United States Department of Agriculture

Soil Conservation Service

2121-C 2nd Street
Davis, CA 95616
(916) 449-2814

Subject: BAP - Hydrologic Unit Planning Assistance, Garcia River, Mendocino County

Date: July 18. 1991

To: Denis Nickel, Area Conservationist
SCS, Santa Rosa

File Code: 390-11

The Mendocino County RCD has received funds from the California Coastal Conservancy to develop a Garcia River Enhancement Plan. It is being written by the RCD'S consultant, Jack Monschke. Jack compiled a list of tasks that need to be done to develop the Enhancement Plan. He included SCS staff at Ukiah as one of the groups assigned to complete some of the tasks. Since money was not made available to complete all the tasks assigned to the SCS, Tom Schott used the available money to have an interdisciplinary, Hydrologic Unit Planning (HUP) team tour the watershed and provide input for Jack during the one-week trip.

Lyle Steffen and Edward Schmit were part of the HUP team. Their trip report is attached. It looks like the HUP team has done an excellent job in providing recommendations to Jack and Tom. Please feel free to contact Lyle or Ed if you have questions or comments on their work.

MONTE J. COLLINS
Assistant State Conservationist (WR)

Attachment

cc:
Charles K. Davis, SCE, Davis, w/ att
Rome Rivera, WRPS Leader, Davis, w/ att
Luana Kiger, SRC, Davis, w/ att
Carole Jett, SSS, Davis, w/ att
Tom Schott, DC, Ukiah, w/ att

GARCIA RIVER WATERSHED ENHANCEMENT PLAN

HYDROLOGIC UNIT PLANNING ASSISTANCE
(GEOLOGY AND HYDROLOGY)

USDA - SCS 7/9/91

BACKGROUND

The anadromous fishery in the Garcia River has almost disappeared. Based on conversations with fishermen in Point Arena, the fishery experienced a sharp drop about 30 years ago. They felt that sediment in the river from logging in the watershed was filling in all the "fish holes" so the salmon and steelhead could no longer live or spawn in the river. They also felt that their neighbors with land along the river who have started to mine gravel from the active river bed are doing a good job of removing the excess sediment from the river. The majority of residents with a long family history in the area want the fishery restored.

There is another group of local people, some of whom live on the river, that do not believe gravel mining is good for the river. They have formed a "Friends of the Garcia River" group organized to oppose gravel mining in the river. Although many of these people do not have long family histories in the area, their main interest in the river is also to restore the fishery.

PURPOSE OF TRIP

The loss of the anadromous fishery and its possible connection to sedimentation problems caused by logging in the watershed prompted the California Coastal Conservancy to grant funds to the Mendocino County RCD to develop an enhancement plan for the river and its watershed. The RCD hired a private consultant, Jack Monschke Watershed Management, to write up a list of tasks to be accomplished to develop the enhancement plan. Part of those tasks involved the SCS staff at the Ukiah field office. Tom Schott requested Hydrologic Unit Planning (HUP) team assistance to help him accomplish the tasks or provide guidance in getting the work done.

Lyle Steffen and Ed Schmit met with an interdisciplinary group of SCS and outside agency specialists the week of April 1-4 to tour the Garcia River Watershed and review the draft Watershed Enhancement Plan.

ITINERARY

The group met at the Ukiah field office on Monday afternoon, April 1. Tom Schott and Jack Monschke reviewed some of the basic data available and the tasks in the enhancement plan. Some of the other participants discussed their knowledge of historical resource problems on the river, primarily the loss of the anadromous fishery and recent gravel mining.

The next day was spent touring the watershed from top to bottom. Main access and timber haul roads were used to traverse the upper watershed. A recently mined portion of the lower river was walked to observe the impacts of gravel mining and to look at California Department of Fish & Game's restoration efforts. The river crossing at State Highway 1 and the mouth of the river at the ocean were observed late in the afternoon.

Most of the third day was spent in the rental unit at Irish Beach discussing what was seen and to provide Jack input for the enhancement plan. A draft gravel management plan was developed and numerous ideas on how to address the other issues identified in the enhancement plan were recorded by midafternoon. Two other landowners along the river were visited the rest of the day. These were reaches of the river that had not been mined. One of the landowners toured his property with us and described impacts of floods and the drought on the river.

The fourth morning was spent reviewing the gravel management plan with the consulting engineer who developed the initial environmental assessment for the first gravel mining on the river. The group adjourned at noon on April 4.

OBSERVATIONS ON EROSION & SEDIMENTATION

1. There are numerous gully and streambank erosion problems in the upper watershed that appear to be caused by the disruption of natural drainage and the concentration of flows due to road building and logging activities. These erosion sources are man-caused or accelerated erosion as opposed to natural or geologic erosion.

2. There appears to be accelerated soil erosion occurring from numerous natural landslide areas in the upper watershed. The accelerated erosion appears to be due to road building and logging activities.

3. Soils and rainfall appear to support excellent ground cover and canopy cover in the upper watershed. Sheet and

rill erosion from forested slopes is negligible, even in logged areas.

4. Primary sediment sources in the upper watershed appear to be sheet and rill erosion from road surfaces and road cut slopes, accelerated mass wasting from landslides undercut by roads and streams, gullies on road fill slopes and streambank erosion.

5. The entire upper Garcia River system carries boulder, cobble and gravel-sized bedload now just as it has for millions of years in the past. The absence of braided channels and central bars in the lower reaches of the river indicate that the river's capacity to move bedload sediment has not been exceeded. There is little sand and no silt deposited on the gravel bars in the lower ten miles which is another indication that the river is still capable of transporting coarse sediment in periods of high runoff.

However, numerous local landowners and fisherman have testified that all the fishing holes on the river, some up to 30 feet in depth, have been filled in for the past 30 to 40 years. It appears that fine-grained sediments carried by the river after the peaks of storm flows have passed, and during low-volume runoff events, are dropping out and filling in the holes.

Historically, the Garcia River provided excellent habitat for both King Salmon and Steelhead. There were shallow, fast moving reaches of the river separated by deep holes. These holes covered large areas and were filled with slow-moving but very deep water. It is not known if these holes have filled in for any length of time in the past. Due to the long history of the fishery on the river, it is probable that the long-term deposition currently being experienced is not part of the natural flow regime of the Garcia River.

It is not known for certain why these holes have not been scoured out during the numerous major runoff events that have occurred since the holes were first filled 30 to 40 years ago. One hypothesis may be that the river does not attain the depth or velocity of flow needed to generate the force required to remove the fine sediments deposited in the holes. This change in depth or velocity could be due to a rise in sea level which decreases the gradient of the lower end of the river. Sea level has been rising a few millimeters per year for the past century. However, the river also follows the San Andreas Fault along its lower reaches. The lower, ocean side of the fault appears to drop relative to the higher, mountain side of the fault. The movement on the fault (during earthquakes) appears to increase the gradient of the Garcia River. If the above hypothesis is correct, then the more constant, low rate of sea level rise is occurring faster than the sporadic, high rate of land level change due to earthquakes.

A second hypothesis may be that the river's hydrograph has changed through time due to changes in the upper watershed. The network of roads, skid trails, landings and logged areas may have shortened the time of concentration for runoff from the upper watershed. Base flow, which is primarily derived from ground water seeping into streams, has probably decreased. The numerous road cut slopes intercept ground water and release it to surface flows sooner than if it had flowed through the subsurface and outletted into a stream. The amount of ground water stored in slopes is subsequently decreased so the period of base flow is decreased. Downcutting in streams has also contributed to a lowering of the regional ground water table.

These changes in the river's hydrograph have probably resulted in more flashy flows. The period of high water in the river is probably shorter and the peak flows have probably increased. Coupled with the new sources of sediment in the watershed, increased sediment loads are probably now being delivered to the lower Garcia River in comparison with the pre-logging era that ended in the 1950's. The combination of the increased sediment load and the decreased base flows may have contributed to filling in the fishing holes on the river. The changes in the flow regime in the river have also probably disrupted the life-cycle of the anadromous fishery.

6. There is some historical information available on the physical condition of the natural resources in the watershed. The USGS operated a stream gage on the river for two short periods (1952-1956 & 1963-1983). Aerial photographs exist for parts of the watershed back to 1937 and topographic contour maps of the outlet date back to the 1920's. However, there are no records of erosion and sediment rates prior to intensive logging after the 1950's. There are also no records of the numbers of fish in the Garcia River system over time and there is no documentation of changes in the fishery habitat (changes in river substrate, changes in riparian vegetation, changes in water temperature, changes in sediment loads (quantities and particle sizes), etc.). Without this kind of information, it is difficult to relate changes in the fishery to changes in the watershed.

RECOMMENDATIONS

1. Jack Monschke recorded the group's recommendations regarding the development of a gravel management plan for the river and also the recommendations regarding how to complete some of the other tasks identified in the draft enhancement plan. He has revised the enhancement plan based on those recommendations so no further discussion of the individual recommendations will be made in this report.

