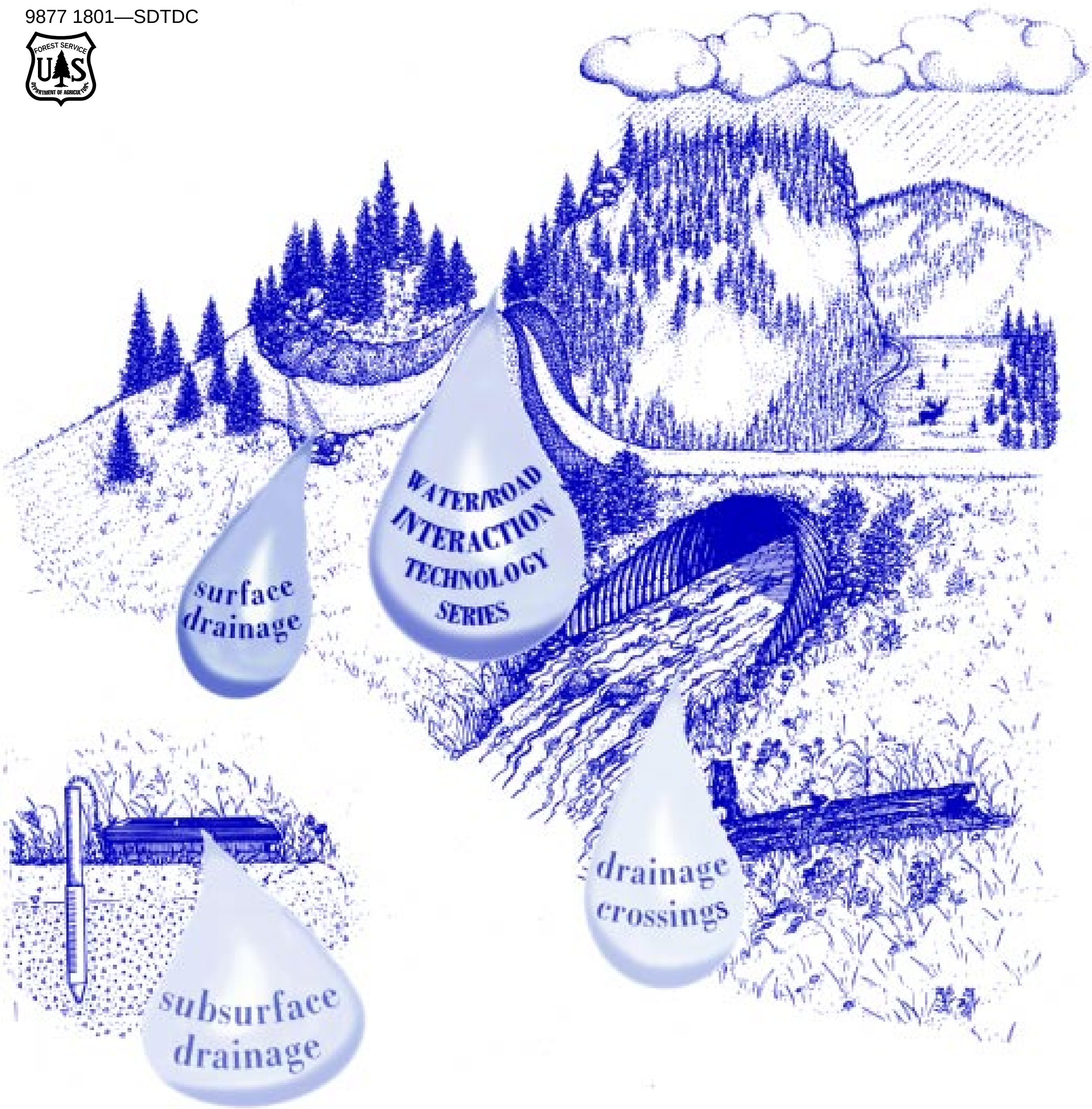
United States
Department of
Agriculture

Forest Service

**Technology &
Development
Program**

7700—Transportation System
2500—Watershed and Air Management
June 1998
9877 1801—SDTDC

The X-DRAIN Cross Drain Spacing and Sediment Yield Model



HOW TO RUN

X-DRAIN can be run directly from the CD without installing it on the computer. Both the CD and appendix A contain instructions for installing this application on your PC; included are hardware requirements, how to remove the application from your PC, and application features. The CD contains an introductory video, documentation, and software.

The X-DRAIN Cross Drain Spacing and Sediment Yield Model

William J. Elliot, P.E., PhD
Project Leader, Rocky Mountain Research Station

Susan M. Graves
Hydrologist, Rocky Mountain Research Station

David E. Hall
Computer Specialist, Rocky Mountain Research Station

Jeffry E. Moll, P.E.
Senior Project Leader, San Dimas Technology and Development Center

San Dimas Technology and Development Center
San Dimas, California

June 1998

ACKNOWLEDGMENTS

A project of this scope requires the efforts of many people. The authors gratefully acknowledge the Washington Office Engineering Staff and the Technology and Development Program Engineering Steering Committee for providing project guidance and funding.

The following persons are thanked for beta testing software, reviewing documentation, and providing comments on use and applications:

Lois Bachensky, Transportation System Manager, Region 2

Corky Ohlander, Hydrologist, Region 2

Mike Nicolo, Hydrologist, Cherokee National Forest, Region 8

Billy Hawse, Civil Engineering Technician, Monongahela National Forest, Region 9

CONTENTS

INTRODUCTION

The X-DRAIN model is a user-friendly computer program based on the Water Erosion Prediction Project (WEPP) and is designed to estimate sediment yield from roads, landings, skid trails, and foot trails as affected by climate, soil, local topography, and transportation system characteristics. X-DRAIN can be used to determine optimum cross drain spacing for existing or planned roads, and for developing and supporting recommendations concerning road construction, reconstruction, realignment, closure, obliteration, or mitigation efforts based on sediment yield. The model estimates sediment yield produced by a given road or road system by summing sediment quantities from each unique road segment or road length between cross drains.

This report provides a brief background of WEPP, discusses applications of X-DRAIN, and details examples to assist the field user with software implementation. Appendix A contains instructions for installing this application on the PC. Included are hardware requirements, application features, and removal of the application from the PC. Other appendices provide background information useful for proper application of the model.

Roads have been identified as the major source of sediment in most forest watersheds due to surface erosion or mass failure. Practices to control sedimentation from roads are well known, and have been incorporated into road design and cross drain spacing guides for many years (Packer and Christensen 1977). Such guidelines, however, merely provide percentage estimates of sediment reduction at best, and their applications are limited to the specific soils and climates where they were developed. There have been numerous cases in recent years where forest planners needed sediment yield from a given road, but had limited tools for estimating the amount.

