RBF CONSULTING

QSP Training
Module 2
Erosion Theory

Erosion Mechanisms and RUSLE

Presentation Agenda

Erosion Theory

- Types of Erosion

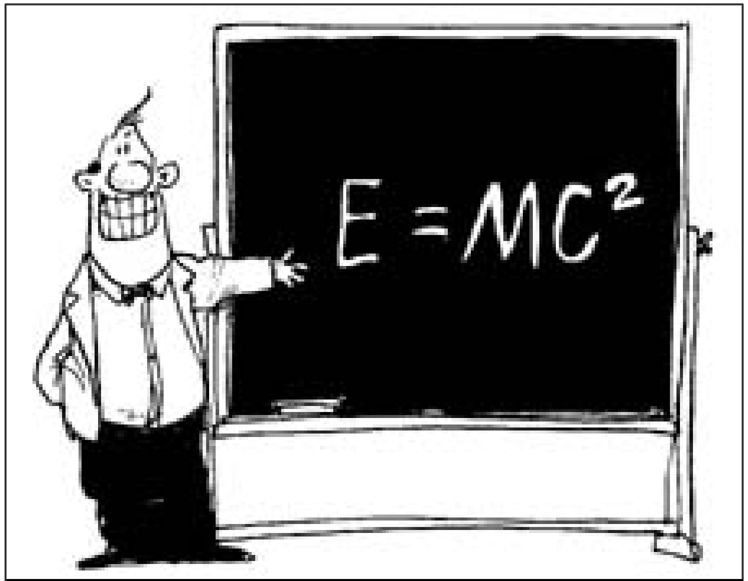
Sedimentation Processes

- Overview

Erosion Prediction (RUSLE)

- Example Using RUSLE

Erosion is Relative



Where:

E=Erosion of the Soil

M= Mechanical Disturbance

C=Construction Period

What is erosion?

Soil erosion is the process by which soil particles become detached by water, wind, or gravity and are transported from their original location

- **What do we need to understand about erosion?**
  - Understand how to prevent it
  - Understand how it varies for site conditions
  - Understand the causes
  - Understand how to predict it
- **Why is it bad?**
  - Turbid water:
    - Reduces light
    - Abrades fish gills
    - Deposits and covers vegetation
    - Contains metals, nutrients, other
    - Can get you fined.

What is Sedimentation?

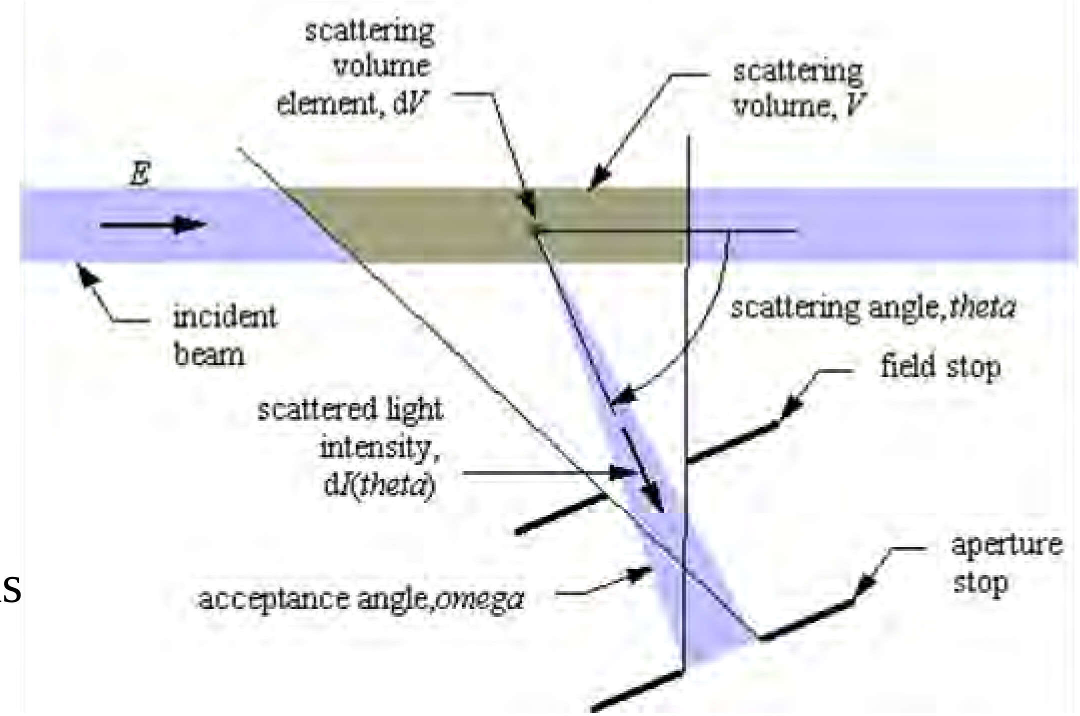
- To settle soil particles from suspension in quiescent conditions.
- If you don't have erosion, you do not need sedimentation.

Types of Erosion

- Splash/Raindrop Erosion
- Sheet Erosion (Interrill erosion)
- Rill Erosion
- Gully Erosion
- Channel Erosion
- All types occur on a construction site, but have different solutions to reduce or eliminate them

What is Turbidity?

- Turbidity is measured in Nephelometric Turbidity Units (NTUs)
- The instrument used for measuring it is called a nephelometer or turbidimeter, which measures the intensity of light scattered at an angle as a beam of light passes through a water sample



Raindrop Erosion

- Primary source of erosion
- Raindrop erosion is often imperceptible
- Indicators
  - Pedestals
  - Stains
  - Gravelling or Lag
- Prevent by: Protecting Soil

http://www.dot.ca.gov

Splash Erosion

- Rain drops striking bare soil directly at 5-20 mph
  - Detaches soil particles
  - Particles can then be transported by the action of water and/or wind

Sheet Erosion (Interrill Erosion)

- The removal of a uniform thin layer of soil by raindrop splash or water run-off
- Surface film of water 1/16" – 1/8" deep
- This process may occur unnoticed on exposed soil even though raindrops are eroding large quantities of soil
- Prevention: Soil binders or covers

Rill Erosion

- Sheet flows that become concentrated into conveyance
- Well-defined channels
- Small enough to step across
- Often end part way up a slope but can extend to crest by “headcutting”
- Increased velocity and turbulence
- The rate of rill erosion can be approximately **100 X greater than sheet erosion**.
- Prevention: Cover or segment slope

Gully Erosion

- Several rills may form throughout a slope and eventually may join together to form Gullies
- The rate of gully erosion can be approximately **100 X greater than rill erosion**
- Prevention: Control of flow, armoring

Gully Erosion

- Look for the following visual cues:
  - Large, deep cuts in soil
  - Single cuts
  - Often too large to step across
  - Often found in areas without evidence of other erosion types

Key Point – Gully and Rill erosion are caused by concentrated flows. Always treat the "problem" first – not the symptom.

Channel Erosion and Sedimentation

- Total sediment load in a channel is made up of bed material load and wash load.
- Bed Material Load: Composed of grain sizes in bed and banks. Moves along the bed and in suspension.
- Wash Load: Originates from land surface, very fine, very small settling velocity – function of supply, not hydraulics – computed by RUSLE/MUSLE

Sediment Load Classification

<table>
<tr><th></th><th></th><th colspan="2">Classification System</th></tr>
<tr><th></th><th></th><th>Based on Mechanism of Transport</th><th>Based on Particle Size</th></tr>
<tr><td rowspan="3">Total sediment load</td><td>Wash load</td><td rowspan="2">Suspended load</td><td>Wash load</td></tr>
<tr><td>Suspended bed-material load</td><td rowspan="2">Bed-material load</td></tr>
<tr><td>Bed load</td><td>Bed load</td></tr>
</table>

