Chapter VIII

PROCEDURAL EXAMPLES

this chapter has been prepared by the coordinators for chapters III-VII

CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This chapter provides examples of silvicultural activities on two hypothetical watersheds—one in a rain dominated hydrologic region (Grits Creek) and one in a snow dominated region (Horse Creek). It demonstrates the procedural analyses that would be conducted to evaluate the potential non-point source pollution associated with each example. Where such potential non-point source pollution would exceed established water quality objectives, the procedure for considering control opportunities, thereby revising the original silvicultural plan, is explained.

All figures, tables, and worksheets mentioned within this chapter are referenced according to their original chapter number. Only figures unique to chapter VIII have been given "VIII" numbers.

PROCEDURAL EXAMPLE FOR GRITS CREEK—A RAIN DOMINATED HYDROLOGIC REGION

DESCRIPTION OF AREA AND PROPOSED SILVICULTURAL ACTIVITY

Foresters from the Appalachian Hardwood Products Company[1] inventoried a 356-acre tract of hardwoods (fig. VIII.1) owned by the company in the southern Appalachians. The watershed is at a latitude of 35°N. The baseline leaf area index (LAI) is 6. Dominant aspect is southwest, and the average rooting depth for the watershed is 4 feet. The tract was divided into timber compartments A, B, and C (fig. VIII.1) based upon stand composition; management prescriptions were proposed for each. A description of each timber compartment and the prescribed management options follows.

Compartment A is an 84-acre stand along the ridgetop of the watershed. It is composed of low quality northern red oak and a dense laurel-rhododendron understory. Trees are short and branchy because of repeated ice damage, and the growth potential is low in these steep, rocky, shallow soils. Because of high recreation use and the poor site condition for timber production, the company forester recommended that no silvicultural activity be conducted.

Poor oak-hickory stands are present on the lower slopes in compartment B, producing little timber; but soils are deep, well watered, and capable of timber production. The proposed residual leaf area index is estimated to be 2. The forester recommended that the 180-acre timber stand be regenerated by clearcutting all woody vegetation after harvesting mechantable timber.

Compartment C, 92 acres, contains a 40-year-old stand of excellent yellow poplar mixed with overmature remnants of other cove hardwoods. It was originally estimated that the yellow poplar would be from 85 to 120 feet high at age 50, but the growth rate of the overcrowded stand has slowed during the last 7 years. A thinning has been recommended by the company forester to increase growing space for crop trees. Additional cuts will be required at 20-year intervals. The proposed residual leaf area index is estimated to be 3. Compartment C would be reevaluated for a possible clearcut in 40 years, in accordance with the company's policy of even-aged management. Then the site would be regenerated to yellow poplar or other desirable species.

Based upon these management prescriptions, engineering and harvesting system analyses were made. Two alternatives were developed for analysis using the basic steps outlined in "Chapter II: Control Opportunities," Appendix II.A, example two. The significant resource impacts were "bare soil" and "compaction." Based on a knowledge of the site and professional judgment, the following control opportunities were selected.

1. Prescribe yarding and skidding layout.
2. Revegetate treated areas promptly, as local conditions dictate.

The two engineering and harvesting alternatives were based on different yarding systems, road locations, and revegetation prescription. Alternative A was based on tractor yarding with road locations shown in figure VIII.2. Alternative B was based on cable yarding systems and required an additional road (fig. VIII.2) to achieve reasonable yarding distances. Revegetation of all roads, including running surfaces, was planned in Alternative B. Both alternatives were analyzed and the results compared to water quality objectives.

Water Quality Objectives

Water quality objectives were established for the Grits Creek area by the Regional Planning Commission in conjunction with State 208 planners. The established objectives required that channel stability be maintained, that total potential sediment discharge be limited to 25.5 tons/yr and that water temperature increases be no greater than 3° F.

[1]This is intended to be a fictitious company name; any similarity to an actual company is entirely coincidental.

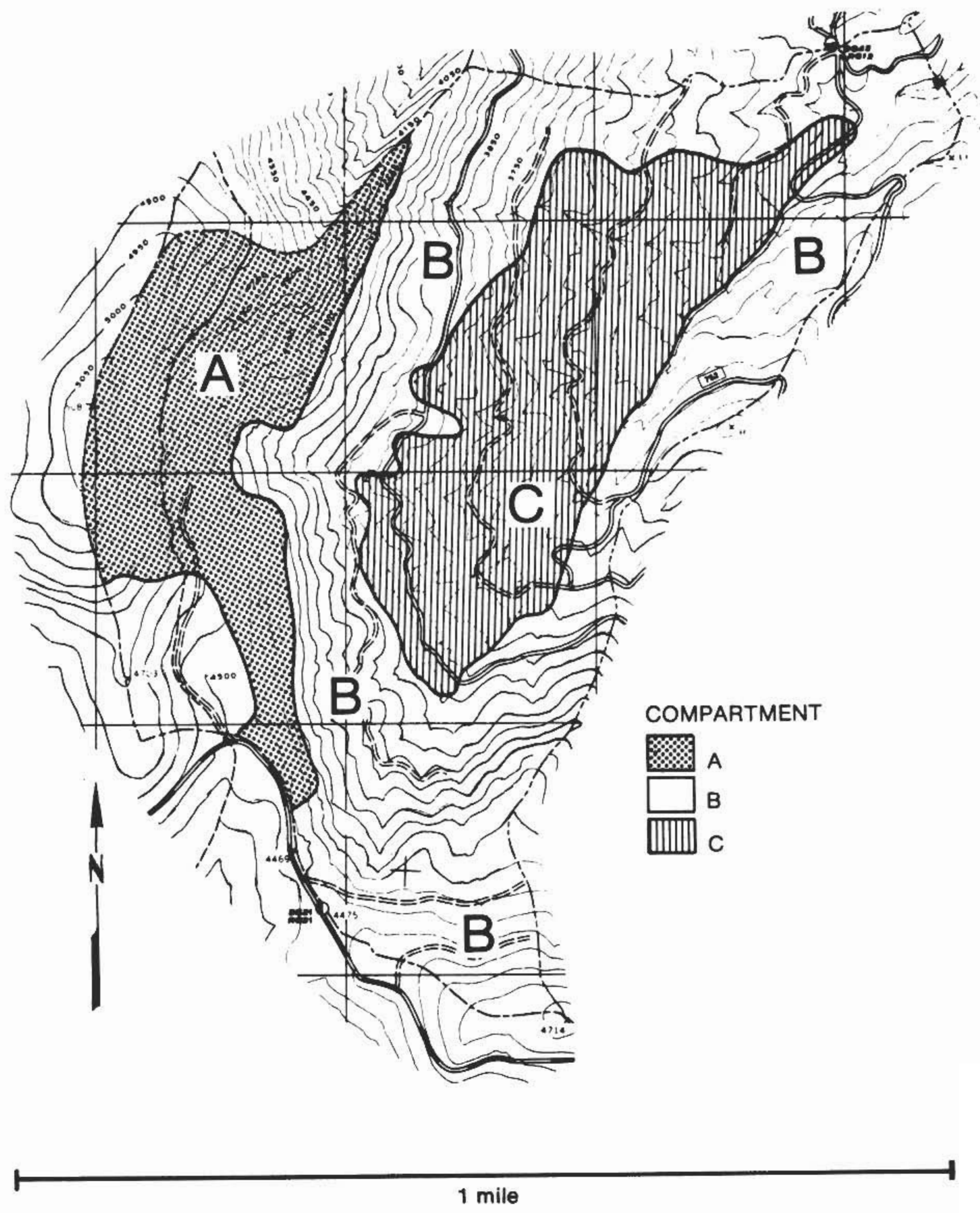

Figure VIII.1.—Timber compartments for Grits Creek watershed.

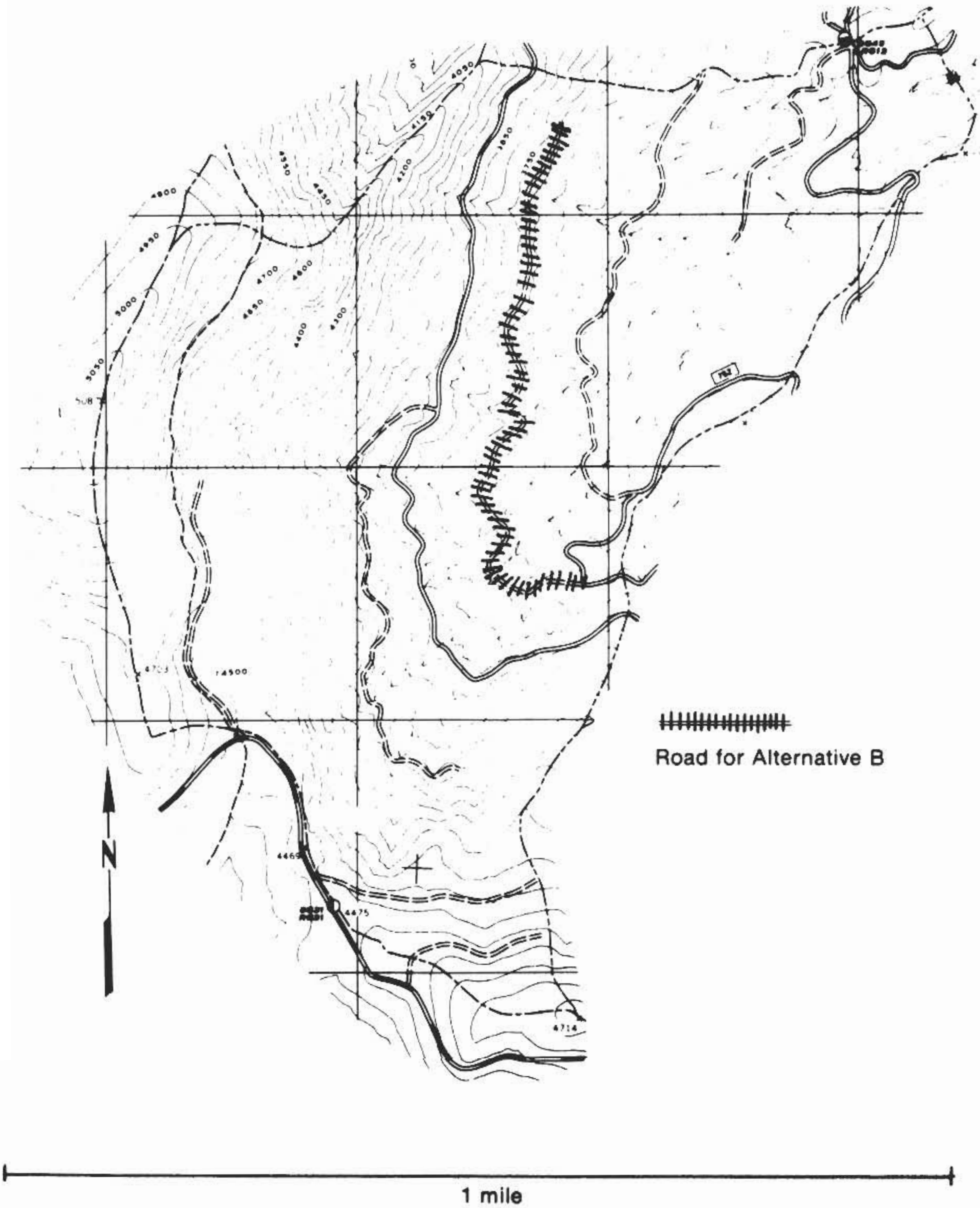

Figure VIII.2.—Road constructed for Alternative B, Grits Creek watershed.

DATA BASE

The collected data are presented in table VIII.1 and worksheets IV.1, IV.2, V.1, and VII.2. (Proposed and revised worksheets are located at the end of section "Procedural Example for Grits Creek—. . .") Soils were mapped by the Soil Conservation Service. All data presented are required, unless otherwise specified, for a complete water resource evaluation of Grits Creek, the major drainage in the tract. The complete evaluation requires analyses within the following categories (numbers for the corresponding chapters in this handbook appear in parentheses):

Hydrology (III)
Surface Erosion (IV)
Total Potential Sediment (VI)
Temperature (VII)

HYDROLOGY ANALYSIS

The hydrology analysis serves as a guide to estimate change in potential streamflow associated with silvicultural activities in rainfall dominated regions. The methodology and procedures presented in this document are only guidelines to complement professional judgment for a particular situation.

Water Available For Streamflow— Existing Conditions

Step 1. — The first step in the hydrologic evaluation of Grits Creek is to estimate the water available for streamflow under existing conditions using worksheet III.1. The necessary procedures are outlined below. (Numbers in parentheses refer to items or columns on the worksheet.)

(1) Watershed name. — Grits Creek may be treated as a single watershed unit for hydrologic evaluation (see "Chapter III: Hydrology").

(2) Hydrologic region. — Grits Creek is located in hydrologic region 2, Appalachian Mountains and Highlands. The region is also described in chapter III.

(3) Total watershed area. — Drainage size is 356 acres.

(4) Latitude. — The latitude of Grits Creek is 35°N. This is necessary input since evapotranspiration was found to be a partial function of latitude in region 2.

(5) Season. — The seasons for rainfall dominated regions are: fall (September, October, November); winter (December, January, February); spring (March, April, May); and summer (June, July, August).

(6) Compartment. — The entire watershed is considered to be unimpacted under existing conditions (i.e., no areas affected by previous silvicultural activities).

(7) Silvicultural state. — Watershed areas are grouped into zones of similar hydrologic response as identified by silvicultural or vegetational state. For Grits Creek, the only silvicultural state is "forested." There is a single silvicultural prescription for the existing condition consisting of a single silvicultural state — forested.

(8) Area, acres. — The silvicultural zone is "forested," and this forested area is 356 acres.

(9) Area, %. — This refers to the percentage of the prescription area in each silvicultural state. In this case, the forested area is 100 percent (1.00 as a decimal percent) of the prescription area.

(10) Precipitation. — Enter estimates of seasonal precipitation to the nearest 0.1 cm. For Grits Creek, precipitation averaged 23.3, 75.2, 60.5, and 27.0 cm for fall, winter, spring, and summer, respectively. Analysis requires precipitation and evapotranspiration to be entered in centimeters.

(11) Baseline ET. — Baseline evapotranspiration (ET) for a latitude of 35°N is taken from figure III.11. Respective values for fall, winter, spring, and summer are 20.1, 8.9, 13.0, and 39.1 cm.

(12) Basal area. — Since the leaf area index is known, basal area is not needed.

(13) Leaf area index. — The leaf area index has been estimated as 6 for Grits Creek. Leaf area index does not change with seasons since leaf fall is taken into account when ET estimates are determined.

(14) ET modifier coefficient. — Evapotranspiration modifier coefficients, as functions of leaf area index and season, are obtained from figure III.16. For undisturbed forested areas, the ET modifier coefficent is 1.0 for all seasons.

(15) Rooting depth modifier coefficient. — Rooting depth modifier coefficients are taken from figure III.19 for an average soil depth. In this example, all rooting depth modifier coefficients are equal to 1.0.

Table VIII.1.--A summary of information required for the analysis procedures, Grits Creek watershed

Description of the information required	Information requirements by chapter[1/] III	IV	V	VI	VII	Information for watershed
Information on hydrology						
Flow--hydrograph or flow duration curve	O					
Bankful				X,P		N/A
Baseflow					X,P	Lower reach: 0.5cfs; middle reach: 0.3cfs; Upper reach: 0.2 cfs
Representative flows to be used to establish suspended and bedload rating curves				X		Figure VIII.10
Width stream						
Bankful				X		N/A
Baseflow (average width flowing water)					X	Lower reach: 5.0 ft; middle reach: 3.5 ft; upper reach: 2.0 ft
Depth stream (bankful)				X		N/A
Water surface slope				X		N/A
Suspended sediment for representative flows				X		Figure VIII.10
Bedload sediment for representative flows				X		N/A
Channel stability rating				X		Fair
Orientation stream--azimuth					X	35°
Low flow period (date)					X	Last week of August
Percent streambed in bedrock					X	75%
Bedrock adjustment factor					P	Figure VII.9; 0.15
Length reach exposed					X	Lower reach: 2,000 ft; middle reach: 1,900 ft; upper reach: 1,000 ft
Travel time through reach					X	Lower reach: 65 min; middle reach: 50 min; upper reach: 28 min

1/ P - Data provided in this handbook
O - Optional data, not required for analysis
X - User-provided data

Table VIII.1.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on hydrology--continued						
Normalized hydrographs of potential excess water	P					N/A
Normalized flow duration curves	P					Figure III.22
Date of peak snowmelt discharge	O					N/A
Map of drainage net	X	X	X	X	X	Figure VIII.4
Presence of springs or seeps			X			N/A
Change stream geometry						
Water surface slope				X		N/A
Bankful width				X		N/A
Bankful depth				X		N/A
Information on climate						
Precipitation						
Form	X	O	X			Rain
Annual average	X					186.0 cm
Seasonal distribution	X	O				9/1 to 11/30 : 23.3cm ; 12/1 to 2/28 : 75.2cm ; 3/1 to 5/31 : 60.5cm ; 6/1 to 8/31 : 27.0cm
Storm intensity and frequency		O	X			N/A
Extreme event						
1 yr, 15-minute storm intensity		X				2.5 in/hr
Drop size		O				N/A
Precipitation--ET relationship	P					N/A
Wind direction	X					N/A

Table VIII.1.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on climate--continued						
Snow retention coefficient	X,P					N/A
Date snowmelt begins	O					N/A
Maximum snowmelt rate	O					N/A
Radiation						
Solar ephemeris					P	Figure VII.2
Heat influx					P	Figure VII.7
Iso-erodent map for "R" factor		P				Figure III.1; 300
Information on vegetation						
Species	X				X	Southern and cove hardwood
Height						
Overstory	X	X			X	80 ft
Understory		X			X	10 ft to 60 ft
Riparian vegetation					X	2 ft to 12 ft
Presence phreatophytes			X			N/A
Crown closure (%)					X	Lower reach: 90% overstory, 50% understory; middle reach: 90% overstory, 55% understory; upper reach: 80% overstory, 50% understory
Cover density	P	X				N/A
Leaf area index (pre)	X					6
Basal area	O					N/A
Basal area--C_{dmx} relationship	P					N/A
Ground cover		X				Worksheet III.2

Table VIII.1.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on vegetation--continued						
Percent transmission solar radiation through canopy					X,P	Tables VII.0.1 to VII.0.6, figure VII.0.1; lower reach: 5% pre, 15% post; middle reach: 5% pre, 10% post; upper reach: 5% pre, 10% post
Percent stream shaded by brush					X	Lower reach: 25%; middle reach: 40%; upper reach 65%
Baseline ET	X,P					Figure III.11
ET modifier coefficient	P					Figure III.16
Rooting depth	X					Average
Rooting depth modifier coefficient	P					Figure III.19
Information on soils and geology						
Depth soil	X		X			Worksheet IV.2
Percent sand (0.1-2.0 mm)		X				Worksheet IV.1
Percent silt and very fine sand		X				Worksheet IV.1
Percent clay		X	X			Worksheet IV.1
Percent organic matter		X				Worksheet IV.1
Soil texture		X				Worksheet IV.1
Soil structure		X				Worksheet IV.1
Permeability/Infiltration		X	X			Worksheet IV.1 and worksheet III.7
Presence of hardpan		X	X			No
Nomograph for "K" factor		P				Figure IV.3
Baseline soil-water relationships	X,P					N/A
Soil-water modifier coefficients	P					N/A
Jointing and bedding planes			X			N/A

Table VIII.1.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on soils and geology--continued						
Soils map	O	X	X			Figure VIII.6
Previous mass movements			X			N/A
Number			X			N/A
Location			X			N/A
Unit weight dry soil			X			N/A
Delivery potential			P			N/A
Percent silt and clay delivered			X			N/A
Median size coarse material			X			N/A
Information on topography						
Map (hydrologic region)	X	X	X	X	X	USGS map, figure VIII.4; hydrologic region 2
Latitude	X				X	35°
Size watershed	X					356 acres
Elevation	X					Ranges from 2750 to 4720 ft
Aspect	X					Southwest
Slope						East 53%; west 50%
Length		X				Worksheet IV.2
Gradient		X	X		X	Figure VIII.1 and worksheet IV.2
Dissection			X			N/A
Shape/Irregularity		X	X			Concave and straight
Nomograph for "LS" factor		P				Figure IV.3

Table VIII.1.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on topography--continued						
Surface roughness		x				Moderately rough to smooth
Information on the silvicultural activity						
Past history						
Harvesting	x	o				Some cutting early 1900's
Fires	x	o				N/A
Other disturbances	x	o				N/A
Proposed harvest						
Location units	x	x				Figure VIII.7 and worksheet IV.2
Size cuts	x	x				Figure VIII.7 ; 180 acres clearcut , 92 acres thinned
Leaf area index removed	x					Clearcut 4 ; thinned 3
Cover density removed	x					N/A
Basal area removed	x					N/A
Cover density overstory remaining		x				Worksheet IV.2
Cover density understory remaining		x				Worksheet IV.2
Average minimum canopy height		x				N/A
Slash and duff--litter		o				
Cover percent		x				Worksheet IV.2
Height	x					N/A
Percent bare soil		x				Worksheet IV.2

Table VIII.1.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on silvicultural activity--continued						
Transportation system						
Area disturbed	X	X				Figure VIII.2 and worksheet IV.2
Location	X	X				Figure VIII.2 and worksheet IV.2
Cut slopes (location and slope)		X				Worksheet IV.2; length: 3.5 ft - 8.0 ft; slope 170% – 180%; Figure VIII.2
Fill slopes (location and slope)		X				Worksheet IV.2; length: 2.0 ft - 10.0 ft; slope: 100%; Figure VIII.2
Cut and fill vs. full bench		X	X			Cut/fill
Inslope vs. outslope		X				Outslope
Surface						
Width		X				12 ft to 13 ft
Gradient		X				0% to 1%
Surfacing (amount and kind)		X				Bare earth
Road density			X			N/A
Harvesting system		X	X			Tractor yarding
Landings						
Location	X	X				Figure VIII.2 and worksheet IV.2; along roads
Size	X	X				Worksheet IV.2; variable
Gradient		X				Worksheet IV.2; variable
Ground cover		X				Worksheet IV.2
Time for vegetative recovery of disturbed surfaces		X				N/A

(16) Weighted adjusted ET. — The weighted adjusted ET is calculated by multiplying baseline ET [col. (11)], ET modifier coefficient [col. (14)], rooting depth modifer coefficient [col. (15)], and area as a decimal percent [col. (9)]. Weighted adjusted ET values for fall, winter, spring, and summer are calculated as 20.1, 8.9, 13.0, and 39.1 cm, respectively.

(17) Weighted adjusted seasonal ET. — The sum of weighted adjusted ET values [col. (16)] for a season equals the weighted adjusted evapotranspiration for that season. Values are in centimeters rounded off to one decimal place.

Season	Weighted adjusted seasonal ET
Fall	20.1 cm
Winter	8.9 cm
Spring	13.0 cm
Summer	39.1 cm

(18) Water available for seasonal streamflow. — The difference between weighted adjusted seasonal ET [col. (17)] and seasonal precipitation [col. (10)] is the water potentially available for seasonal streamflow. For Grits Creek, fall, winter, summer, and spring potential streamflows were 3.2, 66.3, 47.5, and −12.1 cm, respectively.

(19) Annual ET. — The sum of adjusted seasonal ET values [col. (17)] is annual ET. This is 81.1 cm for Grits Creek.

(20) Water available for annual streamflow. — The sum of water available for seasonal streamflow values [col. (18)] is the water available for annual streamflow. This is 104.9 cm for Grits Creek.

Water Available For Streamflow—After Proposed Silvicultural Activity

Step 2. — The second step in the hydrologic evaluation of Grits Creek is to estimate the water available for streamflow if the proposed silvicultural activity is implemented. The necessary steps in worksheet III.2 are detailed below. (Numbers in parentheses refer to items or columns in the worksheet.) Since the acreage cut does not change for the two management alternatives, the analysis is the same.

(1)-(5). — Same as worksheet III.1.

(6) Compartment. — For the proposed condition of Grits Creek, there are two compartments: impacted and unimpacted. The impacted compartment includes those areas affected directly or indirectly by the proposed silvicultural activities, while the unimpacted compartment includes areas unaffected by the proposed silvicultural activities.

(7) Silvicultural state. — Watershed areas are grouped into zones of similar hydrologic responses as identified by silvicultural or vegetational state. For the proposed condition of Grits Creek, the unimpacted compartment has one silvicultural state—forested. For the impacted zone, there are two—clearcut and thinned. As with the existing condition, there is one silvicultural prescription. However, this prescription consists of three silvicultural states — forested, clearcut, and thinned.

(8) Area, acres. — For the proposed condition, the silvicultural states are forested, clearcut, and thinned with respective areas of 84, 180, and 92 acres.

(9) Area, %. — The area of each silvicultural state in column (8) is divided by item (3), total watershed area, and rounded off to the third decimal place. In this example, decimal percentage for forested, clearcut, and thinned zones and are 0.236, 0.506, and 0.258, respectively.

(10) Precipitation. — Seasonal precipitation to the nearest 0.1 cm is entered by the user. For Grits Creek, mean seasonal precipitation was 23.3, 75.2, 60.5, and 27.0 cm for fall, winter, spring, and summer, respectively.

(11) Baseline ET. — Baseline ET is the same for each silvicultural state within a season. The values taken from figure III.11 for a latitude of 35°N are 20.1, 8.9, 13.0, and 39.1 cm for fall, winter, spring, and summer seasons, respectively.

(12) Basal area. — Since the leaf area index (LAI) has been estimated, basal area data are unnecessary.

(13) Leaf area index. — Leaf area index (LAI) values have been estimated by a professional *forester as 2 and 3 for clearcut and thinned areas,* respectively.

(14) ET modifier coefficient. — Evapotranspiration modifier coefficients, as functions of leaf area index and season, are obtained from figure III.16. In this example, the modifier coefficients are:

Season	Forested	Clearcut	Thinned
Fall	1.00	0.81	0.90
Winter	1.00	0.65	0.76
Spring	1.00	0.60	0.72
Summer	1.00	0.69	0.84

(15) Rooting depth modifier coefficient. — Rooting depth modifier coefficients are taken from figure III.19 for an average soil depth. Here, all rooting depth modifier coefficients are equal to 1.0.

(16) Weighted adjusted ET. — Multiplication of baseline ET, ET modifier coefficient, rooting depth modifier coefficient, and area as a decimal percent yields adjusted ET values as follows:

Season	Forested	Clearcut	Thinned
Fall	4.74 cm	8.23 cm	4.67 cm
Winter	2.10 cm	2.93 cm	1.75 cm
Spring	3.07 cm	3.95 cm	2.41 cm
Summer	9.23 cm	13.65 cm	8.47 cm

(17) Weighted adjusted seasonal ET. — Summation of adjusted ET values by activity yields weighted adjusted seasonal ET for the watershed. Fall, winter, spring, and summer values are 17.6, 6.8, 9.4, and 31.4 cm, respectively.

(18) Water available for seasonal streamflow. — The difference between weighted adjusted seasonal ET and seasonal precipitation is water available for seasonal streamflow. The respective values are 5.7, 68.4, 51.1, and −4.4 cm for fall, winter, spring, and summer, respectively.

(19) Annual ET. — The sum of weighted adjusted seasonal ET values [col.(17)] is annual ET. This is 65.2 cm.

(20) Water available for annual streamflow. — The sum of column (18), seasonal streamflow, is equal to water available for annual streamflow. This is 120.8 cm.

Flow Duration Curve Development—Existing Conditions

Step 3. — The third step in the hydrologic evaluation is to estimate the flow duration curve for the existing condition. The necessary steps outlined in worksheet III.3 are detailed below. (Numbers in parentheses refer to the items or columns on the worksheet.)

(1), (2). — Same as worksheet III.1.

(3) Water available for annual streamflow — existing condition. — This value has been calculated in worksheet III.1, item (20), to be 104.9 cm.

(4) Annual flow from duration curve for hydrologic region. — Figure III.22 gives the annual flow for watersheds in hydrologic region 2 as 72.0 cm using 11 points to calculate the area beneath the curve.

(5) Adjustment ratio. — Estimated water available for annual streamflow divided by flow, represented by the flow duration curve, equals the adjustment ratio. The adjustment ratio is rounded to the third decimal place and used to correct the given flow duration curve to equal the expected yield. For Grits Creek, it is:

$$\frac{104.9}{72.0} = 1.457$$

(6) Point number. — This is the numerical order of points used to define the flow duration curve.

(7) Percent of time flow is equaled or exceeded. — These values are read at equidistant intervals along the X-axis of figure III.22. The interval is a function of the number of desired points [i.e., if 11 points are used, the interval is 100/(11-1)].

(8) Regional flow. — These are the Y-axis values of figure III.22 corresponding to the X-axis values in column (7). This column is not necessary if a flow duration curve for the existing condition is available.

(9) Existing potential flow. — Regional flow [col. (8)] is multiplied by the adjustment ratio [item (5)] to give the existing potential streamflow. If a flow duration curve for the existing condition is available, no correction is necessary. Column (9) is plotted versus column (2) to yield the flow duration curve for the existing condition (fig. VIII.3).

(10) Existing potential flow (cfs). — Conversion of cm/7 days to cubic feet per second (cfs) is accomplished by multiplying column (7) x area (acres) x 0.002363 for 7-day intervals.

Flow Duration Curve Development— After Proposed Silvicultural Activity

Step 4. — The final step in the hydrologic evaluation of Grits Creek is to estimate the 7-day flow duration curve for conditions after the proposed silvicultural activity has been conducted. The necessary steps outlined in worksheet III.4 are detailed as follows. (Numbers in parentheses refer to the items or columns on the worksheet.)

(1), (2). — Same as worksheet III.2.

(3) Watershed aspect code. — The dominant aspect of Grits Creek is southwest. Hydrologic characteristics dictate that, for the purposes of flow duration curve calculation, an aspect of west be assigned a code of zero for the watershed (this eliminates the aspect adjustment).

(4) Existing condition LAI. — Existing LAI has already been given as 6.

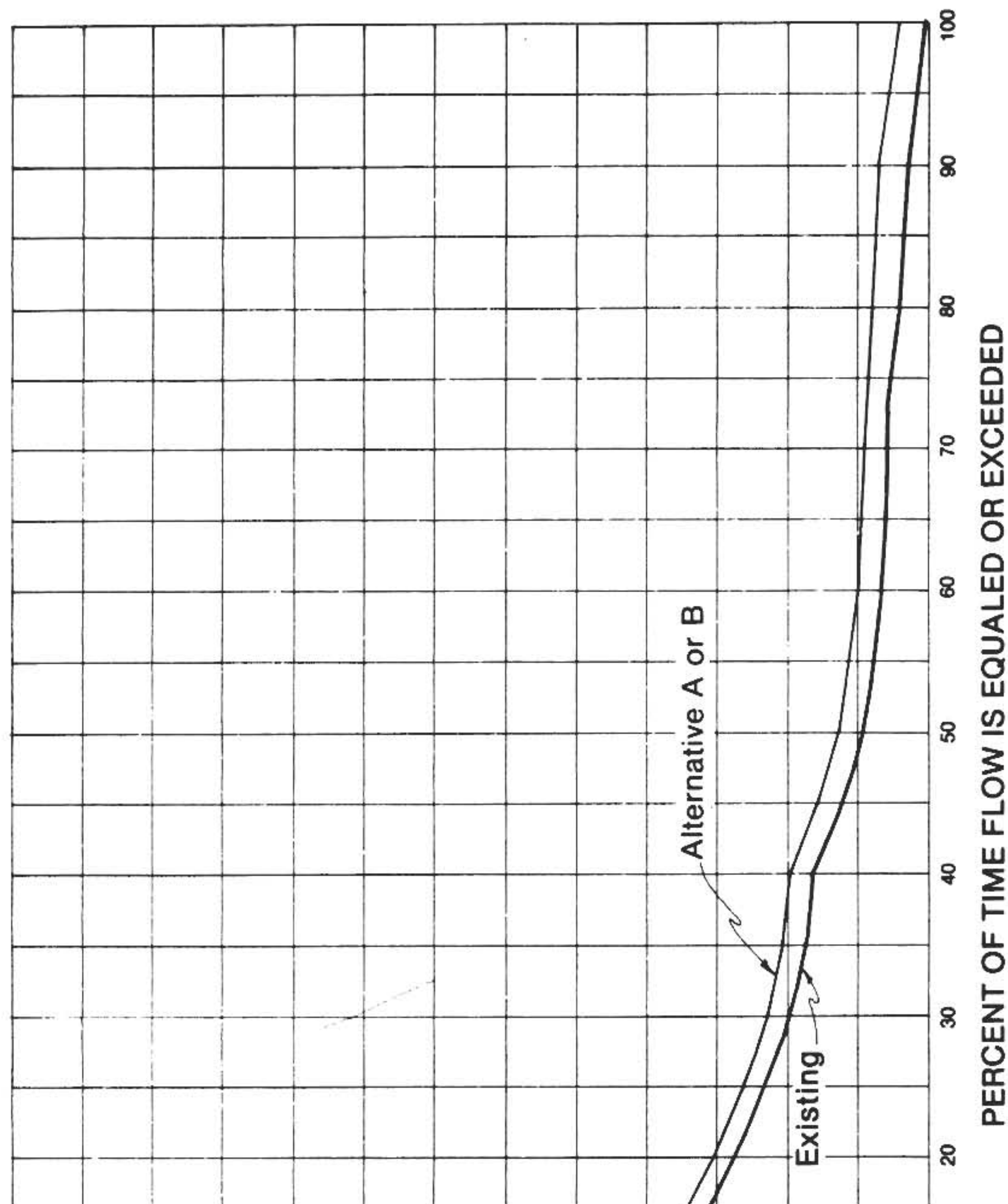

Figure VIII.3.—Annual flow duration curves for existing and alternative A or B conditions, Grits Creek watershed.

(5) Proposed condition LAI. — Proposed condition leaf area index is an area weighted index for the silvicultural states which for this example are forested, clearcut, and thinned areas. Leaf area index values are from worksheet III.2, column (13).

The weighted post-activity index can be calculated as:

weighted forest + weighted clearcut
+ weighted thinned
= weighted average

or

$(6 \times 0.236) + (2 \times 0.506) + (3 \times 0.258) = 3.2$

(6) Change in LAI. — The difference between existing and proposed condition leaf area indices yields the change in leaf area index. In this case, it is $6 - 3.2 = 2.8$.

(7) Rooting depth modifier coefficient. — For Grits Creek, the rooting depth modifier coefficient is 1.

(8)-(12). — The least squares equation coefficients for the example are found in table III.4.

(13)-(15). — Same as columns (6), (7), (9), and (10) of worksheet III.3, respectively.

(16) b_0 . — This is item (8) found in table III.4.

(17) b_1Q_i. — Item (9) × column (15).

(18) b_2CD. — Item (10) × item (6).

(19) b_3AS. — Item (11) × item (3).

(20) b_4RD. — Item (12) × item (7).

(21) ΔQ_i. — Sum of columns (16), (17), (18), (19), and (20).

(22) $Q_i + \Delta Q_i$. — Column (15) + column (21).

(23) $Q_i + \Delta Q_i$ (cfs). — Column (22) x area (acreas) x 0.002363 for 7-day intervals. This is the predicted flow duration curve for the proposed silvicultural activity when plotted against column (14) (fig. VII.3).

SURFACE EROSION ANALYSIS

The quantity of surface eroded material delivered to stream channels from sites disturbed by the proposed silvicultural activities is estimated in two stages. First, the quantity of material that may be made available from a disturbed site is estimated using the Modified Soil Loss Equation (MSLE). Second, a sediment delivery index (SD_I) is estimated. When this is applied to the estimated quantity of surface eroded material available, an estimate of the quantity of material that may enter a stream channel is obtained.

Erosion Response Unit Delineation

Topographic maps (figs. VIII.4 to VIII.7) have been prepared for the Grits Creek watershed, following steps 1 through 7 as discussed in chapter IV. These maps show the drainage net, hydrographic areas, soil groups, and silvicultural activities. Road locations for management alternatives A and B are shown in figure VIII.1. An enlarged map of hydrographic area 13 (fig. VIII.8) shows the composite of cutting units, roads, stream channels, and soil groups used for the soil erosion and sediment delivery example problem.

Steps 1-7. — Prepare topographic maps (ch. IV).

Step 8. — Set up worksheets for estimating potential sediment load from surface erosion.

Worksheets IV.1 and IV.2, have been prepared with field data for Grits Creek management alternative A. Individual soils in the Grits Creek watershed have been grouped where there exist similar texture, organic matter, structure, and permeability characteristics. Worksheet IV.1 shows the three soil groups used for surface erosion evaluation. Data on worksheet IV.1 should not change when different management alternatives are evaluated for the watershed.

Worksheet IV.2 displays various types of data needed for evaluating the effects of management alternative A for Grits Creek watershed, hydrographic area 13. Individual erosion response units are identified and listed. A different erosion response unit is created for each change in management activity, each design change for a given activity (e.g., a road change from a cut-and-fill design to a complete fill for a stream crossing), or each change in environmental parameters affecting erosion (e.g., an change in soil characteristics).

Worksheet IV.3 is a summary of the values used in the MSLE and sediment delivery index for erosion response units in hydrographic area 13 of the Grits Creek watershed. The values for both management alternatives are obtained using the steps and discussions which follow. Only values for alternative A are used to illustrate methods for solving the equations, however, values for alternative B are similarly determined.

Step 9. — List each erosion source area and number by erosion response unit.

For the Grits Creek watershed, the response units have been coded as follows. The treatment types are selection cuts (SC), clearcuts (CC), and

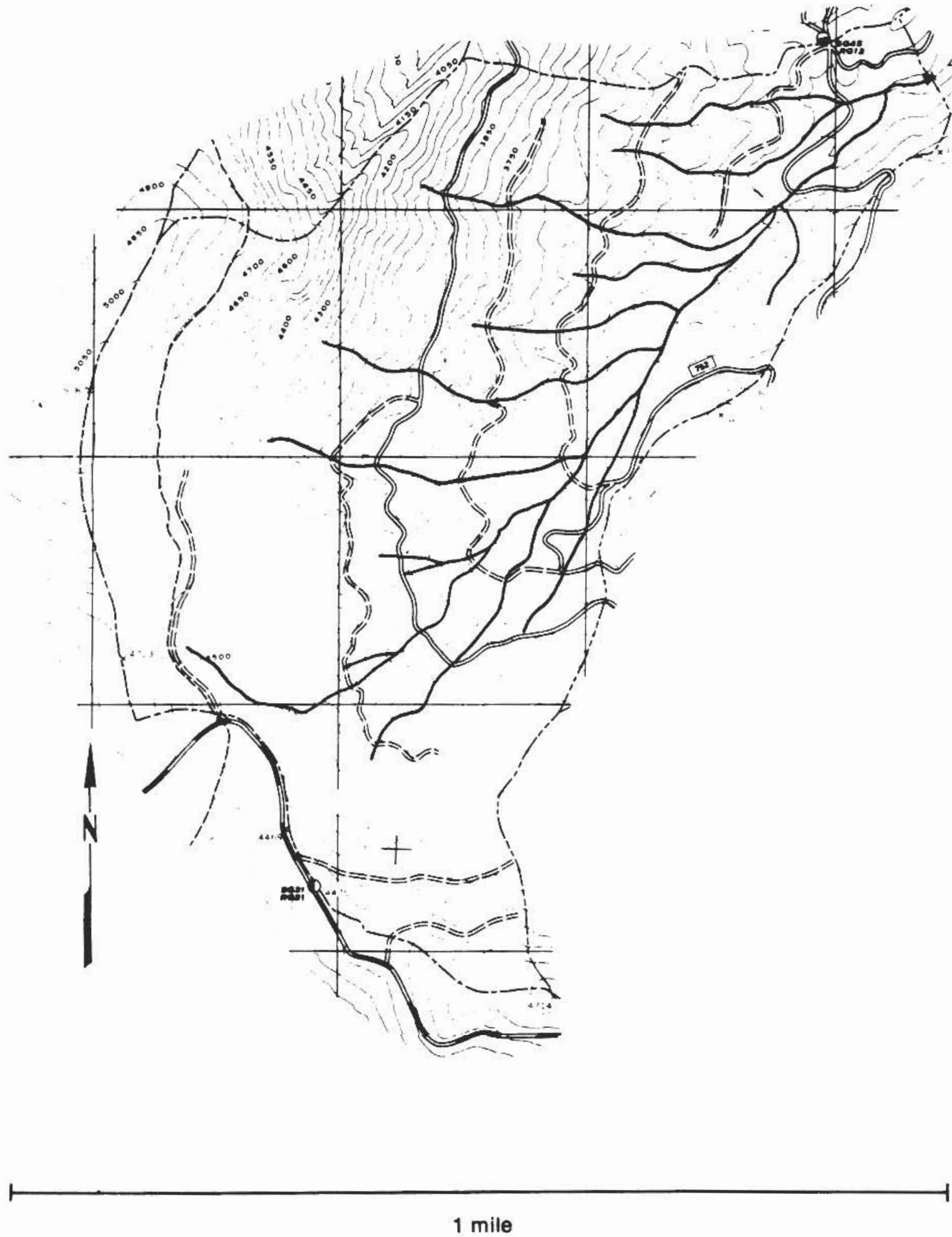

Figure VIII.4.—Drainage net, Grits Creek watershed.