One of the most common forest road conditions leading to sedimentation of streams is shown in figure 1, where a forest road experiences erosion

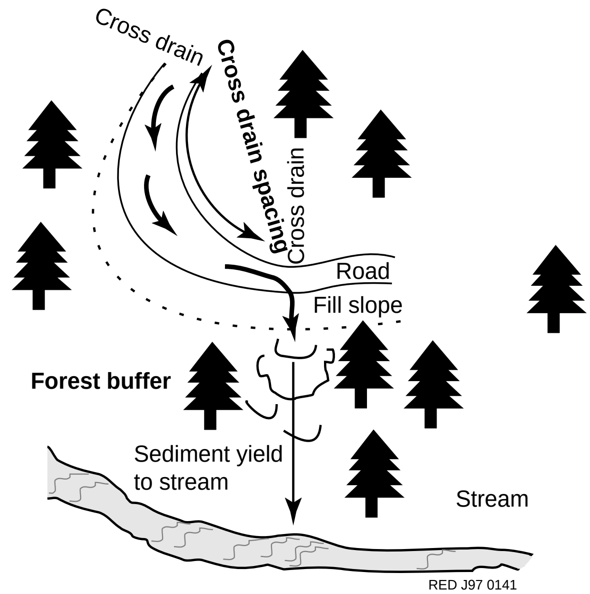


Figure 1—Relationship of road, fill slope, forest buffer, and stream for WEPP cross drain sediment yield study.

between cross drains. The runoff from the cross drain is routed over the fill slope and across a buffer area to the stream. All insloping, flat, rutted, or outsloping roads can be described by this model. Whether the cross drain is a culvert or an open drain will have minimal impact on the sediment delivery. Outsloping roads generally have an equivalent cross drain spacing of about 7 m (23 ft) (Foltz 1996).[a] This increases as wheel tracks develop, requiring grade dip cross drains to effectively remove surface drainage from the traveled way. Only roads that cross streams or drain directly into streams are exceptions to this template (Elliot et al. 1994). The current practice in road stream crossing design is to address each site individually to minimize sedimentation.

THE WEPP MODEL

The WEPP model (Flanagan and Livingston 1995) is a physically based soil erosion model that can provide estimates of soil erosion and sediment yield considering the specific soil, climate, ground cover, and topographic conditions. WEPP simulates the daily conditions that impact erosion,

a. Throughout the document both metric and English standard units are used. X-DRAIN allows for a choice of meters or feet. However, for clarity of information in the tables, only the metric units are shown.

such as the amount of vegetation canopy, the surface residue, and the soil water content. For each day that has a precipitation event, WEPP determines whether it is rain or snow, and calculates the infiltration and runoff. If there is runoff, WEPP routes the runoff over the surface, calculating erosion or deposition rates for at least 100 points on the hillslope. It then calculates the average sediment yield from a hillslope. WEPP has a hillslope version, which was the basis of the data for the X-DRAIN program, and a watershed version. The model has been validated for numerous conditions including forest roads (Elliot et al. 1995).

Methods and Results

To exploit the ability of WEPP to predict sedimentation from roads, and to make the results available for field application, over 50,000 runs of the WEPP model, Version 95.7, were carried out for the soil and topography conditions described in table 1, and the climates described in appendix B. The sediment yield value was recorded for each run. Figure 2 shows some typical results. Additional discussion of the results is presented in Morfin et al. (1996). The data from the runs were stored in a large binary file. Two programs were developed to access the data: a stand-alone version to run in Windows (X-DRAIN 1997) and a version to run over the Forest Service Intranet or the World Wide Web (XDS 1997).

The results have been expressed as the average annual sediment yield in either kilograms of sediment for every meter of road length or pounds of sediment for every foot of road length contributing to a given cross drain. Users can determine the total length of a road in each topographic category, multiply that length by the sediment yield, and then sum the sediment yields from all of the road segments to determine the total sediment load from the road (see example 1). If a segment of a road is contributing sediment to the stream system at a live-water crossing, that contribution will have to be estimated separately with the WEPP model.

Applications

There are several applications for the X-DRAIN model. Planners can estimate sediment produced by a given road system by summing sediment yields for each road segment. Optimum cross drain spacing for existing or planned roads can be determined. Recommendations concerning road reconstruction, realignment, closure, obliteration, or mitigation can be developed and supported by X-DRAIN outputs.

For determining sediment yield from existing roads, the road design or a survey specifies distance between cross drains, traveled way shape, and the gradient of the road for each segment. The slope and distance to a channel can be determined from a field survey or a contour map. The nearest climate (appendix B), and the soil that best describes the onsite soil (appendix C) are selected. From this information, the sediment yield can be determined for each road segment, and the total sediment yield calculated (example 1).

Table 1—Soil and topography conditions in WEPP runs.

Variable	Values
Spacing of cross drains	10, 20, 40, 60, and 100 m
Road gradient	2, 4, 8, and 16 percent
Length of buffer between road and stream	10, 40, 80, and 200 m
Steepness of buffer	4, 10, 25, and 60 percent
Soil textures (see appendices C and D for details)	Clay loam, silt loam, sandy loam, gravelly loam, and gravelly sand

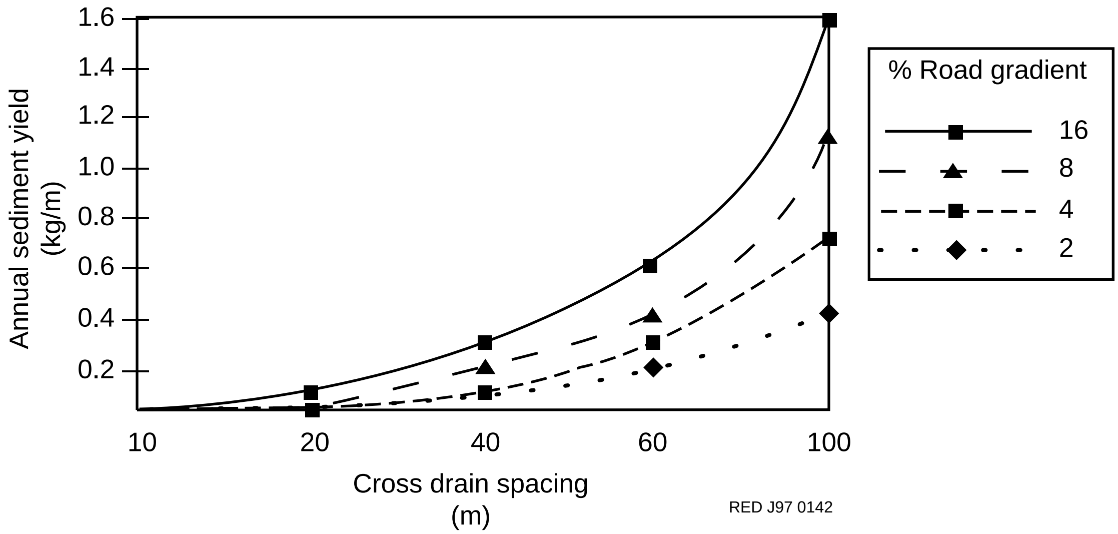


Figure 2—Annual sediment yield versus cross drain spacing for different road gradients for the Wallace, ID climate, with a buffer length of 40 m (131 ft), a silt loam soil, a buffer slope of 25 percent, and a road width of 4 m (13 ft).

