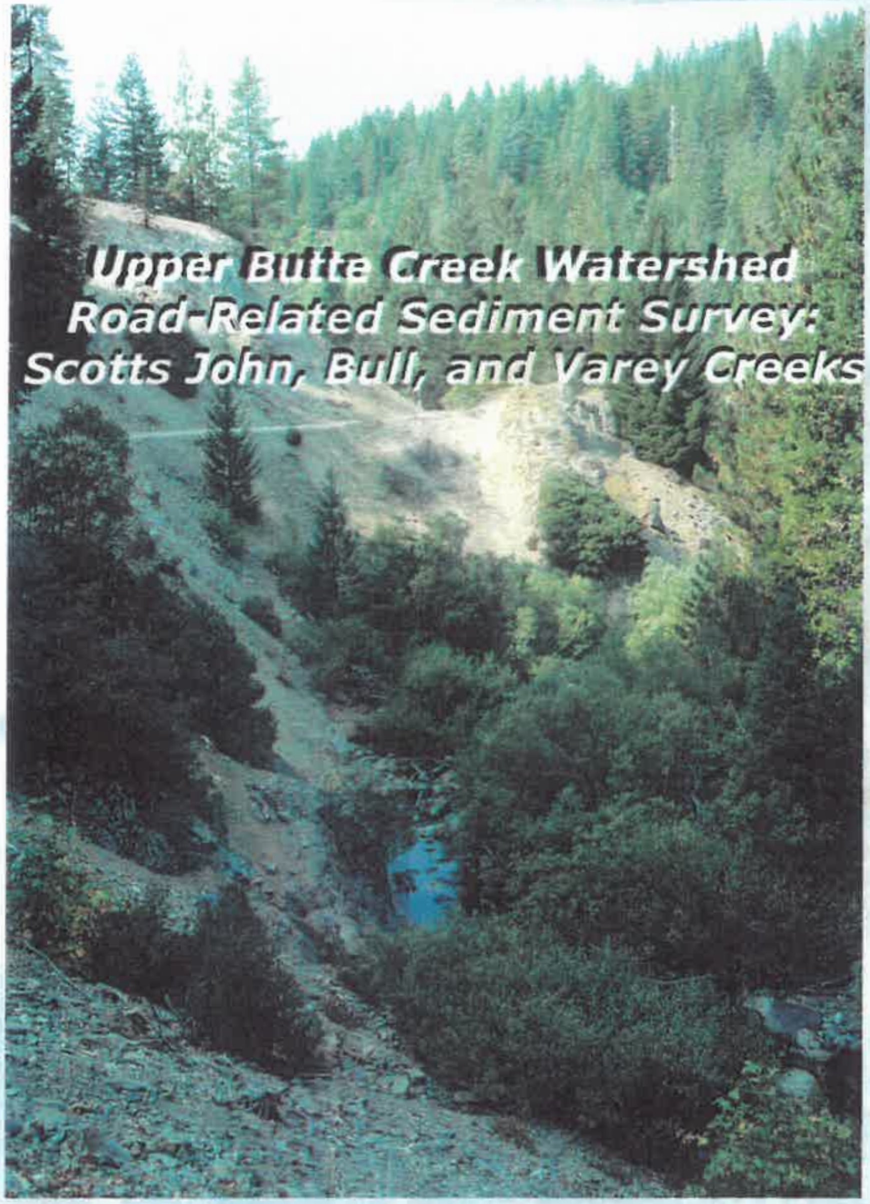
Upper Butte Creek Watershed Road-Related Sediment Survey: Scotts John, Bull, and Varey Creeks



Prepared by:

The Watershed Projects Office,
California State University, Chico

Prepared for:

United States Fish & Wildlife Service

July 2000

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Under Contract # 113328G105
For

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FINAL DRAFT

July, 2000

Front Cover: Photograph of the A-line road, just downstream of its crossing of Bull Creek. Fillslope erosion at this location was inventoried as site A-R3, with direct delivery of sediment to Bull Creek.

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Executive Summary

A survey and analysis of forest roads in selected sub-watersheds of the Butte Creek drainage was undertaken during the summer and fall of 1999. This project was undertaken by the California State University, Chico Research Foundation Watershed Projects Office, with funding through a CALFED grant.

The survey assessed approximately 50 miles of road in three sub-watersheds (Scotts John, Bull and Varey Creeks) of upper Butte Creek. These sub-watersheds comprise approximately 20 percent (11,000 acres) of the timbered upper watershed area. The analysis investigated relationships between site attributes (such as soil type, geology, road design, etc.) and road-related erosion throughout the Butte Creek drainage. All stream crossings (n=130) were inventoried as were all road erosion sites over five cubic yards in eroded volume (n=85). Field data collected was analyzed using a spreadsheet/database, and this data was then incorporated into a Geographical Information System (GIS) for further analysis of trends and graphical output.

In the last 10-20 years, the roads surveyed have contributed approximately 16,000 cubic yards of sediment to the channel network (see table below). 40% of all eroded volume in the study came from just two sites in Bull Creek.

Estimated Road-Related Sediment for all Sampled Watersheds (in cubic yards)

(Volumes are in Cubic Yards)	ROADBED & FILLSLOPE EROSION	STREAM-CROSSING EROSION	ALL ROAD-RELATED EROSION	Average ROAD-RELATED EROSION PER MILE
Bull Creek	6,120	7,606	13,726	472
Scotts John Creek	1350	542	1,892	197
Varey Creek	70	253	323	34
GRAND TOTALS	**7,540**	**8,401**	**15,942**	

Establishing a time frame for erosion at specific sites was difficult. While small trees growing in one large road-related landslide helped to establish an age for the site, much of the erosion surveyed has occurred on roads that have been abandoned for many years. No attempt was made to estimate an average annual erosion rate.

Analysis of site attributes influencing road-related erosion found several trends. In-sloped roads and roads with inboard ditches were found to be highly problematic. Most of the road segments with inboard ditches occur on Forest Service-managed lands in Scotts John Creek. On many of these road segments, the distance between ditch-relief structures - and resulting heavy amounts of runoff - is contributing to the plugging and overtopping of stream crossings and ditch relief structures, and to the erosion of the ditch or road surfaces. **About 70 percent of the road mileage in the Scotts John Creek watershed is directly connected to stream channels - primarily through inboard ditches.**

Landform position and geologic type and were found to be significant attributes relative to road-related erosion. Near-stream areas (typically in lower-slope positions), such as the 26N11 Road in Scotts John Creek and portions of the Skyway in Bull Creek, should be avoided for road placement as any sediment eroded is usually delivered directly to the stream. **Roads in areas of the steeper "Sierran metamorphic" geology were found to contribute more sediment than those roads located on "Cascade volcanic" geology.** Inner-gorge areas were found to represent an extremely high risk for large fillslope failures as well as chronic sedimentation. **Nearly 90% of all erosion surveyed came from midslope and inner-gorge roads.**

Frequency of road maintenance was a key element in road-related erosion. Many erosion sites were found to be the result of rutting of the road surface or plugged culverts. **In the Scotts John Creek watershed, all roads surveyed had had some sort of maintenance three years before the survey took place.**

50% of the 130 stream-crossings surveyed in this had no constructed crossing (no culvert). These sites contributed a total of 50% of all stream-crossing-related erosion.

The analysis undertaken within the sample watersheds identified combinations of site attributes that may represent areas of increased road-erosion hazard. For example, erosion sites located in steep midslope and inner-gorge positions on the metamorphic geology of lower Bull Creek were some of the largest surveyed in this study. The gorge of main-stem Butte Creek cuts through a similar landscape - at least geologically and topographically - in the 11 miles from Grizzly Creek downstream to the Forks of the Butte.

While these sorts of regional trends may help land managers and any future researchers to understand some of the likely "hot spots" for road-related erosion, this study has only established trends resulting from a sampling of three individual sub-watersheds. Road erosion is extremely site-specific by nature. Without an actual survey of the remaining roads in the Butte Creek drainage, these trends can be taken only as rough indicators for what might be found given certain site attributes.

Recommendations

The findings of this study generally coincide with the road surveys done in other areas in the past. Some trends arose during the survey. For example, a lack of maintenance will almost always result in problems - especially where the road configuration includes an inboard ditch. Also it seems apparent from this and preceding studies that - from a sediment standpoint - ridgetops are the best location for roads. Midslope roads may function well if designed properly and well maintained, but can pose problems on steep slopes and in inner-gorge areas. Lower slope roads, and roads in alluvial areas must often negotiate many stream crossings, can be costly to maintain, and must be carefully engineered - if they are to be used at all.

Many of the erosion sites for roads and crossings occurred due to the landform they were located on rather than due to road configuration. Erosion rates were higher in the steeper areas of the metamorphic geology. Future management should avoid building roads through the steep inner-gorge areas of Upper Butte Creek and its tributaries. In Bull Creek, every inner-gorge area that was entered by the A-line road produced considerable sediment.

While accounting for about 18% of the total mileage of roads surveyed, the midslope A-line road in Bull Creek accounted for nearly 70% of all erosion surveyed. On the steep slopes found in Bull Creek, the natural rate of ravel, or sheet erosion of the coarse-grained metamorphic soils appears to be quite high. As all hillslopes are seeking their natural angle of repose, any fill placed on a hillslope is - in the long-term - a temporary installation. The large railroad fills of the A-line may represent the highest erosion risks surveyed in this study.

Most of the problem sites surveyed were associated with undersized or plugged culverts, inadequate cross drain spacing, or fillslope erosion on inner-gorge landforms. In most cases a few fixes could significantly reduce the future potential erosion hazard. Some of these include:

1. Regular maintenance, especially in areas that have been shown to have recurring problems (e.g. on lower slope roads in Scott's John Creek, and insloped stretches of the Skyway).
2. Increasing the number of ditch relief structures (including rolling dips) in areas with inadequate cross drains.
3. Installation of stream crossing structures where none currently exist.
4. Increasing the culvert size where plugging and overtopping have been shown to be a regular problem.
5. Decommissioning or relocating roads which are chronic sources of sediment (e.g. the 26N11 road), or roads which can not currently be maintained.

Introduction

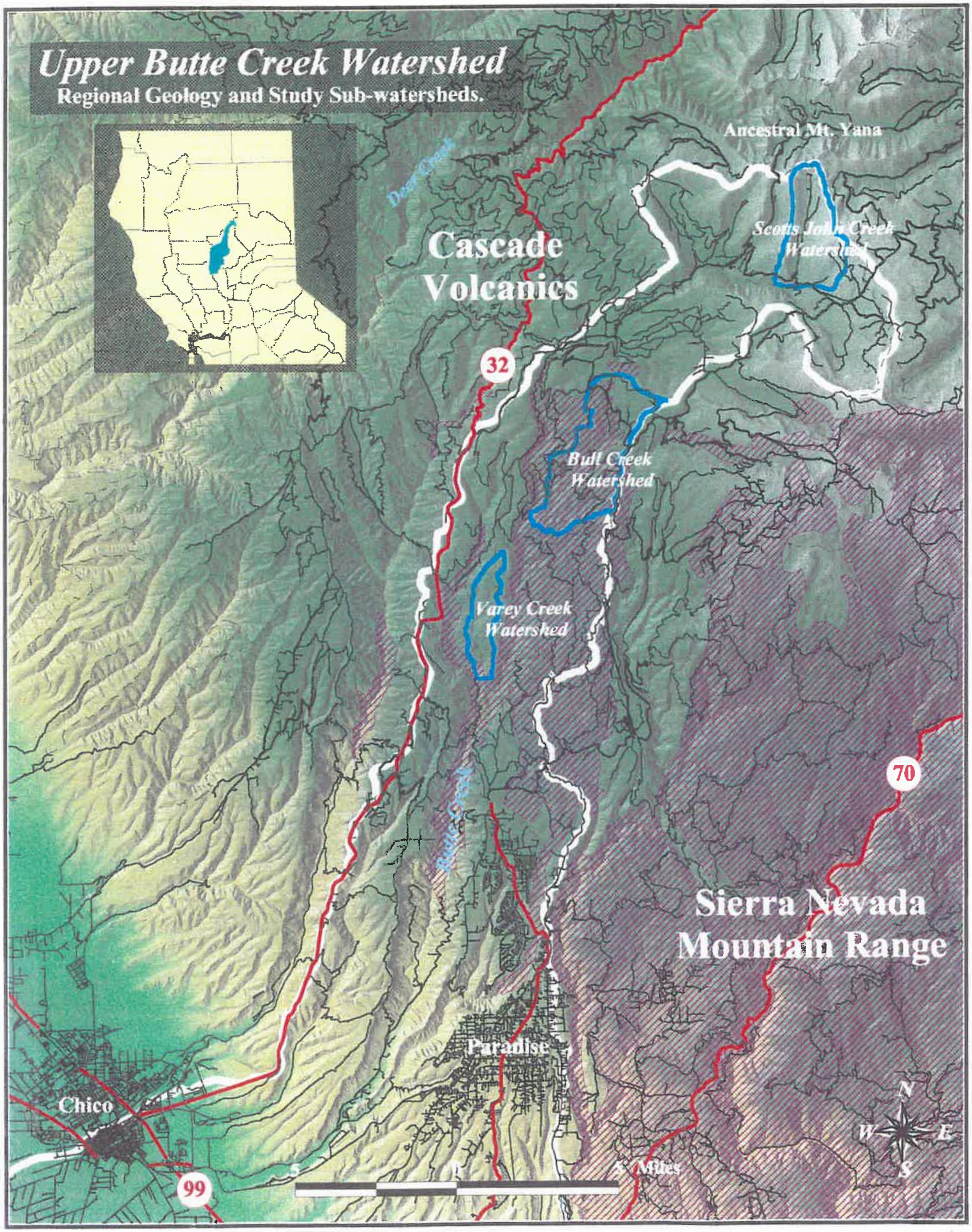
In the Summer of 1999, the California State University, Chico Research Foundation Watershed Projects (WP), operating within the Department of Geography and Planning, and in consultation with Meadowbrook Conservation Associates (MCA) performed an evaluation of stream crossings and forest roads within three selected sub-watersheds of the upper Butte Creek (Butte County, CA) watershed. The project, funded through a CALFED grant administered by the United States Fish and Wildlife Service (USFWS), assessed the impact of forest road networks on hillslope hydrology and accelerated sediment transport.

This report presents the location and nature of road-related erosion sites, lists priority sites, and identifies patterns of problems that can help redirect road construction and road maintenance practices to minimize impacts over the long-term.

Study Area

Butte Creek originates on the western slope of the northern Sierra Nevada/southern Cascade province at an elevation of about 6,500 feet. The upper watershed area covers approximately 150 square miles and drains the northeast portion of Butte County. Butte Creek enters the Sacramento Valley southeast of the city of Chico and meanders southwest to enter the Sacramento River west of the Sutter Buttes. Comprised of several major geologic formations and geomorphic provinces, the physical landscape of the upper watershed is highly heterogeneous. This area lies atop a portion of the connection between the Sierra Nevada and Cascade mountain ranges, with the older Sierran geology (Map 1) adding a complex stratigraphy not found in the Cascadian geology of Deer and Mill Creeks to the north. Climatic variations correspond with elevation, and along with differences in geology, lead to a high degree of variability in soils.

The upper watershed of Butte Creek is comprised primarily of land which is managed for timber production, and the U.S. Forest Service (USFS) Lassen National Forest (LNF) is responsible for the stewardship of approximately 23,000 acres (the entire headwaters area). Sierra Pacific Industries (SPI) owns approximately 36,000 acres in the Butte Creek watershed. The land in SPI ownership is mainly between 2,500 and 5,500 feet elevation, with scattered Forest Service, BLM, and other private inholdings. With the land-use history of the study area evolving from early gold mining and associated timber harvest to railroad logging, selective logging, and plantation forestry, road development has been extensive in the upper watershed. The USFS has identified road density as a factor affecting cumulative watershed effects, and their future management seeks road densities that are "…maintained at or below 2.0 miles/mile^2" (USFS 1998). Road density measurements for the Butte Creek watershed above 2,500 feet elevation (taken from a recent USFS transportation map lacking some of the roads on private timberland) yield a density of 2.9 miles of roads per square mile (miles/mile^2). Surveys in nearby Deer and Mill Creeks have mapped road densities of 3.6 miles/mile^2 and 1.6 miles/mile^2 respectively (MCA, 1996).


Upper Butte Creek Watershed
Regional Geology and Study Sub-watersheds.
Ancestral Mt. Yana
Deer Creek
Cascade Volcanics
Scotts John Creek Watershed
32
Bull Creek Watershed
Varey Creek Watershed
70
Butte Creek
Sierra Nevada Mountain Range
Paradise
Chico
N
W
E
S
5
0
5 Miles
99

Map 1

Background

The Butte Creek drainage is among the last Sacramento River tributaries that provide important migration, holding and spawning habitat for wild spring-run chinook salmon (*Oncorhyncus Tshawytscha*). With the listing of the spring-run chinook salmon as a threatened species by the State of California and the National Marine Fisheries Service (NMFS), management practices on upland regions have come under increasing scrutiny.

At the local level, the Butte Creek Watershed Conservancy and other interested parties are developing a Watershed Management Strategy (WMS) which aims to improve watershed conditions and land-use practices. This planning process identified a "data gap" in the body of knowledge available regarding the extent and condition of forest roads in the watershed.

Numerous studies have documented the relationship between accelerated sediment production and changes in forest hydrology affected by forest roads - particularly those that are poorly designed or unmaintained (Weaver and Hagans, 1994; Reid and Dunne, 1984; Rice et al., 1979; King and Tennyson, 1984; Beschta, 1978; and Bilby et al., 1989). Additionally, it has been found that increased turbidity can have adverse impacts on many aquatic organisms, particularly salmonids (Newcombe and Jensen 1996), and that an increased percentage of fine sediment in spawning substrates can decrease the survival of eggs and alevins in various species of salmon (Cederholm and Reid, 1987). The Forest Service currently has a nationwide backlog of over $8.4 billion for road-related maintenance and capital improvements (Teigen, 1999). Prioritization of the worst of these 'problem roads' for future restoration or removal is a central emphasis in Forest Service Chief Mike Dombeck's Natural Resources Agenda. It was for these reasons that an appraisal of existing conditions related to forest roads in the Butte Creek watershed was compiled.

Project Objectives

This project involved the systematic survey of forest roads with the following objectives:

1) To assess the extent and relative magnitude of sediment contribution from road systems in the watershed;
2) Identify, map, and prioritize specific road-related sediment sources; and
3) Identify patterns of recurring problems that can help redirect road construction and road maintenance practices to minimize problems in the long-term.

Approach, Field Methods, and Data Management

History

The methodology utilized in this study has its roots in road assessment protocols utilized by private consultants in the western United States. In the summer of 1996, Kenneth Cawley and Michael Kossow of Meadowbrook Conservation Associates (MCA) carried out a *Survey of Road-related Sediment Sources in the Deer Creek and Mill Creek Watersheds.* Their methodology followed methods used by the Natural Resource Conservation Service (NRCS) as that agency conducted a thorough inventory of sediment sources, primarily road-related, on Grass Valley Creek, a tributary to the Trinity River. During the preliminary stages of the Deer/Mill Creeks project, MCA contracted with Pacific Watershed Associates, Arcata, CA; (an established consulting firm specializing in forest road-related erosion) to further refine their survey protocols. The MCA methodology underwent peer review by Dr. William E. Weaver, co-author of "Handbook for Forest and Ranch Roads," a definitive manual on forest road design and maintenance issues. Following the completion of the Deer/Mill survey, MCA has been involved in subsequent restoration and monitoring work on the highest-priority road-erosion sites within the Deer Creek drainage.

When the Office of Watershed Projects was funded to undertake this study, Mr. Kossow and Mr. Cawley briefed project staff on the methods used on Deer and Mill Creeks. Project staff modified the methods to adapt the survey to work within a Geographic Information System (GIS)/landscape-analysis approach.

Once an initial survey methodology was field tested, meetings with land managers further refined the survey process. During this time, a minimum threshold of five cubic yards of sediment was established as a lower limit for sites to be inventoried. Any road site with total erosion less than five cubic yards was not inventoried.

Three sub-watersheds of Butte Creek were surveyed: Scotts John, Bull, and Varey Creeks (see Map1, page 5). These areas were chosen to represent examples of the distinct geology and geomorphology, elevation, amounts of precipitation, ownership and land management histories represented within the upper Butte Creek watershed. Relationships between various site attributes and sediment production were queried within and between the sub-watersheds to identify erosional risk factors endemic to any of the major landforms represented. Significant differences in road-related erosion and the attributes affecting road-related erosion were found between the three sub-watersheds.

In the Scotts John Creek watershed, road-system design and maintenance, harvest history, and the various management paradigms prescribed for the landscape have been fairly consistent with the other Forest Service managed lands in the upper Butte Creek watershed. Thus, the survey results from Scotts John Creek may be representative of road-related impacts on Forest Service managed land in Butte Creek's headwaters streams. The mudflow ridge tops of the Varey Creek watershed are fairly similar to approximately 6,400 acres of SPI land along the top of Carpenter Ridge. Bull Creek is somewhat unique geologically as portions of it represent older, more deeply incised metamorphosed volcanic and metamorphosed sedimentary geology that has been surrounded by younger Cascadian mud and lava flows.

Methodology

The field methodology involved systematically surveying and mapping all road segments and stream crossings in each of the three watersheds in the study area. Erosion features larger than the threshold of five cubic yards were inventoried and mapped. As all stream crossings represent a potential erosion hazard, every stream crossing was inventoried, regardless of the volume of fill material that had been or could be eroded. Separate inventory forms were developed for road erosion features and stream crossings (see Appendix A). Physical site characteristics (outlined in the following section) were inventoried in the field to help detect factors that could be identified as road erosion risks. Typically, a field team consisted of two individuals. While one individual would concentrate on quantitative data collection (measuring slopes with a clinometer, checking culvert size and condition, etc.), the other surveyor recorded this information on the data sheet. The recorder would also fill in other site attributes requiring only visual analysis, photograph the higher-volume erosion sites, and draw a field sketch of the site. Raw data collected from the survey is included in Appendix E.

Inventories began in the highest areas of each watershed and continued downslope. This approach was chosen because of the nature of uphill problems contributing to, or causing, problems downslope. Having an understanding of altered hydrology upslope proved helpful in many cases (for instance, on USFS Road 26N11 in Scotts John Creek).

Simple trigonometry was used to estimate volumes. On fills, fill length and width were measured by pacing or hip-chain and heights were measured with a pocket rod. Slopes were measures with a clinometer. The lengths of rills, gullies, and ditch features were measured by pacing or hip-chain. A cross-sectional area for these features was determined by averaging width and depth measurements from several locations, and multiplying this area by the length of the feature to estimate eroded volume.

All sites were flagged, numbered, and mapped at a later time using a differentially corrected Global Positioning System (GPS) receiver accurate to +/- 5 meters. The lengths of all road segments contributing water directly to erosion sites or stream crossings were measured in the field using a hip-chain, pacing, GPS, or a combination of these.

During the field survey, stream crossings and road erosion sites were assigned a priority for repair based upon qualitative assessment of various site attributes. The scale for priorities ranged from 1 (lowest priority), to 5 (highest priority). Attributes used in determining priority included: slope position/proximity to stream, amount of fill material at risk of being eroded, condition of drainage structure, linkage to other sites, and diversion potential and potential diversion distance. Sites that were not hydrologically connected to the stream were usually given a low priority, as were crossings without culverts, which had already lost most of their fill. An example of a high priority site is the blocked ditch at the 26N11-R11.1 site. This site is the first in a 2,500 foot-long series of compounding problems. Repair at this site must be undertaken before repairing any sites downslope in order to realize any change in the way the segment of road is functioning as a transporter of water and sediment.

Perspectives on Survey Methods Related to Estimation of Sediment Volumes

Estimates of road-related erosion for the watersheds surveyed are likely highly conservative, especially if they are used to address possible effects to aquatic organisms, rather than just for maintenance or road system management considerations. Some sites were not surveyed due to the length of time that they had abandoned, or were not surveyed as they were below the five-yard threshold.

Setting some sort of minimum site volume was necessary to accomplish the survey in a timely manner. However, the five-cubic-yard threshold for sediment may be unrealistic in assessing road-related impacts on some smaller tributary creeks. In the case of a large stream such as Butte Creek, five cubic yards of sediment is a 'drop in the bucket' relative to what the stream carries in a typical season. A smaller stream - perhaps one that is fed by primarily sub-surface flow from a small drainage area - may not have the competency to carry the same five cubic yards of sediment.

Approximately 175 cubic yards of sediment have aggraded above the B-4 crossing (on the Skyway), and this accumulation acts as a barrier to the movement of fish observed above the site in upper Bull Creek. The area draining to this site has two inventoried road-related erosion sites that contribute about 60 cubic yards of sediment to streams. Other sources of sediment may have also contributed to the aggradation at the site, and using a smaller threshold to estimate road-related erosion could help to establish the relative magnitude of road-related sediment compared to other watershed disturbances and natural erosion processes.

Major timber harvesting operations accompanied the building of the 100A and 110A Roads in the Bull Creek watershed between 1950 and 1975. Interpretation of 1952 aerial photos shows many spur-roads, which have subsequently been overgrown. Most of the roads built during this time are now in an abandoned state. Many of these roads were not surveyed during field data collection.

Road *surface* erosion is a chronic "background" source of sediment that is present with all roads unless paved. The sediment that does come from road surfaces is usually of fine-grained texture. For this study, no attempt was made to quantify the amount of sediment that is contributed by seasonal, "background" road surface erosion. Road surface erosion is especially important relative to maintenance practices like grading.

Data Management

The field survey data was entered into an electronic spreadsheet to facilitate data storage, management, and queries. For each of the three sub-watersheds, data for road erosion and stream crossings were compiled in separate spreadsheets (essentially databases), allowing queries of road erosion or stream crossing sites to take place independently. From these primary "Master" databases (ROAD and XING for each watershed), specialized databases were created to allow for different queries (such as queries examining only crossing sites without culverts).

Portions of this database were then incorporated into fields in a spatial database, or geographic information system (GIS). Here, analyses examined the relationships between site attributes and landscape-level GIS-derived attribute data including soils, geology, ownership, and landscape position.

GIS Methodology

The existing digital roads coverage from the USFS was improved using Digital Ortho Quarter Quads (DOQQs) and GPS data. The revised road map was overlaid onto a landform map, and all roads were segmented and coded with the type of landform that they traversed. Additionally, the road network was segmented at major road intersections, and at watershed divides, for purposes of quantifying erosion by sub-watershed, road name/number, or road segment. All of these segments were used to quantify eroded volume by road segment and landform type.

The three sub-watershed areas were mapped from a Digital Elevation Model (DEM) provided by the USFS. This model represents the terrain with a grid of 10 meter square cells. Calculations that analyze the relationships between cell values were applied to extract maps of slope, aspect, hillshading, and watershed area. In the Scotts John and Bull Creeks watersheds, the survey area was further subdivided into sub-basins. These smaller basins represented a convenient unit of analysis for identifying smaller areas within the sub-watershed that might be contributing a higher amount of sediment to the "main-stem" stream.

The GPS mapping information for each site was used to place all sites on basemaps, and allowed for interactive mapping of sites by attribute. For example, maps of sites without stream crossings could be developed by displaying only the sites with a "no crossing" code in the database.

Data Sheets and Site Attributes Surveyed

Observations of the following items were taken at each *road erosion* site:

- Erosional feature (i.e. ditch, fillslope,)
- Hillslope (%)
- Cutbank slope (%)
- Aspect (°)
- Roads downslope (y/n)
- Erodability of receiving feature
- Hydrologically connected (y/n)
- Road width
- Prism design
- Roads upslope (y/n)
- Erosion type
- Erosion cause
- Landform
- Fillslope (%)
- Related to other sites (y/n)
- Receiving feature
- Receiving feature currently eroding (y/n)
- Fed by road/ditch (y/n)
- Distance to stream
- Surface material
- Road configuration
- Contributing road grade & length
- Volume delivered by past erosion
- Suggested treatments
- General remarks on maintenance, past causes of erosion, possible future erosion, etc.

If the site involved a ditch relief culvert the following information was also recorded:

- Culvert diameter
- Culvert condition
- Diverted (y/n)
- Material aggrading above inlet (y/n)
- Evidence of overtopping (y/n)
- Culvert grade
- Diversion potential (l/r)
- Potential diversion distance
- Volume of aggraded material
- Pipe being undermined (y/n)

At all *stream crossings* general site attributes were noted and the following specific items were recorded:

- Road width
- Prism design
- Roads upslope (y/n)
- Diversion potential (l/r)
- Diversion distance
- Stream class
- Channel type
- Scoured channel area
- Bedrock exposed (%)
- Impounding sediment upstream (y/n)
- Culvert gradient
- Plugging potential
- Evidence of overtopping (y/n)
- Crossing type
- Surface material
- Road configuration
- Contributing length and road grade
- Diverted (y/n)
- Crossing fed by road/ditch (y/n)
- Aspect (°)
- Stream grade (up & down)
- Substrate
- Condition at time of survey
- Culvert diameter
- Culvert condition
- % plugged
- Pipe being undermined (y/n)
- Inlet

- Outlet structure
- Erosion type
- Erosion cause
- Estimated fill volume
- Volume delivered by past erosion
- Suggested treatments
- General remarks on past causes of erosion, possible future problems, etc.

Not all of the attributes collected were used in the data analysis. Attributes not used in the queries were essential for background information qualitative analysis. Please refer to the Appendix for copies of the data sheets (Appendix A) and for definitions of the attributes (Appendix B) and codes (Appendix C) used for input to the database.

Sub-Watershed Descriptions

Table 1 shows a summary of watershed sizes and road lengths for initial comparison.

Table 1: Summary Table of Road and Watershed Information

	Scotts John Creek	Bull Creek	Varey Creek
Watershed Size (acres)	3,560	5,730	1,710
Watershed Size (square miles)	5.6	9	2.6
Miles of Road	9.6	29.1	9.5
Road Density (Road Miles/ Square Mile)	1.7	3.2	3.6

Scotts John Creek

Scotts John Creek originates along the Pacific Crest Trail at an elevation of about 7,000', and is the highest area of Butte Creek's headwaters (see Map 1). Scotts John Creek receives average annual precipitation of 65-70 inches, much of which arrives as snow that may cover the ground from November to as late as June. The basin drains an area of about 3,500 acres, and falls completely within the Almanor Ranger District of the Lassen National Forest.

