall height, and live ground cover are representative values chosen to compute average annual erosion. The **cover-management description** includes an **operation description** having a **begin growth process** that tells RUSLE2 to use the single entry vegetation description and an **add other residue/cover process** that applies an **external residue** to give the desire ground cover. The **residue description** uses a zero value for the **decomposition coefficient** so

---

[179] See:

Simanton, J.R. and K.G. Renard. 1982. Seasonal change in infiltration and erosion from USLE plots in southeastern. Hydrol. Water Resources in Arizona and Southwest 12:p. 37-46.

Simanton, J.R., Johnson, C W., Nyhan, J.W., Romney, E.M. 1986. Rainfall simulation on rangeland erosion plots. Proc. Rainfall Simulator Workshop, Jan. 1985, Tucson, AZ, pp. 11-17.

Simanton, J.R., Renard, K.G. 1986. Time related changes in rangeland erosion. Proc. Rainfall Simulator Workshop, Jan. 1985, Tucson, AZ, pp. 18-22.

that the residue does not decompose to properly represent the time invariant approach. The cover-management description is a **no-rotation type** with one year **duration**.

Rather than use this time invariant approach, the recommended procedure is to use RUSLE2's full temporal capability when applying it to range and similar lands. Two options are available for determining input values for live root biomass in the vegetation descriptions. One option is to use literature values or to make field measurements. The literature values are highly variable. For example, the reported ratio for root biomass to aboveground biomass ranged from 0.6 to 120 for the northern mixed grass prairie plant community (AH537). A problem with literature values and with field measuring roots, which are very difficult to measure, is knowing the root size above which to discard roots because large roots have little effect on erosion. The most important roots are the fine ones near the soil surface. Even if roots are accurately measured, research has not established the relationship of erosion to root characteristics.

The best option for determining live root biomass input values is to use the RUSLE2 **long-term vegetation tool** to construct vegetation descriptions (see **Section 11.2.6**). This tool uses Table 17.6 values to estimate live root biomass values. A major advantage of using Table 17.6 values is that they have been empirically determined directly from measured erosion data using RUSLE2 definitions and equations.

Although the Table 17.6 values include a buried residue and dead root effect when used in the time invariant C factor procedure, these values give good results when they are used to estimate live root biomass values for temporal vegetation descriptions. The RUSLE2 full temporal method using live root biomass developed from Table 17.6 values gave comparable erosion estimates to those from the RUSLE1.06c time invariant C factor procedure.

The RUSLE2's temporal procedures should be used when applying RUSLE2 to range, pasture, and similar lands rather than the time invariant C factor method.

WEPP data collected for plant communities that occurred at multiple sites provided a limited indication of the uncertainty in RUSLE2 erosion estimates. The south desert shrub plant community occurred at six sites and the southern mixed grass prairie plant community occurred at five sites.[180] Estimated (predicted) and measured (observed) erosion values are shown in Figures 17.2 and 17.3. RUSLE2 estimated erosion values compare reasonably well with measured erosion values for the south desert shrub plant community except for one data point in Figure 17.2 where the predicted erosion was

[180] Data from two additional sites for the south desert shrub plant community and from an additional site for the southern mixed grass prairie plant community were not used in the analysis because these data points were judged to be outliers.

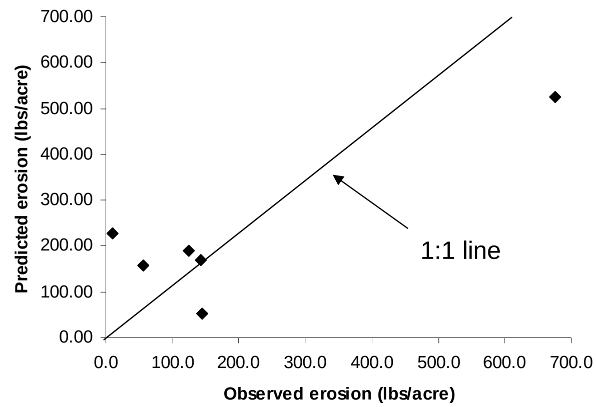

Figure 17.2. Predicted and observed erosion for south desert shrub plant community.

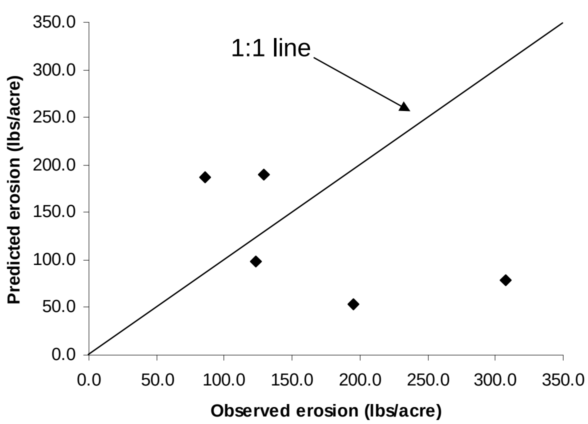

Figure 17.3. Predicted and observed erosion for southern mixed grass plant community.

about 220 lbs/acre while observed erosion was about 10 lbs/acre. However, other than this data point, the data are comparable to scatter in erosion data for cropland at such low erosion rates. Data for the southern mixed grass prairie plant community are shown in Figure 17.3. The error is large for two data points. Based on these results, a RUSLE2 erosion estimate for a particular rangeland site could be in error by a factor of five.

Even a modest evaluation of RUSLE2's accuracy for range and similar lands is essentially impossible because of limited research data (See **Section 17.2)**. The WEPP and Range Study Team datasets are the best available, but these data were produced using rainfall simulators and involved rainfall application at a single point in time rather than at several times during the year and over several years. The WEPP and Range Study Team data do not account for average annual seasonal changes or year to year changes. Even though above and surface ground cover can be measured, below ground measurements can not be easily made to determine the land use residue effect at the time of the experiments. Weather, vegetation, and soil conditions over several years preceding the experiments can greatly affect erosion measured at a single point in time.

