AN ABSTRACT OF THE THESIS OF

Paul J. Krupin for the degree of Master of Science

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Title: QUANTITATIVE BASIN MORPHOLOGY AND CHANNEL STABILITY WITH REFERENCE TO NONPOINT SOURCES OF POLLUTION IN EVANS CREEK

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Dr. Charles Rosenfeld

A Stream Reach Inventory and Channel Stability Evaluation procedure has been used to assess the nature and extent of erosional nonpoint sources of pollution in the Evans Creek basin, a tributary to the Rogue River, in southwestern Oregon.

The study is based upon the results of the Oregon Department of Environmental Quality Section 208 Nonpoint Source Assessment Project. A terrain analysis of Evans Creek has been performed using quantitative basin morphologic techniques. Regressions analysis techniques were used to relate the channel stability conditions of the streams of Evans Creek to the morphologic characteristics of the basins.

The Channel Stability Rating procedure is demonstrated to distinguish differences in the stability of channels under varying conditions of land use and lithology. The inventory procedure identifies and represents in-stream erosional and depositional processes differentially. Quantitative basin morphologic investigations indicate that streams in the Evans Creek basin generally conform to hydrophysical laws of drainage composition. Channel stability has been significantly related to 20 morphologic variables describing areal, linear, textural, relief and shape aspects of the Evans Creek basin in streams logged six to ten years ago, in second growth and in old growth. Channel stability ratings appear to be related to watershed characteristics which reflect the development of potential energy in a drainage basin and influence the way potential energy is expended in the channel system.

Quantitative Basin Morphology and Channel Stability With Reference to Nonpoint Sources of Pollution in Evans Creek, Oregon

by

Paul J. Krupin

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At this time I must express my thanks and humble appreciation to my parents, who have graciously devoted many, many years of their lives to me and have provided their willing assistance throughout this endeavor.

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QUANTITATIVE BASIN MORPHOLOGY AND CHANNEL STABILITY WITH REFERENCE TO NONPOINT SOURCES OF POLLUTION IN EVANS CREEK

I. INTRODUCTION

Increased public concern in the past few years has led to efforts to protect the quality of the waters of the state of Oregon from man's interference. Water pollution can generally be characterized as being derived from either point sources or nonpoint sources. Pollutants from point sources are discharged to the environment at a discrete, discernible location and are generally amenable to chemical treatment. Removal of polluting substances is achieved through effluent processing.

Nonpoint sources, on the other hand, discharge polluting substances to the environment through widely dispersed pathways, are diffuse in nature and cannot be traced to discrete locations. Nonpoint pollution occurs through natural erosional and depositional processes. Man-caused nonpoint pollution often stems from land based activities which accelerate the effects of natural erosional processes. Discharges resulting from nonpoint sources are not amenable to treatment through effluent control and mitigation of the pollution must therefore deal with the activity producing the pollution rather than with the pollution itself.

The State of Oregon Department of Environmental Quality, Water Quality Division has recently developed an interdisciplinary approach to assessing the location, type and severity of water quality problems caused by nonpoint sources of pollution. This technique considers the spatial and temporal relationships between terrain characteristics (geology, soils, slope, vegetation and climate), geomorphic processes, land management practices and the resultant stream water quality. The author of this thesis was a member of the interdisciplinary assessment team which evaluated stream water quality conditions in selected basins of the state. The field work entailed using a modified version of the "Stream Reach Inventory and Channel Stability Evaluation" procedure developed by the Northern Region of the National Forest Service (1975). This thesis is, in part, based upon the stream water quality data generated by the DEQ Stream Assessment Team in the Evans Creek watershed, in the Rogue River basin, near Grants Pass in southwestern Oregon.

The objectives of this thesis are:

1. To evaluate the results of the DEQ channel stability evaluation in Evans Creek with respect to land use and terrain characteristics;

2. To describe how the channel stability evaluation procedure represents erosional and depositional features and processes;

3. To quantify the morphologic attributes of the watersheds in the Evans Creek basin;

4. To relate the results of the channel stability

evaluation in Evans Creek to the morphologic characteristics of the watersheds evaluated.

The thesis framework and organization is presented in Figure 3.

The first portion of the paper describes the study area. The second part addresses the channel stability evaluation in Evans Creek. It is followed by a section which presents the results of a quantitative morphologic investigation of 21 catchments in the Evans Creek basin. The final portion of the paper describes the geomorphological perspective utilized in the analysis, reviews the literature, presents the methods of analysis and results of the analysis relating the channel stability evaluation to the quantitative morphology of the basins and closes with a discussion of the results and conclusion.

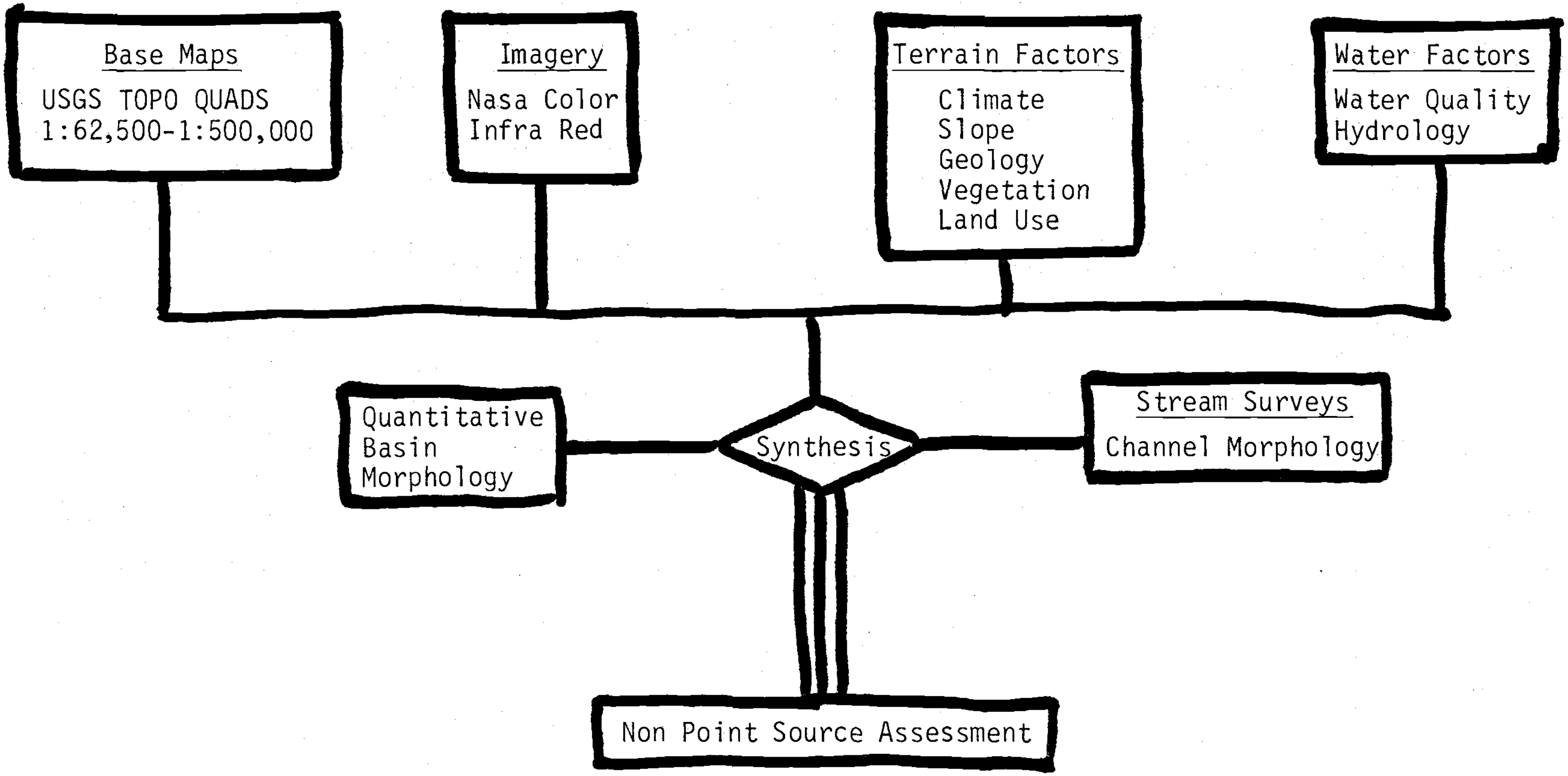

Figure 1. Thesis framework and organization.

II. DESCRIPTION OF THE STUDY AREA

LOCATION

The Evans Creek drainage basin has an area of 206 square miles (533 km.^{2}) and is located in southwestern Oregon on the north side of the Rogue River east of Grants Pass. The watershed is in the northwest quarter of Jackson County at 42^{o}52.5' to 42^{o}15' north latitude and 122^{o}30' to 122^{o}44' west longitude. Evans Creek empties into the Rogue River at the City of Rogue River. The City of Wimer is situated along the mainstream of Evans Creek eight miles north of the City of Rogue River.

The basin is bounded on the west by Jumpoff Joe Creek and Grave Creek (Rogue River basin), on the north by Cow Creek (Umpqua River basin) and on the east and southeast by the West Fork Trail Creek and several smaller tributary streams of the Rogue River.

CLIMATE

Evans Creek is situated in the Western Lowland climate province of Oregon (OSU 1974), which encompasses the Rogue River and other inland valleys in the southwestern portion of the state. The area is cut off from the marine influences that affect much of Western Oregon by the Coast, Klamath, and Siskiyou mountains. The valley portions of the basin receive less annual precipitation than other areas in the province. Still, the basin experiences the warm, dry summers and mild, wet winters characteristic of the region.

Since there are no official weather stations maintained in the Evans Creek basin, thermohyet diagrams were constructed from station data at seven locations which surround the basin (NOAA 1973). The diagrams (Figures 2 and 3) are very similar in form and imply that conditions in the basin are probably comparable.

Much of the precipitation that falls on the basin is related to the movement of cyclonic storms into the area from the Pacific Ocean to the west. Storm frequency is higher during the fall, winter and spring, than during the summer. Annual snowfall ranges from ten to 30 inches and annual precipitation from 20 to 50 inches. Mean minimum January temperatures range from 25 to 31^{o}F and mean maximum July temperatures from 89 to 91^{o}F (NOAA 1973). Elevation exerts a considerable influence on local conditions.

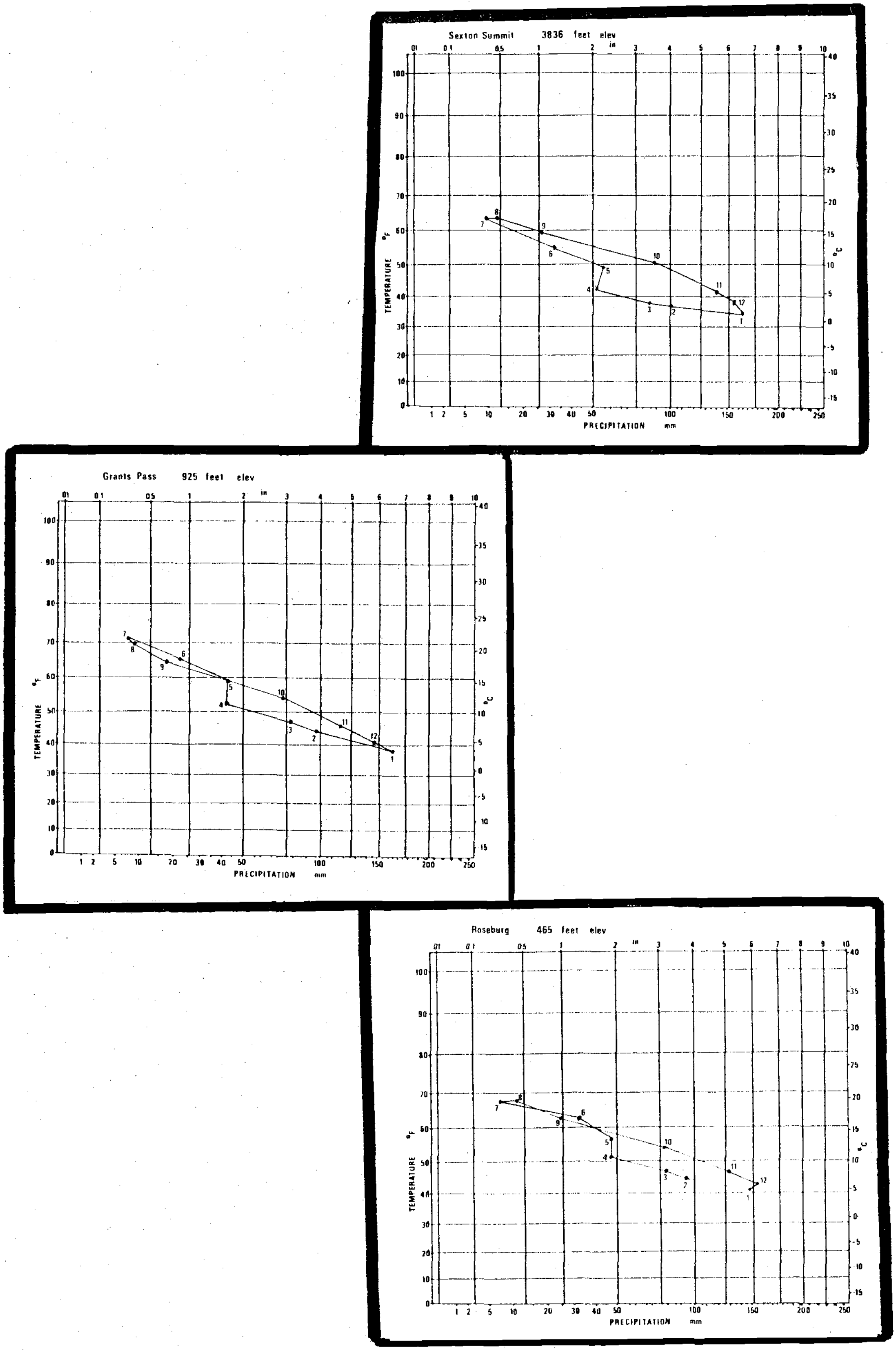

Figure 2. Thermohyet diagrams for selected weather stations in southwestern Oregon.

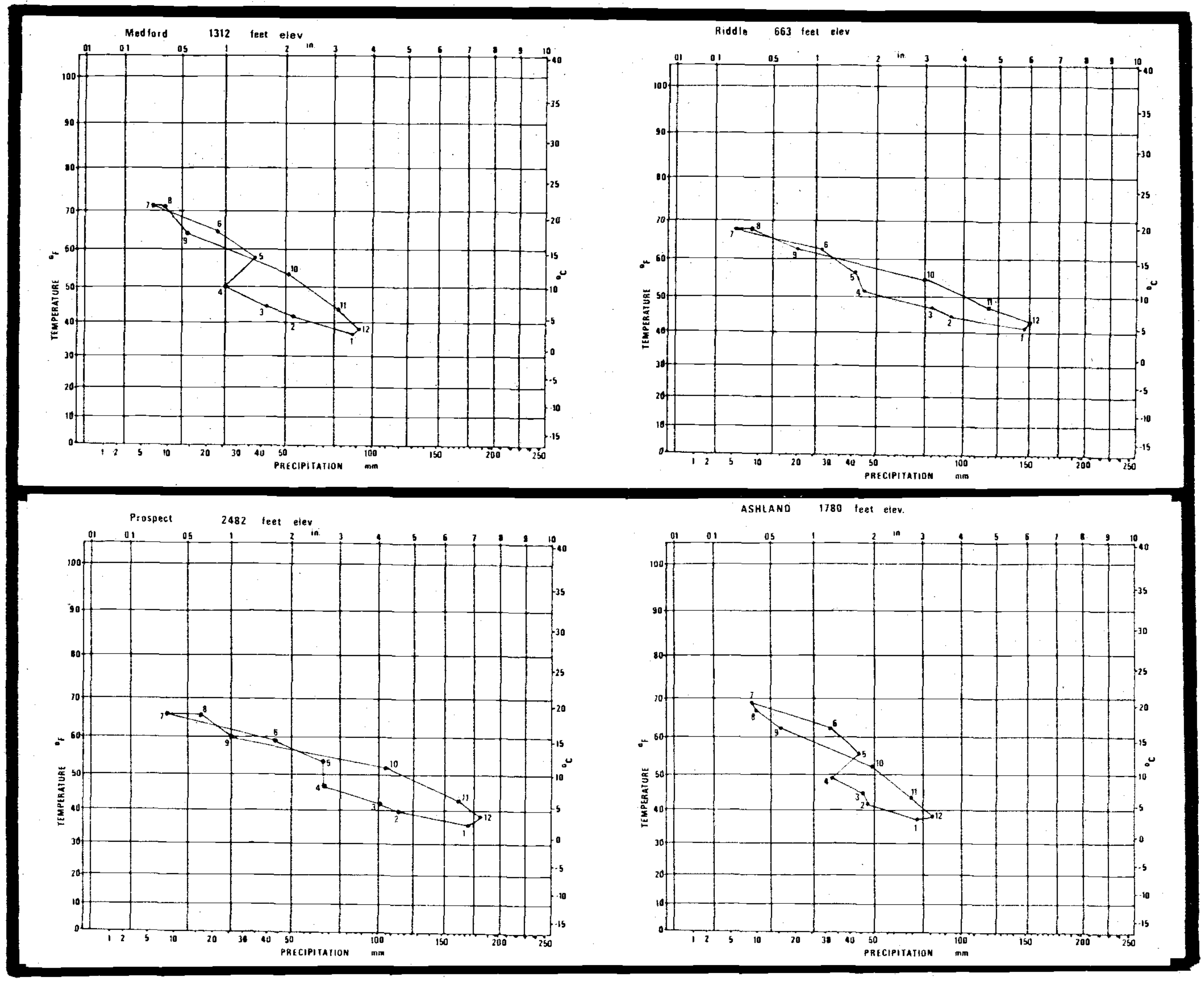

Figure 3. Thermohyet diagrams for selected weather stations in southwestern Oregon.

GEOLOGY

The Evans Creek basin lies within a geologically complex region. Surficial, volcanic, sedimentary, metamorphic and intrusive formations are all represented in the watershed. The ages of the formations range from the Mesozoic (200 million years ago) through the Cenoroic to the present (Beaulieu and Hughes 1977). Baldwin (1964, 1976) recognizes five basic types of geologic materials in the area:

1. Unconsolidated materials
2. Mesozoic sedimentary and volcanic rocks
3. Triassic sedimentary and volcanic rocks
4. Granitic Rocks - chiefly of Mesozoic age
5. Ultramafic and gabbroic rocks chiefly of Mesozoic age.

Beaulieu (1977a, 1977b), in an effort which is part of the Section 208 (Non Point Source) Planning Program for Oregon, has reviewed geologic maps of the area provided by Wells and Peck (1961), Diller (1924), Page and others (1977), Wells and others (1940) and Beaulieu and Hughes (1977). He has identified eleven geologically distinct time rock units in the Evans Creek basin (Table 1).

In order to reduce the number of geologic units and simplify resource management interpretations the Oregon DEQ Stream Assessment Team has grouped the eleven time rock units into six geologic terrain units (Table 2), on the basis of their physical properties, particularly their erosion characteristics. Terrain units were mapped by DEQ Geographer Gary Beach at a scale of 1:62,500. These terrain unit maps were used in the analysis of channel stability presented later in this paper.

TABLE 1. Geologic time rock units in Evans Creek identified for the Section 208 (Non Point Source) Planning Program for Oregon by Beaulieu (1977b)

SYMBOL	TIME ROCK UNIT DESCRIPTION
Q_{al}	Quaternary alluvium
TKS	Tertiary and Cretaceous sedimentary rock
KJ_d	Cretaceous and Jurassic diorite and related rocks
J_g	Galice Formation
sp	serpentinite and related ultramafic rocks
TR_{mg}	Triassic gneiss
TR_{ms}	Triassic schist
T_{moa}	Miocene and Oligocene andesite
T_{mop}	Miocene and Ologocene pyroclastic rocks
ba	Basalt
gb	Gabbro

TABLE 2. The DEQ geologic terrain unit classification and time rock unit groupings.

TERRAIN UNIT	DESCRIPTOR	TIME ROCK UNITS
A	Unconsolidated	Q_{al}
B	Stable Bedrock	TKS, J_g, gb, ba
C	Prone to chemical weathering	KJ_d
D	Prone to regular slides	TR_{mg}, TR_{ms}
E	Prone to bedrock failure	T_{moa}, T_{mop}
F	Sheared bedrock	sp

VEGETATION

The forest overstory in Evans Creek is predominantly coniferous. The biome is dominated by Douglas Fir (*Pseudotsuga menziesii*) and Ponderosa Pine (*Pinus ponderosa*). Western Hemlock (*Tsuga heterophylla*),Western Red Cedar (*Thuja plicata*), Red Fir (*Abies spp*.) and other species can also be found in lesser amounts.

Hardwood forests commonly occupy the riparian zones and the wet valley bottoms. Cottonwood (*Populus trichocarpa*) is found, sometimes in large pure stands but more commonly in associations of Willow (*Salix spp.*) and Alder (Alnus spp.). Ash (*Fraxinus latifolia*) is found along streams, often lichen covered into high elevation forest zones. Vine and bigleaf maple (*Acer circinatum* and *A. macrophyllum*) and Alder (*Alnus spp.*) form associations with Ash, as well as with Buckthorn (*Rhamnus spp.*), Elder (*Sambucus spp.*), Salmonberry and Thimbleberry (*Rubus spp.*), Devilsclub (*Oplopanax horridus*), Salal (*Gaultheria shallon*), Oregon Grape (*Berberis spp.*) and Swordfern (*Polystichum munitum*).

A National Forest Service (1936) timber type map has been used to describe the streamside vegetation in Evans Creek. Land types and forest types are presented in Table 3. Vegetation progressions along selected streams in the Evans Creek basin are illustrated in Figure 4.

Vegetation patterns revealed by the Forest Service survey are characteristic of conditions prior to the period of frequent and extensive timber harvesting (1968 - 1972).

TABLE 3. Land types and forest types

Symbol	Land/Forest Type	Description
NF	Non Forest Land	Includes barrens, towns, cities, natural grass areas, brush, wetlands (swamps and marshes), and agricultural areas with less than 10% of the area in woods.
AG	Agricultural Zones	Areas of land used principally for agriculture but with some incidental wooded areas too small and scattered to be mapped.
DF4	Douglas Fir	Old Growth - forests containing over 60 percent by volume old growth Douglas Fir, regardless of size
DF3	Douglas Fir	Large Second Growth - Forests not yet mature, containing over 60 percent by volume Douglas Fir 20-40 inches dbh
DF2	Douglas Fir	Small Second Growth - young forests, containing over 60 percent by volume Douglas Fir, 6 to 20 inches dbh
DF1	Douglas Fir	Seedlings and Saplings - very young forests containing over 60 percent by volume Douglas Fir, less than 6 inches dbh
PP2	Ponderosa Pine, Large	Forests containing at least 50 percent by volume Ponderosa Pine, Sugar Pine or Jeffrey Pine, more than 22 inches dbh, 150-200 years old or more
PP1	Ponderosa Pine	Seedlings, saplings or poles-Forests on old burns, cut lands, trees less than 12 inches in diameter, less than 1000 board feet of saw timber per acre

TABLE 3. Land types and forest types (continued)

Symbol	Land/Forest Type	Description
PM	Pine Mixture - Large	A mixed forest in which Ponderosa Pine comprises 20 to 50 percent by volume, and is in association with western larch, white fir, Douglas Fir, white pine, red fir, and other species - trees generally more than 12 inches dbh
HD	Hardwoods - Oak, Madrone	Forests composed of 60 percent or more by volume of any species of oak or madrone or associations, of any size class.
F	Deforested Burns	Lands not cut over, but where the stand has been killed by fire, which is less than 10 percent restocked

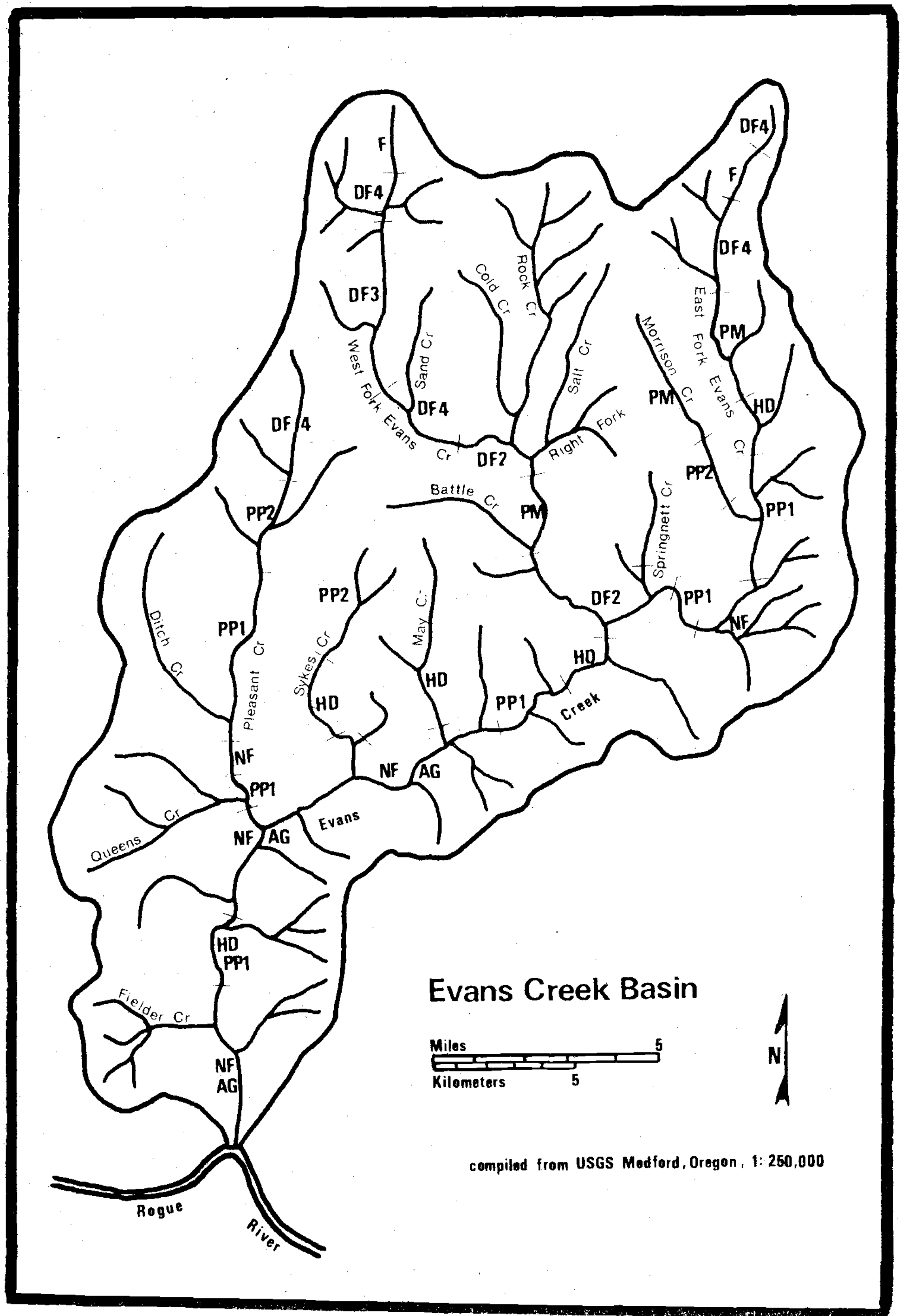

Figure 4. Terrestrial and forest land type patterns along selected streams of Evans Creek.

LAND USE HISTORY

The Evans Creek basin has been subject to a variety of land use practices. Urban land use is limited to the townsites of Wimer and the City of Rogue River. There is an urban-rural fringe around both towns, within the confines of the watershed. Rural residential property and agricultural lands occupy the main Evans Valley, nearby foothills and the flood plains of several tributaries in the lower and middle portions of the basin. Cattle graze freely along many of the lower sections of these streams. During the 1940's and 1950's placer deposits were mined alongside sections of Pleasant Creek (Hazen 1978, personal communication.

Forest land use activities date back to the early 1930's. A road was first built into the West Fork drainage by the Civilian Conservation Corps (CCC) in the late 1930's. A road camp was located near Sand Creek. During World War II the road was extended into the upper protion of the watershed. Just after World War II a road was built along the East Fork of Evans Creek (Carnegie 1978, personal communication).

The BLM began making timber sales in these areas in the 1940's. Sales of public lands continued into the mid 1960's. The land ownership pattern in the forested part of the watershed presently resembles a patchwork quilt. The

Timber Products Company, Boise Cascade, several other small logging companies and the federal government own alternating sections of land (Oregon Department of Revenue 1974).

Timber harvesting, prior to 1965 was primarily limited to the selective cutting of numerous, small tracts of land. A management plan drawn up by foresters at Mason, Bruce and Girard Consultants in Portland, for the Timber Products Company, called for partial cutting of the best stands of timber. A change of ownership occurred in 1967. The new owners of the Timber Products Company dropped the plan, shifted the objectives of the forest management and changed from a partial cut method to a clearcut technique (Alexander 1978, personal communication).