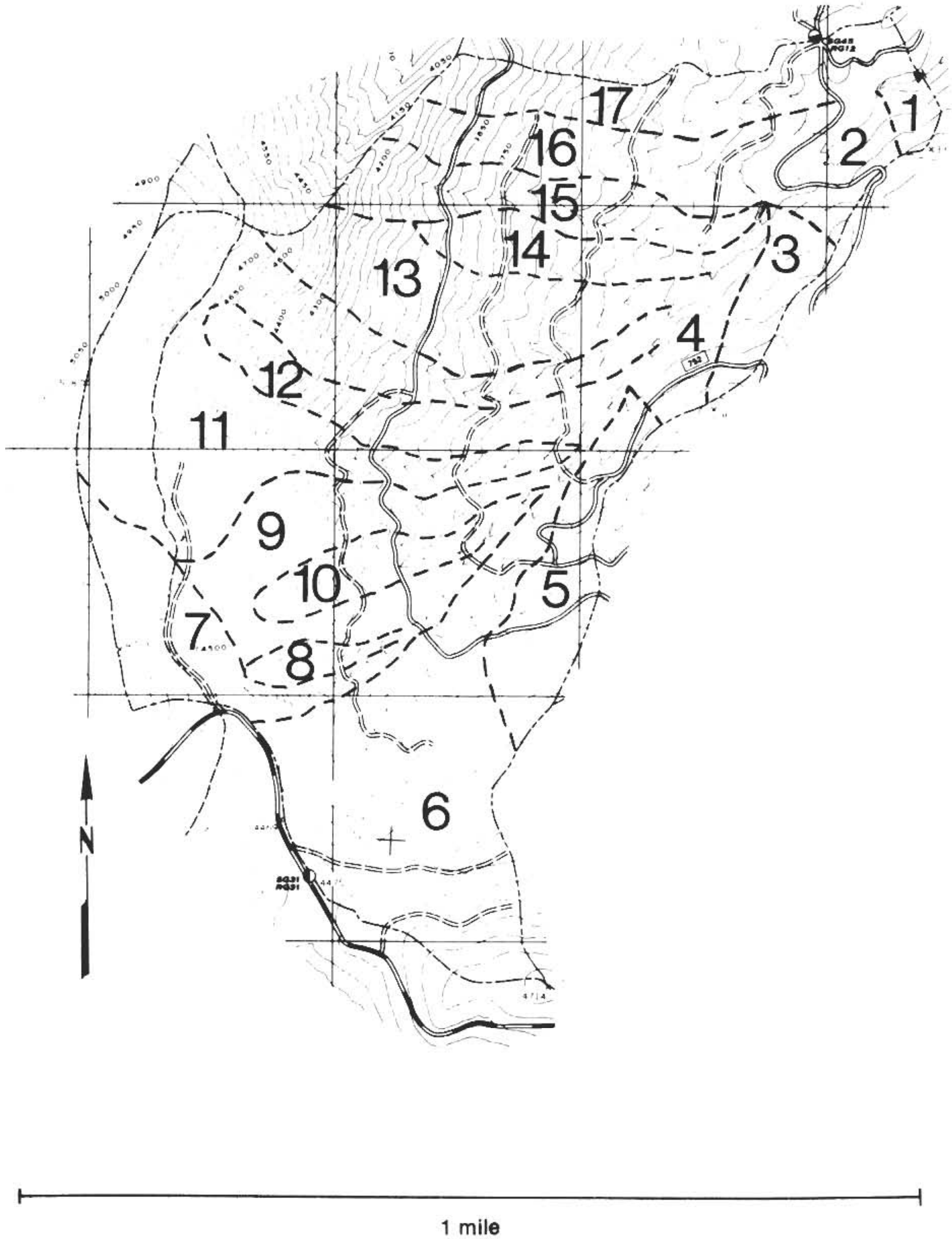

Figure VIII.5.—Hydrographic areas, Grits Creek watershed.

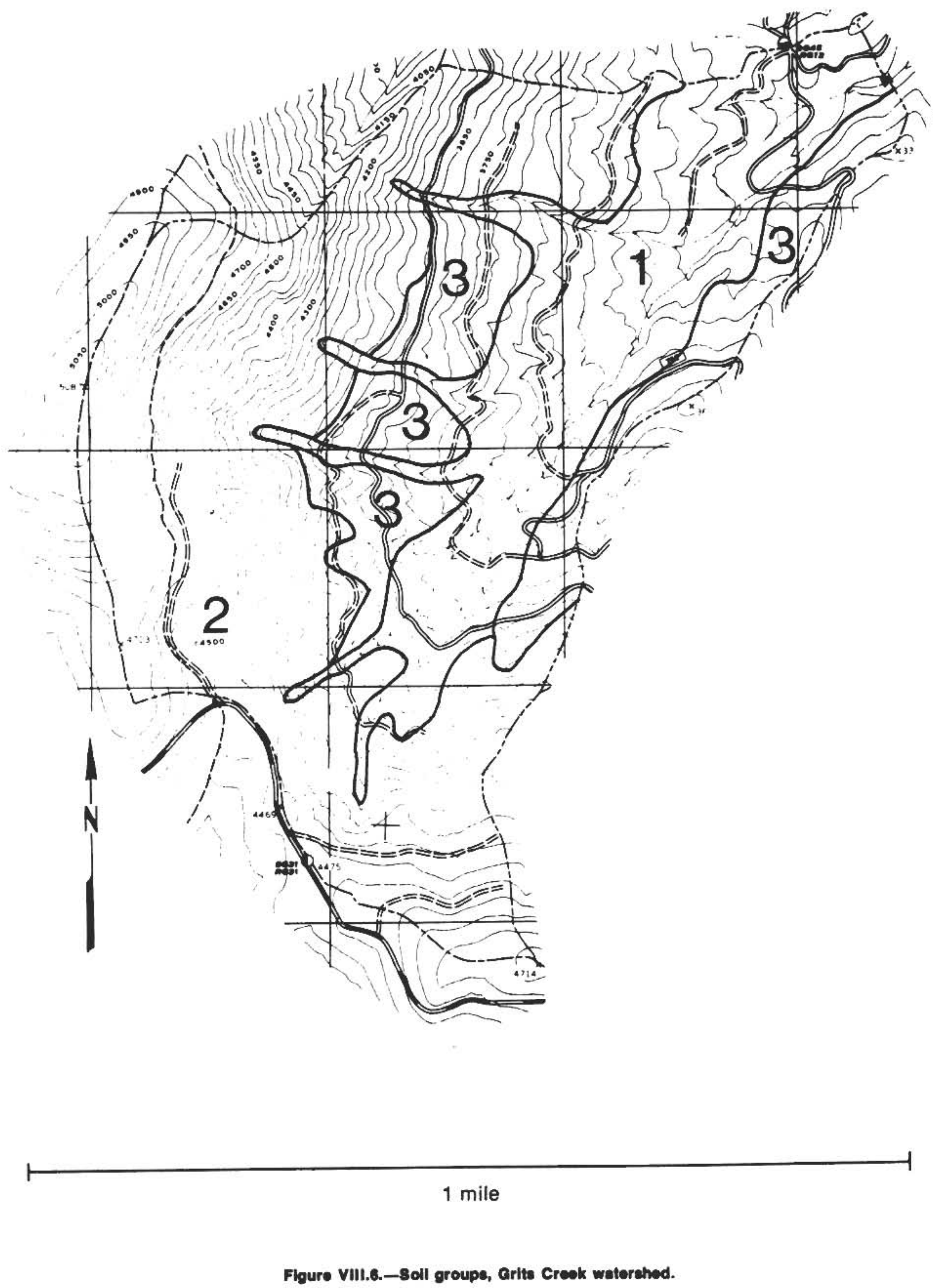

Figure VIII.6.—Soil groups, Grits Creek watershed.

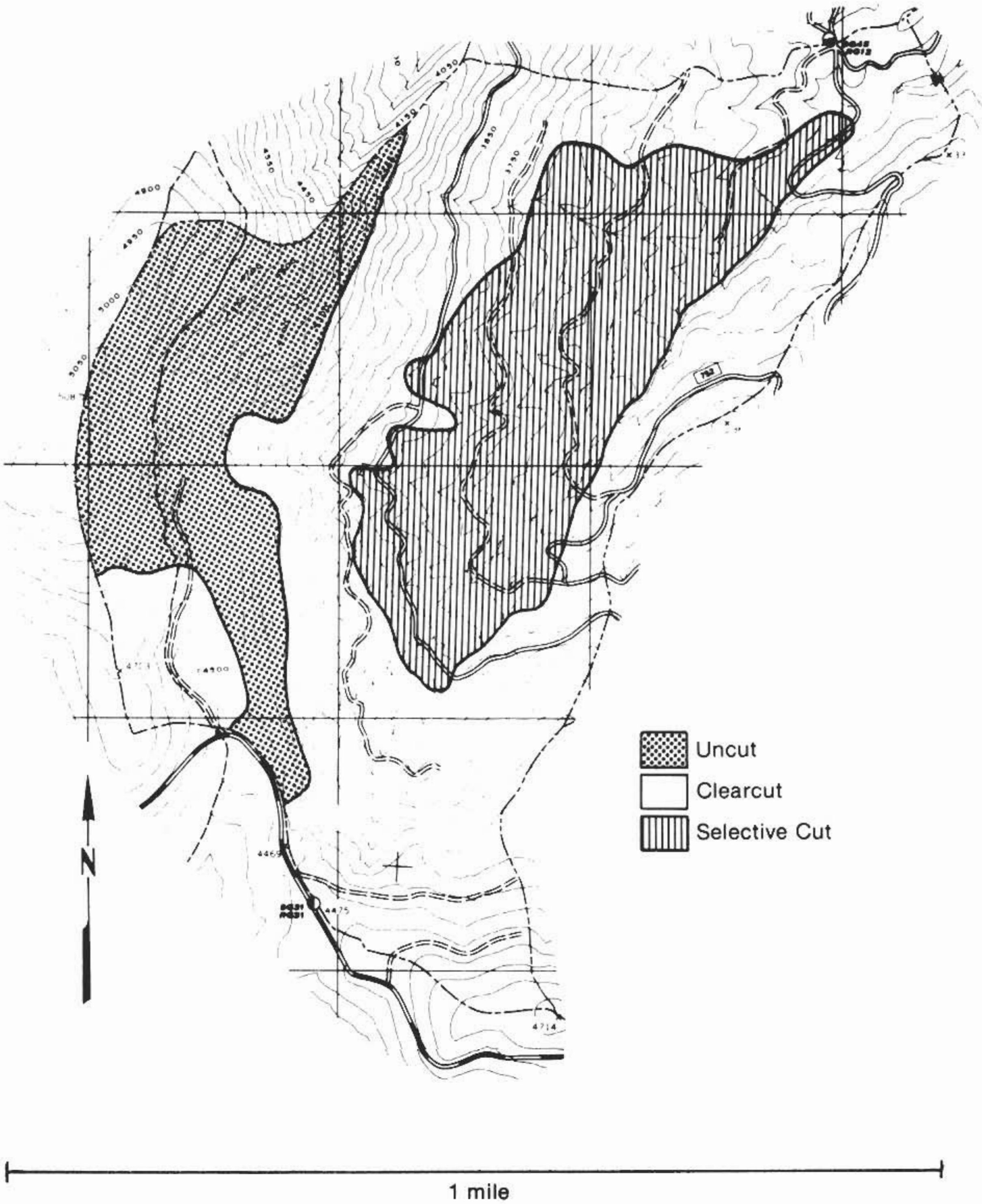

Figure VIII.7.—Silvicultural treatments, Grits Creek watershed.

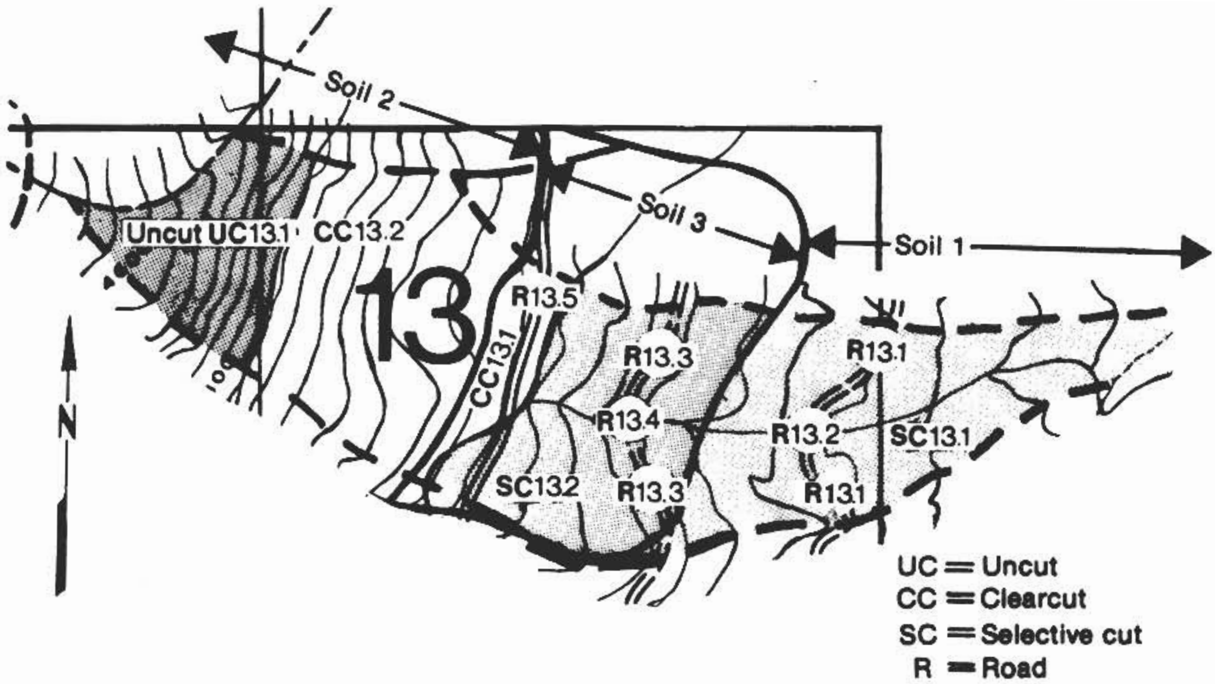

Figure VIII.8.—Enlargement of example hydrographic area showing individual erosion response units.

roads (R). There are no landings, because logs will be yarded to various locations along the side of the road and onto the road surface. The example hydrographic area is number 13. The disturbance types are numbered (e.g., clearcut CC13.1, clearcut CC13.2) to identify them in the following evaluations for soil loss and sediment delivery.

Using The Modified Soil Loss Equation (MSLE)

Step 10. — Working with each erosion response unit individually, determine for each source area (silvicultural activities and roads) the values to be used for each of the following variables:

R — Rainfall factor
K — Soil erodibility factor
LS — Length-slope factor
VM — Vegetation-management factor
Area — Surface area of response unit

Values for these factors are entered on worksheet IV.3 using the following procedures.

Rainfall Factor

For the Grits Creek area, R = 300 (fig. IV.2.) This R value is the same over the entire Grits Creek area and will be used for all erosion response units and both management alternatives.

Soil Erodibility Factor

The K value can be estimated using the nomograph in figure IV.3, or by using equation IV.4. The data for soil group 2 needed to compute the K value using equation IV.4 are found on worksheet IV.1. K must be determined for both topsoil and subsoil. For disturbances which enter the subsoil, such as roads, the subsoil value of K must be used.

Application of the equation to determine the K factor is shown in the following example for topsoil in soil group 2. Because of inflections in the family of curves on the nomograph (fig. IV.3) for percent sand, the equation cannot be used when silt plus very fine sand exceeds 70 percent.

$$K = (2.1 \times 10^{-6})\ (12 - Om)\ M^{1.14} + 0.0325\ (S-2) + 0.025\ (P-3) \quad (IV.4)$$

where:

Om = % organic matter
M = (% silt + % very fine sand) (100 − % clay)
S = structure code
P = permeability code

Substituting values for topsoil (soil group 2) from worksheet IV.1 into equation IV.4:

$$K = (2.1 \times 10^{-6})\ (12-4)\ [40\ (100-20)]^{1.14} + 0.0325\ (2-2) + 0.025\ (2-3)$$

$$K = 0.14$$

Length-Slope Factor

The length-slope factor, LS, is a combination factor which incorporates the slope gradient and the length of the eroding surface into a single factor. The LS factor must be estimated for each erosion response unit.

Two methods may be used to estimate the LS factor on straight slopes. One is to use equation IV.8 to derive the estimated LS value. The second method utilizes a nomograph (fig. IV.4) to estimate the LS value.

The cutting units (SC13.1, SC13.2, CC13.1, and CC13.2) are each different in regard to slope gradient and length. Therefore, LS for each cutting unit must be evaluated separately. Using equation IV.8 and data from worksheet IV.2, the LS value for CC13.1 is calculated as follows for slope length λ = 132 feet and slope gradient s = 12 percent.

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{0.43 + 0.30s + 0.043s^2}{6.613}\right) \left(\frac{10,000}{10,000 + s^2}\right) \quad (IV.8)$$

where:

λ = slope length, in feet
s = slope gradient, in percent
m = an exponent based on slope gradient from equation IV.6

Using data from worksheet IV.2:

$$LS = \left(\frac{132}{72.6}\right)^{0.5} \left(\frac{0.43 + 0.30(12) + 0.043(12)^2}{6.613}\right) \left(\frac{10,000}{10,000 + (12)^2}\right)$$

$$LS = 2.05$$

Similar calculations are made for erosion response units SC13.1, SC13.2, and CC13.2.

To compute the length-slope value for the road sections (R13.1, R13.2, and R13.3), the equation for irregular slopes is used in this example. An alternative method using graphs (figs. IV.5 and IV.6) is discussed in chapter IV. The LS equation for roads is:

$$LS = \frac{1}{\lambda_e} \cdot \sum_{j=1}^{n} \left[\left(\frac{S_j \lambda_j^{m+1}}{72.6^m} - \frac{S_j \lambda_{j-1}^{m+1}}{72.6^m} \right) \left(\frac{10{,}000}{10{,}000 + s_j^2} \right) \right] \qquad \text{(IV.9)}$$

The number of calculations can be reduced by simplifying equation IV.9 to:

$$LS = \frac{1}{\lambda_e} \cdot \sum_{j=1}^{n} \left[S_j \left(\frac{\lambda_j^{m+1} - \lambda_{j-1}^{m+1}}{72.6^m} \right) \left(\frac{10{,}000}{10{,}000 + s_j^2} \right) \right] \qquad \text{(IV.9.1)}$$

where:

λ_e = entire length of a slope, in feet

λ_j = length of slope to lower edge of j^{th} segment, in feet

j = slope segment

s_j = slope gradient, in percent

S_j = dimensionless slope steepness factor for segment j defined by

$$S_j = (0.043 s_j^2 + 0.30 s_j + 0.43)/6.613$$

m = an exponent based on slope gradient

n = total number of slope segments

For the road R13.1, using values in worksheet IV.2 and assuming that no sediment is deposited on the road surface, the computations are as follow:

Slope segment 1 (cut)

λ_1 = 3.5 feet

λ_{1-1} = 0.0 feet (there are no preceding slope segments, hence length is 0.0 ft)

s = 170%

m = 0.6 (for slopes on construction sites; see eq. IV.6)

$$S_1 = \frac{0.043s^2 + 0.30s + 0.43}{6.613}$$

substituting for s:

$$S_1 = \frac{0.043(170)^2 + 0.30(170) + 0.43}{6.613} = 196$$

Substituting S, λ, and m values for j=1 into equation IV.9.1 to the right side of the summation sign gives:

$$196 \left(\frac{(3.5)^{1.6} - (0)^{1.6}}{(72.6)^{0.6}} \right) \left(\frac{10{,}000}{10{,}000 + (170)^2} \right)$$

$$= 28.59$$

Slope segment 2 (roadbed)

λ_2 = 3.5 + 12.0 = 15.5 feet

λ_{2-1} = 3.5 feet

s = 1%

m = 0.6 (for slopes on construction sites)

$$S_2 = \frac{0.043s^2 + 0.30s + 0.43}{6.613}$$

substituting for s:

$$S_2 = \frac{0.043(1)^2 + 0.30(1) + 0.43}{6.613} = 0.117$$

Substituting S, λ, and m values for j=2 into equation IV.9.1 to the right side of the summation sign gives:

$$0.117 \left(\frac{(15.5)^{1.6} - (3.5)^{1.6}}{(72.6)^{0.6}} \right) \left(\frac{10{,}000}{10{,}000 + (1)^2} \right)$$

$$= 0.65$$

Slope segment 3 (fill)

λ_3 = 3.5 + 12.0 + 4.5 = 20.0 feet

λ_{3-1} = 3.5 + 12.0 = 15.5 feet

s = 100%

m = 0.6 (for slopes on construction sites)

$$S_3 = \frac{0.043s^2 + 0.30s + 0.43}{6.613}$$

substituting for s:

$$S_3 = \frac{0.043(100)^2 + 0.30(100) + 0.43}{6.613} = 69.6$$

Substituting S, λ, and m values for j=3 into equation IV.9.1 to the right of the summation sign gives:
gives:

$$69.6 \left(\frac{(20.0)^{1.6} - (15.5)^{1.6}}{(72.6)^{0.6}} \right) \left(\frac{10,000}{10,000 + (100)^2} \right)$$

$$= 107.54$$

Solving the entire equation IV.9.1, using the calculated values where:

$$\lambda_e = 3.5 + 12.0 + 4.5 = 20 \text{ feet}$$

then:

$$LS = \frac{1}{\lambda_e} (\text{slope seg. } 1 + \text{slope seg. } 2 + \text{slope seg. } 3)$$

$$= \frac{1}{20} (28.59 + 0.65 + 107.54)$$

$$= 6.84$$

A similar LS calculation is made for road R13.5. Road R13.2, however, is a fill across a stream channel and becomes two problems, each with two segments. Each segment starts at the middle of the road surface, and the second segment includes one of the fill slopes. An average LS value from both halves of the road is used as the final LS value (1.81) to be entered on worksheet IV.3.

Vegetation-Management Factor

The vegetation-management factor (VM) is used to evaluate effects of cover and land management practices on surface erosion over the entire slope length used for the LS factor. VM factors are determined for all cutting units and roads.

(1) Cutting units. — Worksheet IV.2 has the field data used for calculating a VM factor for the clearcut units (CC13.1 and CC13.2) and the selective cut units (SC13.1 and SC13.2). Example calculations are shown for clearcut CC13.1. The cutting unit is divided into two areas based on the presence or absence of logging residues. A ground cover of slash and other surface residues covers 55 percent of the unit (wksht. IV.2). The remaining 45 percent is scattered with open areas of bare soil and soil duff mixtures averaging 15 feet in diameter.[2]

[2]*Information about the amount of residue is often expressed in tons per acre. Maxwell and Ward (1976) have published photos and tables for parts of Oregon and Washington which relate visual appearance of a site with the volume of residue and amount of ground cover.*

In the 55 percent of the area (CC13.1) covered by slash and other surface residues, fine tree roots are uniformly distributed over 99 percent of the area. In the 45 percent of clearcut area CC13.1 that is open, fine tree roots are uniformly distributed over 80 percent of the open area. All of the overstory and understory canopy has been removed.

Using worksheet IV.4, first, enter percent area as 0.55 and 0.45 for area covered by residues and open area, respectively. Separate calculations are made for the logging residue areas and open areas.

Second, the logging slash represents the mulch and close growing vegetation. Because slash varies in density, assume that small openings a few inches in diameter exist over 40 percent of the surface. from figure IV. 9, the 60 percent cover provides a mulch factor of 0.25. The 45 percent of CC13.1 that is open is assumed to have 45 percent of the surface protected by widely scattered slash. Using figure IV.9, a mulch factor of 0.35 is found for this situation.

Third, zero canopy cover gives a canopy factor of 1.0 for both areas (fig. IV.8).

Fourth, evaluate the role of fine roots that are remaining in the soil. The slash area has fine roots uniformly distributed over 99 percent of its surface area and figure IV. 10 shows a corresponding fine root factor of 0.10. The open area has fine roots uniformly distributed over 80 percent of its area; figure IV.10 gives a corresponding value of 0.12.

Fifth, determine if the open areas are connected with each other such that water can flow downslope from one to another (ch. IV). In this example, the open areas are isolated from each other by bands of logging residue, requiring the use of a sediment filter strip factor of 0.5 (see "Sediment Filter Strips" section of "Chapter IV: Surface Erosion"). If these sediment filter strips did not exist, a factor of 1.0 would be used.

Sixth, using worksheet IV.4, multiply the VM subfactors for logging residue (0.55) (0.25) (1.0) (0.10) = 0.0138. Similarly for the open area: (0.45) (0.35) (0.12) (0.5) = 0.0095. The overall VM factor for CC13.1 is the sum of the two factors: (0.0138) + (0.0095) = 0.023.

Similar calculations are made for CC.13.2, SC13.1, and SC13.2. Values are shown on worksheet IV.4.

(2) Landings. — No landings are planned for Grits Creek.

(3) Roads. — The VM factor must represent two conditions on the road areas: (1) the road running surface, and (2) the cut-and-fill banks that are needed (fig. IV.7).

The average width of disturbed surface for road R.13.1 is 1.8 + 12.0 + 3.1 = 16.9 ft

Running surface $\frac{12.0 \text{ ft}}{16.9 \text{ ft}}$ = 0.7101 = fraction of total width

Cut slope $\frac{1.8 \text{ ft}}{16.9 \text{ ft}}$ = 0.1065 = fraction of total width

Fill slope $\frac{3.1 \text{ ft}}{16.9 \text{ ft}}$ = 0.1834 = fraction of total width

The weighted VM factor for the road R13.1 is calculated and shown on worksheet IV.6. Similar calculations have been made for roads R13.1 and R13.5.

Surface Area Of Response Unit

Total surface area within each treatment unit—clearcuts, selective cuts, and roads—is given in worksheet IV.2 and is entered on worksheet IV.3. All other MSLE factors are also entered into worksheet IV.3. Total potential onsite soil loss is computed by multiplying all the MSLE factors on worksheet IV.3.

Sediment Delivery

Step 12. — The computed potential sediment is delivered to the closest stream channel using a sediment delivery index (SD_I). Worksheet IV. 7 is used to organize the data for each erosion response unit for each factor shown on the stiff diagram (fig. VIII.9).

1. Water availability for sediment delivery is calculated using equation IV.12 for each erosion response unit:

$$F = CRL \qquad \text{(IV.12)}$$

where:

F = available water (ft³/sec)

R = [1 year, 15 minute storm (in/hr)] - [soil infiltration rate (in/hr)]

L = [slope length distance of disturbance (ft)] + [slope length from disturbance to stream (ft)]

$$C = 231 \times 10^{-5} \ \frac{\text{ft}^2 \text{ hr}}{\text{in sec}}$$

The infiltration rate used in determining the R factor is the maximum rate at which water could enter a soil. In actual situations, the water entry rate will usually be somewhat lower than the infiltration rate and can be based on the soil permeability with consideration for effects of various management practices.

Using data from worksheet IV.2 and footnotes from worksheet IV.7, the calculations for CC13.1 are:

$$F = \left(2.31 \times 10^{-5} \ \frac{\text{ft}^2 \text{ hr}}{\text{in sec}}\right) (2.5 \text{ in/hr} - 2.0 \text{ in/hr}) (132 \text{ ft} + 0 \text{ ft})$$

$$F = 0.0015 \text{ ft}^3\text{/sec}$$

2. Texture of eroded material is based on the amount of very fine sand, silt, and clay shown on worksheet IV.1. For this case, it has been assumed that one-half of the clay will form stable aggregates, with the remaining clay influencing the sediment delivery index. For soil group 3 topsoil, the following calculations were made:

$$\text{texture of eroded material} = \frac{\% \text{ clay}}{2} + \% \text{ silt} + \% \text{ very fine sand}$$

$$= \frac{25}{2} + 26 + 19$$

$$= 57$$

3. Ground cover is the percentage of the soil surface with vegetative residues and stems in direct contact with the soil. The ground cover on the area between a disturbance and a stream channel is determined from field observations and used for the sediment delivery index. For CC13.1, 53 percent is shown on worksheet IV.2 for ground cover.
4. Slope shape is a subjective evaluation of shapes between convex and concave. From worksheet IV.2, for CC13.1 the slope shape is concave.
5. Distance is the slope length from the edge of a disturbance to a stream channel. For CC13.1 (wksht. IV.2) the distance is 0.0, because the disturbance extends to the channel.

6. Surface roughness is a subjective evaluation of soil surface microrelief ranging from smooth to moderately rough. Worksheet IV.2 shows a moderate surface roughness for CC13.1.
7. Slope gradient is the percent slope between the lower boundary of the disturbed area and the stream channel. Worksheet IV.2 shows a gradient of 12 percent for the disturbed area.
8. Site specific is an optional factor that was not used in this example. See chapter IV for more discussion of this factor.

The tabulated factors for CC13.1 (wksht IV.7) are plotted on the appropriate vectors of the stiff diagram (fig. VIII.9) as discussed in chapter IV. Use any one of several methods to determine the area bounded by the irregular polygon that is created when points on the stiff diagram are joined. The area of the polygon for this example is 107.9 square units. The stiff diagram has 784 square units. The percentage of the total area enclosed by the polygon is:

$$\left(\frac{107.9}{784}\right)(100) = 13.8\%$$

Entering the X-axis of the probit curve (fig. IV.23) with 13.8 results in a sediment delivery index (SD_I) of 0.02. This is the estimated fraction of eroded material that could be delivered from this disturbance to the stream channel.

Step 13. — Find the estimated quantity of sediment (tons/yr) delivered to a stream channel by multiplying surface soil loss by the sediment delivery index (wksht. IV.3) for each erosion response unit.

Step 14. — Using worksheet IV.8, tabulate quantities of delivered sediment (tons/yr) for each hydrographic area by the erosion source. When completed, this table provides a summary of surface erosion sources and estimated quantities of sediment production from each hydrographic area.

Step 15. — Totals and percentages are shown on worksheets IV.8. The total quantity of delivered material is entered on table VIII.2.

Differences Between Management Alternatives

A second set of worksheets IV.2 to IV.8 show data and results of calculations for Grits Creek alternative B. Specific differences between alternatives A and B can be seen by comparing values in the two sets of worksheets. For example, alternative B results in more of the total surface area covered with residues and mulch and more fine roots. The results of these effects are shown on worksheet IV.3 as the VM factor. For alternative A, CC13.1, VM = 0.023 as compared to VM = 0.003 for alternative B, CC13.1. The lower VM for alternative B indicates that vegetative materials on the ground are more effective in reducing erosion than they are in alternative A. There are similar differences in the VM factor for other cutting units and roads. The net effect is a total of 34.2 tons/yr for alternative A and 6.7 tons/yr for alternative B (wksht. IV.8).

TOTAL POTENTIAL SEDIMENT ANALYSIS

The following steps are diagrammatically shown in figure IV.9.

Step 1. — The stream reach characterization will be obtained on the lower reaches of the third-order stream channel on main Grits Creek.

Step 2. — See figure VIII.3, flow duration curve for Grits Creek.

Suspended Sediment Calculation

Step 3. — Establish suspended sediment rating curve.

a. Obtain sediment rating curve from the measured depth integrated suspended sediment sampling and concurrent stream discharge measurements. A plot of these figures is shown in figure VIII.10.
b. $\log Y = 0.61 + 0.96 \log Q$
   $r^2 = 0.98$
c. Channel stability rating: fair. The analysis outlined by Pfankuch (1975) was used to obtain this value. A correlation between the various ranges in stream channel stability and sediment rating curves as explained in appendix VI.B was obtained for the Grits Creek watershed. Figure VIII.11 indicates the channel stability threshold limit which is the upper limit for a fair rating.

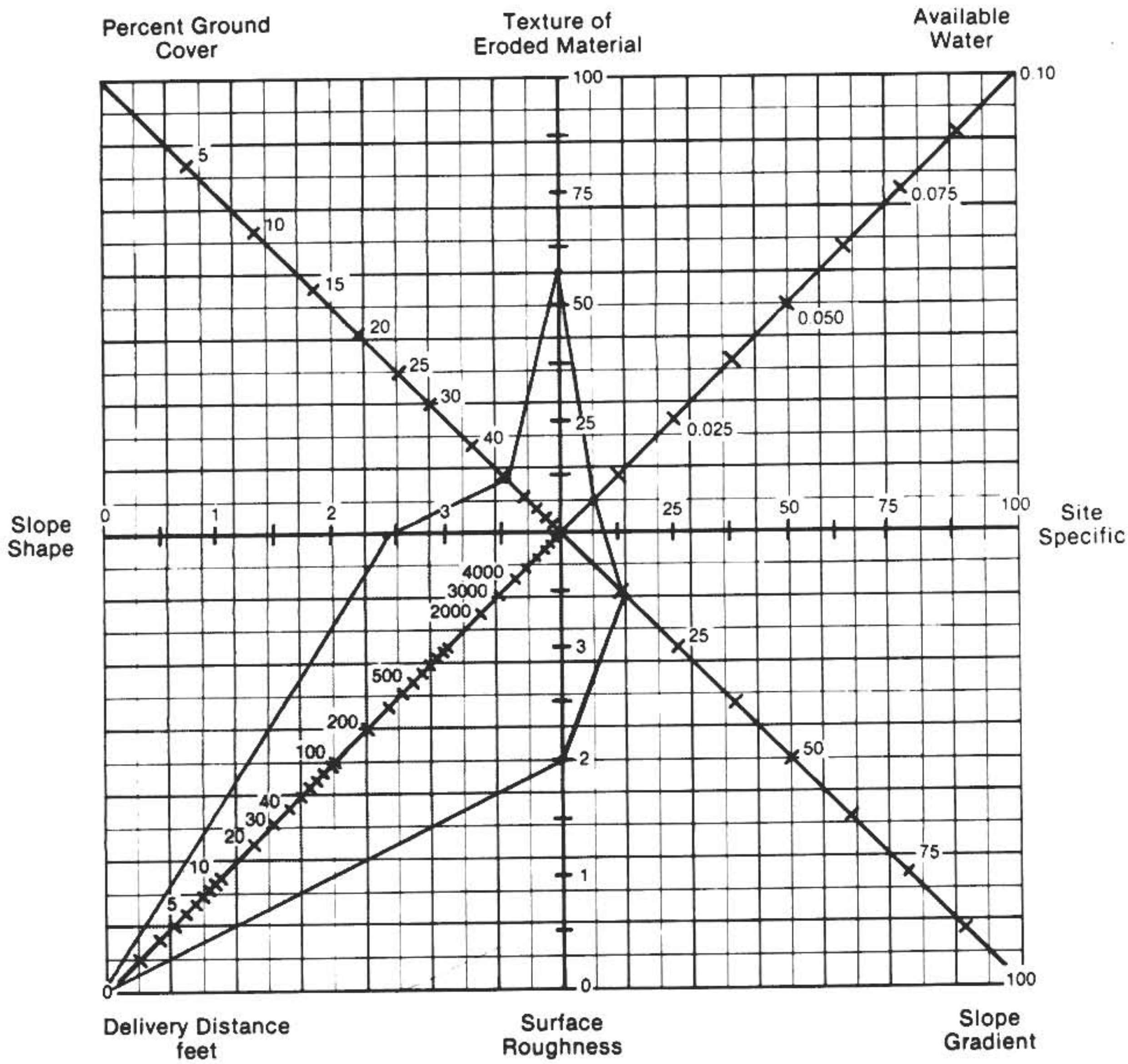

Figure VIII.9.—Stiff diagram for alternative A CC3.1, Grits Creek watershed.

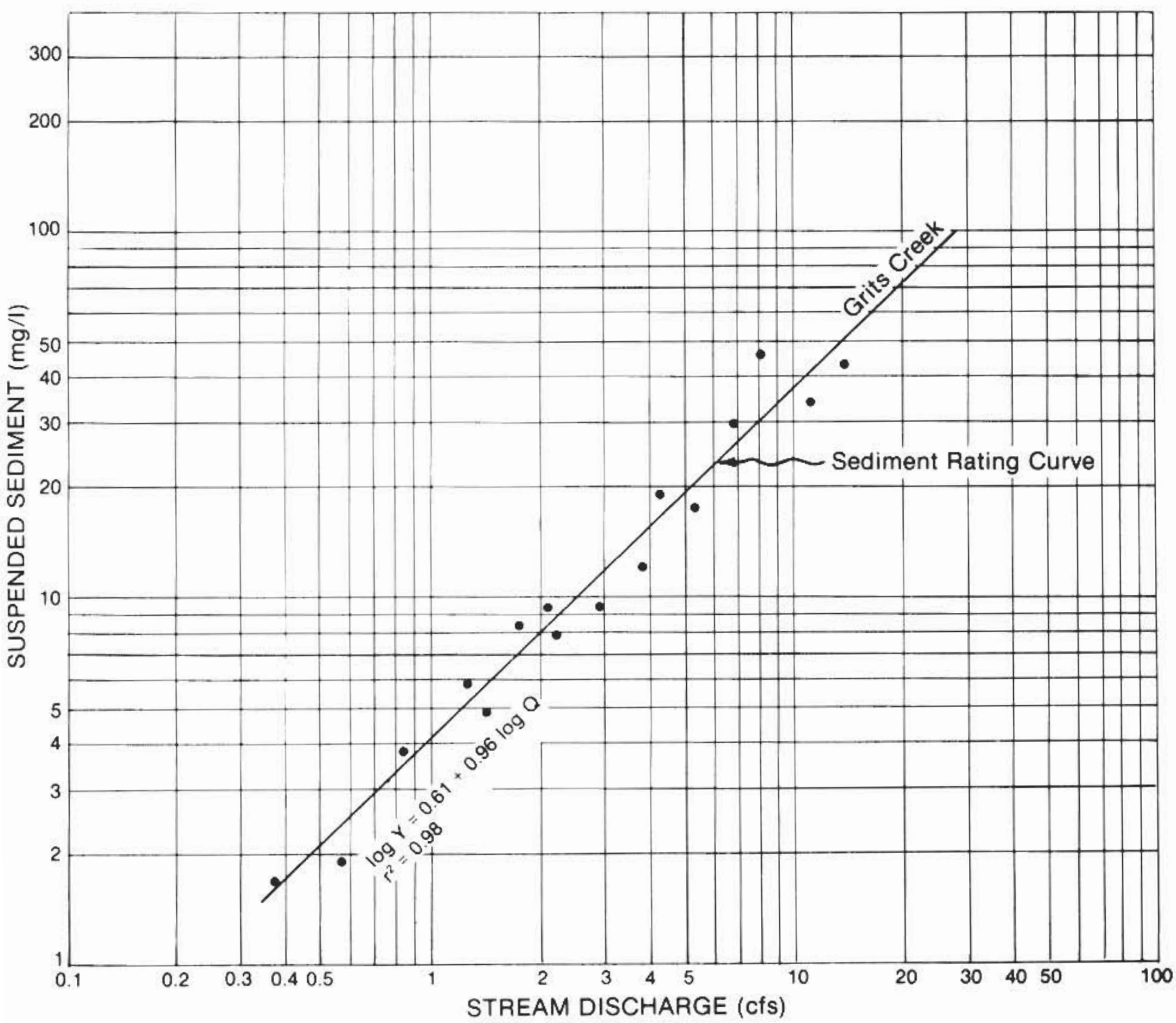

Figure VIII.10.—Sediment rating curve, Grits Creek watershed.