The similarity of erosion generated by simulated rainfall and that produced by natural rainfall on western US rangelands is highly questionable. For example, the erosivity of single simulated storm in both the WEPP and Range Study Team experiments was about 50 US erosivity units whereas the average annual erosivity in much of the western US, where most rangeland occurs, is less than 20 US erosivity units. The data used to determine the Table 17.6 values were from a single simulated storm applied to dry soil conditions. These experiments also involved a second simulated storm applied to moist conditions. Table 17.6 values and results of RUSLE2 evaluations depend greatly on whether one or two storms are used in the analysis. Also, the simulated rainfall was applied in a uniform intensity that can give significantly different erosion when infiltration rates are high and spatially varied than erosion from temporally varied intensity.[181] Applying multiple simulated rainfall multiple times during the year affects the conditions being studied because of the additional rainfall. This effect is very important in the dry climates where most rangeland occurs where the simulated rainfall is a significant portion of the annual rainfall.

Table 17.7. Erosion values from two side by side replicates for WEPP study

Erosion (lbs/ac)		
Low rep	High rep	ratio
8	20	0.42
55	85	0.64
0	56	0.00
34	91	0.37
4	100	0.04
14	27	0.54
0	3	0.00
0	0	-
0	330	0.00
0	0	0.00
26	68	0.38
213	375	0.57
145	194	0.75
0	10	0.00
0	0	-
0	0	-
22	79	0.28
0	20	0.00
350	464	0.75
244	300	0.81
50	203	0.24
0	23	0.00
302	581	0.52
3	48	0.06
7	44	0.16
0	0	-
0	0	-
5	69	0.07
15	43	0.36
0	4	0.00

Accurately measuring the low erosion rates typical of rangeland conditions (e.g., 50 lbs/ac in Figure 17.3) and having small differences, especially on a percentage basis, between replications is almost impossible. Table 17.7 shows a range of the ratio of measured erosion for the two replications in the WEPP study. These ratio values are not particularly meaningful given the low erosion rates. A slight soil disturbance near the end of a plot or a slight shift in the placement of plots could have easily produced significantly different measured erosion values. Expecting RUSLE2 or any other model to precisely fit data for individual sites is unrealistic and unreasonable because of the low erosion rates, spatial and temporal variability, and the difficulty of measuring low erosion rates. These data issues must be considered when evaluating RUSLE2 for its applicability to range and similar lands. RUSLE2 may perform better than the experimental data used to evaluate it.

Is RUSLE2 adequate for conservation and erosion control planning for range, pasture, idle, and similar lands? VERY DEFINITIVELY. RUSLE2 describes the main effects of how the major physical, biological, and ecological variables, affect erosion as conclusively proven by fundamental erosion research. RUSLE2 computes the low erosion rates that have been measured on range, pasture, idle, and similar lands. RUSLE2 accurately represents how changing major variables such as plant community, production level, removal of biomass, and mechanical soil disturbance affects erosion.

[181] Flanagan, D.C., G.R. Foster, and W.C. Moldenhauer. 1988. Storm pattern effect on infiltration, runoff, and erosion. Transactions of American Society of Agricultural Engineers 31(2):414-420.

RUSLE2 can be used as a conservation and erosion control planning tool for rangelands, pasturelands, idle, and other similar lands.

17.4.1.5. Erosion values for construction sites

Published data related to erosion control on construction sites using straw and other mulch types were extensively reviewed during the development of RUSLE1.06.[182] New RUSLE1.06 relationships were developed to describe the reduced effectiveness of mulch on construction sites relative to cropland. These new relationships also describe how mulch conformance to soil surface roughness affects erosion control on construction sites. Also, the effectiveness of simple sediment basins, surface roughness, ridging, and porous barriers on reducing erosion and trapping sediment was also extensively reviewed during the RUSLE1.06 development. Equations, input values, and other information developed for RUSLE1.06, along with information developed since the RUSLE1.06 release were used in the development and evaluation of RUSLE2 for its applicability to construction sites and similar conditions. RUSLE2 works significantly better for construction site conditions than does RUSLE1.06.

17.4.1.6. Erosion values for disturbed forestland

The Dissmeyer-Foster subfactor method used to estimate erosion on disturbed forestland is widely recognized and accepted.[183] The basic subfactor relationships used in that method are used in the RUSLE2. Therefore, RUSLE2 estimates erosion with comparable accuracy as does the Dissmeyer-Foster method. RUSLE2 is substantially better than the USLE with the Dissmeyer-Foster method because of RUSLE2's increased power and capability, such as applying to non-uniform overland flow profiles and improved relationships for computing revegetation of disturbed forestland following mechanical disturbance. RUSLE2 can also be applied to road construction in forested areas and can estimate erosion on logging roads where the runoff occurs as overland flow. RUSLE2 can also be used to evaluate how alternative burning treatments and forest fire affects erosion. Burning removes surface biomass and some buried biomass and roots. RUSLE2 represents burning removing surface and buried biomass, but it does not represent the removal of either live or dead root biomass by burning.

17.4.2. Accuracy of RUSLE2 by statistical measures

---

[182] Toy, T.J. and G.R. Foster (coeditors). 1998. Guidelines for the use of the Revised Universal Soil Loss equation (RUSLE1.06) on mined lands, construction sites, and reclaimed lands. USDI-Office of Surface Mining. Denver. CO.

[183] Dissmeyer, G.E. and G.R. Foster. 1980. A guide for predicting sheet and rill erosion on forest land. Technical Publication SA-TP-11. USDA-Forest Service-State and Private Forestry-Southeastern Area. 40 pp.

An analysis of the statistical fit of the USLE to the experimental natural runoff plot data used to develop the USLE showed that the USLE computes average annual erosion within 25 percent for average annual erosion between 4 and 30 tons/acre and within 50 percent for average annual erosion between about 0.5 and 4 tons/acre.[184] The uncertainty increases rapidly for average annual erosion less than 1 ton/acre and can exceed 500 percent for average annual soil loss less than 0.1 tons/acre (see **Section 17.4.1.4**). The uncertainty also increases, but not greatly, for average annual erosion greater than 30 tons/acre. The uncertainty in RUSLE2's estimates erosion are slightly greater than that for the USLE based on an evaluation of RUSLE1 using the same data and the similarities between RUSLE1 and RUSLE2.[185]

RUSLE2 (and RUSLE1) not fitting the data as well as the USLE is expected. The AH537 soil loss ratio values used in the USLE are essentially direct summaries of the experimental data whereas the soil loss ratio values used by RUSLE2 (and RUSLE) are computed with equations fitted to the AH537 values. As expected, the fitted equations do not exactly fit the data (see **Section 17.4.1.1)**.

