Component VI Sediment Sources Assessment

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Component VI
Sediment Sources Assessment

INTRODUCTION

Erosion that occurs near streams and on surrounding slopes is a natural part of any watershed. Fish and other aquatic organisms in a region are adapted to deal with a range of sediment amounts that enter streams. The amount of erosion in a watershed and the sediment load in the streams vary considerably during the year, with most sediment moving during the few days that have the highest flows. The most significant land-forming events may occur during precipitation or snowmelt events that happen only once every decade or more.

In addition to natural levels of erosion, human-induced erosion can occur. Separating human-induced erosion from natural erosion can be difficult because of the highly variable nature of natural erosion patterns. Furthermore, human-caused erosion may also be highly variable in timing and spatial pattern. While it is nearly impossible to specify when a human-induced change in sediment is too much for a local population of fish and other aquatic organisms to handle, in general, the greater a stream deviates from its natural sediment levels the greater the chance that the fish and other aquatic organisms are going to be affected. Sediment in streams can have a human dimension, too. High sediment levels can increase the cost of treating drinking water, can be aesthetically displeasing, and can decrease fish angling success.

A watershed assessment of erosion and sediment within a watershed requires three steps. First, an inventory of visible signs of erosion is needed . This exercise may include locating and mapping landslide scars, road washouts, or areas with extensive gullying. The second step is to identify and map areas or situations for which erosion and movement of sediment into streams is **likely** to occur in the near future. This exercise may include such tasks as locating and mapping high-risk sections of road, undersized but still-intact culverts at stream crossings, or areas where inappropriate cropping techniques occur on highly erodible soil. The third step is to summarize information in a way that allows identification of human-caused erosion problems for which there is a high priority for developing remedies.

One thing to keep in mind is that both the intensity and density of an erosion process needs to be considered for the sediment assessment to be useful. For example, grossly undersized road culverts that have a high potential of causing road washouts during floods may be a minor sediment problem if only a limited number exist in a watershed, but a major concern if many of these culverts exist.

Methods for assessing erosion and sediment in streams vary with the nature of the human activity and the landscape. Therefore, this sediment assessment is broken into eight modules, each of which addresses the following critical questions.

Critical Questions

1. What are important current sediment sources in the watershed?

    - To determine this, use information on current slope and rural road instability; urban and rural road runoff; surface erosion from crop lands, range lands, and burned lands; and other discrete sources.

2. What are important future sources of sediment in the watershed?

    - Using field observations and road inventory data, compile information on combinations of site factors that have a high probability of becoming important sediment sources.

3. Where erosion problems are most severe and qualify as high priority for remedying conditions in the watershed?

    - Restoration opportunities are identified in the summary tables, which indicate locations where human-caused sediment increases are most severe.

Assumptions

- Sediment is a normal and critical component of stream habitat for fish and other aquatic organisms. The more that sediment levels deviate (either up or down) from the natural pattern in a watershed, the more likely that aquatic habitat conditions will be altered.

- Human-caused increases in sediment commonly occur at a limited number of locations within the watershed and can be identified using a combination of site characteristics and land use practices.

- Sediment movement is often episodic, with most erosion and downstream soil movement occurring during infrequent and intense runoff events.

Materials Needed

The first step in the assessment will be to identify potential sediment sources in the watershed that are high priority for further investigation. A number of existing resources may be available to assist in this preliminary identification and are identified in the Materials Needed to Start Sediment Sources Assessment, below. After you have identified which sediment sources will be evaluated (and thus, which of the eight modules you will follow), refer to Table 1. This table lists which materials are needed to complete each sediment source module.

Materials Needed to Start Sediment Source Assessment

- Watershed Base Map (from Start-Up and Identification of Watershed Issues component)

- Aerial photos (from Start-Up and Identification of Watershed Issues component)

- Refined Land Use Map (from Start-Up and Identification of Watershed Issues component)

Table 1. Materials needed for specific sediment source assessment modules.

Materials	Source 1: Road Instability	Source 2: Slope Instability	Source 3: Rural Road Runoff	Source 4: Urban Area Runoff	Source 5: Crop Land	Source 6: Range Land	Source 7: Burned Areas	Source 8: Other
Watershed Base Map	√	√	√	√	√	√	√	√
Updated road maps	√		√	√				
Aerial photos	√	√	√		√	√	√	√
Peak-flow map	√							
Debris-flow-potential map		√						
Landslide inventories	√	√						
Forest road hazard inventories	√							
City stormwater maps				√				
County soil surveys					√	√		
USFS soil inventories						√		
Recent burn locations							√	

- Stereoscope for 3-D viewing of aerial photographs. Although a mirrored stereoscope (with magnification) is preferable, a simple lens stereoscope is adequate.

- Updated road maps. Request 1:24,000-scale maps. If unavailable, enlarge or reduce whatever map you obtain to a 1:24000 scale (1 inch = 2,000 feet). Likely sources of updated road maps include:

  - US Forest Service (USFS)
  - US Bureau of Land Management (BLM)
  - Department of Forestry, State Lands
  - County
  - Private forest landowners

- Other supplies:

  - Transparency overlays
  - Thin permanent markers (six or more colors)
  - Engineer's ruler (English units, not metric) or map wheel for measuring lengths
  - Calculator
  - Dot grid templates (provided with this manual) or map wheel for measuring area
  - Computer spreadsheet software
  - Worksheet diskette with spreadsheets

Materials Needed for Specific Sediment Source Modules

The materials listed in Table 1 are described in the following list:

- Peak-flow map (50-year **recurrence interval** [1] for peak flows in forest streams). The map can be downloaded from the Oregon Department of Forestry (ODF) Web site at http://www.odf.state.or.us/FP/DEFAULT.HTM. It is also available in hard copy by calling the ODF hydrologist at (503) 378-3589.

- Debris-flow-potential maps. ODF is in the process of mapping debris flow potential for many parts of western Oregon. These maps are scheduled to be available June 1999 from the ODF landslide specialist at (541) 945-7481.

- Landslide inventories. These can be obtained from the same sources as updated road maps (see previous section).

- Forest road hazard inventories. Many forest landowners have recently completed inventories of their road systems using a standard protocol that is also used on state forest lands by the ODF. These inventories include information about recent landslides near roads, road surface condition, and stream crossings. The USFS and BLM may also have road inventory information, but it will not be the same format.

- City stormwater maps. Request these maps from city public works departments. These maps should show roads, streams, lakes, and the stormwater network (pipes, detention facilities, and any processing plants). Make several large-format copies and laminate them for work maps.

- County soil survey books (from Riparian/Wetlands Assessment component)

- USFS soil resources inventories. Obtain these inventories from your local USFS district office if range land managed by the USFS is to be assessed.

- Locations of recent burns

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

Area calculations can be done using **Geographic Information System** (GIS) software instead of the dot grids or map wheel if available. In addition, GIS support allows for better-quality final maps and provides more options for summarizing results.

Necessary Skills

The minimum skills necessary to conduct this assessment include the ability to read topographic maps and basic experience in operating a computer spreadsheet program. Electronic spreadsheets versions of all forms have been created; in many cases the data analysis will be much easier if the sediment source information is directly entered into a spreadsheet (referred to as worksheets throughout this document). Sediment source identification relies on aerial photo interpretation, so experience reading aerial photos will help complete the assessment. At a minimum you should have someone experienced with aerial photo interpretation help you get started to "train" your eye on how to read photo features.

Final Products of the Sediment Sources Component

Final products include maps showing points, road segments, or areas of low to high sediment risk for up to eight of the potential sediment sources. In addition, you will end up with spreadsheet databases of erosional features or areas of erosional risk. From these databases, you will be able to construct summary tables indicating relative sediment-severity ratings for subwatersheds within the watershed. Specific final products will be discussed within each of the eight modules.

METHODS

In this assessment you will be able to evaluate potential contributions of sediment from the following eight sources, with a module devoted to each source: (1) road instability, (2) slope instability, (3) rural road runoff, (4) urban area runoff, (5) sediment from crop land, (6) sediment from range or pasture lands, (7) sediment from burned areas, and (8) sediment from other identified sources. The assessment is conducted using aerial photographs, topographical maps, database inventories, and field verification as time and interest permits. It produces a database and maps that identify sediment sources. Use of a computer spreadsheet will help you complete these summaries and groupings. Each module may be completed by different users with experience or information on that specific source.

Step 1: Update Roads on Watershed Base Map

Before accurate information can be gathered about road-related sediment sources, the Watershed Base Map should be updated to include all roads. The 7.5-minute topographic maps or ODF stream maps used as the Watershed Base Map will probably display only two-thirds of the roads. Roads constructed since the map was made (or updated) will be missing. If you have obtained 1:24,000-scale maps from other sources that show the missing roads, transfer them onto the Watershed Base Map. If a 1:24000-scale map from other sources is unavailable, enlarge or reduce what map you have to achieve a 1:24000 scale (1 inch = 2,000 feet) and transfer roads onto the Watershed Base Map. You can transfer new roads onto the Base Map by placing the road or sub-basin map on a light table or window, overlaying the Base Map, taping both down, and transferring changes to the Base Map.

New roads can also be located on recent aerial photographs and transferred to the maps, but this is often a frustrating and time-consuming task. To do this, first enlarge or reduce color copies of the aerial photographs to match the 1:24000 scale, then follow the procedure described above for transferring roads to the Base Map. This is made more difficult by the variation of scale within each aerial photograph, both in elevation (objects on ridges look larger than objects in valleys) and in proximity to the photo edges. To minimize these problems, use a photo that puts the road in the center of the photo and adjust the position of the photograph underneath the map as needed to get the best fit with other landmarks. See the Start-Up and Identification of Watershed Issues component for more information on working with aerial photographs.

Once the new roads have been added to the Base Maps, assign sequential numbers to points where roads cross streams. These stream-crossing identification numbers will be used later for analysis of sediment sources and the passage of fish through culverts.

Next, make about a dozen, large-format copies of your map. You will want at least one copy to complete each sediment source assessment, it is often useful to have a working copy and a final copy. In addition, the Fish and Fish Habitat analyst will need a copy for the passage barrier assessment. For extra convenience, have your Base Maps laminated to allow easy changes as you mark the maps with the locations of sediment sources. All sediment source features will be labeled with a unique identifying number.

Step 2: Identify Potential Sediment Sources

A first step in evaluating sediment sources in your watershed is to determine which sediment topics are important to the watershed council. You could compile information on all eight of the sediment topics, but this would take quite a bit of time and you would eventually see that some sediment sources are rather insignificant in your watershed. For example, sediment topics for a watershed in the Coast Range with little urban or grazed land could probably be limited to an assessment of sediment from road runoff, road instability, and slope instability (not related to roads). For a watershed in the foothills of the Blue Mountains in eastern Oregon, a watershed council might focus its assessment on sediment from crop land, range land, and road runoff.

Your selection of priority sediment topics may depend, in part, on whether or not there is enough information about your watershed to get started on a topic. For example, if you cannot find aerial photographs for your watershed and major portions of the watershed are inaccessible to the members of the watershed council, you may not get very far addressing the topic of slope instability.

The questions listed in Form S-1, Screen for Sediment Sources in a Watershed, may be useful for helping you to determine which sediment topics should be included in the assessment. As you discuss these issues among yourselves, you can keep track of your progress by filling in Form S-1.

Many of these questions can be answered by the following method:

- Use the updated Watershed Base Map to identify areas of high rural road density.
- Use the Refined Land Use map to identify the presence of specific land uses.

- Your own experience and interviews with landowners who live in the watershed and agency staff working in the watershed.

As an example of this process, Table 2 indicates that a watershed council decided that rural road runoff and instability were the most important sediment sources to be addressed in their assessment. Urban runoff within some tributaries and slope instability (not related to roads) were of lesser importance. They chose not to expend effort on the remainder of the sediment source modules.

Table 2. Example of Form S-1: Screen for sediment sources in a watershed.

Watershed Name: The River Why	Observations	Priority
Source 1: Road instability		
Are rural roads common in watershed?	Yes	2nd
Do many road washouts occur following high rainfall?	Some	
Are many new roads or road reconstruction planned?	Yes	
Source 2: Slope instability (not related to roads)		
Are landslides common in watershed?	Yes	4th
Many high-sediment, large-scale landslides?	None	
Source 3: Rural road runoff		
Is sediment-laden runoff from rural roads and turbidity in streams common?	Yes	1st
Is there a high density of rural roads?	Yes	
Source 4: Urban runoff		
Are many portions of the watershed urbanized?	Some	3rd
Importance of these tributaries to watershed council:	High	
Source 5: Surface erosion from crop land		
Is there much crop land in watershed?	Low	Topic not high priority
Is there much evidence of sediment in streams flowing through crop land?	Little	
Source 6: Surface erosion from range land		
Is there much range land in the watershed?	Low	Topic not high priority
Is there evidence of sediment in streams flowing through range land?	Little	
Source 7: Surface erosion from burned land		
Have many burns occurred recently (last 5 years), especially hot fires?	Few	Topic not high priority
Was there much sediment created by these burns?	Low	
Source 8: Other discrete sources of sediment		Topic not high priority
List or identify any other suspected sources of sediment:	None	

Step 3: Evaluate Sediment Sources

The next step describes how to evaluate each of the eight potential sediment sources. Remember, you will probably not be doing all eight of the modules described herein; only the ones identified in the previous step as important to you.

Source 1. Road Instability

The stability of a rural road depends on how well the road was built and the inherent stability of the land it traverses. In general, roads are most stable if built along ridges, especially where slopes are not steep. Less stable locations include steep terrain at the middle of slopes and near streams. Large amounts of subsurface water cause soils to lose much of their strength, so most road failures occur during high-intensity rainstorms or snowmelt periods that produce saturated soils.

The type of road construction influences the stability of the road. Sidecast roads are constructed by digging into the hillside to form the inside of the road and using the excavated soil to build up the outside of the road (Figure 1). This works well in moderate terrain but can lead to problems on steep slopes. Excavated material used to build up the outer side of the road (the **fill slope**) on a steep slope can be unstable. This unstable wedge of soil may be transformed into a landslide sometime in the future (Figure 1). Alternatively, when **full-bench road construction** is used, soil is excavated to a stable location rather than using it as the outer edge of the road. This type of road construction is more stable but the cost is considerably higher.

