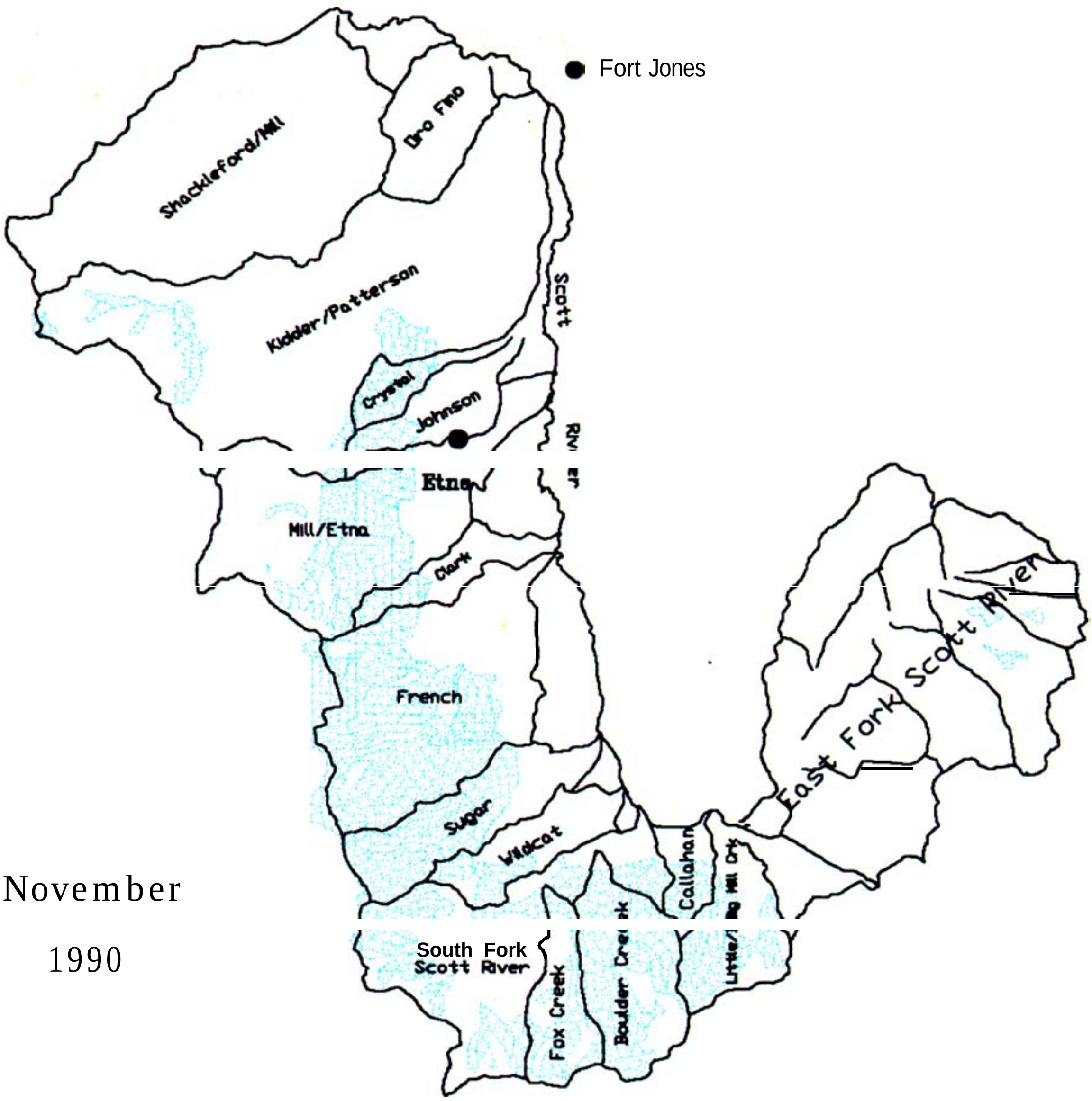
SCOTT RIVER BASIN

GRANITIC SEDIMENT STUDY



November

1990

Siskiyou Resource Conservation District

SCOTT RIVER WATERSHED

GRANITIC SEDIMENT STUDY

by

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SISKIYOU RESOURCE CONSERVATION DISTRICT

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SCOTT RIVER BASIN GRANITIC SEDIMENT STUDY

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ABSTRACT

The extent of the decomposed granitic (DG) sediment problem is examined in the Scott River watershed of Siskiyou County, California. This sand-sized sediment was previously identified to cause spawning habitat impacts for salmon and steelhead and to be an important factor constraining anadromous fish production in the Scott River, a large tributary of the Klamath River. Data was collected during 1989-90 within the 215,500 acre Study Area, which also included the Scott Valley portion of the Scott River and several tributaries. Analysis focuses on three aspects of the problem: (1) sources of granitic sediment production; (2) granitic sediment storage and transport in the Scott River; and (3) extent of impact of granitic sediment on salmon and steelhead spawning habitat in the Scott River and selected tributaries.

To help analyze the large quantity of data, a Geographic Information System (GIS) database was developed of the Study Area, of which 57,000 acres (26%) are granitic soils. Soils developed from granitics are recognized as some of the most erodible. Total upland decomposed granitic erosion is estimated to be about 340,450 tons per year. Road cuts constitute 40% of the amount, streambanks 23% road fills 21%, skid trails 13%, and the balance from road surfaces, other sheet and rill erosion, and landslides. For most years, sediment production in the Study Area is stored in the upper watershed. A delivery ratio of 0.21 is preferred for estimating annual sediment yield to the Scott River, based on results of a recent reservoir study in a similar area. An average yield of 71,500 tons of decomposed granitic sediment is therefore predicted to be delivered to the Scott River each year.

Although the low gradient reaches of the river in Scott Valley represent a natural area of sediment deposition, considerable channel alteration of the Scott River over the years has changed its sediment storage and transport capacities. The greatest amount of sand in channel storage is in the reach between Oro Fino Creek and the State Highway 3 bridge near Fort Jones. Portions of this reach were affected by a diversion dam which acted as a sediment trap from 1958 until its removal in 1987-89. Adjustments in slope and transport capacity will continue to occur

both upstream and downstream until a new equilibrium is established. Sediment transport equations, while very limited in accuracy, were useful in identifying relative sediment transport between reaches and possible contributing factors. The Engelund-Hansen and Ackers-White transport equations appeared the most comparable to actual stream conditions. Prevention and rehabilitation of DG erosion in the uplands of the Scott River watershed would serve to decrease the input side of the local sediment budget and allow more of the DG sand in channel storage to get moved out over the long term.

Existing and potential spawning areas were sampled for grain size composition using 238 McNeil sampler cores at 11 sites in the Scott River, and 55 cores at 6 sites in lower Etna, French and Sugar Creeks. Core samples were sieved into 7 size categories for analysis. Four quality indices were applied to the field data: percentage fines, geometric mean, fredle index, and visual substrate score. For percentage fines less than 6.3 mm, the three worst sites had amounts ranging from 82.1% to 92.7%, amounts which were greater than any reported in the literature. The relative ratings of the various indices for each site are quite consistent except for the fredle index. Quality indices best serve as relative measurements between sites and between years rather than as accurate predictors of emergent survival. The spawning gravel data developed for this study serves as a good baseline for monitoring changes in streambed composition of the Scott River and several tributaries.

CHAPTER 1

INTRODUCTION

Purpose

The 1985 Klamath River Basin Fisheries Resource Plan (CH2M-Hill, 1985) identified "spawning habitat sedimentation" as the second most important factor constraining anadromous fish production in the Scott Subbasin. Findings in the plan noted that decomposed granitic soils (commonly referred to as "DG") are the main source of sediment. This study was designed to better characterize the extent of the DG problem.

Each of the three following objectives is the focus of successive chapters.

<u>Objectives</u>

A. Analyze watershed dynamics and determine sources of granitic sediment production in the Scott River Basin (Chapter 2).
B. Determine granitic sediment storage and transport in the Scott River, within Scott Valley (Chapter 3).
C. Determine the impact of granitic sediment on salmon and steelhead spawning in the Scott River and selected tributaries (Chapter 4).

Each of the chapters provides new data collected during the past two years, and an analysis of the problem based on the new data. In addition, each chapter provides direction for concentrating further studies and restoration efforts.

Sediment Budgets

A sediment budget is the quantitative description of the movement of sediment through the landscape. To be complete, it considers the <u>input rate</u> or <u>sediment production</u> from hillslopes into the stream channels, the <u>storage volume</u>, and <u>discharge rate</u> of sediment (Swanson et al, 1982). A parallel can be seen between these elements of a sediment budget and the first two objectives of this study, which is a preliminary effort to provide some of the necessary data and analysis for a sediment budget of the Scott River. However, this study is focusing only on the decomposed granitic sediment portion of such a budget. It is also beyond the scope of the present effort to measure the actual discharge rate of sediment in the Scott River.

Sediment budgets are useful in providing a measure of the relative importance of both natural and human-induced sediment sources. By identifying the major sediment sources, corrective measures can be applied to the "most beneficial points in the system" (Swanson et al, 1982).

Study Area

The Scott River Basin is located in south-central Siskiyou County, California, about 30 miles south of the Oregon border. The focus of this study is on the areas of the Scott River Basin that may produce decomposed granitic soils as well as the primary areas of sand deposition in the Scott River. Figure l-l represents this region of the watershed, which is located in the western, southwestern and southeastern portions of the Basin. The total area on the map is about 215,500 acres while the granitic soil types (mottled area) encompasses about 57,000 acres (26%).

The sub-basins located within the study area are also indicated on the map. While other subbasins, such as Moffett Creek, may also contribute sediment, they are not sources of decomposed granitic sand and were therefore not included in the Study Area.

The Study Area represents about 42% of the entire Scott River Basin (520,320 acres).

Precipitation

The official Weather Bureau Station for the Scott Valley area is the U.S. Forest Service Ranger District Office in Fort Jones. A summary of the data (for the calendar year) follows:

Station	Elevation (feet)	Period of Record	Mean (inches)	Season	Minimum Maximum
Fort Jones	2,747	1936-89	22.08	1949 1970	10.05 35.07

Two other precipitation stations, located in Etna and in Callahan (USFS Fire Station), have also collected rainfall data over the years.

Precipitation data for the higher elevations have not been collected in the Study Area. Estimates, however, are available from an isohyetal map by Rantz (1968), which indicates 50 inches for the upper watershed boundary. Snowfall is common at elevations above 4000 feet throughout much of the winter (November to March).

Runoff

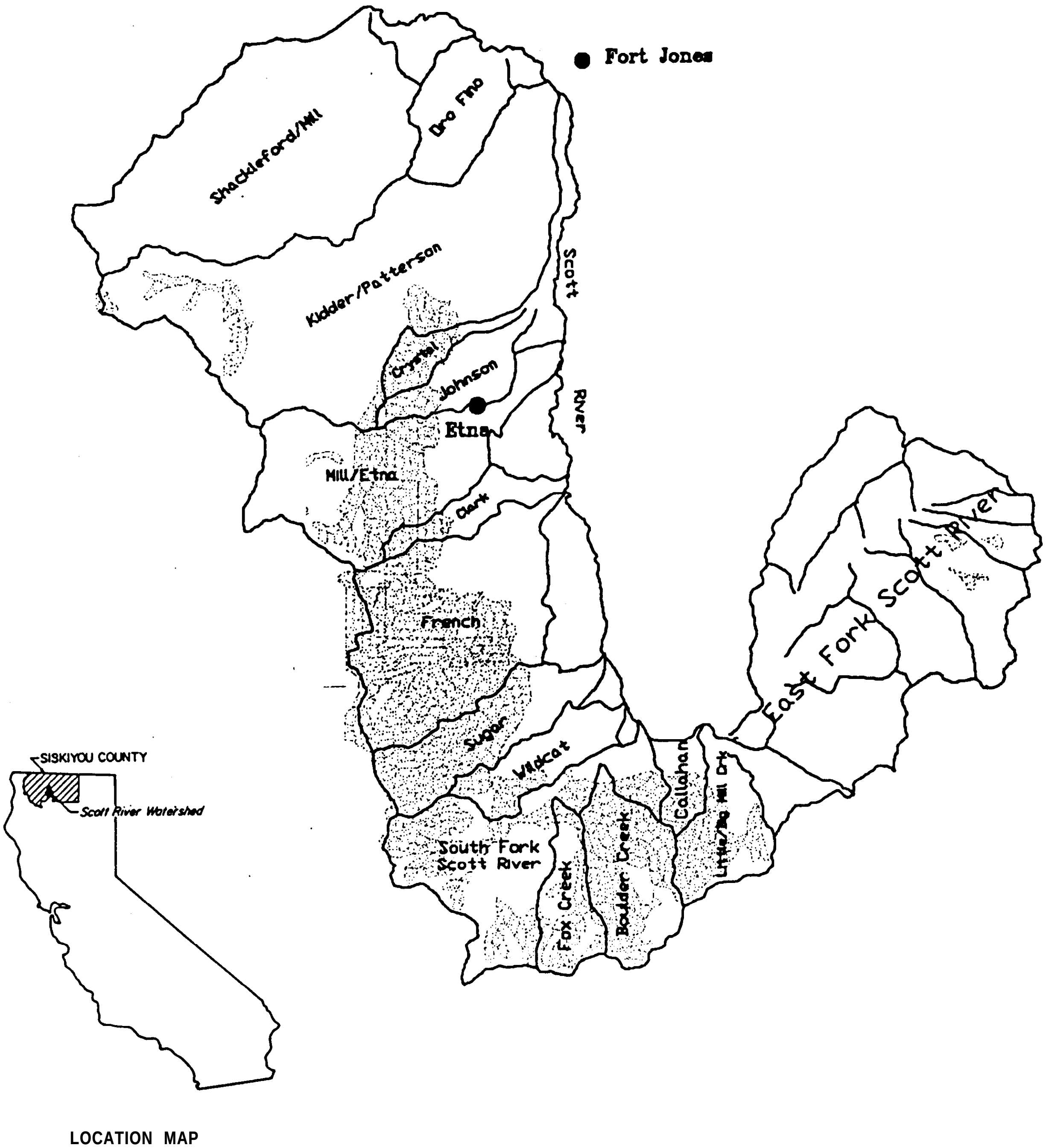
The Scott River is a principal tributary of the Klamath River. Annual discharge at the U.S.G.S. gage station below the Scott Valley averages 489,800 acre-feet. Runoff characteristics are described in detail in Chapter 3.

Topography

The Salmon Mountains encompass the western portion of the

Figure 1-1

Study Area



study area, while the Scott Mountains border the south boundary and the Scott Bar Mountains border the north. The slope of the area varies from less than 2 percent in Scott Valley to over 60 percent in the mountains. Elevation ranges from 2,620 feet at the Scott River at the north end of the valley to over 8,000 feet at several mountain peaks in the southwest.

Geology and Soils

Located within the eastern portion of the Klamath Mountains, the area's bedrock consists of metasedimentary and metavolcanic rocks of Late Jurassic and possibly Early Cretaceous Age. The alluvial fill in the valley contains unconsolidated Pleistocene and Recent deposits. An extensive area of granodioritic rock, intrusive into schists and greenstone, is exposed for about 8 miles in the mountains paralleling the west side of Scott Valley. Every gradation between granite and quartz diorite occurs here. In the frequent shear zones, the granodiorite is "extremely friable and crumbles to the touch" (Mack, 1958).

The granodiorite is the light-colored, coarse parent material for several DG soil types of varying depths and textures. Soils derived from granitics are noncohesive and usually highly erodible (Laake, 1979). Geology and soils are also discussed in Chapters 2 and 3.

Vegetation

Most of the 100 square miles of valley land are under cultivation, primarily in alfalfa, grain and pasture. Riparian shrubs and trees line some portions of the stream system. In the foothills, oaks, junipers, shrubs and grasses predominate, particularly on the drier east side. Mixed conifers (mainly douglas fir, ponderosa pine, sugar pine and incense cedar) cover the upper western and southern watershed. Native hardwoods and understory shrubs are also scattered throughout the forest area (USSCS, 1972).

Resource History of Scott Valley Watershed

What is seen today in the Scott Valley watershed is quite different from 150 years ago. As found in other areas, certain postsettlement changes likely to have had major impacts on the nature of stream systems include beaver removal, mining, deforestation, urbanization, tillage, irrigation, channel alteration, grazing by domestic animals, and fire suppression. Identifying the changes that have occurred to the Scott River's landscape over the years of human activity is important to an understanding of what is happening today.

Early History: Indians and Trappers

The Shasta Tribe (Iruaitsu people) originally occupied the Scott Valley as part of their ancestral territory, sustaining themselves on acorns, deer and salmon. What impact their practices, such as burning, had on the presettlement conditions of the watershed is not known.

In the 1830's the Hudson Bay trappers discovered "Beaver Valley" and the "Beaver River? They reportedly trapped 1800 beaver on both forks of the Scott River in one month. It was "the richest place for beaver I ever saw", claimed one trapper many years later. He also described the Scott Valley as all one swamp caused by the beaver dams. (Wells, 1881)

While not all of the beaver were taken, this major removal likely had a significant effect on the Scott River and its tributaries. Beaver dams slow the movement of water, sediment, and streamside vegetation out of watersheds . As a result, more water is stored, the ground water is recharged, and more diverse vegetation grows along streams. Beaver ponds are also known to provide excellent habitat for young coho salmon (J. Sedell, in Bergstrom, 1985).

In 1853, the earliest map of the "Scott's Valley" indicates that beaver dams were still obvious around Kidder Creek near Greenview (Figure l-2). The map also shows a defined stream channel for the Scott River rather than a marshy area of ill-defined channels. In May 1855, one observer described the Scott River in the valley as "from thirty to forty yards in width, deep in many places, with a current of from five to seven miles per hour" (Metlar, 1856).

Mining History

Gold miners rediscovered the Scott River in 1851, beginning the settlement of the region. Within the study area, gold mining was most extensive in the South Fork of the Scott River and Oro Fino and Shackleford creeks, with lesser activity in French Creek and the East Fork. By 1856, hydraulic mining operations had made the lower Scott River near Scott Bar almost constantly "turbulent and muddy" while the Klamath River was usually "clear and transparent" (Metlar, 1856). To supply the miners over in the Salmon River country, a trail along Etna Creek going over Etna Summit was built, cutting into some DG soils. (This trail was gradually widened and eventually became a paved county road.)

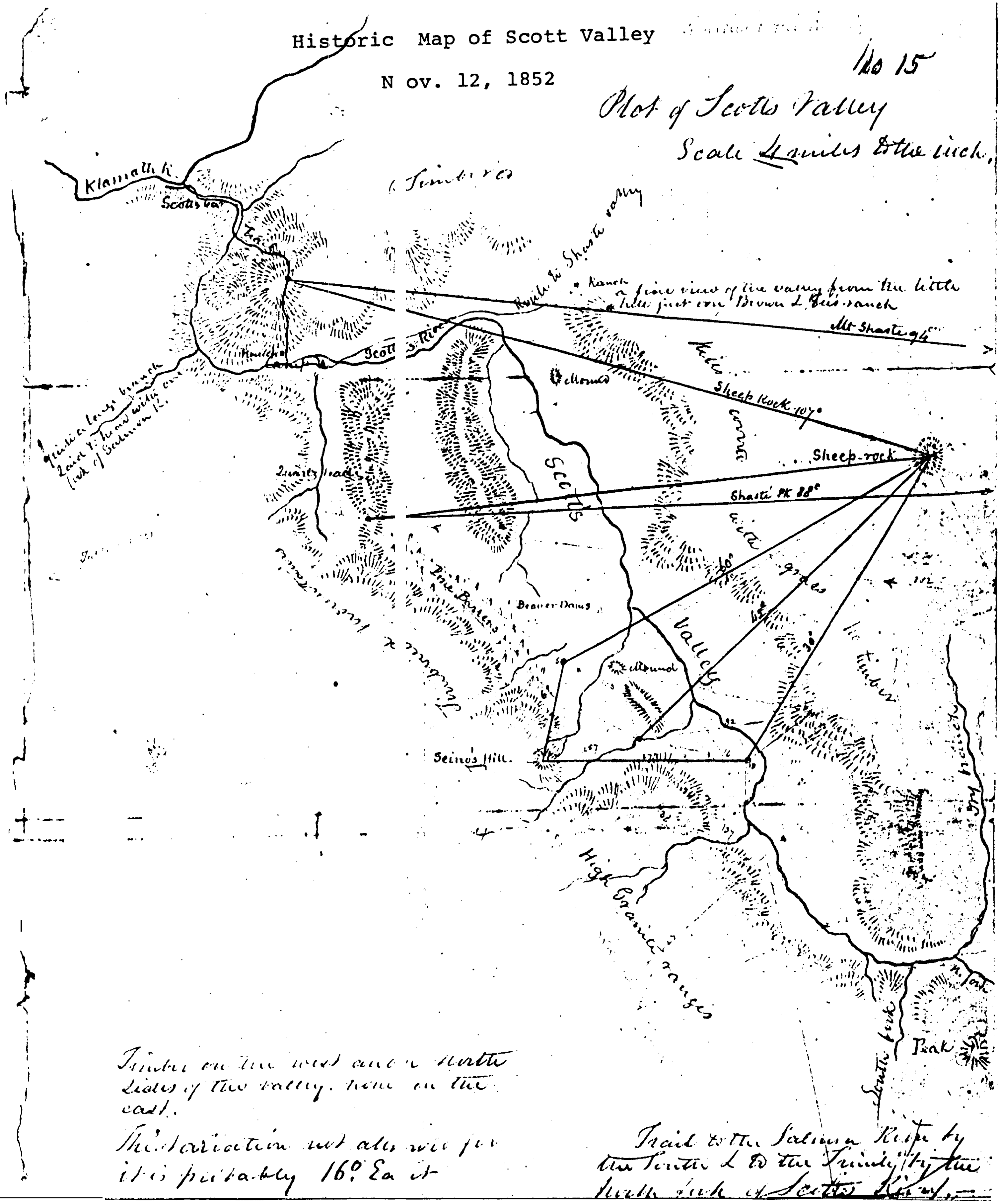
Floods in 1852-53, 1861, 1864, 1875, and 1880 "swept the rivers clear of all mining improvements" (Wells, 1881). In normal times, streams near placer mines were diverted into mining ditches of various capacities and lengths. Some of these ditches are still in operation (though mainly for irrigation) in the South Fork, East Fork, French Creek, Sugar Creek, and Etna Creek drainages.

During the period from 1934 to about 1950, large gold dredges operated on the upper Scott River and Wildcat Creek. The largest Yuba dredge excavated to a depth of 50-60 feet below water line and processed millions of cubic yards of soil and gravel. In its wake were left tailings piles with large cobbles on top, lining

Figure 1-2

Historic Map of Scott Valley

N ov. 12, 1852



the Scott River for about 5 miles below Callahan.

Timber Harvest History

Timber was originally needed for mining as well as for building purposes. Several sawmills were built in Scott Valley in 1852 and 1860, with 11 mills sawing 3.5 million board feet per year by 1880. These mills were primarily located in Fort Jones, Etna, French Creek, and Kidder Creek (Wells, 1881).

One of the first major roads into the "DG country" was built in 1933-34 by the California Conservation Corps, extending north to south across the upper French, Sugar, and Wildcat Creek drainages and ending up in the South Fork sub-basin. Today this unsurfaced road is referred by most as the "High C" or "C's" road. This access road provided the first opportunity for logging the higher elevations, which were still not entered until the late 1950s according to U.S. Forest Service records.

Logging began more intensively after World War II. In the 1950s, Scott Valley's sawmill industry provided a substantial source of local income, with four mills cutting 40,000 or more board feet per day, and about 9 mills cutting 5,000 or more board feet per day (Mack, 1958). Timber harvest history data is presented and discussed in Chapter 2.

Fire History

Very little information about fire history is available. Although lightening-caused fires are fairly frequent in the mountains, extensive fires are not common in the study area as little volatile brush is present on the west side of the Scott Valley.

The local California Dept. of Forestry office does not map past fires or keep any historical records. The only available data comes from a retired fire control officer from the Klamath National Forest, who personally recorded and published a fire history of Siskiyou County (Morford, 1984). A large map indicating the year of the largest fires was also prepared and can be seen at the County Museum in Yreka. From his book comes the following list of large fires in the study area of Scott Valley:

Year	Location (Township/Range/Section)	Acres Burned
1955	Kidder Creek - 42N/lOW:7	14,562
1954	Sugar Creek - 40N/9W:ll	466
1940	Etna Creek - 42N/9W:22 (41N?)	260
1924	Crystal Creek - 42N/9W:5	8,900
	Etna Creek - 42N/lOW:32	160
	Kidder Creek - 42N/lOW:15,22	600

By far the largest fire of record was the 1955 Kidder Creek fire, which occurred only a few months before the disastrous December 1955 flood. Adjacent portions of the Patterson Creek drainage were also burned at that time. The massive fires of 1987 did not burn any significant acreage in the upper Scott River watershed.

Stream Channel Modifications

In addition to the beavers and mining, other human activities have altered the original stream channel shape, size and location. Chapter 3 provides an extensive discussion of stream channel changes.

Water Use History

Hay cutting and cattle grazing began in 1851 in Scott Valley to support the miners (Wells, 1881). Stream diversions to irrigate pastures and crops also began early. Pumping of ground water now supplements surface water sources. Water rights to Scott River surface water were adjudicated by the State of California in 1980. In 1988, the estimated agricultural water demand in the Scott Valley was about 96,400 acre-feet on 34,100 irrigated acres (C. Ferchaud, CDWR, pers. comm.).

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CHAPTER 2

UPLAND SEDIMENT SOURCES

Introduction

Objective: To identify and estimate the relative importance of upland sources of granitic sediment affecting the Scott River within Scott Valley.

A granitic watershed's response to land use activities is very different and sometimes unique compared to watersheds of other geologic types. Soils developed from granitics are recognized as some of the most erodible and natural erosion occurs continuously at a higher rate compared to most other soils (Anderson, 1976, for example).

Because of the preliminary nature of this study the emphasis was kept to use of existing databases, aerial photoanalysis, and limited field activity to derive results. Results are reasonable estimates rather than statistically precise measures.

Components of the Natural System That Impact Erosion Rates

The following components of the natural environment control erosion rates in specific ways that are not always well understood.

Weather

Precipitation patterns. Precipitation averages are important in assessing erosion for the following reasons: 1) They reflect the potential for overland flow and runoff given equivalent slope conditions: 2) When viewed in relation to average temperatures, they represent the potential for natural cover on the landscape; 3) Despite the importance of episodic climatic events dominating the timing of sedimentation into stream channels, mean annual precipitation has been shown to be a relatively precise indicator of climatic stress on sedimentation in Northern California (Anderson, 1976); and 4) Precipitation averages tend to parallel rainfall intensities, which have a more direct impact on erosion rate.

A measure of short duration precipitation intensity is the two-year, six-hour level of rainfall, which in our study area ranges from 0.95 inches at Ft. Jones (1944-1983 records, Dept. of Water Resources, 1986) to about 3.0 inches at the highest elevatio and McDonough, 1976).

Rain-snow relationships. The relative percentage of rain versus snow for different portions of the watershed affects erosion rates. Snow will be generally protective of the soil surface from rain, wind and dry ravel erosion, but rapid melting can increase erosion. Snowmelt can increase, decrease or delay peak flows (Harr, 1981; Harr and McCorison, 1979), depending on interacting climatic patterns, aspect, and antecedent watershed conditions. It can also affect how water is routed to stream channels. On south-facing slopes in forest openings, either natural or the result of timber harvest, the formation of density layers in the snowpack can cause delivery of water downslope into channels rather than vertically into the soil profile (Smith 1974, 1979).

Forest openings affect the rate of snowmelt, hence the volume and pattern of peak flows. Sediment yields triggered by snowmelt from logging treads on granitic roads in the Idaho Batholith were less than yields triggered by rainfall by several orders of magnitude (Vincent, 1982).

On the whole it is believed that snowpack at the higher elevations in our study area decreases the potential for erosion, except during rain-on-snow events which trigger large runoffs such as occurred during the 1964 flood. In a study by Anderson (1976), when rain-snow relationships are considered with using mean annual precipitation values in Northern California, an increase in precipitation by a factor of three produces only a 36 percent increase in reservoir deposition. Based on data from this same work, snow comprises about 17 percent of total precipitation at 3500 ft. elevations at the latitude of our study area, 30 percent at 4500 ft., 48 percent at 5500 feet, and 68 percent at 6500 feet.

Topography and Hydrology as They Impact Upslope Sedimentation

Granitic landscapes are generally shaped by differential weathering, glaciation and surface processes such as shallow debris slides and dry creep (or ravel). Stream action, earthflows and slumps are typically less important than in other geologic types (Seidelman, 1984, Baldwin and de la Fuente, 1987). Landscape patterns such as slope steepness, aspect, elevation and drainage density differentially affect rates of sedimentation. These elements are discussed separately below.

Slope. In equivalent climates, steep slopes can dominate erosion rates, as soil loss increases much more rapidly than runoff with slope. The angle of repose for granitic rock decreases as it decomposes (Durgin, 1977), and is determined to be about 35 degrees (70 percent) for DG soils (Lumb, 1962; Gray and Megahan, 1981). Studies have shown an increase in the occurrence of debris slides above this angle up to 42 degrees (90 percent) (Megahan, 1978). Steeper slopes tend to be bedrock and not prone to these superficial slides. Seidelman (1984) suggests that slopes over 30 degrees (60 percent) be considered sensitive in weathered granitic terrain. Such slopes are often anchored by tree roots, so are quite vulnerable to timber harvest disturbance.

Only about two percent of the slopes on DG in the Scott River watershed are mapped at gradients of between 60 and 90 percent (at a resolution of 1.6 acres). This does not include road cuts, cliffs, steep inner gorges and channel sides which are averaged with gentler slopes so do not show up at this elevation model resolution. In effect, there is considerably more area with 60 to 90 percent slope than is found on the map.

Aspect. Aspect plays a role in erosion rates. Prevailing winds during storms cause more precipitation to fall on south and west exposures. Runoff and erosion are higher due to more rainfall and less *cover* because these aspects also dry faster and have thinner soils. Warmer exposures are more affected by freeze-thaw cycles than cooler aspects, although amount of ground cover can complicate this pattern.

Twenty-four percent of the DG area in the Scott River watershed faces between south and west.

Elevation. DG soils at the upper elevations are more erodible because of coarse grain sizes more typical there. Physical weathering predominates at these elevations because of cooler temperatures, whereas chemical weathering, clay formation and flood flows are maximized at intermediate elevations so higher sedimentation rates occur there (Anderson, 1976). Higher elevations also have more snowpack protection, and more slope and streambed armoring by granitic boulders. Depth to bedrock also plays a role as debris slides are more common in granitic soil more than two feet deep (Wilson and Hicks, 1975). The mid-elevations are more eroded despite higher percentages of silt and clay and deeper soil development. This phenomenon is noticeable in the Study Area and has been documented by Colwell (1979) in the Sierras. The lower elevations (less than 3000 feet) have less erosion hazard due to lower rainfall and gentler slopes. Geomorphology (stable versus unstable landforms) can complicate elevation patterns of soil development (Tom Laurent, Klamath National Forest, pers. comm.).

Drainaae pattern Table 2-l shows the major subwatersheds of the Study Area, their total area and proportion underlaid by granitic soils. Table 2-2 is a descriptive summary of drainage patterns by watershed. Figure 2-l depicts Study Area hydrology with watershed boundaries in black and the streams color-coded by their order. Streams were ordered based on those mapped on recent USGS 7-1/2' topographic quadrangles, using the stream order classification of Strahler (1957). The blue-line streams highest in the watershed were considered first order. We did not infer unmapped first-order streams as described by Goudie (1981).

Table 2-1. Major subwatersheds of the western Scott River watershed, their total areas and proportions underlaid by granitic soils. The granitic Study Area is about 89 square miles.

Watershed	Total Area (Acres)	Granitic Terrain (Acres)	% of Watershed in DG	% of all DG
Shackleford/Mill	31869	2104	7	4
Kidder/Patterson	39919	3311	8	6
Crystal	2316	1886	81	3
Johnson	4394	843	19	1
Mill/Etna	17399	6495	37	11
Clark	3247	1007	31	2
French	20584	12984	63	23
Sugar	8149	5929	73	10
Wildcat	5074	1418	28	2
South Fork	15115	6600	44	12
Fox	4605	2857	62	5
Boulder	7992	6552	82	12
Little/Big Mill	5876	3138	53	6
East Fork	46686	527	1	1
"Callahan"	2307	1230	53	2
TOTALS	215532	56881	26	100

Table 2-2. Descriptive summary of watershed drainage patterns.

	Entire Watershed			Granitic Portion of Watershed						
Watershed	Drainage Density (Mi./Sq. Mi.)	Length of All Streams (Miles)	Length of Ditches (Miles)	Length of DG Streams (Miles)	Order 1 Streams (Miles)	Order 2 Streams (Miles)	Order 3 Streams (Miles)	Order 4 Streams (Miles)	Order 5 Streams (Miles)	Length of Ditches (Miles)
Shackleford/Mill	2.3	116.0	16.6	5.4	2.5	1.4	1.5		-	
Kidder/Patterson	2.5	156.0	20.3	8.7	5.2	1.8	1.7		-	
Crystal	1.7	6.1		1.8	1.1	0.7			-	
Johnson	2.9	19.6	5.4	1.7	1.0	0.7			-	
Mill/Etna	2.1	56.6	5.5	10.8	6.0	2.5	0.4	1.9	-	
Clark	2.5	12.5	Lt.7	1.3	1.3				-	
French	3.1	100.0	20.6	33.7	16.9	7.9	6.3	0.2	-	2.4
Sugar	3.5	44.0	15.7	14.0	6.4	1.6	2.0	2.2	-	1.8
Wildcat	3.2	25.2	8.2	3.0	2.1	0.5			-	0.4
South Fork	2.4	57.6	10.7	19.2	9.1	3.6	1.9	1.1	1.4	2.1
Fox	1.8	13.3	0.6	5.6	2.6	1.1	1.5		-	0.4
Boulder	2.1	26.1	0.7	13.6	7.0	3.3	3.3		-	
Little/Big Mill	2.2	20.5		6.6	3.7	2.9			-	
East Fork	2.0	144.0	30.7	1.4	0.8	0.6			-	
'Callahan"	3,3.1l	11.2	2.8	2.1	1.9	0.2			-	
Totals		809	183	129	68	29	19	5	1	7

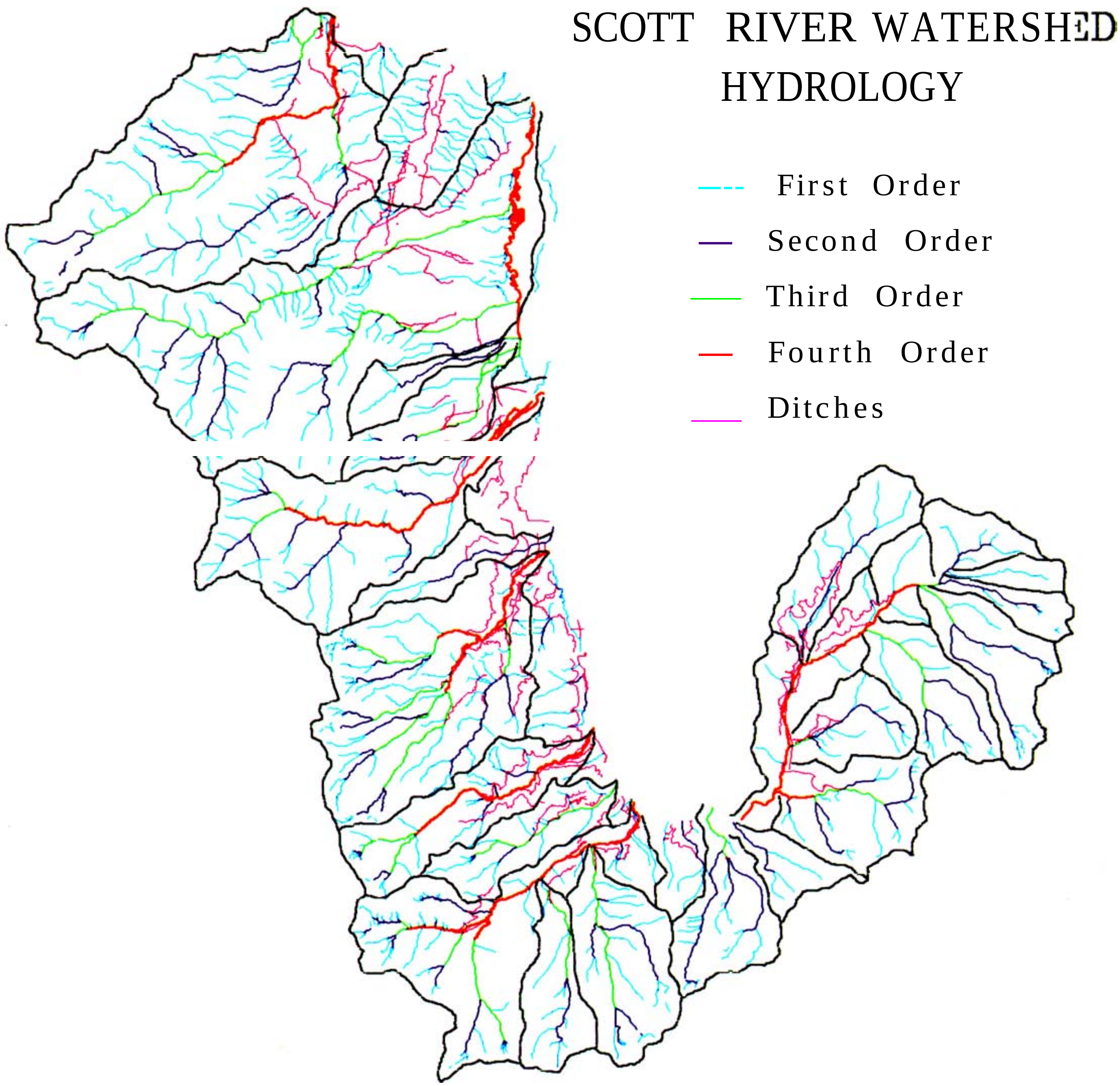

SCOTT RIVER WATERSHED
HYDROLOGY
First Order
Second Order
Third Order
Fourth Order
Ditches

Figure 2-1

The steep, narrow canyons that typically dissect the Study Area facilitate the movement of soil particles into the stream system. Silt-sized particles and organic debris are expected to move constantly through the system and come from throughout the watershed. Sand-sized and larger particles are washed from roads and other sources and stored as lag deposits in swales and low-order channels until the larger storms can flush the system. This process of colluvial sediment storage and periodic flushing is evident in the Scott River watershed; It has been identified elsewhere by others and noted as the source of episodic sediment pulses (Pillsbury, 1976; Dietrich and Dunne, 1978; Dietrich et al., 1982; Tsukamoto et al., 1982; Costa, 1984; Dietrich and Dorn, 1984; Rolle et al., 1987; and USDA-Forest Service, 1990).

Also recognized by some workers in granitic terrain are high streambank erosion rates due partly to the erodibility of the coarse grain sizes and partly to the development of "stepped," alluviated reaches in between areas of bedrock (Wahrhaftig, 1965; California Resources Agency, 1969; Seidelman, 1984). Transport capacity is reduced in the alluvial reaches. Low gradient, alluvial reaches vegetated with willows and alders are evident in larger Study Area watersheds below sites of serious, upper streambank erosion created by the 1964 flood, probably caused by debris torrents in the low-order, well-armored channels (see Pierson, 1977, for a discussion of debris torrents). These are clearly sites of long-term storage. Seidelman also believes aggradation in granitic streambeds to be temporary and localized, due to the predominance of sand-sized material that is relatively easily moved.

Finally, Seidelman (1984) has observed **the** lack of interaction between soil disturbance, including inner gorge debris slides, and high stream flows in granitic terrain compared to other geologic types. He suggests that fish habitat and reservoir storage are reduced in direct proportion to volume of sediment deposited into streams (rather than a synergistic or cumulative relationship). He concludes that "it is likely that the most significant stream flow effect of soil disturbance is the interception of subsurface flow by roads incised into bedrock," instead of any effect on peak flows. This phenomenon associated with granitic roads is discussed more thoroughly later in this report.

Soils

Soils for the Study Area were mapped by the Soil Conservation Service on private land (USDA-SCS, 1983) and the U.S. Forest Service on public land (USDA-FS, 1982). The classification systems differ somewhat between the agencies, as can be seen in Table 2-3, where soil types, their erosion hazard ratings and acreages are listed. (The Forest Service classified soils to the family level, while the Soil Conservation Service used the series level.) The soil surveys' delineation of soils is different in some locations than that of granitic geology defined on the smaller scale, USGS Weed quadrangle geology map (1:250,000) (Wagner, 1987). Discrepancies are evident on the map, Figure 2-2.

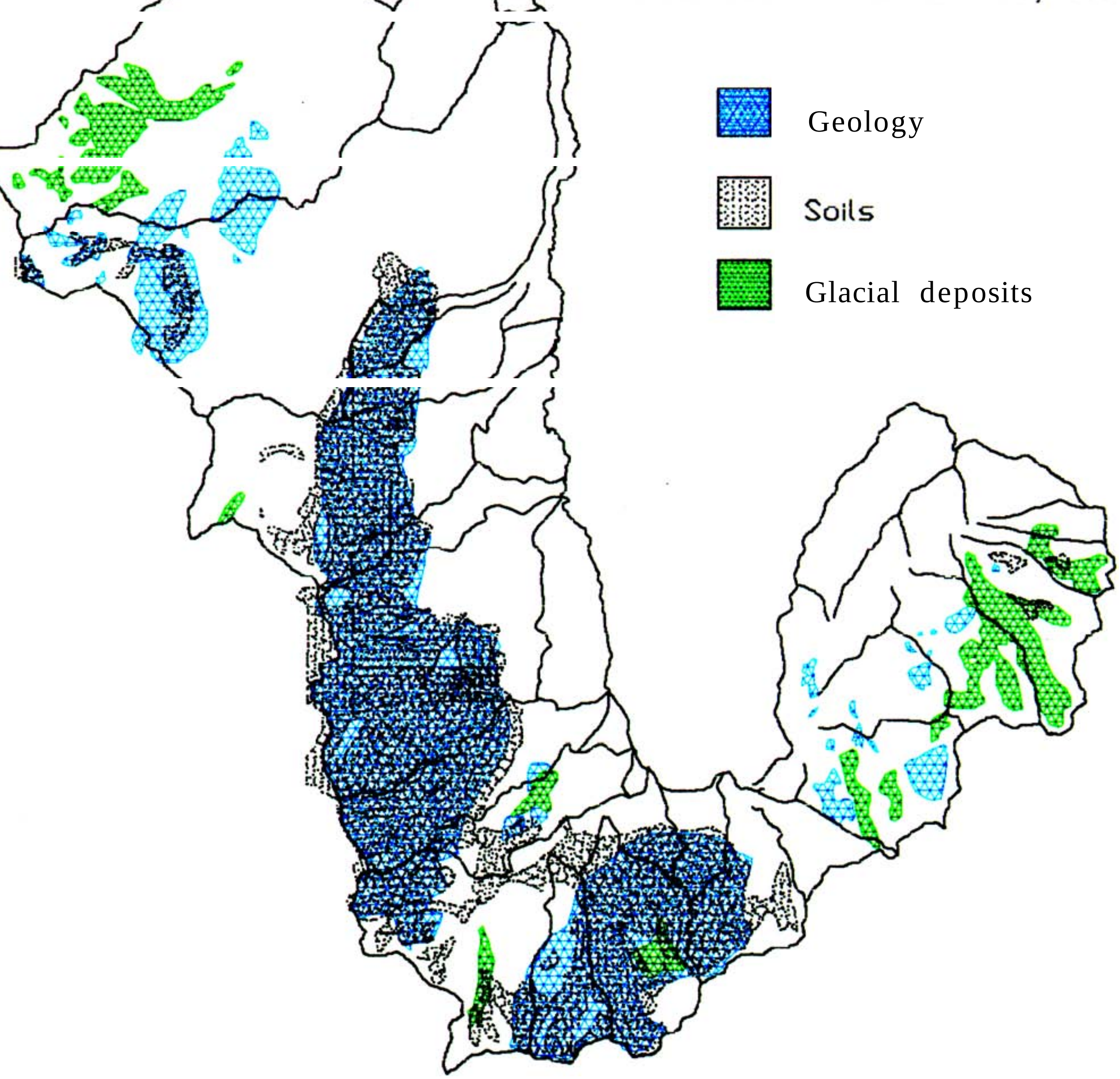
Table 2-3. Granitic soil types of the Study Area from the Soil Conservation Service and Forest Servoce surveys, their erosion hazard ratinas and acreages.

Map **Code**	Soil Type	Percent Slope	Erosion Hazard	Acres
U.S.	Forest Service survey:			
124	Entic Xerumbrepts-Gerle	30-90	high	3388
127	Gerle-Entic Xerumbrepts	50-90	high	11073
128	Gilligan-Chawanakee	30-90	high	3549
130	Gilligan-Holland	15-70	high	8356
162	Lithic Xerumbrepts-Rock Outcrop	15-90	high	421
165	Nanny (glacial till)	2-30	moderate	5267
166	Nanny (glacial till)	30-50	moderate	6261
189	Teewinot-Endlich	50-90	very high	11572
U.S.	Soil Conservation Service survey:			
119	Chaix-Chawanakee gravelly coarse sandy loam	5-30	mod.-high	693
120	Chaix-Chawanakee gravelly coarse sandy loam	30-50	high	4222
121	Chaix-Chawanakee gravelly coarse sandy loam	50-70	very high	8280

The parent material of these soil types ranges in composition from "hard granitic rock" to "soft, disintegrated decomposed granitic rock." Rock composition ranges from coarse-grained quartz monzonite to diorite. Soil depth typically ranges from less than 10 inches on the Chawanakee and Teewinot, to more than 60 inches on glacial till or the more developed Holland type. Surface textures range from loam to very gravelly sandy loam, with most soils in the gravelly sandy loam category. The Chawanakee surface layer is less than four inches deep (one inch in the Forest Service survey). Subsoils have a greater range in texture depending on their development, from gravelly clay loams of Goldridge and Holland types, to the gravelly loamy sands of Nanny and Entic Xerumbrepts. The Teewinot soil lacks a subsoil. Chawanakee has the highest proportion of rock outcrop, typically about 25 percent of ground cover.

SCOTT RIVER WATERSHED

GRANITIC GEOLOGY/SOILS



Geology and Hydrology

Soils derived from granitics are widely agreed to be some of the most erodible of any rock type. In a northern California study based on surface aggregation ratio as a measure of erodibility, soils developed from acid igneous (granitic) rock were found to be two and one-half times more erodible than basalt (Andre and Anderson, 1961). They also produced three and one-half times more sediment to reservoirs than soils from other parent materials (Anderson, 1976).

Importance of subsurface hydrology. The most important hydrologic process affecting erosion in DG soils is the subsurface, lateral flow of water at the saprolite-bedrock interface. When these flows are intercepted by forest roads the hydrology of the entire watershed can be affected. The road concentrates the water, diverting it onto fill slopes and from one stream channel to another. Overloaded channels will respond to the increased flows with what can be serious streambank erosion or downcutting, while fill slopes may gully or slough. Megahan (1972) believes this process increases total runoff volume from a watershed, but may not affect peak flows depending on how the excess is re-directed through the watershed. In his study, a single road located at the lower end of a watershed intercepted 35 percent of subsurface flows, resulting in runoff 7.3 times the direct runoff from roads.

