EROSION, CHANNEL CHANGE, AND SEDIMENT TRANSPORT IN THE BIG LOST RIVER, IDAHO

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CONTENTS

Page

Hydrologic conditions

Relation of water discharge to sediment discharge

ILLUSTRATIONS

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

TABLES

CONVERSION FACTORS

For readers who prefer to use metric units, conversion factors for terms in this report are listed below. Chemical constituent concentrations are given in mg/L (milligrams per liter), which is equal to parts per million within the range of values presented in this report.

Multiply	By	To obtain
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot (ft^3)	0.02832	cubic meter
foot (ft)	25.40	meter
foot squared per second (ft^2/s)	0.093	meter squared per second
inch (in.)	0.3048	millimeter
mile (mi)	1.609	kilometer
pound per cubic foot (lb/ft^3)	16.01	kilogram (dry mass) per cubic meter
square mile (mi^2)	2.590	square kilometer
ton (short)	0.9072	megagram

Temperature in °C (degrees Celsius) can be converted to °F (degrees Fahrenheit) as follows:

$$°F=(1.8)(°C)+32.$$

All water temperatures are reported to the nearest 0.5°C.

GAGING-STATION NUMBERING SYSTEM

The gaging stations in this report are numbered in downstream order in accordance with the permanent numbering system used by the U.S. Geological Survey; for example, 13120500 (Big Lost River at Howell Ranch near Chilly, Idaho). The prefix (13) indicates that the station is in the Snake River basin. In this report, station numbers ending in two zeros are shortened by omission of the zeros.

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ABSTRACT

In the upper Big Lost River basin, changes in the hydraulic geometry of the river channel appear to coincide with runoff cycles. Sediment deposition occurred in the 1940's to mid-1960's during relatively dry periods. Downcutting in the Big Lost River channel during the 1970's was constrained by partially armored beds and drop structures. As a result of these vertical constraints, lateral shifting of the channel and bank undercutting increased and resulted in high concentrations of coarse sediment per unit discharge in the reach between Howell and Chilly. Deposition of eroded material occurred downstream, about 1 mile above Mackay Reservoir. Fine suspended sediment entered the reservoir and was transported through the system without settling, owing to the low trap efficiency of the reservoir. Comparison of reservoir survey data and results of cesium-137 analyses indicate that about 95 percent of the initial (1917) reservoir storage capacity still (1981) exists.

INTRODUCTION

Since construction of Mackay Dam on the Big Lost River in 1917, numerous conflicts have arisen concerning land and water use in the Big Lost River basin. Grazing practices on rangelands in the watershed above Mackay Reservoir, emplacement of structures designed to conserve water during drought periods (particularly for the 1930's drought), and construction of diversions for irrigation have affected the river regimen. One effect is the erosion of riverbanks along a 30-mi reach of the Big Lost River above the reservoir. In addition to loss of valuable agricultural lands, deposition of the eroded materials has resulted in further channel instability downstream. Roads, bridges, and irrigation works have been threatened, and wildlife and fisheries habitats related to the river and the reservoir have been degraded.

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Under Section 208 of Public Law 92-500 (Federal Water Pollution Control Act), the Butte Soil Conservation District (headquarters in Mackay, Idaho), was designated the coordinating agency to organize and conduct a "nonpoint source water-quality assessment" along the problem reach. A multidisciplinary group, consisting of local, Federal, and State organizations, was assembled to address the many interrelated environmental aspects for this assessment. The U.S. Geological Survey undertook an investigation of stream discharge and sediment transport, the results of which are reported herein.

Purpose and Scope

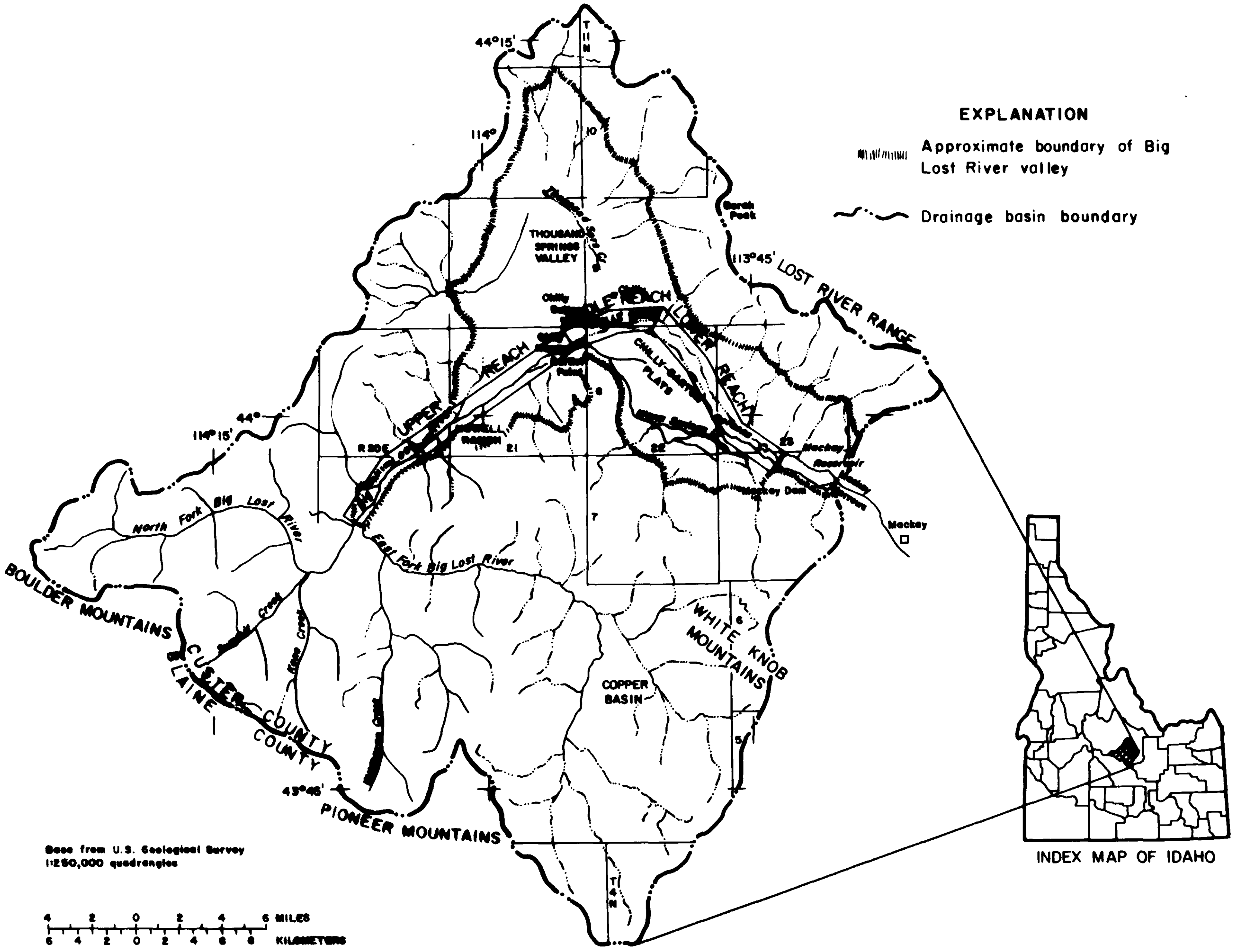
Primary purposes of this study are to: (1) Describe and evaluate effects of stream discharge and hydraulic geometry on erosion, sediment transport, and deposition in the Big Lost River system above the dam on Mackay Reservoir; and (2) provide land- and water-resource managers and users the basic knowledge for determining how the stream system might respond to man-caused changes in the natural stream environment.

All available hydrologic data collected prior to this study and specific data collected during this study were analyzed with respect to the erosion and sedimentation problems. The prior data consisted primarily of stream-discharge and ground-water level records. The specific data consisted of sediment-sample analyses, current stream-discharge measurements, and channel and reservoir cross-section surveys.

Description of Study Area

The study area occupies about 790 mi^2 of the Big Lost River basin above Mackay Reservoir in Custer County, south-central Idaho (fig. 1). The area is bounded on the northeast by the Lost River Range, on the west and southwest by the Boulder and Pioneer Mountains, and on the southeast by the White Knob Mountains. Elevations range from about 6,000 ft above sea level at Mackay Reservoir to 12,656 ft at Borah Peak in the Lost River Range; elevations of 12 other peaks in the surrounding mountains are greater than 11,000 ft.

The focal area of study includes 30 mi of the Big Lost River channel above the inflow to the reservoir (fig. 1). For discussion purposes, this part of the channel is divided into upper, middle, and lower reaches. The upper reach extends from the confluence of the North and East Forks of



Base from U.S. Geological Survey 1:250,000 quadrangles

Figure 1. -- Location of study area.

the Big Lost River to Chilly Buttes; the middle reach extends from Chilly Buttes to the intersection of the Big Lost River with Thousand Springs Creek; the lower reach extends from the intersection with Thousand Springs Creek to Mackay Reservoir.

Previous Reports

No previous reports on erosion and sedimentation processes in the Big Lost River basin are known to have been published. However, several reports deal, in part or wholly, with aspects of the hydrology. In an early report on ground-water resources of the Snake River Plain, Stearns and others (1938, p. 243-258) briefly discussed gains and losses in the Big Lost River, leakage from Mackay Reservoir, and potential for development of the surface- and ground-water resources in the Big Lost River valley. In a similar report on ground water for irrigation in the Snake River basin, Mundorff and others (1964, p. 109-122) discussed water resources in the Big Lost River basin. In addition, their report included an annual water budget of the basin above and below Mackay Reservoir.

Crosthwaite and others (1970a) provided fairly detailed descriptions of the physiography, hydrogeology, and water-resource conditions in the Big Lost River basin, along with a quantitative analysis of water yield. In a supplemental report, Crosthwaite and others (1970b) considered water use and management in the basin.

More pertinent to the study described herein is a report on the Big Lost River Water Quality Management Plan (Butte Soil Conservation District, 1982). The planning report presents an overview of the 208 project needs and describes the project area and study objectives. Best-management practices (BMP's) that were tried for demonstration are listed, as well as alternative BMP's that were selected for implementation to solve erosion and sedimentation problems in the project area.

Acknowledgments

The authors are grateful for the assistance, support, and contributions provided by many State, Federal, County, and local natural-resource agencies and individuals during the progress of this study. Also, many landowners in the study area allowed access to their properties and supplied pertinent information. Special thanks are given to Dan Schaffer, U.S. Bureau of Land Management, who contributed significantly to the field work and drafted several illustrations used in this report. In addition, thanks are given to Anthony Bennett and William Jolley of the U.S. Department of Agriculture, Soil Conservation Service, who also assisted in the field work.

CURRENT CONDITIONS IN THE BIG LOST RIVER CHANNEL

Existing erosional and depositional features are described to provide the Butte Soil Conservation District and other agencies a basis for evaluating the effectiveness of current land use and erosion control practices along the Big Lost River channel. Where local sediment problems are identified, a coordinated plan of corrective strategies can be developed. Features were identified and their positions located on recent (1981) aerial photographs. Number of log jams and number and magnitude of cutbanks and bank failures and their relative positions along the main channel are shown, along with the river profile, in figure 2.

Upper Reach

The upper reach of the Big Lost River channel flows across a well-vegetated flood plain and is relatively narrow and straight. The most common erosional features are small cutbanks and bank failures in alluvium along the concave side, or outside, of meander bends. The largest active natural erosional feature is a bank failure along the base of a landslide at the upper end of the reach near the confluence of the North and East Forks. Several miles above Chilly Buttes, where vegetation is sparse and previously uncultivated land is being converted to agricultural use, cutbanks are common in flood-plain deposits. Bank failures commonly are caused by debris jams where accumulations of downed trees and branches deflect the flow of water into the adjacent bank. Bank protection measures (gabions) and streambed aggradation are shown in figures 3a-c. Channel migration, meanders, and abandoned channels are also evident in figure 3d.

Middle Reach

The middle reach includes the Chilly Sinks, which is an area where the river loses considerable flow into the ground. The Chilly Sinks are divided into two sections--a smaller sink above the Chilly Bridge and a larger sink below the Chilly Bridge (fig. 4a). The upper sinks are not as heavily aggraded or severely eroded as the lower sinks (figs. 4b-c). Bank vegetation is present, but adjacent riparian vegetation on the flood plain is sparse or absent to about 1 mi upstream from the bridge, where bank and flood-plain vegetation is abundant because of shallow ground water. Channel meanders are cut into stands of trees and the flow diverges around aggraded gravel deposits and log jams, leaving islands of trees in the middle of the flood plain. Part of the sediment carried through the upper sinks

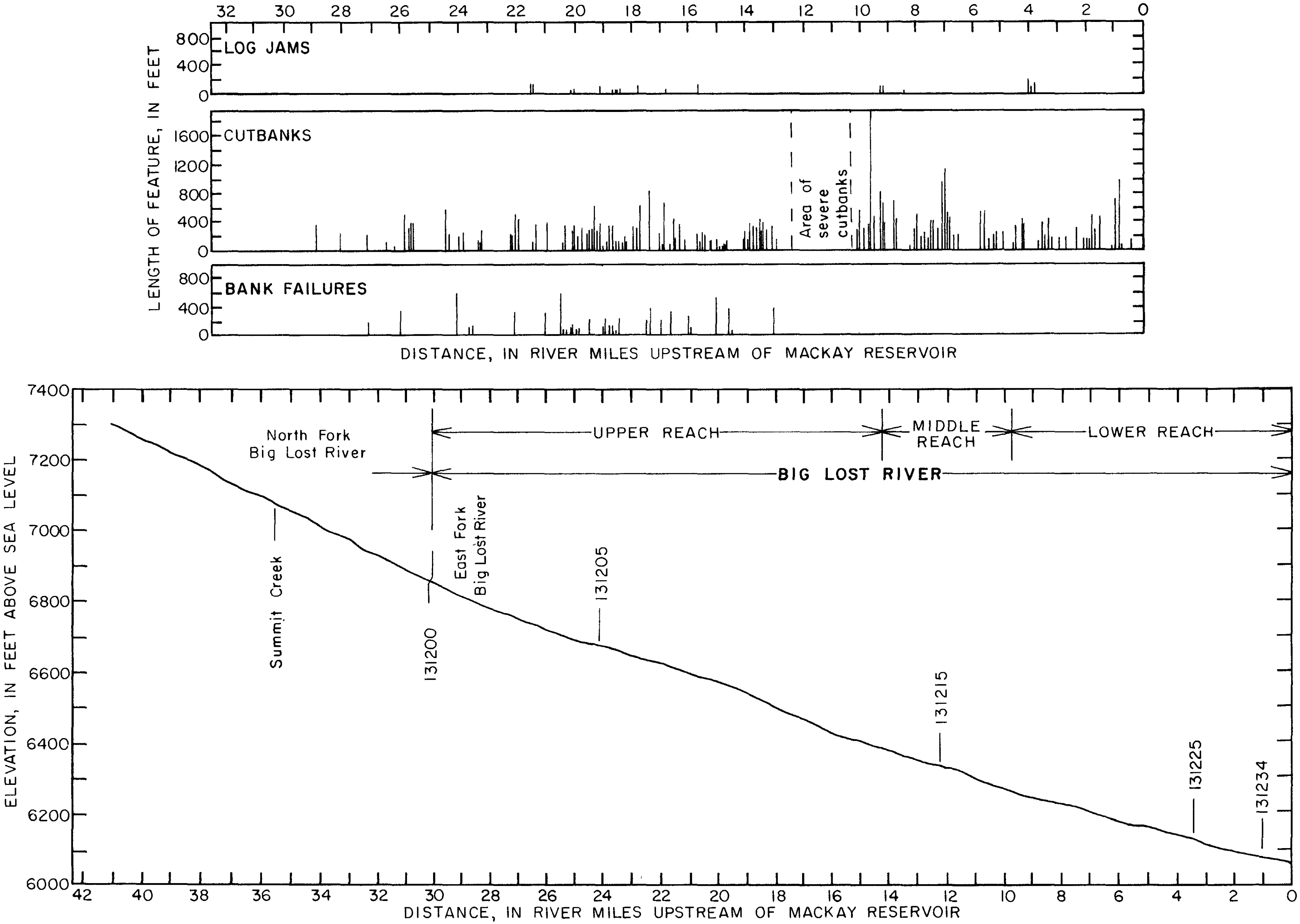


Figure 2. -- Elevation profile of the river and the locations and extent of log jams, cutbanks, and bank failures.

a. View just downstream from site 131205, gabions in background. Arrow shows direction of flow.

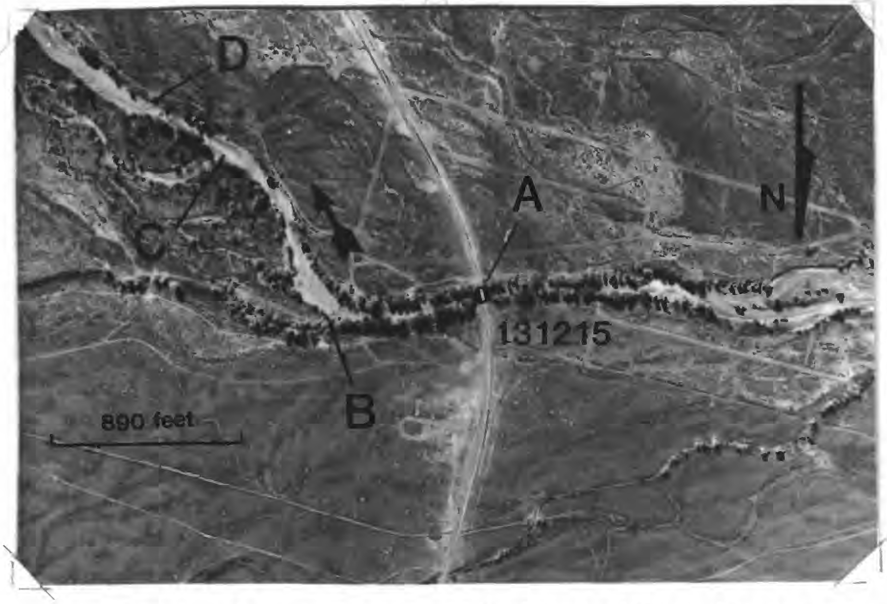
b. View downstream along left bank showing tiers of demonstration gabions. Arrow shows direction of flow.

Figure 3.--Bank erosion, bank protection measures, and streambed shift in the upper reach of the Big Lost River.

c. View upstream showing lateral extent of gabions along left bank. Arrow shows direction of flow.

d. Aerial view of gabion site (1980), where river is eroding 30-foot high bank (A). Arrow shows direction of flow.

Figure 3.--Bank erosion, bank protection measures, and streambed shift in the upper reach of the Big Lost River--Continued.

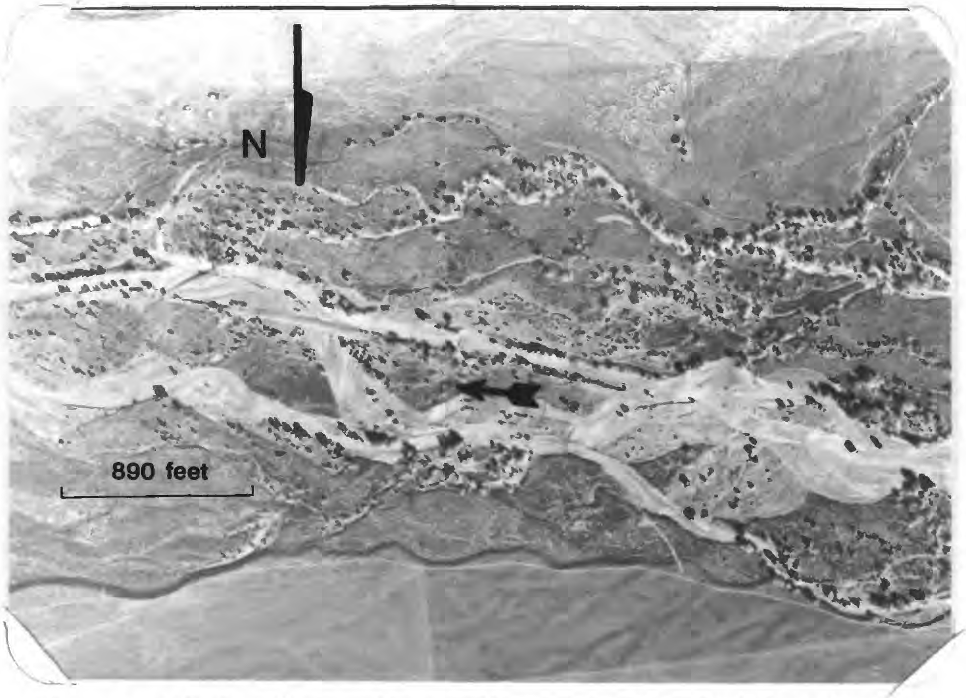


a. Aerial view of (A) Chilly Bridge (131215), (B) diversion, (C) bypass canal, and (D) drop structure. Arrow shows direction of flow.

b. View upstream of drop structure. Note streambed is flush with top. Arrow shows direction of flow.

Figure 4.--Erosional and depositional features in the middle reach of the Big Lost River.

c. View downstream of drop structure; note coarse bed material down center of channel. Arrow shows direction of flow.



d. Aerial view of remains of the Chilly Bypass Canal downstream of drop structure. Arrow shows direction of flow.

Figure 4.--Erosional and depositional features in the middle reach of the Big Lost River--Continued.

is deposited upstream of Chilly Bridge. As aggradation increases the elevation of the streambed, bank heights are reduced and overbank flows occur. Bank erosion by lateral channel migration is severe.

Below the Chilly Bridge in the lower sinks, bank vegetation is sparse and the banks are unprotected against erosion. Depth to ground water is greater than in the upper sinks, and the channel becomes braided (fig. 4d) near the Chilly Bypass Canal, which channelizes a 2.5-mi long section of the river. Channel erosion features are continuous along this reach of river and include long, high cutbanks at the outside of river meanders, braided channels, alluvial flood-plain channels, and eroding and shifting channels at the drop structures (fig. 4a). Channel alterations along the canal require continuous maintenance and repair because of repeated channel shifting during periods of high flow.

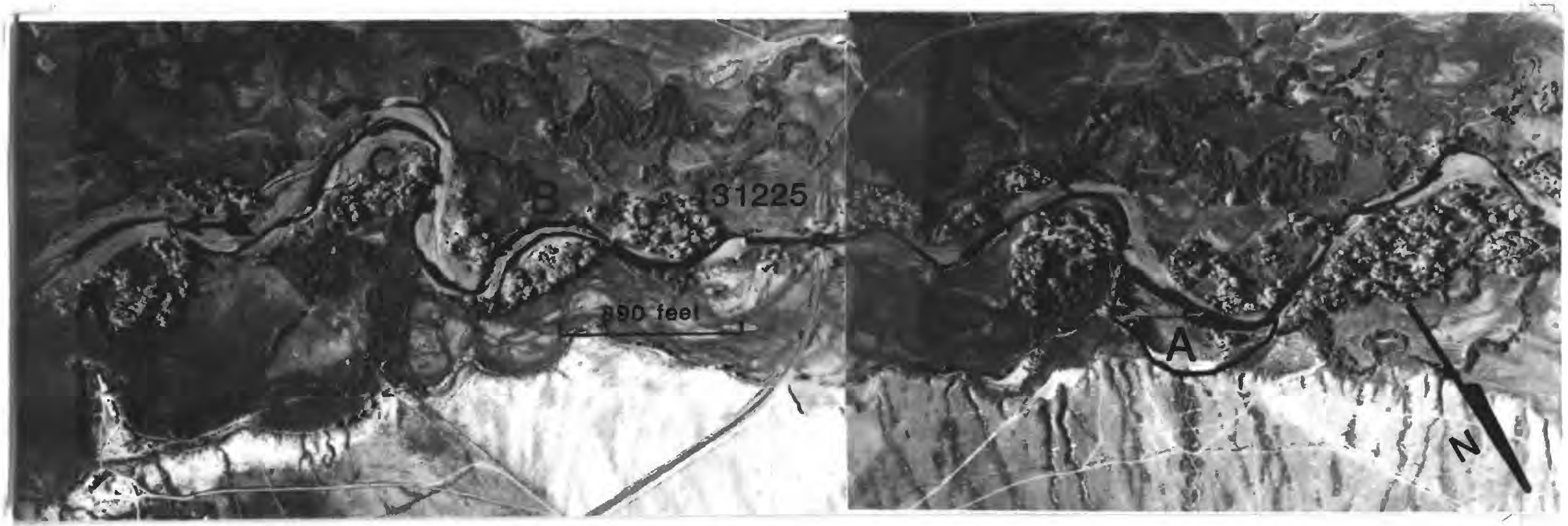
Severe erosion, channel shifting, and deposition near the Chilly Bypass Canal demonstrate effects of aggradation at drop structures on alluvial channels transporting large sediment loads.

At the end of the bypass reach, bank and adjacent flood-plain vegetation grow in response to shallow ground water. The frequency of active erosional features decreases where the former sinuous, braided channel has been narrowed, straightened, and better defined.

Lower Reach

The river meanders in a wide flood plain bounded on the east by the large alluvial fans of the Lost River Range and on the west by the terrace gravels of Chilly-Barton Flats. Undisturbed land is covered with dense vegetation; agricultural land and land continuously used for grazing are sparsely vegetated. Large cutbanks occur at meanders where bank vegetation is lacking. During periods of high flow, shallow loam soils are stripped away and loose deposits of sand and gravel are exposed, eroded, and transported downstream. In areas supporting hardwood stands, the incidence of cutbanks actually may increase because of tree falls and the ease with which the loosely compacted bed and bank materials erode in response to deflection of water by debris jams. Figures 5a-b show aerial views of the lower reach.