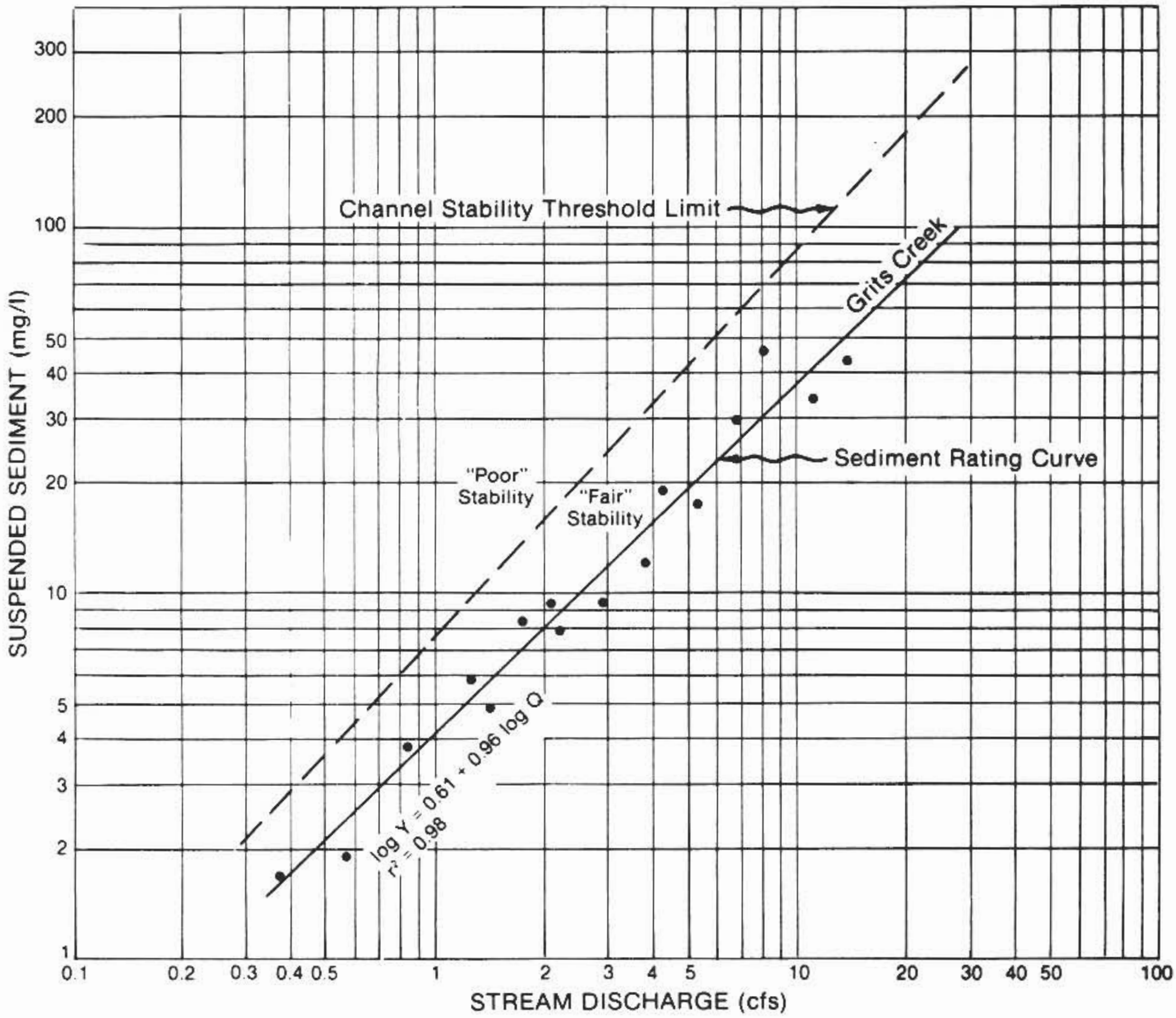

Figure VIII.11.—Channel stability threshold limits in relationship to the sediment rating curve, Grits Creek watershed.

Step 4. — Calculate pre-silvicultural activity potential suspended sediment discharge.

a. Using worksheet VI.1, columns (1) through (4). Use sediment rating curve (fig. VIII.10) for concentration values in column 3.

b. Record the total of 11.6 tons/yr on worksheet VI.3, line A.

Step 5. — Calculate post-silvicultural activity potential suspended sediment discharge (due to streamflow increases).

a. Using worksheet VI.1, columns (1), (5), (6), and (7).

b. Record the total of 19.6 tons/yr due only to flow increase on worksheet VI.3, line B.

Step 6. — Convert selected limits (mg/l) into units compatible with the analysis (tons/yr).

Maximum limits were set using the stream channel stability-sediment rating curve relationship for the watershed. Since the channel stability rating was fair, the threshold limit between the fair and poor stability classes was used (fig. VIII.11). For example, using 20 cfs, a value of 70 mg/l from the poor curve and 190 mg/l from the channel stability threshold limit curve are obtained, resulting in a 120 mg/l increase. The concentrations from the threshold line between fair and poor were used in worksheet IV.1, column (8). Using columns (2), (8), and (9) of worksheet VI.1, a total of 25.5 tons/yr is obtained and recorded on worksheet VI.3, line C.

Bedload Calculation

Step 7. — Bedload measurements were taken, but because of the heavily armored channel, no bedload was caught in a Helley-Smith sampler. Bedload rates appear to be negligible except in the event of a flood.

Step 8. — Not applicable because no bedload material was caught in sampler.

Step 9. — Calculate pre-silvicultural activity potential sediment discharge (suspended and bedload).

a. From step 4, (suspended sediment) = 11.6 tons/yr.

b. Record on worksheet VI.3, line K.

Step 10. — Not applicable—no bedload material.

Total Potential Sediment Calculation

Step 11. — The proposed activity contributed no sediment from soil mass movement processes.

Step 12. — Not applicable—no bedload material.

Step 13. — Not applicable—no bedload material.

Step 14. — Determine total delivered tons of suspended sediment from surface erosion.

a. Surface erosion source = 34.2 tons/yr

b. Record on worksheet VI.3, line D.1.

Step 15. — Compare total potential post-silvicultural activity suspended sediment (mg/l) to selected limits (tons/yr). On worksheet VI.3:

Add totals of:

Surface erosion (line D.1)	34.2 tons/yr
Total post-silvicultural activity suspended sediment discharge due to flow related increases (line B)	19.6 tons/yr
Soil mass movement (washload) (line D.4)	0.0 tons/yr
Total	53.8 tons/yr
Subtract the total pre-silvicultural activity suspended sediment discharge (line A) from the previously determined figure	11.6 tons/yr
The remainder is the total increase in potential suspended sediment discharge (line I.1)	42.2 tons/yr
Subtract the maximum allowable increase in suspended sediment discharge (line C) from the total increase in potential suspended sediment discharge (line I.1)	25.5 tons/yr
The remainder is the net change (this may be either a positive or negative number)	+16.7 tons/yr

Step 16. — Total potential post-silvicultural activity sediment discharge—all sources:

Summation of steps 5, 10, 11, and 14.

a. Post-silvicultural activity suspended sediment (flow related increases) (step 5, wksht. VI.3, line B) = 19.6 tons/yr

b. Bedload—not applicable.

c. Soil mass movement volume —not applicable.

d. Surface erosion (step 11, wksht. VI.3, line D.1 = 34.2 tons/yr

Total	53.8 tons/yr

Record on line L, worksheet VI.3.

Step 17. — Total potential sediment discharge increase resulting from silvicultural activity:

a. Subtract total potential pre-silvicultural activity sediment discharge (step 9) from total potential post-silvicultural activity sediment discharge (step 16)

Total post-worksheet IV.3, line L	53.8 tons/yr
Total pre-worksheet VI.3, line K	11.6 tons/yr
Total potential sediment increase	42.2 tons/yr

b. Record on worksheet VI.3, line M.

The total potential sediment increase is also recorded in table VIII.2 for management alternative A and table VIII.3 for management alternative B.

Channel Impacts

Step 18. — Not applicable to Grits Creek because direct channel impacts from debris, width constrictions, or gradient changes are not anticipated with the proposed action.

Step 19. — Not applicable.

Step 20. — Not applicable.

Step 21. — Not applicable.

TEMPERATURE ANALYSIS

Grits Creek was segmented into four reaches for temperature evaluation purposes (wksht. VII.2 and fig. VIII.12). This was necessary because of the variety of silvicultural activities—partial and clearcut—and length of stream involved—more than 1 mile from headwater to mouth. The first reach consists of an open meadow, 600 feet long, with no vegetative shade. The trees to be cut near the mouth are distant enough from the stream that they provide no shade. Therefore, the proposed silvicultural activity will not directly impact water temperature near the mouth. The partial cut area is approximately 3,800 feet along the center portion of the watershed. Since the evaluation procedure is valid for reaches up to 2,000 feet, this section of stream was divided into two reaches—a lower reach 2,000 feet long, and a middle reach of 1,800 feet. The headwater portion of the stream is in a clearcut; the upper reach is 1,000 feet long.

Following is the evaluation for each stream reach and an integration of the individual reaches to arrive at an estimated maximum daily potential temperature increase at the mouth. The analysis is the same for both management alternatives since the exposure to the stream has not changed.

Lower Reach

Computing H, Adjusted Incident Heat Load

Step 1. — Determine H (i.e., incident heat load) based upon latitude of site, critical time of year (month and day), and orientation of stream.

Step 1.1. — Select the solar ephemeris that most closely approaches the latitude of the site, 35°N (fig. VII.2).

Step 1.2. — Locate the declination in the solar ephemeris (fig. VII.2) that corresponds to the date when maximum water temperature increase is anticipated: last week August; therefore, a declination of +10°.

Step 1.3. — Once the declination, +10°, is known, determine the azimuth and solar angle for various times during the day from the solar ephemeris (fig. VII.2) and record the values in worksheet VII.1. Azimuth readings are found along the outside of the circle and are given for every 10°. Solar angle (i.e., degrees above the horizon) is indicated by the concentric circles and ranges from 0° at the outermost circle to 90° at the center of the circle. The time is indicated above the +23°27' declination line and is given in hours, solar time. Note that the time of day shown on worksheet VII.1 is given as daylight savings time (DST).

Step 1.4. — Evaluate the orientation of the sun (i.e., azimuth and angle determined in step 1.3 above) with the stream, and determine what vegetative shading effectively shades the stream. To do this, compare stream effective width with shadow length. Determine the maximum solar angle (i.e., maximum radiation influx to stream)

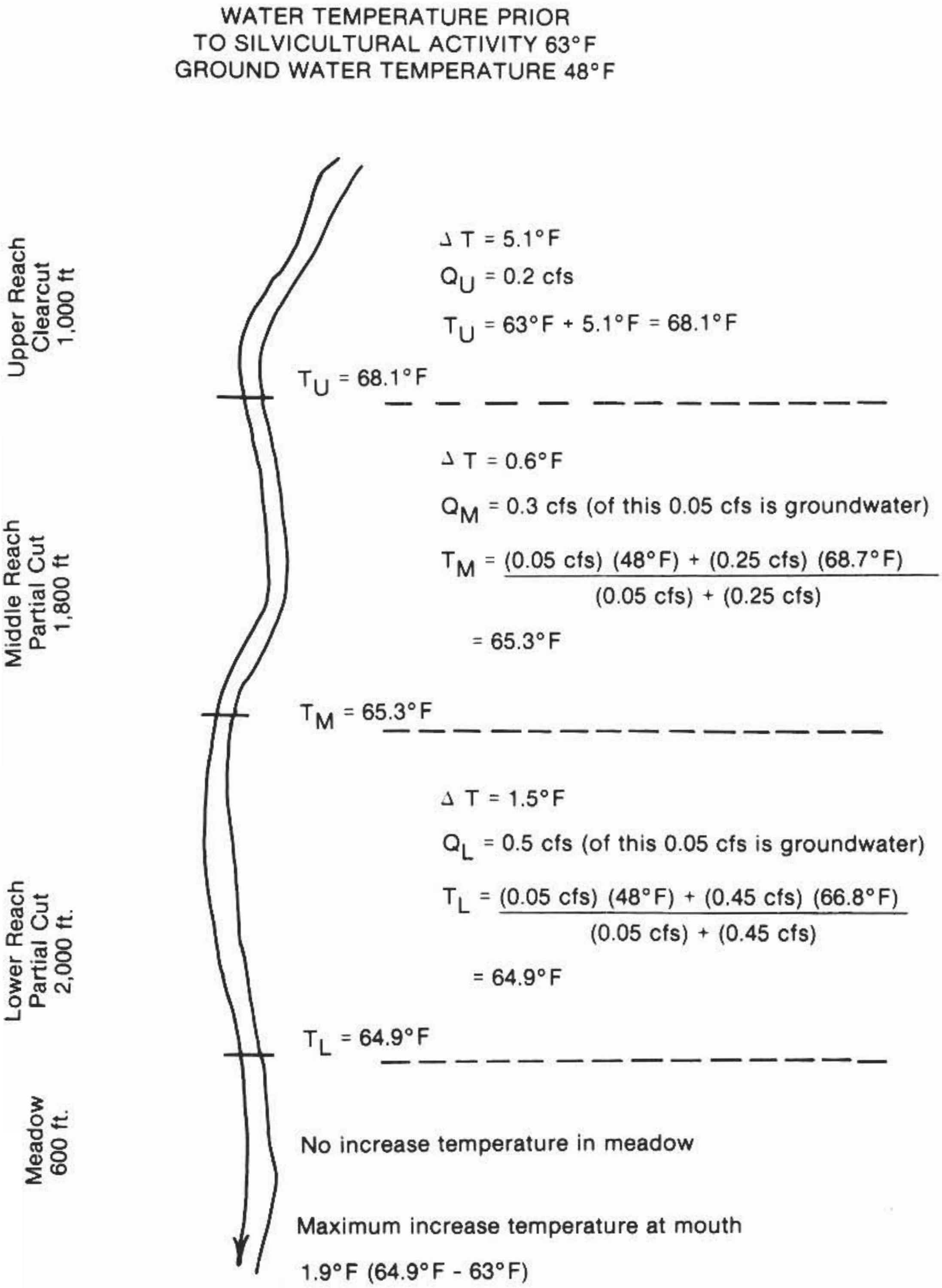

Figure VIII.12.—Water temperature evaluation, Grits Creek watershed.

that will occur when the stream is exposed following the silvicultural activity. Height of the existing vegetation immediately adjacent to the stream is 80 feet.

Step 1.4.1. — The direction the shadows fall across the stream will determine effective width of the stream.

Effective width is computed using the following formula:

$$EW = \frac{\text{measured average stream width}}{\text{sine} \mid \text{azimuth stream} - \text{azimuth sun} \mid} \qquad \text{(VII.4)}$$

Azimuth of the particular stream is 35°. For example, at 12 p.m. (wksht. VII.1) EW would be equal to:

$$EW = \frac{4 \text{ ft}}{\text{sine} \mid 35° - 148° \mid} = 4.4 \text{ ft}$$

The absolute value of azimuth of the stream subtracted from the azimuth of the sun must be less than a 90°-angle. Should the difference exceed 90°, subtract this absolute value from 180° to obtain the correct acute angle. Then the sine is taken of this computed acute angle.

Step 1.4.2. — Shadow length is computed using the formula:

$$S = \frac{\text{height vegetation}}{\text{tangent solar angle}} \qquad \text{(VII.5)}$$

For example, at 12 noon, S would be equal to:

$$S = 80 \text{ ft/tangent } 62° = 42.5 \text{ ft}$$

Summary of steps 1.4.1 and 1.4.2: The existing trees that are scheduled to be cut provide shade to the streams. The only time when trees might not shade the stream is 2:15 p.m., when the stream's effective width is infinity (sun is oriented with the stream) and the shadow length is only 46.2 feet. Therefore, removal of the vegetation would result in exposure of the water surface to increased solar radiation.

The proposed silvicultural activity would have the maximum impact on water temperature at 1 p.m. (solar noon) when the solar angle (65°) and radiation are greatest.

Step 1.5. — Topographic shading should be evaluated to determine if the water course would be shaded by topographic features. For topographic shading, the percent slope of the ground must exceed the percent slope of the solar angle, (i.e., tangent of the solar angle). In this case,

side slope east = 53%

side slope west = 50%

Solar angle expressed as percent for:

8 a.m. DST	= 32%
9 a.m.	= 58%
1 p.m.	= 214%
5 p.m.	= 58%
6 p.m.	= 32%

Therefore, topographic shading is possible before 9 a.m. and after 5 p.m. There is no topographic shading the rest of the day.

Step 1.6. — Calculate the incident heat load for the site. This is obtained from reading the values shown on figure VII.7. The following is done to read values from this figure:

Step 1.6.1. — Select the correct curve (shown in fig. VII.7) obtained from the correct solar ephemeris (fig. VII.2): in this example, 35°N latitude, given a declination of +10° results in a solar angle of 65°. Note that the midday value will always have an orientation, i.e., azimuth, of due south.

Step 1.6.2. — In figure VII.7, interpolate between the 70° and 60° curves to obtain the 65° value.

Step 1.6.3. — Determine the critical period, which in step 1.4 was found to be 1 p.m. DST.

Step 1.6.4. — Find the average H value. In this example, the travel time through the reach is estimated to be 1 hour, so it is not necessary to find an average value. From figure VII.7, with a 65° midday angle, the H value for 1 p.m. is approximately 4.3 BTU/ft^2–min.

Step 1.7. — Because bedrock acts as a heat sink, reducing the heat load absorbed by the water, the H value must be corrected for this heat loss.

C is obtained from figure VII.9. In the example, bedrock comprises 75 percent of the streambed; therefore, H should be reduced by 15 percent.

$$H_{adjusted} = [\% WH] + [\% B(1.00 - C)H] \qquad (VII.6)$$

where for Grits Creek:

- W = percent streambed without bedrock = 25%
- H = unadjusted heat load = 4.3 BTU/ft² – min
- B = percent streambed with rock = 75%
- C = correction factor from figure VII.9 = 0.15

Therefore,

$$H_{adjusted} = [0.25 \times 4.3\ BTU/ft^2 - min] + [0.75(1.00 - 0.15) \times 4.3\ BTU/ft^2 - min]$$

$$H_{adjusted} = 3.82\ BTU/ft^2 - min$$

Computing Q, Stream Discharge

Step 2. — Determine stream discharge following the proposed silvicultural activity during the critical summer low-flow period when maximum temperatures are anticipated. In this example, a pre-activity baseflow measurement during the critical summer period was taken. Discharge during the critical period was 0.5 cfs.

Computing A, Adjusted Surface Area

Step 3. — Determine the adjusted surface area of **flowing water** exposed by the proposed silvicultural activity.

Step 3.1. — Total surface area of flowing water

$$A_{total} = LW \qquad (VII.7a)$$

where:

- L = length of reach exposed
- W = width of flowing water

$$A_{total} = 2{,}000\ ft \times 5\ ft = 10{,}000\ ft^2$$

Step 3.2. — Total surface area shaded by brush

$$A_{shade\ brush} = LW\ (\%\ shaded\ by\ brush\ only) \qquad (VII.7b)$$
$$= 2{,}000\ ft \times 5\ ft \times 25\%$$
$$= 2{,}500\ ft^2$$

Step 3.3. — Surface area exposed under current vegetative canopy cover: correct for transmission of light through the existing stand that has a 90-percent overstory crown closure and a 50-percent understory crown closure. Since only vertical crown closure values are available, estimate the percentage transmission of solar radiation through the canopy. In using figure VII.D.1 for crown closures greater than 70 percent, assume a 5-percent transmission of solar radiation.

$$A_{presently\ exposed} = (A_{total} - A_{shade\ brush}) \times \%\ transmission\ through\ existing\ vegetation \qquad (VII.7c)$$
$$= (10{,}000\ ft^2 - 2{,}500\ ft^2) \times 5\%$$
$$= 375\ ft^2$$

Step 3.4. — The adjusted surface area that will be exposed to increased solar radiation if all vegetation is removed is:

$$A_{adjusted} = A_{total} - A_{presently\ exposed}$$
$$= 10{,}000\ ft^2 - 375\ ft^2$$
$$= 9{,}625\ ft^2$$

Step 4. — Estimate ΔT, maximum potential daily temperature increase in °F if all vegetation is removed from lower reach. Solve equation VII.3a.

$$\Delta T = \frac{A_{adjusted} H_{adjusted}}{Q} \times 0.000267 \qquad (VII.3a)$$

$$A_{adjusted} = 9{,}625\ ft^2$$
$$H_{adjusted} = 3.82\ BTU/ft^2 - min$$
$$Q = 0.5\ cfs$$
$$= 19.6°F$$

$$\Delta T = \frac{(9{,}625\ ft^2)\ (3.82\ BTU/ft^2 - min)}{0.5\ cfs} \times 0.000267$$

The proposed silvicultural activity will only result in a partial cut of the overstory, leaving a vertical crown closure of 50 percent. The understory will not be cut; however, some loss is to be expected during removal of the overstory. Understory vertical crown closure remaining after the silvicultural activity is expected to be 45 percent. It is estimated that the percent transmission of solar radiation through the canopy will be 15 percent. The brush shading the stream will remain.

Therefore,

$$A_{total} = 2{,}000\ ft \times 5\ ft = 10{,}000\ ft^2$$
$$A_{shade\ brush} = 2{,}000\ ft \times 5\ ft \times 25\% = 2{,}500\ ft^2$$
$$A_{shade\ remaining\ canopies} = (10{,}000\ ft^2 - 2{,}500\ ft^2) \times 85\% = 6{,}375\ ft^2$$
$$A_{adjusted} = A_{total} - (A_{presently\ exposed} + A_{shade\ brush} + A_{shade\ remaining\ canopies})$$
$$= 10{,}000\ ft^2 - (375\ ft^2 + 2{,}500\ ft^2 + 6{,}375\ ft^2)$$
$$= 750\ ft^2$$

Step 4. — Estimate ΔT, maximum potential daily temperature increase in °F if the proposed silvicultural activity is implemented. Solve equation VII.3a.

$$\Delta T = \frac{A_{adjusted} H_{adjusted}}{Q} \times 0.000267 \qquad \text{(VII.3a)}$$

$$A_{adjusted} = 750 \text{ ft}^2$$
$$H_{adjusted} = 3.82 \text{ BTU/ft}^2\text{-min}$$
$$Q = 0.5 \text{ cfs}$$

$$\Delta T = \frac{(750 \text{ ft}^2)\ (3.82 \text{ BTU/ft}^2\text{-min})}{0.5 \text{ cfs}} \times 0.000267$$

$$= 1.5°F$$

Middle Reach

Computing H, Adjusted Incident Heat Load

Step 1. — The only difference between the lower reach and the middle reach, when estimating H, is that the average width of flowing water is reduced from 5 feet to 3.5 feet. Thus, the effective stream width values would change, but the final H adjusted value would remain unchanged—3.82 BTU/ft²–min.

Computing Q, Stream Discharge

Step 2. — A pre-silvicultural activity baseflow measurement during the critical summer period was taken for this reach. Discharge during the critical period was 0.3 cfs.

Computing A, Adjusted Surface Area

Step 3. — Determine the adjusted surface area of **flowing water** exposed by the proposed silvicultural activity.

Step 3.1. — Total surface area of flowing water

$$A_{total} = LW \qquad \text{(VII.7a)}$$
$$= 1{,}800 \text{ ft} \times 3.5 \text{ ft}$$
$$= 6{,}300 \text{ ft}^2$$

Step 3.2. — Total surface area shaded by brush

$$A_{shade\ brush} = LW\ (\%\ \text{stream shaded by brush only}) \qquad \text{(VII.7b)}$$
$$= 1{,}800 \text{ ft} \times 3.5 \text{ ft} \times 40\%$$
$$= 2{,}520 \text{ ft}^2$$

Step 3.3. — Surface area exposed under current vegetative canopy cover: correct for transmission of light through the existing stand that has a 90-percent overstory crown closure and a 55-percent understory crown closure. Since only vertical crown closure values are available, estimate the percentage of solar radiation through the canopy. Again it is estimated that only 5-percent transmission of solar radiation is allowed through the canopies (fig. VII.D.1)

$$A_{presently\ exposed} = (A_{total} - A_{shade\ brush})\ \%\ \text{transmission through existing vegetation} \qquad \text{(VII.7c)}$$
$$= (6{,}300 \text{ ft}^2 - 2{,}520 \text{ ft}^2) \times 5\%$$
$$= 189 \text{ ft}^2$$

Step 3.4. — The adjusted surface area that will be exposed to increased solar radiation if all vegetation is removed is:

$$A_{adjusted} = A_{total} - A_{presently\ exposed}$$
$$= 6{,}300 \text{ ft}^2 - 189 \text{ ft}^2$$
$$= 6{,}111 \text{ ft}^2$$

Step 4. — Estimate ΔT, maximum potential daily temperature increase in °F if all vegetation is removed from middle reach. Solve equation VII.3a

$$\Delta T = \frac{A_{adjusted} H_{adjusted}}{Q} \times 0.000267 \qquad \text{(VII.3a)}$$

$$A_{adjusted} = 6{,}111 \text{ ft}^2$$
$$H_{adjusted} = 3.82 \text{ BTU/ft}^2\text{-min}$$
$$Q = 0.3 \text{ cfs}$$

$$\Delta T = \frac{(6{,}111 \text{ ft}^2)\ (3.82 \text{ BTU/ft}^2\text{-min})}{0.3 \text{ cfs}} \times 0.000267$$

$$= 29.7°F$$

The proposed silvicultural activity will only result in a partial cut of the overstory, leaving a crown closure of 50 percent. The understory will not be cut; however, some loss is expected during removal of the overstory. Understory vertical crown closure is expected to be 50 percent. It is estimated that the percent transmission of solar radiation though the canopy will be 10 percent. The brush shading the stream will remain.

Therefore,

$$A_{total} = 1{,}800\text{ ft} \times 3.5\text{ ft} = 6{,}300\text{ ft}^2$$

$$A_{shade\ brush} = 1{,}800\text{ ft} \times 3.5\text{ ft} \times 40\% = 2{,}520\text{ ft}^2$$

$$A_{shade\ remaining\ canopies} = (6{,}300\text{ ft} - 2{,}520\text{ ft}) \times 90\% = 3{,}402\text{ ft}^2$$

$$A_{adjusted} = A_{total} - (A_{presently\ exposed} + A_{shade\ brush} + A_{shade\ remaining\ canopies}) = 6{,}300\text{ ft}^2 - (189\text{ ft}^2 + 2{,}520\text{ ft}^2 + 2{,}402\text{ ft}^2) = 189\text{ ft}^2$$

Step 4. — Estimate ΔT, maximum potential daily temperature increase in °F if the proposed silvicultural activity is implemented. Solve equation VII.3a.

$$\Delta T = \frac{A_{adjusted} H_{adjusted}}{Q} \times 0.00027 \qquad \text{(VII.3a)}$$

$$A_{adjusted} = 189\text{ ft}^2$$
$$H_{adjusted} = 3.82\text{ BTU/ft}^2\text{-min}$$
$$Q = 0.3\text{ cfs}$$

$$\Delta T = \frac{(189\text{ ft}^2)\ (3.82\text{ BTU/ft}^2\text{-min})}{0.3\text{ cfs}} \times 0.000267$$

$$= 0.6°\text{F}$$

Upper Reach

Computing H, Adjusted Incident Heat Load

Step 1. — The only difference between the lower and middle reaches and the upper reach, when estimating H, is that the average width of flowing water is reduced to 2.5 feet. Because of this, the effective stream width values would change, but the final H adjusted value would remain unchanged—3.82 BTU/ft²-min.

Computing Q, Stream Discharge

Step 2. — A pre-silvicultural activity baseflow measurement was taken for this reach during the critical summer period, resulting in a value of 0.2 cfs.

Computing A, Adjusted Surface Area

Step 3. — Determine the adjusted surface area of **flowing water** exposed by the proposed silvicultural activity.

Step 3.1. — Total surface area of flowing water

$$A_{total} = LW \qquad \text{(VII.7a)}$$
$$= 1{,}000\text{ ft} \times 3.0\text{ ft} = 3{,}000\text{ ft}^2$$

Step 3.2. — Total surface area shaded by brush

$$A_{shade\ brush} = LW\ (\%\text{ stream shade by brush only}) \qquad \text{(VII.7b)}$$
$$= 1{,}000\text{ ft} \times 3.0\text{ ft} \times 65\% = 1{,}950\text{ ft}^2$$

Step 3.3. — Surface area exposed under current vegetative canopy cover; correct for transmission of light through the existing stand that has an 80-percent overstory crown closure and a 60-percent understory crown closure. Since only vertical crown closure values are available, estimate the percentage of solar radiation through the canopy. It is estimated that only 5-percent transmission of solar radiation is allowed through the canopies (fig. VII.D.1).

$$A_{presently\ exposed} = (A_{total} - A_{shade\ brush})\ \%\text{ transmission through existing vegetation}$$
$$= (3{,}000\text{ ft}^2 - 1{,}950\text{ ft}^2) \times 5\% = 53\text{ ft}^2$$

Step 3.4. — The adjusted surface area that will be exposed to increased solar radiation if all vegetation is removed is:

$$A_{adjusted} = A_{total} - A_{presently\ exposed} = 3{,}000\text{ ft}^2 - 53\text{ ft}^2 = 2{,}947\text{ ft}^2$$

Step 4. — Estimate ΔT, maximum potential daily temperature increase in °F if all vegetation is removed from the upper reach. Solve equation VII.3a.

$$\Delta T = \frac{A_{adjusted} H_{adjusted}}{Q} \times 0.000267 \qquad \text{(VII.3a)}$$

$$A_{adjusted} = 2{,}947\text{ ft}^2$$
$$H_{adjusted} = 3.82\text{ BTU/ft}^2\text{-min}$$
$$Q = 0.2\text{ cfs}$$

$$\Delta T = \frac{(2{,}947\text{ ft}^2)\ (3.82\text{ BTU/ft}^2\text{-min})}{0.2\text{ cfs}} \times 0.000267$$

$$= 15.0°\text{F}$$

The proposed silvicultural activity will be a commercial clearcut resulting in the complete removal of the overstory and understory canopies. The dense laurel and rhododendron brush along the stream will not be removed.

Therefore,

$$
\begin{aligned}
A_{total} &= 1{,}000\text{ ft} \times 3\text{ ft} \\
&= 3{,}000\text{ ft}^2 \\
A_{shade\ brush} &= 1{,}000\text{ ft} \times 3\text{ ft} \times 65\% \\
&= 1{,}950\text{ ft}^2 \\
A_{adjusted} &= A_{total} - (A_{presently\ exposed} \\
&\quad + A_{shade\ brush}) \\
&= 3{,}000\text{ ft}^2 - (53\text{ ft}^2 + 1{,}950\text{ ft}^2) \\
&= 997\text{ ft}^2
\end{aligned}
$$

Step 4. — Estimate ΔT, maximum potential daily temperature increase in °F if the proposed silvicultural activity is implemented. Solve equation VII.3a.

$$\Delta T = \frac{A_{adjusted} H_{adjusted}}{Q} \times 0.000267 \qquad \text{(VII.3a)}$$

$$
\begin{aligned}
A_{adjusted} &= 997\text{ ft}^2 \\
H_{adjusted} &= 3.82\text{ BTU/ft}^2\text{-min} \\
Q &= 0.2\text{ cfs}
\end{aligned}
$$

$$\Delta T = \frac{(997\text{ ft}^2)\ (3.82\text{ BTU/ft}^2\text{-min})}{0.2\text{ cfs}} \times 0.000267$$

$$= 5.2°\text{F}$$

The Mixing Ratio Formula

The lower reach of Grits Creek is to be partially cut, with a potential temperature increase of 1.5°F. The middle reach will also be partially cut, with a potential temperature increase of 0.6°F. The upper reach is to be clearcut, with a potential temperature increase of 5.1°F.

An estimate of the integrated impact on the water temperature is necessary so that a comparison can be made with the water quality objective—allowing a maximum temperature increase of 3°F.

A mixing ratio formula will be used to estimate the downstream temperature impacts. The water temperature before the silvicultural activity was 63°F, and the groundwater temperature measured at a spring was 48°F.

For the upper reach, the estimated water temperature increase, 5.1°F, is added to the pre-silvicultural activity water temperature 63°F, to estimate the temperature of the water as it leaves the proposed clearcut area, 5.1°F + 63°F = 68.1°F.

The water temperature entering the middle reach will be 68.1°F. The estimated water temperature increase in the middle reach is 0.6°F. However, the two values should not be added to get an estimate of the water temperature leaving the middle reach because groundwater influxes within this reach will mitigate the water temperature increase caused by the proposed silvicultural activity. The following mixing ratio formula should be used:

$$T_D = \frac{D_M T_M + D_T T_T}{D_M + D_T} \qquad \text{(VII.9)}$$

where:

T_D = temperature downstream where the middle and lower reaches are separated

D_G = discharge of groundwater, 0.05 cfs

D_t = discharge immediately below partial cut, 0.30 cfs

T_G = temperature groundwater, 48°F

T_T = stream temperature below silvicultural activity which is equal to the temperature above plus computed temperature increase, 68.7°F

$$T_T = T_A + \Delta T$$

T_A = temperature streams above treated (partial cut) area, 68.1°F

ΔT = temperature increase, 0.6°F

Therefore,

$$T_D = \frac{(0.05\text{ cfs})\ (48°\text{F})\ +\ (0.25\text{ cfs})\ (68.7°\text{F})}{(0.05\text{ cfs})\ +\ (0.25\text{ cfs})}$$

$$= 65.3°\text{F}$$

The water temperature entering the lower reach will be 65.3°F. The estimated water temperature increase in the lower reach is 1.5°F. Again, the two values should not be added as explained above. The following mixing ratio formula should be used:

$$T_D = \frac{D_G T_G + D_T T_T}{D_G + D_T} \qquad \text{(VII.9)}$$

where:

T_D = temperature downstream where lower reach ends

D_G = discharge of groundwater, 0.05 cfs

D_T = discharge immediately below partial cut, 0.50 cfs

T_G = temperature of groundwater, 48°F

T_T = stream temperature below silvicultural activity which is equal to the temperature above plus computed temperature increase, 66.8°F

$$T_T = T_A + \Delta T$$

T_A = temperature stream above treated (partial cut) area, 65.3°F

ΔT = temperature increase, 1.5°F

Therefore,

$$T_D = \frac{(0.05\ \text{cfs})\ (48°\text{F}) + (0.45\ \text{cfs})\ (66.8°\text{F})}{(0.05\ \text{cfs}) + (0.45\ \text{cfs})}$$

$$= 64.9°\text{F}$$

The estimated overall water temperature increase at the mouth would be 1.9°F (64.9°F − 63°F = 1.9°F). This value is entered in the tables VIII.2 and VIII.3 for both management alternatives.

ANALYSIS REVIEW

The estimated outputs are summarized in tables VIII.2 and VIII.3 for Grits Creek alternatives A and B, respectively. These estimates must be compared to the water quality objectives to determine if one or both of the alternatives are acceptable.

In determining acceptability of the alternatives, accuracy of the estimations must be considered. The two major sources of variation affecting accuracy of outputs are: (1) models, which by their very nature, cannot completely represent all factors affecting the estimated output, and (2) quality of input data — there is a decrease in the accuracy of the estimated output as the quality of the input data decreases. Establishing an acceptable level of accuracy for the estimated outputs is left to the professional judgment of a user who understands the strengths and weaknesses of the models and data sets used.

The computed outputs for total potential sediment from all sources and the potential temperature changes are compared to the water quality objective at the mouth of the watershed. The water quality objective for Grits Creek was to maintain channel stability, limit total potential sediment discharge to 25.5 tons/yr, and limit the maximum temperature increase to 3°F. The post-silvicultural activity total suspended sediment discharge from all sources was 26.3 tons/yr for alternative B and 53.8 tons/yr for alternative A (tables VIII.2 and VIII.3). Although alternative B resulted in 0.8 tons/yr in excess of the allowable maximum, it was judged to be within the accuracy range for the data and models used. Since both alternatives were consistent with temperature objectives, the mix of controls in alternative B was considered acceptable from a water quality standpoint.

Table VIII.2

Summary of quantitative outputs for: Alternative A, Grits Creek

Chapter	Line No.	Output description		Computed value: Pre-activity	Computed value: Post-activity	Chapter reference (worksheets)
Hydrology: Chapter III	1	Water available for annual streamflow		104.9 cm	120.8 cm	III.1, III.2
	2	Increase in water available for annual streamflow			15.9 cm	III.1, III.2
	3	Peak discharge		13.1 cm	13.1 cm	III.3, III.4
	4	Date of peak discharge		N. A.	N. A.	
	5	Hydrograph		N. A	N. A.	
	6	7-day flow duration curve		fig. VIII.3	fig. VIII.3	III.3, III.4
Surface Erosion: Chapter IV	7	Surface soil loss		N. A.	3300 tons/yr	IV.3
	8	Sediment delivered to stream channel		N. A.	34.2 tons/yr	IV.8
Soil Mass Movement: Chapter V	9	Hazard index				
	10	Weight of sediment	Coarse >0.062 mm			
	11		Fine <0.062 mm	(No soil Mass Movement)		
	12		Total			
	13	Acceleration factor				
Total Potential Sediment: Chapter VI	14	Sediment discharge due to flow change	Bedload	0.0 tons/yr	0.0 tons/yr	VI.3 line E VI.3 line F
	15		Suspended	11.6 tons/yr	19.6 tons/yr	VI.3 line A VI.3 line B
	16		Total	11.6 tons/yr	19.6 tons/yr	VI.3 line K VI.3 line G
	17	Total suspended sediment discharge from all sources		11.6 tons/yr	53.8 tons/yr	VI.3 line A line I.1 + A
	18	Increase in total potential bedload plus suspended sediment from all sources			42.2 tons/yr	VI.3 line M
Temperature: Chapter VII	19	Potential temperature changes			1.5°F	VII.2

Table VIII.3

Summary of quantitative outputs for: Alternative B, Grits Creek

Chapter	Line No.	Output description		Computed value: Pre-activity	Computed value: Post-activity	Chapter reference (worksheets)
Hydrology: Chapter III	1	Water available for annual streamflow		104.9 cm	120.8 cm	III.1, III.2
	2	Increase in water available for annual streamflow			15.9 cm	III.1, III.2
	3	Peak discharge		13.1 cm	13.1 cm	III.3, III.4
	4	Date of peak discharge		N.A.	N.A.	
	5	Hydrograph		N.A	N.A.	
	6	7-day flow duration curve		fig VIII.3	fig VIII.3	III.3, III.4
Surface Erosion: Chapter IV	7	Surface soil loss		N.A.	240 tons/yr	IV.3
	8	Sediment delivered to stream channel		N.A.	6.7 tons/yr	IV.8
Soil Mass Movement: Chapter V	9	Hazard index				
	10	Weight of sediment	Coarse >0.062 mm			
	11		Fine <0.062 mm	(No Soil Mass Movement)		
	12		Total			
	13	Acceleration factor				
Total Potential Sediment: Chapter VI	14	Sediment discharge due to flow change	Bedload	0.0 tons/yr	0.0 tons/yr	VI.3 line E VI.3 line F
	15		Suspended	11.6 tons/yr	19.6 tons/yr	VI.3 line A VI.3 line B
	16		Total	11.6 tons/yr	19.6 tons/yr	VI.3 line K VI.3 line G
	17	Total suspended sediment discharge from all sources		11.6 tons/yr	26.3 tons/yr	VI.3 line A line I.1+ A
	18	Increase in total potential bedload plus suspended sediment from all sources			14.7 tons/yr	VI.3 line M
Temperature: Chapter VII	19	Potential temperature changes			1.5°F	VII.2

Worksheets for Grits Creek
alternatives A and B

Worksheets are presented in numerical order with all III.1-III.4 alternative A, followed by III.1-III.4 alternative B; IV.1-IV.8 alternative A, followed by IV.1-IV.8 alternative B, etc.

WORKSHEET III.1

Water available for streamflow for the existing condition in rainfall dominated regions

(1) Watershed name Grits Creek (2) Hydrologic region 2 (3) Total watershed area (acres) 356 (4) Latitude 35°

Season name/ dates (5)	Silvicultural prescription: Compartment (6)	Silvicultural prescription: Silvicultural state (7)	Area: Acres (8)	Area: Percent (9)	Precipitation (cm) (10)	Baseline ET (cm) (11)	Basal area (ft²/ac) (12)	Leaf area index (13)	ET modifier coef. (14)	Rooting depth modifier coef. (15)	Weighted adjusted ET (cm) (16)	Weighted adjusted seasonal ET (cm) (17)	Water available for seasonal streamflow (cm) (18)
Fall 9/1 - 11/31	Unimpacted	Forested	356	1.000	23.3	20.1		6	1.0	1.0	20.1		
	Impacted												
	Total for season		356	1.000	23.3						20.1	20.1	3.2
Winter 12/1 - 2/28	Unimpacted	Forested	356	1.000	75.2	8.9		6	1.0	1.0	8.9		
	Impacted												
	Total for season		356	1.000	75.2						8.9	8.9	66.3
Spring 3/1 - 5/31	Unimpacted	Forested	356	1.000	60.5	13.0		6	1.0	1.0	13.0		
	Impacted												
	Total for season		356	1.000	60.5						13.0	13.0	47.5
Summer 6/1 - 8/31	Unimpacted	Forested	356	1.000	27.0	39.1		6	1.0	1.0	39.1		
	Impacted												
	Total for season		356	1.000	27.0						39.1	39.1	-12.1
(19) Annual ET (cm)												81.1	
(20) Water available for annual streamflow (cm)													104.9

Item or Col. No.	Notes
(1)	Identification of watershed or watershed subunit.
(2)	Descriptions of hydrologic regions and provinces are given in text.
(3),(4)	Supplied by user.
(5)	Seasons for rainfall dominated regions are fall (September, October, November), winter (December, January, February), spring (March, April, May), and summer (June, July, August).
(6)	The unimpacted compartment includes areas not affected by the silvicultural prescription. The impacted compartment includes areas affected by the silvicultural prescription.
(7)	Areas of similar hydrologic response as identified and delineated by vegetation or silvicultural state.
(8)	Supplied by user.
(9)	Column (8) ÷ item (3).
(10)	Measured or estimated by the user.
(11)	From figures III.10 to III.12; or user supplied.
(12)	Supplied by user. Unnecessary if leaf area index is known.
(13)	From figures III.13 and III.14; or user supplied.
(14)	From figures III.15 to III.17.
(15)	From figures III.18 to III.20.
(16)	Calculated as (11) x (14) x (15) x (9); or user supplied.
(17)	Seasonal sum of column (16).
(18)	Column (10) - column (17).
(19)	Sum of column (17).
(20)	Sum of column (18).