Differences in stage of decomposition. An important characteristic of granitic soils is the stage of bedrock decomposition, as this affects the quantity and grain size of material available for transport. An entire spectrum of granitic weathering can occur among regions or even on the same slope. One area can have unweathered rock high on a slope to deep soils with well-developed, clay-rich subsoils on the sideslopes and toe (Durgin, 1977). Such progressions have been observed in the English Peak batholith of the Klamath Mountains (Rice et al. 1985) and is noteworthy in our Study Area with, for example, the Holland soil type when it occurs near slope toes, alluvial fans or stable landforms. Influencing the rate of parent rock decomposition are mineralogy, rock texture, porosity,fractures and joint structure. Of the four main minerals involved (quartz, biotite, plagioclase and orthoclase), biotite and plagioclase dominate the erosion process. Locally, the granodiorite is about 15 to 20 percent biotite and 60 percent sodic plagioclase (Mack, 1958). They expand by hydrolysis and oxidation, disintegrating into gruss and then sands, loamy sands or sandy loams. The quartz component remains unchanged except for disaggregation. This process occurs easiest when the minerals are in contact with soil water solutions in the zone of soil aeration (Ruxton and Berry, 1957; Durgin, 1977).

Within the soil profile, exposed portions of the granitic substrate that are wet only seasonally erode very slowly. Below this, typically, is a zone of weathered granite where chemical weathering predominates and more than 85 percent of the rock is weathered. Deeper is disintegrated granite where physical weathering predominates, then bedrock (Durgin, 1977; Rolle et al. 1987). It is in the zone of chemical weathering in the soil profile and intermediate weathering with respect to the stage of decomposition (such gradations as can be seen on slopes or by elevation) where erosion activity is maximized.

In general, differences in bedrock weathering are probably overshadowed by differences in precipitation pattern, slope steepness and internal soil drainage. This conclusion has been reached by Clayton et al. (1979) in the Idaho batholith and Seidelman (1984) for the Sierra Nevada.

Surface processes. Under unburned, natural conditions, overland flow is not important compared to other erosive processes in DG terrain because of high permeability, good ground cover and the need for rapid, turbulent flow to carry the large grain sizes (Bloom, 1978). However, forest fires, road building and log skidding are activities that facilitate concentration of flows and currents in the sheetwash, hence of rills, gullies and ephemeral channels. Burned and other disturbed sites in the Scott River area frequently show evidence of turbulent, concentrated flow. However, the soil's non-cohesive grains tend to fall in on themselves (dry ravel) after some time, often erasing the tell-tale signs of these processes. Dry ravel or creep of loose particles can be an important surface process in DG soils. In an Idaho study (Megahan, 1978), it was found to increase the rate of soil loss by an order of magnitude and constitute 15 percent of total loss. In the Study Area significant amounts of soil have been observed to be dislodged and moved off-slope by rainsplash on disturbed sites during even mild summer storms.

Important to surface erosion processes in DG are organic matter and clay contents. Whereas clay acts as the primary binding agent in the soil, organic matter is more important in protecting the soil surface. Both are important to soil fertility and water-holding capacity. Both are selectively removed by surface erosion. For most soils, erodibility increases when organic matter decreases. For sandy soils, however, the opposite is true within the soil profile (Fink, 1970; Meeuwig, 1971). Components of the organic matter (fungal hyphae at high elevations (Tom Laurent, Klamath National Forest, pers. comm.)) coat the sand grains, making them hydrophobic and more easily disaggregated and moved off slope. This is thought to be a major limiting factor in the capacity of Sierra Nevada DG soils to absorb high-intensity summer rains (Meeuwig, 1971; Colwell, 1979; Seidelman, 1984). It has also been reported in the Shasta-Trinity National Forest (Holcomb et al. 1990). This water repellancy occurs with dry soil. When the sun dries out the soil surface between storms (and the air temnerature is warm), water repellancy returns. These conditions are most common in the Spring and Fall (Tom Laurent, Klamath National

Forest, pers. comm.). The higher the clay fraction of the soil, the less this is a problem as the organic matter will preferentially bond with the clay, leaving less to bond with the sand. Apparently, enough litter and duff must be maintained on DG soils to protect the soil surface, but large amounts in the soil profile can become detrimental.

Slumps, earthflows, and large rotational slides are not important processes in Scott River granitics or elsewhere in granitic terrain (Megahan, 1974, Baldwin and de la Fuente, 1987). (They are important in coastal areas to the west.) Both natural and use-related slides occurring in soil material above bedrock are common, as has been observed in other DG areas (Durgin, 1977; Gray and Megahan, 1981; Rolle et al., 1987). However, Scott River debris slides are apparently less common than in neighboring granitic terrain such as the Little North Fork of the Salmon River (Jay Power, Klamath National Forest, pers. comm.). This may be due to lower rainfall.

These shallow debris slides are important because they become avalanches and sometimes debris torrents during periods of high rainfall. A debris torrent mobilizes much more material than the volume of the original slide and hence is truly a "cumulative" impact (Juan de la Fuente, Klamath National Forest, pers. comm.). In the Study Area debris slides are the major component of stream upper bank erosion, and an important process in roadbank erosion (dry ravel is thought to be the primary mechanism on roads except for at stream crossings and fill failures). In some studies these slides were found to be responsible for much of the sand and larger particles delivered to reservoirs (e.g. Rolle et al., 1987) from roads and low-order channels (Costa, 1984). This process needs further evaluation in the Scott River area than could be provided by this study. Debris slide activity is affected by any increase in peak subsurface flows (which can be caused by timber harvest as it affects vegetative controls on soil moisture levels), a decrease in surface root density (also affected by timber harvest), or slope changes such as occur with road building.

Vegetative Cover and the Effects of Land Use

<u>Native cover and erosion conditions</u>. Native vegetation on granitic terrain in the Scott River area is mainly mixed conifers, including Ponderosa pine, Douglas fir, white fir, sugar pine and incense cedar. At the higher elevations there is also mountain hemlock, red fir and western white pine. Hardwoods include madrone, black oak, canyon live oak, tanoak, hazelnut and dogwood. Understory vegetation may include any of the following: pinemat manzanita, chinquapin, greenleaf manzanita, snowbrush, deerbrush, rose, currant, whiteleaf manzanita, thinleaf huckleberry, huckleberry oak, phlox, sunflower family, pink family, Adders tongue, stonecrop, Pacific trillium or swordfern.

Vegetative cover protects slopes from soil loss by intercepting incoming precipitation, and then controlling soil moisture levels through transpiration and regulation of snow accumulation and melt rates. Tree roots add cohesion to granitic soils, and along with trunks anchor slopes beyond what could be supported based on soil structure alone (Anderson, 1970; Gray and Megahan, 1981; Megahan and King, 1985). Roots can provide up to 80 percent of the soil shear strength in a saturated soil (O'Loughlin and Watson, 1981). An example in the Study Area of inner gorge debris flows on steep slopes possibly caused by the removal of anchoring vegetation is just below the intersection of Sugar Creek with the "High CC" road, on the north-facing bank. Additionally, vegetation provides ground cover and catchments for soil moving downslope.

There are differences in DG soil erodibility under a range of vegetation types, although these differences are probably minor in the big picture of sediment impacts on fisheries. Such differences are due to differential root distribution, plant secretions, chemical make-up of decomposition products, and volume of annual litter (Wallis and Willen, 1963).

Conditions under loaaing The predominant land use activity in the Study Area with respect to sediment production is timber harvest. Most roads in the area were built for and continue to be mainly used for hauling timber. The impacts of roads and timber harvest on granitic terrain hydrology is not as well understood as in other geologic types, especially the ability of a granitic watershed to recover from such disturbance. No paired watershed studies are available to document these effects in the Klamath Mountain batholiths.

If logging activity is considered apart from road building, effects on sediment yield are important but frequently minor in comparison to other sources, especially roads. Impacts are minimized by high soil permeability and possibly a high proportion of precipitation as snow. Harvest impacts on granitic soils may become serious, however, depending on how the harvest area and skid trails relate to bedrock outcrops, streams, and compacted areas such as roads and landings and ephemeral draws. Increases in soil loss due to logging usually are at least an order of magnitude less than that from roads, and are typically a single order of magnitude or less above background loss rates. For example, Megahan et al. (1978) reported a 50 percent higher erosion rate off of treeless plots than those with seedling trees.

The most important effect of logging on DG soils has to do with how it can change subsurface hydrology. The importance of vegetative cover for stabilizing granitic soils has already been discussed. Tree harvest results in an increase in soil moisture storage during the growing season. This causes a rise in small stormflow peaks, but not those of large storms (Seidelman, 1984).

Further effects include reduced infiltration capacity due to compaction, increased channeling of flows on bared soil (especially skid trails), weakening of slopes anchored by vegetative material and changes in snow melt relationships in openings. These impacts are probably greatest on southwest exposures. All of these factors can increase debris slide activity especially on slopes supporting heavy timber stands (Rice et al. 1985). There may be a lag before this activity shows up depending on the rate of root decay versus new root growth--the slide hazard peaks two to ten years after disturbance on granitics (Nakano, 1971).

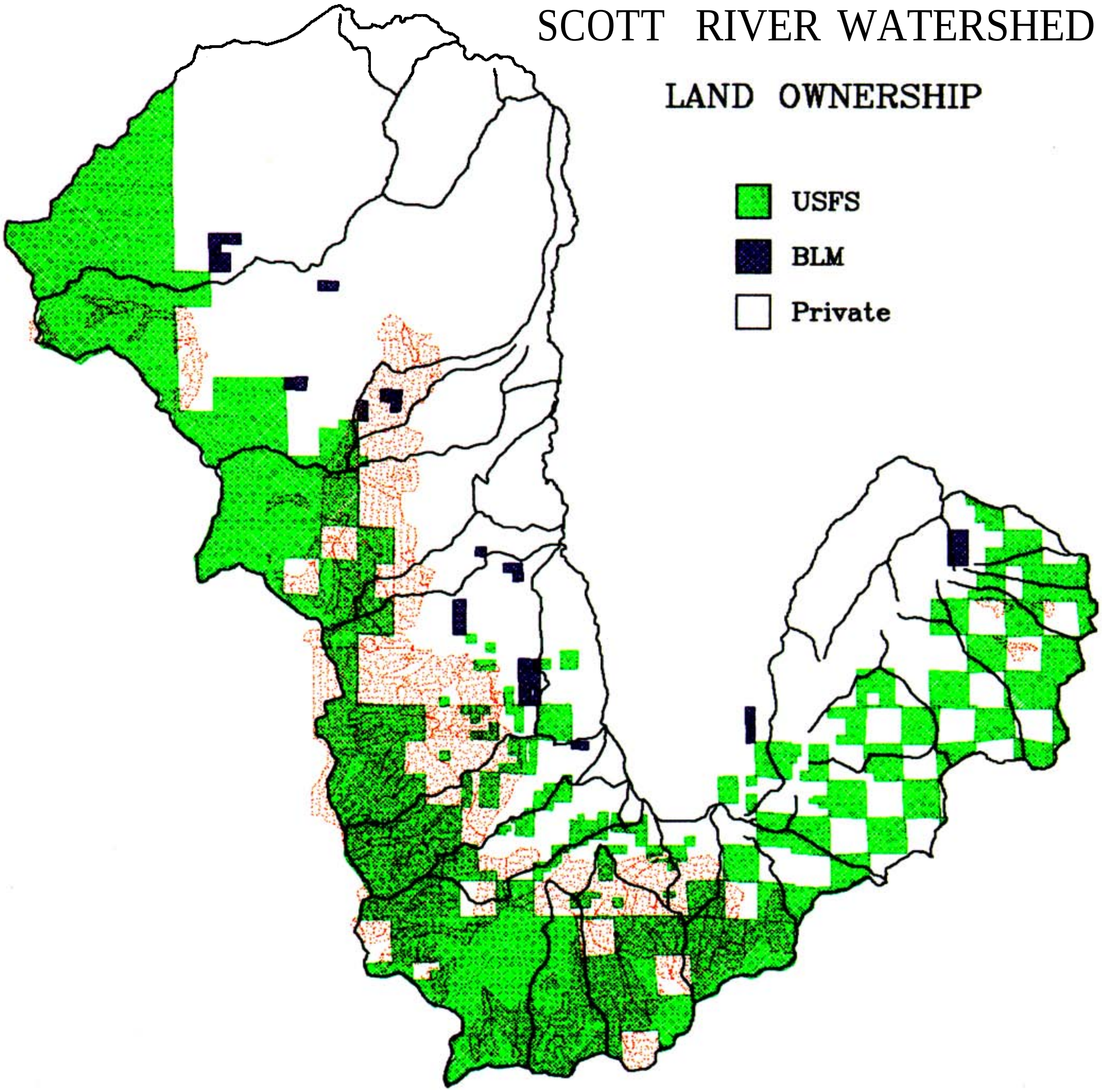
Method of harvest. Soil loss with respect to method of harvest is directly related to the amount of soil disturbed and bared by harvest activity, especially the density of skid trails and roads required to access the timber. Megahan (1981) found tractor logging on granitics to result in 28 percent of the soil disturbed, ground cables with 23 percent, suspended cables with five percent and helicopter logging with two percent. Similarly, Swanston and Dyrness (1973) found tractor yarding in granitics to result in 35.1 percent bare soil, hi-lead in 14.8 percent and skyline in 12.8 percent. In a Trinity County study on mixed soil types, skid trails averaged four to eight percent (6-12 km/sq.km) for clearcut areas (Scott et al., 1980). Contrary to public opinion, clearcutting may be less damaging to the soil resource than other harvest methods because of lower road and skid trail densities. We estimate from aerial photos that in the Study Area about eight percent of the area harvested is in roads and skid trails.

Table 2-4 shows total acres harvested by watershed and by ownership in our Study Area. Number of acres harvested is based on a compilation of California Department of Forestry; BLM and U.S. Forest Service records. The areas described are conservative because records of timber harvests were not available from before 1958 on public land, and before 1974 on private land. Thirty-two percent of all DG acreage has been harvested. Figure 2-3 depicts areas of public and private land in relation to soils derived from granitics.

Table 2-4. Total acres harvested on DG soils by watershed and percent of all DG harvested by ownership. Data are from 1958-1988 for public lands, 1974-present for private lands. If a site was re-entered, only the most-recent acreage is included.

Watershed	DG Acres Harvested	DG Acres Unharvested	Percent Harvested Private	Percent Harvested Public
Shackleford/Mill	0	2104	0	0
Kidder/Patterson	792	2519	94	6
Crystal	1501	385	78	22
Johnson	460	383	97	3
Mill/Etna	2083	4412	88	12
Clark	30	976	100	0
French	6260	6724	76	24
Sugar	2007	3923	64	36
Wildcat	553	865	29	71
South Fork	2688	3912	46	54
Fox	2229	628	46	54
Boulder	2519	4034	40	60
Little/Big Mill	416	2721	69	31
East Fork	312	215	72	28
"Callahan"	337	894	68	32
TOTAL	22187	34695	66	34

Roads. Many studies on all soil types identify road construction as the largest source of accelerated sedimentation in forest streams (for example, U.S. Environmental Protection Agency, 1975). Roads intercept and divert subsurface flows, as well as concentrate and channelize surface runoff. In a study of forest soils around the Sacramento Valley basin, road-induced mass wasting was the largest source of erosion and sedimentation. Average losses were 80 tons/acre/year off the road prism, with 50 tons/acre/year going to streams (USDA-Forest Service, 1983). Two miles of road in a granitic watershed produced almost twice the sediment yield as 14 nearby watersheds that were undisturbed in Idaho (Megahan, 1971). In Trinity County's Grass Valley Creek, roads represent about six percent of the area disturbed but produced about half of the sediment due to logging (USDA-Soil Conservation Service, 1986). Fine sediment (less than 0.85mm) accumulated in basins above natural levels when the roaded area reached 3.0 percent of the (non-granitic) watershed area. A watershed with about four percent roaded area increased sedimentation four-fold over the background rate, and a watershed with four to seven percent roaded area produced 15 to 23 percent fines in channels versus 10 percent in the background condition (Cedarholm et al., 1982). Traffic alone can increase sedimentation on roads. Any traffic will likely double sedimentation on haul


SCOTT RIVER WATERSHED
LAND OWNERSHIP
USFS
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roads. Heavy use increased sedimentation 130-fold over an abandoned road in non-granitic terrain (Reid and Dunne, 1984).

Despite the volume of data relating high rates of erosion to forest roads, Seidelman (1984) cautions against making conclusions about how this relates to watershed hydrology and sedimentation rates from one region to another. He contrasts the work in the Caspar Creek watershed in the California redwoods (Rice et al., 1979) with Coyote Creek in southern Oregon (Harr et al. 1979). In Caspar Creek with 15 percent of the area in roads, skid trails and landings, there was no related increase in large stormflow peaks. In Coyote Creek, with similar levels of disturbance, these peaks were increased. He concludes that information on processes can be transferred among regions, such as the mechanism of road interception of subsurface flows, but not on their secondary effects.

Finally, historic aerial photos show most existing logging roads below the High **cc** road to be in place by the mid-1960%. Roads above the High CC became commonplace starting in the early 1970's.

Methods

Approach Selected and Definitions

Field inventories and construction of sediment budgets are the most widely accepted means of organizing data on erosion, sediment yield, and general health of watersheds. However, there is no universally accepted methodology for estimating and measuring the variables affecting erosion and sedimentation. Sediment models useful in the field lag far behind theoretical understanding, and there are many gaps in the theory. For this reason, we selected methods that focus on relative values rather than fixed numerical results, and that allow easy recalculation of results as better data become available or as conditions change.

The multi-staged approach selected to assess erosion and sedimentation in the Study Area includes field work, aerial photointerpretation, and use of a geographical information system (GIS) for Study Area stratification, data extrapolation, and soil erosion and sediment modeling. The GIS helped organize the data pertinent to the erosion problem from various maps, and was a tool for analyzing sets of layer, polygon and attribute resource data, such as topography, geology, soils, vegetation and land use. Soil erosion modeling was conducted with the GIS and with specialized data bases developed for the purpose. This approach to evaluating soil erosion is becoming more common (Pelletier, 1985; Snell, 1985;

Hessron and Shanhotez, 1988; Prato et al. 1989).

Some definitions applicable to this report are appropriate before discussing methods in more detail. **Weathering** involves processes that affect the stage of decomposition of bedrock and parent material. Physical or chemical weathering may dominate the breakdown of granitic rock depending on elevation and position in the soil profile. **Soil erodibility** has to do with site-specific physical, chemical, topographic and environmental variables that affect how easily soil particles are dislocated off a slope. **Soil erosion** is defined as the amount of soil loss by raindrop or runoff from a particular slope. **Sheet and rill erosion** is a result of raindrop impact and surface water flows in sheets or rills. **Channel erosion** is a result of concentrated flows in gullies or streams. **Sediment yield** is the amount of soil erosion delivered to a watercourse. Only a portion of soil eroded off a slope is actually delivered to streams, so sediment yield is most directly related to water quality and riparian habitat changes, while erosion more directly affects site productivity.

Estimates of soil erosion and sediment yield are presented in average annual terms in this report. We recognize that this approach does not reflect the importance of on-slope storage and episodic events in the process of moving sediment into the stream systems. However, short-term values contain a randomness component that can be hard to evaluate. Average annual values are used for their ease of data availability given limited sampling time, ease of comparison to other study areas, and ease of comparison among various land use categories in a single study area. As mentioned earlier, mean annual climatic values have been shown to be relatively precise indicators of at least climate's effect on sedimentation in northern California (Anderson, 1976).

Procedure for Roads and Skid Trails

Soil loss from roads and skid trails involves sheet, rill, channel and subsurface flows. These losses were derived directly from the field by transecting road and skid trail samples, estimating the area voided by soil loss and extrapolating results to the entire watershed (Steffen, 1983). Length and height of voided areas were assessed directly, while lateral recession rates (depth per year) were estimated using the descriptive categories shown in Table 2-5 (after Steffen, 1983). After multiplying by the density of the granitic substrate (we used 100 lbs. per cubic foot), the result is in tons per year for the length of road sampled. This method tends to somewhat overestimate actual losses, so it is necessary to be conservative in the field (Lyle Steffen, Soil Conservation Service, pers. comm.). For road surface erosion, bare road was assumed to erode a minimum of five tons/acre/year, visible rills indicated a loss of about 10 tons/acre/year and a high density of rills indicated more than 10 tons/acre/year.

Table 2-5. Road cut and fill lateral recession rate categories and descriptions (after Steffen, 1983).

Lateral Recession Rate (ft/yr)	Category	Description
0.01-0.05	Slight	Some bare roadbanks but active erosion is not readily apparent. Some rills but no vegetative overhang. Ditch bottom is grass or noneroding.
0.06-0.15	Moderate	Roadbank is bare with obvious rills and some vegetative overhang. Minor erosion or sedimentation in ditch bottom.
0.16-0.30	Severe	Roasdbank is bare with rills approaching one foot in depth. Some gullies and overhanging vegetation. Active erosion and sedimentation in ditch bottom. Some fenceposts, tree roots or culverts eroding out.
0.30+	Very Severe	Roadbank is bare with gullies, washouts, and slips. Severe vegetative overhang. Fenceposts, powerlines, trees and culverts eroded out. Active erosion and sedimentation in ditch bottom.

Road surface erosion was the most difficult component of road erosion to evaluate because much judgment had to be used regarding maintenance patterns that affect visual evidence of soil movement. Main access roads such as the High CC and Blue Jay were assumed to have been graded annually. Most of these roads had been rocked within the last ten years (Jay Power, Klamath National Forest, pers. comm.). Secondary roads were generally assumed to have not been graded for at least a few years. An underestimate of maintenance activity would result in an underestimate of surface erosion on these roads.

Since the scope of this project did not allow us to get a statistical sample of roads for the Study Area, an effort was made to improve sampling precision by stratifying the area into uniform units by subwatershed, level of road use, and whether the road was paved, rocked or unsurfaced. Position of the road within the watershed and whether sampled sections were on private or public land were tracked. Also recorded were number of gullies and their voided area: number and condition of stream crossings, culverts and water diversion structures: sediment yield estimates; and comments on watershed cover conditions. On skid trails, the Universal Soil Loss Equation was run for every trail mapped using the slope from the digital elevation model and assuming 50 percent ground cover (based on field observations). This was to separate sheet and rill from other types of erosion. Data were extrapolated for each subwatershed using total length of skid trails and roads in each category calculated from the GIS.

Table 2-6 shows, by watershed, miles, area and density of roads. Table 2-7 depicts similar data for skid trails. Skid trails were mapped off of 1986 aerial photos (1:24,000 color IR stereo pairs) and digitized to arrive at lengths. The area in skid trails is quite conservative as those with 100 percent vegetative cover were not recorded. Average skid trail width was assumed to be ten feet (a conservation estimate based on field observations) to arrive at area in trails. Road lengths were digitized from U.S.G.S. 7-1/2 minute "preliminary" topographic quads based on early 1980's aerial photos and field checking. Estimates of area in roads are based on field data collected of road widths and heights of cuts and fills. Figure 2-4 depicts roads and skid trails.

Table 2-6. Road mileage, area, and density by watershed and by granitic portion of each watershed.

Watershed	Road miles	Road miles on granitics	Road acres	Road acres on granitics	Road density (ft/acre)	Density on granitics (ft/acre)	Density on granitics (mi/sq.mi)
Shackleford /Hill	153	10	764	48	25	31	3.7
Kidder/Patterson	155	13	773	67	21	13	1.6
Crystal	20	17	101	84	46	55	6.7
Johnson	31	11	155	56	38	45	5.6
Mill/Etna	75	29	372	142	23	26	3.2
Clark	20	5	100	23	33	29	3.6
French	119	74	594	367	31	29	3.5
Sugar	41	18	202	92	26	20	2.4
Wildcat	38	4	188	21	39	71	5.3
S. Fk. Scott	93	20	465	99	33	27	3.3
Fox	23	15	117	73	27	21	2.5
Boulder	50	42	251	209	33	38	4.7
Little/Big Hill	22	7	107	33	19	17	2.0
East Fk. Scott	175	14	102	69	20	39	4.8
"Callahan"	19	9	96	45	43	40	4.9
TOTALS	1034	288	4387	1428	25	27	3.2

Table 2-7. Skid trail mileage, area and density on granitic portion of each watershed.

Watershed	Skid trail miles on granitics	Skid trail acres on granitics	Density on granitics (ft/acre)	Density on granitics (mi/sq.mi.)
Shackleford/Mill	0	0	0	0
Kidder/Patterson	6.7	8.1	6.5	0.8
Crystal	3.3*	4.0*	10.9*	1.3*
Johnson	2.4	2.9	9.6	1.2
Mill/Etna	9.7	11.7	8.9	1.1
Clark	2.6	3.2	16.5	2.0
French	82.9	100.4	32.4	3.9
Sugar	25.4	30.7	27.0	3.3
Wildcat	2.1	2.6	21.2	2.7
S.Fk. Scott	8.0	9.7	10.8	1.3
Fox	0.2	0.28	0.33	.04
Boulder	25.9	31.4	23.6	2.9
Little/Big Mill	5.5	6.7	13.8	1.7
East Fk. Scott	9.3	11.2	26.0	3.2
"Callahan"	7.3	8.9	16.7	2.0
TOTALS	191	232	17.7	2.1

*Field sampling results show area currently with higher density of skid trails than other watersheds, but recent harvesting is not evident on 1986 aerial photos used for these data.

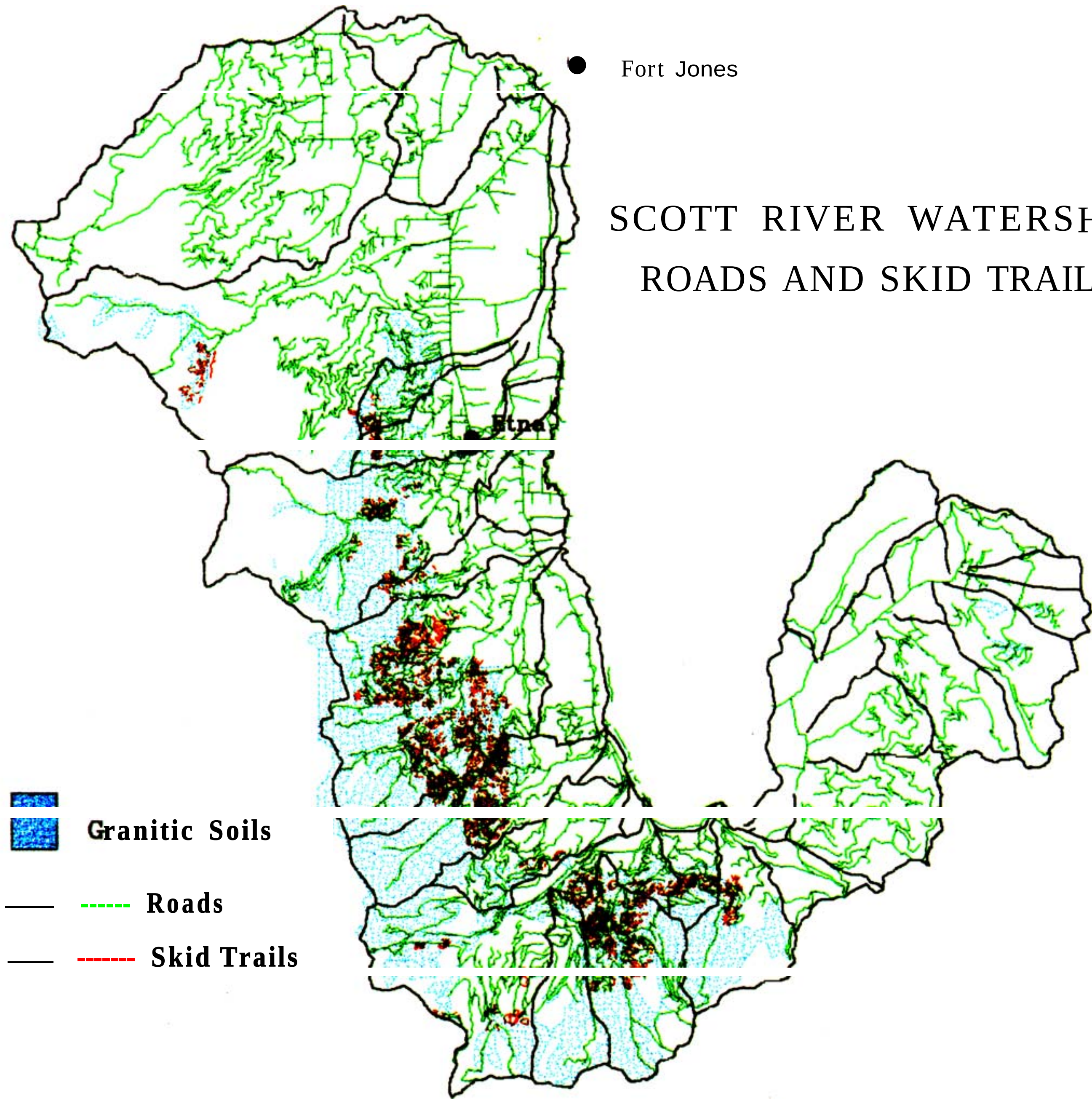
Procedure for **Streambanks**

Streams maintain an equilibrium among their slope, size of sediment particles, quantity of sediment transported, and quantity of water carried (Simons and Senturk, 1976). One of the most common causes of streambank erosion in any watershed is increased runoff from upland areas due to lack of cover.

Streambank erosion was estimated by adapting the direct volume procedure described for roads, above, to aerial photo surveys and a field survey conducted by the U.S. Forest Service in 1982 and 1983 (U. S. Forest Service, Klamath National Forest Scott River District, 1983). In the field survey, upper channel banks were rated for mass wasting and lower channel banks for cutting. The ratings used are described in Pfankuch (1975).

Conservative area and lateral recession rates were assigned in this study to each category. For mass wasting, the values were the length of the subsample times a height of 5, 2, 1 and 0 feet for poor, fair, good and excellent categories. The lateral recession rates were 0.5, 0.3, 0.13 and 0 feet per year. Fox Creek, Boulder Creek and nearby watersheds were assigned higher values for mass wasting because vegetation cover along the streambanks sampled was

SCOTT RIVER WATERSHED ROADS AND SKID TRAILS



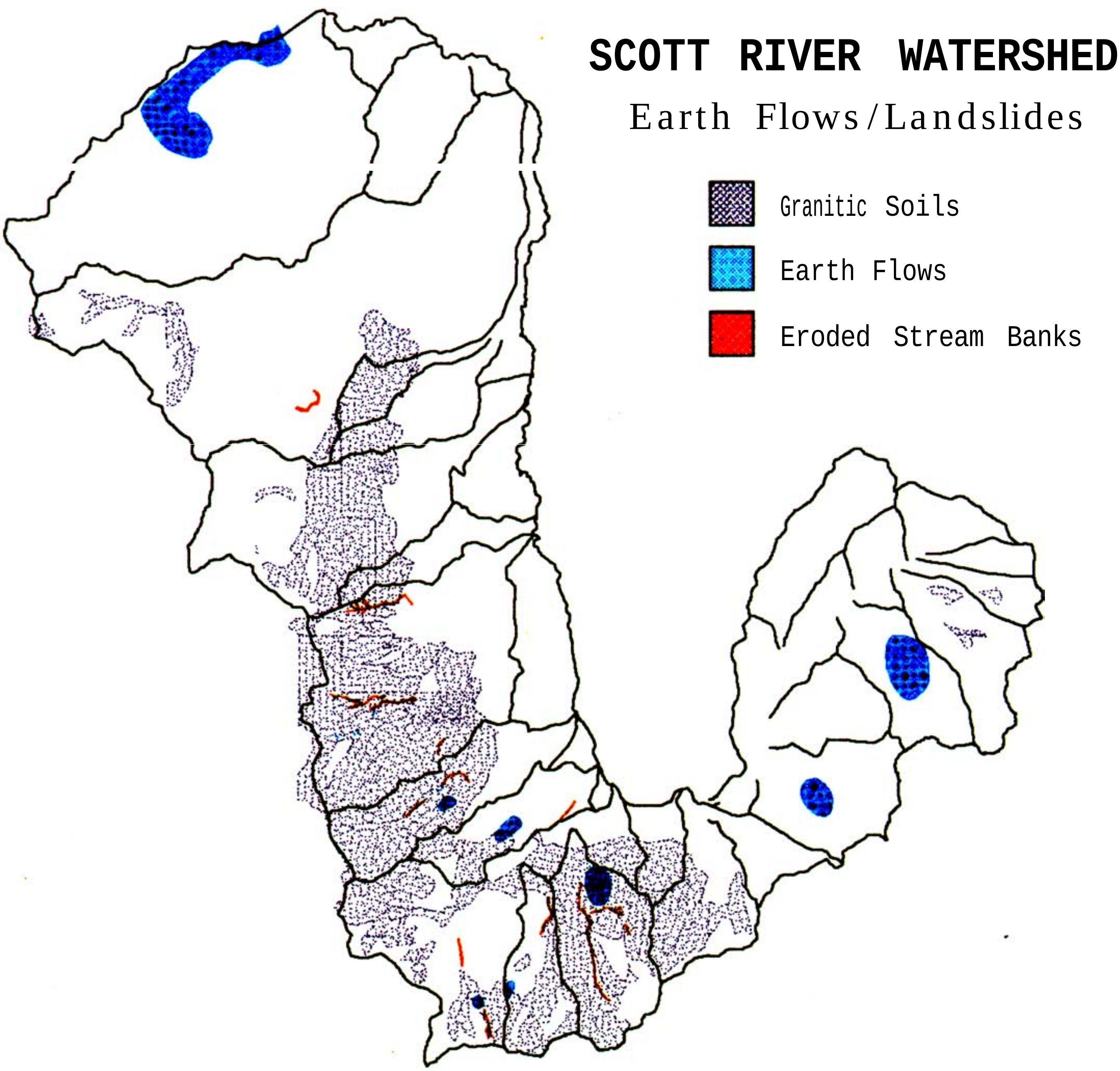
frequently described as poor to fair, that is, less than 50 percent ground cover. Area of cut banks was taken directly from rating, multiplied by the sample length. Lateral recession rates were 0.5, 0.3, 0.13 and 0 feet per year. The percent noneroding area and eroding area in each category for the sample was extrapolated to the length of streams in the subwatershed (multiplied by two because of the two streambanks). This work was supplemented by marking all visible areas of streambank cutting or mass wasting from historic and current aerial photos (1944 and 1955 black and white 1:24,000 pairs; 1971 and 1986 color infrared 1:24,000 pairs). A map of serious streambank erosion sites visible from aerial photos is presented in Figure 2-5, along with earthflow-slump sites (after Baldwin and de la Fuente, 1987).

Limited emphasis was placed on field work for streambanks because of earlier reports that this represented an "isolated" and "minor" component of erosion problems in the area (USDA-River Basin Planning Staff, 1971).

Procedures for Hillslopes, Timber Harvest Units and Landslides

The USLE, modified for forest conditions in the west (Curtis et al. 1977, Dissmeyer and Foster, 1984), served as the basis for evaluating erosion off of vegetated slopes in the Study Area. We recognize the problems with the use of this model. The USLE enjoys thousands of plot years of research results (Singer et al. 1976), and many professionals and agencies have made it a standard despite its lack of data refinement for conditions in western United States. Other limitations include: threshold and temporal effects are ignored, forms of erosion besides sheet and rill are not evaluated, it is fundamentally based on tilled agricultural slopes of 20 percent or less, and, when portions of the equation are averaged over areas, results do not reflect the way variables actually interact in a watershed nor do they accurately relate sediment to its source area. Interactive effects may affect accuracy of predictions, such as that between rainfall and cover, or between surface erosion and landslides involving subsoil layers. On coarse-textured soils such as DG, there is an interaction between the transportability of particles, part of the "K" value in the USLE, and slope. In general, the "K" value for DG soils appears to underestimate actual soil erodibility. Finally, both soils and climate data are often too broad-based (and in climate's case, too much based on low-elevation stations) for the USLE to be useful on a site-specific basis for short-term predictions of actual rates.

However, most workers agree that use of the USLE is appropriate for getting relative erosion rates and making planning decisions--the assignment of dollars and resources. The interaction of variables in the equation follows well-documented trends and can be used to compare potential long-term effects of


SCOTT RIVER WATERSHED
Earth Flows/Landslides
Granitic Soils
Earth Flows
Eroded Stream Banks

alternate methods for managing forested areas and aid in identification of major sediment source areas (Wischmeier, 1984), the goal of this study. Good correlation between USLE predictions and experimental trough work has been documented in the Klamath National Forest (Tom Laurent, Klamath National Forest soil scientist, pers. comm.). Additionally, where it has been tested in California forests, the USLE came within 82 percent of actual values, closer than any other method (Dodge et al., 1976).

The USLE takes the form A = RKLSCP. "A" is soil loss in tons per acre per year (or other units as defined by the individual study). "R" is an estimate of the effects of rainfall and runoff based on two-year, six-hour precipitation intensity records. "K" is an estimate of the soil's inherent erodibility based on experimental values from benchmark soils. "LS" is an estimate of the topographic effect of slope and slope length. "C" is the effects of canopy and ground cover on raindrop impact, and "P" is the effect of conservation practice--usually considered to be unity on forest land.

We applied the USLE to Study Area lands using the GIS so the various factors could be overlaid and analyzed for every approximately 1.6-acre block of land. This was made possible by the availability of digital elevation model tapes based on the 1:250,000 Weed quadrangle from the U.S. Geological Survey and Defense Mapping Agency.

"R" value Erosion rates increase with tendency to large, infrequent storms. The R value was derived from rainfall intensity records (California Dept. of Water Resources, 1986; Elford and McDonough, 1976), and adjusted by elevation using an isobar map of mean annual precipitation (USDA-Soil Conservation Service, 1972). Maximum values up to 284 were lowered because of the expected percentage of precipitation falling as rain versus snow at higher elevations (Anderson, 1976). R values ranged from 24 to 150. This compares with values used for Grass Valley Creek DG areas in Trinity County ranging from 55 to 150.

"K" value. Values for erodibility are adjusted by soil type and are related to factors such as texture, permeability, percent sand, organic matter content, soil structure and clay mineralogy. We used values provided by the Soil Conservation Service and Forest Service for the various soils, generally around 0.20. This was done by digitizing soil survey maps for the Study Area and assigning the appropriate K value to each polygon of soil mapped.

"LS" value. Erosion rates increase exponentially with slope and slope length. Percent slope was taken directly from the digital elevation model grid cells. Slope length was taken to be uniformly 25 feet. Fifteen feet is thought to be the minimum limit to which the USLE is applicable. Slope lengths are short in forested situations, and are generally less important because there tend to be patches of duff and bare soil even in disturbed areas. The value is close to what others have reported for DG soils, although the range is zero to 100 feet. In areas of heavy ground cover or slopes between zero and five percent, the slope length is taken to be zero.

"C" value. Cover values were expected to dominate the erosion process on equivalent slopes, and USLE results were expected to be most sensitive to these values. Cover is also the most important factor affected by use, so it represents the main cause of differences between potential and observed erosion. There are multiple, variable components or "subfactors" of cover in forest situations: amount of bare soil, canopy cover, soil reconsolidation, fine roots and onsite depression storage (Curtis et al. 1977). We first estimated cover values for the undisturbed forest. Field experience has shown and others have noted (USDA-Soil Conservation Service, 1986; Holcomb et al. 1990) that ground cover and root networks are naturally not as plentiful on granitic soils than in the surrounding forest. Chaix and Chawanakee soils are often bare, especially on southern and western aspects, although they commonly have a "one-inch mat of undecomposed and partially decomposed needles, leaves, twigs, bark and other organic debris" (USDA-Soil Conservation Service, 1983). A default value of 15 percent bare soil was used for undisturbed forest, based on the literature and our field observations, with 25 percent on southern and western aspects, and no bare ground on slopes up to five percent. Canopy above bare soil was assumed to be 85 percent, with 75 percent on southern and western aspects. Soil reconsolidation (soil generally becomes less erodible with time after disturbance) was scored at 0.45. Fine roots in the bare soil area were rated at 70 percent, with 50 percent on southern and western aspects. Five percent of the soil was assumed to be in fragments more than three inches in size (see Dissmeyer and Foster, 1984, for a complete explanation of these subfactors).

For forested areas disturbed by timber harvest, logging activities were divided into high-impact and low-impact categories. High-impact logging included clearcuts, selection, shelterwood and seed tree methods. Low-impact included sanitation, salvage and overstory removal. High-impact logging was assumed to leave 30 percent bare ground apart from roads and skid trails (the result of our field transects), and low-impact 18 percent bare ground. (We ignored the fact that private landowners generally do not burn slash while the U.S. Forest Service does.) Both were adjusted to undisturbed values linearly over 35 years. These values are similar to those cited by Rice (1979) from various studies: selection harvesting left 28 percent (Idaho DG soils), 15.5 percent (eastern Washington), and 20.9 percent (eastern Washington); clearcuts 29.4 percent (eastern Washington), 26.1 percent (eastern Washington), and 77 percent (northern California); and ground cable 18.8 percent (western Oregon), 15.8 percent (western Oregon), and 23 percent (Idaho DG soils).

Canopy cover values were obtained from digitized U.S. Forest Service vegetation map cover classes--the midpoints of these classes were used (USFS-Klamath National Forest, 1989). Otherwise, canopy cover over bare soil was assumed to be five percent for high-impact conditions and 20 percent for low-impact, adjusted to undisturbed values linearly over 35 years. Fine roots in bare soil areas was assumed to be 25 percent (our field work result was 15 percent, Shasta County workers averaged 26 percent (cited in Berry, 1983) and Mendocino County workers 34 percent (Berry, 1983)). Bare soil reconsolidation subfactor was assumed to go from 1.0 to 0.45 over 35 years. Onsite depression storage was rated at 0.05.

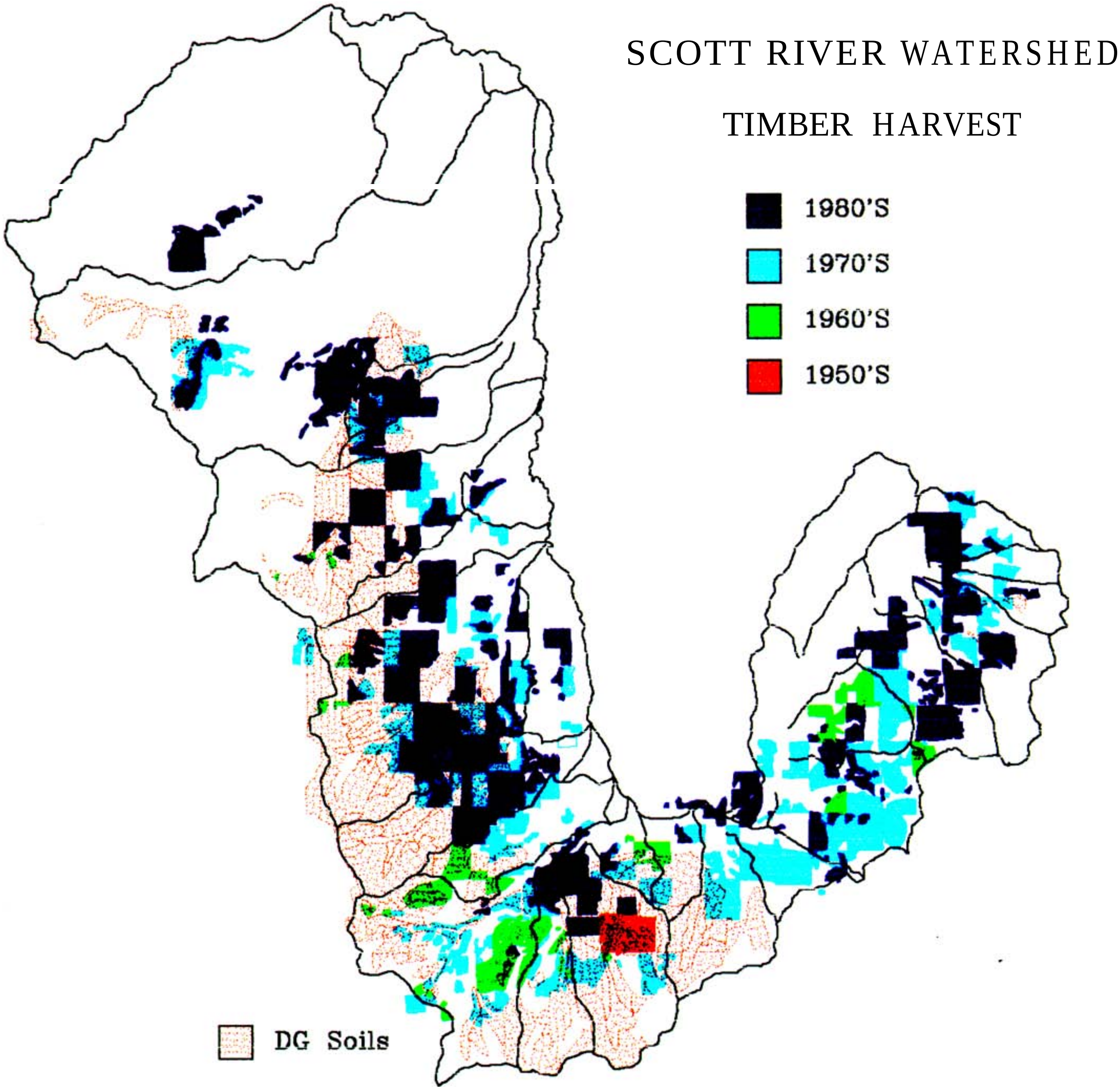
Figure 2-6 shows timber harvest patterns. About 75 percent of logging on private lands is estimated to be by tractor, and 25 percent by cable (Bob Williams, California Department of Forestry, pers. comm., 1989). In addition to the sites in the Figure, aerial photos from 1955 show extensive logging at the lower elevations outside of Callahan (especially in the Little/Big Mill Creek drainage) and Etna (up through Whiskey, Johnson and Kidder creeks), and some in the French Creek drainage. More recent (post-1986) sites not shown on the map are in Crystal Creek and the Glendenning Fork of Kidder Creek.

Landslides were assumed to move at a maximum rate of 0.75 feet per year to a depth of 2.5 feet.

Sediment Yield **Estimates**

Several methods were used to estimate sediment yield and these were compared to literature values. It was hoped that the redundancy would help provide some confidence to results as we have no sedimentation data from stream gages to calibrate values, and no single model has been generally accepted for sediment yield calculations.

Reservoir sediment survev Reservoir sediment surveys are good sources of data for sediment yield estimates in similar watersheds because the survey integrates all the sedimentation processes occurring in the upland watershed during the period of record. Recently, a survey was completed for Antelope Reservoir in Plumas County (Dept. of Water Resources, 1990), a watershed with 64 percent granitics upslope and similar rainfall (36 inches at nearby Greenville, elevation 3600 ft.) and drainage area (70.8 sq. mi.) to the subwatersheds in our Study Area. Road density is slightly lower (2.2 mi./sq. mi.) than most subwatersheds in our Study Area. Antelope Reservoir survey results indicate an average sediment yield rate of 570 tons/sq.mi./year for the period 1964-89. The Soil Conservation Service (1988) had earlier estimated total upslope erosion to be 188,100 tons per year.