Cutbanks range in length from 100 to 1,000 ft (fig. 5a) and usually are 4-6 ft high. Flow from springs (fig. 5b) on the flood plain or adjacent to the main channel forms narrow, meandering channels that parallel the river down the



a. Aerial view near site 131225. Note (A) flood-plain source of fine materials during high flows, (B) erosion of banks, and (C) deposition on wide point bar. Arrow shows direction of flow.

b. Aerial view near site 131234. Note (A) diversion, (B) change in vegetation at fence line, (C) spring in flood plain, (D) area of deposition, and (E) zone of backwater from reservoir. Arrow shows direction of flow.

Figure 5.--Erosional and depositional features in the lower reach of the Big Lost River.

valley toward Mackay Reservoir. Coarse sediments eroded and transported from the upper and middle reaches are deposited in the lower reach. The deposits fill the channel at high flows and are reworked as the thalweg (deepest part of channel) or multiple channels shift during falling stages. Immediately upstream of the reservoir, the channel is braided and zones of overbank deposition are apparent.

Current Channel Response to Artificial Controls

From the previous discussion, it is apparent that stream channels change from place to place in response to imposed factors, whether they are man-induced or natural. Unless constrained naturally by exposed rock in the riverbed, adjustments in channel width, depth, and sinuosity may progress both upstream and downstream from an area of induced aggradation or degradation. Adjustments in channel shape or pattern will affect the water velocity and bed-material distribution in a section.

In the 1930's, an irrigation diversion and weir was constructed on the middle reach of the Big Lost River near Chilly Bridge (figs. 4a-c). Upstream from these structures, the hydraulic gradient was reduced, the water depth was increased, and flow velocity was decreased. Fine material was transported through the diversion and coarse sediment was deposited above the weir. Below the weir, a scour hole developed as the raised energy head upstream caused increased velocities downstream (fig. 4c). Eventually, the streambed was armored, and channel changes progressed farther downstream.

Channel changes that resulted from installation of the diversion and weir were short term and local as long as the sediment-to-water discharge ratio remained constant. Subsequent change from the established equilibrium because of increased discharge or decreased sediment supply has caused further stream channel adjustment (fig. 4d).

Gabions installed to reduce streambank erosion at one location may induce erosion elsewhere. Prior to 1981, erosion of 30-ft high banks on the right side of the channel below Howell Ranch was severe (figs. 3a and d). In an attempt to halt the erosion, a three-tiered, 400-ft section of gabions was installed along the right bank. The riverbanks were then seeded (figs. 3b-c). Erosion of the right bank was halted. However, the channel continued to erode its bed at the base of the gabion because upstream load was reduced relative to energy of the water-sediment mixture.

If coarse material remaining on the bed prohibits further scour or gradient reduction and the current is deflected toward the left bank downstream, the locus of bank cutting may merely be shifted by the gabions. Bank cutting will still proceed to enlarge the channel (fig. 3c) and reduce the gradient, primarily in response to reduced coarse load and increased discharge. Roughness at the surface of the gabions may or may not reduce stream velocity. If the hydraulic gradient is thereby increased, velocity and shear may increase and be redirected toward the bed, which creates a scour hole at high flows. Bed material transported and deposited downstream (fig. 3a) could provide continuity in the flow regime by decreasing the depth and increasing the stream velocity.

HYDROLOGIC CONDITIONS

Surface Water

Twenty-six stream-gaging stations in the Big Lost River basin were established between 1903 and 1968 by the U.S. Geological Survey. Measurements at 23 of the 26 existing stations were analyzed for this study.

During this study, discharge measurements were made periodically (April-July 1981) at five sites to define the distribution of streamflow and sediment transport. A few of these measurement sites were at discontinued gaging-station locations. Gaging stations, measurement sites, and periods of streamflow records are listed in table 1. Locations of the stations and sites are shown in figure 6.

Flow-Duration Curves

The streamflow-duration curves shown in figures 7a-e indicate the magnitude and duration of flow for past periods of record. That is, they show the percentage of time specified discharges were equaled or exceeded during the periods of record examined. For the Big Lost River basin, the curves indirectly provide an indication of the relative sediment-transport potential at an individual site among selected historic periods. Generally, the steeper the slope of the curves, the greater the potential for bedload transport in gravel streams and the less stable the channel. The flatter the slope, the less potential for bedload transport and the more stable the channel. The greater the separation of curves applying to different time periods at a station, the greater the potential for channel instability. Transport of gravels is likely to occur during periods of high water discharge.

Table 1.--Data sites and types of data available

[A, discharge measurement; B, sediment; C, cross-section survey; D, reservoir contents; E, hydraulic geometry; F, quality of water]

Station No.	Station name	Period of record	Types of data
131196	Summit Creek above Kane Creek	1966-68	A,E
131197	Summit Creek below Kane Creek	1966-68	A,E
131198	North Fork Big Lost River near Chilly	1957-59, 1966-68, 1973, 1975-78	A,E,F
131200	North Fork Big Lost River	1944-81	A,E,F
131201	East Fork Big Lost River near Mackay	1966-68	A,E
131202	Star Hope Creek near Mackay	1966-68	A,E
131202.4	East Fork Big Lost River	1957-59, 1973, 1975-78	A,E,F
131202.5	do--	1957-58, 1966-67	A,E
131203	Wild Horse Creek	1966-68, 1977	A,E
131204	East Fork Big Lost River	1967-68	A,E
131205	Big Lost River at Howell Ranch	1904-48, partial 1949-81, complete	A,B,E,F
131210	Big Lost River below Chilly	1921-22, 1967-68	E,F
131215	Big Lost River at Chilly Bridge	1920, 1966-67, 1981	A,B,C,E,F
131220	Thousand Springs	1913-14, 1921-22, 1966-68, 1977	E,F
131225	Big Lost River below Chilly Sinks	1921-22, 1981	A,B,C,E,F
131234	Big Lost River above East and West Channels	1981	A,B,C,E
131235	Big Lost River, East Channel	1919-59, 1977	A,E
131240	Big Lost River, West Channel	1919-59, 1977	A,E
131240.3	Hamilton Springs	1967, 1978	E,F
131245	Warm Springs, East Channel	1919-59, 1977	A,E
131250	Warm Springs, West Channel	1919-59, 1977	A,E
131255	(1)	1919-59	A
131260	Mackay Reservoir	1919-81	D
131270	Big Lost River below Mackay Reservoir	1903-06, 1912, 1915-81	A,E,F

[1] Surface inflow to Mackay Reservoir, sum of stations 131235 to 131250, not shown in figure 6.

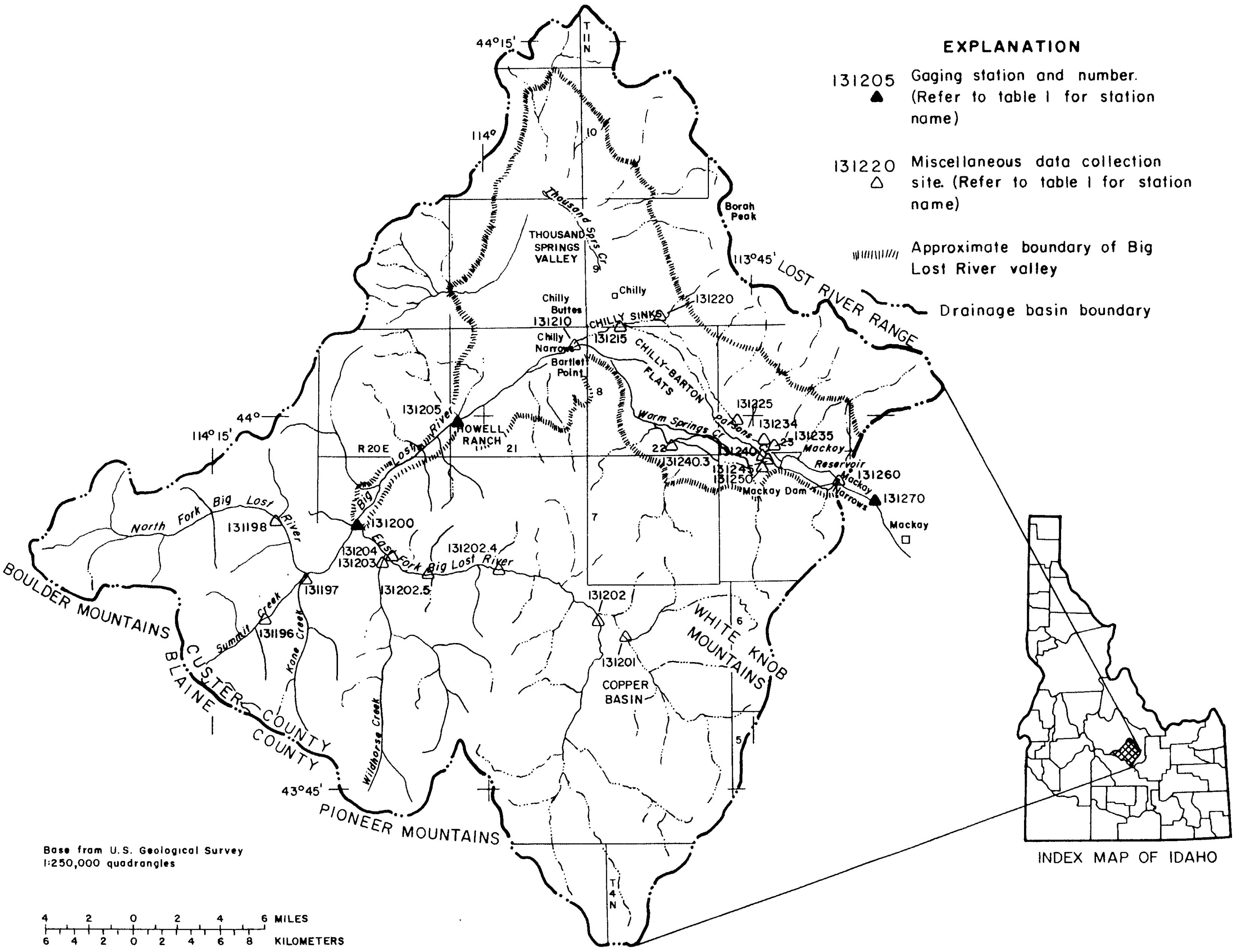


Figure 6. -- Locations of gaging stations.

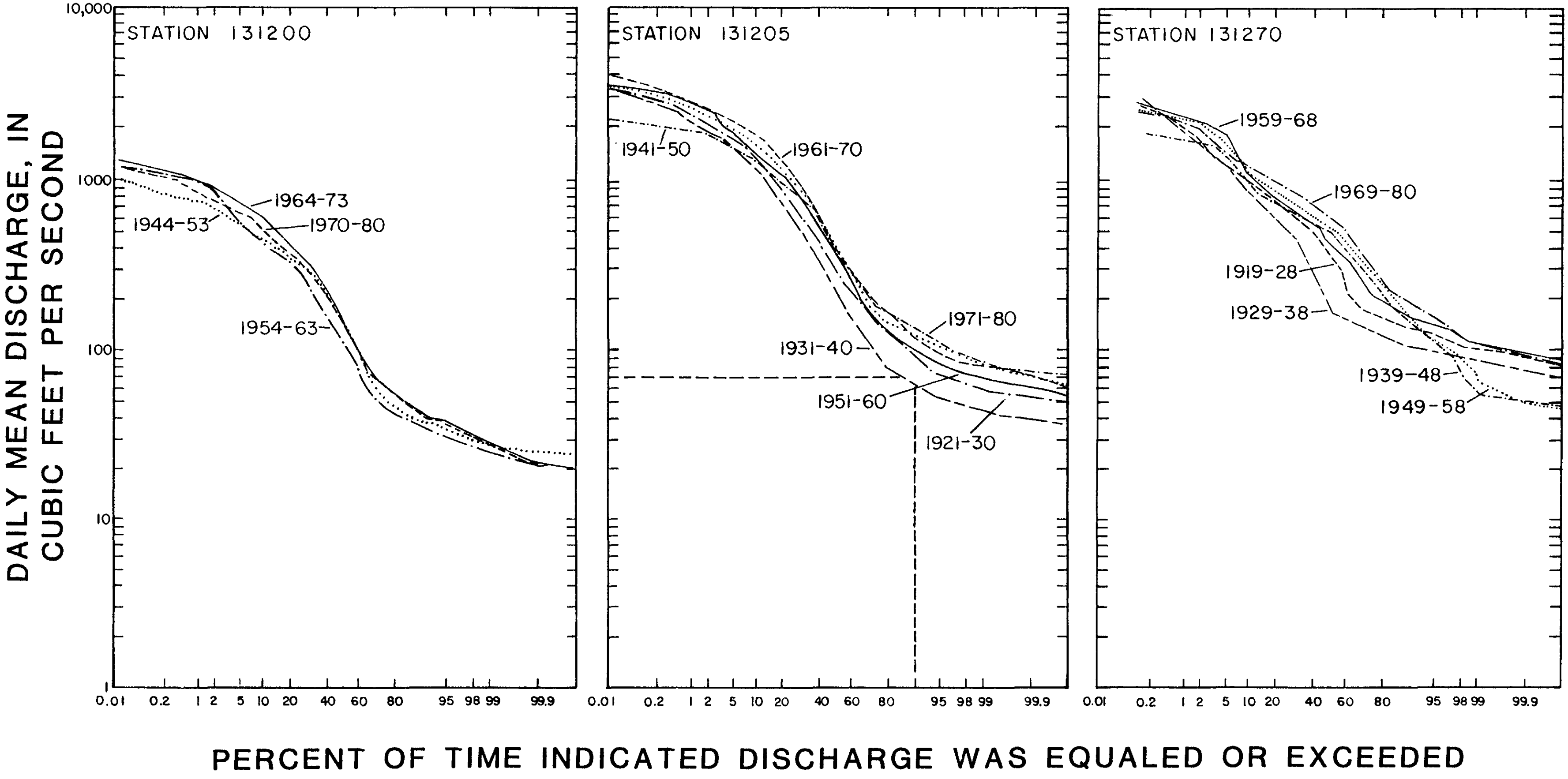


Figure 7.-- Flow-duration curves for selected gaging stations.

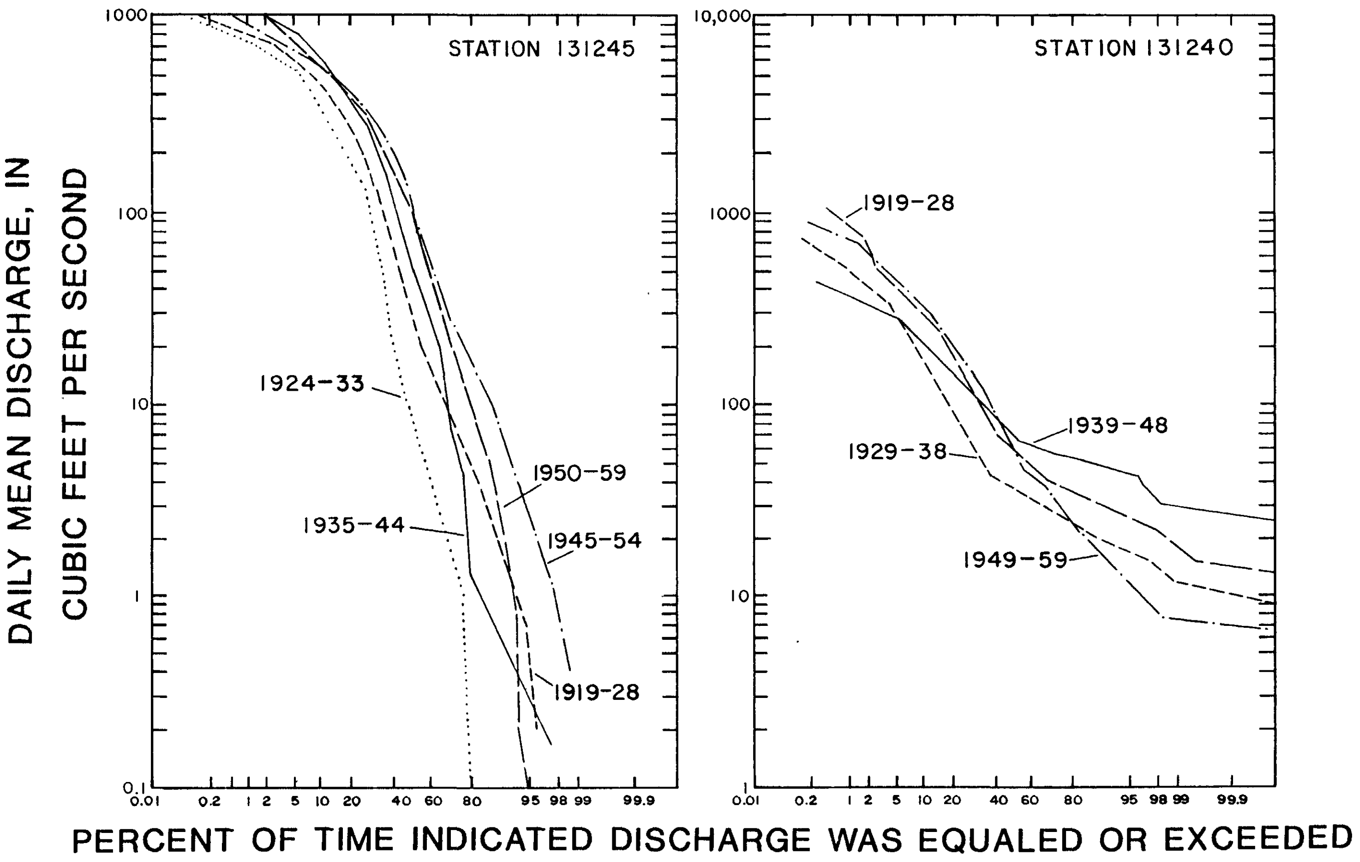


Figure 7. -- Flow-duration curves for selected gaging stations--Continued.

The daily flow hydrographs (figs. 8a-b) show the variation of daily mean discharge for each day of the year during the indicated period of record. In this study, the curves were used as guides to select periods and frequencies for sediment-sample collection. Generally, sediment discharge is expected to be highest during periods of high flow and lowest during periods of low flow. Therefore, it is desirable to sample at a greater frequency during high flows than during low flows. However, sediment samples must be collected for the entire range of expected flows to establish a water-sediment discharge relation.

Superposition of the 1981 daily discharge hydrograph on the long-term hydrograph (figs. 8a-b) shows that the water-discharge distribution during the period of sediment sampling (April-August 1981) was reasonably representative of an average year. However, runoff in 1981 peaked earlier than average, presumably the result of warm rain on snow. It is uncertain whether this early runoff may have affected the sediment availability relative to the sediment-water discharge relations described later in this report.

Peak Flows

The magnitude and frequency of peak flows on the Big Lost River at Howell Ranch, selected as the representative station in the basin, are depicted by the curve shown in figure 9. The curve is based on the highest instantaneous peak flow for each year during the period of record, 1904-81. The peak flow for 1981, during sediment-sample collection, was 2,960 ft^3/s on June 9. As shown in figure 9, this flow would be expected to recur on the average of once in about every 4 years. The curve in figure 9 does not show the time distribution of the peak flows; peak flows are plotted by year of occurrence in figure 10. To further define the time distribution, the peak flows are ranked by decades of occurrence, as tabulated below. The tabulation shows that the period 1951-80 had, on the average, the highest peak flows.

Decades	Average peak discharge (in cubic feet per second)
1951-60	2,670
1961-70	2,570
1971-80	2,480
1911-20	2,310
1921-30	2,120
1941-50	1,920
1931-40	1,570

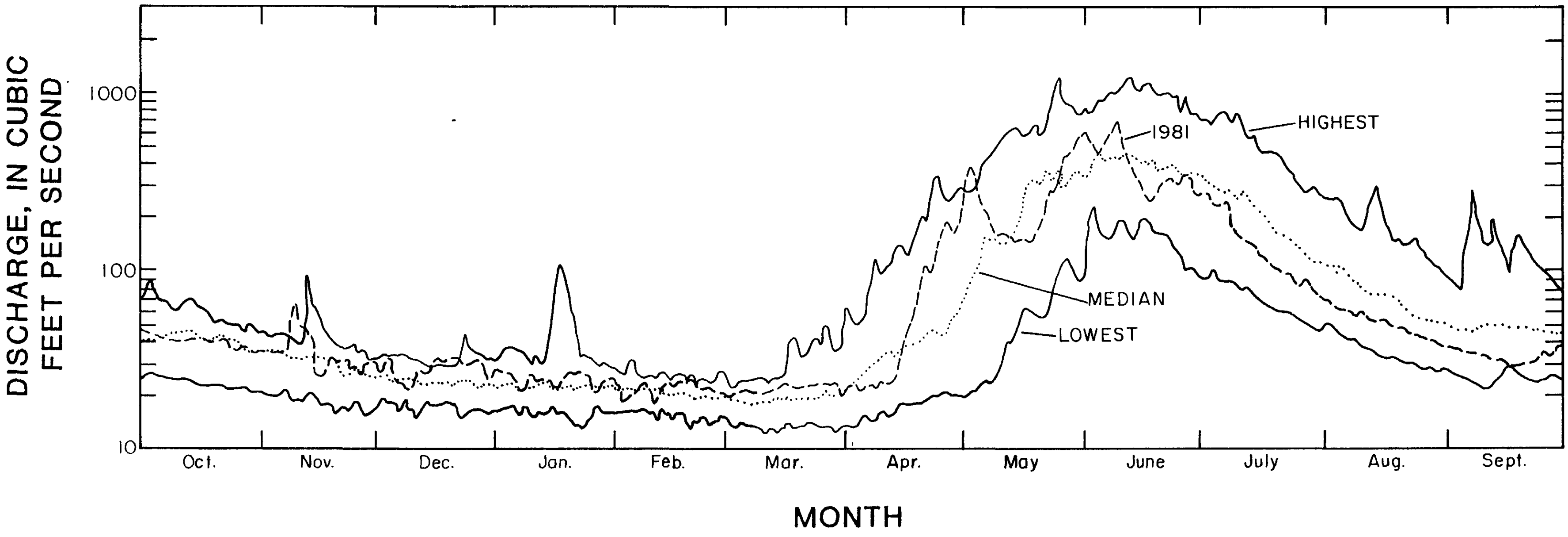


Figure 8a. -- Hydrographs of highest, lowest, and median daily flow for the period 1961-80, and daily hydrograph for 1981 water year for station 131200.

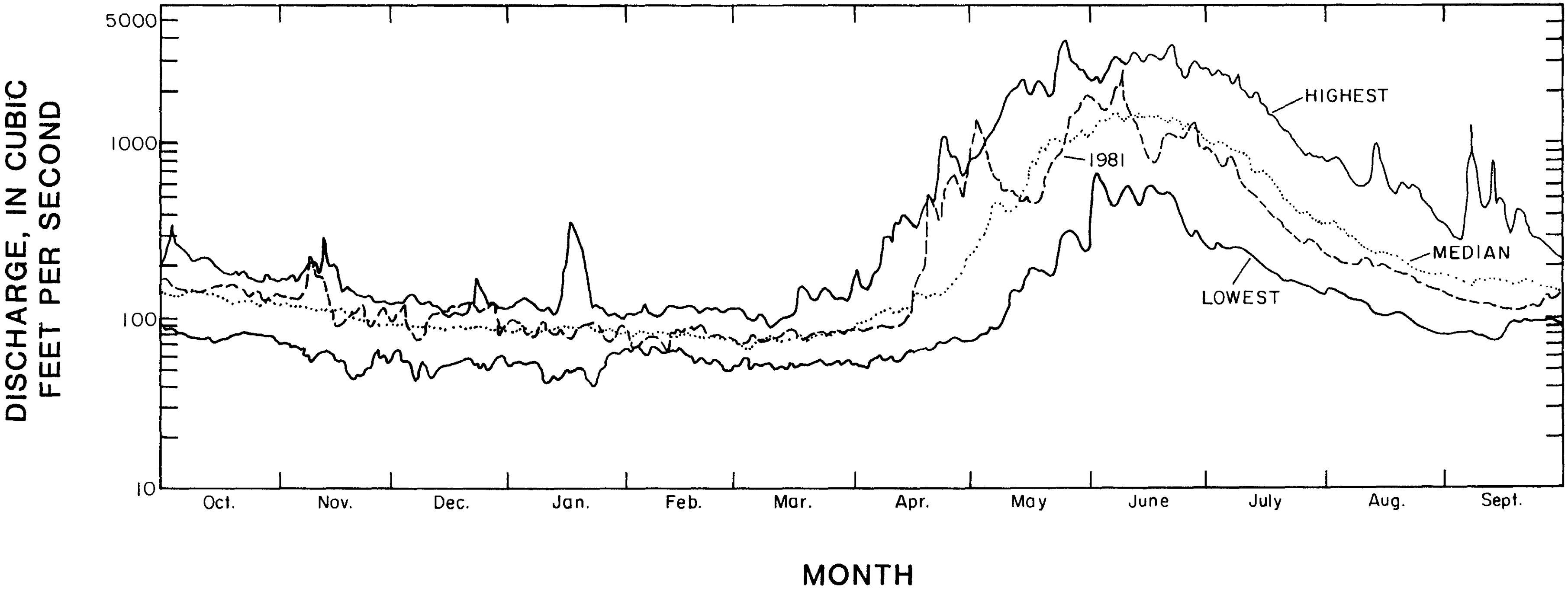


Figure 8b. -- Hydrographs of highest, lowest, and median daily flow for the period 1961-80, and daily hydrograph for 1981 water year for station 131205.