Even though the fit of RUSLE2 to the experimental data is slightly less than the USLE fit, RUSLE2 is superior to the USLE because of RUSLE2's increased power and capability. In contrast to the USLE, RUSLE2 can be applied to conditions where experimental data have not been collected to empirically determine soil loss ratio values. Although the USLE has a cover-management subfactor procedure for "undisturbed, pasture, and idle lands," the procedure is deficient and should not be used. The RUSLE2 subfactor procedure is much better than the USLE procedure.

A statistical analysis of the fit of the USLE to the experimental data is not particularly robust because the natural runoff plot data have a high degree of unexplained variability.[186] A difference of 30 percent in measured erosion between adjacent plots is common for conditions where little difference would be expected. The difference in measured erosion between replicate plots can not be explained by measured differences in soil, topography plot preparation, or plot condition. Data quality must often be compromised in finding a hillslope where an adequate number of replications can be installed without excessive variation in soil or topographic properties that affect erosion

---

[184] Risse, L.M., M.A. Nearing, A.D. Nicks, and J.M. Laflen. 1993. Error assessment in the Universal Soil Loss Equation. Soil Sci. Soc. Am. J. 57: 825-833.

[185] See:

Rapp, J.F. 1994. Error assessment of the Revised Universal Soil Loss Equation using natural runoff plot data. M.S. Thesis. University of Arizona, Tucson.

Tiwari, A.K., L.M. Risse, and M.A. 2000. Evaluation of Wepp and its comparison with USLE and RUSLE. Trans. ASAE 43:1129-11135. (Based on this paper, RUSLE is slightly better than the process-based model WEPP.)

[186] Nearing, M.A., G. Govers. and L.D. Norton. 1999. Variability in soil erosion data from replicated plots. Soil Sci. Soc. Amer. J. 63: 1829-1835.

(see **Section 17.2**). Too few replications at individual locations, non-uniform coverage of the major variables that affect erosion and differences in statistical designs between locations in numerous studies prevent the use of common statistical methods to evaluate RUSLE2's statistical accuracy. The number of variables affecting erosion is very large, which in turn requires a large and high quality database to statistically evaluate RUSLE2. If the database is too small and does not uniformly cover the range of variables affecting erosion, erroneous conclusions are drawn. For example, Risse et al.[187] concluded that contouring does not affect erosion. However, when a proper dataset on contouring is assembled and analyzed, the analysis shows that contouring has a major effect on erosion although its effect is highly variable (see **Section 14.1**).[188]

Because RUSLE2 is, for the most part, empirically derived, RUSLE2's adequacy is determined by the data used to derive it. Therefore, RUSLE2's adequacy for a particular application is largely determined by how well the plots and small watersheds (<5 acres) used to derive RUSLE2 represent actual field conditions.

RUSLE2 provides an accurate representation of how major variables affect erosion as measured by plots and small watersheds (<5 acres).

17.4.3. Qualitative assessments of RUSLE2's accuracy

Qualitative assessments of RUSLE2's accuracy are useful in guiding conservation planning decisions. The following sections provide qualitative assessments of where RUSLE2 works best and where it is less well suited.

17.4.3.1 Temporal values

RUSLE2 is designed to estimate average annual erosion. It is not designed to estimate erosion from individual storms, specific time periods, probability distributions of erosion by storm, season, or year. Also, it is not designed to estimate erosion for a storm with a given recurrence interval. Information in AH537 can be used to construct probability

[187] Risse, L.M., M.A. Nearing, A.D. Nicks, and J.M. Laflen. 1993. Error assessment in the Universal Soil Loss Equation. Soil Sci. Soc. Am. J. 57: 825-833.

[188] The Risse et al. and Tiwari et al. papers are considered definitive papers on statistical evaluations of the USLE and RUSLE. However, these papers' shortcomings affect interpretation of their results. The evaluations described in both papers used only a portion of the available data (e.g., Tiwari et al. used only 1600 plot-years of data for 20 locations while Risse et al. used only 1700 plot-years of data at 23 locations out of more than 10,000 plot-years of data at 43 locations used to develop the USLE and RUSLE). The natural runoff plot data used to develop the USLE are not uniformly distributed for the main variables that affect rill-interrill erosion. Choosing an unbiased 20 percent sample from the entire dataset is difficult. For example, the evaluation dataset chosen by Risse et al. was biased. The dataset included 2 plots from Morris, MN, 13 plots at Guthrie, OK, and 18 plots from LaCrosse, WI. Neither paper provides information to show that the evaluation results were unbiased. Such statistical evaluations are not robust and their validity is questionable.

distributions for annual erosivity at individual locations that can be used in RUSLE2 to compute probability distributions of annual erosion for average soil and cover-management conditions. **RUSLE2** can not consider deviations in cover-management conditions by day, season, or year from the average condition.

An advanced user can compute erosion with RUSLE2 for a single storm. The erosion computed for this storm represents the average erosion produced by the storm occurring in many years on the storm's date.[189] Although RUSLE2 is not recommended for estimating erosion for individual storms, RUSLE2's accuracy for individual storms is comparable to that for process-based models like WEPP.[190] Other research has also shown that simple empirical models fitted to observed data perform as well as or better than process-based hydrologic models.

The USLE equation structure, which is used in RUSLE2, is said to underestimate erosion when average annual erosion and erosion from individual storms is large.[191] However, this statement does not accurately represent this equation structure. The USLE equation structure is fitted to estimate average annual erosion values. Consequently, it is self evident that this equation structure, when properly fitted to the data, both underestimates and overestimates large erosion. This equation structure underestimates erosion when a large storm produces an unusually high runoff relative to storm amount because the storm occurred on very moist soil. RUSLE2 has no explicit runoff term to represent increased runoff for a given rainstorm. Conversely, the equation structure overestimates erosion when the same storm occurs on very dry soil that produces low runoff. Estimating runoff is more difficult than estimating erosion based on W.H. Wischmeier's experience.[192] Process-based models' equation structure should give them an inherent advantage over RUSLE2 for estimating erosion for single storms, but that capability is barely realized in practical applications. The advantage of process-based models is lost because of

---

[189] The RUSLE2 is designed for conservation and erosion control planning where average annual erosion is used in the planning process. As a consequence, the RUSLE2 computer program is not designed to accept inputs for specific storms and, therefore, is inconvenient for computing erosion for individual storms.
[190] See:
Tiwari, A.K., L.M. Risse, and M.A. Nearing. 2000. Evaluation of Wepp and its comparison with USLE and RUSLE. Trans. ASAE 43:1129-11135.

Nearing, M.A. 1998. Personal communication.