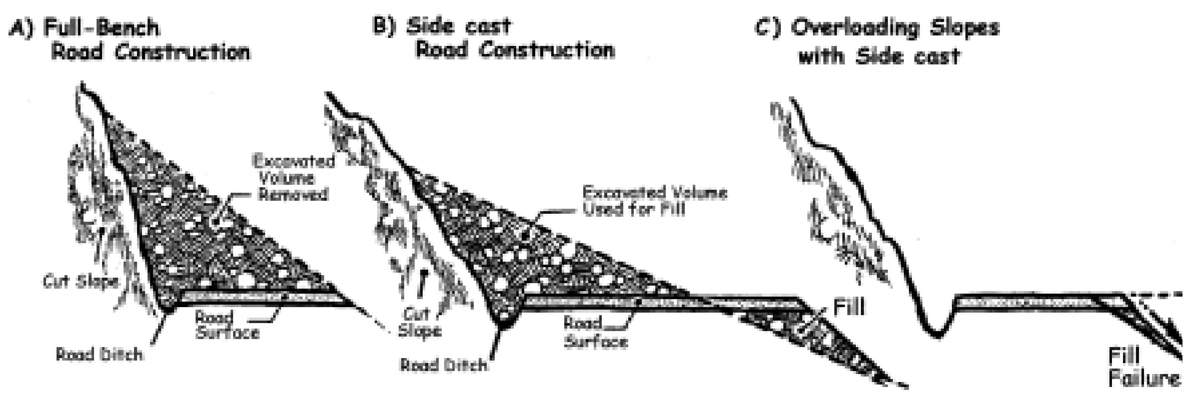


Figure 1. The type of road construction influences the stability of the road. Sidecast roads, built by digging into the hillside to form the inside of the road and using the excavated soil to build up the outside of the road, can cause failure on steep slopes. In full-bench road construction, soil is excavated to a stable location rather than using it as the outer edge of the road.

Road **cut slopes**, the inside slope of the road, may also become unstable, and sections of the cut slope can fall or creep into the road during wet weather. Small cut-slope failures can end up diverting ditch water onto the road surface or fill slope, creating gullies or triggering a landslide. An inherently unstable section of hill slope can be made even less stable when a road is excavated into the base of the unstable area.

Finally, road crossings with culverts that fail can cause large pulses of sediment to enter channels. Culverts that are inadequate to pass a flood flow or get plugged with floating wood can wash out the road or divert it down the road, thereby creating gullies.

Understanding rural road instability in a watershed involves two investigations. One involves collecting information about recent road washouts and possible factors that caused their failure, and the other involves identifying high-risk situations within the watershed that are likely to lead to road washouts in the future.

Gather Information

Road Inventory Databases

Information about road conditions and recent road-related landslides in your watershed may come from a number of sources. Forest landowners are good potential sources. Many have recently completed inventories of their road systems using a standard protocol also used on state forest lands by the ODF. These inventories include information about recent landslides near roads, road surface condition, and stream crossings. The protocol for these road inventories can be obtained from the ODF Web site at http://www.odf.state.or.us/FP/DEFAULT.HTM. Road inventory information may also be available from the USFS and BLM, but it will not be the same format. Remember, private landowners are under no obligation to share inventories. Allow extra time to obtain information from public agency databases; while they are required to provide their information upon request, they are often understaffed and may be slow to respond.

Road inventory databases have several weaknesses:

- Database features are sometimes difficult to match with a map location. Since the locations of features are usually determined in the field by measuring the distance from the last road junction, base map errors and field measurement errors may cause the landslide to be plotted in the wrong place. To confirm the accuracy of inventory site locations, use other nearby features noted in the inventory that also appear on the map. For example, if major stream crossings bracket a landslide, the distance to the landslide may be checked by comparing the noted distances with distances measured on the map.

- The database may not be up-to-date; recent road repairs may not be noted in the inventory. And, of course, road problems that developed after the inventory was completed will be missing. The database originator will know if the database is updated as road problems are fixed.

Aerial Photographs

Recent aerial photographs can be very useful for also identifying existing road-related landslides throughout the watershed. However, you will find that denser stands of trees greater than 30 years old will conceal landslides on aerial photographs.

Field surveys made by driving around the watershed are a good source of information and helpful for verifying the information compiled from other road inventories and aerial photographs. However, this activity is time-consuming, and some areas may be inaccessible due to locked gates or denial of permission to enter the area by the landowner.

Map and Compile Existing Road Instability Information

Compile information on existing road-related instability by marking landslide locations on the Base Map, and recording landslide information on Form S-2, Information on Existing Road-Related Instability. Locations are recorded where a landslide either appears in the aerial photographs, is described in a road hazard inventory, or is noted during a field visit.

Use Form S-2, or the ROADLAND Worksheet, to compile information on the subwatershed, and on the landslide type, whether or not it reached a stream, what distance it traveled, and road position. After marking the landslide on the Base Map, assign it a unique number and enter the information into the worksheet. Table 3 provides an example of information gathered on existing road-related instability.

Table 3. Example Form S-2: Information on existing road-related instability.

Number	Subwatershed	Landslide Type	Reached Stream?	Distance Traveled (ft)	Road Location
101	Deer	Debris flow	Yes	2,200	Mid-slope
102	Deer	Debris flow	No	1,000	Near ridge
103	Elk	Road prism failure	No	200	Mid-slope
104	Skunk	Culvert washout	Yes	-	Near stream

Number: Unique identification number.

Subwatershed: Subwatershed in which landslide occurs.

Landslide Type: Debris flow = initiates as shallow landslide in steep area and then flows down a channel, picking up additional soil, logs, and water. Road prism failure = downhill movement of the road cut or road fill; does not initiate a debris flow. Culvert washout = road fill partially or completely missing where the road crosses a stream.

Reached Stream?: Whether or not the landslide material ended up in the stream.

Distance traveled: The distance from initiation point to where the landslide stopped (not applicable to culvert washouts).

Road Location: General location of road: near ridge, mid-slope, near stream.

Map and Compile Potential Road Instability Information

Identifying the location of potential high-risk landslides or road washouts in the watershed allows a council to focus on preventing road instability. This information can be obtained from road inventory data and road surveys. In this portion of the assessment you will identify locations where (1) water is flowing over the road surface and fill slopes, (2) large cracks or slumps in the fill portion of the road, and/or (3) stream crossings that have undersized culverts. Culverts sizes are evaluated using a method adapted from the ODF in which you first document the current culvert capacity and then you compare this to the capacity needed.

Use Form S-3, Culvert Capacity and Risk of Large Amounts of Sediment Entering Stream, or the CULVERT Worksheet, to determine if the existing culvert is appropriately sized. First enter the subwatershed name and the unique number for each culvert (Columns 1 and 2). Identify the owner of the road in Column 3, if known. Then enter the current culvert size (from field information or road inventory data) in Column 4. Fill in current culvert capacity (Column 5) with values from Table 4. This table shows the flow capacity of both round culverts and of **pipe-arch culverts** of various standard sizes (pipe arches are wider than they are tall).

You will use the peak-flow map (50-year recurrence interval for peak flows in forest streams) from ODF to determine how large a culvert is needed for a stream crossing; enter the information in Column 6. In western Oregon and some of eastern Oregon, this map shows lines of equal value of peak flow associated with 50-year recurrence interval ranging from 50 to 600 cubic feet per second

Table 4. Capacity of culverts of various sizes.

Round Culverts		Pipe-Arch Culverts	
Diameter (inches)	Capacity (cfs)	Span x Height	Capacity (cfs)
15	3.5	22" x 13"	4.5
18	5.5	25" x 16"	7
21	8	29" x 18"	10
24	12	36" x 22"	16
27	16	43" x 27"	26
30	20	50" x 31"	37
33	26	58" x 36"	55
36	32	65" x 40"	70
42	47	72" x 44"	90
48	67	6'-1" x 4'-7"	130
54	88	7'-0" x 5'-1"	170
60	115	8'-2" x 5'-9"	240
72	180	9'-6" x 6'-5"	340
84	260	11-'5" x 7'-3"	470
96	370	12'-10" x 8'-4"	650
108	500	15'-4" x 9'-3"	930
120	670		
132	840		

(cfs) per square mile of drainage area. In much of eastern Oregon you will see areas that have a regional average value. Culverts installed on nonfederal forest roads are required to at least pass a peak flow of the magnitude shown for your location on the map. For example, if your watershed is in the central Coast Range and the 200 line runs through it, culverts need to be sized to handle at least 200 cfs of flow for each square mile of drainage area upstream of the site.

You can measure the drainage area of a site using the Base Map. Starting from the culvert site, delineate the drainage boundary by drawing a line that is always perpendicular to the elevation contours (see method for delineating watersheds in the Start-Up and Identification of Watershed Issues component). Measure the area bounded by the line using a map grid or map wheel (see method for calculating drainage area in Start-Up component) and enter the value in Column 7. Multiply the drainage area (Column 7) times the peak flow value (Column 6). For example, a site that has a design criteria of 200 cfs per square mile and a drainage area of 0.65 square miles needs a culvert that passes 131 cfs (200 x 0.65 = 131). Enter the multiplied value in Column 8.

To determine the appropriate culvert size corresponding to the design flow, refer to Table 4. Find the culvert size required to pass the calculated peak flow value (from Column 7) and enter the value in Column 9. In the above example, the minimum culvert size is a 72-inch circular culvert or a 7'-x-5'1" pipe arch. Now, look up the capacity of the current culvert in Table 4 and write it down in Column 5. If the current culvert was 48 inches in diameter, the capacity would be 67 cfs. Next, calculate a ratio (Column 10) of the 50-year flow (Column 6) divided by the current culvert's capacity (Column 5). In the example above, this ratio would be 131/67= 2.0.

The height of the fill at the stream is important information for evaluating the consequences of a road washout. If a culvert washes out, the amount of soil entering the stream can be low if the fill is small or large if the fill is high. Enter fill height (estimated at the outside edge of the road surface) in Column 11. Next, assign culverts to various risk classes (low through extreme) as shown at the bottom of Form S-3. The risk class goes in Column 12. An example of an inventory of culvert information is shown in Table 5.

Identify Road Segments at Risk

The three risk factors used to identify potential road instability are cracks and slumps in roads (cracks/slumps), water running down a road or onto an unstable fill (water/fill), and undersized culverts in high fills at stream crossings (culvert). Use information within road surveys or your own knowledge of the watershed to identify locations where cracks and slumps in roads exist. Do the same for locations where water is running down a road or onto an unstable fill. Assign each location a unique identification number and mark on the Base Map the location of each site and the identification number.

Combine information about all three risk factors into Form S-4, High-Risk Road Segments for Existing Roads, or the ROADRISK Worksheet (including only culverts with a hazard rating of high, very high, or extreme). Table 6 provides an example of what information to include.

Table 5. Example Form S-3: Culvert capacity and risk of large amounts of sediment entering stream.

1 Sub-watershed	2 Num.	3 Road Owner-ship	4 Current Culvert/ Pipe-Arch Size	5 Current Culvert Capacity (cfs)	6 ODF Peak-Flow Value (cfs/mi²)	7 Drainage Area (mi²)	8 50-Year Peak Flow (Col. 6x7) (cfs)	9 Culvert/ Pipe-Arch Size Needed for 50-Year Peak Flow	10 Ratio of 50-Yr Flow to Current Capacity	11 Fill Height (ft)	12 Hazard Rating *
Deer	201	USFS	30"	20	200	0.65	131	72"	6.5	20	Extreme
Elk	202	County	30"+30"	40**	200	0.44	88	54"	2.2	18	Very high
Elk	203	Un-known	9'-6"x 6'-5"	340	200	2.73	545	12'-10"x8'-4"	1.6	3	Moderate
Skunk	204	County	60"	115	200	0.38	75	54"	0.7	35	Low
Skunk	205	State	72"	180	200	0.60	119	72"	0.7	3	Very low

* Hazard rating:

- Very low — Fill height is 15 feet or less and ratio is less than 1.25.
- Low — Fill height is greater than 15 feet and ratio is less than 1.25.
- Moderate — Fill height is 15 feet or less and ratio is between 1.25 and 1.75.
- High — Fill height is greater than 15 feet and ratio is between 1.25 and 1.75; or, fill height is 15 feet or less and ratio is between 1.76 and 3.
- Very high — Fill height is greater than 15 feet and ratio is between 1.76 and 2.99; or, fill height is 15 feet or less and ratio is greater than 3.
- Extreme — Fill height is greater than 15 feet and ratio is greater than 3.

** Stream crossing had two 30"-diameter culverts.

Table 6. Example Form S-4: High-risk road segments for existing roads.

Sub-Watershed	Num.	Feature Type	Hazard Rating of Culvert	Road Ownership
Deer	201	Culvert	Extreme	Forest Service
Deer	251	Water/fill	-	Forest Service
Deer	252	Water/fill	-	Private landowner
Elk	202	Culvert	Very high	County
Elk	253	Cracks/slumps	-	Private landowner
Skunk	254	Water/fill	-	Private landowner
Skunk	255	Cracks/slumps	-	Private landowner

Map 1 in Appendix VI-A provides an example of a finished map showing information compiled for both existing and potential road instability sites.

Summary: Road Instability

A final step in this process is to create summary tables (Form S-5, Summary of Information on Road Instability, or the ROADINST Worksheet) that allow subwatersheds and/or land ownership classes to be compared. Existing road instability (from Form S-2) and high-risk areas for future instability (from Form S-4) are both entered into the table but are evaluated separately. The number of sites in a subwatershed are divided by the subwatershed area and displayed on a per-unit basis. Table 7 provides an example of the summary table. An expanded version can be constructed by breaking down each subwatershed summary into road ownership classes.

This example highlights several issues that should be examined and discussed, including: a high density of landslides in the Deer and Eagle subwatersheds; a high density of high-risk culverts in the Eagle subwatershed; and a high density of road cracks, slumps, and road water in the Skunk and Bear subwatersheds. Note in what locations within these subwatersheds the landslides are occurring. Examine the Base Map to see if landslides are more common nearest streams or nearest ridge-tops. Does slope steepness explain the variation in landslide clusters? Check if landslides occur in clumps along only a few roads or are evenly spread out. Examine the map and see if landslides tend to clump according to land ownership. Such examination will help you determine landslide causes.

The example also highlights another issue: the high density of high-risk culverts in one subwatershed. Refer to the Base Map to determine why. Does the road mostly follow streams, thereby requiring many stream crossings? Do a high percentage of these high-risk culverts occur on a certain land ownership? Do the high-risk culverts occur mainly within one size class of stream? Answers to these questions may require the help of a road engineer to help unravel the spatial variability of high-risk culverts and suggest remedies.

Table 7. Example Form S-5: Summary of information on road instability.