WORKSHEET III.2

Water available for streamflow for the proposed condition in rainfall dominated regions

(1) Watershed name Grits Creek (2) Hydrologic region 2 (3) Total watershed area (acres) 356 (4) Latitude 35°

Season name/ dates (5)	Silvicultural prescription: Compartment (6)	Silvicultural prescription: Silvicultural state (7)	Area: Acres (8)	Area: Percent (9)	Precipitation (cm) (10)	Baseline ET (cm) (11)	Basal area (ft^2/ac) (12)	Leaf area index (13)	ET modifier coef. (14)	Rooting depth modifier coef. (15)	Weighted adjusted ET (cm) (16)	Weighted adjusted seasonal ET (cm) (17)	Water available for seasonal streamflow (cm) (18)
Fall 9/1 - 11/31	Unimpacted	Forested	84	.236	23.3	20.1		6	1.00	1.0	4.74		
	Impacted	Clearcut	180	.506	23.3	20.1		2	.81	1.0	8.23		
		Thinned	92	.258	23.3	20.1		3	.90	1.0	4.67		
	Total for season		356	1.000	23.3						17.64	17.6	5.7
Winter 12/1 - 2/28	Unimpacted	Forested	84	.236	75.2	8.9		6	1.00	1.0	2.10		
	Impacted	Clearcut	180	.506	75.2	8.9		2	.65	1.0	2.93		
		Thinned	92	.258	75.2	8.9		3	.76	1.0	1.75		
	Total for season		356	1.000	75.2						6.78	6.8	68.4
Spring 3/1 - 5/31	Unimpacted	Forested	84	.236	60.5	13.0		6	1.00	1.0	3.07		
	Impacted	Clearcut	180	.506	60.5	13.0		2	.60	1.0	3.95		
		Thinned	92	.258	60.5	13.0		3	.72	1.0	2.41		
	Total for season		356	1.000	60.5						9.43	9.4	51.1
Summer 6/1 - 8/31	Unimpacted	Forested	84	.236	27.0	39.1		6	1.00	1.0	9.23		
	Impacted	Clearcut	180	.506	27.0	39.1		2	.69	1.0	13.65		
		Thinned	92	.258	27.0	39.1		3	.84	1.0	8.47		
	Total for season		356	1.000	27.0						31.35	31.4	-4.4
(19) Annual ET (cm)												65.2	
(20) Water available for annual streamflow (cm)													120.8

Item or Col. No.	Notes
(1)	Identification of watershed or watershed subunit.
(2)	Descriptions of hydrologic regions and provinces are given in text.
(3),(4)	Supplied by user.
(5)	Seasons for rainfall dominated regions are fall (September, October, November), winter (December, January, February), spring (March, April, May), and summer (June, July, August).
(6)	The unimpacted compartment includes areas not affected by the silvicultural prescription. The impacted compartment includes areas affected by the silvicultural prescription.
(7)	Areas of similar hydrologic response as identified and delineated by vegetation or silvicultural state.
(8)	Supplied by user.
(9)	Column (8) ÷ Item (3).
(10)	Measured or estimated by the user.
(11)	From figures III.10 to III.12; or user supplied.
(12)	Supplied by user. Unnecessary if leaf area index is known.
(13)	From figures III.13 and III.14; or user supplied.
(14)	From figures III.15 to III.17.
(15)	From figures III.18 to III.20.
(16)	Calculated as (11) x (14) x (15) x (9); or user supplied.
(17)	Seasonal sum of column (16).
(18)	Column (10) - column (17).
(19)	Sum of column (17).
(20)	Sum of column (18).

WORKSHEET III.3

Flow duration curve for existing condition
rain dominated regions

(1) Watershed name Grits Creek (2) Hydrologic region 2

(3) Water available for annual streamflow existing condition (cm) 104.9

(4) Annual flow from duration curve for hydrologic region (cm) 72.0

(5) Adjustment ratio (3)/(4) 1.457

Point number i (6)	Percent of time flow is equaled or exceeded (7)	Regional flow (cm/7 days) (8)	Existing potential flow Q_i (cm/7 days) (9)	Existing potential flow Q_i (cfs) (10)
1	0	9.0	13.1	11.0
2	10	2.7	3.9	3.3
3	20	1.9	2.8	2.4
4	30	1.4	2.0	1.7
5	40	1.2	1.8	1.5
6	50	.7	1.0	.8
7	60	.5	.7	.6
8	70	.4	.6	.5
9	80	.3	.4	.3
10	90	.2	.3	.25
11	100	0	0	0

Col. No. Notes

(1) Identification of watershed or watershed subunit.
(2) Descriptions of hydrologic regions and provinces are given in text.
(3) Item (20) of worksheet III.1.
(4) From figure III.22.
(5) Item (3) ÷ item (4).
(6) Number of each point taken from figure III.22; or user supplied.
(7) X-axis of figure III.22.
(8) From figure III.22; or user supplied (unnecessary if col. (9) is user supplied).
(9) Column (8) x item (5); or user supplied.
(10) Column (9) x area (acres) x 0.002363.

WORKSHEET III.4

Flow duration curve for proposed condition
rain dominated regions--annual hydrograph unavailable

(1) Watershed name Grits Creek (2) Hydrologic region 2 (3) Watershed aspect code (AS) 0

(4) Existing condition LAI 6.0 (5) Proposed condition LAI 3.2 (6) Change in LAI (CD) 2.8

(7) Rooting depth modifier coefficient (RD) 1 (8) b_0 -.03 (9) b_1 -.03 (10) b_2 .13 (11) b_3 .02 (12) b_4 .03

Point number i (13)	Percent of time flow is equaled or exceeded (14)	Existing potential flow Q_i (15)	b_0 (16)	b_1Q_i (17)	b_2CD (18)	b_3AS (19)	b_4RD (20)	ΔQ_i (cm) (21)	$Q_i + \Delta Q_i$ (cm) (22)	$Q_i + \Delta Q_i$ (cfs) (23)
1	0	13.1	-.03	-.39	.36	0	.03	-.03	13.1	11.0
2	10	3.9	-.03	-.12	.36	0	.03	.24	4.1	3.4
3	20	2.8	-.03	-.08	.36	0	.03	.28	3.1	2.6
4	30	2.0	-.03	-.06	.36	0	.03	.30	2.3	1.9
5	40	1.8	-.03	-.05	.36	0	.03	.31	2.1	1.8
6	50	1.0	-.03	-.03	.36	0	.03	.33	1.3	1.1
7	60	.7	-.03	-.02	.36	0	.03	.34	1.0	.8
8	70	.6	-.03	-.02	.36	0	.03	.34	.9	.76
9	80	.4	-.03	-.01	.36	0	.03	.35	.8	.67
10	90	.3	-.03	-.01	.36	0	.03	.35	.7	.59
11	100	0	-.03	0	.36	0	.03	.36	.4	.34

Item or Col. No.	Notes
(1)	Identification of watershed or watershed subunit.
(2)	Descriptions of hydrologic regions and provinces given in the text.
(3)	Northern aspect = +1, southern aspect = -1, eastern or western aspect = 0.
(4)	Area weighted average for existing condition.
(5)	Area weighted average for proposed condition.
(6)	Item (4) - item (5).
(7)	Area weighted average.
(8)-(12)	From tables III.3 to III.5.

Item or Col. No.	Notes
(13)	Column (6) of worksheet III.3.
(14)	Column (7) of worksheet III.3.
(15)	Column (9) of worksheet III.3.
(16)	Item (8).
(17)	Item (9) x column (15).
(18)	Item (10) x item (6).
(19)	Item (11) x item (3).
(20)	Item (12) x item (7).
(21)	Columns (16) + (17) + (18) + (19) + (20).
(22)	Column (15) + column (21).
(23)	Column (22) x area (ac) x 0.002363 for 7-day intervals.

WORKSHEET IV.1

Soil characteristics for the Grits Creek watershed

Soil group		Percent sand 2.0–0.1 mm	Percent very fine sand 0.10–0.05 mm	Percent "coarse silt" 0.062–0.05 mm[1/]	Percent silt 0.05–0.002 mm	Percent clay <0.002 mm	Percent organic matter	Soil structure		Soil permeability	
								MSLE code	Descriptive	MSLE code	Inches per hour
1	Topsoil	40	17	2	18	25	4.0	2	FINE GRANULAR	3	0.6-2.0
1	Subsoil	55	16	1	14	15	1.0	4	MASSIVE	3	0.6-2.0
2	Topsoil	40	18	2	22	20	4.0	2	FINE GRANULAR	2	2.0-6.0
2	Subsoil	60	17	1	13	10	1.0	4	MASSIVE	2	2.0-6.0
3	Topsoil	30	19	3	26	25	4.0	2	FINE GRANULAR	3	0.6-2.0
3	Subsoil	40	17	2	23	20	1.0	4	MASSIVE	3	0.6-2.0

1/The "coarse silt" particle size group is not part of the USDA classification system, but 0.062 mm represents an upper limit of particle size that is used when estimating suspended sediment transport in streams. For this use only the "coarse silt" size within the USDA very fine sand classification is presented.

WORKSHEET IV.2

Grits Creek watershed erosion response unit management data for use in the MSLE and sediment delivery index, hydrographic area 13, alternative A.

Erosion response unit	Slope length of disturbed area (ft)	Slope gradient of disturbed area (%)	Length of road section [1] (ft)	Average width of disturbance (ft)	Area (sq.ft.)	Area [2] (acres)
1. SC 13.1	176	8				6.1
2. SC 13.2	286	16				5.7
3. CC 13.1	132	12				1.4
4. CC 13.2	484	20				6.4
5. R 13.1			543	16.9		0.21
6. CUT	3.5	170		1.8		
7. BED	12.0	1		12.0		
8. FILL	4.5	100		3.1		
9. R 13.2 [3]			24	18.0		0.01
10. FILL	2.0	100		1.4		
11. BED	13.0	0		13.0		
12. FILL	5.0	100		3.6		
13. R 13.5			616	23.0		0.33
14. CUT	8.0	180		3.9		
15. BED	12.0	1		12.0		
16. FILL	10.0	100		7.1		
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						

1/ *Approximately 200 feet between water diversion dips.*

2/ *1 acre = 43,560 ft^2*

3/ *This road crosses a stream. It is separated from the rest of the road because sediment is delivered directly into a channel.*

WORKSHEET IV.2--continued

	Area with surface residues			Open area				
	Percent of total area	Percent of surface with mulch	Percent of area with fine roots 4/	Percent of total area	Percent of surface with mulch	Percent of area with fine roots	Are open areas separated by filter strips?	Percent of total area with canopy
1.	40	85	99	60	55	85	YES	45
2.	45	85	99	55	50	80	YES	45
3.	55	60	99	45	45	80	YES	0
4.	60	60	99	40	45	85	YES	0
5.								
6.	0	0	0	100	0	0	NO	25
7.	0	0	0	100	0	0	NO	0
8.	60	85	50	40	0	0	NO	25
9.								
10.	60	85	50	40	0	0	NO	25
11.	0	0	0	100	0	0	NO	0
12.	60	85	50	40	0	0	NO	25
13.								
14.	0	0	0	100	0	0	NO	0
15.	0	0	0	100	0	0	NO	0
16.	60	85	50	40	0	0	NO	0
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								

4/ *Not applicable to scalped areas until vegetation is reestablished.*

WORKSHEET IV.2--continued

	Average minimum height of canopy (m)	Time for recovery (mo)	Average dist. from disturbance to stream channel (ft)	Overall slope shape between disturbance and channel	Percent ground cover in filter strip	Surface roughness (qualitative)	Texture of eroded material 5/ (% silt + clay)	Percent slope between disturbance and channel
1.	2	↑	0	CONCAVE	88	MODERATE	47	8
2.	2		0	CONCAVE	86	MODERATE	57	16
3.	–		0	CONCAVE	94	MODERATE	57	12
4.	–		0	CONCAVE	90	MODERATE	50	20
5.			138	CONCAVE	88	MODERATE	38	8
6.	2							
7.	–							
8.	2							
9.			0	STRAIGHT	0	SMOOTH	38	100
10.	2							
11.	–	UNKNOWN						
12.	2							
13.			193	CONCAVE	86	MODERATE	50	16
14.	2							
15.	–							
16.	2							
17.			0	STRAIGHT	0	SMOOTH	50	100
18.	2							
19.	–							
20.	2							
21.			193	CONCAVE	94	MODERATE	50	12
22.	–							
23.	–							
24.	–	↓						
25.								

5/ *It has been assumed that ½ of the clay remains on-site as stable aggregates and that the rest of the clay plus very fine sand and silt enter the sediment delivery system.*

WORKSHEET IV.3

Estimates of soil loss and delivered sediment by erosion response unit for hydrographic area 13 of Grits Creek watershed

Erosion response unit [1]	Soil unit [2]	R	K	LS	VM	Area (acres)	Surface soil loss (tons/yr)	SD_I	Delivered sediment (tons/yr)
SC13.1	T1	300	0.09	1.31	0.012	6.1	2.6	0.02	0.05
SC13.2	T3	300	0.18	4.33	0.014	5.7	18.7	0.02	0.37
CC13.1	T3	300	0.18	2.05	0.023	1.4	3.6	0.02	0.07
CC13.2	T2	300	0.14	5.92	0.023	6.4	36.6	0.0	0.0
R13.1	S1	300	0.24	6.84	0.870	0.21	90.0	0.01	0.90
R13.2	S1	300	0.24	1.81 [3]	0.822	0.01	1.1	0.14	0.2
R13.5	S3	300	0.29	13.47	0.818	0.33	316	0.01	3.2

1/ SC - *Selection cut*
CC - *Clearcut*
R - *Road*

2/ T - *Topsoil*
S - *Subsoil*

3/ *Average of two LS values, one for each half of the road, starting at the center line and including a fill slope.*

WORKSHEET IV.4

Estimated VM factors for silvicultural erosion response units
Grits Creek watershed, hydrographic area 13.

	Logging residue area					Open area						
Erosion response unit	Fraction of total area	Mulch (duff & residue)	Canopy [1]	Roots	Sub VM	Fraction percent of total area	Mulch (duff & residue)	Canopy [1]	Roots	Filter strip	Sub VM	Total VM [3]
SC13.1	0.40	0.10	0.98 [2]	0.10	.0039	0.60	0.28	0.90	0.11	0.5	.0083	0.012
SC13.2	0.45	0.10	0.98	0.10	.0044	0.55	0.32	0.88	0.12	0.5	.0093	0.014
CC13.1	0.55	0.25	1.0	0.10	.0138	0.45	0.35	1.0	0.12	0.5	.0095	0.023
CC13.2	0.60	0.25	1.0	0.10	.015	0.40	0.35	1.0	0.11	0.5	.0077	0.023
R13.1 CUT [4]	0.0	–	–	–	0.0	1.00	1.0	0.88	–	1.0	0.880	0.88
BED	0.0	–	–	–	0.0	1.00	1.0	1.00	–	1.0	1.0	1.0
FILL	0.60	0.10	0.88	0.21	0.011	0.40	1.0	0.88	–	1.0	0.352	0.36
R13.2 FILL	0.60	0.10	0.88	0.21	0.011	0.40	1.0	0.88	–	1.0	0.352	0.36
BED	0.0	–	–	–	0.0	1.00	1.0	1.00	–	1.0	1.0	1.0
FILL	0.60	0.10	0.88	0.21	0.011	0.40	1.0	0.88	–	1.0	0.352	0.36
R13.5 CUT	0.0	–	–	–	0.0	1.00	1.0	1.0	–	1.0	1.0	1.0
BED	0.0	–	–	–	0.0	1.00	1.0	1.0	–	1.0	1.0	1.0
FILL	0.60	0.10	1.0	0.21	0.013	0.40	1.0	1.0	–	1.0	0.4	0.41

1/ *Canopy effects only apply to open areas without residue and duff.*

2/ *Example calculation: From worksheet IV.2, 85% of the surface has mulch, leaving 15% without mulch. If the canopy is uniformly distributed over 45% of the total area, then only 15% of the canopy can cover the area without mulch. Therefore: (0.15)(0.45)(100) = 7% of the area without mulch, that is covered by the canopy. This results in a VM = 0.98.*

3/ *Enter on worksheet IV.3.*

4/ *VM for roads is for a recovered condition.*

WORKSHEET IV.6

Weighting of VM values for roads in Grits Creek watershed, hydrographic area 13.

Erosion response unit	Cut or fill: Fraction of total width	Cut or fill: VM	Roadbed: Fraction of total width	Roadbed: VM	Fill: Fraction of total width	Fill: VM	Weighted VM
R13.1	(0.1065)	(0.88)	+ (0.7101)	(1.0)	+ (0.1834)	(0.36)	= 0.870
R13.2	(0.0778)	(0.36)	+ (0.7222)	(1.0)	+ (0.2000)	(0.36)	= 0.822
R13.5	(0.1696)	(1.0)	+ (0.5217)	(1.0)	+ (0.3087)	(0.41)	= 0.818

WORKSHEET IV.7

Factors for sediment delivery index from erosion response units in

Grits Creek watershed, hydrographic area 13.

Erosion response unit	Water availability 1/	Texture of eroded material	Percent ground cover between disturbance and channel	Slope shape code	Distance (edge of disturbance to channel) (ft)	Surface roughness code	Slope gradient (%)	Specific site factor	Percent of total area for polygon	SD_I 5/
SC13.1	0.002 2/	47	67	2.5	1	2	8	—	12.3	0.02
SC13.2	0.003 2/	57	66	2.5	1	2	16	—	13.1	0.02
CC13.1	0.0015 2/	57	53	2.5	1	2	12	—	13.2	0.02
CC13.2	0.0 3/	50	67	2.5	1	2	20	—	—	0.0 6/
R13.1	0.012 4/	38	67	2.5	138	2	8	—	7.0	0.01
R13.2	0.001 4/	38	0	2.0	24	1	100	—	30.9	0.14
R13.5	0.016 4/	50	53	2.5	193	2	12	—	8.2	0.01

1/ Maximum 15 min. annual storm of 2.5 in/hr.
2/ Infiltration rate of 2.0 in/hr (based on soil permeability).
3/ Infiltration rate of 3.0 in/hr (based on soil permeability).
4/ Infiltration rate of 0.1 in/hr (based on soil permeability).
5/ Enter on worksheet IV.3.
6/ When water availability is zero, then the sediment delivery index is zero.

WORKSHEET IV.8

Estimated tons of sediment delivered to a channel for each hydrographic area and type of disturbance for Grits Creek watershed, Alternative A.

Hydrographic area	Cutting units					Roads								Total tons/yr	Percent
	SC_1	SC_2	CC_1	CC_2	CC_3	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8		
1			0.06	0.05		1.1	0.8	0.2	0.6					2.61	7.7
2			0.05	0.05		0.3	0.2	0.8						1.40	4.1
3			0.06	0.06		0.6								0.72	2.1
4			0.06	0.05		1.2								1.31	3.8
5			0.08			2.5	0.2	0.2	0.2	2.2				5.38	15.8
6			0.04			0.3	0.8	0.2	0.8	0.2				2.34	6.4
7			0.05	0.04		1.2	0.2							1.49	4.4
8			0.04			0.3	0.2							0.54	1.6
9	0.04	0.04	0.04	0.04		0.3			0.2	0.3				0.96	2.8
10	0.04		0.04			0.3	0.2	1.0	0.2					1.78	5.2
11	0.04	0.04	0.05	0.05		0.3	0.2	0.3	0.2	0.3	0.2			1.68	4.9
12	0.0		0.0			0.2	0.5	0.5	0.5					1.70	5.0
13	0.05	0.37	0.07	0.0		0.9	0.2			3.2				4.79	14.1
14	0.0	0.0	0.0			0.9	0.2			0.9				2.0	5.9
15	0.03	0.0	0.04	0.0		0.8	0.2			0.9	0.1			2.07	6.1
16	0.02	0.0	0.0			0.6	0.2			0.8				1.62	4.8
17			0.05	0.0		0.6	0.2			0.8				1.65	4.8
Column total	0.73	0.34	0.22	0.45		12.4	4.3	3.2	2.7	9.6	0.3			34.24	
Disturbance total	1.07		0.67			32.5									
Percent	3.1		2.0			94.9									

WORKSHEET IV.2

Grits Creek watershed erosion response unit management data for use in the MSLE and sediment delivery index, hydrographic area 13, alternative B.

Erosion response unit	Slope length of disturbed area (ft)	Slope gradient of disturbed area (%)	Length of road section (ft)	Average width of disturbance (ft)	Area (sq.ft.)	Area (acres)
1. SC13.1	176	8				6.1
2. SC13.2	286	16				5.7
3. CC13.1	132	12				1.4
4. CC13.2	484	20				6.4
5. R13.1			543	16.9		0.21
6. CUT	3.5	170		1.8		
7. BED	12.0	1.0		12.0		
8. FILL	4.5	100		3.1		
9. R13.2 3/			24	18.0		0.01
10. FILL	2.0	100		1.4		
11. BED	13.0	0		13.0		
12. FILL	5.0	100		3.6		
13. R13.3			543	16.6		0.21
14. CUT	4.0	170		2.0		
15. BED	11.0	2		11.0		
16. FILL	5.0	100		3.6		
17. R13.4 3/			26	18.0		0.01
18. FILL	2.5	100		1.8		
19. BED	12.0	0		12.0		
20. FILL	6.0	100		4.2		
21. R13.5			616	23.0		0.33
22. CUT	8.0	180		3.9		
23. BED	12.0	1		12.0		
24. FILL	10.0	100		7.1		
25.						

1/ *Approximately 200 feet between water diversion dips.*

2/ *1 acre = 43,560* ft^2

3/ *This road section crosses a stream. It is separated from the rest of the road because sediment is delivered directly into a channel.*

WORKSHEET IV.2--continued

	Area with surface residues			Open area				
	Percent of total area	Percent of surface with mulch 4/	Percent of area with fine roots	Percent of total area	Percent of surface with mulch	Percent of area with fine roots 4/	Are open areas separated by filter strips?	Percent of total area with canopy
1.	40	100	99	60	80	99	YES	45
2.	45	100	99	55	75	99	YES	45
3.	60	100	99	40	85	99	YES	0
4.	65	95	99	35	80	99	YES	0
5.								
6.	0	0	0	100	0	0	NO	25
7.	60	85	60	40	0	60	NO	0
8.	100	85	100	0		100		25
9.								
10.	100	85	100	0		100		25
11.	60	85	60	40	0	60	NO	0
12.	100	85	100	0		100		25
13.								
14.	0	0	0	100	0	0	NO	25
15.	60	85	60	40	0	60	NO	0
16.	100	85	100	0		100		25
17.								
18.	100	85	100	0		100		25
19.	60	85	60	40	0	60	NO	0
20.	100	85	100	0		100		25
21.								
22.	0	0	0	100	0	0	NO	0
23.	60	85	60	40	0	60	NO	0
24.	100	85	100	0		100		0
25.								

4/ *Not applicable to scalped areas until vegetation is reestablished.*

WORKSHEET IV.2--continued

	Average minimum height of canopy (m)	Time for recovery (mo)	Average dist. from disturbance to stream channel (ft)	Overall slope shape between disturbance and channel	Percent ground cover in filter strip	Surface roughness (quali- tative)	Texture of eroded material 5/ (% silt + clay)	Percent slope between disturbance and channel
1.	2		0	CONCAVE	67	MODERATE	47	8
2.	2		0	CONCAVE	66	MODERATE	57	16
3.			0	CONCAVE	53	MODERATE	57	12
4.			0	CONCAVE	54	MODERATE	50	20
5.			138	CONCAVE	67	MODERATE	38	8
6.	2							
7.								
8.	2	UNKNOWN						
9.			0	STRAIGHT	0	SMOOTH	38	100
10.	2							
11.								
12.	2							
13.			193	CONCAVE	53	MODERATE	50	12
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								

5/ *It has been assumed that ½ of the clay remains on-site as stable aggregates and that the rest of the clay plus very fine sand and silt enter the sediment delivery system.*

WORKSHEET IV.3

Estimates of soil loss and delivered sediment by erosion response unit for hydrographic area 13 of Grits Creek watershed

Erosion response unit [1/]	Soil unit [2/]	R	K	LS	VM	Area (acres)	Surface soil loss (tons/yr)	SD_I	Delivered sediment (tons/yr)
SC 13.1	T1	300	0.09	1.31	0.004	6.1	0.86	0.02	0.02
SC 13.2	T3	300	0.18	4.33	0.005	5.7	6.7	0.02	0.13
CC 13.1	T3	300	0.18	2.05	0.003	1.4	0.46	0.02	0.01
CC 13.2	T2	300	0.14	5.92	0.005	6.4	8.0	0.0	0
R 13.1	S1	300	0.24	6.84	0.153	0.21	15.8	0.01	0.16
R 13.2	S1	300	0.24	1.81 [3/]	0.063	0.01	0.08	0.14	0.01
R 13.3	S3	300	0.29	7.74	0.162	0.21	23.0	0.01	0.23
R 13.4	S3	300	0.29	6.03 [3/]	0.059	0.01	0.31	0.16	0.05
R 13.5	S3	300	0.29	13.47	0.194	0.33	75.0	0.01	0.75

1/ SC - Selection Cut
CC - Clearcut
R - Road

2/ T - Topsoil
S - Subsoil

3/ Average of two LS values, one for each half of the road, starting at the center line and including a fill slope.

WORKSHEET IV.4

Estimated VM factors for silvicultural erosion response units
Grits Creek watershed, hydrographic area 13

	Logging residue area					Open area						
Erosion response unit	Fraction of total area	Mulch (duff & residue)	Canopy	Roots	Sub VM	Fraction percent of total area	Mulch (duff & residue)	Canopy [1]	Roots	Filter strip	Sub VM	Total [3] VM
SC13.1	0.40	0.02	1.0	0.1	.0008	0.60	0.12	0.95 [2]	0.1	0.5	.0034	.0042
SC13.2	0.45	0.02	1.0	0.1	.0009	0.55	0.15	0.94	0.1	0.5	.0039	.0048
CC13.1	0.60	0.02	1.0	0.1	.0012	0.40	0.09	1.0	0.1	0.5	.0018	.0030
CC13.2	0.65	0.05	1.0	0.1	.0033	0.35	0.12	1.0	0.1	0.5	.0021	.0054
R13.1 [4] CUT	0.0	—	—	—	0.0	1.00	1.0	0.87	—	1.0	.0870	.870
BED	0.60	0.1	1.00	0.18	0.011	0.40	1.0	0.18	—	1.0	.072	.083
FILL	1.00	0.1	0.98	0.10	0.010	0.0	—	—	—	—	0.0	.010
R13.2 FILL	1.00	0.1	0.98	0.10	0.010	0.0	—	—	—	—	0.0	.010
BED	0.60	0.1	1.00	0.18	0.011	0.40	1.0	1.0	0.18	1.0	.072	.083
FILL	1.00	0.1	0.98	0.10	0.010	0.0	—	—	—	—	0.0	.010
R13.3 CUT	0.0	—	—	—	0.0	1.00	1.0	0.87	–	1.0	0.870	.870
BED	0.60	0.1	1.00	0.18	0.011	0.40	1.0	0.18	—	1.0	0.072	.083
FILL	1.00	0.1	0.98	0.10	0.010	0.0	—	—	—	—	0.0	.010
R13.4 FILL	1.00	0.1	0.98	0.10	0.010	0.0	—	—	—	—	0.0	.010
BED	0.60	0.1	1.00	0.18	0.011	0.40	1.0	1.0	0.18	1.0	0.072	.083
FILL	1.00	0.1	0.98	0.10	0.010	0.0	—	—	—	—	0.0	.010
R13.5 FILL	0.0	—	—	—	0.0	1.00	1.0	0.87	–	1.0	0.870	.870
BED	0.60	0.1	1.00	0.18	0.011	0.40	1.0	0.18	—	1.0	0.072	.083
FILL	1.00	0.1	0.98	0.10	0.010	0.0	—	—	—	—	0.0	.010

1/ *Canopy effects only apply to open areas without residue and duff.*

2/ *Example calculation: From worksheet IV.2, 80% of the surface in the open area has mulch, leaving 20% without mulch. If the canopy is uniformly distributed over 45% of the total area, then only 20% of the canopy can cover the area without mulch. Therefore: (0.20)(0.45)(100) = 9% of the area without mulch, that is covered by the canopy. This results in a VM = 0.95.*

3/ *Enter on worksheet IV.3.*

4/ *VM for roads is for a recovered condition.*

WORKSHEET IV.6

Weighting of VM values for roads in
Grits Creek watershed, hydrographic area 13.

Erosion response unit	Cut or fill: Fraction of total width	Cut or fill: VM	Roadbed: Fraction of total width	Roadbed: VM	Fill: Fraction of total width	Fill: VM	Weighted VM
R13.1	(0.1065)	(0.870)	+(0.7101)	(0.083)	+(0.1834)	(0.010)	= 0.153
R13.2	(0.0778)	(0.010)	+(0.7222)	(0.083)	+(0.2000)	(0.010)	= 0.063
R13.3	(0.1205)	(0.870)	+(0.6627)	(0.083)	+(0.2169)	(0.010)	= 0.162
R13.4	(0.1000)	(0.010)	+(0.6667)	(0.083)	+(0.2333)	(0.010)	= 0.059
R13.5	(0.1696)	(0.870)	+(0.5217)	(0.083)	+(0.3087)	(0.010)	= 0.194

WORKSHEET IV.7

Factors for sediment delivery index from erosion response units in

Grits Creek watershed, hydrographic area 13

Erosion response unit	Water availability[1]	Texture of eroded material	Percent ground cover between disturbance and channel	Slope shape code	Distance (edge of disturbance to channel) (ft)	Surface roughness code	Slope gradient (%)	Specific site factor	Percent of total area for polygon	SDI[5]
SC13.1	0.002[2]	47	88	2.5	1	2	8	—	11.9	0.02
SC13.2	0.0033[2]	57	86	2.5	1	2	16	—	12.7	0.02
CC13.1	0.0015[3]	57	94	2.5	1	2	12	—	12.1	0.02
CC13.2	0.0[3]	50	90	2.5	1	2	20	—	—	0.0[6]
R13.1	0.012[4]	38	88	2.5	500	2	8	—	5.1	0.01
R13.2	0.001[4]	38	0	2.0	24	1	100	—	30.9	0.14
R13.3	0.016[4]	50	86	2.5	700	2	16	—	6.1	0.01
R13.4	0.001[4]	50	0	2.0	26	1	100	—	22.3	0.16
R13.5	0.016[4]	50	94	2.5	700	2	12	—	5.6	0.01

1/ *Maximum 15 min. annual storm of 2.5 in/hr.*
2/ *Infiltration rate of 2.0 in/hr (based on soil permeability).*
3/ *Infiltration rate of 3.0 in/hr (based on soil permeability).*
4/ *Infiltration rate of 0.1 in/hr (based on soil permeability).*
5/ *Enter on worksheet IV.3.*
6/ *When water availability is zero, then the sediment delivery index is zero.*

WORKSHEET IV.8

Estimated tons of sediment delivered to a channel for each hydrographic area and type of disturbance for Grits Creek watershed, alternative B

Hydrographic area	Cutting units					Roads								Total tons/yr	Percent
	SC_1	SC_2	CC_1	CC_2	CC_3	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8		
1			0.01	0.01		0.2	0.1	0.01	0.1					0.43	6.4
2			0.01	0.01		0.03	0.01	0.1						0.16	2.4
3			0.01	0.01		0.1								0.12	1.8
4			0.01	0.01		0.2								0.22	3.3
5			0.02			0.6	0.01	0.01	0.01	0.5	0.2			1.35	20.1
6			0.01			0.03	0.1	0.01	0.1	0.01	0.1	0.01		0.37	5.5
7			0.01	0.01		0.2	0.01	0.1						0.33	4.9
8			0.01			0.03	0.01							0.05	0.7
9	0.01	0.01	0.01	0.01		0.03	0.01	0.1	0.01	0.03				0.22	3.3
10	0.01		0.01			0.03	0.01	0.2	0.01	0.1				0.37	5.5
11	0.01	0.01	0.01	0.01		0.03	0.01	0.03	0.01	0.03	0.01	0.03	0.01	0.20	3.0
12	0.0		0.0			0.01	0.1	0.1	0.1					0.31	4.6
13	0.02	0.13	0.01	0.0		0.2	0.01	0.2	0.05	0.7				1.32	19.7
14	0.0	0.0	0.0			0.1	0.01	0.1		0.1				0.31	4.6
15	0.01	0.0	0.01	0.0		0.1	0.01	0.1	0.05	0.1	0.02			0.40	6.0
16	0.01	0.0	0.0		0.0	0.1	0.01	0.1	–	0.1				0.32	4.8
17			0.01	0.0		0.1	0.01	–	–	0.1				0.22	3.3
Column total	0.07	0.15	0.15	0.07	0.0	2.09	0.42	1.16	0.44	1.77	0.33	0.04	0.01	6.70	
Disturbance total	0.22		0.22			6.26									
Percent	3.3		3.3			93.4									

WORKSHEET VI.1

Suspended sediment quantification for Grits Creek
(Pre and Post for Alternatives A and B)

(1) Time increment (a) With hydrographs use date; with flow duration curves use % of 365 days	(1) (b) Number of days pre-silvicultural activity	(1) (c) Number of days post-silvicultural activity	(2) Pre-silvicultural activity flow (cfs)	(3) Suspended sediment concentration (mg/l)	(4) Total increment suspended sediment cols. (2) x (3) x (1.b) x .0027 (tons)	(5) Post-silvicultural activity flow (cfs)	(6) Suspended sediment concentration (mg/l)	(7) Total increment post-silvicultural activity suspended sediment cols. (5) x (6) x (1.c) x .0027 (tons)	(8) Maximum concentrations from selected water quality objective (mg/l)	(9) Maximum sediment discharge cols. (2) x (8) x (1.b) x .0027 (tons)
1	3.6	3.6	8.8	32.0	0.30	8.9	34.0	0.33	75.0	0.74
5	18.2	18.2	5.5	18.0	0.89	5.9	22.0	1.08	46.0	2.26
10	36.5	36.5	3.3	12.0	1.18	3.5	14.0	1.38	26.0	2.56
20	73.0	73.0	2.3	8.0	1.58	2.5	9.0	1.78	17.0	3.35
30	109.5	109.5	1.7	6.0	1.77	1.9	7.0	2.07	13.0	3.84
40	146.0	146.0	1.2	4.0	1.58	1.7	6.0	2.36	8.1	3.15
50	182.5	182.5	0.8	3.0	1.18	1.1	4.0	1.97	6.0	2.96
60	219.0	219.0	0.5	2.0	1.18	0.8	3.0	1.77	3.6	2.13
70	255.0	255.0	0.4	1.5	1.03	0.7	2.8	1.93	2.6	1.79
80	292.0	292.0	0.3	1.2	0.95	0.6	2.5	1.97	2.0	1.58
90	328.0	328.0	0.2	NEGLI	NEGLI	0.5	2.0	1.77	1.3	1.15
100	365.0	365.0	0	NEGLI	NEGLI	0.3	1.2	1.18	—	—

(Totals are rounded to nearest tenth)

Total 11.6 tons/yr

Total 19.6 tons/yr

Total 25.5 tons/yr

Summary:
Total pre-silvicultural activity suspended sediment discharge = 11.6
Total post-silvicultural activity suspended sediment discharge = 19.6
Total maximum sediment discharge = 25.5

WORKSHEET VI.3

Sediment prediction worksheet summary

Subdrainage name Grits Creek (Alternative A) Date of analysis 6/2/78

Suspended Sediment Discharge

A. Pre-silvicultural activity total potential suspended sediment discharge (total col. (4), wksht. VI.1) (tons/yr) 11.6

B. Post-silvicultural activity total potential suspended sediment discharge (total col. (7), wksht. VI.1) (due to streamflow increases) (tons/yr) 19.6

C. Maximum allowable potential suspended sediment discharge (total col. (9), wksht. VI.1) (tons/yr) 25.5

D. Potential introduced sediment sources: (delivered)

1. Surface erosion (tons/yr) 34.2
2. Soil mass movement (coarse) (tons/yr) 0
3. Median particle size (mm) –
4. Soil mass movement-- washload (silts and clays) (tons/yr) 0

Bedload Discharge (Due to increased streamflow)

E. Pre-silvicultural activity potential bedload discharge (tons/yr) 0

F. Post-silvicultural activity potential bedload discharge (due to increased streamflow) (tons/yr) 0

Total Sediment and Stream Channel Changes

G. Sum of post-silvicultural activity suspended sediment + bedload discharge (other than introduced sources) (tons/yr) 19.6 (sum B + F)

H. Sum of total introduced sediment (D) = (D.1 + D.2 + D.4) (tons/yr) 34.2

I. Total increases in potential suspended sediment discharge

1. (B + D.1 + D.4) - (A) (tons/yr) 42.2
2. Comparison to selected suspended sediment limits (I.1) - (C) (tons/yr) ± 16.7

J. Changes in sediment transport and/or channel change potential (from introduced sources and direct channel impacts)

1. Total post-silvicultural activity soil mass movement sources (coarse size only) (tons/yr) ___0___

2. Total post-silvicultural soil mass movement sources (fine or washload only) (tons/yr) ___0___

3. Particle size (median size of coarse portion) (mm) ___—___

4. Post-silvicultural activity bedload transport (F) (tons/yr) ___0___

Potential for change (check appropriate blank below)

Stream deposition ____

Stream scour ____

No change ___✓___

K. Total pre-silvicultural activity potential sediment discharge (bedload + suspended load) (tons/yr) ___11.6___ (sum A + E)

L. Total post-silvicultural activity potential sediment discharge (all sources + bedload and suspended load) (tons/yr) ___53.8___ (sum G + H)

M. Potential increase in total sediment discharge due to proposed activity (tons/yr) ___42.2___ (subtract L - K)

WORKSHEET VI.3

Sediment prediction worksheet summary

Subdrainage name Grits Creek (Alternative B) Date of analysis 6/9/78

Suspended Sediment Discharge

A. Pre-silvicultural activity total potential suspended sediment discharge (total col. (4), wksht. VI.1) (tons/yr) — 11.6

B. Post-silvicultural activity total potential suspended sediment discharge (total col. (7), wksht. VI.1) (due to streamflow increases) (tons/yr) — 19.6

C. Maximum allowable potential suspended sediment discharge (total col. (9), wksht. VI.1) (tons/yr) — 25.5

D. Potential introduced sediment sources: (delivered)

1. Surface erosion (tons/yr) — 6.7
2. Soil mass movement (coarse) (tons/yr) — 0
3. Median particle size (mm) — –
4. Soil mass movement-- washload (silts and clays) (tons/yr) — 0

Bedload Discharge (Due to increased streamflow)

E. Pre-silvicultural activity potential bedload discharge (tons/yr) — 0

F. Post-silvicultural activity potential bedload discharge (due to increased streamflow) (tons/yr) — 0

Total Sediment and Stream Channel Changes

G. Sum of post-silvicultural activity suspended sediment + bedload discharge (other than introduced sources) (tons/yr) — 19.6 (sum B + F)

H. Sum of total introduced sediment (D) = (D.1 + D.2 + D.4) (tons/yr) — 6.7

I. Total increases in potential suspended sediment discharge

1. (B + D.1 + D.4) - (A) (tons/yr) — 14.7
2. Comparison to selected suspended sediment limits (I.1) - (C) (tons/yr) — ± 10.8

J. Changes in sediment transport and/or channel change potential (from introduced sources and direct channel impacts)

1. Total post-silvicultural activity soil mass movement sources (coarse size only) (tons/yr) 0

2. Total post-silvicultural soil mass movement sources (fine or washload only) (tons/yr) 0

3. Particle size (median size of coarse portion) (mm) —

4. Post-silvicultural activity bedload transport (F) (tons/yr) 0

Potential for change (check appropriate blank below)

Stream deposition ____

Stream scour ____

No change ✓

K. Total pre-silvicultural activity potential sediment discharge (bedload + suspended load) (tons/yr) 11.6 (sum A + E)

L. Total post-silvicultural activity potential sediment discharge (all sources + bedload and suspended load) (tons/yr) 26.3 (sum G + H)

M. Potential increase in total sediment discharge due to proposed activity (tons/yr) 14.7 (subtract L - K)

WORKSHEET VII.1

Variation of solar azimuth and angle with time of day

Time of day (Daylight savings time)	Solar azimuth (degrees)	Stream[1/] effective width (EW) (ft)	Solar angle (degrees)	Shadow[2/] length (S) (ft)
12:30	155	1.6	70	25.4
1:00 Solar noon	180	2.1	72	22.7
1:30	205	4.4	70	25.5
2:10 Oriented Width Stream	225	Infinity	68	28.2
2:30	235	8.6	65	32.6
2:45	240	5.8	60	40.4
3:10	245	4.4	55	49.0

1/ $EW = \frac{\text{measured average stream width}}{\text{sine } |\text{ azimuth stream} - \text{azimuth sun }|}$

2/ $S = \frac{\text{height vegetation}}{\text{tangent solar angle}}$

WORKSHEET VII.2

Evaluation of downstream temperature impacts

Stream reach	$A_{adjusted}$ ft²	$H_{adjusted}$ BTU/ft²-min	Q Surface cfs	Q Subsurface cfs	ΔT 1/ °F	T 2/ °F
UPPER	997	3.82	0.2		5.2	68.1
MIDDLE	189	3.82	0.25	0.05	0.6	65.3
LOWER	750	3.82	0.45	0.05	1.5	64.9

1/ $\Delta T = \frac{A_{adjusted} \times H_{adjusted}}{Q} \times 0.000267$ where Q is surface flow only.

2/ T from mixing ratio equation.

PROCEDURAL EXAMPLE FOR HORSE CREEK—A SNOW DOMINATED HYDROLOGIC REGION

DESCRIPTION OF AREA AND PROPOSED SILVICULTURAL ACTIVITY

The Timber Management Assistant on the Glacier Ranger District, Rocky National Forest[3], prepared a 5-year timber management plan for the district. After cruising the Horse Creek drainage, he determined that a sale of 600,000 board feet of lodgepole pine was warranted based upon the stand condition and timber market.