The second application of this program is to evaluate impact of alternative cross drain or waterbar spacing for any road (including skid trails) on sediment delivery. The necessary input information is collected, X-DRAIN runs are made, and the output table studied to determine spacing giving a sediment yield of either zero or near zero. Cross drain spacing can subsequently be optimized (examples 2 and 4).

Another application is as an aid to identifying sections of road that are the best candidates for closure, reconstruction, realignment, or mitigation measures to make best use of limited funding (example 3). In terms of mitigation, the application of imported aggregate to a clay or silt loam subgrade can be evaluated by selecting the gravelly loam soil. The application of aggregate to a sandy loam road can be evaluated by selecting the gravelly sand soil.

Other applications of the model include determining erosion from footpaths or bike trails by specifying a narrow width such as 1 m (3 ft). Log landings or similar cleared areas that are eroding and are less than 30 m (100 ft) wide may be analyzed. Should the user desire to model more complex or detailed conditions, or use climates beyond the scope of this study, it is necessary to run the WEPP model.

Discussion

Field research shows the range of sedimentation amounts observed will vary by at least 30 percent from the mean. Minimum observed values are frequently less than half the maximum observed values (Elliot et al. 1994; Elliot et al. 1995; Tysdal et al. 1997). Validation work has shown values predicted by WEPP generally fall within the range of observed values. Users are encouraged to avoid placing too much emphasis on small differences between values. For conditions not modeled, the output relationships are reasonably continuous, and interpolation between results appears to be valid. It is not advisable to extrapolate beyond the values presented, as relationships are not linear.

It was assumed there would be no condition where road gradient was steeper than the buffer; so for such a combination, the output table has a blank entry. Results are rounded to one or two significant digits (see table A1 in appendix A), with a minimum value of 0.01 kg/m (0.01 lb/ft). Any values less than 0.01 kg/m (0.01 lb/ft) are displayed as zero in the table.

In a limited analysis of the sensitivity of sediment yield to the various input factors, Morfin et al. (1996) found sediment yield was particularly sensitive to cross drain spacing, road gradient, and buffer length. It was less sensitive to buffer slopes above 25 percent. In their study, sediment yield was sensitive to both climate and soil type.

In some cases, users may wish to estimate percent of eroded sediment in the sand size class for environmental impact analysis. WEPP predicts size distribution of eroded sediment by dividing sediment into sand, silt, and clay particles; small aggregates made up of clay and silt; and large aggregates made up of clay, silt, and sand. Generally, sand deposits first, and clay and small aggregates last. A series of runs were made with the WEPP 97.3 model for the Eagle, CO climate, to determine predicted sand content values as particles and in the large aggregates for a range of sediment yields (table 2). The predicted values appear to be reasonable, but users are encouraged to compare these predictions with local observations, as size distribution predictions have not been validated for forest conditions.

In analyzing results for several climates where a significant part of the precipitation occurred as snow, WEPP predicted larger sediment yields than for climates with similar precipitation and no snow fall. Earlier studies suggested WEPP was overpredicting snowmelt rates (Elliot et al. 1996). After the runs for this study were completed, a snowmelt prediction error was identified in the WEPP code. A revised version of the WEPP model (1997) was developed and is now available with modified snowmelt routines. Runs were made with this modified version of WEPP, and it was noted that sediment yields were reduced from less than 5 percent for most climates to as much as 50 percent for the Deadwood Dam, ID climate. The predicted results from the new release are within the range of field observations, although generally lower than those presented in the cross drain data set. The climates that are dominated by snowmelt are noted in appendix B.

This study assumed runoff water followed the road from one cross drain to the next (figure 1). This template can be applied to a variety of conditions and provides a reasonable estimate of sediment yield (table 3). If the site template presented in figure 1 is not adequate to describe the site conditions, then site-specific runs can be made with the WEPP model with the aid of the templates

Table 2—Predicted sand content as particles and in large aggregates for different sediment yield amounts for the Eagle, CO climate.

	Percent sand particles and in large aggregates				
Soil	Clay	Silt	Sand	Gravelly loam	Gravelly sand
On site sand content	30	30	60	40	70
Sediment Yield (kg/m)	In delivered sediment				
0.05	28	14	60	33	63
0.1	29	9	56	33	64
0.5	30	17	55	34	60
1.	30	20	50	34	57
5.	29	25	(52)[a]	33	(58)[a]

a. These values predicted for Wallace, ID climate; the Eagle, CO climate did not have sediment yields as large as 5 kg/m (17 lb/ft) for these soils.

Table 3—Adapting cross drain inputs to model different conditions.

Condition	Cross drain application
Road with flat traveled way	Enter width of traveled way in width box and read output direct.
Insloping road with no ditch treatment and no ruts	Enter width of traveled way plus inside ditch in width box.
Insloping road with rocked or gravel ditch and no ruts	Enter width of traveled way in width box and select 10 m for spacing of cross drains.
Outsloping road without ruts	Enter width of traveled way in width box and select 10 m for spacing of cross drains.
Outsloping road with ruts	Enter width of traveled way. Read the results fo the observed spacing of cross drains.
Bladed and compacted skid trail	Select appropriate native surface soil and appropriate topographic variables for first year erosion. Subsequent years will decline rapidly as vegetation is reestablished on the skid trail to near zero by year 5.
More complex conditions	Run the WEPP model for the specific conditions.

developed by Elliot and Hall (1997). If the road drains directly into channels, then the cross drain template is not valid, and the WEPP watershed version may be the more appropriate modeling tool (Tysdal et al. 1997).

Examples

Example 1

Find the sediment yield from a 346-m length of proposed road for the Spruce Creek Timber Sale in the Boise National Forest described in table 4. The road width is 4 m (13 ft).

X-DRAIN was run once for each of the three buffer lengths. Sediment yield values were interpolated for the last two road segment gradients. The sediment yields per unit length of road from the program were multiplied by the appropriate drain spacings to determine the total sediment yield for each road segment.