2. Edward Schmit recommends the following hydrology information should be developed for the river. This information should be useful in any enhancement schemes. The information could also be used for any sediment transport analyses made in the future or if any trends in the flow regime are studied:

a. Historical flows need to be documented. A narrative discussion of historical floods and their associated rainfall should be written. Sources of information include newspapers, interviews and other published reports. Information should include antecedent moisture conditions and the duration for each flood. The narrative should also relate any geomorphic changes in the river due to past floods.

b. The annual peak flows need to be analyzed using the Water Resources Council Bulletin 17b procedures. The Garcia flow record should be extended using adjacent stream gages. One extension has been made by Graham Matthews & Associates using the Navarro River. A flow frequency curve should be developed for the river. The peak flows estimated by frequency should be compared to other published data such as the Regional Equations used by the US Geological Survey and the US Army Corps of Engineers.

c. A "Volume Duration Probability" (VDP) analysis should also be done using standard procedures. A range of frequencies, the 100-, 50-, 25-, 10-, 5- and 2-year events, should be analyzed.

3. Lyle Steffen recommends that the attached erosion and sediment data be utilized in the enhancement plan until additional funds are available for more detailed, on-the-ground studies that would identify and quantify the sources of sediment in the watershed and the appropriate treatments. Additional studies need to be made to corroborate the assumptions used to develop this information for the Garcia River Watershed:

a. The overall sediment rate for the Garcia River Watershed should be based on rates established for the area in Attachment 2, excerpts from the North Coastal River Basins Report (SCS, 1970). Information from Attachment 2 is summarized in Attachment 3. Attachment 1 contains general information on watershed conditions in the vicinity up to 1955. Most of the erosion damages due to logging may have occurred during the major tractor-logging activities from 1950-1970.

b. The routing of sediment load in the watershed based on grain size (Attachment 4) should be used as documentation that the overall rate estimated in Attachment 1 and 2 is realistic.

c. The distribution of sediment load by source should be based on Attachment 5. Data from the Grass Valley Creek Watershed Study (SCS, 1986) and the North Coast River Basins Study were combined with observations made in the field to derive the distribution proposed in Attachment 5.

d. The LNDTRT and ALTERN spreadsheets should be used to document the potential costs of land treatment in the watershed. Attachments 6 and 7 are graphs showing the costs of land treatment versus the percent reduction in sediment load in the river. The spreadsheets (both the files on diskette and printouts of the analyses made for the Garcia River) were provided to the Ukiah field staff and Jack Monschke on a separate trip on June 10.

e. The SDRGAR.WK1 spreadsheet should be used to rank subwatersheds in the Garcia River Watershed by their potential to deliver sediment to downstream areas. Attachment 8 is a printout of the spreadsheet results for a typical subwatershed. An explanation of the factors is also included as Attachment 9. A diskette with the spreadsheet file was provided to the Ukiah field staff and Jack Monschke on a separate trip on June 10.

4. It is recommended that the Ukiah field staff follow up this HUP assistance with a request for the SCS Water Resources Planning Staff to consider doing one or more of the following tasks in the enhancement plan:

a. Resource inventory
b. Erosion and sediment yield study
c. Land treatment study
d. Development of a Stream Corridor Improvement Plan for the lower Garcia River above and/or below the Highway 1 crossing.

5. It is recommended that a professionally facilitated public meeting be held in Point Arena to identify potential conflicts and common interests of all the groups interested in the future of the Garcia River. It appears that a common interest is in restoring the anadromous fishery in the river. Little progress will occur on the ground if the people that live and work in the watershed do not feel that they have ownership in the Garcia River Enhancement Plan

Lyle Steffen

LYLE J. STEFFEN
State Geologist

Edward Schmit

EDWARD SCHMIT
State Hydrologist

Attachments

Summary of Published and Unpublished Information on Sedimentation in Drainage Basins of the Pacific Coast States

Elliot M. Flaxman and Robert D. High, Geologists, Engineering and Watershed Planning Unit, Portland OR, USDA, Soil Conservation Service, June 1955.

North Coast of CA:

1. Ridgewood and Morris reservoir sedimentation surveys (Mendocino County) indicate sediment yields are low to moderate. These are the only reservoirs surveyed in the area. They are both grass-forest watersheds in high rainfall areas. Vegetative regrowth is rapid after disturbance. No surveys exist in areas where known accelerated erosion is occurring.

2. Bedload of medium sand to boulders is common in the bottoms of streams. These deposits accumulate in the bed, diverting currents and accelerating bank erosion. Bridge sections on Russian River do not indicate continuous aggradation or scour.

3. Coarse gravel deposited on the floodplain adjacent to the Russian River is damaging agricultural land. Other flood deposits do not appear to impair ag production.

4. Nothing is known about potential sediment problems in harbors or with municipal or domestic water supplies.

5. Most of sediment load is fine-grained. USGS sieve analyses of samples from the Russian River indicate 70% of the sediment load is very fine sand, silts and clays, almost all the sand is medium-sized or smaller.

6. Direct measurement of bedload has been made at one location-the mouth of Mark West Creek in the Russian River Watershed.

7. Dominant sediment sources appear to be sheet and minor gully erosion on sloping vineyard land and the steep open woodland and grass areas where overgrazing and geologic erosion are occurring.

The two reservoir sediment surveys indicate sediment from grass and woodland in good condition is fairly low-0.3 ac-ft per square mile or less. Information from disturbed areas is lacking. A one year sampling program on the East Fork of the Russian River indicates a higher sediment rate-0.7 ac-ft per square mile from a watershed that has been overgrazed and burned.

Gravel sources appear to be from rock outcrops on steep slopes. Land treatment would probably not reduce this source.

8. No active, modern valley trench development is occurring. No extensive gully systems are known except in the vineyards in the Russian River valley walls. Overgrazed uplands west of the Russian River valley and in the headwaters of Dry Creek have networks of minor gullies and landslides and slumps occur on barren slopes with outcrops of serpentine. A series of stabilizers on the East Fork of the Russian River in Potter Valley have stopped the downcutting that was initiated by diverting Eel River water. The deep gorges on Sulphur Creek and on the Russian River below Hopland is the result of an active geologic erosion cycle. The streams of the upper Russian in ancient times formerly flowed west to the Pacific. Headward erosion on the Russian River intercepted and cut off these drainages. This stream piracy has caused a rejuvenated cycle of erosion.

9. It is not known if overgrazing has accelerated the landslides typical of the grasslands. "It is believed that little can be done to control the sources of gravel now clogging some of the streams except where bank erosion is making more of this material available in alluvial reaches."

Ridgewood (Walker) Reservoir on Forsythe Creek, 5.9 sq. mi.
1930-1949 0.28 ac-ft/sq. mi., 0.48 tons/ac (@50 pcf)

Morris Reservoir on James Creek, 5.22 sq. mi., 1924-1949
0.22 ac-ft/sq. mi., 0.37 tons/ac (@50 pcf)

Suspended Sediment Station, 15N, 12W, Russian River
1952-1953, 0.66 ac-ft/sq. mi., 1.51 tons/ac (@70 pcf)

North Coastal Area of California and Portions of Southern Oregon River Basins Report. Appendix No. 2, Sediment Yield and Land Treatment, Klamath, Trinity and Smith River Basins; Russian River, Mendocino Coastal and Clear lake Basins, USDA, Soil Conservation Service, Forest Service and Economic Research Service, in cooperation with California Department of Water Resources, June 1972.

Average Sediment Yield

Northern basins--5,940 ac-ft/yr from 10,795 sq. mi.
(0.55 ac-ft/sq. mi./yr)

Southern basins--4,950 ac-ft/yr from 4,041 sq.mi.
(1.22 ac-ft/sq. mi./yr)