The sale has been designed as a group of 24 small clearcut blocks of approximately 12.5 acres each. The blocks have been designated in the field with orange marking paint. Engineering has flagged the center lines of the roads that will need to be constructed and has surveyed the actual location, collecting sufficient data to design the roads to forest standards. See figures IV.17 and IV.18 foı the road locations and layout of proposed clearcut blocks.

Resource specialists have been asked to review the proposed sale and to evaluate potential impacts. Information from a general soil survey of the area is available.

Water Quality Objectives

The established water quality objectives required that suspended sediment discharge be limited to 38.6 tons/yr and that water temperature increases be no greater than 1.5°F for the Horse Creek drainage.

[3]*This is intended to be a fictitious forest; any similarity to an actual forest is entirely coincidental.*

DATA BASE

Necessary data have been obtained from resource specialists in timber, soils, hydrology, and engineering.

The collected data are presented in table VIII.4. A complete water resource evaluation includes analyses in the following categories (numbers for the corresponding chapters in this handbook appear in parentheses):

Hydrology (III)
Surface Erosion (IV)
Soil Mass Movement (V)
Total Potential Sediment (VI)
Temperature (VII)

HYDROLOGY ANALYSIS

Horse Creek is situated in hydrologic region 4, a snow dominated region. The procedure presented in "Chapter III: Hydrology" for the snow dominated regions (including wkshts. III.5, III.6, III.7, and III.8, proposed and revised worksheets are located at the end of section "Procedural Example For Horse Creek—. . .") is applied to estimate potential volume and timing of the streamflow under the present conditions and under the conditions that would exist if the proposed silvicultural activity is implemented. Necessary data for conducting this evaluation is presented in table VIII.4.

Water Available For Streamflow—Existing Conditions

Step 1. — The first step in the hydrologic evaluation of Horse Creek is to estimate the water available for streamflow under the existing conditions. The following details the necessary steps outlined in worksheet III.5. (Numbers in parentheses refer to items or columns on the worksheet.)

Table VIII.4.--A summary of information required for the analysis procedures, Horse Creek watershed

Description of the information required	Information requirements by chapter[1/]					Information for watershed
	III	IV	V	VI	VII	
Information on hydrology						
Flow--hydrograph or flow duration curve	O					
Bankful				X,P		0.73 cfs
Baseflow					X,P	0.4 cfs
Representative flows to be used to establish suspended and bedload rating curves				X		Worksheet VI.1 Figure VIII.16 , Figure VIII.17
Width stream						
Bankful				X		4.8 ft
Baseflow (average width flowing water)					X	1.5 ft
Depth stream (bankful)				X		0.5 ft
Water surface slope				X		0.005 ft/ft
Suspended sediment for representative flows				X		Figure VIII.17
Bedload sediment for representative flows				X		Worksheet VI.4
Channel stability rating				X		Fair
Orientation stream--azimuth					X	225°
Low flow period (date)					X	2nd week of July
Percent streambed in bedrock					X	90%
Bedrock adjustment factor					P	Figure VII.9 ; 0.18
Length reach exposed					X	530 ft
Travel time through reach					X	20 minutes

1/ P - Data provided in this handbook
O - Optional data, not required for analysis
X - User-provided data

Table VIII.4.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on hydrology--continued						
Normalized hydrographs of potential excess water	P					Figure III.61 and table III.13
Normalized flow duration curves	P					N/A
Date of peak snowmelt discharge	O					June 19th
Map of drainage net	X	X	X	X	X	Figure IV.14 and figure IV.15
Presence of springs or seeps			X			Yes
Change stream geometry						
Water surface slope				X		0.0250 ft/ft
Bankful width				X		2.5 ft
Bankful depth				X		0.8 ft
Information on climate						
Precipitation						
Form	X	O	X			Snow; maximum snowpack does not exceed 20" water equivalent
Annual average	X					34.3"
Seasonal distribution	X	O				10/1 to 2/28: 16.1"; 3/1 to 6/30: 12.1"; 7/1 to 9/30: 6.1"
Storm intensity and frequency		O	X			May exceed 6"/24 hrs with recurrent interval greater than 10 years
Extreme event						
1 yr, 15-minute storm intensity		X				1.75 in/hr
Drop size		O				N/A
Precipitation--ET relationship	P					Figures III.24 to III.26
Wind direction	X					Northwest

Table VIII.4.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on climate--continued						
Snow retention coefficient	X,P					Figure III.6
Date snowmelt begins	O					N/A
Maximum snowmelt rate	O					N/A
Radiation						
Solar ephemeris					P	Figure VII.3
Heat influx					P	Figure VII.7
Iso-erodent map for "R" factor		P				Figure IV.2
Information on vegetation						
Species	X				X	Lodgepole pine
Height						
Overstory	X	X			X	70 ft
Understory		X			X	N/A
Riparian vegetation					X	N/A
Presence phreatophytes			X			N/A
Crown closure (%)					X	65%
Cover density	P	X				33%
Leaf area index (pre)	X					N/A
Basal area	O					200 ft^2/acre
Basal area--C_{dmx} relationship	P					Figure III.41
Ground cover		X				Worksheet IV.2

Table VIII.4.--continued

Description of the information required	Information requirements by chapter III	IV	V	VI	VII	Information for watershed
Information on vegetation--continued						
Percent transmission solar radiation through canopy					X,P	Figure VII.0.1 ; 8%
Percent stream shaded by brush					X	15%
Baseline ET	X,P					Figures III.24 to III.26
ET modifier coefficient	P					Figure III.46
Rooting depth	X					N/A
Rooting depth modifier coefficient	P					N/A
Information on soils and geology						
Depth soil	X		X			Worksheet IV.1 ; 5 ft
Percent sand (0.1-2.0 mm)		X				Worksheet IV.1
Percent silt and very fine sand		X				Worksheet IV.1
Percent clay		X	X			Worksheet IV.1
Percent organic matter		X				Worksheet IV.1
Soil texture		X				Worksheet IV.1
Soil structure		X				Worksheet IV.1
Permeability/Infiltration		X	X			Worksheet IV.1 and worksheet IV.7
Presence of hardpan		X	X			Yes
Nomograph for "K" factor		P				Figure IV.3
Baseline soil-water relationships	X,P					N/A
Soil-water modifier coefficients	P					N/A
Jointing and bedding planes			X			Bedding planes horizontal or dipping into slope; minor joints at angles less than the natural slope; joints may concentrate water.

Table VIII.4.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on soils and geology--continued						
Soils map	O	X	X			Figure IV.16
Previous mass movements			X			Worksheet V.5
Number			X			Figure VIII.15
Location			X			Figure VIII.15
Unit weight dry soil			X			90 lbs/ft^3
Delivery potential			P			Figure V.11
Percent silt and clay delivered			X			24%
Median size coarse material			X			10mm
Information on topography						
Map (hydrologic region)	X	X	X	X	X	USGS map, figure IV.1; Hydrologic region 4
Latitude	X				X	40½°
Size watershed	X					600 acres
Elevation	X					Ranges from 9,100 ft to 11,100 ft
Aspect	X					Southwest
Slope						Average : 30%
Length		X				Worksheet III.2
Gradient		X	X		X	Figure IV.13 and worksheet III.2
Dissection			X			500 ft to 300 ft between drainages
Shape/Irregularity		X	X			Smooth
Nomograph for "LS" factor		P				Figure IV.3

Table VIII.4.--continued

Description of the information required	Information requirements by chapter					Information for watershed
	III	IV	V	VI	VII	
Information on topography--continued						
Surface roughness		x				Moderate to Smooth
Information on the silvicultural activity						
Past history						
Harvesting	x	o				N/A
Fires	x	o				N/A
Other disturbances	x	o				N/A
Proposed harvest						
Location units	x	x				Figure IV.18, worksheet IV.2
Size cuts	x	x				Figure IV.18; 300 acres + 11 acres of roads
Leaf area index removed	x					N/A
Cover density removed	x					100%
Basal area removed	x					100%
Cover density overstory remaining		x				Worksheet IV.2
Cover density understory remaining		x				Worksheet IV.2
Average minimum canopy height		x				0.5 m
Slash and duff--litter		o				N/A
Cover percent		x				Worksheet IV.2
Height	x					2 ft
Percent bare soil		x				Worksheet IV.2

Table VIII.4.--continued

Description of the information required	Information requirements by chapter III	IV	V	VI	VII	Information for watershed
Information on silvicultural activity--continued						
Transportation system						
Area disturbed	x	x				Worksheet IV.2 ; 11.5 acres
Location	x	x				Figure IV.17
Cut slopes (location and slope)		x				Worksheet IV.2 ; length 4.8 ft ; slope 66.7%
Fill slopes (location and slope)		x				Worksheet IV.2 ; length 4.8 ft ; slope 66.7%
Cut and fill vs. full bench		x	x			Cut/fill
Inslope vs. outslope		x				Worksheet IV.2 ; outslope
Surface						
Width		x				12 ft
Gradient		x				Worksheet IV.2 ; 0.0
Surfacing (amount and kind)		x				Worksheet IV.2 ; bare
Road density			x			2% = (11.5 acres roads / 465 acres total)
Harvesting system		x	x			Tractor skidding
Landings						
Location	x	x				Figure IV.17
Size	x	x				Worksheet IV.2
Gradient		x				Worksheet IV.2
Ground cover		x				Worksheet IV.2
Time for vegetative recovery of disturbed surfaces		x				1 year

(1) Watershed name. — Horse Creek can be evaluated as a single hydrologic unit. Division of the basin into hydrologic subunits based upon energy aspect or silvicultural zone is, therefore, unnecessary.

(2) Hydrologic region. — Horse Creek is within hydrologic region 4. Hydrologic regions are described in chapter III.

(3) Total watershed area. — There is one silvicultural prescription for the existing condition with an area of 600 acres.

(4) Dominant aspect. — The most representative aspect for Horse Creek is southwest.

(5) Vegetation type. — Lodgepole pine is the most hydrologically significant vegetation type.

(6) Annual precipitation. — Annual precipitation averages 34.3 inches.

(7) Windward length of open area. — There are no clearcuts on Horse Creek; the watershed is undisturbed.

(8) Tree height. — Average tree height is 70 feet.

(9) Season. — There are three hydrologic sons in region 4: winter (October, November, December, January, February); spring (March, April, May, June); and summer and fall (July, August, September).

(10) Compartment. — Since the area is undisturbed, with no previous silvicultural activity, there are no impacted areas.

(11) Silvicultural state. — Watershed areas are grouped into zones of similar hydrologic response as identified and delineated by silvicultural or vegetational state. For Horse Creek, the only silvicultural state is "forested."

(12) Area, acres. — Horse Creek is undisturbed. There are no meadows or roads within the basin; the watershed is completely forested. Therefore, unimpacted forested area equals the silvicultural prescription area, which is the total watershed area of 600 acres.

(13) Area, %. — This refers to the percentage of watershed area in each silvicultural state. In this case, the unimpacted forested area is 100 percent (1.00 as a decimal percent) of the total watershed area.

(14) Precipitation. — Precipitation averaged 16.1, 12.1, and 6.1 inches for winter, spring, and summer and fall seasons, respectively.

(15) Snow retention coefficient. — Since there are no clearcuts or other open areas within the watershed, snow redistribution is not a factor.

(16) Adjusted snow retention coefficient. — Since snow redistribution is not a factor, there is no adjustment.

(17) Adjusted precipitation. — (No adjustments to the precipitation estimates are necessary.)

(18) ET. — Baseline evapotranspiration (ET) is obtained from figures III.24 to III.26. For Horse Creek, baseline ET is 2.1, 7.6, and 9.2 inches, respectively, for winter, spring, and summer and fall.

(19) Basal area. — The basal area for the forested zone is 200 ft^2/ac.

(20) Cover density, %. — For a basal area of 200 ft^2/ac, figure III.41 gives a cover density of 33 percent.

(21) Cover density, $\%C_{dmax}$. — In the case of Horse Creek, a cover density of 33 percent was judged sufficient for full hydrologic utilization. Therefore, it is considered to be C_{dmax}, so the percentage is 100.

(22) ET modifier coefficient. — The modifier coefficient is 1 for all seasons since the cover density is at C_{dmax}.

(23) Adjusted ET. — (No adjustments are necessary.) Values for Horse Creek are 2.1, 7.6, and 9.2 inches for winter, spring, and summer and fall, respectively.

(24), (25), (26), (27), (28), (29) Water available for streamflow. — The following formula is used to calculate water available for seasonal streamflow by silvicultural state:

$$Q = A\,(P - ET) \qquad \text{(III.15)}$$

where:

- Q = water available for seasonal streamflow for a silvicultural activity
- A = silvicultural activity area as a decimal percent of the total prescription area [col. (13)]
- P = adjusted precipitation inches [col. (17)]
- ET = adjusted ET inches [col. (23)]

(30), (31), (32), (33), (34), (35) Water available for annual streamflow. — The sum of water available for streamflow by season represents annual streamflow. For Horse Creek, the unimpacted forested zone generates 14.0 + 4.5 + (−3.1) = 15.4 inches of water available for annual streamflow. (Negative values imply storage depletion.)

Water Available For Streamflow—After Proposed Silvicultural Activity

Step 2. — The second step in the hydrologic evaluation of Horse Creek is to estimate the water available for streamflow if the proposed silvicultural activity is implemented. The following details the necessary steps outlined in worksheet III.6. (Numbers in parentheses refer to the items or columns in the worksheet.)

(1), (2), (3), (4), (5), (6). — Same as worksheet III.5.

(7) Windward length of open area. — All roads and clearcuts on Horse Creek are treated as single clearcuts with a windward length of 6 tree heights and a total area of 311.5 acres (11.5 acres in roads).

(8), (9). — Same as worksheet III.5.

(10) Compartment. — For the proposed condition of Horse Creek, there will be two compartments: impacted and unimpacted. The impacted compartment includes those areas affected (directly or indirectly) by the proposed silvicultural activities, while the unimpacted compartment includes areas unaffected by the proposed silvicultural activities.

(11) Silvicultural state. — For the proposed condition, Horse Creek will have one silvicultural state for the unimpacted compartment (forested) and two for the impacted compartment (forested and clearcut). The set of silvicultural states comprises the single silvicultural prescription for the proposed condition.

(12) Area, acres. — The 135 acres in the northeast corner of the watershed will not be impacted by the proposed silvicultural activity. The remaining 465 acres in the watershed will be directly or indirectly impacted by the proposed silvicultural activity. Trees will be completely removed from 311.5 acres, consisting of 300 acres clearcut and 11.5 acres in roads. The remaining 153.5 impacted acres will not be harvested, but will be affected by snow redistribution. For the purposes of calculation, clearcuts and roads are classified as clearcut (impacted), while the unharvested area affected by snow redistribution is classified as forested (impacted).

(13) Area, %. — Column (12) is divided by item (3) giving decimal percent areas of 0.225, 0.256, and 0.519 for forested (unimpacted), forested (impacted), and clearcut (impacted) areas, respectively.

(14) Precipitation. — This corresponds to column (14) of worksheet III.5.

(15) Snow retention coefficient. — From figure III.6 the snow retention coefficient for a clearcut 6H in windward length is 1.3. The snow retention coefficient for the forest (unimpacted) remains 1.0, while that for the forested (impacted) area is not defined by figure III.6.

(16) Adjusted snow retention coefficient. — For the forested (unimpacted) area, it is assumed that there is no net change in precipitation from snow redistribution. The adjusted snow retention coefficient for the clearcut area is determined by weighting the snow retention coefficient as follows:

$$\rho_{oadj} = 1 + (\rho_o - 1)\ \frac{0.50}{X} \qquad \text{(III.3)}$$

where:

ρ_{oadj} = adjusted snow retention coefficient for the clearcut area

ρ_o = snow retention coefficient from figure III.6 = 1.3

$$X = \frac{\text{clearcut area (including roads)}}{\text{total impacted area}}$$

This is the percent of impacted area to be clearcut. Substituting values:

$$X = \frac{311.5 \text{ ac}}{(311.5 \text{ ac} + 153.5 \text{ ac})}$$

Substituting values for Horse Creek:

$$\rho_{oadj} = 1 + (1.3 - 1)\left[\frac{0.50}{311.5/(311.5 + 153.5)}\right] = 1.22$$

The adjusted snow retention coefficient for the forested area in the impacted compartment is calculated using the following formula:

$$\rho_f = \frac{1 - \rho_{oadj}X}{1 - X} \qquad \text{(III.13)}$$

where:

ρ_f = adjusted snow retention coefficient for the impacted forested area

ρ_{oadj} = adjusted snow retention coefficient for the clearcut = 1.22

$$X = \frac{\text{clearcut area (including roads)}}{\text{total impacted area}}$$

This is the percent of impacted area to be clearcut. Substituting values:

$$X = \frac{311.5 \text{ ac}}{(311.5 \text{ ac} + 153.5 \text{ ac})}$$

Substituting values for Horse Creek:

$$\rho_f = \frac{1 - [(1.22)\ ((311.5)/(311.5 + 153.5))\ ]}{1 - [311.5/(311.5 + 153.5)]}$$
$$= 0.55$$

(17) Adjusted precipitation. — Multiplying the precipitation value in column (14) by the adjusted snow retention coefficient in column (16) gives adjusted precipitation. For example, the adjusted precipitation for the clearcut area of Horse Creek is $16.1 \times 1.22 = 19.6$ inches.

(18) ET. — Same instruction as worksheet III.5.

(19) Basal area. — For forested areas, the basal area greater than 4 in dbh is 200 ft^2/ac, while the clearcut basal area greater than 4 inches dbh is zero. These data are needed to estimate cover density, if cover density is not supplied by the user.

(20) Cover density. — For a basal area of 200 ft^2/ac, figure III.41 gives a cover density of 33 percent. For a basal area of zero, the cover density is zero.

(21) Cover density,%C_{dmax}. — A cover density of 33 percent has been judged sufficient for full hydrologic utilization and has been assigned the value of C_{dmax}. Division of cover density percent in column (17) by C_{dmax} gives %C_{dmax} when multiplied by 100.

(22) ET modifier coefficient. — The %C_{dmax} can be entered into figure III.46 to obtain the ET modifier coefficient. For a %C_{dmax} of 100, figure III.46 gives ET modifier coefficients of 1.0 for all seasons. For a %C_{dmax} of zero, the ET mdifier coefficients from figure III.46 are 0.60, 107, and 0.55 for winter, spring, and summer and fall, respectively.

(23) Adjusted ET. — Multiplying ET in column (18) by the ET modifier coefficient in column (22) yields the adjusted ET.

(24), (25), (26), (27), (28), (29) Water available for streamflow. — Multiplication of the treatment area (as a decimal percentage of the watershed area, item 13) times the difference between adjusted precipitation and adjusted evapotranspiration (item 17- item 23) is an estimate of area weighted contribution to total watershed flow that will be derived from the treatment (or state) area by season and is entered in one of the columns from 24-29.

For example, for the clearcut in winter:

$$Q = 0.519(19.6-1.3) = 9.5 \text{ inches}$$

(30), (31), (32), (33), (34), (35) Water available for annual streamflow. — The summation of seasonal streamflows is an estimate of the water available for annual streamflow. Horse Creek values are 3.5, 1.1, and 13.5 inches for the (unimpacted) forested, (impacted) forested, and clearcut areas, respectively.

Streamflow Discharge And Timing — Existing Conditions

Step 3. — The third step in the hydrologic evaluation of Horse Creek is to estimate the discharge and timing of the existing condition. The following details the necessary steps outlined in worksheet III.7. (Numbers in parentheses refer to the items or columns in the worksheet.)

(1), (2). — Same as worksheet III.5 and III.6.

(3) Date or interval. — Based on previous knowledge of the area, peak discharge for Horse Creek occurs June 19. Six-day intervals centered around this date are listed in column (3).

(4) Forested (unimpacted),%. — Values from the forested column of table III.13 are entered into column (4) with a peak discharge of 0.1575 percent occurring on June 19.

(5) Forested (unimpacted), inches. — Forested, (unimpacted), percent [col. (4)] is multiplied by potential streamflow for the existing condition from the forested (unimpacted) zone [item (30), wksht III.5] which is 15.4 inches.

(6) Forested (unimpacted), cfs. — Each value in column (5) forested (unimpacted) in inches, is multiplied by the following factor:

$$\frac{\text{total watershed area (ac)}}{\text{(12 in/ft) (1.98) (number of days in interval)}}$$

For example, on May 26, 0.92 inches is converted to cfs as follows:

$$\text{cfs} = \frac{(600)\ (0.92)}{(12)\ (1.98)\ (6)} = 3.87 \text{ cfs}$$

(7) - (21). — Not applicable to the existing condition of Horse Creek.

(22) Composite hydrograph. — The sum of columns (6), (9), (12), (15), (18), and (21) gives the composite hydrograph in digital form. A plot of column (3) versus column (22) yields the existing condition hydrograph (fig. VIII.13).

Streamflow Discharge And Timing — After Proposed Silvicultural Activity

Step 4. — The final step in the hydrologic evaluation of Horse Creek is to estimate the discharge and timing of the streamflow if the proposed silvicultural activity is implemented. The following details the necessary steps outlined in worksheet III.8. (Numbers in parentheses refer to the items or columns on the worksheet.)

(1), (2). — Same as worksheet III.5, III.6, and III.7.

(3) Date or interval. — The date of peak snowmelt discharge for Horse Creek is June 19, the peak discharge date for the forested (unimpacted) zone. Six-day intervals are labeled accordingly.

(4) Forested (unimpacted), %. — Same instructions as worksheet III.7.

(5) Forested (unimpacted), inches. — Column (4) is multiplied by potential streamflow for the proposed condition from the forested (unimpacted) zone [item (25), wksht. III.6]. For Horse Creek this value is 3.5 inches.

(6) Forested (unimpacted), cfs. — Each value in column (5), is multiplied by the following factor:

$$\frac{\text{total watershed area (ac)}}{\text{(12 in/ft) (1.98) (number of days in interval)}}$$

$$= \frac{600}{(12)\ (1.98)\ (6)} = 4.209$$

(7), (8), (9). — Not applicable for the Horse Creek example.

(10) Forested (impacted),%. — These values are taken from the forested column in table III.13.

(11) Forested (impacted), inches. — Column (10) is multiplied by potential streamflow for the proposed condition from the forested (impacted) zone [item (32), wksht. III.6]. For Horse Creek this value is 1.1 inches.

(12) Forested (impacted), cfs. — Conversion of inches to cfs involves multiplication of each value in column (11) by:

$$\frac{\text{total watershed area (ac)}}{\text{(12 in/ft) (1.98) (number of days in interval)}}$$

$$= \frac{600}{(12)\ (1.98)\ (6)} = 4.209$$

(13) Clearcut (impacted),%. — Percent potential streamflow distribution for open areas is taken from the open column of table III.15. Note that peak discharge from clearcut areas occurs before peak discharge from forested areas.

(14) Clearcut (impacted), inches. — Column (13) is multiplied by potential streamflow for the proposed condition from the open (impacted) zone [item (33), wksht. III.6]. For Horse Creek this value is 13.5 inches.

(15) Clearcut (impacted), cfs. — Convert inches to cfs by multiplying values in column (14) by the factor:

$$\frac{\text{total watershed area (ac)}}{\text{(12 in/ft) (1.98) (number of days in interval)}}$$

$$= \frac{600}{(12)\ (1.98)\ (6)} = 4.209$$

(16) - (21). — Not applicable for the Horse Creek example.

(22) Composite hydrograph. — The sum of columns (6), (9), (12), (15), (18), and (21) for each interval gives the composite hydrograph for the entire Horse Creek watershed (in cfs) (fig. VIII.13).

SURFACE EROSION ANALYSIS

The quantity of surface eroded material delivered to stream channels from sites disturbed by the proposed silvicultural activities is estimated in two stages. First, the quantity of material that may be made available from a disturbed site is estimated using the Modified Soil Loss Equation (MSLE). Second, a sediment delivery index (SD_I) is estimated. When this is applied to the estimated quantity of available surface eroded material, an estimate of the quantity of material that may enter a stream channel is obtained.

Erosion Response Unit Delineation

Steps 1-7. — A method for preparing the maps (or overlays) for these steps is discussed in chapter IV. Figures IV.14 to IV.19 show the results of these steps for the drainage net, hydrographic areas, soil

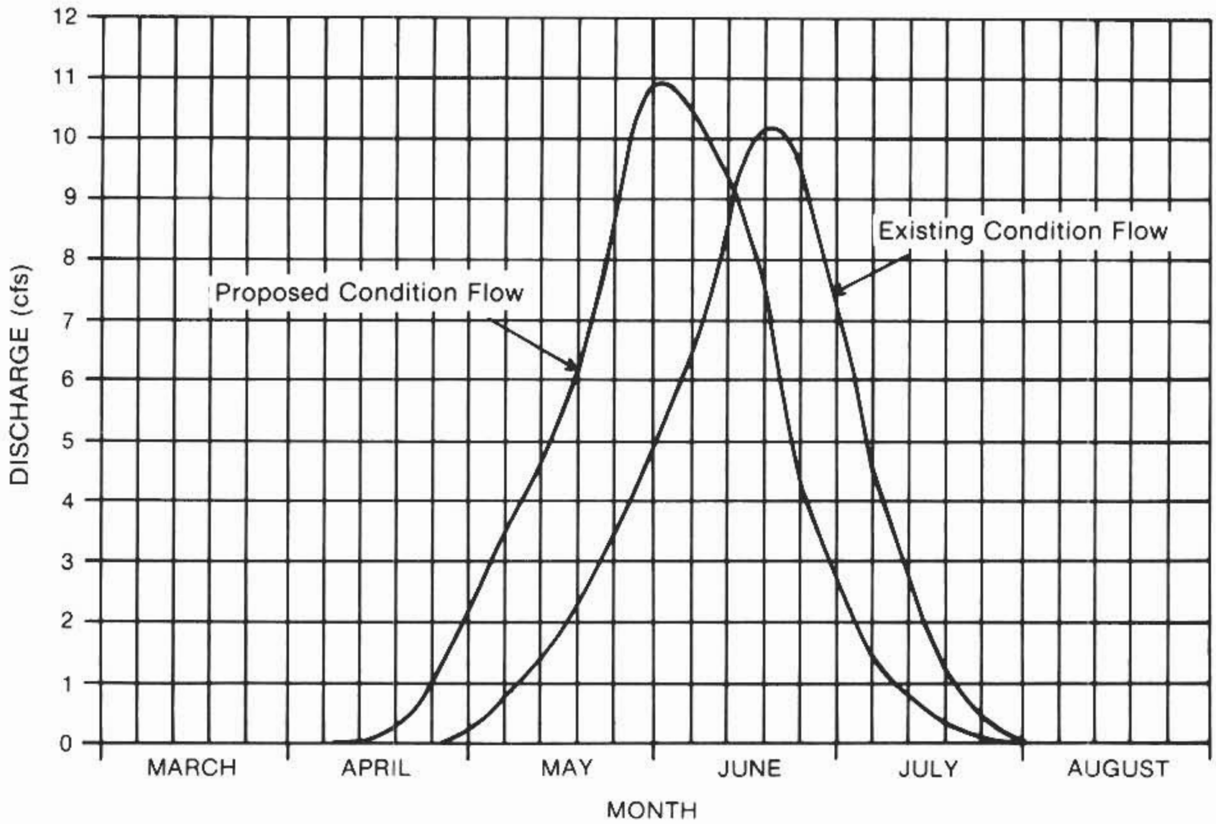

Figure VIII.13.—Pre- and post-silvicultural activities annual hydrograph, Horse Creek watershed.

groups, location of cutting units, roads, and landings.

Step 8. — Set up worksheets for estimating potential sediment load from surface erosion.

Worksheets IV.1 and IV.2 show field data for erosion response units by hydrographic area and type of disturbance. Individual soils in the Horse Creek watershed have been grouped according to similar texture, organic matter, structure, and permeability characteristics. Worksheet IV.1 shows the three soil groups used for surface erosion evaluation. Data on worksheet IV.1 should not change when different management proposals are evaluated for the watershed.

Worksheet IV.2 displays various types of data needed for evaluating the effects of the proposed management of Horse Creek watershed, hydrographic area 3 (fig. IV.15). Individual erosion response units are identified and listed. A different erosion response unit is created for each change in management activity, each design change for a given activity (e.g., road change from a cut-and-fill design to a complete fill for a stream crossing), or each change in environmental parameters affecting erosion (e.g., a change in soil characteristics).

Worksheet IV.3 is a summary of the values used in the MSLE and sediment index for erosion response units in hydrographic area 3 of the Horse Creek watershed. The values for both management proposals are obtained using the steps and discussions which follow. Only values for the proposed plan are used to illustrate methods for solving the equations; however, values for the revised plan are similarly determined

Step 9. — List each erosion source area and number by erosion response unit.

For the Horse Creek watershed, the response units have been coded as follows. The treatment types are clearcuts (CC), landings (L), and roads (R). The example hydrographic area is number 3. Disturbance types are numbered sequentially (e.g., clearcut CC3.1, clearcut CC3.2, etc). to identify them in the following evaluations for soil loss and sediment delivery.

Using The Modified Soil Loss Equation (MSLE)

Step 10. — For each erosion response unit and source area (silvicultural activities and roads), determine the values to be used for each of the following variables:

R - Rainfall factor
K - Soil erodibility factor
LS - Length-slope factor
VM - Vegetation-management factor
Area - Surface area of response unit

Values for these factors are entered on worksheet IV.3 using the following procedures.

Rainfall Factor

This value is obtained from figure IV.2. For the Horse Creek area, R = 45. This R value is the same over the entire Horse Creek area and will be used for all erosion response units.

Soil Erodibility Factor

The K value can be estimated using the nomograph in figure IV.3, or by using equation IV.4. The data for soil group 2 needed to compute the K value using equation IV.4 are found on worksheet IV.1. K must be determined for both topsoil and subsoil. For disturbances which enter the subsoil, such as roads, the subsoil value of K must be used.

Application of the equation to determine the K factor is shown in the following example for soil group 2 topsoil. This example is also plotted on the nomograph (fig. IV.3) for the subsoil. Because of inflections in the family of curves on the nomograph (fig. IV.3) for percent sand, the equation cannot be used when silt plus very fine sand exceed 70 percent.

$$K = (2.1 \times 10^{-6})\,(12\text{-}Om)\,M^{1.14} + 0.0325\,(S\text{-}2) + 0.025\,(P\text{-}3) \qquad \text{(IV.4)}$$

where:

Om = % organic matter
M = (% silt + % very fine sand) (100 − % clay)
S = structure code
P = permeability code

Substituting values for topsoil (soil group 2) from worksheet IV.1 into equation IV.4:

$$K = (2.1 \times 10^{-6})\,(12\text{-}4)\,[40\,(100\text{-}10)]^{1.14} + 0.0325\,(4\text{-}2) + 0.025\,(4\text{-}3)$$

$$K = 0.28$$

The K value of the subsoil (0.30) may be determined from either the nomograph or equation.

Length-Slope Factor

The length-slope factor, LS, is a combination factor which incorporates the slope gradient and the length of the eroding surface into a single factor. The LS factor must be estimated for each erosion response unit.

Two methods may be used to estimate the LS factor on straight slopes. One method is to use equation IV.8 to derive the estimated LS value. The second method utilizes a nomograph (fig. IV.4) to estimate the LS value.

The cutting units (CC3.1 and CC3.2) are each different in regard to slope gradient and length. Therefore, LS for each clearcut unit must be evaluated separately. Using equation IV.8 and data from worksheet IV.2, the LS value for CC3.1 is calculated as follows for slope length λ = 100 feet and slope gradient s = 38 percent.

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{0.43 + 0.30s + 0.043s^2}{6.613}\right) \left(\frac{10{,}000}{10{,}000+s^2}\right) \quad (IV.8)$$

where:

λ = slope length, in feet

s = slope gradient, in percent

m = an exponent based on slope gradient from equation IV.6

Using data from worksheet IV.2:

$$LS = \left(\frac{100}{72.6}\right)^{0.5} \left(\frac{0.43 + 0.30(38) + 0.043(38)^2}{6.613}\right) \left(\frac{10{,}000}{10{,}000+(38)^2}\right)$$

LS = 11.5

A similar calculation is performed for clearcut CC3.2 and landing L3.1. All values are tabulated in worksheet IV.3.

Road R3.1 is outsloped with a typical cross section shown in figure IV.7. Road R3.2 is assumed to be fill, over culverts. Average dimensions will be the same as for R3.1 with the cutbank changed to a fill slope.

To compute the length-slope value for the road sections (R3.1, R3.2,) the equation for irregular slopes is used in this example. An alternative method using graphs (figs. IV.5 and IV.6) is discussed in chapter IV.

$$LS = \frac{1}{\lambda_e} \cdot \sum_{j=1}^{n} \left[\left(\frac{S_j \lambda_j^{m+1}}{72.6^m} - \frac{S_j \lambda_{j-1}^{m+1}}{72.6^m}\right) \left(\frac{10{,}000}{10{,}000 + s_j^2}\right)\right] \quad (IV.9)$$

The number of calculations can be reduced by simplifying equation IV.9 to:

$$LS = \frac{1}{\lambda_e} \cdot \sum_{j-1}^{n} \left[S_j \left(\frac{\lambda_j^{m+1} - \lambda_{j-1}^{m+1}}{72.6^m}\right) \left(\frac{10{,}000}{10{,}000 + s_j^2}\right)\right] \quad (IV.9.1)$$

where:

λ_e = entire length of a slope, in feet

λ_j = length of slope to lower edge of j segment, in feet

j = slope segment

s_j = slope gradient, in percent

S_j = dimensionless slope steepness factor for segment j defined by:

$$(0.043s_j^2 + 0.30s_j + 0.43)/6.613$$

m = an exponent based on slope gradient

n = total number of slope segments

For the road R3.1, using values in worksheet IV.2 and assuming that no sediment is deposited on the road surface, the computations are as follows:

Slope segment 1 (cut)

λ_1 = 4.8 ft

$\lambda_{1\text{-}1}$ = 0.0 ft (there are no preceding slope segments, hence length is 0.0 ft)

s = 66.7%

m = 0.6 (for slopes on construction; see eq. IV.6)

$$S_1 = \frac{0.043s^2 + 0.30s + 0.43}{6.613}$$

substituting for s:

$$S_1 = \frac{0.043(66.7)^2 + 0.30(66.7) + 0.43}{6.613} = 32$$

Substituting values of S, λ, and m for j=1 into equation IV.9.1 to the right of the summation sign gives:

$$32 \left(\frac{(4.8)^{1.6} - (0)^{1.6}}{(72.6)^{0.6}}\right) \left(\frac{10,000}{10,000 + (66.7)^2}\right)$$

$$= 20.83$$

Slope segment 2 (roadbed)

$\lambda_2 = 4.8 + 12.0 = 16.8$ ft

$\lambda_{2\text{-}1}$ = slope length = 4.8 ft

s = 0.5%

m = 0.6 (for slopes on construction sites)

$$S_2 = \frac{0.043s^2 + 0.30s + 0.43}{6.613}$$

substituting for s:

$$S_2 = \frac{0.043(0.5)^2 + 0.30(0.5) + 0.43}{6.613} = 0.09$$

Substituting S, λ, and m values for j=2 into equation IV.9.1 to the right side of the summation sign gives:

$$0.09 \left(\frac{(16.8)^{1.6} - (4.8)^{1.6}}{(72.6)^{0.6}}\right) \left(\frac{10,000}{10,000 + 0.5^2}\right)$$

$$= 0.54$$

Slope segment 3 (fill)

$\lambda_3 = 4.8 + 12.0 + 4.8 = 21.6$ ft

$\lambda_{3\text{-}1}$ = slope length = 16.8 ft

s = 66.7%

m = 0.6 (for slopes on construction sites)

$$S_3 = \frac{0.043s^2 + 0.30s + 0.43}{6.613}$$

substituting for s:

$$S_3 = \frac{0.043(66.7)^2 + 0.30(66.7) + 0.43}{6.613} = 32$$

Substituting S, λ, and m values for j=3 into equation IV.9.1 to the right side of the summation sign gives:

$$32 \left(\frac{(21.6)^{1.6} - (16.8)^{1.6}}{(72.6)^{0.6}}\right) \left(\frac{10,000}{10,000 + (66.7)^2}\right)$$

$$= 76.53$$

Solving the entire equation IV.9.1, using the calculated values

where:

$\lambda_e = 4.8 + 12.0 + 4.8 = 21.6$ ft

then:

$$LS = \frac{1}{\lambda_e}(\text{slope seg. 1} + \text{slope seg. 2} + \text{slope seg. 3})$$

$$= \frac{1}{21.6}(20.83 + 0.54 + 76.53)$$

$$= 4.53$$

A similar LS calculation is made for road R3.2. Road R3.2 is a fill, over culverts across a stream channel, however, and it becomes two problems, each with two slope segments. Each segment starts at the middle of the road surface, and the second segment includes one of the fill slopes. An average value (4.3) for the LS factor using the two LS values just determined by splitting the road in half is entered on worksheet IV.3.

Vegetation-Management Factor

The vegetation-management factor (VM) is used to evaluate effects of cover and land management practices on surface erosion over the entire slope length used for the LS factor. Values for VM are determined for all cutting units, roads, and landings.

(1) Cutting units. — Worksheet IV.2 has the field data used for calculating a VM factor for clearcut units CC3.1 and CC3.2. Example calculations are shown for clearcut CC3.1. The cutting unit is divided into two areas based on presence or absence of logging residues. A ground cover of slash and other surface residues covers 65 percent of the unit (wksht. IV.2). The remaining 35 percent is scattered in open areas of soil averaging 10 feet in diameter.[4] In both areas, fine tree roots are uniformly distributed over 90 percent of the clearcut block. All of the overstory and understory canopy has been removed.

Using worksheet IV.4, first enter percent area as 0.65 and 0.35 for area covered by residues and open

[4]Information about the amount of residue is often expressed in tons per acre. Maxwell and Ward (1976) have published photos and tables for parts of Oregon and Washington which relate visual appearance of a site with the volume of residue and amount of ground cover.

area, respectively. Separate calculations are made for the logging residue and open areas.

Second, the logging slash represents the mulch and close growing vegetation. Because slash varies in density, assume that small openings a few inches in diameter exist over 10 percent of the surface. From figure IV.9, the 90-percent cover provides a mulch factor of 0.08. The 35 percent of CC3.1 that is open is assumed to have 10 percent of the surface protected by widely scattered slash. Using figure IV.9, a mulch factor of 0.78 is found for this situation.

Third, zero canopy cover gives a canopy factor of 1.0 for both areas (fig. IV.8).

Fourth, evaluate the role of fine roots that are remaining in the soil. Since they are uniformly distributed over 90 percent of the entire clearcut area, the value, 0.10, from figure IV. 10 can be used for both logging residue and bare areas.

Fifth, determine if the open areas are connected with each other, such that water can flow downslope from one to another (ch. IV). In this example, the open areas are isolated from each other by bands of logging residue, requiring the use of a sediment filter strip factor of 0.5 (see "Sediment Filter Strips" section of chapter IV). If sediment filter strips did not exist, a factor of 1.0 would be used.

Sixth, using worksheet IV.4, multiply the VM subfactors for logging residue (0.65) (0.08) (1.0) (0.10) = 0.005. Likewise, the subfactors for bare area are: (0.35) (0.78) (1.0) (0.1) (0.5) = 0.014. The overall VM factor is the sum of the VM subfactors: (0.005) + (0.014) = 0.019.

Clearcut CC3.2 will have 60-percent logging residue cover and 40-percent bare, with bare areas averaging 10 feet in diameter. Fine roots will be uniformly distributed over 85 percent of both areas. There will not be any canopy. Bare areas will have filter strips between them. The assumptions about residue density are the same as for CC3.1. Values are shown on worksheet IV.4.

(2) Landings. — Landing L3.1 is assumed to represent a surface described in table IV.3 as "freshly disked after one rain," with a VM factor of 0.89.

(3) Roads. — The VM factor must represent two conditions on the road areas: (1) the road running surface, and (2) the cut-and-fill banks that are needed (fig. IV.7).

The following assumptions have been made for road erosion response units R3.1 and R3.2.

a. All cut-and-fill slopes will be seeded and fertilized within 10 days after completion of the road section.
b. Vegetation will be fully established within 1 year.

During the first year, the VM factor will be changing constantly from bare soil to a vegetated surface on the cut-and-fill slopes. To account for this change, VM is estimated monthly; total those months with erosive rainfall or runoff, and then divide by the total number of erosion months to obtain an average VM value for those time periods with potential for erosive rainfall and/or snowmelt runoff (wksht. IV.5). Use the method described for clearcuts to estimate VM for the site by month. The VM factor will be effected initially by the ground cover (fig. IV.9). As the vegetation matures, canopy and fine roots will also influence the VM factor.

Summing the VM values from worksheet IV.5 and dividing by 8 months (3.36/8 = 0.42) gives a VM value of 0.42 to use for the first year following construction with cut-and-fill slopes.