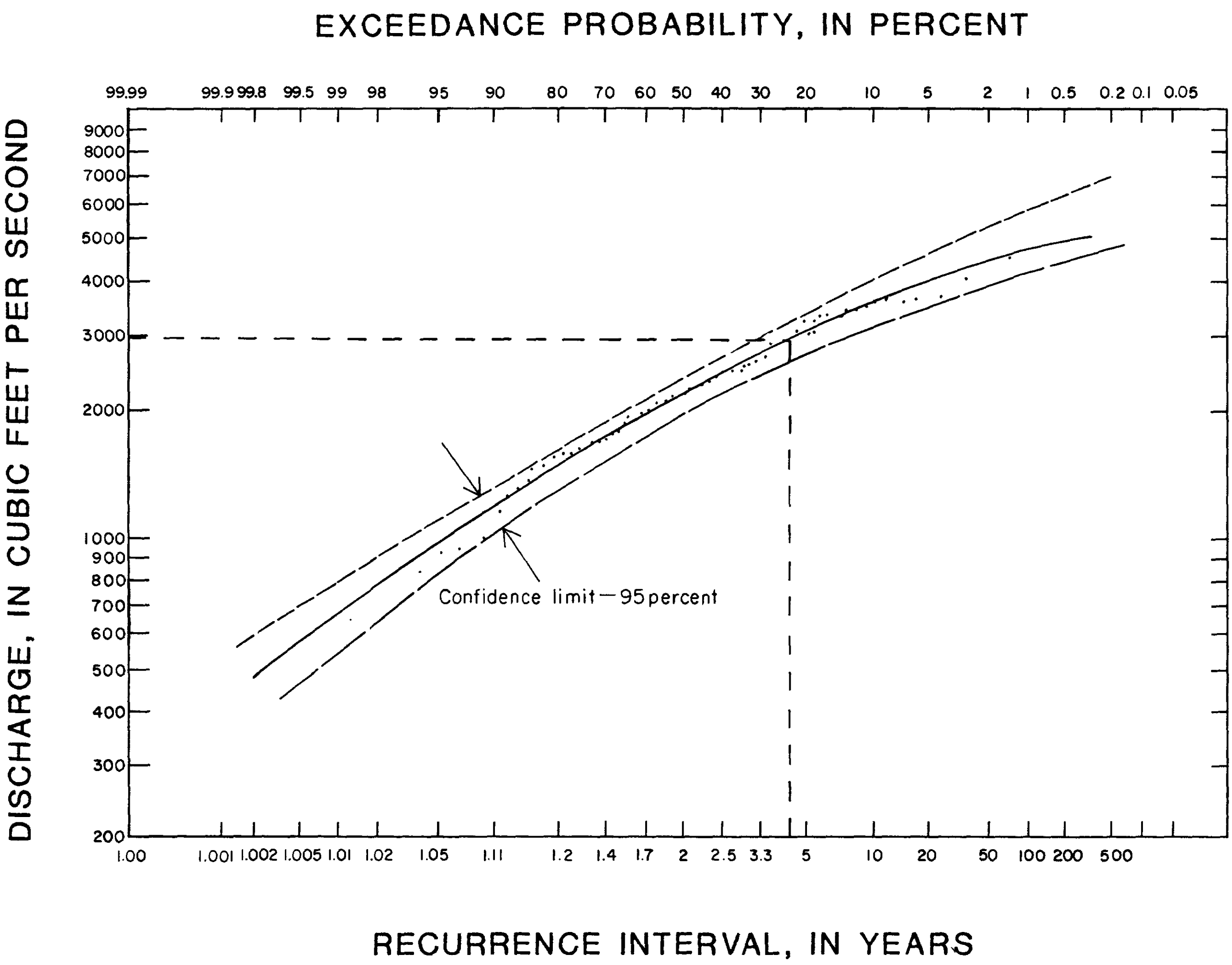


Figure 9. -- Magnitude and frequency of peak flows for the period 1904-81 at station 131205.

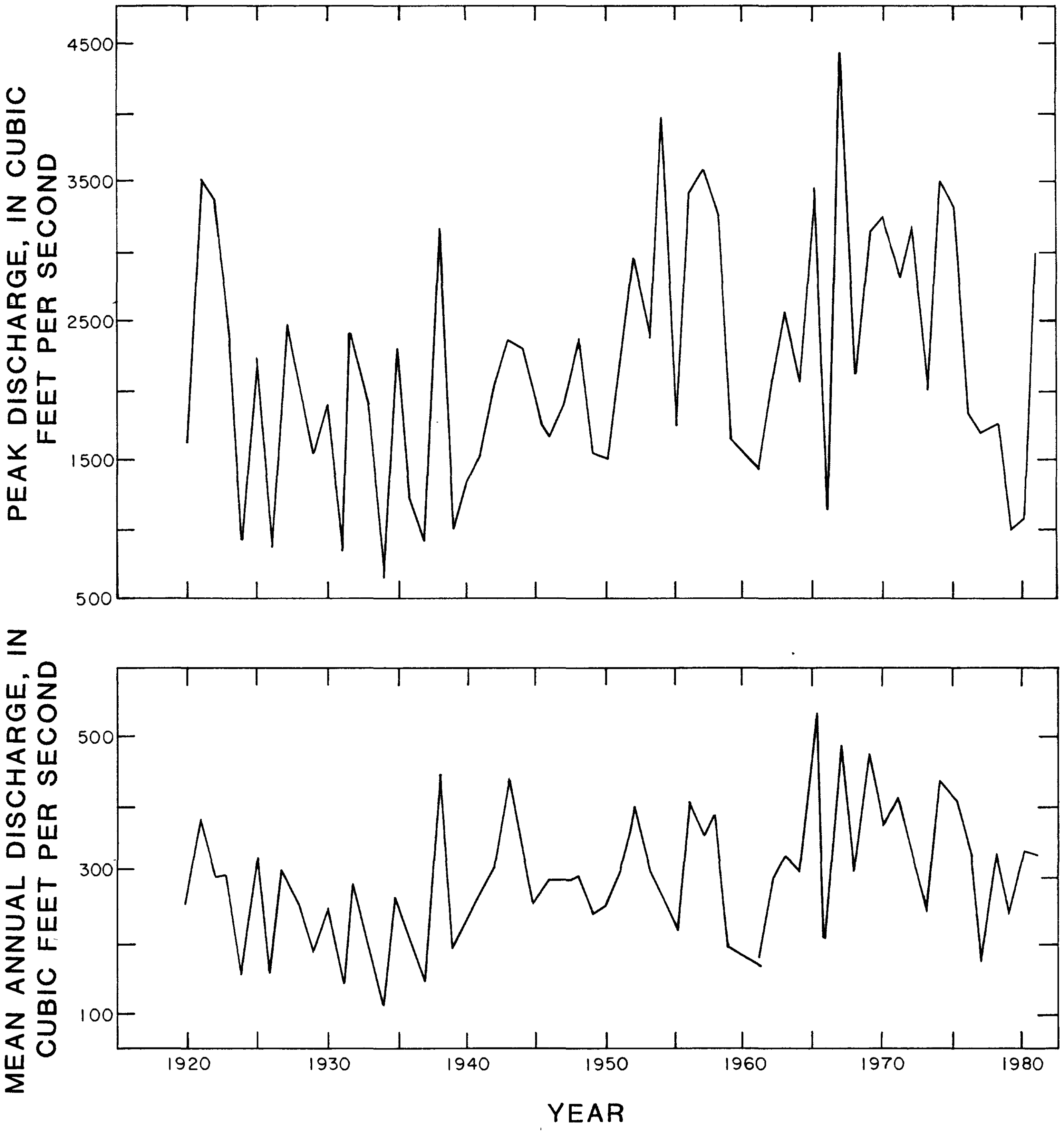


Figure 10. -- Peak discharge and mean annual discharge for the period 1920-81 at station 131205.

Departure From Mean Flows

The foregoing streamflow characteristics (figs. 7-10) may or may not reveal significant trends in the relative wetness or dryness in the basin for past years--trends that are needed for a basic understanding of factors that governed past hydrologic conditions in the basin. Cumulative departure graphs (fig. 11) are a more revealing measure for yearly or time-period comparisons. These graphs indicate the occurrence of a wet period (early 1920's) separated by a 15-year dry period (1925-40), followed by a 20-year normal period (1940-60), in turn followed by a 15-year wet period (1960-75). The graphs further indicate that hydrologic conditions now prevailing in the basin may be similar in wetness to those of the early 1920's. This is a significant factor in the hydraulic geometry to channel-change relations discussed later in this report.

Ground Water

Ground water originates from rainfall and snowmelt. Ground-water distribution in the Big Lost River basin is controlled by geology. A large part of water that enters the subsurface reappears as spring flow or streamflow and then disappears as underflow in the alluvial fill of the valleys.

The major zone of recharge occurs at higher elevations near the basin boundaries. Along the mountain front of the Lost River Range, the alluvial material is coarse, relatively free of silt and clay, and readily permeable. Streams descending and traversing the mountain fronts rapidly lose water into the ground. Seepage losses can be so great that the entire surface flow disappears. These losses contribute significantly to ground water, particularly in the alluvial fill of the Thousand Springs and Big Lost River valleys (fig. 1). However, much of the ground water in the alluvial valleys later is returned to streamflow by seepage.

Generally, in most of the Big Lost River valley, the water table is less than 50 ft from the land surface. Near the rivers and streams, it is often as close as 5-10 ft from the surface. In the gaining reaches, it is at or above river elevation. In alluvial fan deposits on the flanks of the main valley, depth to water may exceed 300 ft.

Changes in water levels between 1968 and 1981 were measured in 20 wells in the study area. These measurements did not indicate whether basin-wide water levels had changed

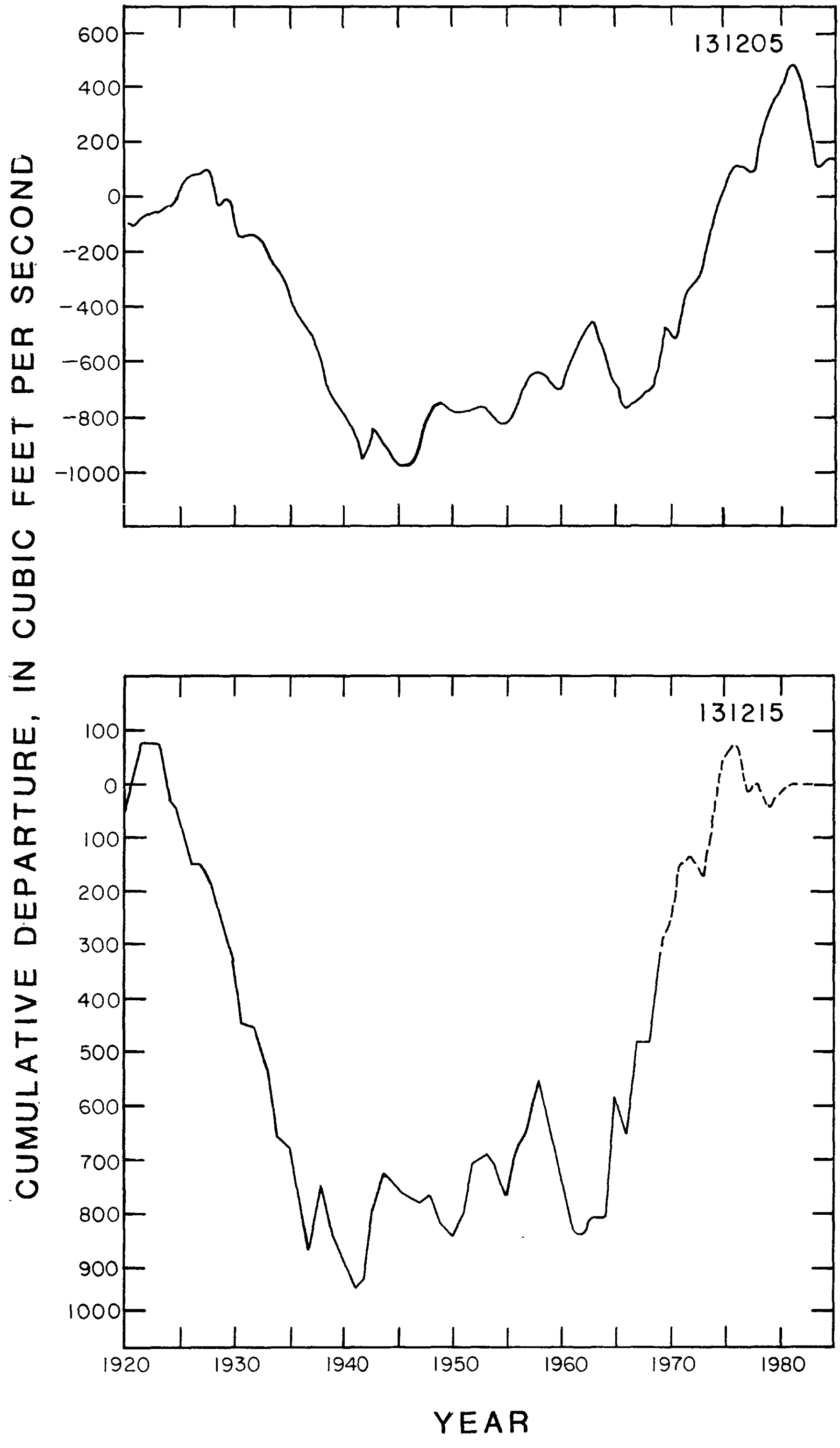


Figure 11. -- Cumulative departure from mean annual discharge for the period 1920-81 at stations 131205 and 131215.

between September 1968 and September 1981. The hydrograph of the only continuous record of water level in the study area is shown in figure 12.

Insufficient data were collected during this study to determine the effect of changes in ground-water levels on sediment transport in the Big Lost River. If ground-water levels rose in response to above-normal precipitation, as is indicated by cumulative departure curves of precipitation, attendant increased discharge from springs may cause initial increases in sediment loads in the Big Lost River from erosion along spring-fed tributaries. However, continued wetter years eventually may increase vegetation cover and negate this sediment supply.

A more complete discussion of ground-water conditions in the basin is provided by Crosthwaite and others (1970a).

RELATIONS BETWEEN SURFACE AND GROUND WATER IN REACHES OF THE BIG LOST RIVER

A distinctive characteristic of the Big Lost River basin is the large interchange of water between streams and the subsurface. The Big Lost River alternately loses water to and gains water from alluvial deposits. At medium and low flows, all the surface flow in the main stem of the Big Lost River disappears into the alluvium in the Chilly Sinks (fig. 1). The underflow reappears in several large springs in the alluvial flood plain along and east of the river in the lower reach. Some of the spring discharge is from the drainage basin of Thousand Springs Creek. A major part of year-round surface inflow to Mackay Reservoir is from the discharge of these major springs.

Upper Reach

The East and North Forks supply most of the flow in the Big Lost River. High runoff results from snowmelt in the late spring. Just upstream of gaging station 131200, the North Fork has cut through alluvium and flows on consolidated rock, causing nearly all the ground water in the alluvium to discharge into the stream. Crosthwaite and others (1970a) reported an average ground-water loss of about 7 ft^3/s in the reach between the two forks and station 131205. Because surface flows of North Fork Big Lost River are gaged at a rock outcrop, any ungaged losses or gains in flow may be assumed to be from the East Fork drainage. Based on the long-term records at stations 131200 and 131205 and on the reported loss of 7 ft^3/s, an annual mean flow of 224 ft^3/s was calculated for the East Fork Big Lost River.

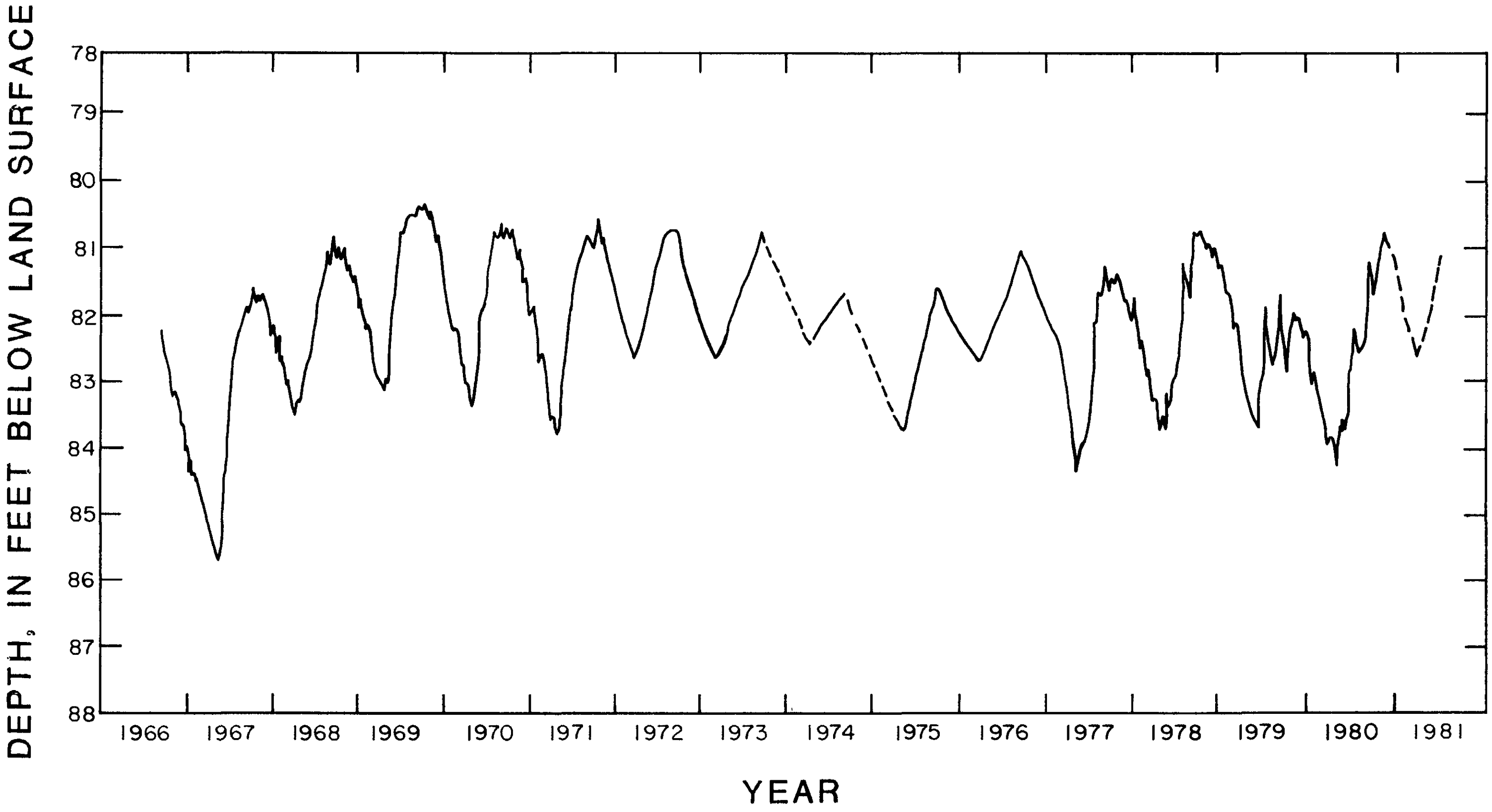


Figure 12. -- Ground-water levels in a well in SW¼ NW¼ NW¼, sec. 14, T. 9 N., R. 21 E., for the period 1966-81.

(Dashed lines represent estimated record between measurements)

Middle Reach

Large volumes of water percolate from the middle reach into the alluvial fill of the Chilly Sinks. Average ground-water recharge or loss of surface flow to ground water for the period 1944-68 was 170 ft^3/s (Crosthwaite and others, 1970a). Average ground-water recharge during the period 1944-81, as determined in this study, was 195 ft^3/s. Measured streamflow losses average 45 ft^3/s at Howell Ranch to 120 ft^3/s at Chilly Store (Crosthwaite and others, 1970a). The river channel through the sinks is completely dry for about 8 months of the year (figs. 4b and d). During extended periods of dryness, the sinks are capable of absorbing more than 1,000 ft^3/s. Mean annual flow passing the sinks is 128 ft^3/s.

Lower Reach

Thousand Springs Creek, which is fed by ground water, drains about 150 mi^2 of the basin and its surface flow averages 25 ft^3/s. Downstream from the confluence of Thousand Springs Creek and the Big Lost River are numerous smaller springs adjacent to the river flood plain (fig. 5b). These springs feed the main channels, as well as the meandering flood-plain channels, of Warm Springs and Parson Creeks, which discharge separately into Mackay Reservoir.

RELATION OF WATER DISCHARGE TO SEDIMENT DISCHARGE

Sediment Discharge

Total sediment discharge of a stream can be divided into two parts: (1) Fine sediment discharge, which consists of particles smaller than 0.062 mm, usually not found in significant quantities on the streambed; and (2) coarse sediment discharge, which consists of particles larger than 0.062 mm, usually found in appreciable quantities on the streambed.

All the fine sediment and generally most of the coarse sediment are transported in suspension. These suspended sediments usually are sampled through the depth of flow to within 0.3 ft of the streambed. This sampled part of the total sediment discharge is referred to as the suspended-sediment discharge. Data on suspended-sediment discharge are published in the annual water-resources data report for Idaho (for example, see U.S. Geological Survey, 1981).

Part of the coarse sediment is transported by sliding, skipping, and rolling along the bed. This part, in nearly continuous contact with the bed, is referred to as the bedload. For this report, it is assumed that bedload moves in a zone that extends from the surface of the bed to 0.3 ft above the bed.

Total sediment discharge is the sum of the suspended-sediment discharge and the bedload.

Most fine sediment available for transport in the Big Lost River system originates from overland erosion of rangeland and from streambed erosion. Most water discharge is assumed to be sufficient to transport all materials finer than 0.062 mm that enter the river system.

Most coarse sediment transported by the Big Lost River is derived from scour of the channel bed during periods of high flow. The coarse sediment moving downstream is replaced by material carried to the main channel by major tributaries, such as the North and East Forks of the Big Lost River. Coarse sediment is supplied to tributaries from eroding hillsides, landslides, slumps, and debris flows. Thus, sediment continuously feeds the main channel of the Big Lost River, and streambed elevations tend to remain fairly constant. However, man's activities, such as gravel mining or placement of structures in the stream system, generally affect the supply of gravel as well as the competence of the stream to transport coarse sediment.

The volume of coarse sediment transported depends primarily on availability and particle size of source materials and on hydraulics of streamflow. To attain equilibrium conditions, the channel adjusts itself, or becomes competent, to transport delivered coarse loads.

Suspended Sediment

Stream-water samples were collected periodically at five sites to determine the suspended-sediment concentration of the water-sediment mixture. The samples were taken at selected verticals in the stream cross section and were collected using standard depth-integrating samplers (U.S. Interagency Committee on Water Resources, 1963), in accordance with procedures described by Guy and Norman (1970).

Ten of the samples, collected during peak flows on June 9 and 10, were analyzed to determine the average particle-size distribution of transported sediment (table 2). Concentrations of suspended sediment collected during this time ranged from 109 to 610 mg/L.

Table 2.--Particle-size distribution of suspended sediment

			Percent finer than size indicated (mm)											
Station No.[1]	Date sampled	Time (hour)	0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.25	0.50	1	2	4
131200	6- 9-81	0930	22	30	39	50	63	73	87	96	99	100		
	6-10-81	1000	12	16	20	24	31	38	52	66	79	89	96	100
131205	6- 9-81	1000	22	30	39	50	63	71	84	94	99	100		
	6-10-81	1130	14	19	28	38	48	58	75	85	95	98	100	
131215	6- 9-81	1125	18	25	32	40	50	57	67	76	90	94	95	100
	6-10-81	1315	12	16	23	29	36	41	49	61	73	98	100	
131225	6- 9-81	1445	24	34	43	53	64	73	84	94	98	100		
	6-10-81	1445	20	28	33	41	49	59	64	77	95	99	100	
131234	6- 9-81	1715	14	20	25	31	38	43	54	68	82	97	98	100
	6-10-81	1640	16	24	31	40	48	54	64	72	91	98	100	

[1] Refer to table 1 for station names.

Suspended-sediment discharge is reported in tons per day, as computed from the product of stream-water discharge, sediment concentration, and the coefficient 0.0027.

Bedload

Sediment transported within a vertical height of 3 in. from the streambed was sampled using a bedload sampler (Helley and Smith, 1971) specifically designed for collecting coarse sediment. Field tests indicate that the sampler's trap efficiency is near 100 percent for particle sizes between 0.5 and 16 mm (Emmett, 1979).

Samples were collected to determine discharge and size distribution of particles coarser than 0.2 mm (bag-mesh size) and finer than 76 mm (orifice dimensions). Sampling time (usually 30 seconds per vertical), number of equally spaced sampling verticals (8-20), and stream width were recorded for each composite sample.

Bedload discharge is reported in tons per day, as computed from the product of transport rate of coarse sediment in grams per second per foot of stream width, width of the streambed, and 0.00635, a conversion factor to express the product in tons per day. Samples collected at selected sites were composited, dried, and weighed to determine mean bedload discharge. The particle-size distribution at selected sites for several dates is shown in figure 13.

Bed and Bank Materials

Bed and bank materials are the major source of the sediment load in the Big Lost River, and samples of these materials were collected during low- or no-flow periods. The particle-size distributions of bed material were determined for the stream cross sections listed in table 3. At stations 131215 and 131225, size was determined from photographs by using the optical method of Ritter and Helley (1969). At station 131234, bed material samples were collected by shovel. These samples were dried, sieved, and weighed to determine particle-size distribution. Sampling depths ranged from the streambed surface to 0.8 ft below the surface. At this station, the average mean particle size was 16 mm (gravel) and about 14 percent of the material was finer than 1 mm.