For the first two segments, the sediment yields were zero for all road gradients and drain spacings for buffer lengths over 80 m (262 ft). The sediment yields for the last two were interpolated from the X-DRAIN results in table 5. The total estimated sediment yield from this particular road section is 350 kg (772 lb), from the two segments nearest the stream. From these results, the road designer may target mitigation measures to reduce sedimentation from those segments near the stream. Such measures might include additional rocking of the traveled way with quality gravel (as is currently practiced), or reducing cross drain spacing from 100 m (328 ft) to 20 m (66 ft).

Example 2

An existing 4-m (13-ft) wide road in the Boise National Forest is within 10 m (33 ft) of a creek. The buffer slope to the creek is 10 percent. The gradient of the road is 4 percent. What is the recommended spacing of cross drains?

The climate and soil are the same as in example 1. From a single X-DRAIN run, the spacing to achieve no sedimentation is 20 m (66 ft). If cross drains are spaced at 60 m (196 ft), then the annual sediment yield is only 0.1 kg/m (0.067 lb/ft) length, which may also be acceptable. An increase in drain spacing to 100 m (328 ft) increases the sedimentation by a factor of 7 from the 60-m (196-ft) spacing, which is not likely to be recommended.

Table 4—Details of a proposed road segment in the Boise National Forest. The buffer slope is about 25 percent. The nearest climate station is Deadwood Dam. The site is on the Idaho Batholith, a coarse-grained soil most closely described as a gravelly sand.

Segment	Drain Spacing (m)	Road Gradient (%)	Buffer Length (m)
1	90	3.7	200
2	56	5	140
3	100	9	10
4	100	6	10
Total	**346**		

Table 5—Topographic observations from road design and interpolated sediment yields.

Segment	Road Gradient (%)	Drain Spacing (m)	X-DRAIN Yield (kg/m)	Interpolated (kg/m)	Total (kg)
1	2 ,4	100	0, 0	0	0
2	4, 8	60	0, 0	0	0
3	8 ,16	100	1.8, 2.6	1.9	190
4	4, 8	100	1.4, 1.8	1.6	160
				Total	**350**

Example 3

There are three old logging roads located on a hillside in the Boise National Forest. Each is 4 m (13 ft) wide. The forest wishes to retain the lowest road possible to allow access for recreational fishing and related wildlife administration. They wish to put in cross drains only every 100 m (328 ft) to allow for ease of maintenance, and to minimize discomfort to road users. The gradients of all three roads are 4 percent. One road is 10 m (33 ft) from the stream with a 10 percent buffer slope, the second is 80 m (262 ft) from the stream with a 25 percent buffer slope, and the third is 200 m (656 ft) from the stream with a 60 percent buffer slope. Which road should be used? A run is made for each condition with the results in table 6.

From table 6, it appears that the middle road should be developed for the access, and the bottom road mitigated in some way to eliminate the risk of sedimentation. A recommended mitigation could be to outslope the road, rip it, and seed it (Moll 1996). The top road appears to offer no risk from sedimentation due to erosion, but at such steep gradients, it should be inspected for risk of instability.

Table 6—Results of X-DRAIN runs on 3 logging roads in Boise National Forest.

Run	Buffer Length (m)	Burrer Slope (%)	Sediment Yield (kg/m)
1	10	10	0.7
2	80	25	0
3	200	60	0

Example 4

A skid trail is believed to be a potential erosion source in a recently harvested site in West Virginia on a clay loam soil. The slope of the hillside is 10 percent, the distance to the nearest channel is 40 m (131 ft), and the slope of the skid trail is 8 percent. The width of the trail is 3 m (10 ft), and the total length is 100 m (328 ft). What is the recommended spacing of waterbars to prevent soil from entering the stream?

The West Virginia climate and clay loam soil are selected as are the buffer slope steepness and length. On the output screen for an 8 percent slope, the sediment yield is zero for a waterbar spacing of 10 m (33 ft), and only 0.08 kg/m (0.05 lb/ft) for a spacing of 20 m (66 ft). This would be the erosion in year 1, and each subsequent year would experience about a 20 percent reduction in erosion as the vegetation regrows. Table 7 demonstrates estimation of the erosion for the first 5 years of the skid trail until vegetation has regenerated.

The manager may decide that the sediment yield from the 20-m (66-ft) spacing is tolerable, but not the yield from the 40-m (131-ft) spacing.

Table 7—Estimate of erosion for first 5 years of skid trail.

	Sediment Yield (kg/m or t/km)		
Year	10-m spacing	20-m spacing	40-m spacing
1	0	0.08	0.6
2	0	0.064	0.48
3	0	0.048	0.36
4	0	0.032	0.24
5	0	0.016	0.12
6	0	0	0
Total	0	0.24	1.8
Total (100 m)	0	24 kg	180 kg

LITERATURE CITED

Elliot, W. J., R. B. Foltz, and M. D. Remboldt. 1994. Predicting Sedimentation from Roads at Stream Crossings with the WEPP Model." Presented at the 1994 ASAE International Winter Meeting, Paper No. 947511. St. Joseph, MI: ASAE.

Elliot, W. J., R. B. Foltz, and C. H. Luce. 1995. "Validation of the Water Erosion Prediction Project (WEPP) Model for Low-Volume Forest Roads." Proceedings of the Sixth International Conference on Low-Volume Roads. Washington DC: Transportation Research Board. 178-186.

Elliot, W. J., C. H. Luce and P. R. Robichaud. 1996. "Predicting Sedimentation From Timber Harvest Areas with the WEPP Model." Proceedings of the Sixth Federal Interagency Sedimentation Conference. Las Vegas, NV. IX:46-53.

Elliot, W. J., and D. E. Hall. 1997. "Water Erosion Prediction Project (WEPP) Forest Applications." General Technical Report INT-GTR-365. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station.

Flanagan, D. C., and S. J. Livingston. 1995. WEPP User Summary. NSERL Report No. 11, W. Lafayette, IN: National Soil Erosion Research Laboratory. 131 pp.

Foltz R. B. 1996. "Traffic and No-Traffic on an Aggregate Surfaced Road: Sediment Production Differences." Proceedings of the Seminar on Environmentally Sound Forest Road and Wood Transport, Sinaia, Romania, June, 1996. Rome, Italy: FAO.

Moll, J. E. 1996. "A Guide for Road Closure and Obliteration in the Forest Service." Publication 7700-Engineering, 967 1205. San Dimas, CA: USDA Forest Service Technology and Development Center.

Morfin, S., B. Elliot, R. Foltz, and S. Miller. 1996. "Predicting Effects of Climate, Soil and Topography on Road Erosion with WEPP." Presented at the 1996 International Meeting of the American Society of Agricultural Engineers, Paper No. 965016. St. Joseph, MI: ASAE.

Packer, P. E., and G. F. Christensen. 1977. Guides for Controlling Sediment from Secondary Logging Roads. Ogden, UT: USDA Forest Service Intermountain Forest and Range Experiment Station, and Missoula, MT: USDA Forest Service Northern Region.