The VM for the roadbed (1.24) for R3.1 is obtained from table IV.3 for compacted fill without surfacing.

$$\text{Total width for exposed surface} = 2.9\text{ ft} + 12\text{ ft} + 2.9\text{ ft} = 17.8\text{ ft}$$

$$\text{Running surface} = \frac{12.0\text{ ft}}{17.8\text{ ft}} = 0.6742 = \text{fraction of total width}$$

$$\text{Each cut or fill slope} = \frac{2.9\text{ ft}}{17.8\text{ ft}} = 0.1629 = \text{fraction of total width}$$

The weighted VM factor for R1.1 and R1.2 is calculated from data on worksheet IV.2 and shown on worksheet IV.6.

Surface Area Of Response Unit

Total surface area within each treatment unit—clearcuts, landings, and roads—is given in worksheet IV.2 and is entered onto worksheet IV.3. All other MSLE factors are also entered onto worksheet IV.3. Total potential onsite soil loss is computed by multiplying all factors on worksheet IV.3.

Sediment Delivery

Step 12. — The computed potential surface soil loss is delivered to the closest stream channel using the sediment delivery index (SD_I). Worksheet IV.7 is used to organize the data for each erosion response unit, for each factor shown on the stiff diagram (fig. IV.22).

1. Water availability for sediment delivery is calculated using equation IV.12 for each erosion response unit.

$$F = CRL \qquad (IV.12)$$

where:

F = available water (ft^3/sec)

R = [1 yr, 15 min storm (in/hr)] − [soil infiltration rate (in/hr)]

L = [slope length distance of disturbance (ft)] + [slope length from disturbance to stream (ft)]

$C = 2.31 \times 10^{-5} \frac{ft^2\ hr}{in\ sec}$

The infiltration rate, used in determining the R factor, is the maximum rate at which water could enter a soil. In actual situations, the water entry rate will usually be somewhat lower than the infiltration rate and can be based on the soil permeability, with consideration for effects of various management practices.

Using data from worksheet IV.2 and footnotes from worksheet IV.7, the calculations are:

$$F = \left(2.31 \times 10^{-5} \frac{ft^2\ hr}{in\ sec}\right) (1.75 \text{ in/hr} - 0.26 \text{ in/hr}) (100 \text{ ft} + 15 \text{ ft})$$
$$= (2.31 \times 10^{-5}) (1.49) (115)$$
$$= 0.004 \text{ ft}^3\text{/sec}$$

2. Texture of eroded material is based on the amount of very fine sand, silt, and clay shown on worksheet IV.1. For this case, it has been assumed that half of the clay will form stable aggregates with the remainder influencing the sediment delivery index. For soil group 2 topsoil, the following calculations were made:

$$\text{texture of eroded material} = \frac{\%\ clay}{2} + \%\ silt + \%\ \text{very fine sand}$$
$$= \frac{10}{2} + (15) + (25)$$
$$= 45$$

3. Ground cover is the percentage of the soil surface with vegetative residues and stems in direct contact with the soil. The ground cover on the area between a disturbance and a stream channel is determined from field observations and used for the sediment delivery index. For CC3.1, 90 percent is shown on worksheet IV.2 for ground cover.
4. Slope shape is a subjective evaluation of shapes between convex and concave. From worksheet IV.2 for CC3.1 the slope shape is straight.
5. Distance is the slope length from the edge of a disturbance to a stream channel. For CC3.1 (wksht. IV.2), the distance is 15 feet.
6. Surface roughness is a subjective evaluation of soil surface microrelief ranging from smooth to moderately rough. Worksheet IV.2 shows a moderate surface roughness for CC3.1.
7. Slope gradient is the percent slope between the lower boundary of the disturbed area and the stream channel. Worksheet IV.2 shows a gradient of 38 percent for the disturbed area.
8. Site specific is an optional factor that was not used in this example. See chapter IV for more discussion of this factor.

The tabulated factors for CC3.1 (wksht. IV.7) are plotted on the appropriate vectors of a stiff diagram (fig. VIII.14) as discussed in chapter IV. Use one of the several methods to determine the area bounded by the irregular polygon that is created when points on the stiff diagram are joined. The area of the polygon for this example is 94.94 square units. The stiff diagram has 784 square units. The percentage of the total area enclosed by the polygon is:

$$\left(\frac{94.94}{784}\right)\left(100\right) = 12.1\%$$

Entering the X-axis of the probit curve (fig. IV.23) with 12.1 results in a sediment delivery index (SD_I) or 0.02. This is the estimated fraction of eroded material that could be delivered from the disturbance to the stream channel.

Step 13. — Find the estimated quantity of sediment (tons/yr) delivered to a stream channel by multiplying surface soil loss by the sediment delivery index (wksht. IV.3) for each erosion response unit.

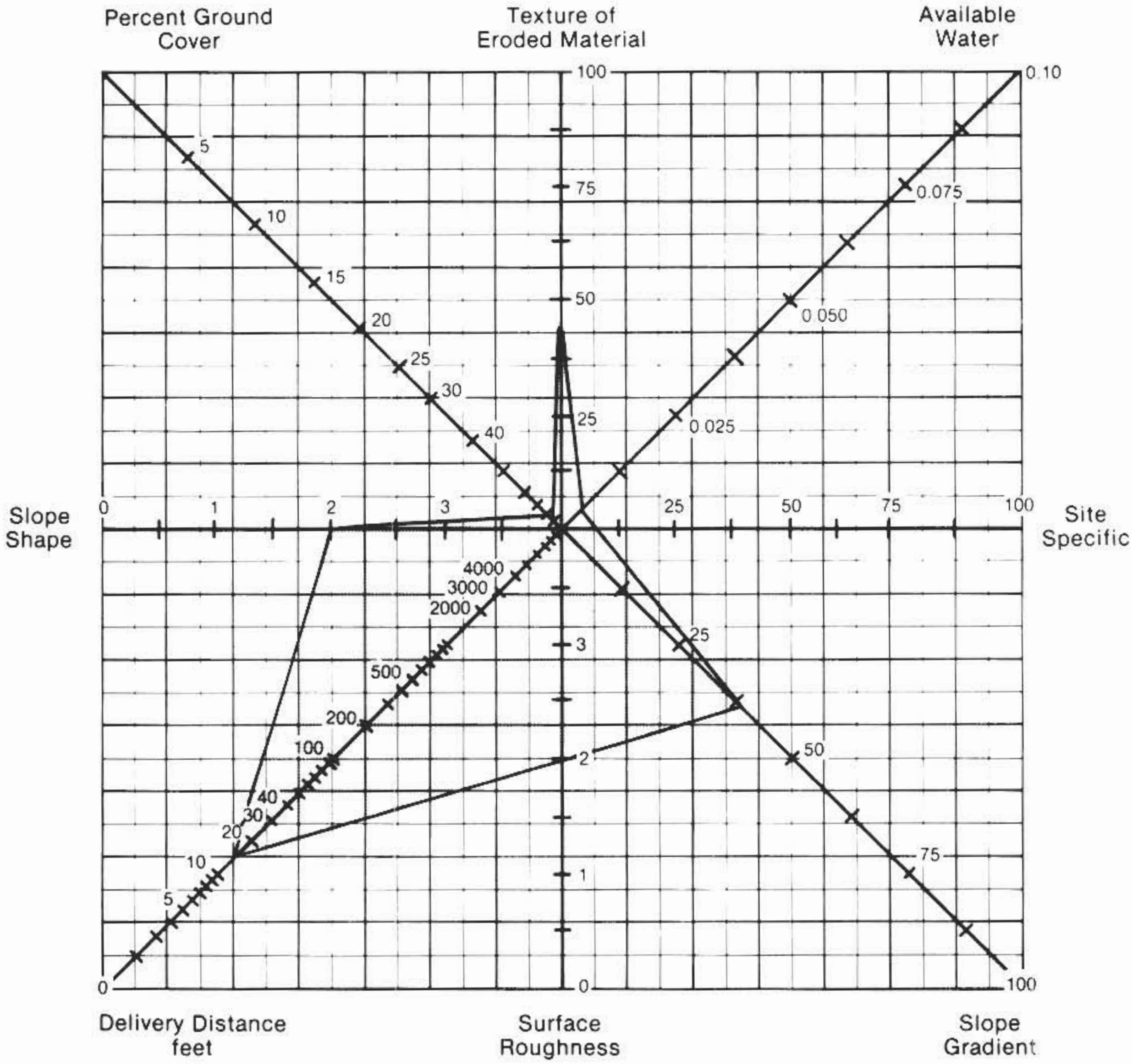

Figure VIII.14.—Stiff diagram for CC3.1 proposed plan, Horse Creek watershed.

Step 14. — Using worksheet IV.8, tabulate quantities of delivered sediment (tons/yr) for each hydrographic area by the erosion source. When completed, this table provides a summary of surface erosion sources and estimated quantities of sediment production from each hydrographic area.

Step 15. — Totals and percentages are shown on worksheet IV.8. The total quantity of delivered material is shown in table VIII.5.

SOIL MASS MOVEMENT ANALYSIS

A step-by-step description, using the Horse Creek data, was presented in "Chapter V: Soil Mass Movement." The following discussion summarizes the results of that detailed description.

Evaluation of the existing soil mass movement hazard (fig. VIII.15) in the Horse Creek drainage is based upon seven natural site factors using table V.5 and worksheet V.1. Based upon the information collected and presented in the beginning of the example, the natural soil mass movement hazard index is medium, with a factor summation of 31. The value 31 falls within the medium hazard range (21-44).

The proposed silvicultural activity will result in an increased soil mass movement hazard. Worksheet V.2 is completed based upon the proposed silvicultural activity. The information required to complete this worksheet is presented in table VIII.4. The three silvicultural activity factors total 31. Adding the existing natural hazard value of 31 to the silvicultural activity hazard value of 31 gives the total value for the post-silvicultural activity: 62. This value falls within the high hazard range (greater than 44).

There is evidence of one soil mass movement in Horse Creek watershed approximately 20 years ago on a smooth 67 percent (34°) slope. The dimensions of the failure are 84 feet long, 28 feet wide, and 1.5 feet deep. The bulk density was found to be 90 lbs/ft^3 (1.43g/cm^3).

To evaluate the potential impact of the proposed silvicultural activity on soil mass movement, Horse Creek must be compared to an adjacent watershed, Mule Creek. Mule Creek, which had a silvicultural activity similar to that proposed for Horse Creek, was investigated to ascertain the actual impacts that followed a silvicultural activity. Mule Creek watershed is considerably larger than Horse Creek—3,900 acres vs. 600 acres (1,620 ha vs. 243 ha)—however, both watersheds have similar site characteristics—soils, geology, precipitation, vegetation, etc. Prior to the silvicultural activity in Mule Creek, there had been only one soil mass movement (debris avalanche-debris flow), approximately 25 years ago, on a smooth 84 percent (40°) slope-length 115 feet, width 19 feet, depth 1.5 feet and bulk density 99 lbs/ft^3. During the 4 years since the silvicultural activity, five debris avalanche-debris flows have occurred:

1. Smooth 73 percent (36°) slope—length 80 feet, width 24 feet, and depth 1.5 feet.
2. Smooth 73 percent (36°) slope—length 129 feet, width 26 feet, and depth 1.5 feet.
3. Smooth 55 percent (29°) slope—length 121 feet, width 17 feet, and depth 1.5 feet.
4. Smooth 55 percent (29°) slope—length 113 feet, width 18 feet, and depth 1.5 feet.
5. Smooth 40 percent (22°) slope—length 95 feet, width 23 feet, and depth 1.5 feet.

Using the procedure outlined in chapter V and figure V.8, worksheets V.1, V.2, V.5, and V.6 were completed. Based upon these computations, it was determined that 192 tons of soil mass movement material could potentially be delivered to Horse Creek due to the proposed silvicultural activity. This total is shown on table VIII.5.

TOTAL POTENTIAL SEDIMENT ANALYSIS

Step 1. — The stream reach characterization will be obtained on the lower 1/4 mile of the third-order stream channel on Horse Creek.

Step 2. — See figure VIII.13 pre- and post-silvicultural activity hydrographs.

Suspended Sediment Calculation

Step 3. — Establish suspended sediment rating curve.

a. Data were obtained from depth integrated suspended sediment sampling and concurrent stream discharge measurements taken over a period of 1 year. Samples were taken during representative flows and are plotted in figure VIII.16.

Table VIII.5

Summary of quantitative outputs for: <u>Proposed plan, Horse Creek</u>

Chapter	Line No.	Output description		Computed value: Pre-activity	Computed value: Post-activity	Chapter reference (worksheets)
Hydrology: Chapter III	1	Water available for annual streamflow		15.4 in	18.1 in	III.5, III.6
	2	Increase in water available for annual streamflow			2.7 in	III.5, III.6
	3	Peak discharge		10.2 cfs	10.99 cfs	III.7, III.8
	4	Date of peak discharge		June 15	June 1	III.7, III.8
	5	Hydrograph				
	6	7-day flow duration curve		N. A.	N. A.	
Surface Erosion: Chapter IV	7	Surface soil loss		N. A.	780 tons/yr	IV.3
	8	Sediment delivered to stream channel		N. A.	17.7 tons/yr	IV.8
Soil Mass Movement: Chapter V	9	Hazard index		31	62	V.1, V.2
	10	Weight of sediment	Coarse >0.062 mm	N. A.	122 tons/yr	
	11	Weight of sediment	Fine <0.062 mm	N. A.	70 tons/yr	
	12	Weight of sediment	Total	N. A.	192 tons/yr	V.6
	13	Acceleration factor			3	V.6
Total Potential Sediment: Chapter VI	14	Sediment discharge due to flow change	Bedload	1.4 tons/yr	1.9 tons/yr	VI.3 line E VI.3 line F
	15	Sediment discharge due to flow change	Suspended	7.1 tons/yr	8.8 tons/yr	VI.3 line A VI.3 line B
	16	Sediment discharge due to flow change	Total	8.5 tons/yr	10.7 tons/yr	VI.3 line K VI.3 line G
	17	Total suspended sediment discharge from all sources		7.1 tons/yr	72.5 tons/yr	VI.3 line A line I.1 + A
	18	Increase in total potential bedload plus suspended sediment from all sources			211.9 tons/yr	VI.3 line M
Temperature: Chapter VII	19	Potential temperature changes			1.9 °F	VII.2

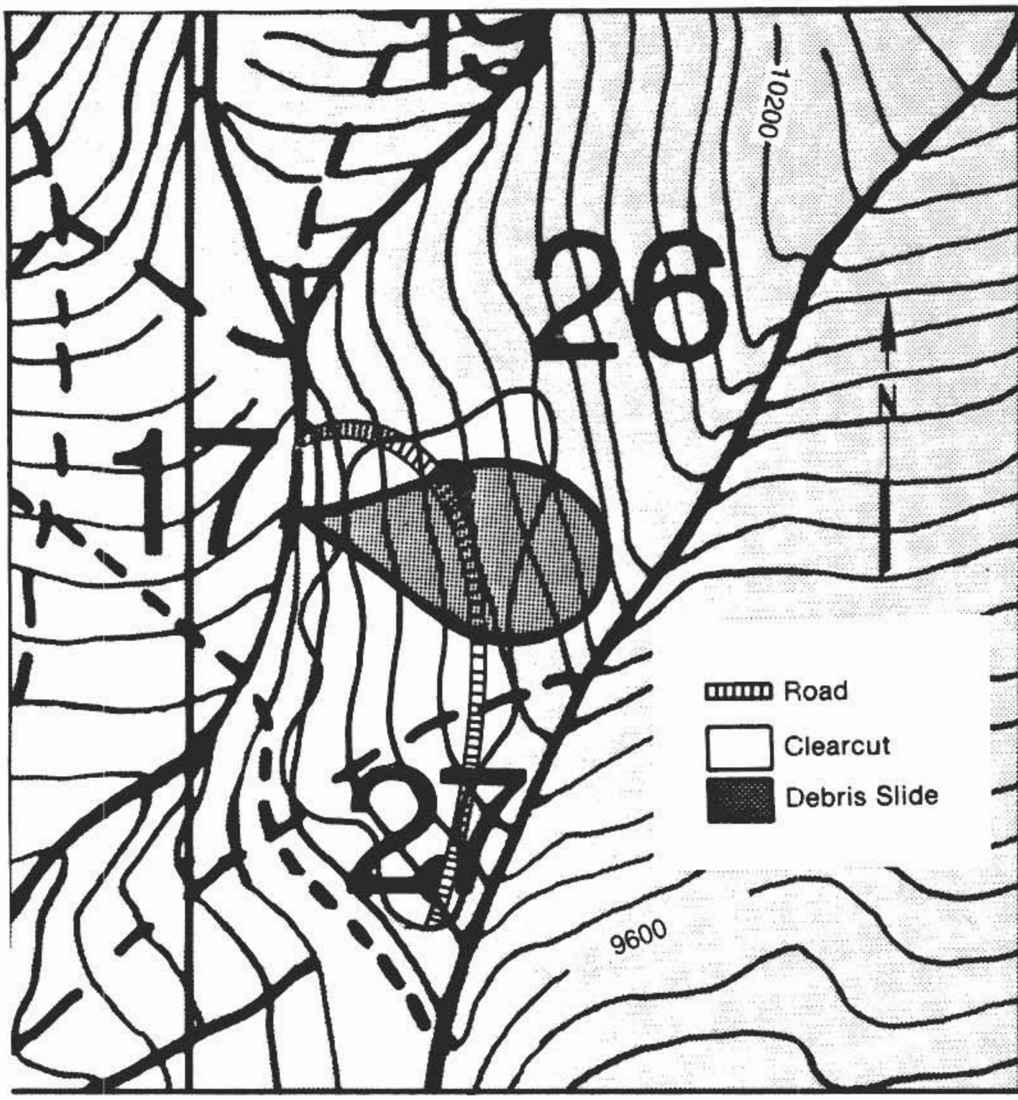

Figure VIII.15.—Horse Creek drainage showing potential areas of mass movement.

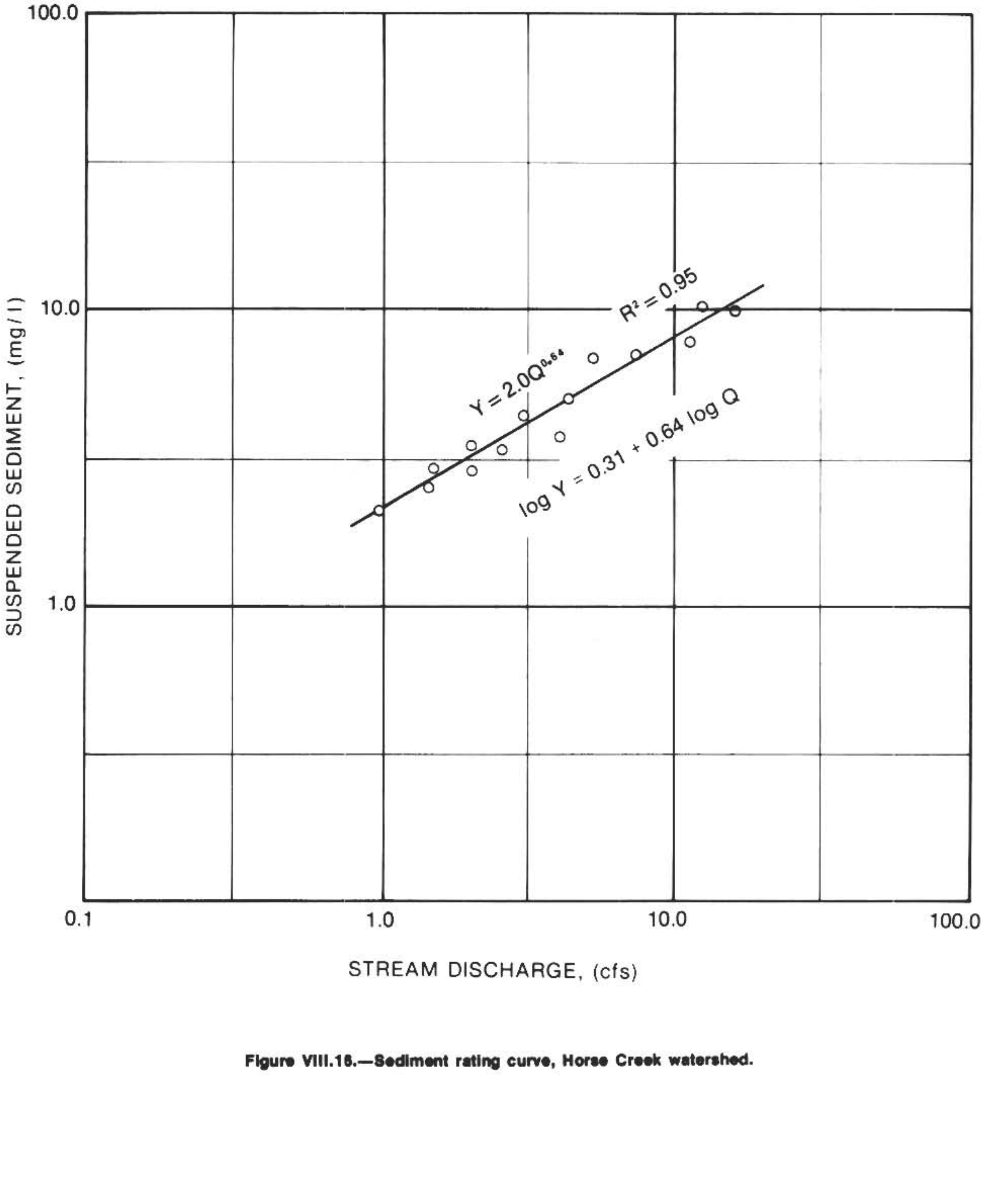

Figure VIII.16.—Sediment rating curve, Horse Creek watershed.

b. $\log Y = 0.31 + 0.64 \log Q$
   $r^2 = 0.95$: coefficient of determination. See figure VIII.16 for plot of data.
c. The channel stability rating procedure by Pfankuch (1975) was used to obtain a fair rating.

Step 4. — Calculate pre-silvicultural activity potential suspended sediment discharge. See figure VIII.13 for pre- and post-silvicultural activity hydrographs. Use data from worksheet VI.1.

a. Use worksheet VI.1, columns (1), (2), (3), and (4).
b. Record the total of 7.1 tons/yr on worksheet VI.3, line A.

Step 5. — Calculate post-silvicultural activity potential suspended sediment discharge (due to streamflow increase).

a. Use worksheet VI.1, columns (1), (5), (6), and (7).
b. Record the total of 8.8 tons/yr on worksheet VI.3, line B.

Note that there is a 24-percent increase in sediment discharge due only to flow increase.

Step 6. — Convert water quality objective from state water quality standards (mg/l) into units compatible with the analysis (tons/yr).

a. Maximum allowable limits as set by state water quality standards for suspended solids is a 30 mg/l increase above existing conditions.
b. Use columns (8) and (9) on worksheet VI.1 to calculate maximum allowable, sediment discharge.
c. Record the total of 38.6 tons/yr on worksheet VI.3, line C.

Bedload Calculation

Step 7. — Establish bedload rating curve.

a. Data points for bedload transport (tons/day) are plotted against stream discharge (cfs), figure VIII.17. Data are shown from worksheet VI.2.
b. $\log Y = -3.43 + 2.18 \log X$
   $r^2 = 0.99$: coefficient of determination

Step 8. — Calculate pre-silvicultural activity bedload discharge.

a. Use columns (1), (2), (3), and (4) on worksheet VI.2.
b. Record the total of 1.4 tons/yr on worksheet VI.3, line E.

Step 9. — Calculate pre-silvicultural activity sediment discharge (suspended and bedload).

a. From step 4, obtain 7.1 tons/yr (suspended sediment) and from step 8, 1.4 tons/yr (bedload sediment) and add for a total of 8.5 tons/yr.
b. Record this total on worksheet VI.3, line K.

Step 10. — Calculate post-silvicultural activity bedload sediment discharge.

a. Use columns (1), (6), (7), and (8) on worksheet VI.2.
b. Record the total of 1.9 tons/yr on worksheet VI.3, line F.

Total Potential Sediment Calculation

Step 11. — Obtain total potential sediment delivered by soil mass movement. Sum the contributions of the coarse size (wksht. VI.3, line D.3) and fine size material (wksht. VI.3, line D.4) to obtain the total soil mass movement contributions which equal 192 tons/yr.

Step 12. — Obtain total potential coarse size sediment delivered by soil mass movement.

a. 24 percent (table IV.1) of delivered soil consists of coarse silts, silt, and clay sizes (only half of the total clay is included in this category) [wksht. IV.1 (soil 2—topsoil)]; thus 76 percent of the delivered soil is coarse material (including the remaining half of the clay, as stable aggregates); therefore, 0.76 × 192 tons = 146 tons/yr of coarse material delivered to streams.
b. Enter this value (146 tons/yr) on worksheet VI.3, lines D.2 and J.1.
c. Median size of coarse portion = 10 mm; record on worksheet VI.3, lines D.3 and J.3.

Step 13. — Determine washload volume delivered from soil mass movement.

a. 24 percent of total delivered volume is washload (tons/yr), therefore,
   total volume soil mass movement = 192 tons/yr

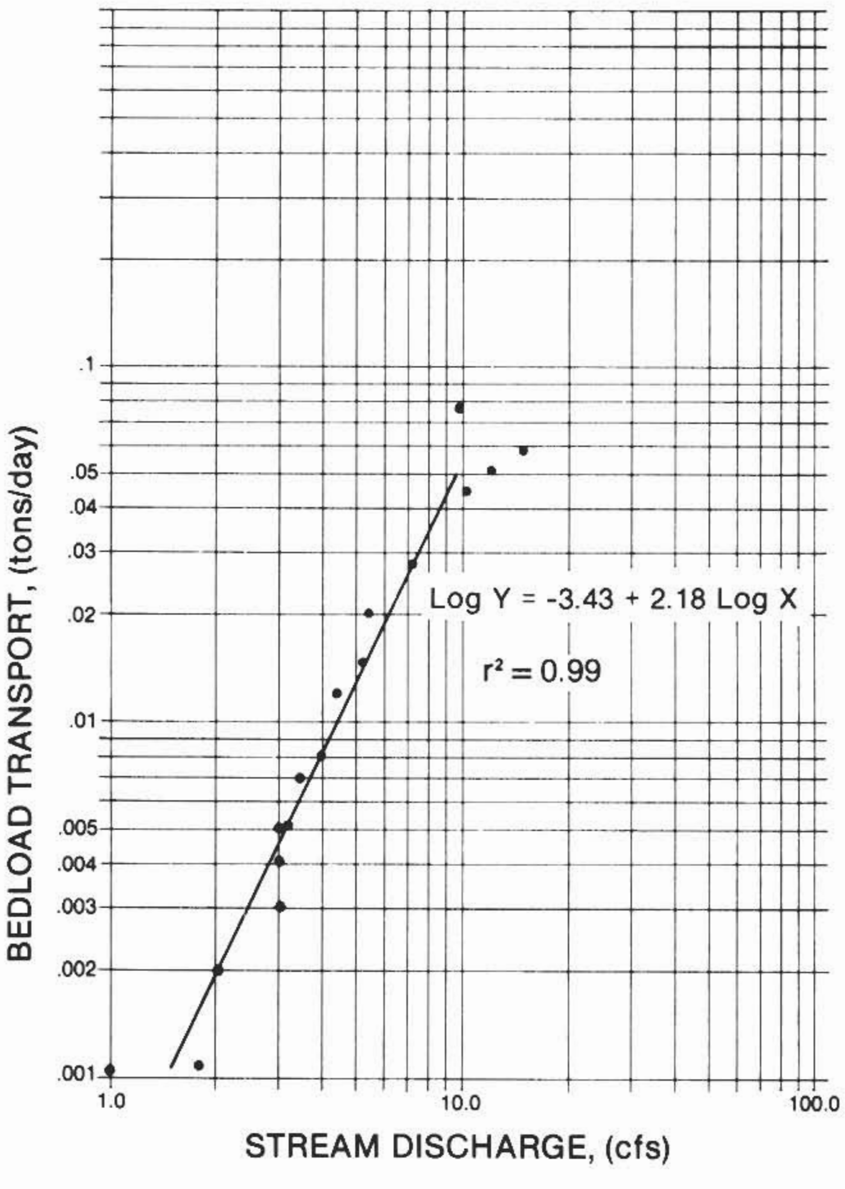

Figure VIII.17.—Bedload rating curve, Horse Creek watershed.

total coarse size soil mass movement = 146 tons/yr
total washload (fine) size = 46 tons/yr

b. Record this total (46 tons/yr) on worksheet VI.3, lines D.4 and J.2.

Step 14. — Determine total delivered tons of suspended sediment from surface erosion.

a. The total of 17.7 tons/yr is obtained from worksheet IV.8.

b. Record this value on worksheet VI.3, line D.1.

Step 15. — Compare total potential post-silvicultural activity suspended sediment (mg/l) to selected limits (tons/yr). On worksheet VI.3:

Add totals of:	tons/yr
Surface erosion (line D.1)	17.7 tons/yr
Total post-silvicultural activity suspended sediment discharge (line B)	8.8 tons/yr
Soil mass movement (washload) (line D.4)	46.0 tons/yr
Total	72.5 tons/yr
Subtract the total pre-silvicultural activity suspended sediment discharge (line A) from the previously determined figure	7.1 tons/yr
The remainder is the total increase in potential suspended sediment discharge (line I.1)	65.4 tons/yr
Subtract the maximum allowable suspended sediment discharge (line C) from the total increase in potential suspended sediment dischrge (line I.1)	38.6 tons/yr
The remainder is the net change (this may be either a positive or negative number) (line I.2)	+26.8 tons/yr

Step 16. — Total potential post-silvicultural activity sediment discharge—all sources.

a. Summation: from steps 5, 10, 11, and 14.

	tons/yr
1. Post-silvicultural activity sediment flow related increases (step 5, wksht. VI.3, line B)	8.8
2. Post-silvicultural activity bedload load, flow related increases (step 10, wksht. VI.3, line F)	1.9
3. Soil mass movement volumes (step 11, wksht. VI.3, line D.2 plus D.4)	192.0
4. Surface erosion source (step 14, wksht. VI.3, line D.1)	17.7
Total	220.4

b. Record on worksheet VI.3, line L.

Step 17. — Increase in total potential sediment discharge resulting from silvicultural activity.

a. Subtract total pre-silvicultural activity sediment discharge (step 9) from total post-silvicultural activity sediment discharge (step 16).

	tons/yr
1. Total post-silvicultural activity (wksht. VI.3, line L)	220.4
2. Total pre-silvicultural activity (wksht. VI.3, line K)	8.5
3. Total potential sediment increase	211.9

b. Record this total increase of 211.9 tons/yr on worksheet VI.3, line M.

Channel Impacts

Step 18. — Channel geometry.

a. Collect channel geometry data for third-order stream being impacted. Record on worksheet VI.5.

1. Water surface slope, measured	0.005 ft/ft
2. Bankful stream width	4.8 ft
3. Bankful stream depth	0.8 ft

b. Channel geometry for the first-order stream being impacted. Record on worksheet VI.5.

1. Water surface slope	0.029 ft/ft
2. Bankful stream width	1.0 ft
3. Bankful stream depth	0.6 ft

Step 19. — Evaluate post-silvicultural activity channel impacts. Determine post-silvicultural activity changes that impact the channel, which would influence stream power calculations by altering water surface slope and/or bankful stream width. The debris-slide on the stream reach being evaluated will change the water surface slope from 0.029 to 0.250 with an increase in bankful width from 1.0 feet to 1.5 feet.

Step 20. — Establish bedload transport rate-stream power relationship for third-order reach or closest adjacent drainageway that has measured data.

Water surface slope = 0.005
(K) Constant = 62.4 lb/ft^3

Use worksheet VI.4 for calculations (see fig. VIII.18).

Step 21. — Make a qualitative determination of channel change potential based on introduced sediment from soil mass movement and channel impacts: Soil mass movement source (coarse size) 146 tons/yr (wksht. VI.3, line J.1). The debris-slide delivery to the first-order stream is instantaneous.

a. To determine channel response on the delivered material, the following calculations are made:

1. Stream power under bankful discharge for first-order reach (wksht. VI.5, line 2A) 1.32 ft/lb/sec
2. Maximum sediment transport under maximum stream power at bankful discharge (fig. VIII. 18) 0.0018 ft/lb/sec

Based on this calculation, the introduced coarse (0.08 tons/day) size (10mm) soil mass movement material of 142 tons exceeds the transport capability of the stream under bankful stream power (0.08 tons/day). Since bankful discharge has a relatively short duration, the 0.08 tons/day transport would be decreased as discharge, and resultant stream power is reduced over time. The expected channel response would be local deposition of sediment (dominant particle size of 10 mm) on the streambed. This would adjust local slope and the width-depth ratio of the channel (based on similar channel response due to debris-slide impacts on similar channels adjacent to Horse Creek).

b. To determine the change in steam power and bankful discharge for Horse Creek at the first-order reach, the following calculations are made:

$A = (\text{width } 1.0 \text{ ft}) (\text{depth } 0.6 \text{ ft}) = 0.60 \text{ ft}^2$

$S = 0.029$

$\log Q = 0.366 + 1.33 \log 0.60 + 0.05 \log 0.029 - 0.056 (\log 0.029)^2$

$Q = 0.73$ cfs (pre-silvicultural activity)

c. Changes in transport rate due to changes in stream power from:

1. Reduced surface water slope
2. Increased width
3. Reduced depth
4. Reduced bankful discharge

Using worksheet VI.5:

Post-silvicultural activity width 1.5 ft
Post-silvicultural activity depth 0.2 ft
Post-silvicultural activity slope 0.0250
Post-silvicultural activity (Q_b) discharge 0.28 cfs
Post-silvicultural activity stream power (ω) 0.29 ft/lb/sec
Post-silvicultural activity bedload transport rate (fig. VIII.18) 2.6×10^{-5} ft/lb/sec

This value (2.6×10^{-5} ft/lb/sec) is converted to tons/day/ft of width by multiplying by 86,400 sec/day and dividing by 2,000 lb/ton .... 0.001 tons/day/ft

This value (0.001 tons/day/ft) is converted to tons/day by multiplying by 1.5 feet (bankful width of stream).

Thus, a reduction in bedload sediment transport from 0.08 tons/day to 0.002 tons/day would indicate an increase in sediment storage in the channel; until such time, recovery would return to pre-silvicultural activity rates. This would reduce the channel stability rating, and by the imbalance in sediment supply—stream energy, disequilibrium conditions would be expected (this is evaluating the coarse fragment portion of soil mass movement sediment supply only).

e. Difference.

Maximum instantaneous, pre-silvicultural activity transport at bankful (Q_{Bpre}) 0.08 tons/day
Maximum instantaneous, post-silvicultural activity transport at bankful (Q_{Bpost}) 0.002 tons/day
A difference of 0.078 tons/day

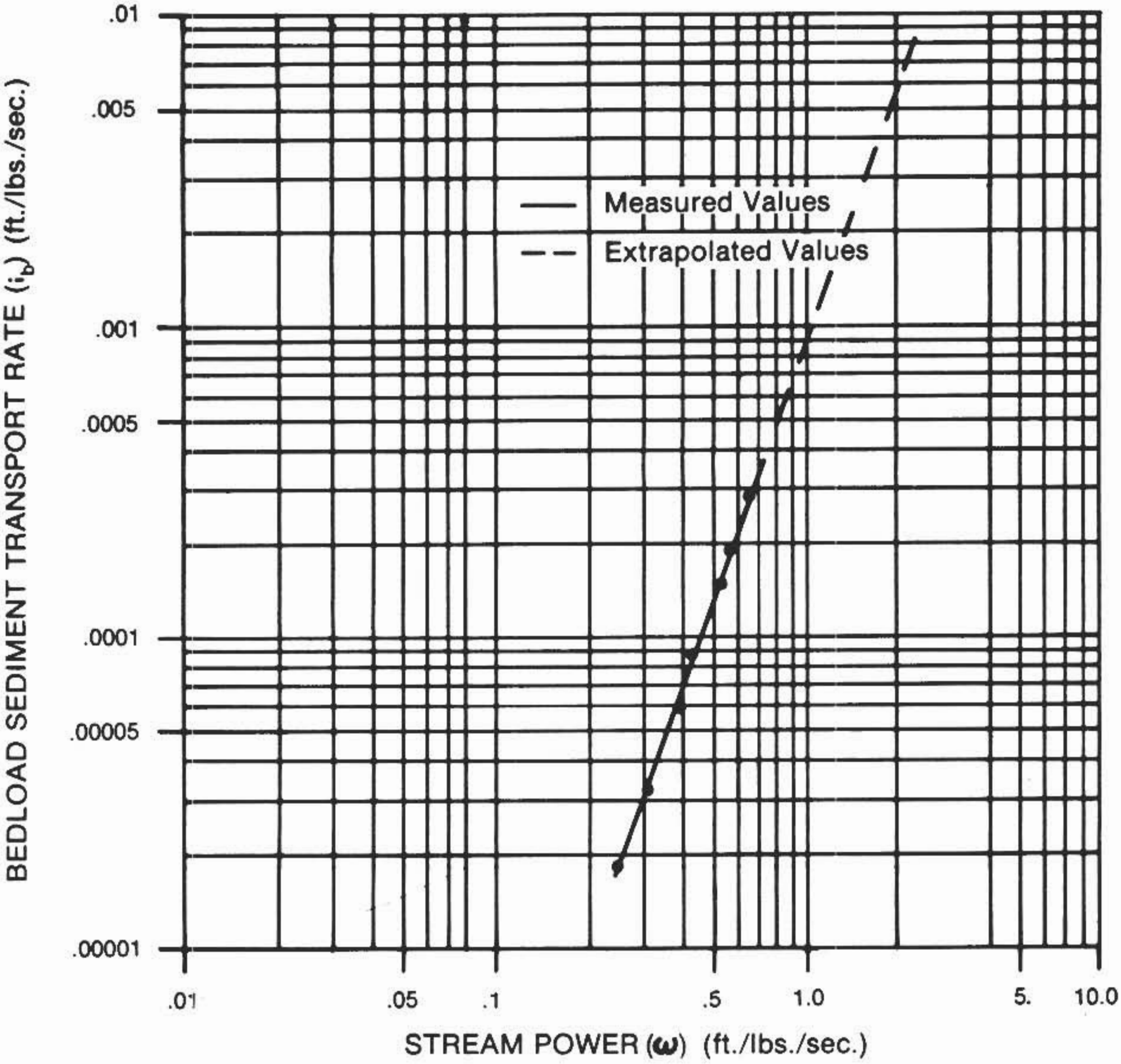

Figure VIII.18.—Bedload transport-stream power relationship, Horse Creek watershed.

TEMPERATURE ANALYSIS

Several of the proposed cutting blocks are close to streams; removal of the trees would expose the streams to increased solar radiation. The additional radiation would result in an increase in the maximum daily water temperature.

The maximum increase in the daily water temperature must be evaluated to determine if the water quality objectives for the stream will be met. The proposed clearcut in hydrographic area 29 was selected to illustrate the procedure to estimate the maximum potential daily temperature increase. All cutting blocks that could impact water temperature would be evaluated similarly.

Computing H, Adjusted Incident Heat Load

Step 1. — Determine H (i.e., incident heat load) based upon latitude of site, critical time of year (month and day), and orientation of stream.

Step 1.1. — Select the solar ephemeris that most closely approaches the latitude of the site, 40 1/2°N.

Step 1.2. — Locate the declination in the solar ephemeris (fig. VII.3) that corresponds to the date when maximum water temperature increase is anticipated: second week in July; therefore, use a declination of +21 1/2°.

Step 1.3. — Once the declination, +21 1/2°, is known, determine the azimuth and solar angle for various times during the day from the solar ephemeris (see fig. VII.6) and record the values in worksheet VII.1. Azimuth readings are found along the outside of the circle and are given for every 10°. Solar angle (i.e., degrees above the horizon) is indicated by the concentric circles and ranges from 0° at the outermost circle to 90° at the center of the circle. The time is indicated above the +23°27′ declination line and is given in hours, solar time.

To determine the solar azimuth and angle that would occur at 12:30 p.m. daylight savings time (DST):

Step 1.3.1. — Follow along the +21 1/2° declination line that is interpolated between the +20° and +23°27′ line. Locate the point that is equal distance between the 11 a.m. (12 noon DST) and noon (1 p.m. DST) time interval. This point represents the 12:30 p.m. DST.

Step 1.3.2. — The solar angle is determined by noting where the point established above (12:30 p.m. with a declination of +21 1/2°) occurs in respect to the solar angle lines present on the figure. The solar angle lines are represented as concentric circles and range from 90° at the center to 0° at the periphery. The point established above falls on the 70° line; therefore, the solar angle is equal to 70°.

Step 1.3.3. — The solar azimuth is determined by noting where the point established in step 1.3.1 occurs in respect to the solar azimuth lines that radiate out from the center of the circle. The point falls midway between the 150° and 160° lines; therefore, the solar angle equals 155°.

More points should be selected about the midday period, when solar radiation is at the greatest intensity.

Step 1.4. — Evaluate the orientation of the sun (i.e., azimuth and angle determined from step 1.3 above) with the stream, and determine what vegetation effectively shades the stream. To do this, compare stream effective width with shadow length. Determine the maximum solar angle (i.e., maximum radiation influx to stream) that will occur when the stream is exposed following the silvicultural activity. Height of the existing vegetation immediately adjacent to the stream is 70 feet.