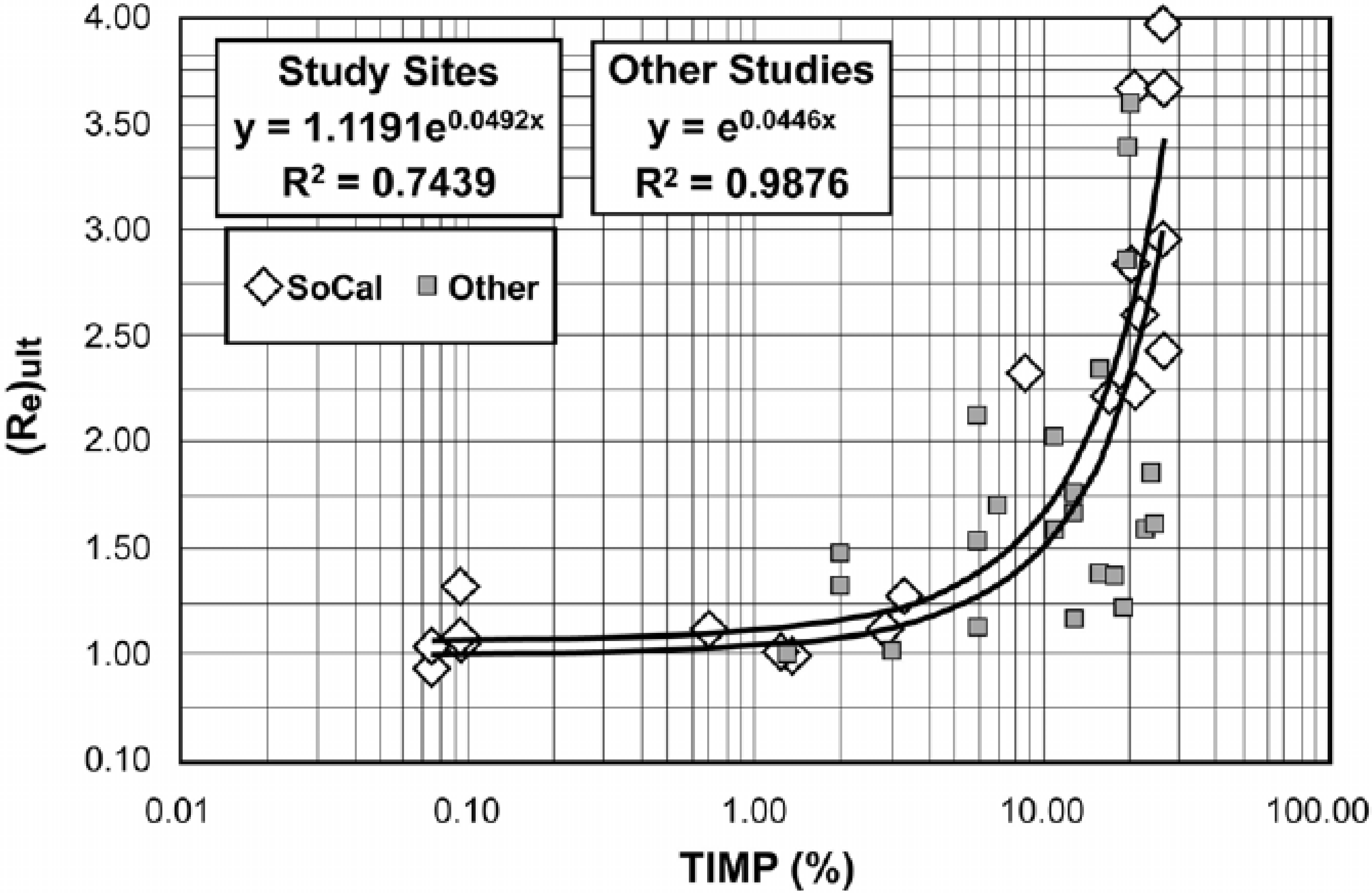
Lane's Relationship

- Channel equilibrium is dependent on four basic factors described by Lane (1955):

- Where: $Q_s \cdot D_{50} \propto Q_w \cdot S$
    - Q_s = Sediment discharge (bed material)
    - D_{50}=Median particle size
    - Q_w=Water discharge
    - S = Channel slope

Impact of Urbanization

- Volume of flow increases from 2 to 16 times with urbanization
- Urbanization has a greater impact on frequent events than on rare events
- Stream degradation (impact – channel erosion) begins at levels of watershed imperviousness (change) of from about 10% (or less)



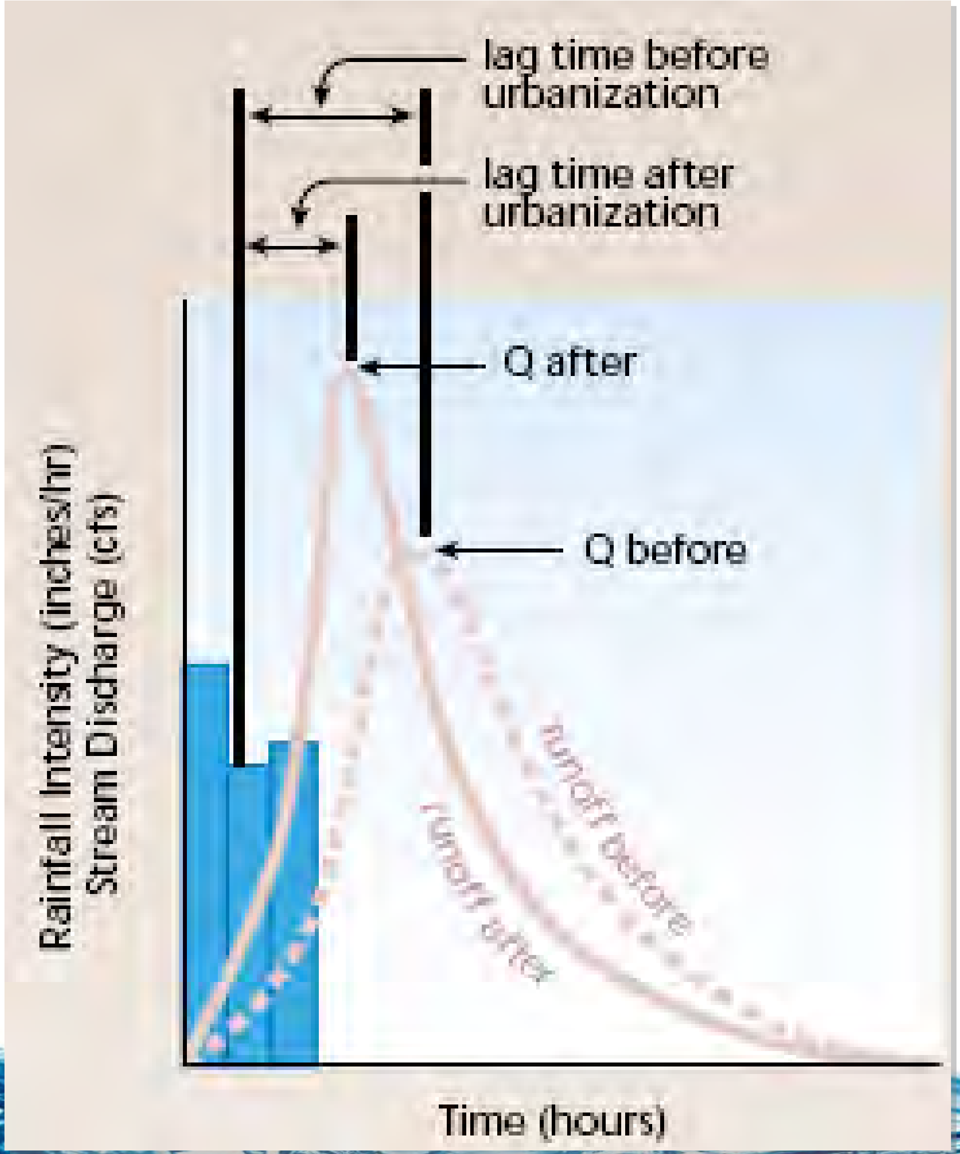
Study Sites
y = 1.1191e^0.0492x
R² = 0.7439
Other Studies
y = e^0.0446x
R² = 0.9876
SoCal
Other
(Re)ult
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.10
0.01
0.10
1.00
10.00
100.00
TIMP (%)

Stormwater

Flow Mitigation - Urbanization

- It is important to reduce **flow volume** since it directly impacts streams, this is also a key mitigation method for improving water quality.
- Peak flow for storms with recurrence intervals from 1 to 10 years should also be controlled for hydromodification impacts.
- For construction sites, these impacts will be controlled by the <u>post-construction BMPs</u>. They must be installed and operational prior to filing the NOT

Urbanization and Flow



Concept Review

- What is most important for channel stability?
    1. Sediment from the watershed
    2. Bed material load
    3. Suspended load
    4. Wash load

Answer: 2. Bed Material Load

Concept Review

- If a channel receives and increase in water discharge (Q_w), what is a likely response?

  1. Decrease in channel slope
  2. Aggradation
  3. Increased meander
  4. Reduced cross section

Answer: 1. and 3.

Concept Review

- Changes to the stream can be caused by:
    1. A change in sediment supply
    2. A change in sediment transport capacity
    3. A change in bank erodability
    4. A change in discharge

All of the above.