The Scotts John Creek watershed has incised into andesite flows which spill across the southern flanks of ancient Mount Yana (see Map 1, page 5), a now-collapsed and eroded Cascade volcano which originated during the Pliocene Epoch, 1.8 to 5 million years ago. Mount Yana was also the source of much of the mudflow material found in the mountain portions of the Butte Creek watershed. The Yana caldera lies to the north of the watershed in the area bounded by Eagle Rocks, Humboldt Summit and Butt Mountain. The soils in this area are considered andisols, formed from parent material of volcanic Cascadian origin. Partially due to the high elevation and cooler climate the soils have weathered to become gray to brown in color and relatively coarse in texture, allowing for a potentially increased susceptibility to erosion. (See Appendix D for descriptions of the soil units).

In the upper-portion of the main-stem watershed, several intermittent headwater-swales converge to form a perennial stream at approximately 6,400 feet elevation. Below this point, the creek flows in a southerly direction for nearly 3 miles. Approximately 1/3rd mile downstream from the 26N27 crossing, a 700-acre tributary enters from the east. The Scotts John Creek channel then turns west and runs parallel with Butte Creek, dropping over 400 feet in less than a mile to the confluence of the two creeks, at approximately 5,400 feet in elevation.

The dominant vegetation within the watershed is mixed-conifer fir forest dominated by California White Fir with Red Fir increasing in dominance at higher elevations. Ponderosa and Sugar Pine occupy some of the more exposed aspects within the basin and increase in dominance as elevation decreases. Chaparral/montane scrub vegetation covers historic burns on the upper slopes of the basin, with large brushfields dominating the upper slopes of areas in the southeastern and far-western portions of the watershed. Isolated groves of aspen and lodgepole pine occur in the lower slope/near-stream areas, and alder and willow dominate the riparian areas. There are several wet meadow areas that support numerous wildflowers and perennial grasses. Much of the basin has been selectively harvested in the past 20 years, and White Fir, Mule Ear, Lupine, and grasses are the dominant cover in these areas.

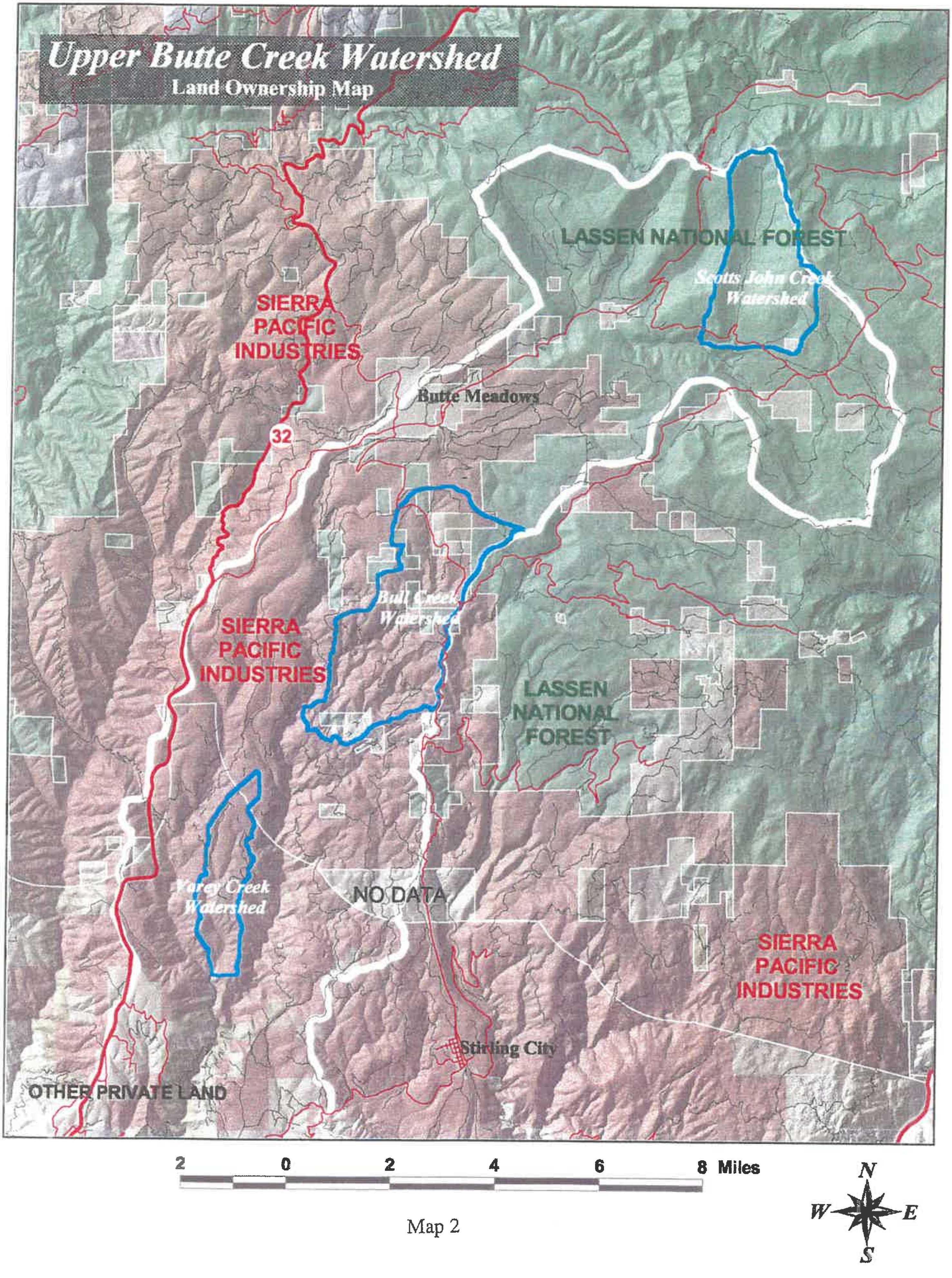
Aside from the main access road through this portion of the Lassen National Forest (the 26N27) the most heavily used road within the watershed is the 26N11 road (see Map 2). It runs parallel to Scotts John Creek, and is within 200 feet of the creek for nearly the entire length of this main-stem valley. The reach of Scotts John Creek above the 26N27 road is fed by many unmapped intermittent tributaries draining from the east. The 26N11 road, running parallel to the creek on the east side of the basin crosses 21 intermittent channels - only five of which appear on the USGS 1:24,000 scale Humboldt Peak and Jonesville topographic quads.

The USFS (USFS 1998) seeks road densities to be "…maintained at or below two miles per square mile." In Scotts John Creek, the road density was found to be 1.724 miles of road per square mile.

Bull Creek

Bull Creek enters Butte Creek from the east about 7 miles downstream of Butte Meadows (see Map 1, page 5). The Bull Creek watershed covers an area of approximately 5,730 acres, and drains the west side of Bull Hill and the south slope of Rimple Ridge - both about 5,300 feet in elevation. The basin receives an average of 60-70 inches of annual precipitation - a substantial portion of which may be delivered as snow. The majority of the basin is owned by Sierra Pacific Industries, with 772 acres in public ownership administered by the USFS.

Much of the Bull Creek watershed drains steep canyons incised through an "island" of Paleozoic (245-544 million years old) metasedimentary and metavolcanic rock which has been surrounded by Mount Yana's much-younger volcanic flows. The Bull Hill area (headwaters of Bull Creek) has volcanic soils similar to those found in Scotts John Creek. Below Bull Hill the landscape becomes much steeper and harsher with shallower soils and more direct solar exposure. This area is represented by numerous outcrops of the metamorphosed volcanic and metamorphosed sedimentary rocks which weather slowly and give rise to soils referred to as ultisols, formed from parent material of Sierran origin. Where soil has formed, it is generally finer in texture than the soils of Scotts John Creek


Upper Butte Creek Watershed
Land Ownership Map
LASSEN NATIONAL FOREST
Scotts John Creek Watershed
SIERRA PACIFIC INDUSTRIES
Butte Meadows
32
Bull Creek Watershed
SIERRA PACIFIC INDUSTRIES
LASSEN NATIONAL FOREST
Varey Creek Watershed
NO DATA
SIERRA PACIFIC INDUSTRIES
Stirling City
OTHER PRIVATE LAND
2
0
2
4
6
8 Miles
N
W
E
S

Map 2

watershed. (See Appendix D for descriptions of the different soil units).

While the soils within the Bull Creek basin support a mixed conifer pine and douglas-fir forest, many of the south and west facing slopes of the steep canyon areas host large stands of black oak and scrub oak. The area was heavily logged earlier in this century by both railroad and truck-based operations. The "A-line" road was originally a railroad grade used for railroad logging in the early to mid 1900s. The Bull Creek watershed endured fires in 1926 and 1928, the effects of which can still be seen in the brushfields that cover large portions of the upper slopes on Rimple Ridge and the Bull Hill area.

In Bull Creek's southwesterly run to Butte Creek, it drops 1,900 feet in about 7 miles and is fed by three major tributaries, Coon, Bottle, and Secret Creeks. The headwaters of Bull Creek originate at an elevation of approximately 5,300 feet on Bull Hill, a broad volcanic ridgetop with extensive young conifer plantations. Several tributaries meet the stream in a low-gradient area along the Skyway/B-line. It flows in this shallow valley for approximately 1.25 miles before the stream begins to drop steadily towards its crossing at the A-line. In this steeper reach, Coon Creek, draining about 780 acres of fairly gentle volcanic ridgetop, joins Bull Creek at about 4,600 feet elevation.

Just above the A-line crossing, Bull Creek begins to drop more rapidly through the deeply incised metamorphosed geology. From the crossing, the creek flows through an extremely steep gorge for a little over three miles and drops about 950 feet to its confluence with Bottle Creek at an elevation of approximately 3,500 feet. Bottle Creek originates atop Bottle Hill at an elevation of about 5,300 feet, and drains approximately 740 acres of land, 180 acres of which are relatively flat plantation land administered by the USFS. The remaining 560 acres cover fairly steep canyon topography.

About 0.4 miles below the Bull/Bottle confluence, Secret Creek's steep gorge enters as a tributary on the left bank of Bull Creek. Secret Creek's two main branches drain 409 acres of steep land. The A-line road contours at mid-slope through the Bull, Bottle and Secret Creek sub-watershed.

The Bull Creek watershed comprises an area of 5,730 acres (8.95 square miles). During field data collection, 29.1 miles of road were surveyed. This yields a road density of 3.25 miles of road per square mile of watershed area. No attempt was made to query road density by ownership.

A historic mass-failure - likely triggered by road construction - is located in a steep side-canyon of Bull Creek along the abandoned 100A road. This site is made up of several landslides, and has delivered an estimated volume of 5,000-8,000 yards^3 of material directly to streams. It appears that a large fill constructed through this inner-gorge area in the period between 1952 and 1975 failed after logging operations in the 1970s, and that the resulting slope disturbance has initiated the more recent landslides. Due to the age of the site - it has 20 year-old trees growing atop it - and difficulty in interpreting the causes;

this site was not included in our analysis. The site typifies the unstable nature of roads and stream crossings built in inner-gorge areas of Bull Creek.

Varey Creek

Located about 6 miles north of the town of Forest Ranch, Varey Creek drains an area of about 1,710 acres on the southern end of Carpenter Ridge. The creek joins the West Branch of Butte Creek about a mile above that stream's confluence with the main-stem of Butte Creek (see Map 1, page 5). The entire basin is owned by Sierra Pacific Industries (SPI) (see Map 2, page 15).

Varey Creek's two intermittent headwater streams originate on gentle ridgetop slopes at about 3,800 feet elevation and become perennial just above their confluence - about two miles downstream of the headwaters. Below the confluence, the creek has sufficient energy to begin incising into more resistant metavolcanic rock that underlies the Tuscan Mudflow geology of the ridgetop. Here the gradient increases considerably, and for the two miles to the confluence with the West Branch of Butte Creek, Varey Creek travels through a landscape much steeper than the relatively flat volcanic ridges of its headwaters. Near its confluence with the West Branch, the landscape and in some instances, the hydrology, have been altered by historic hard rock and placer gold mining operations.

Varey Creek receives from 70-75 inches of annual precipitation, much of which arrives as rain. Due to its lower elevation, snow melts early in this area, and the milder climate supports increased biological activity in the soil, leading to high site productivity for forestry. The soils on the ridgetop areas of the Varey Creek watershed are Cascadian in origin similar to the Bull Hill area and Scotts John Creek. However, the soils here are much redder, showing higher clay content and increased rates of weathering. These soils are considered to be ultisols. In the lower, canyon section of Varey Creek the soils are derived from Sierran parent material and are also referred to as ultisols, although there are some areas on the side slopes of the canyon that have been weathered more heavily and are referred to as alfisols. In general the soils in Varey Creek are of finer texture than the two upper sub-watersheds. (See Appendix D for descriptions of the different soil units).

The dominant vegetation on the ridgetop is a mixed-conifer pine forest comprised of Douglas Fir, Ponderosa Pine, Sugar Pine, White Fir and Incense Cedar. Under a historic harvest regime that has tended to remove large, overstory conifers, oak species have become an aggressive successional on many of the ridgetop areas. Due to the excellent site conditions, present timber management is removing stands dominated by oak in clearcut blocks, and establishing conifer plantations.

Analysis of Survey Data

Utilizing survey data, GIS layers, and spreadsheet calculations, analysis was undertaken to identify relationships and trends in and between the three watersheds. Detailed explanations of how certain queries were executed, especially ones that involved manipulation of database fields, is included in the Scotts John Creek analysis section. The remaining sub-watersheds were queried in the same fashion unless otherwise noted.

Notes on Analysis Methodologies

The following three sections examine the causes of road-related erosion *within* the three study watersheds. While insight into why the findings in one particular watershed may be different from those in another may be given in these sections, analysis *among* the three separate watersheds and the different environmental attributes they represent is reserved for the *"Analysis Between Watersheds And Watershed Attributes"* section. Also, only queries or analysis that produced significant results are included in the following sections. Therefore, one watershed will not necessarily have the same queries as another.

Throughout the rest of this report, note that *"Stream Crossing Erosion,"* should not be confused with *"Road Erosion,"* a term used to describe all other erosion related to the road surface, ditches, fill slopes, ditch relief culverts, etc. Further, the term *"Road-Related Erosion"* describes all sediment originating from both stream crossing and road erosion sites.

Scotts John Creek

Most of the roads in Scotts John Creek are found in lower-slope or mid-slope landform positions (See Table 2). The 26N11 road (the road running just to the east of the main-stem of upper Scotts John Creek) and the 26N27 road (the main, graveled road running through this portion of the Butte Creek drainage basin) comprise 5.2 miles, (or 55%) of this road length. Totals of erosion are listed below in Table 3. Map 3 displays all of the road-related erosion sites in the watershed.

Table 2: Scotts John Creek Watershed: Road Miles by Landform

Landform	Miles of Road by Landform
Alluvial/Meadow	0.3
Headwater/Swale	0.5
Inner-gorge	1.1
Lower Slope	4.3
Mid-Slope	3.4
Total	**9.6**

Table 3: Scotts John Creek Watershed: Road Related Erosion

Scotts John Creek Erosion	ROADS	STREAM CROSSINGS	Total
Volume (cubic yards)	1,010	880	1,890
Percent	53%	47%	100%

- **In the Scotts John Creek watershed, over 80% of all erosion came from roads that were maintained three years before the study was conducted.**

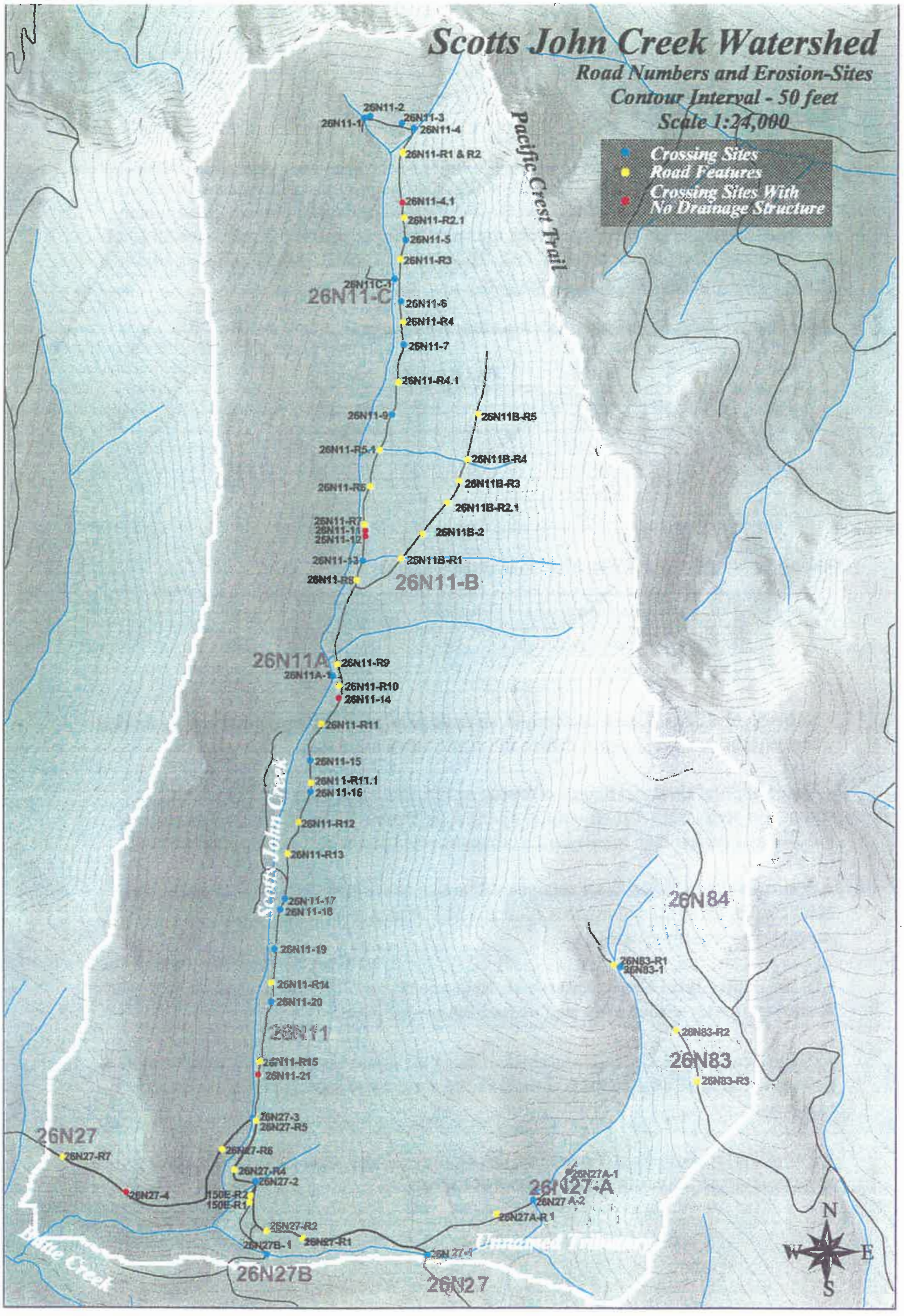
- **About 65% of the total length of roads within the watershed are contributing water and sediments directly to the channel network. 75 % of the road surface of the 26N11 and 26N11B roads is directly connected to the stream channel network.**

- **While USGS 1:24,000 scale topographic maps show only 4 streams crossing the 26N11 road, 25 swales along this road showed evidence of recent scour, and were surveyed as stream-crossing sites.**

- **In the Scotts John Creek watershed, 1040 yards^3 (or 77%) of all erosion occurred at sites that were either in-sloped or had inboard ditches.**

- **In the Scotts John Creek watershed, 70% of all stream crossings have diversion potential. 30% of all stream crossings in the watershed have diverted down the roadway.**

- **Two diverted stream-crossing sites are responsible for over 75% of the eroded volume from *all* crossings with in the watershed.**


Scotts John Creek Watershed
Road Numbers and Erosion-Sites
Contour Interval - 50 feet
Scale 1:24,000
● Crossing Sites
● Road Features
● Crossing Sites With No Drainage Structure
Pacific Crest Trail
26N11-1
26N11-2
26N11-3
26N11-4
26N11-R1 & R2
26N11-4.1
26N11-R2.1
26N11-5
26N11-R3
26N11C-1
26N11-C
26N11-6
26N11-R4
26N11-7
26N11-R4.1
26N11-9
26N11B-R5
26N11-R5.1
26N11B-R4
26N11-R6
26N11B-R3
26N11B-R2.1
26N11-R7
26N11-11
26N11-12
26N11B-2
26N11-13
26N11B-R1
26N11-R8
26N11-B
26N11A
26N11-R9
26N11A-1
26N11-R10
26N11-14
26N11-R11
26N11-15
26N11-R11.1
26N11-16
Scotts John Creek
26N11-R12
26N11-R13
26N11-17
26N11-18
26N84
26N11-19
26N83-R1
26N83-1
26N11-R14
26N11-20
26N11
26N83-R2
26N83
26N11-R15
26N11-21
26N83-R3
26N27-3
26N27-R5
26N27
26N27-R6
26N27-R7
26N27-R4
26N27A-1
26N27-2
26N27-4
150E-R2
150E-R1
26N27-A
26N27 A-2
26N27A-R1
26N27-R2
26N27-R1
26N27B-1
Unnamed Tributary
Battle Creek
26N27-1
26N27B
26N27
N
W
E
S

Map 3

Road Erosion

Road Erosion by Cause

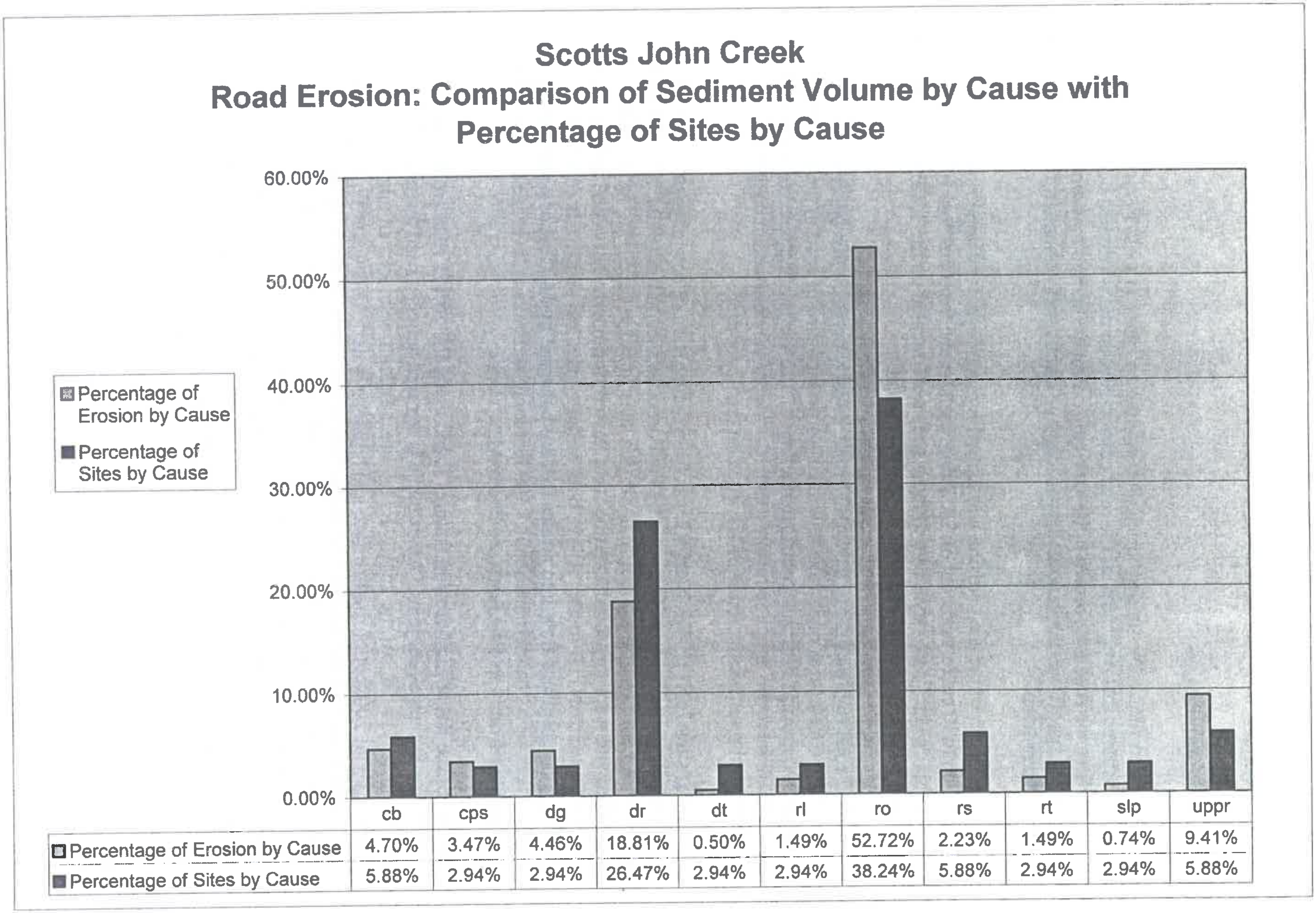
Road erosion sites were queried for erosion volume by cause to yield Figure 1. This graph illustrates that over 50% of the road erosion sites in the watershed occurred in places where the road intercepted hillslope runoff. Erosion caused by problems occurring where ditch runoff was concentrated by inadequate ditch relief accounted for another 19% of the erosion.

While over 50% of the road erosion was caused by intercepted hillslope runoff, 80% of this erosion (430 cubic yards out of 530 cubic yards) came from just four of the thirteen sites in this "cause" category. Two of these sites were located on the 150E road. The other two sites were associated with the 26N11B road.

The 150E road runs parallel to the 26N27 road, directly between this upper road and Scotts John Creek. It is one of the few inner-gorge segments of road in the watershed, and has two erosion sites that contributed a total of 155 yards of material to the stream. Neither site has been active in recent years. Both sites may have been caused by concentrated runoff delivered from the ditch on the upper road.

Erosion at sites 26N11B-R2.1 and R3 was from the incision of new channels through forest stands that were heavily logged by the Forest Service in the 1980s. Sites 26N11B-R2.1 and R3 are two of the larger road-erosion sites found in the Scotts John Creek watershed and were measured as gullies that flowed through the harvested area between the 26N11 and 26N11B roads. Above both of these sites, old skid-trails concentrate surface and subsurface flow into swales that are bolstered by 360 feet of contributing ditch. These new channels are about 1,500 feet long, and have an average cross-sectional area ranging from 1 to 1 ½ feet^2 (see Photo A).

Several of the larger road-erosion features found along the 26N11 road are the results of cumulative drainage problems. An example is the area between road features 26N11-R11.1 and 26N11-18. At the 26N11-R11.1 site, a fallen tree blocks an inboard ditch draining about 200 feet of road-surface and hillslope water. This water flows onto the road surface, passing the stream crossing at 26N11-16 in ruts on the roadbed. This site continues 600 feet to the 26N11-R12 ditch-relief culvert, which is plugged with some of the 40 cubic yards of material eroded from the roadbed and ditch above. The water continues a total of 1,500 feet to the 26N11-18 stream crossing, passing 3 partially plugged culverts and eroding approximately 40 additional cubic yards of sediment along the way (see Photo B). Water has diverted 500 feet past the 26N11-18 stream crossing,



	cb	cps	dg	dr	dt	rl	ro	rs	rt	slp	uppr
☐ Percentage of Erosion by Cause	4.70%	3.47%	4.46%	18.81%	0.50%	1.49%	52.72%	2.23%	1.49%	0.74%	9.41%
■ Percentage of Sites by Cause	5.88%	2.94%	2.94%	26.47%	2.94%	2.94%	38.24%	5.88%	2.94%	2.94%	5.88%

Figure 1

Concentrated flow from the inboard ditch on the upslope road (top edge of harvested area in above photograph) has scoured new channels in the harvested area below the road (lower photo).

Photo A

Many of the inboard ditches in the Scotts John Creek watershed
are contributing fine sediments directly to streams.

Photo B

bringing the total length of these combined sites to about 2,500 feet. In Scotts John Creek, it appears that a lack of routine maintenance (clearing sediment from cross-drain culvert inlets and keeping ditches clear) could be linked to the majority of erosion related to roads.

Road Erosion by Configuration

Road erosion by road configuration was queried in an attempt to find trends related to any particular road configuration types. In the Scotts John Creek watershed, 1040 yards^3 (or 77%) of the road erosion occurred at sites that were either in-sloped or had inboard ditches. This method concentrates flows from road surfaces and upslope areas, often leading to erosion of either ditches, fill-slopes, or hillslopes. It should be pointed out that most of the roads in the watershed are in this sort of configuration. However, when landscape position (landform in the database) is examined along with configuration, we see that 78% (850 out of the 1040 yards^3) of volume from these sites are in lower slope or mid-slope positions. Mid-slope, and particularly lower slope, areas on the landscape are areas that are subjected to large amounts of surface and subsurface hillslope water, due to their topographic position. In-sloped roads and roads with inboard ditches can concentrate much of that water, and erosional forces are higher in these areas.

Relative to stream crossings, the effects of road configuration can be either neutral, or negative, by adding water to a crossing from the road surface.

Stream Crossing Erosion

Stream crossings are potentially an area of high hazard related to erosion. Stream crossings (other than bridges) are essentially "...an earthen dam, placed across a stream channel, that has a small hole (culvert) in the bottom. Plug the hole with sediment, vegetation or wood, and the dam will wash out" (Weaver and Hagans, 1994). When this overtopping occurs, a loss of all fill placed in the watercourse can result. Another possibility - often more damaging in terms of volume of material eroded - is a diversion of the stream down a roadway and/or onto an unprotected hillslope. A stream crossing is said to possess "diversion potential" (DP) if, when it overtops, the stream flows down the road or onto a hillslope rather than back into its natural stream channel. The new "stream" can end up carving a new channel down a hillslope and/or flow into the channel of another micro-drainage or watershed. In any event, the potential for serious erosion from crossings with DP is readily acknowledged by many land managers (Personal Comm., Ken Cawley, MCA 1999; Personal Comm., Greg Napper, LNF 1999).