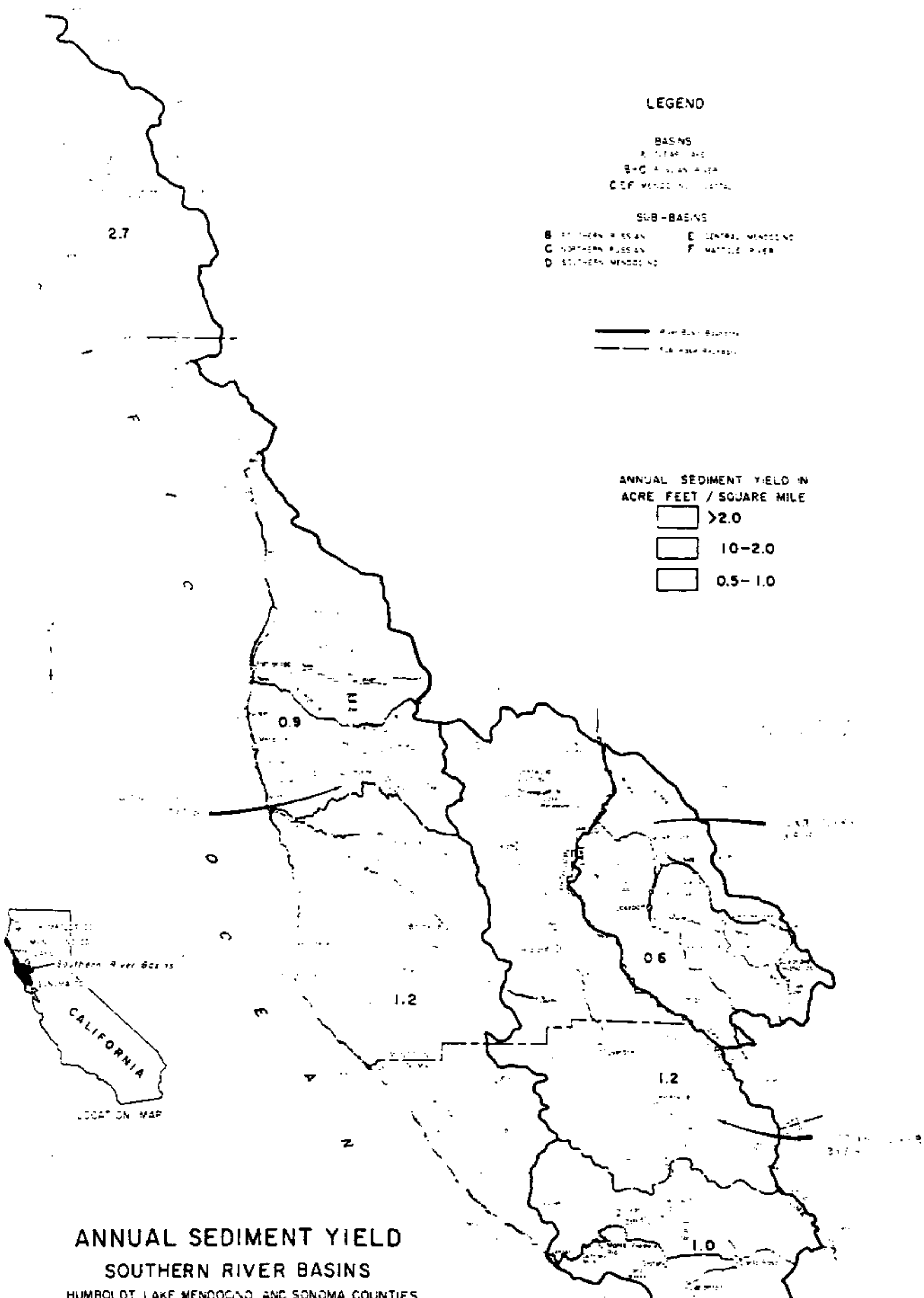
Present Annual Sediment Yields by Source

Basin and Subbasin	Area (Sq.Miles)	Sediment Sources in Acre-Feet Per Year: Stream-banks	Land slides	Sheet & Gully	Total
Southern Basins					
Russian River					
Northern Russian	1,010	630	l60	410	1,200
Southern Russian	475	270	20	170	460
Subtotal	1,485	900	180	580	l,660
Mendocino Coastal					
Mattole River	499	550	400	380	1,330
Central Mendocino	666	190	120	270	580
Southern Mendocino	933	470	230	400	1,100
Subtotal	2,098	1,210	750	1,050	3,010
Clear Lake	458	110	10	160	280
Total	4,041	2,220	940	1,790	4,950

Without a land treatment program, much of the present erosion and sedimentation will increase in the future:

Future Annual Sediment Yields by Source Without Program

Basin and Subbasin	Area (sq. mi.)	Sediment Sources Stream-banks	in Acre-Feet Land slides	Per Year Sheet & Gully	Total
Southern Basins					
Russian River					
Northern Russian	1,010	630	200	430	1,260
Southern Russian	475	270	30	170	470
Subtotal	1,485	900	230	600	1,730
Mendocino Coastal					
Mattole River	499	550	50O	710	l,760
Central Mendocino	666	19C	150	370	710
Southern Mendocino	933	470	290	850	1,610
Subtotal	2,098	1,210	940	l,930	4,080
Clear Lake	458	110	10	160	280
Total	4,041	2,220	1,180	2,690	6,090



ANNUAL SEDIMENT YIELD
SOUTHERN RIVER BASINS
HUMBOLDT, LAKE, MENDOCINO, AND SONOMA COUNTIES, CALIFORNIA
NOVEMBER 1971

Present Sediment Yields From Sheet and Gully
Erosion in the Southern Basins

Basin	Area (sq. mi.)	Acre-Feet Per Year: Directly Influenced By Man				Other		
		Logging	Grazing	Roads	Cultivation	Deer	Natural	Total
Russian River	1,485	20	180	50	40	170	120	580
Mendocino Coastal	2,098	480	250	60	20	110	130	1,050
Clear Lake	458	Trace	30	10	Trace	40	80	160
Total	4,041	500	460	120	60	320	330	1,790

Present Sediment Rates From Sheet and Gully
Erosion in the Southern Basins

Cause of Sediment Yield	Sediment Yield (Acre-Feet/Year)	Percent Of Total	Area Affected (Square Miles)	Sediment Rate (Acre-Feet/sq. mi./Year)
Directly Influenced By Man				
Logging	500	28	720	0.69
Grazing	460	26	3,262	0.14
Roads	120	7	25	4.8 (0.03 Ac-Ft/Mi/Yr.)
Cultivation	60	3	534	0.11
Other				
Deer	320	18	2,972	0.11
Natural	330	18	4,041	0.08
Total	1,790	100		0.44 Avg.

FUTURE SEDIMENT YIELD

Sediment yields from sheet and gully erosion are expected to increase from 1,230 to 1,330 acre-feet per year in the Northern Basins and from

1,790\ to 2,6\ acre-feet per year in the Southern Basins during the next 50 years if the proposed land treatment program is not installed.

These estimates are projected from past sediment rate increases found in sample data, and are modified according to some assumptions regarding the future are and management of the basins.

Since the Northern Basins have a high proportion of national forest land, the sediment rates will probably decrease because of continually improving management practices. At the sane time, however, increased public use will tend to offset this decrease. For example, improvement in read design, construction, and maintenance may result in lower erosion rates, but the increasing public use will require more miles of road. Although sediment rates will decrease, the net sediment yield will not necessarily be reduced.

Management on private lands will also probably improve over the next 50\ years as land becomes more valuable, more laws are passed controlling use, and traditional management practices that are often wasteful are changed by better informed managers. The public is becoming more cognizant of destructive management, and this attitude should result in more restrictions on private land use, especially where timber harvest is concerned. However, many areas, particularly in the Southern Basins, have been abused to the point where sediment yields will remain high for many years. This is especially true for heavily gullied areas, which are almost impossible to heal through rehabilitation programs and which heal very slowly under natural conditions.

Grazing use in national forests is decreasing, and this trend is expected to continue in the future. The Forest Service will limit grazing on most of the badly abused areas, and these will slowly rehabilitate themselves, with or without the application of special programs. In areas where grazing is to be continued in the national forests, livestock numbers are being brought into balance with the capacity of the resource. Sediment yield from all national forest grasslands should remain negligible.

On private lands, the grazing situation is quite different. Although some improvement in management is needed and expected, it is assumed that many areas will continue to be overgrazed, particularly in the Southern Basins. There are presently many grassland areas that have deteriorated through continued heavy use to the point that they cannot recover without remedial programs. Sediment yields on these areas are expected to increase at an accelerated rate unless remedial programs are installed.

Considering all these factors, it seems logical to predict that sediment yields from sheet and gully erosion will increase if remedial programs are not installed and management guidelines are not followed. This increase is projected to be about 100 acre-feet per year in the Northern Basins and about 900 acre-feet per year in the Southern Basins by the year 2020.

Present Sediment Yields and Rates From Landslides

Basin or Subbasin	Drainage Area (Sq. mi.)	Annual Sediment Yield (Acre-Feet)	Annual Sediment Rate (Ac.Ft./ Sq. Mile)
Southern Basins			
Russian River Basin			
Northern Russian	1,010	160	0.16
Southern Russian	475	20	0.04
Subtotal	1,485	180	0.12
Mendocino Coastal Basin			
Mattole	499	400	0.80
Central Mendocino	666	120	0.18
Southern Mendocino	933	230	0.25
Subtotal	2,098	750	0.36
Clear Lake Basin	458	10	0.02
Total	4,041	940	0.21 0.21 avg

Basin	Annual Sediment Yield (Acre-Feet)	Directly Man - Caused (Percent)	Indirectly Man-Caused (Percent)	Natural Causes (Percent)
Klamath-Trinity-Smith	1,850	12	33	55
Russian	180	6	-	94
Mendocino Coastal	750	12	-	88
Clear Lake	10	1	10	89

FUTURE SEDIMENT YIELD

Unless effective land treatment programs are introduced, sediment yield from landslides will increase in the future because of construction and development brought on by the demands of an increased population. In the next 50 years, a sediment yield increase of 25 percent is estimated under these conditions.