In the four year period that followed large areas of the upper portions of the watersheds were harvested. During this period, prior to the Oregon Forest Practices Act, tractor logging was practiced on very steep slopes, forest units were clearcut without buffer strips, landings were built adjacent to streams, cat trails were constructed along the banks of the channels, and logs were skidded in and across the streams. A major problem that resulted was the coverage of stream gravels in rich salmonid spawning reaches, by decomposed materials from accelerated channel and surface erosion (DEQ 1977). Disturbance of the channels was severe in many locations. The passage of the

Oregon Forest Practices Act in 1972 came too late for many of the streams in Evans Creek.

III. CHANNEL STABILITY EVALUATION

THE DEQ '208' BASIN ASSESSMENT PROGRAM

The author of this thesis had the good fortune to be employed by the State of Oregon, Department of Environmental Quality, Water Quality Division during the summer of 1977. As a member of the Section '208' Stream Assessment Team, he helped generate stream survey information which plays a key role in the Oregon '208' Basin Assessment Project, and forms an integral part of this thesis.

The '208' Basin Assessment Project is part of Oregon's Water Quality Management Planning Program, which involves developing a water quality management plan that meets the nonpoint source objectives in Section 208 of Public Law 92-500. This law passed by Congress as the Federal Water Pollution Control Act Ammendments of 1972, stated that

> "planning mechanisms must be developed that will:
>
> (1) identify and evaluate the nature and extent of present or potential nonpoint source problems, and
>
> (2) through a continuing statewide planning process, develop and initiate processes, procedures and methods to control to the extent feasible identified nonpoint source problems."
> (Mullane and Beach 1977)

The Oregon '208' Basin Assessment Project is a major element of the Statewide Planning Program. It is designed to study the stream quality impacts of land use management practices from forestry, agriculture and other activities.

The project is divided into two phases: Phase I is designed to determine the location, type and severity of water quality problems identified by Federal, State, local officials, and the public as nonpoint source pollution; Phase II entails developing and refining a systematic procedure for assessing nonpoint sources of pollution. This objective will be achieved by determining the relationship between terrain characteristics, land management practices and the resultant stream quality for selected basins in the state (Rickert and Beach 1977, Rickert and Beach 1978).

The DEQ has selected several watersheds across the state for comprehensive study (Figure 5). Field surveys of the Molalla and Pudding Rivers, Evans Creek and the Siuslaw River were conducted during the summer of 1977. This thesis is partly based upon the channel stability information generated by the Stream Assessment Team during its visit to Evans Creek.

Evans Creek (Figure 6) was selected by the DEQ because the major nonpoint source problem (indicated by the Oregon Department of Fish and Wildlife) is the coverage of stream gravels in rich spawning reaches by eroded rock from frequent and extensive tractor logging operations. The basin also encompasses major types of geologic materials that are representative of other areas in southwestern Oregon (DEQ memo 1/4/77).

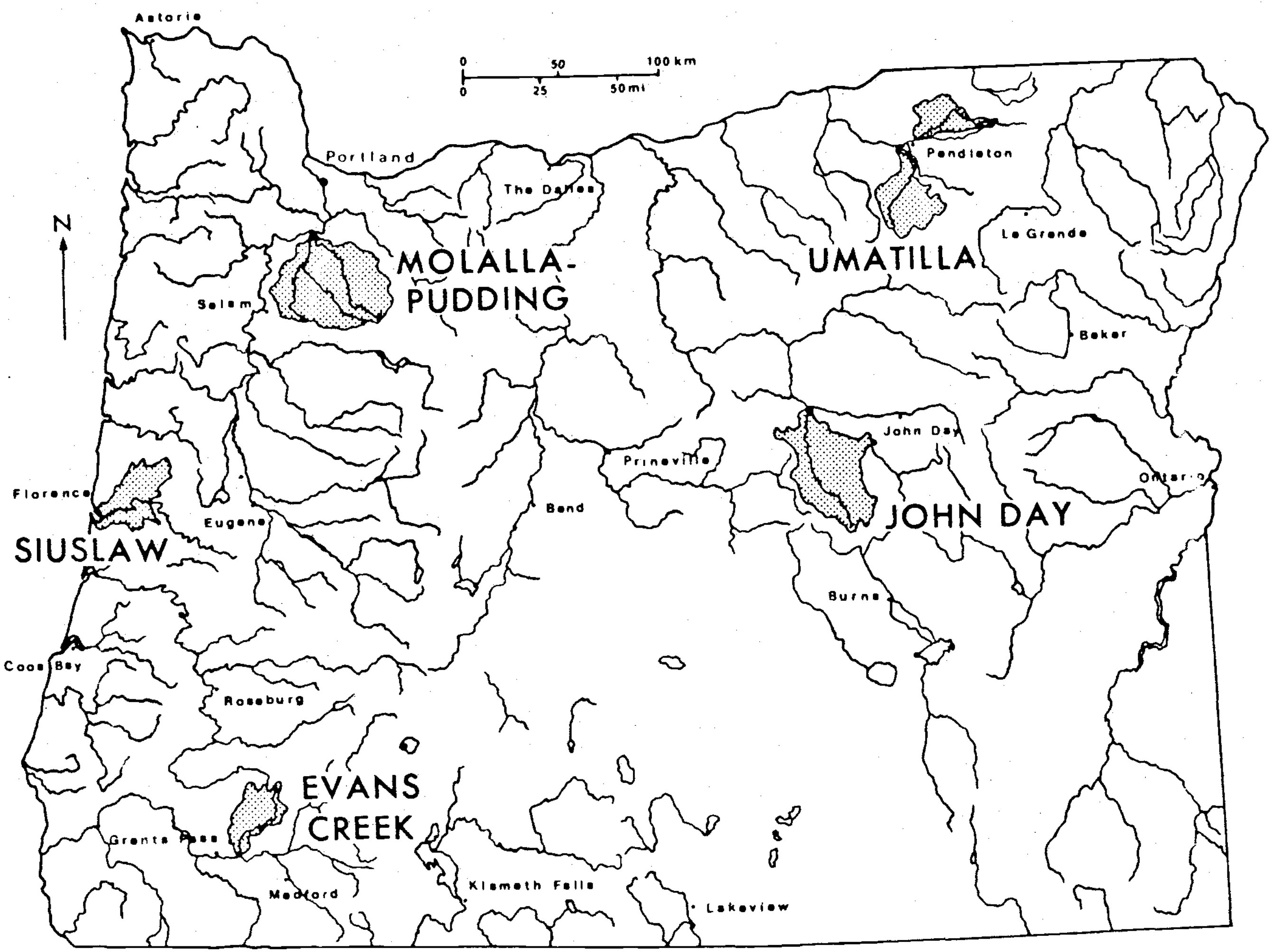

Figure 5. Basins selected for study by the Oregon 208 Basin Assessment Project.

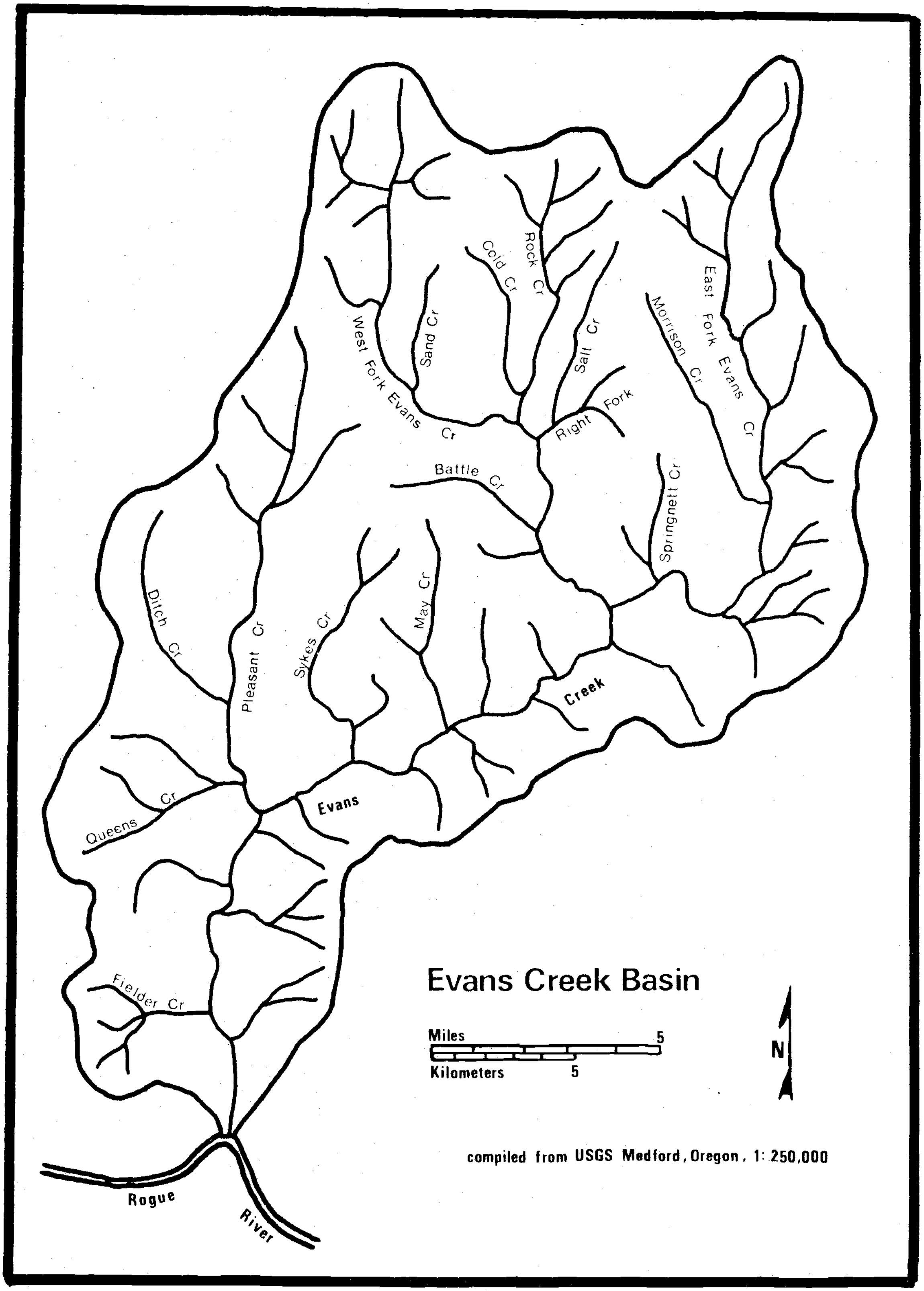

Figure 6. Map of the Evans Creek Basin.

STREAM SURVEYS

The relation of the stream surveys to the Basin Assessment Project is illustrated in Figure 7. Rather than collecting water samples, the Stream Assessment Team is determining the quality of stream environments through reconnaissance field surveys of channel stability and fishery habitat conditions. These characteristics are more permanent than chemical quality conditions, and permit obtaining meaningful information on a large number of streams in a short period of time. Morphological features of the stream are rated in terms of their relation to dynamic processes of erosion and deposition. These features can form in response to land use practices and are unlikely to change if land use is maintained, or recovery from impact is slow (Rickert and Beach 1978).

The Stream Assessment Team has designed a set of field forms for evaluating channel stability and fishery habitat condition. The Channel Stability Rating form (henceforth CSR) is a slightly modified version of the "Stream Reach Inventory and Channel Stability Evaluation" developed by hydrologists from the Northern Region (Region One) of the National Forest Service (USNFS 1975, see appendix). The biological rating system was designed by DEQ biologists Dave Anderson and John Jackson to identify and characterize stream conditions and evaluate the effects of sediment on spawning gravels and rearing habitat.

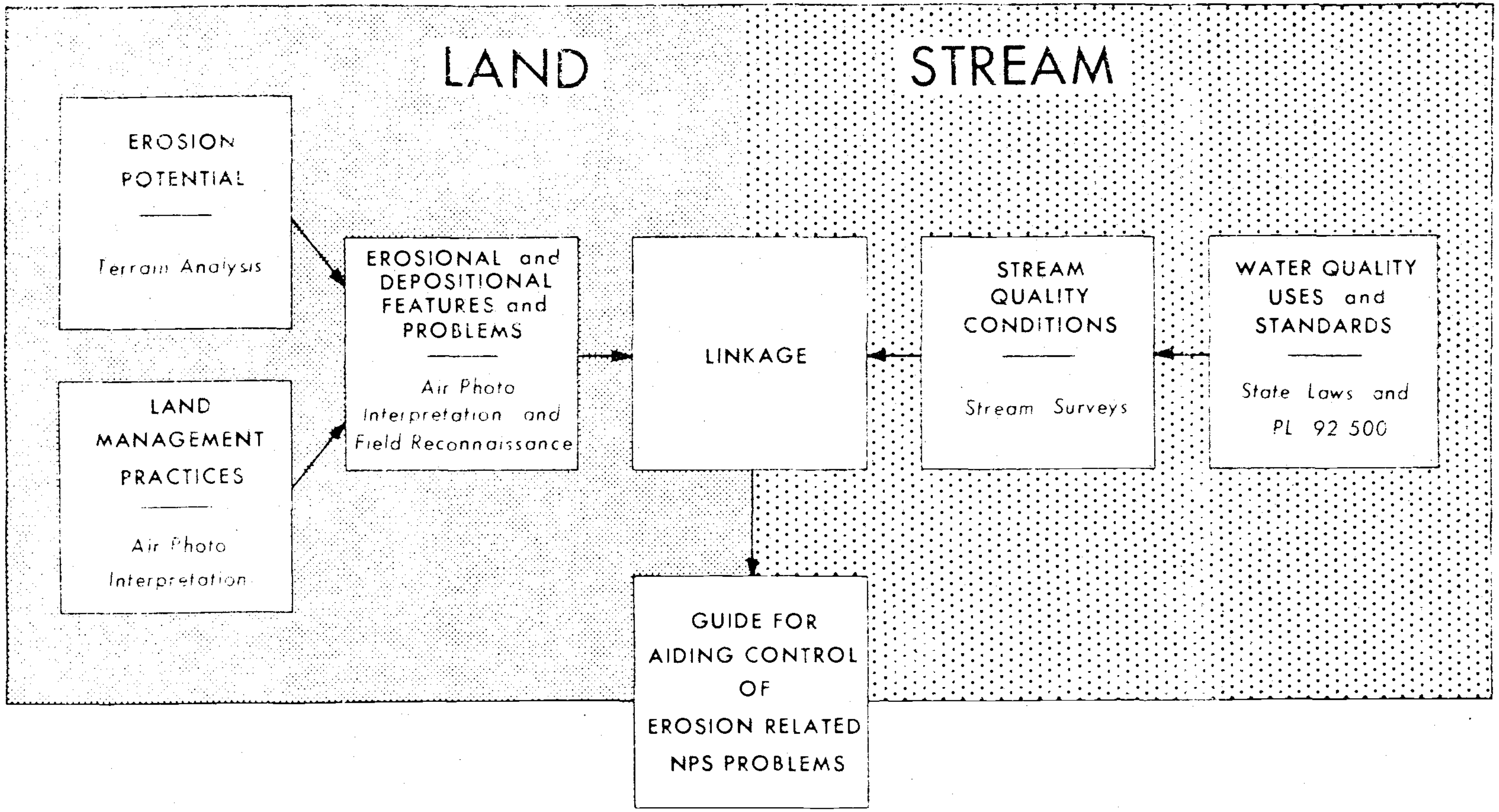

Figure 7. Schematic diagram illustrating Oregon's 208 Assessment approach for developing information to guide the control of erosion related NPS problems.

THE CHANNEL STABILITY RATING PROCEDURE

The "Stream Reach Inventory and Channel Stability Evaluation" attempts to systematically describe the factors which cause erosion in streams. It is based upon a morphological concept that recognizes that a stream channel is a most sensitive and reliable indicator of a watershed's response to its environment. Channel features are produced by the flow regime of the watershed. Instability is determined by the resistance of the streams bed and banks to flow. The channel stability inventory primarily evaluates:

1) the detachability of the bank and bed materials
2) the availability and supply of sediment
3) in-channel disturbance factors
4) available sources of potential energy

Each Channel Stability Rating (or CSR) requires a subjective evaluation of the relative condition of 15 selected characteristics of the stream channel (Figure 8). A rating for individual parameters is assigned a weighted number which describes its effect on channel stability. The ratings for all 15 factors are summed to give an overall channel stability rating. A higher score is indicative of an unstable channel reach.

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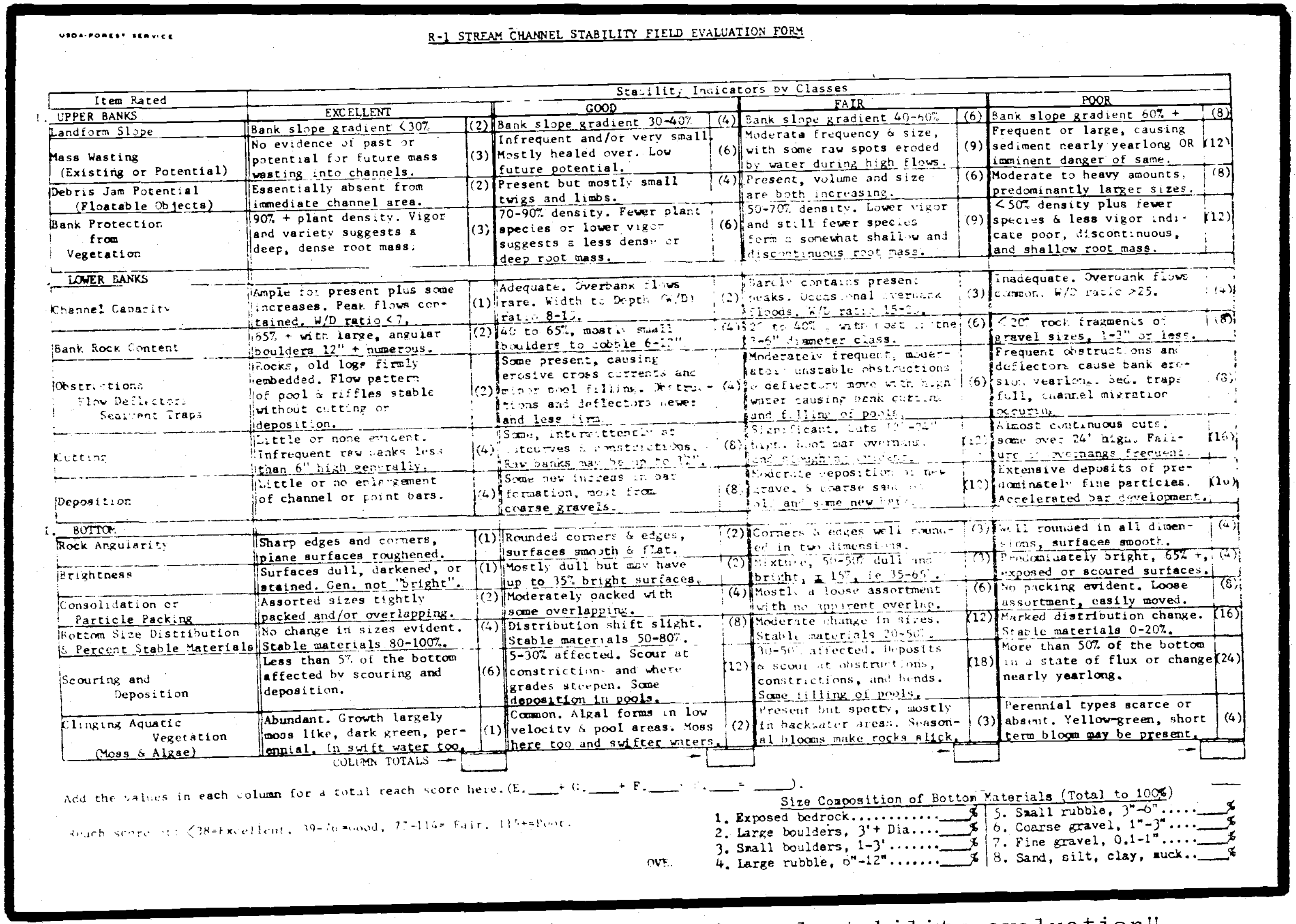

USDA-FOREST SERVICE

R-1 STREAM CHANNEL STABILITY FIELD EVALUATION FORM

Item Rated	Stability Indicators by Classes							
	EXCELLENT		GOOD		FAIR		POOR	
I. UPPER BANKS								
Landform Slope	Bank slope gradient <30%	(2)	Bank slope gradient 30-40%	(4)	Bank slope gradient 40-60%	(6)	Bank slope gradient 60% +	(8)
Mass Wasting (Existing or Potential)	No evidence of past or potential for future mass wasting into channels.	(3)	Infrequent and/or very small. Mostly healed over. Low future potential.	(6)	Moderate frequency & size, with some raw spots eroded by water during high flows.	(9)	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	(12)
Debris Jam Potential (Floatable Objects)	Essentially absent from immediate channel area.	(2)	Present but mostly small twigs and limbs.	(4)	Present, volume and size are both increasing.	(6)	Moderate to heavy amounts, predominantly larger sizes.	(8)
Bank Protection from Vegetation	90% + plant density. Vigor and variety suggests a deep, dense root mass.	(3)	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	(6)	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	(9)	<50% density plus fewer species & less vigor indicate poor, discontinuous, and shallow root mass.	(12)
LOWER BANKS								
Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	(1)	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8-15.	(2)	Barely contains present peaks. Occasional overbank floods. W/D ratio 15-25.	(3)	Inadequate. Overbank flows common. W/D ratio >25.	(4)
Bank Rock Content	65% + with large, angular boulders 12" + numerous.	(2)	40 to 65%, mostly small boulders to cobble 6-12".	(4)	20 to 40%, with most in the 3-6" diameter class.	(6)	<20% rock fragments of gravel sizes, 1-3" or less.	(8)
Obstructions Flow Deflectors Sediment Traps	Rocks, old logs firmly embedded. Flow pattern of pool & riffles stable without cutting or deposition.	(2)	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	(4)	Moderately frequent, moderately unstable obstructions & deflectors move with high water causing bank cutting and filling of pools.	(6)	Frequent obstructions and deflectors cause bank erosion yearlong. Sed. traps full, channel migration occurring.	(8)
Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	(4)	Some, intermittently at outcurves & constrictions. Raw banks may be up to 12".	(8)	Significant. Cuts 12"-24" high. Root mat overhangs and sloughing evident.	(12)	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	(16)
Deposition	Little or no enlargement of channel or point bars.	(4)	Some new increase in bar formation, most from coarse gravels.	(8)	Moderate deposition of new gravel & coarse sand on old and some new bars.	(12)	Extensive deposits of predominately fine particles. Accelerated bar development.	(16)
I. BOTTOM								
Rock Angularity	Sharp edges and corners, plane surfaces roughened.	(1)	Rounded corners & edges, surfaces smooth & flat.	(2)	Corners & edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	(4)
Brightness	Surfaces dull, darkened, or stained. Gen. not "bright".	(1)	Mostly dull but may have up to 35% bright surfaces.	(2)	Mixture, 50-50% dull and bright, ± 15%, ie 35-65%.	(3)	Predominately bright, 65% +, exposed or scoured surfaces.	(4)
Consolidation or Particle Packing	Assorted sizes tightly packed and/or overlapping.	(2)	Moderately packed with some overlapping.	(4)	Mostly a loose assortment with no apparent overlap.	(6)	No packing evident. Loose assortment, easily moved.	(8)
Bottom Size Distribution & Percent Stable Materials	No change in sizes evident. Stable materials 80-100%.	(4)	Distribution shift slight. Stable materials 50-80%.	(8)	Moderate change in sizes. Stable materials 20-50%.	(12)	Marked distribution change. Stable materials 0-20%.	(16)
Scouring and Deposition	Less than 5% of the bottom affected by scouring and deposition.	(6)	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	(12)	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	(18)	More than 50% of the bottom in a state of flux or change nearly yearlong.	(24)
Clinging Aquatic Vegetation (Moss & Algae)	Abundant. Growth largely moss like, dark green, perennial. In swift water too.	(1)	Common. Algal forms in low velocity & pool areas. Moss here too and swifter waters.	(2)	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	(3)	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	(4)
	COLUMN TOTALS →	☐	←	☐	←	☐	←	☐

Add the values in each column for a total reach score here. (E.____+ G.____+ F.____+ P.____= ____).

Reach score of: <38=Excellent, 39-76=Good, 77-114= Fair, 115+=Poor.

OVER

Size Composition of Bottom Materials (Total to 100%)

1. Exposed bedrock..........____%	5. Small rubble, 3"-6".....____%
2. Large boulders, 3'+ Dia....____%	6. Coarse gravel, 1"-3"....____%
3. Small boulders, 1-3'.......____%	7. Fine gravel, 0.1-1".....____%
4. Large rubble, 6"-12".......____%	8. Sand, silt, clay, muck..____%

Figure 8. The "stream reach inventory and channel stability evaluation" procedure of Region One.

Channel Stability, Sediment Yields, Applications

The "Stream Reach Inventory and Channel Stability Rating" procedure (or CSR) was released by the Northern Region of the U.S. National Forest Service in 1975. Forest Service hydrologists tested the CSR's perception of channel processes by relating the channel stability ratings of streams to their sediment rating curves. Regressions analysis was performed on over 80 streams in northern and central Idaho and northwestern Montana (Rosgen 1975). Similar work has been conducted on 27 streams in California, and on streams in the Front Range of the Colorado Rockies.

Quantitative testing of the CSR with sediment yields has not been extensive nor conclusive. While statistically significant relationships have been documented by some hydrologists, others do not find any clear cut relationship.

The CSR is being used by the National Forest Service to evaluate the responses of watersheds to silvicultural practices. In California, LaVen (1977) has described empirical changes in channel stability ratings in response to increasing disturbance of the stream channel from forest land use practices.

In Wyoming, the CSR has been used to evaluate and predict the impact of grazing on stream banks and channel stability (Cooper 1977). In western Oregon, the CSR has been used to evaluate conditions in the Corvallis Municipal Watershed (Sachet 1977), and to describe the influence of a Siuslaw National Forest rock quarry on channel morphology in the Waldport Municipal Watershed (Krupin 1977). Fishery biologists in several states have coupled the CSR with biological habitat and conventional water quality survey methods (Duff and Cooper 1976).

FIELD TECHNIQUES

The DEQ Field Stream Assessment Team consisted of Dave Anderson, John Jackson, James Sachet, and Paul J. Krupin. Team members were "calibrated" during a training period early in July of 1977 to assure consistency in the rating of streams. Field work in Evans Creek was conducted in the first two weeks of August 1977.

Each member of the Stream Assessment Team spends approximately 45 minutes studying a one quarter mile section of stream. Channel Stability, fishery habitat conditions and additional information concerning land use, topography and environmental impacts are noted on standard forms (Appendix A). Numerous photographs are taken to document observations. Stream reach inventories are performed at regular, staggered intervals along the stream channel.

A stream reach inventory represents a homogeneous segment of channel. If conditions changed drastically while walking a reach of stream, two inventories are performed; one in the first section of channel and one in the second.

GENERAL OVERVIEW OF CHANNEL STABILITY IN EVANS CREEK

Channel stability rating data, generated for the streams of Evans Creek by the DEQ Stream Assessment Team, is presented in tabular form in Appendix B. A map of Evans Creek showing the location of the individual stream reaches evaluated by the Stream Assessment Team appears in Figure 9.

A frequency distribution of all the channel stability ratings in the Evans Creek basin is given in Figure 10A. The distribution approximates that of a normal curve fairly well, and is slightly skewed towards the higher scores. A diagram showing the mean channel stability rating, the range of channel stability ratings and number of stream reach inventories in each watershed appears in Figure 10B.

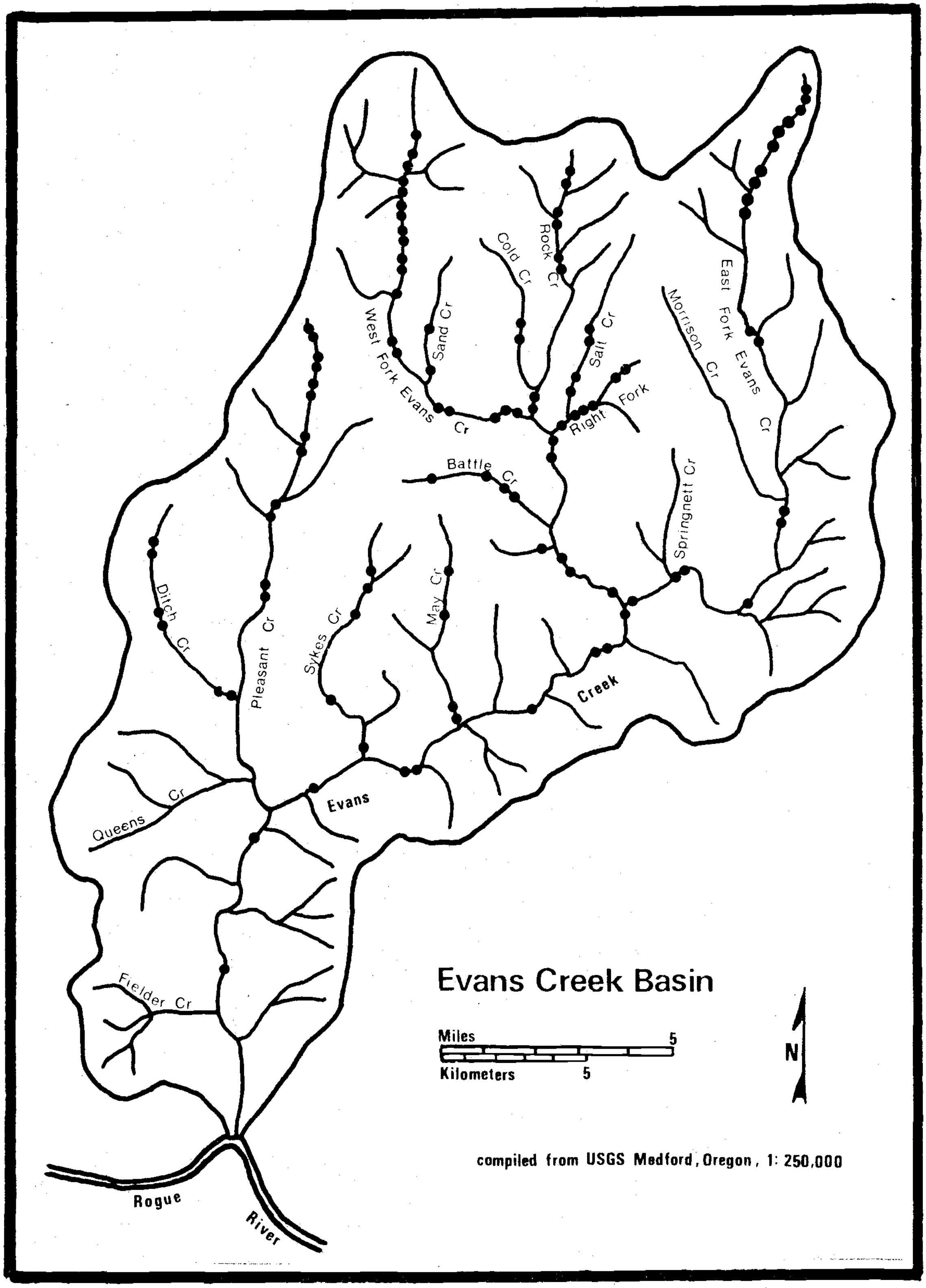

Figure 9. Map showing the location of stream reach inventories in the Evans Creek basin.