Subwatershed	Area (mi^2)	Road Failures that Reached Streams		Sites with High-Risk Culverts		Sites with Cracks and Slumps		Sites with Water Flowing Over Fills	
		#	Density ($\#/mi^2$.)	#	Density ($\#/mi^2$.)	#	Density ($\#/mi^2$.)	#	Density ($\#/mi^2$.)
Deer	4.6	13	2.8	3	0.7	0	0.0	0	0.0
Elk	6.5	2	0.3	4	0.6	2	0.3	5	0.8
Skunk	8.3	15	1.8	10	1.2	18	2.2	20	2.4
Bear	2.1	3	1.4	2	1.0	4	1.9	4	1.9
Eagle	10.1	21	2.1	15	1.5	9	0.9	3	0.3
Total	31.6	54	1.7	34	1.1	33	1.0	32	1.0

Table 7 also highlights the high density of road segments with cracks, slumps, or areas where runoff water flows onto road fills in the Skunk and Bear subwatersheds. In this case, it will take additional evaluation to determine if this is related to side-slope steepness, position on the hill slope, or road-building practices and maintenance on the part of the landowner.

Other information can be brought in to help decipher road instability questions, such as geological information, road age, and rainfall patterns. A geological map of the area may provide information on general rock types; landslides can be more common at the contact zone between two rock types. The era in which the road was built may explain why some are stable and some are unstable. You may be able to assign ages to road segments by estimating the age of the oldest **harvest units** in the general area. Finally, you should consider when the last sustained and high-intensity rainfall occurred and how it might have varied across the watershed. Road instability is seldom noticeable until the road is tested by severe storms.

Source 2. Slope Instability (not related to roads)

Slopes can be unstable for reasons other than roads. Landslides can be a natural part of the landscape, especially where slopes are steep and rainfall is abundant. Landslides include both shallow slope failures that go a short distance and those that travel down a channel, gathering up soil, water, and wood and creating a debris flow (Figure 2). Landslides also include deep-seated failures that creep or ooze downhill at slow rates. A combination of the two can occur when the over-steeped face of a deep-seated landslide becomes the site of shallow slope failures.

Shallow landslides typically occur in very steep terrain. There is some evidence that removal of trees on steep slopes (greater than about 80%) makes an area vulnerable to shallow landslides and can lead to a temporary acceleration of the landslide rate. This window of vulnerability begins when many of the finer roots of the harvested trees become rotten (about 4 years) and ends once the

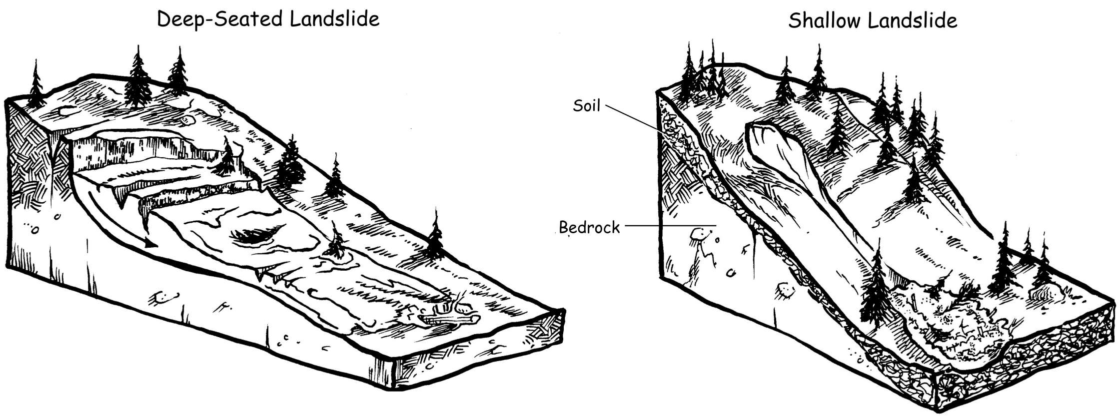


Figure 2. Some landslides travel down a channel, gathering up soil, water, and wood and creating a debris flow. Landslides also include deep-seated failures that creep or ooze downhill at slow rates.

replacement stand has developed a dense root network (about 30 years for wet portions of the state).

Most deep-seated landslides are natural. The only times when human-activities seem to influence these landslides is when a road or other feature undercuts the base of the slide or adds weight to the top of the slide. A deep-seated landslide area can also be triggered by road runoff water diverted onto an unstable slope. Deep-seated landslides are not restricted to steep slopes. Some of the most active and extensive landslides can occur on moderate slopes with weak soils. Deep-seated landslides add sediment to streams by pinching off stream channels. When a stream is constricted by an encroaching landslide, the stream carves away at the base of the landslide, causing the slope to be further destabilized.

Slope instability (unrelated to roads) is evaluated by collecting information about recent landslides and high-risk areas in the watershed that are likely to move in the future. This is done using recent aerial photographs, referring to federal or state agency aerial photograph landslide inventories of portions of the basin, and asking landowners, local fishermen, and fisheries biologists where landslides are located. Deep-seated landslides next to streams can cause chronic turbidity, but are often difficult to identify on aerial photos unless they have bare surfaces.

Finding information on existing landslides will probably be frustrating. You can use recent aerial photographs to detect some landslides but you will seldom be able to observe landslides among dense trees older than about 30 years. You might find that a federal or state agency has already done some aerial photography or ground-based landslide inventories of portions of the basin, but they may not be recent surveys. In many cases, it will probably be better to conduct your own inventory from recent photos so that you can cover the entire watershed, have a current inventory, and be able to gather other information that is useful in this assessment.

Recent Landslides

Begin the mapping of existing landslides by locating landslides seen in the aerial photographs, skipping those that initiate at roads. At first glance, some features may appear similar to a landslide. **Skid trails**, **cable yarding scars**, **landings**, **borrow pits**, and **rock pits** can leave patches of bare soil that appear similar to the scar left by a landslide. You can usually resolve these uncertainties by examining the aerial photographs using a **stereoscope**. A stereoscope will allow you to see the feature in three dimensions. If necessary, take the photos to the field and verify what you see on the ground and what you see in the photographs. Assign a unique number to each landslide located on the aerial photographs and mark the location on the Base Map. Use roads, timber harvest boundaries, and streams for orientation. Observing the landslide in stereo will show its location with respect to nearby ridges and **draws**, which show up on the Base Map. Enter the subwatershed name, unique number, and type of landslide on Form S-6, Current Landslides Not Related to Roads, or the LANDCUR Worksheet. Table 8 provides an example of this.

From the aerial photograph, estimate the age of the vegetation at the landslide's initiation point (see the Start-up Component for guidance on how to read aerial photos). Also determine the distance the landslide traveled from the initiation point and whether or not it reached a stream. Enter this information in the appropriate columns on Form S-6. From the Base Map, determine slope steepness at the initiation point by measuring the distance between 5 contour intervals using the 20-scale of an engineer's scale. Multiply the vertical distance represented by a single contour (usually 40 feet) by 5, divide by the distance between 5 contour intervals, and then multiply by 100, as shown below:

Slope (%) = 5 x 40 feet / distance x 100

If the contour interval of the Base Map happens to be 20 feet, then substitute 20 for 40 in the above equation. Figure 3 provides an example of a landslide in an aerial photo and the measured site characteristics. Map 2 in Appendix VI-A provides an example of a finished map showing information compiled on slope instability not related to roads.

Table 8. Example Form S-6: Current landslides not related to roads.

Sub-watershed	Num.	Type of Landslide	Age of Vegetation (years)	Landslide Reached Stream?	Distance Landslide Traveled (feet)	Slope Steepness at Initiation Point (%)
Deer	301	Shallow	10	Yes	1,700	110
Deer	3702	Deep-seated	20	Yes	200	50
Elk	303	Shallow	5	Yes	1,600	100
Elk	304	Shallow	10	No	900	75
Skunk	305	Unknown	30	No	300	80
Skunk	306	Shallow	5	Yes	800	95
Skunk	307	Deep-seated	10	No	100	45

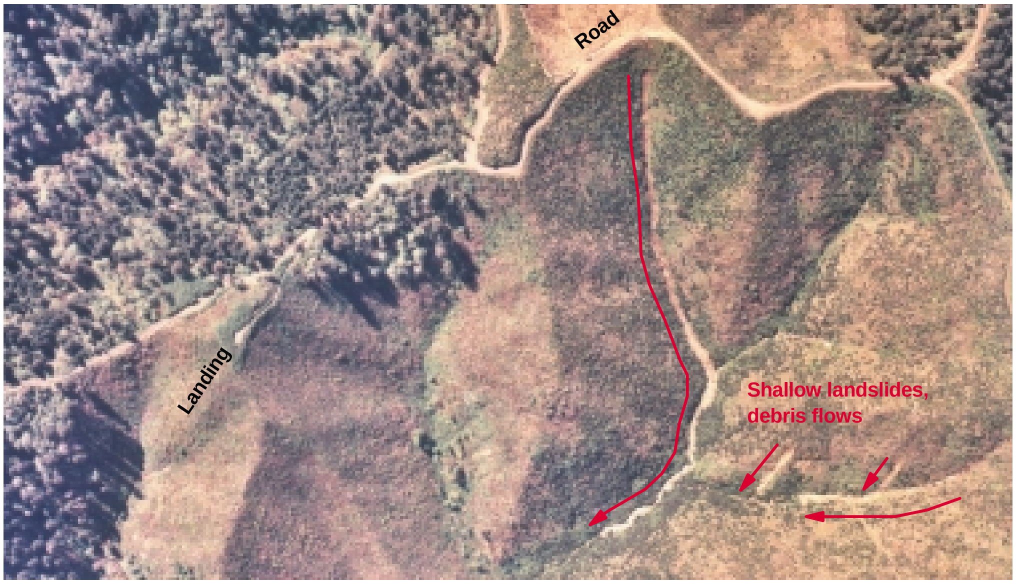


Figure 3. From the aerial photograph, you can estimate the age of the vegetation at a landslide's initiation point, and determine the distance the landslide traveled.

High-Risk Areas for Debris Flows

The ODF is in the process of finishing debris-flow-hazard maps for forested regions of Oregon. These maps will indicate areas prone to landslides and will provide a rating of the degree of landslide hazard. Since the maps are not yet available it is not possible to predict how the final maps will indicate the landslide hazard or **hazard delineations**. The maps will probably consist of polygons of high- and extreme-hazard delineations. The remainder of the area in the watershed will not be marked. To include this information on your Base Map, transfer the outlines of the high- and extreme-hazard polygons using a light table or window. Determine the area of these polygons using a grid or map wheel and compile the information, as demonstrated in Form S-7, Potential for Debris Flows, or the LANDPOT Worksheet. Table 9 provides an example of a completed Form S-7.

Table 9. Example Form S-7: Potential for debris flows.

Subwatershed	Areas Predicted to be High Risk for Debris Flows (mi²)		
	High Hazard	Extreme Hazard	Combined
Deer	0.5	0.2	0.7
Elk	1.1	0.4	1.5
Skunk	0.4	0.1	0.5
Bear	0.2	0	0.2
Eagle	1.2	0.5	1.7
Total	3.4	1.2	4.6

Summary: Slope Instability

Combine information on recent shallow and deep-seated landslides and the potential for future debris into a single summary using Form S-8, Summary of Information on Slope Instability (not related to roads), or the LANDSUM Worksheet. The picture this form presents will be incomplete, because most of the existing landslides hidden by trees will have not been detected. In addition, the landslide potential rating addresses only debris flows and not deep-seated landslides. Nevertheless, the information can help you understand the relative abundance of landslides throughout the watershed. (See Table 10 for an example of a completed Form S-8.)

Information like that displayed in Table 10 can help you understand landslide patterns in the watershed and possible reasons for these patterns. For example, the Elk subwatershed has a low density of current shallow landslides (0.5 / square mile) but a high percentage of the land has a high potential for debris flows (23%). In this case, it would be good to check the aerial photographs and work map to first see if there was an undercount of current shallow landslides in the Elk subwatershed simply because most of the land was covered by older trees that obscure existing landslides. Elsewhere, you can note that there is a higher-than-average density of current shallow landslides in the Eagle subwatershed (1.7), which is in agreement with the higher-than-average percentage of land that is classified as high risk for debris flows (17%).

Other information may help you understand patterns in landslide abundance. A change in geology may cause clusters of landslides to occur. Use a geologic map of basic rock types to see if high landslide density coincides with changes in geology, especially near streams. Also check to see whether or not current shallow landslide density coincides with the extremely steep slopes in the watershed. Finally, consider when the last sustained and high-intensity rainfall occurred and how it might have varied across the watershed. Like road instability, landslide activity unrelated to roads may be common only after a severe storm has hit the area.

Table 10. Example Form S-8: Summary of information on slope instability (not related to roads).

Sub-Watershed	Area (mi^2)	Current Landslides				Debris-Flow High-Risk Areas (combined high and extreme)	
		Shallow Landslides		Deep-Seated Landslides			
		Number (#)	Density (#/mi^2.)	Number (#)	Density (#/mi^2.)	Area (mi^2.)	Percent
Deer	4.6	10	2.2	2	0.4	0.7	15
Elk	6.5	3	0.5	0	0.0	1.5	23
Skunk	8.3	11	1.3	4	0.5	0.5	6
Bear	2.1	3	1.4	0	0.0	0.2	10
Eagle	10.1	17	1.7	6	0.6	1.7	17
Total	31.6	44	1.4	12	0.4	4.6	15

Source 3. Rural Road Runoff

The water draining from roads can move considerable amounts of sediment from the inside drainage ditch and unpaved road surfaces. The road ditch is filled in with sediment from **ravel**, sliding, and erosion of the road cut slope. Usually, roads are designed so water flowing through the ditch picks up this sediment as it flows into streams or small draws. However, some land managers have now adopted a technique whereby roads are designed to divert ditch water onto a stable slope using a **cross-drain culvert** at a site adjacent to but before the stream enters the stream. When the sediment-laden water is diverted onto stable and well-drained slopes, the sediment is filtered out as the ditch water goes subsurface.

The condition and amount of sediment coming from the surface of an unpaved road depends on the quality of the surface rock, road maintenance, weather conditions, and the weight and frequency of traffic. The break-up of the road surface is most rapid during wet weather and when heavy truck traffic is frequent. Poor-quality surface rock quickly breaks down into fine material and develops potholes. If the road is not maintained, ruts then begin to develop.

The amount of sediment potentially contained in runoff from any single road is difficult to estimate because road conditions can change so rapidly. A road surfaced with high-quality rock can be quickly reduced to a quagmire if water is allowed to pool during wet weather and there is heavy truck traffic. Conversely, a road with a poor-quality surface may not degrade much at all if it is used mainly during dry weather.

