UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEDIMENTATION IN HOT CREEK IN VICINITY OF HOT CREEK FISH HATCHERY, MONO COUNTY, CALIFORNIA

Open-File Report 78-661

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CONTENTS

	Page
Abstract	1
Introduction	2
Characteristics of the study area	4
Discussion of problem	6
References cited	9

ILLUSTRATIONS

	Page
Figure 1. Location of study area	3

CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than U.S. customary units, the conversion factors for the terms used in this report are listed below:

Multiply U.S. customary	*By*	*To obtain metric unit*
acre-ft (acre-foot)	1.234	m^3 (cubic meter)
ft (foot)	0.3048	m (meter)
ft/s (foot per second)	0.3048	m/s (meter per second)
ft^3/s (cubic foot per second)	0.02832	m^3/s (cubic meter per second)
in (inch)	25.40	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)

Degree Fahrenheit is converted to degree Celsius by using the formula: $°C = (°F-32)/1.8$.

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ABSTRACT

An accumulation of fine-grained sediment in Hot Creek downstream from Hot Creek Fish Hatchery created concern that the site may be deteriorating as a habitat for trout. The accumulation is a phenomenon that probably occurs naturally in the problem reach. Fluctuation in the weather probably is the basic cause of the deposition of fine-grained sediment that has occurred since about 1970. Man's activities and the Hot Creek Fish Hatchery may have contributed to the problem; the significance of these factors, however, probably was magnified because of drought conditions in 1975-77.

INTRODUCTION

A 2-mi reach of Hot Creek extending downstream from the Hot Creek Fish Hatchery is one of the more attractive sites in California for trout fishing (fig. 1). Fishermen are attracted to the site because of its geographical beauty--a meandering stream in a grass-covered valley surrounded by rugged mountains, usually snowcapped--and because it is a good site for leisurely fishing from either bank. A strong desire exists among interested Federal, State, municipal, and private organizations to preserve the environmental beauty and recreational excellence of the site.

An accumulation of fine-grained sediment (clay to sand sizes) in the 2-mi reach has created concern that the site may be deteriorating as a habitat for trout. The basic environment for trout includes, among other things, low temperature, swift flow, low turbidity, riffles, and shade. The trout prefer to spawn in gravel of about 0.75-in diameter with near-bottom (0.2-0.3 ft) stream velocities of about 2 ft/s. The accumulation of fine-grained sediment, which clogs spaces between gravel-sized particles in the streambed, apparently is harmful to the stream habitat, according to Phillips (1970), because:

1. The interchange between surface water and water within the gravel bed is reduced. This reduces the supply of oxygen to the fish eggs and interferes with the removal of carbon dioxide and ammonia.
2. A barrier to fry emergence if formed.
3. The survival rate after fry emergence probably is reduced because of the loss of escape cover among the gravel particles.
4. A reduction of aquatic organisms that are food for fish probably is effected.

This paper presents qualitative descriptions of some of the factors and conditions that were probably significant to the accumulation of fine-grained sediment in Hot Creek. The study area, including the problem reach which extends from the Hot Creek Fish Hatchery downstream about 2 mi, is the approximately 70-mi^2 watershed drained by Mammoth and Hot Creeks (fig. 1). The information for this report is based on two brief reconnaissance trips into the area, cited references, and principals of geomorphology and sedimentation.