BMP Tool Box – Erosion Control

- Spray on binders
- Spray on mulches
- Spray on matrix
- Hydroseed
- RECPs
- Which is best?
  - Depends on: Design life, slope ratio, soil type and $ you want to spend.

BMP Tool Box – Runoff Control

- Maintain vegetation cover
- Diversion
- Detention
- Which is best?
  - Always use scheduling to maintain cover
  - Divert flows when possible around work area
  - Detention for flow control is a last resort

BMP Tool Box – Sediment Control

- Silt Fence
- Straw Wattle
- Gravel Bag
- Check Dam
- Sediment Basin
- Sediment Trap
- Which is best?
  - None work very well, all are required

Which are More Effective… Erosion Control or Sediment Control?

- Erosion controls are preferred
  - Keep the soil in its place
  - Enhance the protection of the site resources
- Use erosion controls as the primary protection, with sediment controls as a secondary system.
- Erosion controls give you about 85% of the overall program effectiveness

Basic Preventative Measures

1. Schedule site activities to minimize exposed soil area and duration
2. Divert flow around disturbed soil
3. Use temporary soil cover
4. Use sediment controls as a supplement to soil cover

Wind Erosion – WEQ and RWEQ

- **Depending on wind velocity and particle size, soil particles move by saltation, surface creep, and suspension.**
- **May be estimated by:**
  E = f (I x K x C x L x V)

  E= the potential average annual soil loss in tons per acre
  f = a function of
  I = the soil erodivility index. It is related to the percentage of non-erodible soil aggregates larger than 0.84 mm in diameter
  K = the surface roughness factor
  C = the climate factor. It is based on the average wind velocity and surface soil moisture
  L = the unsheltered distance across a field or strip along the prevailing wind erosion direction
  V = the vegetative cover factor

Wind Erosion - Stockpiles

$$E = 1.7(S/1.5)((365-p)/235)(f/15)$$

Where:

E = Total suspended particulates, lb/day/acre of pile

S = silt content, percent

P = number of days per year with ≥ 0.01” rainfall

F = percent time with wind speed > 12 mph at mean pile height

Wind Erosion Control

- Control system for wind erosion work in one of two ways:
  - Reduce wind speed on the soil surface
  - Form a new, less erodible soil surface

Reducing Wind Speed at Soil Surface

- Covering the pile with a wind-impervious fabric or other material
- Changing the pile orientation and shape

Forming a New Less Erodible Surface

- Spraying water to compact and weight the soil particles
- Applying a chemical dust suppressant or soil binder to form a crust or bind the surface soil particles together
- Establishing vegetation
  - Roots bind the soil together; stems and leaves reduce wind speed at soil surface

Pop Quiz – What kind of erosion is it?

Vegetation

A cover of temporary or permanent vegetation is the primary goal of all erosion control efforts

Sediment Yield

Channel Assessment Tool

Sediment Yield Estimation

- Channels must normally be stabilized in response to development
- RUSLE and MUSLE: Methods for estimating sheet erosion. Methods designed to predict average annual soil losses by sheet and rill erosion on upslope areas.
- Can be used to understand sediment contribution before and after project.
- RUSLE gives average annual sediment, MUSLE provides estimate for discrete events

Sediment Yield

- MUSLE Equation:
- Where:
  - Y = Sediment yield (tons/storm)
  - V_w = Runoff volume (acre-ft)
  - q_p = Peak flow (cfs)
  - C_1&C_2 = Coeff's

$$Y = C_1 \left(V_w q_p \right)^{C_2} K \left(LS \right) CP$$

Sediment Yield

- K = Soil erodability factor, defined as the erosion rate in tons per acre.
- LS = Dimensionless slope length factor equal to the ratio of soil loss per unit area.
- C = Dimensionless cropping management factor.
- P = Dimensionless erosion control practice factor.
- $C_1 = 95$, $C_2 = 0.56$

Using RUSLE

The Revised Universal Soil Loss Equation

- The most widely used and tested model
- Used as a tool to estimate erosion rate
- Used to determine if a construction site qualifies for a low rainfall erosivity waiver
- Can be used to test the acceptability of temporary erosion and sediment controls

History of USLE/RUSLE

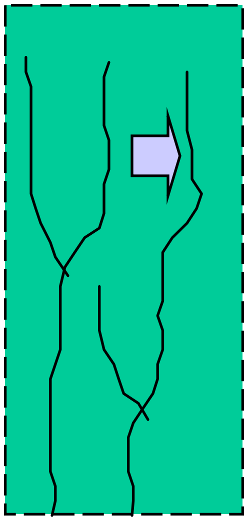
- **1930's** – First model included soil erodibility, rainfall, groundcover for agricultural purposes.
- **1940's** – Slope steepness/ length and practice were added to equation.
- **1956** – USLE was universally adopted by USDA and the Soil Erosion Laboratory was established at Purdue University.
- **1970's** – RUSLE published included revised rainfall data maps, added new conservation practices and combined slope L & S (LS) to reflect a ratio.
- **1990's** – RUSLE 2 developed (Windows Based Program)
- **2000** – Initial testing by NRCS
- **2004** – Implementation and field verification

RUSLE 2

- Computer model used to predict rill & inter-rill erosion caused by rainfall
- Calculates sediment yield on a daily basis
- RUSLE2 is an upgrade of the text-based RUSLE DOS version 1
- The USDA-Agricultural Research Service (ARS) is the lead agency for developing the RUSLE2 model.

Landscape

RUSLE2 Area

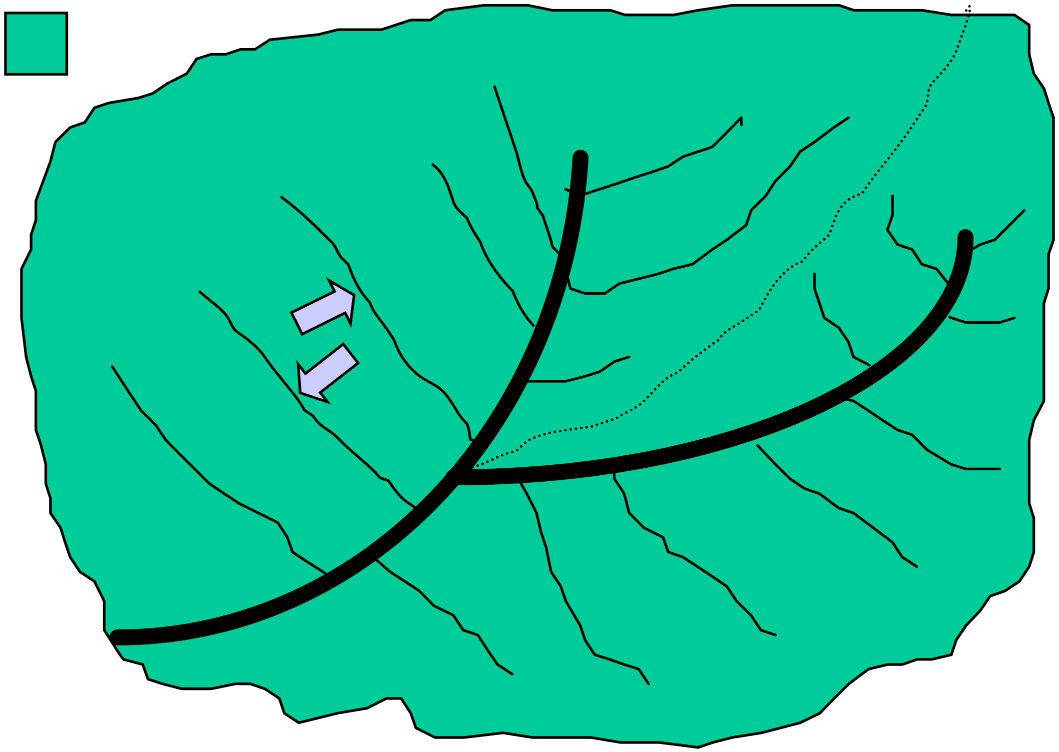


Overland flow

Interrill

Rill

Ephemeral Gully (Concentrated flow)



Erosion Types

Validation of RUSLE

- 10,000 plot-years of data from natural runoff plots
- 2000 plot-years of rainfall simulator data
- Proven by more than 4 decades of worldwide use by its predecessors, USLE and RUSLE