In this section, you will compile information about road segments in the watershed and assign an overall hazard rating that indicates the **general** propensity of that road segment to deliver sediment to streams. Two different assessments are described. The first, a basic assessment, simply identifies site conditions that are conducive for high amounts of sediment in road runoff to enter streams. The second assessment is detailed, and requires much more time but yields more useful information about the road systems in your watershed.

This section covers road runoff from rural roads. Rural roads are all roads except those that are within cities and towns and are hooked up to a stormwater drainage system.

Basic Rural Road Runoff Assessment

Some basic information about roads and the likelihood of sediment delivery to streams can be obtained by reviewing base maps and aerial photographs. From the maps, you can identify sections of road that are within 200 feet of a stream, either laterally or longitudinally (see Figure 4). Throughout the watershed, these are the road segments more likely to have ditches that flow directly into the stream and are the most difficult to keep sediment-laden runoff water from entering streams. You can also identify on the topographic maps where these road segments close to the streams also have steep slopes (greater than 50%) uphill of the road. Roads with steep side slopes usually have more soil accumulating in the road ditches than roads with less steep side slopes. Plugged road ditches are common cause of road surfaces breaking down. Also, you can gather some road information from the aerial photographs. Use the color of the road to determine whether the surface is paved, rock, or dirt. Finally, local experience by landowners and land managers can provide information on whether or not a road is a high-use road. By combining all these sources of information you can identify where in the watershed higher-risk situations exist for road runoff.

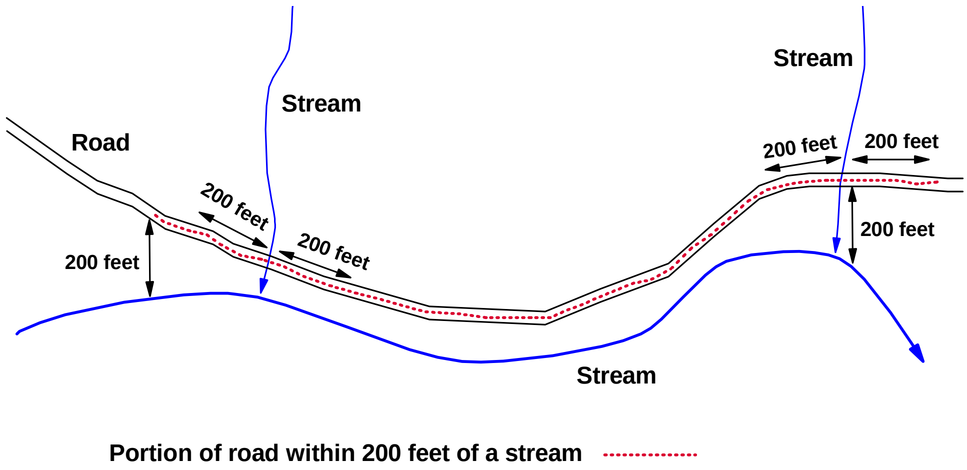


Figure 4. From maps, you can identify sections of road that are within 200 feet of a stream, which may help you determine the likelihood of sediment delivery to streams.

On the Base Map, identify and highlight road segments (400 feet or longer) within 200 feet of a stream, either laterally or longitudinally (see Figure 4). Assign the road segment a unique number and measure its length. Record this information on Form S-9, Basic Information on Road Segments Close to Streams with Steep Slopes, or the RUNOFF Worksheet. For each of the road segments, also determine which segments have a side slope greater than 50%.

You can identify 50% slopes by examining the spacing between contour lines. The contour lines on a topographic map (1:24000) with a contour interval of 40 feet are spaced slightly closer than the smallest units on the 20-scale of an engineer's scale where the slope is 50%. Measure the length of those portions of the road segment that have slopes greater than 50%. Finally, use the color of the road on aerial photographs to determine whether the surface is paved, rock, or dirt. By combining this information, higher-risk situations for road runoff can be identified. Table 11 provides an example of a completed Form S-9, and Map 3 in Appendix VI-A provides an example of a finished map showing basic information compiled on rural road runoff.

Table 11. Example Form S-9: Basic information on road segments close to streams with steep slopes.

Subwatershed	Num.	Distance <200' from Stream (feet)	Distance <200' from Stream and Slope >50% (feet)	Road Surface	Road Use
Deer	401	1,800	600	Paved	High use
Deer	402	2,200	0	Rock	Low use
Deer	403	1,200	400	Rock	Low use
Deer	404	900	800	Dirt	High use
Elk	405	1,400	300	Rock	High use
Elk	406	3,100	1,700	Rock	Low use
Elk	407	600	0	Rock	Low use
Elk	408	1,500	300	Rock	Low use

Detailed Rural Road Runoff Assessment

The mileage of road within in a watershed is usually too great for a watershed council to gather detailed information on each road section; however, in some areas of the watershed this information may have already been gathered by private forest landowners and state forest land managers. Most of these inventories use a standard protocol so information can be shared and combined. This information may be added to your assessment if you are willing to deal with difficulties matching database records to Base Map locations; be prepared for the process to take a long time.

Table 12 provides an example of information collected on road runoff that is included in a typical road inventory database. You will be taking information from tables such as these and summarizing them for inclusion in a summary table. You will also be adding the location of each road to the Base Map. The variables are listed below the table. Descriptions for ditch condition, cut-slope condition, surface condition, surface material, and road use are the average conditions for the road section beginning at the previous feature noted and extending to the current feature. See the ODF Forest Road Hazard Inventory Protocol (available from the hydrologist at the ODF, 503-378-3589) for more information.

Raw inventory data may be summarized (on Form S-10, Summarized Runoff-Related Information for a Single Road, or the SEDROADS Worksheet; see Table 13 for an example) for a single road by adding up road lengths or occurrences for each classification that a variable takes. Features for all roads within a subwatershed can then be summed as illustrated later in this section.

Summary: Basic Assessment

Summarize information on road segments near streams by subwatershed using Form S-11, Summary of Information on Road Runoff—Basic Assessment, or the RUNOFF Worksheet. Table 14 provides an example of a completed form. For each of the various categories (Roads <200' from a Stream; also with Steep Slopes, also with High Use, and also with Low Use), the lengths of road are summed and a density value calculated by dividing road length by subwatershed area. A variation could be constructed by including information about the road surface in the summary, yielding 26 rather than 10 columns and making it a more detailed table.

Summary information like this can help you identify areas where high-risk roads are common. For example, both the Skunk and Eagle subwatersheds have an unusually high density of roads within 200 feet of a stream. The situation in Skunk is likely to be of more concern because it also has the highest density of these segments that have steep slopes uphill of the road. Furthermore, the Skunk subwatershed has the greatest density of high-use roads.

Patterns like these should lead you to examine the base maps again and note where in the Skunk subwatershed these conditions are most prevalent. The Skunk subwatershed would be a high priority for a site visit (pick a very rainy day when the road is being used) to see whether or not these indicators of high sediment in runoff water coincide with actual conditions.

A variation of Table F14 could be constructed by including information about the road surface in the summary. As you can imagine, the introduction of the variable, Road Use, with its three categories (paved, rock, dirt) makes for a messier table. With the addition of Road Use you will end up with 26 columns rather than the 10 shown in Table F14.

Table 12. Example of runoff-related information in a road inventory database.

Eagle Creek Road									
Stationing (feet)	**Feature**	**% Grade (+/-)**	**Ditch Condtn.**	**Cut-Slope Condtn.**	**Surface Condtn.**	**Surface Material**	**Culvert Condtn.**	**Filtering Opportun.**	**Road Use**
0	Start rd.	0							
231	Grade Break	5	Good	Good	Good	Rock			Active
641	X drain culvert	3	Good	Good	Good	Rock	Good		Active
1191	Grade Break	7	Good	Ravel	Good	Rock			Active
1708	X drain culvert	-7	Good	Good	Good	Rock	Good		Active
2263	Road junction	-9	Good	Good	Good	Rock			Active
2619	X drain culvert	16	Good	Ravel	Good	Rock	Good		Active
3004	Stream crossing	10	Good	Ravel	Good	Rock	Good	No	Active
3520	X drain culvert	11	Good	Good	Good	Rock	Damaged		Active
3667	X drain culvert	9	Good	Ravel	Good	Rock	Good		Active
4093	X drain culvert	11	Good	Ravel	Good	Rock	Good		Active
4570	X drain culvert	11	Good	Ravel	Good	Rock	Good		Active
4870	Stream crossing	7	Good	Ravel	Good	Rock	Good	No	Active
5623	Stream crossing	7	Good	Good	Good	Rock	Good	No	Active
5778	Stream crossing	12	Good	Good	Good	Rock	Good	No	Active
6129	X drain culvert	9	Full	Good	Rutted	Dirt	Plugged		Inactive

Stationing (feet):	Distance from the starting point of the survey to the beginning of the road segment.
Feature:	Grade breaks; cross-drain culverts; stream crossings; road junctions.
% Grade:	The gradient of the road in percent.
Ditch Condition:	Good; downcutting, diverted onto road; full of sediment.
Cut-Slope Condition:	Good; ravel problems; sloughed into road.
Surface Condition:	Good; rutted; bermed; eroded.
Surface Material:	Rock; dirt; pavement.
Culvert Condition:	Good; damaged; plugged by sediment.
Filter Opportunity:	Yes; no; possibly (whether or not site conditions would allow diversion of ditch water onto a stable slope before it enters a stream).
Road Use:	Active; inactive.

Table 13. Example Form S-10: Summarized runoff-related information for a single road.

Road Name	Variable	Classification	Length (feet)	Occurrences (#)
Eagle Creek Road	Overall road length	-	7,742	-
Eagle Creek Road	Ditch condition	Good	5,778	-
Eagle Creek Road	Ditch condition	Full	1,964	-
Eagle Creek Road	Cut-slope condition	Good	5,101	-
Eagle Creek Road	Cut-slope condition	Ravel	2,641	-
Eagle Creek Road	Surface condition	Good	5,778	-
Eagle Creek Road	Surface condition	Rutted	1,964	-
Eagle Creek Road	Surface material	Rock	5,778	-
Eagle Creek Road	Surface material	Dirt	1,964	-
Eagle Creek Road	# Culverts	-	-	15
Eagle Creek Road	Culvert condition	Good	-	12
Eagle Creek Road	Culvert condition	Plugged / Damaged	-	3
Eagle Creek Road	# Stream crossings	-	-	6
Eagle Creek Road	# Stream crossings	Ditch water can be filtered	-	0
Eagle Creek Road	Road use	Active	5,778	-
Eagle Creek Road	Road use	Inactive	1,964	-

Table 14. Example Form S-11: Summary of information on road runoff—basic assessment.

Sub-watershed	Area (mi^2)	Roads < 200' from Stream		Roads < 200' from Stream and Slope > 50%		Roads < 200' from Stream and High Use		Roads < 200' from Stream and Low Use	
		Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)
Deer	4.6	2.5	0.5	1.5	0.3	0.5	0.1	2.0	0.4
Elk	6.5	3.3	0.5	0.6	0.1	2.0	0.3	1.3	0.2
Skunk	8.3	9.6	1.2	8.0	1.0	7.5	0.9	2.1	0.3
Bear	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eagle	10.1	14.5	1.4	5.5	0.5	1.5	0.2	13.0	1.3
Total	31.6	29.9	0.9	15.6	0.5	11.5	0.4	18.4	0.6

Summary: Detailed Assessment

The detailed information from the road inventories that was compiled for each subwatershed (Table 13) offers many options for summarizing the data. There are too many variables for you to construct a single table. Instead, combine several variables in a way that allows you to look at one aspect of road runoff. Table 15 provides an example of how the condition of road ditches and of culverts could be combined to examine road maintenance issues.

Table 15. Example summary of some of a road-runoff detailed assessment.

Subwatershed	Area (mi^2)	Roads with Ditches in Good Condition		Roads with Ditches Filled with Sediment		Culverts in Good Condition		Culverts Plugged	
		Length (mi.)	Density ($mi./mi^2$)	Length (mi.)	Density ($mi./mi^2$)	Length (mi.)	Density ($mi./mi^2$)	Length (mi.)	Density ($mi./mi^2$)
Deer	4.6	21.0	4.6	5.2	1.1	65	14.1	26	5.7
Elk	6.5	12.0	1.9	1.0	0.2	112	17.2	21	3.2
Skunk	8.3	9.5	1.1	6.0	0.7	71	8.6	39	4.7
Bear*	-	-	-	-	-	-	-	-	-
Eagle	10.1	35.5	3.5	2.0	0.2	154	15.3	24	2.4
Total	29.5	78.0	2.6	14.2	2.2	402	13.6	110	3.7

* No road inventories were completed for this subwatershed.

In this example, the Deer subwatershed has the highest density of sediment-filled ditches that no longer convey water on the inside of the road. In addition, this subwatershed has the highest density of plugged culverts. This suggests that roads are not being maintained as well as roads elsewhere in the watershed. Refer to the Base Map and, after sketching in land ownership on the map, check to see if the problems are confined to one or more groups of land managers. You might also check the geology and Base Maps to see if there is anything different about the terrain in that area. The depth of your investigation into road surface runoff may be limited only by the time you have to work the numbers.

Source 4. Runoff From Urban Areas

Sediment in urban areas enters streams differently than elsewhere in the watershed. In cities and towns, most sediment is delivered to streams via the stormwater system. The stormwater system is the maze of underground pipes and ditches that convey runoff from streets, other paved areas, and roofs to a nearby stream, river, or lake. The sediment within stormwater can come from a number of sources, including wind-deposited soil, degrading pavement, sand applied to roads during icy conditions, and erosion from yards and from construction sites. The sediment within stormwater also includes a large component of organic matter.

Different types of land within an urban setting produce different amounts of sediment. Residential neighborhoods produce the least amount of sediment per square mile. Commercial areas produce moderate loads of sediment, and heavy industrial areas produce even higher amounts. The highest amounts occur in areas that are actively being developed. Earth disturbances and bared surfaces usually makes sediment production the highest within a town, albeit the sediment production usually decreases once the construction is complete.

A particular problem with sediment from urban areas is that pollutants are often attached to the sediment particles. Many heavy metals, toxic compounds, nutrients, and bacteria readily attach to sediment particles derived from urban sources. Of major concern are zinc, copper, oil and grease, yard pesticides, and phosphorus. These compounds are known to be harmful to fish and other aquatic life at high concentrations. A number of innovative ways have been developed to remove urban sediments and their attached pollutants before they reach streams or lakes. One simple method for removing sediment is to simply allow much of the sediment to settle in a **detention pond** or underground basin before bypassing the water to a stream or lake. Well-designed detention ponds can remove about one-half of the sediment in stormwater. A more expensive but very effective solution is to temporarily store the stormwater, and then process it at the sewage treatment plant during nonpeak periods.

