Forest Erosion Simulation Tools: FOREST

This model is available for downloading at
http://www.warnercnr.colostate.edu/frws/people/faculty/macdonald/model.htm

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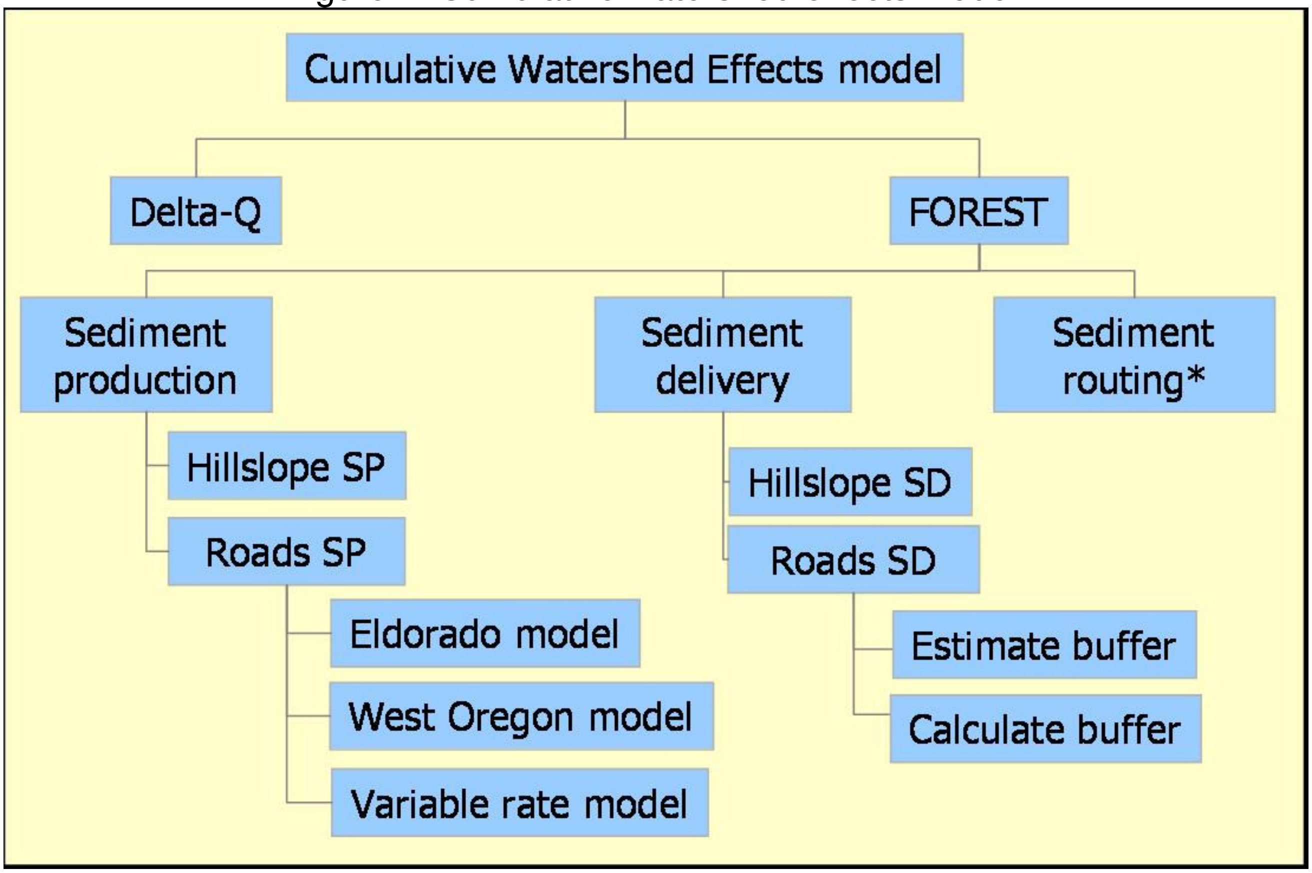
1. Introduction

For many years land managers have been concerned by the hydrologic and erosional changes wrought by disturbances such as timber harvest, road construction, and fires. The changes of concern include the alteration of peak, median and low flows, the degradation of water quality due to increased sediment inputs, and changes in channel morphology. Natural or anthropogenic disturbances have been shown to increase surface erosion by orders of magnitude over undisturbed hillslopes (Megahan and Kidd 1971, Coe 2004). The cumulative impacts of multiple disturbances over space and time are of great concern to resource managers but are poorly understood. In response to the need to understand and predict the effects of different land management scenarios, we are developing a suite of spatially explicit, cumulative effects models for forested watersheds. The overall goal is to provide land managers with a set of tools to assess changes in runoff, surface erosion, and downstream sediment transport due to forest harvest, roads, and fires (Figure 1). The Delta-Q model calculates changes in flow. The FOREST model (FORest Erosion Simulation Tools) calculates changes in the sediment regime. This document covers the sediment production and hillslope delivery components of FOREST. Sediment routing is under construction.

Instructions for Delta-Q are in a separate file at http://www.warnercnr.colostate.edu/frws/people/faculty/macdonald/model.htm or if you have installed the model software, this documentation is in your installation directory at ..\documentation\ DeltaQ_docs.PDF.

Figure 1. Cumulative watershed effects model



*Model not yet available

FOREST model overview

Hillslope sediment production

The hillslope sediment production model uses polygon GIS layers of land disturbances (fire and timber management) to calculate sediment production. This model assumes a linear recovery of the post-disturbance landscape to pre-disturbance or background rates of sediment production. The user provides a GIS polygon layer of disturbances with the date of disturbance. For each type of disturbance users must input an initial erosion rate and the number of years that it takes for the hillslope to recover to pre-disturbance levels of sediment production. The user also provides a background sediment production rate or accepts the default rate. Help files with lists of measured values are provided to help users select values that are appropriate for their sites. Predicted sediment production rates can be modified by inputting another GIS layer that adjusts for factors such as fire severity or soil type categories. The user can input separate background rates of erosion and erosion weights for each different category in the additional layer. The model creates annual sediment production GIS grids for each disturbance type. Annual sediment production grids are combined by maximum cell value. The model results in GIS grids with annual maximum sediment production rates for each disturbance and combined disturbances in Mg/ha yr and summary tables of results for individual and combined disturbances.

Roads sediment production

Road sediment production is treated separately because roads are linear features rather than polygons and they are presumed not to exhibit any recovery over time. Three methods can be used to calculate road sediment production in FOREST:

1) An empirical equation developed on the Eldorado National Forest in the central Sierra Nevada of California (Coe 2004):

SP (kg/yr) = -356 + 106 * graded + 3.3 * area * road gradient + 0.6 * storm erosivity

- graded can take values of "1" for roads that have been graded within the last few years or are heavily used and "0" for roads that are neither.
- area (m^2) of the road segment is the user-defined width times the arc length of the road segment. Arc lengths can be adjusted within the model.
- road gradient (m/m) is calculated by the model using the roads layer and an elevation grid provided by the user.
- storm erosivity (MJ mm / ha h yr) is the total annual storm energy times the maximum 30-min rainfall intensity for an area. Help is provided in the form of isoerodent maps.

2) An empirical equation for sediment production from roads in Oregon (Luce and Black 1999).

SP (kg/yr) = *a* * length * (road gradient)^2

- The default value for the *a* coefficient is 717, but model users can change this to better represent their area of interest.
- The length (m) of each road segment is taken from a GIS layer.
- The road gradient (m/m) is calculated by the model using the roads layer and an elevation grid provided by the user.

3) Users can directly input the amount of sediment produced per unit area by different road types or users can join a pre-constructed look-up table of sediment production rates to their roads layer. Input values can be developed from field measurements or from other models, for example, WEPP:Road.
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2. Installation notes and instructions

- All program files and documentation are located in FOREST_DQ2006.zip. Unzip FOREST_DQ2006.zip to a temporary directory– it is in winzip format. Using Windows Explorer, you should see the following files:
- Setup.lst, Cemod.cab, Setup.exe.

  To install FOREST and DeltaQ, double Click on setup.exe to start the setup program. It will lead you through the usual questions – are all other applications closed, where do you want to put the program - follow the defaults.

PLEASE DO NOT INSTALL THIS PROGRAM IN THE **PROGRAM FILES** DIRECTORY OR ANY DIRECTORY WITH A SPACE IN THE NAME.

Licenses and Systems

Forest and DeltaQ require an Arc9.x license and software located on the PC. Previous versions were tested with Arc 8.2, but the current version has not. There is a good chance that it will work on Arc8. It has not been tested with less than a full copy of ArcGIS including ArcInfo installed. This version was tested in Windows XP Pro.

This software will not work on UNIX systems.

Error Messages

If you get a message that says "**Unable to generate log file**…", please talk to your systems administrator; you do not have permissions to load the software onto your PC.

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3. Spatial data requirements

Notes:

1. All GIS layers, i.e., coverages and grids must be in the same projection. Units must be meters.
2. Polygon coverages must have polygon topology (ArcInfo: *build yourcovername poly*; Arc Catalog: *coverage properties\build*).
3. All coverages must be in the same workspace.
4. Users must have write access to the workspace containing the coverages. CEMod contains a utility to copy coverages between workspaces.
5. Data must not contain commas. Commas are commonly used to separate the different fields and may lead to errors in reading the data.

Hillslopes disturbances

The user will need to provide the following spatial layers:

- ArcInfo polygon watershed coverage to specify the area of interest. The user will be asked to select a character field containing the names of watersheds.
- At least one ArcInfo coverage of disturbance:
    - Forest management activities with fields containing year (format = numeric yyyy) and type of harvest or activity (format =character);
    - Fires with fields containing year (format = numeric yyyy) and fire severity.

  Land cover polygons without any disturbance type are assigned a background rate of sediment production and assumed to be undisturbed for sediment delivery calculations. See sediment production and delivery model documentation for details.

- ArcInfo stream coverage.
- Additional coverage of a controlling factor (optional). This layer must contain a character field that identifies different categories for this factor, e.g. soil types, fire severity.
- Elevation grid with elevations in meters.
- Soil grid with values: clay and silt loam=1 or sandy loam=2).

Roads

Required coverages:

- ArcInfo polygon watershed coverage. The user will be asked to select a character field containing the names of watersheds.
- ArcInfo roads coverage.
- ArcInfo stream coverage.

Eldorado Model (Coe 2004)

- The roads layer must contain a numeric field signifying recently graded (1) or ungraded (0) roads.
- Elevation grid in meters.

West Oregon Model (Luce and Black 1999)

- Elevation grid in meters.

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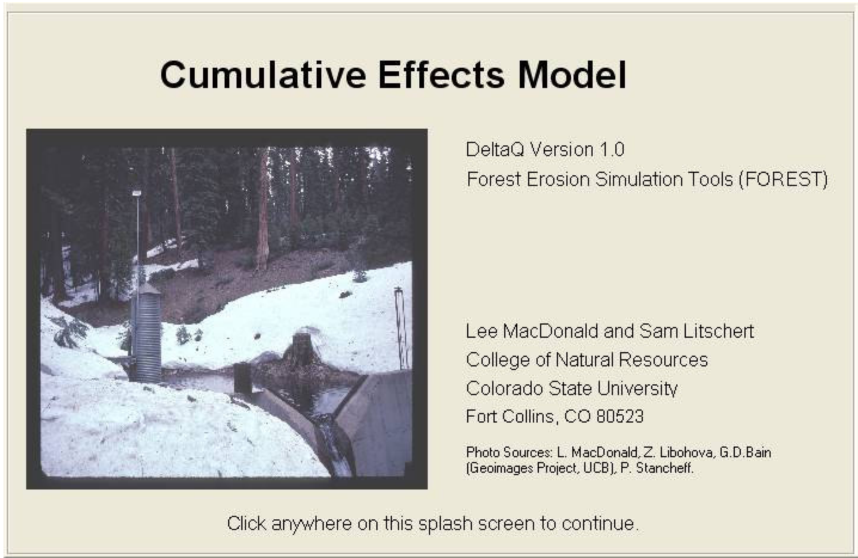
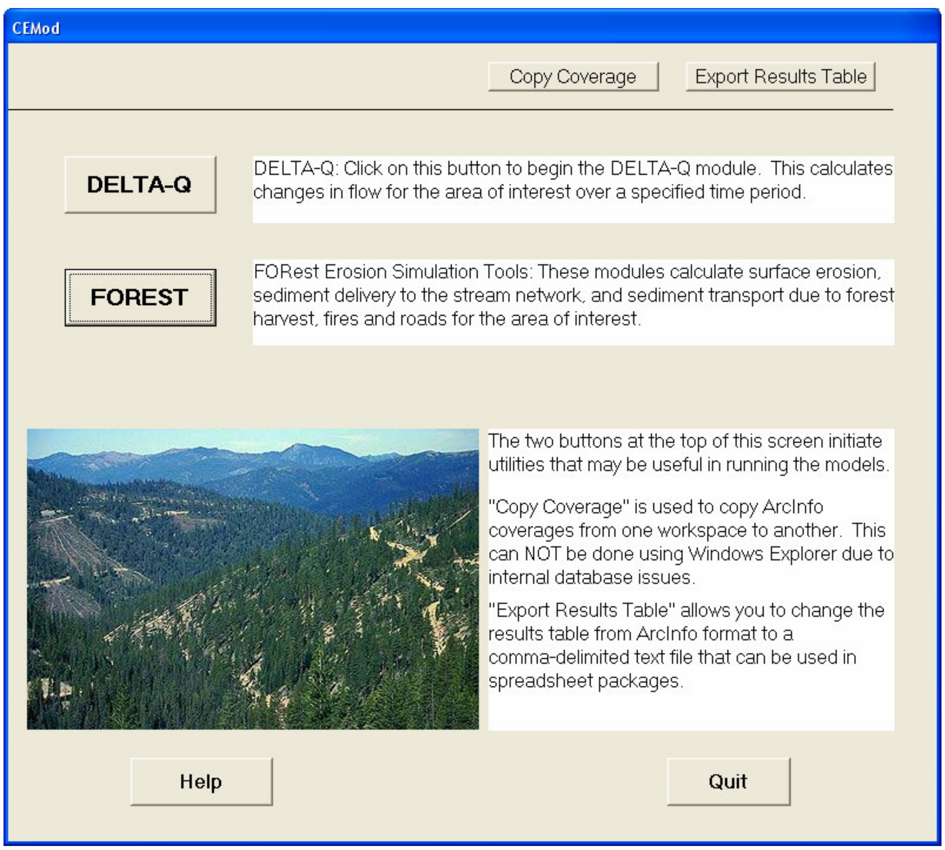
4. Instructions for FORest Erosion Simulation Tools (FOREST)



Click on the initial splash screen to bring up the main menu.