Step 1.4.1. — The direction the shadows fall across the stream will determine effective width of the stream. Effective width is computed using the following formula:

$$EW = \frac{\text{measured average stream width}}{\text{sine}\ |\ \text{azimuth stream - azimuth sun}\ |} \qquad \text{(VII.4)}$$

The azimuth of the particular stream used for this example is 225°. Effective width varies depending on the time of day. For example, at 12:30 (wksht. VII.1) EW would be equal to:

$$EW = \frac{1.5\ \text{ft}}{\text{sine}\ |\ 225° - 155°\ |} = 1.6\ \text{ft}$$

The absolute value of the azimuth of the stream subtracted from the azimuth of the sun must be less than a 90° angle. Should the difference exceed 90°, subtract this absolute value from 180° to obtain the correct acute angle. The sine is then taken of this computed acute angle.

Step 1.4.2. — Shadow length is computed using the formula:

$$S = \frac{\text{height vegetation}}{\text{tangent solar angle}} \qquad \text{(VII.5)}$$

For example, at 12:30, S would be equal to:

$$S = 70 \text{ ft/tangent } 70° = 25.5 \text{ ft}$$

Note, the **only** periods of the day that should be considered are those when existing vegetation that will be eliminated by the silvicultural activity effectively shades the stream (i.e., when the shadow length extends onto some portion of the stream). Those periods of the day when the stream is not effectively shaded by the existing vegetation will not have an increase in net radiation if the vegetation is removed by the silvicultural activity. Also, there may be periods of the day when the stream is effectively shaded by existing vegetation that will **not** be removed by the silvicultural activity; therefore, the proposed silvicultural activity will have no impact on water temperature.

Summary of steps 1.4.1 and 1.4.2: The existing trees that are scheduled to be cut provide shade to the stream. The only time when the trees do not shade the stream is about 2:10 p.m., when the stream's effective width is infinity (sun is oriented with the stream) and the shadow length is only 28.1 feet. Therefore, removal of this vegetation would result in exposure of the water surface to increased solar radiation.

The proposed silvicultural activity would have the maximum impact on water temperature at 1 p.m. (solar noon) when the solar angle and radiation are greatest.

Step 1.5. — Topographic shading should be evaluated to determine if the water course would be shaded by topographic features. For topographic shading, the percent slope of the ground must exceed the percent slope of the solar angle (i.e., tangent of the solar angle). In the present example, the

side slope = 30%
solar angle = 72° or 308%

Thus, topographic shading is not possible due to the angle of the sun and relatively gentle topographic relief.

Step 1.6. — Calculate the incident heat load for the site. This is obtained from reading the values shown in figure VII.7. To read these values, apply the following:

1. Select the correct curve (shown in fig. VII.7) obtained from the correct solar ephemeris (fig. VII.3): in this example, 40°N latitude, given a declination of +21 1/2°: 72°. (Note that the midday value will always have an orientation, i.e., azimuth, of due south.)
2. In figure VII.8, interpolate between the 70° and 80° curve to obtain the 72° values.
3. Determine the critical time period, which in step 1.4 was found to be 1 p.m.
4. Find the average H value. In this example, the travel time through the reach is only 0.3 hours, so it is not necessary to find an average H value. From figure VII.8, with a 72° midday angle, the H value for 1 p.m. is approximately 4.7 BTU/ft^2–min. (Note: If the solar ephemeris had been used for 45°N latitude, the H value would have be approximately 4.8 BTU/ft^2–min. If the solar ephemeris had been used for 35°N latitude, the H value would have been 4.5 BTU/ft^2–min). Figure VII.8 illustrates the procedure used to obtain H.

Step 1.7. — Because bedrock acts as a heat sink, reducing the heat load absorbed by the water, the H value must be corrected to reflect this heat loss.

$$H_{adjusted} = WH + [B\,(1.00 - C)\,H] \qquad \text{(VII.6)}$$

where for Horse Creek:

- W = percent streambed without bedrock = 10%
- H = unadjusted heat load = 4.7 BTU/ft^2–min with a solar ephemeris for 40°N latitude (step 3.6)
- B = percent streambed with rock = 90%
- C = correction factor = 18% (see explanation for C directly below)

(Note: All percent values used in eq. III.6 are in decimal form.)

Now, C is obtained from figure VII.9. In the example, bedrock comprises 90 percent of the streambed; therefore, H should be reduced by 18 percent.

Thus,

$$H_{adjusted} = [0.1 \times 4.7] + [0.9 \times (1.00 - 0.18) \times 4.7] = 3.94 \text{ BTU/ft}^2\text{–min}$$

Computing Q, Stream Discharge

Step 2. — Determine stream discharge following the proposed silvicultural activity during the critical summer low-flow period when maximum temeratures are anticipated. A pre-activity baseflow measurement during the critical summer period was taken. Discharge during the critical period was 0.4 cfs.

Computing A, Adjusted Surface Area

Step 3. — Determine the adjusted surface area of **flowing water** exposed by the proposed silvicultural activity.

Step 3.1. — Total surface area of **flowing water**

$$A_{total} = LW \qquad \text{(VII.7a)}$$

where:

L = length of exposed reach

W = width of flowing water

A_{total} = 530 ft × 1.5 ft
= 795 ft^2

Step 3.2. — Total surface area shaded by brush

$$A_{shade\ brush} = LW(\%\ \text{stream shaded by brush only}) \qquad \text{(VII.7b)}$$

$$= 530\ ft \times 1.5\ ft \times 0.15$$

$$= 120\ ft^2$$

Step 3.3. — Surface area exposed under current vegetative canopy cover; correct for transmission of light through the existing stand that has a 65 percent crown closure. Since only vertical crown closure values are available, estimate the percentage transmission of solar radiation through the overstory canopy. Values for these estimates may be obtained from figure VII.D.1. A crown closure of 65 percent permits about 8 percent transmission of solar radiation.

$$A_{presently\ exposed} = (A_{total} - A_{shade\ brush}) \times \%\ \text{transmission through existing vegetation} \qquad \text{(VII.7c)}$$

$$= (795\ ft^2 - 120\ ft^2 \times 0.08)$$

$$= 54\ ft^2$$

Step 3.4. — The adjusted surface area that will be exposed to increased solar radiation if all vegetation is removed is

$$A_{adjusted} = A_{total} - A_{presently\ exposed} \qquad \text{(VII.7d)}$$

$$= 795\ ft^2 - 54\ ft^2$$

$$= 741\ ft^2$$

Step 4. — Estimate ΔT, maximum potential daily temperature increase in °F if the proposed silvicultural activity is implemented. Solve equation VII.3a

$$\Delta T = \frac{A_{adjusted} H_{adjusted}}{Q} \times 0.000267 \qquad \text{(VII.3a)}$$

A = 741 ft^2

H = 3.94 BTU/ft^2 − min

Q = 0.4 cfs

$$\Delta T = \frac{(741\ ft^2)\ (3.94\ BTU/ft^2 - min)}{0.4\ cfs} \times 0.000267$$

$$= 1.9\ °F$$

The Mixing Ratio Formula

The following example is provided to illustrate the use of the mixing ratio formula for evaluating downstream water temperature impacts. The water temperature increase associated with the proposed clearcut in hydrographic area 29 has previously been evaluated, and a maximum potential daily temperature increase of 1.9°F was estimated. With similar evaluations made for proposed clearcuts in hydrographic areas 27 and 28, an estimate of the water temperature of the main stream draining this area can now be obtained.

The data and results of the individual water temperature evaluations are recorded on worksheet VII.2. The pre-silvicultural activity stream water temperature is 55°F. The sequence of steps to obtain an estimate of the water temperature of the main stream draining this area follows.

Hydrographic area 27 stream reach. — The estimated maximum potential daily stream temperature increase (2.5°F) is added to the pre-silvicultural activity stream temperature (55°F) to obtain an estimate of the water temperature (57.5°F) below the proposed clearcut draining this hydrographic area.

Hydrographic area 28 stream reach. — The estimated maximum potential daily stream temperature increase (2.1°F) is added to the pre-silvicultural activity stream temperature (55°F) to obtain an estimate of the water temperature (57.1°F) below the proposed clearcut draining this hydrographic area.

To estimate the water temperature below the confluence of the streams draining hydrographic areas 27 and 28, the mixing ratio formula may be used.

$$T_D = \frac{D_M T_M + D_T T_T}{D_M + D_T} \qquad \text{(VII.8)}$$

where:

T_D = temperature downstream after the tributary (hydrographic area 28) enters the main stream (hydrographic area 27)

D_M = discharge main stream = 0.4 cfs

T_M = temperature main stream above tributary = 57.5°F

D_T = discharge stream draining treated area = 0.3 cfs

T_T = temperature stream below treated area equals temperature above plus computed temperature increase (i.e., Brown's model) or

$T_T = T_A + \Delta T = 55°F + 2.1°F = 57.1°F$

T_A = temperature stream above treated area = 55°F

ΔT = temperature increase computed using Brown's model = 2.1°F

Therefore,

$$T_D = \frac{(0.4\text{ cfs})(57.5°F) + (0.3\text{ cfs})(57.1°F)}{(0.4\text{ cfs}) + (0.3\text{ cfs})}$$

$$= 57.3°F$$

The main stream below the confluence will have a water temperature of 57.3°F.

Hydrographic area 29 stream reach. — The estimated maximum potential daily stream temperture increase (1.9°F) is added to the pre-silvicultural activity stream temperature (55°F) to obtain an estimate of the water temperature (56.9°F) below the proposed clearcut draining this hydrographic area.

To estimate the water temperture below the confluence of the main stream and the stream draining hydrographic area 29, the mixing ratio formula may be used.

$$T_D = \frac{D_M T_M + D_T T_T}{D_M + D_T} \qquad \text{(VII.8)}$$

where,

T_D = temperature downstream after the tributary (hydrographic area 29) enters the main stream

D_M = discharge main stream = 0.7 cfs

T_M = temperature main stream above tributary = 57.3°F

D_T = discharge stream draining treated area = 0.4 cfs

T_T = temperature stream below treated area equals temperature above plus computed temperature increase (i.e., Brown's model)

$T_T = T_A + \Delta T = 55°F + 1.9°F = 56.9°F$

T_A = temperature stream above treated area = 55°F

ΔT = temperature increase computed using Brown's model = 1.9°F

Therefore,

$$T_D = \frac{(0.7\text{ cfs})(57.3°F) + (0.4\text{ cfs})(56.9°F)}{(0.7\text{ cfs}) + (0.4\text{ cfs})}$$

$$= 57.2°F$$

The main stream below the confluence will have a water temperature of 57.2°F or a maximum daily temperature increase of 2.2°F. This same procedure is used to evaluate other tributary streams further downstream.

Groundwater influence has previously been demonstrated in the Grits Creek example.

ANALYSIS REVIEW

Interpretation Of The Analysis Outputs

The proposed silvicultural plan has been evaluated in the preceding discussion and estimated values from various outputs are shown in table VIII.5. These outputs are compared to previously determined water quality objectives. When considering whether these objectives have been met or not, it is important to consider the reliability of the computed values as previously discussed in the analysis review for Grits Creek. A review of the data reliability and the computed outputs for Horse Creek indicates the possibility that the water quality objectives will not be met; therefore, a revised silvicultural plan that includes a different mix of controls should be prepared and evaluated.

Comparing Analysis Outputs To Water Quality Objectives

Two potential non-point source pollutants must be controlled—total potential sediment and water temperature. Evaluation of the individual components of the estimated total potential sediment value (216 tons), clearly indicates the major contribution of potential sediment is from soil mass movement (192 tons). The surface erosion (17.7 tons) and increased flow (6.3 tons) contributions, although significant, are an order of magnitude less than the soil mass movement. Therefore, first priority is to evaluate control opportunities for minimizing the soil mass movement non-point source. The second priority is to consider control opportunities for the surface erosion component.

The sediment contribution from increased streamflows cannot be significantly altered without major reductions in amount of area harvested or changes in the cutting pattern. Since the proposed silvicultural plan has an optimum layout of cutting units, and their contribution to increased flow was small, no further consideration of flow-related controls is necessary.

Since existing stream temperatures (55°F) are suitable for the fishery resource and the area is undisturbed, mitigative controls before the activity are unnecessary; only preventive controls need be considered.

Following is a discussion of the procedures applied to select a different mix of controls that could be implemented to meet the water quality objectives—first for total potential sediment and then for temperature. These procedures are discussed in chapter II, appendix A, "Example Three: Selecting Controls When Plans Do Not Meet Water Quality Objectives." After identifying control opportunities, the favorable and adverse impacts of the controls, along with possible interactions, are evaluated before finally selecting control opportunities to be used.

Control Opportunities For Soil Mass Movement

Since it is very difficult to apply effective mitigative controls after a large soil mass movement occurs, only preventive control opportunities will be evaluated. Table II.2 of "Chapter II: Control Opportunities" presents the potential resource impacts and control opportunities.

Soil mass movement initiation or acceleration in the Horse Creek watershed may be caused by road construction, due to large fill sections, and loss of root strength, due to vegetative removal. Based upon this assessment of the causes of soil mass movement, controls for slope configuration changes and vegetative changes are reviewed in table II.2, and preventive controls are identified.

Once the possible preventive control opportunities have been identified, table II.3 is used to determine which variables that influence soil mass movement are affected by the various control opportunities. That portion of table II.3 dealing with slope configuration and vegetative change is examined. From the possible control opportunities for slope configuration change, it is apparent that some controls influence several variables and would, therefore, be more effective in controlling soil mass movement than controls that influence only one. The following preventive control opportunities affect the principal variables influencing soil mass movement:

1. Bench cut and compact fill
2. Full bench section
3. Reduce logging road density
4. Road and landing location
5. Slope rounding or reduction in slope cut

Possible preventive controls for vegetative change are:

1. Cutting block design
2. Maintain ground cover

From this list of possible control opportunities, the proposed silvicultural activity was modified for soil mass movement by:

a. Elimination of cutting block 14 on the unstable area. The volume of timber not removed in this unit has been obtained elsewhere by making slight changes to enlarge other cutting units on stable terrain.
b. Removal of the road and landings in hydrographic areas 26 and 27 that served cutting block 14.

By incorporating these controls, the soil mass movement hazard index will be reduced from high to moderate. Worksheet V.2 is completed based upon the above preventive controls. The new silvicultural activity factor total is 7. Combining this with the natural total of 31 gives the new total value for the modified silvicultural activity of 38, which falls within the medium hazard range (21-44) for soil mass movement.

Control Opportunities For Surface Erosion

By reviewing worksheet IV.8, the maps (figs. IV.14 to IV.18), and using professional judgment, the following resource impacts and conditions were noted:

Problem No. 1: Some landings were located close to a stream, allowing direct delivery of eroded material.

Problem No. 2: Because there was no road surfacing included in the proposed silvicultural plan, erosion resulted from bare road surface.

Control opportunities for Problem No. 1, road and landing location, are discussed under resource impacts for soil compaction, bare soil, excess water, and water concentration. Bare soil and compaction are directly related to the number of landings and miles of road in the proposed silvicultural activity area. Since the initial plan has incorporated the minimum number of landings and miles of roads, controls listed here are not as applicable as controls for excess water and water concentration. Using sections B and C of the "Control Opportunities" chapter, the following applicable controls were selected:

Excess water

1. Cutting block design
2. Waterside area
3. Revegetate treated areas

Water concentration

1. Reduce road grades
2. Road and landing location
3. Waterside areas

The cutting block designs have been carefully chosen, and there is little opportunity to make significant changes. The proposed silvicultural plan already contains provisions for revegetating treated areas. The remaining control, waterside areas, is discussed below.

Under "water concentration," the control opportunity "reduce road grades" is not practical, since the road locations are determined by minimum grades to reach benches and suitable cutting blocks. Considering the control opportunity "road and landing location," it was determined that there were opportunities to make some slight modifications in landing locations by moving them back from stream channels. At the same time, the control opportunity "waterside areas" (leaving some area to act as a sediment filter strip) was also utilized to reduce the amount of sediment delivered to a channel.

Using the same calculation procedures outlined in chapter IV and in the example for the proposed silvicultural plan, a new analysis was made using revised values for the different landing locations (wkshts. IV.2 to IV.4 and IV.6 to IV.8).

By moving a landing a short distance away from a stream channel, three factors affecting sediment delivery are changed (compare wksht. IV.7 for both plans—proposed and revised). First, the distance from the edge of the disturbance to the stream channel is increased, creating more area for sediment deposition; second, the amount of ground cover between the disturbance and channel increases; third, the surface roughness increases slightly. The net result is a change in the sediment delivery index from 0.11 under proposed management, to 0.01 in the modified plan. This would reduce the amount of eroded material that might be delivered to a stream by 91 percent for each landing next to a stream. The total from all landings has been reduced from 0.9 tons/yr to 0.03 tons/yr (wksht. IV.8 for both plans).

Control opportunities for Problem No. 2, "no road surfacing," are found in section B under bare soil, with "protection of road bare surface areas with non-living material" being the most practical. A decision was made to use 6 inches of crushed gravel on all roadbeds. The same procedures outlined under roads should be applied to the proposed silvicultural plan, except that the VM factor has now been changed for the running surface from 1.24 (wksht. IV.6, proposed) to 0.005 (wksht. IV.6, revised). The weighted VM factor for the road is now 0.17, which compares with a value of 0.91 for the proposed plan. A summary on worksheets IV.8 (for both plans) shows that the total for all roads has now been reduced from 8.1 tons/yr to 1.3 tons/yr, or an 84 percent reduction.

Control Opportunities For Temperature

To meet the temperature water quality objective, the maximum potential daily temperature increase must be reduced by applying preventive controls. Table II.2 of "Chapter II: Control Opportunities" presents potential resource impacts and control opportunities to be evaluated. Water temperature increases resulting from silvicultural activities are caused by removal of vegetation that shades the stream. Therefore, controls for stream shading are reviewed in table II.2.

Three preventive control opportunities are presented that could be used to meet the water quality objectives:

1. Cutting block design
2. Directional felling
3. Waterside area

Directional felling away from the stream is already specified in the proposed silvicultural plan and so is not an alternative. Both cutting block design and waterside areas are viable control opportunities.

Cutting block design. — Using the basic procedure presented in "Chapter VII: Temperature," compute the maximum length of stream channel that could be exposed with a resultant maximum potential daily temperature increase of 1.5°F.

From the previous evaluations: The stream reach length that would be exposed if the proposed silvicultural activity was implemented was 530 feet. Maximum potential daily temperature increase would be 1.9°F. The water quality objective limits the maximum potential daily temperature increase to 1.5°F (temperature objective). A direct relationship can be established to estimate the reach of stream that could be exposed (length objective).

$$\frac{\Delta T}{T_{obj}} = \frac{L}{L_{obj}}$$

where:

ΔT = potential daily temperature increase

T_{obj} = allowable daily temperature increase

L = potential exposed stream length

L_{obj} = allowable exposed stream length

$$L_{obj} = \frac{1.5°F}{1.9°F} \times 530 \text{ ft} = 418 \text{ ft}$$

By modifying the proposed cutting block design so that no more than 418 feet of the stream is exposed, the water quality objective will be met.

Waterside areas. — Using the basic procedure presented in "Chapter VII: Temperature," compute the minimum crown closure that is required to prevent a maximum potential daily temperature increase greater than 1.5°F.

From the previous evaluation:

A_{total} = 795 ft²

$A_{shade\ brush}$ = 120 ft²

$H_{adjusted}$ = 3.94 BTU/ft²−min

Q = 0.4 cfs

Estimate the maximum $A_{adjusted}$ value that would result in a ΔT value of 1.5°F, water quality objective.

$$\Delta T = \frac{(A_{adjusted})(H_{adjusted})}{Q} \times 0.000267$$

$$1.5°F = \frac{(A_{adjusted})\,(3.94 \text{ BTU/ft}^2-\text{min})}{0.4 \text{ cfs}} \times 0.000267$$

Rearranging the equation gives:

$$A_{adjusted} = \frac{(1.5°F)\,(0.4 \text{ cfs})}{(3.94 \text{ BTU/ft}^2-\text{min})\,(0.000267)} = 570 \text{ ft}^2$$

$$A_{adjusted} = A_{total} - A_{presently\ exposed}$$

Rearranging the equation gives:

$$A_{presently\ exposed} = A_{total} - A_{adjusted} = 795 \text{ft}^2 - 570 \text{ ft}^2 = 225 \text{ ft}^2$$

$A_{presently\ exposed} = (A_{total} - A_{shade\ brush}) \times$ percent transmission through existing vegetation

Rearranging the equation gives:

percent transmission through existing vegetation $= A_{presently\ exposed} / (A_{total} - A_{shade\ brush})$

$$= \frac{225 \text{ ft}^2}{795 \text{ ft}^2 - 120 \text{ ft}^2} = 0.34$$

From figure VII.D.1, 34 percent transmission corresponds to a crown close of 35 percent. A reduction in the amount of vegetation removed from the streamside zone so that 35 percent crown closure existed after the silvicultural activity would meet the water quality objectives for temperature.

The forest manager, after reviewing both viable control opportunities and discussing the alternatives with other resource specialists, selected the waterside area control. Using this control, only mature overstory trees were removed, leaving a productive understory for other uses.

Table VIII.6

Summary of quantitative outputs for: Revised Plan, Horse Creek

Chapter	Line No.	Output description		Computed value Pre-activity	Computed value Post-activity	Chapter reference (worksheets)
Hydrology: Chapter III	1	Water available for annual streamflow		15.4 in	18.1 in	III.5, III.6
	2	Increase in water available for annual streamflow			2.7 in	III.5, III.6
	3	Peak discharge		10.2 cfs	10.99 cfs	III.7, III.8
	4	Date of peak discharge		June 15	June 1	III.7, III.8
	5	Hydrograph				III.7, III.8
	6	7-day flow duration curve		N.A.	N.A.	
Surface Erosion: Chapter IV	7	Surface soil loss		N.A.	490 tons/yr	IV.3
	8	Sediment delivered to stream channel		N.A.	9.8 tons/yr	IV.8
Soil Mass Movement: Chapter V	9	Hazard index		31	38	V.2
	10	Weight of sediment	Coarse >0.062 mm	N.A.	N.A.	
	11		Fine <0.062 mm	N.A.	N.A.	
	12		Total	N.A.	0.0 tons/yr	V.6
	13	Acceleration factor			3	V.6
Total Potential Sediment: Chapter VI	14	Sediment discharge due to flow change	Bedload	1.4 tons/yr	1.9 tons/yr	VI.3 line E VI.3 line F
	15		Suspended	7.1 tons/yr	8.8 tons/yr	VI.3 line A VI.3 line B
	16		Total	8.5 tons/yr	10.7 tons/yr	VI.3 line K VI.3 line G
	17	Total suspended sediment discharge from all sources		7.1 tons/yr	18.6 tons/yr	VI.3 line A line I.1 + A
	18	Increase in total potential bedload plus suspended sediment from all sources			12.0 tons/yr	VI.3 line M
Temperature: Chapter VII	19	Potential temperature changes			1.5°F	VII.2

Revised Silvicultural Plan

Based on these possible control opportunities, a revised silvicultural plan was prepared that consisted of the following changes:

1. Leave vegetation on the unstable area in hydrographic area 26, eliminating cutting block CC14.
2. Increase slightly all other cutting units to accommodate loss of timber from cutting block CC14.
3. Eliminate road and landings to serve cutting block CC14.
4. Move some landings further away from streams.
5. Use 6 inches of crushed rock on all road surfaces.
6. Use waterside areas with a crown closure of 35 percent to shade streams.

The summary of computed outputs for the revised silvicultural plan with these controls is shown on table VIII.6.

The next step is to assess the possible adverse impacts of these controls. With the removal of more timber on other cutting units, it is expected that the surface erosion figures would increase; however, the changes were insignificant on all but hydrographic areas 14 and 16. These two areas show an increase of 0.2 tons/yr of delivered sediment (wksht. IV.8 for both proposed and revised plans).

For this hypothetical example, the net effect of these controls has been a reduction in all non-point source pollutant outputs (table VIII.6). The soil mass movement hazard index was reduced from 61 to 39. The anticipated impacts of the introduced material on the first-order drainage has been eliminated. The delivered sediment from surface erosion sources has been reduced from 17.7 to 9.8 tons/yr. The transport efficiency of the stream channel will be maintained and is capable of handling the available sediment without major channel adjustments and stability change. Considering the water quality objectives, limiting suspended sediment discharge to 38.6 tons/yr and allowing a maximum water temperature increase of 1.5°F, the revised silvicultural plan is determined to be acceptable from a water quality standpoint.

Worksheets for Horse Creek, proposed and revised plans

Worksheets are presented in numerical order with all III.1-III.4 proposed followed by III.1-III.4 revised, IV.1-IV.8 proposed followed by IV.1-IV.8 revised, etc.

WORKSHEET

Water available for streamflow for the

(1) Watershed name Horse Creek (2) Hydrologic region 4

(5) Vegetation type Lodgepole pine (6) Annual precipitation 34.3 inches

Season name/dates (9)	Silvicultural prescription: Compartment (10)	Silvicultural prescription: Silvicultural state (11)	Area: Acres (12)	Area: % (13)	Precipitation (in) (14)	Snow retention coef. (15)	Adjusted snow retention coef. (16)	Adjusted precipitation (in) (17)
WINTER 10/1 - 2/28	Unimpacted	Forested	600	1.000	16.1	1.0	1.0	16.1
	Impacted							
	Total for season		600	1.000	16.1			
SPRING 3/1 - 6/30	Unimpacted	Forested	600	1.000	12.1	1.0	1.0	12.1
	Impacted							
	Total for season		600	1.000	12.1			
SUMMER and FALL 7/1 - 9/30	Unimpacted	Forested	600	1.000	6.1	1.0	1.0	6.1
	Impacted							
	Total for season		600	1.000	6.1			
	Unimpacted							
	Impacted							
	Total for season							

Water available for annual streamflow (in)			
	Unimpacted	Forested	(30)
			(31)
	Impacted		(32)
			(33)
			(34)
			(35)

existing condition in snow dominated regions

(3) Total watershed area (acres) 600 (4) Dominant energy-aspect Southwest

(7) Windward length of open area (tree heights) 0 (8) Tree height (feet) 70

ET (in) (18)	Basal area (ft^2/ac) (19)	Cover density % (20)	Cover density $\%C_{dmax}$ (21)	ET modifier coef. (22)	Adjusted ET (in) (23)	Water available for streamflow (in) (24)	(25)	(26)	(27)	(28)	(29)
2.1	200	33	100	1.0	2.1	14.0					
7.6	200	33	100	1.0	7.6	4.5					
9.2	200	33	100	1.0	9.2	-3.1					
						15.4					

Notes for Worksheet III.5

Item or Col. No.	Notes
(1)	Identification of watershed or watershed subunit.
(2)	Descriptions of hydrologic regions and provinces are given in the text.
(3)-(8)	User supplied.
(9)	Seasons for each hydrologic region are described in the text.
(10)	The unimpacted compartment includes areas not affected by silvicultural activity. The impacted compartment includes areas affected by silvicultural activity. Impacted areas do not have to be physically disturbed by the silvicultural activity. For example, if an area is subject to snow redistribution due to a silvicultural activity, it is an impacted area.
(11)	Areas of similar hydrologic response as identified and delineated by vegetation or silvicultural activity.
(12)	User supplied.
(13)	Column (12) ÷ item (3).
(14)	User supplied.
(15)	From figure III.6 or appendix A or user supplied.
(16)	Snow retention coefficient adjustment for open areas:

$$\rho_{oadj} = 1 + (\rho_o - 1)\left(\frac{.50}{X}\right)$$

where:

ρ_{oadj} = adjusted snow retention coefficient for open areas (receiving areas)

ρ_o = snow retention coefficient for open areas

$$X = \frac{\text{open area (in acres)}}{\text{impacted area (in acres)}}$$

Snow retention coefficient adjustment for forested source areas (impacted forest areas):

$$\rho_f = \frac{1- \rho_{oadj}\ X}{1-X}$$

where:

ρ_f = adjusted snow retention coefficient for areas affected by snow redistribution (source areas)

$$X = \frac{\text{open area (in acres)}}{\text{impacted area (in acres)}}$$

(17) Column (14) x column (16)

(18) From figures III.24 to III.40 or user supplied.

(19) User supplied (not required if % cover density is user supplied).

(20) From figures III.41 to III.45 or user supplied.

(21) (Column (20) ÷ C_{dmax}) x 100 where C_{dmax} is the % cover density required for complete hydrologic utilization. C_{dmax} is determined by professional judgment at the site.

(22) From figures III.46 to III.56.

(23) Column (18) x column (22).

(24)-(29) The quanitity [column (17)-column (23)] x column (13).

(30) Sum of column (24).

(31) Sum of column (25).

(32) Sum of column (26).

(33) Sum of column (27).

(34) Sum of column (28).

(35) Sum of column (29).

WORKSHEET

Water available for streamflow for the

(1) Watershed name Horse Creek (2) Hydrologic region 4

(5) Vegetation type Lodgepole Pine (6) Annual precipitation 34.3 inches

Season name/dates (9)	Silvicultural prescription: Compartment (10)	Silvicultural prescription: Silvicultural state (11)	Area: Acres (12)	Area: % (13)	Precipi-tation (in) (14)	Snow retention coef. (15)	Adjusted snow retention coef. (16)	Adjusted precipi-tation (in) (17)
WINTER 10/1 - 2/28	Unimpacted	Forested	135.0	.225	16.1	1.00	1.00	16.1
	Impacted	Forested	153.5	.256	16.1	—	.55	8.9
		Clearcut	311.5	.519	16.1	1.3	1.22	19.6
	Total for season		600.0	1.000	16.1			
SPRING 3/1 - 6/30	Unimpacted	Forested	135.0	.225	12.1	1.00	1.00	12.1
	Impacted	Forested	153.5	.256	12.1	—	.55	6.7
		Clearcut	311.5	.519	12.1	1.3	1.22	14.8
	Total for season		600.0	1.000	12.1			
SUMMER and FALL 7/1 - 9/30	Unimpacted	Forested	135.0	.225	6.1	1.0	1.0	6.1
	Impacted	Forested	153.5	.256	6.1	1.0	1.0	6.1
		Clearcut	311.5	.519	6.1	1.0	1.0	6.1
	Total for season		600.0	1.000	6.1			
	Unimpacted							
	Impacted							
	Total for season							

Water available for annual streamflow (in)			
	Unimpacted	Forested	(30)
			(31)
	Impacted	Forested	(32)
		Clearcut	(33)
			(34)
			(35)

proposed condition in snow dominated regions

(3) Total watershed area (acres) 600 (4) Dominant energy-aspect Southwest

(7) Windward length of open area (tree heights) 6 (8) Tree height (feet) 70

ET (in) (18)	Basal area (ft²/ac) (19)	Cover density % (20)	Cover density %C_{dmax} (21)	ET modifier coef. (22)	Adjusted ET (in) (23)	Water available for streamflow (in) (24)	(25)	(26)	(27)	(28)	(29)
2.1	200	33	100	1.00	2.1	3.2					
2.1	200	33	100	1.00	2.1			1.7			
2.1	0	0	0	.60	1.3				9.5		
7.6	200	33	100	1.00	7.6	1.0					
6.1	200	33	100	1.00	6.1			0.2			
7.6	0	0	0	1.07	8.1				3.5		
9.2	200	33	100	1.00	9.2	-0.7					
9.2	200	33	100	1.00	9.2			-0.8			
9.2	0	0	0	.55	5.1				0.5		
						3.5					
								1.1			
									13.5		

Notes for Worksheet III.6

Item or Col. No.	Notes
(1)	Identification of watershed or watershed subunit.
(2)	Descriptions of hydrologic regions and provinces are given in the text.
(3)-(8)	User supplied.
(9)	Seasons for each hydrologic region are described in the text.
(10)	The unimpacted compartment includes areas not affected by silvicultural activity. The impacted compartment includes areas affected by silvicultural activity. Impacted areas do not have to be physically disturbed by the silvicultural activity. For example, if an area is subject to snow redistribution due to a silvicultural activity, it is an impacted area.
(11)	Areas of similar hydrologic response as identified and delineated by vegetation or silvicultural activity.
(12)	User supplied.
(13)	Column (12) ÷ item (3).
(14)	User supplied.
(15)	From figure III.6 or appendix A or user supplied.
(16)	Snow retention coefficient adjustment for open areas:

$$\rho_{oadj} = 1 + (\rho_o - 1)\left(\frac{.50}{X}\right)$$

where:

ρ_{oadj} = adjusted snow retention coefficient for open areas (receiving areas)

ρ_o = snow retention coefficient for open areas

$$X = \frac{\text{open area (in acres)}}{\text{impacted area (in acres)}}$$

Snow retention coefficient adjustment for forested source areas (impacted forest areas):

$$\rho_f = \frac{1 - \rho_{oadj} X}{1-X}$$

where:

ρ_f = adjusted snow retention coefficient for areas affected by snow redistribution (source areas)

$$X = \frac{\text{open area (in acres)}}{\text{impacted area (in acres)}}$$

(17) Column (14) x column (16)

(18) From figures III.24 to III.40 or user supplied.

(19) User supplied (not required if % cover density is user supplied).

(20) From figures III.41 to III.45 or user supplied.

(21) (Column (20) ÷ C_{dmax}) x 100 where C_{dmax} is the % cover density required for complete hydrologic utilization. C_{dmax} is determined by professional judgment at the site.

(22) From figures III.46 to III.56.

(23) Column (18) x column (22).

(24)-(29) The quanitity [column (17)-column (23)] x column (13).

(30) Sum of column (24).

(31) Sum of column (25).

(32) Sum of column (26).

(33) Sum of column (27).

(34) Sum of column (28).

(35) Sum of column (29).

WORKSHEET

Existing condition hydrograph

(1) Watershed name Horse Creek

Date or interval (3)		Distribution of water								
	Unimpacted						Impacted			
	Forested									
	% (4)	Inches (5)	cfs (6)	% (7)	Inches (8)	cfs (9)	% (10)	Inches (11)	cfs (12)
APRIL 8	.0000	.00	.00						
14	.0000	.00	.00						
20	.0000	.00	.00						
26	.0000	.00	.00						
MAY 2	.0050	.08	.34						
8	.0150	.23	.97						
14	.0250	.39	1.64						
20	.0400	.62	2.61						
26	.0600	.92	3.87						
JUNE 1	.0825	1.27	5.35						
7	.1050	1.62	6.82						
13	.1400	2.16	9.09						
19	.1575	2.43	10.23						
25	.1400	2.16	9.09						
JULY 1	.1050	1.62	6.82						
7	.0650	1.00	4.21						
13	.0375	.58	2.44						
19	.0175	.27	1.14						
25	.0050	.08	.34						
31	.0000	.00	.00						

Item or Col. No.	Notes
(1)	Identification of watershed or watershed subunit.
(2)	Descriptions of hydrologic regions and provinces are given in text.
(3)	Supplied by user. Either date snowmelt begins or date of peak snowmelt runoff.
(4),(7), (10),(13), (16),(19)	Digitized excess water distribution (%) from tables III.11 to III.22 for forested and open condition. Interpolate between forested and open for other conditions.

III.7

for snow dominated regions

(2) Hydrologic region 4

available for annual streamflow									
Impacted (continued)									Composite hydrograph
% (13)	Inches (14)	cfs (15)	% (16)	Inches (17)	cfs (18)	% (19)	Inches (20)	cfs (21)	cfs (22)
									.00
									.00
									.00
									.00
									.34
									.97
									1.64
									2.61
									3.87
									5.35
									6.82
									9.09
									10.23
									9.09
									6.82
									4.21
									2.44
									1.14
									.34
									.00

(5),(8),(11),(14),(17),(20) — Digitized excess water distribution (%) multiplied by water available for annual streamflow gives flow in inches.

(6),(9),(12),(15),(18),(21) — To convert from area inches to cfs, the area-inch hydrograph is multiplied by:

$$\frac{\text{Total watershed area (in acres)}}{\text{(12 in/ft) (1.98) (Number of days in interval)}}$$

(22) — Sum of columns (6), (9), (12), (15), (18), and (21) gives the composite hydrograph for the entire watershed in cfs.

WORKSHEET

Proposed condition hydrograph

(1) Watershed name Horse Creek

Date or interval (3)		Distribution of water								
		Unimpacted						Impacted		
		Forested						Forested		
		% (4)	Inches (5)	cfs (6)	% (7)	Inches (8)	cfs (9)	% (10)	Inches (11)	cfs (12)
APRIL	8	.0000	.00	.00				.0000	.00	.00
	14	.0000	.00	.00				.0000	.00	.00
	20	.0000	.00	.00				.0000	.00	.00
	26	.0000	.00	.00				.0000	.00	.00
MAY	2	.0050	.02	.08				.0050	.01	.04
	8	.0150	.05	.21				.0150	.02	.08
	14	.0250	.09	.38				.0250	.03	.13
	20	.0400	.14	.59				.0400	.04	.17
	26	.0600	.21	.88				.0600	.07	.29
JUNE	1	.0825	.29	1.22				.0825	.09	.38
	7	.1050	.37	1.56				.1050	.12	.51
	13	.1400	.49	2.06				.1400	.15	.63
	19	.1575	.55	2.31				.1575	.17	.72
	25	.1400	.49	2.06				.1400	.15	.63
JULY	1	.1050	.37	1.56				.1050	.12	.51
	7	.0650	.23	.97				.0650	.07	.29
	13	.0375	.13	.55				.0375	.04	.17
	19	.0175	.06	.25				.0175	.02	.08
	25	.0050	.02	.08				.0050	.01	.04
	31	.0000	.00	.00				.0000	.00	.00

Item or Col. No.	Notes
(1)	Identification of watershed or watershed subunit.
(2)	Descriptions of hydrologic regions and provinces are given in text.
(3)	Supplied by user. Either date snowmelt begins or date of peak snowmelt runoff.
(4),(7),(10),(13),(16),(19)	Digitized excess water distribution (%) from tables III.11 to III.22 for forested and open condition. Interpolate between forested and open for other conditions.

III.8

for snow dominated regions

(2) Hydrologic region 4

available for annual streamflow									Composite hydrograph
Impacted (continued)									
Clearcut									
% (13)	Inches (14)	cfs (15)	% (16)	Inches (17)	cfs (18)	% (19)	Inches (20)	cfs (21)	cfs (22)
.0000	.00	.00							.00
.0025	.03	.13							.13
.0075	.10	.42							.42
.0250	.34	1.43							1.43
.0425	.57	2.40							2.52
.0650	.88	3.70							3.99
.0825	1.11	4.67							5.18
.1075	1.45	6.10							6.86
.1475	1.99	8.38							9.55
.1650	2.23	9.39							10.99
.1450	1.96	8.25							10.32
.1150	1.55	6.52							9.21
.0625	.84	3.54							6.57
.0250	.34	1.43							4.12
.0075	.10	.42							2.49
.0000	.00	.00							1.26
.0000	.00	.00							.72
.0000	.00	.00							.33
.0000	.00	.00							.12
.0000	.00	.00							.00

(5),(8), (11),(14), (17),(20) — Digitized excess water distribution (%) multiplied by water available for annual streamflow gives flow in inches.

(6),(9), (12),(15), (18),(21) — To convert from area inches to cfs, the area-inch hydrograph is multiplied by:

$$\frac{\text{Total watershed area (in acres)}}{\text{(12 in/ft) (1.98) (Number of days in interval)}}$$

(22) — Sum of columns (6), (9), (12), (15), (18), and (21) gives the composite hydrograph for the entire watershed in cfs.

WORKSHEET IV.1

Soil characteristics for the Horse Creek watershed

Soil group		Percent sand 2.0-0.1 mm	Percent very fine sand 0.10-0.05 mm	Percent "coarse silt" 0.062-0.05 mm[1/]	Percent silt 0.05-0.002 mm	Percent clay <0.002 mm	Percent organic matter	Soil structure: MSLE code	Soil structure: Descriptive	Soil permeability: MSLE code	Soil permeability: Inches per hour
1	Topsoil	10	40	12	30	20	7.0	3	MEDIUM TO COARSE GRANULAR	5	0.06-0.2
	Subsoil	20	30	8	25	25	1.0	4	PRISMATIC	5	0.06-0.2
2	Topsoil	50	25	4	15	10	4.0	4	BLOCKY	4	0.2-0.6
	Subsoil	40	20	3	15	25	1.0	4	BLOCKY	5	0.06-0.2
3	Topsoil	65	15	2	10	10	4.0	2	FINE GRANULAR	3	0.6-2.0
	Subsoil	70	15	9	5	10	2.0	3	COARSE GRANULAR	2	2.0-6.0

1/The "coarse silt" particle size group is not part of the USDA classification system, but 0.062 mm represents an upper limit of particle size that is used when estimating suspended sediment transport in streams. For this use only the "coarse silt" size within the USDA very fine sand classification is presented.

WORKSHEET IV.2

Horse Creek watershed erosion response unit management data for use in the MSLE and sediment delivery index, hydrographic area 3, proposed plan.

Erosion response unit	Slope length of disturbed area (ft)	Slope gradient of disturbed area (%)	Length of road section (ft)	Average width of disturbance (ft)	Area (sq.ft.)	Area (acres) 1/
1. CC 3.1	100	38				8.0
2. CC 3.2	150	30				6
3. L 3.1	68	5		210		0.33
4. R 3.1			680	17.8		0.31
5. CUT	4.8	66.7		2.9		
6. BED	12.0	0.5		12.0		
7. FILL	4.8	66.7		2.9		
8. R 3.2 2/			30	17.8		0.01
9. CUT	4.8	66.7		2.9		
10. BED	12.0	0.5		12.0		
11. FILL	4.8	66.7		2.9		
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						

1/ 1 acre = 43,560 ft^2

2/ This road section crosses a stream. It is separated from the rest of the road because sediment is delivered directly into a channel.