At station 131205, visual analysis of photographs and field inspection of the streambed indicated that the bed material was considerably coarser than at the stations described above. From particle-size counts, the estimated average diameter of bed material at this station was about 40 mm.

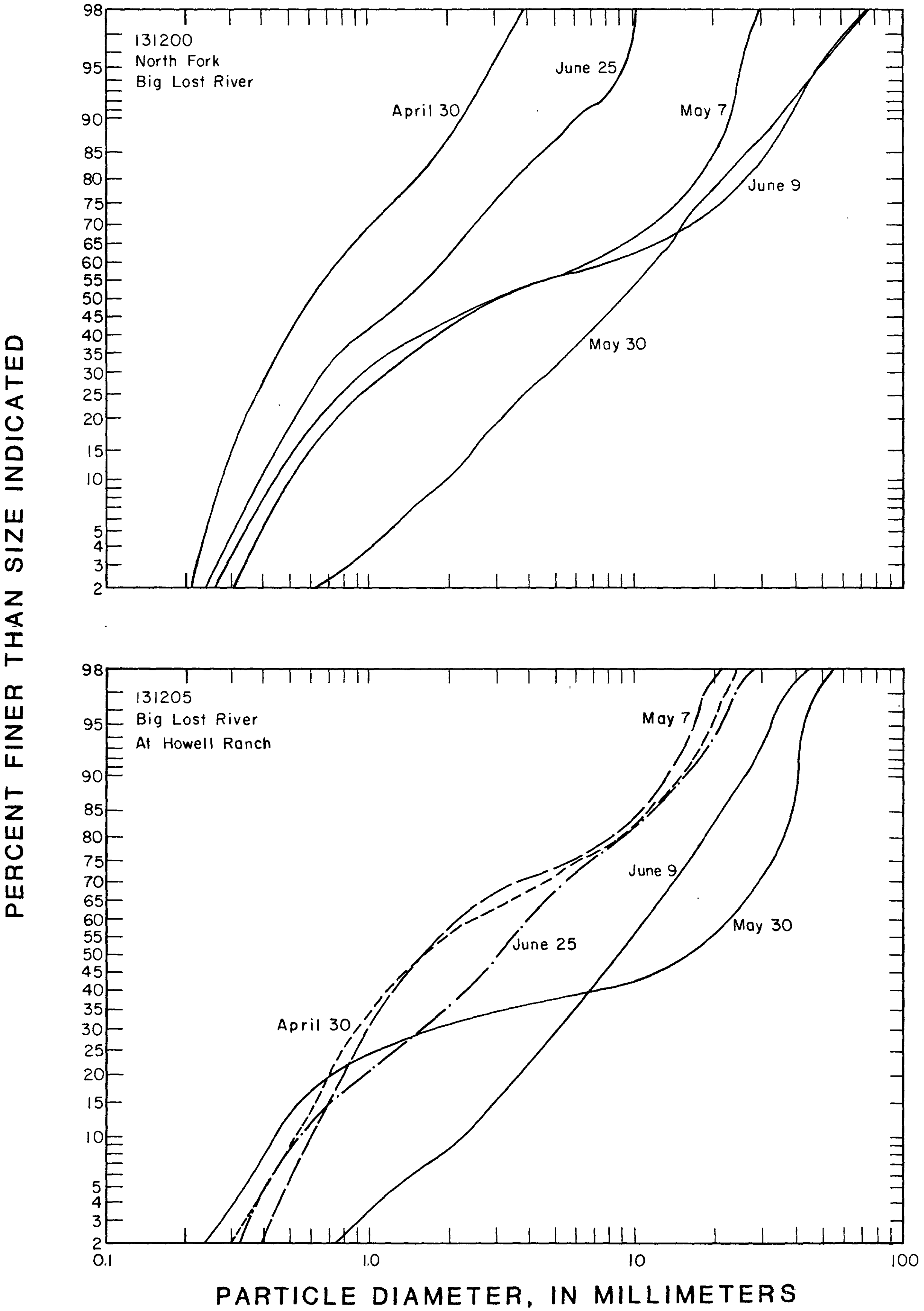


Figure 13. -- Particle-size distribution of bedload for selected dates and sites.

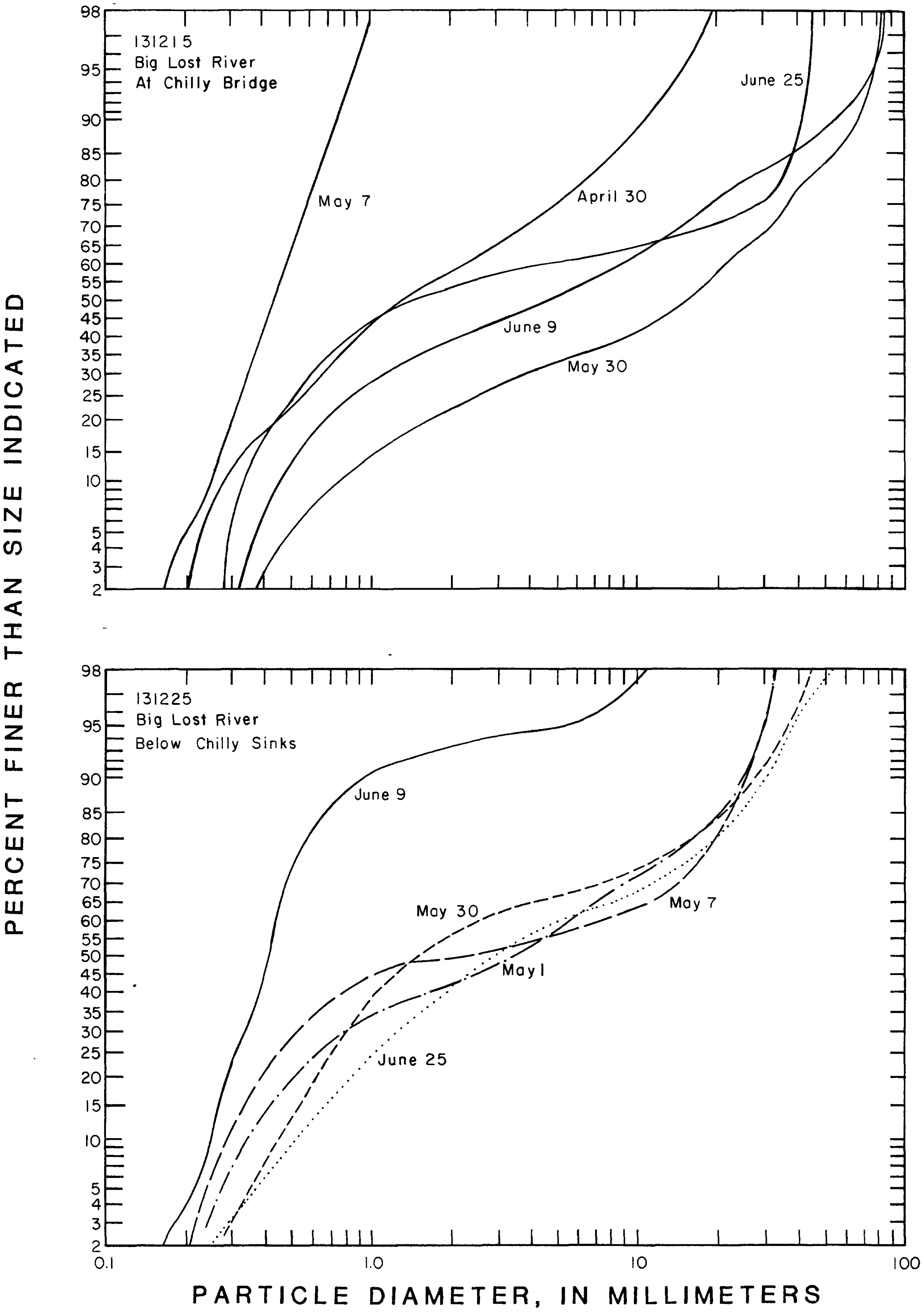


Figure 13. -- Particle-size distribution of bedload for selected dates and sites--Continued.

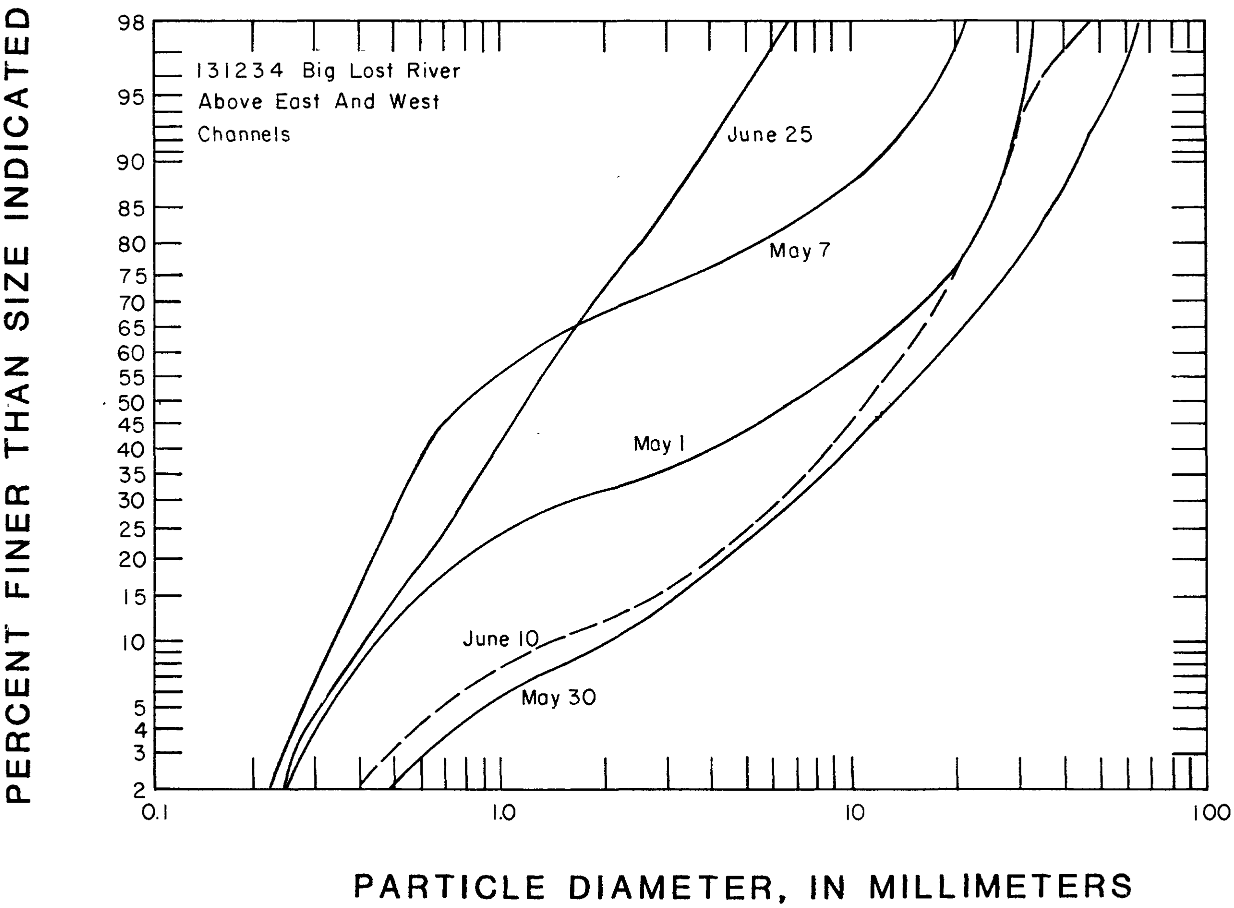


Figure 13. -- Particle-size distribution of bedload for selected dates and sites--Continued.

Table 3.--Particle-size distribution of bed material

Location of cross section near station 131215 (see fig. 14)	Percent finer than size indicated (mm)[1]																			
	0.35	0.50	0.71	1	1.4	2	2.8	4	5.7	8	11	16	23	32	45	64	90	128	181	256
1												1	2	3	7	12	21	39	65	100
2											1	2	8	21	38	52	66	100		
3													1	2	5	9	16	19	38	100
4											2	3	12	28	46	73	100			
5											1	2	5	12	22	34	48	77	100	
6													2	6	16	35	68	87	100	
7												1	3	5	9	22	51	87	100	
8											1	2	11	40	68	82	91	100		
9													1	2	5	10	16	45	68	100
10												1	5	13	26	44	63	77	100	
12												4	12	33	58	77	100			
13-14 (sieve)	1	2	4	6	8	10	12	15	17	22	29	40	52	68	82	94	100			
15												2	3	8	14	24	36	61	100	
16												3	9	23	36	59	96	100		
17												1	4	11	21	38	73	100		
18												1	2	5	10	22	44	60	100	
18 (bar)												1	2	5	9	18	37	69	100	

[1] Optical analysis (by method of Ritter and Helley, 1969).

Location of cross section near station 131225 (see fig. 14)	Percent finer than size indicated (mm)[2]																			
	0.18	0.25	0.35	0.50	0.71	1	1.4	2	2.8	4	5.7	8	11	16	23	32	45	64	90	128	181
1													1	3	8	18	47	86	100		
2													1	3	10	27	59	82	100		
3													1	12	25	39	56	66	96	100	
4													1	9	21	43	75	92	95	100	
5													1	2	7	21	42	68	95	100	
5 (sieve)	1	2	4	8	13	18	20	22	24	26	30	36	42	53	64	68	79	89	100		
6													1	3	10	22	44	69	97	100	
7														1	4	12	33	54	84	100	
8													2	19	38	61	84	100			
9														2	11	29	58	72	89		100
10												1	5	9	18	44	79	92	100		

[2] Optical analysis (by method of Ritter and Helley, 1969).

Location of cross section near station 131234 (see fig. 14)	Percent finer than size indicated (mm)[3]																			
	0.06	0.12	0.18	0.25	0.35	0.50	0.70	1	1.4	2	2.8	4	5.7	8	11	16	23	32	45	64	90
1							1	2	3	4	5	7	10	14	20	30	45	59	83	100	
2 *						1	2	4	5	7	8	10	12	15	19	24	29	39	56	78	100
2 **				1	2	6	10	16	19	23	27	31	34	40	46	54	61	71	80	100	
2 ***				1	2	6	12	17	21	26	31	36	40	47	55	64	75	86	95	100	
3	2	6	13	21	34	43	51	57	61	66	70	73	75	78	83	87	91	94	96	100	
5			1	2	3	7	10	15	19	21	24	28	32	38	46	56	67	80	88	97	100
6			1	2	3	7	9	13	16	20	23	26	30	37	47	59	79	96	100		
7					1	2	3	5	6	7	8	10	11	14	18	25	33	44	61	81	100
8			1	2	4	7	11	15	18	22	25	29	32	39	48	59	69	76	83	94	100
9			1	2	3	7	11	15	17	19	21	25	28	34	42	52	63	76	90	96	100
10		1	3	7	20	35	40	43	45	46	49	52	57	64	73	85	93	100			
12		1	2	3	4	8	12	15	17	20	22	25	28	33	43	53	65	79	92	97	100
13			1	2	4	6	8	10	13	15	18	22	25	28	38	49	65	87	97	100	
Average (11)			1	2	4	8	11	14	16	18	20	23	26	32	39	49	61	74	83	94	100

[3] Sieve analysis.
* At surface.
** 0.2-0.4 feet below surface.
*** 0.4-0.8 feet below surface.

Two bank material samples were taken at stations 131225 and 131234 in August 1981. These samples were assumed to represent the channel-bank and flood-plain materials in the lower reach. Both samples are classified as fine sand (table 4).

Water-Sediment Discharge Relations

The sediment discharge of a stream at a particular cross section commonly is represented on a logarithmic plot showing the relation between suspended-sediment discharge and stream discharge. For this study, plots between instantaneous sediment and stream discharge for silt and clay, sand, bedload, and total sediment load were made. Regression equations representing these plots are summarized in table 5. In general, the exponents of the equations decrease from one cross section (station) to the next in the downstream direction, whereas the coefficients increase.

Each of the empirical equations in table 5 was used to calculate the total tonnage of sediment-transport loads in the Big Lost River for the period October 1, 1980, to September 30, 1981, as shown in table 6. The total loads suggest several possible trends. One trend is the consistency of the silt load, which is independent of changes in water discharges at each station on the Big Lost River but not on the North and East Forks. Another trend is that bedload increases proportionately with sand load in the upper reaches of the river system. The most obvious trend is the decrease of coarse sediment load between stations 131215 and 131225.

The average total load transported in the Big Lost River during 1981, on the basis of the average of the annual total load at the last four stations in table 6, was about 22,000 tons. If minimal errors existed in determination of total loads at each site, then the difference between the actual values at each site should indicate the occurrence of scour or fill between sites. Fill appears to be occurring between stations 131215 and 131225, and scour appears to be occurring between stations 131205 and 131215 and stations 131225 and 131234. The 22,000-ton value may not be indicative of the magnitude of sediment load delivered to Mackay Reservoir, for much of this load appears to be deposited in the channel prior to reaching the backwaters of the reservoir. Also, the load differences associated with scour and fill are statistically equivalent to the errors associated with regression equations used to derive annual loads. Additional support for this interpretation of scour and fill is provided in the next several sections.

Table 4.--Particle-size distribution of bank material

Station No.[2]	Percent finer than size indicated (mm)[1]																
	0.062	0.12	0.18	0.25	0.35	0.50	0.71	1	1.4	2	2.8	4	5.7	8	11	16	23
131225	18	36	61	76	89	92	95	97	98	98	99	99	100				
131234	3	17	32	41	50	51	55	60	66	82	86	87	88	97	98	99	100

[1] Sieve analysis.
[2] Refer to table 1 for station names.

Table 5.--Summary of regression equations relating sediment discharge to water discharge
(Sediment discharge in tons per day, water discharge in cubic feet per second)

[n, number of samples; r^2, square of correlation coefficient; Q, discharge]

Station No.[1]	Silt and clay	n	r^2	Sand	n	r^2	Suspended	n	r^2	Bedload	n	r^2	Total	n	r^2
131200	$3.15\times10^{-7}Q^{3.09}$	22	0.88	$1.21\times10^{-7}Q^{3.28}$	22	0.91	$1.62\times10^{-6}Q^{2.97}$	26	0.91	$2.35\times10^{-7}Q^{3.06}$	25	0.63	$2.04\times10^{-6}Q^{2.99}$	25	0.87
131205	$7.31\times10^{-7}Q^{2.64}$	19	.88	$1.72\times10^{-6}Q^{2.54}$	19	.94	$4.97\times10^{-6}Q^{2.48}$	22	.95	$1.31\times10^{-6}Q^{2.42}$	22	.55	$7.08\times10^{-6}Q^{2.47}$	22	.93
131215	$2.25\times10^{-6}Q^{2.55}$	23	.95	$1.74\times10^{-7}Q^{2.93}$	23	.93	$1.47\times10^{-6}Q^{2.72}$	28	.96	$2.31\times10^{-8}Q^{3.15}$	25	.80	$8.40\times10^{-7}Q^{2.85}$	25	.95
131225	$4.05\times10^{-6}Q^{2.52}$	23	.93	$4.58\times10^{-6}Q^{2.45}$	23	.94	$7.83\times10^{-6}Q^{2.51}$	27	.93	$2.18\times10^{-5}Q^{2.18}$	26	.66	$1.88\times10^{-5}Q^{2.43}$	27	.93
131234	$3.80\times10^{-3}Q^{1.54}$	23	.74	$5.68\times10^{-4}Q^{1.86}$	23	.85	$5.92\times10^{-4}Q^{1.93}$	28	.39	$1.52\times10^{-3}Q^{1.50}$	24	.78	$5.27\times10^{-3}Q^{1.62}$	24	.72

[1] Refer to table 1 for station names.

Table 6.--Summary of total water and sediment discharge, October 1, 1980, to September 30, 1981

[Each column represents result of individual relations (see table 5) calculated for each daily discharge and summed for the year. Refer to table 1 for station name. Water discharge is in cubic feet per day; sediment discharge is in tons per year]

Station No.	Water discharge	Suspended silt and clay	Sand	Silt, clay, and sand	Bedload	Total load
131200	35,422	2,090	2,580	5,170	1,300	7,360
131204	[1](85,626)	(5,790)	(6,390)	(11,600)	(1,570)	(14,800)
131205	121,048	7,880	8,970	16,800	2,870	22,200
131215	81,000	8,480	10,400	19,000	6,820	27,900
131225	75,600	7,050	4,910	12,700	3,660	17,600
131234	75,800	8,720	10,900	18,200	2,690	20,400

[1] Parentheses indicate water and sediment quantities were calculated by the difference in values between stations 131205 and 131200.

Channel Surveys

Channel cross sections were surveyed along three selected reaches of the Big Lost River in spring and summer 1981 to determine the net volume change of bed material resulting from peak flows. A total of 18, 11, and 13 cross-section sites were established along reaches near stations 131215, 131225, and 131234 (fig. 14). A summary of volume change of bed material in each reach is given in table 7. Volume of material removed or deposited in each reach was calculated as the average change of cross-sectional area times the length of the reach. A total of 82,000 ft^3 of material was deposited in the three reaches between May and July 1981. The weight of material transported or deposited equals the volume times an estimated density of 100 lb/ft^3 for the bed material. Rate of deposition or erosion in each reach is the total weight of bed material divided by the number of days between cross-section surveys. Increases in volume and rate of deposition downstream may reflect an increase in availability of coarse sediment and(or) a decrease in transport capacity of the river above the reservoir.

Changes in Streambed Elevations

Fluctuations in streambed elevations reflect scour and fill processes and the behavior of stream-channel cross sections relative to prevailing low- and high-water discharges. Streambed elevations in the Big Lost River system were determined from discharge measurements made at selected gaging stations (table 1). Average elevations, with reference to gage datum, were determined by subtracting the average depth of water from the gage height of the water surface at the time of measurement. Scour and fill occur seasonally (fig. 15), generally in response to seasonal changes in streamflow. Elevations for the North Fork Big Lost River at Wild Horse were analyzed for three different sections (fig. 16) because a rock outcrop in the channel upstream of station 131200 and an old wooden bridge that constricts the channel downstream of the station caused differences in scour and fill relations within a relatively short distance. Except for the section at the bridge, which scours with increasing discharge, rises in streambed elevation generally indicate influxes of coarse material (larger than 0.062 mm) at the sections. This material is assumed to be transported downstream from points at which streambed elevations are shown to decrease.

Streambed elevations at stations on tributary streams (fig. 15) generally reach a maximum during the snowmelt-runoff season in late May to early June. In the Big Lost

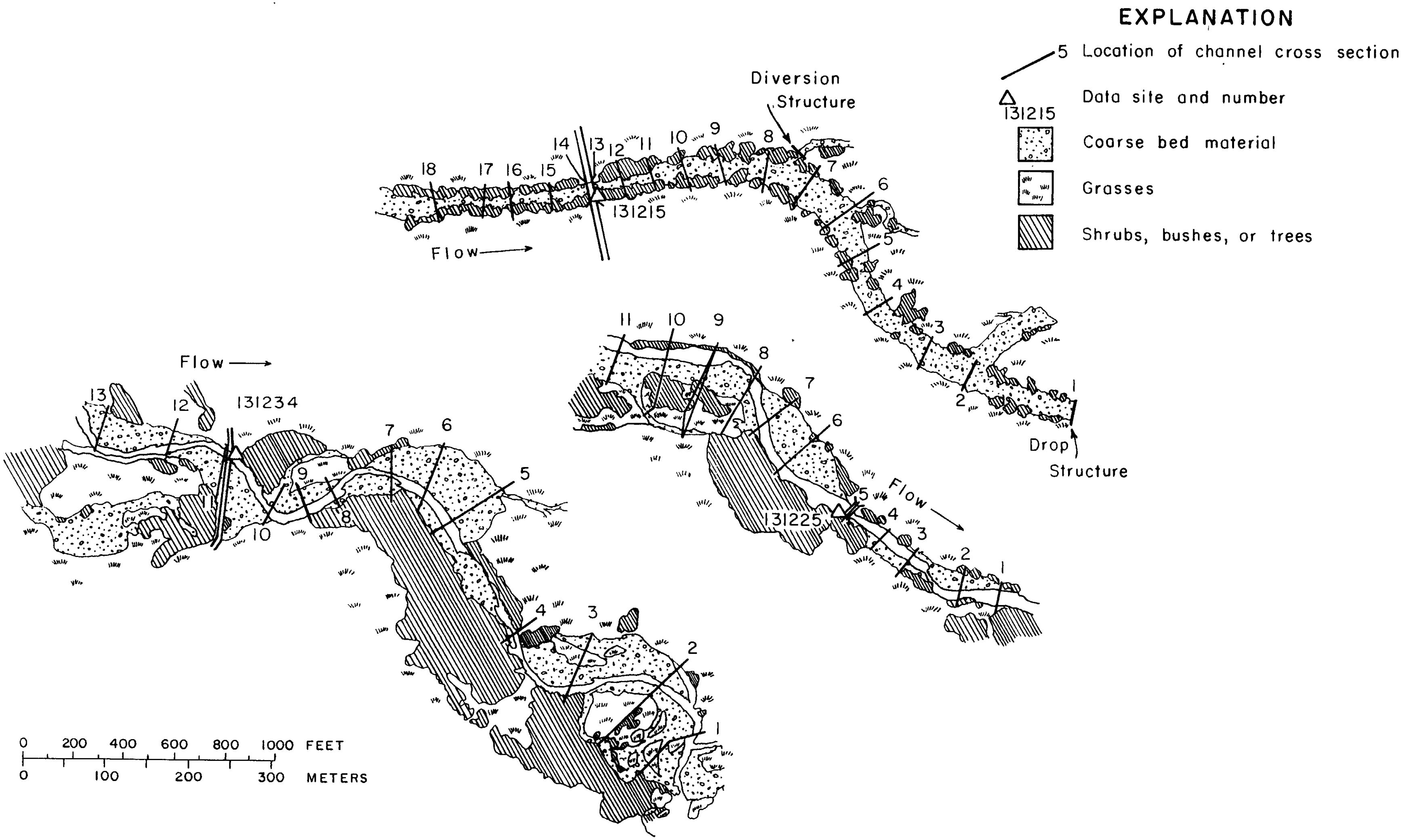


Figure 14. -- Locations of surveyed cross sections.