SCOTT RIVER WATERSHED
TIMBER HARVEST
1980'S
1970'S
1960'S
1950'S
DG Soils

Sediment delivery ratio. Use of a sediment delivery ratio (SDR) applied to an estimate of gross erosion for a watershed can provide a first cut at sediment yield values. It is a first cut because data relating SDR's to drainage area are widely scattered. This is because there are many watershed variables besides area that relate to sediment yield (for example: shape, cover condition, channel density, slope length and complexity, and rainfall). One method for arriving at an SDR is called the slope-continuity procedure developed by Flaxman (1974)for watersheds in western United States. This method was used in the Grass Valley Creek watershed in Trinity County (USDA-Soil Conservation Service, 1986). Cross sections of primary stream channels are drawn and a ratio between producing and depositional areas determined, or steep and flat areas. This is, again, a first cut at estimating sediment yield.

PSIAC method The Pacific Southwest Interagency Committee (1974) developed a generalized method appropriate for making preliminary estimates of sediment yield. The method has been adapted for forested lands in the Trinity River Basin (Dybdahl et al. 1990). It relies on nine factors for making estimates: surface geology; soils: storm frequency, duration and intensity: size of peak flow and volume per unit area; slope steepness and floodplain development; ground cover: land use including road densities: upland erosion severity: and channel and sediment transport variables. PSIAC is one of the few approaches that allows consideration of current land use. The method requires considerable judgement to apply properly, as well as development of a regional sediment yield curve. Results should be backed up with supporting evidence.

Fifty-eight sediment samples were collected from road ditches, road culverts and eroding streambanks throughout the Study Area and analyzed for texture to determine the grain size of sediment entering the stream system.

Eroding cut bank, French Creek

Figure 2-7

Eroded skid trail, Crystal Creek

Eroding slopes and cut banks

Sediment delivery from landslide, Sugar Creek near intersection with High CC road.

Figure 2-8

Root exposure on receding cut bank.

Streambank scour, E. Boulder Ck.

Results and Discussion

Roads

The results of our road sampling erosion evaluation are shown below:

Table 2-8. Road erosion sampling summary, Scott River watersheds, 1989.

Sample Number	Watershed	Paved, Rocked, or Unsurfaced	Length of Sample(ft)	Tons/ Mile	Acres/ Mile	Tons/ Acre	T/Mile Gut	T/Mile Fill	T/Mile Surf ace
1	French	U	3735	762	6.10	125	476	249	38
2	French	U	4545	1005	6.15	163	797	151	57
3	French	U	2250	778	4.57	170	346	357	74
4	French	P	1026	669	2.50	268	530	139	0
5	French	R	1692	365	3.43	106	222	137	6
6	Hiner 's*	R	261	506	3.82	132	243	243	0
7	Hiner 's*	U	1616	203	3.42	59	42	144	20
8	Hiner 's*	U	1894	761	4.12	185	429	223	22
9	N.Fk.French*	U	9185	614	4.53	136	414	192	8
10	Horse Range*	R	7920	518	4.32	120	347	152	19
11	Horse Range*	U	1589	1299	6.64	196	515	761	27
12	Horse Range*	U	1000	1399	6.66	210	634	845	105
13	East Boulder	U	6773	391	3.98	98	261	119	11
14	Bould.-B.Jay	R?	3879	726	5.65	128	437	278	11
15	Boulder/Wolf	U	4946	736	4.80	153	362	307	14
16	Wk./Grizzly	U	8612	996	5.88	169	621	294	15
17	Kidder/Shelly	U	4838	942	5.78	163	654	224	11
18	Etna	P	8136	834	3.56	235	582	202	0
19	Crystal	U?	8892	406	3.99	102	292	107	7
20	Crystal	R	2606	1668	1.26	230	1196	467	5
21	Crystal	R	11691	861	5.36	161	595	167	5
22	Sugar	U	4541	1786	6.45	277	1214	517	55
23	Sugar	R	10044	596	5.28	113	412	133	5

*Sub-basin of French Creek

Average annual erosion for the entire road prism **was 737** tons per mile, or 149 tons per acre. Erosion from the road surface alone averaged about 11 tons per acre. These values are within the range reported by others on granitic forest roads. A study on forest roads on a number of geologic types in the Sacramento Valley Basin (USDA-Forest Service, 1983) where erosion plots were placed near stream crossings in first- and second-order basins reported **80** tons per acre of losses overall, and 103 tons per acre on granitic soils. I estimate Grass Valley Creek road evaluations to average about 565 tons per mile per year (USDA-SCS, 1986). The mostly-granitic Antelope Lake watershed on the East Branch North Fork Feather River in Plumas County (USDA-SCS, 1988) produced estimates of 524 tons per mile per year, with 315 tons per mile per year from the cut banks. Measurements over a seven-year period in the Silver Creek study area of the Idaho Batholith resulted in reports of 0.4-9.6 tons per mile per day, averaging 3.5 tons per mile per day (Megahan, 1974; Megahan et al. 1983). This implies an annual rate of 1278 tons per mile.

Sixty-four percent of road erosion was from the cut slope, which was our highest category of soil loss from all sources at 40 percent of the total (see Fig. 2-9). Erosion from the road prism constituted 62 percent of all losses. This compares with Grass Valley Creek where about 49 percent of all erosion was due to roads, even though road density (51.6 feet/acre) is higher there than in any of our Study Area watersheds, except possibly Crystal Creek (see Table 2-6). In the watershed study on the East Branch North Fork Feather River (USDA-SCS, 1988), roads were 57 percent of all erosion, with cut slopes alone comprising 36 percent of losses from all sources. In the subwatershed with granitics (Antelope Lake), roads were about 43 percent and cut banks 26 percent of all losses. In the Sacramento Basin study on forest roads on all geologic types (USDA-Forest Service, 1983), road cuts comprised 43 percent of all losses, but 28 percent when stream crossings were calculated separately. Reports on watersheds on the North Coast tend to have streambank erosion as the highest category because of the predominance of mass wasting there (e.g. Anderson, 1970, Kelsey, 1989).

The high values for cut banks were expected because it is the cut that intercepts the subsurface flow of water from the slopes above it. Also, cut banks generally cover more area than the fill or the road surface, are steeper, deeper, less vegetated and experience more freeze-thaw cycles with rain. The road surface is very compacted compared to the cut or fill, requiring more erosive energy to dislodge soil material. In simulated rainfall experiments conducted in the Idaho Batholith (Burroughs et al., 1984), the cutslope and ditch were found to yield eight to twelve times as much sediment as the road surface. Our sediment yield from cut banks was 26 times that of the road surface (see the section on sediment yield), but our sample ratio was raised by including paved surfaces while the Idaho study involved unsurfaced and rocked roads only.

On insloped roads, material lost from the cut bank has less opportunity for storage than that of the fill, unless it is removed from the slope toe or road ditch by maintenance. Material eroded from fill slopes is often trapped behind logs and vegetative debris on the hillslope, although it was not uncommon during field work to see fill failures on outsloped roads or across from the end of an eroding skid trail, with material delivered a few to hundreds of feet into channels. Road fills were usually at least partially vegetated and had significantly better cover than cut banks.

Although rocking protects the road surface, a more important benefit is that there is less disturbance of the cut bank toe because of reduced road maintenance needs (Lyle Steffen, Soil Conservation Service, pers. comm.). The cut bank is thus more likely to stabilize itself by deposition resulting in a less steep slope. A disadvantage of surface rocking is that it can cause the road to be more prone to fill failure as water has less opportunity to infiltrate the road surface and is diverted onto the fill.

Skid Trails

We found, conservatively, about 300 acres of skid trails on DG soils averaging about 239 tons per acre of annual soil loss, based on the same direct volume sampling procedure applied to roads. The portion of these losses due to sheet and rill erosion was approximately 12.6 tons per acre. Skid trails sampled in French Creek averaged 148 tons per acre of soil loss, while the highest rates were found in Crystal Creek, averaging 417 tons per acre for the watershed. This soil was frequently delivered to roads where it is either removed by maintenance or becomes part of the sediment delivered off road surfaces. The soil from skid trails was also seen diverted by waterbars onto hillslopes and swales, where it is either stored until flushed out by a large storm, delivered annually by ravel and sheetwash, or protected from movement downslope by ground cover conditions.

Streambanks

Streambanks averaged 382 tons per mile per year throughout the Study Area. Nearly three times the average was estimated for some of the watersheds near Callahan, such as Boulder and Fox creeks because of large areas of upper bank scour that remain completely unvegetated.

Besides documenting the location of scoured stream channels, a look at historical aerial photos confirmed that most of this erosion was triggered by the 1964 flood. Slide Creek (a Fox Creek trinutary) was gutted earlier, as 1944 aerial photos show its banks in similar condition as today. The large gully in Paradise Hollow of French Creek watershed is barely evident in 1944 photos. It grew to nearly its current proportions with the 1964 flood, and later photos show it to be widening. The gutted streams are generally high up in their watersheds in first- or second-order channels. The bank scour appears unrelated to logging, as there had been little or no harvest activity in surrounding terrain except on Kidder Creek. The affected streams include upper Kidder and Patterson creeks, the north fork of North Fork French Creek, produce 6.8 times the natural rate excluding roads in the Klamath Mountains of southwestern Oregon. However, our values include the entire granitic watershed, not just the harvested portions.

In general, sheet and rill values reported on granitics are lower than those on other geologic types (e.g. Berry, 1983) since it is not a primary mode of soil erosion in this geologic type. An exception may occur on sites disturbed such as by fire, especially when water repellancy is present (Tom Laurent, Klamath National Forest, pers. comm.). Despite the relatively low values for sediment yield from sheet and rill erosion compared to other sources (especially when water quality is the main concern), losses from this mode of erosion can be extremely important to a site's productivity for growing trees. Sheet and rill values may be underestimated due to the lack of slope data resolution for steep channel edges, cliffs and inner gorges.

Table 2-10. Average annual sheet and rill erosion on DG under natural (geologic) conditions and with current timber harvest patterns.

Watershed	Geologic Sheet & Rill Tons/Acre	Current Sheet & Rill Tons/Acre
Shackleford/Mill	.03	.03
Kidder/Patterson	.03	.07
Crystal	.02	.15
Johnson	.03	.12
Mill/Etna	.05	.10
Clark	.04	.04
French	.03	.07
Sugar	.03	.05
Wildcat	.02	.04
South Fork	.04	.09
Fox	.04	.07
Boulder	.04	.09
Little/Big Mill	.03	.04
East Fork	.03	.10
"Callahan"	.02	.05

Soil Loss Summary

Table 2-11 summarizes average annual erosion rates by watershed and source, and Table 2-12 displays the same information in percent. Figures 2-9 and 2-10 depict the breakdown of totals by source and by watershed, respectively.

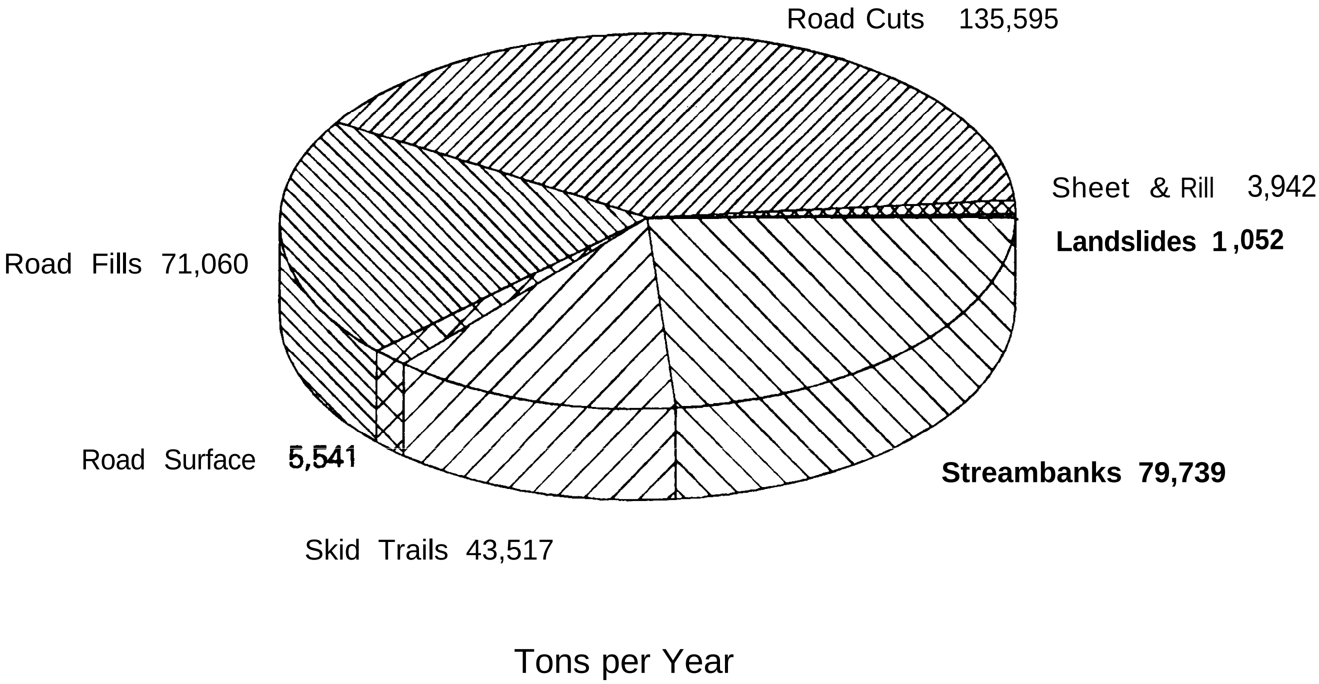
As always in this kind of study, results should be considered reasonable estimates and in the context of reports from other studies as described above.

Table 2-11. Summary of estimated soil loss by watershed and by source, in total tons.

	Sheet & Rill	Road Cuts	Road Fill	Road Surface	Skid Trails	Streambanks	Landslides	Total
Shackleford/Mill	60	294	101	5	0	933	0	1,393
Kidder/Patterson	193	7,299	2,500	123	1,936	3,683	0	15,734
Crystal	265	10,471	3.366	95	1,668	811	0	16,676
Johnson	104	3,368	1,808	225	1,209	1,093	0	7,807
Mill/Etna	585	17,864	8,636	058	1,732	3281	0	32,956
Clark	42	2.223	1.193	149	474	544	0	4,625
French	858	31,384	15,856	1,798	14,859	14,487	53	79,295
sugar	274	11,701	5,767	651	4.544	6.560	189	29,686
Wildcat	57	6,203	2,724	r 267	629	478	135	10,493
South Fork	550	21,068	10,179	483	2,347	2,788	158	57,573
Fox	176	3,682	3.019	135	68	11,101	120	18.301
Boulder	539	13,372	10.680	493	7,599	19,058	397	52,138
Little/Big Mil	127	1,792	1,520	69	1,621	9202	0	14,331
East Fork	52	1,160	561	46	2,677	2,089	0	6,585
'Callahan'	60	3.7 14	3.150	144	2,154	3,631	0	12,853
Total	3,942	155.595	71,060	5.541	43,517	79,739	1,052	340.446

Table 2-12. Percent of soil loss contributed by various sources for each sub-basin.

	Sheet & Rill	Road Cuts	Road Fill	Road Surface	Skid Trails	Streambanks	Landslides	Percent of Total
Shackleford/Mill	4	21	7	0	0	68	0	0.4
Kidder/Patterson	1	47	16	1	12	23	0	4.6
Crystal	2	62	20	1	10	5	0	4.9
Johnson	1	44	23	3	15	14	0	2.3
Mill/Etna	2	54	26	3	5	10	0	9.7
Clark	1	48	26	3	10	12	0	1.4
French	1	40	20	2	19	18	0	23.3
Sugar	1	39	20	2	15	22	1	8.7
Wildcat	1	59	25	3	6	5	1	3.1
South Fork	1	57	28	1	6	7	0	11.0
Fox	1	20	17	1	0	60	1	5.4
Boulder	1	25	21	1	15	36	1	15.3
Little/Big Mill	1	13	11	0	11	64	0	4.2
East Fork	1	18	9	1	40	31	0	1.9
"Callahan"	0	29	25	1	17	28	0	3.8
Percent of all loss	1	40	21	2	13	23	0	100.0



Total Annual Erosion - 340,446 Tons

Figure 2-9.

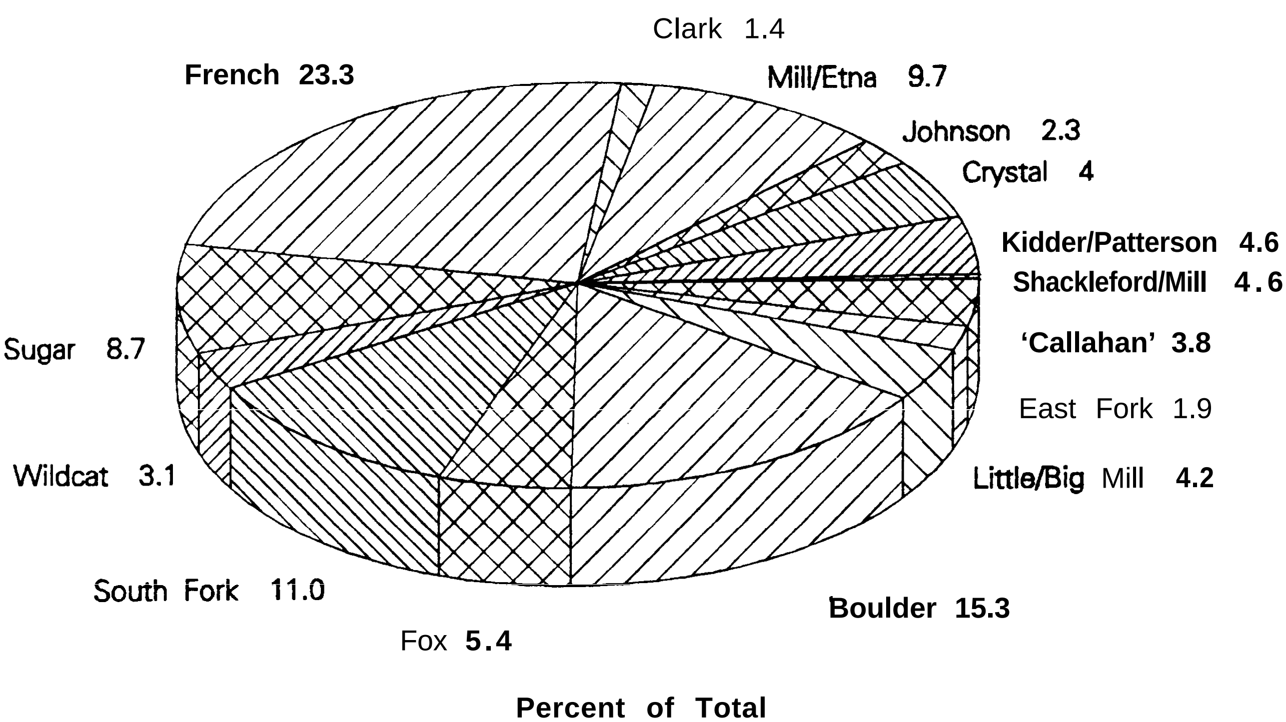


Figure 2-10.

The results show that if we were to spatially lump erosion over the entire Study Area, we would be getting about six tons per acre per year of loss. Soil loss tolerance for the granitic soil is generally about two tons per acre per year, and 1 ton per acre per year on the shallow Chawanakee sites. Results higher than one or two tons per acre mean the soil profile is being mined faster than soil formation rates.

Sediment Storage and Yield

Storage Sediment production off Study Area slopes is great enough that in most years it is stored in the upper watershed rather than transported to the Scott River. Primary storage sites appear to be hillslope swales, hillslopes outside of swales, upper stream banks, channel margins and fans, and channel bedload (see Fig. 2-11). These areas become sources of small annual amounts and large, episodic pulses of sediment.

Sediment deposits in upslope swales are common throughout the Study Area. They are irregularly-shaped and often bare or with needle cover only, suggesting that deposition of soil material into storage in these swales is an ongoing process. The minimum age of these deposits can be concluded by aging new vegetation. Excavations performed by Klamath National Forest scientists in the English Peak-Batholith suggest a whole range of ages, from twenty to hundreds or thousands of years (Juan de la Fuente, Klamath National Forest, pers. comm.). Such a range may reflect the variability with which storms affect even a small area. The swale feature can be hundreds or thousands of years old with new material deposited on top of it. Recent (1974) debris slides examined in the Little North Fork of the Salmon River showed that after 16 years, about nine inches of soil material were deposited in a failed portion of the swale (Tom Laurent, Klamath National Forest, pers. comm.).

In almost all cases of streambank gutting, there is a downstream section populated with willows and alders where at least some of the resulting sediment has been stored along channel margins. Storage behind boulders, trees and other debris in the stream channels is generally temporary and not enough to cause more than minor bank and bottom erosion (see USDA-Forest Service, 1983). There are a few exceptions in the Boulder and Fox Creek drainages. Apparently, this form of long-term sediment storage is not as important as has been found in more coastal northern-California drainages and in the Idaho batholith (Swanson et al., 1982). In general, Study Area tributary streams are well-armored and bouldery especially in their upper reaches. A possible exception is Crystal Creek which has a bed and alluvial fan of gravel, sand and clay, compared to the more bouldery material of neighboring streams (Mack, 1958).

Material eroded from fill slopes, road surfaces, skid trails and harvest sites is largely stored by the hill slopes and swales until extreme events. However, sediment from stream crossings and road cut banks (especially those with an inboard ditch) likely enters the drainage system more directly and with less lag time. Erosion from lower streambanks is expected to be exported from the system annually with a sediment yield of close to 100 percent, whereas upper banks are a long-term but persistent source with sediment yield of perhaps 35 percent.

Sediment yield. If a standard sediment delivery ratio (Roehl, 1962) is applied for the size of our Study Area, the average annual sediment delivered to the Scott River from upslope areas would be about 10 percent of all losses. If we calculate a sediment delivery ratio based on the Antelope Reservoir survey, where similar methods were used to estimate upslope erosion, the result is 21 percent. A sediment delivery of 55 percent was used in the SCS' Grass Valley Creek study in Trinity County, based on the proportion of watershed in gentle versus steep slopes (areas of deposition versus areas of delivery). The PSIAC method provides a means of estimating yield without using a ratio. The various methods and the resulting estimates in total tons are summarized in Table 2-13.

Table 2-13. Sediment yield estimates using various delivery ratios and PSIAC method, with our preferred method highlighted.

Delivery Ratio	Tons/Year
.55	188,200
.21	**71,494**
.10	**34,045**
PSIAC	62,770

The reservoir survey method is preferred, given similar climatic and watershed conditions, and implies about 1.3 ton/acre sediment delivery off of slopes to about 6 tons per acre eroded. PSIAC results were very close, and showed differential yield rates by watershed, shown in Table 2-14. The differences among watersheds are due to varying areas of gentle slopes (Shackleford, French, Wildcat, Little/Big Mill and East Fork watersheds had higher proportions of slopes less than 15 percent, so more opportunity for deposition); varying road densities and harvest activity: and differences in our subjective evaluation of upslope erosion problems.

Table 2-14. PSIAC sediment yield results by watershed, in tons per square mile.

Watershed	Tons/Sq.ZMi.
Shackleford/Mill	497
Kidder/Patterson	1010
Crystal	2365
Johnson	3472
Mill/Etna	122
Clark	1177
French	236
Sugar	564
Wildcat	1376
South Fork	401
Fox	1415
Boulder	681
Litle/Big Mill	755
East Fork	2248
"Callahan"	2720

In the Idaho batholith there has been some work showing sediment yield to be less than ten percent of on-site road erosion in a watershed less than 300 acres in size (Megahan et al., 1983). Because of this, we would find figures higher than our preferred value to warrant lots of corroborating evidence. The sediment yield values estimated here are generally low compared to those for Grass Valley Creek in Trinity County. Estimates for Grass Valley Creek range from about 67,000 to over 200,000 tons (50,000 to 150,000 cubic yards (Doug Denton, Dept. of Water Resources, Red Bluff, pers. comm., 1990), for a study area half the size of ours. Estimates for our Study Area are about the same as those for their lowest subwatershed, at about 1.3 tons per acre per year yielded (USDA-SCS, 1986). Table 2-15 depicts sediment yield results from several reservoir surveys of watersheds of similar size to our Study Area (Dendy and Champion, 1978), and estimates for Grass Valley Creek and Ashland, Oregon watersheds. The Ashland Creek results were from a study where reservoir sediment was dredged (Rolle et al. 1987). It involves a granitic watershed during a time period without extreme events.

Table 2-15. Estimate of granitic sediment yield for Scott River sub-basins compared to sediment surveys for watersheds of similar size,and estimates for Grass Valley Creek and Ashland Creek.

Watershed	Drainage Area(Sq.Mi.)	Mean Annual Tons/Sq.Mi	Years of Record
Scott River watersheds	89	803	
Little Stony Ck., Stonyford	98	443	1910-1962
Stony Creek, Stonyford	197	326	1928-1960
Bear River, Auburn	129	1140	1928-1935
Emigrant Gap, Ashland, OR	61	466*	1925-1951
Ashland Ck., Ashland, OR	19	10	1976-1987
Grass Valley Ck., Trinty Co.	37	1800-4000	--

*Assumes density of 100 pcf

Different erosion sources have different delivery rates to channels. Presuming our erosion and overall sediment yield estimates to be reasonable, we apportioned the sediment delivery ratio among the various erosion sources, as depicted in Figure 2-9. We assumed five percent of sheet and rill erosion on hillslopes to be yielded annually, 21 % of road cut losses, 15 percent for road fills, 20 percent for the road surface, seven percent for skid trails, 35 % for streambanks (mostly upper banks), and 20 percent for earthflows.

Accelerated versus Natural Erosion and Sediment Yield

Of the total soil eroded, about half the sheet and rill erosion and most of the streambank losses could be considered natural. This means that about 76 percent of erosion is accelerated, or caused by man's impact on the watersheds. About 60 percent of sediment yield is accelerated (most of streambank erosion results in sediment yield to streams, while most of sheet and rill erosion does not).

Grain Size Distribution

Analysis of sediment grain size revealed no statistical difference between samples from road ditches and culverts compared to streambanks. The average percent fines (less than 0.85mm) was 43 percent. This implies that an average of about 31,000 tons of fine material are added to the Scott River from upland sources per year. Grain size distribution results are shown in Table 2-16.
These values are similar to those reported for granitic soils in the SCS Soil Survey.

Table 2-16. Grain sizes of 58 sediment samples collected from road ditches, culverts and eroding streambanks.

	Mean Percentages						
	>25.0mm	>12.5mm	>6.3mm	>4.75mm	>2.36mm	>.85mm	<.85mm
Roads	2.2	2.1	4.4	3.9	16.4	26.8	44.3
Streams	0	4.3	7.9	5.6	17.5	22.2	42.6

Needs for Further Study

A better understanding of granitic sediment storage on slopes and in the tributary channels would contribute much to quantifying the impact of increased erosion on fisheries of the Scott River. This would include aging of sediment stored in upslope swales and in channel margins by excavation or looking at new vegetation, and a study on debris torrents apparently important in granitic terrain sedimentation patterns.

Future work should specifically address the historic impact of flood flows on the system. Since the impact of increased sedimentation on peak flows is unknown, we can presently say little about how man's effect on these watersheds might alter how very large stormflows are dealt with.

The question of how to control or mitigate sedimentation from roads needs to be studied with specific reference to granitics. Further work on road sedimentation should also include field measurements of the relative proportion of sediment coming from the cut as opposed to the road surface.

In general, future work should emphasize direct measurements of sediment yield and estimates of factors controlling sedimentation rates.

Granitic Sediment *Sources*

340,450 Tons/Year

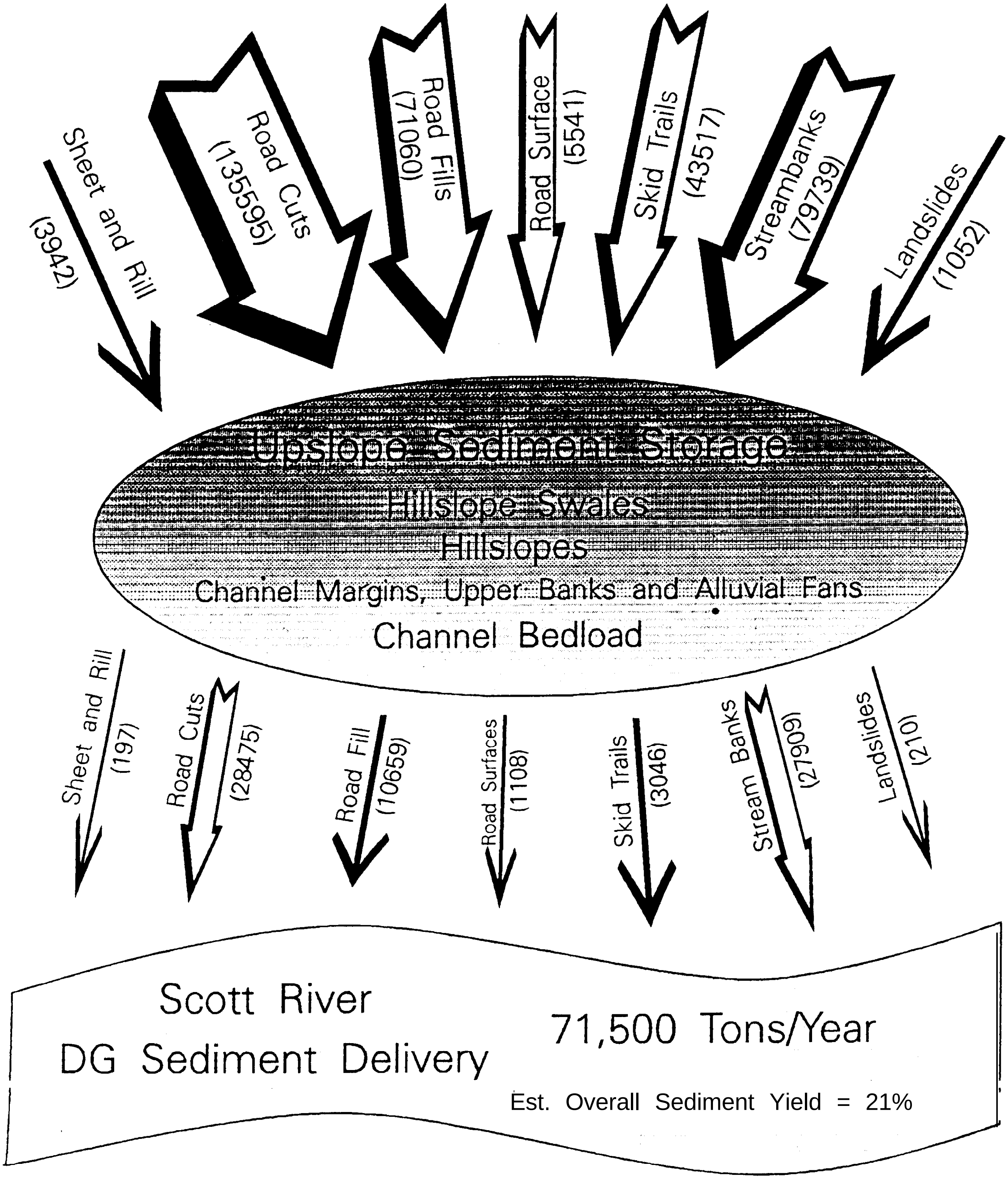


Figure 2-11.

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CHAPTER 3

SEDIMENT STORAGE AND TRANSPORT

INTRODUCTION

Objective: To determine sediment storage and transport in the mainstem Scott River within Scott Valley

This study is the first analysis to be done of sediment storage or transport capacity in the Scott River. Other stream systems in Northern California, such as Redwood Creek and the Trinity, Van Duzen and Sacramento Rivers, have had extensive analyses performed in recent years (Kelsey, et al, 1981; Fredericksen, Kamine and Associates, 1980; Kelsey, 1980; CDWR, 1984). Geologists seek to quantify almost every aspect of sediment transport and storage in a drainage basin when performing a comprehensive sediment budget (Swanson, et al, 1982). As a preliminary evaluation, this chapter's intent is to develop an approximate volume and size of sediment in channel storage and an approximate transport rate of sediment through the Scott River. Concern is focused on the heavy sedimentation by granitic sand of the salmon and steelhead spawning habitat of the mainstem Scott River.

Chapter 2 evaluated the hillslope sources, rates, and amounts of decomposed granitic (DG) sediment production in each sub-basin of the Scott Valley. Only a portion of the eroded material ends up in the stream system annually. Once deposited in the steeper reaches of the tributaries, the sediment usually becomes transported downstream quite rapidly (Beschta, 1987). Certain sites within the lower gradient reaches (i.e., upper streambanks, channel margins and fans, and channel bedload) are where most of the sediment deposition occurs. The amount yielded to the Scott River from its tributaries was estimated to be 21% of the total granitic sediment production in the basin, for an average annual yield of 71,500 tons.

One needs to know what happens to sediment after it enters the river to be able to evaluate the effects of altered sediment input or channel transport capacity (L. Reid, USFS, pers. comm.). Where the sediment ends up depends on the volumes and grain sizes introduced to the stream, the sediment transport capacity and competence, and the "opportunities for detention" along the stream. Competency is defined as the largest grain a stream can move as bedload of the stream, which varies according to streamflow. Capacity implies the maximum amount of debris of a given size that a stream can carry as bedload, and is dependent upon stream gradient, discharge, and caliber of the load (Morisawa, 1968).

Background

An understanding of both natural and artificial factors affecting the behavior of the Scott River is important background for interpreting the present sediment transport and storage conditions.

Valley Geology

Since the hillslope geology was described in the previous chapter, a brief discussion of the valley's geology is the focus in this chapter. The valley alluvium is composed of older deposits from the Pleistocene age and of younger fill of Recent age (Mack, 1958). The older alluvium is exposed mainly at the edge of the valley near Callahan, Quartz Valley, Etna Creek, and French Creek. Old alluvial fans were formed by Shackleford and Etna Creeks and, where exposed, have been mined extensively for gold. Most of the valley fill consists of Recent alluvium from (1) stream channel and flood plain deposits, and (2) alluvial-fan deposits. Thickness ranges from a few feet at the valley margins to probably more than 400 feet in the center of Scott Valley where it is widest.

According to the U.S. Geological Survey's geology study of the valley area, the composition of the alluvial deposits varies greatly (Mack, 1958). The west side tributaries from Etna north to Quartz Valley have built large "bouldery and cobbly " alluvial fans, and their channel deposits contain differing amounts of granitic bouldery debris: Patterson Creek contains about 20%, Kidder Creek about 10%, and Etna Creek about 40% granitic material. In contrast, the Crystal Creek fan is not as bouldery nor as large as the fans deposited by the others and is composed almost entirely of granitic gravel, sand and clay. This deposit becomes impermeable throughout much of its extent because of the high clay content derived from the weathering of feldspar in the granodioritic bedrock of the Crystal Creek area. The western alluvial fan deposits become less coarse as they move downslope, with fine sand, silt and clay predominating near the toe of the fans.

In the floodplain between Etna and Fort Jones, the alluvium contains highly permeable sand and gravel in beds averaging as much as 5 feet in thickness, alternating with beds of clay which range from several inches to several feet thick. This depositional sequence probably reflects the constant shifting of the Scott River during the alluviation of the valley, where lenses of sand and gravel were deposited in old channels which are included within and extend through clayey sediments of flood-plain origin (Mack, 1958).

During much of the early evolution of the Scott River, it was an actively degrading stream which was cutting down in response to intermittent regional uplift. Former ridges in the valley between the western tributaries were eroded and the channels gradually changed. Eventually, the Scott River and its tributaries began to aggrade their course. During the Recent epoch, the Scott River channel migrated to the east side of the valley.

Hydrology

Hydrologic characteristics of the Scott River are derived from 45 years of data (1942 to 1987) at the U.S. Geological Survey's gage station located less than a mile downstream of Scott Valley (River mile 20.5).Figure 3-1 illustrates the mean monthly discharge at this station. On the average, the months of November through May have the highest discharge and are quite comparable. Snowmelt runoff contributes to late spring flows, which explains why the runoff remains high during lower precipitation. Flows decline during June and July and remaining low from August until October.

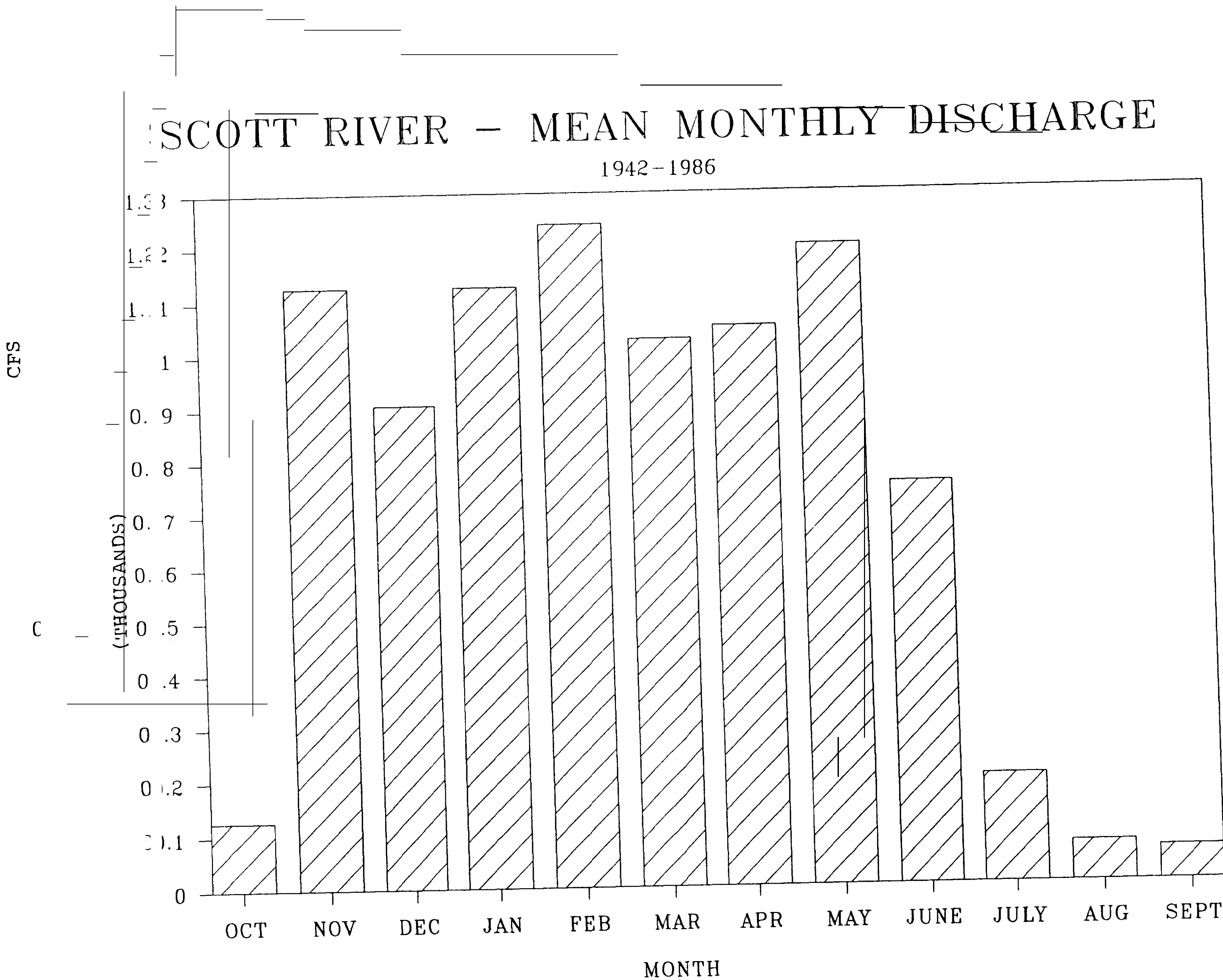
Annual comparisons are found in Figures 3-2 and 3-3. While the average annual discharge is 489,800 acre-feet per year, the yearly totals have varied from a low of 54,200 acre-feet (a-f) in water year 1977, to a high of 1,083,OOO a-f in 1974. Other high runoff years were 1958, 1956, and 1983. The highest maximum daily discharges do not necessarily coincide with these highest runoff years. The flood of December 1964 had the highest daily discharge of 39,500 cubic feet per second (cfs), followed by the floods of 1974 at 30,900 cfs and 1955 at 30,200 cfs. However, the maximum peak discharge, or the highest instantaneous value, of record was 54,600 cfs on 12/22/64, and the next highest was 36,700 cfs on l/16/74.

Before the period of record at the USGS station, the flood of 1861 was the largest one mentioned in historical accounts. Helley and LaMarche (1973) determined from geological and botanical evidence in the Scott River canyon below the valley that the 1861 and 1955 floods were of equal magnitude though less severe than the 1964 flood. However, they also found that the 1964 flood was exceeded by an earlier flood that occurred about 1600 and that llfloods of the 1964 magnitude have occurred in the more recent past.

The tributaries have only short gaging records or none at all, although some are gaged during the summer by the State Watermaster for adjudication monitoring. The only suspended sediment data collected on the Scott River was for four dates during the 1955-56 water year (USGS, 1960). No local bedload sampling has been conducted.

History of Channel Alterations

Alterations have been made in the Scott River's shape and location through both natural and artificial means. As described in Chapter 1,the removal of the beaver population from the Scott Valley in the 1820s was the first unnatural change in the landscape. The 1861 flood, in combination with mining debris, caused the upper Scott River to alter its course from the west side to the east side of the valley downstream of Callahan



SCOTT RIVER - MEAN MONTHLY DISCHARGE
1942-1986
CFS
(THOUSANDS)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
MONTH

Figure 3-1

SCOTT RIVER—TOTAL DISCHARGE

1942—1989

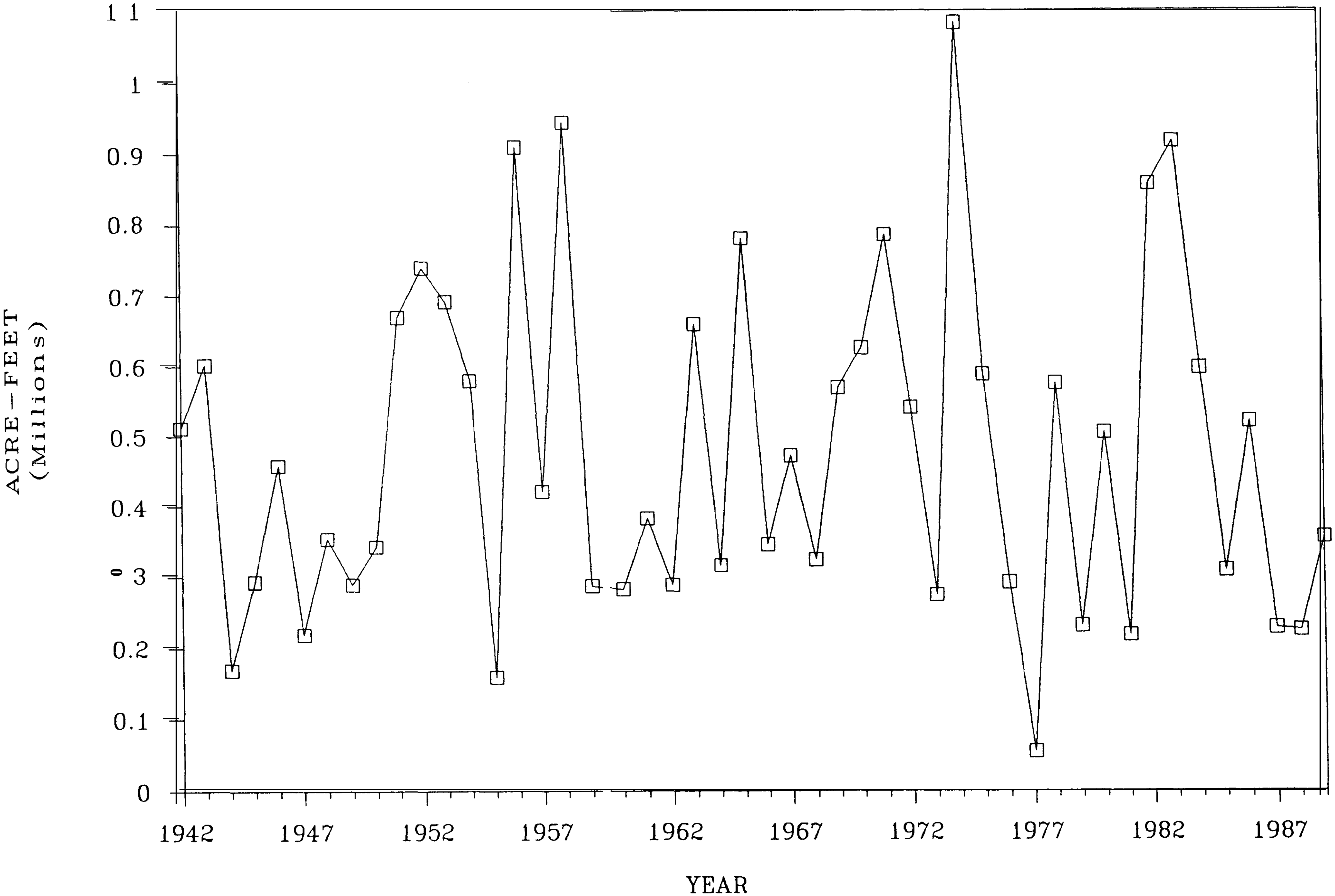
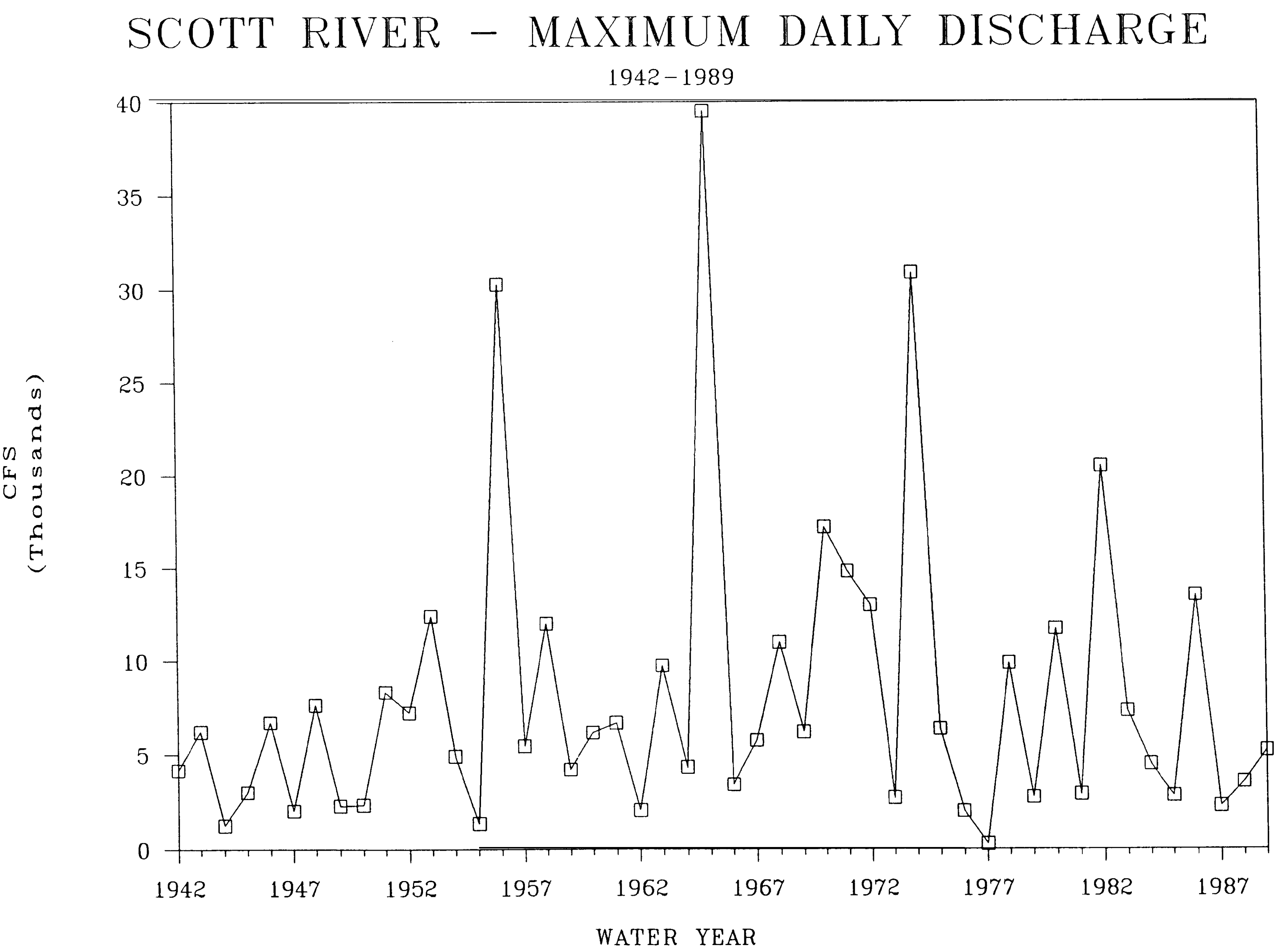


Figure 3-2



SCOTT RIVER - MAXIMUM DAILY DISCHARGE
1942-1989
CFS
(Thousands)
0
5
10
15
20
25
30
35
40
1942
1947
1952
1957
1962
1967
1972
1977
1982
1987
WATER YEAR

Figure 3-3

(Jackson, 1963). This historic channel is still apparent on aerial photos, as are the "oxbow" patterns of abandoned channels throughout the valley.