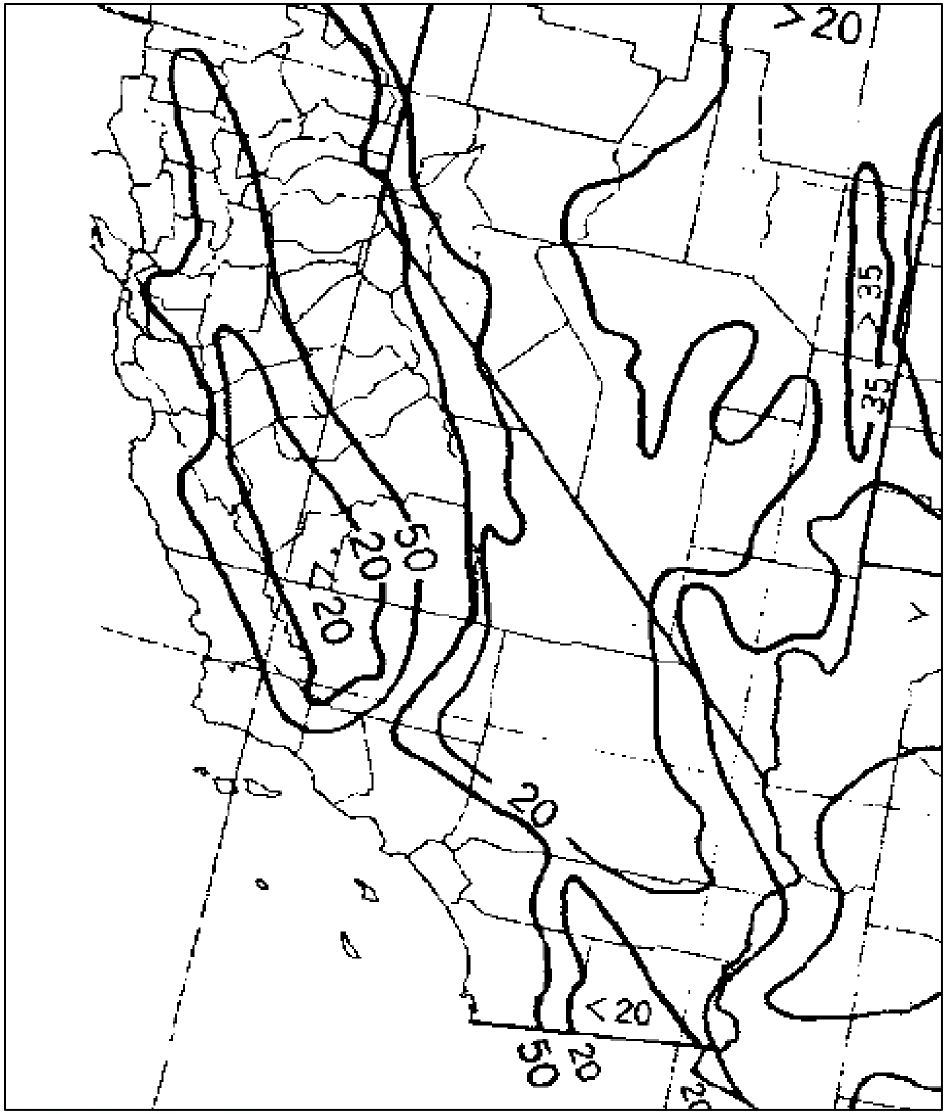
RUSLE

$$\mathbf{A = R \cdot K \cdot LS \cdot C \cdot P}$$

- Rainfall (*R*) (energy)
- Soil Erodibility (*K*)
- Slope Length and Steepness Factor (*LS*)
- Conservation Factor (*C*)
- Support Practices (*P*)

Rainfall Runoff Erosivity Factor (R)

Rainfall Erosivity Factor for a given geographic location



Map for R - Factor

R = E x I/n

Where,

E = kinetic raindrop energy

I = maximum 30-minute storm intensity

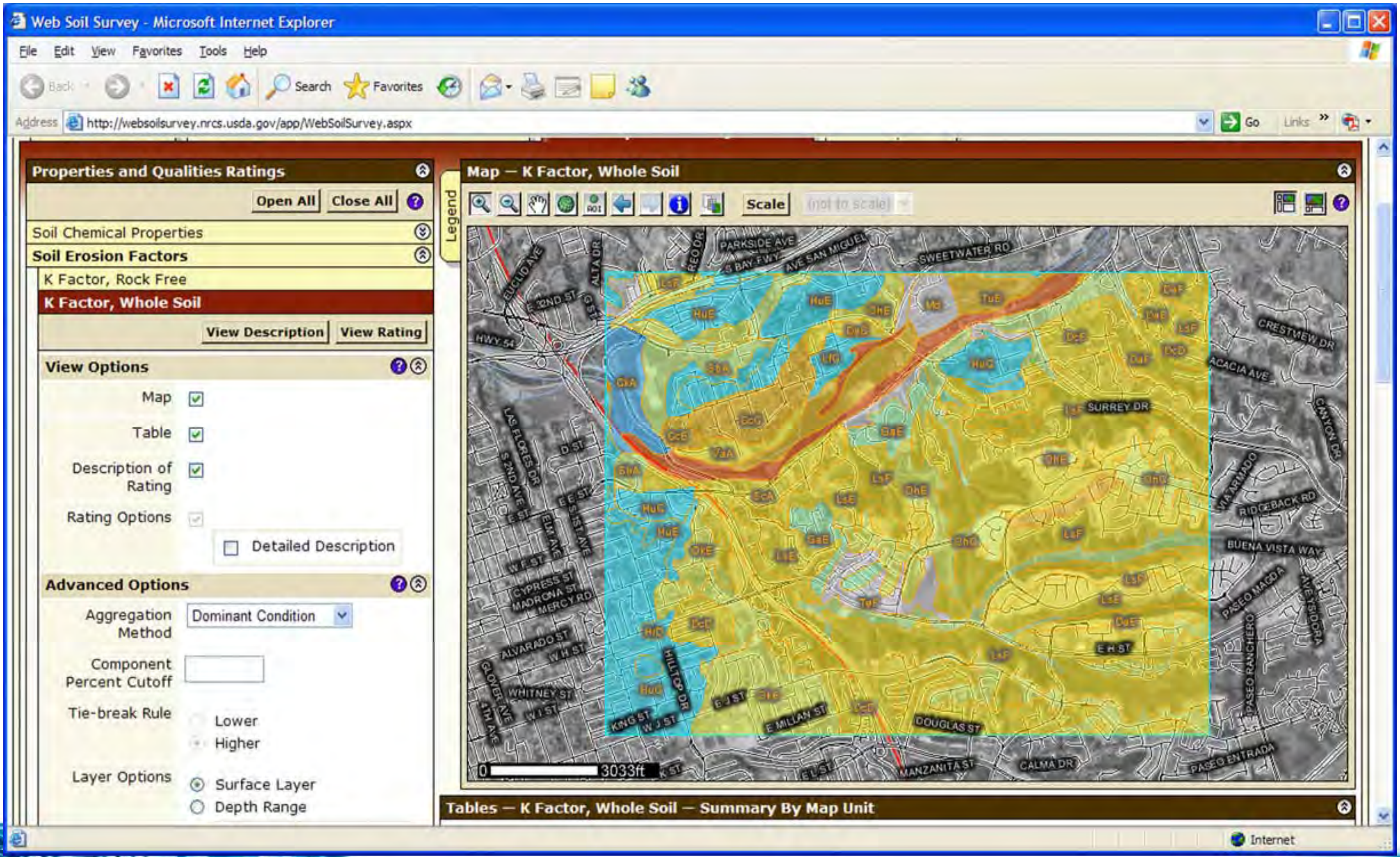
n = number of rainfall events

Soil Erodibility (K)

The ease with which soil is detached by drop *impact* or tractive force for *surface flow* or *both.*