Table 7.--Erosion and deposition in selected reaches, May to July 1981

[+ indicates erosion; - indicates deposition]

Station No.[1]	Cross sections	Average change in volume, in cubic feet	Net change in reach, in cubic feet	Rate of deposition, in tons per day
131215	1- 3	+3,600		
	4-12	-11,000		
	13-14	+1,100		
	15-16	-7,600		
	17-18	+9,500	-4,400	-2.7
131225	1	+1,200		
	2- 4	-14,000		
	5- 6	+7,500		
	7-11	-10,500	-15,800	-7.8
131234	1	+1,400		
	2- 4	-103,000		
	5-11	+50,000		
	11-13	-10,200	-61,800	-37.7

[1] Refer to table 1 for station names.

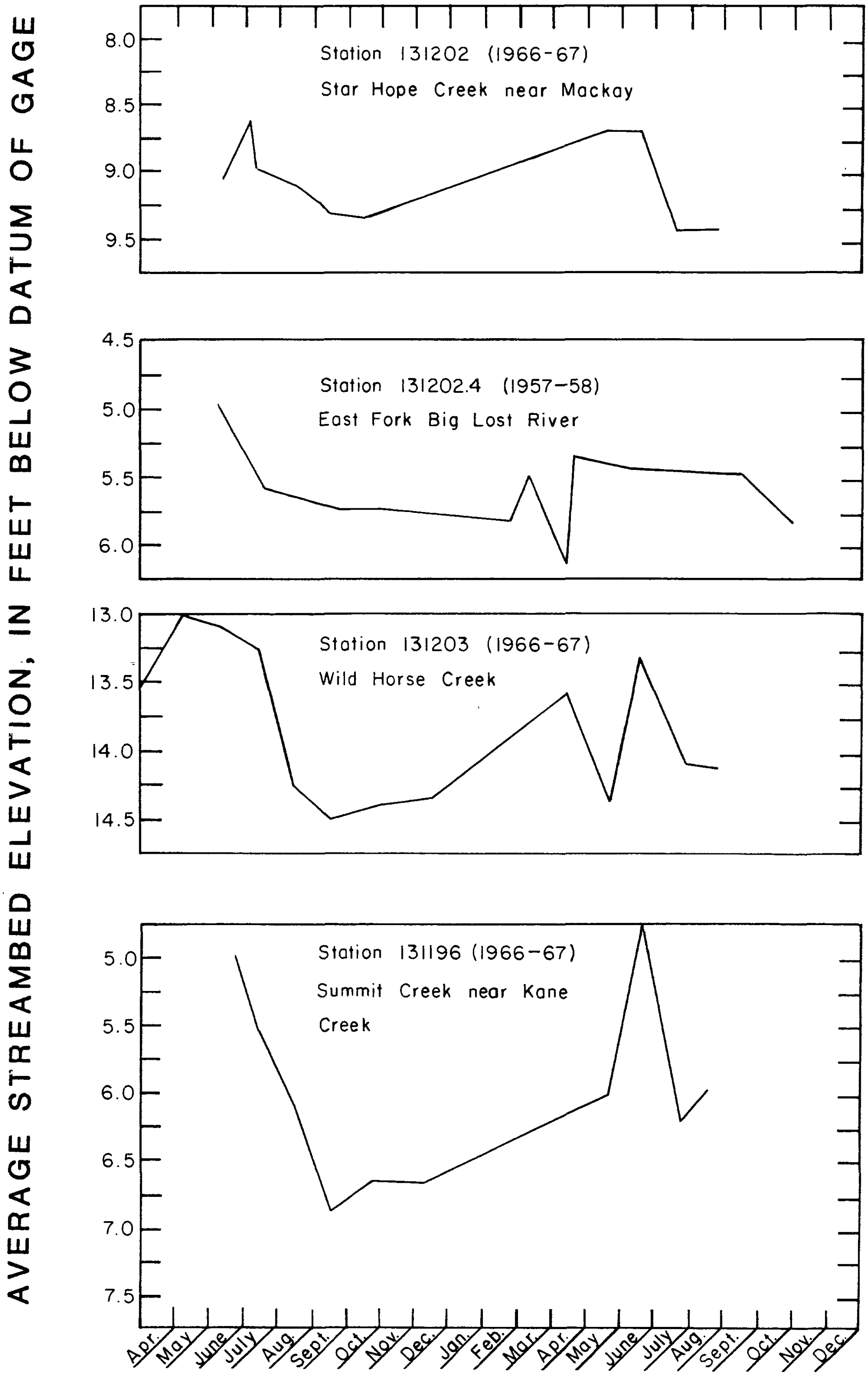


Figure 15. -- Monthly changes in average streambed elevations for selected tributaries.

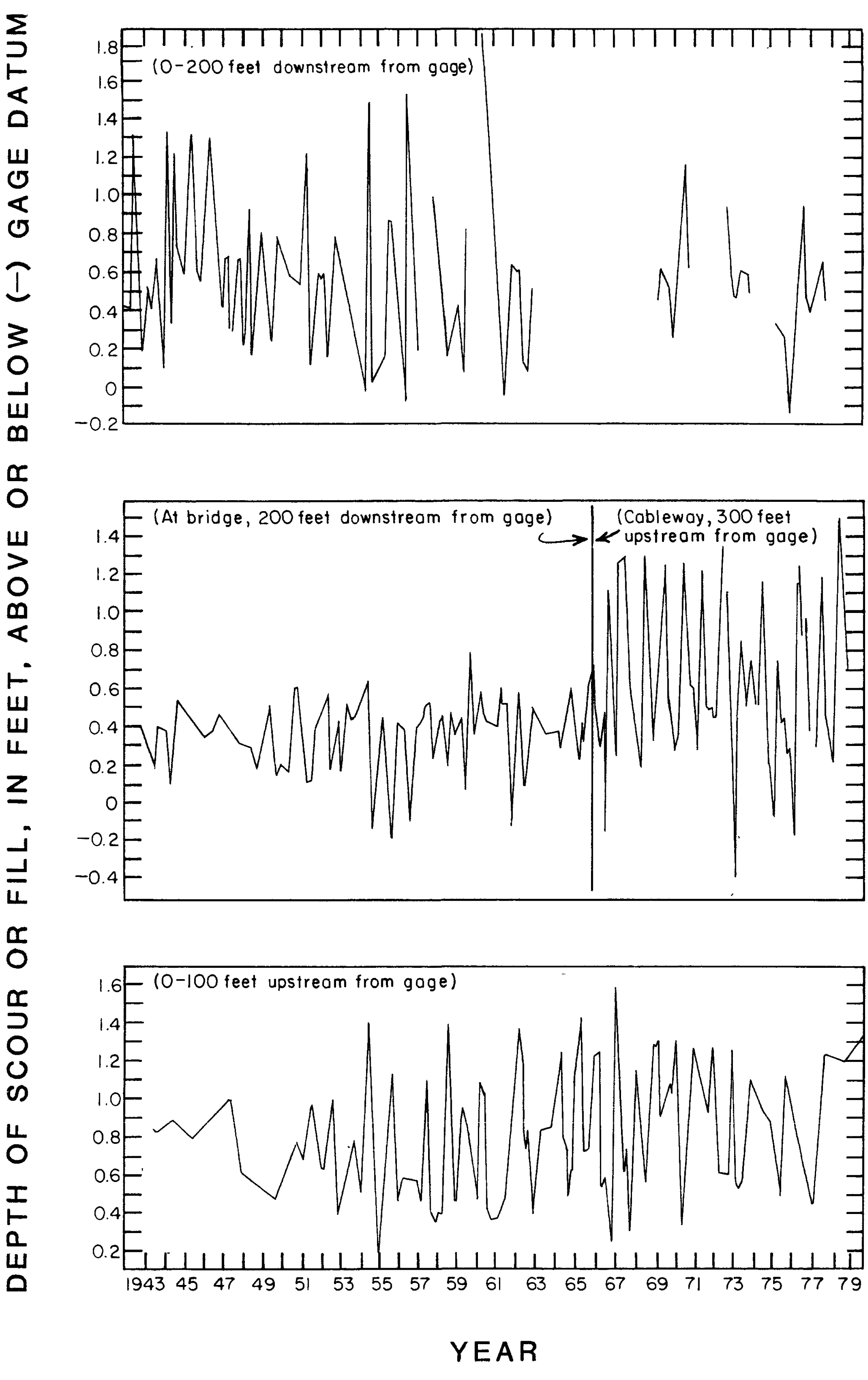


Figure 16. -- Scour and fill of the streambed at three cross sections in the stream channel for the period 1944-80 near station 131200.

River, fluctuations in streambed elevation were most dramatic during periods of peak flow (1938, 1958, 1965, and 1967) when material was usually deposited. Gradual changes (fig. 17) are less dramatic but appear to be persistent over time and generally appear to coincide with runoff periods. A trend toward degradation persisted from the late 1920's to about 1940. A trend toward aggradation occurred during the early 1940's to mid-1960's, followed by the current trend toward degradation. For the period of record, the streambed was somewhat higher in 1981 than it was 4 decades earlier. Since about 1927, the trend of the Big Lost River below the reservoir (fig. 18) has been degradation, which would be expected.

HYDRAULIC GEOMETRY

Hydraulic geometry relations of natural channels were described by Leopold and Maddock (1953). They provided empirical relations of W (width), D (depth), and V (velocity) to Q (water discharge). These hydraulic variables usually are plotted as graphs and described as simple power functions: $W=AQ^B$, $D=CQ^F$, and $V=KQ^M$; where A, C, and K are numerical coefficients and B, F, and M are numerical exponents.

Hydraulic variables at a section in a stream reach often are described, using q (unit discharge), by the continuity and the energy (Bernoulli) equations. For comparison of the hydraulic variables of channel cross sections in the Big Lost River, Q was divided by W, and the resultant q was plotted against V and D on logarithmic graph paper, where: $V=K'q^{M'}$, $D=C'q^{F'}$, $F'+M'=1.0$, $C'xK'=1.0$, $M'=\frac{\Delta \text{Log } V}{\Delta \text{Log } q}$, and $F'=\frac{\Delta \text{Log } D}{\Delta \text{Log } q}$.

W is not treated as a constant (B=0) but as an independent variable. The effects of W on hydraulic geometry are integrated into the changes of M' and F'. By reduction of the number of dependent variables, the continuity relation of V to D in natural channels is believed to be better understood.

Hydraulic geometry relations for each cross section in the Big Lost River basin were evaluated using statistical regressions by location, time, and discharge. Data for Q, V, D, and W were obtained from cross-section stream measurement notes. The data were grouped by (1) measurement location (± 10 ft); (2) year, decade, and period of record; and (3) categories of low to high discharge. For the measurements available at station 131205, Big Lost River at

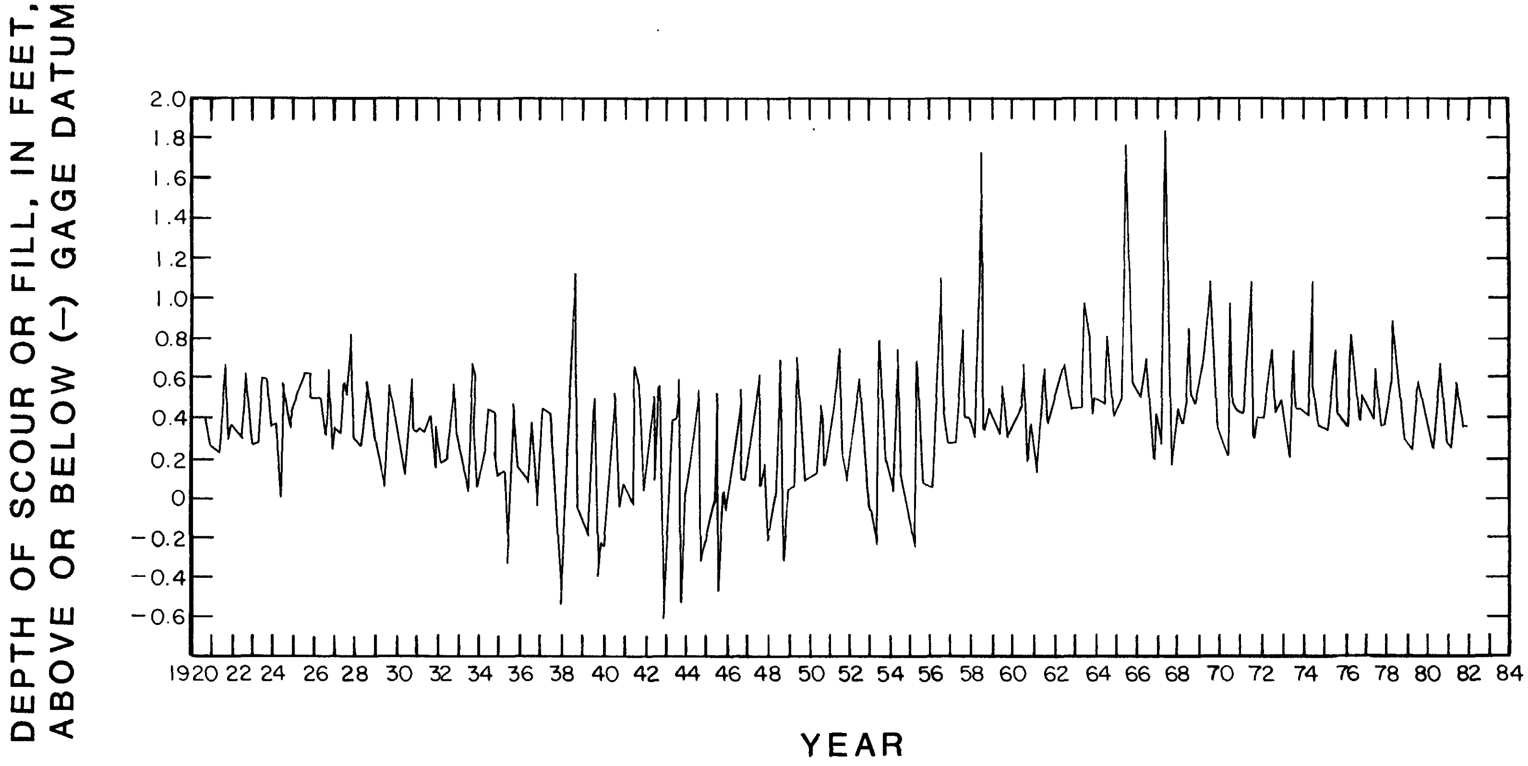


Figure 17. -- Scour and fill of the streambed for the period 1920-81 near station 131205.

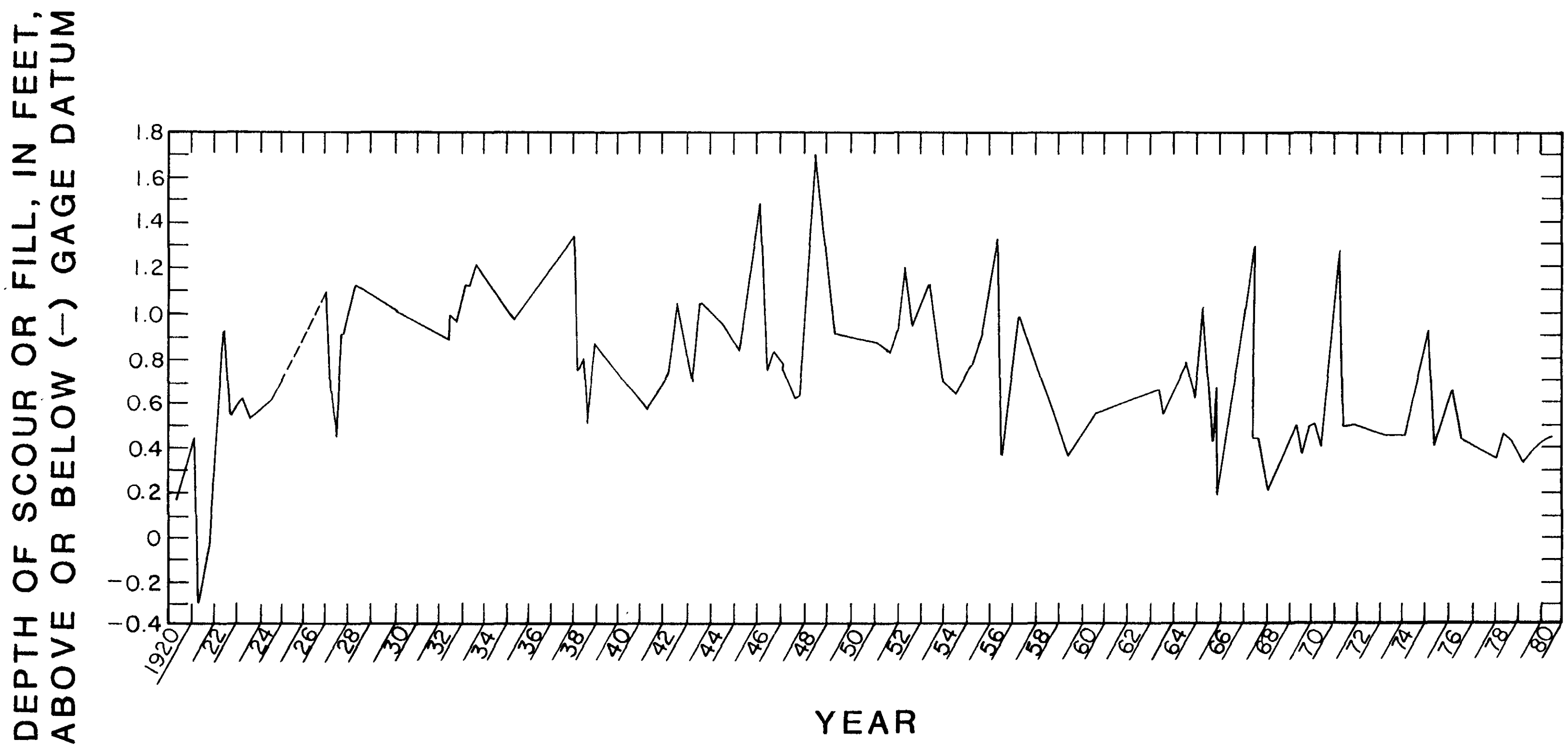


Figure 18. -- Scour and fill of the streambed for the period 1920-80 near station 131270.

(Dashed lines represent estimated record between measurements)

Howell Ranch, relations of D to q are shown in figure 19 and of V to q in figure 20. Statistical relations for these data are summarized in table 8. Relations of V and D to q for tributary sites are shown in table 9 and, for main channel sites, in table 10.

For the Big Lost River at Howell Ranch, the above regressions of V to q were compared with each other by plotting the velocity exponent against the velocity coefficient as shown in figure 21. Exponents and coefficients from the regressions of D to q give somewhat similar plots as might be expected because $F'=1.0-M'$ and $C'=1.0/K'$ (fig. 22). Finally, values of V and D (table 8) on a yearly basis are compared using $q=20$ ($(ft^3/s)/ft$) (figs. 23 and 24).

These V and D relations (tables 8-10) often appear consistent, whether grouped by years or by site, to the extent that the scatter of points can be represented by lines drawn through the plotted coefficients and exponents of the regression equations for each stream. A family of lines can be drawn (fig. 25) representing different hydraulic regimes defined by q and F (Froude number), where $F=V/\sqrt{gD}$ (g=gravitational constant). Froude numbers and lines shown are based on a q near or at bankfull stage. Each line represents multiple combinations of K' and M' for the V relation where any chosen combination of exponent and coefficient along the line at bankfull q gives a similar value of V. Application of regression equations for any other q will give different values of V.

These lines are believed to represent continuity (or equilibrium) between sections under uniform flow conditions. That is, a constant F along a line assumes continuity between sections because F also can be expressed as a direct function of the total energy head and Se (energy slope). Se can be described by the Chezy and Manning formulas (Chow, 1959, p. 93 and 99), $V=C(RSe)^{\frac{1}{2}}$ and $V=\frac{1.49}{n}R^{2/3}Se^{\frac{1}{2}}$, where C=Chezy roughness coefficient and R=hydraulic radius.

F (for q considered) would be expected to vary slightly between adjacent sections as slight changes in C or R and Se occur. F can be assumed to be nearly equal to or proportional to $\frac{1.49}{n}R^{1/6}Se^{\frac{1}{2}}$ or $F \simeq CSe^{\frac{1}{2}}$, where $C=\frac{1.49}{n}R^{1/6}$ (Chow, 1959, p. 100).

Initial changes in exponents and coefficients caused by scour and fill among sections may not be indicative of long-term adjustments of channel slope by degradation and

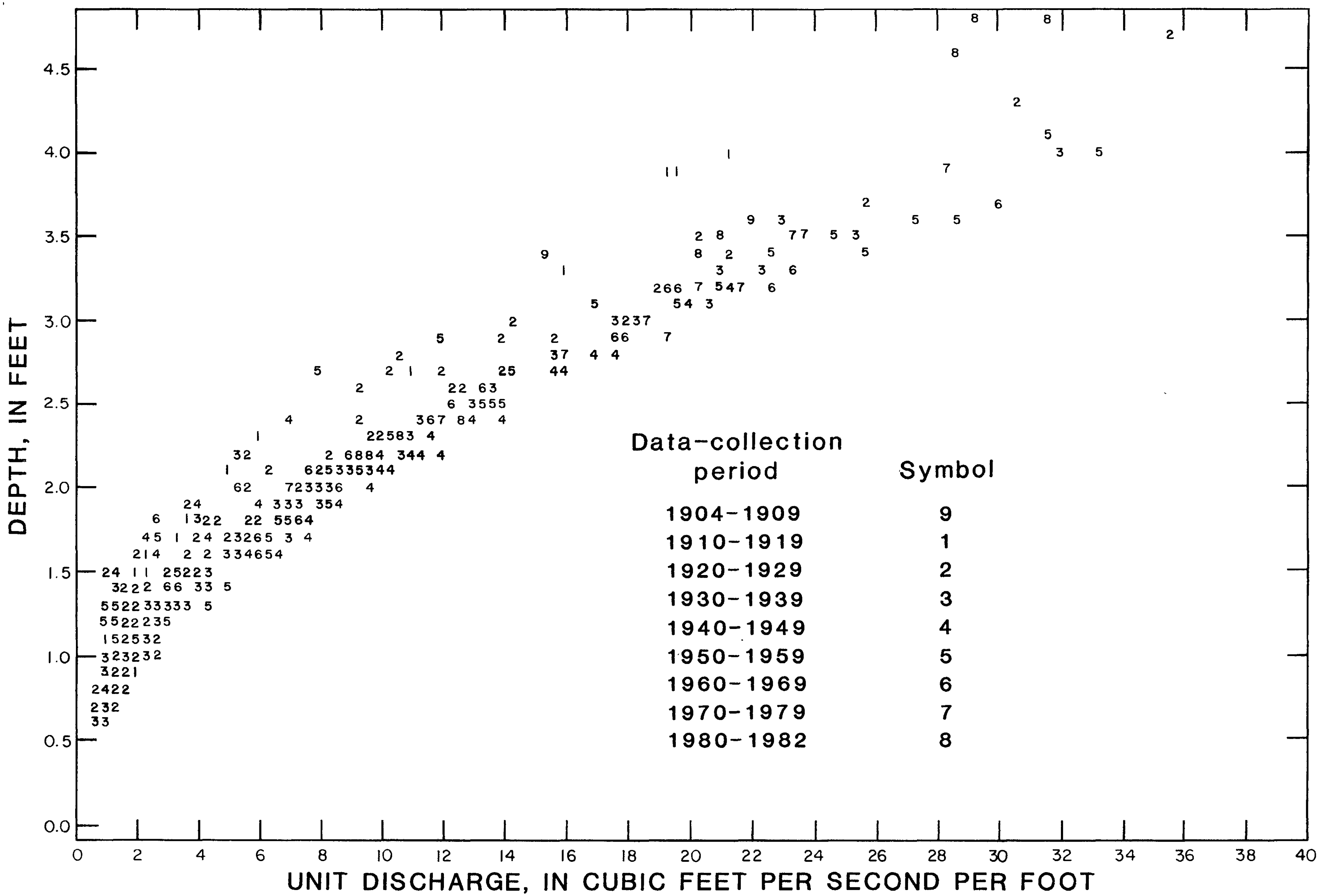


Figure 19. -- Relation of depth to unit discharge, Big Lost River at Howell Ranch, station 131205.