Mining activities have left a strong imprint throughout the Scott River watershed. Placer mining in the South Fork, Oro Fino, and Shackleford/Mill drainages probably removed many tons of soil from the streambanks in the late 1800s (Wells, 1880; 0. Lewis, pers. comm.). "Mining silt" from hydraulic mining above Callahan (South Fork, and Grouse Creek) was a significant problem in the upper Scott River in 1934, according to fishery biologists surveying the area (CDFG, 1934; Taft and Shapovalov, 1935).

Large gold dredges also transformed the upper river area during the period 1934 to about 1948. In the early 1940s, at least 4 bucket or dragline dredges were operating in the upper valley. Large quantities of "gravel" were washed: 800,000 cubic yards from one operation along Wildcat Creek in 1940; 245,000 cubic yards from another company along the main Scott in 1941 (Averill, 1946). For washing, 10,000 gallons per minute of water were pumped from a pond at the largest operation, whose dredge operated 24 hours per day and had a capacity of 210,000 cubic yards per month. The pond supposedly collected the wash water, except when the dredge worked the active stream channel. All that is left today at these dredger sites are 25 foot high tailings piles for about 5 miles from Sugar Creek to Callahan. Since a dredge tailing pile is usually deposited in reverse order of the original alluvial deposits above bedrock, cobbles are found on the surface (Ahnert, 1990). Downstream effects may still be present also.

At the turn of the century, the river channel at the northern end of Scott Valley was very winding and heavily vegetated with cottonwood and willow. The valley often became a lake during high water (Jackson, 1963; 0. Lewis, pers. comm.). To bring this land into agricultural production, landowners removed the "brush" and straightened the channel. The middle portions of the river also were altered for flood control. At the request of the County, the Corps of Engineers came to work in the valley in the summer of 1938, clearing much of the riparian vegetation, straightening the channel in places, and constructing levees in portions of the river from Horn Lane to past Fort Jones (Reaches 7 to 3) (0. Lewis, pers. comm.). Floods followed in 1938-39 and 1940-41, causing extensive bank erosion. Aerial photographs of the valley from 1944 reveal large sections of river with little or no riparian vegetation, as well as a very wide channel (600 to 900 feet) near the mouth of Oro Fino Creek (Reaches 2 and 3). This area looks very similar today (Figures 3-4 and 3-5).

Over the years, landowners have put in pilings, revetments and rock riprap to protect the streambanks. Following major floods, debris and "coarse bedload material" have been removed from problem areas of the stream and the channel reshaped. Proposals to construct additional levees along the main stem were determined to be economically infeasible in 1967 (McCreary Koretsky, 1967). The most recent channel straightening was done in

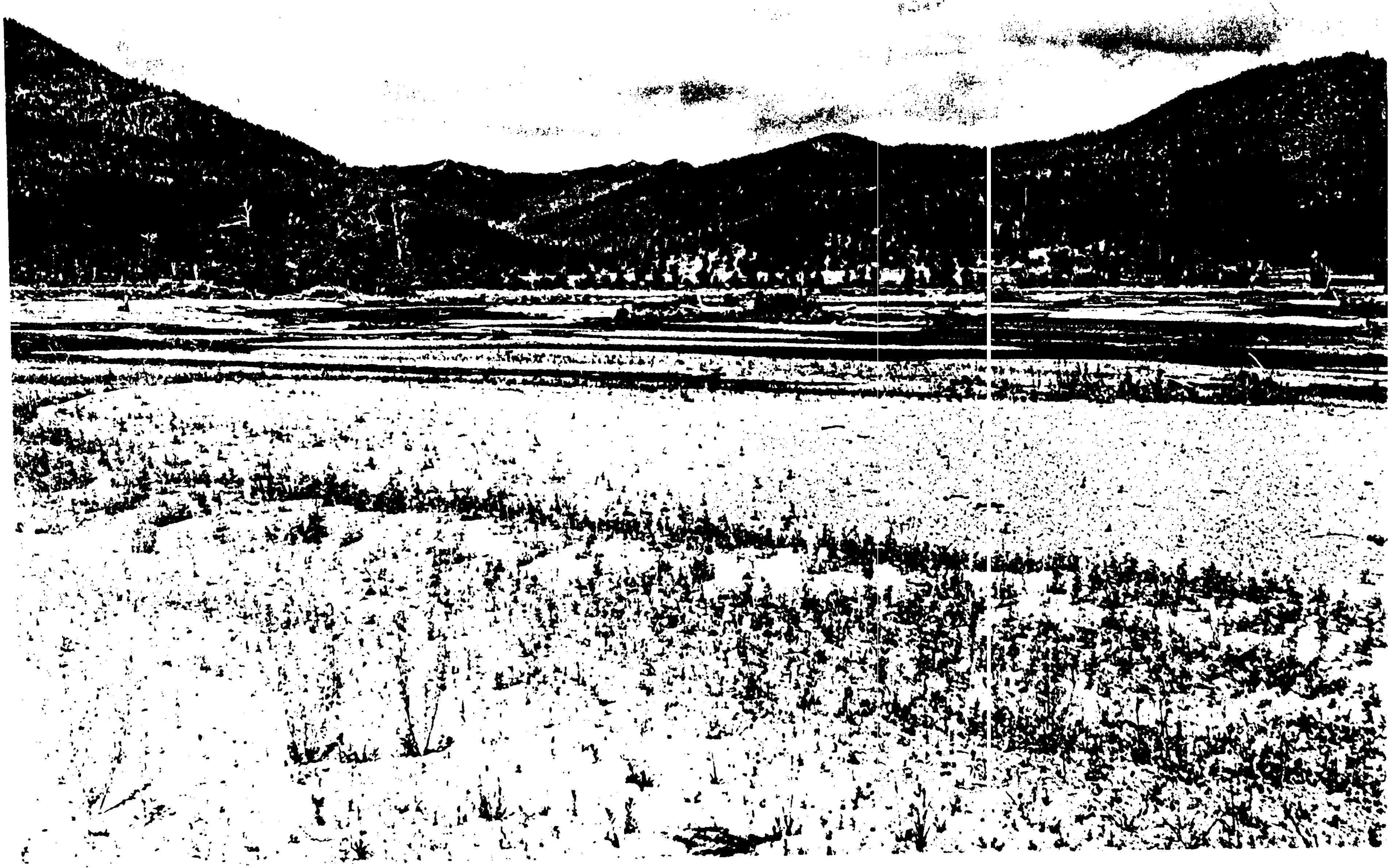


Figure 3-4. Lower Scott River, Early 1950s."Formerly 75-100' wide, now 700'" (SCS photo)

the early 1980s in the lower mile or so of Kidder Creek, just above its confluence with the Scott River.

Another type of alteration was the construction of two diversion dams by the Scott Valley Irrigation District, one at Young's Dam (Reach 8 and 9) in 1917, and another at the mouth of Moffett Creek below Fort Jones (Reach 3) in 1956-57. The upper one was washed out in the 1955 and 1964 floods and was rebuilt with sheet piling in 1965. The lower dam was partially removed in 1987 and completely removed in 1989 (M. Bryan, SVID, pers. comm.). While the diversion dams do not store water, they have trapped sediment and thereby altered the stream gradient above and below the structures.

Commercial Sand and Gravel Extraction

A factor affecting the sediment budget is the extraction of sand and gravel in the mainstem Scott and its upper tributaries. Only one commercial operation is presently located within the main channel of the Scott River; it is downstream of Fort Jones below the mouth of Moffett Creek. The operator reported the removal of 30,768 tons (about 25,000 cubic yards) through gravel bar skimming in 1989, but the quantity varies each year according to the demand (E, Schoonmaker, pers. comm.). Sand production at this site is greater than the market demand, although the commercial quality is very good. Commercial and county operations are also located on Kidder Creek near Greenview, and in the tailings pile outside of the main channel near Callahan.

METHODS

The calculation of sediment storage and transport requires specific information about the river: channel morphology, channel gradient, grain size distribution of sediment, and flow regimes. In addition to current data, historic data is needed if trends are to be evaluated.

Existing Data

Historic cross-sections of the Scott River and its tributaries were sought by examining bridge records of the Siskiyou County Road Department and the California Dept. of Transportation (CalTrans). No blueprints could be found for any of the existing County bridges crossing the Scott River, most of which were built following the 1955 and 1964 floods. Since these structures were constructed by the County under emergency conditions, streambed elevations were probably not accurately determined and the drawings would likely not be useful (0. Lewis, pers. comm.). However, blueprint copies were obtained of some of the existing State Highway 3 bridges from CalTrans' Redding Office archives. These include the following, with bridge number and year constructed: Scott River near Fort Jones (#2-57)-1956, Kidder Creek (#2-56).1956, Patterson Creek (#2-38).1963, East Fork Scott River (#2-185).1978.

Aerial photos of the Scott Valley from August 1944 were available at a scale of 1"=660' for evaluation of channel width. On-site photos were also available from the Soil Conservation Service for various locations for the period from the early 1950s to 1965.

New Field Work

New field work included the surveying of a total of 12 new cross-sections: one at each of the seven bridges crossing the Scott River from Callahan to the Meamber Bridge as well as five other sites between the bridges. Bridges were selected because they provide reasonably permanent sites which can be easily accessed and monitored, whereas non-permanent sites on private land can become inaccessable or lost in future years. However, bridge sites have certain limitations due to possible scour or constriction effects. An important concern is how representative the bridge sites are for the reaches being evaluated. While the bridges all had revetted banks, these banks were continuous with rock riprap placed for streambank erosion control along much of the banks of the Scott River. The bridge sites were not always typical of the stream width in each reach, particularly in the most meandering reaches where the range in width could be great. However, performing accurate cross-sections at each change in width, as suggested by Chang (1988) and Reid (pers. comm.), within the 34 mile long study area of the Scott River was beyond the scope of this study.

Additional sites on the river were also surveyed where needed to better define and analyze reaches for sediment transport (e.g., north end of valley; below the forks near Callahan). These non-bridge cross-section sites were marked on each streambank with steel rebar so they could be located for remeasurement. All survey work was conducted by a local engineering technician from the USDA Soil Conservation Service, using standard SCS methods. Field notes for each site can be found in the SCS office in Etna.

As noted in Table 3-1, the surveyed cross-sections became the downstream and upstream boundaries of defined reaches, which were then used for sediment storage and transport analyses. Each reach was of a different length, ranging from 2.0 to 6.3 miles, with an average length of 3.5 miles. Water levels during the low flow period of July through September 1989 were used to calculate the slope of each reach. Figure 3-5 describes the location and number of each cross-section and reach. In addition, cross-sections were also made for baseline purposes at the State Highway 3 bridges on the East Fork and South Fork of the Scott River.

<u>Grain Size Composition</u>

Streambed grain size composition was measured using a McNeil bed sampler in various locations but always at riffle or run sites. Both the surface and subsurface layers of the streambed

Table 3-1

Scott River Reach Descriptions

Reach #	Cross-Section	River Mile	Length (miles)	Site Location	Water Elev.	Slope (Ft/Mi)
	1	21.2		End of Valley	2635.38'	
1			3.2			6.44
	2	24.4		Meamber Bridge	2656.00'	
2			5.2			5.39
	3	29.6		Scott v. Ranch	2683.86'	
3			3.0			7.79
	4	32.6		Hwy. 3 Bridge	2704.20'	
4			2.1			3.98
	5	34.7		Island Rd. Bridge	2712.55'	
5			4.4			6.38
	6	39.1		Eller Ln. Bridge	2732.26'	
6			2.0			6.51
	7	41.1		Rancho del Sol Bridge	2745.28'	
7			2.8			6.30
	8	43.9		Horn Lane Bridge	2762.93'	
8			1.8			11.40
	9A	45.7		Young's Dam-below	2783.45'	
			0.3			
	9B	46.0		Young's Dam-above	2795.84'	
9			3.6			15.60
	10	49.6		Fay Lane Bridge	2851.99'	
10			6.3			40.48
	11	55.9		Below Fks. at Callahan	3107.04'	

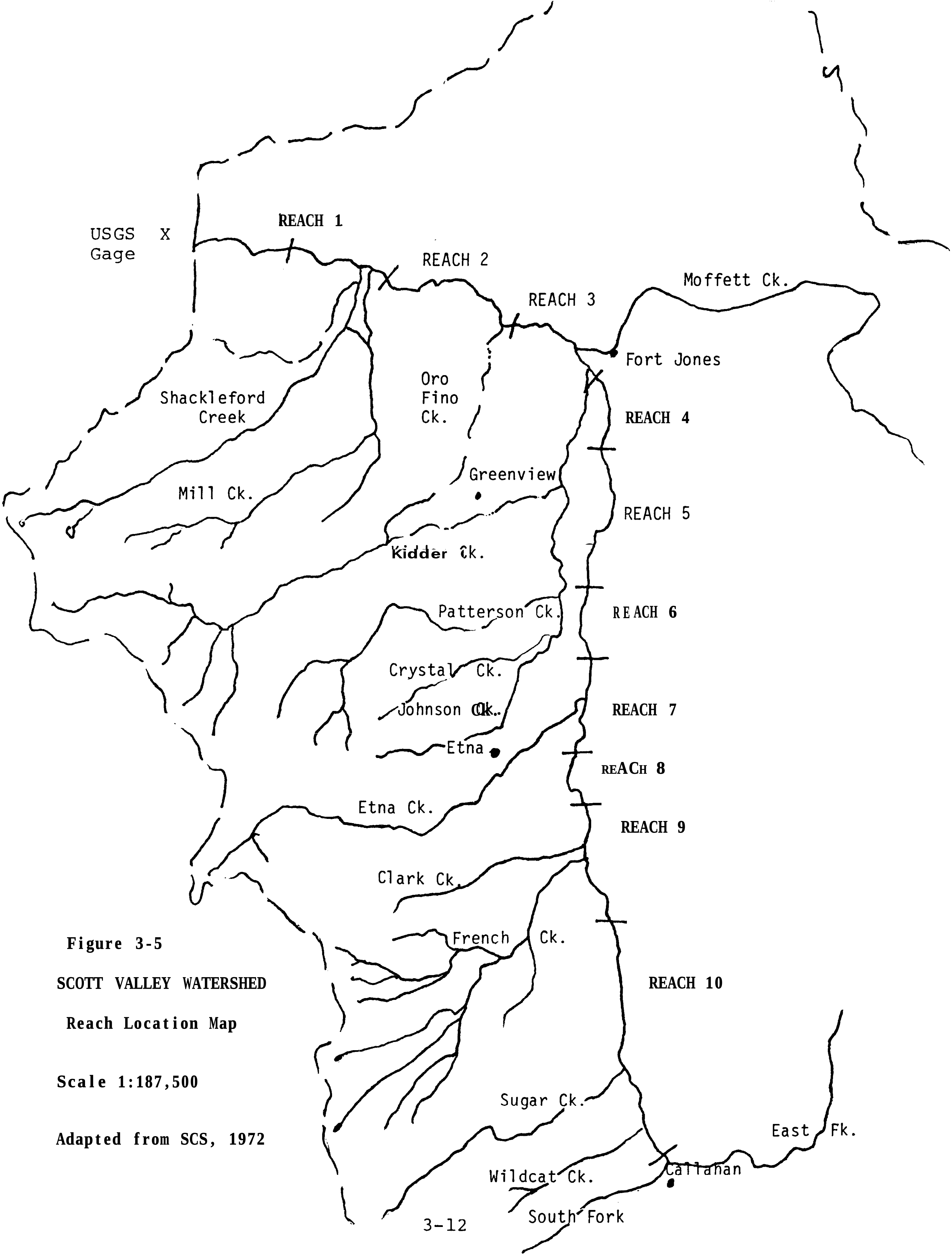


Figure 3-5

SCOTT VALLEY WATERSHED

Reach Location Map

Scale 1:187,500

Adapted from SCS, 1972

were sampled down to 6 inches to a maximum diameter of 6 inches, applying the methods described in Chapter 4. Only in the upper reach was material found larger than 6 inches. Randomized Wolman pebble counts (Wolman, 1954) were not attempted because several of the reaches are predominantly sand and the subsurface composition was also of concern. Pools were not sampled because they were quite infrequent in certain reaches or were too deep to sample. Since only riffles were sampled, the resulting sediment characterization or index only represents the riffles in each reach and not the entire sediments in the channel.

Sieves of six different mesh sizes were used to develop seven size distributions, primarily in the gravel and sand categories. Table 3-2 defines particle size classification, which can vary depending on the system is used. For example, other granitic bedload sediment studies have analyzed for diameters up to 6.35 mm, although this size is technically larger than "sand" (Bjornn et al, 1977; Stowell et al, 1983). The sediment terminology in Table 3-2 for stream substrate materials comes from Lane, 1947, as described in Platts et al, 1983.

Streambed sediment samples were taken in each reach except for Reaches 6 and 8. No tributaries entered at these reaches. Similar slopes were sufficient to allow the grain size composition of Reach 5 to also be used for Reach 6, while surface similarities of the sample site in Reach 7 were the basis for using the same grain size results for Reach 8.

Table 3-2
Grain Size Classification

Classification	Particle diameter size millimeters	inches	Selected Sieve Size
Large cobbles	256-128	**10-5**	
Small cobbles	128-64	5-2.5	
Course gravel	64-16	2.5-0.6	25mm
Medium gravel	16-8	0.6-0.3	12.5,6.35mm
Fine gravel	8-4	0.3-0.16	4.75mm
Very fine gravel	4-2	0.16-0.08	2.36mm
Very course-course sand	2-0.5		0.85mm
Medium sand	0.5-0.25		
Fine-very fine sand	0.25-0.062		
Silts	0.62-0.004		
Clays	0.004-0.00024		

One problem in accurately measuring sand movement is that sand is transported as both bed load and as suspended load, with most of the sand grains carried in suspension near the bottom of the water column (Morisawa, 1968). Suspended load grains are nearly always less than 0.5 mm in diameter (Dunne and Leopold, 1978), which is finer than much of the decomposed granitic sand found in the Scott River. As a result, suspended sediment and turbidity sampling were rejected as useful measurements of sand movement. Sampling of the bedload was not attempted for several reasons. Most bedload movement occurs at high velocities, which in the Scott River would require special bed-load samplers to accommodate peak flows ranging from 5,000 to 54,000 ft /sec^3 (cfs). Chang (1988) observes that the dynamic processes involved in sediment transport will yield different rates at the same location at the same time and cautions that "sampling bed load is a difficult operation that requires experienced operators to obtain reliable results". Even such experienced samplers as the California Dept. of Water Resources are reluctant to rely on bedload sampling data for use in sediment transport analyses due to the inaccuracies of the results (K. Buer, CDWR, pers. comm.). Beschta (1987) also complains about the "relatively unsophisticated nature" of bedload measurement techniques, which cause attempts at calibrating existing bedload equations with 'observed' data to be of "limited utility?

Sediment Storage

The following data were used to estimate the alluvial sediment storage for each reach:

- USGS topographic maps at 7.5 minute (1:24,000) scale;
- Surveyed cross-section data for cross-sections at the end of each reach - 1989;
- Recent color IR aerial photographs at various scales: 1:40,000 (magnified 8X); 1:12,000.
- Results of sieve analyses for bed material.

Volumes for each reach were calculated for the deposits in the active and semi-active channels. The active channel is defined here as the area where sediment is transported during moderate annual flows and contains little or no vegetation. Semi-active channels are those mobilized during peak flows every 1 to 5 years and have some annual or shrubby vegetation. Since the bankfull capacity of the Scott River is exceeded about once in every three years, all deposits within the banks fall into these two categories (McCreary Koretsky 1967). Deposits above the banks within the flood plain could not estimated as they tend to be plowed back into the fields.

First, the area of deposits within the stream channel were evaluated from aerial photos and topo maps and planimetered for size. Next, the depth above the thalweg was determined from the average of the two cross-sections at each end of the reaches (excluding the streambank portion). The area of each reach was multiplied times the average depth to determine the volume in cubic yards. To translate to weight, the volumes in the reaches determined to be predominantly sand from grain size analysis (reaches 3 and 4) were multiplied by 1.35 tons per cubic yard (100 lb per cubic foot), moderately sandy Reaches 5 and 6 by 1.50

tons/cu.yd. (110 lb/cu.ft.) and the rest of the reaches by 1.62 tons /cu. yd. (120 lb/cu.ft.), since these are the ranges of bulk densities common to sand and gravel bed streams (CDWR, 1984; E.Schoonmaker, Contractor's Sand & Gravel, pers. comm.)

The depth of the transportable sediment in storage below the thalweg is difficult to measure. One indicator of depth is the stability of the rock riprap projects along the streambanks which are engineered by the Soil Conservation Service. Since about 1960, these boulder-size rocks have been placed in trenches from 3 to 4 feet below the streambed at the edge of the channel at various locations in the valley (except Reach 10) and most have withstood high water flows to date, with some settling (A. Lewis, SCS, pers. comm.). If the streambed was moving at the edge of the channel at this depth, the rocks would have been undermined and fallen into the channel.

Another indicator is the depth of bridge pier footings. The County Engineer in charge of bridge construction after the 1955 flood recollects that the footings were about 25 feet below the bed at Meamber Bridge and about 10 feet below for Horn Lane (0. Lewis, pers. comm.). These bridges survived the 1964 flood. Scour occurs at high flows at bridge piers, which could exaggerate the depth of bedload movement (Chang, 1988).

Sieve analysis results were applied to the sediment quantities in each reach to estimate the quantity of sand-size or smaller sediment (% finer than 2.36mm sieve).

Sediment **Transport**

The following data were used to estimate sediment transport capacities:

- Streamflow data for USGS stream gages: Scott River near Fort Jones and Moffett Creek near Fort Jones;
- Map of Scott Valley showing locations of cross-sections and reaches within the study area;
- Surveyed cross-section data for cross-sections at the end of each reach;
- Results of sieve analyses for bed material;
- Photos of the river for each reach.

A flow duration curve was prepared for the Scott River at the USGS gaging station near Fort Jones (RM 20.5). Runoff multipliers were determined for each reach using basin areas, precipitation, and the differences in runoff between the two gages. Sediment sizes from the sieve data were plotted and D50's (i.e., median grain size) were determined for the bed sediment for each reach.

Cross-sections were plotted and interpolated cross-sections were estimated for various flows to represent the hydraulic characteristics of each reach. Slopes of each reach were determined from the surveyed water surface elevations at the ends of each reach. Manning's roughness (n) was estimated from site photos and from similar sites. For example, Trinity River studies of sandy reaches have used n=0.03 (Frederickson, Kamine, and Assoc., 1980). Velocity was estimated for each reach using Manning's equation, with the hydraulic radius (R) assumed to be 0.95 times the depth (they are about equal in wide channels) (Morisawa, 1968; Dunne and Leopold, 1978).

To calculate potential annual sediment transport capacity, the flow duration curve was divided into several increments. An average flow was used to represent each increment. Hydraulic characteristics and a sediment transport rate were calculated for each increment. The sediment transport rate was then multiplied by the period of time represented by the increment. Sediment transport capacity for the increments were summed to determine the potential annual sediment transport capacity for each reach.

Three sediment transport equations were investigated:

1. Meyer-Peter-Muller, "MPM" (in Gomez and Church, 1989);
2. Engelund-Hanson, "E-H" (in Chang, 1988);
3. Ackers-White, "A-W" (in Chang, 1988);

The MPM equation in the Gomez and Church article was discovered to be incorrectly described but, after consultation with Michael Church of the University of British Columbia, was corrected.

These three equations were selected for several reasons. Since no one sediment transport formula has been widely accepted or recognized as being very appropriate for practical application, it seemed best to examine formulas offering a range of results (L. Reid, USFS, personal communication). A comparison is offered in Table 3-3 below.

Table 3-3
A Comparison of the Sediment Transport Equations

	Meyer-Peter-Muller MPM	Engelund-Hansen E-H	Ackers-White **A-W**
1.	Bedload only	Bedload and suspended load	Bedload and suspended load
2.	Shear stress approach	Stream power approach	Stream power approach
3.	Coarse Sediment 6.4 -30 mm	Fine sediment 0.15 mm	Fine to medium 0.04 - 4.0 mm

The MPM formula is primarily designed for gravel bed streams while the E-H and A-W equations are for sand bed channels. MPM also uses shear stress in its formula, which is the tractive force, or the permissible velocity, per unit area applied to the channel boundary on which bed load moves by rolling, sliding, and sometimes saltating (Chang, 1988).

All existing sediment transport formulas were derived by relying on calibration using flume and field data supposedly under steady uniform flow conditions. The formulas for the above three methods can be found in Appendix A. The common factors in each equation include velocity, slope, depth, grain size, roughness and width. Since the equations determine transport capacity in metric tons, the results were converted into short tons to allow comparisons with hillslope sediment yield and channel storage estimates.

Results and Discussion

Stream Profile and Cross-Sections

Figure 3-6 presents the stream gradient from the river's mouth up to its headwaters, including the slope of the major tributaries to Scott Valley, as based on proximate elevations from the 7.5 minute USGS quadrangle maps. The valley represents a low gradient section between two high gradient areas. Although the upper reaches of a river are usually steeper, most rivers do not have such a lengthy "plateau" in the middle of their profiles. The lower reaches are areas of deposition and typically the flattest (Morisawa, 1968).

For another perspective, a longitudinal profile based on 1989 low water elevations of the Scott River from its north end (River Mile 21.2) south to Callahan (River Mile 55.9) is described in Figure 3-7. The numbered reaches, as noted in Table 3-1, are also indicated on this figure. This profile is a more accurate one for illustrating the current relative slopes of the valley reaches. Its general concave shape is the result of a number of interdependent factors, all relating to the stream seeking to maintain a balance between its capacity to move sediment and the amount and size of sediment to be moved (Morisawa, 1968).

Each of the newly surveyed cross-sectional profiles is depicted in Appendix B. Channel width varies from 100 feet at Eller Lane Bridge to 725 feet at Scott Valley Ranch (RM 29.6).

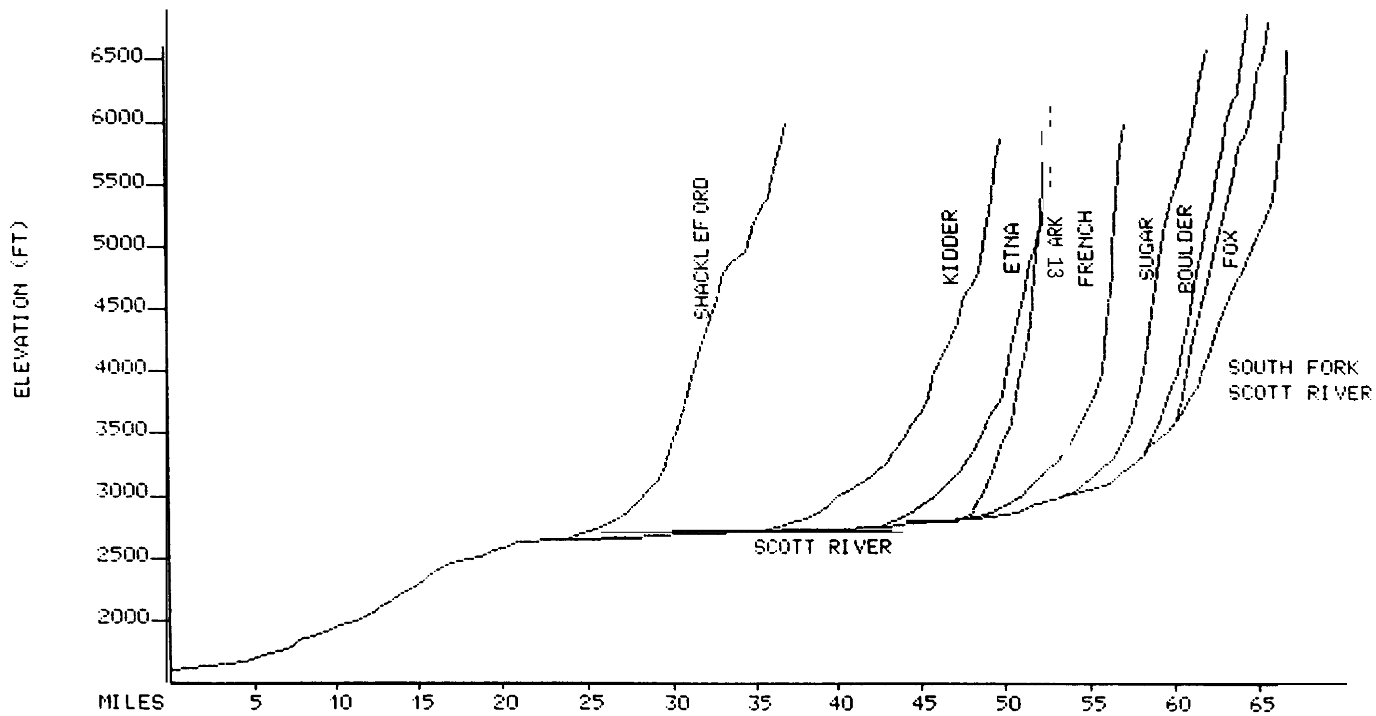


Figure 3-6. Stream Profile of Scott River from Mouth to Headwaters

SCOTT RIVER STREAM PROFILE

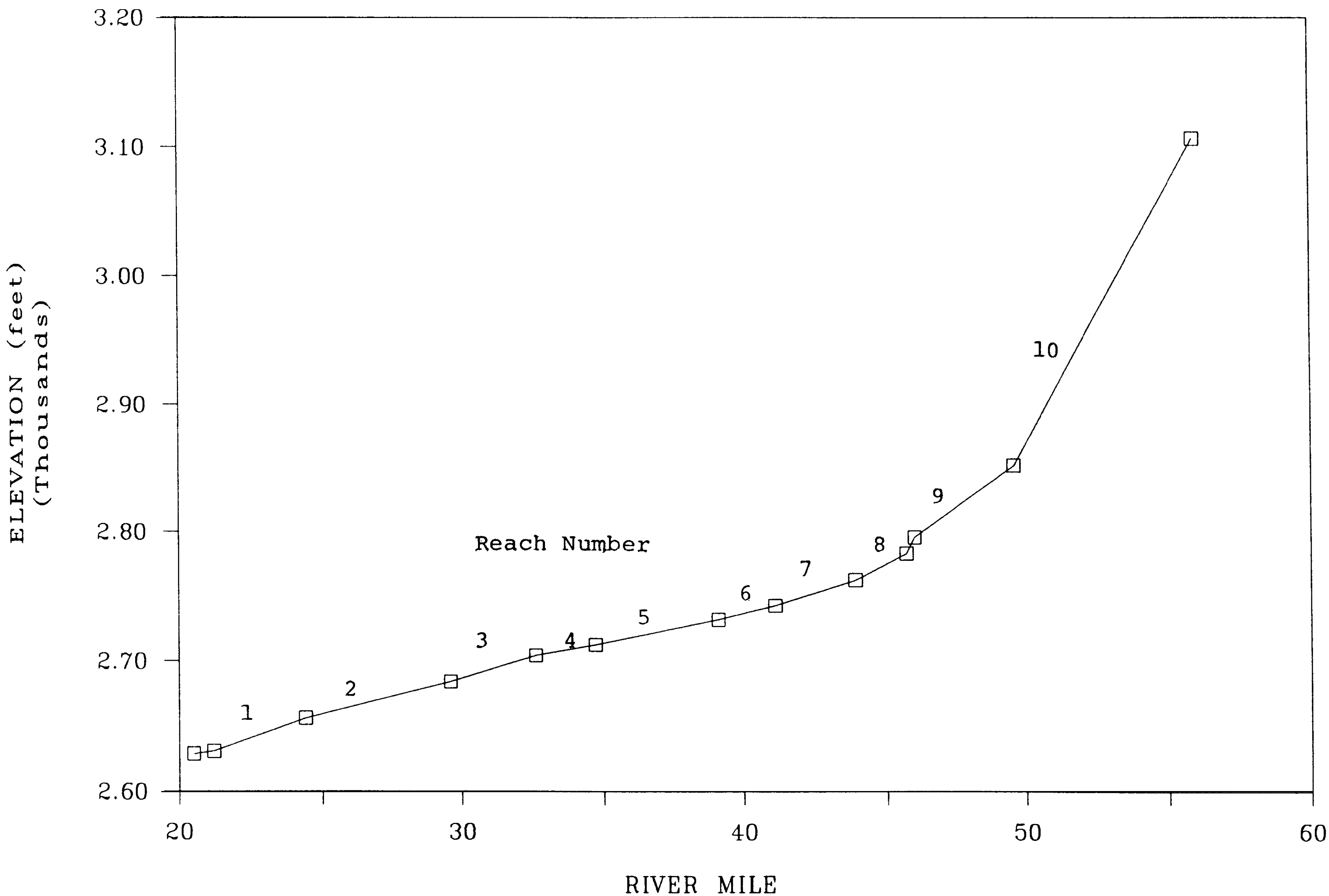
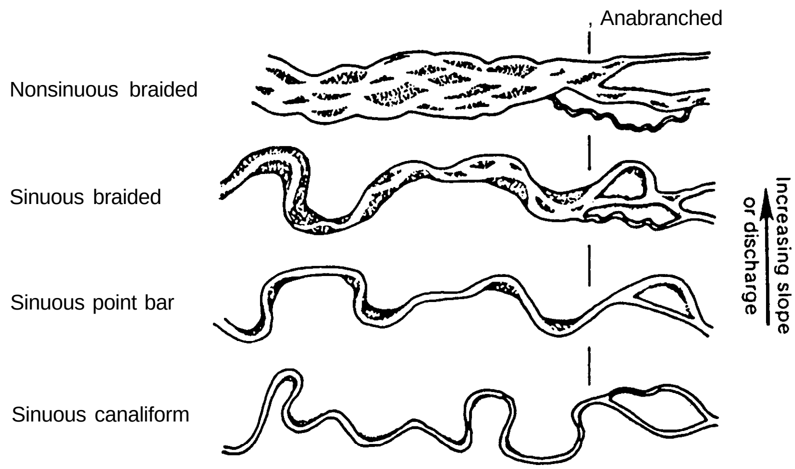


Figure 3-7

Most of the reaches can be described as the "sinuous point bar" type of river channel; Reaches 2 and 3 have portions that are more of the "sinuous braided" type, while Reaches 4 and parts of 5 are "sinous canaliform? Figure 3-8 illustrates these various shapes (Brice, 1983 in Chang, 1988). The differences mainly are related to slope, discharge, and the silt-clay content of the banks (canaliform has the most).

Figure 3-8. River Classification



Grain Size Composition

The grain size distribution results from the 1989 sieving effort are shown in Table 3-4 (n=238). Reaches 3 and 4 contained the highest percentage of fine sediments: 65% and 51%, respectively, of less than 2.36mm. Reach 10, the most upstream site, had the coarsest sediments with 49% greater than 25.0mm. Although the grain size became finer downstream as one would expect, at Reach 2 the size began to get coarser and Reach 1 was coarser than Reach 2.

A decrease in downstream grain size is an indication of either selective sorting (i.e., the stream is not competent to transport those grain sizes beyond a certain reach) or abrasion or possibly both (Morisawa, 1968; L. Reid, USFS, pers. comm.). Decomposed granitic rock breaks apart very easily.

Table 3-4

Grain Size Composition by Reach
Dry weights (grams)

Reach[1]	Sieve Size (nun) (% Retained) >25.0	>12.5	>6.30	>4.75	>2.36	>0.85	<0.85	TOTAL
1	2205 38%	976 16%	778 13%	235 4%	413 7%	722 12%	538 9%	5867
2	1809 32%	973 17%	792 14%	253 4%	451 8%	736 13%	606 11%	5620
3	64 1%	121 3%	3 9 8%	238 5%	792 18%	1994 44%	928 21%	4506
4	193 5%	116 3%	506 12%	313 7%	928 22%	1293 30%	902 21%	4251
5	231 5%	994 21%	867 18%	305 6%	613 13%	907 19%	811 17%	4728
7	1375 25%	1075 20%	798 15%	262 5%	504 9%	827 15%	558 10%	5399
9	2262 38%	934 16%	550 9%	195 3%	404 7%	895 15%	693 12%	5933
10	2868 49%	665 11%	669 11%	188 3%	407 7%	609 10%	415 7%	5821

1/ Sieve results for Reach 5 were applied to Reach 6, and results from Reach 7 were used for Reach 8.

Sediment Storage

Estimated storage in the main Scott River channel above the thalweg is described for each reach and sub-reach in Table 3-5. Since each reach is of a varying length, the average stored sediment per mile is also presented. Cumulative storage from the upstream to downstream reaches is listed in the far column, amounting to approximately 10.45 million tons of sediment.

Reach 2 contains the greatest amount of sediment of any of the reaches, followed by Reach 10. However, these two are also the longest reaches and a more accurate comparison between sites would be on a per mile basis. Reach 3 contains the highest quantity per mile and has slightly more than Reach 2. Not surprisingly, these reaches are the widest, ranging from about 250 to 900 feet. The smallest amount is in Reach 5, which is also the narrowest part of the river.

Applying the grain size compositions to the amount of stored sediment in each reach gives an indication of the amount of sand-sized sediment (<2.36mm) found within the channel. Figure 3-9 depicts the relative quantities of sand and total sediment by location. While Reach 2 has the highest total sediment in storage, Reach 3 has the greatest amount of sand. Reach 1 has the smallest amount.

Based on the only available historical cross-section, the Scott River's channel near Fort Jones seems to have undergone some degradation since 1956. As shown in Figure 3-10, the 1989 bed elevation apparently ranges from 1 to 10 feet lower than that of 33 years ago. The 1956 elevation reflects the aggradation caused by the 1955 flood deposition. A period of degradation likely followed until the 1964 flood once again deposited sediment. The cycle was probably repeated with the 1974 flood (of similar magnitude to the 1955 flood). With no large flood since then, the last 15 years seem to have been a period of net degradation.

Much of the sediment delivered to the Scott River in the 1955 and 1964 floods was eventually deposited on the wide valley floor. Alluvial flood plains commonly serve as temporary or long-term storage (Beschta, 1987). In 1955, 6,300 acres were inundated while 26,520 acres were flooded in 1964. Although quantities of sediment are now difficult to determine, observations seem to verify this assumption. Photographs taken shortly after each flood by the SCS office in Etna indicate large areas covered by recent sediment (Figures 3-11 and 3-12). The white streaks on this Feb. 1965 photo were identified to be mainly sand (F. Jackson, pers. comm.). At specific sites, flood "silt" was reportedly 6" to 36" deep on portions of farmland near the middle reaches (2 to 5) of the Scott River (A. Lewis, SCS, pers.comm.). These deposits were plowed back into the field and the farmland regraded to accommodate irrigation flows before replanting.

Table 3-5
Estimated Volume of Stored Sediment by Reach
Above the Thalweg

Reach		Location	Volume Per Reach	Volume Per Mile	Cumulative Volume (short tons)
	10A	Callahan to Wildcat Ck.	983,789		983,789
	10B	Wildcat Ck. to Sugar Ck.	780,129		1,763,918
	10C	Sugar Ck.to Fay Lane	406,055		2,169,973
10		SubTotal	2,169,973	344,440	
	9A	Fay Lane to French Ck.	815,270		2,985,243
	9B	French Ck. to Clark Ck.	326,569		3,311,812
	9c	Clark Ck. to Young's Dam	405,833		3,717,645
9		SubTotal	1,547,672	396,839	
8		Young's Dam to Horn Lane	418,636	232,576	4,136,281
	7A	Horn Lane to Etna Ck.	334,919		4,471,200
	7B	Etna Ck. to Rancho del Sol	281,386		4,752,586
7		SubTotal	616,305	220,109	
6		Rancho del Sol to Eller Lane	483,446	241,723	5,236,032
5		Eller Lane to Island Rd.	699,651	159,012	5,935,683
4		Island Rd. to Hwy. 3 Bridge	334,677	159,370	6,270,360
	3A	Hwy. 3 to Kidder Ck.	132,669		**6,403,029**
	3B	Kidder Ck. to Scott V. Ranch	1,191,564		7,594,593
3		SubTotal	1,324,233	441,411	
2		SV Ranch to Meamber Bridge	2,750,445	528,932	10,345,038
	1B	Meamber Br. to Shackleford Ck.	111,396		10,456,434
	1A	To End of Valley	274,713		
1		SubTotal	386,109	120,659	

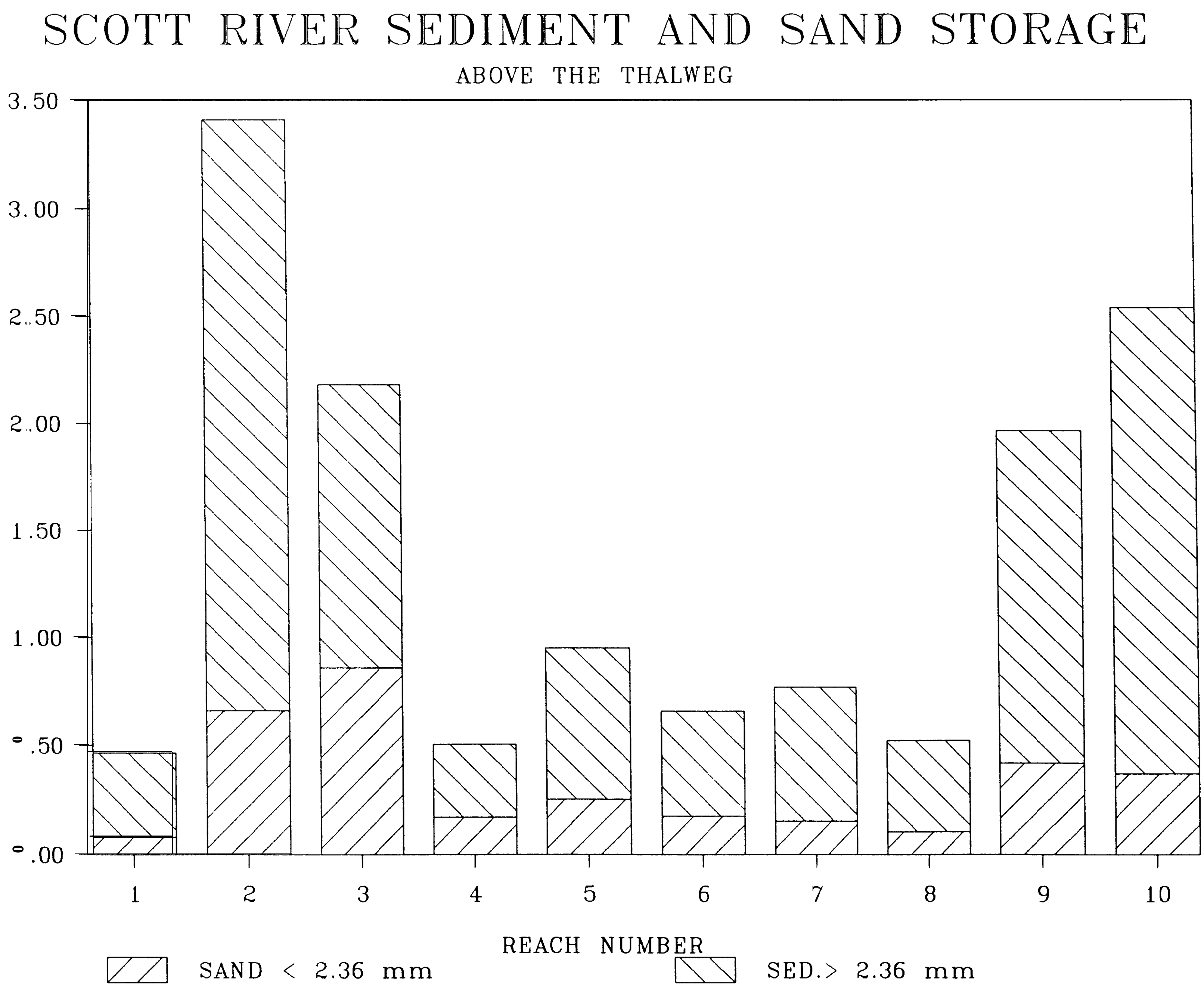

SCOTT RIVER SEDIMENT AND SAND STORAGE
ABOVE THE THALWEG
TONS (Millions)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1
2
3
4
5
6
7
8
9
10
REACH NUMBER
SAND < 2.36 mm
SED.> 2.36 mm

Figure 3-9

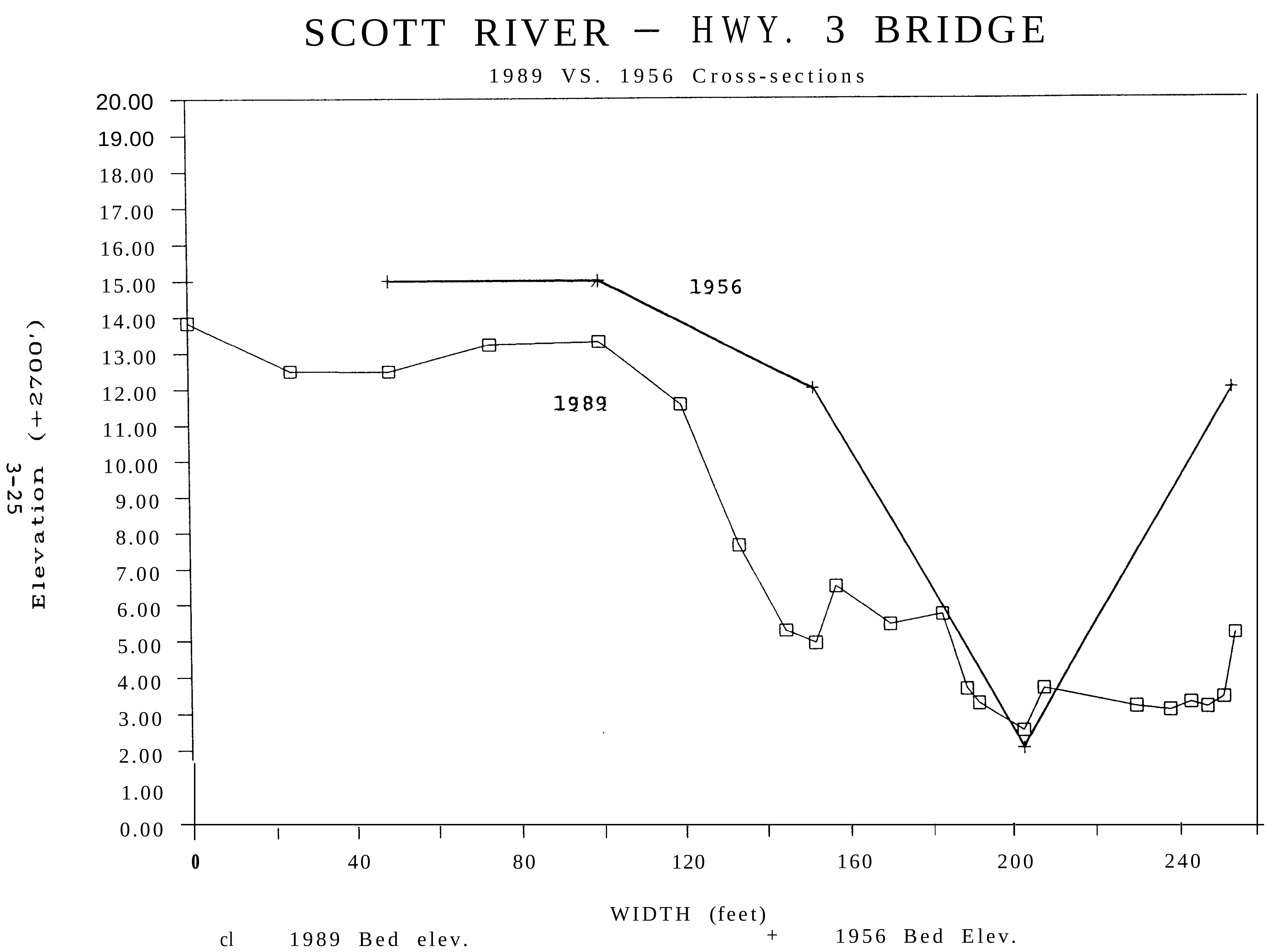

SCOTT RIVER – HWY. 3 BRIDGE
1989 VS. 1956 Cross-sections
Elevation (+2700')
1956
1989
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
0
40
80
120
160
200
240
WIDTH (feet)
cl 1989 Bed elev.
+ 1956 Bed Elev.