Present Annual Sediment Yield From Streambanks In The Southern Basins

Basin or Subbasin	Area (sq. mi.)	Sediment Yield (Acre -Feet/Year) Stream Orders 2nd	3rd	4th	5th	6th	7th	8th	9th	Totals	Sediment Rate (Af/Sm/Yr.)
Russian River											
Northern Russian	1,010	190	140	80	60	90	70	-	-	630	0.62
Southern Russian	475	50	60	20	10	10	120	-	-	270	0.57
Subtotal	1,485	240	200	100	70	100	190	-	-	900	0.61
Mendocino Coastal											
Mattole	499	170	180	70	130	-	-	-	-	550	1.10
Central Mendocino	666	80	30	20	40	10	10	-	-	190	0.29
Southern Mendocino	933	120	90	120	80	60	-	-	-	470	0.50
Subtotal	2,098	370	300	210	250	70	10	-	-	1,210	0.58
Clear Lake	458	20	10	30	20	30	Tr	-	-	110	0.24
Total	4,041	630	510	340	340	200	200	-	-	2,220	0.55

Length of Stream Channels in The Southern Basins

		Stream Length (Miles)								
		Stream Orders								
Basin or Subbasin	Area (Sq. mi.)	2nd	3rd	4th	5th	6th	7th	8th	9th	Totals
Russian River										
Northern Russian	1,010	1,560	530	180	60	70	30	-	-	2,430
Southern Russian	475	690	200	70	40	10	60	-	-	1,070
Subtotal	1,485	2,250	730	250	100	80	90	-	-	3,500
Mendocino Coastal										
Mattole	499	670	200	70	50	-	-	-	-	990
Central Mendocino	666	980	380	90	80	30	30	-	-	1,590
Southern Mendocino	933	1,360	440	200	120	60	-	-	-	2,180
Subtotal	2,098	3,010	1,020	360	250	90	30	-	-	4,760
Clear Lake	458	430	150	90	30	20	Tr	-	-	720
Total	4,041	5,690	1,900	700	380	190	120	-	-	8,980

Annual Sediment Rate Per Mile of Stream In The Southern Basins

Basin or Subbasin	Area (sq. mi.)	Sediment Rate (Acre-Feet/Mile/Year) Stream Orders 2nd	3rd	4th	5th	6th	7th	8th	9th	Subbasin Average
Russian River										
Northern Russian	1,010	0.12	0.26	0.44	1.00	1.29	2.33	-	-	0.26
Southern Russian	475	0.07	0.30	0.29	0.25	1.00	2.00	-	-	0.25
Average	-	0.11	0.27	0.40	0.70	1.25	2.11	-	-	0.26
Mendocino Coastal										
Mattole	499	0.25	0.90	1.00	2.60	-	-	-	-	0.56
Central Mendocino	666	0.08	0.08	0.22	0.50	0.33	0.33	-	-	0.12
Southern Mendocino	933	0.09	0.20	0.60	0.67	1.00	-	-	-	0.22
Average	-	0.12	0.29	0.58	1.00	0.78	0.33	-	-	0.25
Clear Lake	458	0.05	0.07	0.33	0.50	1.50	Tr	-	-	0.15
Average For Basins	-	0.11	0.27	0.49	0.87	1.05	1.67	-	-	0.25

ATTACHMENT 2 (CONT.)

Most streambank erosion is caused by natural geologic and hydrologic conditions, but some was directly influenced by man's activities. Only the 2nd, 3rd, and 4th orders were analyzed because watershed areas above the larger stream order samples all contained some form of man's activities, and natural sediment rates could not be determined. Within the scope of this study, there is no effective way to analyze the influence of man's activity on streambank erosion in the larger stream orders, but it is considered to be less than that in the smaller stream orders.

Basin	Total Sediment Yield From All Streams (Acre-Feet/Year)	Sediment Yield Directly Influenced By Man From 2nd, 3rd & 4th Order (Acre-Feet/Year)	Percent Of Total
Klamath	1,330	310	23
Trinity	1,240	240	19
Smith	290	70	24
Russian	900	120	13
Mendocino	1,210	280	23
Clear Lake	110	30	27
Total	5,080	1,050	21 avg.

The table shows that at least 21 percent, or 1,050 acre-feet per year, of sediment yield from streambanks is directly influenced by man. In the Northern Basins, essentially all of this influence came from tractor logging operations and associated spur roads. In the Southern Basins, about 80 percent of the sediment yield from this influence came from tractor logging operations; the rest was from grazing and other activities, as indicated in the following tabulation:

Sediment Yield Directly Influenced By Man (Acre-Feet/Year)

Basin	Logging	Grazing and Other Activities	Total
Russian	84	36	120
Mendocino Coastal	240	40	280
Clear Lake	26	4	30
Total	350	80	430

FUTURE SEDIMENT YIELD

Unless an effective land treatment program is installed, the future sediment yield from streambanks is expected to continue at about the present rate of 5,080 acre-feet per year for the next 50 years. The present sediment yield for the 24-year study period is higher than the average for the last 50 years. One reason is that major storms, such as that of December 1964, leave most of the streambanks bare and subject to heavy erosion for many years. The subsequent regrowth of vegetation along the banks is sometimes retarded by the less intense storms.

A D D E N D U M

SPECIAL SEDIMENT STUDIES

Two special sediment studies were made to check the soundness of field estimates of sediment yield. One consisted of measuring sediment deposition in eight reservoirs in the Southern Basins, and the other consisted of analyzing and interpreting suspended sediment data from seven gaging stations in the Russian River Basin and 11 in the Klamath River Basin. The results of these two studies serve as checks on the field estimates of sediment yield.

RESERVOIR SEDIMENT SURVEYS

In the Southern Basins, sediment surveys were made on eight reservoirs -- McGuire, Lazy Creek, M.S. Wilson, Ridgewood (Walker Ranch), Wood, Frediani, Hill, and Trentadue. The surveys were made between 1965 and 1967, and the pertinent data are shown in the table on the next page. A map showing the location of the reservoirs and suspended sediment gaging stations is on the page following the table.

Reservoir Sedimentation Summary

	Unit	Reservoir							
		Ridgewood	McGuire	Lazy Creek	Wilson	Wood	Frediani	Hill	Trentadue
1. Year constructed	-	1930	1954	1955	1952	1959	1961	1961	1962
2. Year surveyed	-	1966 *1	1967	1967	1967	1965	1965	1965	1963
3. Age (last survey)	Years	36	13	12	15	6	4	4	3
4. Capacity (last survey)	Acre-Ft.	216	7.07	19.50	13.02	46.76	4.61	21.04	9.86
5. Drainage area	Sq. Miles	5.7	0.08	0.67	0.17	1.69	0.59	0.18	0.04
6. Dry unit weight of sediment	Lb./Cu./Ft. (Tons/Acre-Ft.)	78 (1,699)	60 *2 (1,307)	67 (1,459)	60 *2 (1,307)	79 1,721	87 1,895	65 1,416	66 1,437
7. Trap efficiency 3*	Percent	74	87	65	75	65	51	87	93
B. Annual sediment accumulation in reservoir	Acre-Ft./Yr.	3.6	0.018	0.62	0.07	1.15	0.43	0.10	0.12
9. Annual sediment yield per watershed (Item 8 & 7)	Acre-Ft./Yr.	4.9	0.021	0.95	0.09	1.77	0.84	0.11	0.13
10. Annual sediment yield per unit of area (Item 9 & 5)	Acre-Ft./Sq. Mile	0.66	0.26	1.42	0.32	1.05	1.42	0.61	3.16
11. Annual sediment yield per unit of area (Item 10 X 6)	Tons/Sq. Mile	1,461	340	2,072	418	1,807	2,691	864	4,541
12. Annual sediment yield per watershed (field estimate)	Acre-Ft./Yr.	4.0	0.02	0.68	0.062	2.60	0.55	0.13	0.11
13. Comparison check (Item 12 & Item 9)	Ratio	0.82	0.95	0.72	0.69	1.47	0.65	1.18	0.85

*1 Also surveyed in 1949 by the SCS.

*2 Estimated

*3 Gunner H. Brune, "Trap Efficiency of Reservoirs", American Geophysical Union Transactions, Vol. 34, No. 3, pp. 407-418, (1964).

Mean Annual Sediment Discharge for the Period 1940-65

Station (Number)	Period of Record by Water Years *1		Drainage Area (Sq.Miles)	Suspended Sediment		With bedload est at 10% (tons/yr)	Volume in Acr-ft /Yr.	
	Water	Sediment		Per Sq. Mi. (Tons/Yr.)	Total (Tons /Yr.)		Lost from Watershed	Deposits in reservoir
Russian River Basin								
Russian near Ukiah (4610)	1953-65	1964-65	99.7	1600	160,000	176,000	90	110
E. Fork Russian near Calpella (4615)	1942-65	1964-65	93	800	73,800 *3	81,000	40	50
Russian near Cloverdale (4630)	1952-65	1964.65	502	1300	653,000	718,000	360	450
Big Sulphur Cr.near Cloverdale (4632)	1958-65	1964-65	82.3	2800	230,000	253,000	123	160
Maacama Cr. near Kellogg (4639)	1961-66	1964.65	43.2	600	26,000	27,000	13	17
Dry Cr. near Geyserville (4652)	1960-65	1964-65	162	4300	697,000	767,000	380	480
Potter Valley Tailrace near Potter V. (4710)	1909-65	1964-65	*4	-	3,200	3,200	-	-
Klamath, Trinity, Smith River Basins								
Shasta near Yreka (5175)	l946-65	1956 1959-62	796	25	20,000	22,000	11	14
Scott near Fort Jones (5195)	1942-65	1956 *6	653	800	-	-	-	-
Klamath near Selad V. (5205)	1960-65	1956 *6	6,980	40	-	-	-	-
Klamath near Someabar (5230)	1942-65	1956 *6	8,500	200	-	-	-	-
Trinity near Lewiston (3255)	1940-60 *5	1956-60	728	300	218,000	240,000	120	131
Weaver Cr. near Douglas City (5258)	1959-65	1963-65	48	500	24,000	26,000	13	16
N. Fk. Trinity near Helens (5265)	1958-65	19b3-65	151	200	30,000	33,000	16	21
S. Fk. Trinity near Salyer (5290)	1951-65	1956 1958-65	898	1,500	1,347,000	1,447,000	740	930
Trinity near Hoopa (5300)	1940-65	1957-65	2,865	1,700	4,870,500	5,358,000	2,680	3,370
Klamath near Klamath (5305)	1931-65	1956 *6	12,100	1,000	-	-	-	-
Smith near Crescent City (5325)	1940-65	1956 *6	609	300	-	-	-	-

*1 A water year is the 12-month period October 1 through September 30. The year is designated by the calendar year in which it ends and includes the first nine months of that year.