Tysdal, L. M., W. J. Elliot, C. H. Luce, and T. Black. 1997. "Modeling Insloped Road Erosion Processes with the WEPP Watershed Model." Presented at the ASAE Annual International Meeting, Paper No. 975014. St. Joseph, MI: ASAE.

Water Erosion Prediction Project (WEPP) v. 95.7. 1995. West Lafayette IN: Agriculture Research Service, National Soil Erosion Lab. Superseded by WEPP 1997.

Water Erosion Prediction Project (WEPP) v. 97.3. 1997. West Lafayette IN: Agriculture Research Service, National Soil Erosion Lab. <http://soils.ecn.purdue.edu/WEPP>

X-DRAIN V. 1.0. 1997. Computer software. Moscow, ID: USDA Forest Service, Rocky Mountain Research Station. 16- and 32-bit versions available on-line at <http://forest.moscowfsl.wsu.edu/4702/ x-drain.html>.

XDS. 1997. Cross Drain Spacing Model v. 1.0. Computer software. Moscow, ID: USDA Forest Service, Rocky Mountain Research Station. Runs on-line at <http://forest.moscowfsl.wsu.edu/4702/ xds/xds.html>.

APPENDICES

APPENDIX A

USER GUIDE TO THE CROSS DRAIN SPACING AND SEDIMENT YIELD MODEL (X-DRAIN)

William J. Elliot, P.E., PhD
Project Leader, Rocky Mountain Research Station

David L. Renner
Computer Consultant, Moscow, ID

INTRODUCTION

The cross-drain spacing/sediment yield application, X-DRAIN, is a computer program designed to assist road and watershed managers in estimating sediment yields from roads, landings, foot trails, and skid trails as affected by climate, soil, local topography, and road design. X-DRAIN also aids cross drain spacing optimization. Estimates of sediment yield provided by X-DRAIN were derived from 52,800 runs, for 30 years of climate data, using the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston 1995; Morfin et al. 1996). Information on updates and known issues are available as hard copy or over the Internet from the Rocky Mountain Research Station.

APPLICATION REQUIREMENTS

X-DRAIN is available for both 16-bit and 32-bit systems.[a] It will run under either Windows 3.x or Windows 95 operating systems. The 32-bit system is optimized for Windows 95 and will run only on that system. Both versions of X-DRAIN provide the same estimates of sediment yield for a given set of input parameters.

The minimum recommended hardware configuration for Windows 3.x is a 486 CPU with 4 MB RAM. The minimum recommended configuration for Windows 95 is a 586 (Pentium) CPU with 8 MB RAM. In addition, a CD-ROM drive for installation is needed. Approximately 4 MB of free hard disk space is recommended for storing the application and other required files.

APPLICATION INSTALLATION

X-DRAIN can be installed from a CD or from a file downloaded from the Internet. If you download X-DRAIN from the Internet, follow the directions provided on the web site.

Close all other applications before attempting to install the X-DRAIN application. Failure to do so may result in an unsuccessful installation of the program. The procedures listed below outline the installation procedure for Windows 3.x or Windows 95:

Windows 3.x (16-bit X-DRAIN only)

1. Close all open Windows applications.

2. If you are installing from a CD-ROM, insert the installation disk.

3. Open the Windows Program Manager. Select the **File** menu item, followed by the **Run** menu item.

4. In the command line portion of the Run dialog box that appears, enter ***a:\setup16.exe***, where a: is the designation of your computer's CD drive.

5. Follow the instructions provided by the installation procedure.

Hard copy source:	Internet addresses:
William Elliot, Project Leader	
Rocky Mountain Research Station	WEPP@forest.moscowfsl.wsu.edu
1221 South Main	http://forest.moscowfsl.wsu.edu/4702/x-drain.html
Moscow, ID 83843	
Tel 208 882 3557	

a. A version that runs over the Internet using any standard browser can be accessed from http://forest.moscowfsl.wsu.edu/4702/xds/xds.html.

NOTE: During the installation process, the user will be asked to specify a directory location where the program files will be stored. Less than 2 MB of files will be placed in this directory. You may accept the directory location suggested by the installation procedure or select your own. To continue, click the large computer icon button located on the left hand side of the installation setup screen.

Upon successful installation, an X-DRAIN group and program icon will be created within Windows Program Manager. The program is initiated by double-clicking on the program icon.

Windows 95 (either 16-bit or 32-bit X-DRAIN)

1. Close all open Windows applications.
2. If you are installing from a CD-ROM, insert the installation disk.
3. Click the **Start** icon—typically located in the lower left corner of the Windows 95 screen—followed by the **Run** menu item.
4. In the command line portion of the Run dialog box that appears, enter ***a:\setup32.exe***, where **a:** is the designation of your computer's CD drive.
5. Follow the instructions provided by the installation procedure.

NOTE: During the installation process, the user will be asked to specify a directory location where the program files will be stored. Less than 2 MB of files will be placed in this directory. You may accept the directory location suggested by the installation procedure or select your own. To continue, click the large computer icon button located on the left hand side of the installation setup screen.

Upon successful installation of the application, an X-DRAIN program icon is automatically inserted into the Windows Programs list. The program is started by clicking on this program icon.

Installation without a CD drive may be done from the network (see box on previous page) or the appropriate installation files can be copied to two floppy disks (see Readme.txt).

APPLICATION REMOVAL

Windows 3.x

The 16-bit X-DRAIN application is removed "manually" in Windows 3.x. Use Windows File Manager to delete the files in the directory where the program was installed. Also delete the X-DRAIN Group and Item icons from the Program Manager. Files that were copied into the Windows directories should not be removed.

Windows 95

Under Windows 95, the method to remove X-DRAIN depends on which version was installed. The 16-bit X-DRAIN application is removed "manually." Use Windows File Manager or Windows Explorer to delete the files in the directory where the program was installed. Also delete the X-DRAIN program name from the Programs list. Files that were copied into the Windows directories should not be removed.

The 32-bit X-DRAIN application is removed with the automated uninstall program. Click the **Add/ Remove Programs** icon in the Control Panel. Select the **X-DRAIN** program entry in the list of program names provided, and then click the **Add/ Remove…** button. Files copied to the user's computer during the installation procedure are automatically removed.

APPLICATION FEATURES

The X-DRAIN application is composed of three primary screens:

- ***a set-up screen***
- ***an input screen***
- ***a display screen***

X-DRAIN Setup Screen

The X-DRAIN setup screen (figure A1) is displayed only the first time the application is run. It displays a brief description of the program and allows the user to specify the system of units (**meters** or **feet**) to be used in computing and reporting sediment yield results (either kg/m or lb/ft). The default unit system of "Meters" is automatically highlighted when the setup screen appears. The desired unit scale is selected by clicking the button next to the unit description, then clicking the **OK** button.