[191] Risse, L.M., M.A. Nearing, A.D. Nicks, and J.M. Laflen. 1993. Error assessment in the Universal Soil Loss Equation. Soil Sci. Soc. Am. J. 57: 825-833. (In fact, Figure 1 in this paper shows that the USLE does not underestimate erosion for measured high erosion relative to moderate erosion. Figure 1 does show that the USLE overestimates erosion for low measured erosion. The overestimation occurs for annual erosion less than 1 ton/acre.)

[192] **Wischmeier**, W.H. 1966. Relation of field plot runoff to management and physical factors. Soil Sci. Amer. Proc. 30:272-277.

Wischmeier, W.H. mid 1970's. personal communication.

estimation errors in runoff and the many variables that are functions of environmental variables in these models.[193] The cumulative effect of having many more variables to calibrate in process-based models than in the USLE equation structure diminishes process-based model performance. Too often calibration of process-based models results in fitting unexplained variability rather than main effects.

17.4.3.2. Soils

Difficulty in estimating runoff from input climate data is the major reason why an explicit runoff term is not used in RUSLE2 except for computing the effect of support practices on erosion where an index-based approach is used to capture main effects.

RUSLE2 is most applicable to medium textured soils. It works moderately well for fine textured soils and acceptably for coarse textured soils and least well for high sand soils. Errors can be large when applied to rangeland coarse textured soils in the Southwestern US and to soils on reclaimed mined land having a very high content of large rock fragments. Technical judgment can be used in assigning soil erodibility factor values to overcome some of these difficulties (see **Section 7**).

RUSLE2 should not be applied to organic soils, such as peat.

17.4.3.3. Topography

RUSLE2 works best for overland flow path lengths between 50 (15 m) and 300 ft (100 m) long. It works moderately well for overland flow path lengths less than 20 ft long, including overland flow path lengths as short as 1 inch (25 mm), and for overland flow path lengths between 300 and 600 ft (100 and 200 m). It works acceptably for overland flow path lengths between 600 and 1000 ft long (200 and 300 m).

RUSLE2 should not be applied to overland flow path lengths greater than 1000 ft (300 m). The RUSLE2 program will not accept input values greater than 1000 ft (305 m).

RUSLE2 works best for overland flow path steepness between 3 and 20 percent. It works moderately well for steepness less than 3 percent and between 20 and 35 percent. It works acceptably for steepness between 35 and 100 percent. It should not be applied to steepness greater than 100 percent.

---

[193]Tiwari, A.K., L.M. Risse, and M.A. Nearing. 2000. Evaluation of Wepp and its comparison with USLE and RUSLE. Trans. ASAE 43:1129-11135.

RUSLE2 should not be used for overland flow path steepness greater than 100 percent. The RUSLE2 program does not accept input values greater than 100 percent

RUSLE2 can be applied to all overland flow path profile shapes, including those where deposition occurs (see **Section 5.2**). Its erosion estimates for the eroding portions of overland flow paths are significantly more accurate than deposition estimates for the depositional portions. Accurately estimating deposition by overland flow is very difficult because a slight change in overland flow hydraulics can greatly affect deposition. RUSLE2 estimates are most accurate for uniform cover-management along an overland flow path. RUSLE2 is less accurate where cover-management varies enough along the overland flow path to significantly affect runoff because RUSLE2 does not explicitly consider runoff in its detachment computations. Overland flow path segment lengths can be adjusted to partially to account for this RUSLE2 limitation (see **Section 8.4**).

17.4.3.4. Geographic Region

RUSLE2 works best where rainfall occurs regularly, rainfall is the dominant precipitation, and average annual rainfall exceeds 20 inches. **RUSLE2** works acceptably in low rainfall regions like the western US. In these areas, RUSLE2 results should be interpreted as representing average erosion for sites having conditions like the field site rather than representing erosion on the actual field site. RUSLE2 erosion estimates are more accurate for actual field sites in high than in low rainfall regions. RUSLE2's accuracy is significantly reduced in low rainfall regions where annual erosion is low, especially if it is less than 1 ton/acre. **RUSLE2** can be used to estimate erosion in the special winter condition represented by the Northwest Wheat and Range Region. Special adjustments are needed for other regions where Req-type effects occur (see **Section 6.3.3**).

RUSLE2 does not explicitly estimate erosion caused by snowmelt.

17.4.3.5. Land Use

RUSLE2 is land use independent. It applies to all land uses where mineral soil is exposed to the erosive forces of raindrop impact and Hortonian overland flow. RUSLE2 works best for all land uses where annual erosion exceeds 1 ton/acre. **RUSLE2** works best for cropland, construction sites, land fills, and moderate to highly disturbed military training sites. It works moderately well on pastureland, mine spoil and disturbed forestland. It works acceptably on rangeland, abandoned crop and pastureland, and similar wildlife lands with few trees.

RUSLE2 should not be used for undisturbed forestland.

17.4.3.6. Irrigation

RUSLE2 can be used to estimate erosion by rainfall on lands where irrigation is used.

RUSLE2 cannot estimate erosion by furrow, flood, or similar types of surface irrigation.

17.4.3.7. Processes

RUSLE2 estimates rill and interrill erosion from rainfall and its associated runoff produced as Hortonian overland flow. It estimates sediment yield from overland flow paths, from diversion/terrace type channels where deposition occurs, and from impoundments like small sediment basins and impoundment terraces (see **Section 5.2**).

RUSLE2 does not estimate erosion or deposition in concentrated flow areas like within-field ephemeral gullies, incised gullies, and stream channels. RUSLE2 does not estimate erosion by mass wasting or by piping (i.e., water flowing through "pipes" in the soil).

17.5. Relation of RUSLE2 to other USLE/RUSLE erosion prediction technologies

The USLE was first used for local field office conservation planning by the USDA-Soil Conservation Service in the early 1960's. AH282, published in 1965, documented this USLE version. The next version of the USLE was documented in AH537, and it remains the standard USLE version. RUSLE1 was first released in 1992. The NRCS officially adopted RUSLE1.05 for local field office conservation planning in the mid 1990's. RUSLE1.05 is documented in AH703. RUSLE1.06, intended to replace RUSLE1.05, was released in 1998 and documented in the OSM manual for applying RUSLE1.06 to construction, mine, and reclaimed lands.[194] An erroneous impression is that RUSLE1.05 should be applied to cropland and RUSLE1.06 to disturbed lands. All versions of RUSLE1.06 apply to all lands. RUSLE1.06c was released in 2003. Changes were made so that RUSLE1.06c erosion estimates more closely correspond with RUSLE2's estimates than those from previous RUSLE1.06 versions.