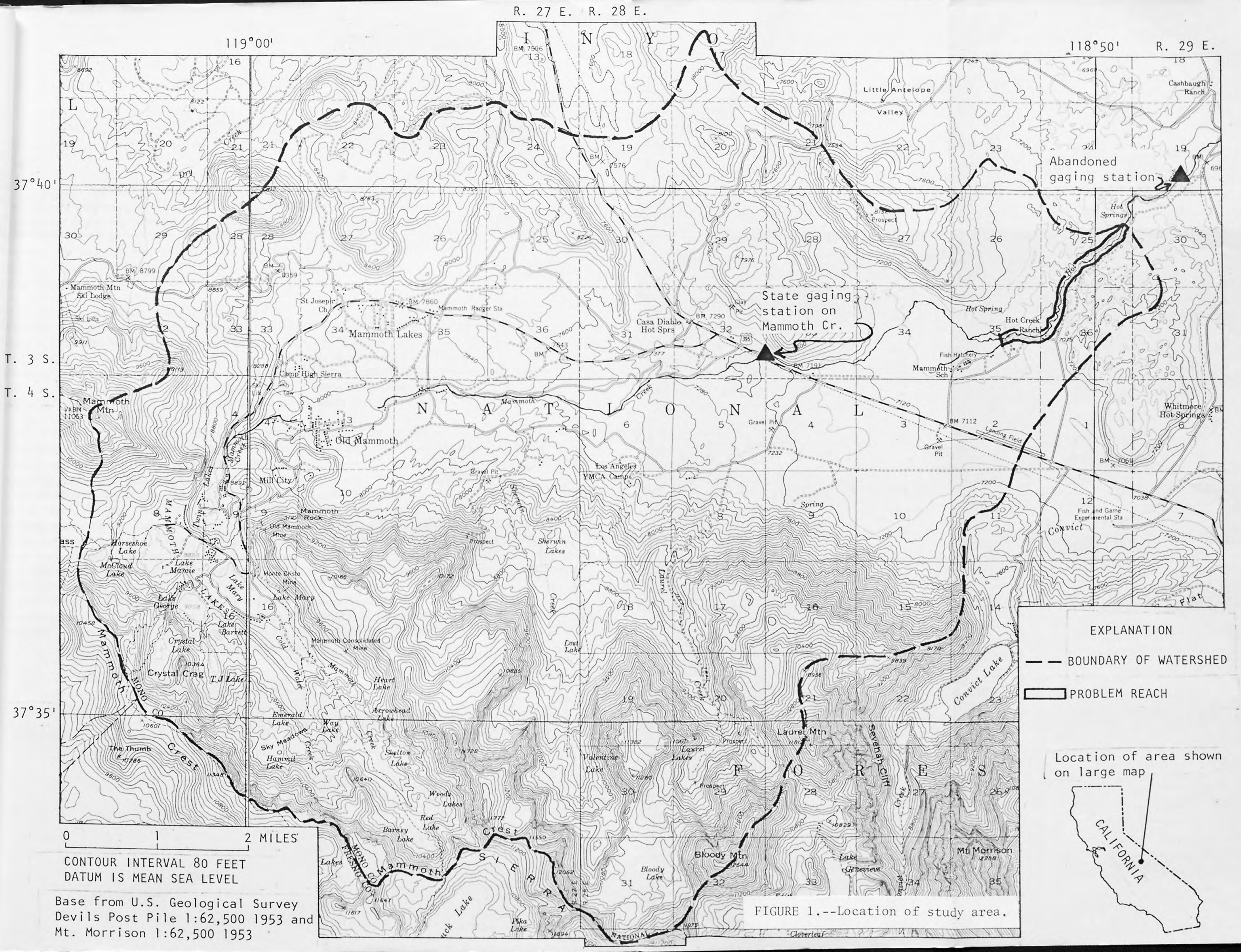

FIGURE 1.--Location of study area.

CHARACTERISTICS OF THE STUDY AREA

The study area is on the east side of the Sierra Nevada and about 20 mi south of Mono Lake and 8 mi west of Lake Crowley (not shown in fig. 1).

Topographically, it is typical of many small basins in the Basin and Range physiographic province (Fenneman, 1931); the main valley is wide and flat in places, and the mountain ranges are narrow and rugged. Altitudes are generally between 7,000 and 12,000 ft. The basin has been shaped by volcanism, structural deformation, glaciation, and differential weathering. Along streams in the valley, alluvial deposits overlie glacial and volcanic debris.

Summer daytime temperatures in the valley frequently reach 100°F. Winter temperatures in the mountains usually are below freezing. Precipitation ranges from an average annual mean of about 10 in near the Hot Creek Fish Hatchery to more than 60 in in the mountains. Polar Pacific, Tropical Pacific, and Tropical Gulf airmasses account for most of the precipitation in the study area. About 70-80 percent of the precipitation in the mountains occurs between November and April.

Two distinct types of storms characterize the seasonal pattern of precipitation in the study area. Storms in July and August are mainly of the local convective type, commonly called a thunderstorm, and storms in the rest of the year are generally of the convergence, or frontal, type. The thunderstorm is characterized by rainfall of high intensity and short duration in a small area. Although thunderstorms may occur at many locations on a given day, there is little conformity in either rates or amounts of rainfall that may occur at different places because localized atmospheric conditions are the predominating factors involved. The convergence, or frontal, storm is an atmospheric disturbance of a general nature and commonly distributes much moisture over a large area. A convergence storm may occur when airmasses of dissimilar characteristics meet or override one another or when warm air converges toward a center and is forced upward. Although thunderstorms occur mainly in July and August and frontal storms occur primarily in September to April, thunderstorm activity accompanies some frontal storms.