X-DRAIN will retain the most recent units selection as the default each time the program is started. The units may be changed from the initial setting at any time with the menu option located on the input screen.

X-DRAIN Input Screen

On the X-DRAIN input screen (figure A2), the user selects a climate, soil type, hillside topography, and road width to estimate sediment yield for different combinations of road gradients and cross drain spacings. Selections may be made using a mouse, or by using the **Tab**, the **Shift-Tab**, and the arrow keys.

Climate

A scroll bar located within the climate list allows the user to scroll among the various available climates. The climate description window,[b] located directly below the climate list, provides descriptive information for a climate and is designed to assist the user in selecting a climate most appropriate to the location being studied. In some cases, the most appropriate climate may not be the one geographically closest to the location being simulated. Select the most appropriate climate based on the latitude, longitude, elevation, and annual precipitation displayed in the Climate Description window.

Soil Type

Five soil types are available within X-DRAIN and details to assist the user in selecting an appropriate soil type are provided in Appendix C.

Buffer Topography

The buffer is assumed to be a forested area between the outlet from a road cross drain or waterbar and an ephemeral or perennial channel. The buffer slope steepness and horizontal length nearest to those of the site conditions being simulated are selected. Users may wish to look at several combinations of buffer length and steepness, and then interpolate between values to determine a more exact topography. Extrapolation beyond the largest or smallest values is discouraged.

Road Width

You may enter any numeric value for road width between 1 and 30 meters (between 3 and 100 feet). See table 3 for guidance on entries for road width; it may be only the traveled-way width or the sum of the traveled-way and ditch width, depending upon what is being modeled.

Run Program

Once the required inputs have been selected by the user, pressing the **Run Program** button (or pressing **Alt-r**) displays a table of sediment yield values on the X-DRAIN display screen.

Exit Program

Clicking the **Exit Program** button (or pressing **Alt-x** or **Alt-F4**) on the input screen terminates the program. The user may also exit the program by pressing the **Esc** key on the keyboard or by the other standard methods of exiting a Windows program.

---

b. The climate description data are for display only and can not be altered by the user. The display can be copied to the Windows clipboard by highlighting the text and pressing **Ctrl-c** or clicking the right mouse button (Windows 95 only).

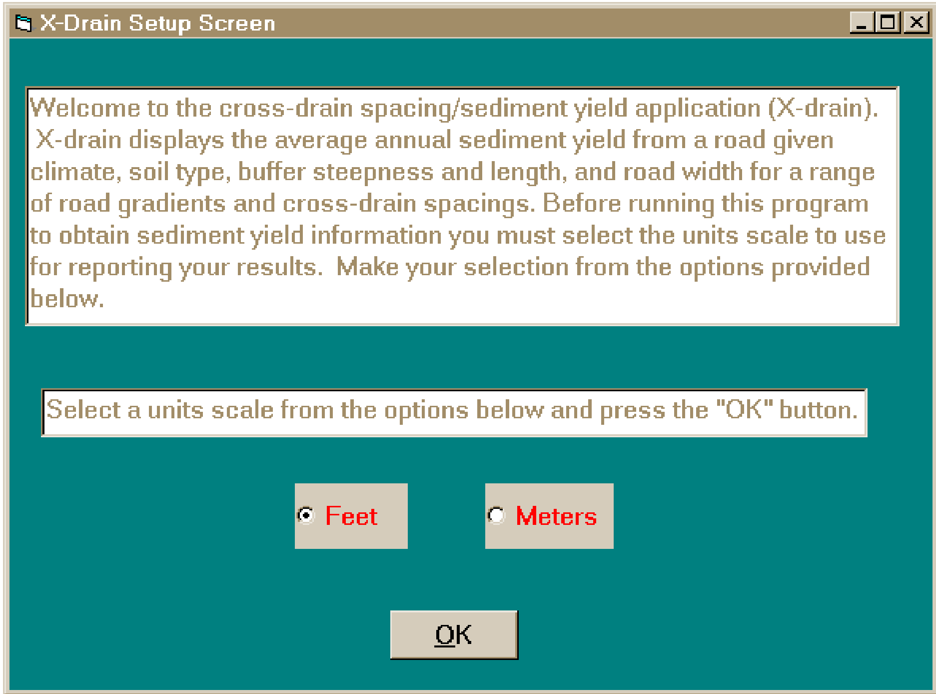


Figure A1—X-DRAIN setup screen with feet selected as the unit system.

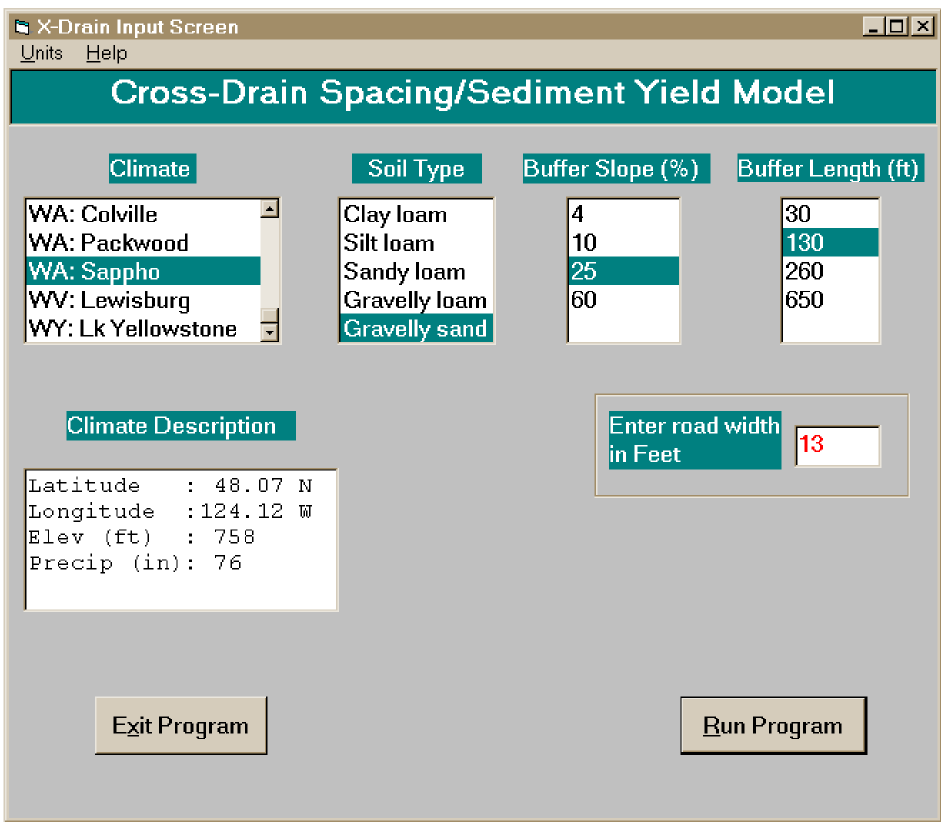


Figure A2—X-DRAIN input screen with feet selected as unit system.