*2 Volumes are based on estimated dry unit weight (bulk density) of 2000 Tons/Acre-Ft. (92 lbs./cu.ft.) for soil in place. The estimated weight of 1540? Tons/Acre-Ft. (73 lbs./cu.ft.) reflects the effect of bulking such as would be expected

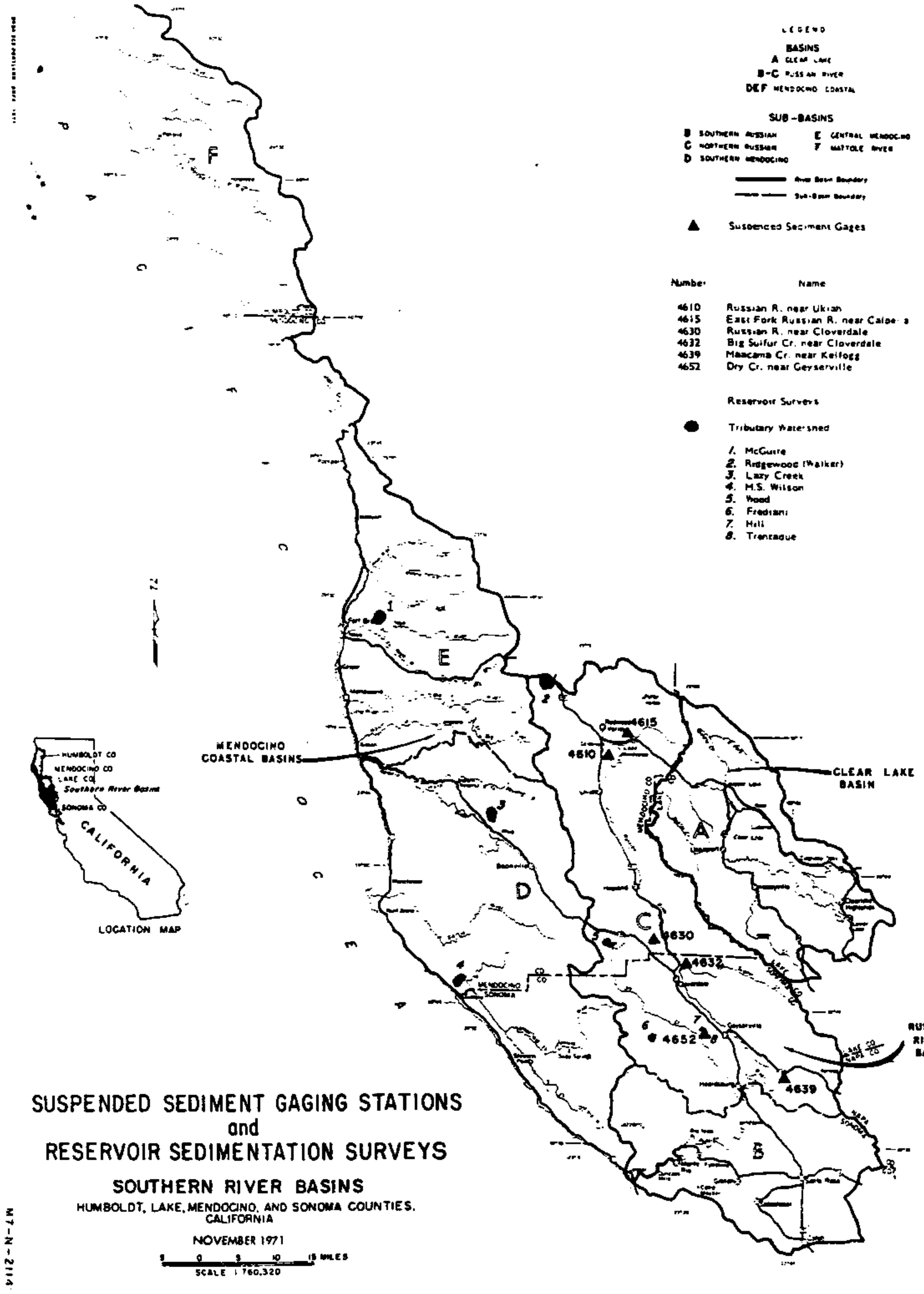
*3 Rate is net for watershed after subtracting 3200 Tons per year estimated to be contributed by Eel River water diverted through the Potter Valley tailrace.

*4 Water is diverted from Eel River above Van Arsdale Dam. After passing through powerhouse, part of it is used for irrigation in Potter Valley and remainder flows into East Fork Russian River. Sediment is essentially all suspended.

*5 Unregulated flows prior to construction of Lewiston Dam.

*6 One year of sediment record. Record is very scanty and computed yields should be considered only as estimates for the one year of record shown.

ATTACHMENT 2 (CONT)



ATTACHMENT 3

FILE: GARCIA1.WK1 USDA - SCS 5/24/91

GARCIA RIVER STUDY — MENDOCINO COUNTY AVERAGE SEDIMENT YIELD BASED ON RESERVOIR SEDIMENT SURVEYS

Reservoir	Drainage Area (mi2)	Years Since Last Survey	Sediment Yield (tons/sq mi)
Ridgewood	5.7	36	1461
McGuire	0.08	13	340
Lazy Creek	0.67	12	2072
Wilson	0.17	15	418
Wood	1.69	6	1807
Frediani	0.59	4	2691
Hill	0.18	4	864
Trentadue	0.04	3	4541
Overall Average Sediment Yield			1774
Average Without High and Low Values			1552

AVERAGE SEDIMENT YIELD BASED ON SUSPENDED SEDIMENT RECORDS

Station (Number)	Length of Sediment Record (yr)	Drainage Area (mi2)	Sediment Yield ** (tons/sq mi)
Russian R near Ukiah (4610)	12	99.7	1760
E. Fork Russian near Calpella (4615)	23	93	880
Russian R near Cloverdale (4630)	13	502	1430
Big Sulphur Crk nr Cloverdale (4632)	7	82.3	3080
Maacama Cr near Geyserville (4639)	5	43.2	660
Dry Crk near Geyserville (4652)	5	162	4730
Overall Average of All Values			2090
Average Without High and Low Values			1788
Average from "Annual Sediment Yield Map" North Coast River Basin Study (SCS, 1970) 1.2 ac-ft/mi2 @ 90 pcf = 2350 tons/mi2			2350
Mendocino Coastal annual sediment yield (page 42 in above reference)			2810
Southern Mendocino Coastal annual sediment yield (p 42 of River Basin study)			2310

ATTACHMENT 4

FILE: GARCIA2.WK1 USDA - SCS 5/29/91

GARCIA RIVER STUDY — MENDOCINO COUNTY

A sediment yield of 2,300 tons per square mile will be used in this analysis. This is based on the rate estimated for Mendocino Coastal watersheds in the North Coast River Basins Report (SCS, 1970).

There is 98.5 square miles of drainage area above the USGS gage site on the Garcia River (just downstream of the confluence with the North Fork of the Garcia River). Assume an additional 15.5 square miles of drainage area for the watershed below the gage. The total drainage area is then 114 square miles which yields a total of 262.200 tons of sediment in an average runoff year. The distribution of this sediment by grain size is assumed to be:

60% clays and silts		157300
30% sands		78700
10% gravels		26200
	Total	262200

By routing this sediment load to the ocean, by grain size, an estimate of the rate of sedimentation filling the lagoon area could be made:

Overbank flooding occurs in high runoff years. These events can be averaged over a long period of time into an average annual event so some sediment is lost to deposition on the floodplain on an average annual basis:

20 % of total load is lost to floodplain:

15%	of fines deposit on floodplain	23600
4%	of sands deposit on floodplain	3100
1%	of gravels deposit on floodplain	2600
	Total	29300

262200 - 29300 = 232900 tons/yr sediment yield to lagoon

95% of fines reach the ocean		127000
80% of sands reach the ocean		60500
20% of gravels reach the ocean		4700
	Total	192200

192200 tons/yr / 232900 tons/yr = 82%

The lagoon traps about 18 % of the sediment that reaches the lagoon in an average annual year.

232900 - 192200 = 40700 tons/yr deposition

Three fourths of this sediment is deposited on uplands and one fourth is deposited in tidal area.