While no crossing is failsafe - in that it may be overtopped and washed out - crossings that do *not* possess diversion potential are typically considered to be "failsoft" (Weaver and Hagans 1994). If a failsoft crossing does overtop and wash out, not much more than the volume of fill material used to carry the road across the stream channel will be eroded In the Scotts John Creek watershed, 70% of stream crossings have diversion potential. Of these, 43% have diverted. This translates to 30% of all the crossings in the Scotts John watershed showing evidence of past diversion. One such site is the 26N27A-1, where an undersized culvert was exceeded and diverted the stream 700 feet down the road, eroding 325 cubic yards in the process. Another is site 26N27-1, where a diverted crossing during the heavy precipitation in late December, 1996 ran 3,500 feet down the road and led to ditch and hillslope erosion down the road totaling nearly 350 cubic yards. Field observations in the summer of 1997 compared with field surveys during this project indicate that the site has seen substantial reconstruction since 1997. Reconstruction and grading of the road surface filled and obscured some erosion features, so estimates of ditch erosion surveyed in the area affected by this diversion are probably conservative. Together, these two sites represent 76% of the eroded volume for *all* crossings, demonstrating how damaging diverted stream crossings can be.

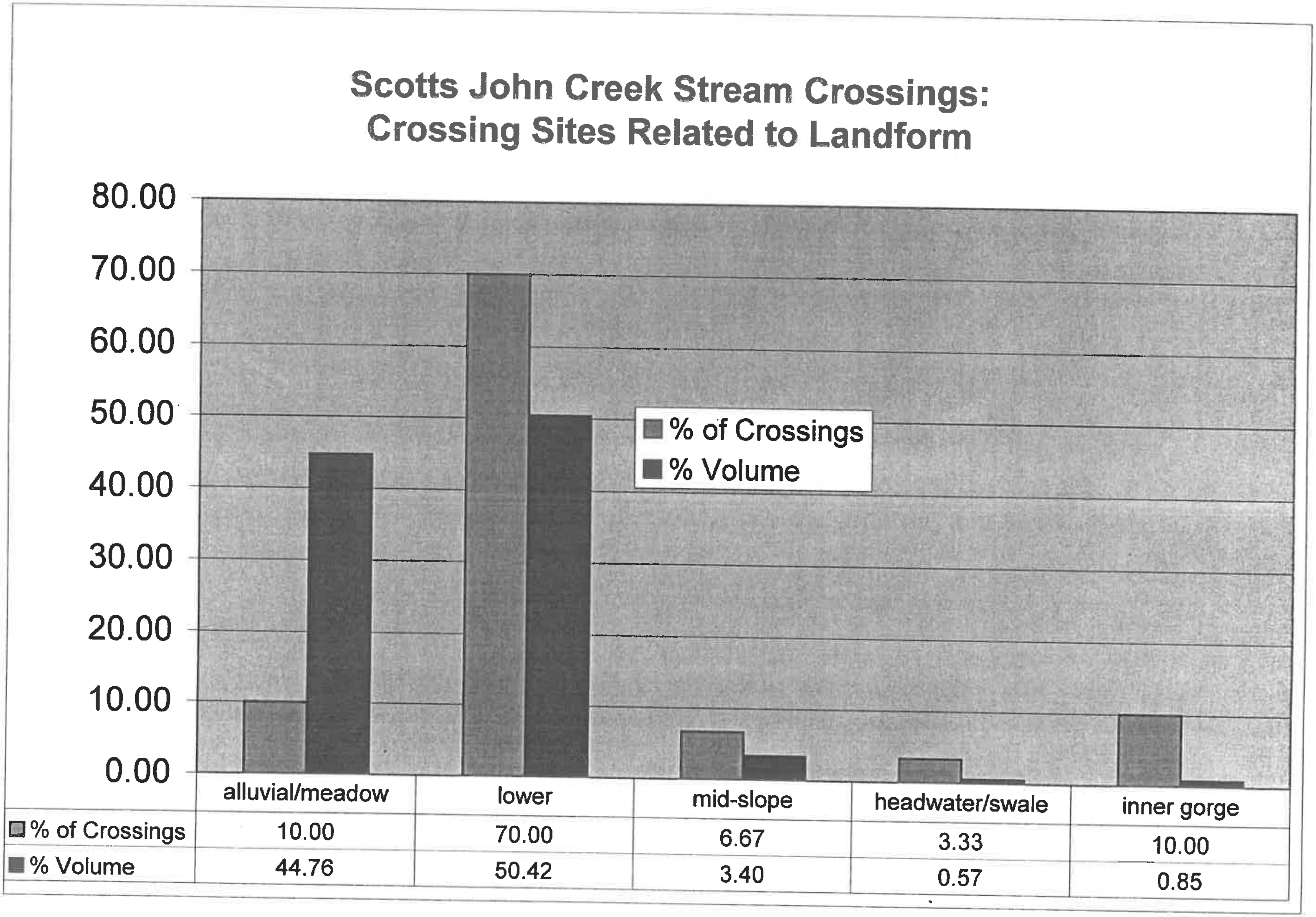
Stream crossing erosion accounted for 47% of the erosion in the watershed. While 46% of the volume eroded at stream crossings came from alluvial-meadow locations, these locations amounted to just 13% of the sites (see Figure 2). All of the alluvial-meadow erosion came from two of the three sites. While three alluvial-meadow sites represent only 10% of the total number of crossings they contributed 45% of the total erosion for all stream crossings.

The cause of stream crossing erosion was queried for the Scotts John Creek watershed. Culverts plugging with sediment and those effected by intercepted hillslope runoff each contributed approximately 40% of the erosion for stream crossings. However, while these two causes amounted to over 80% of the stream crossing erosion, they represent just 33% of the crossing sites. This indicates that the transfer of intercepted water to stream crossings (by inboard ditches), as well as a lack of timely maintenance has likely led to many of the problems with stream crossings in the Scotts John Creek watershed.

Stream Channel Extension

Roads and inboard ditches can act to extend stream channel networks by collecting hillslope runoff and road-surface water, and delivering this water directly to stream crossings. This new "streambed" increases the drainage density of the watershed, and can speed the delivery of runoff to streams, thereby increasing the magnitude of peak flows (Wemple et al., 1996). Additionally, these new channels deliver suspended sediment and bedload material to existing stream channels, thereby altering natural sediment regimes. Many culverts are sized only to pass the water of the drainage that lies above them, and water delivered by a road or ditch may increase their likelihood of overtopping. In the Scotts John Creek watershed, 93% of all stream crossings are fed by roadways. The average amount of road draining to crossings (including contributing input from the left and right) was found to be 490 feet.

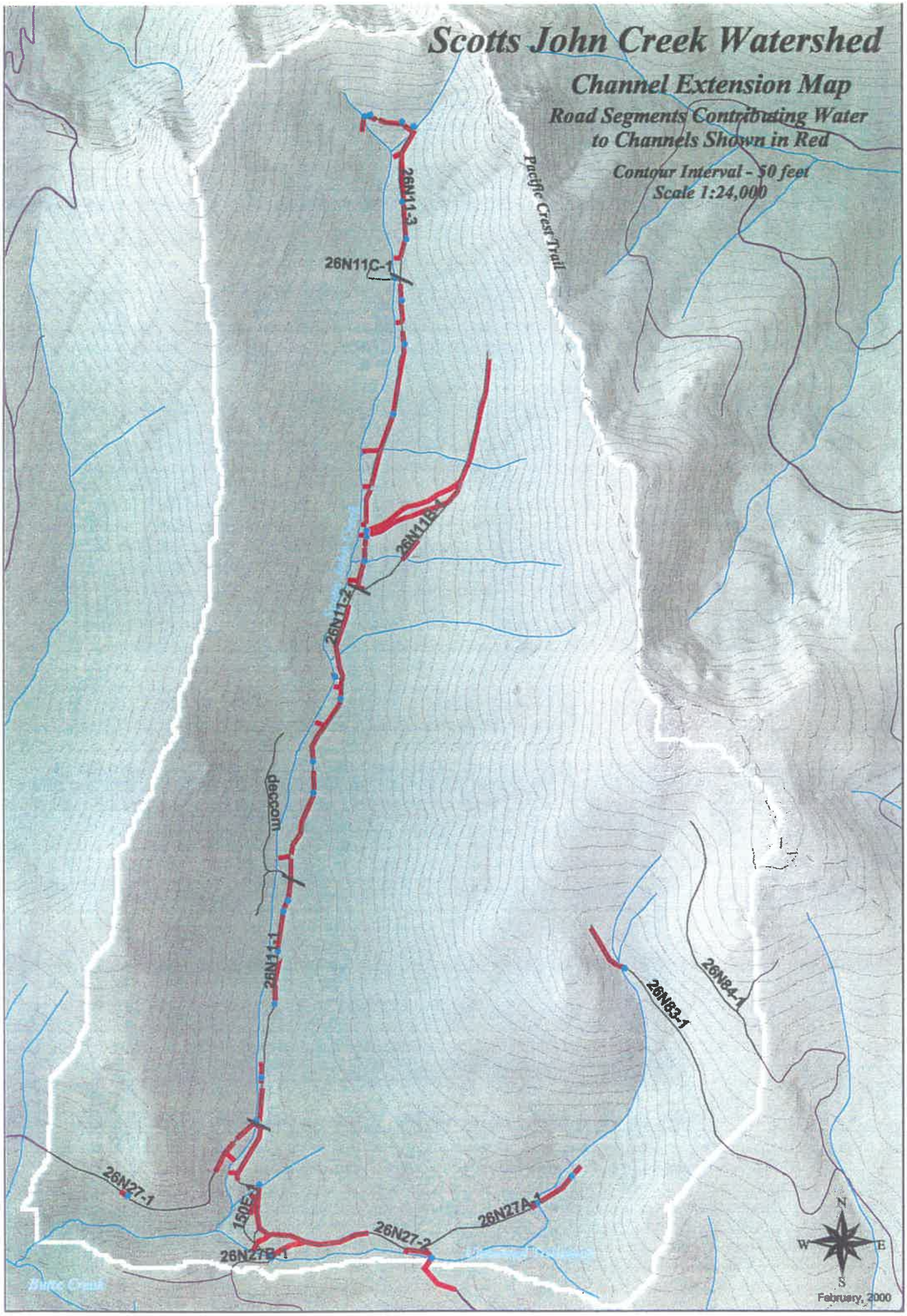
A channel extension map was prepared for all three sub-watersheds (Map 4). These maps used the "Contributing Length" information from the field surveys to illustrate graphically the amount of ditch or road-surface feeding water directly to a near-stream erosion site or to the *inlet* of a drainage structure. The resulting maps portray the hydrologic connectivity between the transportation system and the stream channel network. In the Scotts John Creek watershed, 9.6 miles of road have created 6.1 miles of



Scotts John Creek Stream Crossings:
Crossing Sites Related to Landform

	alluvial/meadow	lower	mid-slope	headwater/swale	inner gorge
▨ % of Crossings	10.00	70.00	6.67	3.33	10.00
■ % Volume	44.76	50.42	3.40	0.57	0.85

Figure 2


Scotts John Creek Watershed
Channel Extension Map
Road Segments Contributing Water to Channels Shown in Red
Contour Interval - 50 feet
Scale 1:24,000
Pacific Crest Trail
26N11-3
26N11C-1
26N11B-1
26N11-2
deccom
26N11-1
26N83-1
26N84-1
26N27-1
150E
26N27B-1
26N27-2
26N27A-1
Butte Creek
N
W
E
S
February, 2000

Map 4

new channel. This translates to about 65% of the total length of roads being directly connected to the channel network. Seventy-five percent of the road surface of the 26N11 and 26N11B roads is directly connected to the stream channel network.

Scotts John Creek Stream Crossing Overtopping and Diversion Potential

In the Scotts John Creek watershed, nine out of 23 culverted crossings show evidence of overtopping (See Table 4). Eight of the overtopped crossings have diversion potential (DP), and of the eight with DP, six are diverted down roads. Seventy percent of all stream crossings (including those *without* constructed crossings) have DP and of these, 43% have diverted (30% of *all* crossings).

Table 4: Scotts John Creek Constructed Stream Crossings

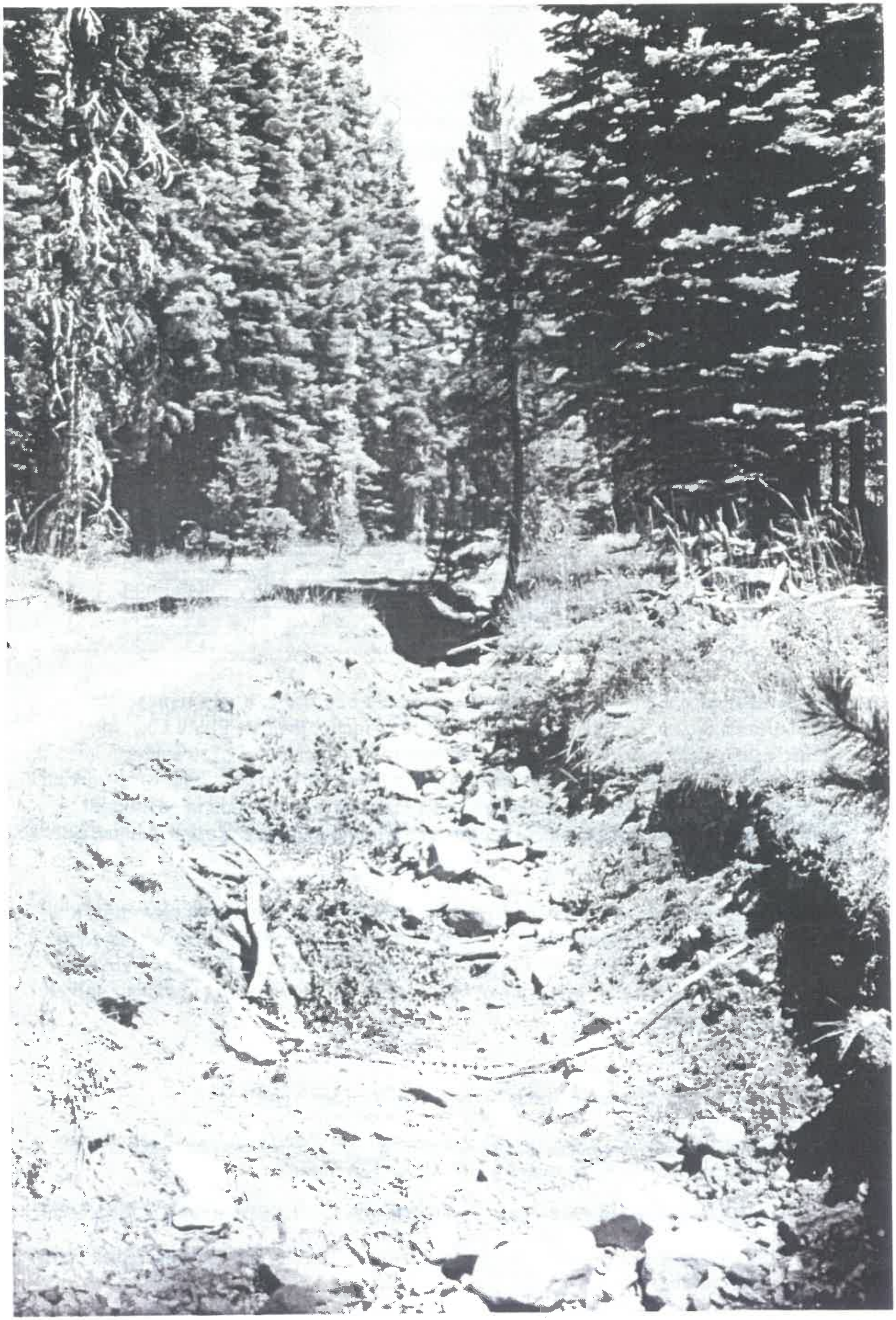
	Not Overtopped	Overtopped
Number of Crossings	14	9
Percent of Crossings	60%	40%
Crossings with Diversion Potential	9	8
Crossings Diverted	0	6

While overtopping can be (and frequently is) a *cause* of erosion, it also represents a hazard or an indicator that the crossing is not fully functioning (see Photo C). No specific in-the-field investigation was conducted to assess cause of overtopping. Instead, the site attributes related to the physical processes involved in overtopping were queried to investigate causal mechanisms. Below are a series of queries made in an attempt to identify site attributes that may have caused overtopping of stream crossings in the Scotts John Creek watershed.

Only stream crossings with drainage structures were queried. Humboldt crossings, low-water crossings, and streams without crossings were not queried. In other words, there had to be a crossing to overtop for the site to be queried here. The 26N11A-1 crossing that was entirely blown-out, was not included here as the opportunity to analysis culvert attributes was gone.

Queries were run to determine trends in the following (See Table 5):

> **The average stream grade (here the average of "Stream Grade Upstream" and "Stream Grade Downstream") that caused a culvert to be overtopped.**
>
> **The average ratio between the pipe grade and the grade of the stream entering the crossing.**
>
> **The relationship between the cross sectional area of the stream and the cross sectional area of the crossing inlet.**



Diverted stream crossings (such as this one, on the 26N-27A road) have contributed much of the road-related sediment surveyed within the Scotts John Creek watershed.

Photo C

Table 5: Overtopping Queries for Scotts John Creek Constructed Stream Crossings

	Not Overtopped	Overtopped
Average Gradient	11.28%	8.28%
Average Ratio of Pipe Grade to Stream Grade Upstream	.48	.69
Average Ratio of Channel XS Area to Pipe XS Area	1.32	1.88
Average of Total Contributing Length	407	611

The query results shown above suggest that undersized culverts on lower-gradient stream channels may be at higher risk for overtopping in the Scotts John watershed. The influence of added water contributed by road segments and ditches to stream crossings was analyzed to determine if this had an influence on overtopping. While it was found that all overtopped crossings were fed by roads, so too were all but one of the crossings that did not overtop. Overtopped crossings were fed by an average 611 feet of road. Crossings that were not overtopped, averaged 407 feet of contributing roadway. This difference in contributing length may be a factor in the cause of overtopped crossings in this watershed. Again, a threshold may have been exceeded, this time relative to the amount of road drainage added to a stream crossing.

In summary, it was found that essentially all stream crossings in Scotts John Creek watershed were undersized to some extent, but for overtopped culverts, a threshold may have been exceeded relative to the degree of undersizing. Further, it was found that although nearly all culverts are fed by the road system, the amount of road connected might again be another threshold that, if exceeded, may add to the exceedence of culvert capacity. These two factors, coupled with a lack of timely maintenance, appear to be the likely causes of culvert overtopping in the Scotts John Creek watershed.

Discussion

Road-Related Erosion by Landform

All road-related erosion sites, including road sites and stream crossings were queried by landform to examine the relationship this variable has with road related erosion. Table 6 below, shows that the majority of erosion sites (60%) were located on lower-slope roads. This corresponds with field observations during surveying that lower-slope roads appeared to be in the worst condition (in particular, large portions of the 26N11 road). However, while this landform had the most sites and volumetrically contributed the most sediment, on a site-for-site basis, alluvial/meadow areas appear to be more at risk.

Table 6: Scotts John Creek Watershed Road-Related Erosion by Landform Type

	Alluvial/ Meadow	Headwater/ Swale	Inner-gorge	Lower Slope	Mid-Slope	Total
Volume (cubic yards)	410	10	232.5	740	500	1892.5
• Percent Erosion	21.66%	0.53%	12.29%	39.10%	26.42%	100.00%
Percentage of Sites	5.45%	3.64%	10.91%	60.00%	20.00%	100.00%
Percent of Road Miles by Landform	2.95%	5.10%	11.50%	45.18%	35.27%	100%

Alluvial/meadow sites contributed over 20% of the erosion in the watershed, but amounted to just 5% of all sites. This was bolstered by two sites on the 26N27A road, created by diverted stream crossings. Combined, these sites contributed 340 cubic yards of sediment.

The high percentage (60%) of "lower-slope" sites can be attributed to the 33 stream crossings and erosion sites located on the 26N11 road. The 26N11 road (which accounted for 64% of the "lower-slope" road miles) contributed 21% of the total erosion in the watershed.

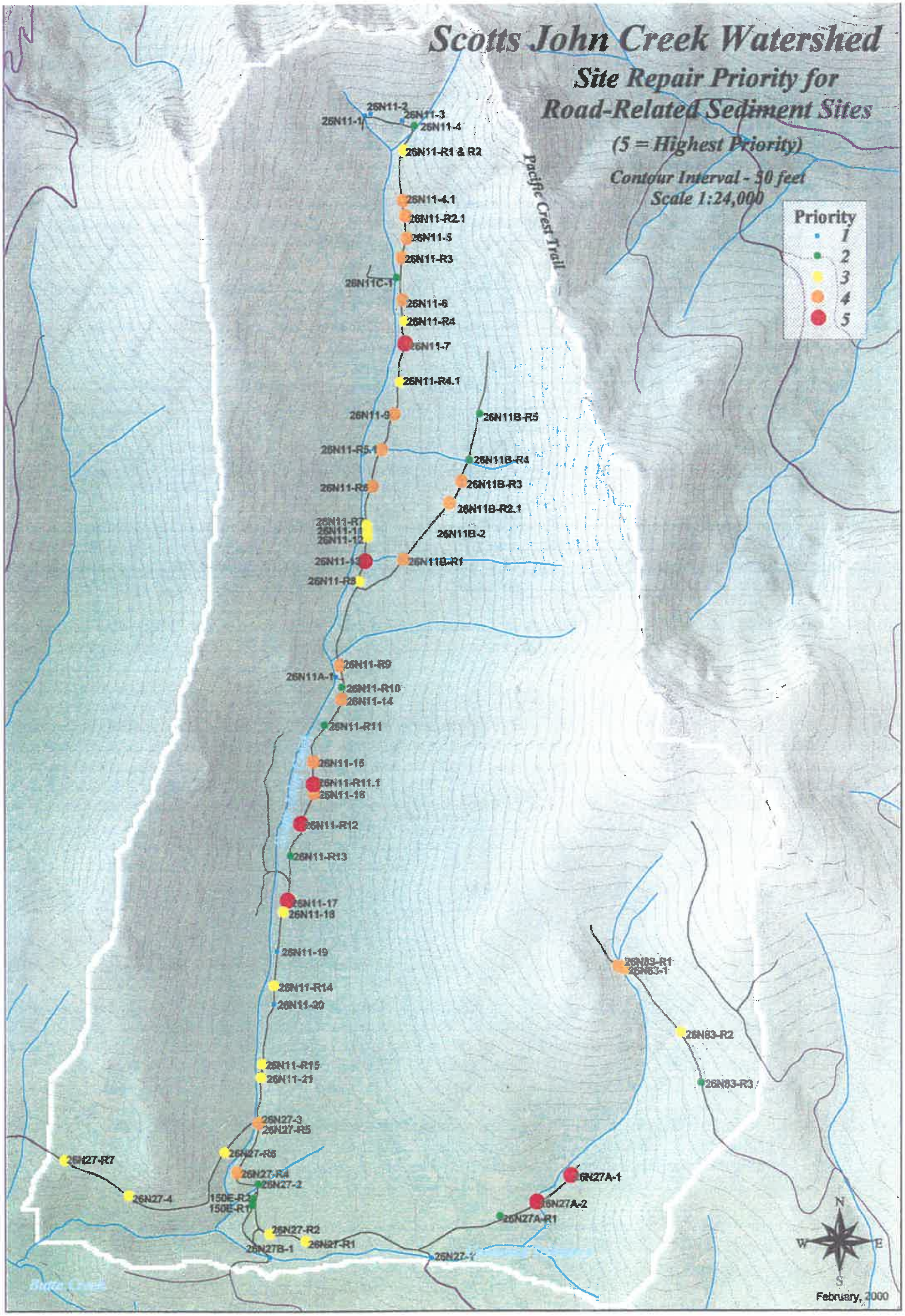
Prioritization

In an attempt to identify priority areas for possible repair, erosion by road segment was queried to find areas in the road system that contributed the most sediment. Mostly due to the diverted stream crossing at the 26N27-1 site, road segment 26N27-2 contributed approximately 25% of the erosion in the entire watershed. The 26N11 road contributed about 20% of the erosion. One diverted stream crossing on the 26N27A road contributed 325 yards of sediment to the channel network, accounting for about 17% of all erosion in the basin.

While the above approach was useful to find the sites where the majority of the erosion *has already taken place*, surveyors used a qualitative approach based on field observations to prioritize sites for possible maintenance, reconstruction or other work (see Map 5). In Table 7 (next page), "Fill Volume" indicates the amount of fill in the stream channel associated with the road crossing the stream. *As overtopped culverts have the potential to erode large volumes of fill material from stream crossings, fill volume provides an indication of the "worst-case" erosion hazard at a site based on full erosion of the fill.* Fill volumes were not estimated for Road Features as it is difficult to predict what road prism erosion could take place at any particular site. The sites in the following table were given priority levels of either four or five, and should receive priority for drainage upgrades or maintenance in Scotts John Creek. See Map 5 (page 35) for locations of the priority sites listed in Table 7, and for other sites with lower Priority Levels as well.

Table 7: Priority Sites in Scotts John Creek

SITE ID	Priority	Feature Type	Fill Volume
26N27A-2	5	arch	240
26N27A-1	5	cmp	100
26N11-7	5	cmp	36
26N11-R11.1	5	RD FTR	na
26N27-1	5	cmp	75
26N83-1	4	cmp	150
26N11-9	4	cmp	30
26N11-6	4	cmp	34
26N11-5	4	cmp	100
26N11-4.1	4	nox	2
26N11-16	4	cmp	20
26N11-15	4	cmp	80
26N11-14	4	nox	1
26N11B-R2.1	4	RD FTR	na
26N11B-R3	4	RD FTR	na
26N11-17	5	Cmp	18
26N11-13	5	Cmp	12
26N11-R12	5	RD FTR	na
26N27-R.9	4	RD FTR	na
26N11B-R1	4	RD FTR	na
26N11-R6	4	RD FTR	na
26N11-R9	4	RD FTR	na
26N27-R.8	4	RD FTR	na
26N11-R2.1	4	RD FTR	na
26N11-R3	4	RD FTR	na
26N27-R4	4	RD FTR	na
26N11-R5.1	4	RD FTR	na
26N27-R5	4	RD FTR	na
26N83-R1	4	RD FTR	na


Scotts John Creek Watershed
Site Repair Priority for
Road-Related Sediment Sites
(5 = Highest Priority)
Contour Interval - 50 feet
Scale 1:24,000
Priority
1
2
3
4
5
Pacific Crest Trail
26N11-2
26N11-3
26N11-1
26N11-4
26N11-R1 & R2
26N11-4.1
26N11-R2.1
26N11-5
26N11-R3
26N11C-1
26N11-6
26N11-R4
26N11-7
26N11-R4.1
26N11-9
26N11B-R5
26N11-R5.1
26N11B-R4
26N11-R6
26N11B-R3
26N11B-R2.1
26N11-R7
26N11-11
26N11-12
26N11B-2
26N11-1
26N11B-R1
26N11-R8
26N11-R9
26N11A-1
26N11-R10
26N11-14
26N11-R11
26N11-15
26N11-R11.1
26N11-16
26N11-R12
26N11-R13
26N11-17
26N11-18
26N11-19
26N83-R1
26N83-1
26N11-R14
26N11-20
26N83-R2
26N11-R15
26N11-21
26N83-R3
26N27-3
26N27-R5
26N27-R6
26N27-R7
26N27-R4
6N27A-1
26N27-2
26N27-4
150E-R2
150E-R1
6N27A-2
26N27A-R1
26N27-R2
26N27-R1
26N27B-1
26N27-1
Butte Creek
N
W
E
S
February, 2000

Map 5

Bull Creek

In Bull Creek, the majority of the roads were located in mid-slope positions (See Table 8). Over 1/2 of this mileage is on the A-line and B-line (Skyway) Roads. The A-line crosses several tributaries to Bull Creek, and in doing so, winds back into the steep and deeply incised "inner-gorge" areas (see Map 6). These areas hosted some of the largest erosion sites surveyed in the entire study (see Photo D).