Regular street cleaning can make quite a difference in how much sediment ends up in stormwater. Normal mechanical sweeping does a moderately good job of reducing sediment in curbs and parking lots. Vacuum-assisted cleaning following mechanical sweeping removes an even larger portion of the surface sediments, especially those sediments that are small and do not readily settle out in detention ponds. Table 16 provides a summary of the factors that influence stormwater sediment loads within urban areas.

Work Maps

Use work maps acquired from the public works department to evaluate sediment from a city in your watershed. The maps should show roads, streams, lakes, and the stormwater network (pipes, detention facilities, and any processing plants). Take the map to a photocopy shop and make several large-format copies. Delineate the stormwater watershed boundary or boundaries on the maps. These boundaries may not be the same as the natural drainage boundaries, because stormwater pipes may shuttle water from one sub-basin to another. Create separate stormwater subwatersheds if one set of pipes drain to one stream and another set to another stream. Using the streets on the map and aerial photographs as a guide, along with your knowledge of the city, further classify the stormwater watersheds into urban area types (residential, commercial, heavy industrial, and developing urban). Mark these boundaries on the map.

Next, meet with the person at the public works department most familiar with the stormwater system, and ask about city street-cleaning practices for various portions of the city. Add boundaries to your map that show where the street-cleaning activities indicated in Table 16 are performed. Ask about sediment removal efforts such as detention ponds or basins that were constructed to settle out some of the sediment load and highlight these features on the map. Ask how effective the detention facilities have been for trapping sediment. Also, ask if any of the stormwater is being conveyed to the sewer treatment plant for processing. Add boundaries to the map showing these sediment removal zones (Table 16). Finally, ask about any areas within the urban growth boundary that will be developed within the next 5 years. Highlight these areas on the map and label them “developing urban.”

Table 16. Factors that influence sediment loads within urban stormwater.

	Classification	Rating	Code
1. Urban area type: Relative sediment production per unit area of land	Residential	Low	L1
	Commercial	Moderate	M1
	Heavy industrial	High	H1
	Developing urban	Very high	VH1
2. Street cleaning: Amount of curbside and parking-lot sediment eliminated	None or infrequent	Small	S2
	Frequent mechanical	Moderate	M2
	Vacuum-assisted	Large	L2
3. Sediment removal: Amount of sediment removed from stormwater	None	None	N3
	Detention ponds/basins	Moderate	M3
	Treatment plant processing	High	H3

Summary: Urban Runoff

Transfer information from the work map to a final map. Using various colors and styles, redraw the boundaries for the information you collected. Assign a unique number to each polygon on the map. Next, assign a code for each polygon on the map that represents the combination of conditions for that polygon (Table 16). The code will have three parts. The first part indicates the urban area type, the second indicates street-cleaning methods, and the third indicates any processes for removing sediment from the stormwater before it enters the stream.

An example of a code for a polygon would be L1/M2/N3. This code would indicate:

- L1- Area has a relatively low amount of sediment production (residential housing).
- M2 - Sediment removal from streets and parking lots is moderate (regularly cleaned with mechanical sweeping).
- N3- Sediment removal from stormwater does not occur.

Use a grid or map wheel to determine the area of each of the polygons within each stormwater watershed, and calculate the percentage of total area that falls within each polygon. Enter this information on Form S-12, Information on Urban Runoff Polygons, or in the URBAN Worksheet. Table 17 provides an example of polygon attributes and their area. Map 4 in Appendix VI-A provides an example of a finished map showing basic information compiled on urban runoff.

Table 17. Example Form S-12: Information on urban runoff polygons.

Stormwater Subwatershed	Polygon #	Polygon Area (acres)	Area as a Percentage of Total	1. Sediment Production	2. Street Cleaning	3. Sediment Removal
Oak Creek	501	2,555	79	L1	M2	N3
Oak Creek	502	250	8	VH1	M2	N3
Oak Creek	503	360	11	M1	M2	M3
Oak Creek	504	50	2	H1	M2	M3
Total		3,215	100			
Johnson Creek	506	1,550	69	L1	M2	M3
Johnson Creek	507	120	5	VH1	M2	M3
Johnson Creek	508	420	19	M1	M2	M3
Johnson Creek	509	160	7	H1	M2	M3
Total		2,250	100			

This analysis can help identify opportunities for minimizing the sediment that enters urban streams and lakes. For example, 87% of the Oak Creek subwatershed has no sediment removal infrastructure (N3). Oak Creek is mostly residential (L1), with some developing areas (VH1); in Johnson Creek, detention basins (M3) service all of the residential and developing areas (69% of total). One could then assume that, all else being equal, Oak Creek suffers from a much higher load of urban sediment than does Johnson Creek. If the construction of detention basins is not an option, an alternative worth considering is the use of better street cleaning (L2) in those areas without detention basins (M3).

A detailed engineering study would be required to assign actual sediment amounts to each of the relative ratings shown in Table 16. If such a study is completed, you would be able calculate estimated sediments loads (tons of sediment per acre per year) for each polygon.

Source 5 Sediment from Crop Land

Evaluating soil erosion for crop land is complicated, since erosion from crop land is related to many factors, such as the types of crops planted, soil type, farming practices, steepness of the land, and the timing of erosion-causing events. Most erosion and sediment movement occurs during unusual events such as summer thunderstorms, quick snowmelt, or high-intensity rainfall. For much soil movement to occur, these unusual events must coincide with the crop land being vulnerable to erosion. When a field is covered by vegetation with thick roots, a high-intensity rainfall will not create much erosion. Yet, when that same field is freshly plowed, a high-intensity rainfall may cause extensive erosion.

Erosion on crop land is often difficult to spot. **Rills** that form during a runoff event may disappear once a field is tilled or the crop begins to grow and cover the soil, or soil eroded from the top of a slope may simply be deposited at the bottom of the slope in an even layer. The best place to look for signs of excessive erosion is along draws and streams, especially if the land is relatively flat next to the channel. Here, you would expect to find thick mounds of newly deposited soil near the banks following a severe runoff event that caused much erosion.

An approach used in this manual for evaluating the potential for soil erosion makes use of information about the susceptibility of the soil to erosion, the slope of the land, the type of crop planted, and general farming practices. You will classify areas according to these factors and use your own experience and observations by others to determine which combinations of these factors have low, medium, or high soil erosion potential in your watershed. The decision process is set up as follows:

If: erodibility class of the soil is W, **and** slope steepness class is X, **and**

crop type is Y, **and** the farming practice is Z,

Then: soil erosion rating is V.

You will map information about soil erodibility class, slope steepness class, crop type, and farming practice on a site-specific basis and then use site observations of actual erosion to assign a relative erosion rating (low, moderate, high). You will track combinations of site characteristics that lead to high erosion rates, and apply this information across the watershed.

Task 1

Use county soil survey books to determine the soil erodibility class. All of the county soil surveys, except some that have not been updated since 1970, will have a table about the physical and chemical properties of soils. The table includes a column called "Erosion Factors." Here, you will find that each soil type has been assigned a value for K. The erosion factor K indicates the susceptibility of a soil to **sheet erosion** and rill erosion by water. The higher the value, the more susceptible the soil is to erosion. Some soil surveys provide a K value for various soil depths; use the K value associated with about the top 12 inches of soil. Many soil types have roughly the same K values. To simplify this assessment, aggregate the soils into three K value classes: low (<.20), moderate (.20 to .40) and high (>.40), and compile information in a three-column table. An example of this is shown for a set of soils in Umatilla County in Table 18.

Task 2

Transfer K classes to the topographic base maps. Make photocopies of the soil maps (those in the watershed with crop lands, and those with range lands if they also will be assessed) in the soil survey book. Reduce the soil maps by 20% (or 80% of the original size) when photocopied to achieve 1:24000 scale (the soil map scale is 1:20000). Although more expensive, you can make color copies in order to retain the aerial photograph backdrop in the soils maps. This is helpful when transferring the field boundaries to the Base Map.

Use a colored marker to highlight the boundaries of the three K classes on the soils maps. Keep your table of soil types and K classes (like Table 18) handy to determine where the boundaries should go, and label the K-value zones as Low, Medium, or High. Transfer these boundaries and labels to the Base Map using a light table or window, adjusting the soil map as needed to ensure alignment.

Table 18. Example of soil types segregated by K values.

Soil Types		
Low K* < .20	Moderate K .20 - .40	High K > .40
2D	6E	1C
3D	7F	1D
4C	8F	1E
5C	9F	12B
10E	24	13B
17	25E	14B
43F	26	16D
51D	27	17B
56B	28	18D
	32	20B
		22B

* K = Susceptibility of the soil to water erosion.

Task 3

Delineate zones of common steepness on the Base Map. The slope steepness classes used in this module are <10%, 10 to 20%, 20 to 40%, and >40%. Use the 20-scale on an engineer's ruler to measure the contour line. Refer to Table 19 to determine the distance between contour lines for each steepness zone. This distance varies depending on the map contour interval . Check the map legend for the contour interval (either 40 feet, 20 feet, or 10 feet). When drawing in the boundaries of the slope steepness classes, ignore very small islands of one class that fall within another class.

Task 4

Transfer field boundaries to the Base Maps. Reduced color copies of the soils maps provide the best information on field boundaries. Use recent aerial photographs to determine general crop types and to add or revise any fields not on the soils maps. Use a light table or window to transfer field boundaries onto the Base Map, labeling each field or groups of fields with codes indicating the same crop type (Table 20).

This results in a Base Map with polygons representing various combinations of soil erosion susceptibility, slope steepness, and crop type. Map 5 in Appendix VI-A provides an example of a finished map showing information compiled on surface erosion from crop land.

Table 19. Distance between contour lines for each slope steepness class.

Map Contour Interval	Slope Steepness Class	Distance Between Contour Lines (feet)
40 feet	<10%	>400
	10 to 20%	200 to 400
	20 to 40%	100 to 200
	>40%	<100
20 feet	<10%	>200
	10 to 20%	100 to 200
	20 to 40%	50 to 100
	>40%	<50
10 feet	<10%	>100
	10 to 20%	50 to 100
	20 to 40%	25 to 50
	>40%	<25

Table 20. General crop types.

Crop Type	Label
Wheat	W
Other grain	G
Grass seed	GS
Hay	H
Corn	C
Other row crops	R
Berries	B
Orchards	O
Vineyards	V
Christmas trees	CT
Nursery operations	N
Poplar plantations	P
Other	Oth

Task 5

Next, create a database of observations on how combinations of site factors and farming practices influence erosion in your watershed. This is the most difficult but perhaps the most informative task. Observations are best made immediately after a high-runoff period and during the time when fields are most vulnerable to erosion. For wheat, this may be when the field is fallow. Christmas tree farms may be most vulnerable the first winter after the site has been prepared for a new planting. For a grass field, this may be during the fall rains immediately after a new planting.

Site observations are meant to be a collaborative process that includes not only the analysts but also farmers and others with knowledge of farming practices in the watershed. During a site observation you will be noting several items. First, examine the area for signs of moderate or high erosion. Erosion severity classes for crop land are defined as follows:

- High: Deep rills or gullies. Extensive deposits of sediment on flatter areas near or in streams and draws. Deep sediment deposits at culvert inlets or at the uphill sides of elevated roads.

- Moderate: Shallow but numerous rills. Shallow deposits of sediment on flatter areas near streams and draws. Shallow sediment deposits at culvert inlets or at the uphill of elevated roads.

- Low: Otherwise.

You will also want to note the condition of the field previous to recent runoff events (e.g., freshly plowed, fallow, early stage of crop growth, crop removed, crop occupies site), as well as the crop planted or to be planted. Next, look for evidence of soil conservation measures used by the farmer, or better yet, contact the farmer and ask about any soil conservation measures used on that field. Mark the location where the field was observed and assign it a unique number. Soil conservation measures for crop land include:

- Crop rotation: Cover crops are planted for the winter in order to prevent erosion and runoff when winter rains or spring snowmelt arrives.

- Contour cultivation: On gently sloping land, fields are tilled on the contour rather than up and down the slopes in order to retard the velocity of overland flow of water. Not effective on steep slopes.

- Strip cropping: A cropping technique in which alternate strips of different crops are planted in the same field, usually on the contour.

- Conservation tillage: Any tillage system that reduces tillage and leaves at least 30% of the field surface covered with crop residue after planting is completed.

- Riparian strips: Establishment of buffers or grass, shrubbery, and trees along channels to slow runoff and prevent scouring of the channel banks and bottom.

Enter the information from the Base Map with that obtained from field observations in Form S-13, Database for Tracking Field Observation and Mapped Information on Crop Land and Range Land, or the CROP Worksheet. Table 21 provides an example of a completed Form S-13 for crop land.

Summary: Crop Land

After a number of observations have been included in the database, you may start to see patterns developing. For example, combinations of the soil K factor, slope steepness, and field conditions may result in moderate erosion when normal wheat-farming practices are used but low when certain conservation practices are used. Enter summary information in Form S-14, Summary of Crop Land and/or Range Land, Grazing Erosion Observations, or in the CROPSUM Worksheet. Table 22 provides an example of a completed Form S-14. The various combinations of site and farming practices are listed and the number of observations with low, medium, or high erosion are summarized.

The information gained from a data set like the one shown in Table 22 provides insight into combinations of site factors where an improved farming practice would yield the greatest reduction in incidences of moderate to high soil erosion. One of the main benefits of this approach is that the information is tailored to your watershed. From observations made by the watershed council and farmers, you can begin to develop rules-of-thumb that apply to the watershed.

Source 6. Sediment from Range Land and Pasture

Soil erosion on range land and pasture (referred to as range land in the remainder of this section) is usually more subtle than on cropped areas. Like crop land, sediment movement from range land occurs during infrequent and unusual runoff events, such as summer thunderstorms, quick snowmelt, or high-intensity rainfall. However, the grass itself is a significant barrier to soil movement. Dense grass and the associated root mass present reduces soil movement when unusual runoff events occur. Large-scale gullying and rilling usually occur only on the most heavily overgrazed lands. Few people witness these periods of soil movement, and in steeper terrain, there may be no clear evidence that soil erosion has occurred.

Grazing often occurs on steeper slopes where natural sediment movement is relatively high, which makes it difficult to separate natural erosion from grazing-caused erosion. In addition, areas near streams are often most vulnerable to erosion. These areas are usually green into late summer and fall. Animals are attracted to the green vegetation. When intense grazing occurs in the late summer and fall, these streamside areas are left with sparse foliage and root mass during potential high-flow periods in winter and spring.