Click on the FOREST button to access sediment production and delivery models for hillslope disturbances and roads, and to combine these effects. To run the different options click on:

- Calculate sediment production from hillslope disturbances,

- [Calculate sediment production from roads](#),
- [Calculate sediment delivery from hillslopes and roads.](#)

Note: before quitting the program, you can copy any coverages or tables created by the program to other names in order to save them. When the program quits it will delete many of the interim files it has created to avoid cluttering up your hard drive with unrecognizable and seemingly meaningless junk (which is actually essential to the running of this model). However deletions by the user of some of the aforementioned junk may prove to be detrimental to future model runs. Any grids named by the user will not be deleted.

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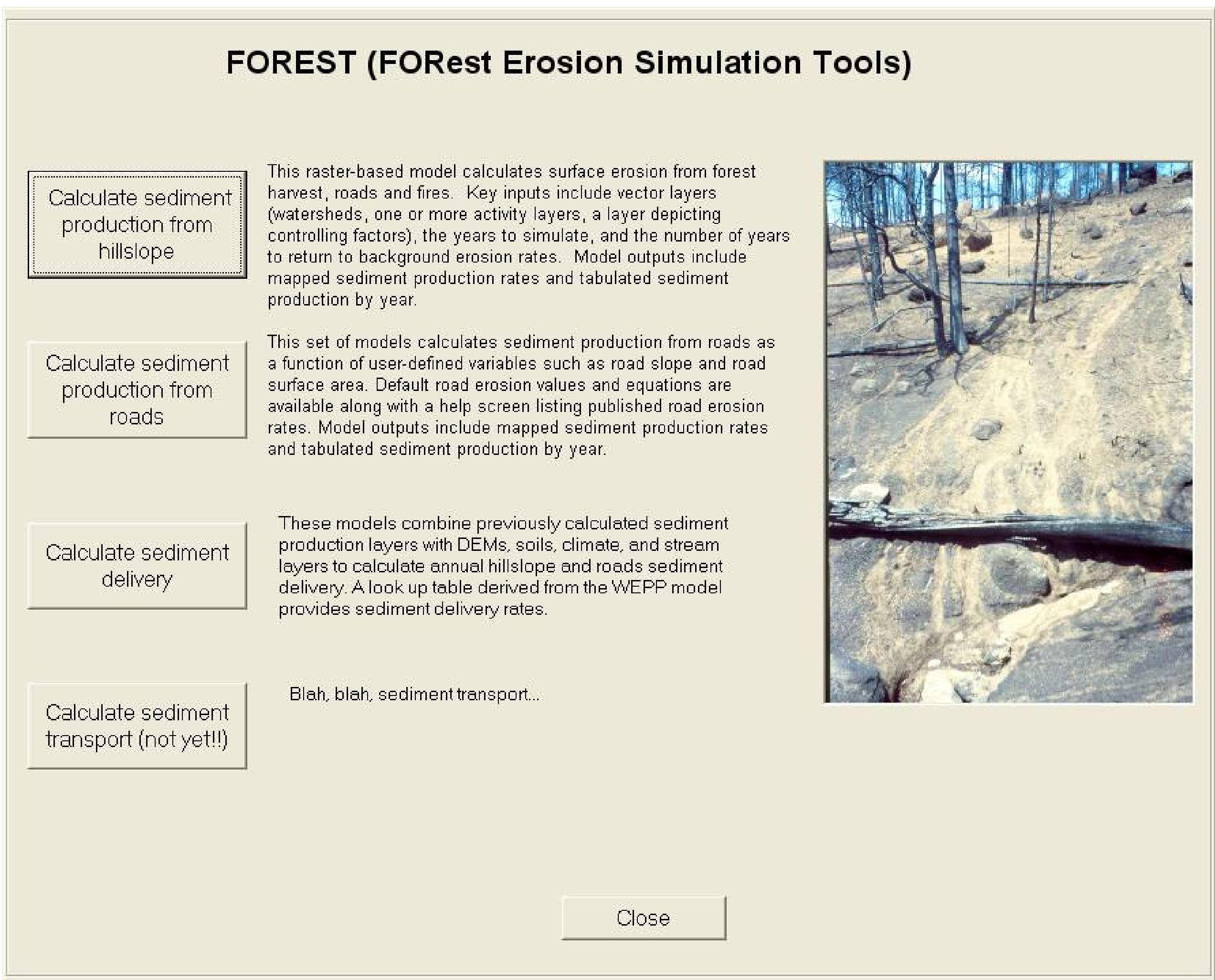


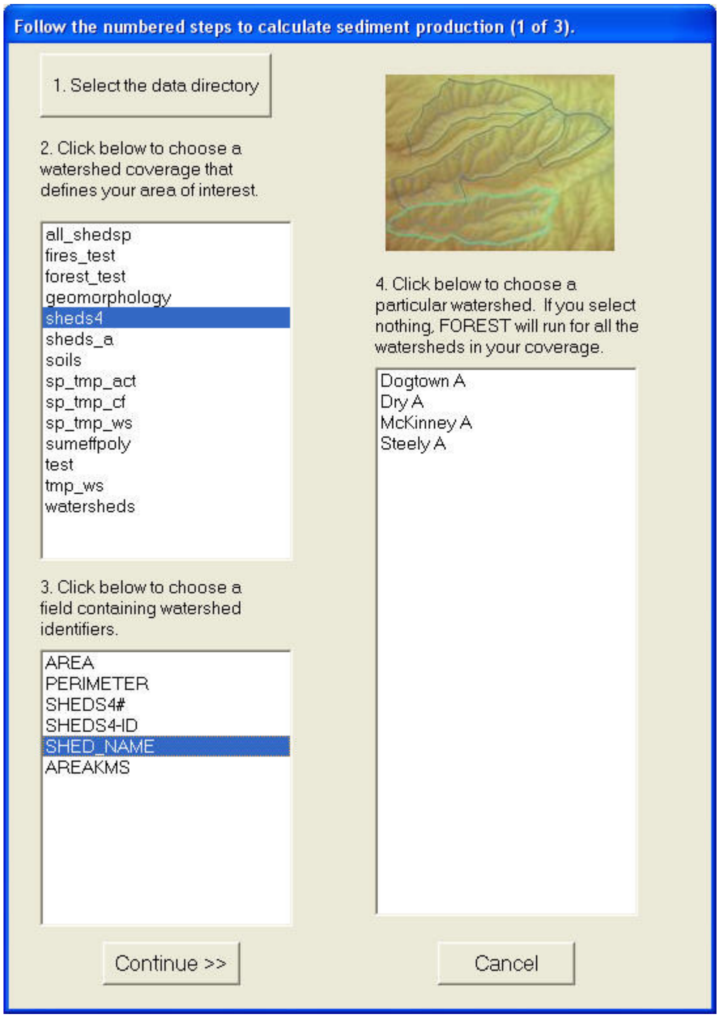
Calculate sediment production from hillslopes disturbances

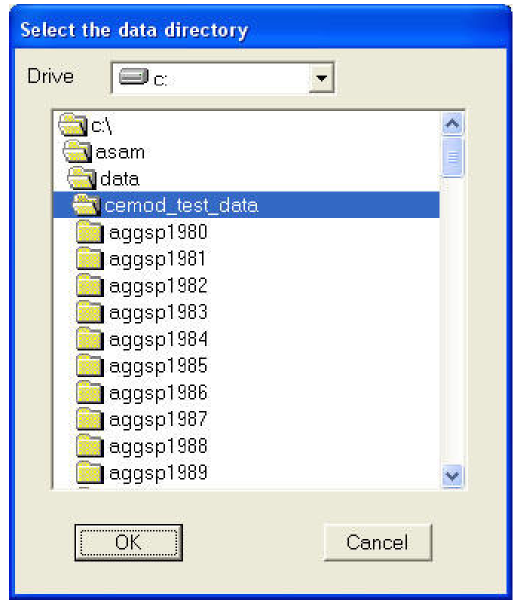
The hillslope sediment production model calculates sediment production from areas of fire and timber harvest using a linear recovery equation. A series of three forms lead the user through data inputs for hillslope sediment production and delivery. Details of the required GIS input layers are listed in Section 3: spatial data requirements. The user must provide initial erosion rates and the number of years to recovery for each type of disturbance, years to model, and select a grid cell size for output grids.

The hillslope sediment production model combines the results of the sediment production grids for fire and timber harvest by using the maximum value for each grid cell. The input layer names and values are saved in a parameter file in the user-selected data directory. This file is used to calculate sediment delivery, and it also means that the user can return to the model run at a later date to view inputs (except initial erosion values and years to recovery) and calculate sediment delivery. Note that the layers clipped to the watershed(s) are saved under a different name to preserve the original data. These new layer names are saved to the parameter file at the end of the sediment production calculation and will appear in input form 2 if the load parameter file button is clicked after sediment production has been calculated.

The hillslope sediment production model outputs sediment production GIS grids for fire, timber harvest, and combined effects (hillspyyyy), and two summary tables of total, mean, minimum, maximum, and standard deviation for separate and combined sediment production (see below for tables).

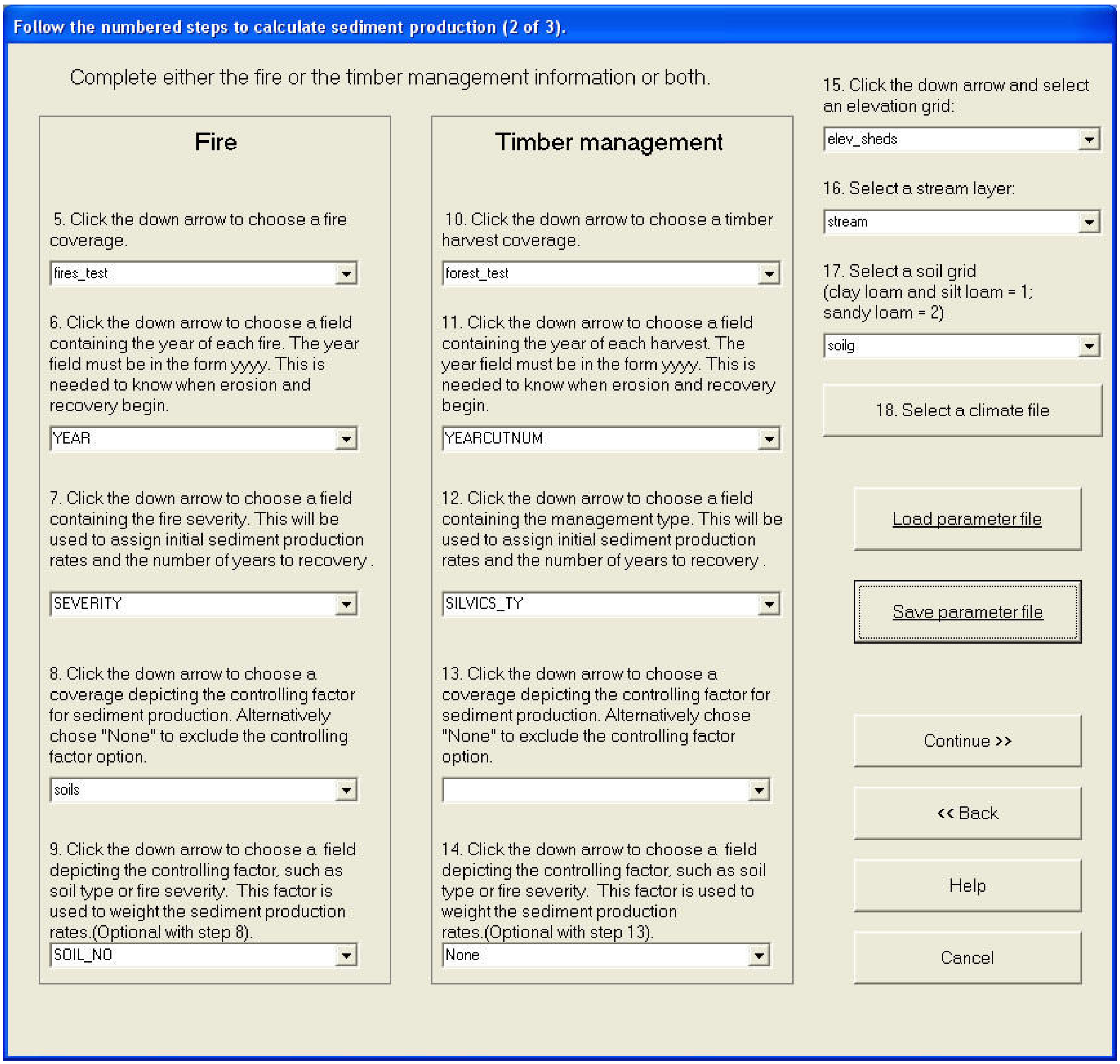
Input form 1: When you click on the "Calculate SP from activities and events", the form (Follow the numbered steps...1 of 3) will appear. This form allows the user to select the data directory and define the watershed of interest. If step 4 (Choose a watershed) is skipped, all of the watersheds will be processed if data are available.