Table 8: Bull Creek Watershed: Road Miles by Landform

Landform	Miles of Road by Landform	Percent of Miles by Landform
Alluvial/Meadow	0.53	1.8%
Headwater/Swale	0.79	2.7%
Inner-gorge	3.73	12.8%
Lower Slope	2.76	9.5%
Mid-Slope	13.13	45.1%
Ridge	8.17	28.1%
Total	**29.11**	**100.0%**

Table 9: Bull Creek Watershed: Road Related Erosion

Bull Creek Erosion	ROADS	STREAM CROSSINGS	Total
Volume (cubic yards)	6,120.5	7,606	13,726.5
Percent	44.59%	55.41%	100%

- **59% of all non-stream-crossing erosion came from came from just one site (the A-R5).**

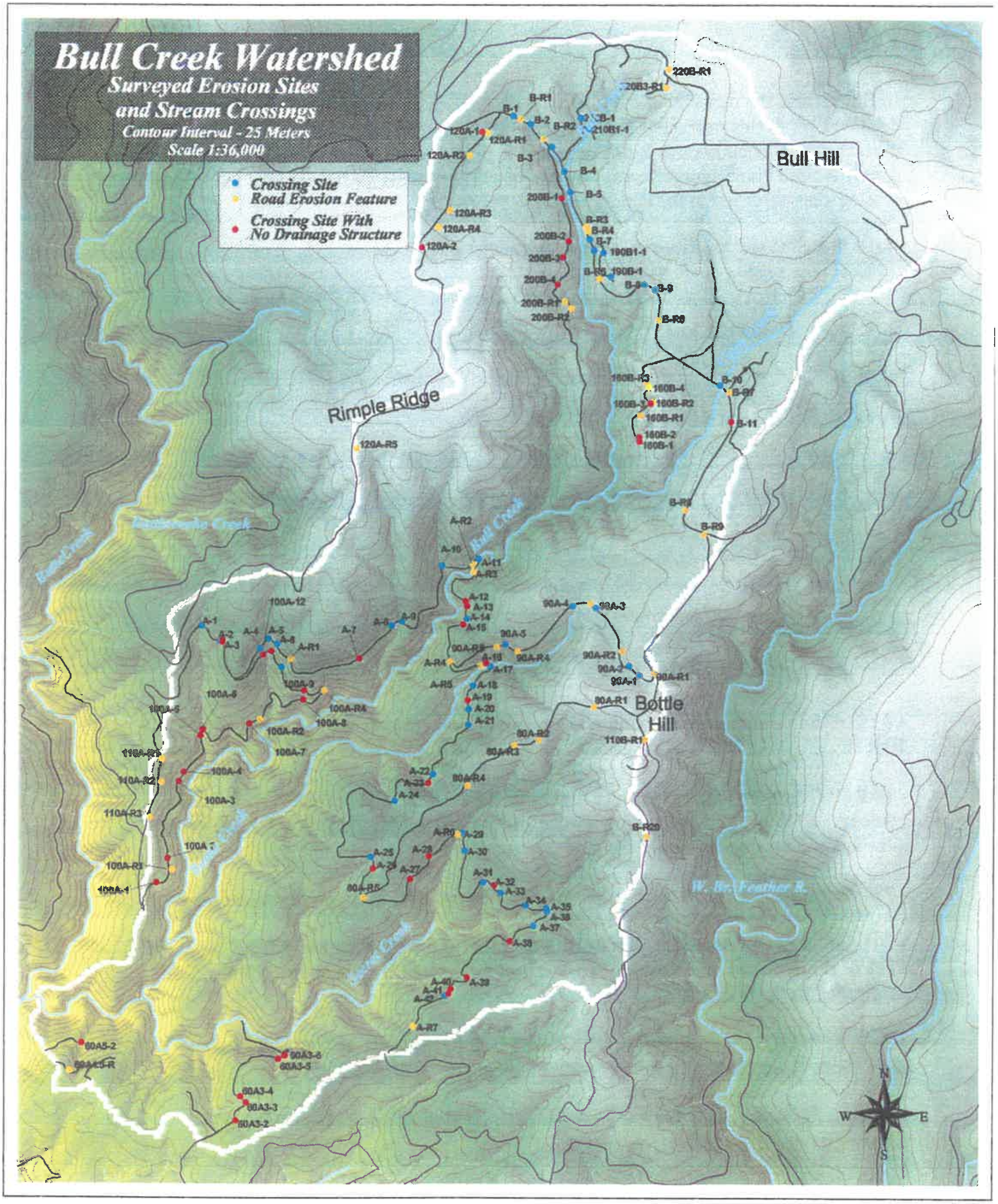
- **In Bull Creek, erosion rates were higher in the steeper areas of the metamorphic geology. 87% of the total volume eroded from road sites in Bull Creek came from sites located on slopes greater than 40%.**

- **Fill encroachment on stream channels caused over 20% of all road site erosion.**

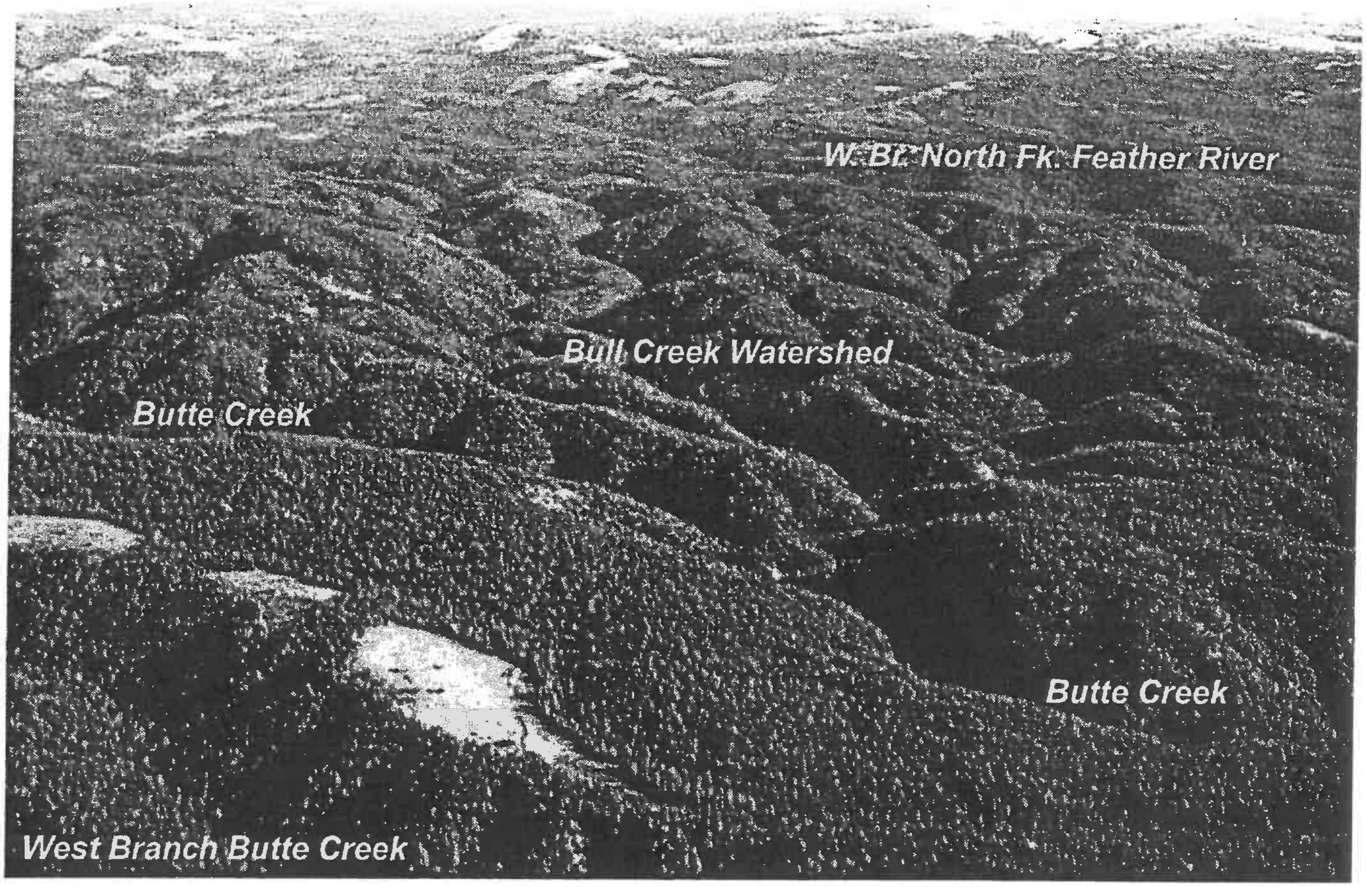
- **50% of all road-related erosion in Bull Creek originated in "inner-gorge" areas. 82% of the roadbed and fillslope erosion (not associated with stream-crossings) originated in these areas.**

- **59% of the stream crossings in Bull Creek lack drainage structures. These sites contribute about 25% of the stream-crossing related sediment.**

- **Within the Bull Creek watershed, 95% of the length of the B-line (Skyway) delivers its drainage directly to a channel.**


Bull Creek Watershed
Surveyed Erosion Sites
and Stream Crossings
Contour Interval - 25 Meters
Scale 1:36,000
● Crossing Site
● Road Erosion Feature
● Crossing Site With No Drainage Structure
Bull Hill
Rimple Ridge
Bottle Hill
Bull Creek
W. Br. Feather R.
N
S
E
W
220B-R1
20B3-R1
B-R1
B-1
B-2
B-R2
B-1
210B1-1
120A-1
120A-R1
120A-R2
B-3
B-4
B-5
200B-1
120A-R3
120A-R4
120A-2
B-R3
B-R4
B-7
200B-2
190B1-1
200B-3
B-R5
190B-1
200B-4
B-8
B-9
200B-R1
200B-R2
B-R6
160B-R3
160B-4
B-10
B-R7
160B-3
160B-R2
160B-R1
B-11
160B-2
160B-1
120A-R5
B-R8
B-R9
A-R2
A-10
A-11
A-R3
A-12
A-13
A-14
A-15
100A-12
A-1
A-2
A-3
A-4
A-5
A-6
A-R1
A-7
A-8
A-9
90A-4
90A-3
90A-5
90A-R5
90A-R4
A-R4
A-16
A-17
A-R5
90A-R2
90A-2
90A-1
90A-R1
100A-9
100A-6
100A-5
100A-R4
100A-8
100A-R2
100A-7
A-18
A-19
A-20
A-21
80A-R1
110B-R1
80A-R2
80A-R3
110A-R1
110A-R2
100A-4
100A-3
110A-R3
A-22
A-23
A-24
80A-R4
100A-2
100A-R1
100A-1
B-R20
A-R6
A-29
A-30
A-25
A-26
A-28
A-27
80A-R5
A-31
A-32
A-33
A-34
A-35
A-36
A-37
A-38
A-40
A-39
A-41
A-42
A-R7
80A5-2
80A5-R
80A3-6
80A3-5
80A3-4
80A3-3
80A3-2

Map 6



In the Bull Creek watershed (shown above), many of the stream crossing sites located on abandoned midslope roads have blown out, as in the example below.

Photo D

Road Erosion

Road Erosion by Cause

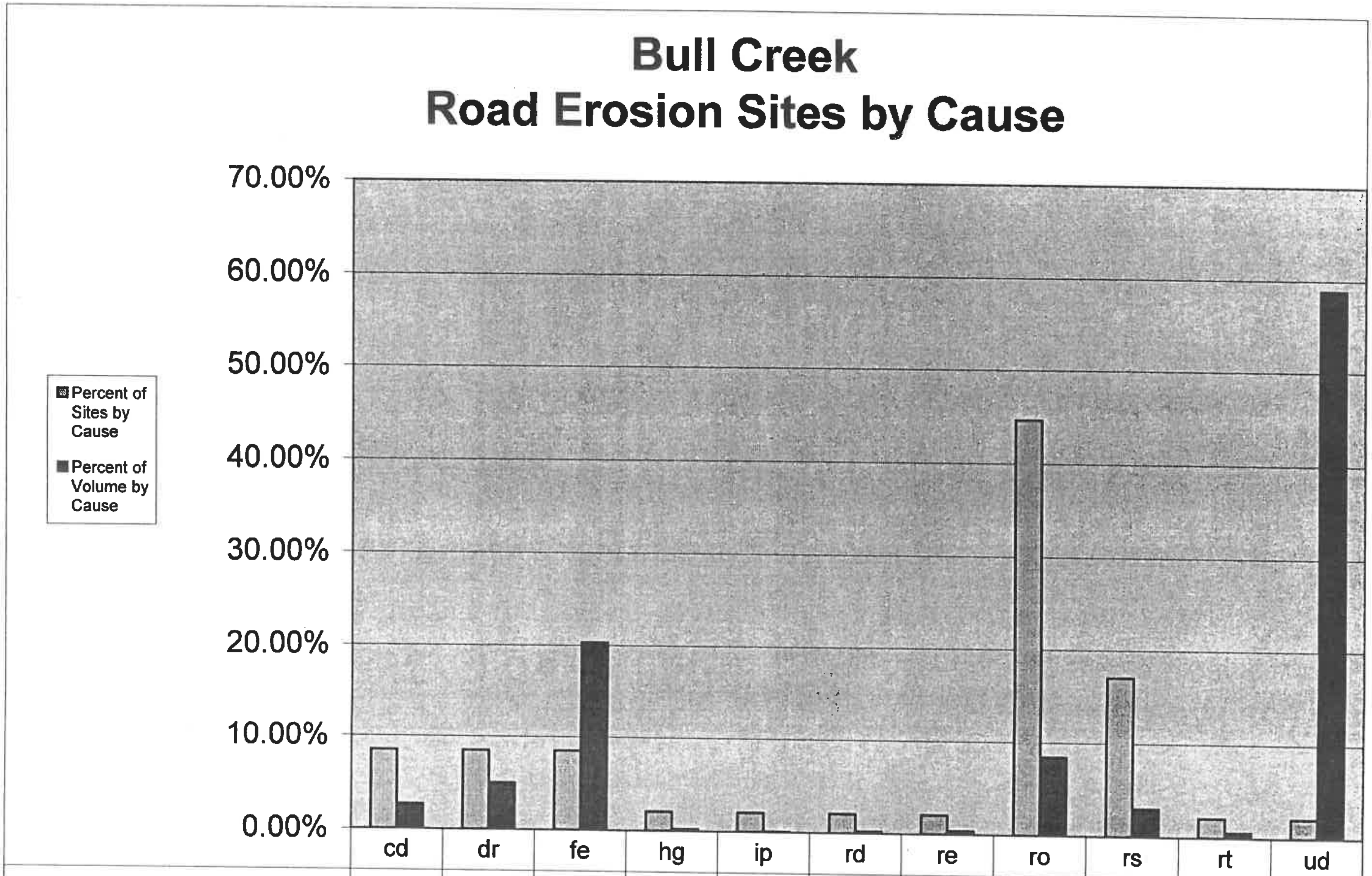
Road erosion sites in the Bull Creek watershed were queried by cause (see Figure 3). Of the 6,120 cubic yards of erosion from road sites in the watershed, 59% came from one site (the A-R5). This 3,600 cubic yard site is located along Bottle Creek, and although it was the only site surveyed at which an exact causal mechanism for failure could not be determined, the area has been heavily modified by historic railroad construction. 1952 aerial photographs show an old railroad fill crossing Bottle Creek downstream of the present A-line crossing, and the A-R5 site is located at the outlet of an old culvert through the old railroad fill. The old pipe is perched 20 vertical feet above the current creekbed, and appears to have passed water onto an unprotected fillslope.

While about 60% of the *sites* surveyed were caused by either intercepted hillslope runoff or road surface runoff, these sites accounted for less than 12% of the *eroded volume* from road sites.

Fill-encroachment (see Photo E) as a cause was disproportionately related to the number of sites by this cause. While this cause was less than 9% of *all sites*, fill encroachment on stream channels caused over 20% of the *eroded volume* from road sites. The A-R2 and A-R3 sites have contributed 1,225 cubic yards of sediment directly to Bull Creek. Both of these sites are located on the A-line road, within the "inner-gorge" of Bull Creek directly downstream of the Bull Creek/A-line crossing (see Photo F).

Road Erosion by Landform

A query of road erosion sites by landform (Figures 4a and 4b) reveals that in the Bull Creek watershed, "inner-gorge" areas are a high-risk area for road erosion. Figure 4a shows that on the basis of the raw data, "inner-gorge" landform produced 82% of the non-stream-crossing erosion, yet comprised less than 15% of the sites. On the A-line road, four sites in the "inner-gorge" areas of Bull, Bottle, and Secret Creeks combined to produce a total of 4,975 cubic yards of erosion. These sites represent 82% of all of the sediment delivered from "inner-gorge" road sites, and comprise 81% of all road site erosion. When the A-R5 site (totaling 3,600 yards^3) is removed, as displayed in Figure 4b, "inner-gorge" locations still contribute 56% of the erosion from road sites. Midslope roads are, however, significant in their role in contributing sediment (see Figure 4b), delivering 26% of the erosion for road sites.

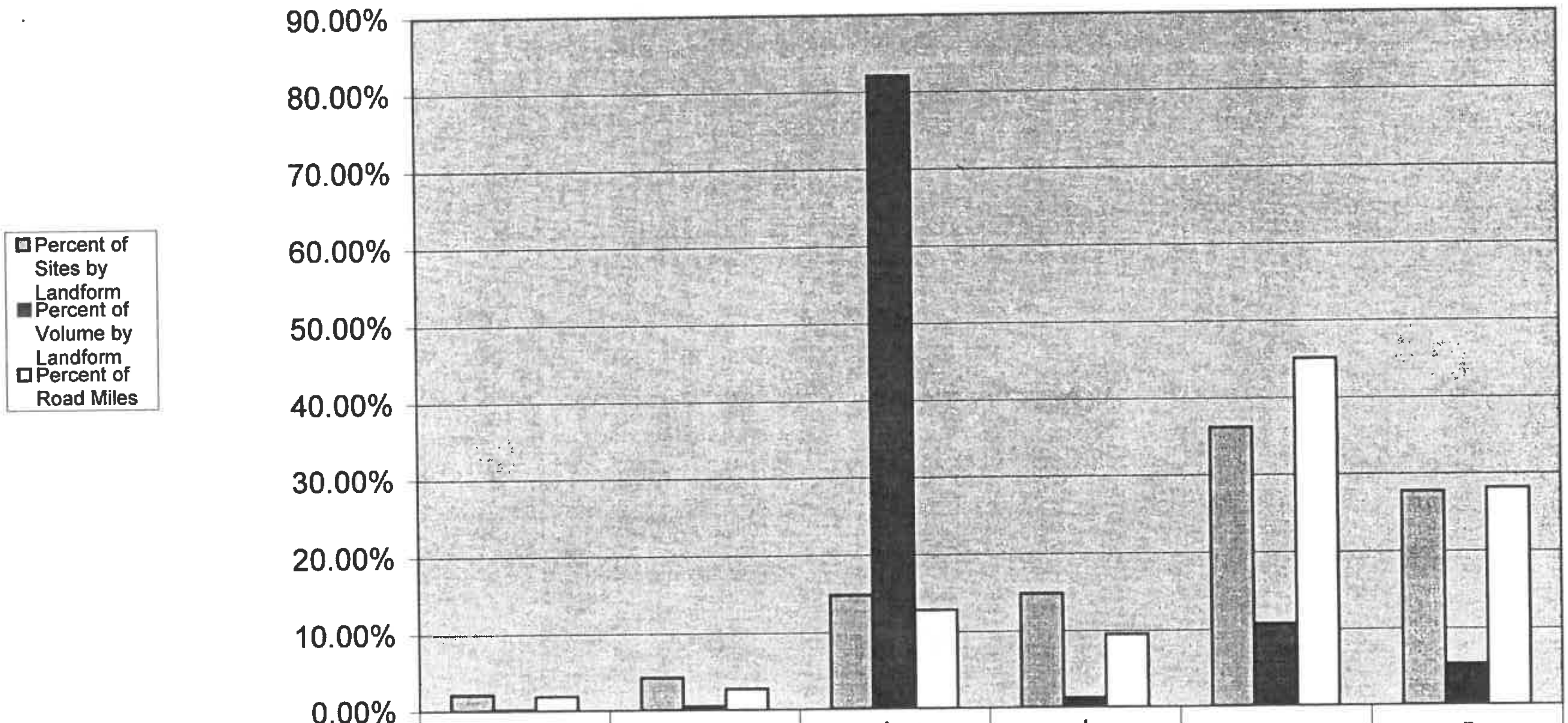


Bull Creek
Road Erosion Sites by Cause

	cd	dr	fe	hg	ip	rd	re	ro	rs	rt	ud
☐ Percent of Sites by Cause	8.51%	8.51%	8.51%	2.13%	2.13%	2.13%	2.13%	44.68%	17.02%	2.13%	2.13%
■ Percent of Volume by Cause	2.74%	5.06%	20.30%	0.25%	0.08%	0.25%	0.41%	8.46%	3.07%	0.57%	58.82%

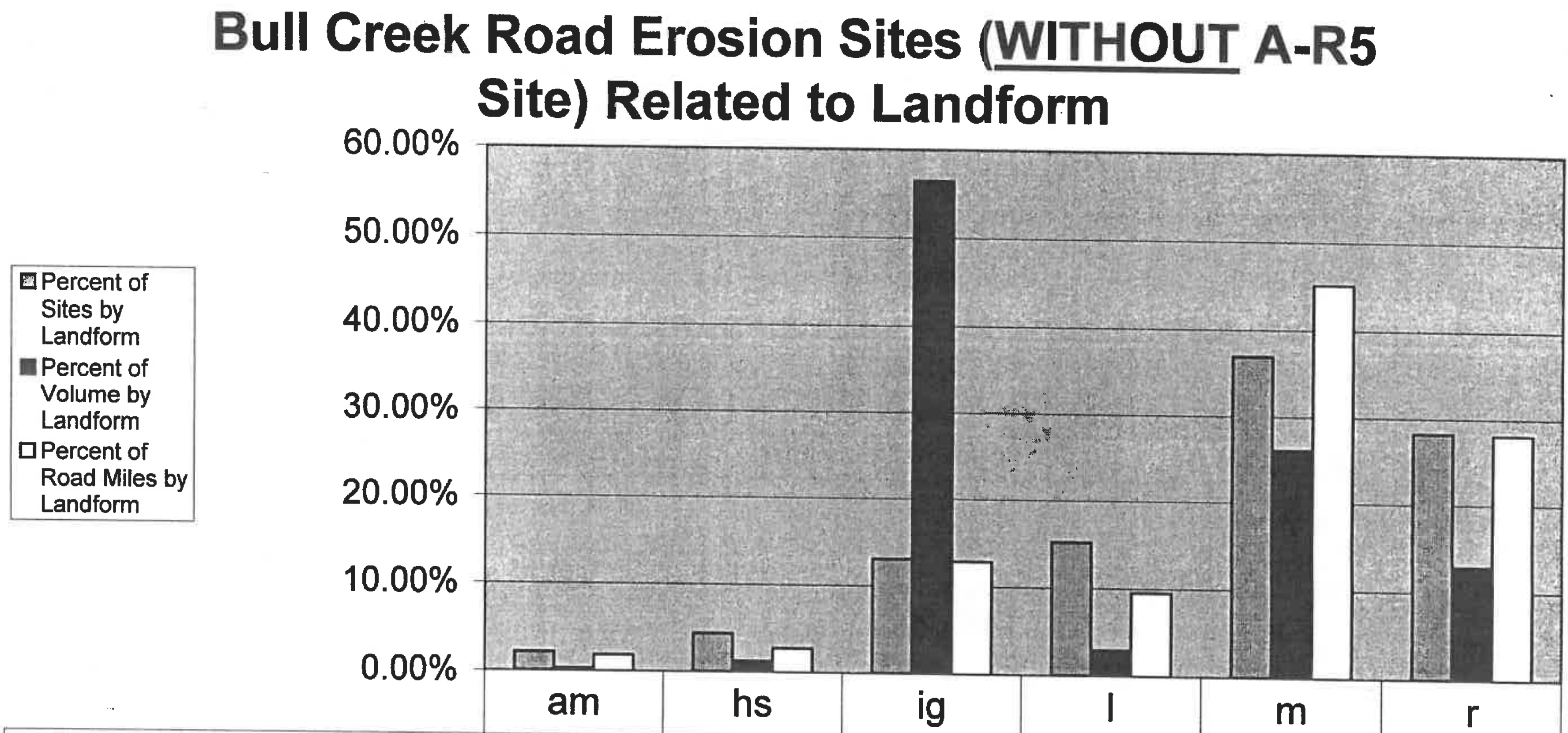
Figure 3

Bull Creek
Road Erosion Sites Related to Landform



	am	hs	ig	l	m	r
▨ Percent of Sites by Landform	2.13%	4.26%	14.89%	14.89%	36.17%	27.66%
■ Percent of Volume by Landform	0.12%	0.53%	82.06%	1.23%	10.74%	5.32%
☐ Percent of Road Miles by Landform	1.84%	2.72%	12.82%	9.47%	45.09%	28.06%

Figure 4a


Bull Creek Road Erosion Sites (WITHOUT A-R5 Site) Related to Landform

	am	hs	ig	l	m	r
▨ Percent of Sites by Landform	2.17%	4.35%	13.04%	15.22%	36.96%	28.26%
■ Percent of Volume by Landform	0.30%	1.29%	56.44%	2.98%	26.09%	12.91%
☐ Percent of Road Miles by Landform	1.84%	2.72%	12.82%	9.47%	45.09%	28.06%

Figure 4b

Two examples of fillslope erosion on the A-Line road in the Secret Creek Basin of the Bull Creek Watershed

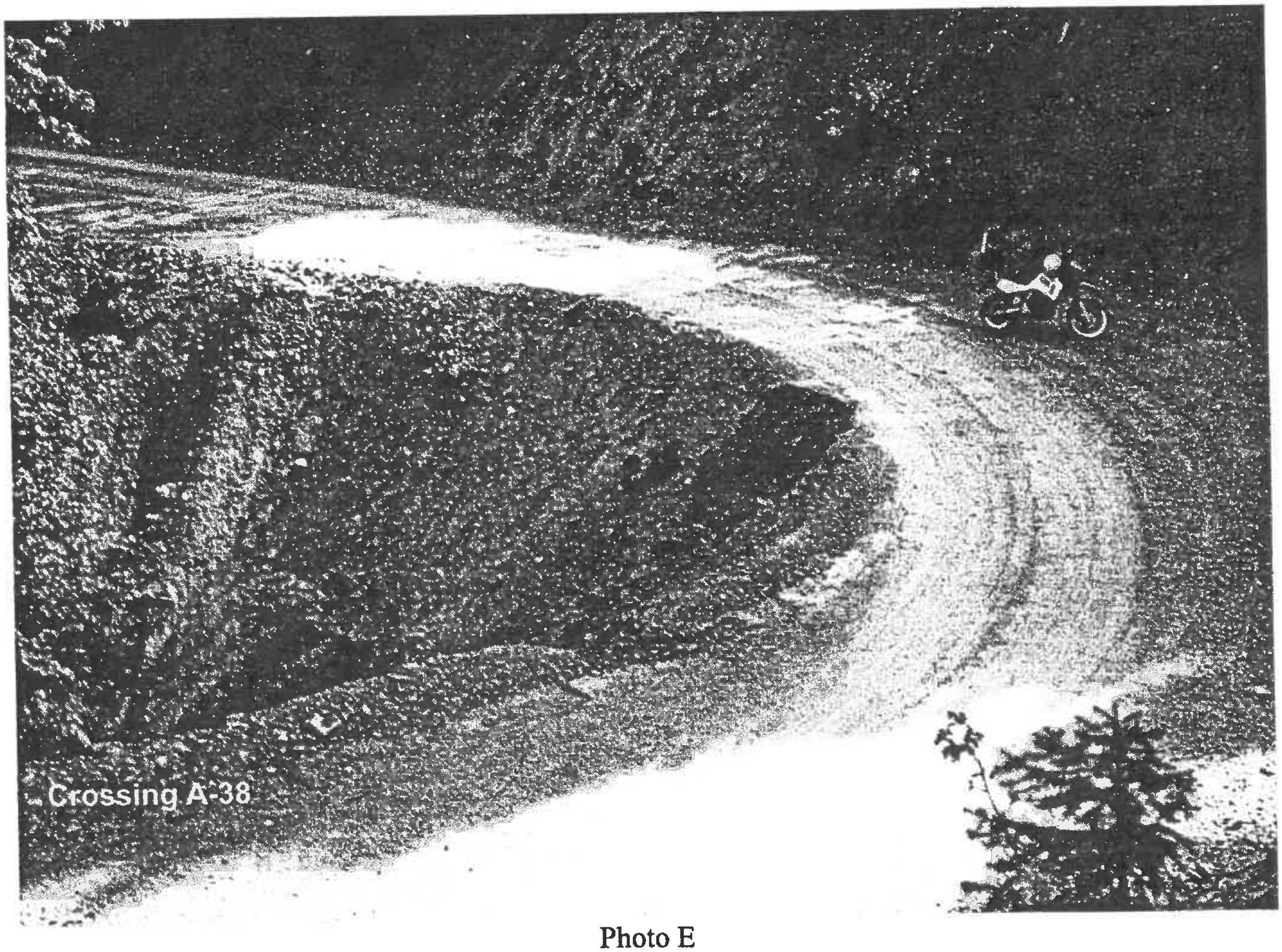
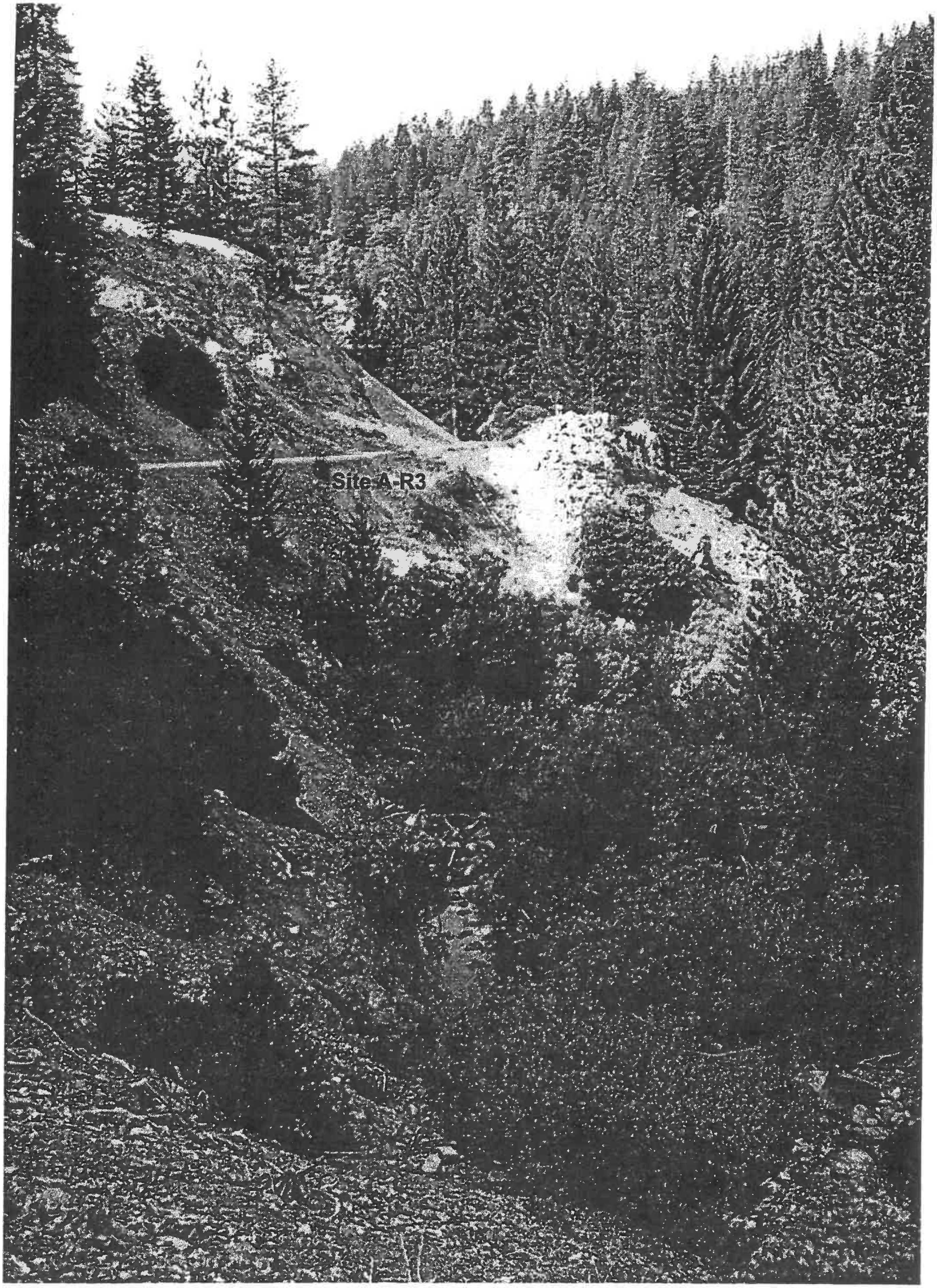


Photo E



Fillslope erosion from the A-Line road in the inner-gorge area
just downstream of the Bull Creek crossing.