Table 21. Example Form S-13: Database for tracking field observation and mapped information on crop land.

Sub-Watershed	Observation	K Class	Slope Steepness Class	Crop	Farming Practices	Field Condition	Actual Erosion	Runoff Event
Deer	601	Medium	10 to 20	Wheat	Normal	Fallow	Moderate	Observed after a late-summer thunderstorm
Deer	602	Medium	10 to 20	Wheat	Normal	Stubble	Low	Observed after a late-summer thunderstorm
Bear	603	Low	<10	Wheat	Normal	Fallow	Low	Observed after a late-summer thunderstorm
Elk	604	Low	10 to 20	Wheat	Riparian strips / conservation tillage	Stubble	Low	Observed after a late-summer thunderstorm
Skunk	605	High	10 to 20	Wheat	Normal	Stubble	High	Observed after a late-March snowmelt
Skunk	606	High	10 to 20	Wheat	Conservation tillage	Fallow	Moderate	Observed after a late-March snowmelt
Skunk	607	High	20 to 40	Wheat	Conservation tillage	Fallow	High	Observed after a late-March snowmelt

Table 22. Example Form S-14: Summary of crop-land erosion observations for wheat.

Crop: wheat

K Class	Slope Class	Farming Practice	Field Condition	Number of Observations by Erosion Class			
				Low	Mod-erate	High	Total
Low	<10	Normal	Fallow	4	2	0	6
Low	<10	Normal	Stubble	8	0	0	8
Low	<10	Conserv. tillage	Fallow	9	0	0	9
Low	<10	Conserv. tillage	Stubble	7	0	0	7
Low	10 to 20	Normal	Fallow	3	3	0	6
Low	10 to 20	Normal	Stubble	4	3	0	7
Low	10 to 20	Conserv. tillage	Fallow	5	2	0	7
Low	10 to 20	Conserv. tillage	Stubble	6	2	0	8
Moderate	<10	Normal	Fallow	4	5	0	9
Moderate	<10	Normal	Stubble	4	2	0	6
Moderate	<10	Conserv. tillage	Fallow	5	4	1	10
Moderate	<10	Conserv. tillage	Stubble	6	2	0	8
Moderate	10 to 20	Normal	Fallow	1	2	3	6
Moderate	10 to 20	Normal	Stubble	1	3	1	5
Moderate	10 to 20	Conserv. tillage	Fallow	1	4	3	8
Moderate	10 to 20	Conserv. tillage	Stubble	3	6	0	9

Some of the best places to detect sediment movement on range land is along draws and streams. Here, the runoff water slows down and deposits some of its load of sediment. Another place to look for signs of high sediment movement is at culvert inlets and the uphill side of elevated roads.

Potential soil erosion from range land is evaluated much like crop-land potential erosion. Grazing areas are first subdivided by slope class and the erodibility class of the soil (K). Then you make observations of soil erosion following high-runoff events during the time of year that the soil is most vulnerable to movement. Areas are classified according to site factors and observed soil erosion, and ultimately, rules-of-thumb will be developed that apply to your watershed. The decision process is set up as follows:

If: erodibility class of the soil is X, **and** slope steepness class is Y, **and**

grazing practice is Z,

Then: soil erosion potential is W.

You will map soil erodibility class and slope steepness class ahead of time. Information about grazing practices and soil erosion is gathered during site observations. The erodibility class of soils

(K) you will use for range land is the same that was developed for crop land. Use county soil surveys and the techniques described in the crop-land section (Task 5) to determine the erodibility class of soils. County soil surveys do not include soil typing on USFS land, so if USFS lands are to be assessed, use the soil resources inventory for the local district office. USFS soil inventories are not the same as county soil surveys and seldom contain the K values for each soil type, but most will at least have a low, moderate, and high erodibility rating for each soil. Assume that the USFS low rating corresponds with soils for which K is <.20, moderate corresponds with soils for which K is between .20 and .40, and high corresponds with soils for which K is >.40.

The soil steepness classes do not have to be as detailed for range land as for crop land, so soil steepness is compressed into two classes; 40% or less, or >40%. Use the same procedures described in Tasks 1 through 4 to record K class and slope steepness information on the Base Map, or simply display range-land information on the crop-land map. Map 6 in Appendix VI-A provides an example of a finished map showing information compiled on surface erosion potential for range land.

After mapping range-land information, create a database of observations on how combinations of site factors and grazing practices influence erosion patterns. Factors to note include erosion severity, plant condition, and soil conservation measures employed (methods described in the next few paragraphs). Observations are meant to be a collaborative process that includes not only your observations but ranchers and others with knowledge of grazing practices in the watershed. Assign a unique number to each field observation and mark and label the location on the map. Then, enter the information on Form S-13, Database for Tracking Field Observation and Mapped Information on Crop Land and Range Land, or the RANGE Worksheet. Table 23 provides an example of how site information and erosion observations are compiled for range land. Site observations are best conducted immediately after a high-runoff period and during the time of year when the land is more vulnerable to erosion. In regions that experience thunderstorms and rapid snowmelt, this time is from summer to spring; however, in some areas this window of vulnerability is probably during the winter. During a site observation, assign the area an erosion severity class, and record areas with moderate or high erosion severity as defined in the crop-land section.

Also note plant conditions and soil conservation measures used. Record the foliage and root mass condition of the plants as dense, moderate, or sparse. Examine evidence of soil conservation measures used by the rancher, and contact the rancher to determine these measures. Some soil conservation measures used for range land include:

- Rest rotation: The land is periodically not grazed during the growing season so plants have a chance to replace reserves.

- Controlled stocking: The number of animals is controlled so that forage is at least 4 to 6 inches after grazing and more than 50% of current growth is left intact.

- Distribution control: Animals are moved or excluded by fences so that certain areas do not become degraded (especially streamside areas).

- Plant improvement: The health of browsed plants is enhanced using combinations of fire, seeding, **scarification**, or fertilization.

Table 23. Example Form S-13: Database for tracking field observations and mapped information on crop land and range land.

Sub-Watershed	Observation	K Class	Slope Steepness Class	Plant Cover Condition	Grazing Practices	Actual Erosion	Runoff Event
Deer	701	Medium	<40	Dense	Normal	low	Observed after a late-summer thunderstorm
Deer	702	Medium	>40	Dense	Normal	moderate	Observed after a late-summer thunderstorm
Bear	703	Low	<40	Moderate	Rest rotation	low	Observed after a late-summer thunderstorm
Elk	704	Low	<40	Sparse	Controlled stocking	moderate	Observed after a late-summer thunderstorm
Skunk	705	High	<40	Sparse	Normal	moderate	Observed after a late-March snowmelt
Skunk	706	High	>40	Moderate	Plant improvement (2 years ago)	moderate	Observed after a late-March snowmelt
Skunk	707	High	<40	Sparse	Plant improvement (3 years ago)	low	Observed after a late-March snowmelt

Summary: Range Land

After a number of observations have been included in the database, patterns may develop. For example, combinations of the soil K factor, slope steepness, and plant condition may result in moderate erosion when normal grazing practices are used, but low erosion when certain soil conservation measures are added. Compile site observations on Form S-14, Summary of Crop Land and/or Range Land, Grazing Erosion Observations. Table 24 provides an example showing a comparison of soil erosion under normal grazing practices to soil erosion under controlled stocking. You may wish to construct other tables focusing on other combinations of grazing practices and site conditions. Each table will include various combinations of site conditions and grazing practices, and the number of sites with low, medium, or high erosion. The number of sites can also be expressed as a percentage of the row total to provide a clearer picture of how combinations compare. These tables may be used to target combinations of site factors that indicate sites where improved grazing practices would yield the greatest reduction in moderate to high soil erosion. This approach tailors the information to your watershed; from your own observations, you can begin to develop rules-of-thumb that work for your watershed.

Source 7. Surface Erosion from Burned Areas

Recently burned areas can have a high potential for erosion within the first year or two following the fire. The removal of surface organic matter by fire can release soil that has collected uphill of the

Table 24. Example Form S-14: Summary of range-land erosion observations.

K Class	Slope Class	Grazing Practice	Plant Condition	Number of Observations by Erosion Class			
				Low	Mod-erate	High	Total
Moderate	<40	Normal	sparse	4	2	0	6
Moderate	<40	Normal	mod./dense	8	0	0	8
Moderate	<40	Controlled stocking	sparse	8	1	0	9
Moderate	<40	Controlled stocking	mod./dense	7	0	0	7
Moderate	>40	Normal	sparse	3	4	0	7
Moderate	>40	Normal	mod./dense	4	2	0	6
Moderate	>40	Controlled stocking	sparse	4	3	0	7
Moderate	>40	Controlled stocking	mod./dense	5	2	0	7
High	<40	Normal	sparse	2	5	2	9
High	<40	Normal	mod./dense	3	4	0	6
High	<40	Controlled stocking	sparse	2	7	1	10
High	<40	Controlled stocking	mod./dense	3	6	0	9
High	>40	Normal	sparse	0	6	2	8
High	>40	Normal	mod./dense	0	6	0	6
High	>40	Controlled stocking	sparse	2	6	0	8
High	>40	Controlled stocking	mod./dense	3	2	0	5

organic matter. It also leaves the surface vulnerable to **rain-splash erosion**. Under some conditions, the burned soil surface will actually temporarily repel water. This leads to more of the runoff occurring along the soil surface, thereby causing surface soil movement. Water-repelling soil conditions usually disappear after a few runoff events in Oregon. Fires can also bare the banks of draws and streams. Soil raveling from those bared and steep slopes immediately adjacent to the channel can cause them to partially fill with loose sediment. These sediments are then vulnerable to downstream movement during runoff events.

Fire containment activities such as the construction of temporary access roads and fire lines can sometimes lead to significant inputs of sediment into streams. Access road and fire lines are often built in a hurry and sometimes without much consideration to where excavated soil is placed. Unless these temporary roads and fire lines are carefully obliterated or rehabilitated after the fire, they can also become sources of sediment. Erosion is usually caused by water running down the surfaces of the roads or trails, and is made worse if the fire area later attracts motorcyclists, all-terrain-vehicles, or 4-wheel-drive operators.

Not all fires cause significant increases in stream sediment. Cool fires that consume only part of the surface organic matter may not be a source of accelerated erosion. Fires that skip over stream channels also may have little effect on soil erosion.

In some areas, the forests are now intentionally burned at a frequent interval in order to decrease the likelihood of a catastrophic wildfire that would kill large trees or harm the soil. For many decades, intentional burns have also been used to remove **slash** and brush following the harvest of timber, to treat fields in anticipation of the next crop, or to manage range-land plant health and composition. Nevertheless, recent air quality control measures are making it hard for landowners to find windows of opportunity to burn. The main goal of these air quality control measures is to keep smoke out of populated areas. The incidence of intentional burns has decreased substantially in some parts of the state as a result of the air quality control measures.

Evaluation of surface erosion from burned areas in the watershed will be limited to identifying the presence of recent burns, if any. Your assessment will result in mapping of recently burned areas and combining of various site factors with observations on obvious evidence of erosion.

Task 1

The first step for compiling information on recently burned areas is to determine the boundaries of the fire and transfer them to a topographic base map. You may be able to do this simply by driving through the burned area and noting the relationship of the fire boundary to roads, streams, and ridges. You may also want to use aerial photographs for large burned areas and especially areas that did not burn uniformly. The ODF, USFS, or BLM will sometimes have aerial photographs flown immediately after large-scale fires, so check with them first.

Task 2

Segregate the burn area into two slope steepness classes (40% or less, >40%) and two K factor classes (.40 or less, >.40), as described in the sections on surface erosion from crop land and range land. Add information about fire intensity to the map. This is best done using a combination of site observations and aerial photographs, although you may be able to complete this without aerial photographs if there is good road access into the burn area. Focus mostly on how the fire burned when it encountered streams and draws. Classify according to the three burn intensity classes described below.

- Cool: Original surface organic material is mostly intact. Finer organic material may have been consumed. A majority of shrubs and trees near streams and draws are alive.

- Moderate: Most of the finer original organic material is consumed. About one-half of coarser material still intact. About one-half of shrubs and trees near streams are alive.

- Hot: Nearly all original organic material is consumed. Bare soil dominates. Only larger logs remain on surface. Nearly all shrubs and trees near streams killed by fire.

Each map polygon will have an associated K class, slope steepness class, and burn intensity. For each of the polygons within the fire area, make field observations on the condition of the access roads and fire lines. Note any activity that has led to degradation of access roads and fire lines, whether they are gullied, and whether they have been **waterbarred** and the condition of waterbars. Make field observations of the erosion class of the polygon as indicated by rilling, sediment deposits along or within channels, or sediment pooling at the upstream end of culverts. Classify erosion as follows:

- High: Numerous rills. Extensive deposits of sediment on flatter areas near or in streams and draws. Deep sediment deposits at culvert inlets or at the uphill sides of elevated roads.

- Moderate: Some rills. Shallow deposits of sediment on flatter areas near streams and draws. Shallow sediment deposits at culvert inlets or at the uphill of elevated roads.

- Low: Otherwise.

Map 7 in Appendix VI-A provides an example of a finished map showing information compiled on erosion potential for burned land.

Record information on Form S-15, Database for Tracking Field Observations and Mapped Information on Burned Areas, or the BURN Worksheet. Determine the area of each polygon using a grid or map wheel and add the area to your table. Table 25 provides an example of compiled information.

Summary: Burned Lands

The evaluation of burned areas within the watershed does not lend itself to a summary that can begin to link burn conditions and site conditions to erosion potential. It is mostly limited to a summary of primary information about a single to a few burns. You will complete Form S-16, Summary of Areal Extent of Erosion Classes Within Burns, or the SEDBURN1 Worksheet. Table 26 provides an example of Form S-16, illustrating a format for comparing acreage by erosion class for two fires.

Table 25. Example Form S-15: Database tracking field observations and mapped information on burned areas.

Burn name: Sow Creek fire
Date area burned: 8/98
Date evaluated: 6/99 and 7/99
Years between evaluation and fire: 1.2
Type of fire: Wildfire
Land cover prior to fire: Forested with some meadows on south slopes

Observation	K Class	Slope Steepness Class	Burn Intensity	Condition of Access Roads and Fire Lines	Erosion Class	Area (acres)
801	<.40	<40	Low	Good condition; all waterbarred	low	1,250
802	<.40	>40	Moderate	Good condition; all waterbarred	moderate	510
803	<.40	<40	Low	Good condition; all waterbarred	moderate	450
804	<.40	<40	Moderate	Deeply rutted; 4WD activity	moderate	1,100
805	>.40	<40	Moderate	Deeply rutted; 4WD activity	high	970
806	>.40	>40	Hot	Deeply rutted; 4WD activity	high	410
807	>.40	<40	Hot	Good condition; all waterbarred	moderate	960

Table 26. Example Form S-16: Summary of areal extent of erosion classes within burns.