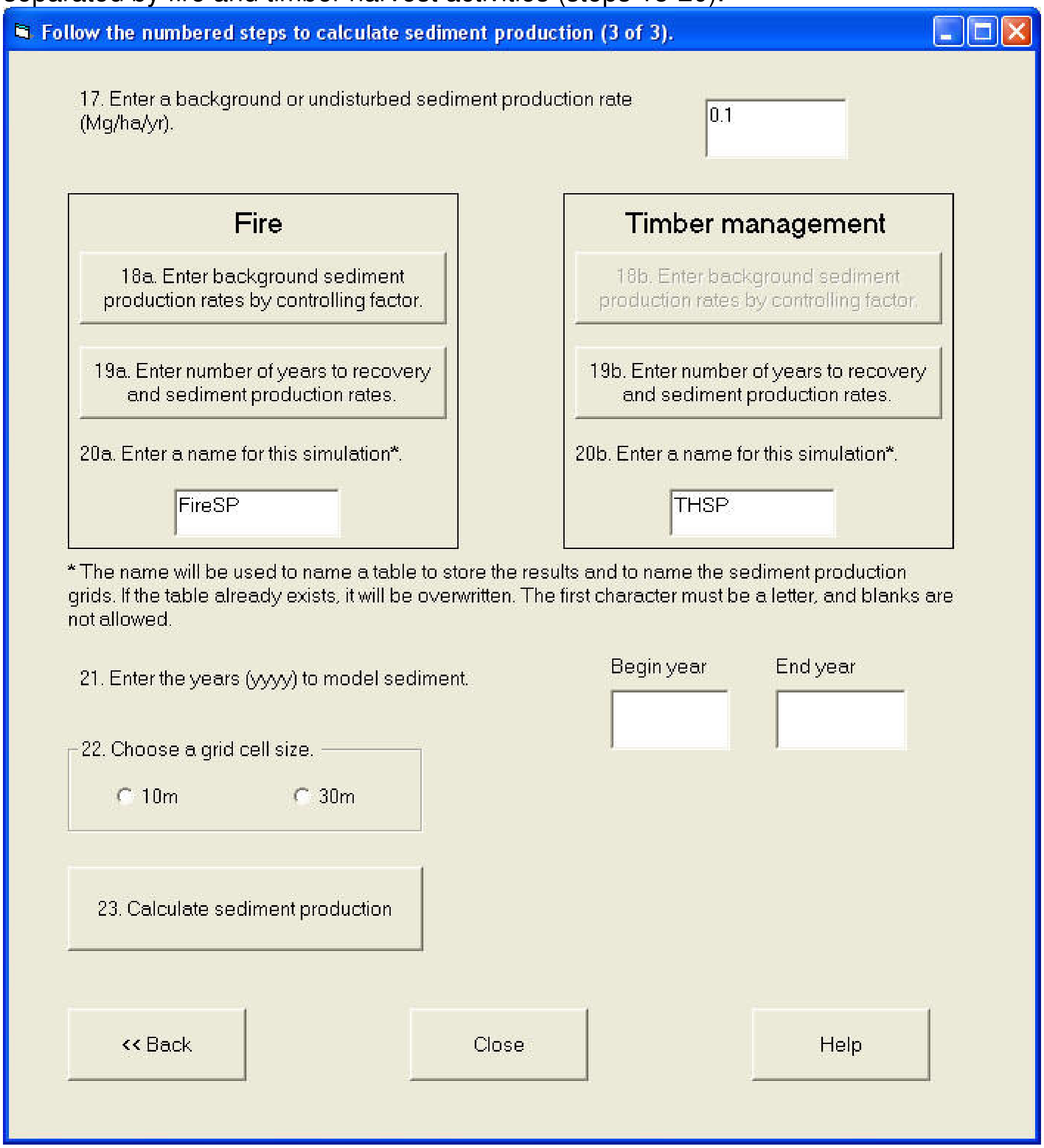
Input form 2: Click on "Continue >>" to bring up the second input form (2 of 3). This form is divided into inputs for fire (steps 5-9), timber harvest (steps 10-14) and layers pertinent to both types of disturbance (15-18). Steps 5, 8, 10, and 13 will automatically list the polygon layers available in your chosen data directory. By choosing an activity layer to process (5,10) and a layer depicting the controlling factor (8,13), a list of available fields of data within the layers will be shown under steps 6, 7, 9, for fire and 11,12,and 14 for timber harvest. The controlling factor layer can be the same as the activity layer and is optional. Choose fields appropriate to each description. For step 17, select a grid that contains the values 1 for fine soils, predominantly clay loam and silt loam and 2 for sandy loam and coarser soils. Clicking on Step 18 shows a dialog window that enables the user to select a climate file. More information on creating and selecting climate files is available in c:\forest\documentation\Create_sediment_delivery_file.doc or where ever the program is loaded.

Saving and Loading data: Having completed all the data entry steps to this point, the user can save a parameter file with these values in it. This enables calculation of sediment delivery in the next step and facilitates multiple model runs for sensitivity analysis. The parameter file saves all names of data inputs from this form, the watershed information from the previous form, sediment production grid names, years and cell size information from the third form. The parameter file does not save erosion rates specified in the third form. The parameter file is located in the user-selected data directory and is called parameter_file_sp.txt. On running the model a second time, when this form appears, the user can "Load parameter file" and these same data will be selected automatically. When the production routines have been run, a second file will automatically be saved (parameter_file.txt), this contains the names of the GIS layers that are clipped to the selected watershed(s) and other parameters for use by the sediment delivery model. Click on "Continue >>".



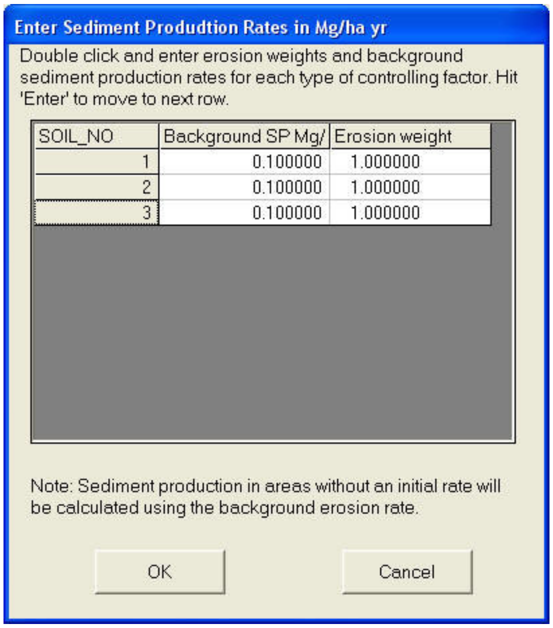
The processing window will appear to let you know that the program is clipping all layers to the chosen watershed(s). For this processing step, the original data layers are copied so that no data are lost or altered.

Input form 3: Similarly to input form 2, sediment production and recovery time inputs are separated by fire and timber harvest activities (steps 18-20).

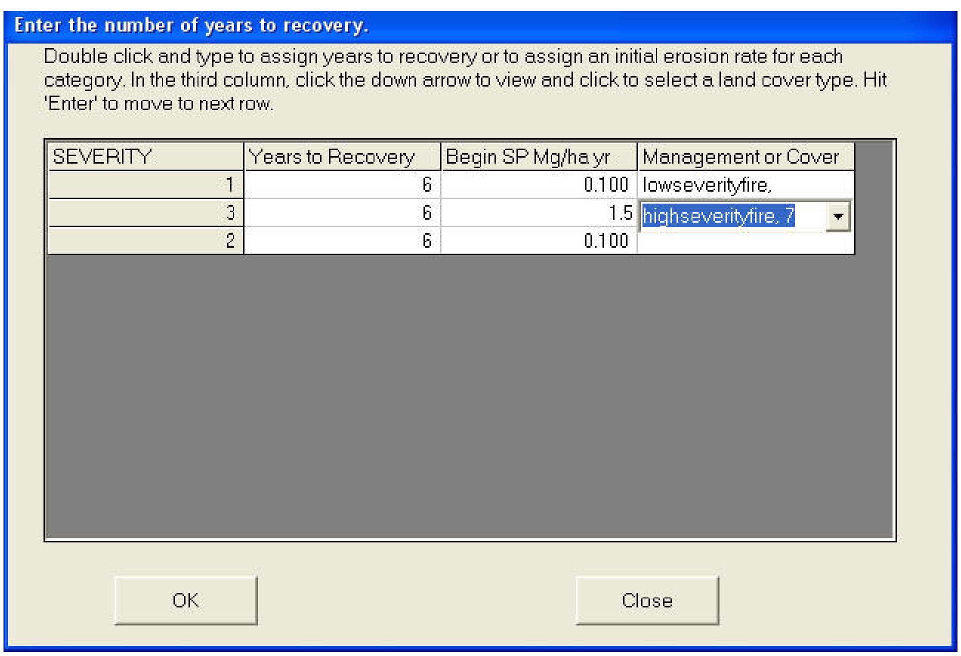


Step 17: the user can enter a background sediment production rate or can accept a default undisturbed sediment production rate of 0.1 Mg/ha/yr (Riebe et al 2000).

Click on step 18 to show the input form for the controlling factor weights. Step 18 is disabled if a controlling factor was not selected in input form 2. In the example, a controlling factor was not selected for timber management, so step 18b is disabled.



Click on step 19 to show the data input form with a line for each type of disturbance in the GIS layer - fire severity is shown in the example below. The user-selected disturbance type will appear in the first column. The second and third columns can be edited for the number of years to recovery and initial sediment production rates respectively. Land cover types <u>must</u> be chosen for each line in the fourth column to calculate sediment delivery and recovery. Click on OK to return to the main input form.



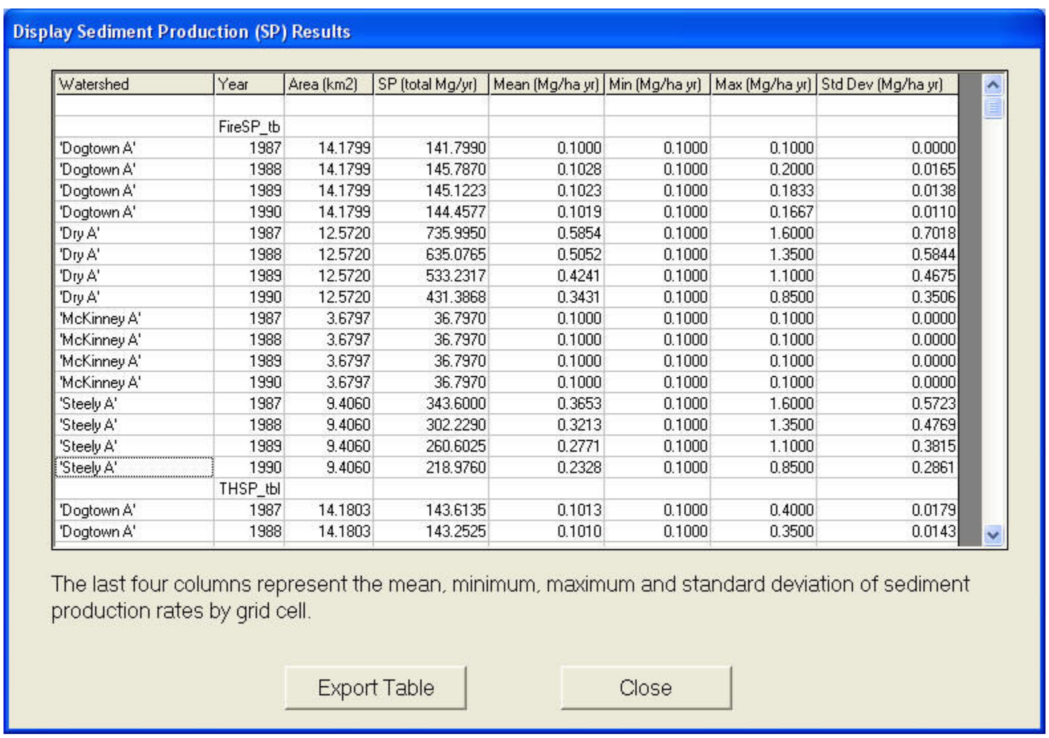
Step 20: Enter a name for this simulation. This will be the prefix for output tables and grids. The character limit is 8, no spaces are allowed, and the name must not begin with a number.

Step 21: Enter the beginning and ending years of a period of time to be simulated by the model or enter the beginning year to simulate one year.

Step 22: Choose a grid cell size: 10 or 30 m, based on the cell size of your elevation grid.

Click on step 23. Calculate sediment production. After calculation, yearly sediment production grids for each disturbance and combined effects (hillspyyyy) will be available in the user-selected data directory with the user-given prefix and year, e.g. firesp1987. By clicking on "Calculate" the parameter file is automatically updated with the names of layers clipped to the selected watershed(s), and items input in the third input form as described above.

Outputs include two summary tables: 1) watershed name, year, watershed area, total, mean, minimum, maximum, and standard deviation sediment production for fire and timber harvest separately and 2) the same column headings for the combined effects.

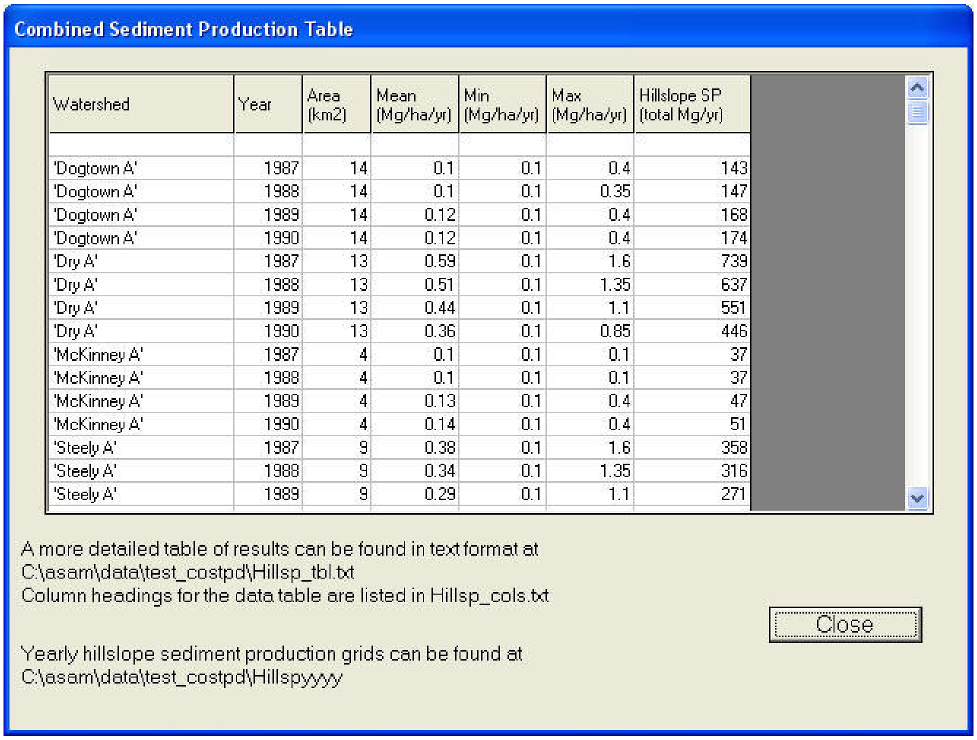

Display Sediment Production (SP) Results

Watershed	Year	Area (km2)	SP (total Mg/yr)	Mean (Mg/ha yr)	Min (Mg/ha yr)	Max (Mg/ha yr)	Std Dev (Mg/ha yr)
	FireSP_tb						
'Dogtown A'	1987	14.1799	141.7990	0.1000	0.1000	0.1000	0.0000
'Dogtown A'	1988	14.1799	145.7870	0.1028	0.1000	0.2000	0.0165
'Dogtown A'	1989	14.1799	145.1223	0.1023	0.1000	0.1833	0.0138
'Dogtown A'	1990	14.1799	144.4577	0.1019	0.1000	0.1667	0.0110
'Dry A'	1987	12.5720	735.9950	0.5854	0.1000	1.6000	0.7018
'Dry A'	1988	12.5720	635.0765	0.5052	0.1000	1.3500	0.5844
'Dry A'	1989	12.5720	533.2317	0.4241	0.1000	1.1000	0.4675
'Dry A'	1990	12.5720	431.3868	0.3431	0.1000	0.8500	0.3506
'McKinney A'	1987	3.6797	36.7970	0.1000	0.1000	0.1000	0.0000
'McKinney A'	1988	3.6797	36.7970	0.1000	0.1000	0.1000	0.0000
'McKinney A'	1989	3.6797	36.7970	0.1000	0.1000	0.1000	0.0000
'McKinney A'	1990	3.6797	36.7970	0.1000	0.1000	0.1000	0.0000
'Steely A'	1987	9.4060	343.6000	0.3653	0.1000	1.6000	0.5723
'Steely A'	1988	9.4060	302.2290	0.3213	0.1000	1.3500	0.4769
'Steely A'	1989	9.4060	260.6025	0.2771	0.1000	1.1000	0.3815
'Steely A'	1990	9.4060	218.9760	0.2328	0.1000	0.8500	0.2861
	THSP_tbl						
'Dogtown A'	1987	14.1803	143.6135	0.1013	0.1000	0.4000	0.0179
'Dogtown A'	1988	14.1803	143.2525	0.1010	0.1000	0.3500	0.0143

The last four columns represent the mean, minimum, maximum and standard deviation of sediment production rates by grid cell.