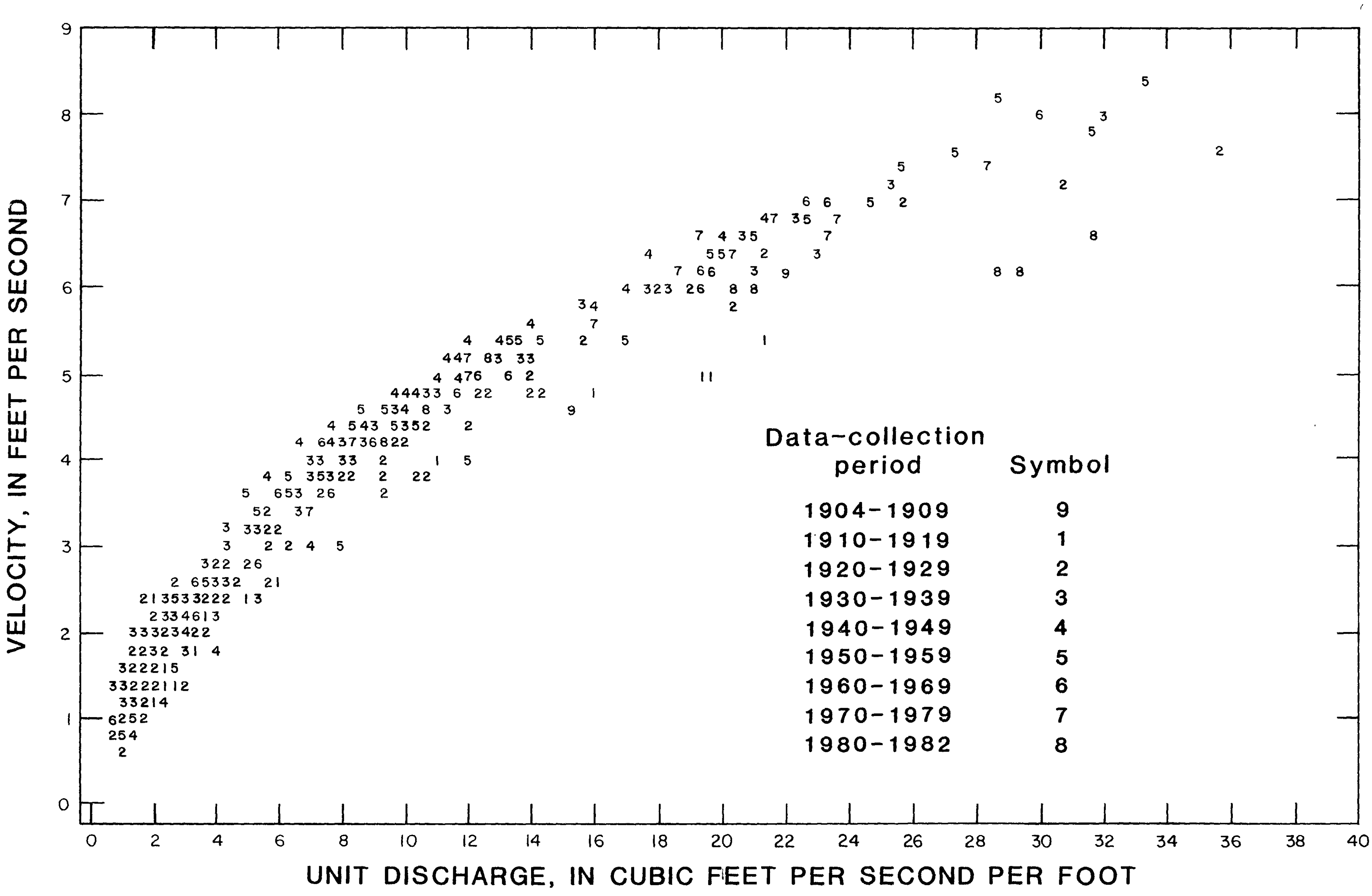


Figure 20. -- Relation of velocity to unit discharge, Big Lost River at Howell Ranch, station 131205.

Table 8.--Hydraulic geometry of the Big Lost River at Howell Ranch, station 131205, for the period 1904-82

[F' EXP, exponent of depth to unit discharge relation; R2 DEPTH, square of the correlation coefficient of depth to unit discharge relation; N, number of samples; M', exponent of velocity to unit discharge relation; R2-VEL, square of the correlation coefficient of velocity to unit discharge relation; C COEFF, coefficient of depth relation; K COEFF, coefficient of velocity relation; VELO, velocity, in feet per second; DEPTH, depth, in feet; UQ, computed unit discharge, at 20 cubic feet per second per foot; FR NO., Froude number; ., relation not used.]

YEAR	F EXP	R2 DEPTH	N	M	R2-VEL	C COEFF	K COEFF	VELO	DEPTH	UQ	FR NO.
4	0.292	0.984	4	0.759	0.988	1.354	0.682	6.63	3.25	21.5	0.65
5	0.364	0.998	6	0.627	0.996	1.215	0.842	5.51	3.61	19.9	0.51
9	0.141	0.981	3	0.848	0.999	2.310	0.447	5.67	3.52	20.0	0.53
10	0.377	0.977	4	0.624	0.990	1.180	0.844	5.47	3.66	20.0	0.50
11	0.428	0.988	7	0.574	0.993	1.051	0.947	5.30	3.78	20.0	0.48
12	0.353	0.989	4	0.647	0.997	1.175	0.850	5.90	3.39	20.0	0.57
21	0.323	0.433	9	0.465	0.573	1.079	1.058	4.26	2.84	12.1	0.45
22	0.370	0.984	9	0.630	0.995	1.148	0.872	5.75	3.48	20.0	0.54
23	0.312	0.891	10	0.687	0.976	1.177	0.851	6.66	3.00	20.0	0.68
24	0.422	0.897	11	0.589	0.888	0.936	1.026	5.99	3.31	19.8	0.58
25	0.531	0.933	6	0.467	0.915	0.694	1.442	5.83	3.41	19.9	0.56
26	0.579	0.900	8	0.420	0.828	0.693	1.443	5.07	3.93	20.0	0.45
27	0.505	.	8	0.495	0.970	0.723	1.385	6.10	3.28	20.0	0.59
28	0.441	.	7	0.559	0.998	0.839	1.191	6.36	3.15	20.0	0.63
29	0.404	0.991	7	0.596	0.996	0.888	1.123	6.69	2.98	20.0	0.68
30	0.418	0.978	10	0.581	0.989	0.854	1.172	6.69	2.99	20.0	0.68
31	0.534	0.996	9	0.466	0.995	0.694	1.441	5.83	3.43	20.0	0.55
32	0.517	0.991	11	0.482	0.990	0.697	1.436	6.09	3.28	20.0	0.59
33	0.494	0.988	12	0.576	0.989	0.703	1.424	6.48	3.08	20.0	0.65
34	0.552	0.990	9	0.453	0.980	0.645	1.533	5.95	3.38	20.1	0.57
35	0.472	0.924	14	0.528	0.938	0.766	1.307	6.35	3.15	20.0	0.63
36	0.504	0.903	10	0.498	0.902	0.729	1.370	6.08	3.30	20.1	0.59
37	0.412	0.898	7	0.588	0.946	0.834	1.199	6.98	2.86	20.0	0.73
38	0.433	0.958	10	0.567	0.975	0.852	1.172	6.42	3.12	20.0	0.64
39	0.354	0.747	8	0.647	0.908	0.669	1.040	7.21	1.94	14.0	0.91
40	0.435	0.951	9	0.565	0.970	0.814	1.229	6.67	2.99	20.0	0.68
41	0.381	0.969	8	0.619	0.988	0.873	1.145	7.32	2.73	20.0	0.78
42	0.238	0.786	9	0.763	0.974	1.232	0.810	7.97	2.51	20.0	0.89
43	0.387	0.919	7	0.613	0.966	0.929	1.077	6.75	2.96	20.0	0.69
44	0.295	0.894	4	0.707	0.980	1.099	0.908	7.54	2.66	20.0	0.82
45	0.450	0.855	6	0.549	0.897	0.816	1.228	6.37	3.14	20.0	0.63
46	0.451	0.996	6	0.549	0.997	0.738	1.352	7.01	2.85	20.0	0.73
47	0.423	0.858	6	0.577	0.918	0.817	1.225	6.89	2.90	20.0	0.71
48	0.385	0.962	6	0.616	0.985	0.914	1.093	6.91	2.90	20.0	0.72
49	0.445	0.998	8	0.555	0.999	0.751	1.330	7.02	2.85	20.0	0.73
50	0.429	0.968	6	0.570	0.982	0.776	1.289	7.11	2.81	20.0	0.75
51	0.428	0.969	7	0.571	0.983	0.795	1.259	6.97	2.87	20.0	0.73
52	0.480	0.996	6	0.519	0.996	0.724	1.382	6.55	3.05	20.0	0.66
53	0.461	0.958	8	0.551	0.972	0.750	1.265	6.79	2.98	20.3	0.69
54	0.428	0.982	8	0.572	0.990	0.821	1.218	6.75	2.96	20.0	0.69
55	0.433	0.960	7	0.566	0.977	0.830	1.206	6.58	3.04	20.0	0.67
56	0.449	0.996	9	0.551	0.997	0.977	1.259	5.56	3.75	24.6	0.60
57	0.482	0.998	7	0.518	0.998	0.747	1.338	6.32	3.16	20.0	0.63
58	0.428	0.988	7	0.572	0.993	0.850	1.175	6.52	3.07	20.0	0.66
59	0.430	0.974	6	0.572	0.985	0.877	1.137	6.30	3.18	20.0	0.62
60	0.466	0.973	8	0.535	0.980	0.811	1.231	6.11	3.28	20.0	0.60
61	0.447	0.960	6	0.551	0.973	0.822	1.219	6.36	3.14	20.0	0.63
62	0.454	0.994	7	0.546	0.996	0.802	1.248	6.40	3.13	20.0	0.64
63	0.464	0.994	7	0.536	0.995	0.792	1.262	6.28	3.18	20.0	0.62
64	0.476	0.997	8	0.520	0.995	0.750	1.346	6.40	3.12	20.0	0.64
65	0.531	0.994	8	0.471	0.993	0.649	1.536	6.29	3.19	20.1	0.62
66	0.503	0.963	7	0.497	0.963	0.682	1.467	6.50	3.08	20.0	0.65
67	0.397	0.972	10	0.603	0.988	0.940	1.062	6.47	3.09	20.0	0.65
68	0.465	0.997	8	0.533	0.998	0.772	1.296	6.39	3.13	20.0	0.64
69	0.448	0.993	3	0.611	0.945	0.768	1.123	7.00	2.94	20.6	0.72
70	0.459	0.987	7	0.540	0.991	0.755	1.325	6.68	2.99	20.0	0.68
71	0.470	0.991	7	0.530	0.993	0.772	1.295	6.34	3.15	20.0	0.63
72	0.456	0.993	8	0.544	0.995	0.751	1.331	6.79	2.95	20.0	0.70
73	0.466	0.948	6	0.536	0.962	0.750	1.331	6.62	3.03	20.1	0.67
74	0.499	0.995	6	0.501	0.995	0.743	1.347	6.04	3.31	20.0	0.59
75	0.479	0.999	4	0.546	0.996	0.752	1.248	6.40	3.16	20.2	0.63
76	0.500	0.987	6	0.499	0.987	0.703	1.424	6.35	3.15	20.0	0.63
77	0.429	0.975	6	0.571	0.987	0.751	1.329	7.36	2.72	20.0	0.79
78	0.477	0.982	6	0.521	0.986	0.721	1.393	6.64	3.01	20.0	0.67
79	0.497	0.989	7	0.504	0.989	0.702	1.423	6.43	3.11	20.0	0.64
80	0.457	0.993	4	0.542	0.995	0.775	1.293	6.57	3.05	20.0	0.66
81	0.551	0.994	8	0.449	0.991	0.716	1.397	5.36	3.73	20.0	0.49
82	0.501	0.993	7	0.499	0.993	0.730	1.369	6.10	3.28	20.0	0.59

Table 9.--Relations of velocity and depth to unit discharge for streams tributary to the Big Lost River

[n, number of samples; V, velocity; r^2, square of correlation coefficient; D, depth; q, unit discharge; ----, relation not determined by regression.]

Station No.[1]	Period of measurement record	n	V relation	r^2	D relation	r^2
131196	1966-68	5	$1.11\ q^{0.603}$	0.951	$0.91\ q^{0.394}$	0.889
131197	1967-68	7	$1.42\ q^{.614}$	.938	$.71\ q^{.387}$	.857
131198	1957-58	7	$1.52\ q^{.603}$	.953	$.66\ q^{.396}$	.901
131201	1966-68	4	$1.32\ q^{.474}$	.702	$.77\ q^{.521}$	.734
131202	1967-68	7	$1.14\ q^{.703}$	.918	$.88\ q^{.298}$	.667
13120240	1957-58	11	$1.58\ q^{.500}$	----	$.60\ q^{.520}$	----
13120250	1958	3	$1.23\ q^{.659}$	----	$.78\ q^{.372}$	----
131203	1966-68	10	$1.12\ q^{.754}$	.975	$.89\ q^{.247}$	.809
131204	1967-68	7	$1.02\ q^{.659}$	----	$.96\ q^{.367}$	----

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[1] Refer to table 1 for station names.

Table 10.--Summary of relations of velocity and depth to unit discharge

[r^2, square of correlation coefficient; n, number of samples; ---, mean value not determined.]

		Velocity			Depth			
Station No.[1]	Regression period	Coefficient	Exponent	r^2	Coefficient	Exponent	r^2	n
131200	1944-49	0.79	0.660	0.99	1.28	0.341	0.99	14
	1950-59	.93	.590	.98	1.10	.409	.95	46
	1960-69	1.02	.650	.92	.95	.406	.92	82
	1970-80	.97	.666	.95	1.05	.328	.89	93
	1944-80	1.00	.603	---	1.00	.397	---	--
	1981	1.33	.462	.98	.75	.538	.98	26
[2]131205	1904-10	.80	.664	.99	1.24	.347	.99	18
	1911-14	.89	.616	.99	1.12	.384	.99	13
	1920-29	1.15	.566	.94	.91	.434	.93	65
	1930-39	1.29	.549	.95	.80	.542	.92	84
	1940-49	1.12	.637	.96	.93	.363	.89	60
	1950-59	1.23	.588	.98	.82	.412	.97	56
	1960-69	1.16	.540	.96	.78	.468	.96	61
	1970-80	1.33	.538	.96	.74	.478	.96	54
([3])	1904-09	.698	.696	.96	1.458	.298	.81	4
	1910-19	1.514	.410	.96	.665	.588	.98	5
	1920-29	1.448	.472	.94	.691	.528	.95	12
	1930-39	1.486	.483	.97	.673	.517	.97	13
	1940-49	----	----	---	---	----	---	10
	1950-59	1.433	.502	.96	.699	.498	.96	15
	1960-69	1.233	.551	.98	.810	.450	.96	14
	1970-79	1.741	.434	.96	.571	.568	.98	10
	1980-82	3.03	.219	.87	.330	.781	.99	6
([4])	1904-80	1.22	.549	.94	.82	.451	.94	491
	1981	1.56	.416	.99	.45	.673	.99	24
131215	1921	1.07	.545	---	.93	.454	---	8
	1981	1.89	.366	.94	.45	.673	.92	29
131225	1981	1.52	.433	.95	.65	.568	.97	27
131235	1919-59	1.24	.492	---	.81	.507	---	286
131240	1919-59	1.33	.551	---	.74	.448	---	401
131234	1981	2.29	.323	---	.48	.645	.99	28

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[1] Refer to table 1 for station names.
[2] Less than 1,000 cubic feet per second.
[3] Greater than 1,000 cubic feet per second.
[4] All discharges greater than 10 cubic feet per second.

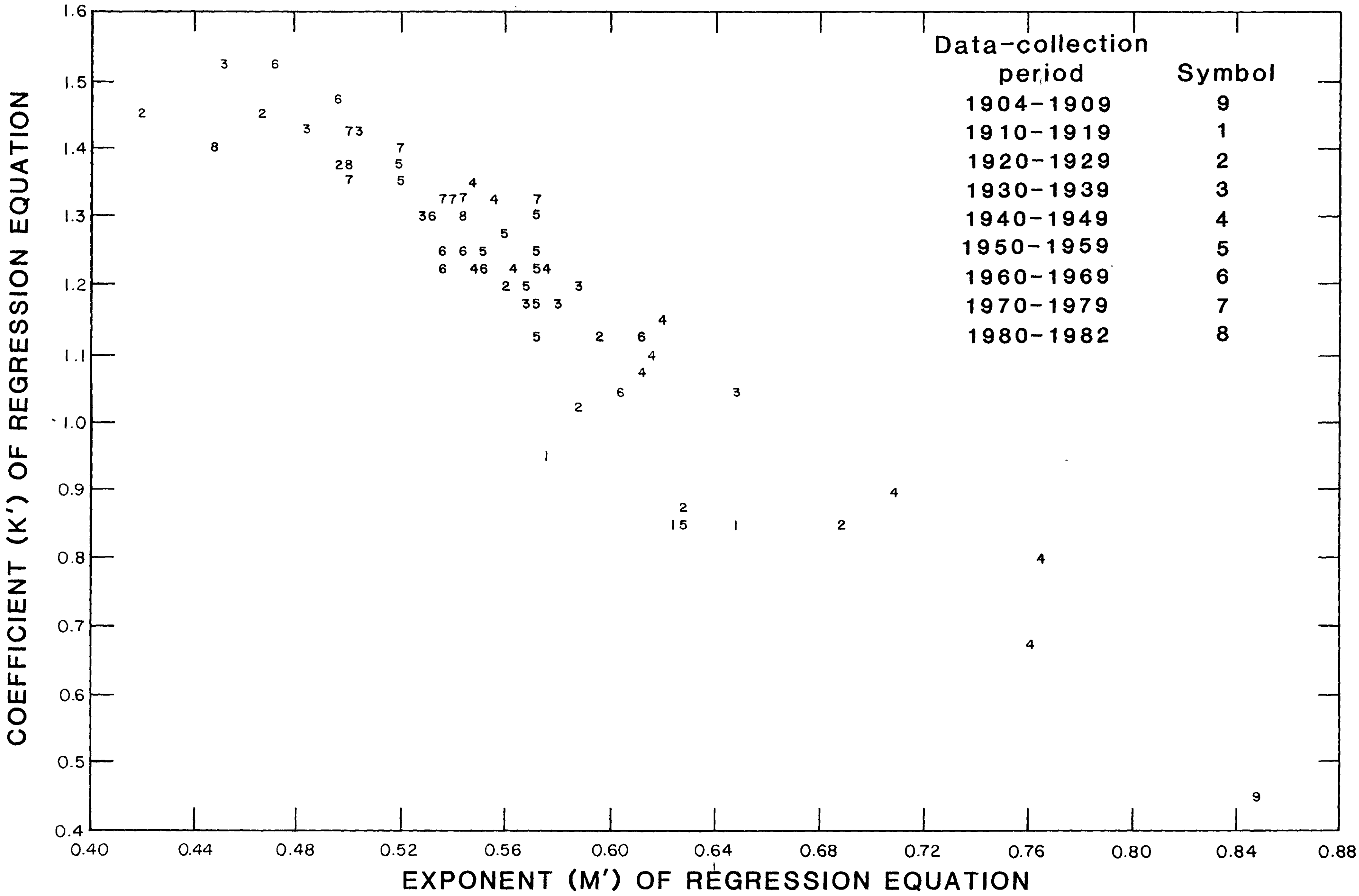

Figure 21. -- Hydraulic geometry of velocity relations of the Big Lost River at Howell Ranch, station 131205, for the period 1904-82.

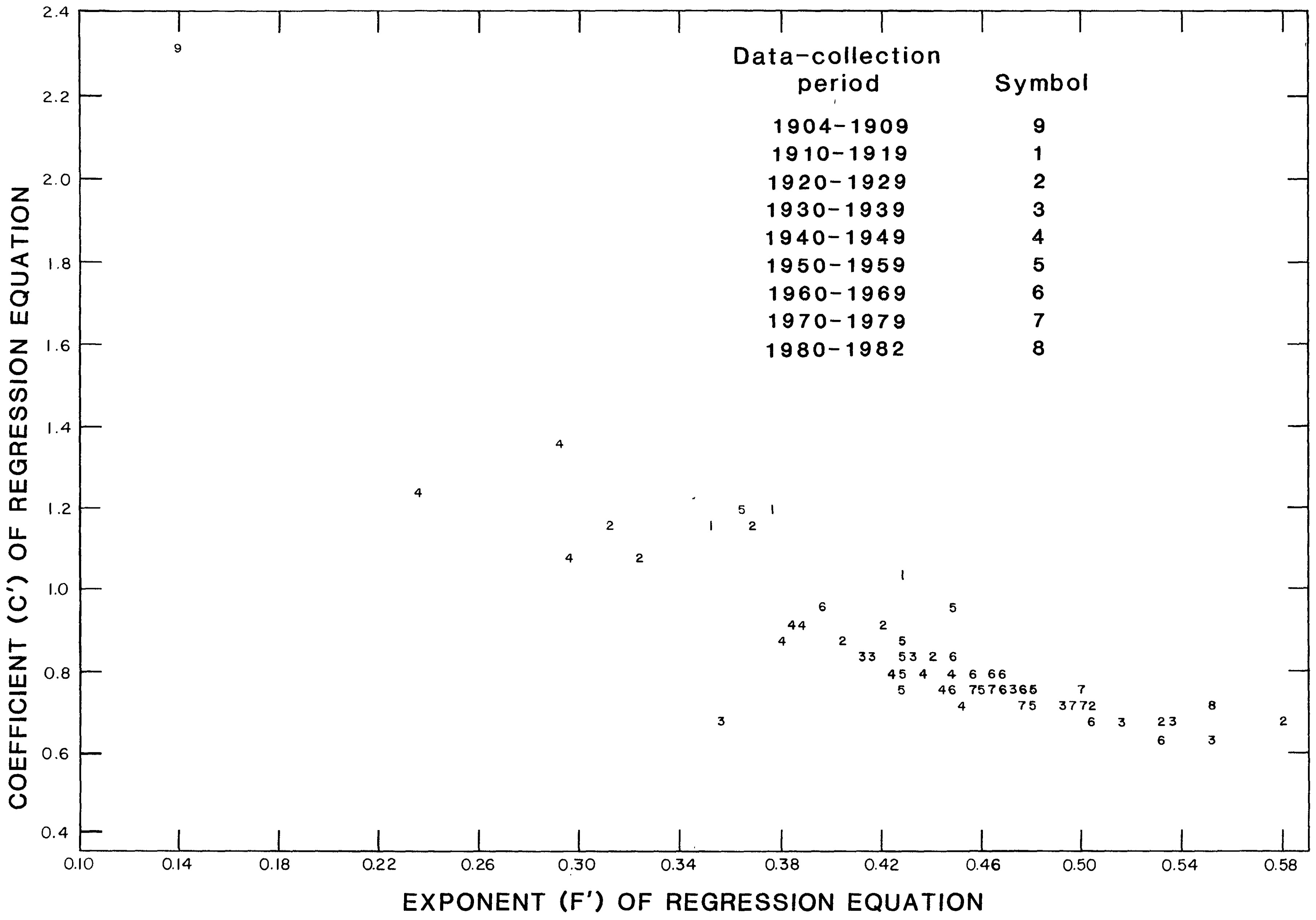

Figure 22. -- Hydraulic geometry of depth relations of the Big Lost River at Howell Ranch, station 131205, for the period 1904-82.