Burn Name	Area and % of Total Area by Erosion Class							
	Low Erosion		Moderate Erosion		High Erosion		Total	
	Acres	%	Acres	%	Acres	%	Acres	%
Sow Creek fire	1,250	22	3,020	53	1,380	25	5,650	100
Little Pig Creek fire	420	17	1,120	44	980	39	2,520	100

Source 8. Other Discrete Sources

Other discrete sources of accelerated soil erosion and stream sedimentation may be present in your watershed. This manual does not include procedures for evaluating these sources, but they should be documented during this assessment process. Your documentation should include not only those sources that currently are a source of sediment, but also those that have strong potential to become a source in the future. A partial listing of other discrete sediment sources and their potential influence on streams follows:

- In-channel gold mining: Periods of chronic turbidity; deposition of fine sediments.
- Mining spoil piles: **Calving-off** of piles or surface erosion into nearby streams; turbidity and deposition of fine sediments.
- Gravel pit drainage: Chronic turbidity.
- Winter animal holding areas near streams: Trampling of banks—surface runoff over compacted soils; chronic turbidity; deposition of fine sediments.
- Road sanding: Chronic turbidity; deposition of fine sediments.
- Wind erosion: Chronic turbidity; deposition of fine sediments.

Step 4: Evaluate Confidence in Assessment

Rate your confidence in the quality and completeness of information you compiled for your watershed assessment of sediment sources (Form S-17, Confidence Evaluation). For each source, rate the **quality** of information (where it existed for the watershed) as Good, Fair, or Poor; rate the completeness of the information (Not Missing, Partially Missing, Mostly Missing). Explain the factors that prevented you from compiling good information for the entire watershed. Skip sources that you did not include in your assessment.

REFERENCES

Alt, D.D., and D.W. Hyndman. 1996. Roadside Geology of Oregon. Mountain Press Publishing Co. Missoula, Montana.

Anderson, H.W. 1954. Suspended Sediment Discharge as Related to Streamflow, Topography, Soil, and Land Use. Transactions of the American Geophysical Union 35(2):268-281.

Benda, L., and T. Dunne. 1987. Sediment Routing by Debris Flow. Pages 213-224 in: Erosion and Sedimentation in the Pacific Rim. IAHS Publication No. 165.

Bilby, R.E. 1985. Contributions of Road Surface Sediment to a Western Washington Stream. Forest Science 31(4):827-838.

Bilby, R.E., K. Sullivan, and S.H. Duncan. 1989. The Generation and Fate of Road-Surface Sediment in Forested Watersheds in Southwestern Washington. Forest Science 35(2):453-468.

Bisson, P.A., and R.E. Bilby. 1982. Avoidance of Suspended Sediment by Juvenile Coho Salmon. North American Journal of Fisheries Management 2:371-374.

Booth, D. 1991. Urbanization and the Natural Drainage System—Impacts, Solutions, and Prognosis. Northwest Environmental Journal 7(1):93-118.

Duncan, S.H., R.E. Bilby, J.W. Ward, and J.T. Heffner. 1987. Transport of Road-Surface Sediment Through Ephemeral Stream Channels. Water Resources Bulletin 23(1):113-119.

Lisle, T.E. 1987. Channel Morphology and Sediment Transport in Steepland Streams. Pages 287-298 in: Erosion and Sedimentation in the Pacific Rim. IAHS Publication No. 165.

Megahan, W. F. 1987. Increased Sedimentation Following Helicopter Logging and Prescribed Burning on Granitic Soil. Pages 259-260 in: Erosion and Sedimentation in the Pacific Rim. IAHS Publication No. 165.

Newcombe, C.P., and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Systems. North American Journal of Fisheries Management 11:72-82.

Sessions, J., J.C. Balcom, and K. Boston. 1987. Road Location and Construction Practices: Effects on Landslide Frequency and Size in the Oregon Coast Range. Western Journal of Applied Forestry 2(4):119-124.

Tasker, G.D., and N.E. Driver. 1988. Nationwide Regression Models for Predicting Urban Runoff Water Quality at Unmonitored Sites. Water Resources Bulletin 24(5):1091-1101.

GLOSSARY

borrow pit: An area where rock or soil is excavated from the hillside.

cable yarding scar: An area within a timber harvest unit that is bare due to logs dragging on the ground as they are being moved by cables to the road.

calving-off: The rapid movement of soil from the steep leading edge of a large landslide.

cross-drain culvert: A culvert that drains water which collects within the inside ditch of a road to the outside slope of the road.

cut slope: The sloping excavated surface on the inside of a road.

detention pond: A pond constructed to temporarily store water, thereby allowing sediment to settle out of the water.

draw: A very small stream that may have flowing water only during the wet season.

fill slope: The outer edge of a road that extends downhill of the road surface.

full-bench construction: A practice of constructing a road on steeper slopes whereby excess excavated soil or rock is hauled away in trucks to a stable storage area rather than disposed of by pushing it downhill of the road.

Geographic Information System (GIS): A computer system designed for storage, manipulation, and presentation of geographical information such as topography, elevation, geology etc.

harvest unit: An area from which trees have been harvested.

hazard delineation: Mapping the boundaries of areas with inherently unstable slopes.

landing: An area adjacent to a road where logs accumulate and are loaded onto trucks during timber harvesting.

pipe-arch culvert: A corrugated pipe that is wider than it is tall.

ravel: Erosion caused by gravity, especially during rain, frost, and drying periods. Often seen on steep slopes immediately uphill of roads.

recurrence interval(s) (return interval): Determined from historical records. The average length of time between two events (rain, flooding) of the same size or larger. Recurrence intervals are associated with a probability. (For example, a 25-year flood would have a 4% probability of happening in any given year.)

rills: Very shallow gullies that can develop on a hillslope that is eroding.

rock pit: An area where rock is excavated from a hillside and is usually processed as road-surfacing material.

scarification: The mechanical loosening of compacted soil usually using subsoilers attached to a crawler tractor.

sheet erosion: Soil erosion caused by surface water that occurs somewhat uniformly across a slope.

skid trail: Trail that develops when logs are hauled by ground-based machinery to a landing.

slash: Detached tree limbs, branches, and other woody material that is left on the ground after a timber harvest is completed.

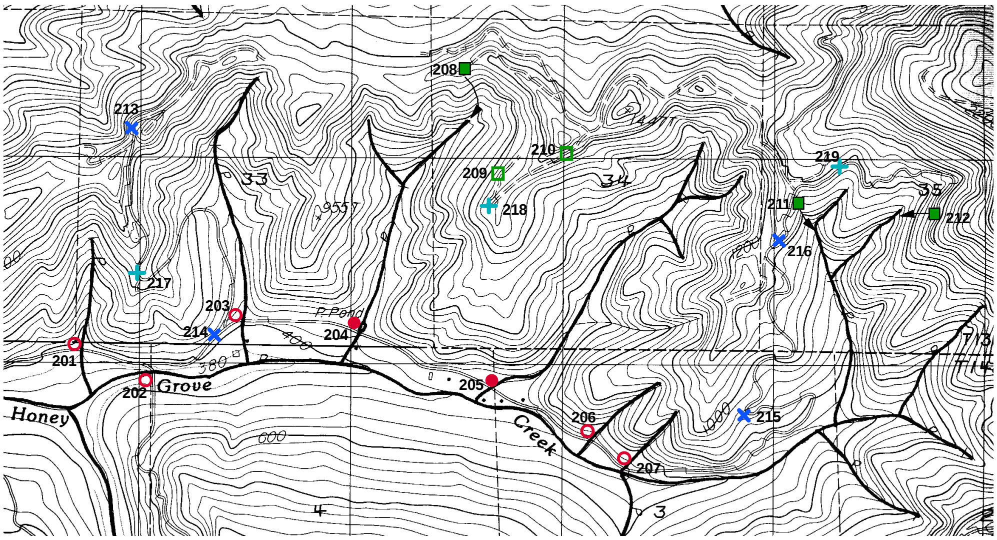
stereoscope: An instrument used to observe stereo aerial photographs in three dimensions.

waterbar: A deep trough in a skid trail or road that is excavated at an angle to drain surface water from the skid trail or road to an adjacent area that is not compacted.

Appendix VI-A
Examples of Finished Sediment-Source Maps

APPENDIX VI-A: EXAMPLES OF FINISHED SEDIMENT - SOURCE MAPS

Road Instability



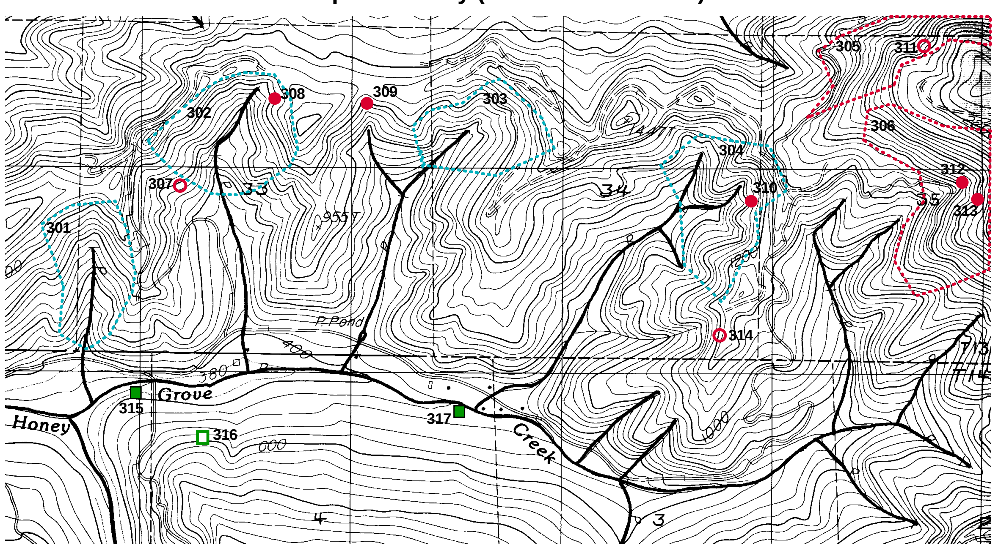
Stream culvert; very low to moderate
high to extremely high

Road failure; reached stream
id not reach stream

Cracks and slumps
Water flowing over fill

Map 1. Example of a finished map showing information compiled for both existing and potential road instability sites.

Slope Instability (not related to roads)



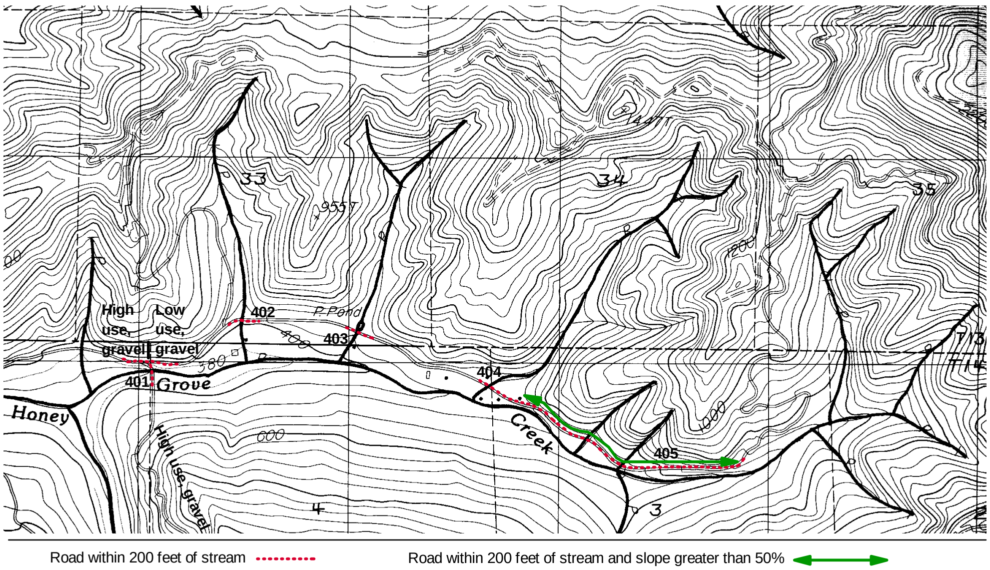
Existing shallow landslides:
reached stream
did not reach stream

Existing deep-seated landslides:
reached stream
did not reach stream

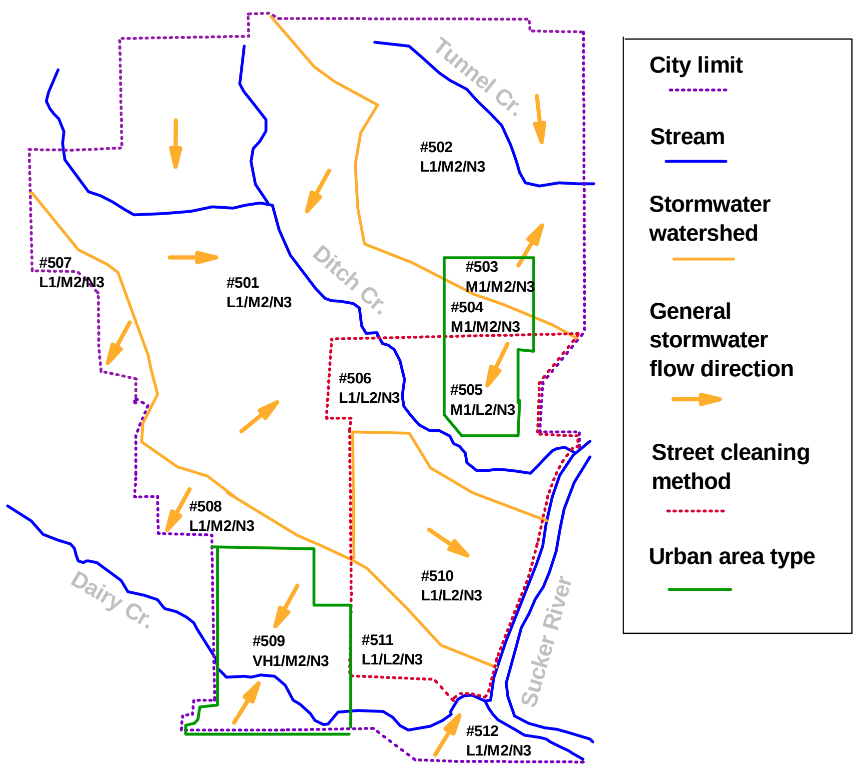
Potential for shallow landslides:
High
Extreme

Map 2. Example of a finished map showing information compiled on slope instability not related to roads.