Photo F

Road Erosion by Road Grade

A rather odd occurrence is the relationship between road grade and eroded volume and erosion sites. Typically, steeper road grades would be expected to produce more extensive erosion. The A-line road is an old railroad grade, ranging in road grade from one to three percent, on the average of sites surveyed. When road erosion sites were queried by road grade, 83% of the erosion was found to be coming from sites within the road grade class of 1 to 3%, yet the sites from this road class represent only 19% of all sites. This coincides with the fact that the bulk of the road erosion is coming from several large sites on the relatively flat A-line. While 51% of the sites were on roads of 3 to 6% road grade, they contributed only 11.7% of the volume.

Road Erosion by Hillslope

Road erosion sites were queried by hillslope. 87% of the total volume eroded from road sites in Bull Creek came from sites located on slopes greater than 40%. Conversely, erosion from sites with hillslopes ranging from 0-40% totaled only 13%. From this it appears that road site erosion in Bull Creek is concentrated in areas of steeper slopes. This is consistent with assessments showing the bulk of the road site erosion coming from "inner-gorge" (by definition, steeper) areas.

Road Erosion by Configuration

The 3,600 yard^3 "A-R5" road erosion site is not included in this analysis as road configuration at this site appears to not be a driving force in the failure at the A-R5. Rather, it appears that the site is more related to an old railroad fill upstream. Including the A-R5 site gives a distorted view of the affects of road configuration on road erosion in Bull Creek.

Total road erosion not including the A-R5 site comes to 2,520.5 yards^3. Counter to what was found in Scotts John Creek, of the 2,520.5 yards^3 found in Bull Creek, 1,960 yards^3 (or 78% of the eroded volume) were from sites that were *not* in-sloped or drained by inboard ditches. In fact, 1,462.5 yards^3 were found to be coming from sites that were *out-sloped*—a configuration that is usually the most desirable. Out-sloped roads drain water directly across the road surface, more like a natural hillslope. Intercepted groundwater is allowed to flow across the road instead of concentrating and is more likely to disperse and infiltrate when it does so in a diffuse manner such as this rather than concentrated at a ditch relief culvert.

In the case of out-sloped roads in the Bull Creek watershed, three inner-gorge sites contribute 1,375 yards^3 of road erosion to the out-sloped total - with all of this volume coming from steep, unprotected fillslopes. Perhaps most important in the case of these three sites, the base of these fills lie directly on the edge of the stream channels, and are being undermined by streams. In these places, out-sloping may be increasing soil moisture and destabilizing the slope to some extent, but it is the undermining rather than the road configuration that is likely the dominant causal mechanism for the erosion.

Stream Crossing Erosion

Stream Crossing Erosion by Landform

In the Bull Creek watershed, 55% of the all road-related sediment delivery was associated with stream crossings. The majority of this erosion (78%) came from crossings on mid-slope roads, which represented over 60% of the sites surveyed (see Figure 5). Again, this can be directly attributed to the large number of sites on the A-line. 5,257 yards^3 (69.1%) of the erosion from all stream crossings came from the midslope A-line road. One such mid-slope site on the A-line was the A-8 site, where 3,000 yards^3 of erosion occurred (details discussed below in "*Stream Crossing Erosion by Cause*").

"Inner-gorge" areas amounted to 22% of the stream crossing sites, and contributed 18% of the stream crossing erosion. Sites on the A-line contributed 80% of the sediment delivered from "inner-gorge" stream crossings.

Stream Crossing Erosion by Cause

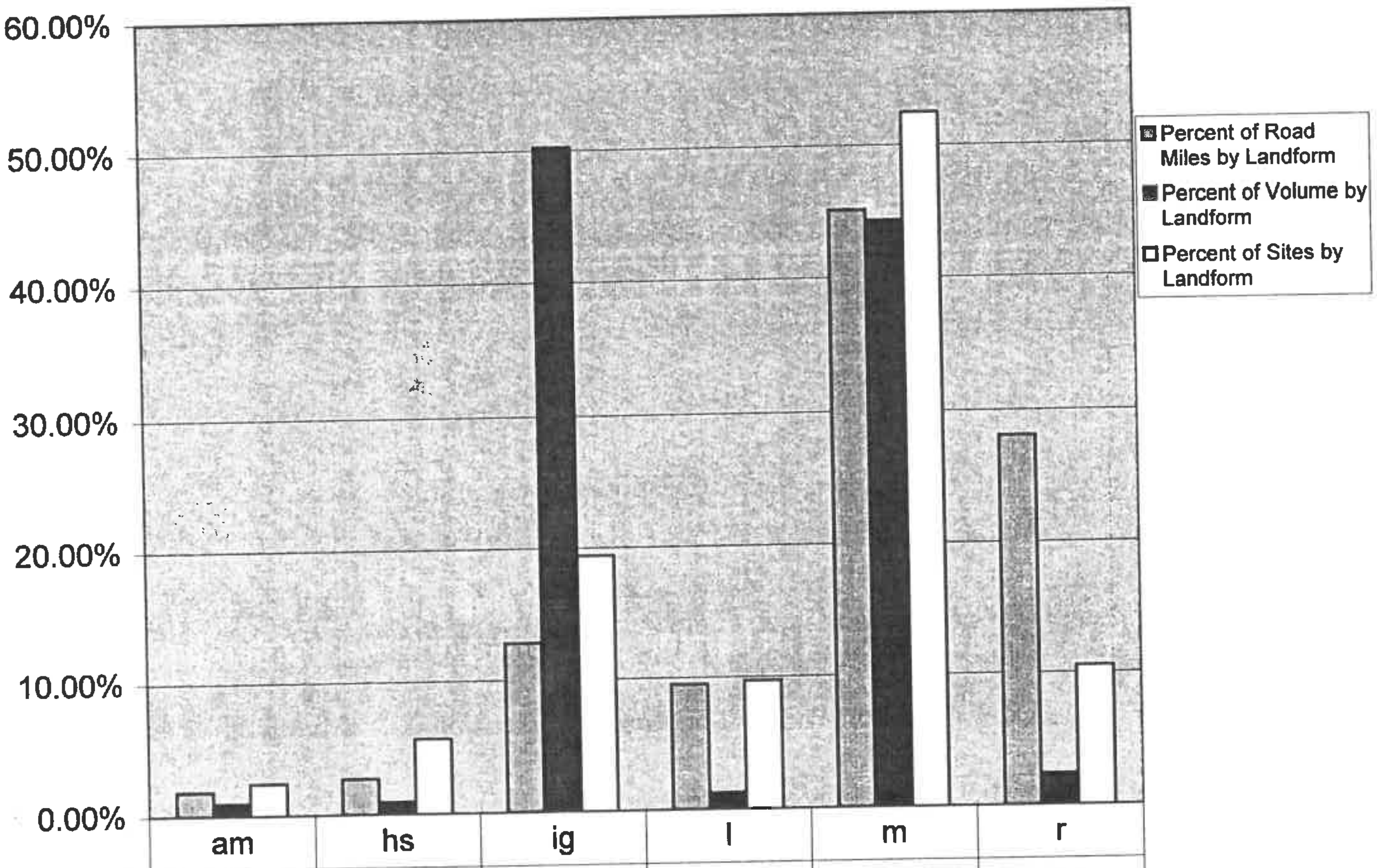
Of the stream crossings in Bull Creek, 59% lack a mechanism for conveying stream flow. "No Crossing" (code NOX) was found to be the most frequent cause of erosion for Bull Creek stream crossings. It should be noted that many of these un-culverted crossings are "ephemeral swale" features that show signs of scour. The 1997 high-precipitation event scoured many swales that had not likely experienced overland flow for some time.

Sites without crossings contributed nearly 25% of the stream crossing-related erosion in the Bull Creek watershed. If the A-8 site (with 3,000 yard^3 erosion on the A-line) is not included in the analysis, sites without constructed crossing have delivered 41% of all stream crossing-related erosion.

The 3,000 yard^3 gully attributed to the A-8 stream crossing site on the A-line contributed 40% of all stream crossing-related erosion surveyed in the Bull Creek watershed. This volume appears to be the result of a historic diversion of the A-8 (or possibly the A-9) stream crossing site, but re-engineering of this area on the A-line in the 1990s makes determining an exact cause impossible. The most likely explanation is that the A-8 stream crossing overtopped during a heavy storm and that the gullying occurred 200' down the road where the water flowed onto the fillslope.

Another noteworthy cause of stream crossing erosion comes from sites where culverts plugged with sediment (code "cps"). These sites comprised 18% of the sites surveyed, and were responsible for 19% of the stream crossing erosion (about 1,400 cubic yards). Such a cause ties in with the results of the analysis undertaken below.

Bull Creek:
Road-Related Erosion (ALL sites) Related to Landform



	am	hs	ig	l	m	r
▨ Percent of Road Miles by Landform	1.84%	2.72%	12.82%	9.47%	45.09%	28.06%
■ Percent of Volume by Landform	0.93%	0.93%	50.23%	1.26%	44.28%	2.37%
☐ Percent of Sites by Landform	2.42%	5.65%	19.35%	9.68%	52.42%	10.48%

Figure 5

Bull Creek Stream Crossing Overtopping and Diversion Potential

As stated in the Scotts John section, stream crossings that were found to have evidence of overtopping are of special concern. In Bull Creek, 19 of 34 constructed crossings show evidence of overtopping (see Table 10). Of the overtopped stream crossings, thirteen have diversion potential, and of those thirteen, four have diverted down roads. Note that of *all* stream crossings (including all *constructed* crossing and those *without crossings*), 33% had DP and of those with DP, 44% diverted (14% of all crossings).

Table 10: Bull Creek Constructed Stream Crossings

	Not Overtopped	Overtopped
Number of Crossings	15	19
Percent of Crossings	44%	56%
Crossings with Diversion Potential	5	13
Crossings Diverted	2	3

Again, while the sample size was fairly small, the set of queries outlined here was attempted to see if any trends emerged relative to stream crossing overtopping. Only stream crossings with constructed crossing were queried. Humboldt crossings, low-water crossings, and streams with no crossings were not queried. Queries were generated using the same data and modified data items as in the Scotts John analysis. Queries were run to determine trends in the following (see Table 11):

> **The average stream grade (here the average of "Stream Grade Upstream" and "Stream Grade Downstream") that caused a culvert to be overtopped.**
>
> **The relationship between the cross sectional area of the stream and the cross sectional area of the crossing inlet.**

Table 11: Overtopping Queries for Bull Creek Constructed Stream Crossings

	Not Overtopped	Overtopped
Average Stream Gradient	27%	35%
Average Ratio of Pipe Grade to Stream Grade Upstream	0.63	0.64
Average Ratio of Channel XS Area to Pipe XS Area	0.82	1.33

It appears that steeper stream crossings overtopped, while lower-gradient crossings were not overtopped. The inconsistency between these findings and results on Scotts John Creek - where lower gradient stream crossings were more likely to overtop - is probably best explained by the steeper Sierran geology of the Bull Creek area.

Another query investigated whether undersized culverts (culvert cross sectional area smaller than stream cross sectional area) induced overtopping. The average ratio between stream and culvert cross sectional area (see Table 11) that was associated with overtopping was 1.33, indicating the stream cross sectional area was 33% larger than the culverts (culvert undersized). On crossings that were not overtopped, the ratio was 0.82, indicating that the culvert was 18% larger than the stream (culvert adequate). In Bull Creek, this attribute appears to be a fairly good indicator for why stream crossings are overtopped.

Stream Crossing Overtopping by Landform

In Bull Creek, where steeper stream gradients were associated with overtopped crossings, an examination of *landform* at these sites may prove insightful. Below, Table 12 illustrates the percent of crossings (including all crossing types and those without crossings) by landform. Mid-slope crossing sites are clearly dominant.

Table 12: Percent of All Bull Creek Stream Crossings by Landform

Bull Creek Stream Crossings	Alluvial/ Meadow	Headwater/Swale	Inner-gorge	Lower Slope	Mid-Slope
Percent of Total	4.40%	5.49%	21.98%	7.69%	60.44%
Percent Overtopped	5.26%	0.00%	5.26%	0.00%	89.47%

Discussion

Road-Related Erosion by Landform

All road-related erosion sites (including road sites and stream crossing sites) were included in a query by landform to identify landform positions producing the greatest amounts of erosion (see Figure 5).

Mid-slope roads comprise 45% of the road miles in the watershed, comprise 52% of the erosion sites surveyed, and produce 44% of the total eroded volume (See Table 13). Inner-gorge roads account for just 13% of the road miles in the watershed, comprise just 19% of the sites surveyed, but produced 50% of the erosion. Again, sites on the A-line road dominate these statistics.

Table 13: Bull Creek Watershed: Road-Related Erosion by Landform Type

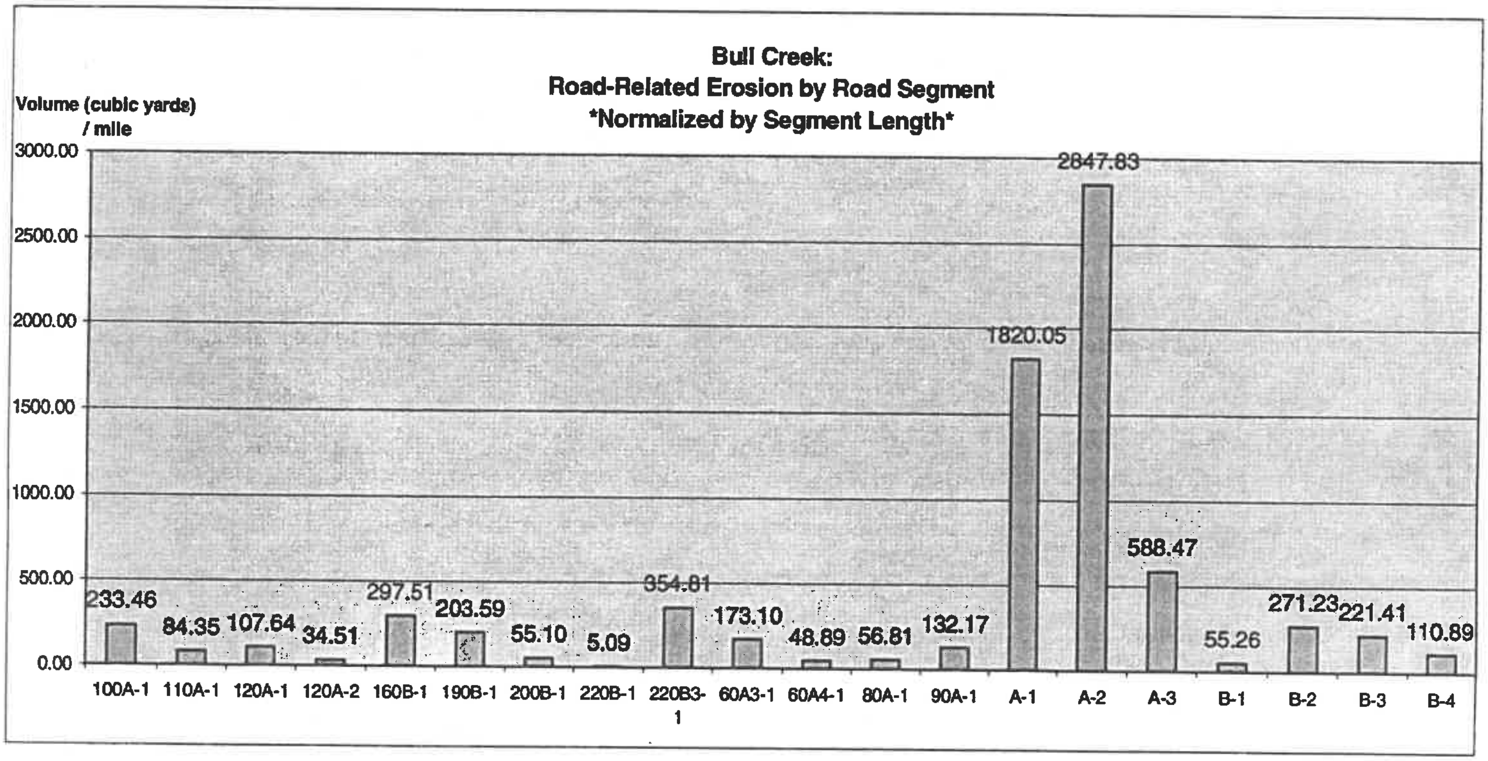
	Alluvial/Meadow	Headwater/ Swale	Inner-gorge	Lower Slope	Mid-Slope	Ridge	Total
Volume (cubic yards)	127	127	6,895	172	6,078	325	13,724
Percent Erosion	0.9%	0.9%	50%	1.3%	44%	2.4%	100%
Percentage of Sites	2%	5%	19%	9%	52%	10%	100%
Percent of Road Miles by Landform	2%	3%	13%	9%	45%	28%	100%

Erosion by Road Segment

(See Map 7 for Bull Creek road segments)

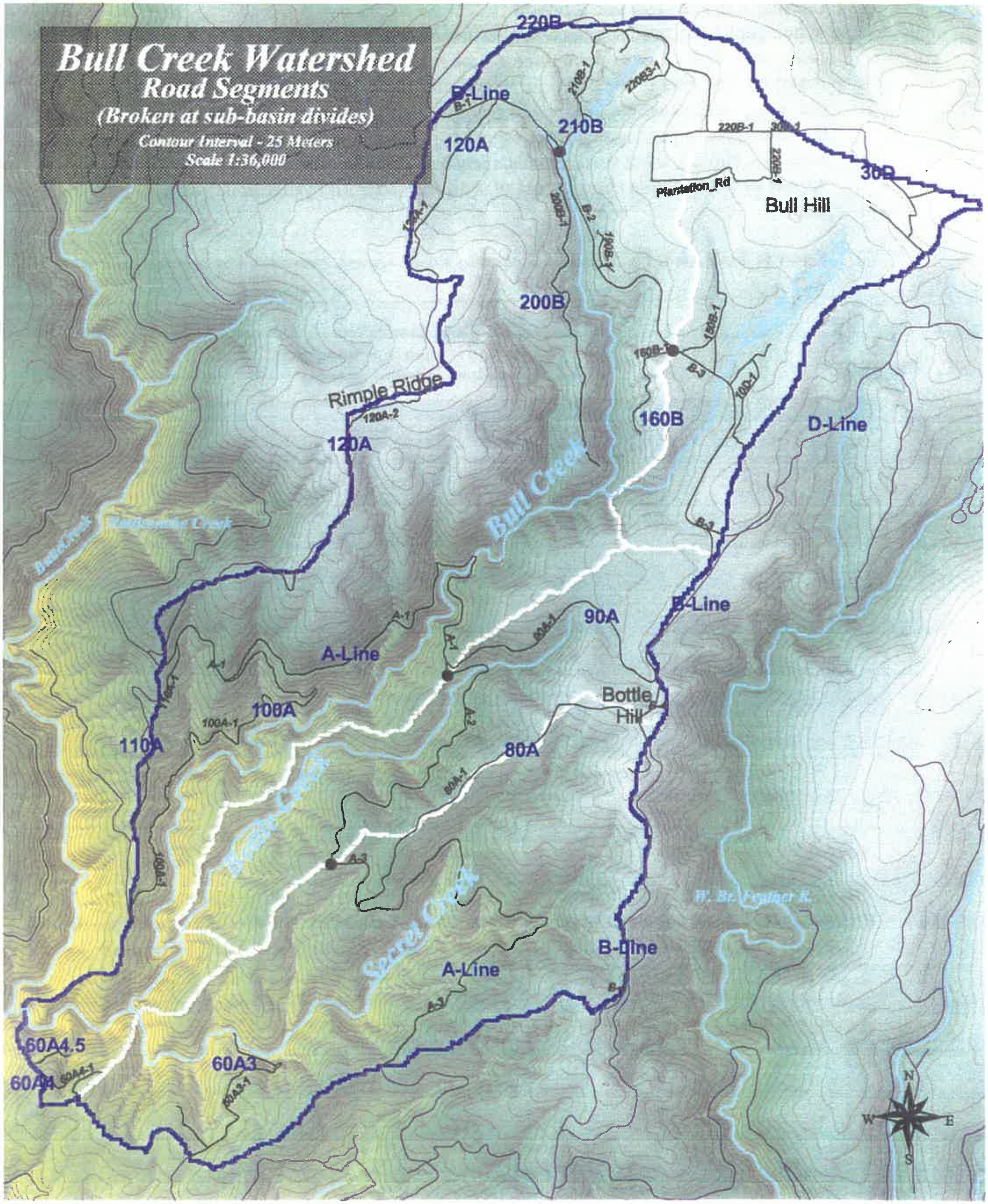
When queried by road segment, similar trends emerge. Of all the erosion in the watershed, 83% occurs on the three A-line road *segments* (A-1, A-2, and A-3). The major erosion *sites* in the inner-gorge and mid-slope areas (*sites* A-8, A-R5, and A-38) of the A-line road skew the data heavily. To account for this, the volumes were normalized by miles of road per segment (See Figure 6). Though the trends for the three "A-line sites" are similar, other road *segments* (such as 220B3-1, 160B-1, B-2, and 100A-1) appear as considerable contributors of sediment (over 200 yards^3/mile) on a mile-for-mile basis .

Figure 6: Bull Creek: Road-Related Erosion by Road Segment, Normalized by Segment Length

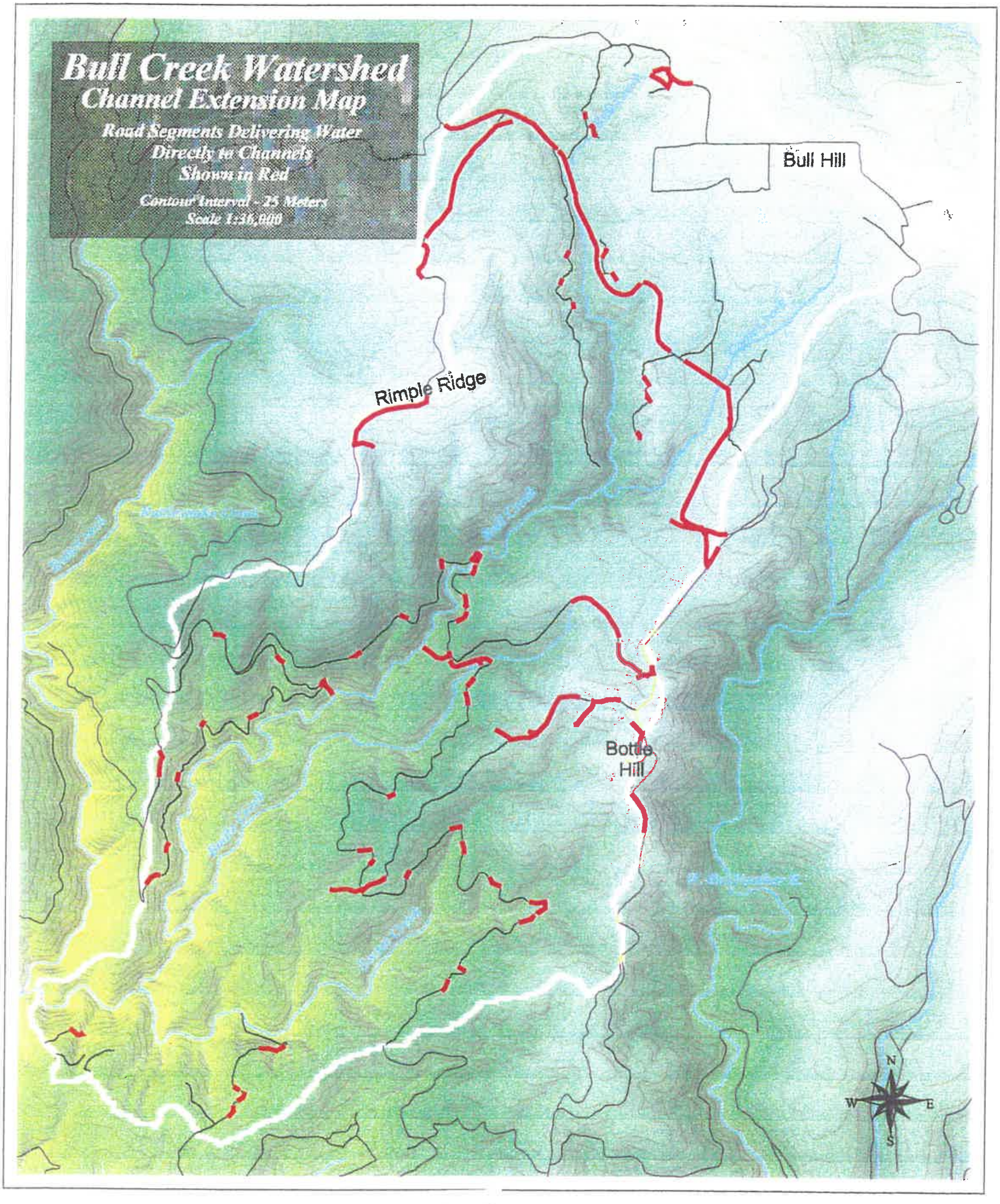


Channel Extension

In Bull Creek 8.62 miles (about 30% of the total 29.12 miles) of the road-surface is connected to the stream system. Of this connected roadway, about 40% comes from the B-line (Skyway) - the only major road in the watershed which is drained by inboard ditches. Within the Bull Creek watershed, 95% of the length of the B-line delivers its drainage directly to a channel. Map 8 graphically illustrates the extent to which the road network is linked to the stream channel network.


Bull Creek Watershed
Road Segments
(Broken at sub-basin divides)
Contour Interval - 25 Meters
Scale 1:36,000
220B
B-Line
B-1
210B-1
220B3-1
210B
120A
220B-1
300-1
220B-1
Plantation_Rd
300
Bull Hill
120A-1
200B-1
B-2
190B-1
200B
160B-1
150B-1
B-3
100-1
Rimple Ridge
120A-2
120A
160B
D-Line
Bull Creek
Rattlesnake Creek
Butte Creek
B-3
B-Line
A-1
90A
A-Line
A-1
90A-1
A-1
110A-1
100A
100A-1
A-2
Bottle Hill
110A
80A
80A-1
Bottle Creek
100A-1
A-3
Secret Creek
W. Br. Feather R.
B-Line
A-Line
B-1
A-3
60A4.5
60A3
60A4
60A4-1
60A3-1
N
W
E
S

Map 7


Bull Creek Watershed
Channel Extension Map
Road Segments Delivering Water Directly to Channels Shown in Red
Contour Interval - 25 Meters
Scale 1:36,000
Bull Hill
Rimple Ridge
Bottle Hill
N
W
E
S

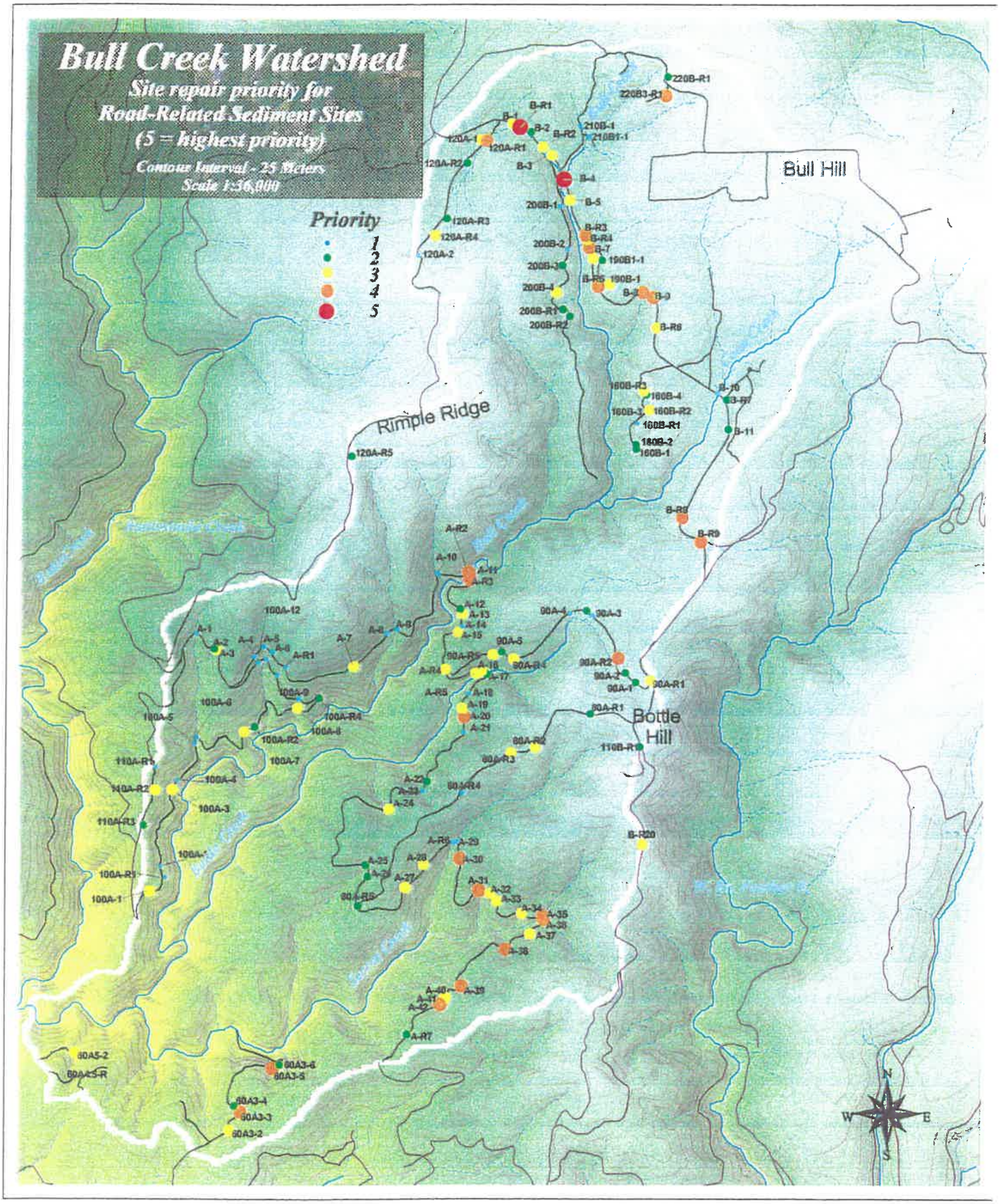
Map 8

Priority Sites

Priority sites for Bull Creek are included in Table 14. See Map 9 for the location of the high priority sites in Table 14 and for sites with lower Priority Levels. In this watershed, the low number of "Priority 5" sites comes from the fact that most large sites that fit the criteria for this category have already contributed much of their sediment in past events. The two sites that are "Priority 5's" are both located on the B-line, and are sites associated with the upper reaches of Bull Creek. Site B-R1 involves a fill encroachment on the tributary that can be alleviated in part by modified maintenance practices. The B-4 site involves a mis-aligned culvert in terms of both grade and plan-view perspectives. The site is causing significant aggradation of sediments upstream of the crossing, trapping fish in an isolated section of the creek just upstream. Also, this site experienced diverted when the crossing failed in 1997.