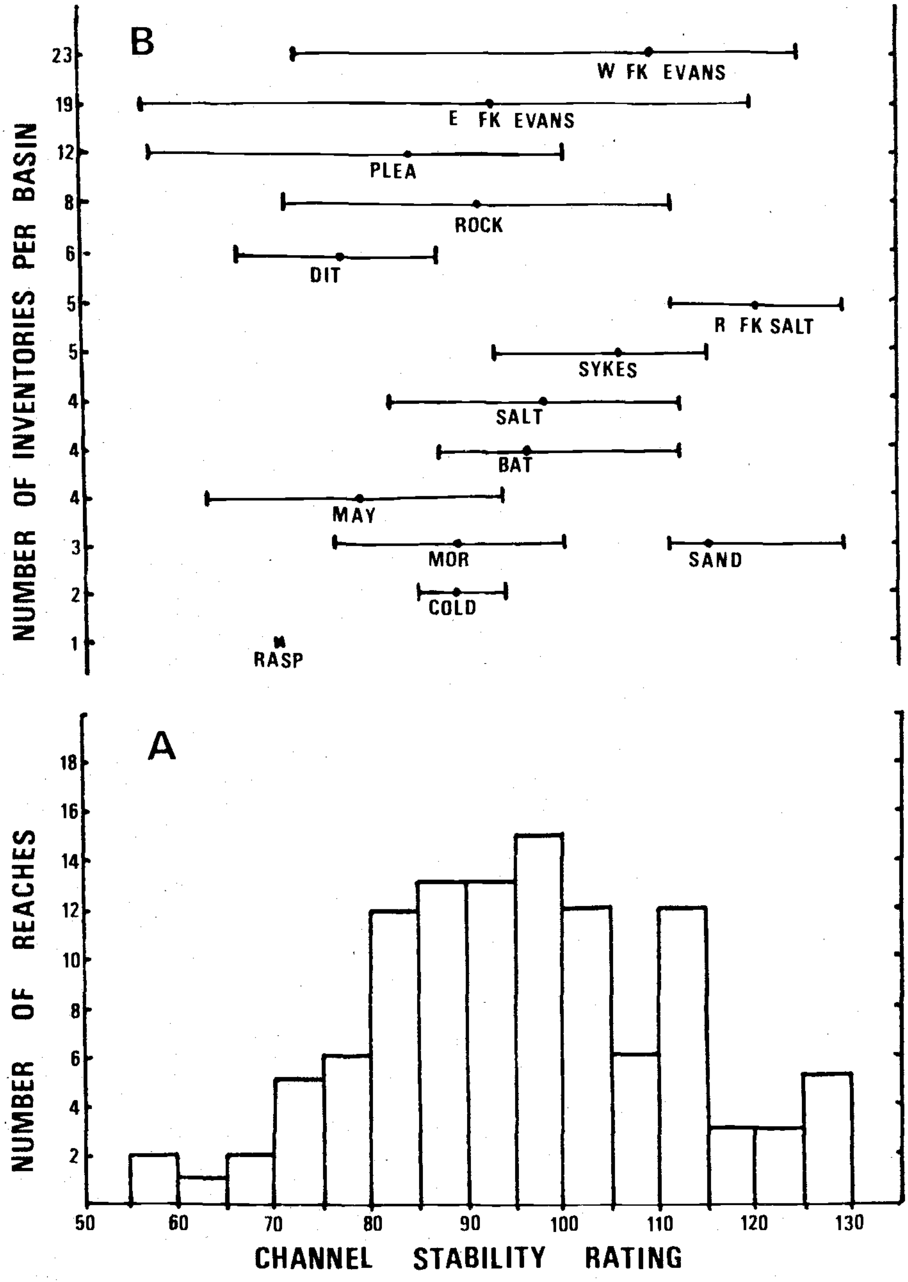

Figure 10. A. Frequency histogram of channel stability in Evans Creek. B. Line graph showing mean channel stability, range of scores, and number of inventories performed in streams of the Evans Creek basin.

CHANNEL STABILITY WITH RESPECT TO LAND USE AND LITHOLOGY

Land Use/Cover Type

One of the objectives of this thesis is to test whether the CSR identifies differences between disturbed and undisturbed fluvial environments. This was accomplished by utilizing information concerning land use on the DEQ field forms. The land use and cover type of each stream reach was characterized in the field. Subsequent analysis was facilitated by grouping the channel stability data of all the streams in the basin according to the classification given in Table 4.

Channel stability ratings in each land use/cover type class were then averaged and are presented in Table 5. The computations reveal that there is a clear ranking of scores with respect to land use activities. Hypothesis testing (Taylor 1977) was then used to see whether the differences in the channel stability of each land use class were statistically significant (Table 6).

The results of this analysis indicate that there are significant differences in the channel stability of stream reaches under varying land use conditions. The recently logged streams are more unstable than those logged years ago. Old growth streams, and streams with herbaceous and/or deciduous cover are more stable than streams that have been logged over. Even though the differences between

TABLE 4. Land use/cover type classification

Land Use/ Cover Type	
1	Logged 0-5 years ago
2	Logged 6-10 years ago without herbaceous and/or deciduous cover
3	Logged 6-10 years ago with herbaceous and/or deciduous cover
4	Second growth
5	Old growth
6	Herbaceous and/or deciduous cover only

TABLE 5. CSR with respect to Land Use in the Evans Creek Basin

Land Use/ Cover Type*	Mean CSR	Standard Deviation	Number of Inventories
1	125.0	5.7	2
2	107.5	9.5	19
3	99.4	8.9	9
4	93.4	18.3	25
5	91.5	17.1	12
6	83.9	11.5	20

*Refer to Table .

TABLE 6. RESULTS FROM STATISTICAL TESTS FOR DIFFERENCES IN CHANNEL STABILITY IN STREAMS REACHES GROUPED BY LAND USE/COVER TYPE

Populations Tested	Z Value	Significant at α equal to
1 Logged 0-5 years ago 2 Logged 6-10 years ago without herbaceous deciduous cover	3.84	0.05
2 Logged 6-10 years ago without herbaceous deciduous cover 3 Logged 6-10 years ago with herbaceous deciduous cover	2.19	.05
3 Logged 6-10 years ago with herbaceous deciduous cover 4 Second growth	1.27	Not significant
4 Second Growth 5 Old Growth	0.31	Not significant
5 Old Growth 6 Herbaceous/deciduous	1.38	.10
3 Logged 6-10 years ago with herbaceous/deciduous cover 5 Old Growth	1.37	.10

land use/cover types '3' and '4' are not statistically significant, mean channel stability scores imply that vegetation is having a stabilizing influence. There is no significant difference in the channel stability of second growth and old growth stream reaches, even though the latter is slightly more stable.

Geologic Parent Materials

Geologic parent materials are important in the consideration of channel stability because of inherent physical properties and erosion characteristics. Certain lithologies may be more prone to channel erosion than others. The objective of the following analysis is to determine how channel stability is related to lithology in the Evans Creek basin.

The analysis procedure is similar to that in the preceding section. Each channel stability rating was given an identifier corresponding to the geologic terrain unit at the location of reach. Channel stability ratings for all the streams in the basin were then grouped according to the terrain unit classification and averaged to get a mean channel stability rating (Table 7). Hypothesis testing (Taylor 1977) was then used to see whether the differences in the channel stability of stream reaches in each geologic terrain unit were statistically significant (Table 8).

The results of this analysis indicate that there are significant differences in the channel stability of stream sections under varying lithologic conditions. Geologic materials that are "Prone to Chemical Weathering" are found to be more unstable than any of the other terrain unit classes. The stability of channel section in "Stable Bedrock" is greater than in any of the other terrain unit

TABLE 7. CHANNEL STABILITY WITH RESPECT TO GEOLOGIC TERRAIN UNIT IN EVANS CREEK*

GEOLOGIC TERRAIN UNIT*		MEAN CHANNEL STABILITY RATING	STANDARD DEVIATION	NUMBER OF INVENTORIES
A	Unconsolidated	90.2	12.6	12
B	Stable Bedrock	76.6	12.8	14
C	Prone to Chemical Weathering	104.2	13.0	31
D	Prone to Regular Slides	95.8	15.0	34
E	Prone to Bedrock Failure	-	-	0
F	Sheared Bedrock	96.7	12.9	3

* Oregon Department of Environmental Quality terrain unit classification

TABLE 8. RESULTS FROM STATISTICAL TESTS FOR DIFFERENCES IN CHANNEL STABILITY IN STREAM REACHES GROUPED BY GEOLOGIC TERRAIN UNIT

Populations Tested	Z Value	Significant to α equal to
C Prone to Chemical Weathering D Prone to Regular Slides	2.42	.05
C Prone to Chemical Weathering F Sheared Bedrock	0.96	Not significant
D Prone to Regular Slides F Sheared Bedrock	0.13	Not significant
D Prone to Regular Slides A Unconsolidated	1.25	Not significant
D Prone to Regular Slides B Stable Bedrock	4.49	.05
A Unconsolidated B Stable Bedrock	2.72	.05

classes. There is no significant difference in the channel stability of stream section found in terrain units "Prone to Regular Slides" and "Sheared Bedrock." Channel sections in the "Unconsolidated" geologic terrain units are found to be more stable than those in all of the terrain unit classes except that of "Stable Bedrock."

Combined Influence

In the preceeding section, channel stability ratings were shown to be sensitive to the independent influences of land use and lithology. It is far more important, however, to consider how channel stability varies under the combined influence of land use and lithology, since certain lithologies may be more sensitive to disturbance by land use practices than others.

This was accomplished by constructing a bivariate matrix from the channel stability data and the land use/cover type and geologic terrain unit classifications. The channel stability data was first grouped by land use/cover type. Each of the resulting data sets was then regrouped by geologic terrain unit. The mean channel stability score for each combined cluster groupings was then computed. An "Impact Matrix," showing how channel stability varies with respect to the combined influence of land use and lithology was thus created and appears in Table 9.

Several relationships between channel stability, land use/cover type and geologic terrain unit can be derived from the matrix:

1. There is a relatively clear ranking of channel stability with respect to lithology within a given land use/cover type. In terms of channel stability, stream reaches in geologic terrain unit 'B' are more stable than those in 'D', which are more stable than those in 'C'.

2. There is a less definitive relationship between channel stability and the land use/cover type within a given geologic terrain unit. Still the trend towards greater stability is evident in the progressively lower channel stability scores of land use/cover types '2', '3', and '4'. It is not clear why channel stability scores are lower in '3' than in '4' in geologic terrain unit 'D'. The seemingly anomalous channel stability rating of old growth in geologic terrain unit 'C' is probably due to the location of the stream reaches with respect to logged over channel sections immediately upstream, particularly in the West Fork of Evans Creek.

3. The presence of herbaceous and deciduous vegetation in the stream corridor is seen to exert a stabilizing influence on channel stability, particularly on the logged over channel sections in geologic terrain units 'C' and 'D'. Stream channels flowing through second growth are generally more stable than those flowing through logged areas.

4. Channel sections covered with herbaceous and deciduous cover are generally less stable than channels with an old growth forest cover in geologic terrain unit 'D', or a second growth forest cover in geologic gerrain units 'A' and 'B', while they are more stable than sections with a forest cover in geologic terrain unit 'C'.

TABLE 9. MATRIX SHOWING CHANNEL STABILITY WITH RESPECT TO THE COMBINED INFLUENCE OF LAND USE/COVER TYPES AND GEOLOGIC TERRAIN UNIT IN EVANS CREEK.

LAND USE/COVER TYPE[a]

		1	2	3	4	5	6
GEOLOGIC PARENT MATERIALS[b]	C	125	109	104	104	109	92
	D		105	91	100	81	89
	F				93		
	A				82		88
	B		95		71		76

a - refer to Table 4

b - refer to Table 2

THE CHANNEL STABILITY RATING AND THE PERCEPTION OF IN-STREAM EROSIONAL AND DEPOSITIONAL PROCESSES

The channel stability rating procedure (CSR) attempts to systematically describe several factors which cause or influence erosion in streams. More specifically, it addresses 15 channel characteristics and considers their individual influence on sedimentation processes, namely erosion and deposition. A single channel stability rating indexes the relative degree to which these processes are active in a stream but does not indicate the relative degree to which each process is operating.

In order to better describe the sedimentation processes acting in the stream channel, the 15 channel stability parameters have been divided into two groups:

1. Sediment Source Factors (S_f)
2. Deposition Factors (D_f)

The Sediment Source Factors (S_f) is computed as the sum of the individual scores of channel stability parameters: Landform Slope, Mass Wasting, Vegetative Bank Protection, Channel Capacity, Bank Rock Content, Obstructions and Flow Deflectors, and Lower Bank Cutting.

The Deposition Factor (D_f) is computed as the sum of the individual scores of channel stability parameters: Debris Jam Potential, Lower Bank Deposition, Stream Bed Consolidation and Bottom Deposition. Tables containing Sediment Source and Deposition Factor data for selected streams in

Evans Creek are presented in Appendix C .

The separation and subsequent grouping of channel stability parameters into sediment source factors and deposition factors reveals that channel erosion and deposition are perceived differentially by the CSR. The numerical weighting of each of the 15 parameters by the designers of the inventory results in deposition factors contributing more than sediment source factors to the total channel stability rating. This is illustrated in Figure 11 which shows the relationship between the Sediment Source Factors (S_f), Deposition Factors (D_f) and the total Channel Stability Rating for stream reaches on the East Fork of Evans Creek.

Channel stability "continuum graphs" for selected streams in Evans Creek were created in order to show how sediment sources and channel deposition, as perceived by the CSR, fluctuate from upstream to downstream (Figures 12, 13 14, 15, 16). The graphs in the upper half of each figure illustrate the computed channel stability Sediment Source Factors and Deposition Factors. The graphs in the lower half of each figure illustrate the percent of the total Channel Stability Rating each Sediment Source Factor or Deposition Factor represents.

It is apparent from the continuum graphs, as demonstrated in the previous discussion, that Sediment Source Factors and Deposition Factors do not contribute equally

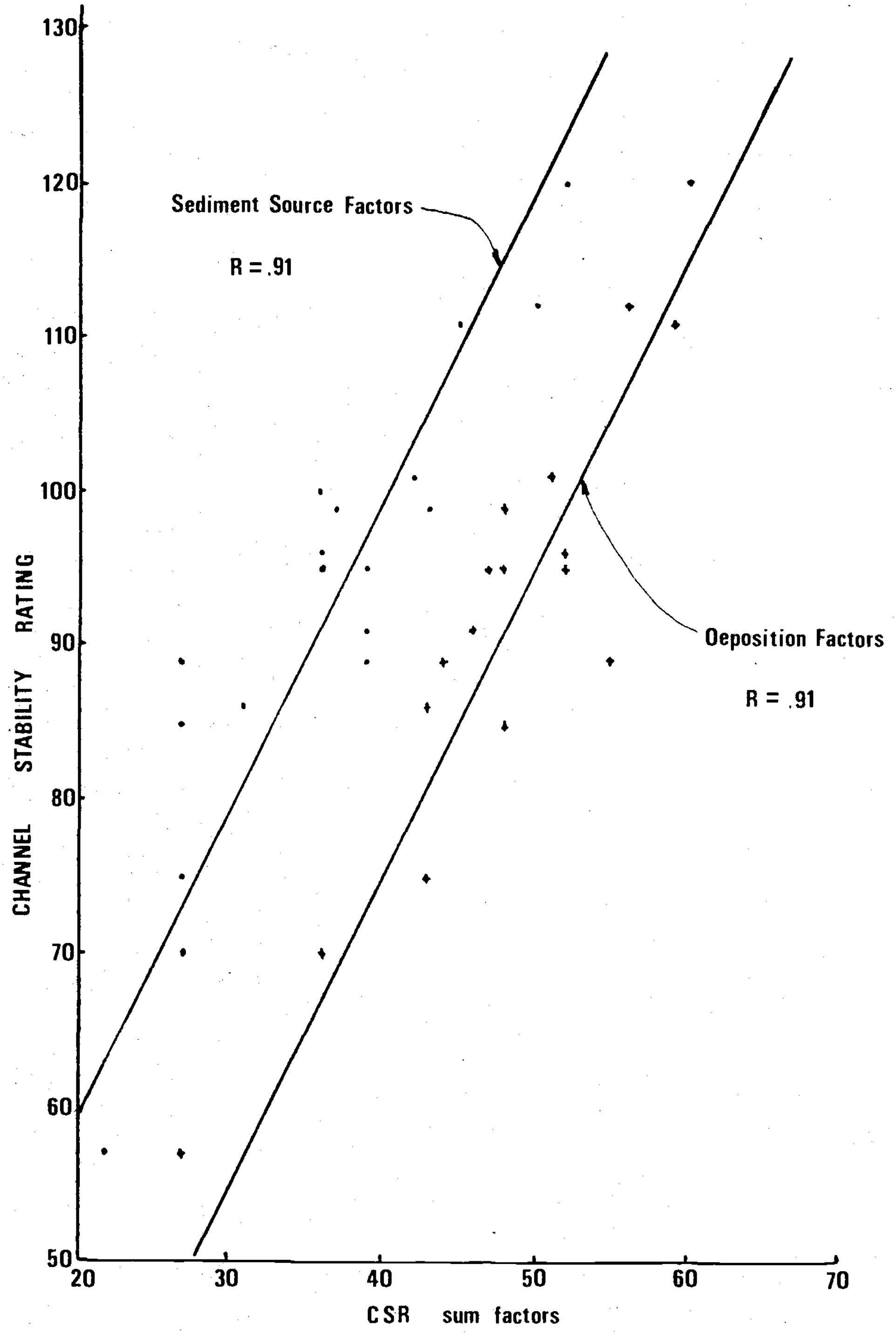

Figure 11. Graph showing how sediment source factors and deposition factors are related to total channel stability ratings in the East Fork of Evans Creek.

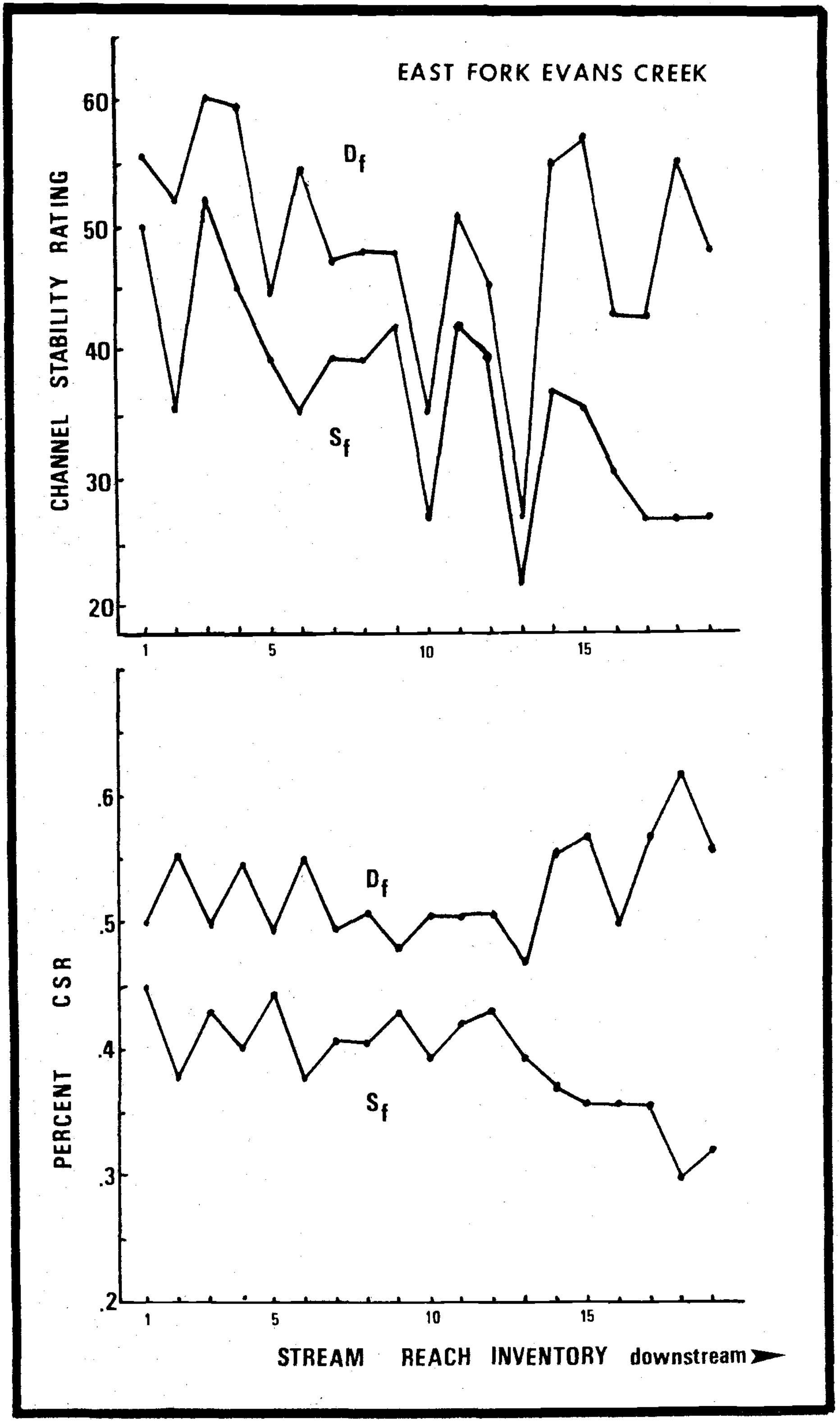

Figure 12. Continuum graphs showing how channel stability Sediment Sources (S_f) and Deposition Sources (D_f) vary from the headwaters to the outlet of East Fork Evans Creek.

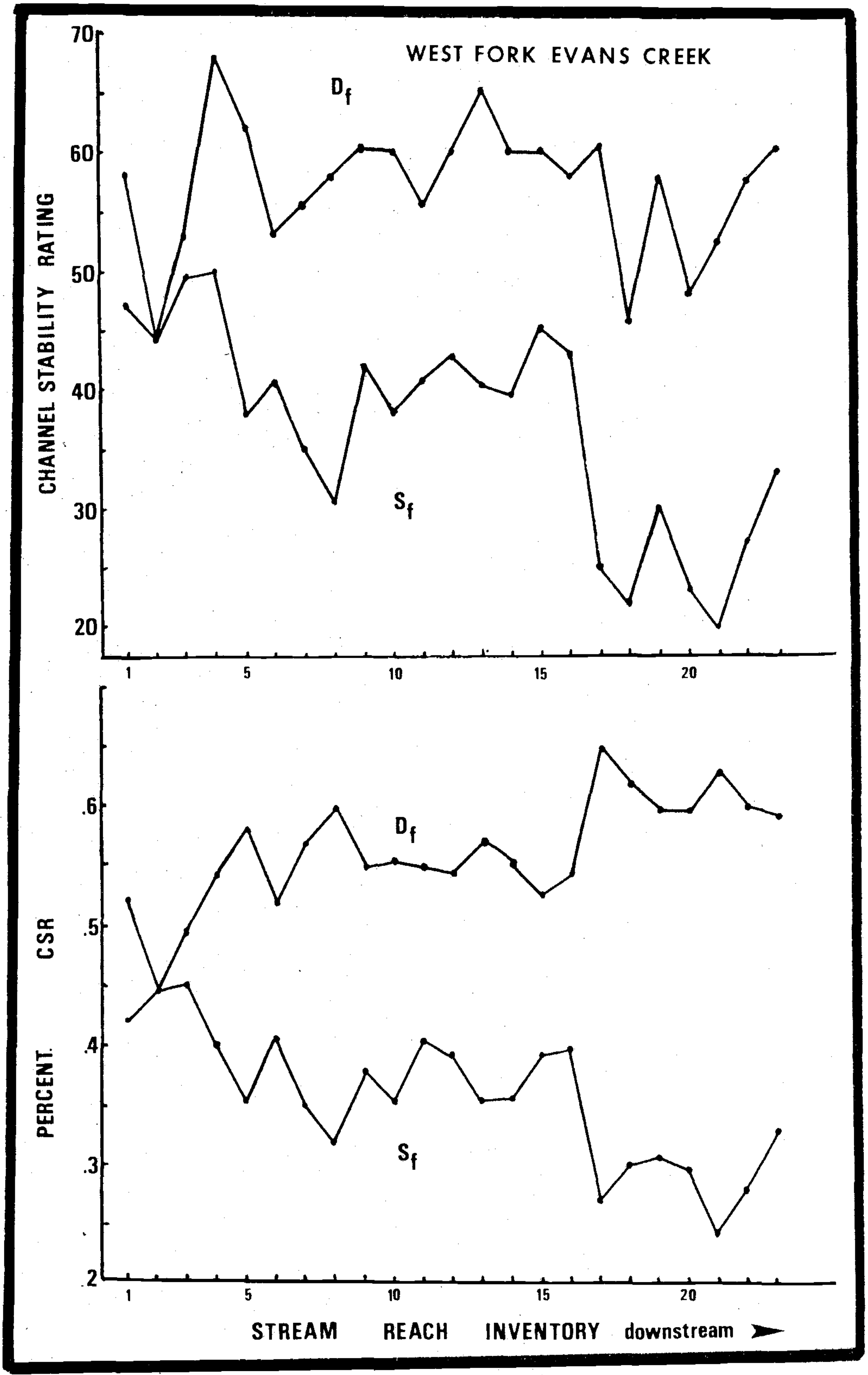

Figure 13. Continuum graphs showing how channel stability Sediment Sources (S_f) and Deposition Sources (D_f) vary from the headwaters to the outlet of West Fork Evans Creek.