Rural Road Runoff

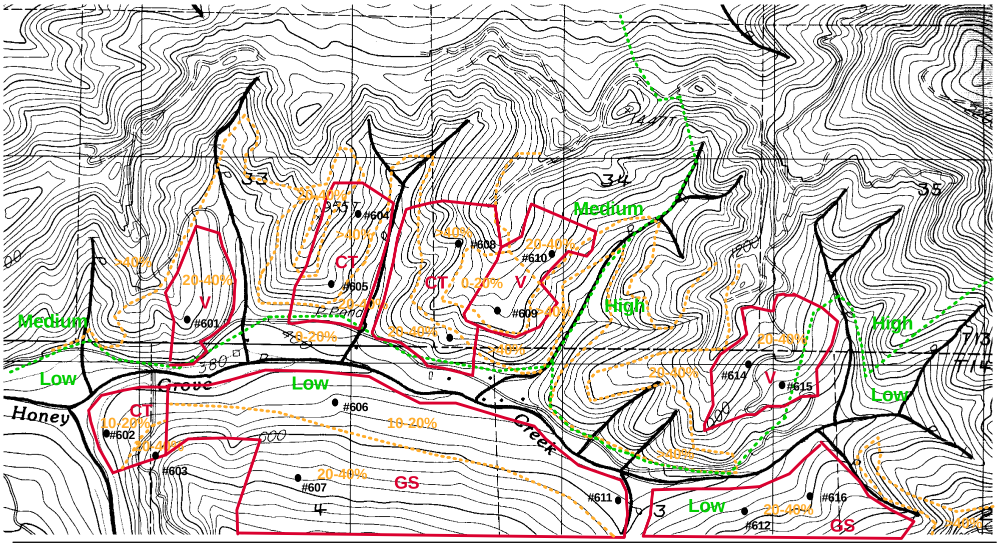


Map 3. Example of a finished map showing information compiled on rural road runoff.



Map 4. Example of a finished map showing basic information compiled on urban runoff.

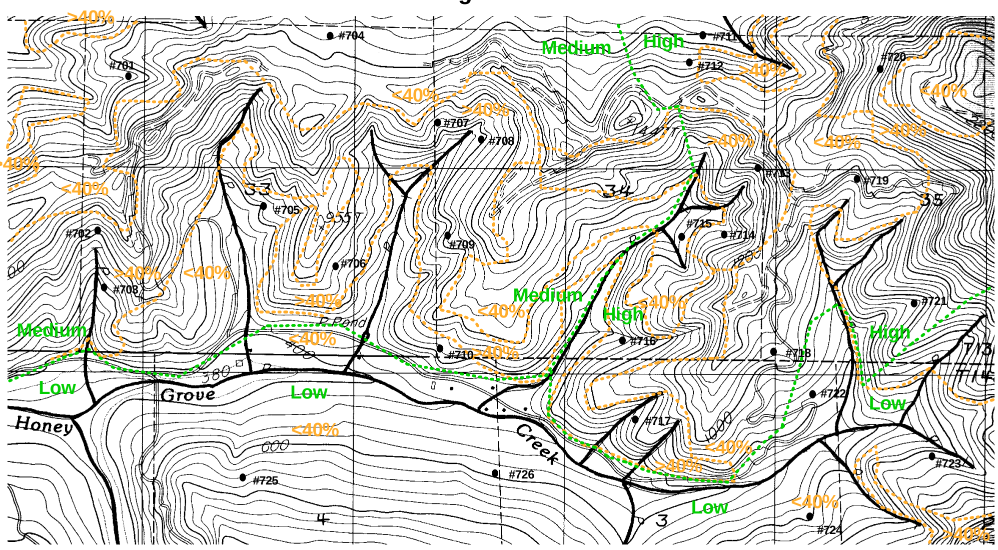
Crop Land



Slope steepness boundaries K class Field boundary Observations #xxx

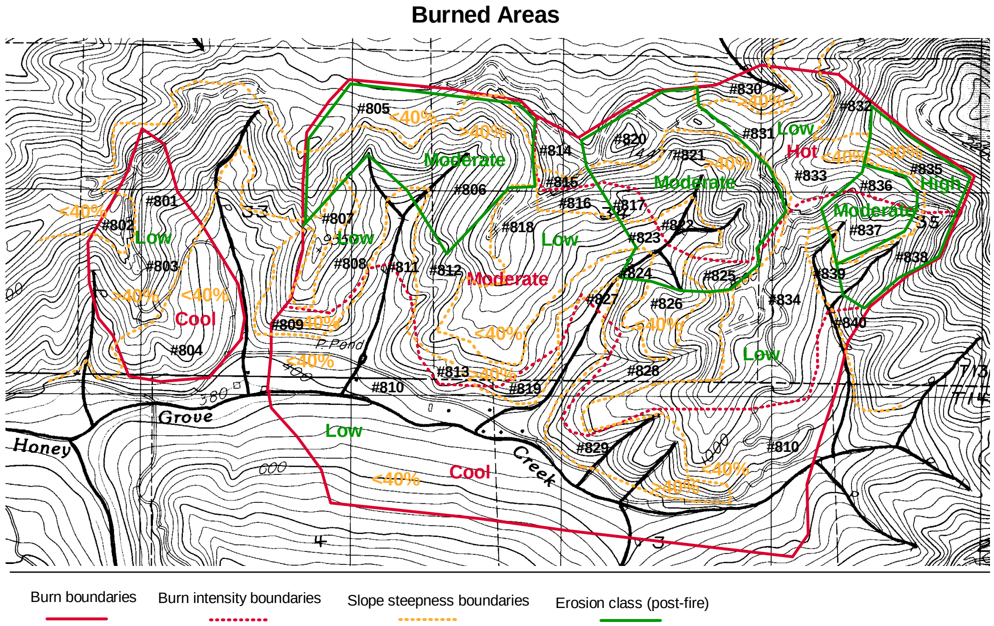
Map 5. Example of a finished map showing information compiled on surface erosion from crop land.

Range Land



Slope steepness boundaries K class Observations #xxx

Map 6. Example of a finished map showing information compiled on surface erosion potential for range land.



Map 7. Example of a finished map showing information compiled on erosion potential for burned land.

Appendix VI-B
Blank Forms

Form S-1: Screen for Sediment Sources in a Watershed

Watershed:

Analyst's Name:

Watershed Name: The River Why	Observations	Priority
Source 1: Road instability Are rural roads common in watershed? Do many road washouts occur following high rainfall? Are many new roads or road reconstruction planned?		
Source 2: Slope instability (not related to roads) Are landslides common in watershed? Many high-sediment, large-scale landslides?		
Source 3: Rural road runoff Are sediment-laden runoff from rural roads and turbidity in streams common? Is there a high density of rural roads?		
Source 4: Urban runoff Are many portions of the watershed urbanized? Importance of these tributaries to watershed council:		
Source 5: Surface erosion from crop land Is there much crop land in the watershed? Is there much evidence of sediment in streams flowing through crop land?		
Source 6: Surface erosion from range land Is there much range land in watershed? Is there evidence of sediment in streams flowing through range land?		
Source 7: Surface erosion from burned land Have many burns occurred recently (last 5 years), especially hot fires? Was there much sediment created by these burns?		
Source 8: Other discrete sources of sediment List or identify any other suspected sources of sediment:		

Form S-2: Information on Existing Road-Related Instability

Watershed:

Analyst's Name:

Num.	Subwatershed	Landslide Type	Reached Stream?	Distance Traveled (ft)	Road Location

Number: Unique identification number.

Subwatershed: Subwatershed in which landslide occurs.

Landslide Type: Debris flow = initiates as shallow landslide in steep area and then flows down a channel, picking up additional soil, logs, and water. Road prism failure = downhill movement of the road cut or road fill; does not initiate a debris flow. Culvert washout = road fill partially or completely missing where the road crosses a stream.

Reached Stream?: Whether or not the landslide material ended up in the stream.

Distance traveled: The distance from initiation point to where the landslide stopped (not applicable to culvert washouts).

Road Location: General location of road: near ridge, mid-slope, near stream.

Form S-3: Culvert Capacity and Risk of Large Amounts of Sediment Entering Stream

Watershed:

Analyst's Name:

1 Sub-watershed	2 Num.	3 Road Owner-ship	4 Current Culvert/ Pipe-Arch Size	5 Current Culvert Capacity (cfs)	6 ODF Peak-Flow Value (cfs/mi²)	7 Drainage Area (mi²)	8 50-Year Peak Flow (Col. 6x7) (cfs)	9 Culvert/ Pipe-Arch Size Needed for 50-Year Peak Flow	10 Ratio of 50-Yr Flow to Current Capacity	11 Fill Height (ft)	12 Hazard Rating *

* Hazard rating:

Very low	Fill height is 15 feet or less and ratio is less than 1.25.
Low	Fill height is greater than 15 feet and ratio is less than 1.25.
Moderate	Fill height is 15 feet or less and ratio is between 1.25 and 1.75.
High	Fill height is greater than 15 feet and ratio is between 1.25 and 1.75; or, fill height is 15 feet or less and ratio is between 1.76 and 3.
Very high	Fill height is greater than 15 feet and ratio is between 1.76 and 2.99; or, fill height is 15 feet or less and ratio is greater than 3.
Extreme	Fill height is greater than 15 feet and ratio is greater than 3.

Form S-4: High-Risk Road Segments for Existing Roads

Watershed:

Analyst's Name:

Sub-Watershed	Num.	Feature Type	Hazard Rating of Culvert	Road Ownership

Form S-5: Summary of Information on Road Instability

Watershed:

Analyst's Name:

Subwater-shed	Area (mi²)	Road Failures that Reached Streams		Sites with High-Risk Culverts		Sites with Cracks and Slumps		Sites with Water Flowing Over Fills	
		#	Density (#/mi².)	#	Density (#/mi².)	#	Density (#/mi².)	#	Density (#/mi².)
Total									

Form S-6: Current Landslides not Related to Roads

Watershed:

Analyst’s Name:

Sub-watershed	Num.	Type of Landslide	Age of Vegetation (years)	Landslide Reached Stream?	Distance Landslide Traveled (feet)	Slope Steepness at Initiation Point (%)

Form S-7: Potential for Debris Flows

Watershed:

Analyst's Name:

Subwatershed	Areas Predicted to be High Risk for Debris Flows (mi²)		
	High Hazard	Extreme Hazard	Combined

Form S-8: Summary of Information on Slope Instability (not related to roads)

Watershed:

Analyst's Name:

Sub-Watershed	Area (mi^2)	Current Landslides				Debris-Flow High-Risk Areas (combined high and extreme)	
		Shallow Landslides		Deep-Seated Landslides			
		Number (#)	Density (#/mi^2.)	Number (#)	Density (#/mi^2.)	Area (mi^2.)	Percent
Total							

Form S-9: Basic Information on Road Segments Close to Streams with Steep Slopes

Watershed:

Analyst's Name:

Subwatershed	Num.	Distance <200' from Stream (feet)	Distance <200' from Stream and Slope >50% (feet)	Road Surface	Road Use

Form S-10: Summarized Runoff-Related Information for a Single Road

Watershed:

Analyst's Name:

Road Name	Variable	Classification	Length (feet)	Occurrences (#)

Form S-11: Summary of Information on Road Runoff—Basic Assessment

Watershed:

Analyst's Name:

Sub-watershed	Area (mi^2)	Roads < 200' from Stream		Roads < 200' from Stream **and** Slope > 50%		Roads < 200' from Stream **and** High Use		Roads < 200' from Stream **and** Low Use	
		Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)

Form S-12: Information on Urban Runoff Polygons

Watershed:

Analyst's Name:

Stormwater Subwatershed	Polygon #	Polygon Area (acres)	Area as a Percentage of Total	1. Sediment Production	2. Street Cleaning	3. Sediment Removal
Total						

Form S-13: Database for Tracking Field Observation and Mapped Information on Crop Land and Range Land

Watershed:

Analyst's Name:

Sub-Watershed	Observation	K Class	Slope Steepness Class	Crop/ Plant Cover Cond-ition	Farming/Grazing Practices	Field Condition	Actual Erosion	Runoff Event

Form S-14: Summary of Crop Land and/or Range Land, Grazing Erosion Observations

Watershed:

Analyst's Name:

K Class	Slope Class	Farming/Grazing Practice	Field Condition/Plant Condition	Number of Observations by Erosion Class			
				Low	Mod-erate	High	Total

Form S-15: Database Tracking Field Observations and Mapped Information on Burned Areas

Watershed:

Analyst's Name:

Burn name:
Date area burned:
Date evaluated:
Years between evaluation and fire:
Type of fire:
Land cover prior to fire:

Observation	K Class	Slope Steepness Class	Burn Intensity	Condition of Access Roads and Fire Lines	Erosion Class	Area (acres)

Form S-16: Summary of Areal Extent of Erosion Classes Within Burns

Watershed:

Analyst's Name:

Burn Name	Area and % of Total Area by Erosion Class							
	Low Erosion		Moderate Erosion		High Erosion		Total	
	Acres	%	Acres	%	Acres	%	Acres	%

Form S-17: Confidence Evaluation

Rate your confidence in the quality and completeness of information you compiled for your watershed assessment of sediment sources. For each source, rate the **quality** of information (where it existed for the watershed) as Good, Fair, or Poor; rate the completeness of the information (Not Missing, Partially Missing, Mostly Missing). Explain the factors that prevented you from compiling good information for the entire watershed. Skip sources that you did not include in your assessment.

1. Rural road instability

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing _______

Factors that prevented compilation of good information for the entire watershed:

2. Rural road runoff

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing _______

Factors that prevented compilation of good information for the entire watershed:

3. Slope instability (not related to roads)

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing _______

Factors that prevented compilation of good information for the entire watershed:

Form S-17: page 2.

4. Urban runoff

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing _______

Factors that prevented compilation of good information for the entire watershed:

____
____
____
____
____

5. Surface runoff from crop land

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing _______

Factors that prevented compilation of good information for the entire watershed:

____
____
____
____
____

6. Surface runoff from range land

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing _______

Factors that prevented compilation of good information for the entire watershed:

____
____
____
____
____

Form S-17: page 3.

7. Surface runoff from burned areas

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing ______

Factors that prevented compilation of good information for the entire watershed:

____
____
____
____
____

8. Other discrete sources of sediment

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing ______

Factors that prevented compilation of good information for the entire watershed:

____
____
____
____
____