Surface water produced in the basin travels to the problem reach by way of Laurel, Sherwin, Mammoth, Cold Water, and Hot Creeks. Much of the water is snowmelt that drains through a series of lakes and finally reaches Mammoth Creek, the major stream in the basin. Runoff is produced during occasional thunderstorms downstream from the lakes. Some of these lakes are: Bloody, Laurel, Valentine, Lost, Sherwin, Barney, Red, Woods, Skelton, Arrowhead, Heart, Way, Hammil, Emerald, T J, Crystal, George, Mary, Mamie, Horseshoe, McCloud, and Twin. Flow in some of the streams of the basin, particularly Laurel Creek, does not contribute directly to Mammoth Creek. Water from these noncontributing streams infiltrates into shallow alluvium, pumice, glacial deposits, and basalt formations (California Department of Water Resources, 1973); however, most of the water probably is discharged by springs, particularly along Hot Creek.

The mean annual flow of Mammoth Creek at U.S. Highway 395, approximately 3.3 mi upstream from the problem reach, was about 13,800 acre-ft (19 ft^3/s) for the period 1932-69 (California Department of Water Resources, 1973). Annual flow ranged from 3,000 to 39,000 acre-ft in that period. Daily flow at the highway ranged generally from 10 ft^3/s, for many days in the period 1932-69, to 280 ft^3/s, during one day in June 1969.

The mean annual flow in Hot Creek at a site 2.5 mi downstream from the problem reach was 40,540 acre-ft (56 ft^3/s) for the 1924-72 period (California Department of Water Resources, 1973). Annual flow ranged from about 23,000 to 72,000 acre-ft in that period. Daily flow at the downstream site ranged from about 30 to 300 ft^3/s.

The difference between average annual rates of flow for the two gaging stations, about 37 ft^3/s, is derived from springs along Mammoth and Hot Creeks. Between 10 and 20 ft^3/s emanates from identifiable springs near the origin of Hot Creek, about 2,000 ft upstream from the confluence of Mammoth and Hot Creeks. The flow from springs near the origin of Hot Creek is routed through the Hot Creek Fish Hatchery, where it picks up organic waste high in nutrients before it is released back to Hot Creek.

The stream channel of Hot Creek in the problem reach has a meandering, shallow, pool-and-riffle form. Characteristically, the channel is about 3 ft deep and 30 ft wide at bankful stage. Normally, the bed of the stream is armored with gravel- to cobble-size particles; the banks are composed mainly of silt- to sand-size particles. The pools presently are filled with fine-grained inorganic sediment (less than 0.1-in diameter). In some places in the problem reach, organic material is mixed with the inorganic sediment. Aquatic vegetation grows on the sediment deposits in the pool.

The flood plain in the problem reach is wide--probably more than 2,000 ft in places. It is densely covered with vegetation, mainly grass. Active migration of the stream channel is evident from old meander scars across the flood plain.

DISCUSSION OF PROBLEM

Precise determinations of the reasons why the fine-grained sediment has accumulated in Hot Creek are not obtainable based on present knowledge because (1) the physical laws of sediment transport are incompletely known, especially for the complex problem of transportation of the wide range of sediment sizes that are carried by natural streams, and (2) sedimentation in natural (unregulated) streams involves many interrelated variables, most of which cannot be assigned meaningful values. The variables relate not only to the available supply of sediment but also to size, shapes, and densities of the particles; rate and velocity of flow; channel width, depth, and slope; bank and bed roughness; channel configuration; and density, temperature, and, at times, even chemical composition of the water. Sedimentation in natural streams involves fluvial processes of geomorphology which may be characterized according to two related aspects: general processes and microprocesses. An understanding of the general processes--processes involving general physics and the gross impacts of long-term geologic and climatic influences and of episodic events--has been gained by many studies in other areas. The general processes are adequately described in literature dealing with sediment transport and geomorphology (Colby, 1963, 1964; Leopold, Wolman, and Miller, 1964). Very little in detail, however, is known about the microprocesses--processes involving a short time scale (relative to geologic time) and the chemistry, physics and biology of the fundamental concepts by which rock material is weathered to soil, detached and transported, and deposited--and sequences of the microprocesses involved in sedimentation in a watershed (Wolman, 1977). Precise determinations of why the accumulation of fine-grained sediment has occurred in Hot Creek would require exact descriptions of the sediment at its source, an understanding of the general processes and microprocesses involved in sedimentation, a model of the erosion-deposition system, and data that are significant to the problem.

The discussion that follows is based on an understanding of the general aspects of fluvial geomorphology, a conceptual model of the microprocesses of sedimentation as applied to the study area, a brief reconnaissance of the problem area, and the hypothesis that accumulation of fine-grained sediment in pools in the problem area is an infrequent event.