[194] Toy, T.J. and G.R. Foster (coeditors). 1998. Guidelines for the use of the Revised Universal Soil Loss equation (RUSLE1.06) on mined lands, construction sites, and reclaimed lands. USDI-Office of Surface Mining. Denver. CO.

Foster et al. describe major differences in these technologies.[195]

17.5.1. Erosivity

The erosivity values given in AH282, AH537, and AH703 were determined from precipitation data collected from the mid 1930's to mid 1950's for the eastern US. The RUSLE2 erosivity values were determined from precipitation data collected from 1960 through 1999 for the entire continental US (see **Section 6.2**). Overall, the erosivity values from the recent data are about 10 percent higher in the Eastern US than erosivity values from the early data. The RUSLE2 erosivity values for the western US are much better than the erosivity values in AH537 or AH703.

RUSLE2 erosivity values should be used in all USLE/RUSLE versions.

Erosivity values in AH537 were reduced along the US Gulf Coast to account for high intensity rainfall ponding water that creates a water depth and reduces raindrop impact erosivity. Erosivity values in AH703 were not reduced to account for this effect. Instead, a ponding subfactor that is a function of the 10 year EI value and slope steepness was used in all RUSLE1 versions, but the ponding subfactor was used only with ridges. RUSLE2 uses a similar ponding subfactor (see **Section 9.2.7**) that is applied regardless of the presence of ridges.

The AH703 10 yr EI values were also based on the 1930's to 1950's precipitation data. The 10 yr EI values were contoured in great detail, which resulted in a 10 yr EI map with long narrow ridges-valleys in the equal value lines. A 10 yr EI map was developed for RUSLE1.06c that eliminated these ridges-valleys to represents main trends across the US appropriate for computing how support practices affect erosion.

The new RUSLE1.06c 10 yr EI map should be used in all RUSLE1 versions.

RUSLE2 uses 10 yr-24 hr precipitation values, which are based on data collected from before the 1960's, rather than 10 yr EI values. Smoothed 10 yr-24 hr precipitation values used in RUSLE2 are shown in Figure 6.18. These values capture the main trends across the Eastern US, much like the new 10 yr EI map developed for RUSLE1.06c.

RUSLE2 uses modern precipitation and temperature data that should also be used in all RUSLE1versions.

---

[195] Foster, G.R., T.J. Toy, and K.G. Renard. 2003. Comparison of the USLE, RUSLE1.06c, and RUSLE2, for application to highly disturbed land. In: First Interagency Conference on Research on Research in the Watersheds. USDA-Agricultural Research Service. Washington, D.C. pp. 154-160.

Use the smoothed 10 year EI map developed for RUSLE1.06c for all RUSLE1 versions.

17.5.2. Soil erodibility

All USLE/RUSLE versions use the same base soil erodibility factor value. RUSLE1.05 and RUSLE1.06b temporally vary the soil erodibility factor value while RUSLE1.06c does not. The resulting erosion difference can be 20 percent in some Midwestern US and Northeastern US location. RUSLE2 uses a new procedure to temporally vary soil erodibility factor values that is much better than the old RUSLE1 procedure, especially in the western US outside of Req type regions. The net soil erodibility factor value computed by RUSLE2 can also differ from RUSLE1.05 and RUSLE1.06 net erodibility factor value by 20 percent. The net soil erodibility value computed by RUSLE2 is close to the base soil erodibility value used by RUSLE1.06c for most of the Eastern US.

The RSULE2 temporal soil erodibility equation also computes average annual soil erodibility values that vary with location, even when soil properties are the same between locations. This effect is greatest in the Western US where soil erodibility values can vary as much as 50 percent from base soil erodibility values.

Do not temporally vary soil erodibility factor values in any RUSLE1 version.

RUSLE2 includes the standard USLE soil erodibility nomograph (AH537, AH703) widely used to estimate soil erodibility values. RUSLE2 also includes a modified version of the USLE soil erodibility nomograph that computes a greater effect of soil structure on soil erodibility than does the standard USLE nomograph (see **Section 7.3.2**). The trend of soil erodibility with soil structure in the standard USLE nomograph is not consistent with the trend identified by fundamental research.

The RUSLE2 modified soil erodibility nomograph should be used in all USLE/RUSLE versions when applied to highly disturbed lands. The standard USLE soil erodibility nomograph can be used on cropland.

The USLE does not consider sediment characteristics. RUSLE1.05 uses a single value deposition coefficient that does not vary with soil properties or upslope deposition. RUSLE1.06b and c use a deposition coefficient that is computed as a function of soil texture, but it does not change with upslope deposition. RUSLE2 computes sediment characteristics values for five sediment classes at the point of detachment as a function of soil texture. RUSLE2 computes how deposition changes the distribution among the sediment classes as deposition occurs. RUSLE2 computed deposition depends on how much upslope deposition has enriched the sediment in fines. RUSLE2 computes an enrichment ratio based on specific surface area, which is a function of soil texture and the portion of the detached sediment that is deposited.

17.5.3. Topography

The USLE slope length exponent varies only with slope steepness for steepness less than 5 percent. The RUSLE1.05 slope length exponent varies with slope steepness over the full range of steepness from zero to 100 percent. Also, the RUSLE1.05 slope length exponent is a function of the rill to interrill erosion ratio where the user selects from one three classes. In RUSLE1.06b and c, the slope length exponent is computed from the rill to interrill erosion ratio where the user selects from land use classes. Also, the RUSLE1.06 slope length exponent is a function of the rill soil erodibility to interrill soil erodibility ratio computed from soil texture. RUSLE2 computes the slope length exponent as a function of soil, steepness, and cover-management variables that affect the rill to interrill erosion ratio (see **Section 8.1.1**).

The slope length exponent used in the USLE and all RUSLE1 versions is constant over the computational period (i.e., duration in cover-management description). In contrast, RUSLE2 computes a slope length exponent value that varies daily as cover-management conditions change daily.

As a minimum, the RUSLE1.05 slope length relationship (AH703) should be used in the USLE.

The slope steepness relationship in the USLE has a quadratic form empirically derived from data collected at La Crosse, WI. This equation does not apply well to slope steepness less than about 2 percent or to slope steepness greater than about 25 percent. The RUSLE1 and RUSLE2 slope steepness relationship is based on a wide ranging dataset and is much more linear than the USLE quadratic relationship. No USLE, RUSLE, or RUSLE2 version varies the slope steepness relationship with any variable including time, soil, or cover-management.