Program Memory

X-DRAIN retains a given set of input values and the selected unit system from one program session to another. Values selected for climate, soil type, buffer length, buffer slope steepness, and road width at the time a session is closed are highlighted when a subsequent session is initiated.[c]

Unit System

Users may change the unit system for computing and reporting sediment yield by clicking the **Units** pull-down menu in the upper left corner of the input screen. Clicking **Units** (**Alt-u**) causes a "pull-down" menu to appear. The user may then select **Feet** or **Meters** (**f** or **m**) as the units system. The system currently selected by the program is indicated by a check mark. If the units are changed, the buffer length and road width values are converted to reflect the selected system. The elevation and precipitation values in the Climate Description window are also converted to the selected unit system.

X-DRAIN Display Screen

The X-DRAIN display screen (figure A3) displays sediment yield information for the climate, soil type, buffer topography, and road width selected on the input screen. Input values are presented on the display screen. Values for buffer length, road width, sediment yield, and cross-drain spacing are reported in the specified unit system. The sediment yields are the average annual amounts predicted by the WEPP model after running the model for 30 years for the given soil and topographic conditions, with a stochastic climate generated by the CLIGEN weather generator distributed with the WEPP model (Flanagan and Livingston 1995).

Sediment yields are displayed as kg/m length or lb/ft length of road contributing to a cross drain or waterbar. Yields are displayed as one or two significant digits following the rounding protocol presented in table A1.

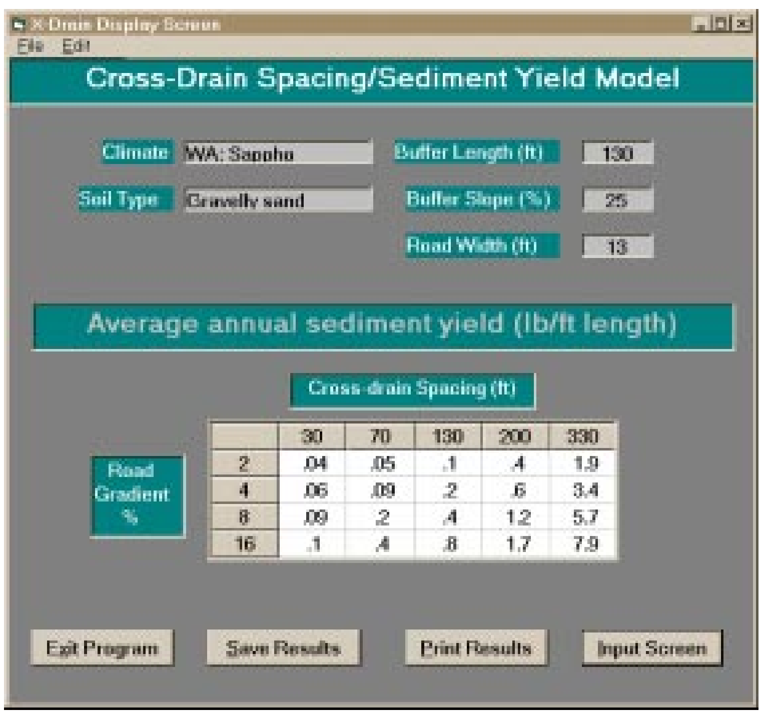


Figure A3—X-DRAIN display screen with feet selected as unit system.

c. Input values are retained between runs only if the program is closed by the program's **Exit Program** button or its shortcuts. If the program is closed by clicking buttons in the top right or left corners of the X-DRAIN screen, input values for the current session are not retained.

Table A1—Rounding protocol for sediment yields (Y) for either kg/m length or lb/ft length.

Range of results	Significant digits
$Y < 0.01$	$Y = 0$
$0.01 \leq Y < 0.95$	One significant digit (0.0x, or 0.x)
$0.95 \leq Y$	Two significant digits (x.x or xx)

Examples of interpreting the sediment yield values provided by X-DRAIN are given in the report body. Yield values reported as "—" indicate conditions where the road gradient is steeper than the buffer slope, which is unlikely to occur. If the road gradient is greater than the buffer slope, the user should consider selecting the steepest buffer slope available.

Command buttons at the bottom of the display screen provide the user with four program options: exiting the program without saving yield results, saving yield results to a disk file, printing yield results, and returning to the input screen. The features provided by the display screen button commands are also available by using the **File** pull-down menu. Clicking **File** (**Alt-f**) activates a pull-down menu that allows the user to select the same exit program, save results, print results, and return-to-input-screen features as provided with the buttons.

Save Results

Selecting the **Save Results** (**Alt-s**) button activates a ***Save As*** dialog box, which prompts the user to select a directory or folder and to enter a filename for the sediment yield information. The yield values are written to the specified file with accompanying header information indicating the input values and units scale selected by the user. The file is formatted for use as an input file for statistical or graphics packages for further analysis. The file can be viewed with any text editor, word processor, or spreadsheet program.

Print Results

Clicking the **Print Results** (**Alt-p**) command button displays a ***Print*** dialog box requesting printer-related information. Users may specify the printer and the number of copies to print. Clicking the **OK** button in this dialog sends the sediment yield information to the printer. The results are printed with header information indicating the input values and units system.

Copy to Clipboard

Sediment yield information may be copied to the Windows clipboard via the **Edit** pull-down menu. Data to be copied are selected by clicking a data cell within the display screen data grid and dragging the mouse to select all desired data cells. (Selected cells are indicated by a change in the background color of the cells.) Data may also be selected by clicking the column or row headings within the grid. Clicking an individual column or row heading selects the entire column or row. Clicking a heading and dragging the mouse to include additional headings selects all cells in the included headings. Clicking in the upper left corner of the data grid selects all data cells within the grid. Relevant row and column heading information is also copied to the clipboard along with the selected data values.

Once selected, data are copied to the clipboard by pressing **Ctrl-c** or by clicking the **Copy** option in the **Edit** menu (or **Alt-e** followed by **c**). From the clipboard, sediment yield information may be pasted directly into other Windows applications such as word processors or spreadsheets for further processing.

LITERATURE CITED

Elliot, W. J., S. M. Graves, and D. E. Hall. 1997. *The X-DRAIN Cross Drain Spacing and Sediment Yield Model.*

Flanagan, D. C. and S. J. Livingston. 1995. *WEPP User Summary*. NSERL Report No. 11, W. Lafayette, IN: National Soil Erosion Research Laboratory. 131 pp.