Typically, for a natural pool-and-riffle stream that carries a relatively large load of sediment of a wide range of sizes, deposition occurs in the pool during periods of relatively low flow. Often the sediment that is deposited is fine grained. The deposition of sediment, among other effects, reduces the channel size, and if flow rate stays constantly low and deposition continues, the velocity of the stream and the ability of the stream to transport sediment are gradually increased. If the flow rate remains low for a significant length of time, a characteristic low-flow channel probably will form (Burkham, 1972, 1976). Stated simply, for a typical natural stream, the accumulation of fine-grained sediment in the pools and along banks results because the stream does not have the hydraulic competence during periods of low flow to carry its load of sediment through the pools. Given a significant length of time before a period of high flow occurs, vegetation may become established on the deposits of fine-grained sediment. This has a tendency to stabilize the low-flow channel (Burkham, 1972). The vegetation may retard the velocity of flow and thus probably further decrease the competence of the stream to carry sediment. When a period of relatively high flow occurs, the stream's ability to transport sediment increases, erosion occurs along the bed and banks of the channel, and, normally, the sediment deposited during periods of low flow is flushed downstream. If high flow occurs for a significant length of time, a characteristic high-flow channel may form (Burkham, 1972).

Hot Creek in the problem reach normally does not carry a large load of sediment. When it does, however, the load probably consists of a wide range of sizes, and fill and scour in the channel probably occurs in a typical fashion.

Another way of describing the sediment transport capability of Hot Creek as it applies to the present problem is that the discharge of fine-grained particles is controlled by the available supply of such particles, and the supply is usually less than the stream can transport. The supply is low because the streamflow is derived from springs or from snowmelt in areas where the supply of easily erodible fine-grained particles is limited. Also, a large part of the surface flow produced in the study basin drains through reservoirs where the sediment settles out before it arrives at the problem reach. The beds of all the main channels in the study area normally are armored with gravel- to cobble-size particles, and the underlying fine-grained particles are therefore not available for erosion.

Relatively large loads of fine-grained sediment can be generated in the study area if a favorable storm pattern develops. Large quantities of readily movable fine-grained sediment--in alluvial deposits and volcanic material--are available in several places in the watershed downstream from lakes. Additionally, significant quantities of fine-grained sediment in a few parts of the basin have been made readily available because of man's activities related to landscaping and construction of buildings and roads, developing a water supply and distribution system for Mammoth Lakes, and developing ski runs. Large loads of fine-grained sediment can be generated when overland flow is produced in these areas, especially when the infrequent thunderstorm produces significant rates of runoff. Fine-grained sediment also can result from erosion of channel banks embedded in alluvial deposits; this may occur during relatively high rates of flow. Depending on the hydraulic competence of the stream to carry fine-grained particles in the problem reach, this sediment may become temporarily stranded in pools.

The accumulation of fine-grained sediment in the problem reach probably is the result of the following factors:

A. A period of relatively high flow in 1969-70 (California Department of Water Resources, 1973) left the stream channel enlarged. The enlargement of the channel was accomplished mainly by the erosion of channel banks as the armored layers of gravel-sand-cobble on the bed resisted erosion.

B. Sediment probably has been deposited (causing fill) in the channel almost continuously since about 1970. The rate of accumulation of sediment may have been relatively rapid in the years 1975-77 because: (1) snow-produced streamflow, which normally carries a relatively low sediment load and therefore acts as a flushing agent for fine-grained particles in the problem reach, was very low, (2) streamflow from thunderstorms, which usually carries a relatively high sediment load, continued to contribute sediment to streams in the study area, (3) the high flows in 1969-70 may have made more material available for transport to the problem reach, and (4) sediment transported to the problem reach is deposited because of the low-flow conditions and because of the condition of the channel, as discussed in A.

C. Activities of man related to landscaping and construction of buildings and roads, developing a water supply and distribution system for Mammoth Lakes, and developing ski runs probably caused more fine-grained sediment to be available for erosion. The significance of this factor probably was magnified because of the factors described in A and B (items 1 and 2).

D. The Hot Creek Fish Hatchery probably contributed to the problem in two ways: (1) it supplied some organic material for deposition, and (2) it supplied nutrients which contribute to the growth of vegetation. The vegetation helps to stabilize deposits of sediment and it may have induced deposition in some areas. The significance of factor D probably is magnified because of factors A and B.

In summary, the accumulation of fine-grained sediment is a phenomenon that probably occurs naturally in the problem reach. Fluctuation in the weather probably is the basic cause of the deposition that has occurred since about 1970. Man's activities and the Hot Creek Fish Hatchery may have contributed to the problem; the significance of these factors, however, was magnified because of drought conditions in the years 1975-77.

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