Table 14: Priority Sites in Bull Creek

Site-Id	Priority	Feature-Type	Fill-VOL
B-R1	5	RDFTR	N/A
B-4	5	cmp	215
A-R2	4	RDFTR	N/A
B-R3	4	RDFTR	N/A
B-R5	4	RDFTR	N/A
B-R8	4	RDFTR	N/A
B-R9	4	RDFTR	N/A
220B3-R1	4	RDFTR	N/A
120A-R1	4	RDFTR	N/A
60A4.5-R1	4	RDFTR	N/A
A-R3	4	RDFTR	N/A
90A-R2	4	RDFTR	N/A
60A3-3	4	nox	200
60A3-5	4	nox	350
A-38	4	nox	1200
A-39	4	nox	1300
A-20	4	cmp	600
A-30	4	cmp	250
A-31	4	cmp	1500
A-35	4	cmp	2200
A-36	4	cmp	800
A-42	4	cmp	70
B-6	4	cmp	300
B-8	4	cmp	120
B-9	4	cmp	36


Bull Creek Watershed
Site repair priority for
Road-Related Sediment Sites
(5 = highest priority)
Contour Interval - 25 Meters
Scale 1:36,000
Priority
1
2
3
4
5
Bull Hill
Rimple Ridge
Bottle Hill
Bull Creek
220B-R1
220B3-R1
B-R1
B-1
B-2
B-R2
210B-1
210B1-1
120A-1
120A-R1
120A-R2
B-3
B-4
200B-1
B-5
120A-R3
120A-R4
120A-2
B-R3
B-R4
200B-2
B-7
190B1-1
200B-3
B-R5
190B-1
200B-4
B-8
B-9
200B-R1
200B-R2
B-R6
160B-R3
160B-4
B-10
B-R7
160B-3
160B-R2
160B-R1
B-11
160B-2
160B-1
120A-R5
B-R8
B-R9
A-R2
A-10
A-11
A-R3
A-12
A-13
A-14
A-15
100A-12
A-1
A-2
A-3
A-4
A-5
A-6
A-R1
A-7
A-8
A-9
90A-4
90A-3
90A-5
90A-R5
90A-R4
A-R4
A-16
A-17
90A-R2
90A-2
90A-1
90A-R1
100A-9
100A-6
A-R5
A-18
A-19
A-20
A-21
80A-R1
100A-5
100A-R4
100A-8
100A-R2
100A-7
80A-R2
80A-R3
110B-R1
110A-R1
110A-4
110A-R2
A-22
A-23
80A-R4
A-24
100A-3
110A-R3
B-R20
A-R6
A-29
A-30
A-25
A-26
A-28
100A-R1
A-27
100A-1
A-31
A-32
A-33
80A-R5
A-34
A-35
A-36
A-37
A-38
A-40
A-39
A-41
A-42
A-R7
80A5-2
80A-5-R
80A3-6
80A3-5
80A3-4
80A3-3
80A3-2
N
S
E
W

Map 9

Varey Creek

The Varey Creek Watershed covers 1,710 acres - 2.64 square miles. It has 9.5 miles of road, yielding a road density of 3.6 miles per square mile. Only seven stream crossings and two road sites were surveyed, and data analysis for this watershed was undertaken in a more qualitative fashion due to the small data set. Map 10 illustrates the location of all road-related erosion sites. Table 15 shows that most erosion (nearly 80%) came from stream crossing sites.

Table 15: Varey Creek Watershed: Road-Related Erosion

Varey Creek Erosion	ROADS	STREAM CROSSINGS	Total
Volume (cubic yards)	70	253	323
Percent	22%	78%	100%

All of the currently maintained roads are on the flatter, ridgetop areas. All of the roads in the lower "gorge" area are abandoned, and the bulk of sediment delivered to streams in the watershed has come from one of these lower-slope roads, the 190G. Out of a watershed total of 323 cubic yards of sediment, 186 cubic yards (58%) came from old crossings with no culverts.

- **All of the erosion surveyed was found to have come from sites on the lower slope (near-stream) positions.**

- **The 80F-R1 site (adjacent to the main ridgetop stream-crossing) was the highest priority site surveyed in Varey Creek.**

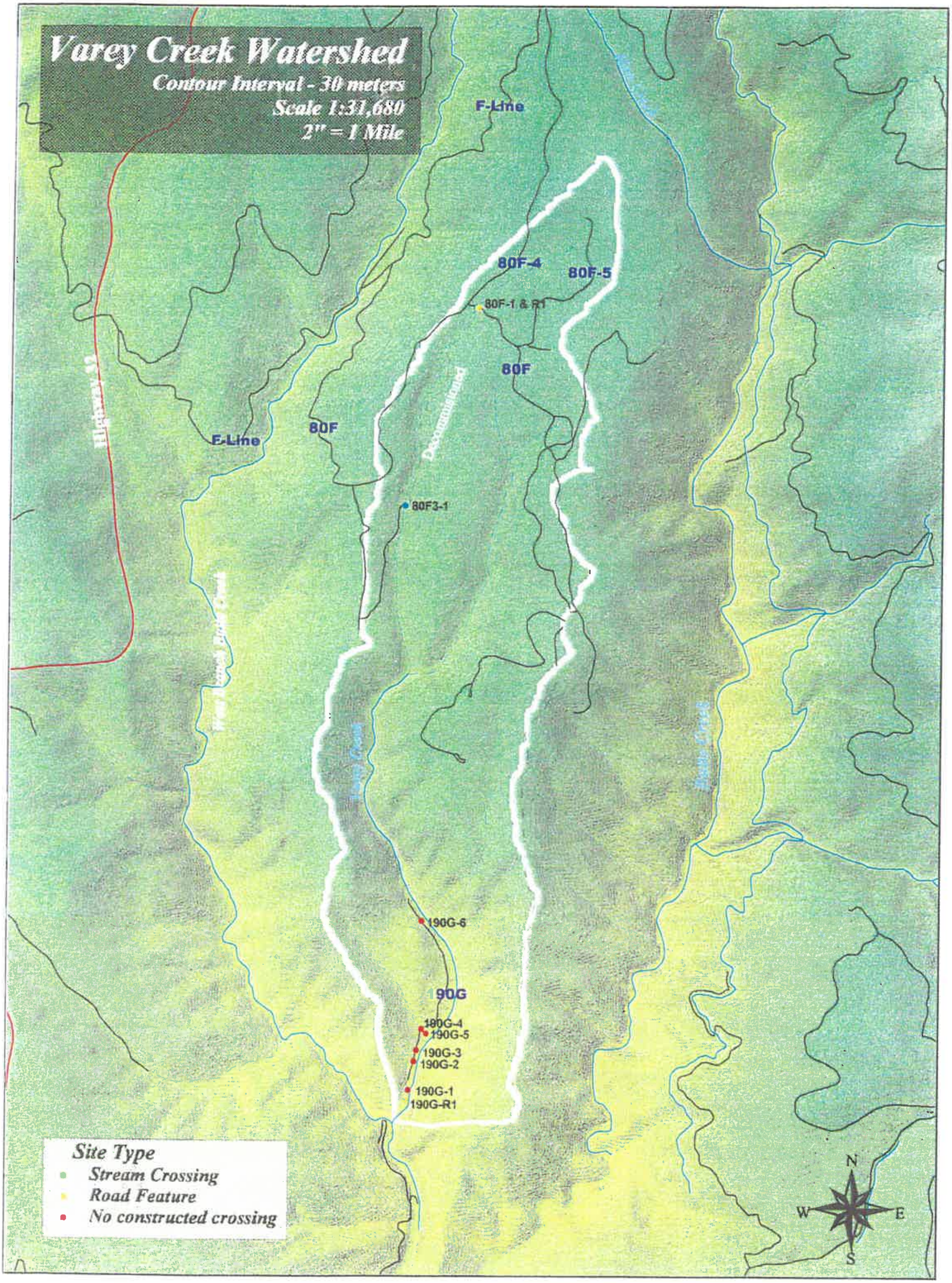
- **With the exception of the 80F-R1 site, stream buffer strips and road-drainage on the ridgetop roads are functioning to keep most fine-sediments out of the stream channels.**

Channel Extension

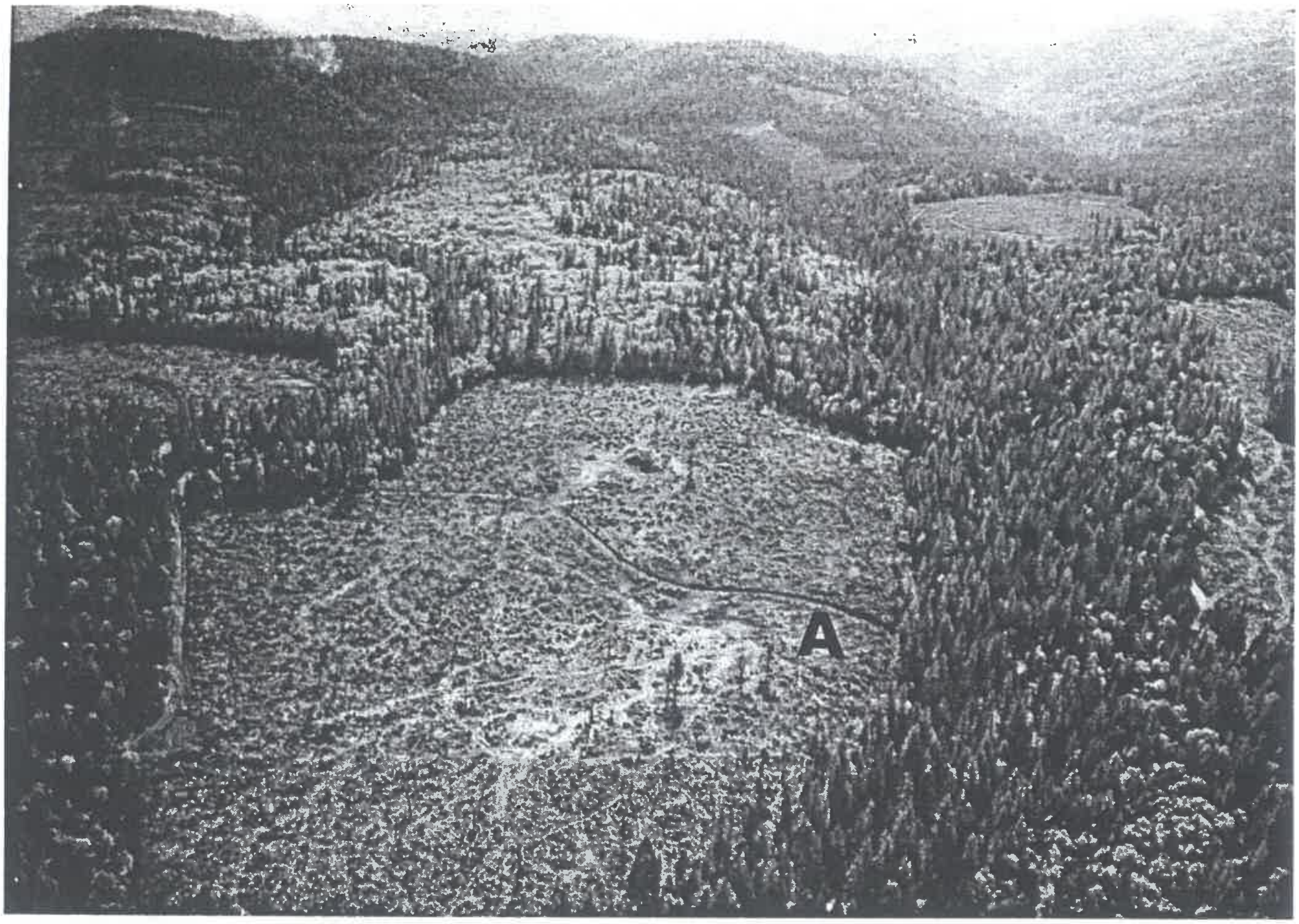
Varey Creek has 0.68 miles of hydrologically-connected road-surface out of a total of 9.5 miles of road - about 7%. Over 1,300 feet (1/3 of the total) of this connected roadway occurs at the crossing on the 80F (see Photos G&H).

Road Erosion by Landform

In Varey Creek, the majority of the road miles by landform fall into the "ridge" category (See Table 16). Most of the upper watershed is located on a relatively flat volcanic ridgetop, mildly incised by the upper reaches of Varey Creek. It is currently being used for commercial timber production. On the ridgetop, old railroad-grades remain in an overgrown state (and were not surveyed) though some have been converted to haul roads. Near-stream roads in the upper portion of the Varey Creek watershed are not extensive. In the ridgetop area, one decommissioned road runs downstream along Varey Creek (beginning at the 80F crossing), and at two points roads cross that stream. In the lower part of the watershed, the 190G Road is the only other near-stream road and is currently


Varey Creek Watershed
Contour Interval - 30 meters
Scale 1:31,680
2" = 1 Mile
F-Line
80F-4
80F-5
80F-1 & R1
80F
Decommissioned
Highway 31
F-Line
80F
80F3-1
190G-6
90G
190G-4
190G-5
190G-3
190G-2
190G-1
190G-R1
Site Type
● Stream Crossing
● Road Feature
● No constructed crossing
N
W
E
S

Map 10



The main stream crossing site (80F-1) in Varey Creek's ridgetop area receives fine sediments from approximately 1,100 feet of entrenched roadway. "A" marks same location on the two different photos.

Photo G

The culvert at site 80F-1 suffers from considerable accumulations of fine sediment delivered from over 1000' of entrenched roadway.

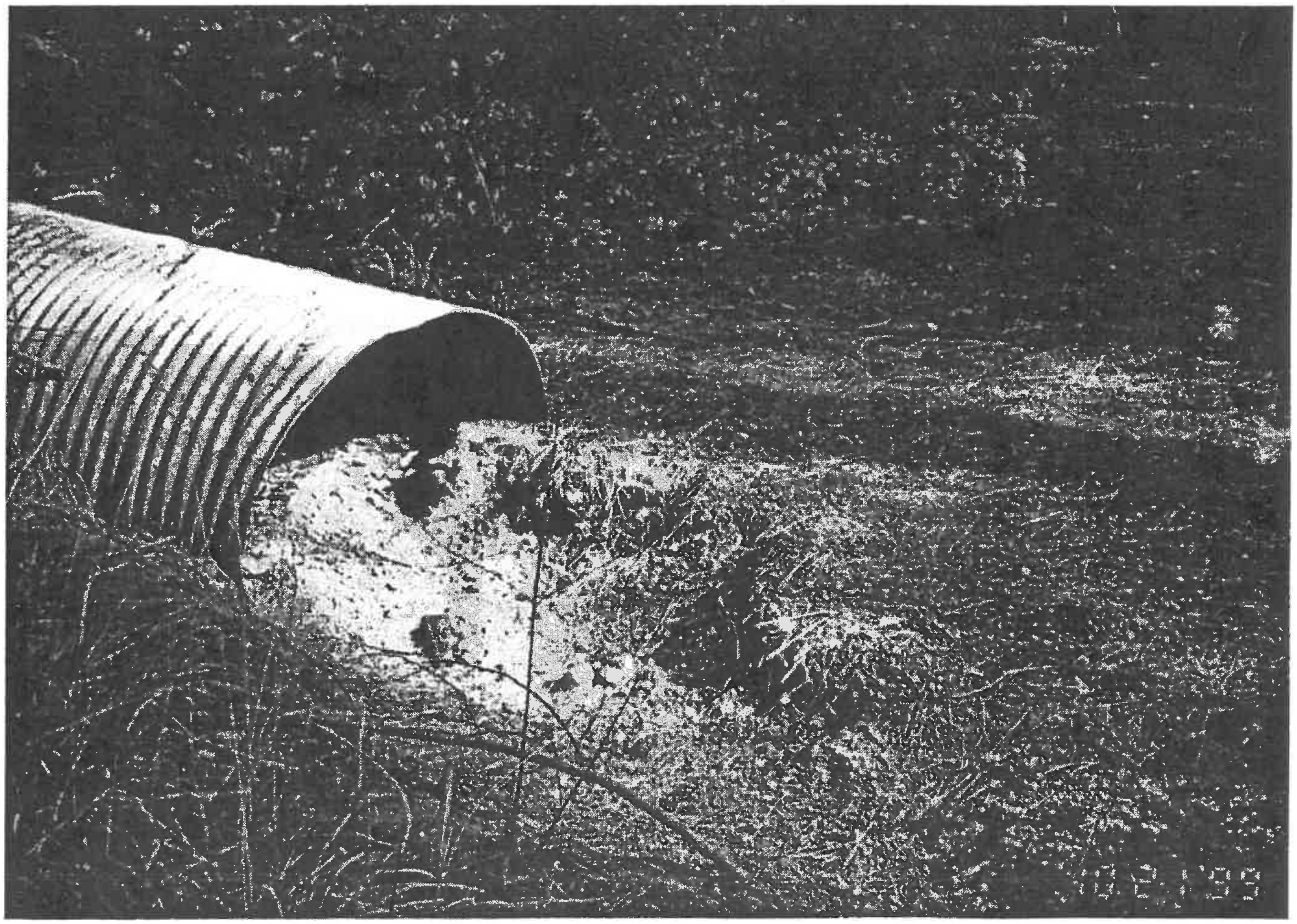


Photo H

abandoned and unused due to the removal of the access bridge by the late-December, 1997 high precipitation event.

Table 16: Varey Creek Watershed: Road Miles by Landform

Landform	Miles of Road by Landform
Headwater Swale	0.18
Lower Slope	2.59
Landing	0.29
Mid-Slope	1.86
Ridge-Top	4.59

The 190G Road is approximately one mile in length, and located within 300 feet of the creek for approximately 3,000 feet. It cuts through a steep landscape that has experienced disturbances from hydraulic and hard-rock mining and historic logging. Of the sediment delivered by this road, 246 of the 306 cubic yards came from stream crossings without culverts (there were no constructed stream crossings on the road). The 60 cubic yards of sediment coming from road features along the lower road were caused by disturbances associated with an old hydraulic-mining site. While three crossing sites on the lower road had diversion potential - with potential distances of 100', 100', and 300' respectively - the average fill volume of these three sites was 50 yards. The lower road has been abandoned for some time. The amount of disturbance necessary to realize minor reductions in sediment yield here makes this one of the lower-priority road-segments surveyed in the three sub-watersheds.

There are few near-stream roads in the ridgetop area of the watershed, and the one abandoned road that parallels the stream on the ridgetop is water-barred and shows no signs of active sediment contribution to the stream. Most of the roads in the ridgetop areas of the watershed are entrenched or out-sloped. No inboard ditches or ditch-relief culverts were found in the watershed. Instead, entrenched ridgetop roads use closely spaced "run-out channels" to funnel road-surface water out onto vegetated, gentle slopes. This strategy seems well-suited to the ridgetop areas in particular - with their deeply weathered soils, gentle slopes, and heavy organic layer all acting to dissipate surface flow.

At the time of the survey, only the 80F-R1 and the 80F3-1 sites were found to be contributing road-related sediment to active channels within the ridgetop area of Varey Creek. New road construction (the opening up of an old railroad grade) was completed during the summer of 1999.

The road erosion site adjacent to the main crossing on the 80F (80F-R1) is fed from the east by approximately 1,300 feet of deeply entrenched road, with a surface area of about 2/3 of an acre (see Photo G, page 56). Due to recent grading of the road in this area, determining a volume for sediment delivered by this site is not possible; but it seems clear that this site is the largest contributor of fine sediments to Varey Creek (see Photo H, page 57). Ditch run-out channels cannot be used to relieve road-surface water here as the road is entrenched as much as seven feet below the surrounding hillslope.

There are two stream crossings in the ridgetop area, one of which (site 80F3-1) is located on an abandoned road and partially plugged with a large log. Stream crossing diversion potential was not an issue of major concern within the ridgetop areas of the watershed, as both ridgetop stream crossings cross the creek in the bottom of draws. The main crossing (80F-1) is located on the only road accessing the eastern side of the ridgetop, and receives seasonally heavy traffic. It is located in a low gradient section of the creek, and its outlet is constricted by accumulations of aggraded sediment delivered by road feature 80F-R1 and other upslope sources (see Photo H).

Analysis Among Watersheds and Watershed Attributes

Erosion by Watershed

For the three watersheds surveyed, an estimated total of 15,942 cubic yards of road-related erosion was surveyed (See Table 17).

Table 17: Estimated Road-Related Sediment Results for All Watersheds (in cubic yards)

(Volume in Cubic Yards)	ROADS	CROSSINGS	ALL ROAD-RELATED EROSION	ROAD-RELATED EROSION PER MILE
Bull Creek	6,120	7,606	13,726	472
Scotts John Creek	1350	542	1,892	197
Varey Creek	70	253	323	34
GRAND TOTALS	7,540	8,401	15,942	

Bull Creek is bisected midslope by the A-line Road. Much of the midslope area in Bull Creek falls upon steep metamorphic geology, and several of the largest erosion sites surveyed occurred in places where the A-line cuts back into the steep inner-gorge areas to cross major tributaries. Subsequently rates of erosion are high for this watershed. This trend is likely consistent on similar landforms and geology in other areas of the Butte Creek watershed.

The lower erosion rate per mile seen in Varey Creek is likely related to fact that the bulk of the roads fall upon the more gentle ridgetop slopes, and are currently delivering little if any sediment to watercourses. Sediment in the upper watershed area is coming from just one site, with the remainder eroding from sites on an un-maintained road in the lower part of the watershed. It seems likely that roads on flatter, volcanic ridgetop areas elsewhere in the Butte Creek watershed will contribute less erosion than those on other landscapes.

Erosion rates in the Scotts John Creek watershed fall in the middle of the other two watersheds. Here, rates appear to be more a function of poor road and crossing design with 35% of all erosion coming from just two crossings and over 50% of the road erosion sites occurring in places where the road intercepts hillslope runoff. Road location is another factor with the near-stream 26N11 road the source of 21% of the total erosion.

If the two large sites on the A-line (the 3,000 yard^3 A-8 site and the 3,600 yard^3 A-R5 site) are removed to reduce the bias brought by these larger sites to results for Bull Creek, the volume per mile falls to the levels shown in Table 18.

While these results are still in the same pattern as overall erosion by watershed, it is important to note that Bull Creek still has the highest rate of erosion per mile.

Table 18: Road-Related Erosion Normalized by Road Miles ***(with sites A-8 and A-R5 removed)***

(Volume in Cubic Yards)	Eroded Volume/Mile
Bull Creek	244
Scotts John Creek	197
Varey Creek	34

Site Attributes Effects on Road-Related Erosion

A summary table showing the four largest erosion sites for both roads and crossings in each watershed is included on the following pages (See Tables 19a and 19b, pages 62 and 63 respectively). Note that Varey Creek has only two road erosion sites and does not contribute the full four sites. Trends in site attributes between the watersheds are discussed in the section following this table.

Codes used in this table are as follows:

Landform:	"l" refers to lower-slope locations
	"m" refers to mid-slope locations
	"hs" refers to headwater-swale locations
	"am" refers to alluvial-meadow sites
Geology:	"and" refers to andesite, or other Cascade volcanics
	"meta" refers to the Sierran metamorphosed sedimentary and volcanics
	"Mudflow" refers to the Tuscan Mudflow
Configuration:	"os" refers to an out-sloped road surface
	"is" refers to an in-sloped road surface
	"entr" refers to an entrenched road surface
	"ibd" refers to inboard ditches on the road surface
	"f" refers to a flat road surface
	"osb" refers to out-sloped road surfaces with a berm

Table 19a: Top Four Stream Crossing Erosion Sites by Watershed

Watershed	Site-Id	Abandoned	Maintained	Landform	Geology	Config-L	Config-R	DP	Diverted?	Feet of Road Feeding Crossing	Volume (yds^3)	CAUSE
SCOTTS JOHN Crossings												
	26N27-1	n	y	m	and	ibd	ibd	y	y	100	347.5	Overtopped culvert led to diversion and ditch erosion
	26N27A-1	y	n	hs	and	f	f	y	y	290	325	Plugged inlet led to diversion and ditch erosion
	26N11A-1	y	n	am	and	f	f	n	n	na	70	Culvert exceeded and blown out--likely due to wood and sediment
	26N27A-2	y	n	hs	and	entr	entr	y	y	1150	15	Plugged inlet led to diversion and incision of new channels
BULL Crossings												
	A-8	n	y	m	meta	os	os	y	y	na	3000	Likely diversion of stream, though exact mechanism unknown
	A-21	n	y	m	meta	osb	is	y	y	na	500	Undersized culvert plugs with sediment and resulted in overtopping and erosion of fill
	A-38	n	y	m	meta	os	os	y	n	na	500	No crossing in steep draw with eroding and sloughing fill
	A-9	n	y	m	meta	is	is	n	n	100	400	Outlet erosion on oversteepened and unprotected fillslope
VAREY Crossings												
	190G-1	y	n	l	meta	is	is	y	y	210	120	No crossing diverted down road to cause fill slump above stream
	190G-4	y	n	l	meta	flat	flat	n	n	100	60	Lack of crossing possibly caused full erosion of fill
	190G-5	y	n	l	meta	is	is	n	n	150	25	No crossing resulted in erosion to bedrock
	190G-2	y	n	l	meta	is	is	y	y	100	15	No crossing forces water to travel down two road segments

Table 19b: Top Four Road Erosion Sites by Watershed

Watershed	Site-Id	Abandoned	Maintained	Landform	Geology	Config-L	Config-R	Feet of Road Contributing	Volume (yds^3)	CAUSE
SCOTTS JOHN Roads										
	150E-R1	n	n	l	and	osb	osb	120	135	Past diversion of upper road ditch water eroded road fill
	26N11B-R2.1	n	y	m	and	ibd	ibd	360	120	Road sfc. water and swale combine to create channels down-slope
	26N11B-R3	n	y	m	and	ibd	ibd	370	100	Road-sfc. water, skidtrail, and swale combine to create channels down-slope
	26N27-R.9	n	y	m	and	ibd	ibd	1120	80	Inadequate ditch relief on steep road causing ditch erosion
BULL Roads										
	A-R5	n	y	l	and	osb	ls	300	3600	"Mystery Pipe and Gully;" See discussion below
	A-R2	n	y	l	meta	os	os	0	675	Fill encroaching on and undermined by creek from Inner-gorge road
	A-R3	n	y	l	meta	os	os	150	550	Fill encroaching on stream from IG road
	B-R8	n	y	r	and	ls	ls	2200	250	DRC water eroding an unprotected hillslope
VAREY Roads										
	190G-R1	y	n	l	meta	ls	os	130	60	Water concentrated in hydro mine rills has eroded fill slope
	80F-R1	n	y	l	mudflow	entr	os	1000	10	Roughly 1000 feet of entrenched road creates rill and gully erosion to crossing

Erosion by Road Configuration

Different trends were observed in road configuration in the three study watersheds as configuration in these separate areas was rather (but certainly not entirely) homogenous. In Scotts John Creek, road erosion sites were commonly associated with a road configuration utilizing an in-board ditch for drainage. This method concentrates flows from road surfaces and upslope areas, often leading to erosion either of ditches, fill-slopes, or hillslopes. Relative to stream crossings, road surface configuration can either be neutral or add water to a crossing from the road surface. The top four crossing sites had lengths of contributing road surface ranging from none to 1150 feet. As demonstrated in the analysis of stream crossing overtopping for Scotts John Creek crossings, length of contributing road drainage is likely a determinant in whether a crossing will remain intact or be exceeded.

In the Bull Creek watershed, road configuration did not appear to the most significant factor contributing to road erosion. Out-sloped roads are designed such that they allow ground and surface water to flow across the road surface without concentrating and exerting greater erosional forces. Yet in Bull Creek, several of the major erosion sites occurred on outsloped roads. Many of the erosion sites for roads and crossings occurred due to the landform they were located on rather than due to road configuration.

In-sloped roads are functionally the same as a road configured with an inboard ditch, except they do not have a *constructed* ditch at the toe of the cutbank. In Varey Creek, erosion on in-sloped road surfaces appears to follow the same trends as in Scotts John Creek, with three of the four largest crossing sites occurring in locations where roads were in-sloped.

Entrenched roads they are completely incised into the land surface, and concentrated road-surface water on long or steep stretches of road in this configuration can cause roadbed and ditch erosion. The 80F-R1 site (Varey Creek) receives water and sediment from over 1000 feet of road surface. Entrenched roadways were not frequently encountered during the survey, but this configuration is used in some areas outside the study area (for example on county roads lower in the Butte Creek drainage). Entrenched roadways may represent chronic sources of road surface erosion, but depending on their position on the landscape (e.g. flat ridgetop areas) this sediment may not be delivered to the channel network.