Export Table Close

Below is the sediment production table for a model run of 1987 - 1990 that shows combined hillslope disturbance sediment production.


Combined Sediment Production Table

Watershed	Year	Area (km2)	Mean (Mg/ha/yr)	Min (Mg/ha/yr)	Max (Mg/ha/yr)	Hillslope SP (total Mg/yr)
'Dogtown A'	1987	14	0.1	0.1	0.4	143
'Dogtown A'	1988	14	0.1	0.1	0.35	147
'Dogtown A'	1989	14	0.12	0.1	0.4	168
'Dogtown A'	1990	14	0.12	0.1	0.4	174
'Dry A'	1987	13	0.59	0.1	1.6	739
'Dry A'	1988	13	0.51	0.1	1.35	637
'Dry A'	1989	13	0.44	0.1	1.1	551
'Dry A'	1990	13	0.36	0.1	0.85	446
'McKinney A'	1987	4	0.1	0.1	0.1	37
'McKinney A'	1988	4	0.1	0.1	0.1	37
'McKinney A'	1989	4	0.13	0.1	0.4	47
'McKinney A'	1990	4	0.14	0.1	0.4	51
'Steely A'	1987	9	0.38	0.1	1.6	358
'Steely A'	1988	9	0.34	0.1	1.35	316
'Steely A'	1989	9	0.29	0.1	1.1	271

A more detailed table of results can be found in text format at
C:\asam\data\test_costpd\Hillsp_tbl.txt
Column headings for the data table are listed in Hillsp_cols.txt

Yearly hillslope sediment production grids can be found at
C:\asam\data\test_costpd\Hillspyyyy

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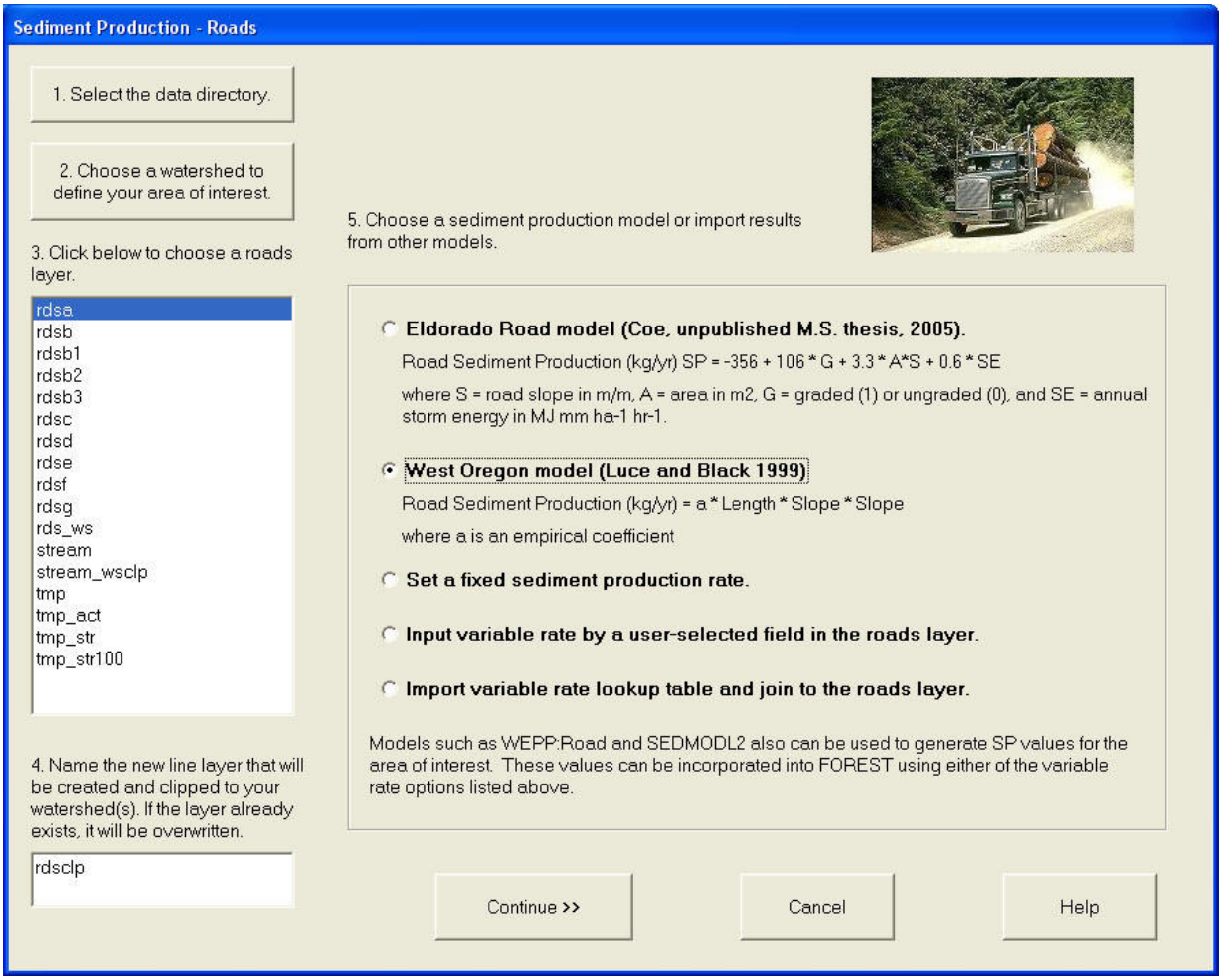
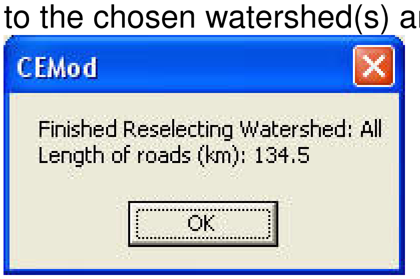
Calculate sediment production from roads

When you click on "Calculate sediment production from roads", a form will appear with instructions and descriptions of the roads models. Help is available in the form of published values of sediment production from roads, with corresponding road slope, traffic, location, and study reference.



Steps 1-2 are described in hillslope SP. Step 3: choose a roads layer from the arc layers listed below. This layer will not be altered but will be copied to a layer of the name specified in step 4. If a layer with the name provided exists, it will be overwritten.

Step 5: Click on one of the options to choose a roads model. The roads layer will be clipped to the chosen watershed(s) and the total road length will be calculated.



Road Erosion Models:

- Eldorado (Coe 2004)

- [West Oregon (Luce and Black 1999)]
- [Variable rate input]
- [Fixed rate input]

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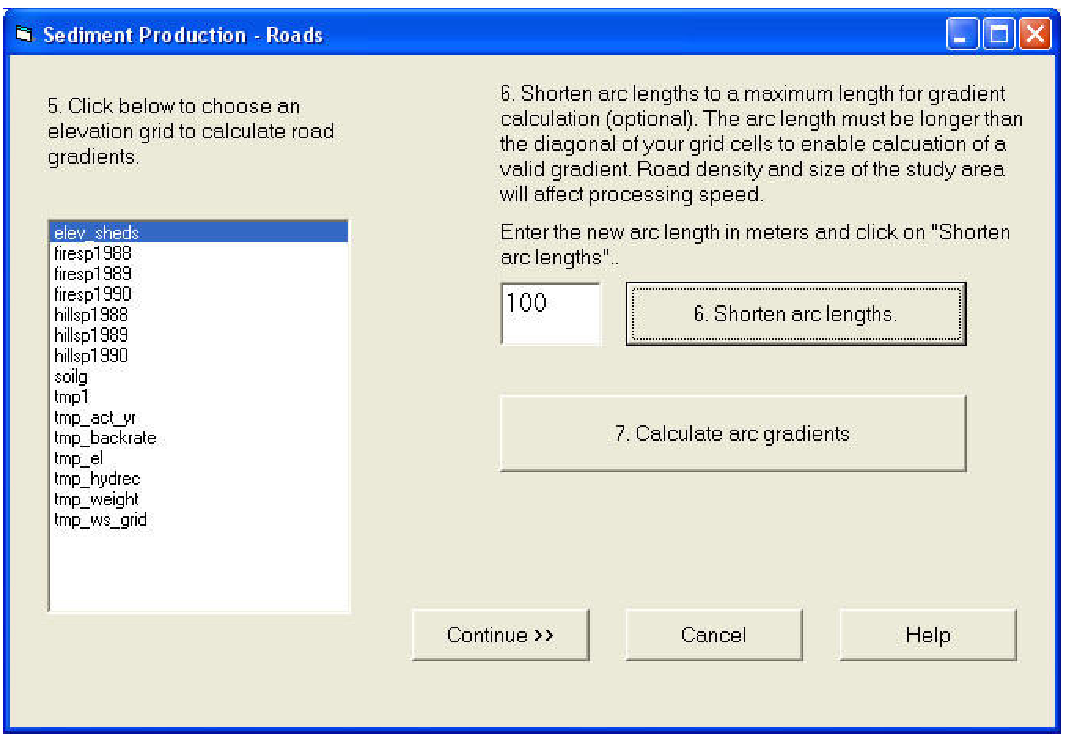
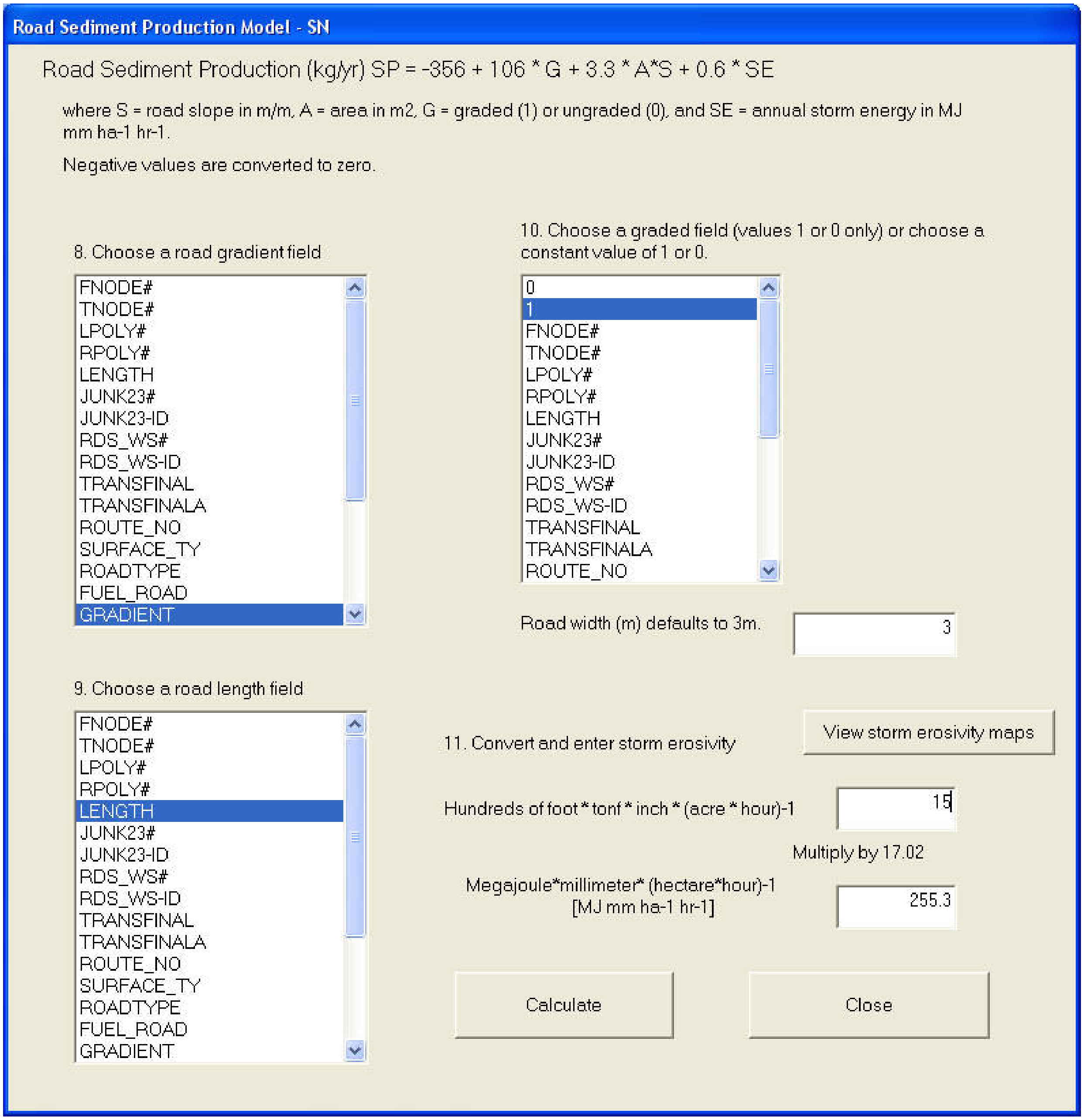
Eldorado road model (Coe 2004)