NRCS Soils Data Base

San Diego County, Lynwood Hills and Bonita Area



Stormwater

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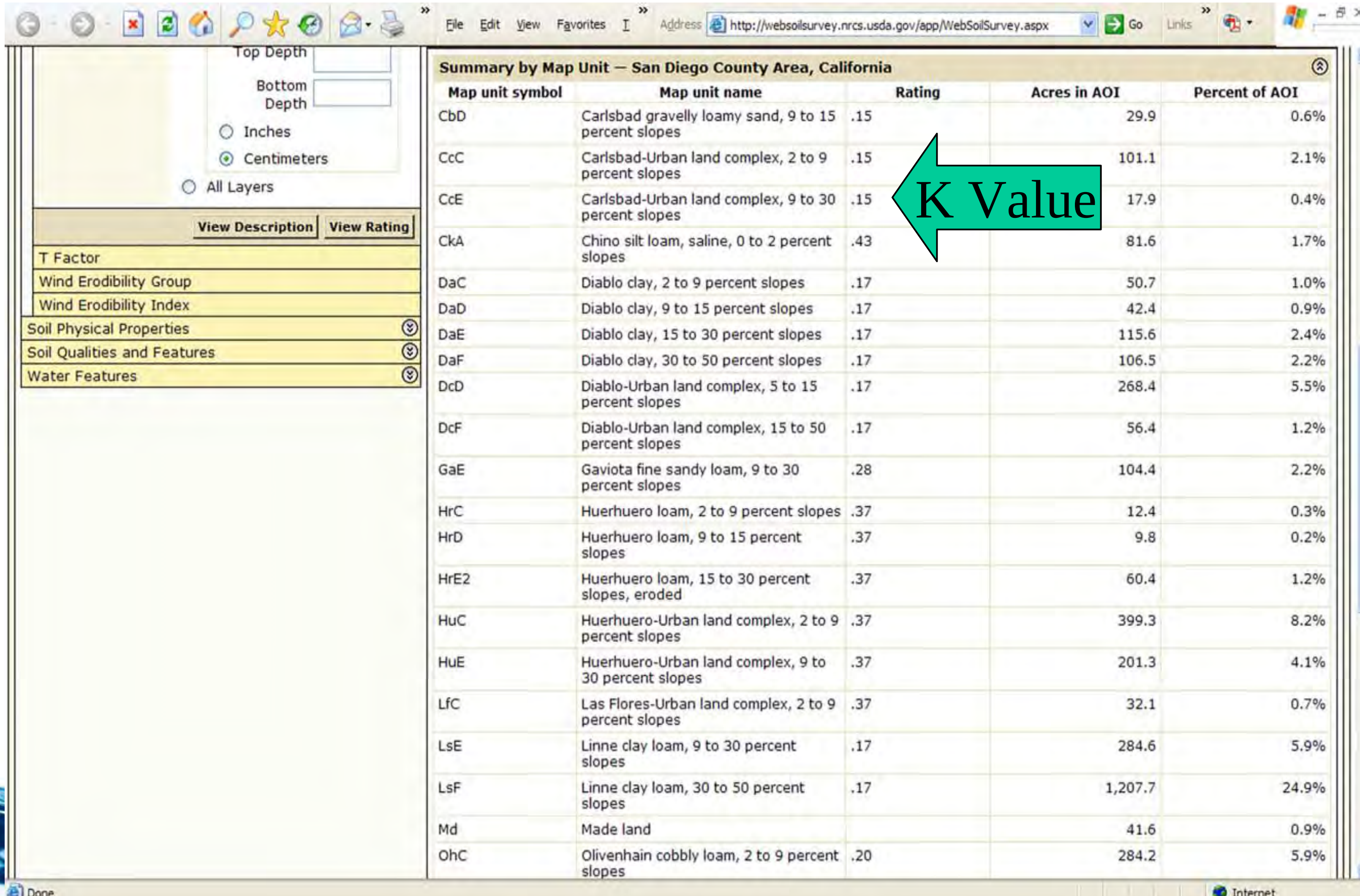
Soil Erodibility Factor “K”

Data from NRCS Web Soil Survey



Summary by Map Unit — San Diego County Area, California

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CbD	Carlsbad gravelly loamy sand, 9 to 15 percent slopes	.15	29.9	0.6%
CcC	Carlsbad-Urban land complex, 2 to 9 percent slopes	.15	101.1	2.1%
CcE	Carlsbad-Urban land complex, 9 to 30 percent slopes	.15	17.9	0.4%
CkA	Chino silt loam, saline, 0 to 2 percent slopes	.43	81.6	1.7%
DaC	Diablo clay, 2 to 9 percent slopes	.17	50.7	1.0%
DaD	Diablo clay, 9 to 15 percent slopes	.17	42.4	0.9%
DaE	Diablo clay, 15 to 30 percent slopes	.17	115.6	2.4%
DaF	Diablo clay, 30 to 50 percent slopes	.17	106.5	2.2%
DcD	Diablo-Urban land complex, 5 to 15 percent slopes	.17	268.4	5.5%
DcF	Diablo-Urban land complex, 15 to 50 percent slopes	.17	56.4	1.2%
GaE	Gaviota fine sandy loam, 9 to 30 percent slopes	.28	104.4	2.2%
HrC	Huerhuero loam, 2 to 9 percent slopes	.37	12.4	0.3%
HrD	Huerhuero loam, 9 to 15 percent slopes	.37	9.8	0.2%
HrE2	Huerhuero loam, 15 to 30 percent slopes, eroded	.37	60.4	1.2%
HuC	Huerhuero-Urban land complex, 2 to 9 percent slopes	.37	399.3	8.2%
HuE	Huerhuero-Urban land complex, 9 to 30 percent slopes	.37	201.3	4.1%
LfC	Las Flores-Urban land complex, 2 to 9 percent slopes	.37	32.1	0.7%
LsE	Linne clay loam, 9 to 30 percent slopes	.17	284.6	5.9%
LsF	Linne clay loam, 30 to 50 percent slopes	.17	1,207.7	24.9%
Md	Made land		41.6	0.9%
OhC	Olivenhain cobbly loam, 2 to 9 percent slopes	.20	284.2	5.9%

T-Factors for Soils

Web Soil Survey - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Interpret Nulls as Zero: Yes / No

View Description | View Rating

Wind Erodibility Group
Wind Erodibility Index
Soil Physical Properties
Soil Qualities and Features
Water Features

Tables — T Factor — Summary By Map Unit

Summary by Map Unit — San Diego County Area, California

Map unit symbol	Map unit name	Rating (tons per acre per year)	Acres in AOI	Percent of AOI
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CcE	Carlsbad-Urban land complex, 9 to 30 percent slopes	2	17.9	0.4%
CkA	Chino silt loam, saline, 0 to 2 percent slopes	5	81.6	1.7%
DaC	Diablo clay, 2 to 9 percent slopes	3	50.7	1.0%
DaD	Diablo clay, 9 to 15 percent slopes	3	42.4	0.9%
DaE	Diablo clay, 15 to 30 percent slopes	3	115.6	2.4%
DaF	Diablo clay, 30 to 50 percent slopes	3	106.5	2.2%
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GaE	Gaviota fine sandy loam, 9 to 30 percent slopes	1	104.4	2.2%
HrC	Huerhuero loam, 2 to 9 percent slopes	2	12.4	0.3%
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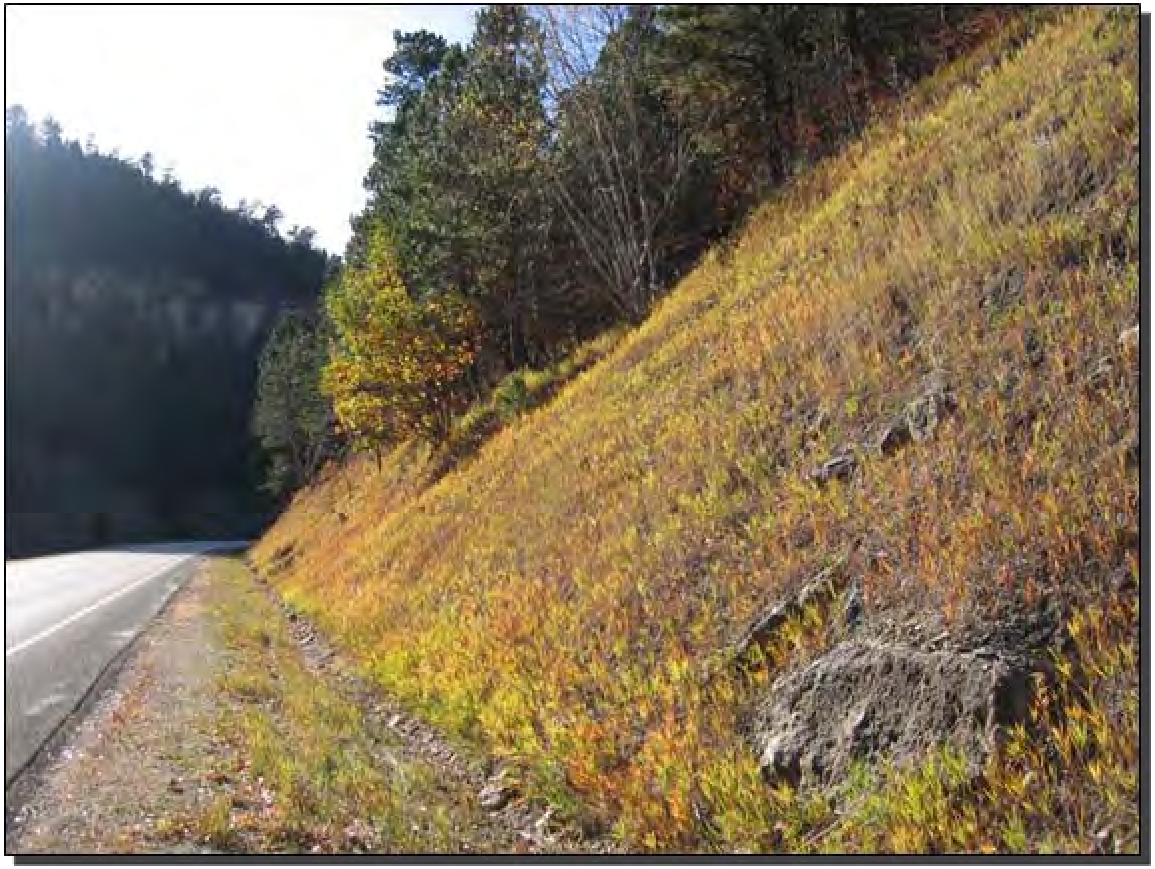
Slope Length and Steepness (LS)