Erosion by Geology

Hard rock geology, as the underlying strata (and as the parent material for soil) has a marked effect on topography, slope stability, and soil erodability. The three study watersheds are underlain by different geology, resulting in lands that have eroded into distinctly different topography. The differences in topography and the stratigraphy among the study watersheds appear to be the most important factors related to road erosion.

Table 20 outlines the eroded volumes for the three different geologic formations encountered in the three surveyed watersheds. Each of the three geology types are further described and discussed below.

Table 20: Road-Related Erosion (in yards^3) by Geologic Type

	"Andesite"		"Sierran Metamorphics"		"Mudflow"	
	Roads	Crossings	Roads	Crossings	Roads	Crossings
Scotts John Creek	1010	882.5				
Bull Creek	4117.5	125	2003	7481		
Varey Creek			60	246	10	7
total	6135		9790		17	
Road Miles by Geology	27.9		12.1		8.2	
Eroded Volume per Mile by Geology	219.9		809.0		2.0	

In the Scotts John Creek watershed, volcanism associated with ancient Mt. Yana has produced geology composed primarily of andesite and occasional pyroclastic rocks. These geologic formations are relatively recent, older only than the Tuscan Mudflow formation that is prominent in the ridgetop areas of Varey creek. In Scotts John Creek, there are few harsh rock outcrops, and the watershed is relatively well weathered by ice and snow. Hillslopes here are gentler, especially when compared to those in the lower portions of the Bull Creek watershed.

The Scotts John Creek watershed is rather homogeneous geologically, not allowing for analysis of geology related to erosion within the watershed itself.

Most of the upper Bull Creek watershed, (generally the ridgetop areas), is composed of the same geologic materials as found in the Scotts John Creek watershed. Bull Hill is a good example of this, with its gentle slopes and low occurrence of rock outcrops. Residing stratigraphically below (as well as downstream of) these upper watershed volcanics, is the Sierra Nevada "Basement Series", a metamorphosed geologic unit that is hundreds of millions of years old and highly fractured. Similar rocks underlie much of the Sierra Nevada Range. Numerous rock outcrops occur in this geology.

Due to the low position on the landscape and stream system, these "Basement Series" areas are subjected to higher erosional forces. Subsequently, these formations are steep, and more susceptible to erosion and human-induced mass-wasting failures. The higher erosion (see above table) associated with this metamorphosed geology are likely a function of the steeper slopes and the crumbly nature of the formation itself. The "Basement Series" geology is mapped as being in all of the inner-gorge areas of the tributaries to Butte Creek from roughly Grizzly Creek to below the Forks of the Butte (see Map 1). The same geology also comprises much of the canyon-sides of the Butte Creek main-stem in this same reach.

Varey Creek, is roughly divided into two distinct rock types. In its lower "gorge-like" reaches, the geology is similar to that in the lower portions of Bull Creek. On the upper ridgetop, the Sierran geology has been coated with a veneer of Tuscan Mudflow, the most recent geologic formation in the upper Butte Creek watershed. All but two of the road-related erosion sites in the Varey Creek watershed were located on the metamorphic geology. It appears that the Tuscan ridgetops, which are quite broad and flat relative to the other geology in the watershed, are fairly stable in terms of road related erosion.

Erosion by Soil Type

As a general rule, at stream crossings, soils are not a major factor relative to failure. At stream crossing erosion sites, factors such as stream grade (a function of the landform and geology), culvert alignment and grade, culvert size, etc, are more important than the soil on the banks of the stream. Counter to this are road erosion sites where the texture, cohesiveness, structure, rock fragment content, etc, of a soil is much more important relative to erosion. It is for these reasons that only road-related erosion by soil type at *road erosion sites* (as opposed to all road-related erosion sites including streams) was examined.

In the Scotts John Creek watershed, soils information was available from the U.S. Forest Service in digital format. This facilitated an easy query of erosion by soil type, presented in Table 21.

Table 21: Road Erosion by Soils: Scotts John Creek

USFS Soils Code	74	80	84	123	128	129	132	Grand Total
Volume (yards^3)	0	265	12.5	0	272.5	385	75	1010
Percent of Total	0.0%	26.2%	1.2%	0.0%	26.9%	38.1%	7.4%	100.00%

Soil survey information from the Forest Service, (included in Appendix D), was analyzed in an attempt to find a trend relative to any certain soil characteristics that may have influenced the findings in Table 21. Soil types 128 and 129 were the dominant soil types in "near-stream" and lower-slope positions, where the majority of the sites were. It appears that road maintenance, design, and landform were more important than the soil type itself.

For the Bull Creek and Varey Creek watersheds, soils information was inferred using parent material (geology) and slope class. Slopes at road-erosion sites were grouped into classes that correspond to those used by the NRCS Soil Survey, and this data is displayed with eroded volumes in Table 22. Some of the general information on soil units - including name, position, elevation, vegetation, and precipitation - is in Appendix D. Additional information will be available when the NRCS Butte County Soil Survey is completed.

Table 22: Bull Creek Road-Erosion Related to Soil (in cubic yards)

	Geology		
Hillslope Class	Metamorphic	Volcanic	Grand Total
4 >50%	885		885
3 30-50%	913	3930	4843
2 15-30%	37.5	102.5	140
1 0-15%	167.5	85	252.5
Grand Total	2003	4117.5	6120.5

Cubic Yards/Mile	185.46	225.00
Cubic Yards/Mile w/out A-R5 Site (volcanic)	185.46	28.28

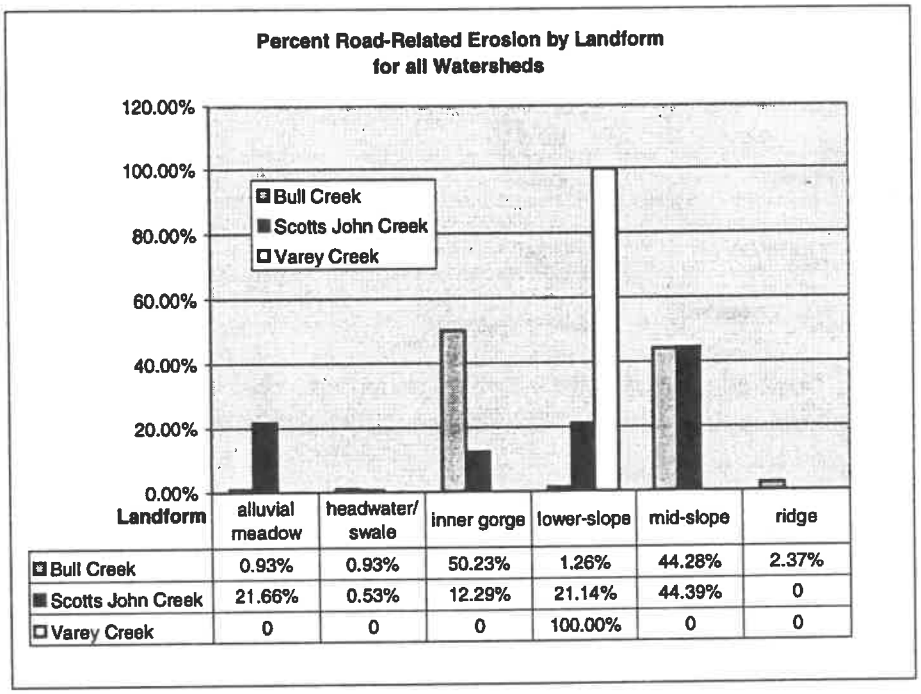
Road site A-R5 (located on slope-class 3 volcanic soils in Bull Creek) amounted to 3,600 yards. Although the exact cause was considered "undetermined," it appears that the failure was related less to soil properties and more to the failure of a historic railroad-fill. For this reason, it is useful to examine the rates of erosion per mile *without the A-R5 site*. As noted in the Geology section above, erosion rates were higher in the steeper areas of the metamorphic geology. It seems that while the soils of these areas are more skeletal and lower in cohesive clays (See Appendix D), the steeper slopes and landscape position may be the driving forces for increased erosion rates in these areas.

In Varey Creek, the limited amount of data (due to the low number of sites, particularly on the Tuscan Mudflow ridgetops) was not conducive to an analysis of soils. In Varey Creek, all erosion related to roads was found to be coming from lower-slope sites, particularly the abandoned 190G Road (see Map 10). The 190G Road (contributing 95% of all Varey Creek erosion) is entirely in metamorphic geology. The deeply weathered ridgetops have produced finer textured, more cohesive soils than in, for example, the lower portion of Bull Creek. The increased biological productivity and resulting biomass on the forest floor (particularly within stream buffer strips) here appear to work well to disperse water and sediment delivered from the road system.

Erosion by Landform

An analysis of erosion by landform for all three watersheds resulted in Figure 7. Trends within individual watersheds were quite strong relative to the representative landforms for which they were chosen. Consequently, data in Figure 7 was not lumped together on a study-wide average. In this way, trends within the three individual watersheds can still be seen, and any trends in landform variability will also be illustrated.

Figure 7: Percent of Road-Related Erosion by Landform for all Watersheds



Landform	alluvial meadow	headwater/ swale	inner gorge	lower-slope	mid-slope	ridge
▨ Bull Creek	0.93%	0.93%	50.23%	1.26%	44.28%	2.37%
■ Scotts John Creek	21.66%	0.53%	12.29%	21.14%	44.39%	0
☐ Varey Creek	0	0	0	100.00%	0	0

In Bull Creek, 94.5% of the erosion in the watershed was found to be coming either from inner-gorge sites (50.2%) or mid-slope areas (44.3%). Again, these landforms coincide with the metamorphic geology and it is difficult to determine if it is the geology and stratigraphy that are responsible by way of determining the landform, or if it is landform independent of these two that may be a reasonable indicator for hazard.

Scotts John Creek has a considerable amount of erosion from mid-slope locations (44.28%), as well as alluvial/meadow areas (21.66%) and lower slopes (21.14%). Diverted stream crossings and new channel incision contributed to the amount of erosion on mid-slope roads.

Erosion Related to Maintenance and Abandonment

Stream crossings and ditch relief culverts likely received some sort of maintenance in 1996. Much of the road-related erosion likely occurred in 1997. *A lack of timely road maintenance (e.g. during large storm events) may be one of the major causes of stream crossing overtopping and general road-related erosion in that watershed.*

In the Bull Creek watershed, all of the top eight road-related erosion sites were found on maintained roads. *In the Bull Creek watershed, landform and geology appear to bear greater influence on road-related erosion than does maintenance.*

In the Varey Creek watershed, all road-related erosion (except for 10 yards^3 contributed from one site on the ridge) came from abandoned roads. The roads in the lower portion of the Varey Creek watershed appear to have been abandoned for a considerable amount of time (20 years or so) judging from conifer regeneration on the road surface in several areas.

In all of the study watersheds, no road-related erosion sites were found on decommissioned roads. The amount of decommissioned roadway encountered during the survey was relatively small. Only a 0.6 mile segment of road in the Scotts John Creek watershed and another 0.9 mile segment of road in the Varey Creek watershed had been decommissioned.

Recommendations and Conclusions

The findings of this study generally coincide with the road surveys done in other areas in the past. Some trends arose during the survey; a lack of maintenance will almost always result in problems - especially where the road configuration includes an inboard ditch. Also it seems apparent from this and preceding studies that - from a sediment standpoint - ridgetops are the best location for roads. Midslope roads may function well if designed properly and well maintained, but can pose problems on steep slopes and in inner-gorge areas. Lower slope roads, and roads in alluvial areas must often negotiate many stream crossings, can be costly to maintain, and must be carefully engineered - if they are to be used at all.

Many of the erosion sites for roads and crossings occurred due to the landform they were located on rather than due to road configuration. Erosion rates were higher in the steeper areas of the metamorphic geology. In the steep inner-gorge areas of Upper Butte Creek and its tributaries, future management should avoid building roads through these areas. In Bull Creek, every inner-gorge area that was entered by the A-line road produced considerable sediment.

While accounting for about 18% of the total mileage of roads surveyed, the midslope A-line road in Bull Creek accounted for nearly 70% of all erosion surveyed. On the steep slopes found in Bull Creek, the natural rate of ravel, or sheet erosion of the coarse-grained metamorphic soils appears to be quite high. As any hillslope is at its natural angle of repose, any fill placed on a hillslope is - in the long-term - a temporary installation. The large railroad fills of the A-line may represent the highest erosion risks surveyed in this study.

Nearly half of the stream-crossing sites surveyed lack drainage structures. The 1997 rain-on-snow event scoured many channels that likely have not flowed for many years. This illustrates the difficulty and expense not only in maintaining a transportation system that is capable of passing the flow of a 100-year or larger storm event, but also in identifying where potential stream channels may be located.

It appears that the volcanic ridgetops (e.g. Upper Varey Creek), which are quite broad and flat relative to the other geology in the watershed, are fairly stable in terms of road-related erosion.

Most of the problem sites surveyed were associated with undersized or plugged culverts, inadequate cross drain spacing, or fillslope erosion on inner-gorge landforms. In most cases a few fixes could significantly reduce the future potential erosion hazard. Some of these include:

1. Regular maintenance of areas that have been shown to have recurring problems.
2. Increasing the number of ditch relief structures (including rolling dips) in areas with inadequate cross drains.
3. Installation of stream crossing structures where none currently exist.

4. Increasing the culvert size where plugging and overtopping have been shown to be a regular problem.
5. Decommissioning or relocating roads which are chronic sources of sediment (e.g. the 26N11 road), or roads which can not currently be maintained.

Acknowledgements

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Bibliography

Beschta, R. 1978. Long-Term Patterns of Sediment Production Following Road Construction and Logging in the Oregon Coast Range. Water Resources Research. 14(6): 1011-1016.

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

Cawley, Ken. Hydrologist/Erosion Control Planner, Meadowbrook Conservation Associates. 1999. Personal Communication.

Cederholm, C.J. and Reid, L. M. 1987. Impact of Forest Management on Coho Salmon Populations of the Clearwater River, WA: A Project Summary. In: Streamside Management, eds. Salo and Cundy. University of Washington, Institute of Forest Resources. Pages 372-398.

King, J. G. and L. C. Tennyson. 1984. Alteration of Streamflow Characteristics Following Road Construction in North Central Idaho. Water Resources Research 20(8): 1159-1163.

Meadowbrook Conservation Associates. 1996. Survey of Road-Related Sediment Sources in the Deer Creek and Mill Creek Watersheds, Tehama County, CA.

Napper, Greg. Transportation Planner, Lassen National Forest. 1999. Personal Communication.

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4): 693-727

Reid, Leslie, and Dunne, Thomas. 1984. Sediment Production From Forest Road Surfaces. Water Resources Research, Vol. 20, No. 11 Pages 1753-1761, Nov. 1984.

Reid, Leslie M. 1999. Research Geomorphologist, United States Forest Service, Pacific

Southwest Research Station, Redwood Sciences Laboratory. Presentation made at the "Sociological and Ecological Consequences of Roads in the Sierra Nevada" Conference, Oct. 22-24, 1999, South Lake Tahoe, CA.

Rice, Raymond M., Tilley, Forest B., and Patricia A. Datzman. 1979. A Watershed's response to Logging and Roads: South Fork Caspar Creek, CA, 1967-1976. Res. Paper PSW-146. United States Forest Service, Pacific Southwest Forest and Range Experiment Station. Berkeley, CA.

Teigen, Mel. 1999. United States Forest Service, Region 5; Regional Engineer. Presentation made at the "Sociological and Ecological Consequences of Roads in the Sierra Nevada" Conference, Oct. 22-24, 1999, South Lake Tahoe, CA.

United States Forest Service 1998. Jonesville Management Area; Cherry Hill, Scotts John and Cirby Compartments; Landscape Analysis and Environmental Assessment . Almanor Ranger District, Lassen National Forest.

Weaver, William E., and Hagans, Danny K. 1994. Handbook for Forest and Ranch Roads. Mendocino County Resource Conservation District, Ukiah CA.

Wemple, Beverley C., Jones, Julia A., and Gordon E. Grant. 1996. Channel Network Extension by Logging Roads in Two Basins, Western Cascades, Oregon. Water Resources Bulletin 32(6) 1195-1207.

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APPENDICES

Table of Contents

Appendix A:

Road Feature
and
Stream Crossing
Data Forms

Road Feature ID# ☐

Butte Creek Road Survey

Road Feature Inventory Form

Date: Crew: Watershed Code:

Road Name: USFS#__________SPI#_________ Photo#: Traffic level: **L M H**

Abandoned: **Y N** Maintained: **Y N** Driveable: **Y N** Decommissioned: **Y N**

Erosional Feature: Roadbed Cutbank Fillslope Ditch Landslide DRC Landing Dip

Landform: Ridgetop Midslope Inner Gorge Spur Ridge Lower (within 200' of str.) Meadow/Alluvial fan Noseslope Headslope

Geology/Soils/Landform notes:_____________________________________

____

____

____

Site Characteristics: Hill Slope (%) ____ Fill Slope (%) ____ Cutbank Slope (%) ____

Is feature related to other sites? Site #_______________ Aspect: _____°

Receiving Feature: **Stream Hillslope Fillslope** Leads to Road Downslope: **Y N**

Receiving feature currently eroding?: **Y N** Erodability of receiving feature: **H M L**

Fed by road/ditch? **Y N** *Hydrologically connected **Y N** * Dist. to stream: _____

Road Info: Road Width: _____ Surface material: _________ Prism Design: ___________

Road Configuration: **L**_________**R** _________ Other roads upslope: **Y N**

Contributing Road Grade & Length: **L** ____/ +/- ___% **R** ____/ +/- ___%

DRC Info: Size (dia.) __________ Culvert Grade (%) _______________

Culvert condition: (inlet) ____ (outlet) ____ (bottom) ____ **(O, C, P, R, B)**

Diversion Potential: **L R** Diverted?: **Y N** Potential Diversion Distance:________

Is material aggrading above inlet: **Y N** Volume of Aggraded Material ____________

Evidence of *Overtopping* **Y N** Is pipe being undermined **Y N**

Maintenance Comments:

____

____

____

Erosion Type: ________________

Volume of sediment delivered by *past erosion*:________________

Erosion Cause: ________ ________ ________

Suggested Treatments: ______ ______ ______

Under current maintenance, will problem reoccur? **Y N**

Past causes of erosion:_____________________________________

____

____

Possible erosion from existing structure/maintenance practices: ____________________

Remarks:

SKETCHES

North

Drawn By: _____

Date: __________

Site ID#:

Butte Creek Road Survey

Stream Crossing Inventory Form

Date: Crew: Watershed Code:

Road Name: USFS#__________SPI#_________ Photo#: Traffic level: **L M H**

Abandoned: **Y N** Maintained: **Y N** Driveable: **Y N** Decommissioned: **Y N**

Slope position: Headwater swale Midslope Inner Gorge Alluvial/Meadow

Geology/Soils/Landform Notes: ______________________________

____

____

____

____

Road Info: Road Width: ______ Surface material: _______Prism Design: _______

Road Configuration: **L**_________ **R** _________ Other roads upslope: **Y N**

Contributing Length and Road Grade: **L**______ / +/- ____%/ **R** ______ / +/- ___%

Diversion Potential: **L R** Diverted?: **Y N** Diversion Distance:_______ Crossing fed by **road/ditch**?: **Y N**

Stream Info: Stream Class: **I II III IV** **Aspect:**______ °

Natural Channel **Manmade Channel** **Swale**

Stream Grade: up ____ down ____ Scoured Channel Area: _____ **ft²**

Substrate: _________ Bedrock Exposed %: _________

Condition @ time of survey: **dry wet flowing**

Impounding sediment upstream of crossing?: **Y N** Volume: _________

Crossing Info:

Culvert **Diameter**: _________ If Arch Pipe: Ht._____Wd._____

Culvert **Gradient**: ______%

Culvert **Condition**: (inlet) _____ (outlet) _____ (bottom) _____ **(O, C, R, P, B)**

Plugging Potential: **L M H** %**Plugged**: (inlet) ____ (outlet) ____ (bottom) ____

Evidence of Overtopping: **Y N** Is Pipe Being Undermined? **Y N**

Crossing Type: Single Plastic/CM Pipe Mult. Plast./Metal pipes

Archpipe

Engineered bridge Log stringer bridge Humboldt bridge

Low water crossing Plate Arch No structure

Inlet Structure: Projecting Mitered Concrete headwall Drop inlet

Beveled inlet Riprap Metal wingwall No structure

Outlet Structure: Downspout Riprap Concrete apron Mitred

None Other ________________ Is erosion occurring at outlet? **Y N**

Fill Volume Characteristics:

Estimated fill volume (associated with Road Construction):___________

Data sheet last updated: 07/18/006:33 PM

Erosion Type: ______________
Volume of sediment delivered by *past erosion*:____________________
Erosion Cause: __________ __________ ___________
Suggested Treatments: _______ _______ _______

Past causes of erosion:____

Possible erosion from existing structure/maintenance practices:____________________

Remarks:

SKETCHES

North

Drawn By: _____
Date: _________

Data sheet last updated: 07/18/006:33 PM

sustain fish migration and spawning.

Class II--those watercourses where fish are always or seasonally present offsite within 1000 feet downstream, and/or watercourses which contain aquatic habitat for non-fish aquatic species. Class III watercourses that are tributary to Class I watercourses (hence within 1000 feet of a fish-bearing watercourse) are specifically excluded.

Class III--watercourses that have no aquatic life present, but still show evidence of being capable of sediment transport downstream to Class I or Class II watercourses under normal high water flow conditions after completion of timber operations.

Class IV--human-made watercourses, usually supplying downstream established domestic, agricultural, hydroelectric or other beneficial uses.

Aspect: Slope direction figured with a compass.

Stream Grade: The gradient, up and down stream, measured beyond the influence of crossing structures.

Scoured Channel Area: The channel cross-sectional area defined by the limits of bed scour and particle sorting, measured far enough above the inlet to eliminate any grade flattening, sediment deposition, or backwater effects from the crossing.

Substrate: Channel substrate was categorized into four classes, including "br" for boulder sized particles (>10" or 256mm), "cb" for cobbles (2.5-10" or 65-256mm), "gr" for gravel (0.1-2.5" or 2-65mm), or "ff" for fines (<0.1" or 2mm). When multiple size classes were present in a channel the dominate one, covering at least 25% of the exposed channel area would be used to classify the channel with a minus sign (-) added to show that there were significant amounts of smaller sized particles.

Impounding Sediment Upstream of Crossing: Is there sediment being held up at the inlet of a crossing? (Y or N, if Y then volume measured)

Culvert Gradient: The longitudinal slope of a culvert's placement, measured in %.

Culvert Condition: Each culvert was checked at the inlet, outlet, and bottom for problems. Conditions were designated by the following codes; "O" for O.K., "C" for crushed, "R" for rusted, "P" for plugged, and "B" for buried. If a culvert was crushed the percent crushed was added next to the "C" designation. If a culvert was plugged the percent plugged was added in its own category.

Plugging Potential: This category was looked at somewhat subjectively, taking into consideration factors such as the gradient of the channel feeding the inlet, the types of material currently in the channel, past evidence of plugging, the size of the channel compared to the size of the culvert inlet, the size of the inlet basin, and the gradient of the culvert. Sites were ranked as "L" for low, "M" for medium, or "H" for high.

Evidence of Overtopping: This category was to record the presence of any signs that would indicate recent overtopping of a crossing. Signs included rills and gullies across the road, evidence of sheet flow across the road at the crossing, or high water marks. (Y or N)

Crossing Type: A list of types of crossings, inlet structures, and outlet structures is shown on the stream crossing data form. (add diagrams)

Estimated Fill Volume: Simple geometry and trigonometry was used to determine the volume of fill placed during construction of each crossing.

Erosion Type: Erosion was categorized into five different types, "RG" for rill and gully erosion of roadbed, cutbanks, and fillslopes, "SLP" for fillslope slumps and slope failures associated with the road, "DT" for downcutting or widening of an inboard ditch, "HC" for active headcutting of the roadbed and/or the fillslope, and "DRC" for problems associated with inlets or outlets of ditch relief culverts (only used for road sites, not stream crossings).

Volume of Sediment Delivered by Past Erosion: An estimate of the amount of erosion from the area immediately adjacent to a crossing or road feature that was influenced by the crossing or road feature and obviously delivered sediment directly to a channel.

Erosion Cause: Refer to Appendix B for a complete listing of erosion causes for each erosion type. Up to three causes were listed for each site in descending order of importance.

Suggested Treatments: Refer to Appendix B for a complete list of treatments used as designations for each site. Up to three treatments were suggested for each site in descending order of importance.

Past Causes of Erosion: Written comments on processes in the past that could have triggered erosion at a particular site.

Possible Erosion from Existing Structure/Maintenance Practices: This category was for further written comments on structural or maintenance problems at a site and the possible consequences that could stem from the problems.

Remarks: This category was for any other pertinent information about a site that did not fit into a specific category.

Appendix B

Definition of Data Terms

The following list further explains those data items from both the Stream Crossing forms and Road Feature forms that are not self-explanatory.

Stream Crossings

Site ID#: Site numbers were assigned by the name of the road followed by a number, beginning with 1. For example 80A-1 represents the first stream crossing surveyed on the 80A road (a SPI road).

Watershed Code: Used to identify which of the three sub-watersheds the site was located in.

Traffic Level: This is a subjective rating based on the apparent frequency of use. "High" (h) was assigned to arterial haul roads such as Butte County road "Skyway". "Medium" (m) was assigned to well used roads that intersected main arterials or were used as connector roads to smaller road systems. "Low" (l) was assigned to all lesser used and abandoned roads.

Abandoned: A road was classified as abandoned if it was well waterbarred, showed signs of no recent maintenance (e.g. unrepaired blowouts), and had low or no traffic. Also some abandoned roads had vegetation growing in the roadbed.

Maintained: A road was considered maintained if there were obvious signs of current maintenance such as grading of the roadbed, cleaning out of culverts and/or inlet basins, or excavation of slough material in ditches or off the road.

Driveable: A road was considered to be driveable if it met the Standard Forest Service Guidelines, stating that a regular passenger vehicle could pass.

Decommissioned: A road was considered decommissioned if stream crossings had been excavated, the road waterbarred, the roadbed ripped and allowed to revegetate, or had the entrance blocked with boulders or a mound of debris to restrict access. The goal is to insure the road is hydrologically disconnected from the stream network

Slope Position: This category was used to give a general understanding of where on the landscape the site was situated. "Headwater Swale" designates an area at the head or top of a drainage. "Midslope" was used as a default category when a site did not meet the criteria of the other categories. Its name is self-explanatory. "Inner-gorge" was assigned to crossings that were located in areas that had steep, unstable slopes found along channels in deeply incised canyons. "Alluvial/Meadow" designates areas also referred to as "toe slopes". These areas include alluvial valleys and the gently sloping outwash fans that form along the edge of a valley where a channels gradient decreases and it is allowed to meander and form a fan of depositional material.

Geology/Soils/Landform Notes: This category was classified using geology and soils maps. Designations used were ???

Surface Material: This category designates the kind of material that made up the road base. "Native" (n) was assigned when no foreign material was brought in to build the road base. "Rock" (r) was assigned when gravel or crushed rock from offsite was brought in to build the road base.

Prism Design: This category describes the type of design that was used to build the road. Roads are classified as one of the following; "Full Bench" (fb) where the hillside is excavated and no fill used in constructing the road. "Partial Bench" (pb) is where a portion of the road is a bench and the rest is fill or "Fill" (f) is where the entire road prism is constructed from fill. (add diagrams)

Road Configuration: Roads were categorized as one of the following configurations; "Outsloped" (os), "Insloped" (is), "Entrenched" (entr), "Inboard Ditch" (ibd), "Berm" (b), "Flat" (f), or "Absent" (a). In certain instances combinations of these designations were used, for example "osb" indicates an outsloped road with a berm.

Other Roads Upslope: This information was determined by viewing road maps of the area, viewing aerial photographs or by field observation. The information was used to determine any local hydrologic link between roads upslope of a site and the site itself.

Contributing Length and Road Grade: The gradient both left and right of a crossing or site was measured with a clinometer. The linear distance of any positive grade feeding water to the site or crossing was recorded as the contributing length of the road.

Diversion Potential: A crossing has diversion potential if the road on either side of a crossing has a downhill slope (negative grade) where overtopped water would run down the road instead of across it.

Diversion Distance: A linear distance to the point down the road that the water could leave the road surface (rolling dip, outsloped section, etc.).

Stream Class: Stream channels were classified using the California Department of Forestry and Fire Protection's Forest Practice Regulations. The stream class definitions are as follows:

> Class I--watercourses or springs serving as domestic water supplies, onsite and/or within 1000 feet downstream of the operations area, and/or those watercourses where fish are always or seasonally present, including habitat to

Sketches: At each site a sketch was included to help during the analysis of the data. Also further information not included on the data sheet could be included with the sketch.

Road Feature

Road Feature ID#: Road features were assigned numbers similar to stream crossings except the number following the road name included a R to designate the site as a road feature. For example 80A-R1 represents the first road feature surveyed on the 80A.

Erosional Feature: Eight features were used for classifying this category, a list of these can be seen on the data form; "DRC" stands for ditch relief culvert. It was possible for more than one feature to be designated for a site, such as roadbed erosion that continues down across the fillslope.

Landform: This category was to give a general understanding of where on the landscape that the feature was located. Sites were classified by one of seven possible landforms. The landform designations are as follows:

Ridgetop – A site located along the top of a major ridgeline. Self-explanatory.
Midslope – Same definition as for stream crossing.
Inner-gorge - Same definition as for stream crossing.
Lower – A site located within 200 feet of a Class I or II flowing stream.
Meadow/Alluvial Fan - Same definition as for stream crossing.
Noseslope – A site located on the nose or end of a ridge.
Headslope – A site located on the slope which makes up the headwaters of a drainage.

Hillslope (%): A reading from a clinometer taken of the representative hillslope in the immediate area of the site.

Fillslope (%): A reading from a clinometer taken of the fillslope adjacent to the site.