(3/4 X 40700 / 85 pcf) X 0.04591 = 16.5 ac-ft/yr deposition
(1/4 X 40800 / 60 pcf] X 0.04591 = 7.8 ac-ft/yr deposition
Total 24 ac-ft/yr deposition

The lagoon area consists of about 80 acres of open water and mud flats and 150 acres of more upland type vegetation. The 16.5 ac-ft/yr deposition over 150 acres is about 1.3 inches of deposition per year. The 7.8 ac-ft/yr over 80 acres is about 1.2 inches of deposition per year. These rates appear high but are probably reasonable. During major runoff events, some sediment may be eroded and moved out of the lagoon which may be one reason there is still some open water and tidal flats remaining in the area.

ATTACHMENT 5

FILE: GARCIA3.WK1 USDA - SCS 5/29/91

GARCIA RIVER STUDY — MENDOCINO COUNTY

Estimates of the amount of sediment contributed by source were made in the North Coast River Basins study (SCS, 1970) on page 42:

Mendocino Coastal Watersheds (ac-ft of sediment yield)

	Strmbks	Landslides	Sheet & Gully	Total
Mattole River	550	400	380	1330
Central Mendocino	190	120	270	580
Southern Mendocino	470	230	400	1100
Subtotal	1210	750	1050	3010

Mendocino Coastal Watersheds (% contribution by source)

	Strmbks	Landslides	Sheet & Gully	Total
Mattole River	41.4	30	28.6	100
Central Mendocino	32.8	20.7	46.5	100
Southern Mendocino	42.7	20.9	36.4	100
Subtotal	40.2	24.9	34.9	100

Based on this data, the following distribution could be used for the Garcia River:

Streambanks	40%
Landslides	20%
Sheet and Gully	40%

GARCIA RIVER STUDY — MENDOCINO COUNTY (cont)

In order to recommend treatments, the individual sources need to be broken down further. The percent contribution by source in the Grass Valley Creek Sediment Study (SCS, 1986) is shown below:

	% of Tot Sed Yield G V Crk	Adjusted % for Garcia
Sheet and Rill Erosion		
Uplands	16	10
Road surfaces	1	1
Road cut slopes	27	25
Road fill slopes	3	2
Streambank Erosion	17	30
Gully Erosion		
Road associated	11	10
Upland tribs	4	2
Landslide Erosion		
Road Associated	10	10
Stream associated	11	10
Streambanks	17%	30 %
Landslides	21%	20 %
Sheet and Gully	62%	50 %

Until additional studies are completed in the Garcia basin, the adjusted percents shown on the right side of the table above will be used to apportion the sediment load by source. Other studies in logged watersheds indicate that logging roads seem to contribute about half the sediment yield from the watershed. The above distribution indicates 48% of the sediment in the Garcia basin is from logging roads.

FILE: GARCIA3.WK1 USDA - SCS 5/29/91

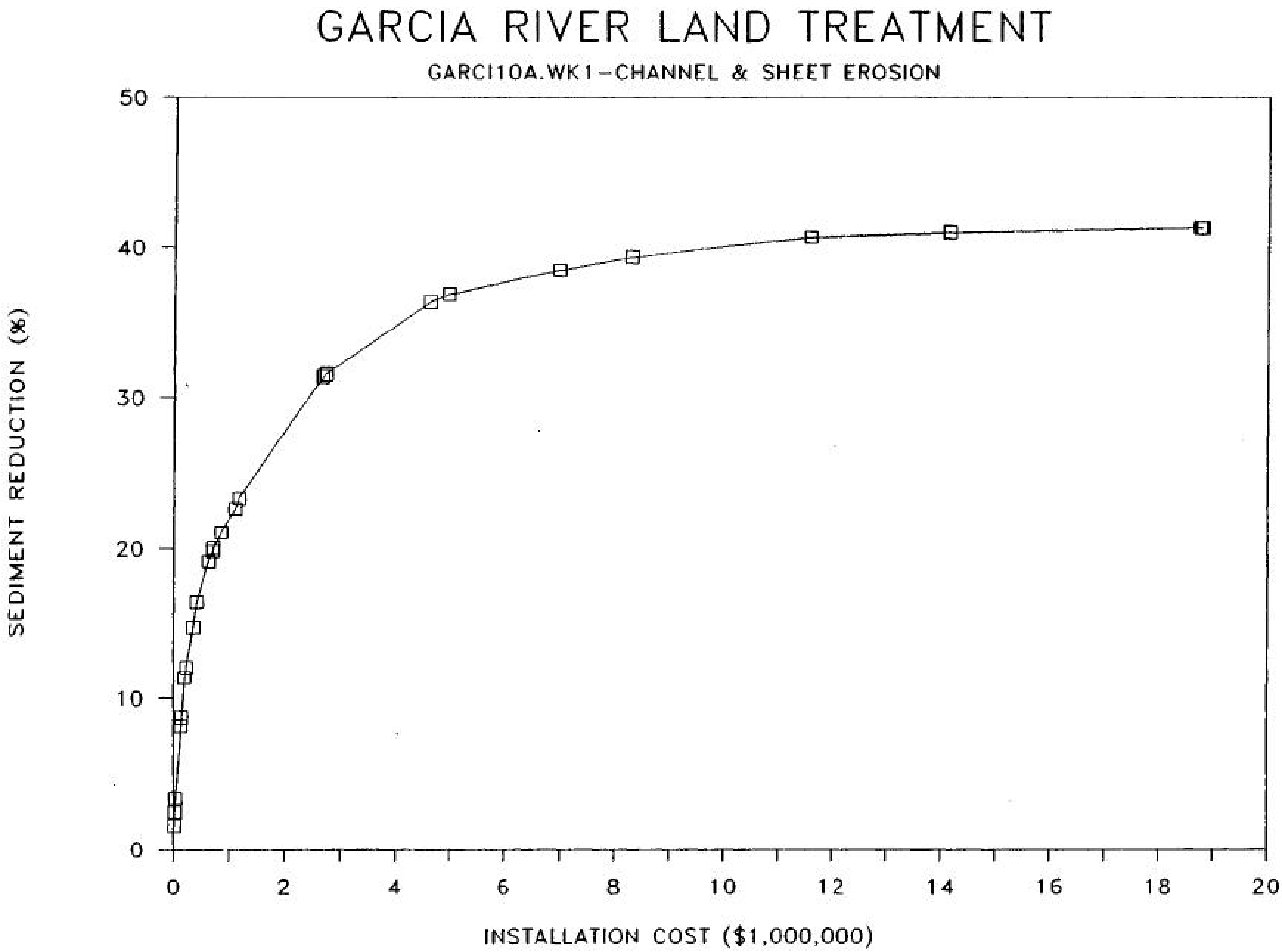
GARCIA RIVER STUDY — MENDOCINO COUNTY (cont)

Based on the percentages shown on the previous page, the 262,200 tons of sediment are distributed among these sources:

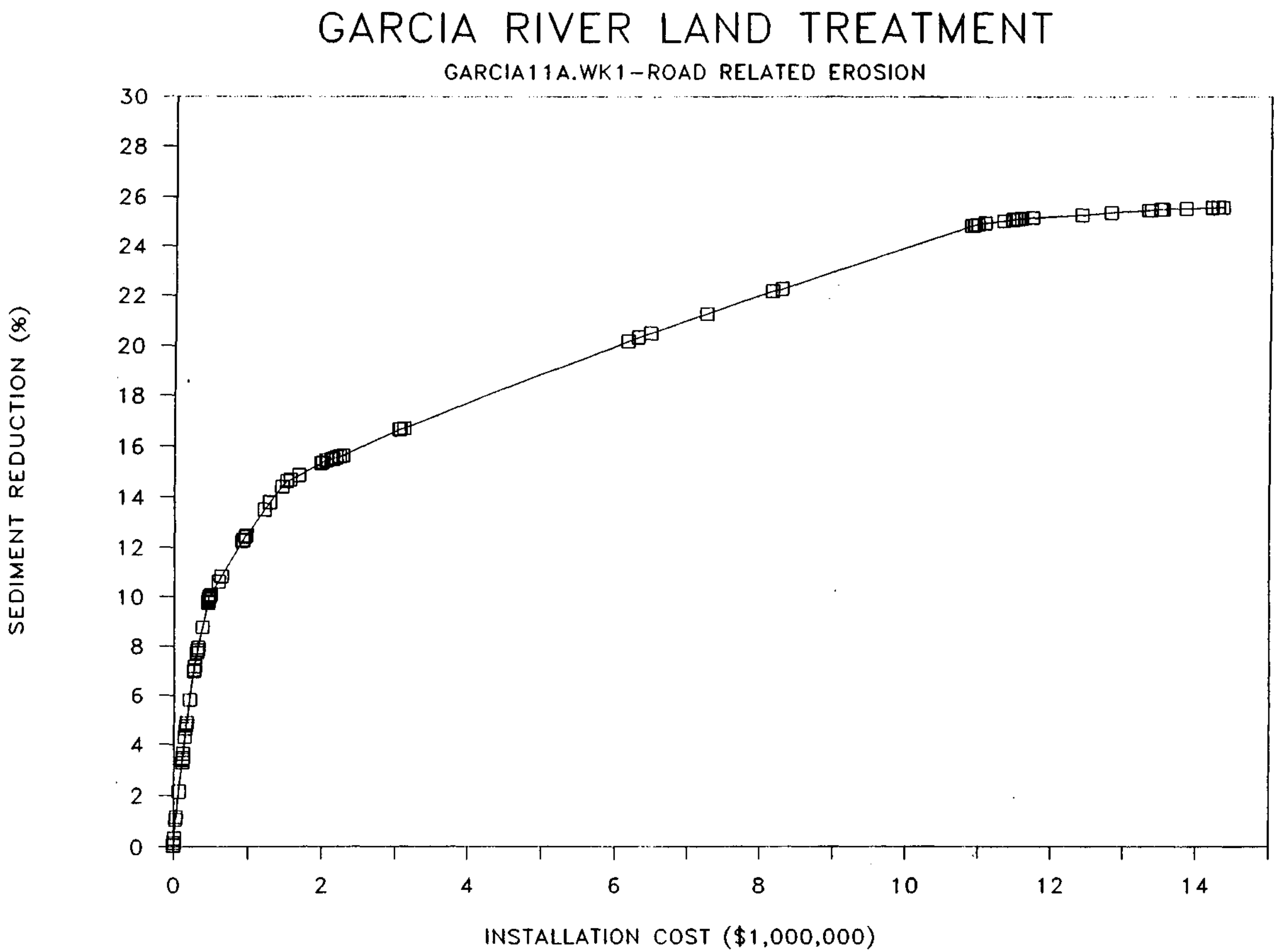
	% of Tot Sed Yield Garcia R	Sed Yield Garcia R (Tons/Yr)
Sheet and Rill Erosion		
Uplands	0.099923	26200
Road surfaces	0.009916	2600
Road cut slopes	0.250190	65600
Road fill slopes	0.019832	5200
Streambank Erosion	0.300533	78800
Gully Erosion		
Road associated	0.099923	26200
Upland tribs	0.019832	5200
Landslide Erosion		
Road Associated	0.099923	26200
Stream associated	0.099923	26200
Total	1	262200