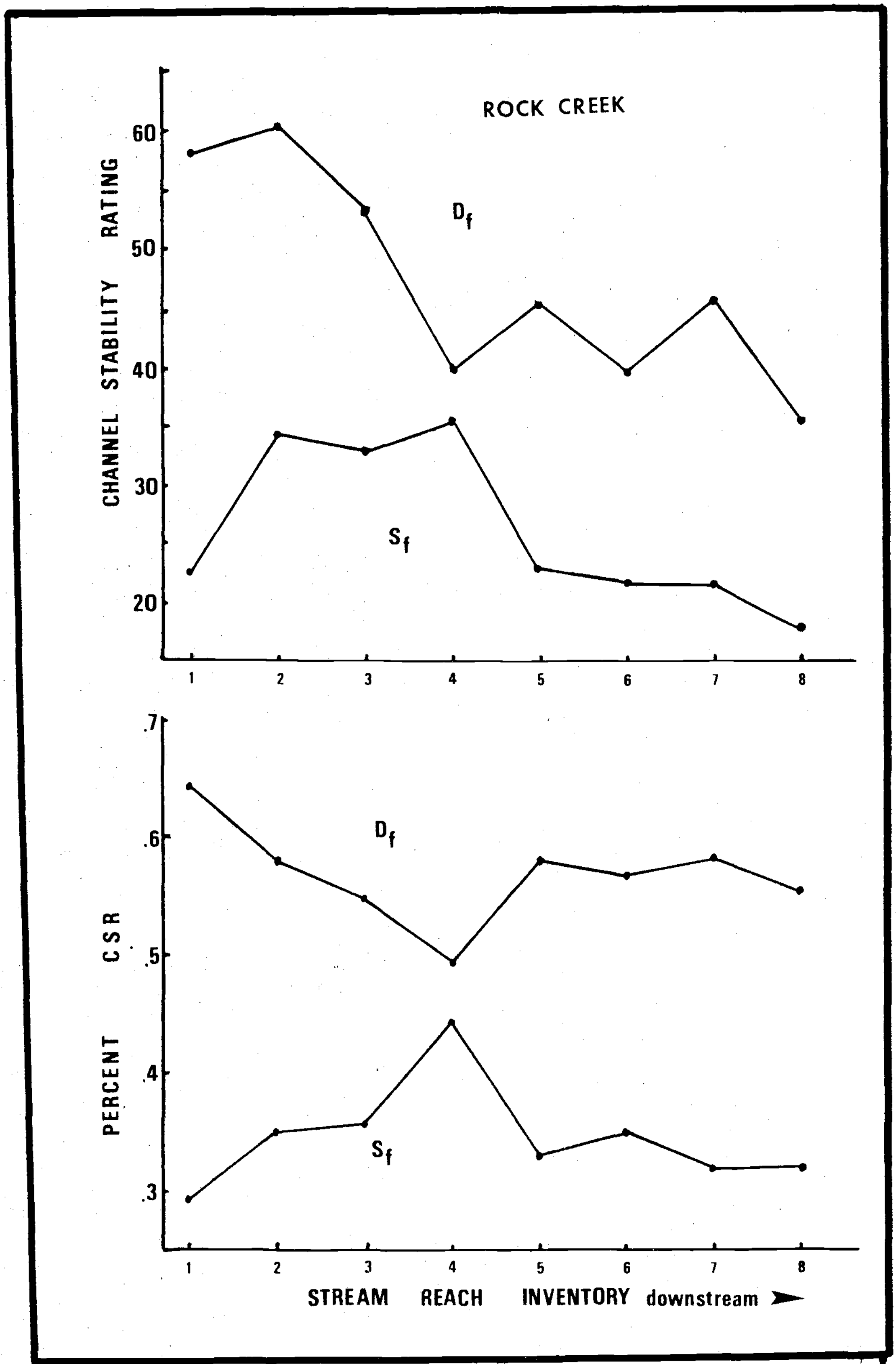

Figure 14. Continuum graphs showing how channel stability Sediment Sources (S_f) and Deposition Sources (D_f) vary from the headwaters to the outlet of Rock Creek.

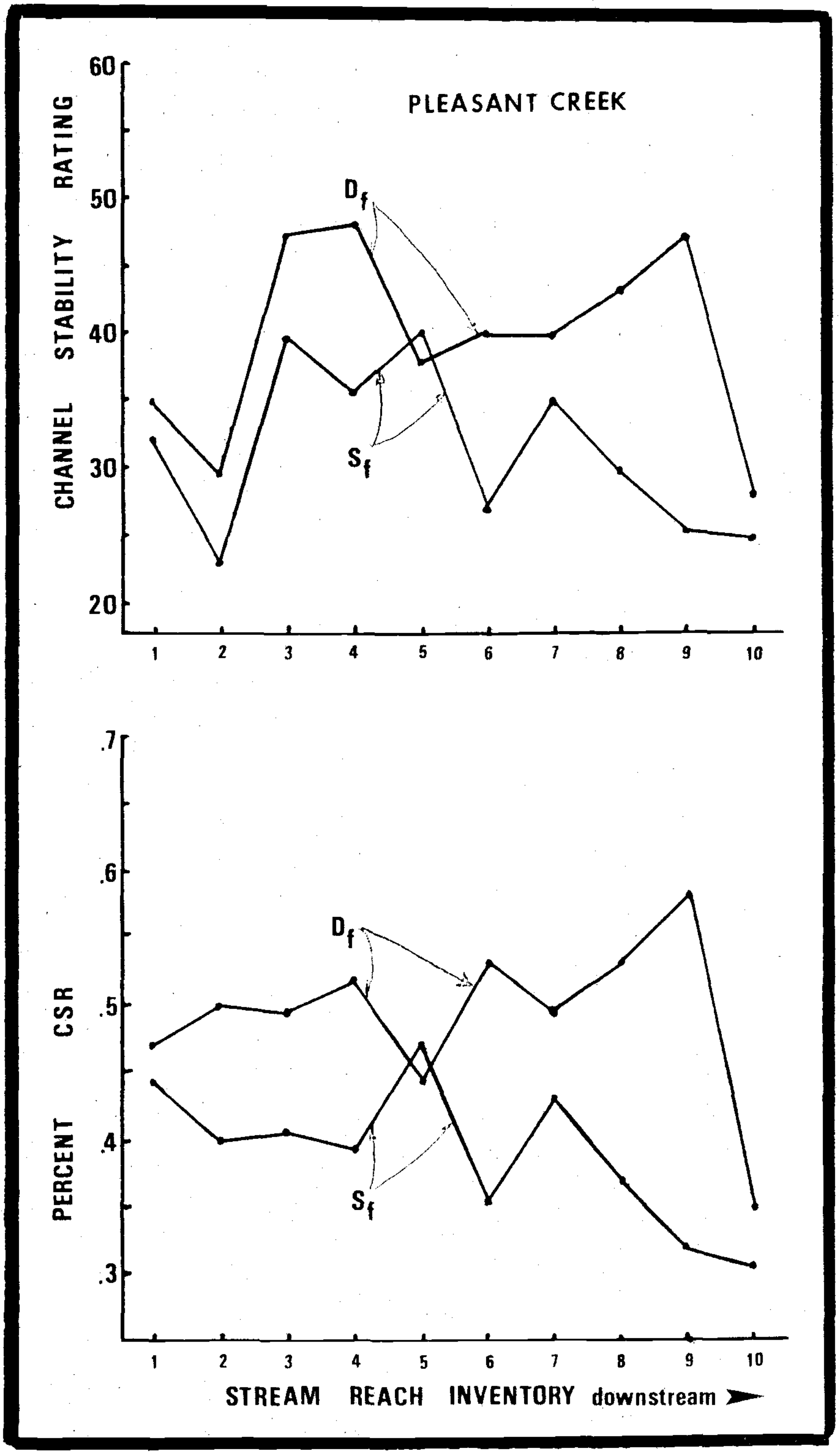

Figure 15. Continuum graphs showing how channel stability Sediment Sources (S_f) and Deposition Sources (D_f) vary from the headwaters to the outlet of Pleasant Creek.

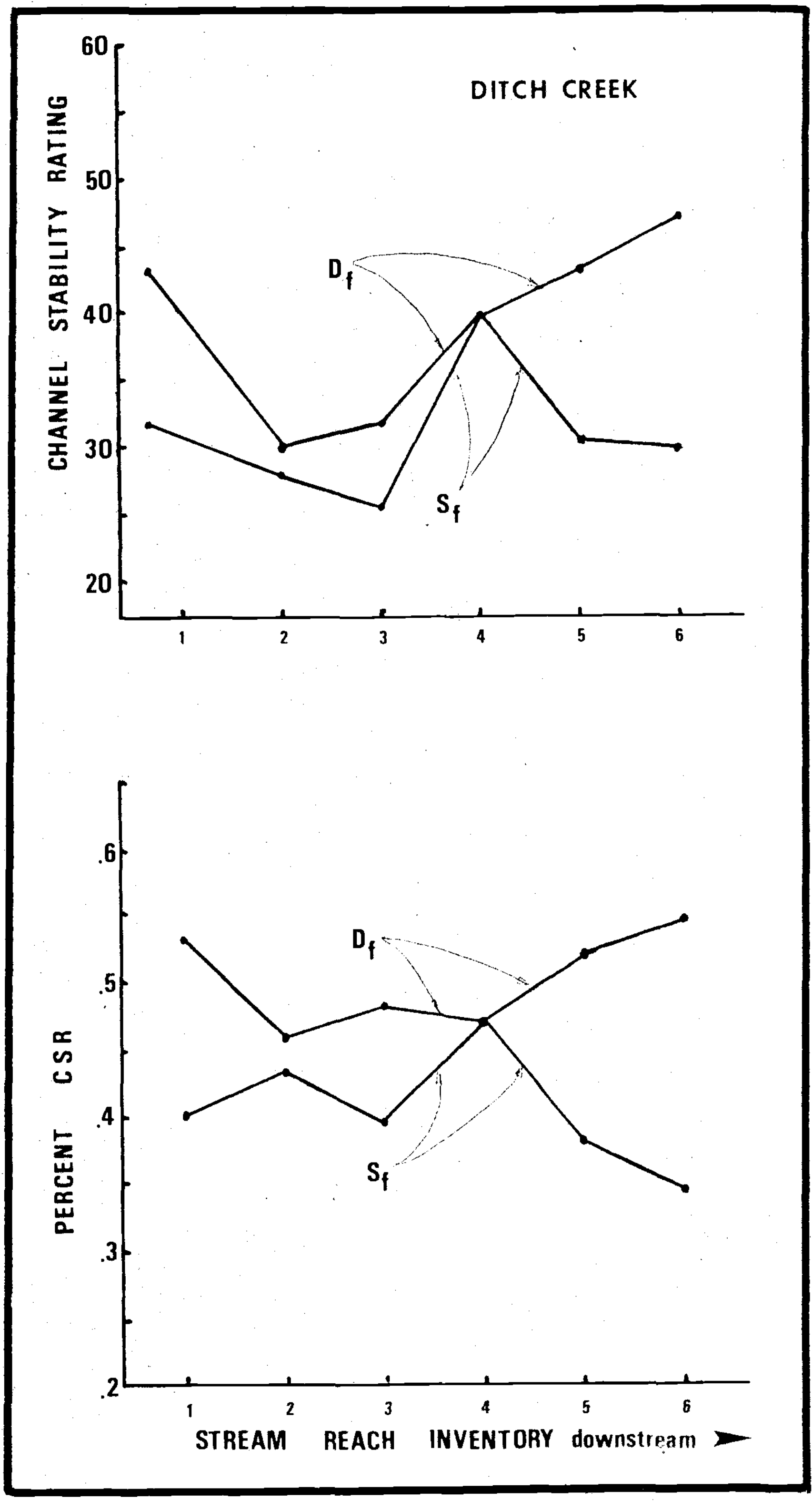

Figure 16. Continuum graphs showing how channel stability Sediment Sources (S_f) and Deposition Sources (D_f) vary from the headwaters to the outlet of Ditch Creek.

to the total Channel Stability Rating of a given stream reach. A single channel stability rating may thus represent a variety of conditions with respect to channel erosion or deposition.

In only two cases did the net contribution to the total (CSR) of the Sediment Source Factor and Deposition Factor equal one another; and only once did the Sediment Source Factor exceed that of the Deposition Factor. The overall channel stability rating is thus more often indicative of the stability of bank and bed deposits than of in-channel sources of sediment.

The continuum graphs also illustrate that sediment sources and deposition need not vary directly with one another along the stream. Reaches can be found where the Sediment Source Factors increase while Deposition Factors decrease, and vice versa. Other reaches can be found where both factors increase or decrease together. Sediment Source Factors tend to decrease in a downstream direction. Deposition Factors may either decrease or increase in a downstream direction or fluctuate with no general trend apparent. The graphs can be used to identify where channel erosion or deposition is excessive along the stream continuum.

IV. QUANTITATIVE BASIN MORPHOLOGY AND CHANNEL STABILITY

BACKGROUND CONCEPTS AND RATIONALE

A drainage basin is a geomorphological system. By considering the position of a watershed in the hydrologic cycle it is apparent that a basin lacks clearly defined boundaries and is therefore an open system because of the way in which energy enters, flows through, and exits the basin. The operation of the hydrologic system is maintained by a constant supply and removal of matter and energy.

Climate, more specifically precipitation, provides the input of mass and energy to the drainage basin. The output is the loss of energy which occurs as water and sediment exit the basin at its outlet. Energy is also expended as water and sediment are transported along the channels and as water erodes the channel in which it flows.

A characteristic of an open system is that it can operate in a steady state, in which the input of energy, the system itself, and the output of energy exist in a delicate state of balance (Chorley 1962). At any single time there is a balance between form and form, between form and process, and between process and process. Dynamic adjustments are made between the components of the overall system. Exchanges of matter and energy are made between sub-systems. When a change takes place in the input or output of matter or energy, a compensating change will occur to minimize the effect of the change and restore the system to a state of balance or steady state (Gregory and Walling 1973).

The term "quasi-equilibrium" refers to the steady state which can exist without constancy of form (Leopold and Langbein 1964). "Dynamic equilibrium" refers to the state which is maintained by adjustments in a continually changing system (Hack 1960). These terms have been applied to describe the relationships between form and process in drainage basins and in stream and river channels.

This study is concerned with the relationships between basin form, channel process and channel form, and how these elements have been modified by man's influence. The overall form of a drainage basin is for the most part a product of past processes operating on a geologic time scale. The form of a drainage basin influences the way in which basin and channel processes operate at any given time. Precipitation inputs to a basin are directly affected by basin characteristics. Rainfall is translated into runoff on the slopes of a watershed. Water flows through the channel network before exiting a basin at its outlet. The form and features of the channel reaches and cross-sections are particularly responsive to changes in streamflow and sediment load.

The potential energy of the precipitation input is determined by its relative elevation with respect to some point of measurement or datum (PE = mgh). The amount of work performed by the water on its way to the outlet is determined by the amount of water in transit, the velocity it attains, on the obstacles it encounters in the channel and on the sediment load it is forced to carry. This study is particularly concerned with the way potential energy expended in the channel results in the formation of erosional and depositoral features. The problem this thesis addresses, is one that requires relating drainage basin characteristics to drainage basin processes and resulting channel form.

In order to accomplish this problem, quantitative basin morphology has been used to describe the physical characteristics of catchments in Evans Creek. A spatial framework, as represented by the areal, linear, textural, relief and shape aspects of the watersheds has been presented. A channel stability rating procedure has been used to describe dynamic watershed processes and to document the occurrence of erosional and depositional features in the streams. Finally, a parametric approach has been used to relate the physical characteristics of the drainage basins to the observed channel stability in the streams.

LITERATURE REVIEW

Basin Characteristics and Watershed Form and Process

Many studies have achieved relating drainage basin form to drainage basin processes. Research has revealed the way in which the physical characteristics influence streamflow and sediment yield. The use of various methods and the analysis of results for specific and varied purposes, make comparison of results from different areas somewhat difficult (Gregory and Walling 1973).

Drainage basin characteristics have been characterized as having areal, lineal, textural, relief and shape aspects. Individually and collectively these factors influence dynamic basin processes. Studies that relate morphological basin characteristics to discharge and sediment production range from using single variable to multivariate analysis techniques.

Glymph and Holton (1969) illustrated how mean annual runoff is related to drainage area in several different areas of the United States. Giusti (1962) has shown that the relationships between flood flows and area, and drought flows and area are different for streams in the Piedmont Province of Virginia. Stall and Fok (1967) have correlated discharge with the morphological structure of the stream network as determined from the Horton-Straher Stream ordering classification system. Morisawa (1967) describes a relationship between mean annual discharge and the length of the longest stream for 96 watersheds in the eastern United States.

Drainage Density, described by Gregory and Walling (1973) as being closely related to and expressive of other basin characteristics, has a considerable influence on the amount and rate of output of a basin. Drainage density has been related to flood flows by Melton (1957) and Sokolov (1969), and to baseflow levels by Orsborn (1970). Studies by Gottschalk (1946) in South Dakota, and Stall and Bartelli (1959) in Illinois, have described relationships and sediment production.

Basin relief has been shown to have a significant influence on runoff and sediment production by Schumm (1954). Drainage basins with high relief generally have more peaked hydrographs than basins with lower relief. The influence of relief on sediment yields is therefore due to the fact that erosion and sediment transport are greatest during peak streamflow events. Schumm (1954) also derived a relationship between mean annual sediment production and the relief ratio of small drainage basin affecting 35 small reservoirs in Utah, New Mexico and Arizona.

DeWiest (1965) and Bowden and Wallis (1970) have described the effect of drainage basin shape on the form of the hydrograph and the time to peak. Strahler (1964) and Morisawa (1967) have described the effects of basin shape as expressed through the pattern of the drainage network on runoff response characteristics.

Nash (1966) has expressed the lag time (defined by Linsley et al. 1975 as the time difference between the centroid of precipitation and the centroid of runoff) as a function of basin area and basin slope.

Anderson (1954, 1957, 1971, 1974) and Anderson and Wallis (1963) have used multivariate regressions analysis techniques to relate sediment yields to land use, climate and watershed characteristics. The morphologic variables included in their analyses are: basin area, channel bifurcation ration, channel slope, length ratios and land slope.

Maner and Barnes (1953) and Maner (1958) evaluated sediment delivery rates (defined by Glymph 1954, as the ratio between annual sediment yield and gross erosion) for watersheds in the central plains states in terms of several basin characteristics (channel length, relief, basin shape, size of sediment contributing area, average land slopes, channel density and relief/length ratios). Roehl (1962) has developed similar relationships between sediment delivery ratios and drainage area, drainage density, stream order, relief/length ratio and other morphologic parameters for watersheds in the Southeastern United States. Yamamoto and Orr (1972) performed a comprehensive morphometric analysis of three basins in the Sturgis Watershed in the Black Hills of South Dakota. They demonstrated that several morphologic parameters could be related to annual water yield by utilizing Strahler's (1957) "Concept of Geometrical Similarity" and dimensional analysis. Lustig (1964) used quantitative geomorphic data to estimate long term sediment yields in the absence of hydrologic data.

QUANTITATIVE BASIN MORPHOLOGY

Introduction

Morphometry, the branch of geomorphology that is concerned with the measurement of the external form of surface landforms, provides the techniques used to quantify the physical attributes of the watersheds in Evans Creek. It is a relatively new science that has recently been adapted and applied to a wide variety of environmental problems. Morphometric parameters have been developed by many researchers and the list of known measurements is ever increasing.

The presentation that follows is primarily concerned with areal, linear, textural, relief and shape aspects of the drainage basins in Evans Creek. The morphometric parameters used in the analysis are summarized in Tables 10, 13, 17, 19 and 23, at the beginning of each section. Measurements and computations were performed according to the definition of the original author. Values thus generated are presented in tabular or graphical form, with a description and discussion of the parameter.

AREAL ASPECTS

Areal aspects of the drainage basins are primarily concerned with the size, type and number of fluvial features in a watershed. Basin area is a characteristic of the overal drainage basin, while order-related parameters portray the areal aspects of the channel network. The morphometric parameters described in this section are summarized in Table 10.

TABLE 10. AREAL ASPECTS OF THE DRAINAGE BASIN AND CHANNEL NETWORK

MORPHOMETRIC PARAMETER	SYMBOL	DERIVED BY	UNITS	REFERENCES
Stream order	u	Ordering system	E	Horton (1945), and others
Number of streams of a given order	N_u	Enumeration	E	Horton (1945), and others
Bifurcation Ratios	Rb	N_u/N_{u+1}	D	Horton (1945), Strahler (1952), Maxwell (1955)
Weighted Bifurcation Ratios	WRb	$\frac{\Sigma Rb_{u:u+1} x (N_u + N_{u+1})}{\Sigma N}$	D	Schumm (1956)
Drainage and Basin Areas	A	Planimetry	L^2	Horton (1945), and others

UNITS

E = Enumerative

D = Dimensionless

L = Length

% = Percent

Stream Order

The quantitative study of drainage networks received great impetus through the work of R. E. Horton (1932, 1945) who classified channel segments by order. Horton's system of classification was later modified by Strahler (1952). The modified Horton-Strahler ordering procedure:

1. defines the most headward finger-tip tributaries to be first order streams; 2) requires that when two streams of the same order (u) join a stream of order (u+1) be created; and 3) requires that when two streams of different order join, the channel reach immediately downstream of the confluence be given the order of the higher of the two combining streams. This technique was used to classify the orders of the streams of the Evans Creek basin.

The actual drainage network was delineated on USGS 15 minute topographic quadrangle maps (Table 11) using the V-notch crenulation method. This technique has been shown to give the best reliable estimates of the actual drainage network by many researchers (Morisawa 1957, 1961; Schneider 1961; Carlston, 1963; Bowden and Wallis, 1964; and Orsborn, 1970).

This method was deemed most appropriate because the study aims were to describe the form of the basin and the character of the dissection. The choice was also affected

TABLE 11. CATCHMENTS IN EVANS CREEK AND USGS 15 MINUTE TOPOGRAPHIC QUADRANGLE MAPS USED IN MORPHOLOGIC AND CHANNEL STABILITY INVESTIGATIONS.

Catchment	Quadrangle
East Fork Evans	Trail, & Tiller, Or. USGS 1:62500
East Fork Evans	Trail, Tiller
Morrison	Trail
Springett	Trail, Wimer
West Fork Evans	Wimer, Days Creek, Or.
Sand	Wimer
West Fork Evans	Wimer, Days Creek
Rock	Wimer
Cold	Wimer
Salt	Wimer
Right Fork Salt	Wimer
Battle	Wimer
Raspberry	Wimer
Evans Creek	Wimer, Gold Hill
May	Wimer
Sykes	Wimer
Pleasant	Wimer
Ditch	Wimer
Queens	Wimer
Fielder	Gold Hill

by the character of the map convention, the map scale and measurement techniques. The channel network derived is best described as being a "relative drainage network" because of the variations induced by compiling from maps of different scales and quality. A source of error lies with the judgment of the author, as topographer and cartographer, in picking out first order channel segments from numerous incipient drainage channels filled with colluvium.

Evans Creek is thus a 5th order stream when it enters the Rogue River. The master orders of the major streams in the Evans Creek basin are presented in Table 11.

TABLE 12. SELECTED AREAL ASPECTS OF EVANS CREEK BASINS

	Stream Order	Total Number of Streams of a Given Order					Total Number		Bifurcation Ratio			Weighted Bifurcation Ratio
		N_1	N_2	N_3	N_4	N_5	N	N1/N2	N2/N3	N3/N4	N4/N5	WR_b
East Fork Evans	4	98	25	7	1		131	3.92	3.57	7.00		4.98
East Fork Evans	4	57	15	5	1		78	3.80	3.00	5.00		4.66
Morrison	3	15	3	1			19	5.00	3.00			5.34
Springett	3	9	2	1			12	4.50	2.00			4.63
West Fork Evans	5	136	32	9	2	1	180	4.25	3.55	4.50	2.00	5.08
Sand	3	7	3	1			11	2.33	3.00			3.21
West Fork	4	49	11	3	1		64	4.45	3.67	3.00		5.16
Rock	4	24	5	2	1		32	4.88	2.50	2.00		5.16
Cold	3	7	2	1			10	3.50	2.00			3.75
Salt	2	8	1				9	8.00				8.00
Right Fork Salt	3	7	2	1			10	3.50	2.00			3.75
Battle	3	16	6	1			25	2.67	6.00			4.38
Raspberry	2	4	1				5	4.00				4.00
Evans Creek	5											
May	3	28	6	1			32	4.17	6.00			5.35
Sykes	3	24	6	1			31	4.00	6.00			5.23
Pleasant	4	97	28	8	1		134	3.46	3.50	8.00		4.71
Pleasant	4	68	19	6	1		94	3.57	3.17	6.00		4.59
Ditch	3	21	6	1			28	3.50	6.00			4.88
Queens	3	8	3	1			12	2.67	3.00			3.45
Fielder	3	11	4	1			16	2.75	4.00			3.83

Stream Numbers and Bifurcation Ratios

Through the use of his stream ordering classification procedure, Horton (1945) was able to derive his now famous "Laws of Drainage Composition". Qualitatively, these laws state that for a given channel network, the number of streams, length of streams and slope of streams can be represented by simple geometric progressions. In order to determine whether the streams in the Evans Creek basin conform to Horton's Laws similar analyses were undertaken (Figures 17, 18, and 30).

The Number of Streams of a Given Order (Table 12) was determined from the stream ordering classification map for all the major sub-basins. These results were portrayed graphically and are presented in Figure 17. A single regression line may be drawn to approximate the simple geometric progression. The linearity expressed in the graphs (which connect values of consecutive orders) indicate the relatively high degree to which the streams of Evans Creek conform to Horton's Law of Stream Numbers.

The Bifurcation Ratio of Horton (1945) and Strahler (1952, 1958) is defined by the ratio of the number of streams of a given order to the number of streams of the next highest order. In a single drainage basin, several bifurcation ratios may thus be derived depending on the master order of the basin (equal to the stream of the

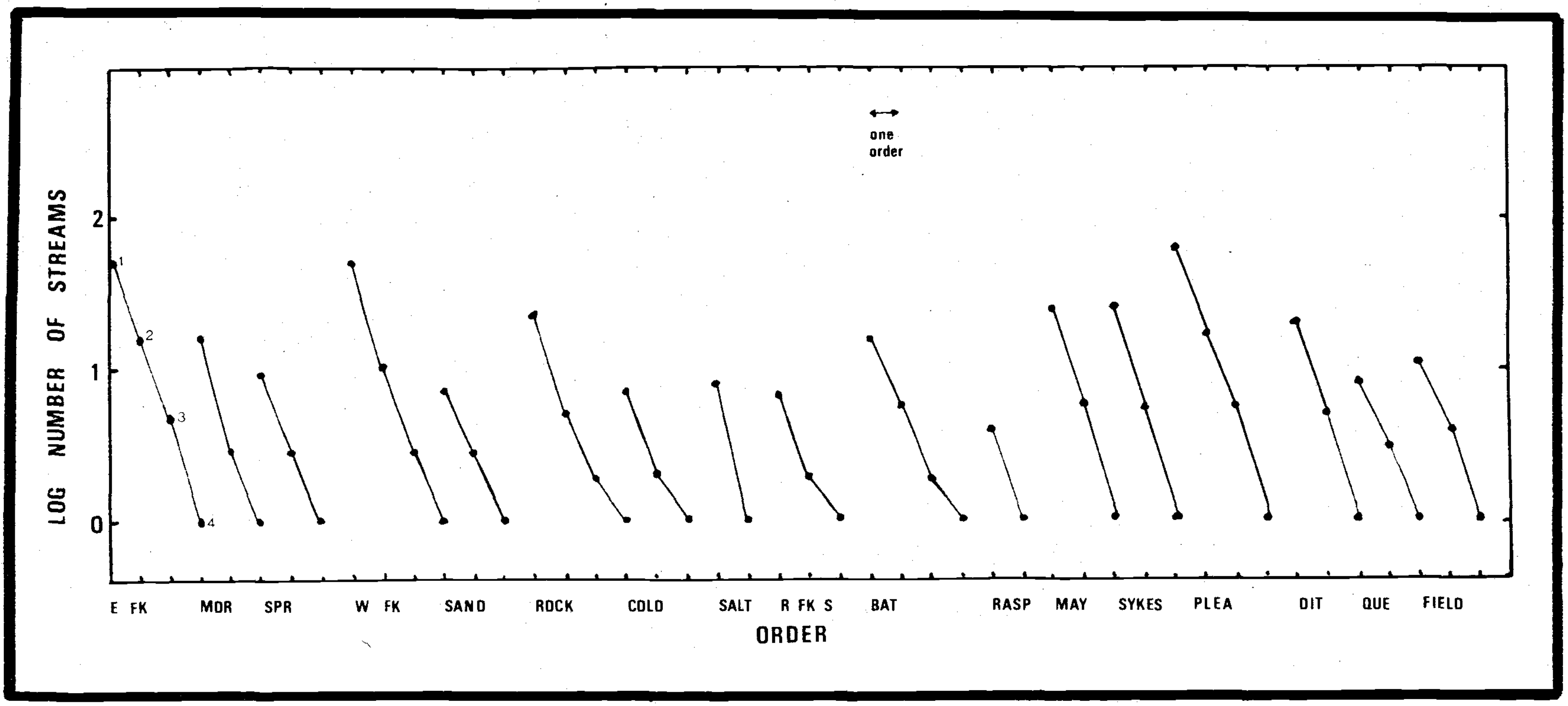

Figure 17. Diagram showing log number of streams versus order for streams in Evans Creek.

highest order). A Weighted Bifurcation Ratio can be computed using the conventions recommended by Schumm (1956).

Strahler (1964) has observed that on a large number of channel networks across the United States, bifurcation ratios ranged between three and five, unless geologic structure exerted a considerable influence on drainage patterns. Individual bifurcation ratios for some of the streams in the Evans are less than three and greater than five, indicating that localized geologic structural controls may be present. Weighted bifurcation ratios generally lie within the range of Strahler, implying that structural influences do not influence drainage networks to any significant degree. Salt Creek is the only stream in which structured controls may be significantly influencing the drainage network.

Drainage Divides and Basin Areas

Watershed boundaries were delineated for each of the major subcatchments on USGS quadrangle maps at a scale of 1:62500. Basin divides were determined (Figure 6) by interpreting the implied direction of surface and subsurface flow from the elevation contours on the maps.

The area of each sub-basin (Table 15) was then measured with a Keuffel and Esser polar planimeter to the nearest tenth of a square mile. It is assumed that the areas derived represents the actual "contributing area" because no "non-contributing areas" were found during the analysis.

LINEAR ASPECTS

Length measurements of drainage basin also are indicative of the size of fluvial features. The emphasis here is placed on distance rather than surficial coverage. Length properties are commonly indicative of steady-state conditions found in drainage basins. The morphometric parameters described in this section are summarized in Table .