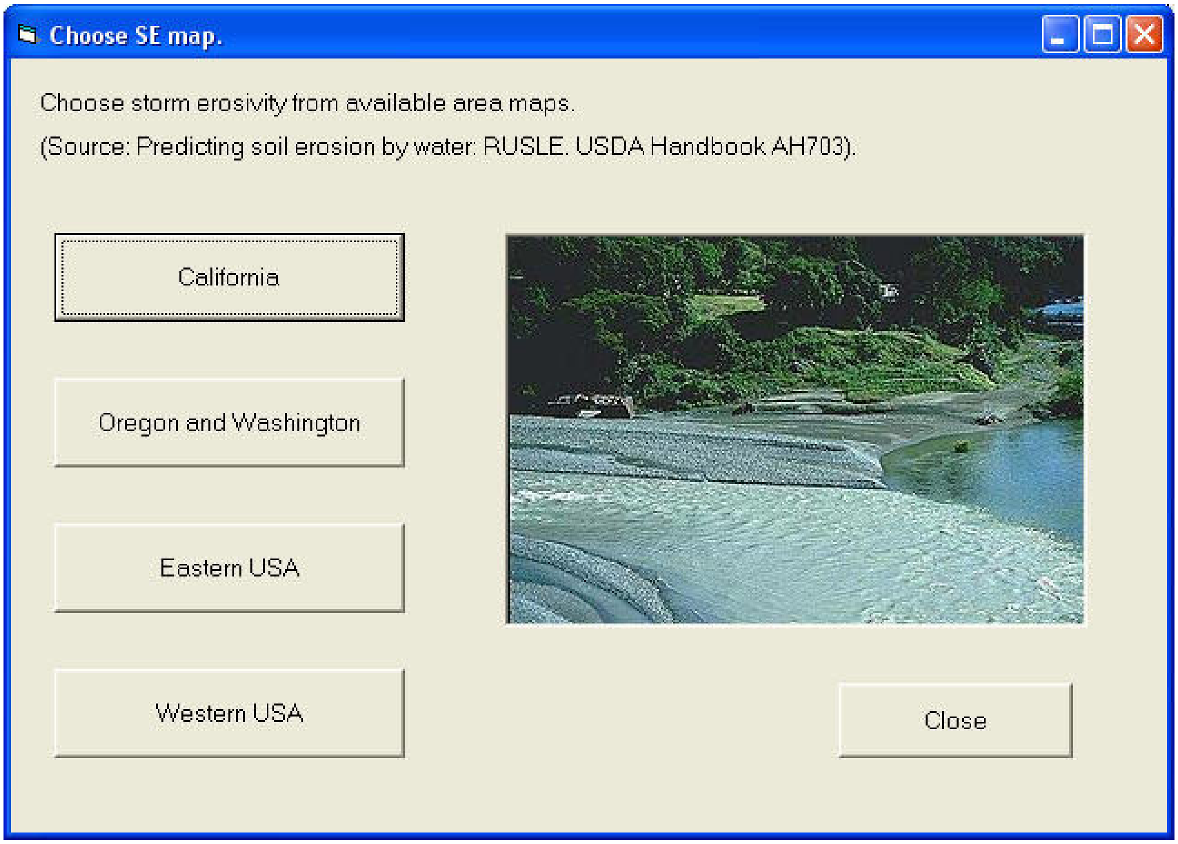
The two empirical models (Eldorado and West Oregon) require calculation of road slopes using an elevation grid (steps 5 and 7). Step 6 (optional) allows the user to divide road arc lengths into smaller lengths. Shortening arc lengths captures more topographic variability so gradients that are subsequently calculated will more closely reflect actual road slopes. However the arc length must be longer than the elevation grid cell size. If both ends of an arc fall in the same grid cell, the gradient value will equal zero.



The input window for the Eldorado model will list fields in the roads coverage in three list boxes. The length and gradient fields are automatically chosen, but can be altered by the user if necessary. The user will need to click on the field that describes whether the road has been graded within the last 2 years (1) or not (0). If this field is not included in the GIS layer, the user can select a constant value of 1 (all roads graded) or 0 (no roads graded).



The default road width is 3 m. The user must determine annual storm erosivity in either metric or English (imperial) units: the form will convert values automatically. Storm erosivity maps are provided for California, Oregon, Washington, and the Eastern and Western USA (Renard et al. 1997)



Click on calculate to continue. A summary window will be displayed with a table of sediment production by watershed. The roads data layer will contain fields called sn_sp and sn_spkg_myr which contains the annual sediment production in kilograms for each road arc and annual sediment production in kilograms per lineal meter.

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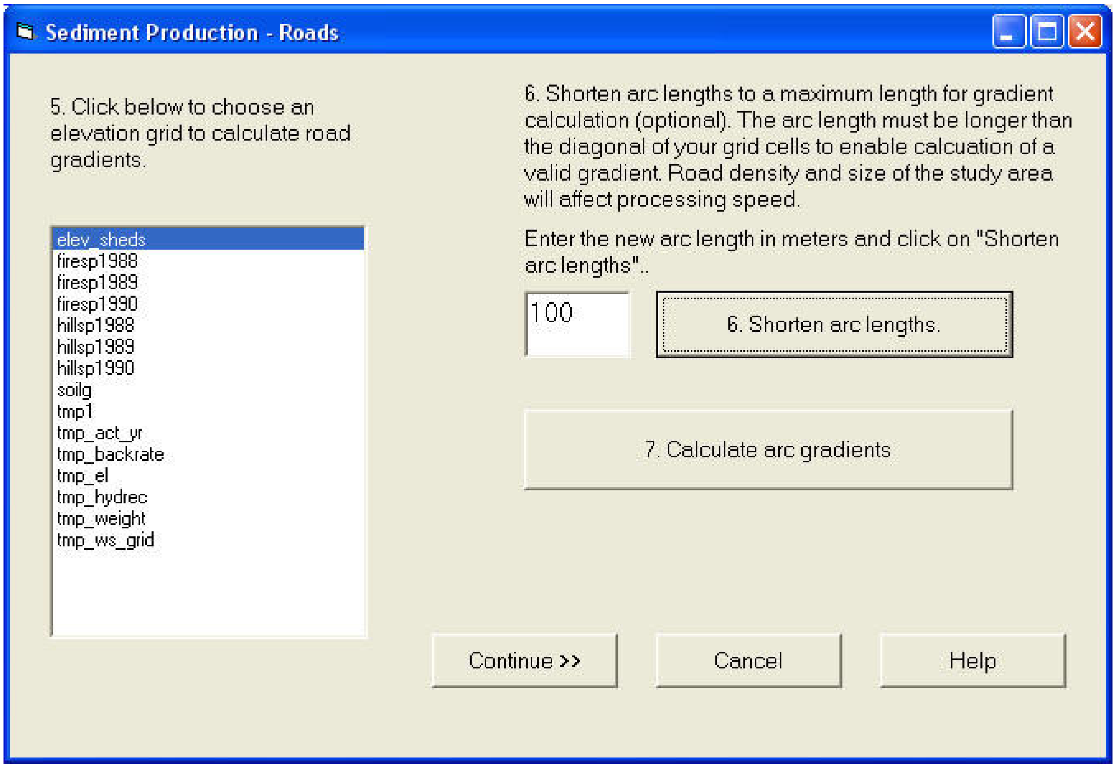
West Oregon road model (Luce and Black 1999)

The empirical models (Eldorado and West Oregon) require calculation of road slopes using an elevation grid (steps 5 and 7). Step 6 (optional) allows the user to divide road arc lengths into smaller lengths. Shortening arc lengths captures more topographic variability so gradients that are subsequently calculated will more closely reflect actual road slopes. However the arc length must be longer than the elevation grid cell size. If both ends of an arc fall in the same grid cell, the gradient value will equal zero. Click on Next to continue.



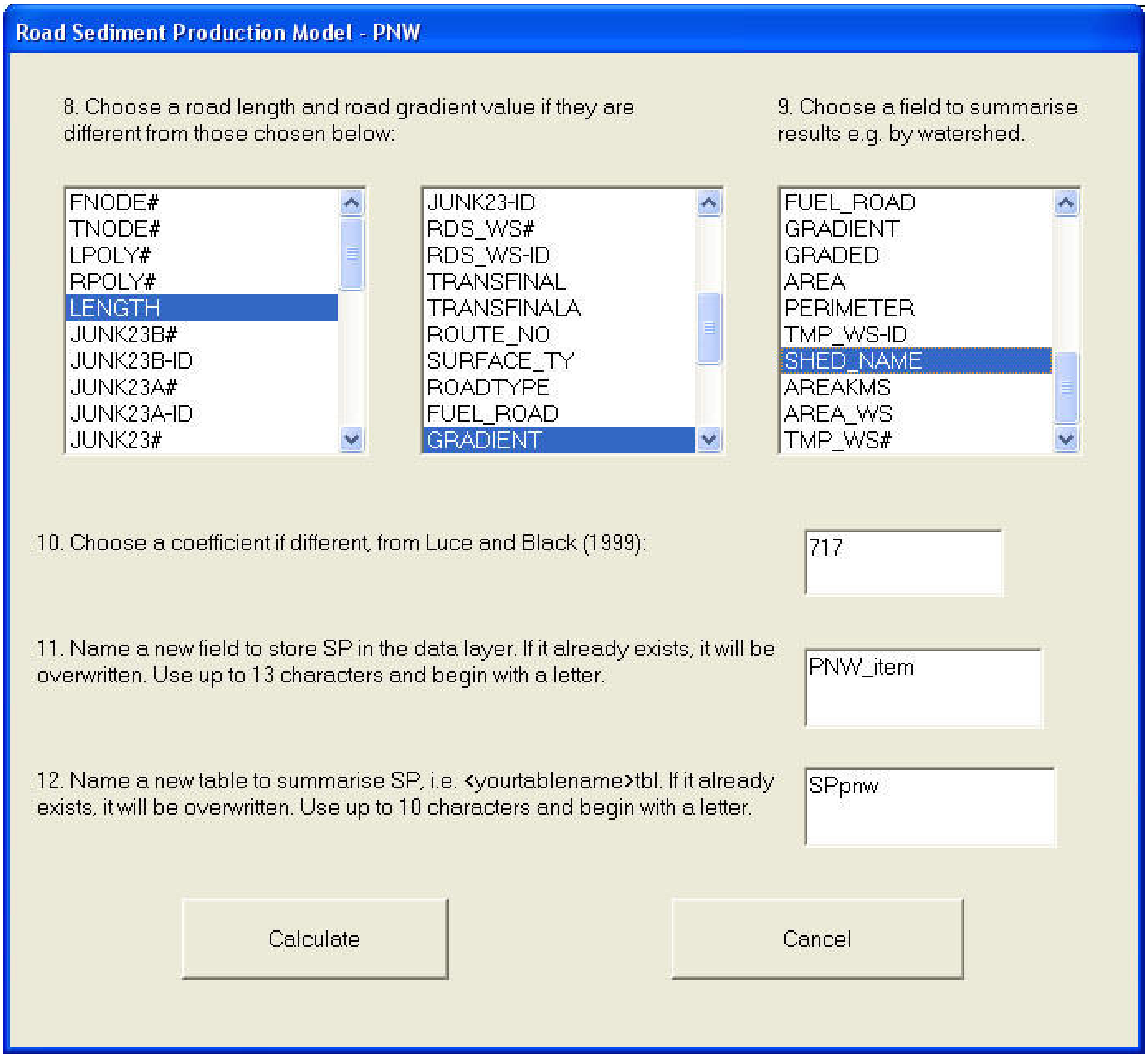
In the West Oregon model window the three list boxes contain fields from the user-selected roads layer. The length and gradient fields are pre-selected but may be changed. The user can choose to summarize sediment production by an additional field such as watershed.

Step 10: Luce and Black found that sediment production was proportional to a coefficient times the road segment length times the road segment slope squared. Since the value of their coefficient was 717, this is the default value. Users can input a different coefficient if they choose.

Step 11: Enter a name for a new field in the roads layer to store sediment production values for each road arc.

Step 12: Give a name for a data table to store summary results.

Click calculate to continue; a table of results will appear. Spatial data is stored in the data layer and field that the user named. Summary results are displayed in a table.