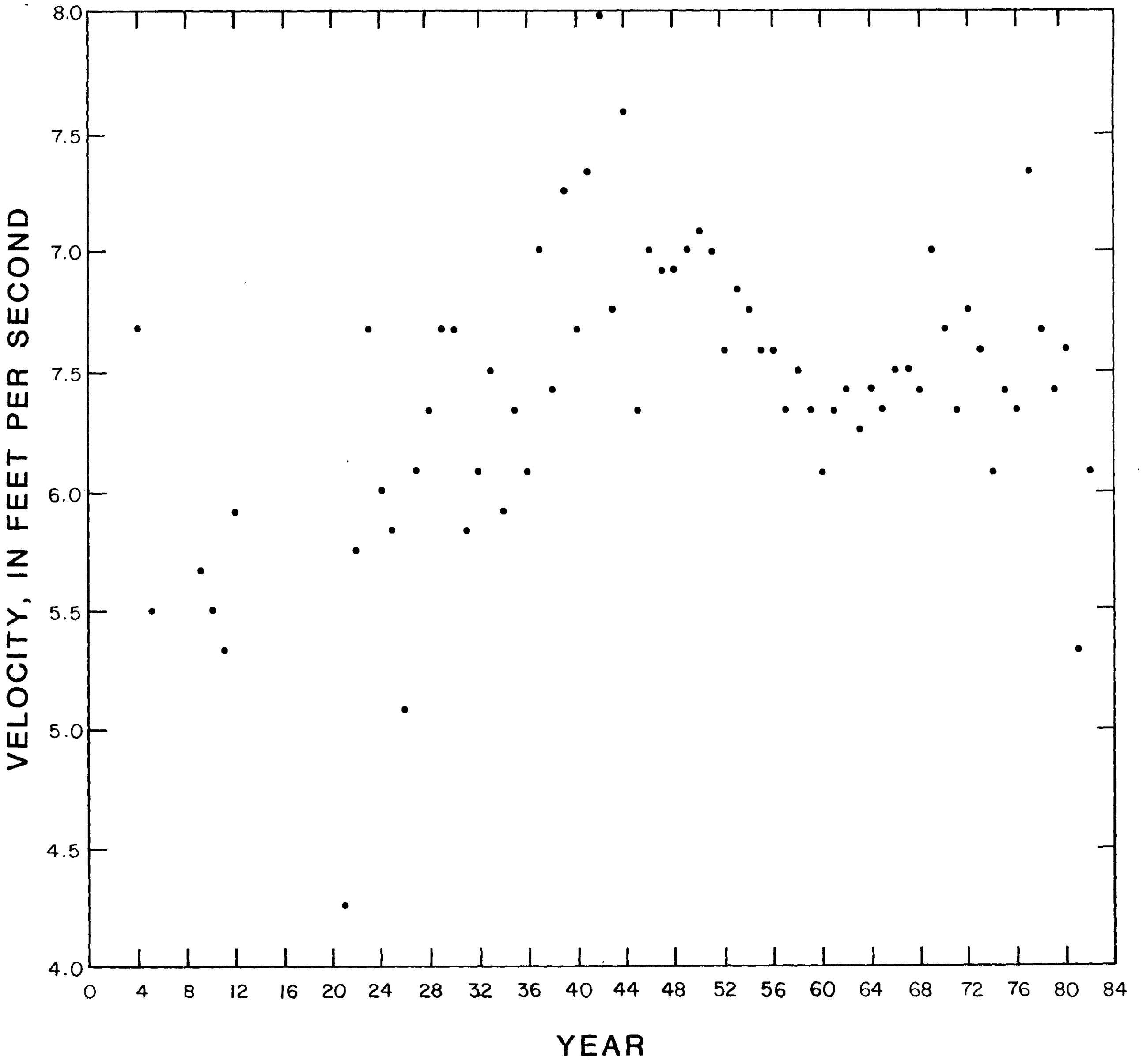

Figure 23. -- Annual values for velocity, Big Lost River at Howell Ranch, station 131205, for the period 1904-82. (Based on yearly hydraulic geometry relations and $q = 20ft^3/ft$)

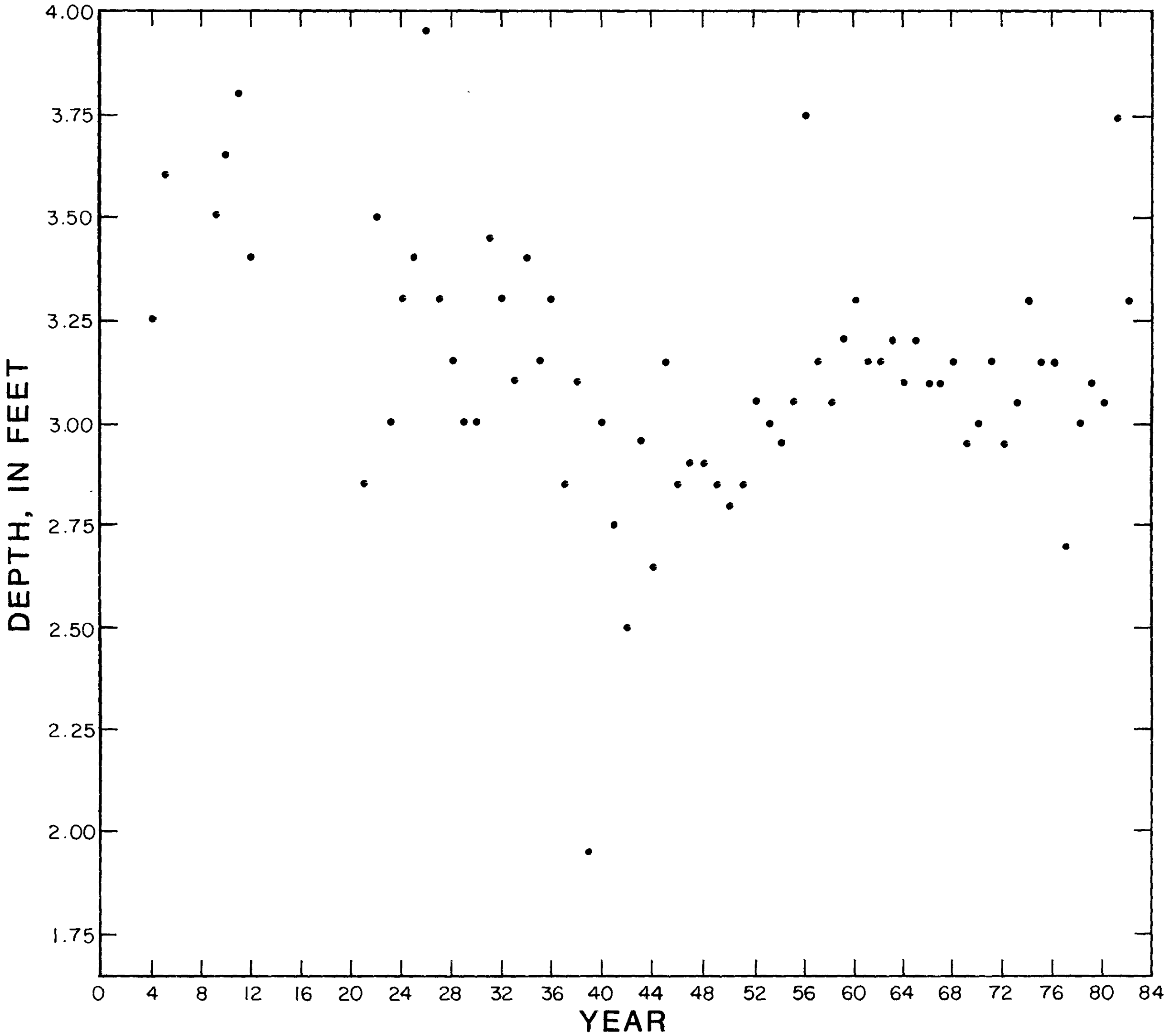

Figure 24. -- Annual values for depth, Big Lost River at Howell Ranch, station 131205, for the period 1904-82. (Based on yearly hydraulic geometry relations and $q=20 ft^3/ft$)

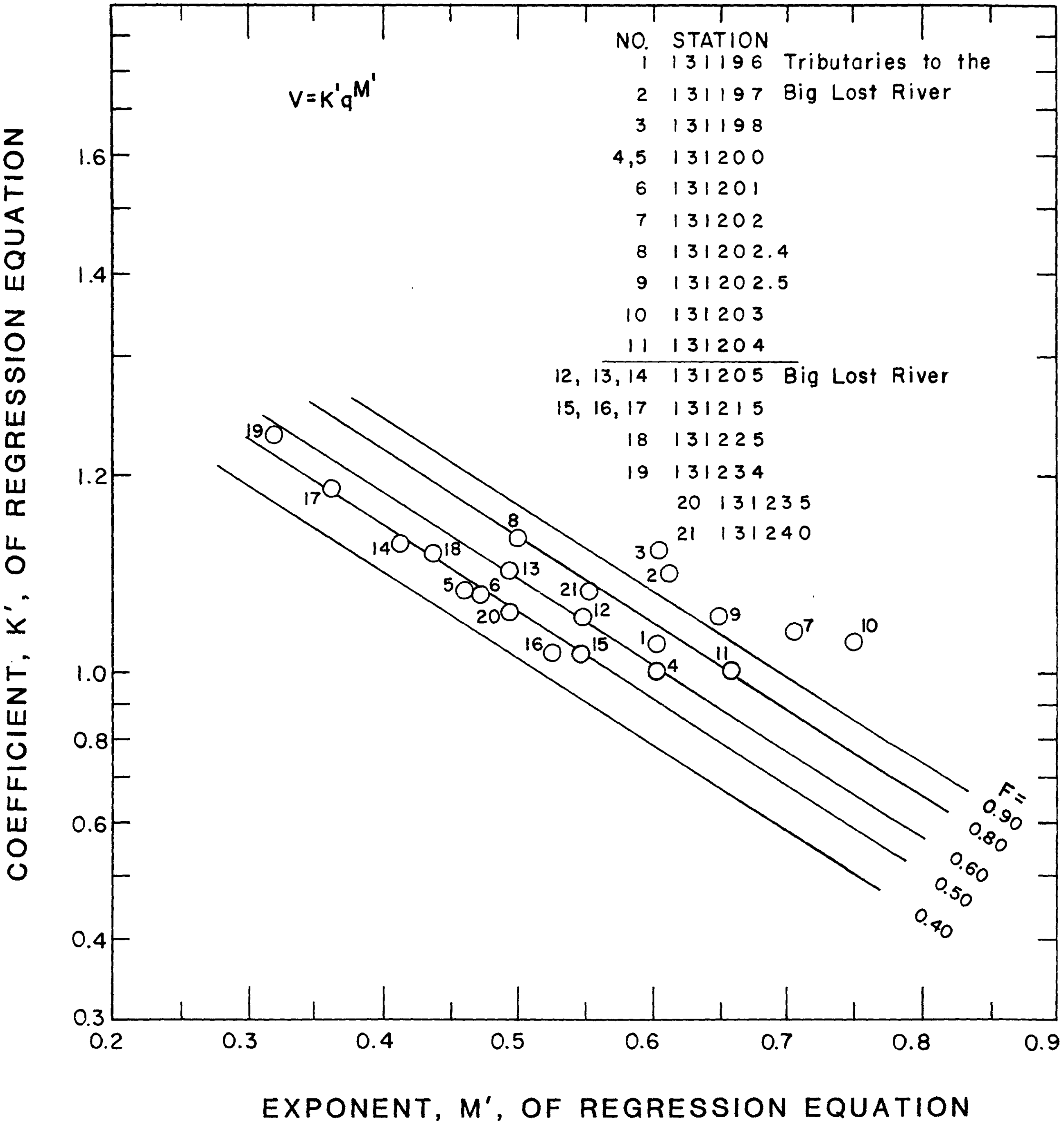

Figure 25. -- Relations of velocity coefficients and exponents of hydraulic geometry regression equations.

aggradation. A shift or change in plotting position with time along a line of constant F is assumed to indicate a change in channel shape caused by seasonal variation in scour and fill and does not indicate a long-term change in the independent variables, such as discharge and supply of sediment from the drainage basin. Such shifting along lines also can occur with changes in velocity distribution, sediment distribution, and temporary changes in channel controls. However, a change in plotting position to another line of constant F may signal or suggest a long-term shift in the independent variables and may be caused by a persistent change either in streamflow or sediment supply. A change in plotting position above an established line of constant F may indicate a period of initial filling, followed by an increase in coarse load transport (possibly in response to a decrease in discharge caused by drought). D relations plotting below the established relation would reflect decreased D and increased V. A change in plotting position of the V relation below the established F line suggests decreased V and increased D that could result in initial scour and a temporary increase in coarse loads, followed ultimately by a decrease in coarse load transport.

An apparent year-to-year shift along a line of a constant F may be due to an inadequately described linear regression equation where two or more relations of V and D to q exist.

Hydraulic geometry analysis was applied to three surveyed reaches (after step-backwater analysis) on the Big Lost River to determine channel change and availability of sediment for transport. Figures 26 and 27 show the hydraulic geometry relations for the reach near Chilly Bridge. Fill along this reach was only about 4,400 ft^3 in 1981, yet channel change trends are discernible. From the regression equations, values of V and D were calculated for low ($q=5$ [(ft^3/s)/ft]) and high ($q=20$ [(ft^3/s)/ft]) flows. The values computed for low and high flows were compared in table 11. Table 11 shows the increase or decrease in V and D for these two values of q. The figures in the right-hand column of table 12 represent the surveyed change, in square feet, between May and July. Comparison of cross-section data derived from the exponents and coefficients of table 11 generally shows channel section areas either scour (+) if D increases and V decreases, or fill (-) if D decreases and V increases. These types of channel adjustments can be expected as equilibrium conditions are sought along the reach.

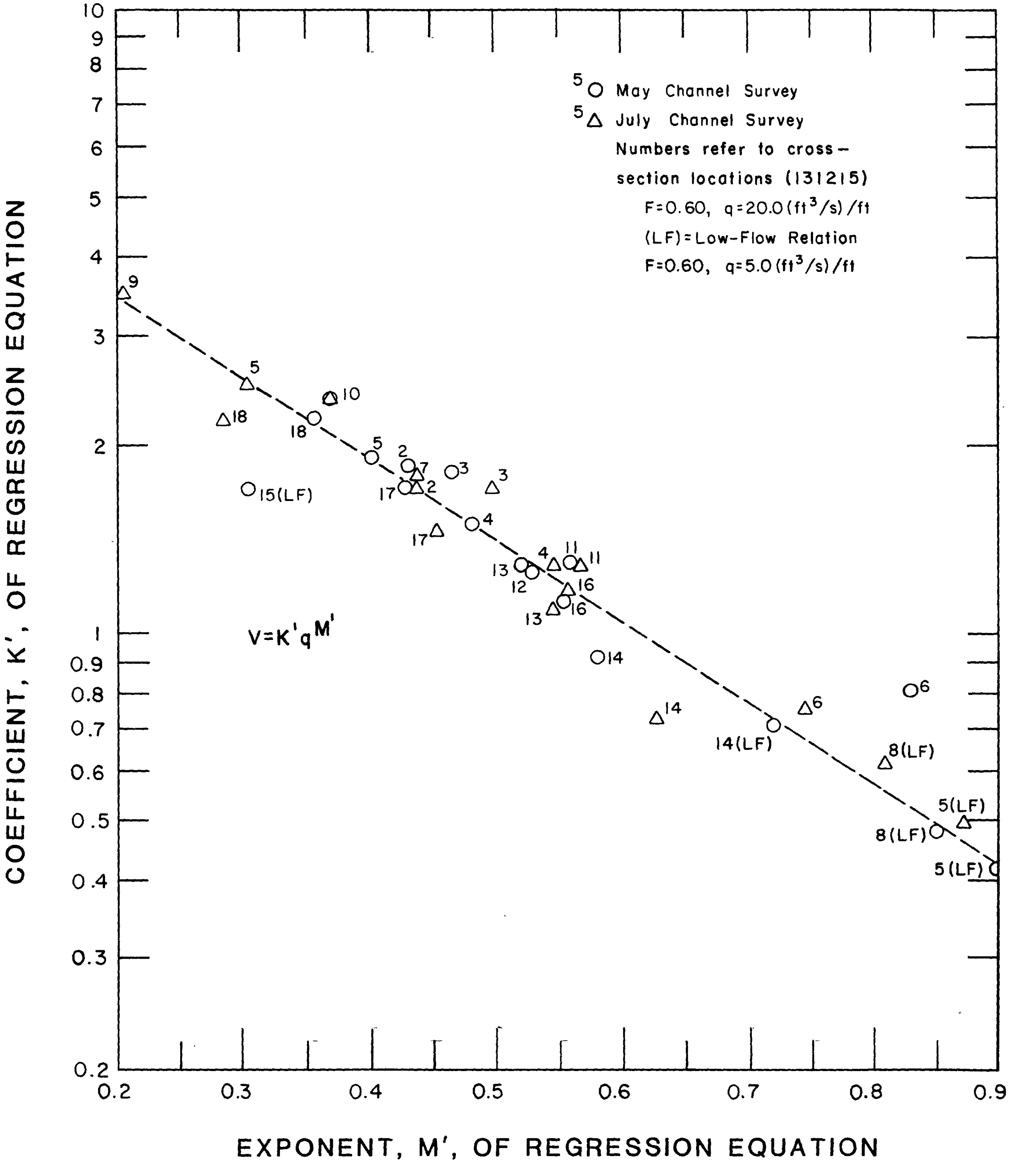

Figure 26. -- Relations of velocity coefficients and exponents of hydraulic geometry regression equations for the surveyed reach near station 131215.

(Velocity determined by step-backwater analysis)

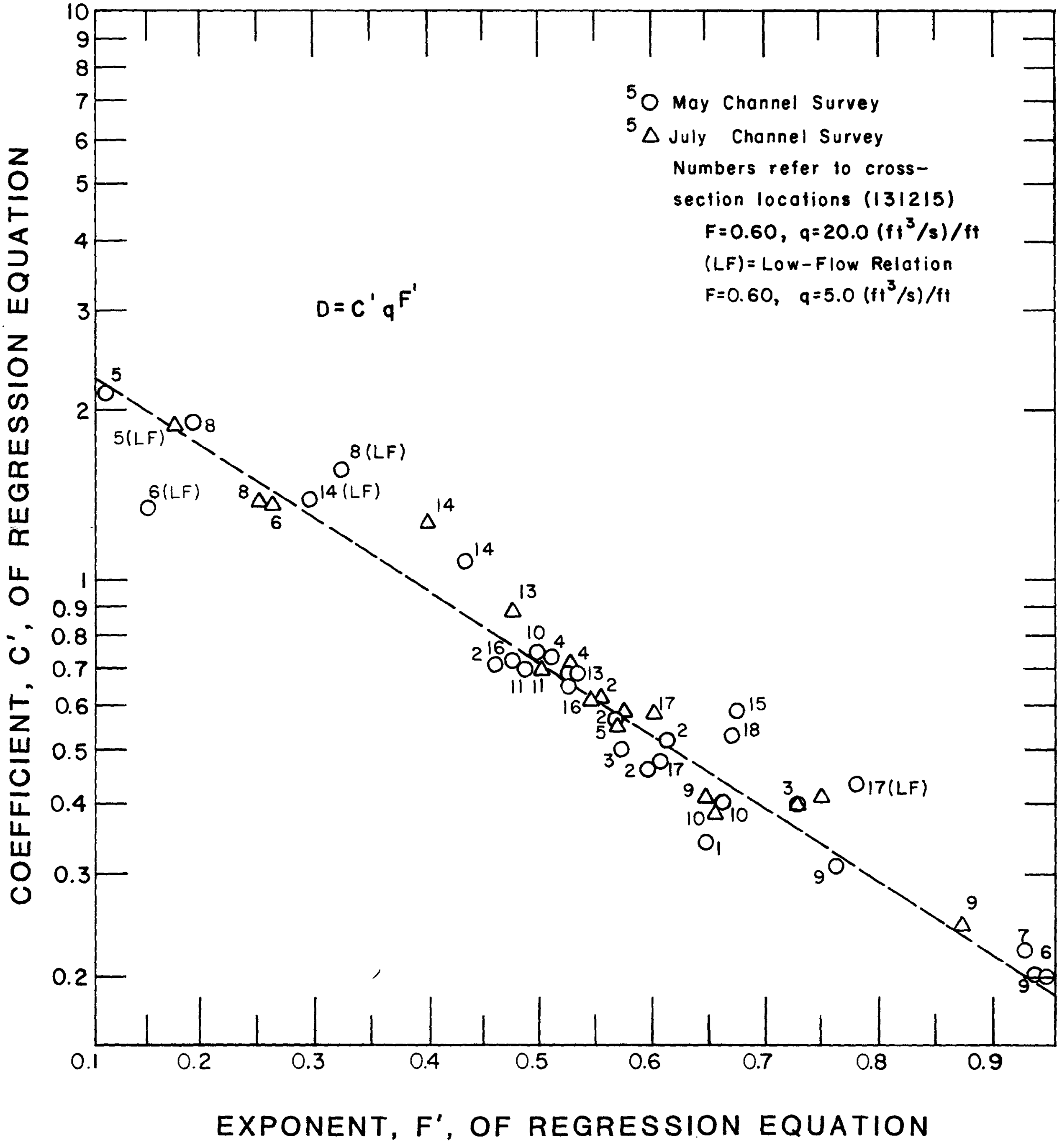

Figure 27. -- Relations of depth coefficients and exponents of hydraulic geometry regression equations for the surveyed reach near station 131215.

(Depth determined by step-backwater analysis)

Table 11.--Hydraulic geometry of the surveyed reach near station 131215, May to July 1981

[V, velocity, in feet per second; D, depth, in feet; q, unit discharge, in cubic feet per second per foot; ?, unknown relation.]

Cross-section No.[1]	May		July		Numerical relation			
					May		July	
	V relation	D relation	V relation	D relation	V	D	V	D
	High-Flow Relations ($q = 20$)							
1	$2.97\ q^{0.358}$	$0.34\ q^{0.642}$	$2.97\ q^{0.358}$	$0.34\ q^{0.642}$	8.68	2.33	8.68	2.33
2	$1.72\ q^{.428}$	$.52\ q^{.618}$	$1.70\ q^{.431}$	$.59\ q^{.576}$	6.20	3.29	6.18	3.30
3	$1.81\ q^{.468}$	$.50\ q^{.576}$	$1.72\ q^{.495}$	$.50\ q^{.576}$	7.35	2.79	7.58	2.79
4	$1.50\ q^{.482}$	$.57\ q^{.570}$	$1.29\ q^{.546}$	$.57\ q^{.570}$	6.36	3.13	6.62	3.13
5	$1.91\ q^{.398}$	$.65\ q^{.528}$	$2.49\ q^{.306}$	$.57\ q^{.570}$	6.26	3.16	6.23	3.12
6	$3.24\ q^{.13}$	$.23\ q^{1.0}$	?	?	4.78	4.60	?	?
7	$2.22\ q^{.359}$	$.56\ q^{.574}$	$1.81\ q^{.432}$	$.55\ q^{.580}$	6.50	3.13	6.60	3.13
8	$.28\ q^{1.04}$	$1.87\ q^{.197}$	$.61\ q^{.811}$	$1.39\ q^{.256}$	6.09	3.37	6.95	2.99
9	$4.95\ q^{.056}$	$.20\ q^{.944}$	$3.43\ q^{.197}$	$.24\ q^{.875}$	5.85	3.42	6.19	3.34
10	$2.33\ q^{.367}$	$.40\ q^{.660}$	$2.42\ q^{.362}$	$.40\ q^{.653}$	7.00	2.90	7.16	2.81
11	$1.29\ q^{.554}$	$.71\ q^{.480}$	$1.26\ q^{.567}$	$.70\ q^{.495}$	6.78	3.03	6.89	3.06
12	$1.23\ q^{.546}$	$.71\ q^{.498}$	$1.28\ q^{.535}$	$.71\ q^{.498}$	6.32	3.17	6.38	3.17
13	$1.28\ q^{.519}$	$.69\ q^{.534}$	$1.10\ q^{.543}$	$.87\ q^{.472}$	6.08	3.40	5.58	3.58
14	$.91\ q^{.578}$	$1.08\ q^{.429}$	$.72\ q^{.626}$	$1.27\ q^{.401}$	5.16	3.92	4.72	4.22
15	$1.25\ q^{.524}$	$.69\ q^{.526}$	$1.25\ q^{.524}$	$.69\ q^{.526}$	5.99	3.33	5.99	3.33
16	$1.12\ q^{.559}$	$.76\ q^{.498}$	$1.17\ q^{.565}$	$.62\ q^{.548}$	5.99	3.36	6.36	3.18
17	$1.86\ q^{.433}$	$.47\ q^{.608}$	$1.46\ q^{.457}$	$.58\ q^{.599}$	6.80	2.91	5.74	3.50
18	$1.75\ q^{.363}$	$.53\ q^{.672}$	$2.20\ q^{.287}$	$.41\ q^{.750}$	5.19	3.95	5.20	3.92
	Low-Flow Relations ($q = 5$)							
1	$2.97\ q^{0.358}$	$.34\ q^{0.642}$	$2.97\ q^{0.358}$	$.34\ q^{0.642}$	5.28	.96	5.28	.96
2	$1.51\ q^{.523}$	$.71\ q^{.463}$	$1.53\ q^{.490}$	$.63\ q^{.561}$	3.48	1.50	3.37	1.55
3	$2.00\ q^{.278}$	$.41\ q^{.739}$	$2.41\ q^{.319}$	$.41\ q^{.739}$	3.13	1.34	4.03	1.34
4	$1.32\ q^{.504}$	$.73\ q^{.512}$	$1.37\ q^{.507}$	$.72\ q^{.534}$	2.97	1.66	3.10	1.69
5	$.42\ q^{.907}$	$2.12\ q^{.137}$	$.49\ q^{.873}$	$1.87\ q^{.177}$	1.79	2.64	2.00	2.49
6	$.80\ q^{.830}$	$1.31\ q^{.166}$	$.76\ q^{.740}$	$1.36\ q^{.268}$	3.04	1.71	2.50	2.09
7	?	$.23\ q^{.940}$	?	?	4.85	1.03	?	?
8	$.49\ q^{.847}$	$1.56\ q^{.321}$	$.61\ q^{.811}$	?	1.90	2.64	2.26	2.21
9	$2.45\ q^{.430}$	$.31\ q^{.766}$	$2.45\ q^{.340}$	$.41\ q^{.647}$	4.89	1.07	4.23	1.17
10	$2.14\ q^{.430}$	$.46\ q^{.596}$	$2.43\ q^{.367}$	?	4.28	1.21	4.39	1.14
11	$1.29\ q^{.554}$	$.72\ q^{.480}$	$1.26\ q^{.567}$	$.70\ q^{.495}$	3.15	1.53	3.14	1.54
12	$1.23\ q^{.546}$	$.71\ q^{.498}$	$1.28\ q^{.535}$	$.71\ q^{.498}$	2.97	1.59	3.04	1.59
13	$1.28\ q^{.519}$	$.69\ q^{.534}$	$1.10\ q^{.543}$	$.87\ q^{.472}$	2.96	1.62	2.63	1.86
14	$.71\ q^{.718}$	$1.38\ q^{.296}$	$.72\ q^{.626}$	?	2.26	2.22	1.98	2.53
15	$1.71\ q^{.307}$	$.58\ q^{.676}$	?	?	2.81	1.72	?	?
16	$1.12\ q^{.559}$	$.76\ q^{.498}$	$1.17\ q^{.565}$	$.62\ q^{.548}$	2.76	1.68	2.91	1.49
17	$2.35\ q^{.204}$	$.44\ q^{.788}$	?	?	3.27	1.55	?	?
18	$1.75\ q^{.363}$	$.53\ q^{.672}$	$2.20\ q^{.287}$	$.41\ q^{.750}$	3.14	1.55	3.50	1.38

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[1] Refer to figure 14 for cross-section locations.