These values will be used in the LNDTRT and ALTERN Lotus 123 spreadsheets to rank land treatment practices by cost-effectiveness (dollars of average annual cost per ton of sediment reduction). The ALTERN spreadsheet will accumulate the total costs and the total percent and tons of sediment reduction.

Attachment 6



Attachment 7



FILE: SDRGAR.WK1 USDA - SCS
DATE: 7/11/91 DRAFT

DOCUMENTATION FILE FOR THE Sample Property PARCEL

SEDIMENT DELIVERY RATIO (SDR) PROCEDURE FOR
TIMBER HARVESTS ON DISINTEGRATED GRANITE SOILS
(Adjusted SDR is the Sediment Delivery Ratio for this parcel.)

ASSUMPTIONS:
1. Geologic SDR for forest land is 10 %
2. If the adjusted SDR is negative, SDR = 0 & deposition occurs

Parcel Name:	Sample Property
Parcel Number:	Number 1 example
Location:	Sec 30 T33N R8W
Date Submitted:	3/90
Reviewed By:	Steffen

Hydro. Condition	HYD	=	60	multiplier is	0.5
Drainage Density	DD	=	9	multiplier is	1
Road Density	RD	=	28.7	multiplier is	1.25
Filter Strip Width	FSW	=	20	multiplier is	1.25
Slope	S	=	60	multiplier is	1.25
Slope Differential	SD	=	50	multiplier is	1

Beginning SDR = 10 %

Adjusted SDR = 63%

Factor	Symbol	Units	SDR Multiplier			
			-1.0	+0.5	+1.00	+1.25
Hydro. Condition	HYD	(na)	<50	51-67	68-77	>77
Drainage Density	DD	mi/mi2	<2.0	2.1-4.0	4.1-10.0	>10.0
Road Density	R	mi/mi2	na	0.1-8.0	8.1-15.0	>15.0
Filter Strip Width	FSW	feet	>100	51-100	26-50	<25
Slope	S	%	<15	15-30	30-50	>50
Slope Differential	SD	%	<-33	-33-+33	+34-+67	>+67

FILE: SDRGAR.DOC USDA-SCS
DATE: 7/12/91 DRAFT

SEDIMENT DELIVERY RATIO (SDR) PROCEDURE FOR TIMBER HARVESTS IN THE GARCIA RIVER WATERSHED

EXPLANATION OF FACTORS:

The following factors are put into a LOTUS 123 spreadsheet (SDRGAR.WK1) which calculates the adjusted SDR for a timber harvest parcel or a subwatershed.

Hydrologic Condition (HYD)

This factor represents a combination of the ability of the soil to hold water and the amount of ground cover disturbance in the parcel or subwatershed within and outside of the roaded areas. Soils can be placed in one of four Hydrologic Groups; A, B, C or D. The water infiltration rate decreases from A to D so runoff increases from A to D. Use existing soil survey maps to determine the dominant soil occurring in the parcel or subwatershed. The soil survey report should also contain a table listing the Hydrologic Group for each soil. If no survey exists, contact the nearest Soil Conservation Service (SCS) or Forest Service (FS) office for assistance.

The SCS has developed runoff curve numbers for the four Hydrologic Groups of soils. Curve numbers for woods-type cover in Good, Fair and Poor condition are listed in Chapter 2 of the Engineering Field Manual in Table 2-3b on page 2-86 (SCS, 1989). Table 2-1 on pages 2-42 to 2-86 also lists the Hydrologic Group for all soil series identified in the United States.

Different timber harvesting techniques are used to determine if the cover condition after logging is Good, Fair or Poor (SCS, 1990). Undisturbed ground cover increases infiltration and decreases overland or concentrated flows. This also means it is more difficult for eroded materials to move overland and enter a stream. The following curve number table is used to determine the value to enter for the Hydrologic Condition parameter in the SDR procedure:

Hydrologic Condition (Harvest Technique)		Curve Numbers For Hydrologic Soil Group			
		A	B	C	D
Helicopter/Select	Good	30	55	70	77
Cable/Select	Good	30	55	70	77
Helicopter/Clearcut	Fair	36	60	73	79
Cable/Clearcut	Fair	36	60	73	79
Tractor/Select	Fair	36	60	73	79
Tractor/Clearcut	Poor	45	66	77	83

Drainage Density (DD)

This factor represents the degree of "connectedness" of the drainage network. A high DD means eroded materials can become sediment yield more easily due to the fact that they have to travel a shorter distance before entering a stream. Drainage Density is the sum of the miles of first order and higher orders of streams

EXPLANATION OF FACTORS (cont)

divided by the corresponding area (square miles) of the timber harvest parcel or subwatershed (0.9 miles of streams / 0.3 square miles of parcel = a drainage density of 3.0 miles per square mile). First order streams are defined as a line connecting the tip of the "V's" formed in contour lines on 7 1/2 minute topographic quadrangles. A second order stream forms below the confluence of two or more first order streams, a third order stream forms below the confluence of two or more second order streams, etc.

Road Density (RD)

Sediment yield has been shown to increase as Road Density increases (Attachment 1). RD is one indication of the amount of disturbance of the forest floor and it is a measure of the increased potential for subsurface and overland flows to be concentrated. Eroded materials have a greater potential to become sediment yield due to the forest floor disturbance and the increased efficiency of the drainage network. Road Density is defined as the sum of the miles of roads and skid trails divided by the corresponding area (square miles) of the timber harvest parcel or subwatershed. Each landing is assumed to equal 0.3 miles of road which should be included in the sum of the miles of roads and skid trails. An 0.4 square mile parcel with 1.4 miles of roads and skid trails and two landings has an RD of 5.0 (2 landings x 0.3 miles of roads per landing = 0.6 miles; 1.4 miles + 0.6 miles = 2.0 miles of roads; 2.0 miles of roads / 0.4 square miles of parcel = 5.0 miles per square mile).

Filter Strip Width (FSW)

Undisturbed forest floor slows surface runoff and increases infiltration. Both these factors tend to increase the rate of deposition of soil particles being carried in the runoff. The FSW is defined as the width, in feet, of undisturbed forest land between the low end of a subwatershed, or the boundary of a timber harvest parcel, and the edge of the bank of a second order stream. "Undisturbed" is defined as land that has not been logged for a minimum of ten years and has a minimum of 70 percent ground cover. Attachment 2 shows the relationship between the diversity of invertebrates on stream bottoms relative to the width of buffer strips along the stream. Less sediment in the stream appears to increase the diversity of species in the stream.

Slope (S)

Steep slopes increase runoff and the energy of the runoff. Both these factors tend to increase sediment delivery. This factor is defined as the slope used in determining the Erosion Hazard Rating for the timber harvest parcel or subwatershed.

Slope Differential (SD)

If runoff from a steep slope encounters a flatter slope, the runoff energy decreases and sediment deposition can occur. Conversely, if runoff from an upper slope encounters an even steeper slope, sediment deposition is less likely. The steeper slope could even cause an increase in the amount of sediment delivered from the slope.

To determine SD, sketch the profile of the hillslope from the high ground within the subwatershed, or timber harvest parcel, to the bank of the nearest second order stream. This profile should generally represent the path of drainage from the top of the subwatershed or parcel down to the stream. Disregard first order streams or other small-scale breaks in slope. The slope differential is defined as the percent of difference between the average slope of the upper part of the profile and the lower part of the profile.