WORKSHEET IV.2--continued

	Area with surface residues [3]			Open area [3]				
	Percent of total area	Percent of surface with mulch	Percent of [4] area with fine roots	Percent of total area	Percent of surface with mulch	Percent of [4] area with fine roots	Are open areas separated by filter strips?	Percent of total area with canopy
1.	65	90	90	35	10	90	YES	0
2.	60	90	85	40	10	85	YES	0
3.	0	—	—	100	UNKNOWN	UNKNOWN	NO	0
4.								
5.	100	70	50	0	—	—		90
6.	0	—	—	100	0	0	NO	0
7.	100	70	50	0	—	—		90
8.								
9.	100	70	50	0	—	—		90
10.	0	—	—	100	0	0	NO	0
11.	100	70	50	0	—	—		90
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								

[3] *Values at end of first year after the disturbance.*

[4] *Not applicable to scalped areas until vegetation is reestablished.*

WORKSHEET IV.2--continued

	Average minimum height of canopy (m)	Time for recovery (mo)	Average dist. from disturbance to stream channel (ft)	Overall slope shape between disturbance and channel	Percent ground cover in filter strip	Surface roughness (qualitative)	Texture of eroded material (% silt + clay) [5]	Percent slope between disturbance and channel
1.	—	UNKNOWN	15	STRAIGHT	90	MODERATE	45	38
2.	—	UNKNOWN	15	STRAIGHT	90	MODERATE	45	30
3.	—	UNKNOWN	0	STRAIGHT	0	SMOOTH	45	5
4.		1 YEAR	100	STRAIGHT	89	MODERATE	48	30
5.	0.5							
6.	—							
7.	0.5							
8.		1 YEAR	0	STRAIGHT	0	SMOOTH	48	67
9.	0.5							
10.	—							
11.	0.5							
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								

5/ *It has been assumed that ½ of the clay remains on-site as stable aggregates and that the rest of the clay plus very fine sand and silt enter the sediment delivery system.*

WORKSHEET IV.3

Estimates of soil loss and delivered sediment by erosion response unit for hydrographic area 3 of Horse Creek watershed

Erosion response unit[1]	Soil unit[2]	R	K	LS	VM	Area (acres)	Surface soil loss (tons/yr)	SD_I	Delivered sediment (tons/yr)
CC 3.1	T2	45	0.28	11.4	0.02	8.0	23.0	0.02	0.5
CC 3.2	T2	45	0.28	9.6	0.02	6.0	15.0	0.02	0.3
L 3.1	T2	45	0.28	0.44	0.89	0.3	1.5	0.11	0.2
R 3.1	S2	45	0.30	4.5	0.97	0.3	18.0	0.01	0.2
R 3.2	S2	45	0.30	4.3[3]	0.97	0.01	0.6	0.22	0.1

1/ CC - Clearcut
L - Landing
R - Road

2/ T - Topsoil
S - Subsoil

3/ Average of two LS values, one for each half of the road, starting at the center line and including a fill slope.

WORKSHEET IV.4

Estimated VM factors for silvicultural erosion response units
Horse Creek watershed, hydrographic area 3.

	Logging residue area					Open area						
Erosion response unit	Fraction of total area	Mulch (duff & residue)	Canopy	Roots	Sub VM	Fraction percent of total area	Mulch (duff & residue)	Canopy	Roots	Filter strip	Sub VM	Total VM [1/]
CC 3.1	0.65	0.08	1.0	0.10	0.005	0.35	0.78	1.0	0.10	0.5	0.014	0.02
CC 3.2	0.60	0.08	1.0	0.11	0.005	0.40	0.78	1.0	0.11	0.5	0.014	0.02

1/ *Enter on worksheet IV.3.*

WORKSHEET IV.5

Example of estimated monthly change in VM factor following construction for road cuts and fills in Horse Creek watershed, hydrographic area 3.

Month	Percent cover and VM subfactors						Monthly VM
	Mulch		Canopy		Roots		
	Percent	VM	Percent	VM	Percent	VM	
Sep.1/	0	1.00	0	1.00			1.00
Oct.3/	8	0.80	12	0.88			0.70
Nov.	20	0.59	22	0.80			0.47
Dec.2/	—		—				—
Jan.2/	—		—				—
Feb.2/	—		—				—
March2/	—		—				—
April4/	10	0.78	10	0.90			0.70
May4/	28	0.50	20	0.82			0.41
June5/	50	0.32	70	0.41	20	0.35	0.05
July5/	60	0.25	83	0.30	40	0.27	0.02
Aug.	70	0.18	90	0.25	50	0.22	0.01

1/ Begin seeding, enough rain is assumed to ensure seed germination.

2/ Snow cover with no erosive precipitation.

3/ Significant canopy effect developing.

4/ Snowmelt runoff occurs, some protective vegetative cover lost during winter.

5/ Significant root network developing from seeded grass.

WORKSHEET IV.6

Weighting of VM values for roads in
Horse Creek watershed, hydrographic area 3.

Erosion response unit	Cut or fill Fraction of total width	VM	Roadbed Fraction of total width	VM	Fill Fraction of total width	VM	Weighted VM
R 3.1	(0.1629)	(0.42)	+ (0.6742)	(1.24)	+ (0.1629)	(0.42)	= 0.97
R 3.2	(0.1629)	(0.42)	+ (0.6742)	(1.24)	+ (0.1629)	(0.42)	= 0.97

WORKSHEET IV.7

Factors for sediment delivery index from erosion response units in

Horse Creek watershed, hydrographic area 3.

Erosion response unit	Water availability[1]	Texture of eroded material	Percent ground cover between disturbance and channel	Slope shape code	Distance (edge of disturbance to channel) (ft)	Surface roughness code	Slope gradient (%)	Specific site factor	Percent of total area for polygon	SD_I[5]
CC3.1	0.004[2]	45	90	2	15	2	38	—	12.1	0.02
CC3.2	0.006[3]	45	90	2	15	2	30	—	11.8	0.02
L3.1	0.003[3]	45	90	2	20	2	5	—	9.3	0.01
R3.1	0.004[4]	48	89	2	100	2	30	—	7.0	0.01
R3.2	0.004[4]	48	0	2	1	1	67	—	35.1	0.22

1/ *Maximum 15 min. annual storm of 1.75 in/hr.*

2/ *Infiltration rate of 0.26 in/hr (based on soil permeability).*

3/ *Ilfiltration rate of 0.10 in/hr (based on soil permeability).*

4/ *Infiltration rate of 0.05 in/hr (based on soil permeability).*

5/ *Enter on worksheet IV.3.*

WORKSHEET IV.8

Estimated tons of sediment delivered to a channel for each hydrographic area and type of disturbance for Horse Creek watershed

proposed management

Hydro-graphic area	Cutting units CC$_1$	CC$_2$	CC$_3$	CC$_4$	CC$_5$	Landings L$_1$	L$_2$	L$_3$	Roads R$_1$	R$_2$	R$_3$	R$_4$	R$_5$	Total tons/yr	Per-cent
1	0.0	0.0				0.0	0.0	0.0	0.0	0.0				0.0	0.0
2	0.3	0.2	0.3	0.2		0.1			0.1	0.2	0.1	0.1		1.6	9.0
3	0.5	0.3				0.2			0.2	0.1				1.3	7.3
4	0.0					0.0	0.0		0.0	0.0	0.1			0.1	0.6
5	0.3	0.1				0.0			0.0	0.1	0.1			0.6	3.4
6	–								0.0	0.0	0.1	0.1		0.2	1.1
7	0.0								0.0	0.1				0.1	0.6
8	0.1								0.1	0.1	0.1	0.1		0.5	2.8
9	0.2	0.2							0.1					0.5	2.8
10	0.2	0.3				0.2			0.2	0.1	0.1			1.1	6.2
11	0.0								0.0	0.2	0.2	0.1	0.1	0.6	3.4
12	0.1	0.0				0.0	0.0	0.0	0.1	0.2				0.4	2.3
13	–								0.2	0.1	0.3			0.6	3.4
14	0.3								0.2	0.1	0.3			0.6	3.4
15	0.0					0.0			0.0	0.3	0.2	0.1		0.6	3.4
16	0.3					0.0			0.0	0.3	0.1			0.7	4.0
17	0.0								0.0	0.3	0.2			0.5	2.8
18	0.0					0.0	0.0		0.0	0.0	0.2	0.1		0.3	1.7
19	0.0								0.1					0.1	0.6
20	0.3	0.1				0.0			0.1					0.5	2.8
26[1]	0.0	0.3				0.1	0.0	0.0	0.2					0.6	3.4
27	0.0	0.5	0.3	0.3	0.4	0.1			0.0	0.2	0.1	0.1		2.0	11.3
28	0.0	0.3	0.1	0.3					0.2	0.1	0.2	0.1		1.3	7.3
29	0.3	0.3	0.1	0.4		0.0			0.2	0.1				1.4	7.9
30	0.0	0.0				0.0			0.0	0.0				0.0	0.0
31	0.0	0.1	0.5			0.0			0.0	0.0				0.6	3.4
32	0.2	0.0				0.2			0.3	0.2				0.9	5.1
Column total	3.1	2.7	1.3	1.2	0.4	0.9	0.0	0.0	2.3	2.8	2.1	0.8	0.1	17.7	
Disturbance total	8.7					0.9			8.1						
Percent	49.2					5.1			45.8						

[1] Hydrographic areas 21, 22, 23, 24, and 25 have no activities.

WORKSHEET IV.2

Horse Creek watershed erosion response unit management data for use in the MSLE and sediment delivery index, hydrographic area 3, revised plan.

Erosion response unit	Slope length of disturbed area (ft)	Slope gradient of disturbed area (%)	Length of road section (ft)	Average width of disturbance (ft)	Area (sq.ft.)	Area (acres) 1/
1. CC 3.1	422	38				8
2. CC 3.2	80	30				6
3. L 3.1	68	5		210		0.33
4. R 3.1			680	20		0.31
5. CUT	4.8	66.7		4.0		
6. BED	12.0	0.5		12.0		
7. FILL	4.8	66.7		4.0		
8. R 3.2 2/			30	20		0.01
9. FILL	4.8	66.7		4.0		
10. BED	12.0	0.5		12.0		
11. FILL	4.8	66.7		4.0		
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						

1/ 1 acre = 43,560 ft^2

2/ This road section crosses a stream. It is separated from the rest of the road because sediment is delivered directly into a channel.

WORKSHEET IV.2--continued

	Area with surface residues 3/			Open area 3/				
	Percent of total area	Percent of surface with mulch	Percent of area with fine roots 4/	Percent of total area	Percent of surface with mulch	Percent of area with fine roots 4/	Are open areas separated by filter strips?	Percent of total area with canopy
1.	65	90	90	35	10	90	YES	0
2.	60	90	85	40	10	85	YES	0
3.	0	–	–	100	UNKNOWN	UNKNOWN	NO	0
4.								
5.	100	70	50	0	–	–	–	90
6.	0	–	–	100	100 5/	0	NO	0
7.	100	70	50	0	–	–	–	90
8.								
9.	100	70	50	0	–	–	–	90
10.	0	–	–	100	100 5/	0	NO	0
11.	100	70	50	0	–	–	–	90
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								

3/ *Values are for the end of the first year following disturbance.*

4/ *Not applicable to scalped areas until vegetation is reestablished.*

5/ *Six inches of crushed gravel, 3/4 inch or smaller in size, placed on running surface.*

WORKSHEET IV.2--continued

	Average minimum height of canopy (m)	Time for recovery (mo)	Average dist. from disturbance to stream channel (ft)	Overall slope shape between disturbance and channel	Percent ground cover in filter strip	Surface roughness (qualitative)	Texture of eroded material [6/] (% silt + clay)	Percent slope between disturbance and channel
1.	—	UNKNOWN	15	STRAIGHT	90	MODERATE	45	38
2.	—	UNKNOWN	15	STRAIGHT	90	MODERATE	45	30
3.	—	UNKNOWN	20	STRAIGHT	90	MODERATE	45	5
4.		1 YEAR	100	STRAIGHT	89	MODERATE	48	30
5.	0.5							
6.	—							
7.	0.5							
8.		1 YEAR	0	STRAIGHT	0	SMOOTH	48	67
9.	0.5							
10.	—							
11.	0.5							
12.								
13.								
14.								
15.								
16.								
17.								
18.								
19.								
20.								
21.								
22.								
23.								
24.								
25.								

6/ *It has been assumed that ½ of the clay remains on-site as stable aggregates and that the rest of the clay plus very fine sand and silt enter the sediment delivery system.*

WORKSHEET IV.3

Estimates of soil loss and delivered sediment by erosion response unit for hydrographic area 3 of Horse Creek watershed

Erosion response unit [1/]	Soil unit [2/]	R	K	LS	VM	Area (acres)	Surface soil loss (tons/yr)	SD_I	Delivered sediment (tons/yr)
CC 3.1	T 2	45	0.28	11.4	0.02	8.0	23.0	0.02	0.5
CC 3.2	T 2	45	0.28	9.6	0.02	6.0	15.0	0.02	0.3
L 3.1	T 2	45	0.28	0.44	0.89	0.3	1.5	0.01	0.01
R 3.1	S 2	45	0.30	4.5	0.17	0.3	3.0	0.01	0.03
R 3.2	S 2	45	0.30	4.3 [3/]	0.17	0.01	0.1	0.22	0.02

1/ CC - *Clearcut*
L - *Landing*
R - *Road*

2/ T - *Topsoil*
S - *Subsoil*

3/ *Average of two LS values, one for each half of the road, starting at the center line and including a fill slope.*

WORKSHEET IV.4

Estimated VM factors for silvicultural erosion response units
Horse Creek watershed, hydrographic area 3.

Erosion response unit	Logging residue area: Fraction of total area	Mulch (duff & residue)	Canopy	Roots	Sub VM	Open area: Fraction percent of total area	Mulch (duff & residue)	Canopy	Roots	Filter strip	Sub VM	Total VM [1]
CC3.1	0.65	0.08	1.0	0.10	0.005	0.35	0.78	1.0	0.10	0.5	0.014	0.02
CC3.2	0.60	0.08	1.0	0.11	0.005	0.40	0.78	1.0	0.11	0.5	0.017	0.02
R3.1 CUT												0.42 [3]
BED						1.00	0.005 [3]	1.0			0.005	0.005
FILL												0.42 [3]
R3.2 FILL												0.42 [3]
BED						1.00	0.005 [2]	1.0			0.005	0.005
FILL												0.42 [2]

1/ Enter on worksheet IV.3.

2/ Six inches of crushed gravel is assumed to have the indicated value.

3/ Average VM from worksheet IV.5 for proposed plan.

WORKSHEET IV.6

Weighting of VM values for roads in
Horse Creek watershed, hydrographic area 3.

Erosion response unit	Cut or fill: Fraction of total width	Cut or fill: VM	Roadbed: Fraction of total width	Roadbed: VM	Fill: Fraction of total width	Fill: VM	Weighted VM
R3.1	(0.20)	(0.42)	+ (0.60)	(0.005)	+ (0.20)	(0.42)	= 0.17
R3.2	(0.20)	(0.42)	+ (0.60)	(0.005)	+ (0.20)	(0.42)	= 0.17

WORKSHEET IV.7

Factors for sediment delivery index from erosion response units in

Horse Creek watershed, hydrographic area 3.

Erosion response unit	Water availability 1/	Texture of eroded material	Percent ground cover between disturbance and channel	Slope shape code	Distance (edge of disturbance to channel) (ft)	Surface roughness code	Slope gradient (%)	Specific site factor	Percent of total area for polygon	SD_I 5/
CC 3.1	0.004 2/	45	90	2	15	2	38	—	12.1	0.02
CC 3.2	0.006 2/	45	90	2	15	2	30	—	11.8	0.02
L 3.1	0.003 3/	45	0	2	1	1	5	—	28.2	0.11
R 3.1	0.004 4/	48	89	2	100	2	30	—	7.0	0.01
R 3.2	0.004 4/	48	0	2	1	1	67	—	35.1	0.22

1/ *Maximum 15 min. annual storm of 1.75 in/hr.*

2/ *Infiltration rate of 0.26 in/hr (based on soil permeability).*

3/ *Infiltration rate of 0.10 in/hr (based on soil permeability).*

4/ *Infiltration rate of 0.05 in/hr (based on soil permeability).*

5/ *Enter on worksheet IV.3.*

WORKSHEET IV.8

Estimated tons of sediment delivered to a channel for each hydrographic area and type of disturbance for Horse Creek watershed, revised plan

Hydrographic area	Cutting units CC_1	CC_2	CC_3	CC_4	CC_5	Landings L_1	L_2	L_3	Roads R_1	R_2	R_3	R_4	R_5	Total tons/yr	Percent
1	0.0	0.0				0.0	0.0	0.0	0.0	0.0				0.0	0.0
2	0.3	0.2	0.3	0.2		0.0			0.02	0.03	0.02	0.02		1.09	11.1
3	0.5	0.3				0.01			0.03	0.02				0.86	9.1
4	0.0					0.0	0.0		0.0	0.0	0.02			0.02	0.2
5	0.3	0.1				0.0			0.0	0.02	0.02			0.44	4.7
6									0.0	0.0	0.02	0.02		0.04	0.4
7	0.0								0.0	0.02				0.02	0.2
8	0.1								0.02	0.02	0.02	0.02		0.18	1.9
9	0.2	0.2							0.02					0.42	4.5
10	0.2	0.3				0.01			0.03	0.02	0.02			0.58	6.2
11	0.0								0.0	0.03	0.03	0.02	0.02	0.10	1.1
12	0.1	0.0				0.0	0.0	0.0	0.02	0.03				0.15	1.6
13									0.03	0.02	0.04			0.09	1.0
14	0.5								0.03	0.02	0.0			0.37	3.8
15	0.0					0.0			0.0	0.04	0.03	0.02		0.09	1.0
16	0.5					0.0			0.0	0.04	0.02			0.38	3.9
17	0.0								0.0	0.04	0.03			0.07	0.7
18	0.0					0.0	0.0		0.0	0.0	0.03	0.02		0.05	0.5
19	0.0								0.02					0.02	0.2
20	0.3	0.1				0.0			0.02					0.42	4.5
26[3]	[4]	[4]				[5]	[5]	[5]	[6]			[6]		0.0	0.0
27	0.0	0.5	0.3	[4]	0.4	[5]			0.0	0.03	0.02	0.02		1.25	13.3
28	0.0	0.3	0.1	0.3					0.03	0.02	0.03			0.80	8.5
29	0.3	0.3	0.1	0.4		0.0			0.03	0.02				1.15	12.2
30	0.0	0.0				0.0			0.0	0.0				0.0	0.0
31	0.0	0.1	0.5			0.0			0.0	0.0				0.60	6.4
32	0.2	0.0				0.01			0.04	0.03				0.28	3.0
Column total	3.5	2.4	1.3	0.9	0.4	0.03	0.0	0.0	0.34	0.45	0.35	0.14	0.02	9.83	
Disturbance total	8.5					0.03			1.30						
Percent	86.5					0.3			13.2						

1/ Values have changed from proposed plan due to application of controls for landings.
2/ Values have changed from proposed plan due to application of controls for roads.
3/ Hydrographic areas 21, 22, 23, 24, and 25 have no activities.
4/ Clearcut erosion response units eliminated by controls for mass wasting.
5/ Landing erosion response units eliminated by controls for mass wasting.
6/ Road erosion response units eliminated by controls for mass wasting.

WORKSHEET V.1

Debris avalanche-debris flow natural factor evaluation form

Index	Slope gradient	Soil depth	Subsurface drainage characteristics	Soil texture	Bedding structure and orientation	Slope configuration	Precipi-tation input
High	30	3	(3)	3	3	3	12
Medium	(15)	(2)	2	(2)	(2)	(2)	(5)
Low	5	1	1	0	1	1	3

Factor summation table

Gross hazard index	Factor range	Natural
High	Greater than 44	
Medium	21 - 44	31
Low	Less than 21	

WORKSHEET V.2

Debris avalanche-debris flow management related factor evaluation form

Index	Vegetation cover removal	Roads and skidways	Harvest methods
High	(8)	(20)	(3)
Medium	5	8	2
Low	2	2	0

Factor summation table

Gross hazard index	Range	Natural + management
High	Greater than 44	31+31 = 62
Medium	21 - 44	
Low	Less than 21	

WORKSHEET V.5

Estimation of volume per failure

	Debris avalanche-debris flow						Slump earthflow					
Slide Number	Natural	Man-induced	Length (ft)	Width (ft)	Depth (ft)	Volume (ft^3)	Natural	Man-induced	Length (ft)	Width (ft)	Depth (ft)	Volume (ft^3)
Horse	Creek											
1	X		84	28	1.5	3,528						
Mule	Creek											
1		X	80	24	1.5	3,880						
2		X	129	26	1.5	5,031						
3		X	121	17	1.5	3,086						
4		X	113	18	1.5	3,041						
5		X	95	23	1.5	3,278						
1	X		115	19	1.5	3,280						

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WORKSHEET V.6

Estimation of soil mass movement delivered to the stream channel

(1) Watershed name Mule Creek

Factor (2)		Soil mass movement type: Debris avalanche-Debris flow, Natural (3)	Debris avalanche-Debris flow, Man-induced (4)	Slump flow, Natural (5)	Slump flow, Man-induced (6)
1 Total volume (V_t) in ft^3		3280	17205	—	—
2 Total number of failures (N)		1	5	—	—
3 Average volume per failure (VA)(ft^3)		3280	3441		
4 Number of failures per slope class	a	1	2		
	b	—	2		
	c	—	1		
5 Number of failures per slope position category	a'			—	—
	b'			—	—
	c'			—	—
	d'			—	—
6 Total volume per slope class or position category (V) in ft^3	V_a $V_{a'}$	3280	6882	—	—
$V = V_A \times N$	V_b $V_{b'}$	—	6882	—	—
	V_c $V_{c'}$	—	3441	—	—
	$V_{d'}$			—	—
7 Unit weight of dry soil material (γ_d) (lb/ft^3)		99	99	—	—

8 Total weight per slope class or position category (W) in tons $W = \frac{V \times Y_d}{2,000}$	W_a $W_{a'}$	163	341	—	—
	W_b $W_{b'}$	—	341	—	—
	W_c $W_{c'}$	—	171	—	—
	$W_{d'}$			—	—
9 Slope irregularity--smooth or irregular		smooth	smooth	—	—
10 Delivery potential (D) as a decimal percent for slope class or position category	D_a $D_{a'}$	0.62	0.50	—	—
	D_b $D_{b'}$	—	0.30	—	—
	D_c $D_{c'}$	—	0.15	—	—
	$D_{d'}$			—	—
11 Total weight of soil delivered per slope class or position category (S) in tons $S = W \times D$	S_a $S_{a'}$	101	171	—	—
	S_b $S_{b'}$	—	102	—	—
	S_c $S_{c'}$	—	26	—	—
	$S_{d'}$			—	—
12 Total quantity of sediment delivered to the stream channel in tons		101 (400)	299	—	—
13 Acceleration factor (f) $f = TS_{silvicultural\ activity}/TS_{natural}$		3		—	
14 Estimated increase in soil delivered to the stream channel due to the proposed silvicultural activity (TS) in tons $TS_{silvicultural\ activity} = TS_{natural} \times f$		—		—	

WORKSHEET V.6

Estimation of soil mass movement delivered to the stream channel

(1) Watershed name Horse Creek

Factor (2)		Soil mass movement type: Debris avalanche-Debris flow, Natural (3)	Debris avalanche-Debris flow, Man-induced (4)	Slump flow, Natural (5)	Slump flow, Man-induced (6)
1 Total volume (V_t) in ft^3		3528	—	—	—
2 Total number of failures (N)		1	—	—	—
3 Average volume per failure (VA)(ft^3)		3528	—	—	—
4 Number of failures per slope class	a	—	—		
	b	1	—		
	c	—	—		
5 Number of failures per slope position category	a'			—	—
	b'			—	—
	c'			—	—
	d'			—	—
6 Total volume per slope class or position category (V) in ft^3	V_a $V_{a'}$	—	—	—	—
$V = V_A \times N$	V_b $V_{b'}$	3528	—	—	—
	V_c $V_{c'}$	—	—	—	—
	$V_{d'}$			—	—
7 Unit weight of dry soil material (γ_d) (lb/ft^3)		90	—	—	—

8 Total weight per slope class or position category (W) in tons	W_a $W_{a'}$	—	—	—	—
$W = \frac{V \times Y_d}{2,000}$	W_b $W_{b'}$	159	—	—	—
	W_c $W_{c'}$			—	—
	$W_{d'}$	—	—	—	—
9 Slope irregularity--smooth or irregular		smooth	—	—	—
10 Delivery potential (D) as a decimal percent for slope class or position category	D_a $D_{a'}$	—	—	—	—
	D_b $D_{b'}$	0.40	—	—	—
	D_c $D_{c'}$	—	—	—	—
	$D_{d'}$			—	—
11 Total weight of soil delivered per slope class or position category (S) in tons	S_a $S_{a'}$	—	—	—	—
$S = W \times D$	S_b $S_{b'}$	64	—	—	—
	S_c $S_{c'}$	—	—	—	—
	$S_{d'}$			—	—
12 Total quantity of sediment delivered to the stream channel in tons		64	—	—	—
13 Acceleration factor (f) $f = TS_{silvicultural\ activity}/TS_{natural}$		From Mule Creek 3.0		—	
14 Estimated increase in soil delivered to the stream channel due to the proposed silvicultural activity (TS) in tons $TS_{silvicultural\ activity} = TS_{natural} \times f$		192		—	

WORKSHEET V.2

Debris avalanche-debris flow management related factor evaluation form

Index	Vegetation cover removal	Roads and skidways	Harvest methods
High	8	20	(3)
Medium	5	8	2
Low	(2)	(2)	0

Factor summation table

Gross hazard index	Range	Natural + management
High	Greater than 44	31 + 7 = 38
Medium	21 - 44	
Low	Less than 21	

WORKSHEET VI.1

Suspended sediment quantification for Horse Creek
(Pre and Post for Proposed and Revised Silvicultural Plans)

(1) Time increment (a) With hydrographs use date; with flow duration curves use % of 365 days	(1) (b) Number of days pre-silvicultural activity	(1) (c) Number of days post-silvicultural activity	(2) Pre-silvicultural activity flow (cfs)	(3) Suspended sediment concentration (mg/l)	(4) Total increment suspended sediment cols. (2) x (3) x (1.b) x .0027 (tons)	(5) Post-silvicultural activity flow (cfs)	(6) Suspended sediment concentration (mg/l)	(7) Total increment post-silvicultural activity suspended sediment cols. (5) x (6) x (1.c) x .0027 (tons)	(8) Maximum concentrations from selected water quality objective (mg/l)	(9) Maximum sediment discharge cols. (2) x (8) x (1.b) x .0027 (tons)
APR 8	6	6				0.00	—	—	—	—
14	6	6				0.13	0.5	NEGLI	—	—
20	6	6				0.42	1.2	0.01	—	—
26	6	6	0.00	—		1.43	2.5	0.06	—	—
MAY 2	6	6	0.34	1.0	0.01	2.52	3.6	0.15	31.0	0.17
8	6	6	0.97	2.0	0.03	3.99	4.9	0.32	32.0	0.50
14	6	6	1.64	2.8	0.07	5.18	5.8	0.49	32.8	0.87
20	6	6	2.61	3.7	0.16	6.86	6.9	0.77	33.7	1.43
26	6	6	3.87	4.8	0.30	9.55	8.6	1.32	34.8	2.18
JUN 1	6	6	5.35	5.9	0.51	10.99	9.4	1.67	35.9	3.11
7	6	6	6.82	6.9	0.76	10.32	9.0	1.50	36.9	4.08
13	6	6	9.09	8.3	1.22	9.21	8.4	1.25	38.3	5.64
19	6	6	10.23	8.9	1.48	6.57	6.7	0.72	38.9	6.45
25	6	6	9.09	8.3	1.22	4.12	5.0	0.33	38.3	5.64
JUL 1	6	6	6.82	6.9	0.76	2.49	3.6	0.15	36.9	4.08
7	6	6	4.21	5.1	0.35	1.26	2.3	0.05	35.1	2.39
13	6	6	2.44	3.6	0.14	0.72	1.6	0.02	33.6	1.33
19	6	6	1.14	2.2	0.04	0.33	1.0	0.01	32.2	0.60
25	6	6	0.34	1.0	0.01	0.12	0.5	NEGLI	31.0	0.17
31	6	6	0.00	—	—	0.00	—	—	—	

(Totals are rounded to nearest tenth)

Total 7.1 tons/yr (col. 4) Total 8.8 tons/yr (col. 7) Total 38.6 tons/yr (col. 9)

Summary:
Total pre-silvicultural activity suspended sediment discharge = 7.1
Total post-silvicultural activity suspended sediment discharge = 8.8
Total maximum sediment discharge = 38.6

WORKSHEET VI.2

Bedload sediment quantification for Horse Creek
(Pre and Post for Proposed and Revised Silvicultural Plans)

(1) Time increment (a) With hydrographs use date; with flow duration curves use % of 365 days		(1) (b) Number of days pre-silvicultural activity	(1) (c) Number of days post-silvicultural activity	(2) Pre-silvicultural activity flow Q_{pre} (cfs)	(3) Bedload transport rate i_{bpre} (tons/day)	(4) Total pre-silvicultural activity bedload discharge cols. (3) x (1.b) B_{pre}	(5) Post-silvicultural activity flow Q_{post} (cfs)	(6) Bedload transport rate i_{bpost} (tons/day)	(7) Post-silvicultural activity bedload discharge cols. (6) x (1.c) B_{post}
APR	8	6	6				0.00	—	
	14	6	6				0.13	NEGLI	
	20	6	6				0.42	NEGLI	
	26	6	6	0.00	—		1.43	.001	.01
MAY	2	6	6	0.34	NEGLI		2.52	.003	.02
	8	6	6	0.97	NEGLI		3.99	.008	.05
	14	6	6	1.64	.001	.01	5.18	.013	.08
	20	6	6	2.61	.003	.02	6.86	.025	.15
	26	6	6	3.87	.007	.04	9.55	.051	.31
JUN	1	6	6	5.35	.014	.09	10.99	.069	.42
	7	6	6	6.82	.024	.15	10.32	.060	.36
	13	6	6	9.09	.046	.27	9.21	.047	.28
	19	6	6	10.23	.059	.36	6.57	.023	.14
	25	6	6	9.09	.046	.27	4.12	.008	.05
JUL	1	6	6	6.82	.024	.15	2.49	.003	.02
	7	6	6	4.21	.009	.05	1.26	.001	.004
	13	6	6	2.44	.003	.02	0.72	NEGLI	
	19	6	6	1.14	NEGLI		0.33	NEGLI	
	25	6	6	0.34	NEGLI		0.12	NEGLI	
	31	6	6	0.00	—		0.00		

(Totals are rounded to nearest tenth)

Total 1.4 tons/yr (column 4)

Total 1.9 tons/yr (column 7)

Summary: Total pre-silvicultural activity bedload discharge = 1.4
Total post-silvicultural activity bedload discharge = 1.9

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WORKSHEET VI.3

Sediment prediction worksheet summary

Subdrainage name Horse Creek (Proposed Silvicultural Plan) Date of analysis 6/2/78

	Suspended Sediment Discharge	
A.	Pre-silvicultural activity total potential suspended sediment discharge (total col. (4), wksht. VI.1) (tons/yr)	7.1
B.	Post-silvicultural activity total potential suspended sediment discharge (total col. (7), wksht. VI.1) (due to streamflow increases) (tons/yr)	8.8
C.	Maximum allowable potential suspended sediment discharge (total col. (9), wksht. VI.1) (tons/yr)	38.6
D.	Potential introduced sediment sources: (delivered)	
	1. Surface erosion (tons/yr) 17.7	
	2. Soil mass movement (coarse) (tons/yr) 146	
	3. Median particle size (mm) 10	
	4. Soil mass movement-- washload (silts and clays) (tons/yr) 46	
	Bedload Discharge (Due to increased streamflow)	
E.	Pre-silvicultural activity potential bedload discharge (tons/yr)	1.4
F.	Post-silvicultural activity potential bedload discharge (due to increased streamflow) (tons/yr)	1.9
	Total Sediment and Stream Channel Changes	
G.	Sum of post-silvicultural activity suspended sediment + bedload discharge (other than introduced sources) (tons/yr)	10.7 (sum B + F)
H.	Sum of total introduced sediment (D) = (D.1 + D.2 + D.4) (tons/yr)	209.7
I.	Total increases in potential suspended sediment discharge	
	1. (B + D.1 + D.4) - (A) (tons/yr)	65.4
	2. Comparison to selected suspended sediment limits (I.1) - (C) (tons/yr)	± 26.8

J. Changes in sediment transport and/or channel change potential (from introduced sources and direct channel impacts)

1. Total post-silvicultural activity soil mass movement sources (coarse size only) (tons/yr) 146

2. Total post-silvicultural soil mass movement sources (fine or washload only) (tons/yr) 46

3. Particle size (median size of coarse portion) (mm) 10

4. Post-silvicultural activity bedload transport (F) (tons/yr) 1.9

Potential for change (check appropriate blank below)

Stream deposition ✓

Stream scour ____

No change ____

K. Total pre-silvicultural activity potential sediment discharge (bedload + suspended load) (tons/yr) 8.5 (sum A + E)

L. Total post-silvicultural activity potential sediment discharge (all sources + bedload and suspended load) (tons/yr) 220.4 (sum G + H)

M. Potential increase in total sediment discharge due to proposed activity (tons/yr) 211.9 (subtract L - K)

WORKSHEET VI.4

Bedload transport-stream power relationship for Horse Creek, Proposed Plan

(1) Water surface slope S (ft/ft)*	(2) Constant (62.4) K (lb/ft^3)	(3) Measured stream discharge Q (cfs)	(4) Stream width W (ft)	(5) Stream power cols. (1) x (2) x (3) / col. (4) (ft/lb/sec)	(6) Measured bedload transport rate i_b (tons/day)	(7) Convert bedload transport from tons/day to ft/lb/sec, [col. (6) x 2,000] ÷86,400 x col. (4) i_b (ft/lb/sec)
0.0050	62.4	10.5	4.8	0.68	.060	1.39×10^{-3}
0.0050	62.4	3.0	4.2	0.59	.035	0.80×10^{-3}
0.0050	62.4	7.0	3.9	0.56	.025	0.58×10^{-3}
0.0050	62.4	5.0	3.5	0.44	.013	0.30×10^{-3}
0.0050	62.4	4.0	3.1	0.41	.008	0.18×10^{-3}
0.0050	62.4	3.0	2.9	0.32	.004	0.92×10^{-3}
0.0050	62.4	2.0	2.5	0.25	.002	$0.46 \times 10^{-}$

Complete the following analysis:

a. Plot value of stream power (ω), column (5) on X-axis and values of bedload transport rate [i_b, column (7)], on double log graph paper.

b. Calculate regression equation and coefficient of determination (r^2).

* Slope values obtained from adjacent stream - extrapolate data to selected stream. If slope changes calculate new stream power values.

WORKSHEET VI.5

Computations for step 21 Horse Creek
(stream name)
(Proposed Silvicultural Plan)

Changes in bedload transport-stream power due to channel impacts

1. Potential changes in channel dimensions

a. Bankful stage width (W_{pre}) 1.0 (W_{post}) 1.5

b. Bankful stage depth (D_{pre}) 0.6 (D_{post}) 0.2

c. Water surface slope (S_{pre}) 0.029 (S_{post}) 0.0250

d. Bankful discharge (Q_{Bpre}) 0.73 (Q_{Bpost}) 0.28

where: $Q_{Bpre} = 0.366 + 1.33 \log A_{pre} + 0.05 \log S_{pre} - 0.056 (\log S_{pre})^2$

where: A = cross-sectional area (a) x (b) 0.6

S = water surface slope (c) 0.029

Calculate Q_{Bpost} using post-silvicultural A and S

$$Q_{Bpost} = 0.366 + 1.33 \log A_{post} + 0.05 \log S_{post} - 0.056 (\log S_{post})^2$$

2.a. Pre-silvicultural activity stream power calculation (ω_{pre})

$$\omega_{pre} = \frac{\underset{(1.c)}{S_{pre}} \times \underset{(K)}{62.4} \times \underset{(1.d)}{Q_{Bpre}}}{\underset{(1.a)}{W_{pre}}} = \frac{(.029)(62.4)(.73)}{(1.0)} = 1.32$$

2.b. Post-silvicultural activity stream power calculation (ω_{post})

$$\omega_{post} = \frac{\underset{(1.c)}{S_{post}} \times \underset{(K)}{62.4} \times \underset{(1.d)}{Q_{Bpost}}}{\underset{(1.a)}{W_{post}}} = \frac{(.025)(62.4)(0.28)}{(1.5)} = 0.29$$

3. Calculate post-silvicultural activity bedload transport rate at bankful discharge, using post-silvicultural activity stream power

WORKSHEET VI.3

Sediment prediction worksheet summary

Subdrainage name Horse Creek (Revised Silvicultural Plan) Date of analysis 6/9/78

Suspended Sediment Discharge

A. Pre-silvicultural activity total potential suspended sediment discharge (total col. (4), wksht. VI.1) (tons/yr) 7.1

B. Post-silvicultural activity total potential suspended sediment discharge (total col. (7), wksht. VI.1) (due to streamflow increases) (tons/yr) 8.8

C. Maximum allowable potential suspended sediment discharge (total col. (9), wksht. VI.1) (tons/yr) 38.6

D. Potential introduced sediment sources: (delivered)

1. Surface erosion (tons/yr) 9.8
2. Soil mass movement (coarse) (tons/yr) 0
3. Median particle size (mm) —
4. Soil mass movement--washload (silts and clays) (tons/yr) 0

Bedload Discharge (Due to increased streamflow)

E. Pre-silvicultural activity potential bedload discharge (tons/yr) 1.4

F. Post-silvicultural activity potential bedload discharge (due to increased streamflow) (tons/yr) 1.9

Total Sediment and Stream Channel Changes

G. Sum of post-silvicultural activity suspended sediment + bedload discharge (other than introduced sources) (tons/yr) 10.7 (sum B + F)

H. Sum of total introduced sediment (D) = (D.1 + D.2 + D.4) (tons/yr) 9.8

I. Total increases in potential suspended sediment discharge

1. (B + D.1 + D.4) - (A) (tons/yr) 11.5
2. Comparison to selected suspended sediment limits (I.1) - (C) (tons/yr) ± 27.1

J. Changes in sediment transport and/or channel change potential (from introduced sources and direct channel impacts)

1. Total post-silvicultural activity soil mass movement sources (coarse size only) (tons/yr) 0

2. Total post-silvicultural soil mass movement sources (fine or washload only) (tons/yr) 0

3. Particle size (median size of coarse portion) (mm) —

4. Post-silvicultural activity bedload transport (F) (tons/yr) 1.9

Potential for change (check appropriate blank below)

Stream deposition ____

Stream scour ____

No change ✓

K. Total pre-silvicultural activity potential sediment discharge (bedload + suspended load) (tons/yr) 8.5 (sum A + E)

L. Total post-silvicultural activity potential sediment discharge (all sources + bedload and suspended load) (tons/yr) 20.5 (sum G + H)

M. Potential increase in total sediment discharge due to proposed activity (tons/yr) 12.0 (subtract L - K)

WORKSHEET VII.1

Variation of solar azimuth and angle with time of day

Time of day (Daylight savings time)	Solar azimuth	Stream1/ effective width (EW) (ft)	Solar angle	Shadow2/ length (S) (ft)
9:00	100°	4.4	30	138.6
10:00	111	4.1	43	85.8
11:00	127	4.0	54	58.1
11:30	135	4.1	58	50.0
12:00	148	4.4	62	42.5
12:30	161	4.9	65	37.3
1:00	180	7.0	65	37.3
1:30	199	14.5	65	37.3
2:00	212	16.4	62	42.5
2:15	215	—	60	46.2
2:30	225	23.0	58	50.0
3:00	233	12.9	54	58.1
4:00	249	7.2	43	85.8
5:00	260	5.6	30	138.6

1/ $EW = \frac{\text{measured average stream width}}{\text{sine} \mid \text{azimuth stream} - \text{azimuth sun} \mid}$

2/ $S = \frac{\text{height vegetation}}{\text{tangent solar angle}}$

WORKSHEET VII.2

Evaluation of downstream temperature impacts

	Stream reach	$A_{adjusted}$ ft²	$H_{adjusted}$ BTU/ft²-min	Q Surface cfs	Q Subsurface cfs	ΔT 1/ °F	T 2/ °F
1.	Area 27	850	4.31	0.4	—	2.5	57.5
2.							
3.	Area 28	565	4.12	0.3	—	2.1	57.3
4.	(Below confluence)						
5.	Area 29	741	3.94	0.4	—	1.9	56.9
6.							
7.	Area 30						57.2
8.	(Below confluence)						

1/ $\Delta T = \frac{A_{adjusted} \times H_{adjusted}}{Q} \times 0.000267$ where Q is surface flow only.

2/ T from mixing ratio equation.

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