The RUSLE slope steepness relationship (AH703) should be used in the USLE.

The USLE irregular slope procedure works well for determining how overland flow path profile shape affects erosion on the eroding portion of the flow path. It is not easily used where cover-management varies along the flow path. **The USLE does not compute deposition on concave flow path profiles.** RUSLE1.05, 1.06b, and 1.06c compute deposition on concave overland flow path profiles but do not vary the deposition coefficient along the overland flow path as deposition changes sediment characteristics. These models are not easily used where cover-management varies along the overland flow path except for rotational strip cropping. RUSLE2 computes how deposition changes sediment properties along the overland flow path that in turn affect downslope deposition. RUSLE2 is easily applied where cover-management varies along the overland flow path in any pattern (see **Section 17.4.3.3**)

17.5.4. Cover-management

RUSLE2 computes soil loss ratio values that can be compared to AH537 values. Also, RUSLE2 can be used to compute soil loss ratio values to use where experimental research has not determined values for the USLE. However, a much better approach is to use RUSLE1.06c rather than the USLE. The cover-management relationships in RUSLE1.06c are comparable to those in RUSLE2 and an error in the RUSLE1.05 and RUSLE1.06b computer programs in the soil biomass subfactor was corrected in RUSLE1.06c. The erosion reduction computed for no-till was reduced between RUSLE1.06b and RUSLE1.06c to be consistent with analysis conducted during the RUSLE2 development. Also, the interaction between canopy cover and ground cover used in the USLE and RUSLE2 is used in RUSLE1.06c but not in other RUSLE1 versions.

The AH537 soil loss ratio values for “conventional tillage” were used to calibrate **RUSLE2** so that the soil loss ratio values computed by **RUSLE2** match, as closely as possible, AH537 values.[196] The AH537 values for conservation tillage were not used in the **RUSLE** calibration because the AH537 values were based on research data collected in the late 1960's and early 1970's that do not represent modern conservation tillage. An extensive set of data from a literature survey was assembled and used to validate **RUSLE2** for no-till and other conservation tillage types.

Several considerations are important to ensure proper comparisons of RUSLE2 computed soil loss ratio values with AH537 and other soil loss ratio values.

RUSLE2 uses a ridge subfactor that is not used by RUSLE1. The effect of ridges is not represented in the AH537 soil loss ratio values except in Table 5-A. for cotton. Daily values of the RUSLE2 C and the ridge subfactors must be multiplied and integrated using the temporal erosivity distribution to compute a RUSLE2 soil loss ratio that can be compared to AH537 soil loss ratios.

The AH537 soil loss ratio values for crop stage four, the period following harvest, were not used to calibrate RUSLE2. Most of the data used to develop AH537 soil loss ratio

---

[196] Soil loss ratio is the ratio of erosion in a given period, like a crop stage, to erosion from the “unit plot” for the same period where all other conditions are the same. A crop stage is a period where cover-management conditions can be assumed to be constant. Equation 5.9 shows how soil loss ratios and crop stage periods are used to compute a cover-management factor value in the USLE.

values for cropland, except for conservation tillage and cotton, were from about 1935 to 1955. Farming practices in this period left corn stalks standing more erect after harvest than do modern combines that shred and spread the stalks. Also, AH537 soil loss ratio values for flat residue are based on a surface cover effect (mulch subfactor) having a b_f value of 0.026 (see equation 9.6), much lower than the now accepted value of 0.035. The data used to determine and evaluate **b** values in **RUSLE2** included the data used to develop the AH537 mulch subfactor curve plus additional data.

Many of the AH537 soil loss ratio values are for yields lower than modern yields, especially for corn. For example, the AH537 yield for high production corn is 112 bu/ac, whereas a modern corn yield is easily 150 bu/ac or more.

Soil loss ratios in AH537 are independent of location, whereas **RUSLE2** computed soil loss ratio values vary with location. For example, **RUSLE2** soil loss ratio values for corn are significantly lower in the upper Midwestern US than in the lower part of the Mid-South US because of the low soil biomass in the Mid-South where a humid, warm climate greatly increases biomass decomposition in comparison with the climate of the upper Midwest. Climate data at Columbia, Missouri were used to calibrate **RUSLE** and to represent typical conditions that would produce soil loss ratio values to compare with AH537 values, except for cotton where climate data from Holly Springs, MS were used.

To make comparisons between RUSLE2 soil loss ratio values and AH537 values, use Columbia, MO climate to compute RUSLE2 soil loss values for all AH537 conditions, except for cotton where the Holly Springs, MS location should be used. Climate data from Pullman, WA or Pendleton, OR should be used to compute RUSLE2 soil loss ratio values and other values to compare with research determined values in the Northwest Wheat and Range Region.

RUSLE2 was calibrated with the RUSLE2 core database. RUSLE2 soil loss ratio values should be computed using the RUSLE2 core database when making comparisons with AH537 values. Also, the RUSLE2 production (yield) level adjustment procedure should be used when comparing RUSLE2 computed soil loss ratio values with AH537 values for different production levels.

Table 10, AH537 is widely used in the USLE to compute erosion on range, pasture, idle, and undisturbed lands. **This procedure should not be used because it has major shortcomings (see Section *17.4.1.4*).** RUSLE2 and RUSLE1.06c provide much better estimates than the USLE for these conditions.[197] Also, RUSLE1.06c is much improved over RUSLE1.05 and earlier RUSLE1.06 versions for these conditions.

[197] Spaeth, Jr., K.E., F.B. Pierson, M.A. Weltz, and W.H. Blackburn. 2003. Evaluation of USLE and RUSLE estimated soil loss on rangelands. J. Range Management 56:234-246.

A major advantage of RUSLE2 and RUSLE1.06c is their land use independence that allows them to be applied to conditions that vary from highly disturbed to undisturbed over the period of interest. Examples include construction sites, reclaimed mine land, disturbed forestland, and landfills from the time of the last disturbance through recovery and stabilization. Also, RUSLE2 and RUSLE1.06c work well for military training sites and similar areas where conditions at the site range from highly disturbed to undisturbed and for rangeland sites that move back and forth with cropland depending on farming economics. If different models are applied to different time periods or to different land use conditions, the likelihood is almost 100 percent that erosion estimates from the different models will differ significantly at common point in time when common estimates are expected. These erosion estimate differences complicate interpretation of the values and raise questions about the validity of one or more of the models. Users may not know the correct erosion estimate, but they can easily recognize that differences are being computed where values should not be different.