A ratio of slope length to steepness

“LS” Topographic Factor

LS FACTORS FOR CONSTRUCTION SITES

Values for topographic factor, LS, for high ratio of rill to interrill erosion.[1]

Slope (%)	Horizontal slope length (ft) <3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

Such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil).

Move to next highest number – do not interpolate

Stormwater RBF CONSULTING

Cover Factor (C)

The C factor indicates how the ***surface cover*** will affect the average soil loss.

Reference Table

Material Category	Material Type	Manning' *n* Values[3] Flow Depth Ranges (ft) 0.0-0.5	0.5–2.0	>2.0	Conservation Factors (*C*)[2] Slope Length < 20ft	20-50ft	>50ft	Cover Factor (C_f)
Rigid	**Concrete**	**0.015**	**0.013**	**0.013**	N/A	N/A	N/A	**1.00**
	Grouted riprap	**0.040**	**0.030**	**0.030**	N/A	N/A	N/A	**1.00**
	Soil cement	**0.025**	**0.025**	**0.020**	N/A	N/A	N/A	**1.00**
	Asphalt	**0.018**	**0.018**	**0.016**	N/A	N/A	N/A	**1.00**
Unvegetated	**Bare soil**	**0.023**	**0.020**	**0.020**	**1.00**	**1.00**	**1.00**	
	Rock cut	**0.045**	**0.035**	**0.025**	N/A	N/A	N/A	
Temporary[3]	**Woven nets (synthetics and, organics)**	**0.016**	**0.015**	**0.015**	**0.11**	**0.21**	**0.30**	**0.80**
	Jute net	**0.028**	**0.022**	**0.019**	**0.10**	**0.12**	**0.18**	**0.76**
	Straw blankets	**0.065**	**0.033**	**0.025**	**0.106**	**0.118**	**0.18**	**0.87**
	Curled wood fiber (excelsior)	**0.066**	**0.035**	**0.028**	**0.11**	**0.21**	**0.30**	**0.85**
	Synthetic and Coir mats TRMs	**0.036**	**0.025**	**0.021**	**0.018**	**0.04**	**0.07**	**0.97**
	Crimped Straw Mulch (2tons/acre)	**0.035**	**0.030**	**0.025**	**0.10**	**0.15**	**0.19**	**0.84**
	Crimped Straw Mulch (4 tons/acre)	**0.050**	**0.035**	**0.030**	**0.02**	**0.04**	**0.07**	**0.97**

Manning's Roughness Coefficients (*n*) for Design of Temporary Erosion Controls[1] And RUSLE Conservation Factors *C* For Selected Materials[2]

[1] Some materials generally identified as Turf Reinforcing Mats (TRMs) become permanent when buried

[2] Values of C are compiled from manufacturers literature, Temple, and Lane

[3] From HEC-15. Values were compiled from several sources see HEC-15 references 5, 8, 13, 14, 15

[4] Some manufacturers publish n values for their products these maybe used at the discretion of the designer. However, since the standard specification allows contractors to select any material on the approved product list it is important to be somewhat conservative when selecting the value of n for design purposes.

Conservation Factors (*C*)

Manning's ***n***

Cover Factors (C_f)

Support Practices (P)

Support practices affect erosion by altering the flow pattern, redirecting, or reducing the runoff.

Practice Factor "P"

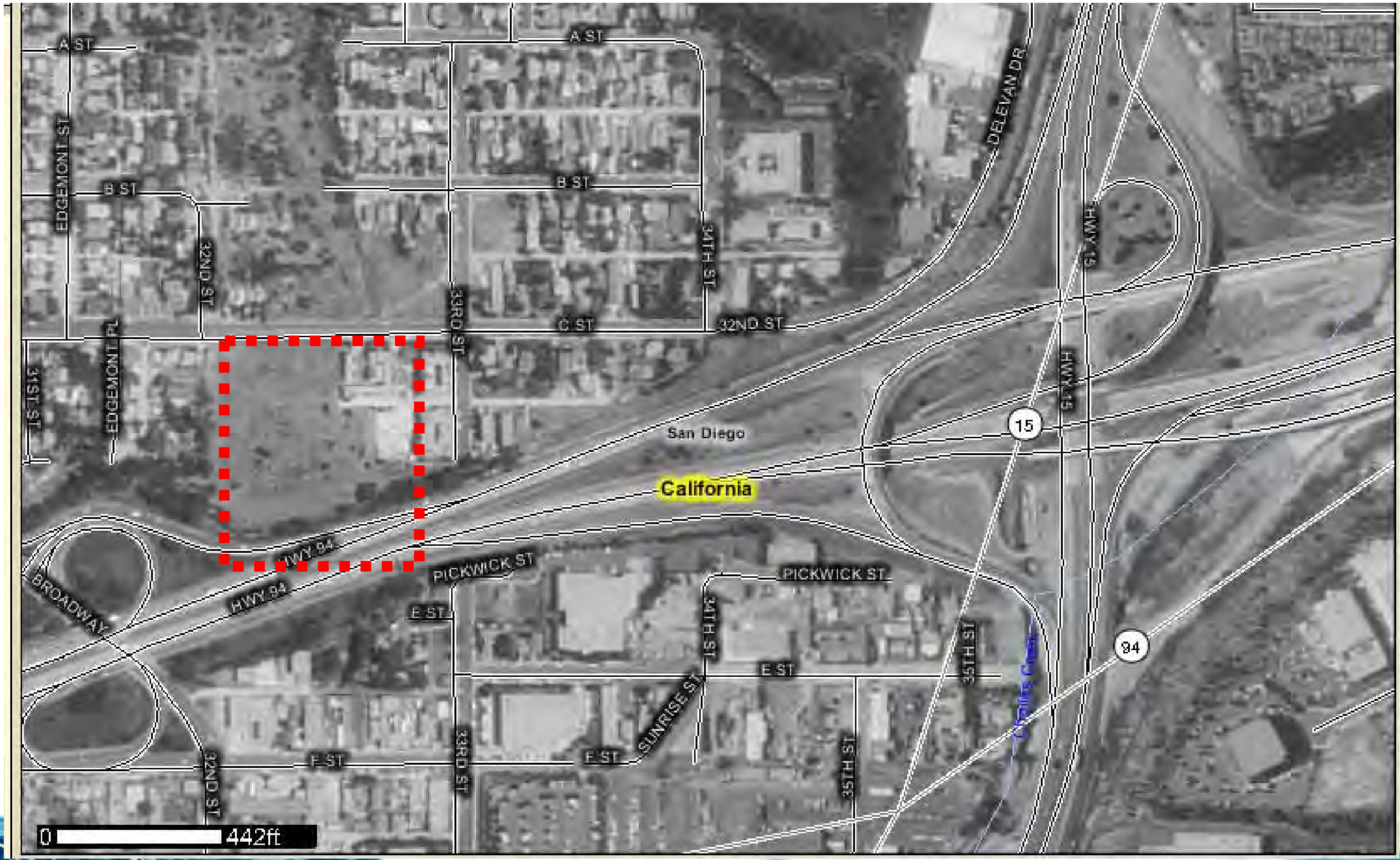
Table 6-14. Some typical P values for barriers constructed on a silt loam soil at Lexington, Kentucky.