Figure 3-10

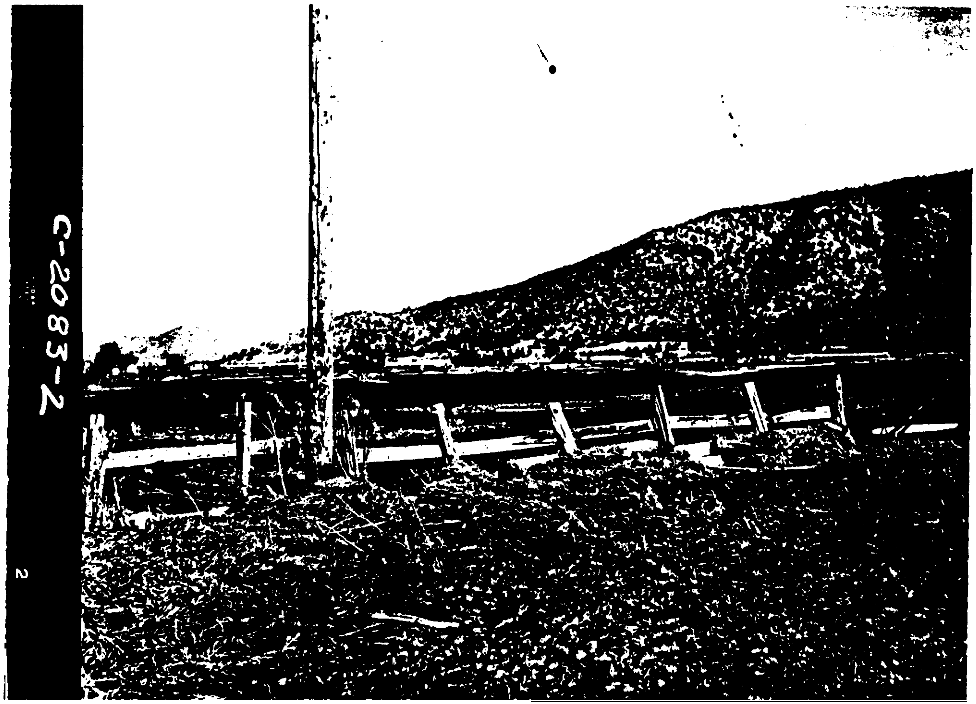


Figure 3-11, Silt and debris piled against fence (Reach 5) after Dec., 1955 flood (SCS photo)

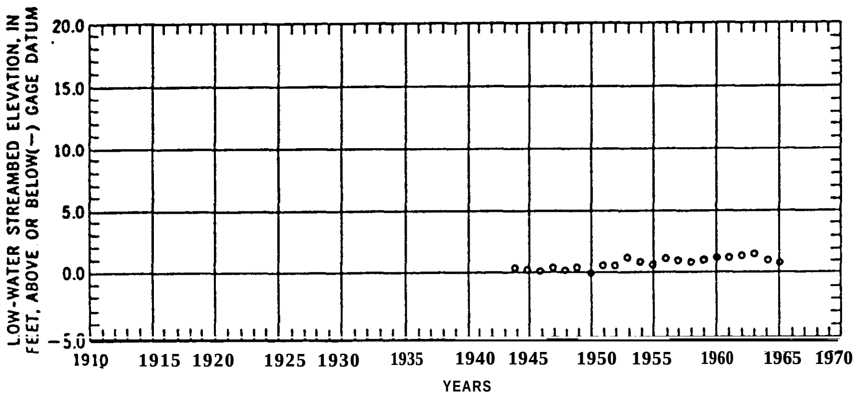
(28)

Figure 3-12.. Upstream of Meamber Bridge (Reach 2), Feb. 1965
"Thousands of yards of gravel and sand deposited here"
(caption on SCS photo)

As the only quantitative measure of downstream channel effect, the low-water streambed at the USGS gage station (RM 20.5) below the valley was surveyed for elevation in 1964 and in 1965. Instead of aggradation, the streambed elevation had degraded by 0.1 foot (Hickey, 1969). The best explanation is that the valley "absorbed" much of the upstream sediment. In contrast, the 1955 flood, which inundated much less valley land, contributed about 1 foot to the streambed at the gage station (Figure 3-13). Upstream, the bed elevation at the former gage station on the East Fork Scott River above Callahan aggraded 0.4 feet, but this small change is not a significant streambed modification (Hickey, 1969).

Figure 3-13

Changes in Bed Elevation at USGS Gage Station, 1944-1965
Scott River near Fort Jones



Another important storage area is the "Big Slough", which parallels the Scott River and drains the tributaries north of Etna Creek (Johnson, Crystal, Patterson creeks). It then combines with Kidder Creek before flowing into the Scott River at RM 32.3. This narrow, shallow channel becomes very sinuous above the confluence with Patterson Creek and experiences frequent overflow and ponding (McCreary Korestsky, 1967). As a result, this drainage probably deposits much of its annual sediment load in its flood plain.

A USGS geology study of the Scott Valley described why these four tributaries flow north and also provided further evidence of sediment deposition in the valley over geologic time (Mack, 1958):

> "During flood stages, the Scott River has apparently built up broad, low natural levees sloping gently away from the channel banks toward the valley margins. The natural levee along its west side prevents the western tributary streams from entering the Scott River via the shortest distance, directly to the east. The phenomenon of deferred tributary junction has thus resulted, because the combined drainage of the western streams has been forced to flow northward parallel to the Scott River for several miles within the confines of the slough between the area of higher fans to the west and the natural levee to the east."

Sediment Transport

Most of **the sand is** moved as bedload rather than as suspended sediment, **as** grains that appear in suspended load are nearly always less than **0.5 mm** (Dunne and Leopold, 1978). This finding is supported by the one available suspended sediment analysis on the Scott River (March 1956), where 100% of the sample was finer than 0.500 mm (fine sand) and 79% was finer than 0.125 mm (silt) (USGS, 1960). As can be seen from the grain size distributions of the streambed (Table 3-5, the reaches varied from 7 to **21%** in the amount of bed material less than 0.85mm.

Table 3-6 summarizes the hydraulic characteristics and average annual sediment transport capacity of the Scott River by reach. (The original results were in metric tons, and were converted to short tons and rounded to the nearest 1,000). The concentration column shows concentrations of sediment for the 0.2 percentile flow (major flood peak) and 60 percentile flow respectively. Although the sediment transport capacities in Table 3-6 are printed to several significant figures, these estimates are accurate only to within one order of magnitude.

Comparison of Formulas

The Engelund-Hansen and the Ackers-White equations produced very similar results and probably represent the best estimate of annual sediment transport capacity of the Scott River with the data available for this study. The Meyer-Peter-Muller equation indicated a substantially greater sediment transport capacity for each reach, although a smaller capacity would be expected for this bedload equation. Several explanations are possible why the MPM equation may have overpredicted sediment transport: 1) it needs to be calibrated to the bedload and bedload data was not available; 2) it is best suited to gravel bed streams; or 3) the available grain size data were from riffle areas only and omitted cobble size (6") and larger material (primarily in Reach 10).

Table 3-7 shows the results of sensitivity analyses on each equation. Effects of changes in Manning's roughness (n), bed material D50 (median grain size), and river slope upon sediment transport capacity for a high flow in Reach 1 are shown. An additional consideration not tested is the effect of cross-section geometry upon sediment transport capacity.

It can be seen from this table that the roughness factor, which influences the calculation of depth and causes the stream energy to be dispersed on friction, has a strong affect on the MPM and A-W results, but none on the E-H. While MPM shows greater transport with higher roughness, A-W indicates less transport capacity. The E-H formula is greatly affected by the D50 grain size, almost doubling transport when the D50 is reduced by .005m (5mm), while the others increase somewhat. Decreasing the slope reduces the transport capacity for each of the equations.

Table 3-6

AVERAGE ANNUAL SEDIMENT TRANSPORT CAPACITY OF THE SCOTT RIVER BY REACH

Reach	Slope	n	D50	MPM		Engelund-Hansen		Ackers-White	
			M	TON	Conc. PPM	TON	Conc. PPM	TON	Conc. PPM
1	0.00120	0.035	0.0150	302,000	353- 51	20,000	39- 4	24,000	100 0
2	0.00100	0.035	0.0125	206,000	295-107	13,000	32- 3	14,000	77- 0
3	0.00130	0.033	0.0017	741,000	511-573	410,000	1065-111	184,000	224-93
4	0.00075	0.030	0.0022	332,000	249-249	111,000	346- 29	84,000	123-33
5	0.00085	0.030	0.0048	316,000	266-222	55,000	138- 17	94,000	131-38
6	0.00123	0.033	0.0048	516,000	448-353	69,000	214- 18	78,000	150-12
7	0.00119	0.035	0.0100	300,000	402-133	22,000	74- 6	23,000	121- 0
8	0.00220	0.037	0.0100	955,000	877-736	88,000	338- 35	129,000	251-39
9	0.00300	0.040	0.0150	884,000	1280-773	57,000	232- 21	64,000	263-27
10	0.00770	0.045	0.0250	239,500	3964-3098	139,000	745- 77	150,000	651-15

Table 3-7

Sensitivity Analysis of Sediment Transport Equations

Reach	Flow cfs	Slope	Width feet	n	Depth M	D50 M	ib Kg/S
Meyer-Peter-Muller							
1	20,000	.0015	165	0.035	4.1	0.015	**138.9**
1	20,000	.0015	165	0.040	4.4	0.015	160.9
1	20,000	.0015	165	0.035	4.1	0.010	155.5
1	20,000	.0015	165	0.035	4.3	0.015	115.2
Engelund-Hansen							
1	20,000	.0015	165	0.035	4.1	0.015	89.88
1	20,000	.0015	165	0.040	4.4	0.015	89.88
1	20,000	.0015	165	0.035	4.1	0.010	165.11
1	20,000	.0015	165	0.035	4.3	0.015	67.51
Ackers-White							
1	20,000	.0015	165	0.035	4.1	0.015	216.90
1	20,000	.0015	165	0.040	4.4	0.015	139.83
1	20,000	.0015	165	0.035	4.1	0.010	241.09
1	20,000	.0015	165	0.035	4.3	0.015	172.57

A comparison of the results in Table 3-6 also confirms these sensitivities. In Reaches 3 and 4, for example, the E-H formula estimates a much higher transport capacity than the A-W method primarily because the grain size is so small in these reaches.

Another interesting variation is the different responses of sediment concentration. MPM shows considerable sediment movement at 0.2 percentile flow (major flood peak) as well as at the lower flow (60 percent occurrence) for each reach. In contrast, A-W shows no movement and E-H shows little movement in reaches 1,2 and 7 at lower flows. These latter methods indicate sediment movement occurs primarily during higher flows.

Unfortunately, sediment transport capacity can only be estimated "rather crudely" with available formulas (L. Reid, USFS, pers. comm.). However, " the formulas may faithfully predict and provide an explanation for spatial variations of sediment yield and particle sorting along the stream?

Comparison of Reaches

While the quantitative differences among the equations may be large, the three methods reveal fairly close estimates of the relative abilities of each reach to transport sediment. Putting the results of Table 3-6 in rank order (l=highest capacity; 10= lowest) reveals the following:

Reach #	MPM	E-H	A-W
1	8	9	8
2	10	10	10
3	4	1	1
4	6	3	5
5	7	7	4
6	5	5	6
7	9	8	9
8	2	4	3
9	3	6	7
10	1	2	2

Reach 1 has one of the lowest abilities for sediment transport, probably related to its low gradient and greater grain size. Shackleford Creek deposits its sediment into this reach, which is a fairly low percentage of the total annual DG contribution (see Table 2-14).

Reach 2 appears to have the lowest capacity for transport of all the reaches. The major influencing factors are likely the lower gradient and the larger grain size. Reach 2 also contains the widest section of river, ranging from 700 to 900 feet in the vicinity of Oro Fino Creek's confluence.

Reach 3 is a critical one for several reasons. It is the location of the deposits from two major tributaries, Kidder/Big Slough (including Patterson, Crystal and Johnson creeks), which contributes about 27% of the total annual DG load to the river, and Moffett. Reach 3 is also where sand and gravel are removed commercially, about 31,000 tons in 1989. Its high transport capacity appears to be related to its small median grain size (1.7mm), large width, small slope, and low roughness. Additionally, the diversion dam acted as a gradient control structure from 1958 to 1987-89. As a result, **Reach 4** upstream has the lowest slope (.0075) of any of the reaches. With the complete removal of the dam in 1989, the river will be seeking readjustment of its equilibrium and the slope of Reach 4 will likely increase while that of Reach 3 decreases. Transport capacities will adjust similarly.

Reach 5 and **Reach 6** are quite similar in transport capacity as well as in width and grain size. Except for MPM, the formulas do not seem very affected by differences in slope or roughness. No tributaries enter in these reaches.

Reach 7 has one of the lowest transport capacities, most likely due to its higher median grain size (10.0 mm) and lower gradient. Etna Creek deposits its sediment load in the middle of this reach, and is a relatively low contributer of DG sand.

Reach 8 is where the river's gradient begins to increase, which improves the transport capacity. While the slope of **Reach 9** is slightly steeper, its larger median grain size (15.0 mm) reduces the capacity for movement. Both French and Clark Creeks contribute DG sand to this reach, amounting to about 11% of the total annual DG yield to the river.

Reach 10 is the steepest in the valley and known for its high velocities and unpredictable behavior for the design of bank stabilization structures (A. Lewis, SCS, pers. comm.). This reach also represents the greatest roughness and highest median grain size (25.0 mm). The majority of DG sediment (58%) is annually deposited in this reach, originating from the South and East Fork, Wildcat and Sugar Creek sub-basins. Results for Reach 10 may be skewed by the method used to sample grain size of the bedload. Although cobbles in the range of 6 to 10 inches were found in this steeper reach, the McNeil sampler's diameter was only 6 inches and therefore larger cobbles were omitted from the samples sieved in the lab. If the actual median size was therefore larger than 25.0mm, the transport capacity would be lower than that estimated here.

The relative magnitude of transport between reaches can also be indicated by using one of the formulas. Figure 3-14 depicts the average annual transport capacities (in short tons) of the Engelund-Hansen equation for each reach. Since stream power typically increases downstream as sediment size decreases, a "balanced" stream system graph would have transport capacity bars which gradually increased in height downstream (K. Buer, CDWR, pers. comm.). However, this graph indicates a river system out of balance, with widely fluctuating transport capabilities. Since sediment input plus storage must equal output, the Scott River system must continue to seek a balance.

Transport Processes

Bedload transport only occurs at significant levels during periods of storm or snowmelt runoff (Beschta, 1987). Increased velocities and turbulence will then stimulate bed load transport in a theoretical sequence of events (Jackson and Beschta, 1982):

Phase I: Initial movement may consist of sand-sized particles (or finer) that were formerly deposited in pools, along channel margins or behind obstructions. The armor layer is not yet disturbed.

Phase II: Disruption of the armor layer is begun following increased velocities. Relatively fine sediment within the interstices of larger particles that comprise the armor layer are

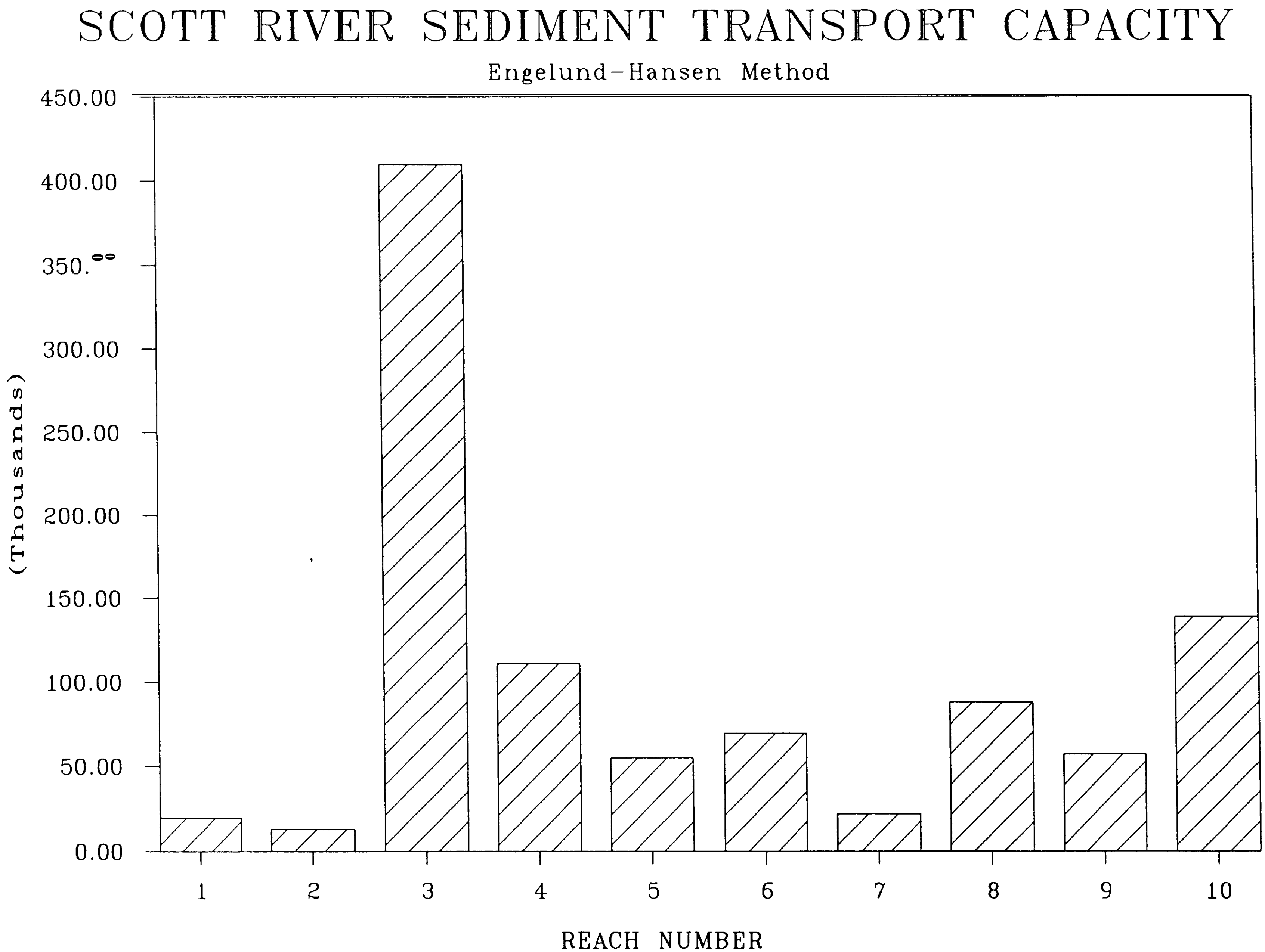

SCOTT RIVER SEDIMENT TRANSPORT CAPACITY
Engelund-Hansen Method
TONS
(Thousands)
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
1
2
3
4
5
6
7
8
9
10
REACH NUMBER

Figure 3-14

removed as bottom velocities (and associated shear stresses) increase. Entrainment of bed material from riffle sections of the channel is also initiated. Velocities and turbulence are great enough to transport riffle sediments entering a pool through it to the next riffle downstream. Once the armor layer is disrupted, the finer bed sediments found below it are rapidly moved. Local scour or degradation of the bed result.

An armor layer was apparent in the Scott River in the sampled riffles and runs, particularly when surface samples were compared with subsurface samples (see Chapter 4).

Analysis of Storage and Transport Data

The sediment transport capacity may differ from the actual sediment transport of the river because of the availability of sediment. The actual sediment transport of a river will only equal the sediment transport capacity if there is an excess of transportable sediment available. This latter situation is probably the case with certain reaches of the Scott River.

A stream seeks to reach a steady state to maintain its capacity (the maximum amount of debris of a given size that a stream can carry in traction as bedload) and competence (the largest size of grain that a stream can move in traction as bedload) so that they are just equal to those required to transport the load provided. It does this by mutual adjustments in the longitudinal profile, cross-sectional morphology, and channel roughness (Morisawa, 1968). If the load is composed of fine gravel and sand and is substantially increased, the likely result will be channel aggradation, widening, and rapid shifting of channels. Areas where valley alluvium and hillslope material are mostly silt or clayey silt will probably experience channel erosion, deepening, and gullying (Dunne and Leopold, 1978).

Since the transport capacity results are approximate, the sediment storage results of Table 3-5 and Figure 3-9 should not be quantitatively compared with the transport figures of Table 3-6 and Figure 3-14. However, comparing the qualitative differences between the reaches suggests some connections. The high transport capacity of Reach 3 and the low capacity of Reach 2 probably have some relationship with the high storage of Reach 2. This latter area was not able to transport the amount of sediment transferred there from upstream. To adjust, the channel widened. Comparing aerial photographs from 1944, 1958, and 1974 of this area revealed that the major channel widening occurred before 1944. Between 1944 and 1974, the channel width has increased about 70 feet (from 400 to 470 feet). Reach 7's low transport capacity also resulted in bank erosion and widening. Between 1944 and 1974, the width increased by 130 feet at a site downstream of the mouth of Etna Creek. Although historic measurements are not available, the slope and channel roughness may also have adjusted.

Implications for the Future

Too much sand in the spawning gravels of the valley and in pools downstream of the valley is the complaint heard by fishery biologists (CH2M-Hill, 1985; West et al, 1990). Whether this sand can be moved out of these areas and the river "cleansed" is the question for the future.

One advantage of having too much sand, as opposed to too much cobble, is that smaller particles are easier to dislodge and they travel at a slower velocity (Beschta, 1987). As transport begins, a sorting process occurs where the larger particles are essentially left behind by the finer particles. If fine particles are not contributed from upstream sources at the same rate as before, then the sediments in transport should become more coarse. "Thus" states Beschta, "only by undergoing scour, transport and deposition can stream bed gravels become 'cleansed' of the finer particle sizes." Although fines can be winnowed from between the particles of the armor layer if gravels remain in place, the percentage of fines within the underlying gravels will likely increase (Beschta and Jackson, 1979).

On the other hand, if the amount of sand supply into the river increases, the net response of the channel will be to fill pools, increase width and decrease depth. Most of the increased sand delivered to the channel, and some of the original gravel riffle material, will deposit in nonriffle stream locations, primarily pools, backwaters, and channel edges. Only when these sinks are full may sand then deposit on riffles. Riffles will be degraded and gravels increasingly smothered by deposited sands even though sediment transport rates will have increased, according to flume experiments (Jackson and Beschta, 1984).

Improved riverbed sediment quality can happen over time in a severely degraded stream, as it did in the South Fork of the Salmon River, Idaho (Megahan et al, 1980). Excessive sand from logging and road activity on steep DG slopes, followed by large storms, had buried prime spawning and rearing areas in the 1950s and 1960s. The U.S. Forest Service responded by placing a moratorium on all road construction and logging activities in the watershed and implementing a variety of watershed rehabilitation practices in 1966. Monitoring revealed a decrease in percentage of sand (<4.76 mm) from about 40% surface and subsurface in spawning areas in 1966 to about 8% surface and 25% subsurface in 1979. "Such a relationship is to be expected," the authors state, "because less energy is required to remove sand from the bed surface than is required to remove sand mixed with gravels within the bed." After the sediment supply to the river was reduced, the adequate sediment transport energy became available to begin removing excess sediment from the system, even during normal runoff and low flow years. However, an equilibrium between input and output of sediment was reached in the late 1970s and little improvement was made over the next 14 years (Platts, 1990).

Prevention and rehabilitation of DG erosion in the uplands of the Scott River watershed would serve to decrease the input side of the local sediment budget and allow more of the present DG sand in channel storage to get moved out. Such an effort is presently underway in the French Creek sub-basin by the Siskiyou Resource Conservation District and the U.S. Soil Conservation Service, who are identifying site-specific DG erosion problems and their solutions. Since roads cause 63% of the total DG erosion in the basin (see Table 2-12), focusing on the control of erosion from road cuts, fills and surfaces should be a high priority.

As found in certain Idaho batholith streams, an above-average snow melt runoff may be needed to dislodge the armor layer on the riffles and allow the trapped sediment to be removed. The main limitation may be the depth of the river during high runoff to adequately remove the riffle armor layer and cleanse the pools of sand in those reaches with low banks and frequent overflow (Bjornn et al, 1977).

Since the floodplain (overbank deposition) and streambanks are important storage sites of sediment, these sites need to be able to gradually release their stored sediments to maintain a balanced system. For example, streambank protection will inhibit bank erosion, thus blocking recruitment of deposited gravels (CDWR, 1984). While this alteration has become a significant problem in the Sacramento River, the magnitude in the Scott River does not seem to be critical at this time.

Further Studies

Further studies could provide more pieces to the sediment storage and transport part of the Scott River's sediment budget puzzle. Recommendations include:

- more cross-sections to better describe the varying widths and depths of the channel, based on recent aerial photo analysis to identify representative sub-reaches;
- sediment samples of uniform parts of point bars and pools, using Wolman pebble counts for each site and reach, to better characterize the channel bed surface grain size;
- characterization of each reach into % riffle, pool, bar, based on large-scale aerial photos;
- approximate cross-sections at the riffle sample sites;
- use of scour chains or other indicator of depth of bed movement during peak runoff

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CHAPTER 4

IMPACTS ON SALMONID SPAWNING

INTRODUCTION

Objective: Determine the impact of fine-grained sediment derived from granitic sources on Scott River salmon and steelhead spawning.

The impact of granitic sand on spawning habitat has received frequent mention as a critical factor limiting the restoration of the anadromous fish populations of the Scott River system (Puckett, 1982; West, 1983; CH2M-Hill, 1985;). The low gradient section of the Scott River through the Scott Valley creates a large amount of existing and potential spawning habitat (CDFG, 1965). However, this area also represents the prime area for deposition of granitic sands and other fines (less that 6.3 mm) that are delivered into the system from upstream sites. Rearing habitat (both summer and winter) is another limiting factor for Salmonid production which can be impaired by excessive sand (Klamt, 1976). While such impairment has been noted in the lower Scott River (West et al, 1990), this effect is beyond the scope of the present analysis.

Effects of Sand and other Fine Sediment on Emergents

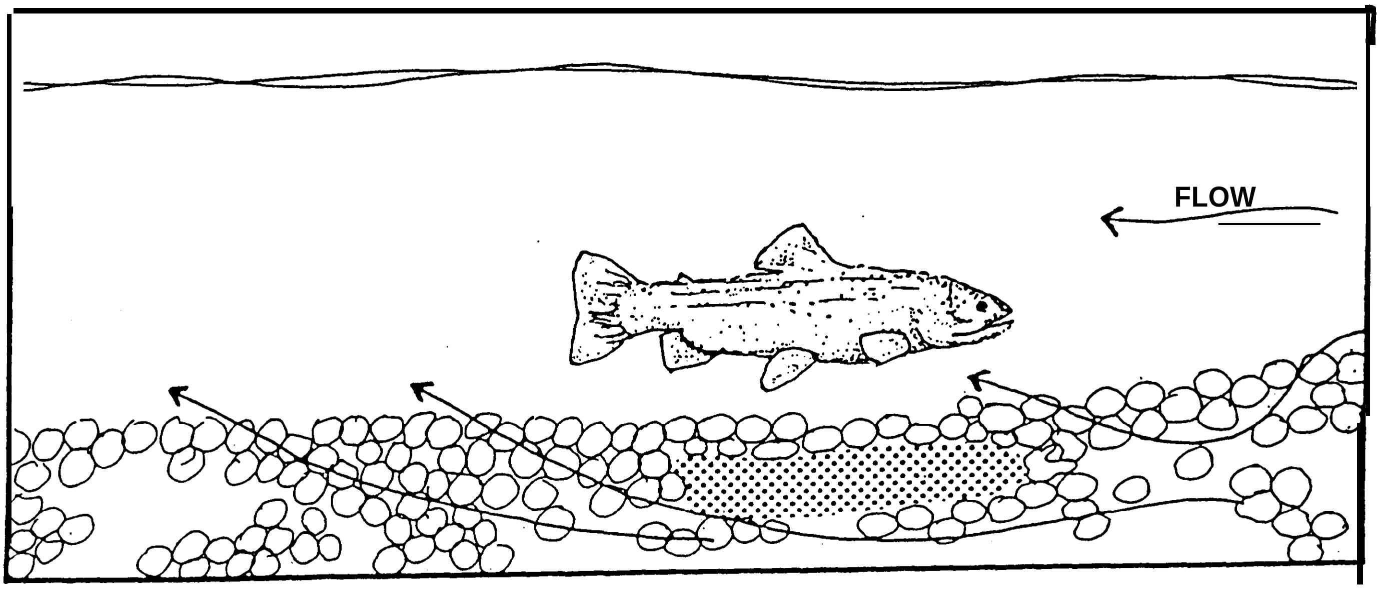
Numerous studies have evaluated the effect of sand and other fine sediments on Salmonid spawning gravel. Their findings have noted three types of influences: (1) the survival of Salmonid embryos from fertilized eggs to fry emerging from the gravels; (2) the size of the emerging fry; and (3) the timing of emergence.

Survival: The amount of dissolved oxygen is the major controlling factor influencing egg mortality (Wickett, 1954; Coble, 1961; Reiser and White, 1988). Large amounts of sediment can cause oxygen deficits by reducing intergravel pore space and subsurface velocities (see Figure 4-l). With low oxygen the embryo can suffocate and with low velocities it can suffer from accumulation of toxic metabolic wastes (free carbon dioxide and ammonia) Alevins and fry have also reportedly been entrapped or "entombed; by fine sediment, preventing their emergence (Tappel and Bjornn, 1983).

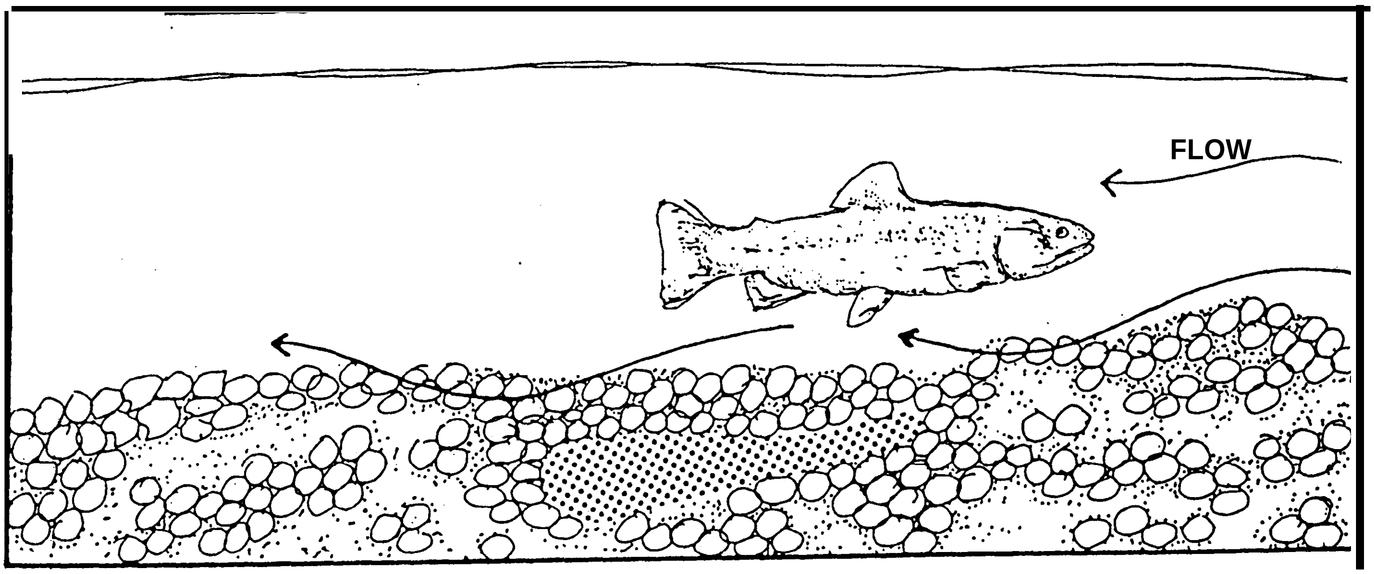
Size: The size of fry emerging from gravels with high percentages of fines can also be affected. In one experiment, steelhead fry were slightly larger in cleaner gravels although chinook salmon fry showed no such variation in size (Tappel and Bjornn, 1983). Coho salmon fry were also reduced in size in sandy gravels (Phillips et al, 1975; Koski, 1966). In the sandy reaches of the upper Trinity River, researchers have noticed "pin-head" fry much smaller than their counterparts in gravelly reaches emerging from redds (M. Stempel, USFWS, pers. comm.). Explanations for this phenomenon vary. With smaller pore spaces, the smaller fry could be better suited for emergence since they can more easily squirm

Figure 4-1

Water Percolation Through Spawning Gravel.



A. Water flow is unimpeded through the gravel.



B. Water flow is obstructed by sands and sediment in the gravel.

Source: CDFG, 1977.

through the confined gravels, or the'greater environmental stress in the egg pocket could reduce growth. How the smaller size of fry affects their later survival is not known, though one would suspect they would be at a disadvantage (Tappel and Bjornn, 1983).
Timing: The timing of emergence is affected by sediment deposition. With a high level of fines, the fry emerge before the yolk sac is completely absorbed. With low fines, they emerge only after total absorption (Tappel and Bjornn, 1983).

When sediment is deposited is also an important factor. During the building of a redd, the female cleans and flushes some of the fine sediments from the gravels. This initially cleaner environment in the egg pocket is critical since eggs in the early incubation period are most vulnerable. Wickett (1954) demonstrated that the embryonic stage before the complete development of the circulatory system (i.e., green egg) is almost entirely dependent on diffusion for the delivery of oxygen. After the circulatory system is developed, the embryo (i.e., eyed egg) is more tolerant of fine sediment and mortality is not as great (Reiser and White, 1988).

History of Scott River's Habitat Quality

The poor quality of the spawning gravels in the valley portion of the Scott River is common knowledge today, but the question needs to be asked, when did the excessive sand deposits begin, or has the river always been that way?

The earliest written account of salmon spawning in the Scott River is from the diary of a miner who was camped in Scott Valley on October 2nd, 1854 (Stuart, 1977):

> During the night we heard continual splashing in the water near where we were sleeping, and couldn't imagine what kind of animal was in the stream all night, as we had seen no sign of beavers in California...In the morning we went to the place whence came the noise and found that all that splashing in the river was caused by salmon fish, from three to four feet long, flopping and jumping in, forcing their way up the stream over the riffles where the water was not deep enough for them to swim... Upon inquiry we were told that every fall these large fish came up from the Pacific Ocean to the upper branches of all the streams as far as they can possibly go and there lay their eggs, then start back to the ocean, but most of them are so bruised and exhausted that they die on the way."

Stream Habitat Ouality

The California Department of Fish and Game (CDFG) has conducted various surveys of the Scott River and some of its tributaries over the years. The oldest known stream survey in the Study Area dates back to June 14, 1934. At the old Scott River bridge 1 mile south of Fort Jones (near the mouth of Kidder Creek), the stream bottom was described as "gravel", water temperature 72 F, "excellent pools and shelter" with "willows dense along shore? Noted problems were mining pollution upstream near Callahan, inadequate screening of diversions, and excessive diversion of water from two big ditches. The surveyors concluded, "from the standpoint of fish life, this section of the Scott River is badly mistreated." Although they commented on the covering of spawning areas with mining silt in upstream locations (i.e., the East Fork and South Fork), no remarks were made about the condition of spawning gravel in the mainstem through the valley.

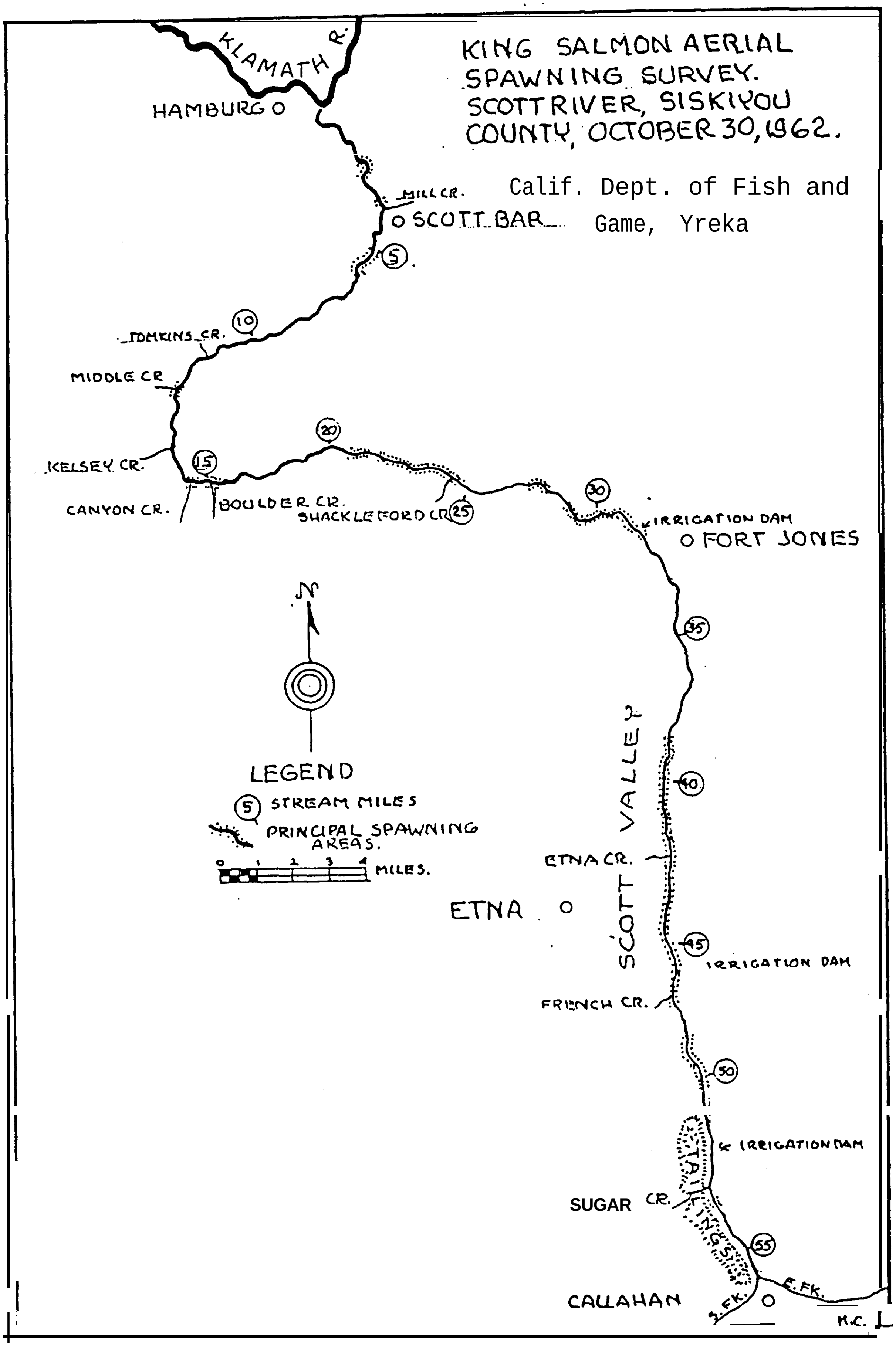
The effect of "mining silt" on stream habitat during this period was well documented by Taft and Shapovalov (1935) in their survey of the Scott and Salmon region. Taking quantitative samples of bottom food organisms at riffles above and below sites affected by mining, they found the average number of food organisms in the samples were <u>alwavs</u> less in mined areas than in non-mined areas. Less food means less capacity for-rearing young steelhead and coho salmon. However, these surveyors also did not mention the quality of spawning riffles in the mainstem Scott River.

With the absence of early comments about too much sand through the Scott Valley portion of the river, one could conclude that (1) it was not a problem at the time, or (2) it was less significant than all of the other noted problems and not a priority to mention, or (3) sand was not considered a problem like silt was at that time.

As of 1948, however, the CDFG fishery biologist for the area had observed the sand in the river (M. coots, pers. comm.). Excessive fine sediments were also noted before the two major floods of December of 1955 and 1964. From the field notes of an aerial survey on Nov. 4, 1951, the surveyor remarked "too sandy" for the stream area from the old Fort Jones bridge (near the mouth of Kidder Creek) to Eller Lane.. A note from Feb. 11, 1955 in CDFG's files for the Scott Rivercommented about the fine gravel and silt making up the stream bed in the vicinity of Fort Jones, creating very poor spawning area for an estimated 7 miles. Similarly, a spawning survey in October 1964 above the Fort Jones bridge observed only silt and sand with "very small patches of gravel" and a "poor spawning area' for about 12 miles upstream. However, the Department indicated in a 1956 report on the Klamath River Basin (Hallock et al, 1956 in CDWR, 1964) that all of the mainstem Scott River below Callahan was a "principal king salmon spawning area".

As seen in Figure 4-2, an aerial survey in October 1962 by CDFG observed king salmon spawning activity from the mouth up to Sugar Creek, with the largest concentration between the USGS gage station (River Mile (RM) 21.0) and an irrigation dam (RM 32.0). Since much of the river's bed in the Scott Valley was "composed of sand, alluvial fill, and small gravel", the biologist believed that salmon spawning activity was confined to areas where the flow velocity was great enough to expose suitable gravels (CDFG, 1962). He also thought that the former bucket dredge operation below Callahan:

Figure 4-2


KING SALMON AERIAL SPAWNING SURVEY. SCOTT RIVER, SISKIYOU COUNTY, OCTOBER 30, 1962.
Calif. Dept. of Fish and Game, Yreka
KLAMATH R.
HAMBURG
MILL CR.
SCOTT BAR
TOMKINS CR.
MIDDLE CR
KELSEY CR.
CANYON CR.
BOULDER CR.
SHACKLEFORD CR.
IRRIGATION DAM
FORT JONES
SCOTT VALLEY
LEGEND
STREAM MILES
PRINCIPAL SPAWNING AREAS.
MILES.
ETNA CR.
ETNA
IRRIGATION DAM
FRENCH CR.
IRRIGATION DAM
TAILINGS
SUGAR CR.
CALLAHAN
E. FK.
S. FK.

"has contributed at least in part to a deterioration of suitable spawning environment in the river and is still continuing. Movement of sand and fines below the dredging activity is quite evident during periods of heavy runoff. Many spawning areas have been displaced by sand."

Complaints about excessive sand in the valley portion of the Scott River have continued throughout the past two decades (Lanse, 1972; CDFG, 1980; CH2M-Hill, 1985).

Surveys of the tributaries also found problems with too much sand. In Etna Creek, a 1971 stream survey above the city's dam commented on areas of gravels which were "semi-compacted with large sand" and pools containing decomposed granitic sands (DG). In French Creek between the mouth and the state highway bridge, a 1968 survey noted that it was "very sandy and probably not used to a significant degree by steelhead for spawning? Although "considerable amounts of DG" were mixed with gravels upstream at the Miner's Creek bridge, a warden's report observed steelhead redds containing uneyed eggs during bridge construction in April 1978. Too many fines were noted in Patterson Creek's spawning gravels downstream of the highway bridge in May 1982, but good spawning gravel was observed above the bridge in May 1974. However, sand was not noted to be a serious problem in a survey of the lower 6 miles of Sugar Creek in April 1974.

Below the valley, degradation of Salmonid habitat was noted by West (1984) at Jones Beach a few miles below the USGS gage station, where "gravels were loose but heavily sedimented with granitic sand? Measurements of spawning gravels at this site revealed they were composed of 41.2% sand and fine sediment smaller than 3.3mm. Moderate concentrations of fines were found at a spawning site below the Trestle Bridge, just above the river's mouth, but little influence of granitic sediment was found. However, 1989 stream survey work by the U.S. Forest Service indicated that granitic sands "heavily influence" spawning and rearing habitat throughout the lower river (West et al, 1990).

Salmon and Steelhead Population

Historically, the spring chinook salmon was the predominant run in the Klamath River system but this run was already greatly reduced in numbers by the early 1920s (Snyder, 1931). The earliest estimate of the number of fall-run chinook salmon in the Scott River was 5,000 spawners in 1955 (CDWR, 1960). During the 1960s decade, CDFG developed estimates based on its annual aerial counts of chinook salmon redds and adults. The average annual chinook spawning population in the early 1960s was estimated to be 8,000 to 10,000 fish (CDFG, 1965; CDWR, 1965). From the available annual CDFG records, however, the number of estimated spawners ranged from 2,000 in 1965 to 5,000 in 1967, with the average over 3,000.

Since 1978, CDFG has pursued a more accurate count of chinook salmon by documenting on-the-ground the number of carcasses of adult and grilse found in selected -stretches of the Scott River during each week of the run in October and November. In addition, a temporary weir is placed near the mouth of the Scott River during the run. Between 1978 and 1989, the total number of chinook salmon extrapolated from these counts has ranged from 1,801 in 1984 to 8,566 in 1987 with an average of 5,636. These total figures are more comparable to the aerial estimates of total fish (adults and grilse) from the 1960s. Counting only the adults, the recent average is 3,812 fall chinook salmon with the annual population estimates for 1978-89 depicted in Figure 4-3.