RUSLE2 can be used to compute soil loss ratio values for any land use where RUSLE2 applies. These values can be used in the USLE for conditions where experimentally derived soil loss ratio values are not available. *RUSLE1.06c should be used rather than the USLE.*

17.5.5. Support practices

17.5.5.1. Contouring

The AH537 contouring subfactor values typically used in the USLE vary only with steepness of the overland flow path. All RUSLE1 versions compute contouring subfactor values that vary with the major variables that affect the relation between erosion and contouring. RUSLE1 uses input values for cover-management condition and ridge height that represent the entire computational period. These inputs are selected to compute average annual erosion. RUSLE2 uses equations similar to those in RUSLE1 to compute daily contouring subfactor values (**see Section 14.1**). A relative row grade of 10 percent and climate data for Columbia, MO should be used when comparing RUSLE2 and RUSLE1 contouring subfactor values with AH537 values. Also, cover-management conditions, including yield, used in RUSLE2 and RUSLE1 should be chosen to represent farming practices in the 1930' to mid 1950's to compute contouring subfactor values to compare with AH537 values.

RUSLE2 computes a net contouring subfactor value by integrating daily contouring factor values with the temporal erosivity distribution values. However, RUSLE2 net contour values are not the proper values to compare with AH537 values. The proper RUSLE2 contouring subfactor value to compare with an AH537 value is the ratio of RUSLE2 computed average annual erosion for a 10 percent relative row grade to average annual erosion for an up and downhill (100 percent) relative row grade. This RUSLE2 contouring subfactor is comparable to AH537 contouring subfactor values computed as the ratio of measured average annual erosion with contouring to measured average annual erosion with up and downhill tillage. Values for this RUSLE2 contouring subfactor value differs from the RUSLE2 net contouring subfactor (see **Section 17.5.6** for a discussion of the reason for this difference).

A difficulty with RUSLE1 is that representative input values for the entire computational period must be chosen. RUSLE2 computes daily contouring subfactor values based on the daily values for cover-management variables. RUSLE2 and RUSLE1 should give similar contouring subfactor values but the values will not compare exactly.

All RUSLE versions describe how major variables affect contouring failure (critical slope length). AH537 values only vary with slope steepness and whether or not strip cropping is used. AH537 gives a single adjustment for conservation tillage conditions. All RUSLE versions were calibrated to give AH537 critical slope lengths for the base Columbia, MO condition (see **Section 14.1.2.5**).

RUSLE2 can be used to compute contouring subfactor values for use in the USLE. The value should be computed as a ratio of average annual erosion values with and without contouring computed by RUSLE2. Actually, RUSLE1.06c should be used rather than the USLE.

17.5.5.2. Strips/barriers

Although Table 14, AH537 list factor values for several rotational strip cropping conditions, AH537 provides no factor values for narrow strips of permanent vegetation or mechanical barriers like fabric (silt) fences. To compare RUSLE2 and RUSLE1 factor values with AH537 values, make RUSLE2 and RUSLE1 computations with and without rotational strip cropping for Columbia, MO using input values that represent farming practices, including yield, in the 1930' to mid 1950's. Compute ratio values using RUSLE2 estimated average annual sediment yield, not detachment or erosion, to compare with AH537 values that were computed as measured sediment yield with strip cropping to measured sediment yield without strip cropping. Similarly, RUSLE1 sediment yield values should be used rather than the P factor values. The RUSLE1 P factor values do not give full credit for deposition as soil saved, whereas the AH537 and RUSLE2 values give full credit for deposition as soil saved for rotational strip cropping.

The AH537 strip cropping factor values do not apply to modern farming practices, including conservation tillage, that leave rough soil surfaces and high residue cover that induce deposition much like dense vegetation strips. The effectiveness of strips is related to sediment production on the more erodible strips relative to transport capacity in the strips having a high hydraulic resistance (see *Section 14.2*).

All RUSLE versions capture how major variables affect the relationship between sediment yield and strips/barriers. RUSLE1 uses inputs for cover-management condition for each strip that represents each year of the computational period. RUSLE2 computes daily factor values as a function of daily cover-management variables. Just as with contouring, RUSLE2 and RUSLE1 factor values for strips/barriers will not agree because of this difference in input even though similar equations are used in both models. Another reason for differences is that RUSLE1.05 uses a single deposition coefficient value, RUSLE1.06 uses a deposition coefficient that is a function of soil texture, and RUSLE2 uses sediment characteristics that are a function of soil texture and upslope deposition.

See **Sections 14.2 and 17.5.5.3** for a discussion of RUSLE2's conservation planning soil loss that gives credit for deposition as soil saved.

RUSLE2 can compute factor values for strips/barriers that can be used in the USLE, but a better approach is to use RUSLE1.06c rather than the USLE.

17.5.5.3. Diversions/terraces/sediment basins

Factor values for diversions, terraces, and small sediment basins reported by Foster and Highfill and the RUSLE1.06 OSM manual are the best values for comparing with RUSLE values.[198] The value of terraces as a soil conservation practice has been debated for several years. The benefit of terraces for shortening the overland flow path length to reduce sediment production and deposition in terrace channels and small sediment basins reducing sediment yield reduction is universally accepted. However, the value of deposition as soil saved is debated. For example, credit was given to deposition in 1965 in AH282 as soil saved but no credit was given in 1978 in AH537. The credit given is a matter of judgment. USDA-NRCS agronomists tend to claim no credit for deposition with terraces but prefer to claim credit for deposition caused by narrow permanent vegetation strips, while USDA-NRCS engineers prefer to claim credit for deposition caused by terraces.[199]

---

[198] See:

Foster, G. R. and R. E. Highfill. 1983. Effect of terraces on soil loss: USLE P factor values for terraces. Journal of Soil and Water Conservation 38:48-51.

Toy, T.J. and G.R. Foster (coeditors). 1998. Guidelines for the use of the Revised Universal Soil Loss equation (RUSLE1.06) on mined lands, construction sites, and reclaimed lands. USDI-Office of Surface Mining. Denver. CO.

[199] This debate among these NRCS disciplines involves a certain amount of self-interest. NRCS agronomists have technical oversight for permanent vegetation strips while NRCS engineers have technical oversight for terraces.