	Structure Type			
Gradient %	**Shortgrass Strip**	**Gravel Bag**	**Stiff Grass Hedge**	**Silt Fence**
<5	0.37	0.21	0.11	0.08
5-10	0.55	0.37	0.21	0.15
10-15	0.67	0.55	0.45	0.37

Example Application

- Find the predicted soil erosion for a site in San Diego County.
- Find the base erosion rate for 1) disturbed soil condition and 2) undeveloped condition for a site near the intersection near the intersection of IH-15 and CA 94.
- The maximum developed slope of 35% and a maximum length of 100ft,
- The existing (undeveloped) average is 30% for 250 ft.

Site IH-15 and CA 94
San Diego



Stormwater RBF CONSULTING

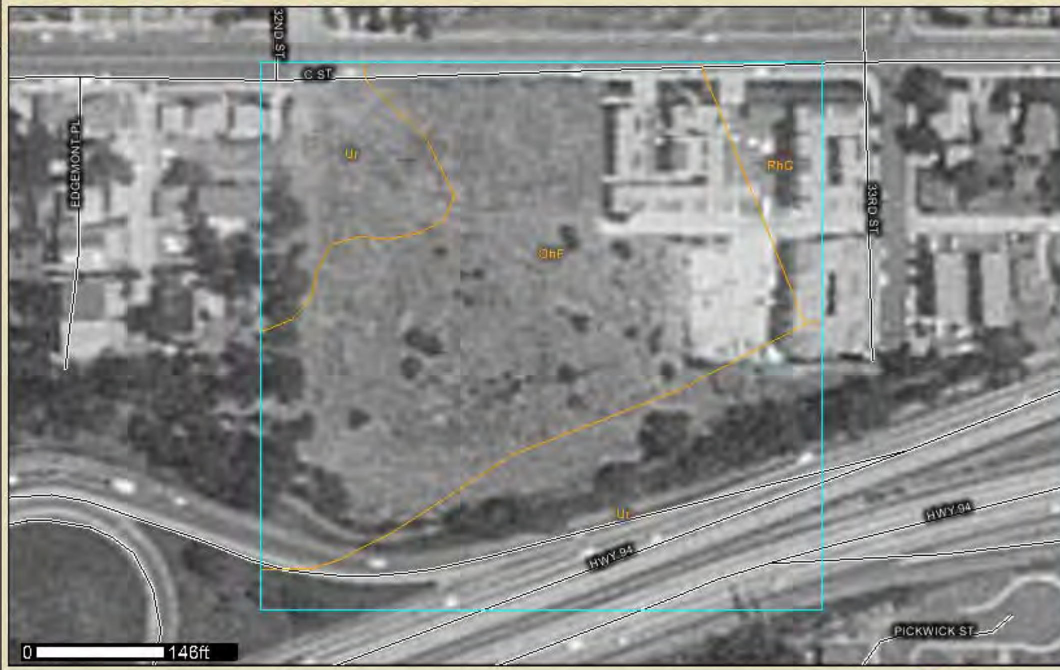
Soil Map

Map Unit Legend

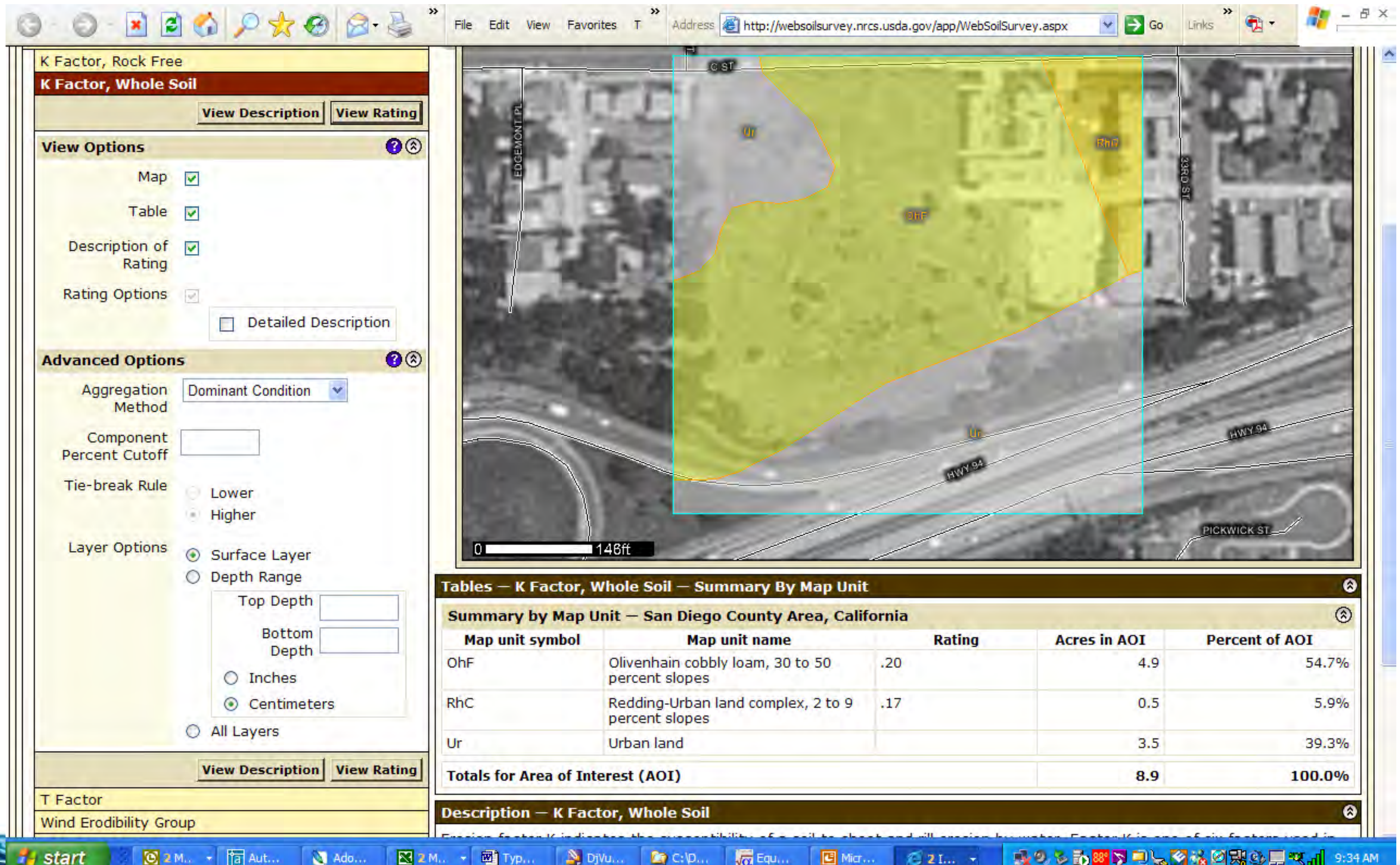
San Diego County Area, California (CA638)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
OhF	Olivenhain cobbly loam, 30 to 50 percent slopes	4.9	54.7%
RhC	Redding-Urban land complex, 2 to 9 percent slopes	0.5	5.9%
Ur	Urban land	3.5	39.3%
Totals for Area of Interest (AOI)		**8.9**	**100.0%**

Soil Map



NRCS K Factor



NRCS T Factor

http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

View Options

- Map ☑
- Table ☑
- Description of Rating ☑
- Rating Options ☑
  - ☐ Detailed Description

Advanced Options

- Aggregation Method: Dominant Condition
- Component Percent Cutoff:
- Tie-break Rule: ◉ Lower ○ Higher
- Interpret Nulls as Zero: ○ Yes ◉ No

View Description | View Rating

- Wind Erodibility Group
- Wind Erodibility Index
- Soil Physical Properties
- Soil Qualities and Features
- Water Features