EXPLANATION OF FACTORS (cont)

If there is no major break in slope on the profile, there is zero percent difference. If there is a break in slope along the profile, the difference in length of the two slope segments must be less than a factor of four times the shorter length before a slope differential should be calculated. If one segment is much longer than the other segment, little change in the SDR probably occurs.

If the upper slope is 220 feet in length and 30 percent and the lower slope is 40 feet long and 45 percent, the difference in slope (220 feet - 40 feet = 180 feet) is more than four times the length of the shorter segment (180 feet / 40 feet = 4.5x) so it is assumed there is a zero slope differential. If the upper slope is 220 feet in length and 30 percent and the lower slope is 100 feet long and 45 percent, there is a +50 percent difference ((45 % - 30 %) / 30 % = +50 %). A slope differential was calculated for this example because the two segments were more equal in length (220 feet - 100 feet = 120 feet difference in length, 120 feet / 100 feet = 1.2x). If the upper slope is 400 feet long and 40 percent and the lower slope is 300 feet long and 25 percent, the slope differential is -37.5 percent ((25 % - 40 %) / 40 % = -37.5 %).

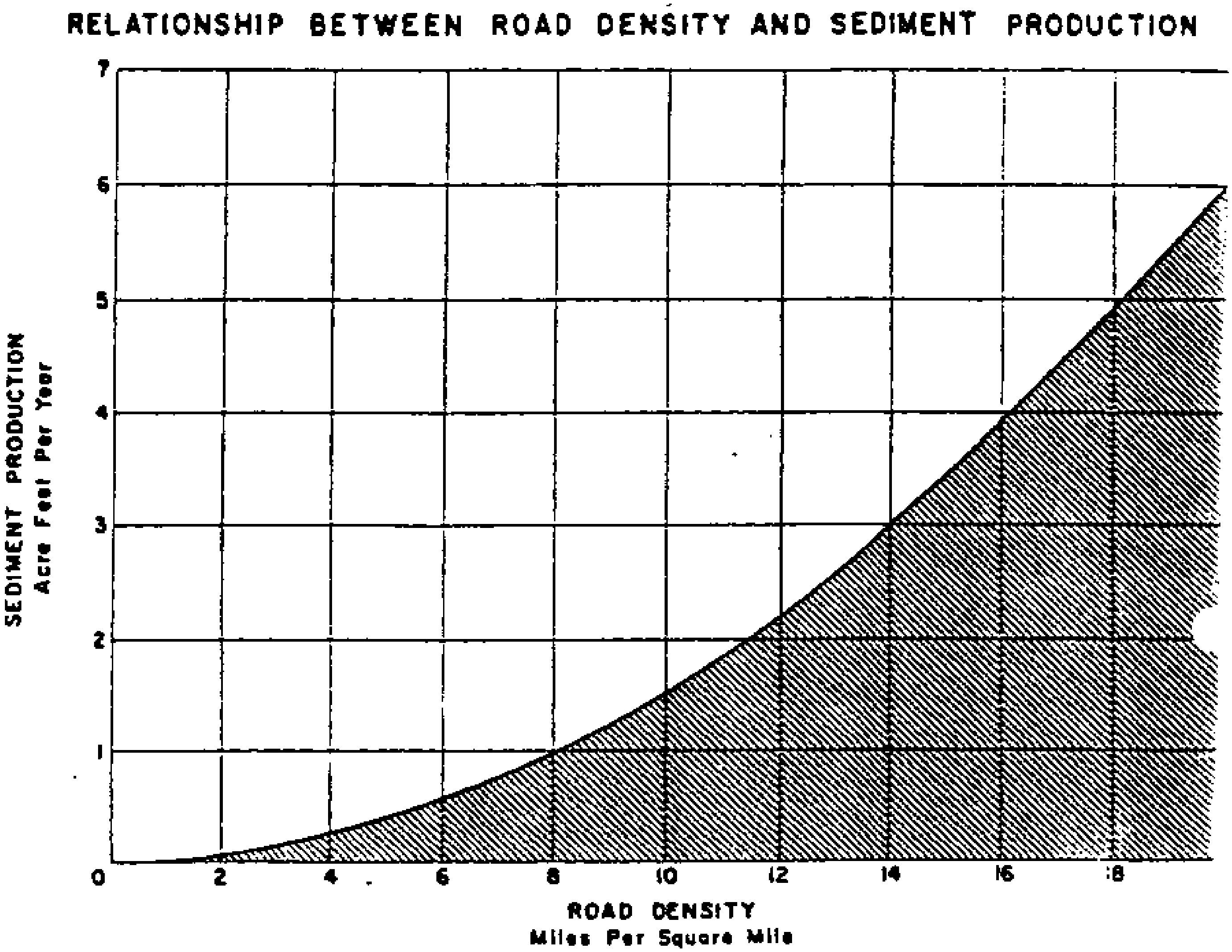


Figure 39. Road Density and Sediment Production. [30]

RECOVERY AFTER LOGGING IN STREAMS WITH AND WITHOUT BUFFERSTRIPS IN NORTHERN CALIFORNIA

by

Don C. Erman

and

Donald Mahoney

CALIFORNIA WATER RESOURCES CENTER
University of California

Contribution No. 186

1SSN 0575 - 4941

June 1983

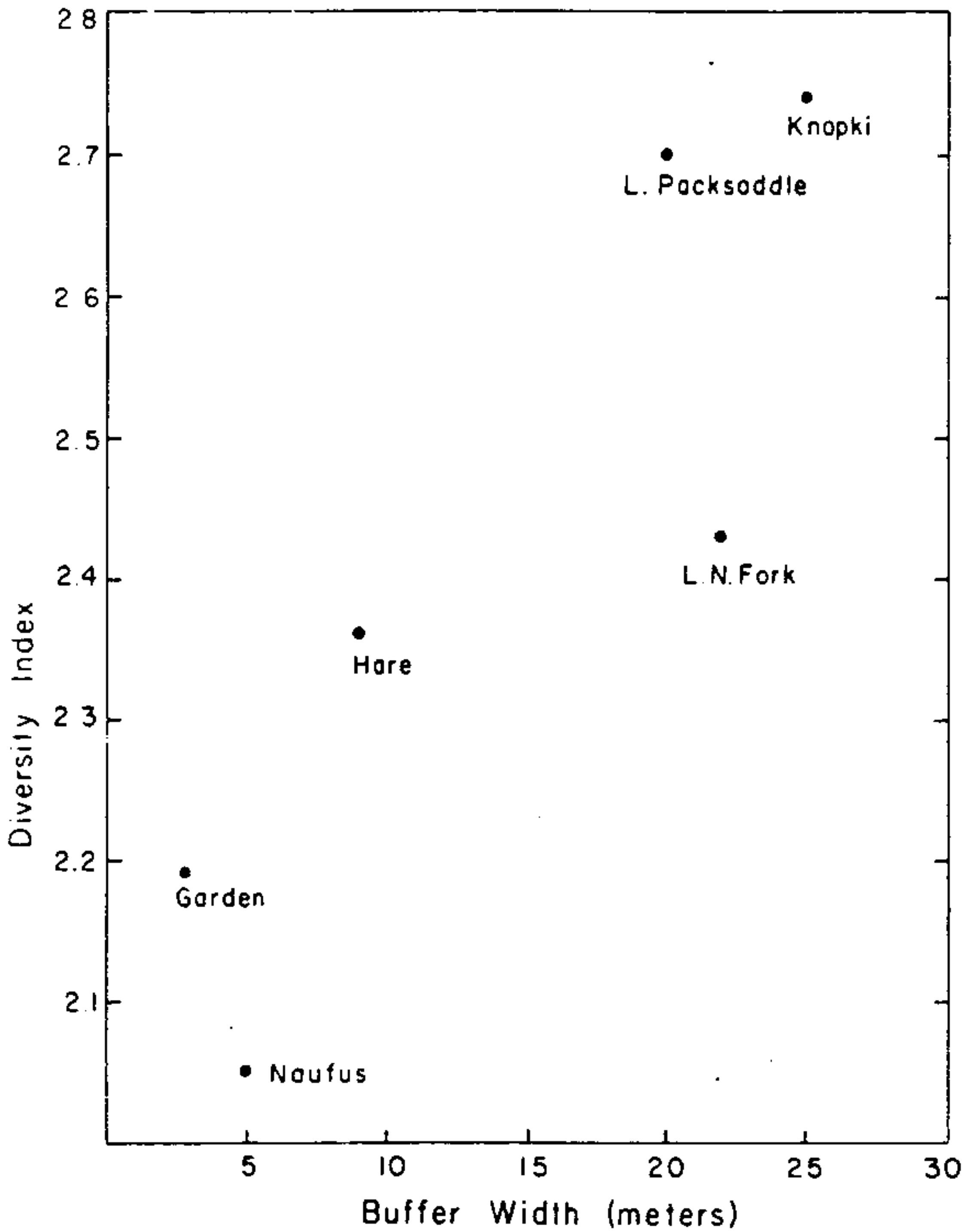


Figure 4. The relationship between buffer width and invertebrate diversity for narrow-buffered streams.