As part of the chinook salmon carcass count, locations of carcasses have been noted for three reaches in the valley over the past 11 years. Other reaches in the valley are not monitored due to the low numbers found or access problems (J. Hopelain, CDFG, pers. comm.) The results are tabulated below in Table 4-l.

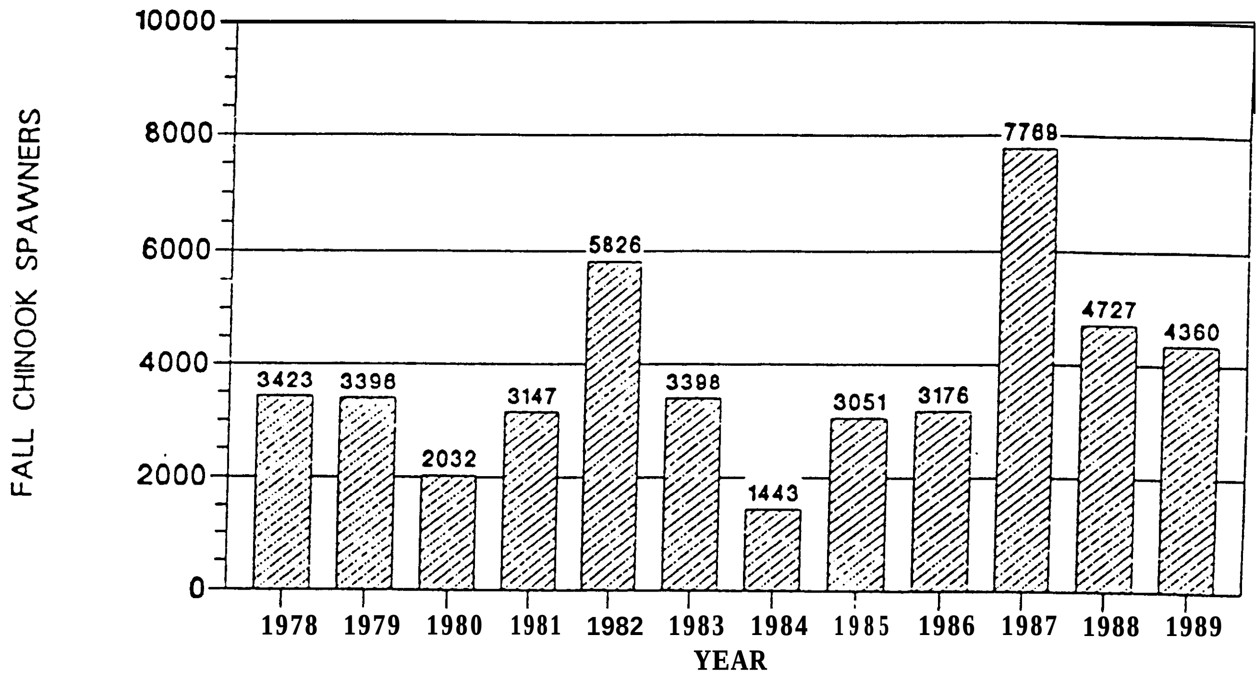
Table 4-l

Summary of Scott River Chinook Salmon Carcass Recovery 1979-1989[1]

Year	Location Canyon-Meamber RM 20.5-25.5	Plant-Pumps RM 28.0-31.5	Sweasey-Fay RM 41.0-49.5	TOTAL
1979	519	114	467	1100
1980	677	168	171	1016
1981[2]	312	13	79	404[2]
1982	810	124	507	1441
1983[2]	222	49	148	419[2]
1984[2]	78	25	28	1312
1985	532	78	260	870
1986	1797	281	442	2520
1987[3]	1271	120	0	1391[3]
1988[3]	800	7	5	812[3]
1989	493	16	22	531
TOTAL	7511	995	2129	10,635
Average	683	90	194	970
Percent	71%	9%	20%	100%
Ave./Mile	137	26	23	57

I/ CDFG carcass numbers represent both adults and grilse (i.e., total carcasses examined)
2/ Partial count due to high water
3/ Low numbers due to low flow

Figure 4-3. Fall chinook spawners in Scott River, 1978-1989.



California Dept. of Fish and Game 1990

Steelhead and coho salmon estimates are much more crude, as no redd, carcass, or weir counts are available. (Their runs tend to be during the higher runoff period when visual estimates are almost impossible and weirs wash out.) In the 1960s, CDFG claimed 2,000 coho salmon and 20,000-40,000 steelhead populated the Scott River in one report (CDWR, 1965) but only 800 coho and 5,000 steelhead in another (CDFG, 1965). No new figures have been officially estimated since then. Some observers believe the present coho salmon population to be near the levels of the 1960s (P. Hubbell, in CH2M-Hill, 1985), while others feel they have declined considerably (J. West, USFS, pers. comm.). If the numbers of the fall-run steelhead reflect the trend of the rest of the Klamath Basin, the Scott River's steelhead population has been declining. Summer steelhead are seen only occasionally by local observers.

Extent of Spawning Habitat

Steelhead and coho salmon have access to more habitat than the chinook salmon by being able to go higher up the tributaries due to their smaller size and the timing of their runs during the winter runoff season. However, the larger chinook may be better able to use the cobbly substrate of the upper Scott River near Callahan. Chinook spawning habitat theoretically includes about 56 miles of the mainstem Scott (from its mouth) and an unknown amount of the lower portions of some of the tributaries, such as Kelsey Creek, South and East Forks, Etna Creek, and French Creek. In 1965, CDFG estimated in a report (CDWR, 1965) that coho salmon had access to 126 miles of habitat in the Scott subbasin, but a recent estimate mentions only 88 miles (CH2M-Hill 1985). Steelhead access should be similar, though current information reportedly indicates 142 miles of available habitat (CH2M-Hill, 1985).

METHODS

The composition of the stream channel substrate was evaluated using both quantitative and qualitative methods. To ensure adequate and equal access to each site, all measurements were taken during the lowest flow period in late August and early September 1989. Since flows during fall chinook runs of recent years had been too low to provide spawner access to much of the study area, the option of sampling redds during October and November was eliminated. In addition, the sampler could not be used in water deeper than about one foot.

The purpose of using the selected methods was to provide fairly easy replicability for future monitoring of changes in the quality of spawning gravels of the Scott River.

Locations

Various locations within the mainstem Scott River and several of the tributaries were sampled. Factors affecting selected sampling sites were vehicle accessibility, landowner approval, and the representativeness of the site. Sample sites were sought from each of the 10 reaches described in Chapter 3 or at least in an area representative of each reach. Since Kidder Creek is an important tributary influencing a critical reach (Reach 3), additional samples were taken upstream and downstream of its confluence with the Scott. Three tributaries, Etna, French and Sugar Creeks, were sampled to provide both baseline data and to develop comparisons with substrate samples taken by CDFG in these streams in 1982. The locations of the sampling sites are identified in Table 4-2 and Figure 4-4.

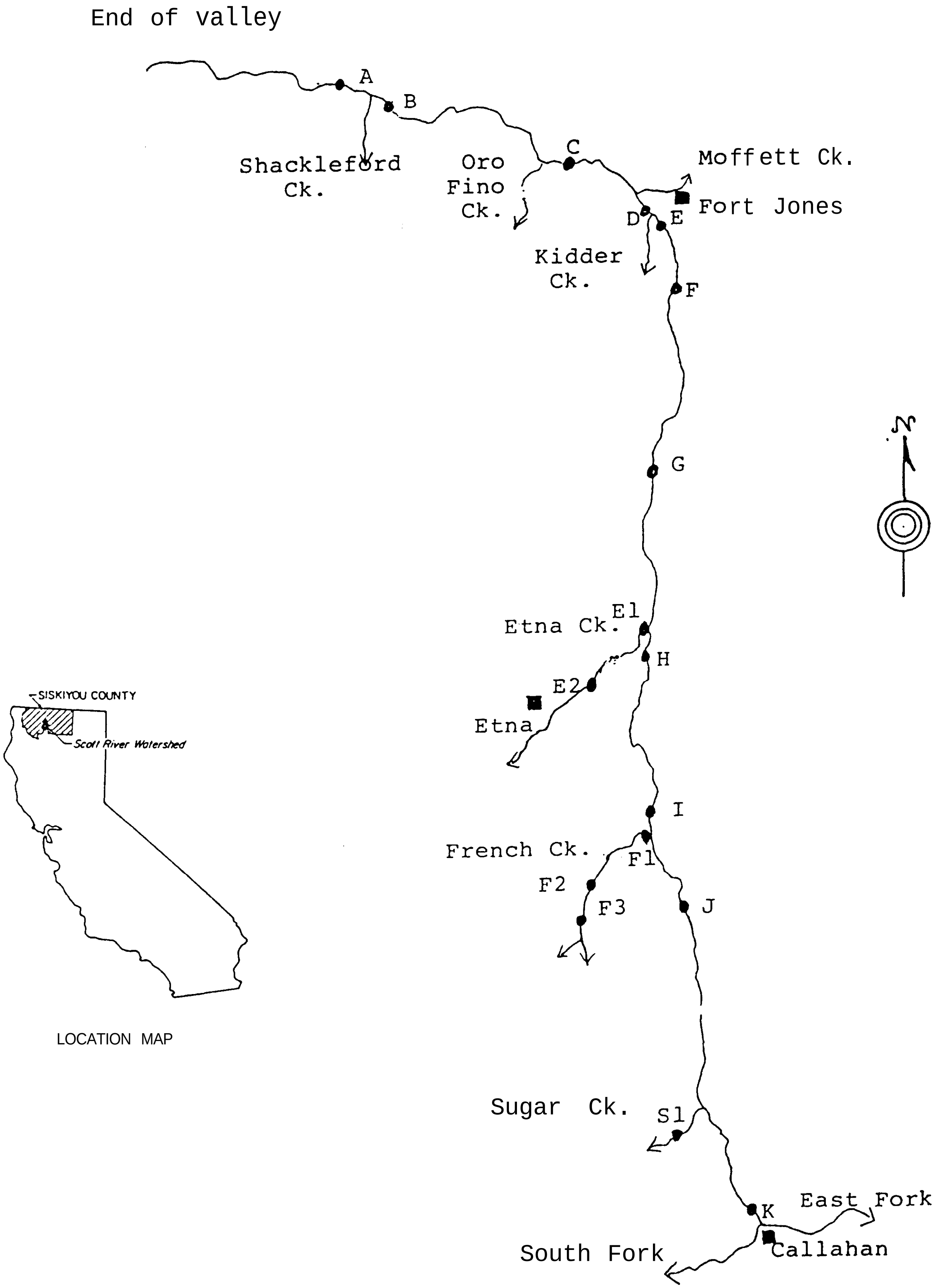
Table 4-2

Locations of Substrate Sampling

Site/Landowner	River Mile	Reach Number	No.of Samples
Scott River			
A - Nutting	23.5	1	25
B - Tozier	24.5	2	20
C - Mason	29.5	3	20
D - Langford	32.2	3	15
E - Anderson	32.3	3	15
F - Tobias/Piersall	34.7	4/5	13
G - Hurlimann	38.8	5	25
H - Whipple	42.5	7	50
I - Spencer	47.2	9	25
J - Barnes	49.7	10	25
K - Hayden	55.7	10	5
		Sub-Total	238
Etna Creek			
El - Near Mouth	0.1	--	15
E2 - At Hwy.3	2.3	--	10
French Creek			
F1 - Near Mouth	0.1	--	5
F2 - Above Hwy.3	0.6	--	5
F3 - Miner's Ck. Br.	1.4	--	10
Sugar Creek			
S1 - Above Hwy.3	0.5	--	10
		TOTAL	293

Figure 4-5

Locations of Sampling Sites



Quantitative Methods

Procedures were arrived at following a review of the literature and discussions with experienced field biologists. However, it should be noted that the issues of what, where, when, and how to measure fish response to sediment levels are currently being debated (Torquemada and Platts, 1988).

Transects

Transects were established at each sampling site. The site was selected to include a riffle and, if possible, a portion of a run above the riffle, as these are the locations most noted for spawning habitat in the Scott River (J. West, USFS, pers. comm.). Each transect was a minimum of 150 feet long, with most 200-300 feet, and one 650 feet. The width of the transects varied, extending from the flowing channel at the streambank on one side to the estimated boundary of spring flow (as determined by deposited algae) on the gravel bar side. Such an area represents the potential spawning habitat available for steelhead and often fall chinook salmon at higher flows.

Rebar stakes were placed at opposite sides of the stream to locate each transect. A measuring tape stretched between the rebar was used to determine sample locations. Other transects were established at 50 foot intervals downstream of the initial one.

Collection of Samples

Samples were taken with a McNeil core sampler, as adapted by the CDFG's Yreka Screen Shop (McNeil and Ahnell, 1960). The diameter of the McNeil tube was six inches, which was deemed adequate for the size of the substrate in most of the study area. It also represents the largest size particles in which most salmonids will spawn (Platts et al, 1983). The core depth of six inches was sufficient to sample the depth excavated by most redds.

The contents of the tube were dug by hand and placed within the sampler. The sampler's contents were then transferred to a labeled 4-5 gallon plastic bucket. After settling for 10 minutes, the water was carefully pored out of the bucket and a lid affixed. These buckets were taken to the laboratory for analysis.

No attempt was made to use freeze-core samplers to preserve stratification of the gravel column (Everest et al, 1980) for several reasons: 1) expense and logistics are greater; 2) the measurement of depth level of highest egg concentration was not the objective, which is the main reason to do freeze coring (Platts, 1989).

Analvsis of Samples

Gravel samples were separated into 7 size classes by wet sieving. In assemblyline fashion in the laboratory, sediments were washed and shaken through six standard sieves with the following mesh sizes: 25.0 mm, 12.5 mm, 6.35 mm, 4.75 mm, 2.36 mm, and 0.85 mm. The materials left in each of the sieves was measured volumetrically (the amount of displaced water) in either a 500 mL or 1000 mL graduated cylinder. The fines and water passing through the smallest screen were placed in a 1000 mL Imhoff cone. After 10 minutes, the settled material often stratified into two layers or sizes and the volumes of each were recorded.

Dry weights were also obtained. Sieved samples from several sites were airdried and weighed. Comparing wet weights to dry weights for the same sieve size allowed a ratio to be obtained. Conversion factors were then applied to the results of the volumetric analysis to get equivalent dry weight in grams for each sieve size as follows: 25 mm = 2.47; 12.5 mm = 2.56; 6.35 mm = 2.54; 4.75 mm = 2.16; 2.36 mm = 1.98; 0.85 mm = 1.6; less than 0.85 mm = 1.0.

Sample Size

As described by Platts et al (1983), the size of the sample at each site needs to strike a balance between the cost of sampling and the cost of making an error. The optimum sample size for the sites was therefore arrived at statistically. At the first site, 50 McNeil samples were obtained and analyzed for grain size composition as this was the number of observations recommended by McNeil and Ahnell (1960). The reliability of this sample was then evaluated using a 95% confidence interval. The margin of error was determined to be very small in comparison to the mean which meant that the sample size did not have to be so large. The sample size was dropped to 25 samples at the next site, and the confidence intervals for those samples appeared adequate to reasonably evaluate the substrate quality. For sites with more uniform substrate, 15 to 20 samples were estimated to be adequate.

Five McNeil samples were randomly taken at the five (5) foot intervals across a transect at each site, with enough transects placed every 50 feet to cover the riffle and some of the run areas, Water depth was measured at each 5 foot interval.

Quality Indices

At least three different quantitative indices for evaluating the quality of spawning gravels for salmonids are currently used (Platts et al, 1983). These indices are developed from field data and are then each related to results of laboratory studies to estimate the survival to emergence of certain Salmonid species.

A computer program using dBASE III+ software was developed to process the data and generate the numbers for each index.

Percentage of Fines

The most traditional indicator of gravel quality is the percentage of fines, usually based on dry weight. The definition of "fines" differs in the literature and includes diameters of

0.84 mm (McNeil and Ahnell, 1964); 2.0 mm (Hausle and Coble, 1976), 3.3 mm (Koski, 1966), 4.6 mm (Platts, 1968) and 6.35 mm (Bjornn et al, 1977). Another study combines two size classes - particles less than 6.4 mm of which at least 20% are less than 0.84 mm (Stowell et al, 1983). The results of the dry weight (in grams) for each sieve size and the total weight of the sample allowed for the calculation of cumulative percentages for each category of fines.

Geometric Mean Diameter

To better evaluate the textural composition of the entire gravel sample, the geometric mean diameter (d_g) is recommended as an indicator of the permeability and porosity of channel sediments (Platts et al, 1979; Shirazi et al, 1979). These researchers suggest that d is a figure which can be more readily analyzed statistically than percent fines. The formula offered below for calculating the geometric mean does not assume a log normal distribution of all grain sizes, which may not occur in small streams, and is the preferred method (Lotspeich and Everest, 1981):

$$d_g = (d_1^{w1} \times d_2^{w2} \times .....d_n^{wn})$$

d_n = midpoint diameter of particles retained on the nth sieve

w_n = decimal fraction by weight of particles retained on the nth sieve

Fredle Index

Since the geometric mean can be insensitive to changes in stream substrate composition, another evaluation procedure divides the geometric mean by a sorting coeffecient and is called the fredle (f) index (Lotspeich and Everest, 1981). It is a fair means of indirectly measuring porosity of a given gravel sample with the following assumptions: no organics, and only mineral substrate (J. Veevaert, USFS, pers.comm.) Mixtures with the same geometric mean can have varying degrees of fine and large material. If the grain size is uniform, then the sorting coefficient is 1 and the index will be the same as the geometric mean. If there is a large amount of coarse as well as fine sediment, then the coefficient will be high and the index will be lower than the geometric mean. The fredle index is calculated as follows:

$$f = d_g/S_o$$

where:

d_g = geometric mean (see above)

$S_o = (d_{75}/d_{25})^{1/2}$

d_{75}, d_{25} = particle size diameters at which either 75 or 25 percent of the sample is finer by weight

A computer program was developed by Tierra Data Systems to determine the cumulative log probability curve from which the percentile values were obtained.

Statistics

All statistical evaluations were performed using the NCSS software (Numerical Cruncher Statistical System, Version 5.02, by Hintze (1989)). The confidence interval (C.I.) was calculated for each sample mean at the 0.5 probability level (95% confidence limit):

C.I. = mean $\pm$ (t) (standard error)

Analysis of variance between sites was analyzed using the Duncan's Multiple Range Test (P<0.05), which compares each sample mean with every other sample mean (Steel and Torrie, 1960).

Qualitative Methods

Qualitative evaluation focuses on visual estimates of the features of the substrate's surface and is used as a quick and less expensive alternative to quantitative sampling of gravels (Torquemada and Platts, 1988). In this study, surface visual analysis was performed according to the Substrate Score methods of Crouse et al, 1981, who found a high correlation between this score and geometric mean particle size (r^2=.93). Estimates of substrate characteristics were made within a one foot square area at five foot intervals across each transect. Using a metric ruler, each square was ranked as indicated in Table 4-3 (from Crouse et al, 1981, as modified from Sandine, 1974).

A Substrate Score is the summation of four ranks: three related to the size of substrate particles and the fourth a level of embeddedness. In a hierarchical design, the predominant or largest particle is assigned a rank from Table 4-3 based on its size; the second most dominant substrate is similarly assigned a rank. The third rank corresponds to the size of the material surrounding the predominant substrate particles. The fourth rank is the level of embeddedness of the predominant substrate by the material ranked in the third evaluation.

The values in the Substrate Score are related to the quality of the habitat: lower values indicate poorer habitat for benthic invertebrates and Salmonid spawning success while higher values indicate high quality habitat.

Table 4-3

Substrate Characteristics and Associated Ranks
for Calculation of Substrate Scores
(after Crouse et al, 1981)

Rank	Characteristic
	Particle type or size
1	Organic cover (over 50% of bottom surface)
2	< 1-2 mm
3	2-5 mm
4	5-25 mm
5	25-50 mm
6	50-100 mm
7	100-250 mm
8	> 250 mm
	Embeddedness*
1	Completely embedded (or nearly so)
2	3/4 embedded
3	1/2 embedded
4	1/4 embedded
5	Unembedded

* Extent to which predominant-sized particles are covered by finer sediments

RESULTS AND DISCUSSION

Sediment Size Composition

The results of the sieve analyses are provided as dry weights (grams) for each site in Appendix C.

Statistical Evaluation

To indicate the reliability of the data, the 95% confidence interval (C.I.) about the sample mean is described for each measurement and the calculated indices: dry weight (Appendix C); percentage composition (Table 4-4); geometric mean (Table 4-7); and Fredle Index (Table 4-8). This interval means that there is a 95% chance that the population mean falls within the identified range, or a 1 in 20 chance that it does not. For example, the fines (less than 0.85 mm) percentage data for the site at the mouth of Etna Creek (Table 4-8) indicates that there is a 95% chance that the mean of the population is between 4.7 and 8.3.

For the sites with the most samples (i.e., 25-50 samples), the confidence intervals are quite small relative to the mean. For sites with fewer samples (15 or less), the intervals tend to be fairly large for some sites (e.g., Site E, Sugar Creek). Fewer samples were taken either because the site appeared quite uniform or the substrate material was very difficult to sample. At the upper site on the Scott River (Site K), only 5 samples were taken due to the large substrate yet the confidence limits were fairly small compared to the mean. This narrow interval indicates the uniform nature of the spawning substrate at that site, while the wider intervals elsewhere indicate a greater variation. For sampling most Scott River sites in the future, a sample size of 20 should probably be the minimum while 25 appears optimum.

Quality Indices

Various quality indices have been developed during the past several decades to evaluate the effect of stream channel substrate on Salmonid survival. The purpose of these indices is to compare: (1) the index with laboratory and field studies which have estimated survival to emergence of different Salmonid species; (2) various spawning sites with one another, and (3) changes in sites over time.

Percentage Fines

Grain size distribution was described in Table 3-4 for the percent retained by each sieve size. To make the data comparable to other fisheries studies, the results are transformed in Table 4-4! to represent the percent less than a certain sieve size. Table 4-4B gives the cumulative percentage totals of just the fine sediments. A maximum diameter of 100 mm and a mean diameter of 40 nun was assumed for the material retained in the largest sieve (25 mm). Figure 4-6 depicts the relative amounts of percent fines less than 6.3 mm for each reach.

Percentage fines is the most traditional approach to estimating the impact on Salmonid reproduction (Platts et al, 1983). Laboratory or field studies comparing percentage fine sediment to percentage emergence have been performed by Koski (1966) for coho salmon, Bjornn (1969) for steelhead and chinook salmon, Phillips et al (1975) for coho salmon and steelhead, McCuddin (1977) for steelhead and chinook, Cederholm et al (1982) for coho, Tappel and Bjornn (1983) for chinook, Hall (1984) for rainbow trout, and Reiser and White (1988) for steelhead and chinook. All of these studies have concluded that fines decrease survival, but a variety of sizes were used in defining "fines".

Table 4-4A

Sediment Composition by Percentage with 95% Confidence Interval (C.I.)

Reach	Site	100.0	25.0	12.5	6.30	4.75	2.36	0.85
		Sieve Size (mm) (Percent Less Than)						
Scott River								
1	A	51.2	12.5	9.6	2.8	4.8	11.2	8.0
	± C.I.	4.1	1.2	1.1	0.5	0.6	1.6	0.9
	B	16.5	23.2	19.1	5.9	10.5	13.6	11.1
	± C.I.	4.0	1.8	2.1	1.1	1.5	2.5	2.1
2	C	31.6	17.4	14.5	4.7	8.0	12.9	11.0
	± C.I.	4.1	2.5	2.1	1.0	1.5	2.1	1.3
3	D	0	2.0	5.3	4.5	15.5	52.5	20.1
	± C.I.	0	0.9	1.4	1.4	5.0	5.5	3.7
	E	2.7	3.5	11.1	6.1	19.8	36.6	19.9
	± C.I.	5.1	2.0	3.1	1.6	3.8	7.9	7.5
4-5	F	3.2	2.8	11.9	7.4	21.8	31.3	21.6
	± C.I.	7.1	1.1	3.6	2.2	3.2	9.9	3.3
5-6	G	4.5	20.4	18.5	6.6	13.0	19.8	17.2
	± C.I.	1.2	2.8	2.0	1.0	1.6	2.2	3.0
7-8	H	25.2	19.9	14.7	4.9	9.4	15.3	10.5
	± C.I.	2.4	1.2	0.9	0.6	0.8	1.6	0.9
9	I	38.0	15.9	9.4	3.4	6.9	14.3	12.2
	± C.I.	4.5	1.8	1.3	0.6	0.7	2.0	2.0
10	J	48.9	11.6	11.4	3.2	7.1	10.4	7.4
	± C.I.	3.6	0.5	1.6	0.3	1.1	1.4	1.0
	K	49.0	12.0	8.6	3.4	7.8	13.0	6.4
	± C.I.	5.3	3.4	2.7	0.6	1.0	3.2	1.4
Tributaries								
El	Etna-mouth	38.4	21.7	12.6	4.7	6.4	9.8	6.5
	± C.I.	9.7	3.1	3.3	1.9	1.7	3.1	1.8
E2	Etna-Hwy 3	48.9	13.4	9.5	3.2	6.8	13.2	5.1
	± C.I.	7.0	3.9	0.9	0.6	0.7	3.1	1.2
F1	French-mouth	40.3	13.2	9.2	2.9	9.4	16.3	8.6
	± C.I.	5.0	1.4	1.2	0.9	1.5	4.3	1.0

Table 4-4A (continued)

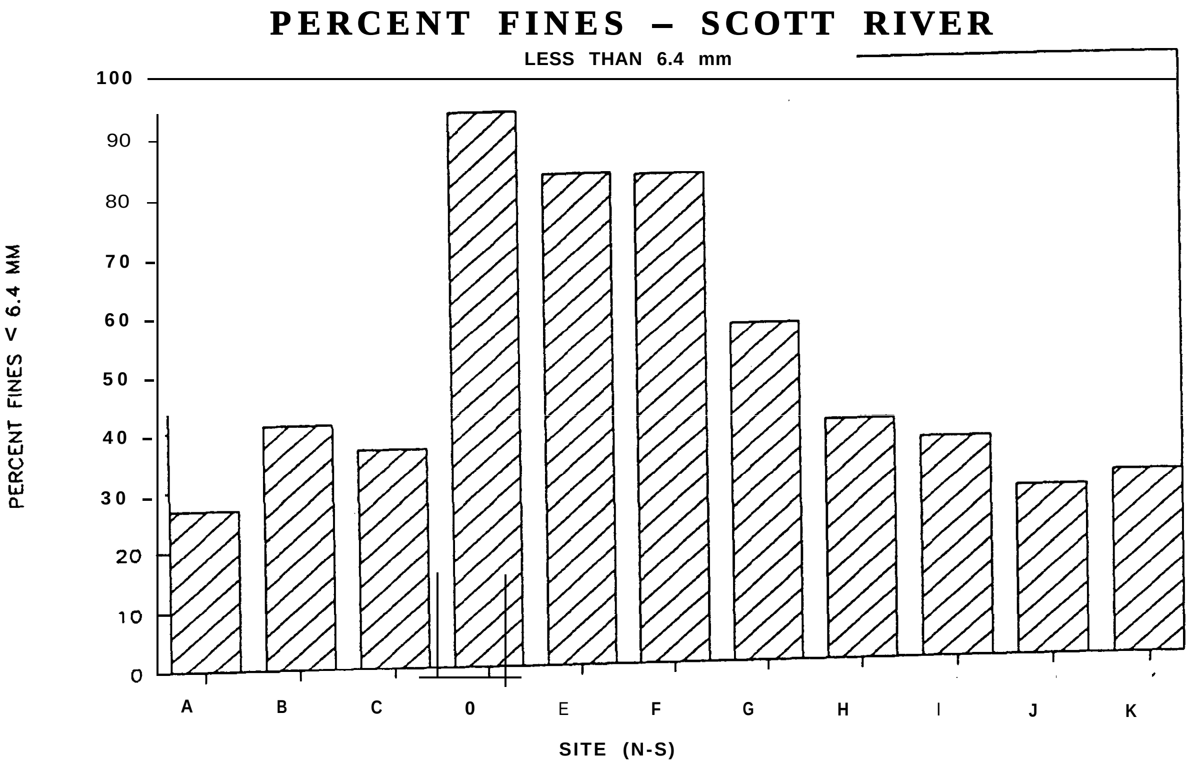
Reach	Site	100.0	25.0	Sieve Size (nun) 12.5	6.30	4.75	2.36	0.85
				(Percent Less Than)				
F2	French-Hwy 3	37.4	11.4	8.4	3.6	11.4	19.4	8.2
	± C.I.	13.0	3.0	2.6	1.4	5.6	8.1	2.4
F3	French-Miner	43.8	12.8	10.4	4.2	11.6	9.4	8.2
	± C.I.	6.4	4.1	1.4	1.0	2.1	1.1	2.2
S1	Sugar-Hwy 3	48.6	12.9	7.9	4.4	8.4	11.7	6.3
	± C.I.	10.7	2.2	2.3	2.6	2.8	3.9	1.7

Table 4-4B

Cumulative Percentage of Fine Sediments
(% less than sieve size)

Site	6.3mm	4.75mm	2.36mm	0.85mm
Scott River				
A	26.8	24.0	19.2	8.0
B	41.0	35.1	24.7	11.1
C	36.5	31.9	23.9	11.0
D	92.7	88.2	72.7	20.1
E	82.4	76.3	56.5	19.9
F	82.1	74.7	52.9	21.6
G	56.7	50.0	37.0	17.2
H	40.1	35.3	25.8	10.5
I	36.8	33.4	26.5	12.2
J	28.2	25.0	17.9	7.4
K	30.6	27.2	19.4	6.4
Tributaries				
El	27.5	22.7	16.3	6.5
E2	28.3	25.1	18.3	5.1
F1	37.2	34.3	24.9	8.6
F2	42.6	39.0	27.6	8.2
F3	33.4	29.2	17.6	8.2
S1	30.8	26.4	18.0	6.3

Figure 4-6


PERCENT FINES – SCOTT RIVER
LESS THAN 6.4 mm
PERCENT FINES < 6.4 MM
100
90
80
70
60
50
40
30
20
10
0
A
B
C
0
E
F
G
H
I
J
K
SITE (N-S)

Studv	Species	Size of Fines
Koski	coho	0.85 mm, 3.3 mm
Bjornn	chinook, steelhead	6.4 mm
Phillips	coho, steelhead	l-3 mm
McCuddin	chinook, steelhead	6.4 mm
Cederholm	coho	0.85 mm
Tappel/Bjornn	chinook	0.85 & 9.5mm
Hall(NCASI)	rainbow trout	0.80 mm
Reiser/White	chinook, steelhead	0.84, 4.6mm

Therefore, it is difficult to put all of these results on one graph for comparison. Regression equations were developed to find the line of best fit for each study's data and have been plotted on one graph in Figure 4-7 (Hall, 1984). As can be seen, the regressions have major differences in placement and slope which Chapman and McLeod (1987) believe can "only partly" be explained by the different categorization of fines.

Since such a range exists, two studies were selected for providing examples of survival based on percentage fines. One study is by Cederholm et al (1982), which uses a particle diameter of less than 0.85 mm for coho and steelhead (Figure 4-8). Data were determined from an artificial stream environment. The other study by Stowell et al (1983) uses those particles less than 6.4 mm, of which at least 20% are less than 0.8 mm in diameter. (All of the samples in the mainstem Scott River qualify by this definition.)

A statistical analysis of the two predictive curves from Stowell et al's report reveals that they must be used only with caution since there is substantial variability in the data. To account for the uncertainty in the curves, lines indicating the 95% confidence limits are important to add to any graph to be used in prediction. Figures 4-9A and 4-9B were developed by a statistician for Stowell's report for these data to provide such upper and lower confidence limits for steelhead and chinook salmon. For example, 40% sand (less than 6.4 mm) corresponds to a rate of fry emergence anywhere from 0% to 55% for chinook salmon, or from 0% to 28% for steelhead. As can be seen in Figure 4-9A, the relationship between percent survival and percent fines appear3 sigmoid rather than linear, which can explain the fairly poor r values for linear regressions (R. Klamt, pers.comm.).

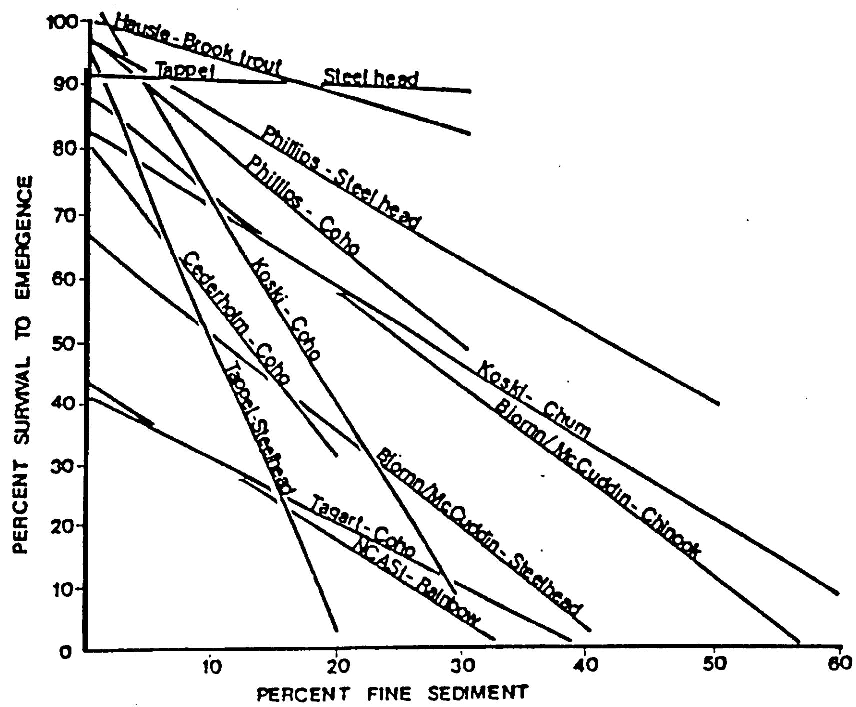


Figure 4-7. Regressions of survival against percentages of fines (Chapman, 1987, adapted Hall, 1984)

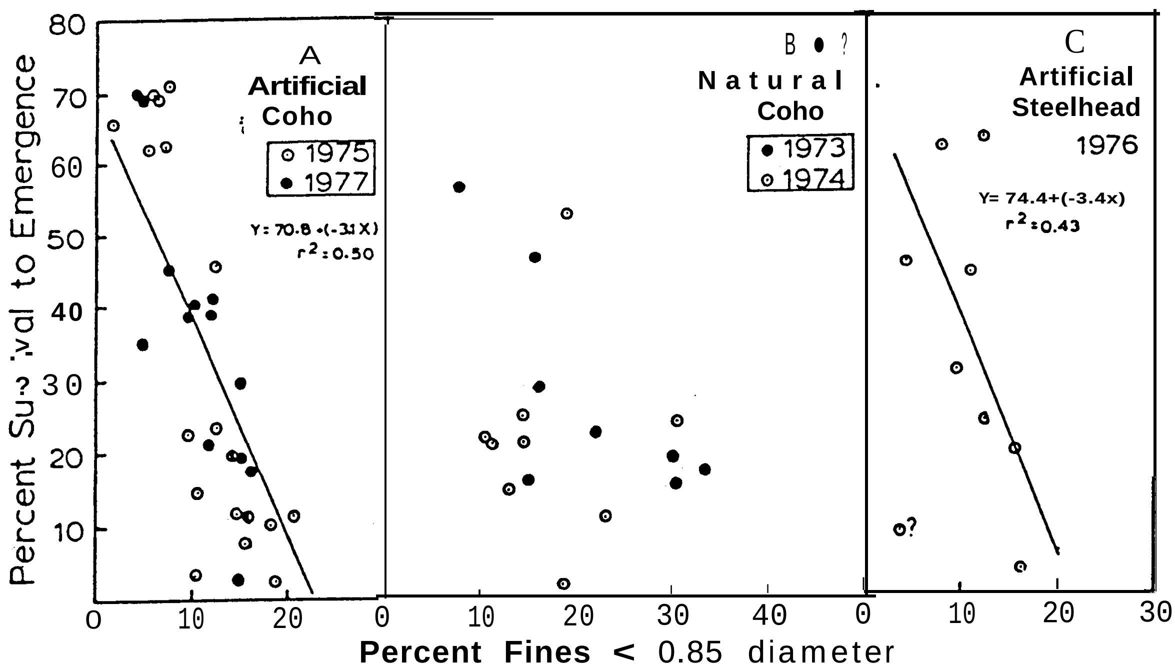


Figure 4-8. Relationship between fines and survival to emergence (Cederholm, 1982).

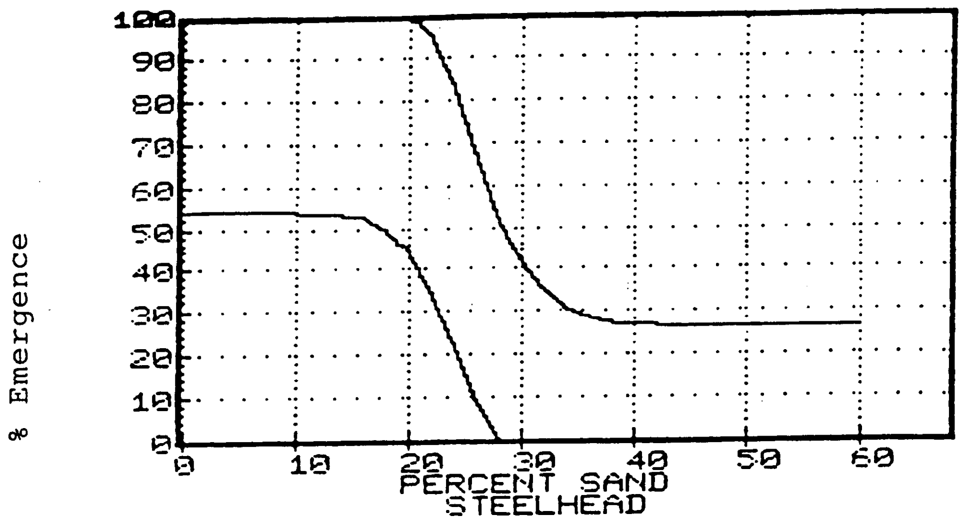


Figure 4-9A. Upper and lower 95% confidence intervals on function fitted to data for steelhead fry emergence and percent fines less tha 6.4mm.

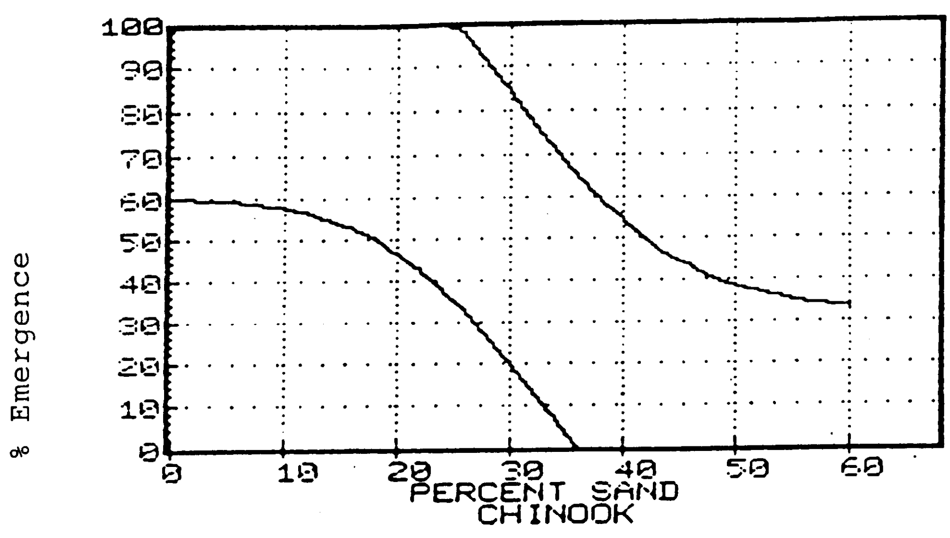


Figure 4-9B. Same as above for chinook salmon fry emergence.

Source: Stowell, et al, 1983, pp. 93-94

Table 4-5

Predicted Rates of Emergence by Percentage Fines
(in percent)

Site	Stowell Steelhead	Stowell Chinook	Cederholm Steelhead	Cederholm Coho
	95% Confidence Limits			
Scott River				
A	O-28-57%	25-60-90%	42%	45%
B	0- 0-26%	O-22-55%	35%	36%
C	0- 3-28%	0-28-60%	35%	36%
D	o- o- ?	o- o- ?	5%	8%
E	0 -0- ?	o- o- ?		1%
F	0 -0- ?	o- o- ?		5%
G	0 -0- ?	o- 4-35%	15%	15%
H	0- 2-26%	O-22-55%	37%	40%
I	0- 3-28%	0-28-60%	33%	30%
J	0-24-50%	25-60-90%	45%	45%
K	0-11-38%	20-52-85%	50%	52%
Tributaries				
El	2-28-57%	25-60-90%	50%	52%
E2	0-24-50%	25-60-90%	52%	52%
F1	0- 2-28%	0-28-60%	38%	42%
F2	0- 0-26%	0-16-50%	38%	44%
F3	0- 5-32%	10-40-75%	38%	44%
S1	0 -	20-52-85%	50%	52%

As can be seen from Table 4-5, the estimates of survival vary considerably depending on the laboratory study, species, and location. This interpretation is based on the means presented in Table 4-4. If data at the ends of the the confidence limits of the mean were also used for interpretation, then the range would be even greater. It also should be noted that no experimental studies have been done with such high levels of fines (80-90% less than 6.3 mm) as found at sites D-F. The highest amount evaluated in the literature appears to be 66% fines less than 6.35 mm (Bjornn et al, 1977).

Although Cederholm et al found little variability between steelhead and coho salmon survival, Stowell et al, as well as others (Bjornn, 1969; McCuddin, 1977), found fairly large survival differences between steelhead and chinook salmon, with steelhead being more sensitive. In contrast, Phillips et al (1975) found coho salmon more sensitive than steelhead. Steelhead embryo survival was strongly related to substrate material less than 0.85 mm and only weakly related to sediment less than 9.5 mm, while the opposite was true for the survival of chinook salmon embryos (Tappel and Bjornn, 1983). Particle sizes from 1.70 to 4.76 mm were more harmful to chinook salmon than steelhead embryos. Compared to other grain sizes, fine sediment less than 0.84 mm in diameter was also found in another study to be the most detrimental to incubating eggs and to the quality of resulting fry, although green chinook salmon eggs appeared more sensitive than green steelhead eggs (Reiser and White, 1988).

By location, certain sites were definitely worse than others in terms of impacting survival of Salmonid fry. Sites **D - F** have predicted survival rates of 0 to 10% for all species. Sites B, C, H, I, and Fl-F3 are comparable with predicted survivals of 0 to 40 percent or so. In contrast, sites A, J, K El, E2, and S1 have lesser amounts of fines and an estimated survival of 2 to 90%, with a mean of about 50-60%.

<u>Historic Trends</u>

The effects over time can only be compared at three sites at this date. In 1982, the California Dept. of Fish and Game collected McNeil samples at one site on Etna Creek (Hwy.3 bridge) and two sites on French Creek (Hwy. 3 and Miner's Creek bridges). Only the 0.85 mm sieve was used to define percent fines. As can be seen in Table 4-6 below, 1989 samples taken in comparable number and at the same sites reveal a 4.5 to 6.5 % reduction in the percentage of fines smaller than 0.85 mm. Such a variation could reflect the time of year (May 1982 vs. August 1989), normal annual fluctuation, the variability of the sampling method, or a reduction in sediment delivery. One might expect higher fines in August after deposition than during May's snowmelt runoff. However, May 1982 was a year of above average runoff. How the other sediment sizes changed cannot be known.

Table 4-6

Historic Comparison of Percent Fines
with Tributary Sites, 1982 vs. 1989

Site	No. of Samples	May 1982[1] >0.85mm	May 1982[1] <0.85mm	No. of Samples	Aug. 1989 >0.85mm	Aug. 1989 <0.85mm
Etna Ck. - Hwy.3	8	88.2%	11.8%	10	94.9%	5.1%
French Ck. - Hwy.3	5	87.3%	12.7%	5	91.8%	8.2%
French Ck. - Miner's Bridge	4	85.1%	14.9%	5	91.8%	8.2%

l/ Unpublished **CDFG** data from May 1982 gravel sampling

Geometric Mean Diameter

The dg indicator is "assumed to be a sufficient 1st order of magnitude indicator, for it can be conveniently related to spawning success" (Shirazi et al, 1979). Table 4-7 presents the geometric mean diameters for each site, including the values for the upper and lower 95% confidence intervals. The assumption is that the larger the d value the better the gravel quality. The relative geometric me% n values for each site are depicted in Figure 4-10.

Correlation of the dg to spawning success, or the percentage embryo survival, have been provided by several studies. Shirazi and Seim, (1981) translated the percentage data from different studies into geometric mean diameter and analyzed all of the relationships for steelhead and coho salmon on one graph (Figure 4-11). Tappel and Bjornn (1983) offered some additional laboratory results for steelhead and chinook salmon (Figure 4-12). No confidence limit lines were placed on these graphs by their authors to increase the accuracy of interpretation.

Comparing the geometric mean diameters from the Scott River data with these two graphs provides the survival estimates of Table 4-7. One of the first observations is that the sites change in relative quality compared to their ranking in the previous index because the total sediment composition is taken into account.

Based on the Shirazi graph, no sites would have survival rates lower than 30%, which is higher than the estimates from the percentage fines index discussed above. The best sites (A, J, and S1) would have estimated survival rates of 65-70%. Based on the Tappel and Bjornn graph alone, no site would have lower than 82% survival. Therefore, all sites would rate as very good quality. Such a high rating does not seem to hold up when comparing actual substrate conditions **or** preferred spawning sites in the Scott River and its tributaries, as discussed previously.

The major difference between the two estimates is that the Shirazi and Seim analysis of several studies showed that a dg of 15 was needed for excellent (90%) survival while Tappel and Bjornn's study showed a level of 10 was needed. This latter study used gravels with identical geometric means but observed higher survival rates. The only explanation for the difference offered by Tappel and Bjornn was that the gravel mixtures had different compositions and therefore the use of the geometric mean is limited as an index of gravel quality. Similarly, Lotspeich and Everest (1981) concluded that using d alone as an indicator can lead to inaccurate conclusions about gravel quality.