TABLE 13. LINEAR ASPECTS OF THE DRAINAGE BASIN

MORPHOMETRIC PARAMETER	SYMBOL	DERIVED BY	UNITS	REFERENCES
Stream Length	L	Linear Measure	L	Horton (1945), Strahler (1952, 1954, 1957)
Mean Length of a given order	$\bar{L}_u$	Linear Measure	L	Horton (1945), Strahler (1952, 1954, 1957)
Total Length of a given order	ΣL_u	Linear Measure	L	Horton (1945), Straher (1952, 1954, 1957), and Schumm (1963)
Length Ratio	R_L	L_u/L_{u+1}	D	Horton (1945)
Basin Perimeter	P	Opisometry	L	Smith (1950)
Basin Length	L_b	Linear Measure	L	Schuman (1956, 1963)
Maximum Width	MW	Linear Measure	L	Maxwell (1960)
Ratio	$R_{1/Rb}$	Computation	D	Horton (1945)

Stream Lengths

The length of every stream segment was measured off the USGS quadrangle maps to 0.02 inches using an engineers scale. Map distances were converted to ground distances. The lengths were then organized by order, summed to give total length of stream by basin, and divided by the number of streams of a given order to give the mean length of stream of a given order (Table 14).

Stream Length Ratios (Table 14) were computed by dividing the mean length of a stream of a given order, by the mean length of a stream of the next highest order, following the conventions established by Horton (1945) and Strahler (1958).

The mean stream length data was graphically portrayed (Figure 18) in order to see if the streams of the Evans conform to Hortons "Law of Stream Lengths", which states that average stream lengths increase with stream order. The line graphs (connecting values of consecutive orders) indicate that the general trend of all the streams is in accord with Horton's Law. Several of the streams do not exhibit the strict linearity implied by Horton (1945), Chorley (1957), and Morisawa (1962). The lack of fit may be due to the stream ordering system, lithologic influences or other basin characteristics.

TABLE 14. SELECTED LINEAR ASPECTS OF EVANS CREEK WATERSHEDS

	Mean Length of Streams of a Given Order (Miles)					Length Ratios (Dimensionless)			Total Length of Streams of a Given Order (Miles)				
	L_1	L_2	L_3	L_4	L_5	L1/L2	L2/L3	L3/L4	L_1	L_2	L_3	L_4	L_5
East Fork Evans													
East Fork Evans	.53	.66	.66	7.60		.83	1.00	.87	30.21	9.90	3.30	7.60	
Morrison	.45	1.20	3.29			.38	.36		6.75	3.60	3.29		
Springett	.49	.65	2.17			.75	.29		4.41	1.30	2.17		
West Fork Evans													
Sand	.71	.79	2.09			.90	.38		4.97	2.37	2.08		
West Fork Evans	.57	.67	.69	5.05		.85	.97	.14	27.96	7.42	2.07	5.05	
Rock	.58	.85	.49	5.17		.68	1.73	.09	13.92	4.25	.98	5.17	
Cold	.65	2.87	1.37			.23	2.09		4.55	5.74	1.37		
Salt	.57	4.50				.12			4.56	4.50			
Right Fork Salt	.63	.83	1.04			.75	.80		4.41	1.66	1.04		
Battle	.41	.44	2.99			.93	.15		6.56	2.64	2.99		
Raspberry	.61	1.31				.47			2.44	1.31			
Evans Creek													
May	.54	.51	3.73			1.05	.14		13.50	3.06	3.73		
Sykes	.59	.74	4.65			.80	.16		14.16	4.44	4.65		
Pleasant													
Pleasant	.45	.70	.89	6.58		.64	.79	.14	30.60	13.30	5.34	6.58	
Ditch	.56	.31	4.80			1.81	.13		11.76	1.86	4.80		
Queens	.54	.88	2.40			.61	.37		4.32	2.64	2.40		
Fielder	.64	.76	2.18			.84	.35		7.04	3.04	2.18		

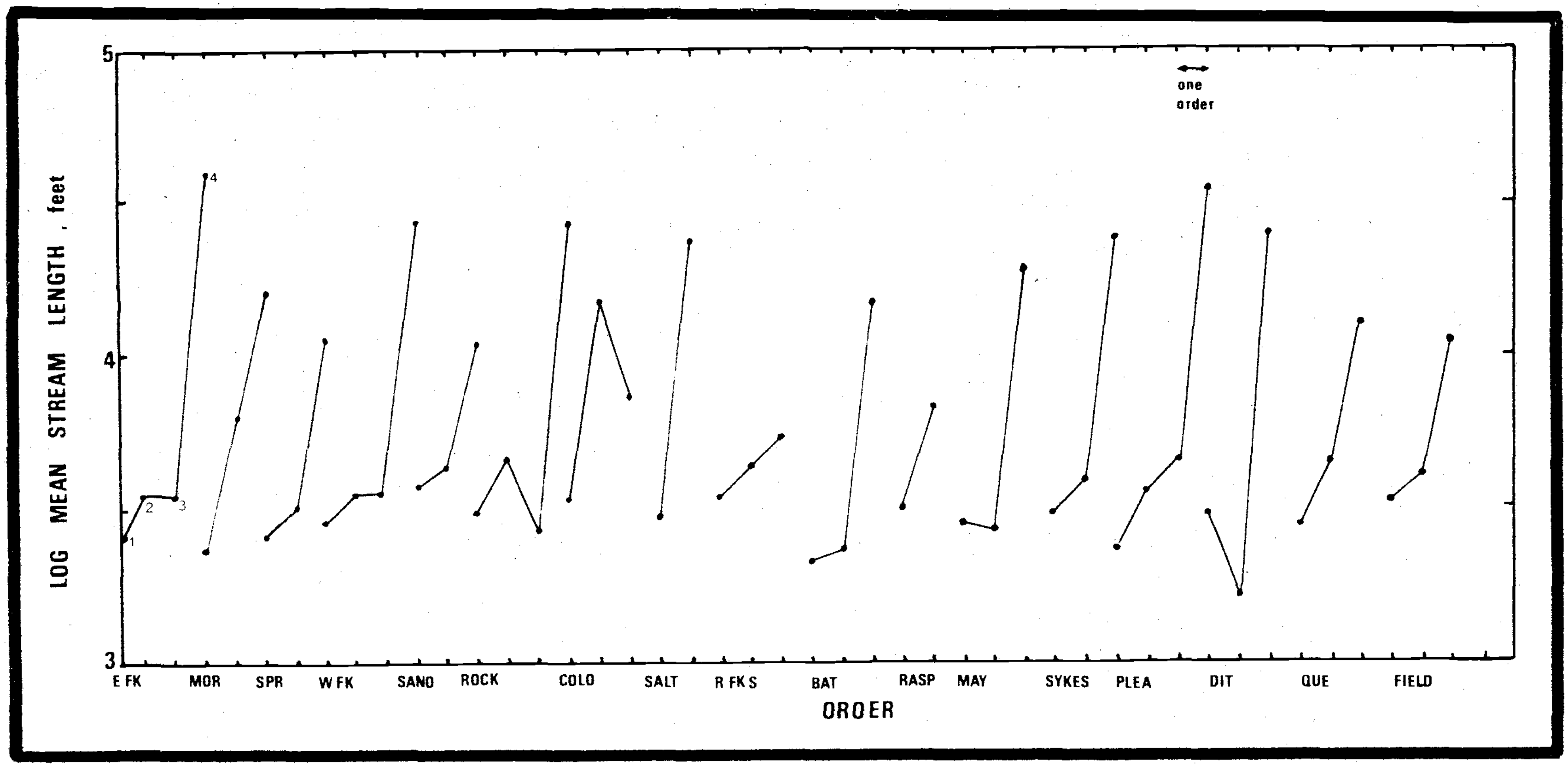

Figure 18. Diagram showing log mean stream length versus order for streams in Evans Creek.

Total stream length data was also graphically portrayed (Figure 19) in order to see if the streams conform to Strahler's "Revised Law of Stream Lengths", which states that the total lengths of streams of a given order tends to decrease with increasing order. Again, the general trend is to follow the morphometric law. In half of the streams of the Evans, however, there is a definite trend for the total length of stream of the highest order to be greater than that of the next highest order. This upturn is evident in almost all of the other basins. Cold Creek is the only exception.

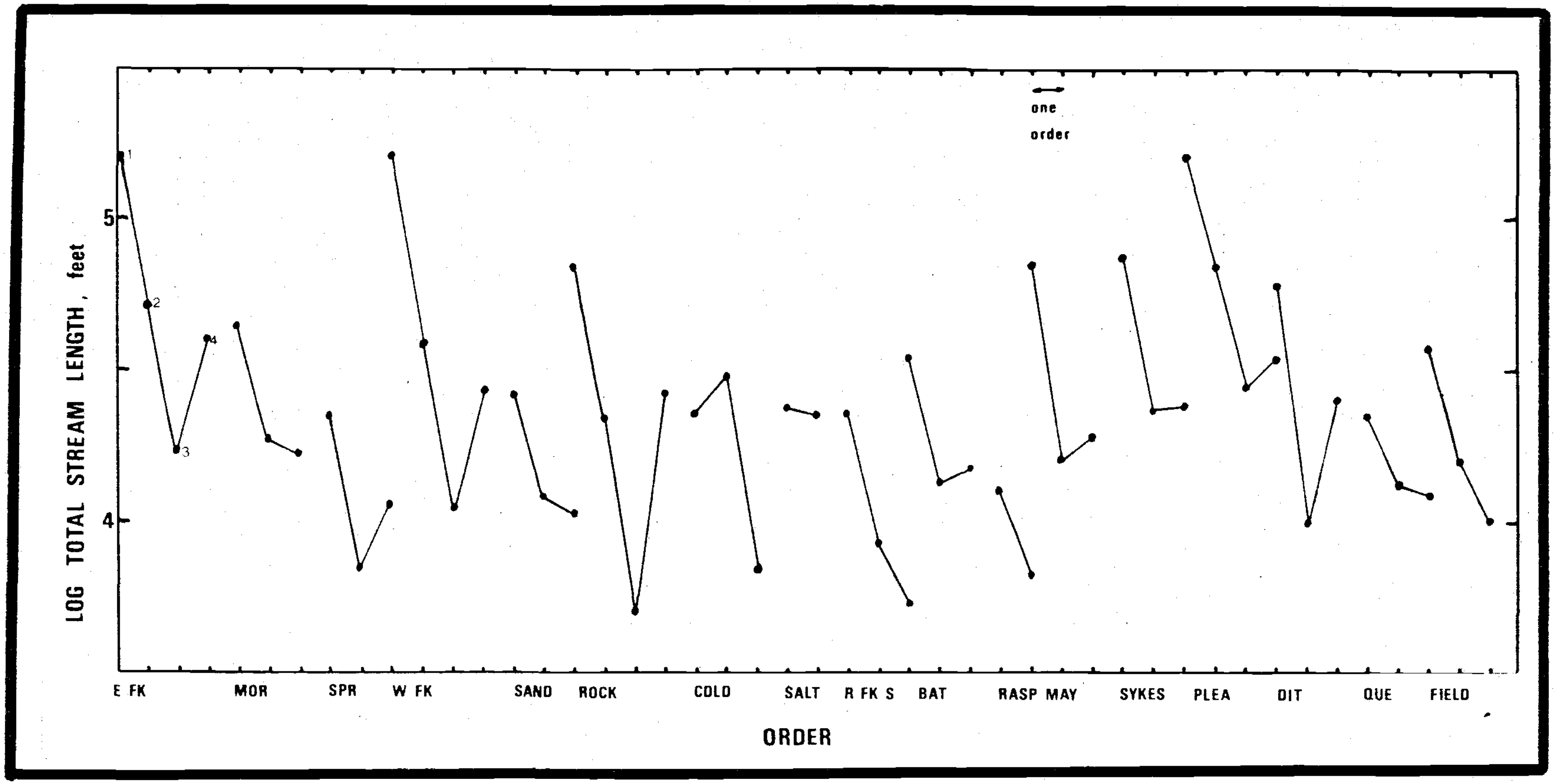

Figure 19. Diagram showing log total stream length versus order for streams in Evans Creek.

TABLE 15. AREA AND TOTAL LENGTH OF STREAMS IN EVANS CREEK WATERSHEDS

	Total Length of Streams (Miles)	Basin Areas (MI^2)
East Fork Evans	100.74	50.7
East Fork Evans	51.01	24.20
Morrison		6.80
Springett		4.20
West Fork Evans	142.89	63.10
Sand	9.42	2.90
West Fork Evans	42.52	26.10
Rock	23.33	14.50
Cold	11.66	4.60
Salt	9.06	4.80
Right Fork Salt	7.47	3.30
Battle	12.20	4.80
Raspberry	3.76	1.80
Evans Creek		
May	20.28	7.10
Sykes	23.19	8.70
Pleasant	79.86	45.30
Pleasant	55.82	22.80
Ditch	18.45	8.50
Queens	9.32	5.60
Fielder	12.25	6.40

Basin Perameter, Basin Length, and Maximum Width

These additional linear morphometric perameters (Table 16) were measured in order to facilitate analysis of basin shape and relief factors. Basin Perimeter was measured using a Keuffel and Esser Opisometer to .05 inches. Basin length and maximum width were measured to .02 inches using an engineers scale. Map distances were converted to ground distances.

TABLE 16. SELECTED LINEAR ASPECTS OF EVANS CREEK WATERSHEDS

	Length of Basin L_B (MI)^2	Basic Perimeter P_B (MI)^2	Maximum Width MW (MI)^2
East Fork Evans	17.66	38.10	4.70
East Fork Evans	11.04	25.85	3.20
Morrison	6.2	14.10	1.70
Springett	3.62	9.20	1.80
West Fork Evans	17.62	37.10	3.90
Sand	3.48	8.10	1.50
West Fork Evans	11.33	24.50	3.90
Rock	7.08	15.50	3.10
Cold	4.43	10.75	1.50
Salt	6.42	12.15	1.40
Right Fork Salt	2.59	7.40	2.10
Battle	3.88	9.95	1.80
Raspberry	1.83	5.60	1.70
Evans Creek			
May	5.18	12.10	2.50
Sykes	7.10	14.70	2.80
Pleasant	13.30	35.40	6.50
Pleasant	10.18	21.30	4.20
Ditch	5.61	14.60	2.50
Queens	3.67	12.60	3.10
Fielder	3.59	10.20	3.00

TEXTURAL ASPECTS

The texture of a basin indicates the degree to which the surface of the watershed has been dissected by fluvial processes. Textural indices are derived by combining areal and linear characteristics into a single perimeter. They are a good indicator of the response of a watershed to its physical environments and imposed climatic conditions over geologic time. Morphometric parameters used in the following analysis are summarized in Table 17.

TABLE 17. TEXTURAL ASPECTS OF THE DRAINAGE BASIN

MORPHOMETRIC PARAMETER	SYMBOL	DERIVED BY	UNITS	REFERENCES
Drainage Density	Dd	$\Sigma L_u/A_u$ or L/A	L^{-1}	Horton (1945), Smith (1950) Langbein (1947), Morisawa (1957)
Constant of Channel Maintenance	C	$A_u/\Sigma L_u$ or A/L or $1/Dd$	L	Schumm (1956), Strahler (1957)
Length of Overland Flow	l_o	$1/2Dd$	L	Horton (1945)
Stream Frequency	F_s	$\Sigma N/A$	L^{-2}	Horton (1945)
Drainage Intensity	D_i	$F_s Dd$	L^{-3}	Faniran (1968)

UNITS

E = Enumerative

D = Dimensionless

L = Length

% = Percent

Drainage Density

An important index which has been commonly used to express the texture of fluvially eroded topography is Drainage Density. It is defined by Horton (1945) as the length of streams per unit area, and is thus independent of order. Drainage densities, calculated by dividing the total length of streams in a given drainage basin by the area of the basin, are presented in Table 18.

An attempt was made to visually portray drainage densities over the whole of the Evans Creek basin, in order to illustrate the variation of drainage density within the basin. A square mile grid was applied to the stream order map and drainage densities per square mile were calculated for the entire basin. This data was then plotted on a frequency diagram of drainage area vs drainage density (Figure 20). A natural ordering technique was used to cluster the data into four classes, designed to encompass the peaks revealed by the multimodal distribution. A choroplethic map of drainage density (Figure 21) was then created using the four classes and the grid map.

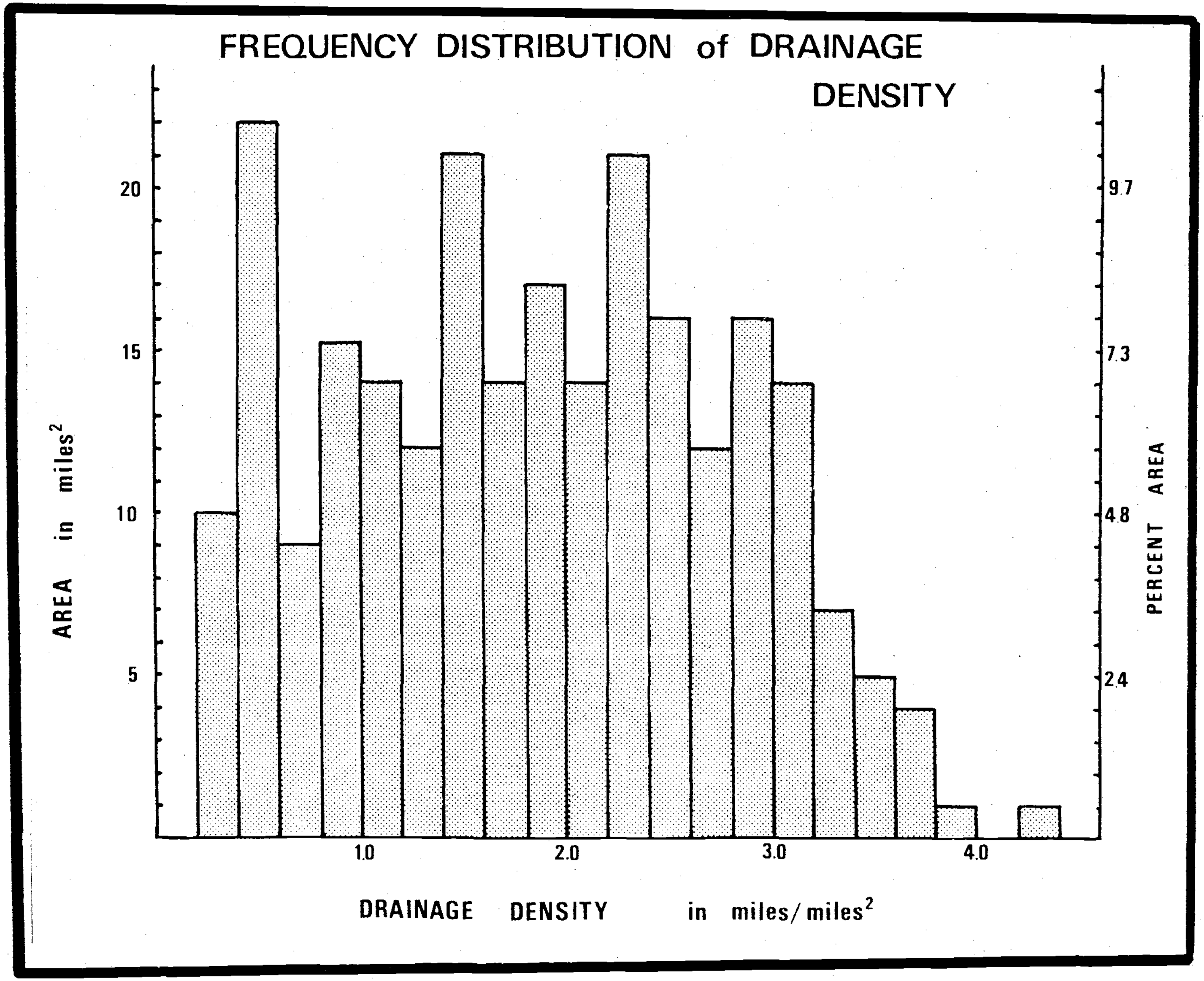

Figure 20. Frequency distribution of drainage density in Evans Creek.

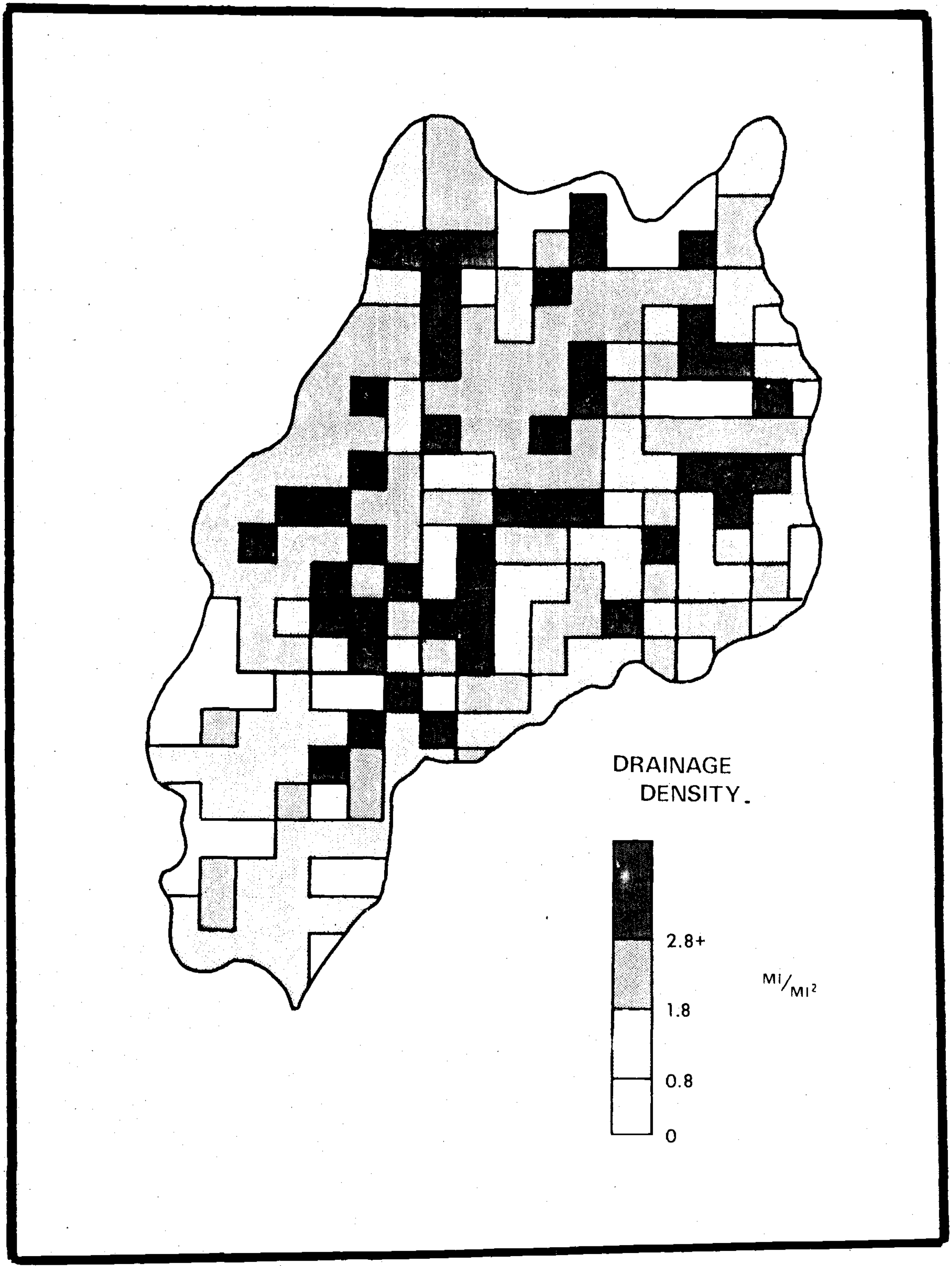

Figure 21. Choroplethic map of drainage density.

Stream Frequency

Another commonly used textural index is stream frequency, defined by Horton (1945) as the number of streams per unit area. It is thus dependent upon order. Values were computed by dividing the total number of streams in a basin by the area of the basin (Table 18).

Both the stream frequency and drainage density reflect the effects of topographic, lithologic, climatologic, pedologic and vegetational controls on the drainage network. The relationship between stream frequency and drainage density is portrayed graphically in Figure 22.

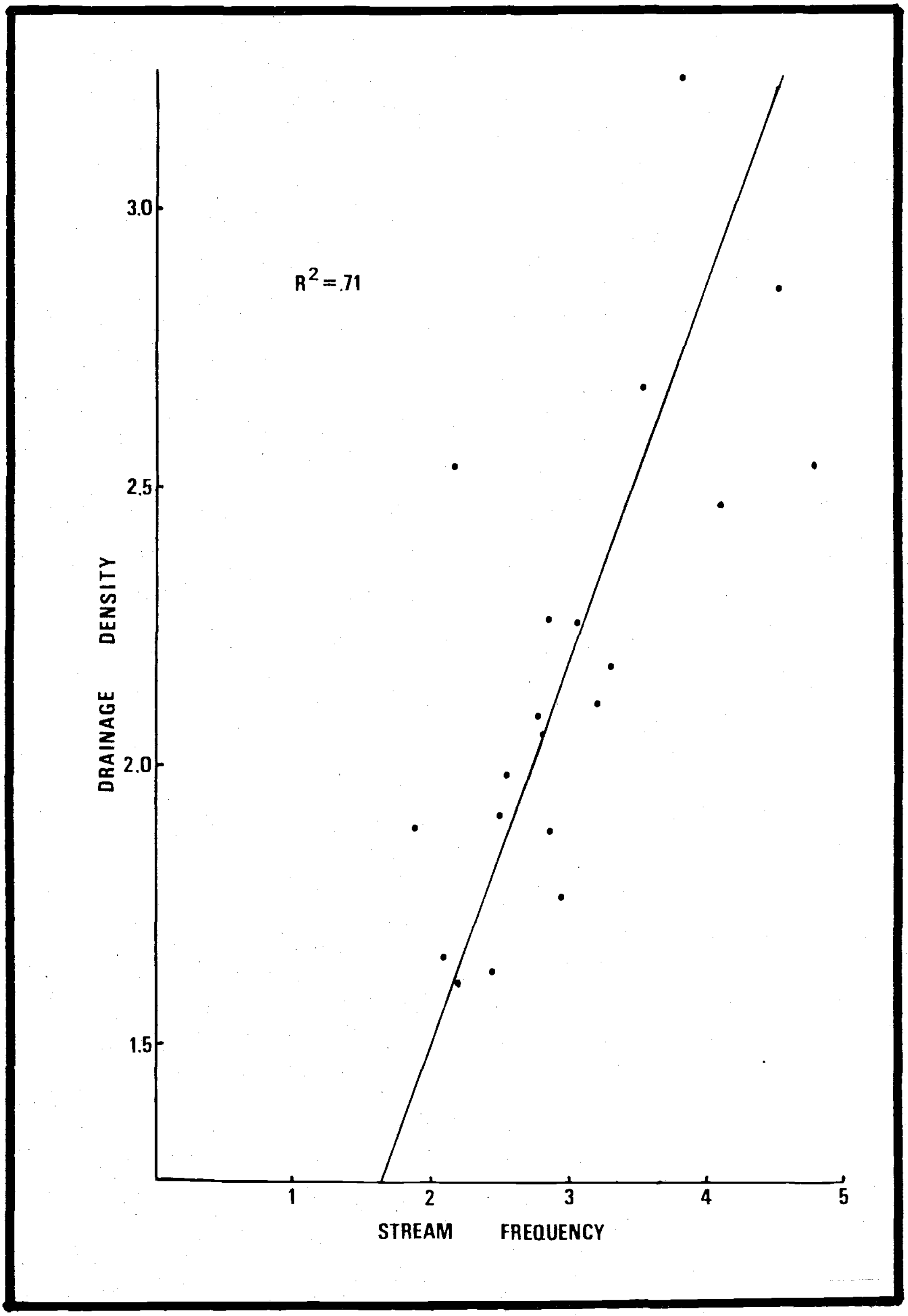

Figure 22. Graph showing the relationship between drainage density and stream frequency in the East Fork of Evans Creek.

Constant of Channel Maintenance

The Constant of Channel Maintenance is defined by Schumm (1956) to be the amount of drainage area required to maintain one foot of channel. Values for the streams of the Evans (Table 18) were calculated as being equal to the reciprical of drainage density times 5,280, following the guidelines established by Schumm.

Length of Overland Flow

The Length of Overland Flow is defined as the distance water must flow over the ground before it reaches a stream channel. Horton (1945) observed that it is approximately equal to half of the average distance between stream channels. Following the conventions established by Horton (1945), the lengths of overland flow were computed as the reciprical of two times the drainage density (Table 18). Overland flow is generally unimportant because of the high infiltration rates of surficial materials. The length of overland flow may, however, be used to index the distance water must travel below the surface of the ground prior to reaching a stream channel.

Drainage Intensity

Drainage Intensity is a combined morphometric index proposed by Faviran (1968). It is defined as the product of drainage density and stream frequency. One advantage of using drainage intensity lies in the fact that it expresses the amount of total channel flow better than any other single morphometric parameter. Drainage intensities were calculated for the streams of the Evans and are presented in Table 18.

Ratio of R_l to R_b

According to Horton (1945) the ratio of the length ratio to the bifurcation ratio is a factor that is very important with respect to the drainage composition and the physiographic development of the drainage basin. Horton related channel storage capacity to the problems of flood routing and flood stage. Channel storage, he observed, is directly related to total stream length. From the total length of streams of a given order, the channel storage contributed by streams of each order in a basin can be computed; and by summation the total channel storage can be determined.

Drainage basins with similar drainage densities may have significantly different storage capacities. Since higher order streams are wider and deeper, they contain more channel storage per unit length than streams of lower order. Thus, when the ratio of R_l to R_b is high the greater length of larger channels results in increased channel storage (Horton 1945).