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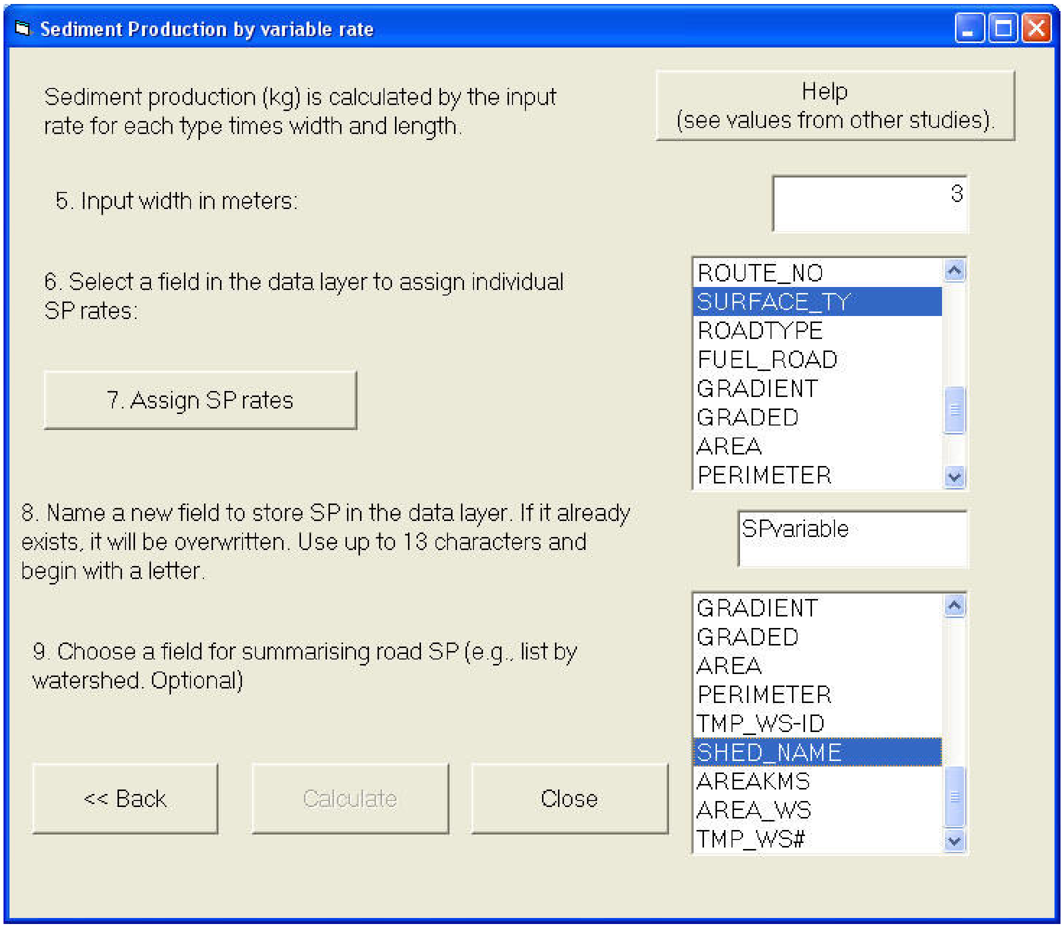
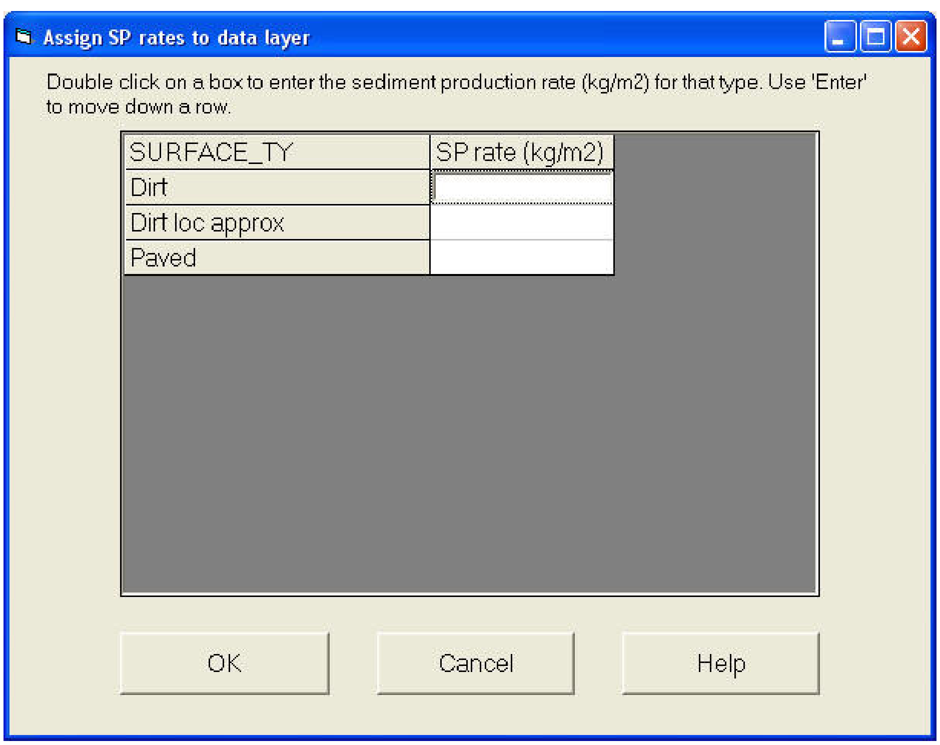
Variable rate input road model

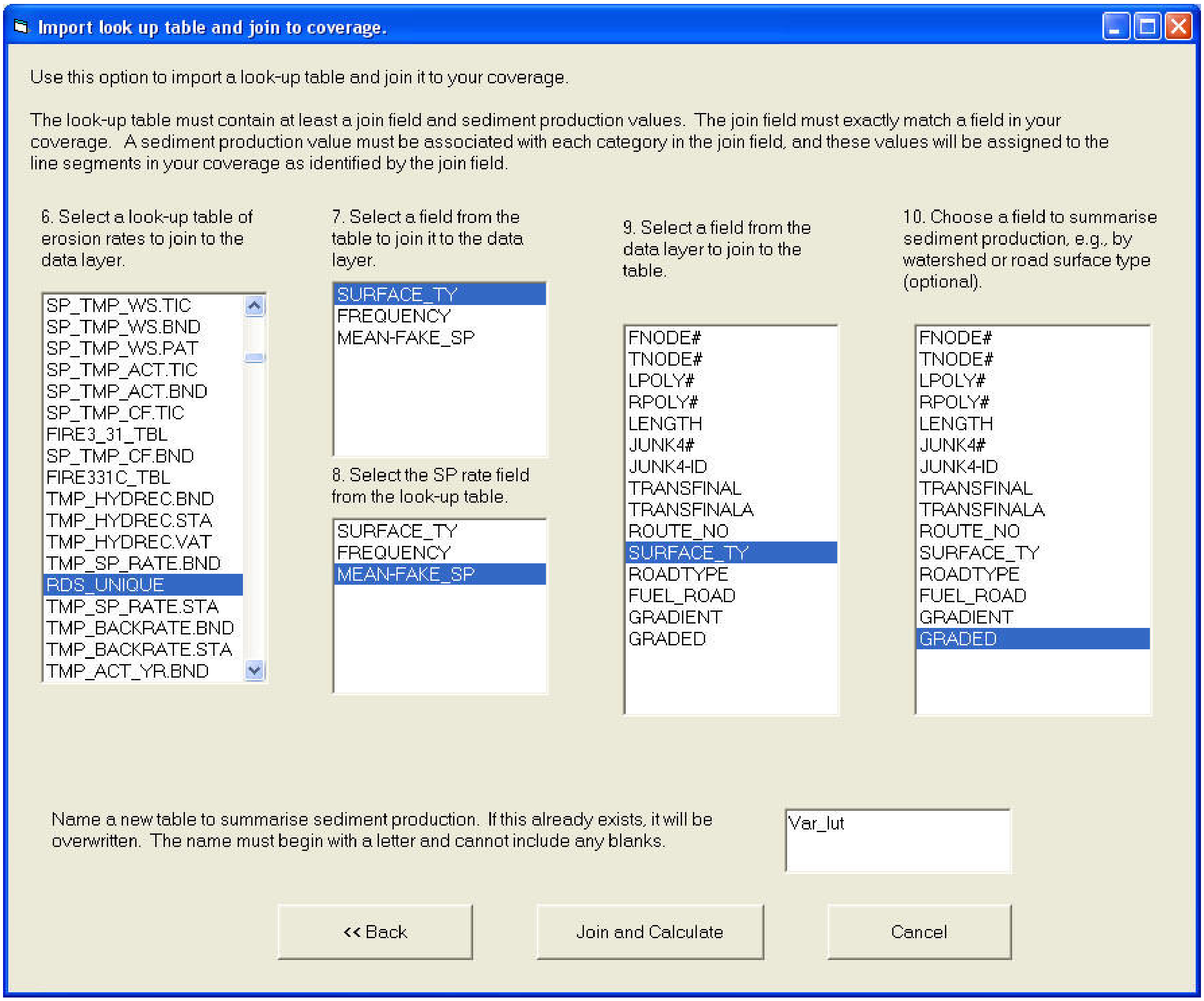
The user can input a series of sediment production rates that correspond to road attributes. These sediment production rates can be developed from field measurements or a model such as WEPP:Road. Two variable rate methods are provided to enable the user to do this and they are described below.

1) The user can select a field in the roads layer that contains attribute data and input sediment production rates for each different type of attribute (e.g., surface type) in steps 6 and 7. The program will input the values into the roads layer, summarize by a field (e.g., watersheds), and calculate total road sediment production.


Sediment Production by variable rate
Sediment production (kg) is calculated by the input rate for each type times width and length.
Help
(see values from other studies).
5. Input width in meters:
3
6. Select a field in the data layer to assign individual SP rates:
ROUTE_NO
SURFACE_TY
ROADTYPE
FUEL_ROAD
GRADIENT
GRADED
AREA
PERIMETER
7. Assign SP rates
8. Name a new field to store SP in the data layer. If it already exists, it will be overwritten. Use up to 13 characters and begin with a letter.
SPvariable
9. Choose a field for summarising road SP (e.g., list by watershed. Optional)
GRADIENT
GRADED
AREA
PERIMETER
TMP_WS-ID
SHED_NAME
AREAKMS
AREA_WS
TMP_WS#
<< Back
Calculate
Close

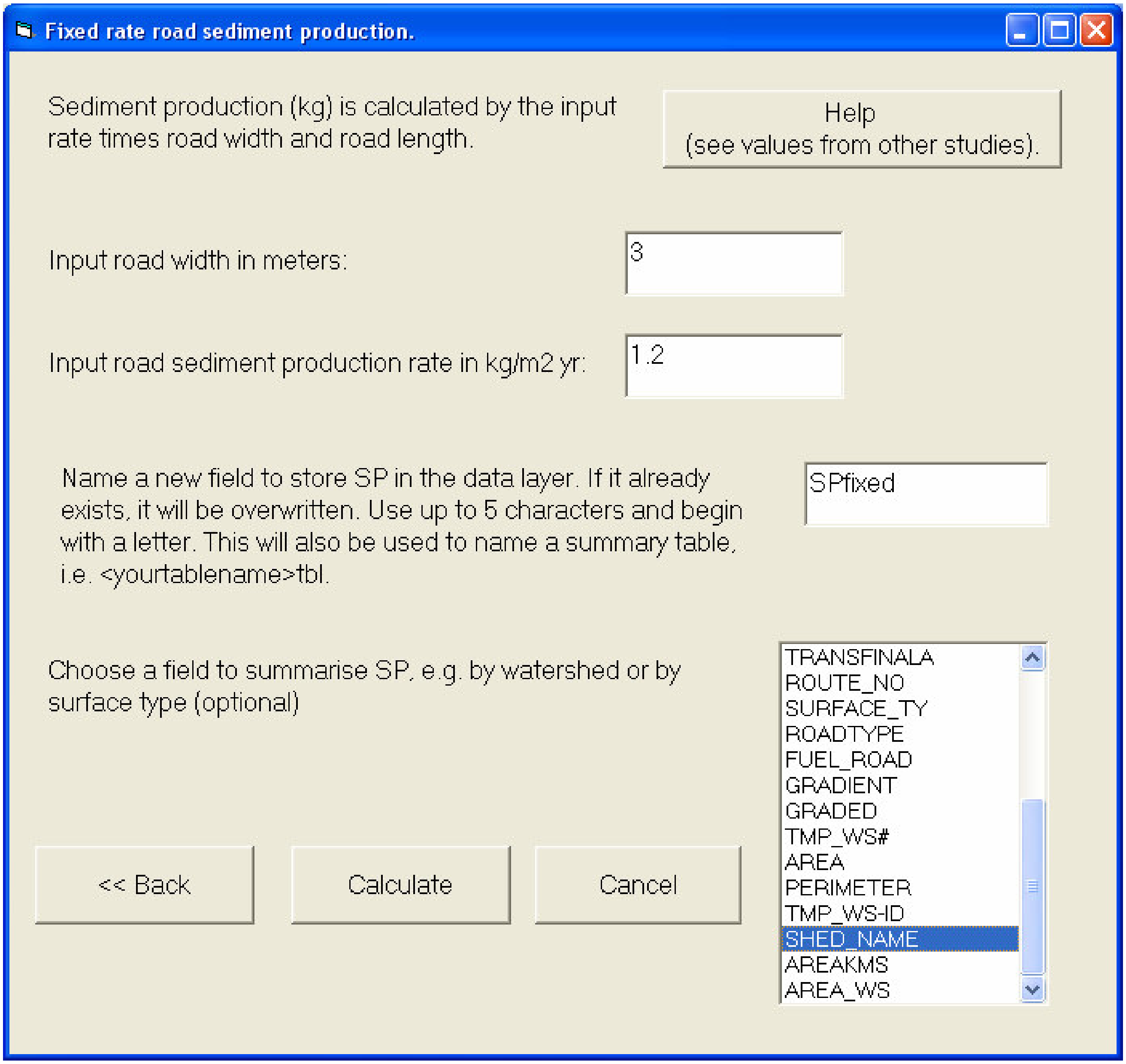

Assign SP rates to data layer
Double click on a box to enter the sediment production rate (kg/m2) for that type. Use 'Enter' to move down a row.
SURFACE_TY
SP rate (kg/m2)
Dirt
Dirt loc approx
Paved
OK
Cancel
Help

2) The user can create their own look-up ArcInfo table of sediment production rates with a feature attribute field that corresponds to a feature attribute field, such as surface type, in the roads coverage table. The two fields must be defined identically. The program will join the tables based on the feature attribute field so that the roads layer will contain the correct erosion rate for each road arc. In step 10, the user can choose to summarize results by a field in the coverage. The program will calculate total road sediment production and display a summary table.



Fixed rate road model

If the user selects the fixed sediment production rate the following window will appear. The user can provide values the road width and the road sediment production rate in kg/m^2 yr. The program assigns the values to each road segment and calculates the total sediment produced.