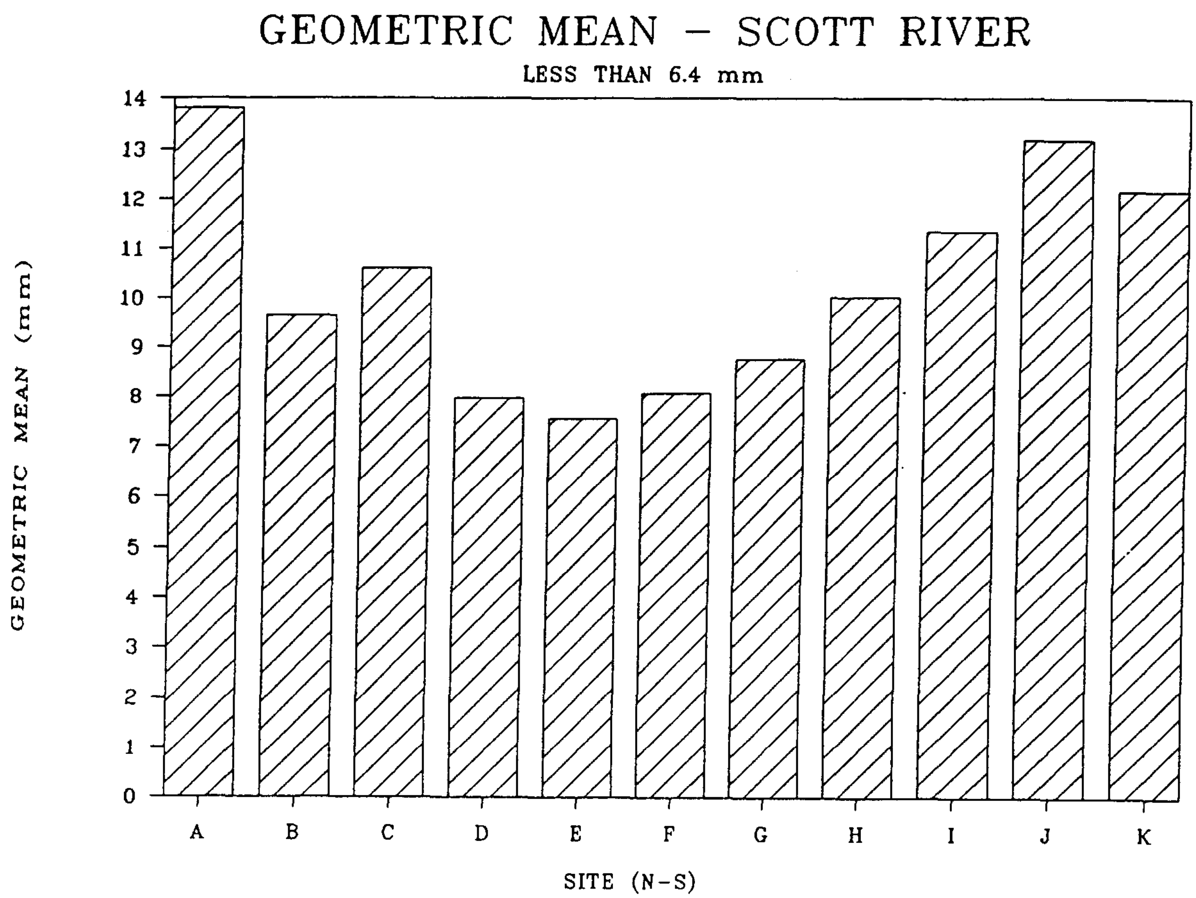
Table 4-7

Geometric Mean Diameter and Estimated Survival
(with 95% Confidence Interval)

Reach	Site	dg	95% C.I. Lower	Upper	% Estimated Survival Shirazi /1	Tappel /2
Scott River:						
1	A	13.81	12.74	14.87	70%	90%
	B	9.64	9.43	9.85	42%	88%
2	C	10.61	10.11	11.11	45%	90%
3	D	7.98	7.53	8.42	30%	85%
	E	7.56	7.46	7.66	30%	82%
4	F	8.08	7.53	8.62	30%	85%
5-6	G	8.78	8.61	8.95	35%	86%
7-8	H	10.03	9.81	10.26	42%	90%
9	I	11.34	10.68	12.00	50%	90%
10	J	13.20	12.38	14.02	65%	90%
	K	12.17	10.33	14.02	55%	90%
Tributaries:						
	El	12.38	10.67	14.08	58%	90%
	E2	13.19	12.13	14.26	65%	90%
	F1	9.68	8.23	11.14	42%	88%
	F2	11.07	8.88	13.27	50%	90%
	F3	11.98	10.94	13.03	55%	90%
	S1	13.29	9.54	17.05	65%	90%

1/ Steelhead and coho salmon
2/ Steelhead and chinook salmon

Figure 4-10


GEOMETRIC MEAN - SCOTT RIVER
LESS THAN 6.4 mm
GEOMETRIC MEAN (mm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
A
B
C
D
E
F
G
H
I
J
K
SITE (N-S)

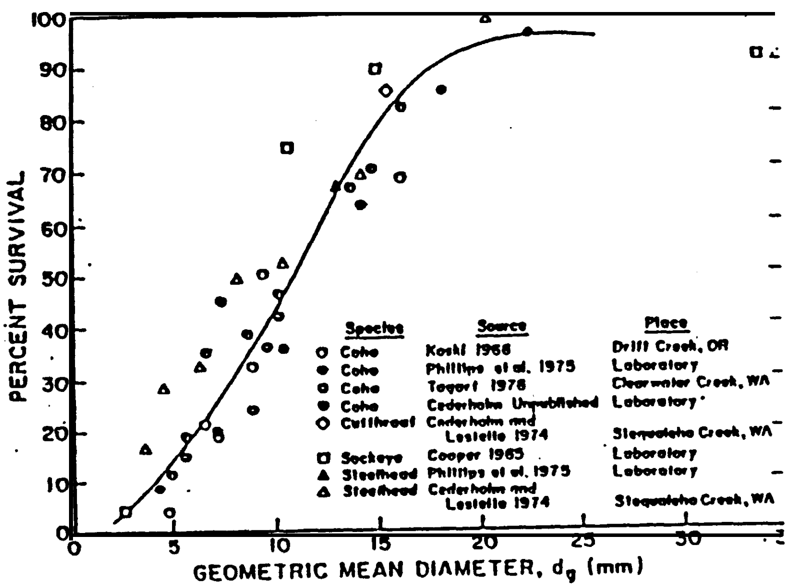


Figure 4-11. Relationship between percent embryo survival and substrate composition as expressed by d_g (from Shirazi et al, 1981)

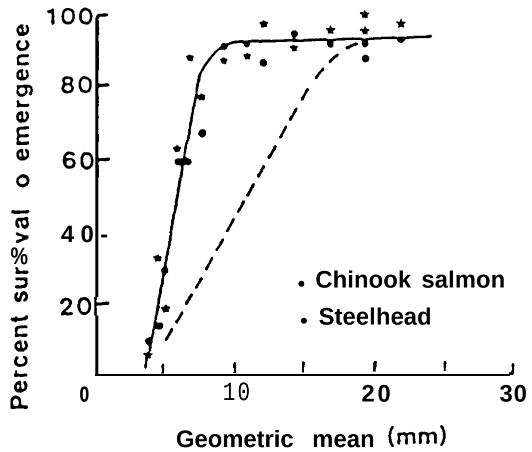


Figure 4-12. Relationship between d_g of each experimental gravel mixture and steelhead and chinook salmon embryo survival. Solid line fitted by eye to data from laboratory tests. Broken line represents curve from Shirazi (1979) (Tappel and Bjorn, 1983).

Fredle Index

The fredle index (f) was specifically developed to overcome the limitations of using a single measurement (percent fines or geometric mean) to describe substrate composition by providing a description of substrate porosity (Platts et al, 1983). Table 4-8 describes the mean fredle index (and confidence limits), while **Figure 4-13 compares the relative fredle value for each site.**

Table 4-8

Fredle Index (f) Results with 95% Confidence Intervals and Estimated Survival Rates

Reach	Site	Fredle Index	95% C.I. Lower	Upper	Estimated Survival 1/ Steelhead	Coho	Chinook
Scott River							
1	A	5.43	4.22	6.64	78-90%	65%	98%
	B	3.19	2.88	3.51	60-70%	45%	70%
2	C	3.25	2.84	3.66	60-70%	45%	70%
3	D	4.34	4.07	4.60	70-88%	60%	88%
	E	3.75	3.31	4.20	65-80%	52%	80%
4-5	F	3.57	3.24	3.90	65-75%	50%	75%
5-6	G	2.79	2.67	2.92	55-60%	40-65%	60%
7-8	H	3.02	2.81	3.23	58-65%	42-66%	65%
9	I	3.19	2.62	3.76	60-70%	45%	70%
10	J	4.80	4.04	5.56	75-90%	60%	90%
	K	3.82	2.41	5.24	65-80%	52%	80%
Tributaries							
	El	5.53	3.69	7.36	78-90%	65%	98%
	E2	4.66	3.63	5.70	75-90%	60%	90%
	F1	2.78	2.10	3.46	55-60%	40-65%	60%
	F2	2.95	1.72	4.17	58-65%	42-66%	65%
	F3	3.59	3.15	4.03	65-75%	50%	75%
	S1	5.70	2.03	9.38	80-90%	70%	98%

1/ Based on compilation by Chapman (1988)

Relationships of survival as correlated with the fredle index are provided in Figure 4-14, as compiled by Chapman (1988). Based on the regression lines from Koski (1966), Tappel and Bjornn (1983), and Lotspeich and Everest (1981), estimates of survival for three species were determined for each site (Table 4-8).

These survival estimates are higher than those predicted from percent fines (Table 4-5), but comparable to the geometric mean predictions for most sites for coho salmon (Table 4-7). For survival of steelhead and chinook salmon emergents, the fredle predictions are inbetween the two geometric mean predictions. The difference between coho salmon and steelhead survival at a given

Figure 4-13

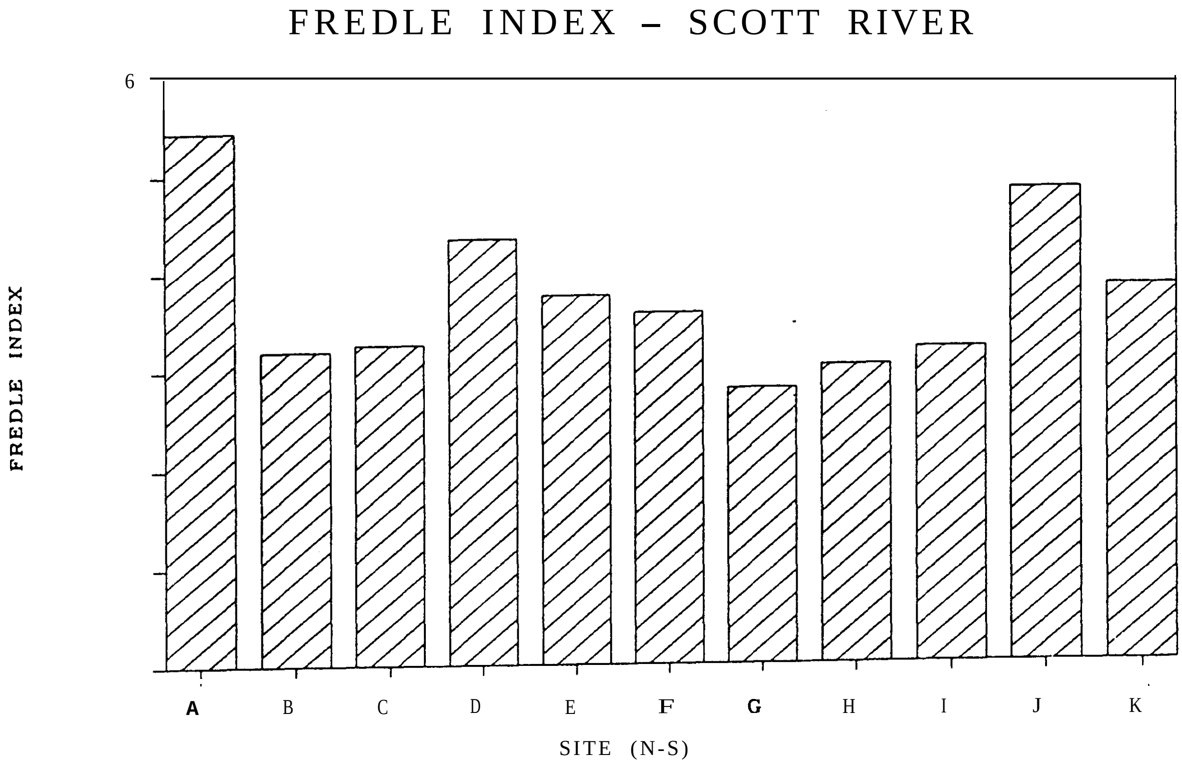
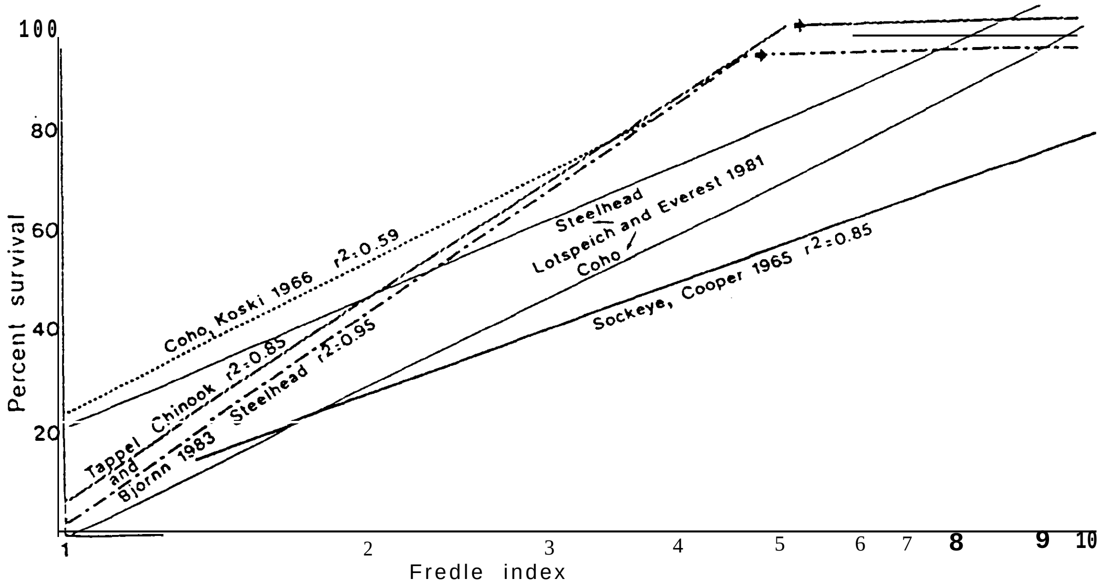


Figure 4-14



Survival to **emergence** in relation to the fredle index for natural coho salmon rcdds (Koski 1966) and for chinook salmon and steelhead **(Tappel** and Bjomn 1983) and sockeye salmon (Cooper 1965) in laboratory **gravel mixes.** Heavy **arrows indicate the upper** ends of regressions for the Tappel and Bjornn data; at higher fredle indexes. survival exceeded 90%. Regression lines for steclhcad and coho salmon are also plotted from Lotspeich and Everst (1981) for the late part of the incubation period in laboratory gravels. (Lotspeich and Everst 1981 **used data** from Phillips et al. 1975.)

"f" value may be related to differences in the cranial diameter of alevins and their relative ability to maneuver through pore spaces in gravel (Platts et al, 1983). Mean gravel size, which directly influences the fredle value, is also related to the size of spawning fish and therefore species of fish (i.e., bigger fish can spawn in bigger gravels) (Kondolf, 1988).

Among the sites, the fredle index surprisingly does not predict a lower rate of survival for the obviously sandy sites D-E-F as the two other indices did. In fact, for chinook salmon, the fredle correlation indicates some of the higher rates of emergence at these sites, despite percentages of fines (less than 6.35 mm) over 80%. A graphic comparison of the fredle index for each site is found in Figure 4-13, where the taller the bar, the better the site.

While the fredle index was designed to be an improved measure of spawning substrate quality, it appears to suffer from several inadequacies (Kondolf, 1988). Its sorting coefficient assumes that poorly sorted gravels are those with more interstitial fine sediment. However, poor sorting can also be derived from a small amount of particles which are much larger than the rest of the distribution. In addition, the sorting coefficient $((d_{75}/d_{25})^{1/2})$ reflects only the middle 50% distribution and is not sensitive to changes in percentiles smaller than the 25th. Kondolf (1988) feels this "may be a serious shortcoming" because of studies (McNeil and Ahnell, 1964; Cederholm et al, 1982 and others) which identify fines less than 0.85 mm as being critical to survival. As noted before, sites D-E-F contain about 20% fines of this size.

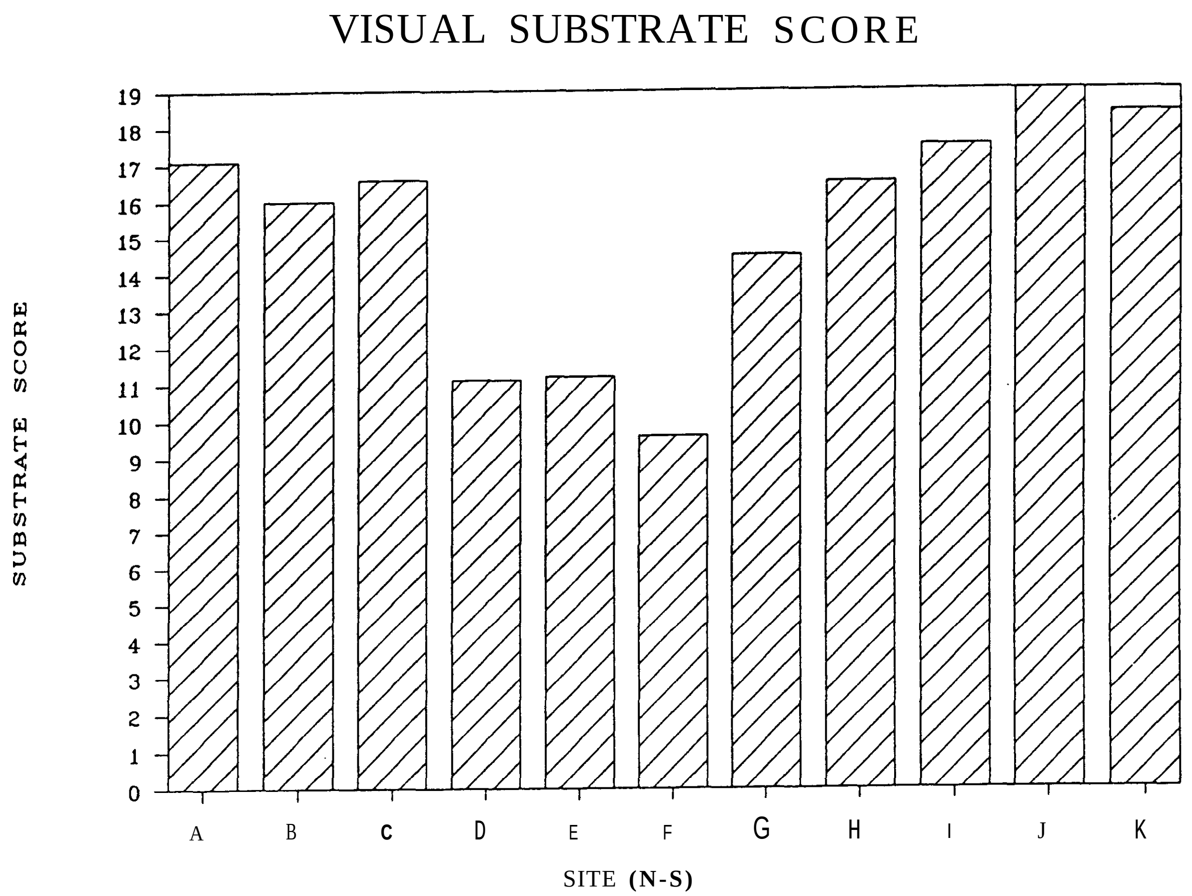
Visual Analysis

The visual rating of surface substrate is summarized as a Substrate Score for each site (Table 4-9), with comparisons depicted in Figure 4-15. This score includes an evaluation of embeddedness. Site F had the lowest visual score and therefore represents the worst surface quality, along with sites D and E. Sites J and K represent the best surface areas.

A statistical correlation was attempted to relate (1) substrate score with geometric mean particle size, and (2) embeddedness rating with percent fines (0.85 mm). The highest coefficient of determination was very low $(r^2=.29)$ for geometric mean. In contrast, Crouse et al (1981) found a high correlation $(r^2=.93)$ between average geometric mean and substrate score. However, their study was based on laboratory streams with substrate particle size of higher geometric means (10 to 40) than those experienced in the Scott River system.

The main problem with the Substrate Score method for the Scott River is the high amount of fines. Not enough distinction can be made with the current system among many of the sites. At riffle areas, the fines are also often washed off the surface so the surface quality does not indicate the amount of fines below the surface. This factor probably explains why the statistical

Figure 4-15


VISUAL SUBSTRATE SCORE
SUBSTRATE SCORE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
A
B
C
D
E
F
G
H
I
J
K
SITE (N-S)

correlation was not high between the qualitative surface evaluation and the quantitative subsurface measurement.

Platts and Megahan (1975) and Megahan et al (1980) found visual estimates (the Platts ocular method) of spawning substrate to be useful for evaluating decomposed granitic sand trends in the South Fork of the Salmon River watershed in the Idaho Batholith, where the same observer has estimated the conditions over time. Other studies have found surface appearance of gravels to be "inadequate and often misleading" (Everest et al, 1981) or observed generally weak relationships between subsurface core data and surface visual data (r values below 0.29) (Torquemada and Platts, 1988). However, the latter report noted that surface sand was significantly related ($p<0.05$) to subsurface sediment less than 4.7mm in samples taken from undisturbed areas prior to spawning. They recommended the use of substrate score as the quickest and easiest assessment of surface condition.

Table 4-9

Visual Surface Analysis - Substrate Score

Site	Mean	95% C.I. Lower	Upper	Rank
Scott River				
A	17.1	16.6	17.6	4
B	16.0	15.1	16.8	7
C	16.6	15.8	17.3	5
D	11.1	10.1	12.1	10
E	11.2	10.1	12.1	9
F	9.6	8.7	10.5	11
G	14.5	13.9	15.0	8
H	16.5	15.9	17.1	6
I	17.5	17.0	18.1	3
J	19.0	18.3	19.6	1
K	18.4	16.5	20.3	2
Tributaries				
El	17.6	16.6	18.6	5
E2	18.6	17.7	19.5	3
F1	17.4	16.5	18.3	6
F2	18.0	16.5	19.5	4
F3	19.0	17.5	20.5	1
S1	18.9	17.3	20.5	2

CONCLUSIONS

Use of Quality Indices

Quality indices for the Scott River best serve as relative measurements between sites and between years rather than as predictors of emergent survival. The variations in estimated survival are so great among the numerous studies and indices that they only validate the observation that increasing fines cause decreasing survival. However, the four indices combined may offer insight into the three dimensional properties of the spawning gravels which would be overlooked if only one was used. The visual index rates surface quality, the percentage fines index measures subsurface amounts of selected particle sizes, the geometric mean evaluates subsurface texture and thereby permeability and porosity, and the fredle index measures changes in subsurface sorting of gravels and fines.

The search for a single variable as the ideal index of gravel quality has not worked for at least two reasons: (1) different investigators have used different indices, so results cannot be compared; and (2) gravel requirements differ with life stage, and the appropriate measures vary with those requirements (Kondolf, 1988). For example, geometric mean may be a reasonable indicator of the spawning gravels' "framework size" for construction of a nest by a female. However, a better measure of fine sediment, such as percentage finer than some size, is needed for the incubation and emergence stages. A third reason may be the regional variability of spawning gravels and the relative ability of native stocks to adapt to local conditions. The Scott River situation is different than other streams described in the literature: it does not have the high levels of silt and clay fines (less than 0.85mm) found in many disturbed coastal streams, yet its sand is less coarse (less than 4.75mm) than the sand of the Idaho Batholith streams (less than 9.5mm). Such a variability between regions, as well as within a homogeneous area, has been noted for western Oregon streams (Adams and Beschta, 1980).

One of the problems with the emergent survival relationships is that they are based on particle size as measured in the spawning area, in the laboratory troughs, or in the redd but not in the egg pocket, which may be the most sensitive and important area to measure (Chapman and McLeod, 1987). Laboratory studies of embryo survival, these researchers caution, are only useful in "assessing mechanistic responses rather than as exact analogs of nature that permit accurate assessment of quantitative biological response? As a result, Chapman advocates that survival rates should only be developed from data from an egg pocket and only applied to gravel samples taken from egg pockets. Extrapolating laboratory results to field conditions, as did Stowell et al (1983), is therefore "inappropriate". However, such narrow limitations to data development and interpretation as Chapman proposes would preclude some very useful applications of non-redd field work and quality indices.

One could argue that the results of the Scott River study reflect only pre-spawning conditions and not the actual conditions of the redd or egg pocket. Redd construction is known to have a cleansing effect on the spawning site. In a study of 23 chinook salmon redds in the South Fork of the Salmon River, Idaho, post-spawning measurements of subsurface sediment revealed a decrease in percentage of fine sediment (less than 6.3mm) anywhere from 3.7% to 13.6% at each site. Reducing the quantity of such fines also increased the geometric mean particle size and the fredle index (Torquemada and Platts, 1988). Therefore, the Scott River measurements would have overestimated the quantity of fine sediment affecting the emergence of fry. However, post-spawning measurements in the egg pocket assumes that further deposition of fine sediment does not occur before emergence. In the Scott River, fall chinook fry would be emerging about 2 months after spawning (December through February), while winter steelhead lay their eggs during a more prolonged period, with incubation from mid-December through mid-June (Leidy and Leidy, 1984). Sediment deposition would likely occur during lower flows following runoff peaks in these months. Without evaluating local conditions within redds or egg pockets during incubation and just before emergence, conclusions cannot be made about the longevity and effectiveness of redd construction cleansing.

Comparison of Sites

To summarize the results of the various indices, Table 4-10 presents the mean value for each site. A statistical comparison was made of the sites for three of the indices. Table 4-11 describes the relationships among the Scott River sites: the marked ones are not statistically different, while the unmarked ones are significantly different ($P<0.05$).

Each index reveals a certain clustering of similar sites. While there are differences between indices, the patterns reveal that the downstream sites (A,B,C) tend to be similar to upstream sites (H,I,J,K) and the sites within these two groups are similar with each other. However, the middle sites (D,E,F,G) are significantly different from these two groups and tend to only be similar to each other.

Another way to compare the sites and quality indices is to rank the sites (Scott River separately from the tributaries), with 1 representing the best site for that index (Table 4-12).

Table 4-10

Summary of Index Mean Values

Site	% Fines <6.3	% Fines <0.85	Geo.Mean	Fredle	Visual
<u>Scott River</u>					
A	26.8	8.0	13.8	5.4	17.1
B	41.0	11.1	9.6	3.2	16.0
C	36.5	11.0	10.6	3.3	16.6
D	92.7	20.1	8.0	4.3	11.1
E	82.4	19.9	7.6	3.8	11.2
F	82.1	21.6	8.1	3.6	9.6
G	56.7	17.2	8.8	2.8	14.5
H	40.1	10.5	10.0	3.0	16.5
I	36.8	12.2	11.3	3.2	17.5
J	28.2	7.4	13.2	4.8	19.0
K	30.6	6.4	12.2	3.8	18.4
<u>Tributaries</u>					
El	27.5	6.5	12.4	5.5	17.6
E2	28.3	5.1	13.2	4.7	18.6
F1	37.2	8.6	9.7	2.8	17.4
F2	42.6	8.2	11.1	3.0	18.0
F3	33.4	8.2	12.0	3.6	19.0
S1	30.8	6.3	13.3	5.7	18.9

Table 4-11

Statistically Comparable Sites, Scott River

Geometric Mean

	A	B	C	D	E	F	G	H	I	J	K
A											
B	*										
C											
D											
E				*							
F				*	*						
G		*		*	*	*					
H		*	*				*				
I			*					*			
J	*										
K			*						*	*	

Percent Fine (<0.85)

	A	B	C	D	E	F	G	H	I	J	K
A											
B	*										
C	*	*									
D											
E				*							
F				*	*						
G				*	*	*					
H		*	*								
I	*	*	*					*			
J	*	*	*	*				*	*		
K	*	*	*					*		*	

Visual Substrate Score

	A	B	C	D	E	F	G	H	I	J	K
A											
B	*										
C	*	*									
D											
E				*							
F											
G											
H	*	*	*								
I	*	*	*					*			
J	*										
K	*										

Marked (*) sites are similar while unmarked sites are significantly different.
Duncan's Multiple Range Test
P<.05

Table 4-12

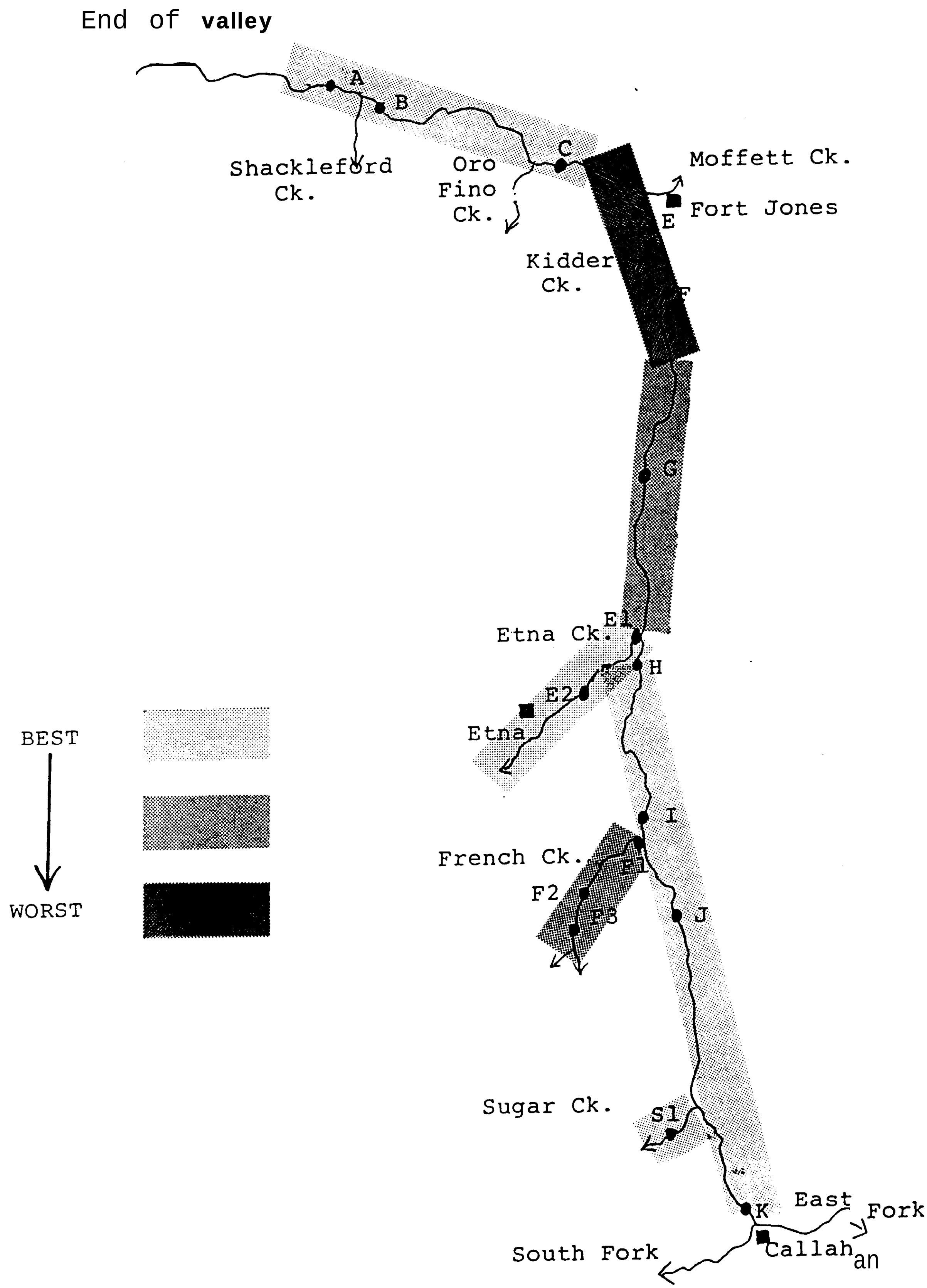
Ranking of Sites by Index

Site	% Fines <6.3	<0.85	Geo.Mean	Fredle	Visual
Scott River					
A	1	3	1	1	4
B	7	6	7	8	7
C	4	5	5	7	5
D	11	10	10	3	10
E	10	9	11	5	9
F	9	11	9	6	11
G	8	8	8	11	8
H	6	4	6	10	6
I	5	7	4	9	3
J	2	2	2	2	1
K	3	1	3	4	2
Tributaries					
El	1	3	3	2	5
E2	2	1	2	3	3
F1	5	5	6	6	6
F2	6	4	5	5	4
F3	4	4	4	4	1
S1	3	2	1	1	2

Although subtle and gross differences are not apparent through ranking, this procedure highlights the relative status of each site. The relative rankings of the various indices are surprisingly consistent, except for the fredle index. Sites A and J are consistently ranked the highest (#l and 2) in the fredle, geometric mean and percent fines (less than 6.3 mm) indices . Site A is at the downstream end of the valley below Shackleford Creek's confluence, while Site J is near the upper end just above the Fay Lane bridge. Except for the fredle index, sites D, E, and F are ranked the lowest. These sites are located in the middle of the valley from Kidder Creek's mouth (RM 32.2) to Island Road bridge (RM 34.7). Based on the comparative analysis of the above indices, the 1989 spawning gravel quality in the valley is rated in Figure 4-16.

The quantitative ranking of these sites as the best and the worst spawning areas correlates with the observations noted in previous spawning surveys, as discussed earlier in this chapter. Recent CDFG chinook salmon carcass recovery surveys, summarized in Table 4-1, have found a predominance of spawning activity (carcass counts per mile = 137) in the lower valley reach, which is where Sites A and B are located. The second reach surveyed (gravel plant to the irrigation pumps at Moffett Creek) had a much lower rate of use (26 per mile) and includes the area of Site C, which is ranked

Figure 4-16. Spawning Gravel Quality in Scott Valley



in the middle (4 to 7) in quality. The third surveyed reach (Sweasey bridge to Fay Lane bridge) was used slightly less (23 per mile) and includes the area of Sites H and I, as well as carcasses drifting down from lower Etna Creek and French Creek. The two river sites ranked in the middle (4 -7) for two indices but low for the fredle index (rank 9,10), while the lower Etna Creek site **(El)** was one of the best sites relative to other tributary sites as well as to the river sites. Lower French Creek (site Fl) was one of the poorest of the tributary sites but in the middle in comparison to river sites.

Other factors, however, confound correlations of carcass counts with quality of spawning areas. Low flows have impeded fall chinook salmon passage upstream to the middle and upper portions of the valley in some years. The diversion structure at the irrigation pumps near the mouth of Moffett Creek was a low flow barrier until its removal in 1989. Flow diversions, although reduced to supporting mainly stock watering needs during the fall and winter months, can contribute to the poor flow conditions in the lower portions of the tributaries and in areas below the main stem diversions.

The spawning gravel data developed for this study provides a good baseline for future evaluation of streambed conditions in the Scott River and several of its tributaries. It is recommended that a similar gravel analysis be repeated at the same sites every five years to monitor changes in streambed composition. Research is also needed to evaluate survival to emergence in local gravels (e.g., egg pocket survival tests) in the Scott River system, rather than relying on correlations performed in the laboratory or in streams from other regions.

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CHAPTER 5

SUMMARY AND CONCLUSIONS

CHAPTER 2: SCOTT RIVER BASIN GRANITIC SEDIMENT SOURCES

SUMMARY

Soils developed from granitics are recognized as some of the most erodible. A granitic watershed's response to land use is very different and sometimes unique compared to watersheds of other geologic types.

Intermediate elevations have higher sedimentation rates than higher and lower elevations, due to chemical weathering, clay formation, and higher flood flows.

The angle of repose for granitic rock decreases as it decomposes, and is determined to be about 70 percent (35 degrees) for soils derived from granitic parent material.

Twenty-six percent of the Study Area contains decomposed granitic soils, or about 56,900 acres.

Granitic portions of the Study Area sub-basins contain about 129 miles of streams including seven miles of diversion ditches. If the entire watershed is considered, there are 809 miles of streams, including 183 miles of diversion ditches.

Soils derived from granitic rocks have high infiltration capacity and permeability: as a result, the most significant effect of soil disturbance on stream flow is the interception of subsurface flow by roads incised into bedrock. The road can concentrate the water and sediment coming off the cut bank, diverting it onto fill slopes and from one stream channel to another. Overloaded channels will respond to the increased flows with what can be serious streambank erosion or downcutting, while fill slopes may gully or slough.

Although roads contribute more sediment, timber harvesting on sandy loam soils can have serious impacts depending upon how ground cover in the harvest area and skid trails relate to bedrock outcrops, streams, and compacted areas such as roads, landings and ephemeral draws.

Thirty-nine percent of the granitic area has been harvested, not including site re-entries, based on data from 1958-1988 for public lands and 1974-present for private lands.

The Study Area contains about 288 miles of roads on granitics, or about 1428 acres. This represents a road density of about 27 feet per acre (3.2 miles per square mile).

There are, conservatively, about 191 mile of skid trails on granitics or about 232 acres. This represents a density of 17.7 feet per acre (2.1 miles per square mile).

Streambank road and skid trail erosion were estimated with procedures that quantified the volume of material lost per year. The USLE (Universal Soil Loss Equation) modified for forest conditions in the west served as the basis for evaluating erosion off of vegetated slopes in the Study Area. The equation was employed on a grid of 1.6 acres using a geographical information system to track the pertinent variables. Despite their limitations, these methods are appropriate for determining relative erosion rates and making planning decisions, such as the assignment of dollars and resources.

Average annual erosion for the entire road prism was 737 tons per mile, or 149 tons per acre. These values are within the range reported by others on sandy loam soils.

Sixty-four percent of road erosion was from the cut bank, which was our highest category of soil loss from all sources at 40 percent of the total.

Losses from skid trails averaged about 239 tons per acre per year. About 12.6 tons per acre of this loss was due to sheet and rill erosion.

Granitic terrane streambanks average 382 tons per mile per year. Nearly three times the average streambank erosion is estimated for Boulder and Fox creeks because of large areas of upper bank scour. About 17 miles of granitic streams in the Study Area are gutted on their upper banks. In most cases, this occurred with the 1964 flood. There has been only limited revegetation of these banks since 1964, as viewed in historic and current aerial photos. The activity appears unrelated to timber harvest as it generally occurs in upper watershed areas where little if any harvesting has occurred.

Losses from sheet and rill erosion on harvest sites are about double the geologic rate of erosion. These and losses from earth flows are minor in comparison to other sources.

Total erosion is estimated to be about 340,450 tons per year. Road cuts constitute 40 percent of this amount, and streambanks 23 percent. Individual sub-basins contribute amounts closely related to the proportion they represent of all granitics in the Study Area, with some minor variance above or below the average.

Erosion rates higher than tolerance values of one to two tons per acre mean the soil is being mined faster than it can be replaced by soil formation processes.

For most years, sediment production in the Study Area is stored in the upper watershed. Primary storage sites include hillslope swales, hillslopes outside of swales, upper streambanks, channel margins and fans, and channel bedload. These areas become sources of small annual amounts and large, episodic pulses of sediment. Channel bedload appears to be a source of annual sediment rather than a site for long-term storage.

· In most cases of streambank scour, there is a downstream alluvial section populated with willows and alders where at least some of the resulting sediment is stored-

· An analysis of grain sizes from road ditches and streambanks suggests that of the material delivered to the Scott River, about 43 percent is "fines" (less than 0.85 mm). This represents about 31,000 tons per year.

A delivery ratio of 0.21 is preferred for estimating sediment yield to the Scott River, based on results of a survey of Antelope Reservoir in Plumas County, which has about the same proportion of granitics as our Study Area. This would predict an average annual yield of 71,500 tons. Results of another sediment yield methodology, developed by the Pacific Southwest Interagency Committee and modified for Trinity County forests by the Soil Conservation Service, came very close to this amount. Results of reservoir surveys from other watersheds are presented for comparison, as well as estimates of sediment yield from nearby granitic watersheds.

· These values suggest that about 60 percent of sediment yield is accelerated, or due to management activities of man.

CHAPTER 3 - SEDIMENT STORAGE AND TRANSPORT

SUMMARY

As concluded by Beschta (1987), "our ability to predict sediment transport accurately is extremely limited" due to the limitations of applying observations from artificial channels to natural stream systems. However, the exercise of applying various transport equations can help recognition of patterns of sediment transport in streams and can assist in understanding why streams move sediment.

o The greatest amount of sand in channel storage can be found in Reach 3, below the State Highway 3 bridge, and Reach 2, above Meamber Bridge.

o Reach 3 has the highest transport capacity, while Reach 2 has the lowest. Such a difference may account for the high storage found in Reach 2.

1944 photos reveal that the channel width and shape of the Scott River have not changed substantially. While some widening has occurred in subsequent years, the widest sections of Reaches 2 and 3 had already been formed. The 1944 channel conditions most likely reflect the work performed in 1938 by the Corps of Engineers, who removed many areas of riparian vegetation, straightened sections of channel, and constructed some levees.

o Channel straightening over the years has increased stream velocities and therefore transport capacities. As a result, the river has less opportunity to overflow its banks and deposit sediment within the flood plain.

o The flood plains of the Scott River and Kidder Creek/Big Slough have stored considerable amounts of sediment from recent floods.

o Sediment transport equations, particularly Engelund-Hansen and Ackers-White, were useful in identifying relative sediment transport between reaches and possible contributing factors.

o Removal of the SVID diversion dam near the confluence of Moffett Creek in 1989 will cause an adjustment in slope and therefore bedload transport for this reach and at least one upstream reach. Downstream effects (e.g., pools filled with sand) have been noticed for the past several years.

o Improved riverbed sediment quality can happen over time in a stream severely degraded by DG sand, as it did in the South Fork of the Salmon River, Idaho, once sediment supply is reduced.

o Prevention and rehabilitation of DG erosion in the uplands of the Scott River watershed would serve to decrease the input side of the local sediment budget and allow more of the present DG sand in channel storage to get moved out. Such an effort is presently underway in the French Creek sub-basin- by the Siskiyou Resource Conservation District and the U.S. Soil Conservation Service, who are identifying site-specific DG erosion problems and their solutions. Since roads cause 63% of the total DG erosion in the basin (see Table 2-12), focusing on the control of erosion from road cuts, fills and surfaces should be a high priority.

CHAPTER 4 - SPAWNING IMPACT

SUMMARY

o Existing and potential spawning sites were sampled using 238 McNeil sampler cores at 11 sites in the Scott Valley portion of the Scott River, and 55 cores at 6 sites in the tributaries of Etna, French and Sugar Creeks.

o Core samples were sieved into 7 categories (less than selected sieve sizes): 100mm, 25.0mm, 12.5mm, 6.35mm, 4.75mm, 2.35mm, 0.85mm.

o Future gravel sampling on the Scott River should use a minimum of 20 and an optimum of 25 samples per site to minimize statistical variation.

o Four quality indices were applied to the field data: (1) Percentage Fines, less than 6.3mm and less than 0.85mm; (2) Geometric Mean of particle size; (3) fredle index; and (4) visual Substrate Score.

o The relative ratings of the various indices are quite consistent except for the fredle index.

o The fredle index should not be used alone to evaluate spawning habitat quality.

o Quality indices best serve as relative measurements between sites and between years rather than as accurate predictors of emergent survival. Predictions of fry survival for the same site ranged from 0% to 88%, depending on the index used.

o The spawning gravel data developed for this study serves as a good baseline for monitoring changes in streambed composition of the Scott River and several tributaries.

o A map indicating the relative spawning gravel quality of the Scott River and several tributaries was prepared based on the results of the quality indices. The worst section is in the area from below Moffett Creek to above the Island Road bridge.

o Scott River's spawning gravel should be monitored at least every two years, using similar procedures and the same sites.

o Research is needed on the survival to emergence of fry in the local gravels, rather than depending on survival predictions developed in the laboratory or streams from other regions.