Morfin, S., B. Elliot, R. Foltz, and S. Miller. 1996. “Predicting Effects of Climate, Soil and Topography on Road Erosion with WEPP.” Presented at the 1996 International Meeting of the American Society of Agricultural Engineers, Paper No. 965016, St. Joseph, MI: ASAE. 11 pp.

APPENDIX B
DETAILS OF CLIMATE STATIONS IN THE STUDY

State	Location	Precipitation (mm)	Latitude (⁰N)	Longitude (⁰W)	Elevation (m)	Record (yr)
AK	Juneau	1336.1	58.37	134.58	3	43
AL	Birmingham	1391.8	33.57	86.75	185	62
AR	Clarksville	1239.1	35.47	93.47	134	39
AZ	Heber	318.4	34.38	110.58	2029	42
CA	Alturas	306.8	41.50	120.53	1359	61
CA	Glenville	494.0	35.72	118.70	954	41
CA	Willits	1282.2	39.42	123.33	411	32
CO	Eagle	282.4	39.63	106.92	1981	44
ID	Deadwood Dam[a]	822.7	44.32	115.63	1639	47
ID	Wallace[a]	922.7	47.50	115.88	899	44
KY	Heidelberg	1165.2	37.55	83.77	201	60
LA	Ruston	1391.8	32.52	92.68	85	62
MI	Watersmeet	758.8	46.28	89.17	490	44
MO	Salem	1108.4	37.63	91.55	365	74
MT	Libby[a]	454.6	48.40	115.53	633	84
MT	Seeley[a]	544.9	47.22	113.52	1228	44
NC	Cullowhee	1279.6	35.32	83.18	640	44
NH	Lancaster	879.9	44.46	71.57	268	42
NM	Taos	327.1	36.42	105.57	2127	44
NV	Tuscarora	301.8	41.42	116.23	185	33
OH	New Lexington	1009.6	39.73	82.22	271	50
OR	Austin[a]	517.5	44.58	118.50	1283	44
OR	North Bend	1611.3	43.42	124.25	3	61
OR	Wickiup[a]	553.9	43.68	121.70	1319	41
PA	Ridgway	1053.7	41.43	78.73	417	66

State	Location	Precipitation (mm)	Latitude (⁰N)	Longitude (⁰W)	Elevation (m)	Record (yr)
SD	Fort Meade	497.1	44.40	103.47	1005	43
TX	Lufkin	1141.4	31.47	94.72	88	85
UT	Heber[a]	418.8	40.50	111.42	1703	64
WA	Colville[a]	470.2	48.53	117.87	566	40
WA	Packwood	1351.3	46.62	121.67	323	42
WA	Sappho	1935.1	48.07	124.12	231	44
WV	Lewisburg	934.7	37.80	80.43	685	44
WY	Lake Yellowstone[a]	415.5	44.57	110.40	2356	64

a. Predicted sediment yields from these stations may be overestimated due to over prediction of snowmelt rates by the WEPP model (version 95.7).

APPENDIX C

CATEGORIES OF COMMON FOREST SOILS IN RELATION TO CROSS-DRAIN SOILS

Cross Drain Soil	Typical Field Soils	Unified Soil Classification
Clay loam	Native-surface roads on shales and similar decomposing sedimentary rock	MH CH
Silt loam	Ash cap native-surface road; alluvial loess native surface road	ML CL
Sandy loam	Glacial outwash areas; finer-grained granitics	SW SP SM SC
Gravelly loam	Loam surfaces that have been graveled	GC
Gravelly sand	Coarse grained granitics, and fine-grained granitics that have been graveled	GM

APPENDIX D
SOIL PROPERTIES IN THE STUDY

Element	Soil				
	Clay	Silt	Sand	Gravelly Loam	Gravelly Sand
Traveled Way					
Gravel %	20	5	5	60	80
Sand %	30	30	60	40	70
Silt %	40	55	35	40	25
Clay %	30	15	5	20	5
Conductivity mm/hr	0.3	0.3	1	2	3
Interrill erodibility	1,000,000	3,000,000	2,000,000	1,000,000	2,000,000
Rill erodibility	0.0002	0.0006	0.0004	0.0003	0.0003
Critical shear	1.5	1.8	2	1.8	2
Organic matter %	0.01	0.01	0.01	0.01	0.01
Fill Slope					
Gravel %	20	5	5	40	40
Sand %	30	30	60	35	65
Silt %	40	55	35	40	30
Clay %	30	15	5	25	5
Conductivity mm/hr	5	8	10	25	40
Interrill erodibility	1,000,000	3,000,000	2,000,000	1,000,000	2,000,000
Rill erodibility	0.0002	0.0006	0.0004	0.00025	0.00035
Critical shear	1.5	1.8	2	1.6	2
Organic matter %	2	2	2	2	2
Forest Buffer					
Gravel %	20	5	5	20	5
Sand %	30	30	60	30	60
Silt %	40	55	35	40	35
Clay %	30	15	5	30	5
Conductivity mm/hr	10	15	20	50	80
Interrill erodibility	1,000,000	3,000,000	2,000,000	1,000,000	2,000,000
Rill erodibility[a]	0.0002	0.0006	0.0004	0.0002	0.0004
Critical shear	1.5	1.8	2	1.5	2
Organic matter %	4	4	4	4	4

a. Recent studies indicate that this value may have been underestimated in the study.

APPENDIX E
USEFUL CONVERSIONS

Multiply	by	to get
mm (millimeters)	0.0394	in. (inches)
m (meters)	39.4	in. (inches)
m (meters)	3.28	ft (feet)
m^2 (square meters)	10.8	ft2 (square feet
kg (kilograms)	2.2	lb (pounds mass)
t (metric tonnes)	1,000	kg (kilograms)
t (metric tonnes)	1.1	short tons
short tons	2,000	lb (pounds)
kg/m	1	t/km
kg/m	0.67	lb/ft
lb/ft	2.64	short tons/mile

Register as a user of X-DRAIN by filling out this form and mailing it to the address on the following page. This page can be removed, folded in thirds, and sent through the mail using the address block on the reverse side.

Or, register on-line at http://forest.moscowfsl.wsu.edu/4702/x-drain.html. Also check the web page for notices of known issues and upgrades).

Or, e-mail registration information to <wepp@forest.moscowfsl.wsu.edu>.

We will use your registration information only for the purposes of letting you know of new versions and known issues with X-DRAIN and for helping us to judge the amount of interest in X-DRAIN.

Name: ____

E-mail address: ____

Postal address: ____

____

____

(Fold here)

To:

William Elliot, Project Leader
USDA Forest Service
Rocky Mountain Research Station
1221 S. Main Street
Moscow, ID 83843

Ref: X-DRAIN Registration