Tables — T Factor — Summary By Map Unit

Summary by Map Unit — San Diego County Area, California

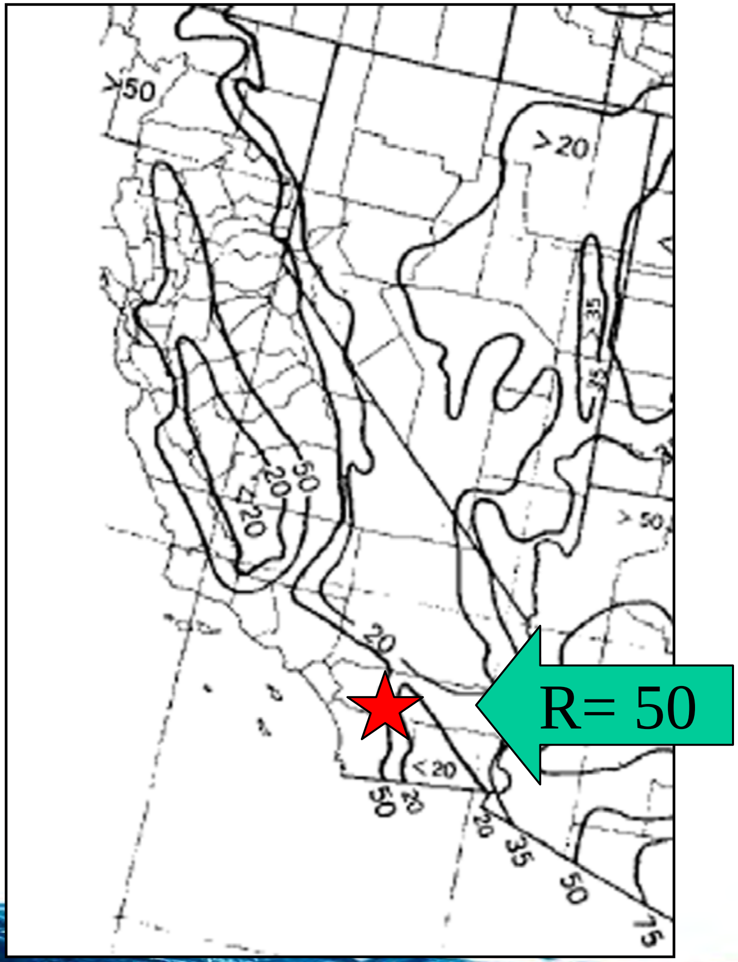
Map unit symbol	Map unit name	Rating (tons per acre per year)	Acres in AOI	Percent of AOI
OhF	Olivenhain cobbly loam, 30 to 50 percent slopes	3	4.9	54.7%
RhC	Redding-Urban land complex, 2 to 9 percent slopes	2	0.5	5.9%
Ur	Urban land		3.5	39.3%
Totals for Area of Interest (AOI)			**8.9**	**100.0%**

Description — T Factor

The T factor is an estimate of the maximum average annual rate of soil erosion by wind and/or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.

Rating Options — T Factor

R-Value



The RUSLE 2 Program has a much more sophisticated weather model generator. Using the program can significantly improve the predictions.

Select the Conservation Practice

Manning's Roughness Coefficients (*n*) for Design of Temporary Erosion Controls[1] And RUSLE Conservation Factors *C* For Selected Materials[2]

Material Category	Material Type	Manning' *n* Values[3] Flow Depth Ranges (ft) 0.0-0.5	0.5–2.0	>2.0	Conservation Factors (C)[2] Slope Length < 20ft	20-50ft	>50ft	Cover Factor (C_f)
Rigid	**Concrete**	**0.015**	**0.013**	**0.013**	N/A	N/A	N/A	**1.00**
	Grouted riprap	**0.040**	**0.030**	**0.030**	N/A	N/A	N/A	**1.00**
	Soil cement	**0.025**	**0.025**	**0.020**	N/A	N/A	N/A	**1.00**
	Asphalt	**0.018**	**0.018**	**0.016**	N/A	N/A	N/A	**1.00**
Unvegetated	**Bare soil**	**0.023**	**0.020**	**0.020**	**1.00**	**1.00**	**1.00**	
	Rock cut	**0.045**	**0.035**	**0.025**	N/A	N/A	N/A	
Temporary[3]	**Woven nets (synthetics and, organics)**	**0.016**	**0.015**	**0.015**	**0.11**	**0.21**	**0.30**	**0.80**
	Jute net	**0.028**	**0.022**	**0.019**	**0.10**	**0.12**	**0.18**	**0.76**
	Straw blankets	**0.065**	**0.033**	**0.025**	**0.106**	**0.118**	**0.18**	**0.87**
	Curled wood fiber (excelsior)	**0.066**	**0.035**	**0.028**	**0.11**	**0.21**	**0.30**	**0.85**
	Synthetic and Coir mats TRMs	**0.036**	**0.025**	**0.021**	**0.018**	**0.04**	**0.07**	**0.97**
	Crimped Straw Mulch (2tons/acre)	**0.035**	**0.030**	**0.025**	**0.10**	**0.15**	**0.19**	[illegible]
	Crimped Straw Mulch (4 tons/acre)	**0.050**	**0.035**	**0.030**	**0.02**	**0.04**	**0.07**	**0.97**

[1] Some materials generally identified as Turf Reinforcing Mats (TRMs) become permanent when buried

[2] Values of C are compiled from manufacturers literature, Temple, and Lane

[3] From HEC-15. Values were compiled from several sources see HEC-15 references 5, 8, 13, 14, 15

[4] Some manufacturers publish n values for their products these maybe used at the discretion of the designer. However, since the standard specification allows contractors to select any material on the approved product list it is important to be somewhat conservative when selecting the value of n for design purposes.

C=0.19

For the first trial use crimped straw at 2000 lbs /acre.

Practice Factor P

Table 6-14. Some typical P values for barriers constructed on a silt loam soil at Lexington, Kentucky.

	Structure Type			
Gradient %	**Shortgrass Strip**	**Gravel Bag**	**Stiff Grass Hedge**	**Silt Fence**
<5	0.37	0.21	0.11	0.08
5-10	0.55	0.37	0.21	0.15
10-15	0.67	0.55	[illegible]	0.37

P=0.37

Slope Length Factor

LS FACTORS FOR CONSTRUCTION SITES

Values for topographic factor, LS, for high ratio of rill to interrill erosion.[1]

Slope (%)	Horizontal slope length (ft) <3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.65	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.89	14.98
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	[illegible]	[illegible]	[illegible]	8.23	10.24	13.94	17.36	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	[illegible]	[illegible]	[illegible]	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	[illegible]	[illegible]		13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

LS=7.44

[1]Such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil).

Example – During Construction

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

$$A = 50 \times .0.20 \times 7.44 \times 0.19 \times 1$$

$$A = 14.14 \frac{\frac{Tons}{Acre}}{Year}$$

$$A = 50 \times .0.20 \times 7.44 \times 0.19 \times 0.37$$

$$A = 5.51 \frac{\frac{Tons}{Acre}}{Year}$$

Note: T for these soils is 3 tons/acre/year

Undeveloped Erosion Rate

The undeveloped condition is approximately 80% rough grass and brush cover with an average long slope of 30% for 250 ft.

Tables of C Values, Undeveloped Lands

TABLE 10.—*Factor* **C** *for permanent pasture, range, and idle land*[1]

Vegetative canopy: Type and height[2]	Vegetative canopy: Percent cover[3]	Cover that contacts the soil surface: Type[4]	Percent ground cover: 0	20	40	60	80	9[illegible]
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	[illegible]
		W	.45	.24	.15	.091	.043	[illegible]
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

C=.013

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

TABLE 11.—*Factor* **C** *for undisturbed forest land*[1]

Percent of area covered by canopy of trees and undergrowth	Percent of area covered by duff at least 2 in deep	Factor C[2]
100-75	100-90	.0001-.001
70-45	85-75	.002-.004
40-20	70-40	.003-.009

[1] Where effective litter cover is less than 40 percent or canopy cover is less than 20 percent, use table 6. Also use table 6 where woodlands are being grazed, harvested, or burned.

[2] The ranges in listed **C** values are caused by the ranges in the specified forest litter and canopy covers and by variations in effective canopy heights.

LS Factor

LS FACTORS FOR CONSTRUCTION SITES

Values for topographic factor, LS, for high ratio of rill to interrill erosion.[1]

Slope (%)	Horizontal slope length (ft)															
	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.36	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	[illegible]	[illegible]	[illegible]	[illegible]	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	[illegible]	[illegible]	[illegible]	[illegible]	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	[illegible]	[illegible]	[illegible]	[illegible]	46.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

LS=11.55

[1] Such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil).

Example: Undeveloped Condition

R and K remain the same as for the disturbed condition, LS and C change and there is no other management practice.

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

$$A = 50 \times .0.20 \times 11.55 \times .013 \times 1$$

$$A = 1.50 \frac{\frac{Tons}{Acre}}{Year}$$

T for these soils is 3 tons/acre/year

Benefits of Using the RUSLE

- Estimate erosion potential W/O BMPs
- Potentially provides tools for optimizing design in some conditions – do what if scenarios
- Calculate BMP effectiveness
- Evaluates impacts of erosion – material leaving site
- Conservation planning – less than soil "T" factor
- It is a defensible methodology if properly applied

Problems of Applying RUSLE

- Few documented C & P values for construction applications at this time (especially P)
- Limited calibration of interaction of C and P factor combinations
- Numerous technical adjustments needed to achieve more accurate predictions
- Does not provide estimates for:
  - gully or streambank erosion
  - sediment yield from watersheds
- Estimates tend to be conservative compared to other methods