The RUSLE2 developers consider deposition in terrace channels and above permanent vegetation strips to have a similar benefit as soil saved. In fact deposition in terrace channels could perhaps merit increased credit because tillage redistributes this deposited sediment over a larger landscape area than tillage redistributes sediment deposited by permanent vegetation strips. RUSLE2 gives consistent credit to deposition as soil saved between terraces and permanent vegetation strips based on location along the overland flow path, except for rotational strip cropping where full credit is given to deposition. Also, the credit given to deposition as soil saved with terraces decreases as terrace spacing increases (see **Section 14.3**). Giving full credit to deposition associated with rotational strip cropping is consistent with AH282 and AH537 values. The RUSLE2 soil conservation planning soil loss value is the RUSLE2 output that reflects credit for deposition as soil saved (see **Section 8.1.5.4**).

RUSLE1.05 computes sediment yield from diversion/terrace channels as a function of channel grade only. That is, the fraction of the sediment load that is deposited in a diversion/terrace channel is independent of the sediment load coming into the channel or transport capacity in the channel. RUSLE2 and RUSLE1.06 compute deposition as a function of sediment characteristics, sediment transport capacity in the channel, and sediment load reaching the channel. If incoming sediment load is less than transport capacity, no deposition is computed. RUSLE1.05 assumes that 95 percent of the sediment that reaches a small sediment basin is deposited. RUSLE2 and RUSLE1.06c compute deposition in small sediment basins as a function of characteristics of the incoming sediment.

RUSLE2 can be used to compute diversion/terrace/sediment basin P factor values for use in the USLE. However, a better approach than using the USLE is to use RUSLE1.06c, which computes diversion/terrace/sediment basin P factors using equations that are similar to those used in RUSLE2.

17.5.6. Computing erosion

RUSLE2 computes net values for the soil erodibility factor K, topographic factor LS, cover-management factor C without the ridging effect, ridge subfactor, ponding subfactor, and contouring subfactor by weighting daily values with the temporal erosivity distribution, exactly in the same way that these computations are made in the USLE for the C factor and in RUSLE1 for the K and C factors.

These RUSLE2 computed factor values can be compared with those for the USLE and RUSLE1. These comparisons give insight into differences among RUSLE2, RUSLE1, and the USLE. The comparisons should be properly made. For example, the RUSLE2 net factor values for cover-management and ridging should be multiplied to obtain a C factor that can be compared with the USLE and RUSLE1 C factor values. Also, the proper RUSLE2 values for the contour and strip cropping factors is to divide the average annual sediment yield for contouring and contouring/contouring/strip cropping on a uniform overland flow path by estimated sediment yield without contouring or strip cropping. The RUSLE2 net contouring subfactor value differs from this RUSLE2 factor value for contouring because the net contouring subfactor only involves the temporal integration of the erosivity distribution while the ratio values involves the temporal integration of the product of all the RUSLE2 factors.

The RUSLE2 computed values for these factors can be multiplied as the USLE and RUSLE1 factor values are multiplied to estimate average annual erosion. However, this erosion value differs from the value computed by RUSLE2 because of differences in the mathematic integration among these models (see **Section 5.4**). RUSLE2 does not compute erosion by multiplying average annual values for individual factors; RUSLE2 computes average annual erosion by computing daily erosion as the product of the daily factor values and summing the daily erosion values. The difference in these mathematical procedures for computing average annual erosion can be as much as 15 percent, depending on cropping-management system and location.

Even if RUSLE2 were to produce net factor values that equaled USLE and RUSLE1 factor values, RUSLE2's computed average annual erosion would not match USLE and RUSLE1's computed average annual erosion. RUSLE2's mathematics properly integrate the temporally and spatially varying governing equations. The USLE and RUSLE1 procedures are approximations.

18. HOW RUSLE2 CAME TO BE

The Universal Soil Loss Equation (USLE) was developed in the late 1950s and became widely used in conservation planning on cropland in the 1960s. Beginning in the 1970s, the USLE was applied to many other land uses in addition to cropland and to other applications besides conservation planning.

The USLE was updated in 1978, but by 1985 the USLE needed another update with passage of the Farm Bill and to incorporate new research information. A project led by USDA-Agricultural Research Service was initiated at a workshop in Lafayette, Indiana in 1985 to update the USLE. This workshop attended by leading U.S. erosion research scientists and USLE users from the USDA-Natural Resources Conservation Service (formerly, Soil Conservation Service) and Forest Service, USDI-Bureau of Land Management, and U.S. Army Corps of Engineers set objectives and approaches for the update.

By 1987, much of the background work on updating the USLE was well underway and some had been completed. The project evolved into much more than an updating of the USLE. The USLE was undergoing a major revision, and hence the updated USLE became what is now referred to as **RUSLE1**, the **R**evised **USLE**. Also, another major addition to the project was the development of a computer program to implement RUSLE1.

Development of **RUSLE2** began in 1993 using RUSLE1 as the starting point. RUSLE2 uses the basic USLE equation structure to compute sediment detachment but differs greatly from the USLE in almost every other way. RUSLE2 is similar to RUSLE1, but RUSLE2 uses new equations, a new mathematical integration procedure, new database values, and is implemented in a modern graphical user interface computer program. Almost all of the mathematical relationships in RUSLE2 have been revised from corresponding relationships in RUSLE1.

RUSLE2 is much more powerful than either the USLE or RUSLE1. The interface for the RUSLE2 computer program, the underlying modeling engine of this computer program, its computational routines, and RUSLE2's mathematical equations make RUSLE2 the most modern, powerful, and easy-to-use erosion prediction technology available for use in conservation and erosion control planning at the local field office level.

RUSLE2 was developed by a group of experienced and nationally recognized erosion scientists, erosion control specialists, and soil conservationists. Data needed to develop and validate RUSLE were incomplete in some cases, which necessitated scientists and users using judgment to fill gaps. USDA-Agriculture Handbook 703 and other RUSLE1 publications, which was the starting point for RUSLE2, have been reviewed by peer scientists in a process typical of the reporting of rigorous research. Erosion scientists, NRCS technical specialists, and many others have made many computations with RUSLE2 to ensure that RUSLE2 works well for every imaginable situation where RUSLE2 will be applied. The scientific documentation for RUSLE2 has been peer reviewed according to standard procedures of the USDA-Agricultural Research Service.

RUSLE2 can be used with full confidence that it meets high scientific standards and produces reliable results for conservation and erosion control planning for all lands where rill and interrill erosion occur by rainfall and Hortonian overland flow.