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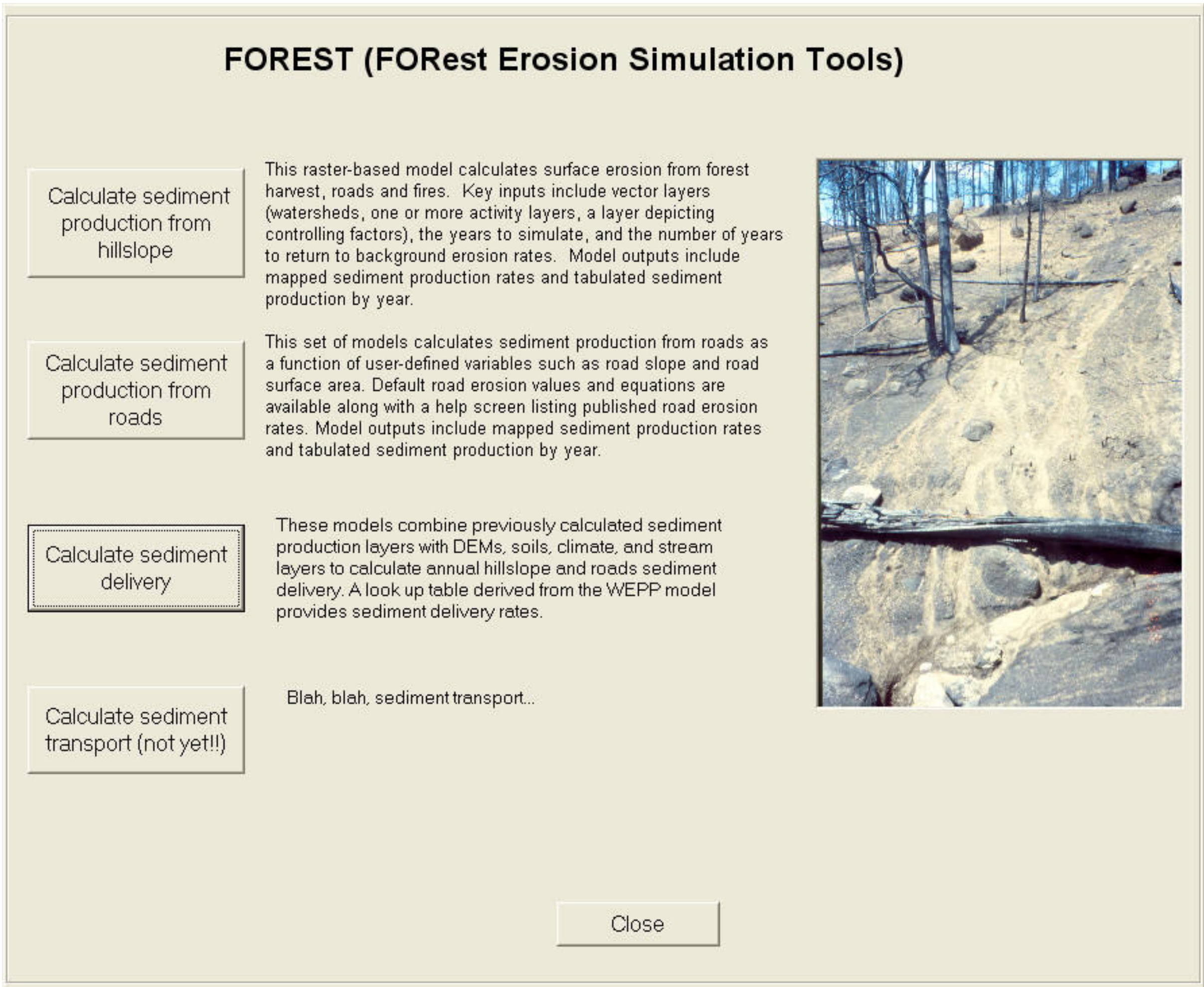
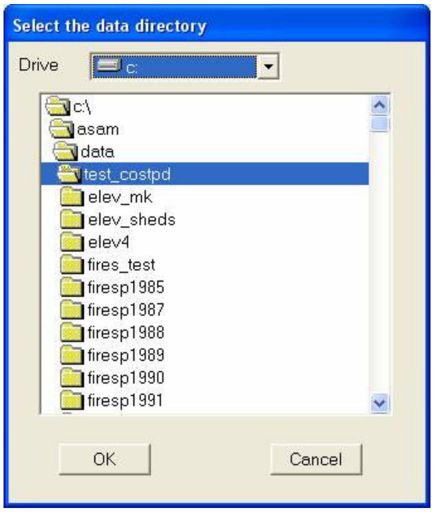
Calculate sediment delivery to streams

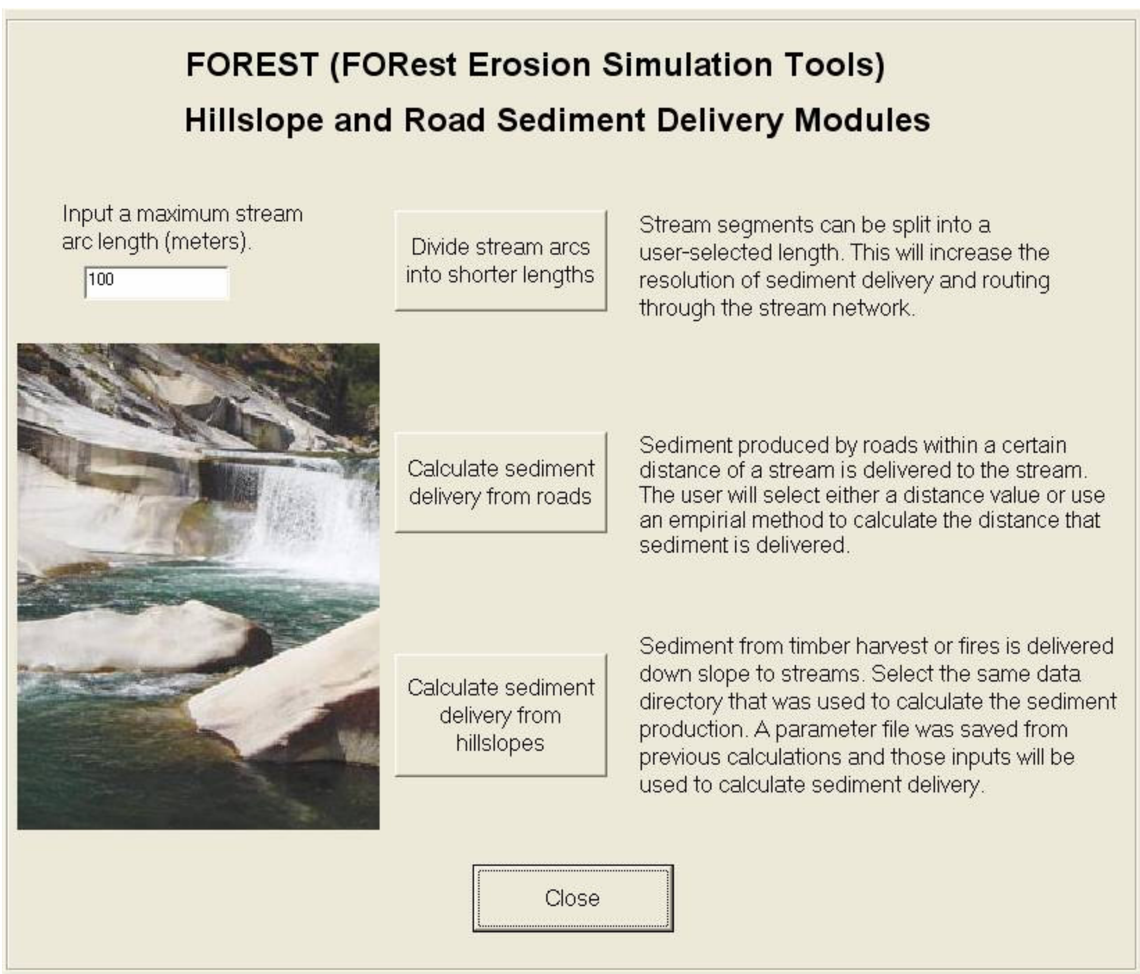
To calculate road and hillslope sediment delivery to streams click on the "Calculate sediment delivery" button in the FOREST window.



The user will be asked to select the data directory where data for the sediment production runs were stored. The parameter file was saved to this directory and is loaded automatically by clicking on "Calculate sediment delivery". The parameter file informs the sediment delivery models what GIS layers to use. This saves the user having to input all the data again. It also means that the user can come back at a later time to run the sediment delivery model.



When the parameter file is loaded, the hillslope and road sediment delivery modules window will show.



[Divide stream arcs into shorter lengths](#)

[Calculate sediment delivery from roads](#)

[Calculate sediment delivery from hillslopes](#)

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Divide stream arcs into shorter lengths

The lengths of stream arcs typically are determined by the digitizer to signify a tributary entry point or a change in feature attribute. Lengths of stream arcs can vary from a few meters to several kilometers. A utility has been programmed to divide stream arcs into shorter lengths to improve the spatial resolution of sediment delivery to stream segments. An increase in the spatial accuracy of sediment delivery to the stream network should help improve the accuracy of routing sediment through the stream network. The user should input the longest length into which stream arcs will be divided, and the longest length cannot be shorter than the selected cell size (i.e., 10 or 30 m). Feature information on each arc will not be lost and arcs will not be joined to create longer arcs.

Warning: The stream division process must be completed before sediment delivery is calculated or else the amount delivered will be wrong.

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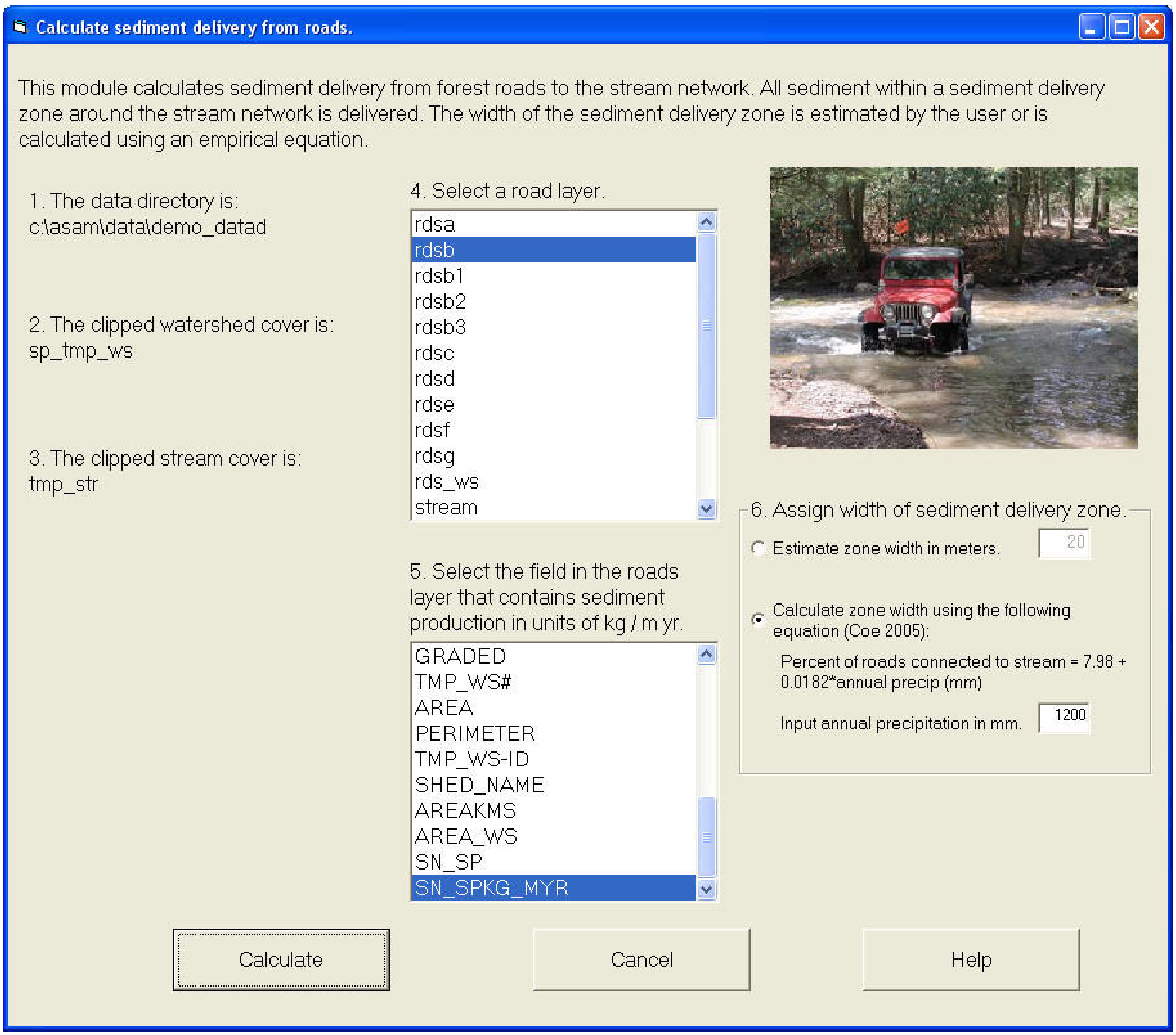
Calculate sediment delivery from roads

The delivery of sediment from roads is based on setting a sediment delivery zone that includes all roads within a certain distance of the stream. There are two ways for the user to determine the width of this sediment delivery zone. The user can estimate a width based on local knowledge, or use the following empirical equation to predict the percent of roads that are connected as a function of the mean annual precipitation:

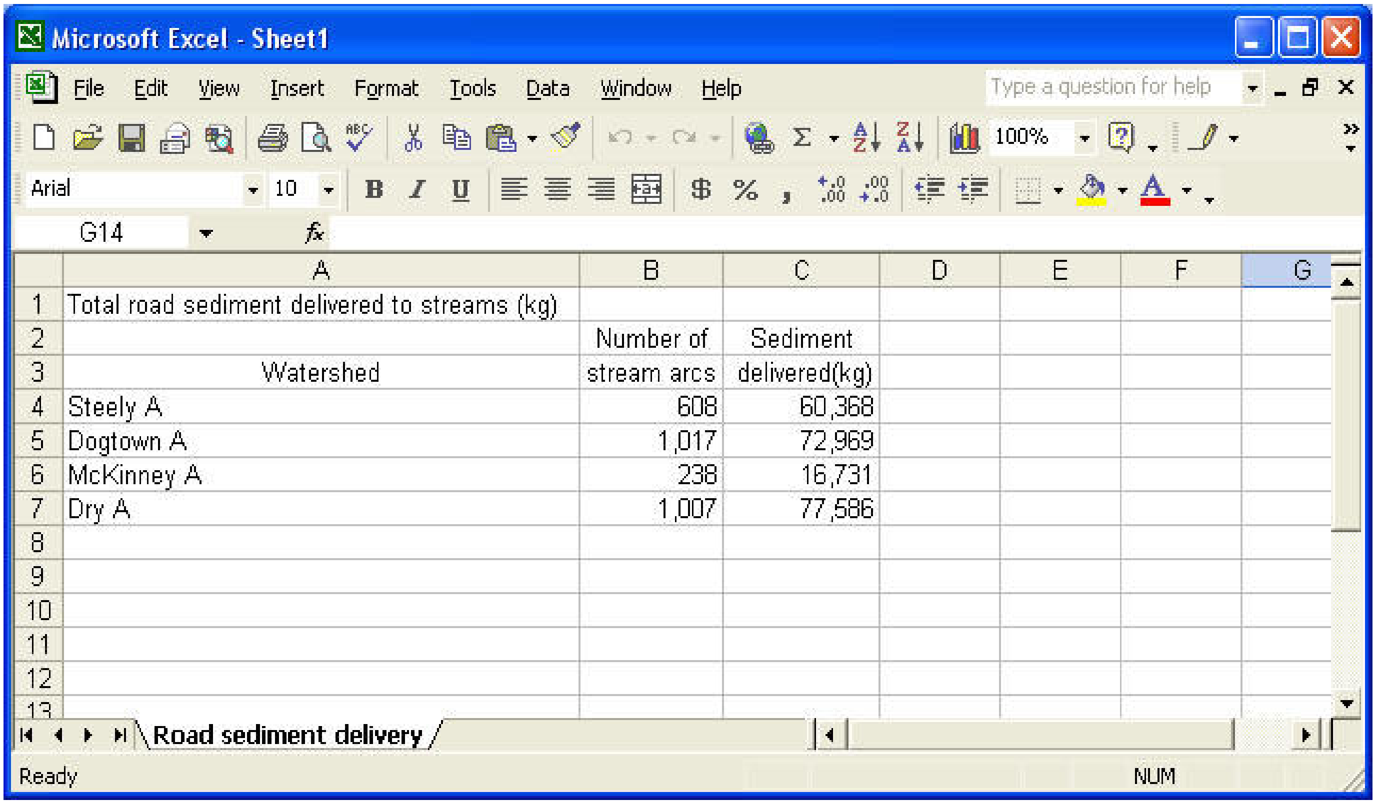
Percent of roads connected to streams = 7.98 + 0.0182 * annual precipitation (mm) (Coe 2005).