Cutbank Slope (%): A reading from a clinometer taken of the cutbank adjacent to the site.

Aspect: Determined the same as for stream crossing.

Receiving Feature: This category describes the area that a site is delivering water and sediment to; either the fillslope, hillslope, or directly into a channel.

Lead to Roads Downslope: Does the erosional feature deliver water and sediment to roads downslope? (Y or N)

Receiving Feature Currently Eroding: Does the receiving feature have the potential to continue delivering sediment? (Y or N)

Erodability of Receiving Feature: This category was looked at subjectively and ranked as "H" for high, "M" for medium, or "L" for low. Factors taken into consideration for this ranking included geology and soil type, slope stability, gradient, amount of organic material on the slope, and the amount of erosion that has already occurred at the site.

Hydrologically Connected: Does the site deliver water and/or sediment to an active channel? (Y or N)

Surface Material: Same definition as for stream crossing.

Prism Design: Same definition as for stream crossing.

Roads Configuration: Same definition as for stream crossing.

Other Roads Upslope: Determined the same as for stream crossing.

Contributing Road Grade and Length: Determined the same as for stream crossing.

Culvert Grade (If site is a DRC): Determined the same as for stream crossing.

Culvert Condition (If site is a DRC): Same definition as for stream crossing.

Diversion Potential (If site is a DRC): Same definition as for stream crossing.

Potential Diversion Distance (If site is a DRC): Same definition as for stream crossing.

Is Material Aggrading Above Inlet (If site is a DRC): Same definition as for stream crossing.

Evidence of Overtopping (If site is a DRC): Same definition as for stream crossing.

Maintenance Comments: This category was used for any other observations of the maintenance practices near a site that might have influenced the amount of erosion.

Erosion Type: Same definition as for stream crossing.

Volume of Sediment Delivered by Past Erosion: Determined the same as for stream crossing.

Appendix C

Definitions of Codes

The following codes were used in filling out the data forms at each site.

Types of Road Erosion

RG = Rill and Gully erosion of roadbed, fillslope and cutbanks
DT = Downcutting or widening of inboard ditch
DRC = Problems associated with ditch relief culverts
SLP = Fillslope slumps and slope failures associated with road
HC = Active headcutting of roadbed and/or fillslope

Road Erosion Causes

CB = Cutbank slough blocking ditch
RO = Hillslope runoff intercepted
DR = Inadequate ditch relief
FL = Dip outlet erosion through loose fill
RL = Poor road location- road in draw
HG = Steep hillslope (>65%)
HC = Active headcutting
UPPR = Problem caused by upslope site

WB = Poor waterbar location/construction
RE = Road entrenched
DX = Ditch feeds to stream crossing
RT = Rutting from wet season use
FE = Fill encroachment on stream
DG = Steep ditch gradient
SB = Drainage structure damaged
UD = Undetermined

Problems associated with ditch relief culverts

IP = Inlet plugs with sediment
OP = Outlet plugs with sediment

CT = Culvert too small
CC = Culvert crushed or damaged

Stream Crossing Causes

NOX = No constructed crossing
PAG = Poor culvert alignment (grade)
OUT = Culvert outlet erosion
CPS = Culvert plugs with sediment
CTS = Culvert too small
HC = Active headcutting
UPPR = Problem caused by site upslope

FE = Fill encroachment
PAP = Poor culvert alignment (plan view)
CPW = Culvert plugs with woody debris
COF = Inadequate compaction of fill
RS = Road surface ruts feeding crossing
RO = Hillslope runoff intercepted by road/ditch
UD = Undetermined

Recommended Treatments for Stream Crossings

MTC = More frequent maintenance on culvert inlets
RDP = Add rolling dip on one or both sides of crossing to either eliminate diversion potential or to reduce amount of road runoff feeding crossing
DRX = Install DRC above stream crossing
PIPE = Install larger culvert
PIPC = Reinstall culvert with adequate fill compaction
RACP = Realign culvert (plan view)
RACG = Realign culvert (grade)
INST = Install culvert (none existing)
RECH = Re-establish original channel (excavate)
ARMR = Armor fillslope with riprap or slash
REPH = Remove Humboldt crossing – replace with culvert or bridge
VEGE = Vegetative stabilization
IDIP = Construct rocked dip for crossing on Class III stream
UPPR = Problem solved by treatment of upslope site

Recommended Treatments for Road Features

MTC = More frequent maintenance of road – grading, cleaning ditches, etc.
DRD = Increase number of rolling dips
DRC = Increase number of ditch relief culverts
OTS = Locally outslope, install rolling dips, and remove berms
RMF = Remove slumping fill material
REC = Reconstruct rolling dip/waterbar
EDC = Energy dissipator at culvert outlet
REL = Relocate road away from channel – close, drain, and obliterate old road

Erosion Cause: Same definition as for stream crossing.

Suggested Treatments: Same definition as for stream crossing.

Under Current Maintenance Will Problem Reoccur: Will the site continue eroding if the current maintenance practices persist? (Y or N)

Past Causes of Erosion: Same definition as for stream crossing.

Possible Erosion from Existing Structure/Maintenance Practices: Same definition as for stream crossing.

Remarks: Same definition as for stream crossing.

Sketches: Same definition as for stream crossing.

Appendix D

Soils Descriptions

The soil unit descriptions for Scotts John Creek are from the Lassen County Soil Survey that was conducted in 1982. The unit descriptions for Bull and Varey Creeks are preliminary, incomplete data from the current Butte County Soil Survey which has an expected completion date of 2002. The preliminary data available for these units is included. For further information on a timeline for incomplete data contact the United States Department of Agriculture, Natural Resource Conservation Service - Chico Soil Survey Office, 717 Wall Street, Chico, CA 95928, (530) 343-2731.

BULL CREEK SOIL DESCRIPTIONS

805 Bottlehill very gravelly sandy loam

Map Unit Components	Bottlehill very gravelly sandy loam
Position, Slope and Elevation	Ridgetops and shoulders; 3-15% slopes; 4000-5300'
Typical Vegetation	Ponderosa Pine, Sugar Pine, White Fir, Incense Cedar, Black Oak, Greenleaf Manzanita;
Precipitation	73-75" ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

806 Bottlehill – Logtrain complex

Map Unit Components	Bottlehill	Logtrain
Position, Slope and Elevation	Ridgetops and shoulders; 15-30% slopes; 3800-5300’	
Typical Vegetation	Ponderosa Pine, Sugar Pine, White Fir, Douglas Fir, Greenleaf Manzanita;	
Precipitation	73-75” ppt.	

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

807 Logtrain - Bottlehill complex

Map Unit Components	Logtrain (40%)	Bottlehill (30%)
Position, Slope and Elevation	Backslopes, shoulders and noses; 30-50% slopes; 3000-5200’	
Typical Vegetation	Ponderosa Pine, Sugar Pine, White Fir, Douglas Fir, Incense Cedar, Black Oak, Tan Oak, Canyon Live Oak	
Precipitation	72-75” ppt.	

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

808 Bottlehill – Walkermine - Logtrain complex

Map Unit Components Bottlehill (50%) Walkermine (20%) Logtrain (20%)

Position, Slope and Elevation Backslopes Backslopes, Noses Backslopes, Headslopes
50-70% slopes; 3200-5200’

Typical Vegetation Ponderosa Pine, Sugar Pine, White Fir, Douglas Fir, Incense Cedar, Black Oak, Tan Oak, Canyon Live Oak, Greenleaf Manzanita;

Precipitation 72-75” ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

809 Walkermine -Bottlehill –Logtrain – Rock outcrop complex

Map Unit Components Bottlehill Walkermine Logtrain Rock outcrop

Position, Slope and Elevation Canyon walls; 70-110% slopes; 2600-5200’

Typical Vegetation Douglas Fir, Tan Oak, Canyon Live Oak;

Precipitation 72-75” ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

VAREY CREEK SOIL DESCRIPTIONS

810 Marpa Tax.– Casierra – Hambone Tax. Complex

Map Unit Components	Marpa Tax. (25%)	Casierra (25%)	Hambone Tax. (35%)
Position, Slope and Elevation	Canyon Sideslopes; 30-50% slopes; 2200-3800'		
Typical Vegetation	Ponderosa Pine, Sugar Pine, Douglas Fir, White Fir, Incense Cedar, Black Oak, Tan Oak, Canyon Live Oak, Big Leaf Maple;		
Precipitation	65-73" ppt.		

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

814 Mountyana Gravelly Loam

Map Unit Components	Mountyana gravelly loam
Position, Slope and Elevation	Ridgetops; 2-15% slopes; 2200-4200’
Typical Vegetation	Ponderosa Pine, Sugar Pine, Douglas Fir, White Fir, Incense Cedar, Black Oak, Tan Oak;
Precipitation	65-73” ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

815 Mountyana gravelly loam

Map Unit Components	Mountyana gravelly loam
Position, Slope and Elevation	Ridgetops and sideslopes; 15-30% slopes; 2200-4200'
Typical Vegetation	Ponderosa Pine, Sugar Pine, Douglas Fir, White Fir, Incense Cedar, Black Oak, Tan Oak
Precipitation	57-72" ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

816 Mountyana gravelly loam

Map Unit Components	Mountyana gravelly loam
Position, Slope and Elevation	Sideslopes; 30-50% slopes; 2200-4000’
Typical Vegetation	Ponderosa Pine, Sugar Pine, Douglas Fir, White Fir, Incense Cedar, Black Oak, Tan Oak
Precipitation	60-72” ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

817 Lydon very gravelly sandy loam

Map Unit Components	Lydon very gravelly sandy loam
Position, Slope and Elevation	Ridgetops and shoulders; 2-15% slopes; 3400-4700'
Typical Vegetation	Ponderosa Pine, Douglas Fir, Incense Cedar, Black Oak, Tan Oak, Whiteleaf Manzanita
Precipitation	60-72" ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

818 Lydon very gravelly sandy loam

Map Unit Components	Lydon very gravelly sandy loam
Position, Slope and Elevation	Ridgetops and sideslopes; 15-30% slopes; 1700-4800'
Typical Vegetation	Ponderosa Pine, Douglas Fir, Incense Cedar, Black Oak, Tan Oak, Whiteleaf Manzanita
Precipitation	50-72" ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

819 Lydon – Rock outcrop complex

Map Unit Components	Lydon – Rock outcrop complex
Position, Slope and Elevation	Sideslopes; 30-50% slopes; 1200-4800’
Typical Vegetation	Ponderosa Pine, Douglas Fir, Incense Cedar, Canyon Live Oak, Tan Oak, Whiteleaf Manzanita, Poison Oak
Precipitation	50-72” ppt.

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

838 Hambone Tax. – Casierra – Marpa Tax.

Map Unit Components	Hambone Tax. (35%)	Casierra (20%)	Marpa Tax. (20%)
Position, Slope and Elevation	Sideslopes; 50-70% slopes; 1600-3600’		
Typical Vegetation	Ponderosa Pine, Sugar Pine, Douglas Fir, Black Oak, Tan Oak		
Precipitation	60-70” ppt.		

Soil Profile Description

Surface Layer

Subsoil

Substrata

Soil Properties and Management Interpretations

Rooting depth (in.)
Underlying material

Erosion Factor

Soil Permeability

LCC

Water Runoff Potential

Hydrologic Soil Group

Available Water Capacity

Scotts John Creek Soil Descriptions

The following pages have been scanned from the
"Soil Survey
of Lassen National
Forest Area, California" (1984)

Prepared by the
USDA Forest Service,
Pacific Southwest Region

In cooperation with
The USDA Soil Conservation Service
&
Regents of the University of California
(Agricultural Experiment Station)

74 Rock Outcrop-Rubble Land Complex

Map Unit Components	**Rock Outcrop**	**Rubble Land**
Approx. Proportion	60%	30%
Position, Slope, and Elevation	Miscellaneous land type on mountain sideslopes and ridgetops; 4,000 to 9,000 feet.	Miscellaneous land type on mountain sideslopes and steep escarpments.
Typical Vegetation & Precipitation	Barren except for widely scattered brush that occurs in fractures in the rock or in small colluvial pockets of soil; 16 to 80 inches ppt.	Somewhat barren, but vegetation may grow up through the rock fragments. The vegetation is growing in soil that is buried by the rock fragments; 16 to 80 inches ppt.

Soil Profile Description

Surface Layer	N/A	N/A
Subsoil	N/A	N/A
Substrata	Protruding bedrock that has all soil eroded off.	Detached rock fragments ranging in size from 3 inches to about 5 feet in diameter.

Soil Properties & Management Interpretations

Rooting Depth (in.), Underlying Material	N/A	N/A
Erosion Factor (K)	N/A	N/A
Max. Erosion Hazard	N/A	N/A
Soil Permeability	N/A	N/A
Soil Manageability		
Class	N/A	N/A
Group	N/A	N/A
Range Site	N/A	N/A
Water Runoff Potential	Very rapid	Very slow to moderate
Hydrologic Soil Group	N/A	N/A
Available Water Capacity (AWC)		
Total (Top 20")	N/A	N/A
Forest Site Class	N/A	N/A
Timber Regeneration Potential		
Plantability	N/A	N/A
Seedling Survival	N/A	N/A
Estimated Engineering Properties; USDA Texture, Unified, and ASSHTO	N/A	N/A
Included Areas	10% Lithic Xerumbrepts	

80 Sheld family, glacial-Aquolls association, 0 to 35 percent slopes

Map Unit Components	Sheld, glacial	Aquolls
Approx. Proportion	60%	30%
Position, Slope, and Elevation	Occurs on upland flats, mountain sideslopes and ground moraines; 0 to 35 percent slopes; 5,200 to 8,000 feet.	Meadows and valleys over the total forest; 0 to 15 percent slopes; 4,000 to 8,000 feet.
Typical Vegetation & Precipitation	Red and white fir, sugar pine, lodgepole pine, mountain hemlock, greenleaf manzanita and chinquapin; 40 to 85 inches ppt.	Annual and perennial grasses, lodgepole pine, alder, aspen, willow and thistle, 40 to 80 inches ppt.

Soil Profile Description

Surface Layer	0 to 16 inches; dark grayish brown cobbly to very cobbly sandy loam; granular structure; 15 to 50 percent rock fragments; pH 6.5 to 6.3.	0 to 9 inches; grayish brown loam or silt loam; granular and blocky structure, slightly hard; pH 5.8 to 6.0.
Subsoil	16 to 42 inches; brown very cobbly to extremely cobbly sandy loam; granular to subangular blocky structure; 50 to 65 percent rock fragments; pH 6.0 to 5.8.	9 to 16 inches; grayish brown sandy loam or silty clay loam; blocky structure, slightly hard; pH 6.2 to 7.6.
Substrata	42 inches; fractured basalt	16 to 60 inches; light brownish gray loamy sand to a clay loam; massive; slightly hard; pH 6.2 to 7.6.

Soil Properties & Management Interpretations

Rooting Depth (in.), Underlying Material	42 inches; basalt	10 to 20 in; gravelly silty clay
Erosion Factor (K)	.24	.17
Max. Erosion Hazard	Moderate	Low
Soil Permeability	Moderate	Moderately slow
Soil Manageability		
Class	3Xp	3W
Group	III	III
Range Site	N/A	3
Water Runoff Potential	slow	Very slow
Hydrologic Soil Group	B	C
Available Water Capacity (AWC)		
Total (Top 20")	2.9 (1.7)	8.2 (3.0)
Forest Site Class	4-5 (II-III)	N/A
Timber Regeneration Potential		
Plantability	Low to moderate	N/A
Seedling Survival	Low	N/A
Estimated Engineering Properties; USDA Texture, Unified, and ASSHTO	0-4; sandy loam Unified: SL ASSHTO: A-2-4, A-4	0-9; silt loam Unified: ML ASSHTO: A-7
	4-42; cobbly sandy loam Unified: SM ASSHTO: A-2-4, A-4	9-16; silty clay loam Unified: ML-CL ASSHTO: A-6
	42; fractured basalt	16-60; gravelly silty clay loam Unified: ML-CL ASSHTO: A-7
Included Areas	10% Yallani family, glacial and Rubble Land	

84 Sheld family, moderately deep-Lithic Xerumbrepts association, 0 to 35 percent slopes.

Map Unit Components	**Sheld, moderately deep**	**Lithic Xerumbrepts**
Approx. Proportion	60%	20%
Position, Slope, and Elevation	Occurs on upland flats; mountain sideslopes, and undulating hills; 0 to 35 percent slopes; 5,200 to 8,000 feet.	Occurs on flat lava flows and on mountain sideslopes and ridgetops; 0 to 35 percent slopes; 3,200 to 8,000 feet.
Typical Vegetation & Precipitation	Red and white fir; sugar pine; incense cedar; Jeffrey pine, ponderosa pine, lodgepole pine; mountain hemlock; chinquapin; greenleaf manzanita and pinemat manzanita; 40 to 85 inches ppt.	Greenleaf manzanita, pinemat manzanita, desert mountain mahogany and sparse Jeffrey pine, ponderosa pine, juniper and incense cedar; 40 to 80 inches ppt.

Soil Profile Description

Surface Layer	0 to 6 inches; dark brown gravelly sandy loam; granular structure; soft; 15 to 30 percent rock fragments; pH 6.0.	0 to 6 inches; brown very gravelly sandy loam; granular structure; soft; 40 percent rock fragments; pH 6.5.
Subsoil	6 to 27 inches; brown very gravelly to extremely gravelly sandy loam to coarse sandy loam; subangular blocky to single grain structure; soft; 40 to 60 percent rock fragments; pH 6.2.	6-10 inches; yellowish brown very gravelly sandy loam; granular structure; 45 percent rock fragments; pH 6.0.
Substrata	Fractured and slightly weathered vesicular basalt.	10+ inches; hard fractured basalt bedrock.

Soil Properties & Management Interpretations

Rooting Depth (in.), Underlying Material	27 inches; basalt	10 inches; basalt
Erosion Factor (K)	.20	.28
Max. Erosion Hazard	Moderate	Moderate
Soil Permeability	Moderately rapid	Moderate
Soil Manageability		
Class	2p	3Px
Group	II	II
Range Site	N/A	N/A
Water Runoff Potential	Slow	Moderate
Hydrologic Soil Group	B	C
Available Water Capacity (AWC) Total (Top 20")	2.1 (1.7)	.8 (.8)
Forest Site Class	5 (III)	7 (Noncommercial)
Timber Regeneration Potential		
Plantability	Moderate	N/A
Seedling Survival	Low	N/A
Estimated Engineering Properties; USDA Texture, Unified, and ASSHTO	0-6; gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4 6-27; very gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4 27+; slightly weathered basalt	0-10; very gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4 10+; hard fractured basalt
Included Areas	20% Rock Outcrop, Rubble Land and Sheld family.	

123 Wintoner-Yallani families complex, 0 to 35 percent slopes

Map Unit Components	Wintoner	Yallani
Approx. Proportion	60%	20%
Position, Slope, and Elevation	Occurs on gently to steeply sloping mountain sideslopes, ridges and canyons; 0 to 35 percent slopes; 5,200 to 7,000 feet.	Occurs on mountain sideslopes, ridges and canyons; 0 to 35 percent slopes; 5,200 to 8,000 feet.
Typical Vegetation & Precipitation	Red and white fir, sugar pine, ponderosa pine, Jeffrey pine, incense cedar and chinquapin; 35 to 50 inches ppt.	Red and white fir, Jeffrey pine, ponderosa pine, sugar pine, lodgepole pine, mountain hemlock, incense cedar, greenleaf manzanita, pinemat manzanita, chinquapin and squaw carpet; 35 to 50 inches ppt.

Soil Profile Description

Surface Layer	0 to 22 inches; yellowish brown to brown gravelly sandy loam to loam; granular structure; soft; 10 to 15 percent rock fragments; pH 7.0 to 6.2.	0 to 8 inches; brown gravelly fine sandy loam; granular structure; soft; 22 percent rock fragments; pH 6.3.
Subsoil	22 to 43 inches; brown to yellowish brown loam to clay loam; subangular blocky to massive structure; slightly hard; 5 to 12 percent rock fragments; pH 6.0 to 5.5.	8 to 39 inches; brown to yellowish brown gravelly to very gravelly fine sandy loam; blocky and massive structure; slightly hard; 30 to 42 percent rock fragments; pH 6.0
Substrata	43 to 50 inches; strongly weathered andesite bedrock.	39 to 60 inches; yellowish brown very gravelly sandy loam; massive; 35 percent rock fragments; pH 6.0.

Soil Properties & Management Interpretations

Rooting Depth (in.)	43 inches; andesite.	60+ inches; basalt
Erosion Factor (K)	.20	.24
Max. Erosion Hazard	Low to moderate	Low to moderate
Soil Permeability	Moderate	Moderately rapid
Soil Manageability		
Class	1	2p
Group	I	I
Range Site	N/A	N/A
Water Runoff Potential	Slow	Slow
Hydrologic Soil Group	B	B
Available Water (AWC) Total (Top 20")	5.6 (2.4)	5.9 (2.1)
Forest Site Class	4 (II)	3 (I)
Timber Regeneration		
Plantability	High	High
Seedling Survival	Moderate	Low to moderate
Estimated Engineering Properties; USDA Texture, Unified, and ASSHTO	0-5; gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4	0-24; gravelly fine sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-4
	5-34; loam Unified: ML ASSHTO: A-7	24-39; very gravelly fine sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-4
	34-43; clay loam Unified: CL ASSHTO: A-6, A-7	39-60; very gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4
	43; weathered andesite	
Included Areas	20% Portola family; Aquolls and Yallani family cobbly	

128 Yallani-Sheld families complex, 0 to 35 percent slopes

Map Unit Components	Yallani	Sheld
Approx. Proportion	60%	20%
Position, Slope, and Elevation	Occurs on mountain sideslopes, ridges and canyons; 5 to 35 percent slopes; 5,200 to 8,000 feet.	Occurs on upland flats; mountain sideslopes, and undulating hills; 0 to 35 percent slopes; 5,200 to 8,000 feet.
Typical Vegetation & Precipitation	Red and white fir, Jeffrey pine, ponderosa pine, sugar pine, lodgepole pine, mountain hemlock, incense cedar, greenleaf manzanita, pinemat manzanita, chinquapin and squaw carpet; 35 to 80 inches ppt.	Red and white fir, sugar pine, incense cedar, Jeffrey pine, ponderosa pine, lodgepole pine, mountain hemlock, chinquapin, greenleaf manzanita and pinemat manzanita; 35 to 85 inches ppt.

Soil Profile Description

Surface Layer	0 to 8 inches; brown gravelly fine sandy loam; granular structure; soft; 22 percent rock fragments; pH 6.3.	0 to 14 inches; brown gravelly and cobbly sandy loam; granular structure; soft; 20 to 30 percent rock fragments; pH 6.5 to 6.0.
Subsoil	8 to 39 inches; brown to yellowish brown gravelly to very gravelly fine sandy loam; blocky and massive structure; slightly hard; 30 to 42 percent rock fragments; pH 6.0	14 to 60 inches; yellowish brown very cobbly loam to sandy loam; subangular blocky structure; soft; 40 to 55 percent rock fragments; pH 5.5.
Substrata	39 to 60 inches; yellowish brown very gravelly sandy loam; massive; 35 percent rock fragments; pH 6.0.	60 inches; slightly weathered basalt and andesite.

Soil Properties & Management Interpretations

Rooting Depth (in.), Underlying Material	60+ inches; basalt	60 inches; andesite and basalt
Erosion Factor (K)	.24	.20
Max. Erosion Hazard	Low to moderate	Moderate
Soil Permeability	Moderately rapid	Moderate
Soil Manageability		
Class	2p	2p
Group	II	II
Range Site	N/A	N/A
Water Runoff Potential	Slow	Slow
Hydrologic Soil Group	B	B
Available Water Capacity (AWC)		
Total (Top 20")	5.9 (2.1)	5.7 (2.2)
Forest Site Class	3 (I)	4 (II)
Timber Regeneration Potential		
Plantability	High	High
Seedling Survival	Low to moderate	Moderate
Estimated Engineering Properties; USDA Texture, Unified, and ASSHTO	0-24; gravelly fine sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-4	0-14; gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4
	24-39; very gravelly fine sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-4	14-34; very cobbly loam Unified: GM-GC, ML-CL ASSHTO: A-1, A-4
	39-60; very gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4	34-60; very cobbly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4
Included Areas	20% Wintoner family; Portola family and Aquolls	

129 Yallani-Sheld families complex, 35 to 50 percent slopes

Map Unit Components	**Yallani**	**Sheld**
Approx. Proportion	50%	30%
Position, Slope, and Elevation	Occurs on mountain sideslopes, ridges and canyons; 35 to 50 percent slopes; 5,200 to 8,000 feet.	Occurs on upland flats; mountain sideslopes, and undulating hills; 35 to 50 percent slopes; 5,200 to 8,000 feet.
Typical Vegetation & Precipitation	Red and white fir, Jeffrey pine, ponderosa pine, sugar pine, lodgepole pine, mountain hemlock, incense cedar, greenleaf manzanita, pinemat manzanita, chinquapin and squaw carpet; 35 to 80 inches ppt.	Red and white fir, sugar pine, incense cedar, Jeffrey pine, ponderosa pine, lodgepole pine, mountain hemlock, chinquapin, greenleaf manzanita and pinemat manzanita; 35 to 85 inches ppt.

Soil Profile Description

Surface Layer	0 to 8 inches; brown gravelly fine sandy loam; granular structure; soft; 22 percent rock fragments; pH 6.3.	0 to 14 inches; brown gravelly and cobbly sandy loam; granular structure; soft; 20 to 30 percent rock fragments; pH 6.5 to 6.0.
Subsoil	8 to 39 inches; brown to yellowish brown gravelly to very gravelly fine sandy loam; blocky and massive structure; slightly hard; 30 to 42 percent rock fragments; pH 6.0.	14 to 60 inches; yellowish brown very cobbly loam to sandy loam; subangular blocky structure; soft; 40 to 55 percent rock fragments; pH 5.5.
Substrata	39 to 60 inches; yellowish brown very gravelly sandy loam; massive; 35 percent rock fragments; pH 6.0.	60 inches; slightly weathered basalt and andesite.

Soil Properties & Management Interpretations

Rooting Depth (in.), Underlying Material	60+ inches; basalt	60 inches; andesite and basalt
Erosion Factor (K)	.24	.20
Max. Erosion Hazard	Moderate	Moderate to high
Soil Permeability	Moderately rapid	Moderate
Soil Manageability		
Class	3gp	3gp
Group	III	III
Range Site	N/A	N/A
Water Runoff Potential	Moderate	Moderate
Hydrologic Soil Group	B	B
Available Water Capacity (AWC) Total (Top 20")	5.9 (2.1)	5.7 (2.2)
Forest Site Class	3 (I)	4 (II)
Timber Regeneration Potential		
Plantability	Moderate	Moderate
Seedling Survival	Low to moderate	Moderate
Estimated Engineering Properties; USDA Texture, Unified, and ASSHTO	0-24; gravelly fine sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-4	0-14; gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4
	24-39; very gravelly fine sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-4	14-34; very cobbly loam Unified: GM-GC, ML-CL ASSHTO: A-1, A-4
	39-60; very gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4	34-60; very cobbly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4
Included Areas	20% Portola family; Inville family and Aquolls	

132 Yallani-Sheld families, moderately deep, cobbly complex, 0 to 35 percent slopes

Map Unit Components	Yallani	Sheld
Approx. Proportion	50%	30%
Position, Slope, and Elevation	Occurs on mountain sideslopes, ridges and canyons; 5 to 35 percent slopes; 5,200 to 8,000 feet.	Occurs on upland flats, mountain sideslopes and ground moraines; 0 to 35 percent slopes; 5,200 to 8,000 feet.
Typical Vegetation & Precipitation	Red and white fir, Jeffrey pine, ponderosa pine, sugar pine, lodgepole pine, mountain hemlock, incense cedar, greenleaf manzanita, pinemat manzanita, chinquapin and squaw carpet; 35 to 80 inches ppt.	Red and white fir, sugar pine, lodgepole pine, mountain hemlock, greenleaf manzanita and chinquapin; 35 to 85 inches ppt.

Soil Profile Description

Surface Layer	0 to 6 inches; dark brown loamy sand; granular structure; loose; pH 6.5.	0 to 12 inches; dark grayish brown gravelly to very gravelly sandy loam or cobbly to very cobbly sandy loam; granular structure; soft; 20 to 40 percent rock fragments; pH 6.8 to 6.5; 20 to 50 percent rock fragments on the surface.
Subsoil	6 to 31 inches; brown very cobbly loam; subangular blocky structure; soft to slightly hard; 55 percent rock fragments; pH 6.5 to 6.8.	12 to 33 inches; yellowish brown very cobbly to extremely cobbly sandy loam; granular to subangular blocky structure; 40 to 65 percent rock fragments; pH 6.0 to 5.8.
Substrata	31 to 42 inches; highly weathered andesite.	33 inches; fractured basalt

Soil Properties & Management Interpretations

Rooting Depth (in.), Underlying Material	31 inches; andesite	33 inches; basalt
Erosion Factor (K)	.20	.24
Max. Erosion Hazard	Low to moderate	Moderate
Soil Permeability	Moderately rapid	Moderate
Soil Manageability		
Class	2p	3Xp
Group	II	II
Range Site	N/A	N/A
Water Runoff Potential	Slow	Slow
Hydrologic Soil Group	B	B
Available Water Capacity (AWC) Total (Top 20")	2.8 (1.8)	2.7 (1.7)
Forest Site Class	4 (II)	5 (III)
Timber Regeneration Potential		
Plantability	High	Low to moderate
Seedling Survival	Low	Low
Estimated Engineering Properties; USDA Texture, Unified, and ASSHTO	0-6; loamy sand Unified: SM ASSHTO: A-4 6-31; very cobbly loam Unified: GM-GC, ML-CL ASSHTO: A-1, A-4 31-42; weathered andesite	0-12; gravelly sandy loam Unified: GM-GC, SM ASSHTO: A-1, A-2-4, A-4 12-33; very cobbly sandy loam Unified: SM ASSHTO: A-2-4, A-4 33; fractured basalt
Included Areas	20% Wintoner family and Lithic Xerumbrepts	

Appendix E:

For
Raw Data
please see
3.5" computer disc
enclosed in "pocket"
on back cover.