TABLE 18. SELECTED TEXTURAL ASPECTS OF EVANS CREEK WATERSHEDS

	Drainage Density	Constant of Channel Maintenance	Stream Frequency	Drainage Intensity	Length of Overland Flow	R_L/R_b
East Fork Evans	1.98	2667	2.58	5.10	.26	
East Fork Evans	2.11	2504	3.22	6.79	.24	.24
Morrison	2.06	2563	2.79	5.74	.24	.10
Springett	1.87	2824	2.86	5.34	.27	.16
West Fork Evans	2.26	2336	2.85	6.45	.22	
Sand	3.24	1625	3.79	12.28	.15	.26
West Fork Evans	1.63	3239	2.45	3.90	.25	.39
Rock	1.61	3280	2.21	3.56	.31	.29
Cold	2.53	2087	2.17	5.49	.19	.56
Salt	1.89	2794	1.88	3.55	.26	.02
Right Fork Salt	2.26	2336	3.03	6.85	.22	.30
Battle	2.54	2079	4.79	12.17	.20	.19
Raspberry	2.09	2526	2.78	5.80	.24	.12
Evans Creek						
May	2.86	1846	4.51	12.90	.17	.14
Sykes	2.67	1978	3.56	9.51	.19	.12
Pleasant	1.76	3000	2.96	5.21	.28	
Pleasant	2.45	2155	4.12	10.90	.20	.15
Ditch	2.17	2433	3.29	7.14	.23	.27
Queens	1.66	3181	2.14	3.55	.30	.18
Fielder	1.91	2764	2.50	4.78	.26	.20

RELIEF ASPECTS

Relief is an important morphologic factor because of its role in dynamic watershed processes. Relief factors indicate the degree to which valleys have been incised and are thus dependent upon the combined effects of climate, lithology and geomorphic processes. Relief parameters are expressed in terms of absolute vertical rise or fall, as a change of relative height per unit of linear horizontal distance, or as a dimentionless value. Morphometric parameters used in the analysis of relief aspects are summarized in Table 19.

TABLE 19. RELIEF ASPECTS OF THE DRAINAGE BASIN

MORPHOMETRIC PARAMETER	SYMBOL	DERIVED BY	UNITS	REFERENCES
Maximum Basin Elevation	H_M	Topo map interpretation	L	Horton (1932, 45) Strahler (1952, 58)
Minimum Basin Elevation	H_M	Topo map interpretation	L	Schumm (1954,1956) and others
Mean Basin Elevation	$H_{\bar{x}}$	$\frac{H_M+H_m}{2}$	L	Schumm (1954,1956) and others
Maximum Basin Relief	H		L	Schumm (1954, 1956) and others
Mean Relief of a given order	$\bar{H}_u$	computation + ordering	L	Schumm (1954,1956) and others
Relief Ration	R_h	H/L	D	Schumm (1956)
Relative Relief	$R_{hp} R_{hw}$	H/P, $H/_{mw}$	D	Melton (1957) and Maxwell (1960)
Ruggedness Number	HDd	HDd	D	Strahler (1958)
Longitudinal Profiles		$\Delta H/\Delta L$	-	
Hypsometric Integral	-	$\int x\, dy$	D	Strahler (1952)
Channel Slope of a given order	Θ_c	$\bar{H}_u/\bar{L}_u$	%	Horton (1945)
Ground Slope Area and percent of basin by class	Θ_g	Planimetry	%	Horton (1945)

Maximum, Minimum, Mean Basin Elevations and Maximum Basin Relief

Elevations were determined by interpreting the elevation contour lines on USGS quadrangle maps. The maximum elevation of each basin is considered to be the highest point in each basin. The minimum elevation is the point at which a sub-catchment stream enters into a mainstream channel. These two factors were averaged to give the mean elevation of each basin. Maximum basin relief is defined as the difference in elevation between the highest and lowest points in a watershed. The results of this analyses are presented in Table 20.

TABLE 20. SELECTED RELIEF ASPECTS OF EVANS CREEK WATERSHEDS

	Maximum Elevation (ft.)	Minimum Elevation (ft.)	Mean Elevation (ft.)	Maximum Basin Relief (ft.)	Relief Ratio (Dimensionless)	Relative Relief (Dimensionless)	Relative Relief (Dimensionless)	Ruggedness Number
East Fork Evans	4582	1460	3021	3122	.03	.016	.125	1.17
East Fork Evans	4582	1755	3169	2827	.05	.021	.167	1.26
Morrison	4556	1755	3156	2801	.09	.038	.312	1.09
Springett	4102	1520	2811	2582	.14	.053	.271	.91
West Fork Evans	5102	1460	3281	3642	.04	.019	.176	1.56
Sand	4160	1980	3070	2180	.12	.051	.275	1.34
West Fork Evans	5102	1460	3291	3642	.06	.028	.177	1.12
Rock	4526	1860	3193	2666	.07	.033	.163	.81
Cold	4526	1934	3230	2592	.11	.046	.327	1.24
Salt	4556	1990	3273	2566	.08	.040	.347	.91
Right Fork Salt	4556	1790	3173	2766	.20	.071	.249	1.18
Battle	3982	1630	2806	2352	.11	.045	.247	1.13
Raspberry	3686	1590	2638	2096	.22	.071	.234	.83
Evans Creek								
May	3620	1250	2435	2370	.09	.037	.180	1.28
Sykes	3620	1190	2405	2430	.06	.031	.164	1.23
Pleasant	4370	1110	2740	3260	.05	.017	.095	1.09
Pleasant	4370	1190	2780	3.80	.06	.028	.143	1.48
Ditch	3725	1190	2458	2535	.09	.033	.192	1.04
Queens	4434	1140	2787	3180	.17	.050	.201	1.04
Fielder	3700	1030	2365	2670	.14	.050	.169	.97

Mean Relief of a Given Order

Following Horton's works, "Laws of Stream Relief" were proposed by Morisawa (1967) and Fok (1971). They are based on the Horton-Strahler ordering system and state that stream relief may be expressed as a semi-logarithmic function of stream order. Stream relief is defined as the difference in elevation between the beginning and ending points of a stream segment of a given order.

Values for mean relief of a given order were computed (Table 21) and were graphically portrayed (Figure 23) in order to see if the streams of the Evans conform to Fok's proposed "Law of Stream Relief." The graphs indicate that relief generally varies inversely with order, though there are exceptions (Morrison Creek and Springnett Creek). Most of the streams also display a tendency for the relief of the highest order to be greater than that of the next highest order.

Supporting evidence for Morisawa's "Law of Stream Relief," comes from the linear relationships shown between log total stream relief and order (Figure 24). The linearity expressed implies that a simple geometric progression can be derived to describe the relationship. Morisawa (1962) believes that departures from a straight line may be due to any number of factors, including lithology and structure.

TABLE 21. MEAN RELIEF AND CHANNEL SLOPE OF STREAMS OF A GIVEN ORDER

	Mean Relief by order (ft.)				Channel Slope by order (%)			
Catchment	H1	H2	H3	H4	S1	S2	S3	S4
East Fork Evans								
East Fork	614	400	247	750	.22	.11	.07	.02
Morrison	588	425	1150		.25	.07	.07	
Spring	600	450	975		.23	.13	.09	
West Fork Evans								
Sand	573	100	270		.15	.02	.02	
West Fork	743	410	135	340	.25	.12	.04	.01
Rock	656	417	180	720	.21	.09	.07	.03
Cold	712	350	386		.21	.02	.05	
Salt	657	1260			.22	.05		
Right Fork Salt	874	610	222		.26	.14	.04	
Battle	756	228	690		.35	.10	.04	
Raspberry	850	820			.26	.12		
Evans Creek								
May	870	436	860		.31	.16	.04	
Sykes	928	287	800		.30	.07	.03	
Pleasant								
Pleasant	982	513	453	660	.41	.14	.10	.01
Ditch	747	280	1000		.25	.17	.04	
Queens	849	475	600		.30	.10	.05	
Fielder	1147	370	317		.34	.09	.03	

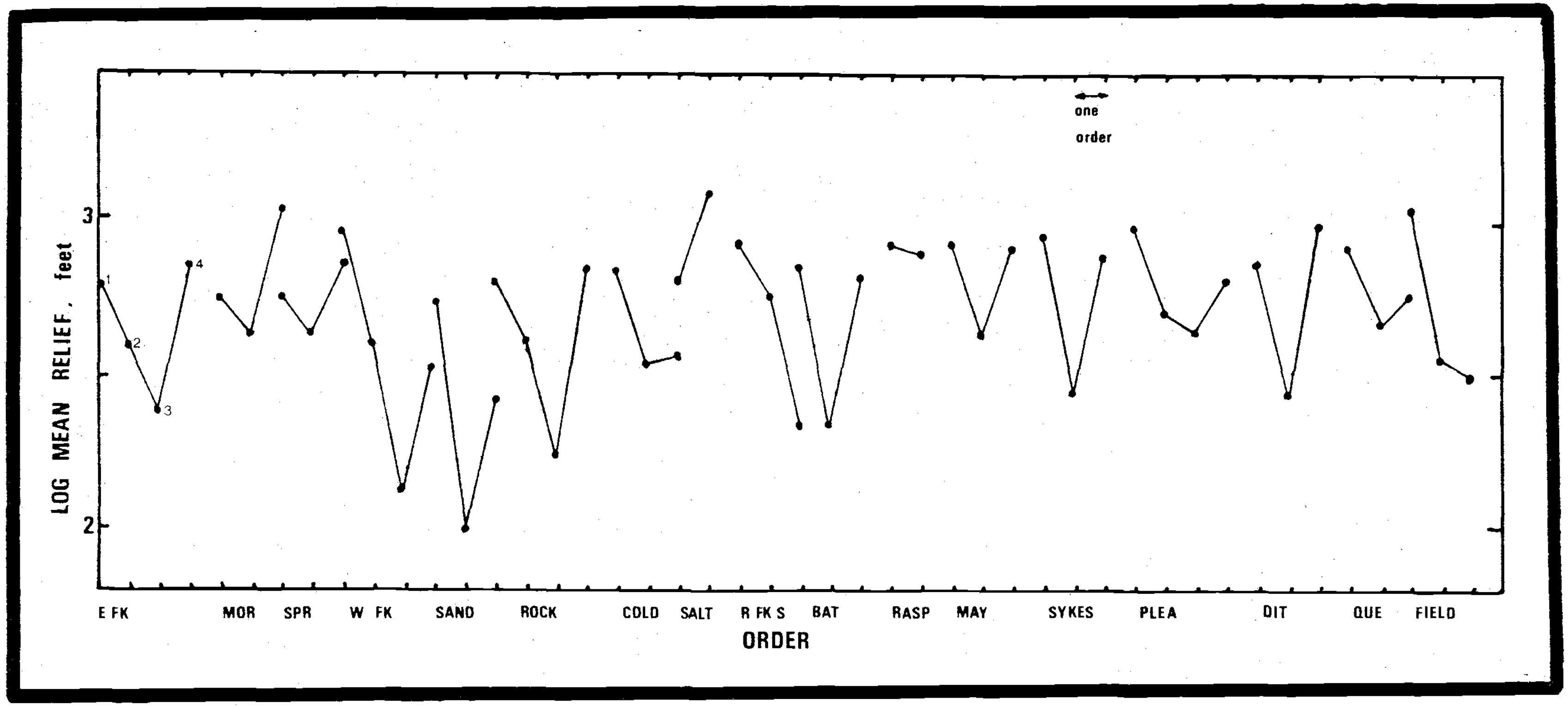

Figure 23. Diagram showing log mean relief versus order for streams in Evans Creek.

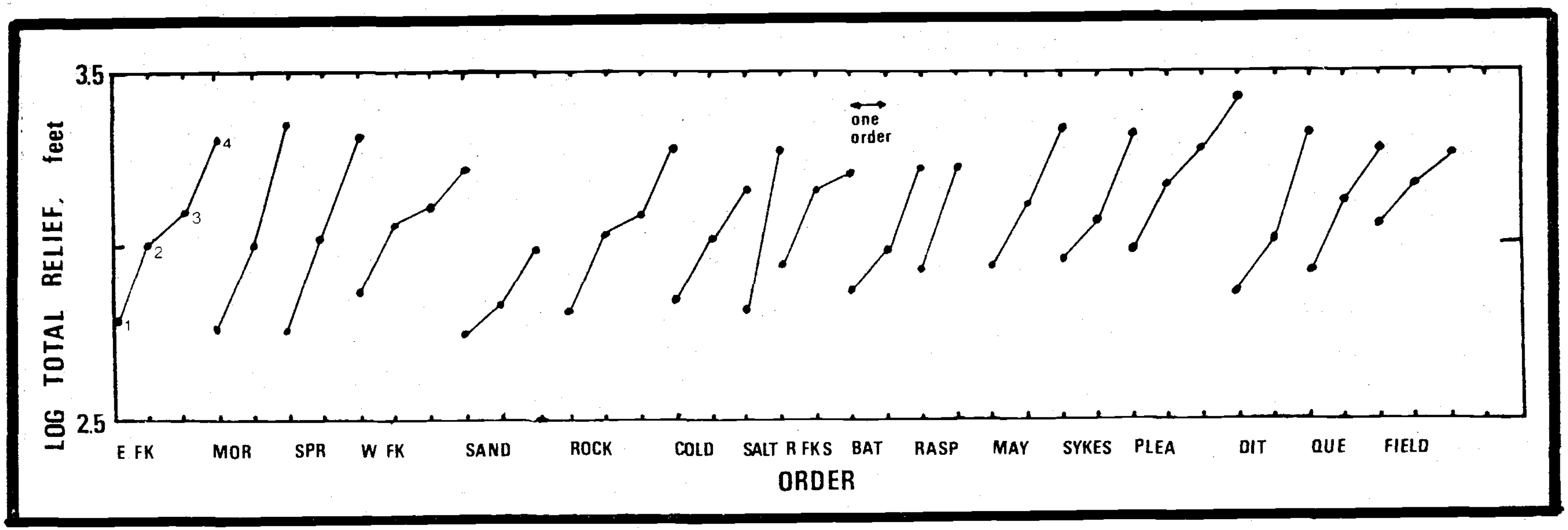

Figure 24. Diagram of log total relief versus order for streams in Evans Creek.

Relief Ratio

In order to relate the relief of a basin to the size of the basin, Schumm (1954) proposed the relief ratio, defined as the total relief of a basin divided by the maximum length of the basin measured parallel to the major drainage lines within the basin. It is therefore a measure of the overall slope of the watershed surface. Relief ratios were computed following Schumm's guidelines and are presented in Table 20.

Schumm (1954, 1963) has shown that the relief ratio is related to stream gradients, drainage density, slope gradients and basin shapes. He has also found that a positive exponential relationship exists between mean annual sediment losses and the relief ratio, and believes that it applies to climatic and topographic regions other than those he studied. Strahler (1957) hypothesized that it would be possible to evaluate sediment loss as a function of landform geometry, climate and hydrology. Lustig (1964) used quantitative geomorphic data to estimate long term sediment yields in the absence of hydrologic data.

Relative Relief

Melton (1957) and Maxwell (1960) have proposed dimensionless relief indices of the same name. Melton's relative relief factor is defined by the ratio of the maximum relief of a basin to its parameter. Maxwell's relative relief factor is defined by the ratio of the maximum relief of a basin to its diameter or width. Values for both relative relief factors were computed and are presented in Table 20.

Ruggedness Number

While exploring the relationships among the factors which control drainage density, Strahler (1958) devised a useful dimensionless index he called the Ruggedness Number, defined as the product of drainage density and relief. Its utility lies in the fact that it relates to both the length and steepness of the slopes of a watershed. Though a single number may represent a variety of conditions, the ruggedness number relates directly to slope erosion processes and may serve as a relative erosion index. Values were computed following Strahler's guidelines and are presented in Table 20.

Longitudinal Profiles

Longitudinal profiles of streams in the Evans were derived by plotting the change in elevation along the stream as a function of distance downstream. The resulting graphs were then broken into segments corresponding to the stream order classification (Figures 25-28). The graphs also show where the individual tributaries are input to mainstem streams.

In general, all the streams exhibit a marked concave upward form. Convexity is evident, however, in the headwaters of several of the streams, and lower down, as the streams cut across lithologies of varying resistance. Knickpoints are evident on almost every profile, and form where rocks of varying resistance erode differentially; and where igneous dikes, and sills cross the stream channel.

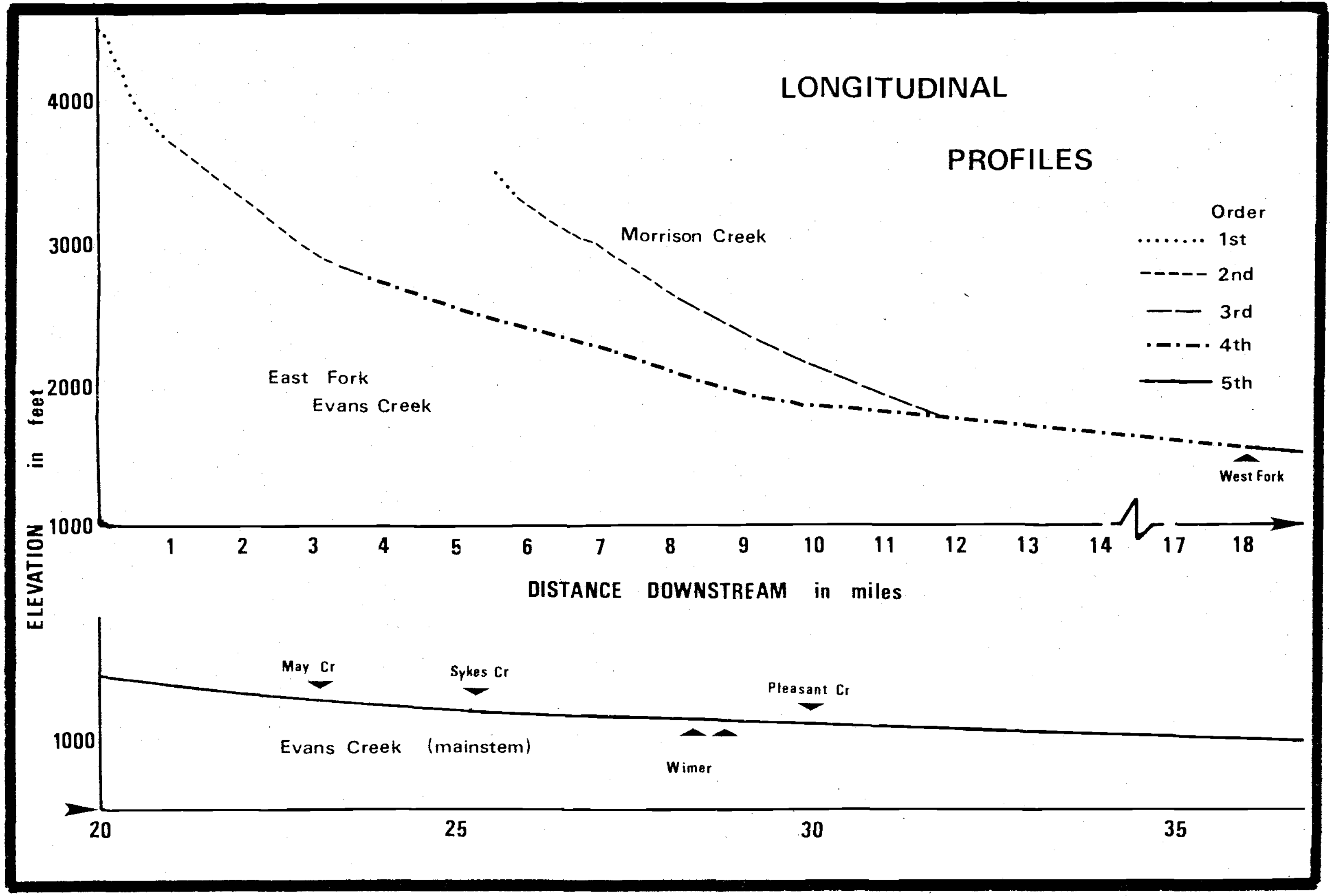

Figure 25. Longitudinal profiles of selected streams in Evans Creek.

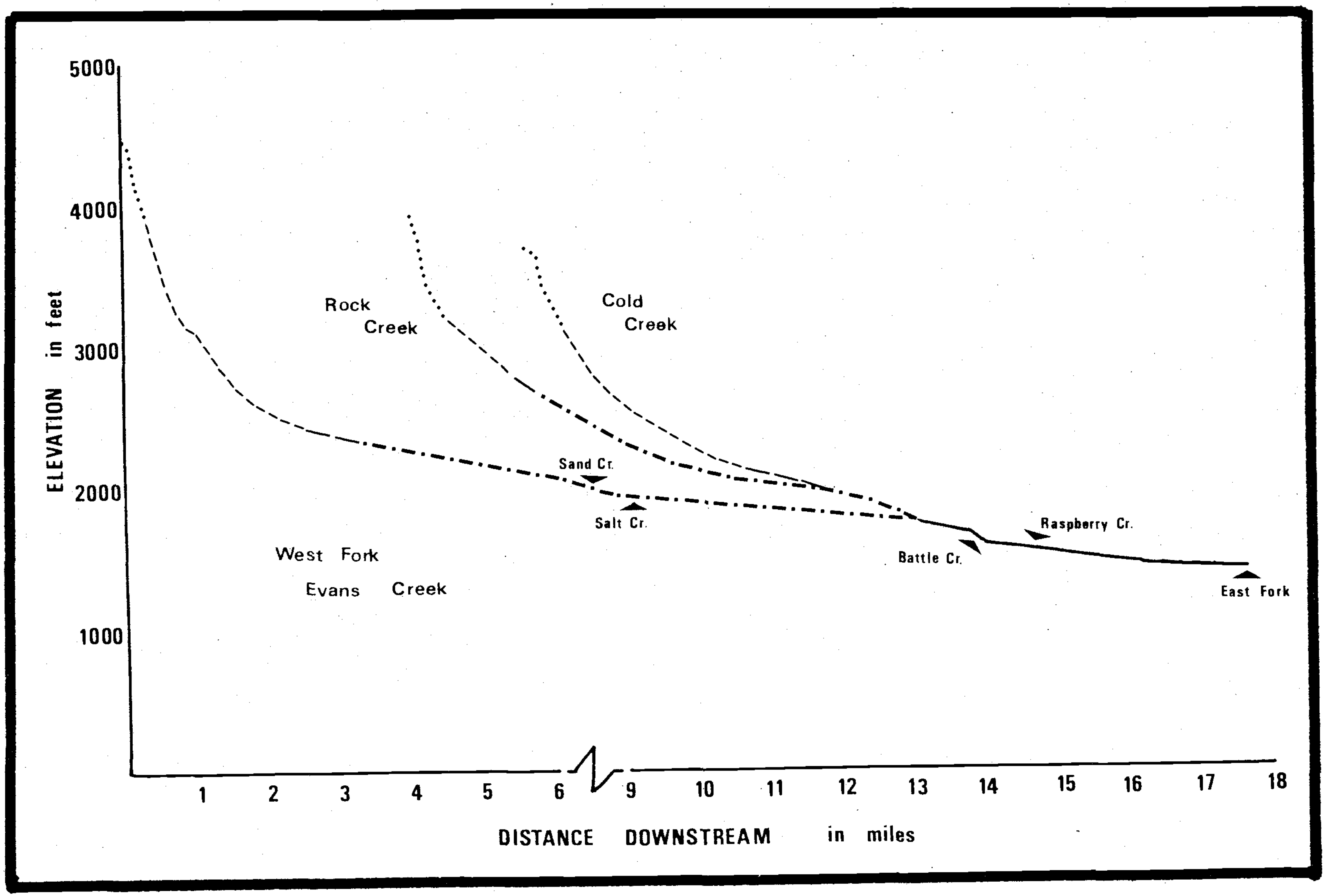

Figure 26. Longitudinal profiles of selected streams in Evans Creek.

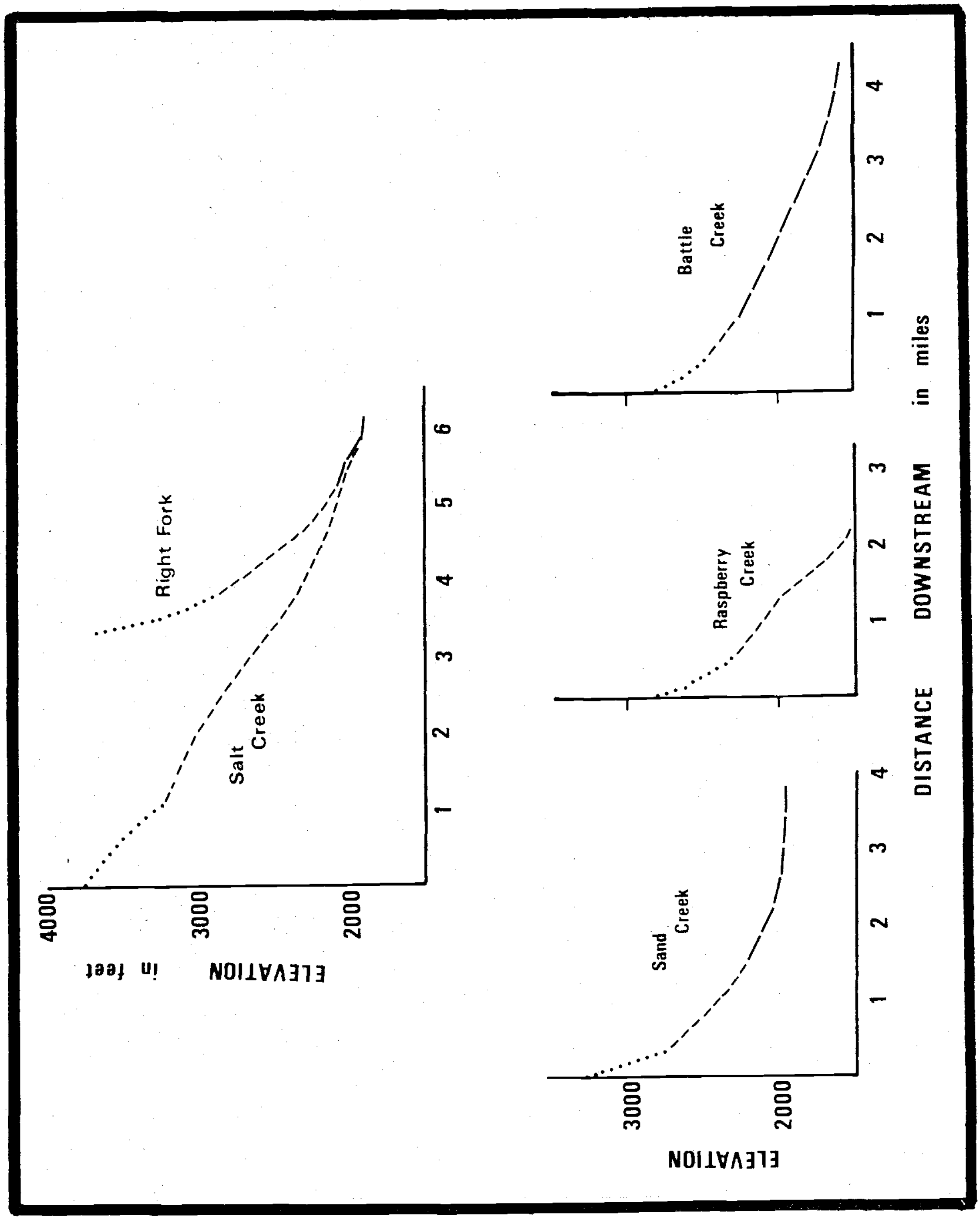

Figure 27. Longitudinal profiles of selected streams in Evans Creek.