If Coe's equation is used, the program first determines the total length of roads in the watershed, and then calculates the length of roads that should be connected. The initial width of the sediment delivery zone is set at 20 m, and the program progressively increases the width of the sediment delivery zone by 10-m increments until the length of roads within this zone equals the length of roads that should be connected. Hence the model is effectively assuming that all of the sediment is delivered from the roads within the sediment delivery zone, and that no sediment is being delivered from the roads outside of the sediment delivery zone.

The directory where the data are stored is loaded automatically along with the stream layer, watershed(s) extent, and roads layer. The user must choose which sediment production field in the roads layer to use since there may be multiple choices. The field should express road sediment production in kg per meter of road length per year. For road layers processed by one of the FOREST models, a field with the suffix ...kg_myr will appear (see example below). The field named SN_SPkg_myr contains sediment production from the Eldorado model (SN = Sierra Nevada); PNWkg_myr corresponds to the West Oregon model (PNW = Pacific North West), SPvarkg_myr is data from the variable rate input and SPfixedkg_myr is data from the fixed rate model.



Click on calculate to continue. If several watersheds were selected, a Microsoft Excel spreadsheet will appear with results by watershed. Results for one watershed will be shown in a message box.



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Calculate sediment delivery from hillslopes

Due to the lack of measured hillslope sediment delivery data, the Water Erosion Prediction project (WEPP) model was used to calculate percent sediment delivered from each hillslope cell to the next cell downslope based on climate, percent slope gradient, soil type, and land cover types. For each climate a look up table for percent sediment delivered was developed for different combinations of slope gradients, upslope and downslope land covers, and soil types. Each combination has a unique code that is used by the program to access the percent sediment delivery from one cell to the cell downslope. (Users can find more details on this process and create their own look up tables by following instructions in

...documentation\create_sediment_delivery_file.doc). Users are encouraged to share look-up tables so these can be disseminated online to help other users.

Slopes are derived from the DEM input by the user. Percent slopes are reclassified by FOREST as follows: slopes less than or equal to 5% are assigned to 1, slopes greater than 5 and less than or equal to 15% are assigned to 10, slopes greater than 15 and less than or equal to 25% are assigned to 20, etc. Slopes over 45% assigned to 50 as sediment delivery is not sensitive to slope once the slope exceeds 50%.

The land cover types are described and recover over time according to the Disturbed WEPP documentation at http://forest.moscowfsl.wsu.edu/fswepp/docs/distweppdoc.html. (See table 4). Cover types recover in this order: high severity fire, low severity fire, short grass, tall grass, shrub, 5 year forest, 20 year forest. All cover types take one year to recover with two exceptions. High severity fires take two years to recover before burned areas are subject to the low severity fire sediment delivery rate. Five year forests grow for 10 years before being subject to the 20 year forest sediment delivery rate. It is assumed that all land returns to the 20 year forest scenario since this represents undisturbed land.

WEPP divides the sediment delivered into five textural classes - sand, silt, clay, large aggregates (which are comprised of a combination of sand, silt, and clay) and small aggregates (which are comprised of just silt and clay). Given the uncertainty involved in hillslope delivery and downstream routing, FOREST groups these five textural classes into two classes--fine and coarse. The fine category includes clay, silt, clay loams and silt loams, while the coarse size class includes sand and sandy loams. A series of WEPP runs were used to determine the relative amounts of fine (SD_f) and coarse (SD_c) sediment being delivered (Table 1). Fine and coarse coefficients were calculated by averaging WEPP runs.

Table 1. Proportions of coarse and fine particles based on WEPP runs.

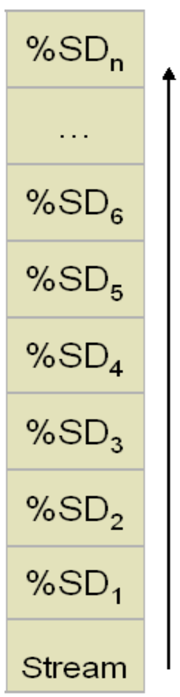
Soil texture	Soil Components	Clay %	Silt %	Sand %	Small aggregate %	Large aggregate %	Percent SD
Fine	Fine	100	100	0	100	52	75
	Coarse	0	0	100	0	48	25
Coarse	Fine	100	100	0	100	25	53
	Coarse	0	0	100	0	75	47

The user-provided GIS layers--elevation, soil type, and land cover--are processed to generate a grid of codes for each year that represent the specific combination of gradients, land covers, and soil types for each cell. This code is then used to access the look up table and develop a grid of percent sediment delivery for each cell to the next cell downslope.

Total percent sediment delivered for each cell is the cumulative product of downslope cells times the percent sediment delivered for the current cell (see diagram below). Total fine sediment delivered for each cell is the product of total percent sediment delivered, sediment production, and SD_f. Total coarse sediment delivered for each cell is the product of total percent sediment delivered, sediment production, and SD_c. A recursive algorithm calculates the sediment delivered for each hillslope drainage pathway by traversing up the stream network starting at the lowest elevation and multiplying percent sediment delivered for each cell.

Total sediment delivered to the downslope stream segment is the sum of sediment delivered from all upslope cells. The user can adjust the length of stream segments to increase resolution of sediment delivered. This algorithm accounts for downslope land covers, slopes, and soils that affect the amount of upslope sediment delivered.

Model outputs include a GIS stream coverage of annual coarse and fine sediment delivered to each stream arc and a Microsoft Excel spreadsheet summary of the sediment delivered to each watershed annually.



Total $\%SD_2 = \% SD_2 * \% SD_1$

Total $\% SD_3 = \% SD_3 *$ total SD_2...

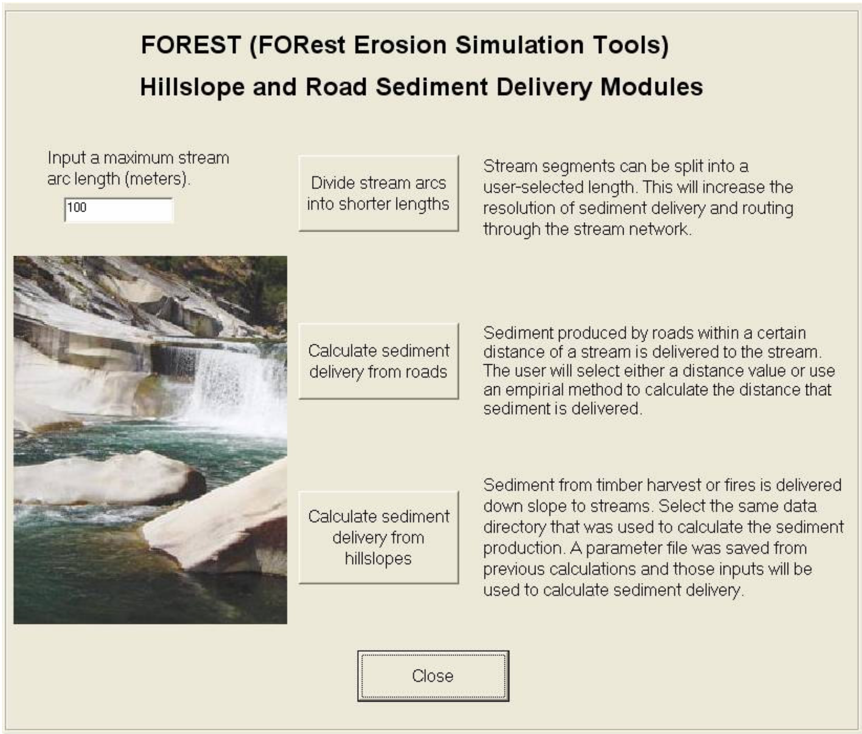
Total $\% SD_n = \% SD_n *$ total SD_{n-1}

Total fine SD_n = total $\% SD_n * SP_n * SD_f$

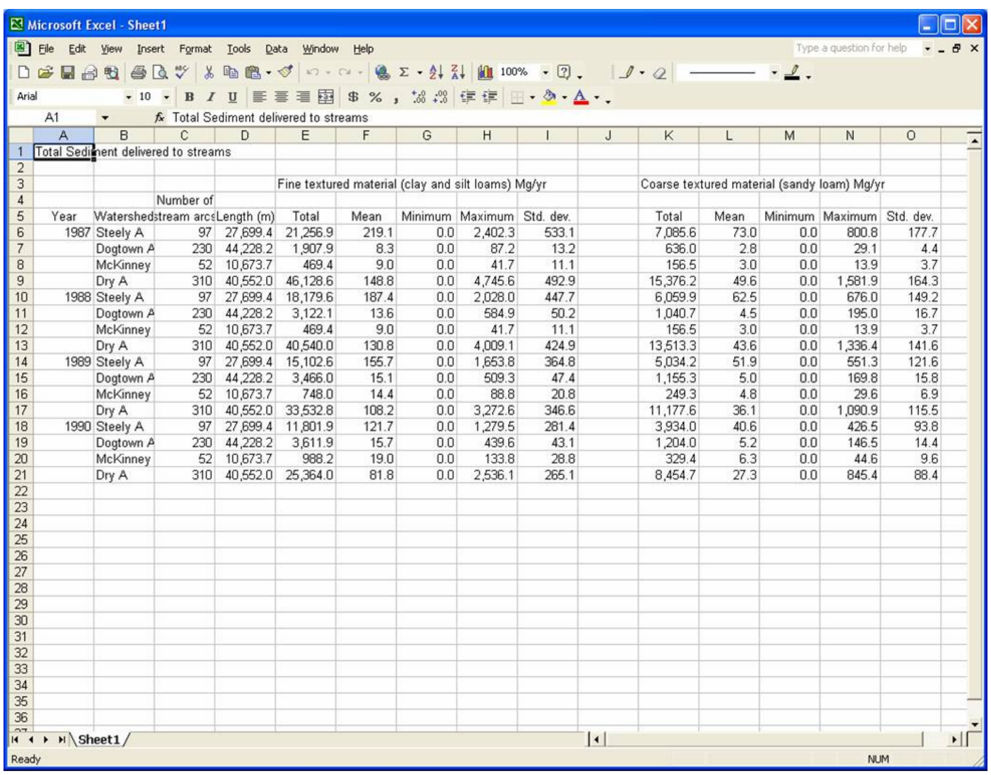
Total coarse SD_n = total $\% SD_n * SP_n * SD_c$

Total SD_n = total fine SD_n + total coarse SD_n

Click on calculate sediment delivery from hillslopes. The user will be prompted to select the same data directory. The layer and sediment production information is automatically loaded using the parameter file. If any layers do not exist or are obsolete, an error message will appear on the screen and the user will need to run the sediment production model again. Results are shown in a Microsoft Excel spreadsheet which the user is prompted to save.



Results from hillslope sediment production.



Total Sediment delivered to streams

Year	Watershed	Number of stream arcs	Length (m)	Fine textured material (clay and silt loams) Mg/yr Total	Mean	Minimum	Maximum	Std. dev.	Coarse textured material (sandy loam) Mg/yr Total	Mean	Minimum	Maximum	Std. dev.
1987	Steely A	97	27,699.4	21,256.9	219.1	0.0	2,402.3	533.1	7,085.6	73.0	0.0	800.8	177.7
	Dogtown A	230	44,228.2	1,907.9	8.3	0.0	87.2	13.2	636.0	2.8	0.0	29.1	4.4
	McKinney	52	10,673.7	469.4	9.0	0.0	41.7	11.1	156.5	3.0	0.0	13.9	3.7
	Dry A	310	40,552.0	46,128.6	148.8	0.0	4,745.6	492.9	15,376.2	49.6	0.0	1,581.9	164.3
1988	Steely A	97	27,699.4	18,179.6	187.4	0.0	2,028.0	447.7	6,059.9	62.5	0.0	676.0	149.2
	Dogtown A	230	44,228.2	3,122.1	13.6	0.0	584.9	50.2	1,040.7	4.5	0.0	195.0	16.7
	McKinney	52	10,673.7	469.4	9.0	0.0	41.7	11.1	156.5	3.0	0.0	13.9	3.7
	Dry A	310	40,552.0	40,540.0	130.8	0.0	4,009.1	424.9	13,513.3	43.6	0.0	1,336.4	141.6
1989	Steely A	97	27,699.4	15,102.6	155.7	0.0	1,653.8	364.8	5,034.2	51.9	0.0	551.3	121.6
	Dogtown A	230	44,228.2	3,466.0	15.1	0.0	509.3	47.4	1,155.3	5.0	0.0	169.8	15.8
	McKinney	52	10,673.7	748.0	14.4	0.0	88.8	20.8	249.3	4.8	0.0	29.6	6.9
	Dry A	310	40,552.0	33,532.8	108.2	0.0	3,272.6	346.6	11,177.6	36.1	0.0	1,090.9	115.5
1990	Steely A	97	27,699.4	11,801.9	121.7	0.0	1,279.5	281.4	3,934.0	40.6	0.0	426.5	93.8
	Dogtown A	230	44,228.2	3,611.9	15.7	0.0	439.6	43.1	1,204.0	5.2	0.0	146.5	14.4
	McKinney	52	10,673.7	988.2	19.0	0.0	133.8	28.8	329.4	6.3	0.0	44.6	9.6
	Dry A	310	40,552.0	25,364.0	81.8	0.0	2,536.1	265.1	8,454.7	27.3	0.0	845.4	88.4

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