APPENDICES

APPENDIX A

SEDIMENT TRANSPORT CAPACITY FORMULAS

1. Meyer-Peter-Muller Formula:

This version is from Gomez and Church (1989), as corrected:

$$i_b = \left(\frac{YS}{v_s - v} - .047 \frac{((v_s - v)/v)\ D}{(0.25/v)(v/g)^{1/3}} \right)^{1.5} W$$

Where: i_b = specific bedload transport rate (dry weight)
Y = Depth (m)
S = slope
D = D_{50} (m)
W = Width (m)
v = specific weight of water
v_s = specific weight of sediment
g = acceleration of gravity

2. Engelund - Hansen Formula:

This version is from Chang (1988):

$$C_s = 0.05 \frac{s}{s-1} \frac{US}{((s-1)gd)^{1/2}} \frac{RS}{(s-1)d}$$

Where: C_s = sediment concentration by weight
U = cross-sectionally averaged velocity
R = hydraulic radius
s = specific gravity of sediment = 2.65
d = median fall diameter of the bed material

3. Ackers-White Formula:

This version is from Chang (1988):

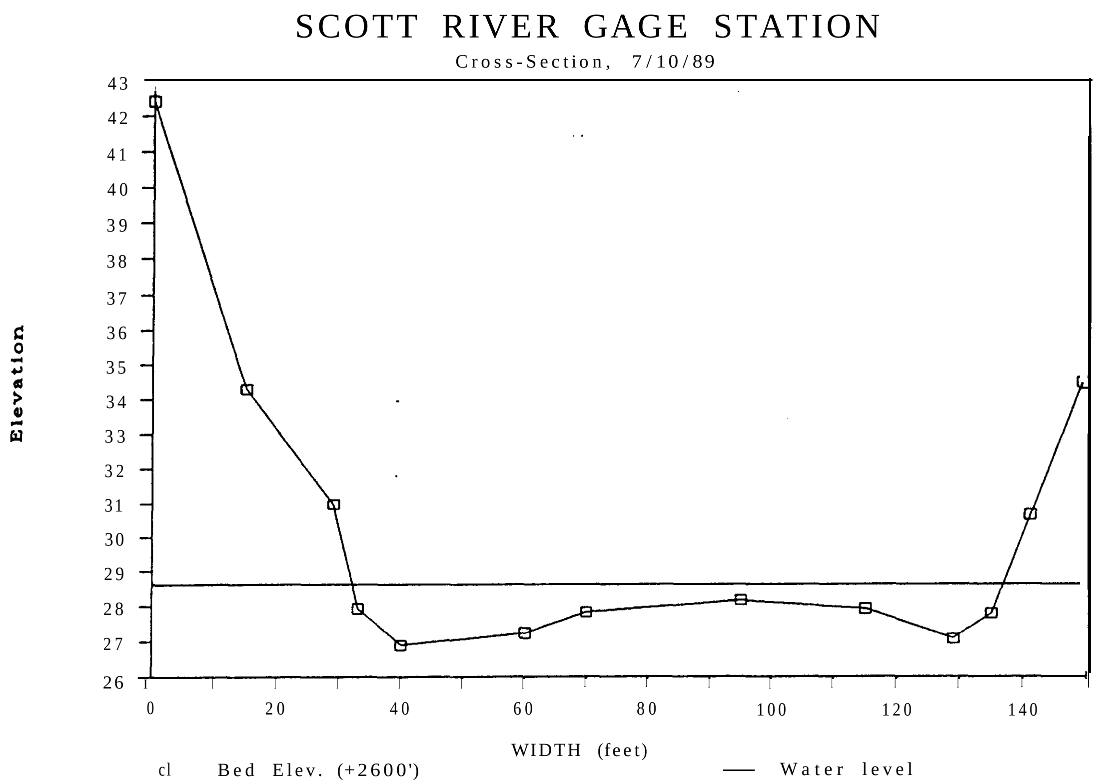
$$C_s = cs \frac{d}{R} \left(\frac{U}{U_*} \right)^n \left(\frac{F_g}{A} - 1 \right)^m$$

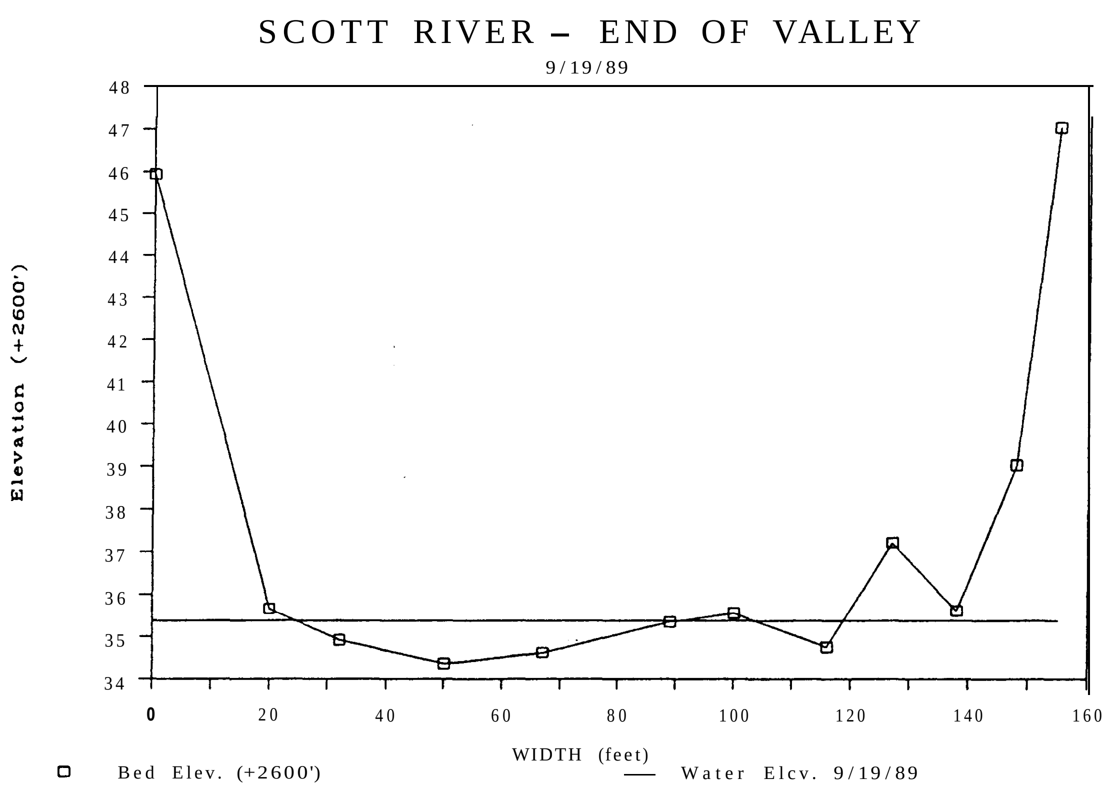
Where: c = 0.025 for d_g > 60
n = transition exponent (0 for bed load only)
A = 0.17 for d_g > 60
m = 1.50 for d_g > 60
F_g = particle mobility

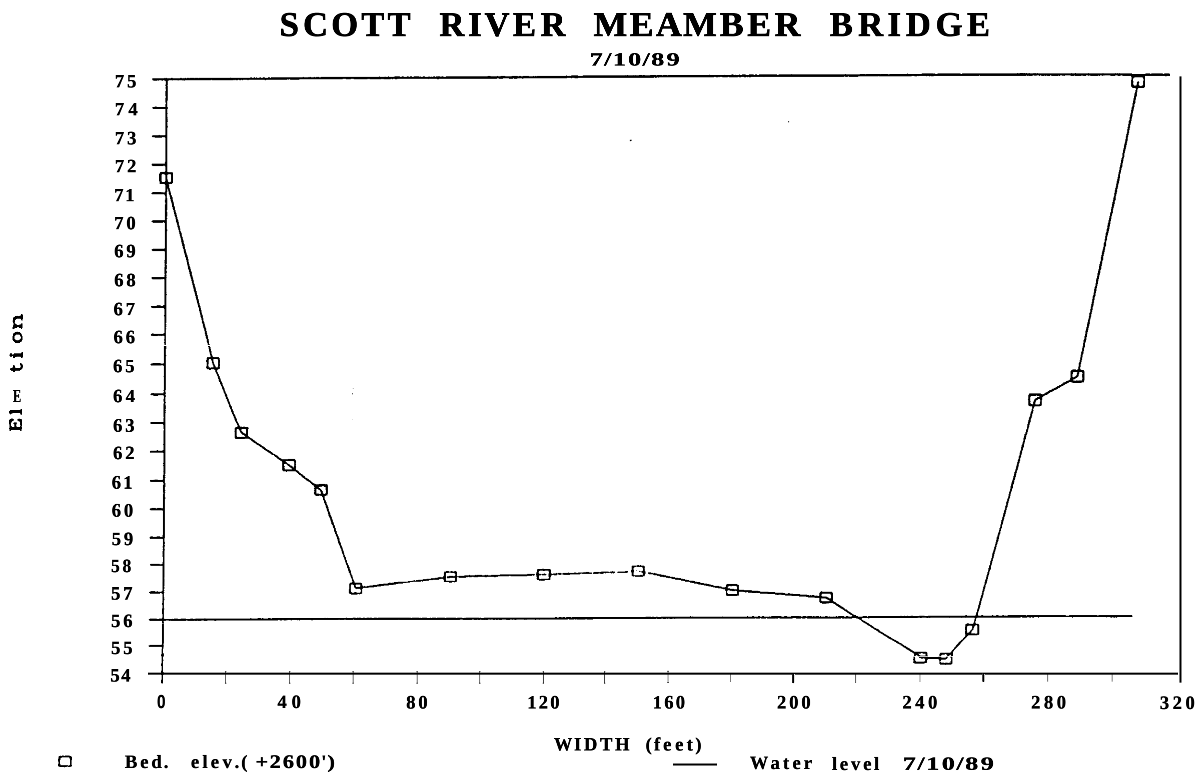
APPENDIX B

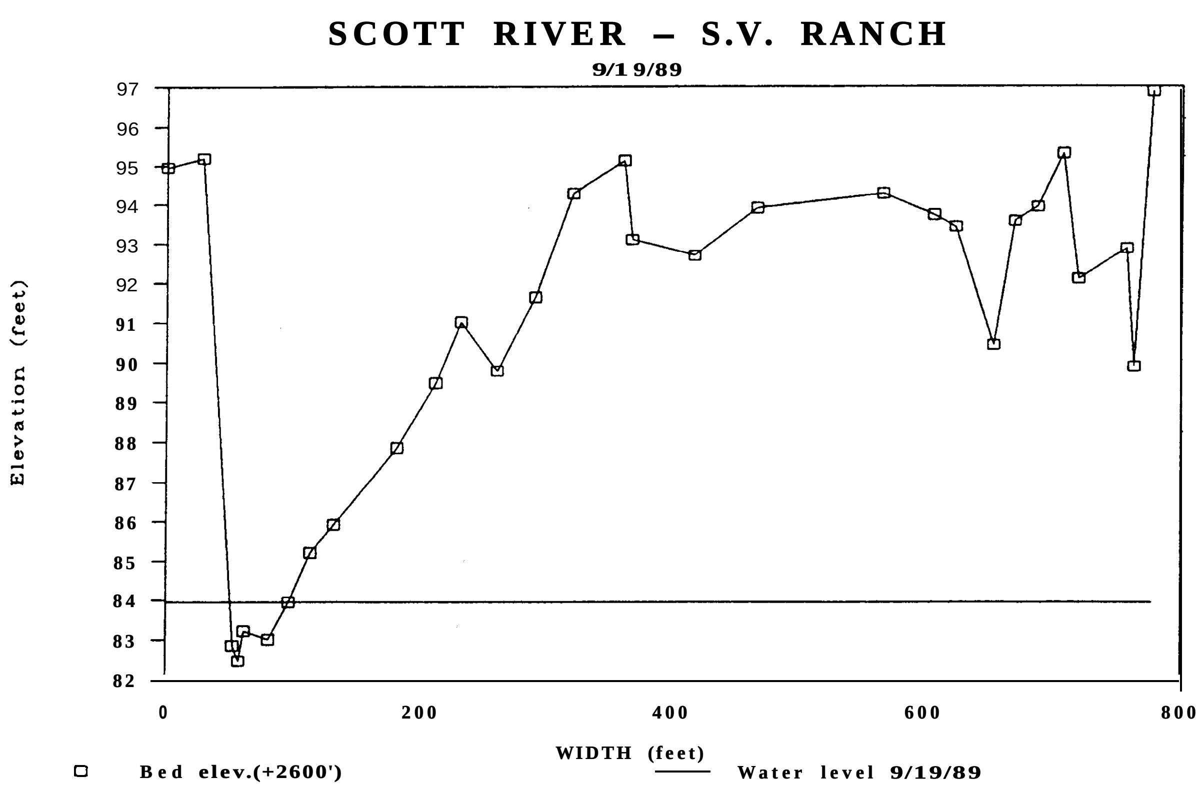
SCOTT RIVER CROSS-SECTIONS

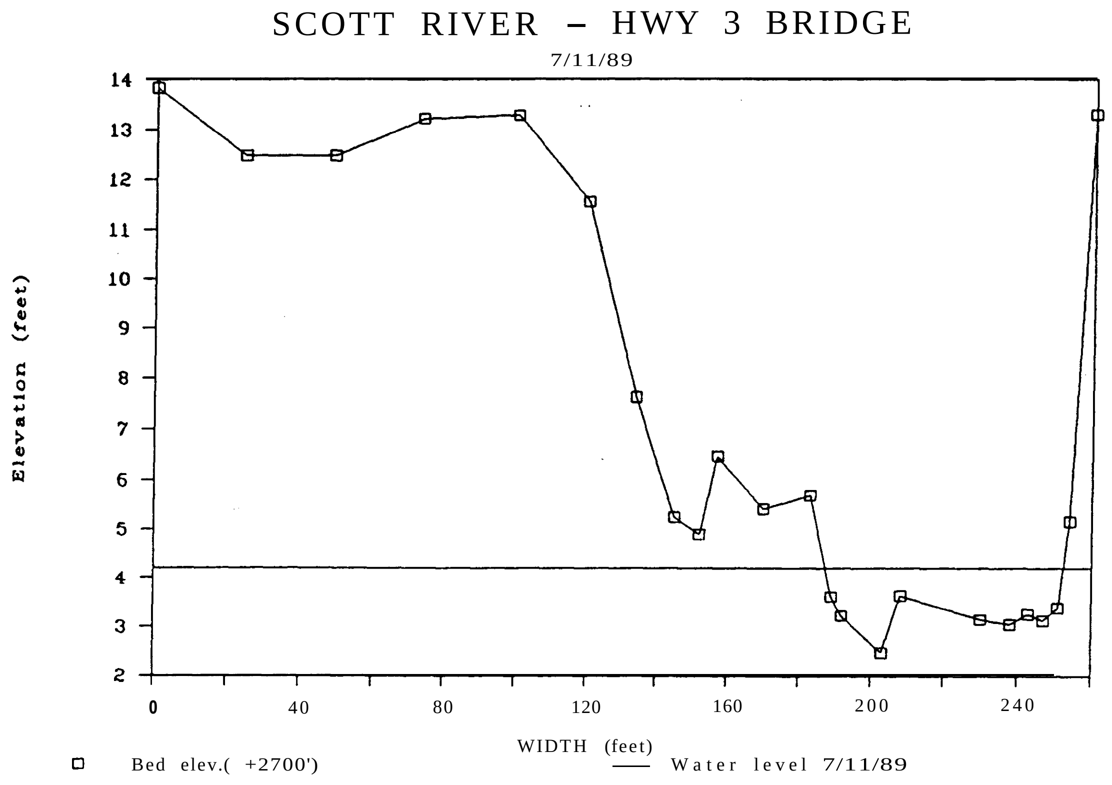
- Scott River Gage Station
- Scott River - End of Valley
- Scott River - Meamber Bridge
- Scott River - Scott Valley Ranch
- Scott River - Highway 3 Bridge
- Scott River - Island Rd. Bridge
- Scott River - Eller Lane Bridge
- Scott River - Rancho del Sol Bridge
- Scott River - Horn Lane Bridge
- Scott River - Below SVID Dam
- Scott River - Above SVID Dam
- Scott River - Fay Lane Bridge
- Scott River - Below Callahan
- East Fork Scott River
- South Fork Scott River

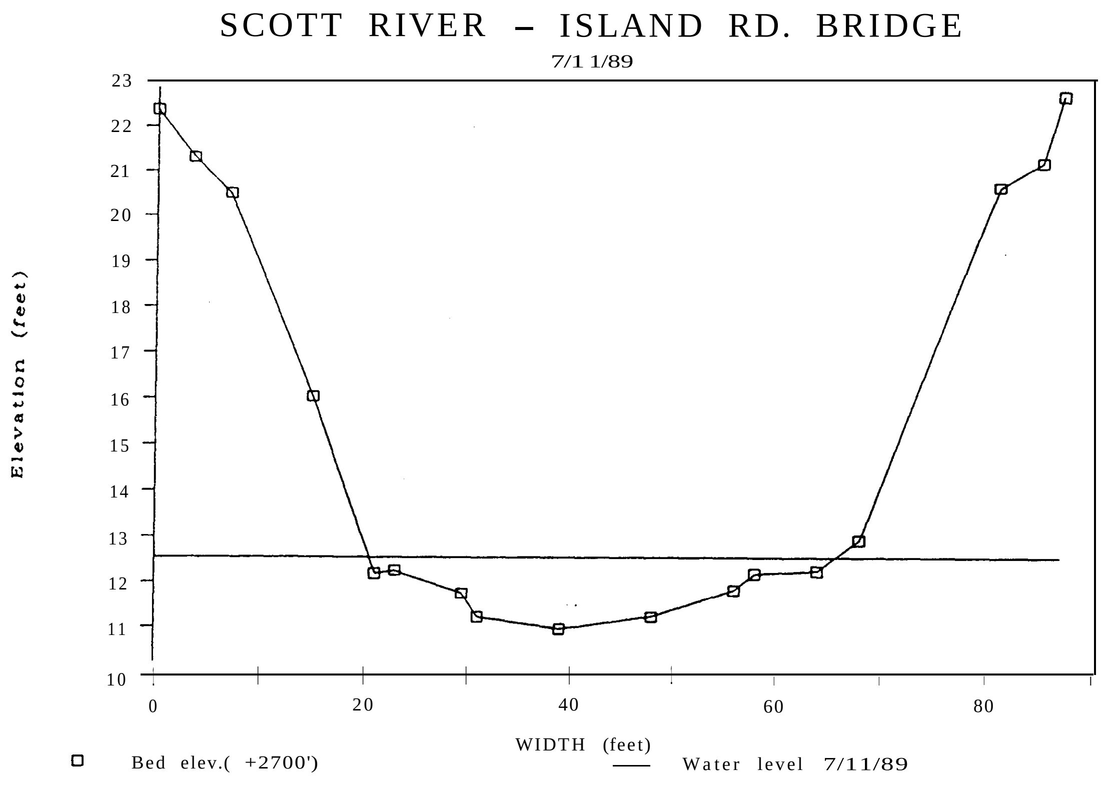

SCOTT RIVER GAGE STATION
Cross-Section, 7/10/89
Elevation
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
0
20
40
60
80
100
120
140
WIDTH (feet)
Bed Elev. (+2600')
Water level

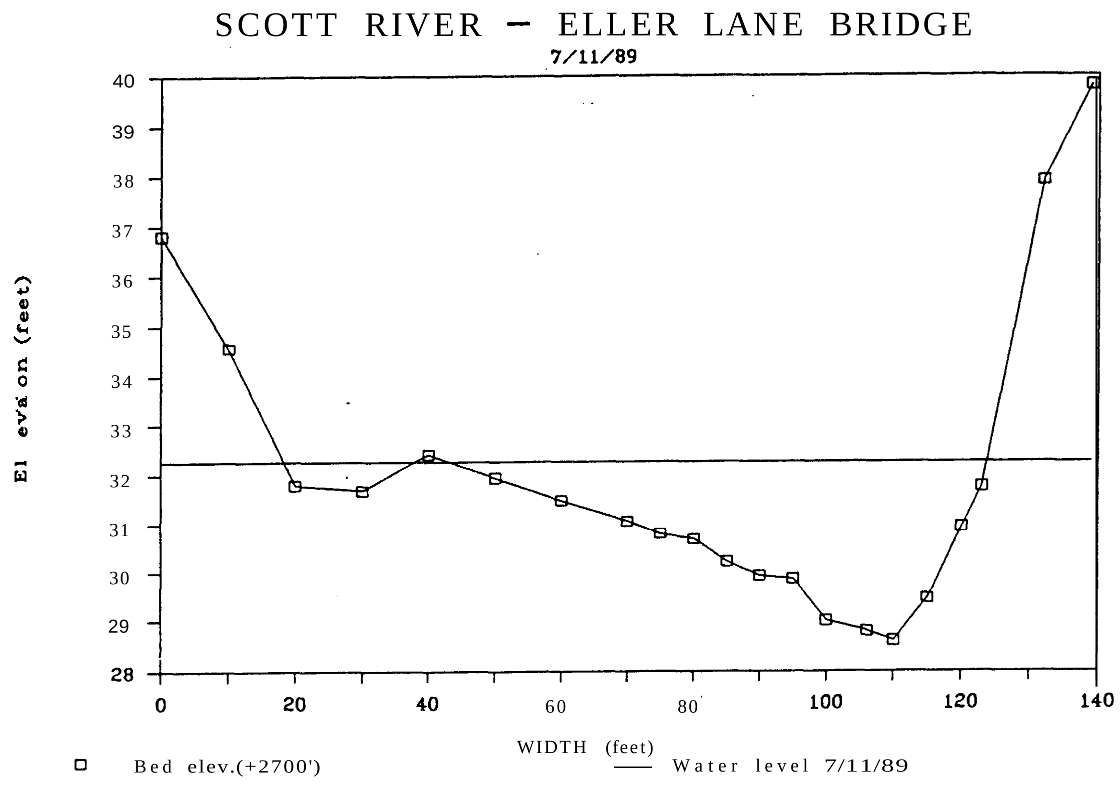

SCOTT RIVER – END OF VALLEY
9/19/89
Elevation (+2600')
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
0
20
40
60
80
100
120
140
160
WIDTH (feet)
Bed Elev. (+2600')
Water Elcv. 9/19/89

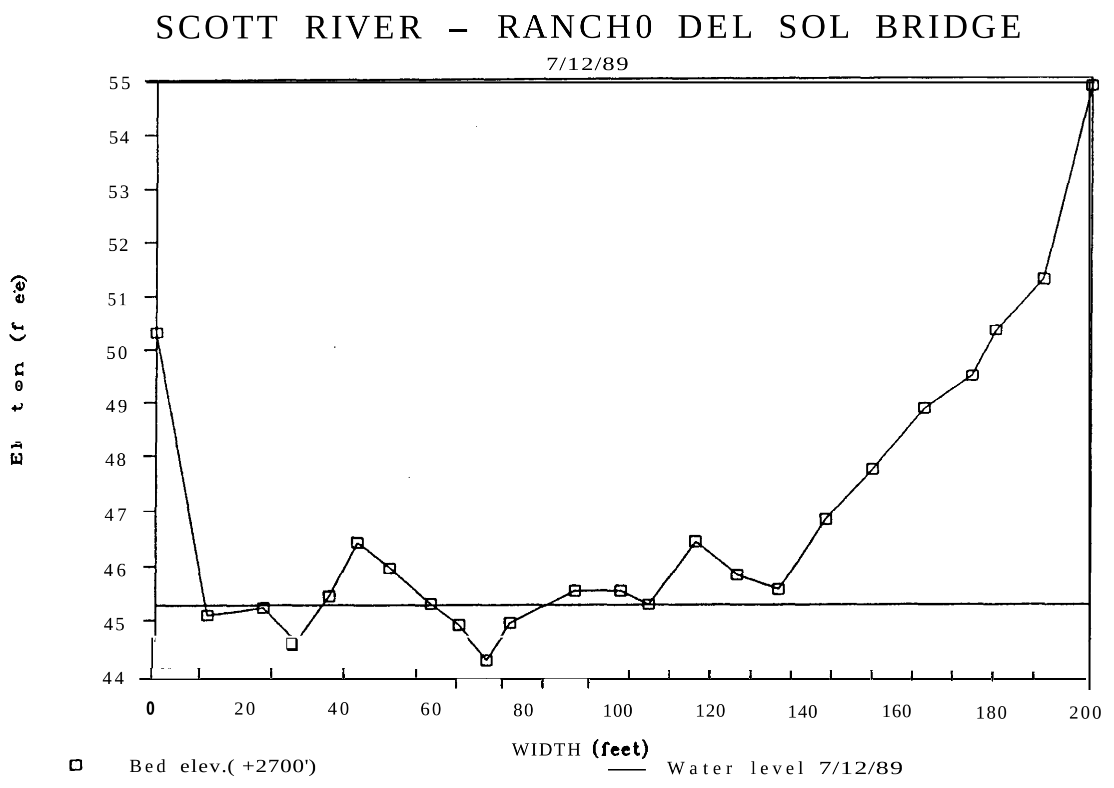

SCOTT RIVER MEAMBER BRIDGE
7/10/89
75
74
73
72
71
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
0
40
80
120
160
200
240
280
320
WIDTH (feet)
Bed. elev.(+2600')
Water level 7/10/89


SCOTT RIVER – S.V. RANCH
9/19/89
97
96
95
94
93
92
91
90
89
88
87
86
85
84
83
82
Elevation (feet)
0
200
400
600
800
WIDTH (feet)
Bed elev.(+2600')
Water level 9/19/89


SCOTT RIVER – HWY 3 BRIDGE
7/11/89
Elevation (feet)
14
13
12
11
10
9
8
7
6
5
4
3
2
0
40
80
120
160
200
240
WIDTH (feet)
Bed elev.(+2700')
Water level 7/11/89

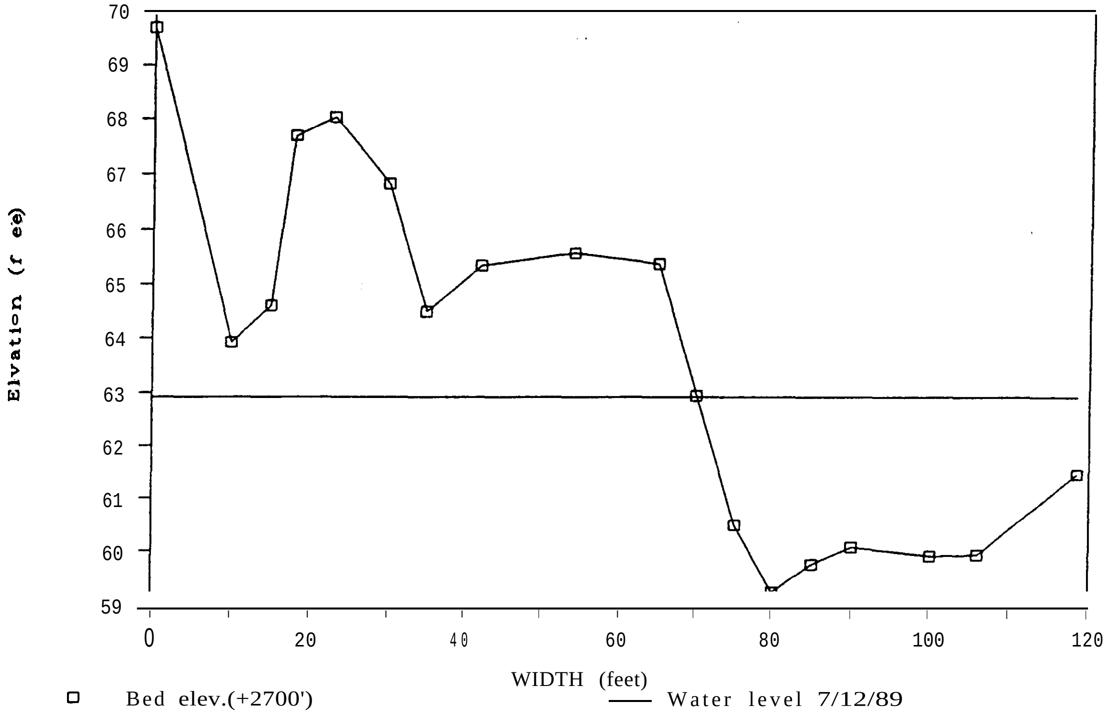

SCOTT RIVER – ISLAND RD. BRIDGE
7/1 1/89
Elevation (feet)
23
22
21
20
19
18
17
16
15
14
13
12
11
10
0
20
40
60
80
WIDTH (feet)
Bed elev.(+2700')
Water level 7/11/89

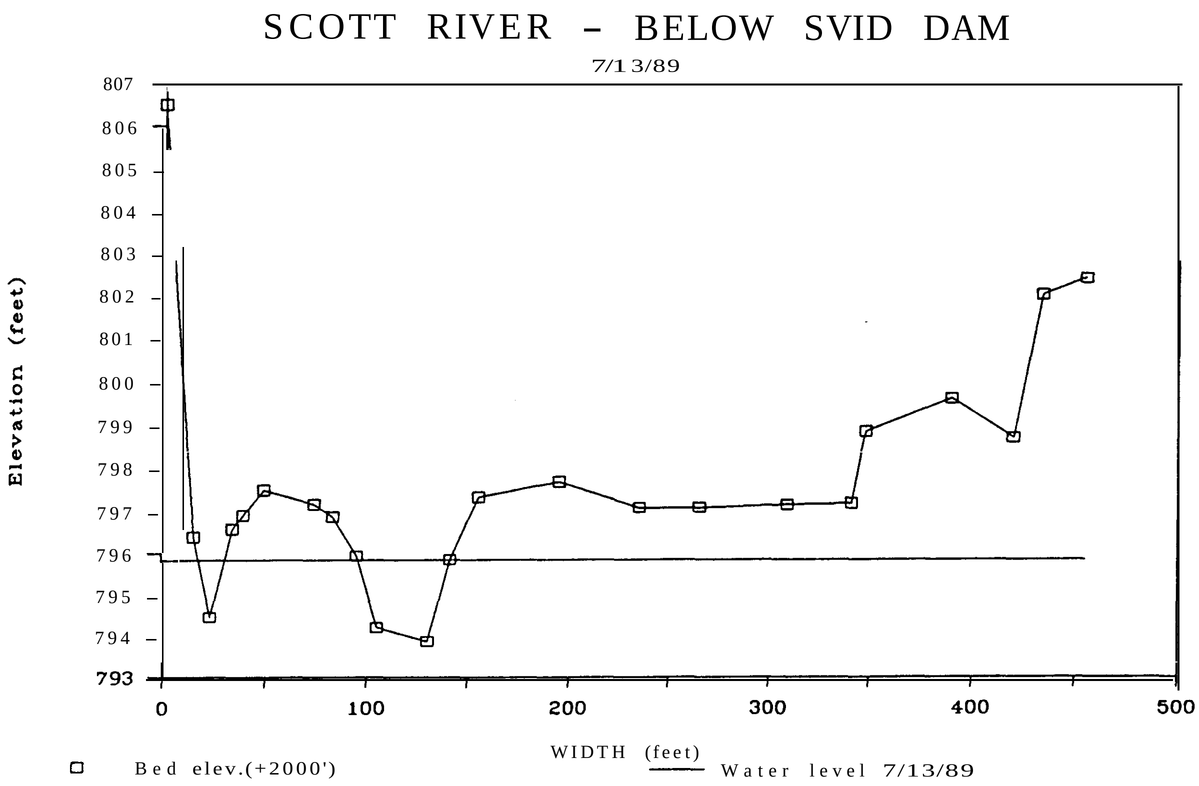

SCOTT RIVER – ELLER LANE BRIDGE
7/11/89
Elevation (feet)
WIDTH (feet)
Bed elev.(+2700')
Water level 7/11/89

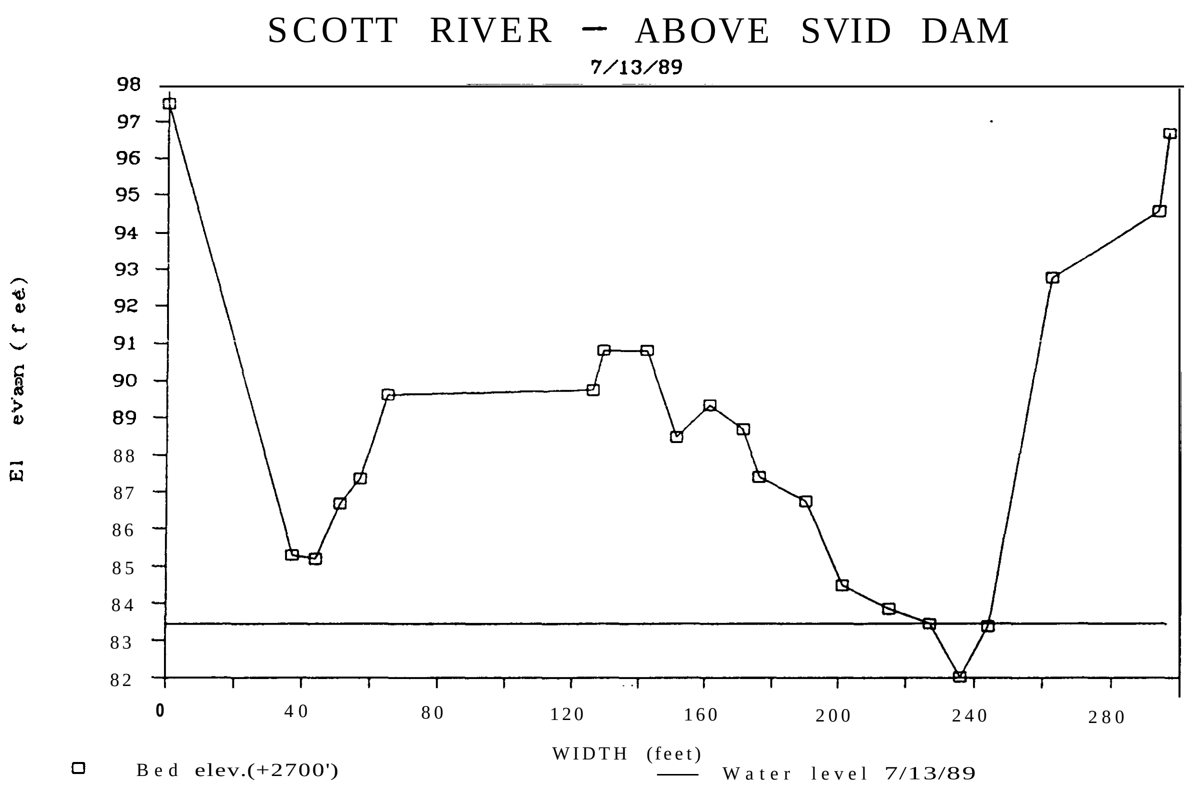

SCOTT RIVER – RANCH0 DEL SOL BRIDGE
7/12/89
WIDTH (feet)
Bed elev.(+2700')
Water level 7/12/89

SCOTT RIVER – HORN LANE BRIDGE

7/12/89

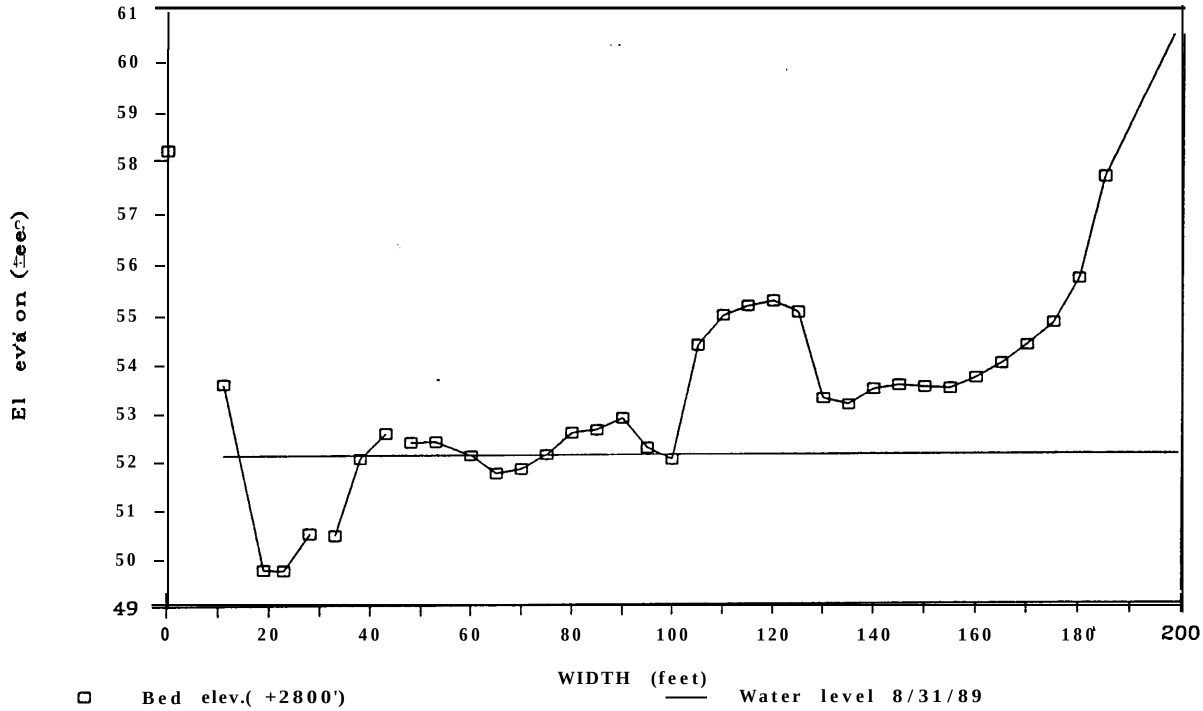



SCOTT RIVER – BELOW SVID DAM
7/13/89
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
Elevation (feet)
0
100
200
300
400
500
WIDTH (feet)
Bed elev.(+2000')
Water level 7/13/89


SCOTT RIVER – ABOVE SVID DAM
7/13/89
98
97
96
95
94
93
92
91
90
89
88
87
86
85
84
83
82
0
40
80
120
160
200
240
280
WIDTH (feet)
Bed elev.(+2700')
Water level 7/13/89

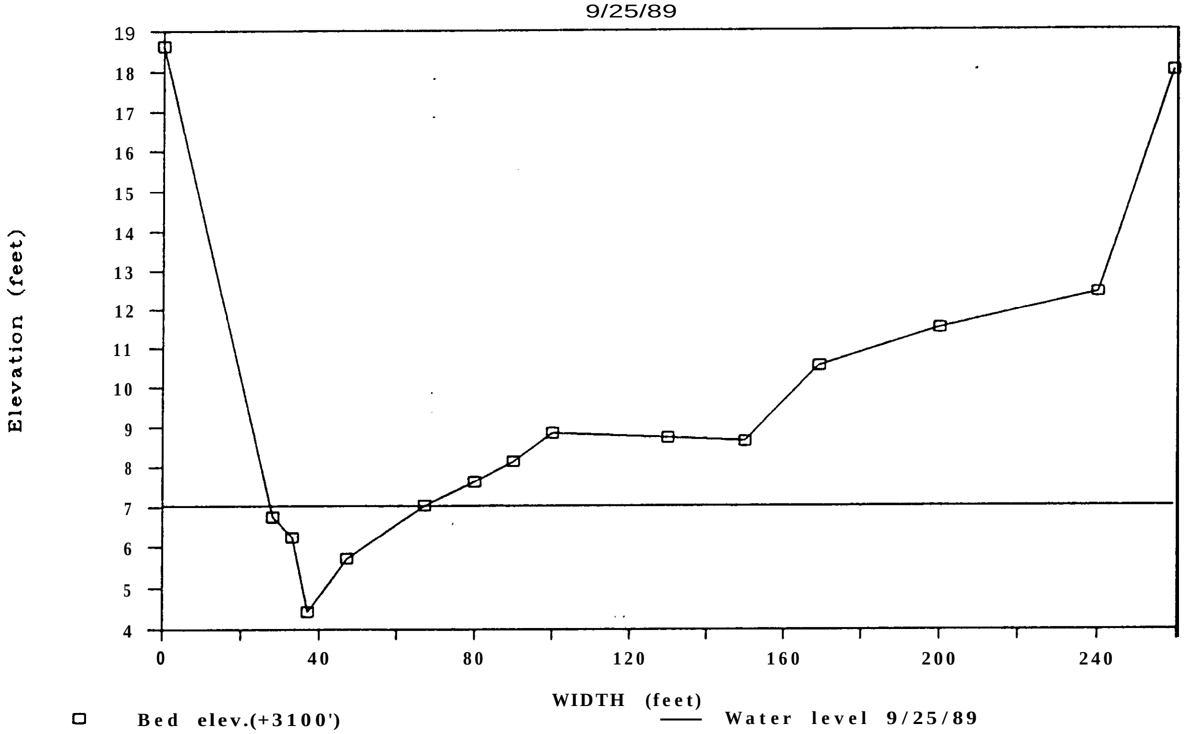
SCOTT RIVER – FAY LANE BRIDGE

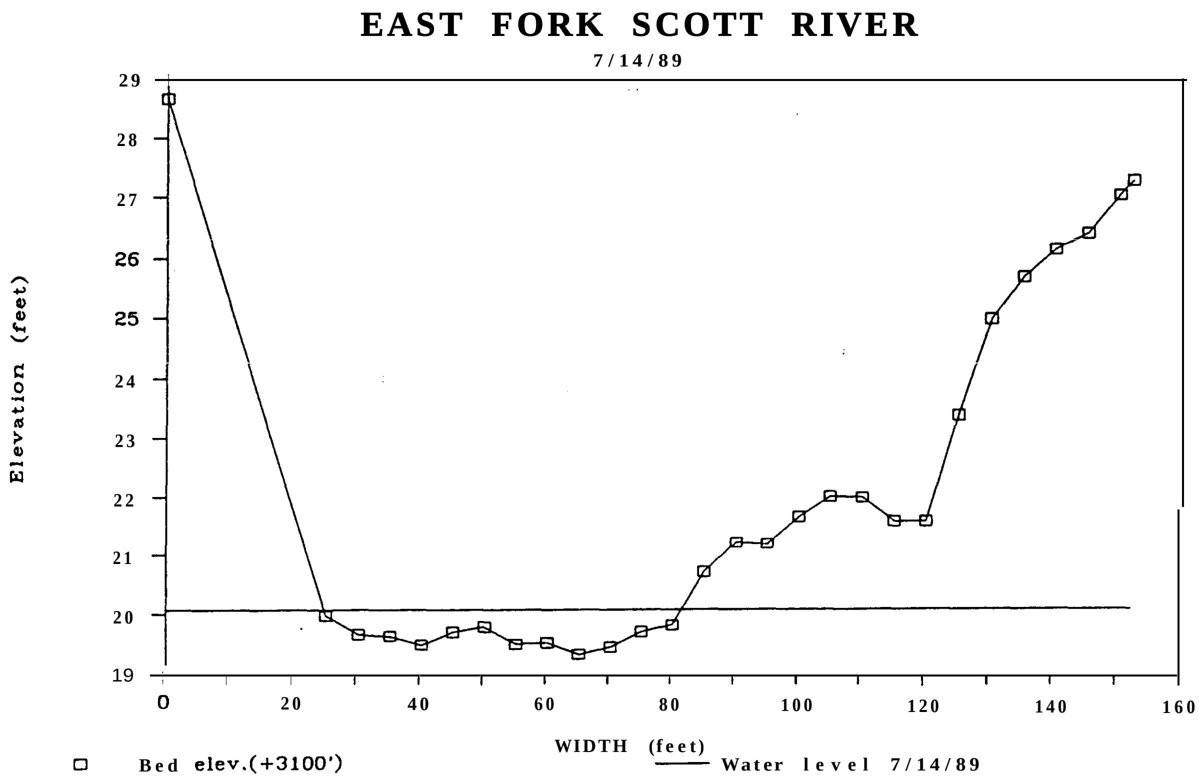
8/31/89

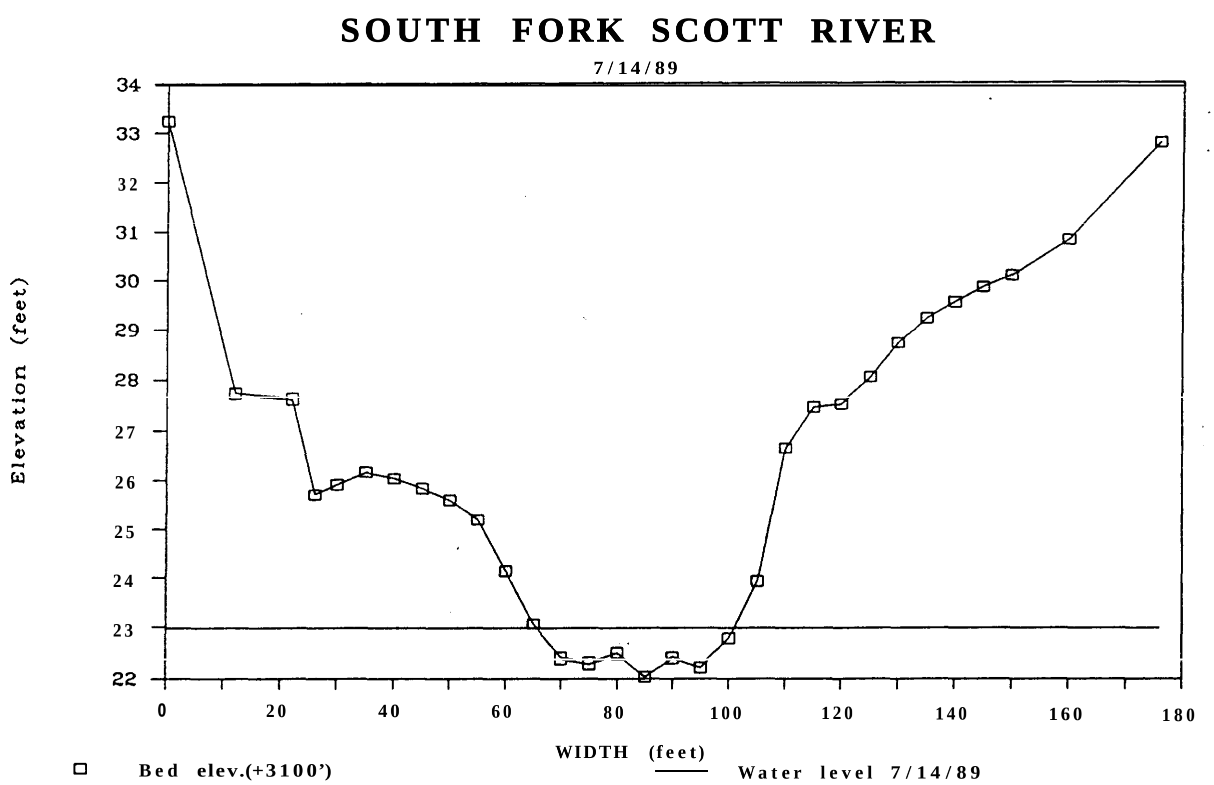


SCOTT RIVER – BELOW CALLAHAN

9/25/89




EAST FORK SCOTT RIVER
7/14/89
Elevation (feet)
29
28
27
26
25
24
23
22
21
20
19
0
20
40
60
80
100
120
140
160
WIDTH (feet)
Bed elev.(+3100')
Water level 7/14/89


SOUTH FORK SCOTT RIVER
7/14/89
Elevation (feet)
34
33
32
31
30
29
28
27
26
25
24
23
22
0
20
40
60
80
100
120
140
160
180
WIDTH (feet)
Bed elev.(+3100')
Water level 7/14/89

APPENDIX C

SPAWNING AREA GRAIN SIZE DISTRIBUTIONS

Dry weight (grams)

95% Confidence Interval (C.I.) Limits - Lower and Upper

Site	D25	D12.5	D6.3	D4.75	D2.36	DO.85	Fines
	Amount retained by sieve size						
Scott River - Downstream to Upstream (North to South)							
A- Nutting	3269	784	603	176	304	726	505
C.I. Lower	2838	702	519	131	259	580	444
C.I. Upper	3700	866	686	222	349	872	566
B - Tozier	873	1215	995	308	549	716	577
C.I. Lower	662	1117	894	253	466	574	480
C.I. Upper	1085	1313	1096	363	631	857	674
C - Mason	1809	972	791	253	450	735	606
C.I. Lower	1509	835	711	213	371	616	529
C.I. Upper	2109	1110	871	292	530	855	682
D- Langford	0	86	231	201	693	2304	890
C.I Lower	0	47	166	132	455	2036	737
C.I. Upper	0	125	295	269	931	2572	1043
E - Anderson	137	155	489	262	880	1675	1002
C.I. Lower	-130	68	362	199	715	1267	516
C.I. Upper	405	241	616	325	1044	2083	1487
F - Tobias	193	116	506	313	928	1293	902
C.I. Lower	-227	74	361	231	771	871	774
C.I. Upper	613	159	651	395	1084	1715	1030
G — Hurliman	216	995	875	306	612	927	806
C.I. Lower	150	816	779	266	537	831	687
C.I. Upper	282	1173	972	346	688	1023	924
H Whipple	1384	1079	800	265	515	837	569
C.I. Lower	1241	1010	749	234	467	740	520
C.I. Upper	1526	1148	850	293	563	934	617
I - Spencer	2274	934	545	195	399	853	706
C.I Lower	1920	819	471	154	355	709	595
C.I. Upper	2627	1049	618	237	443	996	817
J - Barnes	2867	665	669	188	407	609	415
C.I Lower	2450	564	551	166	345	516	375
C.I. Upper	3284	766	787	210	469	702	455

Site	Amount retained by sieve size D25	D12.5	D6.3	D4.75	D2.36	DO.85	Fines
K – Hayden	2724	673	478	185	436	704	353
C.I. Lower	2271	447	322	144	388	577	303
C.I. Upper	3177	899	633	227	483	831	402
<u>Tributaries</u>							
El Etna-Low	2003	1054	613	229	304	488	339
C.I. Lower	1447	948	466	151	244	326	239
C.I. Upper	2559	1159	761	309	364	650	439
E2 Etna-Hwy3	3530	900	676	230	484	922	359
C.I. Lower	2756	738	606	186	419	730	257
C.I. Upper	4304	1060	746	273	548	1115	461
F1 French-L	2304	727	527	170	519	878	472
C.I. Lower	1837	631	423	120	449	696	425
C.I. Upper	2771	823	630	219	588	1060	518
F2 French-H3	2080	647	493	203	628	1079	459
C.I. Lower	1400	446	290	124	305	621	319
C.I. Upper	2760	848	696	281	950	1537	598
F3 French-MB	2497	729	601	234	656	534	408
C.I. Lower	2205	469	509	168	503	435	326
C.I. Upper	2790	990	693	299	808	623	634
Sl Sugar-H3	2663	699	295	238	456	625	341
C.I Lower	1.977	586	557	102	296	407	260
C.I. Upper	3350	811	303	375	615	844	422

APPENDIX D

SUMMARY OF PROJECT EXPENDITURES
1989-90

Salaries	$42,500.00
Travel/Transportation	$ 2,200.00
Overhead	$ 3,800.00
Supplies	$ 1,500.00
TOTAL	$50,000.00

Funding provided by the Klamath River Basin Fisheries Task Force

U.S. Fish and Wildlife Service Cooperative Agreement 89506