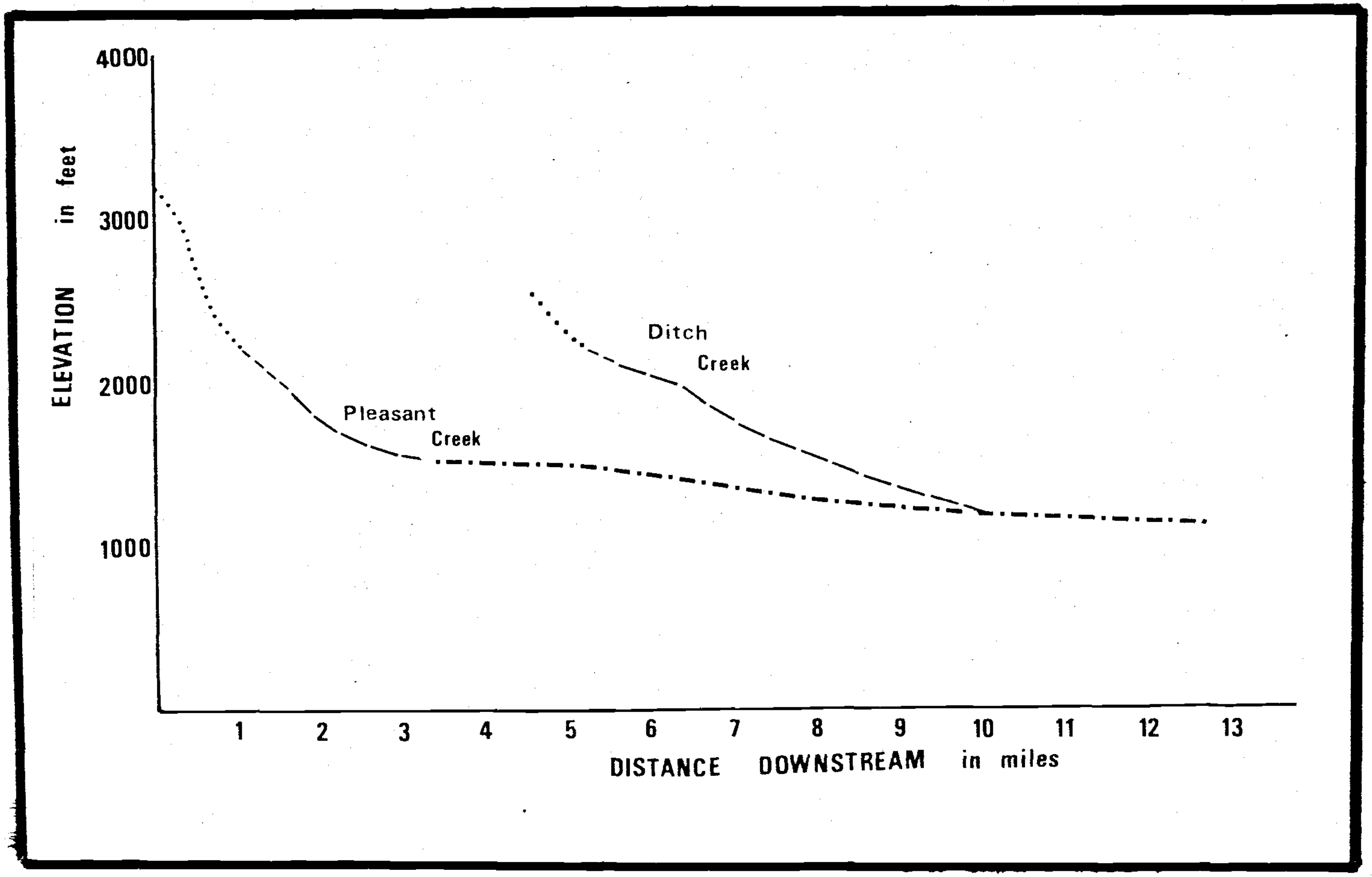

Figure 28. Longitudinal profiles of selected streams in Evans Creek.

Hypsometric (Area-Altitude) Analysis

Hypsometric Analysis, developed by Langbein (1947) and expanded upon by Strahler (1952, 1954, 1957, 1958, 1964), relates the relative horizontal cross-sectional area of a drainage basin to the relative elevation of the basin above its outlet. The percentage hypsometric curve relates the area enclosed by the parameter of a basin, and a given elevation contour to the elevation of the contour and the max relief of the basin. Thus, two ratios are involved: 1. the ratio of relative area to total area (a/A-placed on the X axis; and 2. the ratio of relative height to total height or relief (h/H-placed on the Y axis). (Strahler 1952). The Hypsometric Integral is defined as the relative area lying below the curve.

Percentage hypsometric curves were formulated for nine streams and are presented in Figure 29. The hypsometric integrals are given next to each creek.

Hypsometric functions are indicative of the steady state to which a drainage basin adjusts. The differences revealed between curves of different streams is due to the nature of long term erosional and degradational processes. The hypsometric integral represents how much of the original reference landmass remains. The hypsometric curve implies the nature of the equilibrium attained and the degree of drainage basin development.

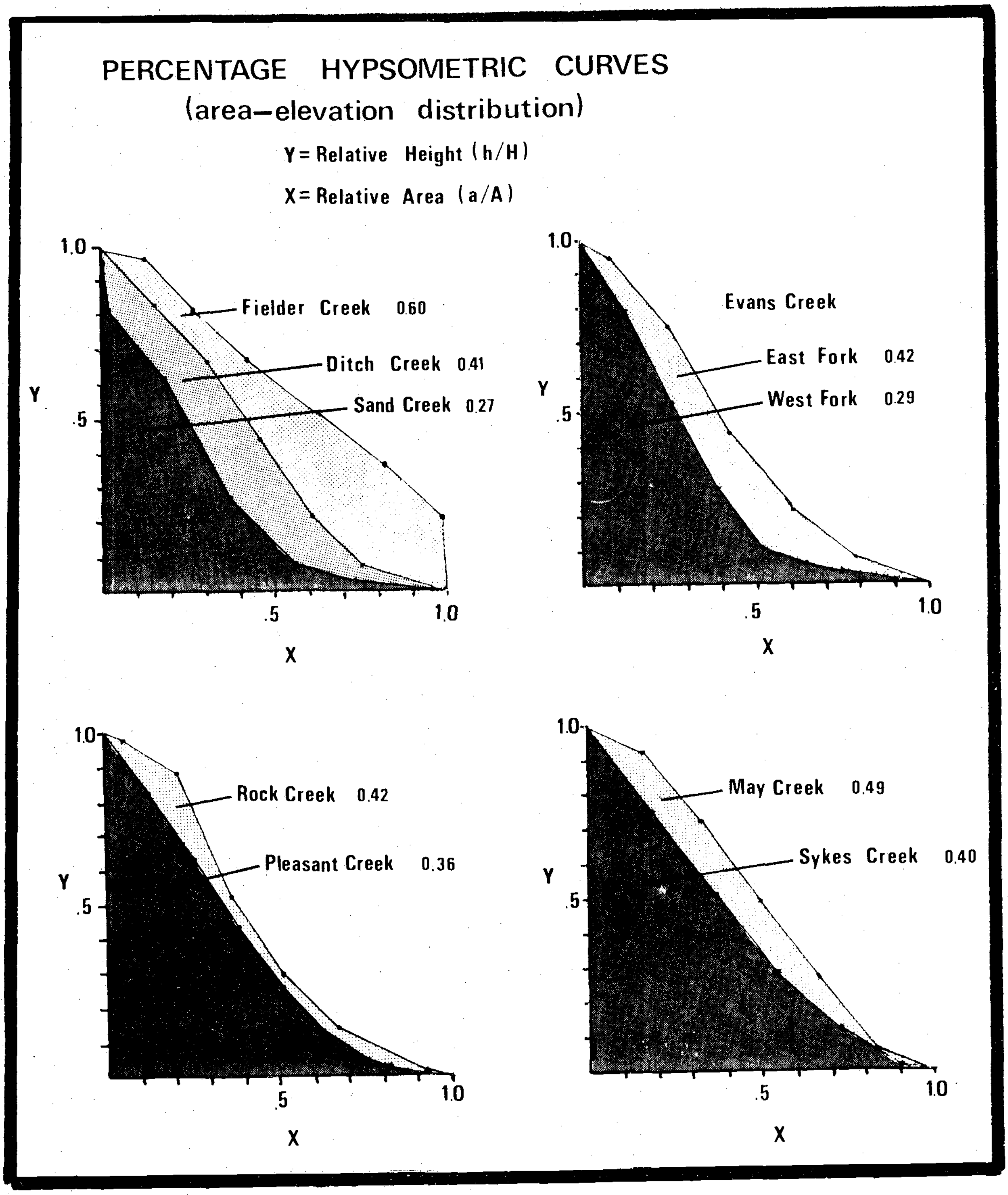

Figure 29. Percentage Hypsometric (area-elevation) curves for selected streams in Evans Creek.

The curves can also be used to compare the differences in elevation distribution between watersheds. Fielder Creek has 67% of its horizontal area above its median elevation; Ditch Creek 42%, Sand Creek 26%, East Fork 39%, West Fork 28%, Rock Creek 39%, Pleasant Creek 35%, May Creek 50%, and Sykes Creek 38%.

These values are also in keeping with the percentages of area of each watershed in the higher slope classes (Table 22).

Channel Slope of a Given Order

The mean channel slopes of a given order (Table 21) were calculated by dividing the mean relief of a given order by the mean length of a given order. This data was graphically portrayed (Figure 30) in order to see if the streams conformed to Horton's "Law of Stream Slopes". Qualitatively, this law states that stream slopes vary inversely with stream order.

The graphs indicate that stream slopes generally decrease with increasing order and thus follow Horton's law fairly closely. The linearity expressed by some of the streams is better for some streams than for others. Cold Creek is the only stream that exhibits a distinctly anomylous character in that its third order stream is steeper than its second order stream.

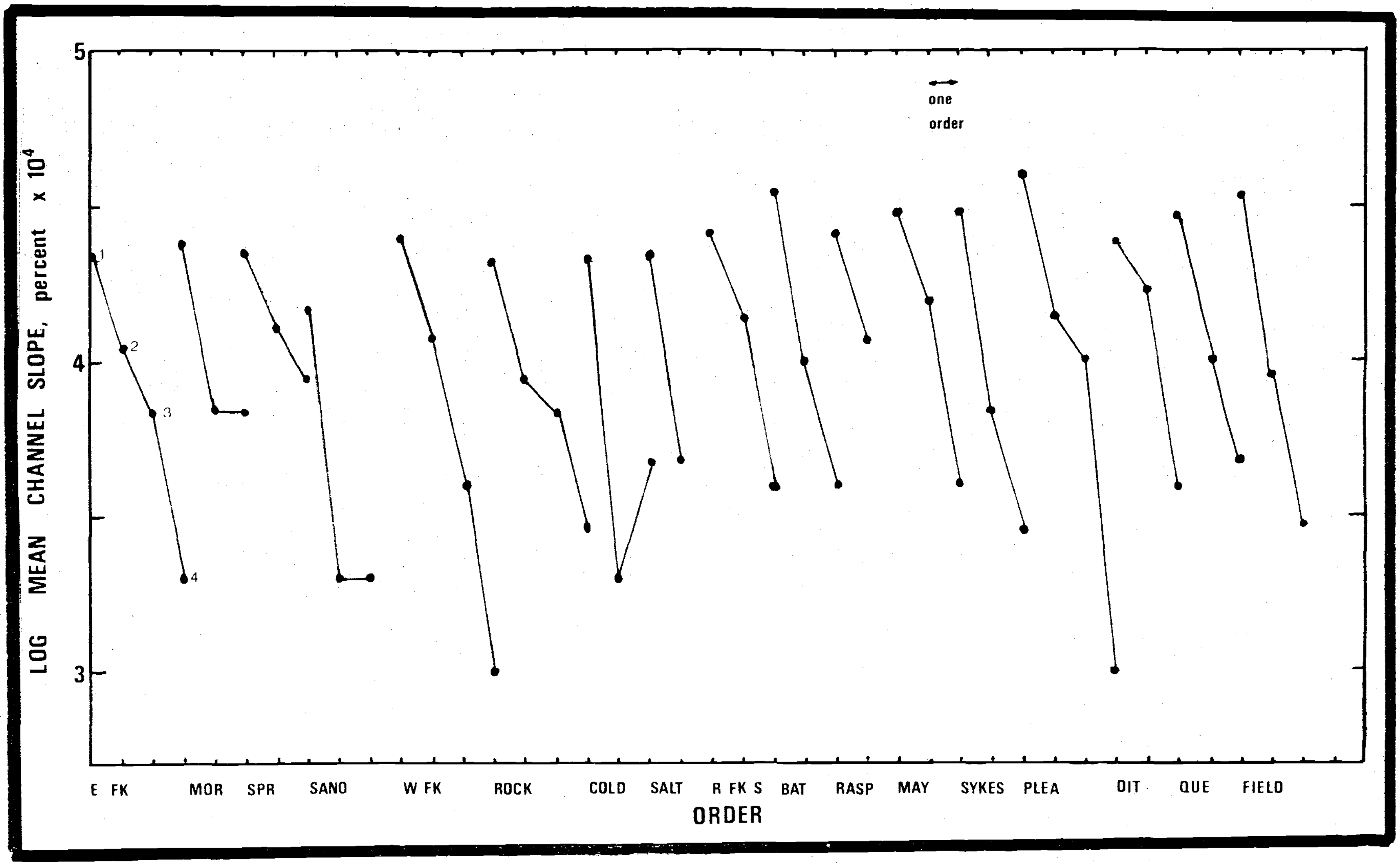

Figure 30. Diagram of log mean channel slope versus order for streams in Evans Creek.

Ground Slope

A slope map of the Evans Creek basin, prepared by Gary Beach at the Oregon Department of Environmental Quality, was used to generate ground slope data. The DEQ slope classification system consists of five classes: I - 0-3%, II 3-12%, III 12-35%, IV 35-60% and V 60%+. The areas of each individual slope polygon was determined using a Keuffel and Esser polar planimeter and was related to the total area of each basin. The areas of a basin by slope class and the percentage of a basin by slope class are presented in Table 22 .

TABLE 22. GROUND SLOPE FACTORS IN EVANS CREEK WATERSHEDS

	Ground Slope Factors									
	Area by Class (Mi^2)					Area (%)				
Catchment	I	II	III	IV	V	I	II	III	IV	V
East Fork Evans (above Morrison)		1.74	15.77	5.77	1.03		7.2	64.9	23.8	4.2
Morrison		.12	4.03	2.53			1.8	60.3	37.8	
Sand		.25	2.29	.47			8.3	76.1	15.6	
West Fork Evans (above Sand)		1.92	11.25	5.25	.24		10.3	60.3	28.1	1.3
West Fork Evans (Sand to Rock)		.58	3.38	.99	.10		11.5	66.9	19.6	1.9
Rock		.11	7.14	2.84	.10		1.1	70.1	27.9	1.0
Cold		.03	2.95	1.66			1.0	63.6	35.8	
Rock (Rock to Cold)		.09	.13	.04			34.6	50.0	15.4	
Salt			3.69	1.08	.05			76.6	22.4	1.0
Right Fork Salt			1.78	1.49	.10			52.8	44.2	3.0
Battle			2.83	1.76	.23			58.7	36.5	4.8
Raspberry		.02	1.02	.75	.10		1.1	54.0	40.0	5.3
May		.38	3.77	2.44	.50		5.4	53.2	34.4	7.1
Sykes		.33	4.67	3.74	.30		3.7	51.7	41.4	3.3
Pleasant (above Ditch)		2.75	14.72	5.59	.05		11.9	63.7	24.2	0.2
Ditch		1.36	3.96	2.94	.22		16.0	46.7	34.7	2.6
Fielder		.26	2.30	3.03	.81		4.1	35.9	47.3	12.7

SHAPE ASPECTS

Shape is useful in qualitatively describing the distinctive form of geographic features. There are, however, very few quantitative measures of shape that convey meaningful information. The shape of a drainage basin can be significantly influenced by several properties of the environment, particularly climate and lithology. The five quantitative measures of drainage basin shape used in this section are summarized in Table 23.

TABLE 23. SHAPE ASPECTS OF A DRAINAGE BASIN

MORPHOMETRIC PARAMETERS	SYMBOL	DERIVED BY	UNITS	REFERENCES
Compactness	L	$p/2\sqrt{\pi A}$		Gravelius (1914), Horton (1932)
Basin Circularity	R_c or C	$4\pi A/p^2$	D	Miller (1953), Gregory and Walling (1973)
Basin Elongation	R_e or E	$2\sqrt{A/\pi/L}$	D	Schumm (1956)
From Factor	F_f	A/L^2	D	Horton (1932)
Shape Factor	S_f	A/L	L	Horton (1945)
Lemiscate	K	$(L^2\pi)/4A$	D	Chorley, Malm, Pogorzelski (1957)

Compactness Ratio and Basin Circularity

Compactness, introduced as a shape factor by Gravelius (1914), is defined by the ratio of the perimeter of a drainage basin to that of a circle of equal area. Basin Circularity, proposed by Miller (1953), is very similar in that it compares the area of a drainage basin to that of a circle with the same perimeter. Basin circularity is therefore equivalent to the square of the inverse of the compactness ratio. A major criticism of both these factors, is that the ratios may be the same for two drainage basins identical in form but with the stream outlets in different positions (Horton 1932, Gregory and Walling 1973). Compactness ratios and basin circularity values are presented in Table 24.

TABLE 24. SELECTED SHAPE ASPECTS OF EVANS CREEK WATERSHEDS

	Compactness C	Basin Circularity C	Shape Factor S_f	Form Factor F_f	Elongation EL	Lemniscate K
East Fork Evans	1.51	.48	2.87	.16	.45	4.83
East Fork Evans	1.49	.45	2.19	.20	.25	3.92
Morrison	1.52	.43	1.09	.17	.47	4.62
Springett	1.27	.62	1.16	.32	.64	2.45
West Fork Evans	1.31	.58	3.58	.20	.51	3.92
Sand	1.34	.56	.83	.24	.55	3.27
West Fork Evans	1.35	.55	2.30	.20	.51	3.86
Rock	1.15	.76	2.05	.29	.61	5.84
Cold	1.41	.50	1.04	.23	.55	3.42
Salt	1.56	.41	.75	.12	.39	6.75
Right Fork Salt	1.15	.76	1.27	.49	.79	1.60
Battle	1.28	.61	1.24	.32	.64	2.45
Raspberry	1.18	.72	.98	.54	.83	1.45
Evans Creek						
May	1.28	.61	1.37	.26	.58	3.02
Sykes	1.40	.51	1.23	.17	.47	4.62
Pleasant	1.49	.45	3.41	.26	.57	3.02
Pleasant	1.26	.63	2.24	.22	.53	3.58
Ditch	1.41	.50	1.52	.27	.59	2.92
Queen	1.51	.44	1.53	.42	.73	1.88
Fielder	1.14	.77	1.78	.50	.80	1.57

Shape Factor and Form Factor

The shape factor, defined by Horton (1932), is the ratio of the width of a basin to the length of a basin. The form factor, also defined by Horton (1932), is the drainage area in square miles divided by the length of the basin squared. The form factor is a useful dimensionless parameter that can be used in connection with maximum flood discharge formulas to index the flood regimes of certain types of streams (particularly those in long, narrow drainage basins). The reciprical of the form factor has been used as a shape factor by the Corps of Engineers (Gregory and Walling, 1970). Shape factors and form factors were computed and are presented in Table 24.

Basin Elongation and Lemniscate

Schumm (1956) proposed the use of elongation as a shape factor and defined it as the ratio of the diameter of a circle with the same area of a basin, to the length of the basin. Elongation suffers from the same problem that plague the compactness ratio and basin circularity. Another objection is that it compares the shape of a drainage basin with that of a circle, whereas most drainage basins are tear-drop or pear-shape.

In order to overcome this latter problem, Chorley, Malm and Pogorzelski (1957) proposed a lemniscate factor which measures how closely a drainage basin shape approaches that of its ideal lemniscate (tear-drop or pear-shaped) counterpart. The lemniscate constant (K) is derived by dividing pi (π) times the length of the basin squared by four times the area of the basin. The higher the value of K, the more elongated the pear shape. When K equals unity, the shape is circular.

V. STATISTICAL ANALYSIS

METHODS OF ANALYSIS

The analysis of channel stability and quantitative basin morphology initially required the design and construction of a computerized data matrix which would facilitate rapid statistical testing. Individual channel stability ratings were: 1. grouped by the land use/cover type classification and 2. identified by the watershed in which the CSR was performed. Calculated or measured values for each of the morphometric parameters were organized in a way that complimented the channel stability rating data sets with respect to watershed identifiers.

A simple linear regressions analysis technique was then used to determine whether relationships between channel stability and basin morphology exist. The 47 morphologic parameters (independent variables) were regressed against each set of channel stability land use/cover type data (dependent variables), with no transformations. Over 240 regressions and product moment correlations were produced. The analysis was performed at the Oregon State University, Milne Computing Center in Corvallis, using the Statistical Interactive Programming System (SIPS).

RESULTS OF ANALYSIS

Scatter diagrams of channel stability versus morphologic variables showed varying degrees of linearity. A trend indicating either an inverse or direct relationship, was apparent on scatter diagrams with product moment correlations of ±0.40. As the correlation coefficient approaches unity, the linearity becomes more and more pronounced and the scatter of the points is reduced.

Channel stability has been found to vary inversely with fourteen and directly with six morphologic perimeters. The morphologic variables that correlated with channel stability with coefficients of at least ±0.40 are presented in Table 25. All of the correlation coefficients are significant at $\alpha = 0.10$. The single variable correlation coefficients presented range from ±0.40 to ±0.94. Morphology is seen to correlate more frequently with channel stability in land use/cover type classes '3', '5', '4' and '1', in that order (refer to Table 4). Land use (cover type class '6' did not correlate with any of the morphometric parameters.

TABLE 25. RELATIONSHIPS AND REGRESSION CORRELATION COEFFICIENTS BETWEEN CHANNEL STABILITY AND MORPHOLOGIC VARIABLES

MORPHOLOGICAL PARAMETER	SYMBOL	CSR LAND USE/ COVER TYPE*	CORRELATION COEFFICIENT
AREAL ASPECTS			
Number of 3rd Order Streams	N_3	5	-0.54
Bifurcation Ratio 3rd/4th Order Streams	R_{bN_3/N_4}	2	-0.47
		3	-0.72
		5	-0.91
LINEAR ASPECTS			
Mean length of 1st Order Streams	$\bar{L}_1$	3	+0.59
		4	+0.47
Mean length of 3rd Order Streams	$\bar{L}_3$	3	-0.46
		4	-0.40
Length Ratio 1st/2nd Order Streams	$\bar{L}_1/\bar{L}_2$	2	+0.40
Length ratio 2nd/3rd Order Streams	$\bar{L}_2/\bar{L}_3$	3	+0.48

*Refer to Figure 4.

TABLE 25. (continued)

MORPHOLOGICAL PARAMETER	SYMBOL	CSR LAND USE/ COVER TYPE*	CORRELATION COEFFICIENT
Total Length of 3rd Order Streams	ΣL_3	3	-0.56
		4	-0.49
		5	-0.66
Total Length of 4th Order streams	ΣL_4	2	-0.48
		3	-0.81
		5	-0.94
Length to Bifurcation Ratio	R_l/R_b	5	+0.67
TEXTURAL ASPECTS			
Drainage Density	Dd	3	-0.64
Constant of Channel Maintenence	C_m	3	+0.65
		5	+0.40
Stream Frequency	F_s	3	-0.60
		5	-0.43
Drainage Intensity	D_i	3	-0.61

*Refer to Figure 4.

TABLE 25 . (continued)

MORPHOLOGICAL PARAMETER	SYMBOL	CSR LAND USE/ COVER TYPE*	CORRELATION COEFFICIENT
RELIEF ASPECTS			
Total Relief	H	3	-0.43
Relief of 3rd Order Streams	H_3	3	-0.66
		4	-0.64
		5	-0.68
Scope of 1st Order Streams	$\bar{S}_1$	4	-0.50
Slope of 3rd Order Streams	$\bar{S}_3$	2	-0.57
		3	-0.47
		5	-0.60
SHAPE ASPECTS			
Form Factor	$A/_L 2$	3	-0.41
Elongation	El	4	-0.44

*Refer to Figure 4 .

DISCUSSION OF RESULTS

The channel stability of streams under a variety of land use conditions has been related to several morphologic characteristics of drainage basins. The following examination of these relationships relies upon concepts and principles presented earlier in this paper, concerned with: 1. how the CSR represents erosional and depositional features and processes and 2. how basin morphologic properties influence basin form and process.

Channel stability was found to be directly related to the mean length of first order streams ($\bar{L}_1$) and to the length ratios of order one to order two, and order two to order three. These parameters seem to indicate that the size of the contributing area has an effect on channel stability. Channel stability ratings are higher (and thus more unstable) when longer streams flow into shorter streams.

Total Relief (H) and the length to bifurcation ratios (R_1/R_b) were also found to have a positive influence on channel stability. The former relationship is in keeping with the findings of Schumm (1954), and Maner (1958) and others, who have shown that sediment factors vary directly with relief. The latter relationship is in accord with Horton's (1945) discussion of the relationship between the length to bifurcation ratio, channel storage capacity, and flood regimes. While the relief factor influences the amount of potential energy input to the basin, the length to bifurcation ratio relates to the way in which potential energy is expended in the stream. The CSR is evidently sensitive to these influences.

Channel stability was found to be inversely related to the number of third order stream (N_3), to the bifurcation ratio of third to fourth order streams, and to the total length of third and fourth order streams. It is possible that the potential energy of the precipitation input to a basin is divided up among the streams in a basin. When there are a higher number of third order streams, the division of available energy is that much greater, leaving less energy to drive channel processes in each stream. Channel stability is lower when third and fourth order streams are longer. Channel stability is evidently conditioned by the distance water and eroded materials must be transported between the upper and lower points in a watershed.

Textural indices of basin morphology, namely, drainage density, stream freqency and drainage intensity were found to be inversely related to channel stability. The constant of channel maintenance, being the inverse of drainage density, had a positive correlation. These relationships are also indicative of the effect of contributing area on channel stability. When the contributing area per unit length of stream is high, channel stability ratings are also high. When the length or number of streams per unit area is high, there is a greater division of the potential energy input by precipitation. Thus, less energy is available to drive sedimentation processes in each stream and channel stability scores are subsequently lower.

Channel stability has been found to be inversely related to the relief of third order streams, the slope of first order-streams and the slope of third order streams. In third order streams, high relief occurs in V-shaped valleys while low relief occurs in wider, flatter valleys. Streams in V-shaped valleys are usually steep and have downcut to bedrock. Channel stability ratings under such conditions are characteristically low because of the way in which the CSR weights deposition factors. Streams in broad, flat valleys have lower gradients, a greater potential for lateral energy expenditure, and increased deposition. Channel stability scores are therefore higher.

Lithology exerts an influence on the slope of first order stream channels which is reflected in the channel stability scores. Streams in the geologic terrain unit "Prone to Chemical Weathering" have lower gradients, and are more easily eroded, have higher CSR's than streams in "Stable Bedrock," which have higher gradients, are more resistant to erosion and have lower CSR's. When gradients are lower deposition is favored over transportation and higher channel stability scores result.

Regressions analysis also indicated that there are relationships between channel stability and basin shape indices: Form Factor (F_f) and Elongation (E_1). Channel stability ratings are lower in long, narrow watersheds and are higher in shorter and wider watersheds.

VI. CONCLUSIONS

CHANNEL STABILITY EVALUATION

1. There are statistically significant differences in the channel stability ratings of stream reaches under a variety of land use conditions. Channels tend to be more unstable when they have experienced direct impact from frequent and extensive tractor logging operations. Channel stability improves as the time since the disturbance increases. Logging impacts are greater when streamside vegetation is disturbed.

2. There are statistically significant differences in the channel stability ratings of stream reaches under a variety of lithologic conditions. Channels in highly weathered, weakly resistant parent materials tend to be more unstable than those in more resistant lithologies.

3. The channel stability rating procedure is capable of perceiving differences in channel conditions resulting from the combined influence of land use and lithology. Vegetation in the stream is found to have a stabilizing influence on channel stability regardless of geologic parent material.

4. The channel stability rating procedure perceives sediment sources and deposition in the channel differentially. Deposition factors almost always contribute a greater amount to the overall channel stability rating of a

given reach. A single channel stability rating may thus represent a variety of conditions with respect to channel erosion and deposition.

5. Sediment sources and deposition may not vary directly with one another along the hydrologic continuum. Erosion and deposition may be different from one channel reach to the next. While sediment sources tend to decrease in a downstream direction, deposition may increase, decrease or show no general trend in any direction.

QUANTITATIVE BASIN MORPHOLOGY

1. Morphometric techniques have been used to evaluate the physical attributes of 21 catchments in the Evans Creek basin. Analysis of the results indicates that there is considerable variation in the morphology of the basins. Differences between watersheds reflect adjustments made in each basin in response to processes that have been operating on a geologic time scale. Lithologic influences are readily apparent and are reflected in the geometric similarity of watersheds in similar geologic parent materials. Geologic structural controls are generally not apparent in the watersheds of the basin.

2. The streams in the Evans Creek basin are found to conform reasonably well to the "Laws of Basin Morphometry": Horton's "Law of Stream Numbers, Stream Lengths and Channel Slopes"; Strahler's "Revised Law of Stream Lengths"; and Morisawa and Fok's proposed "Laws of Basin Relief."

QUANTITATIVE BASIN MORPHOLOGY AND CHANNEL STABILITY

1. Channel stability ratings for streams in the Evans Creek basin have been successfully related to several morphologic characteristics of the watersheds using linear regressions techniques. Channel stability has been found to vary inversely with 14 and directly with six morphologic variables. Single variable correlation coefficients range from 0.40 to 0.94.

2. Channel stability has been found to be directly related to aspects of the drainage basin which describe the size of the contributing area, and the overall height of the watershed.

3. Channel stability has been found to be inversely related to the number of higher order streams in a basin and to basin textural indices.

4. Channel stability has been found to be inversely related to the relief of third order streams and to the slope of first and third order streams. These results are evidently based upon the way in which the Channel Stability Rating procedure perceives erosional and depositional processes.

5. Channel stability has also been related to basin shape factors. Channel stability ratings tend to be lower in long, narrow watersheds and higher in shorter, and wider watersheds.

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APPENDICES

A. DEQ PHYSICAL AND BIOLOGICAL RATING FORM

B. CHANNEL STABILITY DATA

C. CHANNEL STABILITY DATA - SEDIMENT SOURCE AND DEPOSITION FACTORS

APPENDIX

A

DEQ PHYSICAL AND BIOLOGICAL RATING FORM

GENERAL PHYSICAL STREAM DESCRIPTION

Segment Specific

Sample site:________________________ Located in____Sec_____ R_____ T_____

upstream, downstream_____miles

Date: ______________________ Rater(s):________________________

Basin: ______________________ Subbasin: ________________________

Stream Name:______________________ Stream Order:________________________

River Mile: ______________ to River Mile: ______________________

Stream Mouth in: TWP.__________R. __________ S. ______________

Avg. width of Channel: __________ Avg. width of Water Surface:__________

Pool/riffle ratio: __________ Avg. depth: ______________________

Water velocity: __________ Gradient: ______________________

Water temperature: __________ Air temperature: ______________________

Time: ______________________ Weather: ______________________

Terrain unit:__________________

(Circle one or more)

Bottom type is: bedrock, boulder, cobble, gravel, sand, silt/mud

Stream is: braided, straight, slightly meandering, meandering

Channel is: U-shape, V-shape, rectangular

Water is: clear uncolored, clear colored, slightly turbid, moderately turbid, highly turbid

Surrounding land uses: cultivated, grazed, irrigated, dryland, coniferous forest, deciduous forest, grasses, scrub growth, urban

Upstream uses: forestry, agriculture, grazing, industrial, urban

Streamside cover type: coniferous old growth, coniferous 2nd growth, coniferous logged 0 - 5 years, coniferous logged 6 - 10 years, herbaceous, deciduous

Fish species present: ChF, ChS, StW, StS, Co, Rb, Ct, CtS, Bk, Br,
WW__________,
RF______________, other________________________

Forest Practices stream classification: 1, 2

Notes:

8/77

PHYSICAL AND BIOLOGICAL STREAM RATING

COMPONENT	NO IMPACT	MODERATE IMPACT	SEVERE IMPACT
SUBSTRATE Circle appropriate substrate type found in this reach.			
MUD/SILT	Natural bottom type located in low velocity water. Bottom is compact.	Substrate is soft showing evidence of silt movement from year to year.	Bottom shows another substrate was once present.
GRAVEL	Gravel area clean, interstitial spaces clean. Size distribution appears to be normal for the kind of hydraulic forces for stream of this size and location in the watershed. (R)	Interstitial areas showing some filling. Moderate shift in rock mixture in comparison to baseline co dition in same area as a result of scouring or filling.	Gravel underlying another substrate showing evidence that substrate type completely changed or banks show scour with resulting overturn of gravel or elimination of portions of gravel.
BOULDER/ COBBLE	Boulder/cobble area clean showing large interstitial spaces.	Some shift in rock mixture such as sand or gravel accumulating within interstitial areas.	Boulders or cobble present from outside source such as upstream scour or large shift in mixture.
BEDROCK	Bedrock substrate natural in origin fits geologic processes indigenous to area.		Evidence or documentation showing area has been scoured to bedrock, another substrate was present before scour occurred.
SPAWNING GRAVEL	This section used only when rating gravel 1to 5 inches in diameter, at least 6 inches deep and situated such in the stream that it would be utilized for spawning. ----- Gravel pourous silt and sand minimal.	Gravel starting to compact showing a moderate build up of sand and silt in interstitial spaces. Gravel becoming difficult to dig into with foot, making it difficult for fish to spawn or reducing survival rate of eggs or alevins.	Gravel compacted with silt and sand making it very difficult or impossible to dig more than 2-4 inches with foot, thus making it impossible for fish to spawn or seriously reducing survival rate of eggs or alevins. Or, gravel underlying silt or sand.

PHYSICAL AND BIOLOGICAL STREAM RATING

COMPONENT	NO IMPACT	MODERATE IMPACT	SEVERE IMPACT
SILTATION **Effect on rearing**	None. Transition zones normal for velocity and gradient of this section.	Moderate amount of silt on bottom. Quiet water areas show moderate silt build up. Transition zones and interstitial areas beginning to fill, which results in a moderate reduction of instream fish cover.	Silt completely covering bottom. Quiet water areas show major silt build up. Interstitial areas filled or transitional zones show major build up, resulting in a serious reduction of instream fish cover or, rock/cobble three quarters imbedded resulting in a change in insect population.
MASS WASTING	No evidence of mass wasting that has or could reach channel. (R)	Frequency and/or magnitude of the mass wasting situation increases, or some raw spots visible that can be eroded by water during high flows. (R)	Mass wasting not difficult to detect because of the frequency and/or size of existing problem areas or proximity of banks are so close to potential slides that increase in the flow would cut toe and trigger slides. (R)
VEGETATIVE BANK PROTECTION	Trees, shrubs, grass and/or forks combined cover more than 70% to 100% of the ground. Openings in this nearly complete cover are small and evenly dispersed. Vegetation shows no disturbance. (R)	Plant cover ranges from 50% to 70%. Lack of vigor is evident in some individuals and/or species. (R) Condition shows disturbance when compared to baseline in same watershed.	Less than 50% of ground is covered. Trees are essentially absent. Vegetation consists of scattered clumps. (R) Condition shows severe disturbance when compared to a baseline condition in the same watershed.
DEBRIS JAM POTENTIAL Note whether man induced or natural	Debris may be present on banks but is so situated or is of such size that the stream is not able to push or float it into the channel. (R)	Noticeable accumulation of all sizes and the stream is large enough to float it away. (R) Would cause medium size debris jams downstream.	Heavy accumulation of debris is present on banks. High flows will float some away to form debris jams downstream. The remainder will cause bank erosion or channel changes. (R)

PHYSICAL AND BIOLOGICAL STREAM RATING

COMPONENT	NO IMPACT	MODERATE IMPACT	SEVERE IMPACT
OBSTRUCTIONS AND FLOW DEFLECTORS	Logs and other obstructions to flow are firmly embedded and produce a pattern of flow which does not erode banks and bottom or cause sediment build up. (R)	Moderately frequent and quite often unstable obstructions, cause noticeable seasonal erosion of the channel. Considerable sediment accumulates behind these obstructions. (R)	Obstructions and sediment traps so frequent they are intervisible, often unstable to movement and cause a continual shift of sediments. Since traps are filled as soon as formed, the channel migrates and widens or forms a new channel. (R)
DEBRIS PILES	No large debris piles located in channel. Some single or multiple logs or root wads, etc. may be present in channel but not in form of piles.	Debris piles present, but not forming silt deposits behind and are located in areas where flow can be dissipated around in unconfined channel. Channel not showing evidence of accelerated cutting around debris pile. Debris pile not stopping upstream fish passage but has potential to do so. (R & B)	Debris pile present forming silt build up behind and/or is stopping upstream fish passage. Channel showing evidence of accelerated cutting around debris. (R & B)
STREAMBANK CUTTING	Very little cutting is evident or only intermittent cutting is evident along channel outcurves and at prominent natural channel constrictions. Eroding banks are infrequent. Eroded areas are equivalent in length to one channel width or less. (R)	Significant bank cutting occurs frequently in the reach. Cut banks are signicicant in proportion to stream size. Some bank instream cover still present but cutting shows evidence of eliminating some.	Nearly continuous bank cutting. Size of cuts are highly significant in proportion to stream size. Cutting has smoothed banks eliminating overhangs and other forms of bank instream cover.
INSTREAM AQUATIC HIGHER PLANTS	Rock substrates: Good coverage of moss on rocks and debris in or at water level, no rooted aquatic plants or occasional plant in slow water. If natural lack of shade then no moss on rocks.	Rock substrates: Some attached moss, some rooted plants in slow water.	Rock substrates: No moss present, moderate or heavy growths of floating rooted plants in slow water.

PHYSICAL AND BIOLOGICAL STREAM RATING

COMPONENT	NO IMPACT	MODERATE IMPACT	SEVERE IMPACT
INSTREAM AQUATIC HIGHER PLANTS (continued)	Silt/mud substrates: Rooted aquatic plants. Cattails, water-lilies, rushes, sedges are evidence of stable substrate in slow waters.	Silt/mud substrates: Few rooted aquatic plants. Aquatic vegetation located in areas of stream where deposition is not occurring.	Silt/mud substrates: Lack of rooted aquatic vegetation evidence of continually moving and/or rapid build up of sediment.
ATTACHED ALAGE: **Diatoms:**	None or few yellow-brown patches or thin uniform coating on rocks, no crusting on fine sediment. If silt/mud substrate, then thin brown coating on twigs and grass in water. If stream lacking shade because of natural causes (width, substrate, etc.) then moderate thickness to material coating rocks or mud. If patchy appearance then check for insect grazers. If present then look at thickness of algae where insects few or not present to determine impact.	Moderately thick coating of brown material on rocks, twigs, etc. slight crusting on fine sediment. If stream lacking shade due to disturbed streambank vegetation, then moderate build up of brown coating on rocks.	Thick coating and/or brown streamers on rocks, twigs, grass in water. Heavy crusting to fine sediment.
Filamentous Green Algae:	None present or if late summer or lack of natural shade, then thin patchy layer of green streamers on substrate, twigs or grass in moving water. Do not rate algae found in backwater, stagnant areas.	If late summer or lack of shade due to disturbed streambank vegetation then moderate amount of green streamers. If tufts, then tufts composed of fine sheets.	Long slimy green filaments, heavy consolidated layer on fine sediment. Floating masses of algae near edges of stream in moving water.

PHYSICAL AND BIOLOGICAL STREAM RATING

COMPONENT	NO IMPACT	MODERATE IMPACT	SEVERE IMPACT
Blue-Green Algae:	Not seen with unaided eye.	Some dark green to black layer under diatom layer on substrate. May form firm nodules on rocks.	Dark green layer of filaments on rocks and twigs. Heavy consolidated layer on fine sediment.

PERCENTAGE OF STREAM SHADED

0 10 20 30 40 50 60 70 80 90 100

AQUATIC INSECT COMMUNITY

Comments, samples taken, location of samples

FISH, SPECIES, SIZE AND ABUNDANCE

Species	Size	Number/100 feet 0-5	6-50	50+	Method of Collection	Date

R-1 STREAM REACH INVENTORY and CHANNEL STABILITY EVALUATION

REACH LOCATION: Survey Date______ Time_____ Obs.____________

Forest______________________ Rgr. Dist.________________

P.W.I.

Stream______________________ W/S No. __-__-__-__-__-__-__-__

Reach Description & Other Identification________________________

INVENTORY DATA: (observed or measured on this date) Side 2

Stream Width___ft.X Ave.Depth___ft.X Ave.Velocity___f/s=____Flow cfs

Reach Gradient___%, Stream Order___, Turbidity Level _____, Stream Stage______, Sinuosity Ratio _____,

Temperature °F or °C of: Air____Water____, Others____________________

Item Rated	Stability Indicators by Classes							
	EXCELLENT		GOOD		FAIR		POOR	
UPPER BANKS								
Landform Slope	Bank slope gradient <30%	(2)	Bank slope gradient 30-40%	(4)	Bank slope gradient 40-60%	(6)	Bank slope gradient 60% +	(8)
Mass Wasting (Existing or Potential)	No evidence of past or potential for future mass wasting into channels.	(3)	Infrequent and/or very small. Mostly healed over. Low future potential.	(6)	Moderate frequency & size, with some raw spots eroded by water during high flows.	(9)	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	(12)
Debris Jam Potential (Floatable Objects)	Essentially absent from immediate channel area.	(2)	Present but mostly small twigs and limbs.	(4)	Present, volume and size are both increasing.	(6)	Moderate to heavy amounts, predominantly larger sizes.	(8)
Bank Protection from Vegetation	90% + plant density. Vigor and variety suggests a deep, dense root mass.	(3)	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	(6)	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	(9)	<50% density plus fewer species & less vigor indicate poor, discontinuous, and shallow root mass.	(12)
LOWER BANKS								
Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	(1)	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8-15.	(2)	Barely contains present peaks. Occasional overbank floods. W/D ratio 15-25.	(3)	Inadequate. Overbank flows common. W/D ratio >25.	(4)
Bank Rock Content	65% + with large, angular boulders 12" + numerous.	(2)	40 to 65%, mostly small boulders to cobble 6-12".	(4)	20 to 40%, with most in the 3-6" diameter class.	(6)	<20% rock fragments of gravel sizes, 1-3" or less.	(8)
Obstructions Flow Deflectors Sediment Traps	Rocks, old logs firmly embedded. Flow pattern of pool & riffles stable without cutting or deposition.	(2)	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	(4)	Moderately frequent, moderately unstable obstructions & deflectors move with high water causing bank cutting and filling of pools.	(6)	Frequent obstructions and deflectors cause bank erosion yearlong. Sed. traps full, channel migration occurring.	(8)
Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	(4)	Some, intermittently at outcurves & constrictions. Raw banks may be up to 12".	(8)	Significant. Cuts 12"-24" high. Root mat overhangs and sloughing evident.	(12)	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	(16)
Deposition	Little or no enlargement of channel or point bars.	(4)	Some new increase in bar formation, most from coarse gravels.	(8)	Moderate deposition of new gravel & coarse sand on old and some new bars.	(12)	Extensive deposits of predominately fine particles. Accelerated bar development.	(16)
BOTTOM								
Rock Angularity	Sharp edges and corners, plane surfaces roughened.	(1)	Rounded corners & edges, surfaces smooth & flat.	(2)	Corners & edges well rounded in two dimensions.	(3)	Well rounded in all dimensions, surfaces smooth.	(4)
Brightness	Surfaces dull, darkened, or stained. Gen. not "bright".	(1)	Mostly dull but may have up to 35% bright surfaces.	(2)	Mixture, 50-50% dull and bright, ± 15%, ie 35-65%.	(3)	Predominately bright, 65% +, exposed or scoured surfaces.	(4)
Consolidation or Particle Packing	Assorted sizes tightly packed and/or overlapping.	(2)	Moderately packed with some overlapping.	(4)	Mostly a loose assortment with no apparent overlap.	(6)	No packing evident. Loose assortment, easily moved.	(8)
Bottom Size Distribution & Percent Stable Materials	No change in sizes evident. Stable materials 80-100%.	(4)	Distribution shift slight. Stable materials 50-80%.	(8)	Moderate change in sizes. Stable materials 20-50%.	(12)	Marked distribution change. Stable materials 0-20%.	(16)
Scouring and Deposition	Less than 5% of the bottom affected by scouring and deposition.	(6)	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	(12)	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	(18)	More than 50% of the bottom in a state of flux or change nearly yearlong.	(24)
Clinging Aquatic Vegetation (Moss & Algae)	Abundant. Growth largely moss like, dark green, perennial. In swift water too.	(1)	Common. Algal forms in low velocity & pool areas. Moss here too and swifter waters.	(2)	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	(3)	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	(4)
	COLUMN TOTALS →		→		→		→	

Size Composition of Bottom Materials (Total to 100%)

1. Exposed bedrock.........____%	5. Small rubble, 3"-6".....____%
2. Large boulders, 3'+ Dia....____%	6. Coarse gravel, 1"-3"....____%
3. Small boulders, 1-3'.......____%	7. Fine gravel, 0.1-1".....____%
4. Large rubble, 6"-12".......____%	8. Sand, silt, clay, muck..____%

APPENDIX

B

CHANNEL STABILITY DATA

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Evans Main #1	3	6	4	5	2	7	6	6	12	3	3	4	16	21	2	100
Evans Main #2	6	6	3	2	8	2	7	4	8	2	3	8	16	22	1	110
Evans Main #3	4	3	5	9	3	2	2	12	16	4	3	8	16	24	4	115
Evans Main #4	2	3	3	3	3	6	2	4	16	3	3	2	16	24	3	93
Evans Main #5	2	3	2	3	3	3	2	4	16	4	3	6	14	22	3	90
Evans Main #6	2	3	4	3	2	2	2	4	16	3	3	3	14	24	3	88
Evans Main #7	2	3	3	6	3	6	2	4	16	4	3	8	16	22	4	101
Evans Main #8	2	3	2	6	2	3	3	4	8	3	3	5	12	18	4	78
Evans Main #9	2	3	4	3	3	2	3	4	16	3	3	6	12	22	3	89
Evans Main and confluences of East and West Forks	2	3	2	4	3	2	2	4	12	2	3	6	14	18	4	81

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Evans West Fork #1	8	9	8	3	2	3	8	14	14	2	3	6	10	20	1	111
Evans West Fork #2	6	7	6	5	2	8	4	12	11	2	3	6	10	17	1	100
Evans West Fork #3	4	10	6	8	2	7	6	12	12	3	3	7	10	18	1	109
Evans West Fork #4	5	9	4	6	3	7	8	12	16	3	3	8	16	24	1	125
Evans West Fork #5	4	4	6	6	3	6	6	9	16	3	3	4	14	22	1	107
Evans West Fork #6	6	6	6	8	2	7	2	10	14	2	3	3	12	18	2	101
Evans West Fork #7	2	3	4	6	2	4	4	14	16	2	3	4	12	20	3	99
Evans West Fork #8	2	3	6	8	3	3	4	8	12	2	3	8	12	20	3	97
Evans West Fork #9	2	3	6	8	3	8	4	14	16	2	3	6	12	20	3	110
Evans West Fork #10	2	3	5	6	3	6	4	14	16	3	3	4	14	21	3	107
Evans West Fork #11	2	3	2	8	3	8	3	14	16	2	3	6	12	20	3	101
Evans West Fork #12	2	4	6	9	3	6	4	15	12	3	3	6	14	22	2	111
Evans West Fork #13	2	3	7	8	3	6	6	13	16	3	3	4	16	22	3	115
Evans West Fork #14	2	3	5	7	3	5	6	13	15	3	3	4	14	22	3	108

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Evans West Fork #15	2	3	6	10	3	8	3	16	14	3	3	6	12	22	3	114
Evans West Fork #16	2	5	7	10	3	5	7	11	14	2	3	4	13	20	1	107
Evans West Fork #17	2	4	4	4	2	4	3	6	12	2	3	7	14	23	2	92
Evans West Fork #18	4	3	4	6	1	2	2	4	12	1	3	3	6	21	2	74
Evans West Fork #19	4	6	4	9	3	2	2	4	16	2	3	4	12	22	3	96
Evans West Fork #20	2	3	2	6	2	3	2	5	8	2	3	6	14	18	4	80
Evans West Fork #21	2	3	2	4	2	3	2	4	12	3	3	6	12	20	4	82
Evans West Fork #22	2	3	5	7	3	4	4	4	15	4	3	4	12	22	3	95
Evans West Fork #23	2	3	5	6	3	4	3	12	15	3	3	4	14	22	2	101

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Raspberry Creek #1	4	3	4	3	1	2	4	8	8	1	3	4	8	16	2	71

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Battle Creek #1	2	3	7	9	3	8	5	4	12	4	4	8	16	24	3	112
Battle Creek #2	4	6	5	6	2	2	4	8	13	3	3	3	10	18	3	90
Battle Creek #3	6	3	6	9	2	2	4	8	10	2	3	4	8	18	2	87
Battle Creek #4	4	3	8	3	2	3	7	14	8	1	3	4	12	18	3	93

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Salt Creek #1	2	4	8	5	3	6	5	7	11	3	3	5	15	22	2	101
Salt Creek #2	4	6	4	6	2	4	6	8	14	2	3	4	8	19	3	93
Salt Creek #3	6	5	8	12	2	2	6	8	12	3	3	6	6	18	2	99
Salt Creek #4	4	10	7	9	2	4	7	14	14	2	3	4	8	20	4	112
Salt Creek #5	4	3	4	4	2	2	2	4	12	2	3	6	12	20	2	82

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Salt Creek Right Fork #1	8	10	8	9	1	2	6	16	14	1	3	8	8	15	2	111
Salt Creek Right Fork #2	8	6	8	12	1	6	8	4	16	1	3	6	16	22	4	121
Salt Creek Right Fork #3	6	8	6	6	2	4	6	16	16	3	3	6	14	21	4	121
Salt Creek Right Fork #4	2	3	8	12	4	8	8	12	16	3	3	6	16	24	4	129
Salt Creek Right Fork #5	- Not rated, too turbid to see -															

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Rock Creek #1	2	4	7	3	3	4	4	8	13	2	3	8	13	22	2	98
Rock Creek #2	4	5	8	5	3	6	8	8	14	2	3	4	16	23	4	113
Rock Creek #3	2	9	6	5	2	3	6	11	13	3	3	5	13	21	3	105
Rock Creek #4	6	3	6	6	2	7	6	10	8	2	3	3	8	19	1	90
Rock Creek #5	2	3	5	6	3	3	4	7	10	3	3	4	13	18	2	86
Rock Creek #6	4	3	6	5	2	3	5	5	8	2	3	3	8	19	1	77
Rock Creek #7	2	3	5	9	3	2	4	5	13	3	3	7	8	18	3	88
Rock Creek #8	2	3	3	6	2	3	3	4	8	2	3	2	8	19	3	71

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Cold Creek #1	2	3	8	9	3	3	4	6	7	3	3	7	8	16	3	85
Cold Creek #2	4	3	5	5	2	4	4	8	10	2	3	6	14	13	3	94

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distibution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Sand Creek #1	6	11	8	10	2	8	8	8	16	NA	NA	8	16	24	4	129
Sand Creek #2	2	9	7	3	3	8	6	8	13	NA	NA	8	16	24	4	111
Sand Creek #3	2	3	7	9	3	8	6	6	16	2	3	8	16	24	4	117

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Evans Creek East Fork #1	6	9	6	12	1	2	4	16	16	1	3	4	8	22	2	112
Evans Creek East Fork #2	8	5	8	6	1	2	6	8	12	2	3	4	9	19	2	95
Evans Creek East Fork #3	6	9	8	10	2	4	6	15	16	2	3	2	12	22	3	120
Evans Creek East Fork #4	6	12	8	6	2	4	7	8	13	2	3	4	12	22	2	111
Evans Creek East Fork #5	6	3	6	6	2	2	4	16	12	1	3	2	4	20	2	89
Evans Creek East Fork #6	2	6	6	6	3	3	5	11	13	3	3	3	11	19	2	96
Evans Creek East Fork #7	4	3	7	6	3	4	7	12	12	2	3	3	6	19	3	95
Evans Creek East Fork #8	6	6	5	6	2	6	4	9	14	2	3	2	8	19	3	95
Evans Creek East Fork #9	2	5	5	12	4	6	3	11	10	3	3	3	14	16	2	99
Evans Creek East Fork #10	6	6	6	6	1	2	2	4	14	2	3	2	4	10	2	70
Evans Creek East Fork #11	4	7	5	6	2	6	5	12	13	3	3	3	11	19	2	101

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Evans Creek East Fork #12	2	3	4	9	3	4	4	14	12	2	3	3	8	19	1	91
Evans Creek East Fork #13	2	3	3	5	3	3	2	4	6	3	3	4	5	9	2	57
Evans Creek East Fork #14	4	5	4	6	3	4	3	12	14	2	3	3	13	22	1	99
Evans Creek East Fork #15	2	3	4	12	3	6	2	8	14	3	3	3	15	21	1	100
Evans Creek East Fork #16	2	3	2	6	2	6	2	12	12	4	3	2	11	16	3	86
Evans Creek East Fork #17	6	3	3	5	2	4	3	4	12	2	3	2	9	17	NA	75
Evans Creek East Fork #18	2	3	4	5	3	2	4	8	14	3	3	4	14	19	1	89
Evans Creek East Fork #19	2	3	2	9	3	4	2	4	12	3	3	4	12	18	4	85

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Sykes Creek #1	3	11	3	9	3	4	8	16	16	2	3	6	16	22	3	125
Sykes Creek #2	4	3	4	4	2	4	7	14	14	1	3	4	12	20	2	98
Sykes Creek #3	2	3	6	3	2	4	5	14	12	2	3	4	12	18	3	93
Sykes Creek #4	2	3	4	4	2	6	4	14	12	3	3	4	14	20	3	98
Sykes Creek #5	2	9	8	6	2	4	8	8	16	2	3	4	16	24	2	114

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Mays Creek #1	4	3	6	6	3	6	4	8	8	2	3	4	8	15	NA	80
Mays Creek #2	3	3	7	4	3	3	7	12	12	2	3	4	8	20	3	94
Mays Creek #3	2	3	3	4	2	4	2	8	6	2	3	4	8	12	NA	63
Mays Creek #4	6	6	3	6	2	4	3	10	8	2	3	2	8	15	NA	78

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Morrison Creek #1	4	9	7	3	2	2	8	8	13	3	3	4	12	19	3	100
Morrison Creek #2	6	3	5	5	2	2	4	4	12	2	3	5	10	18	2	83
Morrison Creek #3	2	3	4	3	2	4	3	4	12	3	3	3	11	18	3	78

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distribution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Pleasant Creek #1	4	6	6	6	2	2	4	8	8	2	3	4	8	8	2	73
Pleasant Creek #2	2	3	7	4	2	4	4	4	4	1	3	2	9	7	2	58
Pleasant Creek #3	4	7	8	3	2	3	6	10	6	2	3	2	12	19	4	95
Pleasant Creek #4	5	7	8	3	2	3	6	10	12	3	3	5	9	14	3	93
Pleasant Creek #5	6	7	8	7	2	2	4	12	8	2	3	3	7	12	3	86
Pleasant Creek #6	2	3	6	3	3	2	6	8	10	3	3	3	8	13	3	76
Pleasant Creek #7	4	6	6	5	2	4	6	8	10	2	3	4	6	14	2	82
Pleasant Creek #8	2	5	4	6	2	2	3	10	12	2	3	4	9	14	3	81
Pleasant Creek #9	2	4	4	5	2	2	4	7	10	2	3	5	7	21	3	81
Pleasant Creek #10	2	3	3	6	2	5	2	5	3	2	3	3	10	19	3	81
Pleasant Creek #11	2	5	6	9	3	5	5	14	11	3	3	4	11	16	3	100
Pleasant Creek #12	2	3	5	7	2	2	6	13	14	2	3	4	11	17	3	94

STREAM	Land Form Slope	Mass Wasting	Debris Jam Potential	Vegetative Bank Protection	Channel Capacity	Bank Rock Content	Obstruction/Flow Deflector	Cutting	Bank Deposition	Rock Angularity	Brightness	Consolidated/Packing	Bottom Size Distibution	Bottom Deposition	Clinging Aquatic Vegetation	TOTAL
Ditch Creek #1	2	3	8	5	2	4	6	10	10	1	3	4	8	13	2	81
Ditch Creek #2	3	3	6	3	2	3	5	9	5	2	3	3	6	10	2	65
Ditch Creek #3	4	3	2	4	2	4	3	6	12	2	3	2	4	12	3	66
Ditch Creek #4	4	6	5	8	2	3	6	11	13	1	3	3	6	13	2	86
Ditch Creek #5	2	3	3	7	4	4	3	8	14	2	3	4	6	16	3	82
Ditch Creek #6	2	3	6	6	3	5	5	6	12	3	3	3	14	12	4	87

APPENDIX C. CHANNEL STABILITY

SEDIMENT SOURCE AND DEPOSITION FACTORS FOR STREAM REACHES IN SELECTED STREAMS

TABLE . EAST FORK EVANS CREEK

	CSR	S_f	D_f	$\frac{\%CSR}{S_f}$	$\frac{\%CSR}{D_f}$
1	112	50	56	.45	0.50
2	95	36	52	.38	.55
3	120	52	60	.43	.50
4	111	45	59	.41	.54
5	89	39	44	.44	.49
6	96	36	52	.38	.55
7	95	39	47	.41	.49
8	95	39	48	.41	.51
9	99	43	48	.43	.48
10	70	27	36	.39	.51
11	101	42	51	.42	.50
12	91	39	46	.43	.51
13	57	22	27	.39	.47
14	99	37	55	.37	.56
15	100	36	57	.36	.57
16	86	31	43	.36	.50
17	75	27	43	.36	.57
18	89	27	55	.30	.62
19	85	27	48	.32	.56

TABLE . WEST FORK EVANS CREEK

	CSR	S_f	D_f	%CSR S_f	% CSR D_f
1	111	47	58	.42	.52
2	100	44	44	.44	.44
3	109	49	53	.45	.49
4	125	50	68	.40	.54
5	107	38	62	.36	.58
6	101	41	53	.41	.52
7	99	35	56	.35	.57
8	97	31	58	.32	.60
9	110	42	60	.38	.55
10	107	38	60	.36	.56
11	101	41	56	.41	.55
12	111	43	60	.39	.54
13	115	41	65	.36	.57
14	108	39	60	.36	.56
15	114	45	60	.39	.53
16	107	43	58	.40	.54
17	92	25	60	.27	.65
18	74	22	46	.30	.62
19	96	30	58	.31	.60
20	80	23	48	.29	.60
21	82	20	52	.24	.63
22	95	27	58	.28	.61
23	101	33	60	.33	.59

TABLE . ROCK CREEK

	CSR	S_f	D_f	%CSR S_f	%CSR D_f
1	98	28	63	.29	.64
2	113	39	65	.35	.58
3	105	38	58	.36	.55
4	90	40	44	.44	.49
5	86	28	50	.33	.58
6	77	27	44	.35	.57
7	88	28	51	.32	.58
8	71	23	40	.32	.56

TABLE . PLEASANT CREEK

	CSR	S_f	D_f	%CSR S_f	%CSR D_f
1	73	32	34	.44	.47
2	58	23	29	.40	0.50
3	95	39	47	.41	.49
4	93	36	48	.39	.52
5	86	40	38	.47	.44
6	76	27	40	.36	.53
7	82	35	40	.43	.49
8	81	30	43	.37	.53
9	81	26	47	.32	.58
10	81	25	28	.31	.35

TABLE . DITCH CREEK

	CSR	S_f	D_f	%CSR S_f	%CSR D_f
1	81	32	43	.40	.53
2	65	28	30	.43	.46
3	66	26	32	.39	.48
4	86	40	40	.47	.47
5	82	31	43	.38	.52
6	87	30	47	.34	.54