Table 12.--Change in hydraulic geometry of the surveyed reach near station 131215, May to July 1981

[V, velocity; D, depth; ---, no data available; ?, unknown; Δ, change; low-flow values are in parentheses.]

Cross-section No.[1]	ΔV	ΔD	Area of change, in square feet; (-) indicates fill, (+) indicates scour
1	0.00 (0.00)	0.00 (0.00)	0.00
2	-.02 (-.11)	+.01 (+.05)	+11
3	+.17 (+.90	.00 (.00)	+5
4	+.26 (+.13)	.00 (+.03)	-6
5	-.03 (+.21)	-.04 (-.15)	-11
6	-.18 (-.54)	---- (+.38)	-27
7	+.10 (?)	.00 (?)	-20
8	+.86 (+.36)	-.38 (-.43)	-25
9	+.34 (-.63)	-.08 (+.10)	-8
10	+.16 (+.11)	-.09 (-.07)	-6
11	+.11 (-.01)	+.03 (+.01)	-12
12	+.06 (+.07)	.00 (.00)	-6
13	-.50 (-.33)	+.18 (+.24)	+10
14	-.44 (-.28)	+.30 (+.31)	+7
15	.00 (?)	.00 (?)	-31
16	+.37 (+.15)	-.18 (-.20)	-22
17	-1.06 (?)	+.59 (?)	+49
18	+.01 (+.36)	-.03 (-.17)	+28

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[1] Refer to figure 14 for cross-section locations.

SEDIMENTATION IN MACKAY RESERVOIR

Reduced storage capacity in Mackay Reservoir by accumulation of sediment is a major concern to downstream water users in the Big Lost River valley. As a part of this study, several techniques were used to determine the present rate of sediment accumulation in the reservoir and to quantify any reduction in storage capacity since records of inflow began in 1919.

In August 1980, a depth survey using sonar soundings was conducted on the reservoir by the U.S. Bureau of Land Management and Idaho Department of Health and Welfare. Volume of the reservoir calculated from the sonar data as compared with the 1917 capacity-table data indicated a decrease in storage capacity of about 11 percent (from 44,370 acre-ft to 39,370 acre-ft). For the 64-year period, this represents an average storage decrease of about 78 acre-ft/yr, and on the basis of an estimated density for the sediment of 100 lb/ft^3, indicates a sediment-transport rate into the reservoir of about 170,000 ton/yr.

Ten core samples of reservoir bottom material from locations shown in figure 28 were analyzed for sediment size and cesium-137. Particle-size distribution of sieved core samples is shown in figure 29. Cesium-137, a radionuclide with a half-life of 30.2 years, was introduced into the environment in significant quantities as a result of atmospheric testing of nuclear weapons from the early 1950's through about 1964, the period when tests were most numerous. The tendency for cesium-137 to be rapidly sorbed onto clay-sized particles and its short half-life make it a useful indicator of relative sedimentation rates.

Radioisotope analyses of core samples from site L3-2 (fig. 28) indicate no cesium-137 in sediment at a depth greater than 0.5 ft, which was probably deposited at least before the early 1960's and perhaps as long ago as 1950.

If it is assumed that the upper 0.5 ft of reservoir bottom material represents a minimum accumulation owing to a low trap efficiency and flushing of some fines from the reservoir, then about 45,000 ton/yr of sediment has been deposited in the last 20 years.

In August 1981, cross sections were surveyed across the nearly empty reservoir, and ground elevations were compared with those from a 1930 topographic map with a contour interval of 10 ft. Surveyed elevations were within about ± 1.0 ft of drawn contour intervals. During the survey,

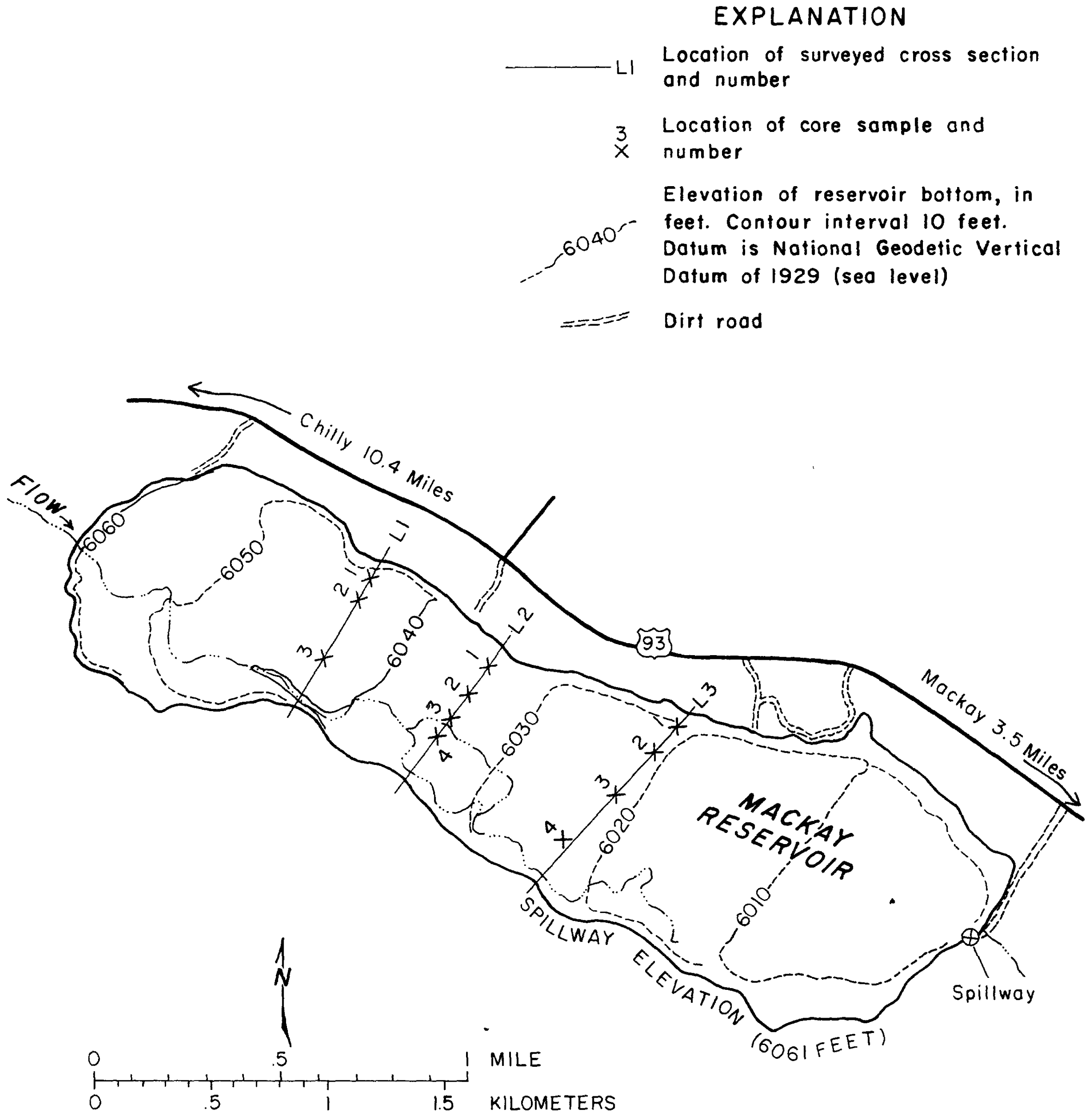


Figure 28. -- Locations of surveyed cross sections and core samples in Mackay Reservoir.

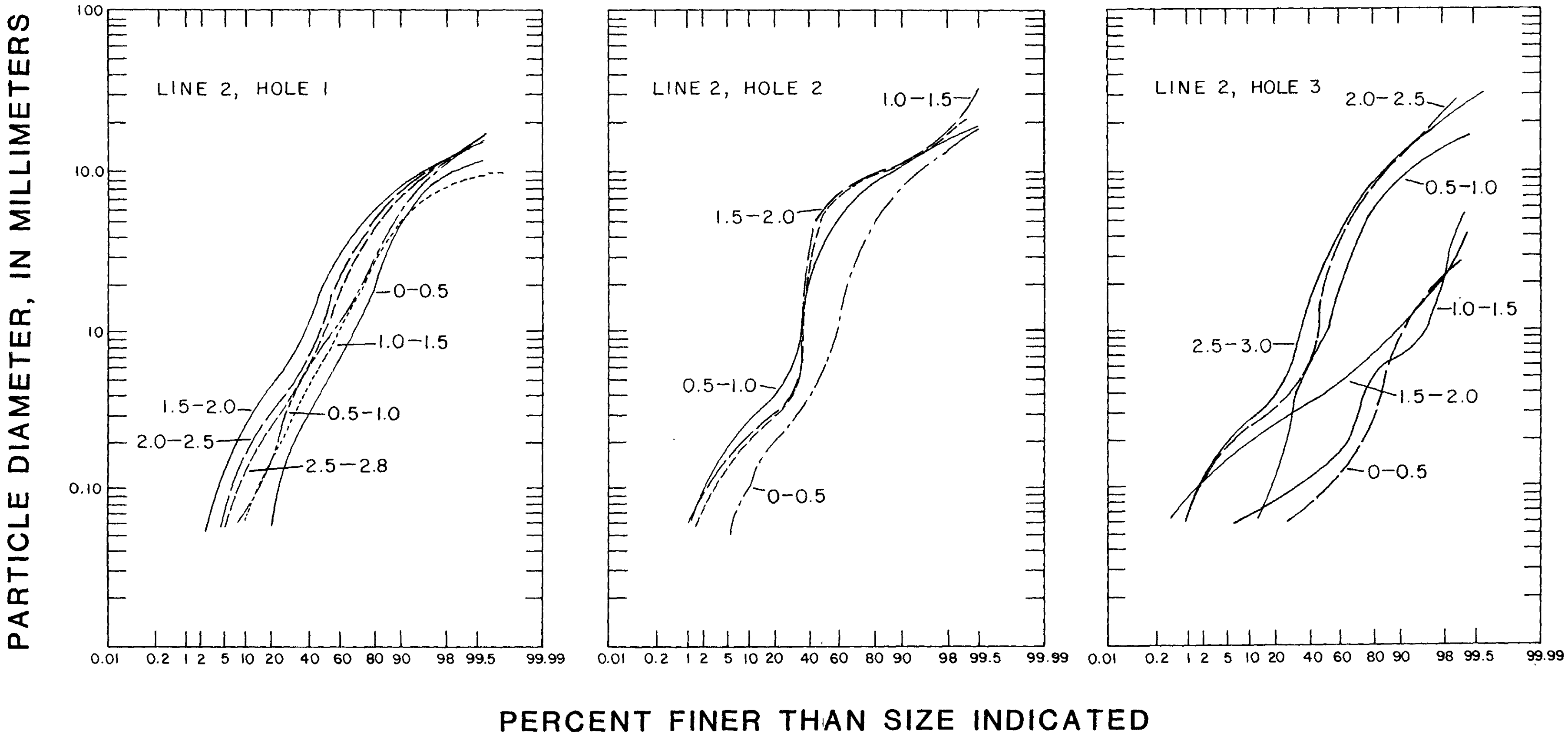


Figure 29. -- Particle-size distribution of sieved core samples from Mackay Reservoir. (Numbers indicate depth interval of core sample, in feet)

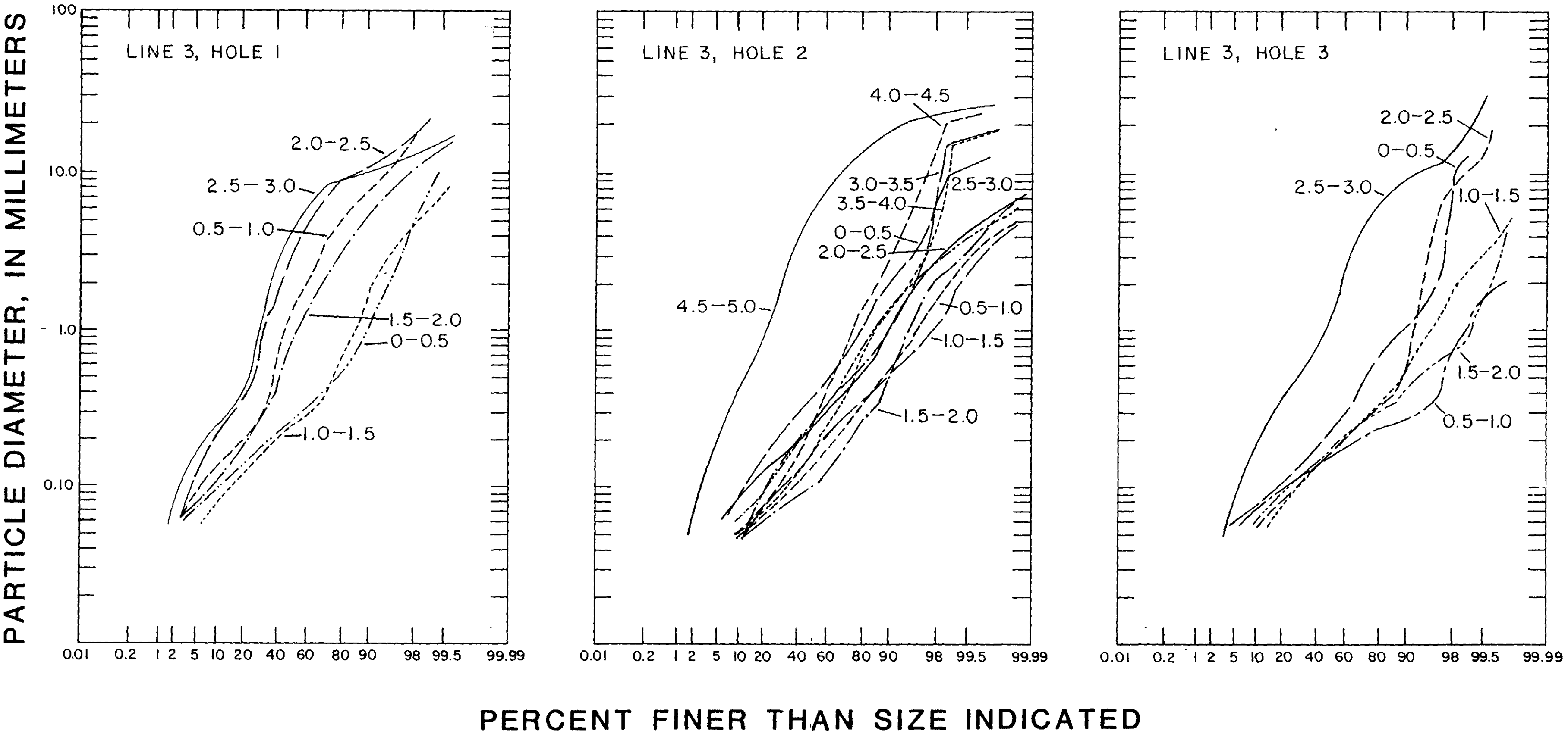


Figure 29. -- Particle-size distribution of sieved core samples from Mackay Reservoir--Continued.

(Numbers indicate depth interval of core sample, in feet) several other observations were made which gave some indication of sediment deposition in the reservoir: (1) Deposition of coarse material near the inlet; (2) old fenceposts in an undisturbed line buried 8 in., which may or may not have been their original depth; (3) old tree stumps with exposed roots; and (4) minimal (less than 1 ft) channel scour.

From the paucity of field data, total deposition of sediment in the reservoir since 1919 is unknown; however, it is probably less than the 5 ft determined by sonar survey. Surveyed channel change and observation of braiding in the lower river segments below site 131234 and above the reservoir indicate deposition of most coarse material may occur before reaching the reservoir. Sediment transport past site 131234 was about 20,000+ tons in 1981. Channel surveys below this site indicate deposition of about 2,600 tons during the same time and may represent deposition of the total bedload or coarse load in the channel above the reservoir. Some deltaic deposition (up to several feet) probably occurs in the shallow upper end of the reservoir. When the low trap efficiency and yearly flushing of sands and clays out of the reservoir are considered, it is unlikely that the original life expectancy of the reservoir is in immediate jeopardy.

APPLICATION OF BEST-MANAGEMENT PRACTICES TO THE STREAM SYSTEM

The application of BMP's discussed in the Big Lost River Water Quality Management Plan (Butte Soil Conservation District, 1982) is expected to benefit downstream water users and recreationists, as well as landowners who employ BMP's. The objectives are to control streambank erosion and preserve reservoir capacity, but application of several BMP's may conflict with these objectives.

Emplacement of gabions in the river should reduce local bank cutting. Hypothetically, the less coarse sediment that is made available for transport, the less deposition that would occur downstream. The current hydrologic regime coincides with this desired intent because increased flows have already reduced sediment availability. The availability of coarse material with time probably would be further reduced by installation of log weirs, riprap, and gabions. Installation and initial presence of these structures probably would initiate local bed scour during initial channel adjustments, followed by a downstream progression of prolonged periods of bank cutting, erosion, and bank failure. Ultimately, most of the derived sediment would be flushed downstream.

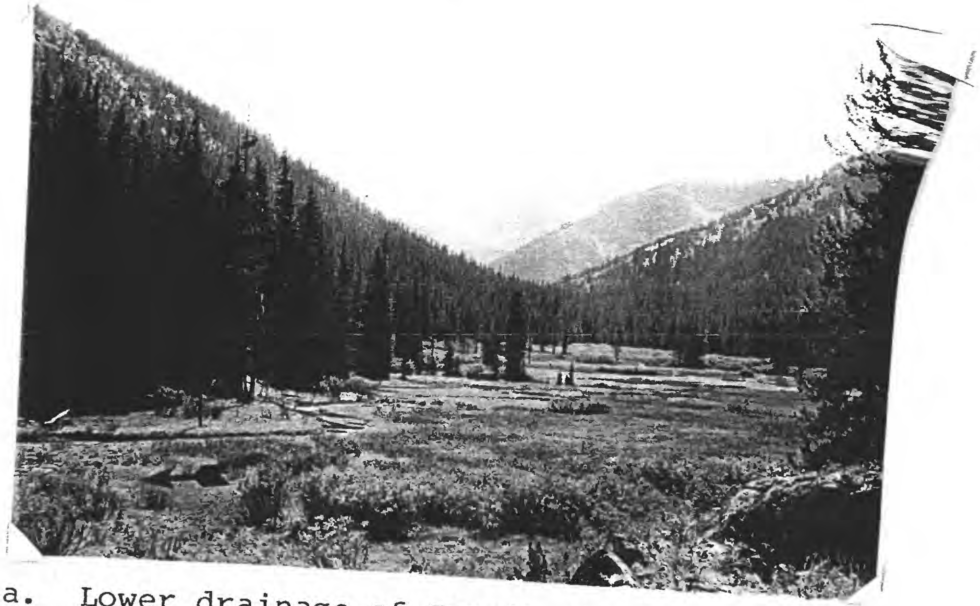
Currently, deposition in the lower reach of the Big Lost River reduces the quantity of coarse sediment transported into the reservoir, thus retaining reservoir capacity and extending reservoir life. Although strategically placed gabions and bank riprap in the lower section of the river might protect riverbanks from annual erosive floods, material previously deposited in the streambed might be flushed into the upper end of the reservoir if the current hydrologic regime remains the same. A reversal to a drier hydrologic cycle would further encourage deposition in the lower reach as long as material was supplied from upstream. Changes to a wetter climate, regardless of bank protection measures, may temporarily increase the downstream transport of coarse bed material. Currently, most coarse material appears to be deposited upstream in bars and riffles.

Land use for livestock grazing in the upper basin tributaries (figs. 30a-b) may conflict with the bank stabilization desires of the fisheries program, as discussed in the management plan.

Trout require streambed habitats that have a natural tendency to change by scour and fill. Sediment in the size range suitable for spawning may be lost if the streambed is armored or the availability of coarse material is reduced by placement of weirs (figs. 30c-d). Deposition of upstream gravels may trigger downstream bank instability by bank undercutting (figs. 30e-h) and channel abandonment. For example, 50 log structures 1.5 ft high and 17 ft wide on a stream with a gradient of 3.5 percent would trap about 1,370 tons of coarse material. Emplacement of large rocks into the lower reaches of the upper basin tributaries would initially induce scour, followed by downstream deposition. Emplacement of large rocks rather than log weirs may be esthetically more desirable to preserve the environment and stimulate the desired pool and riffle sequences.

SUMMARY AND CONCLUSIONS

The objectives of this investigation were to assess past and present channel changes in the Big Lost River system and to consider possible responses of the river system to existing and planned artificial structures. Five streamflow stations were chosen for data collection to define sediment erosion, transport, and deposition zones. Historic records of runoff and channel hydraulics were analyzed on a year-to-year basis for the period 1917-81.

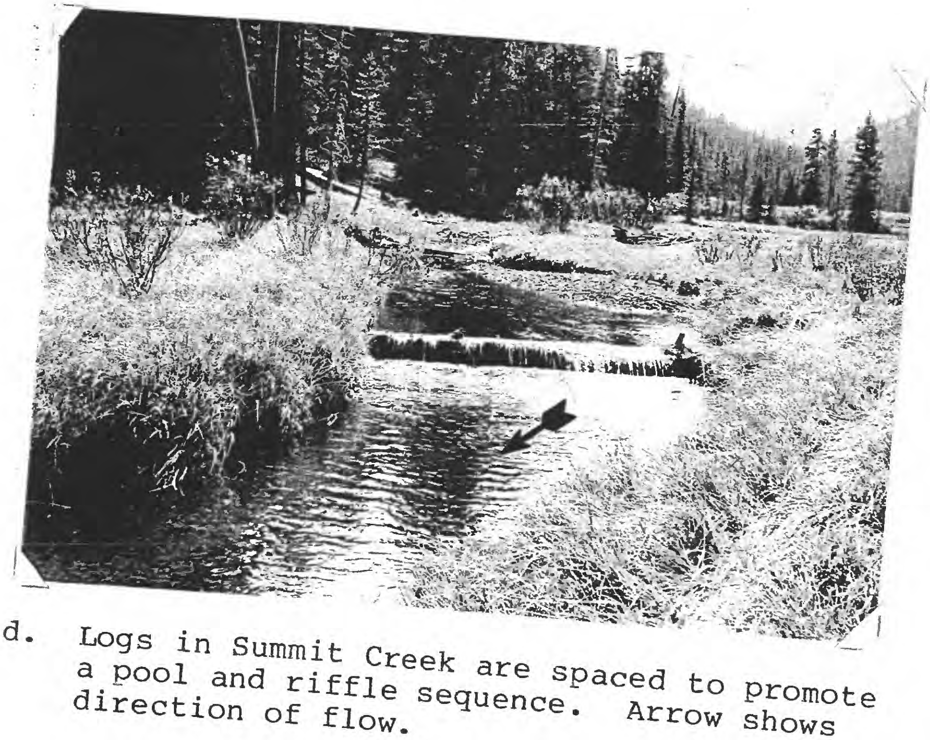


a. Lower drainage of Summit Creek basin. Pioneer Mountains in background. Log weir in stream foreground. Arrow shows direction of flow.

b. Land used for grazing sheep, Summit Creek basin.

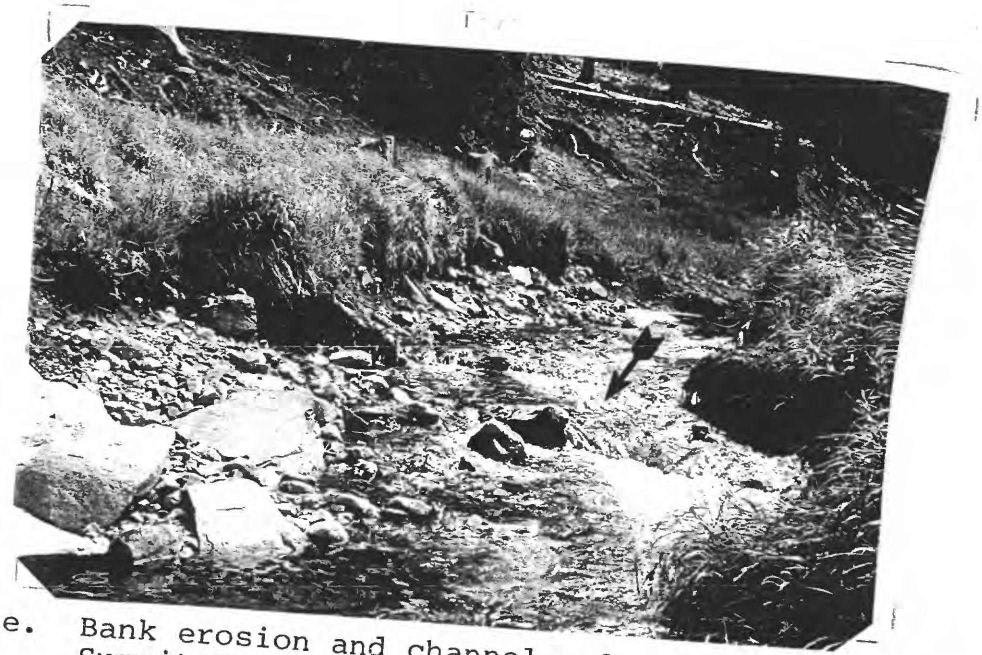
Figure 30.--Lower drainage, land use, and effects of log weirs on the streambed and banks, Summit Creek.

c. Log weirs in Summit Creek, tributary to the North Fork of the Big Lost River. Note deposition behind weir. Arrow shows direction of flow.



d. Logs in Summit Creek are spaced to promote a pool and riffle sequence. Arrow shows direction of flow.

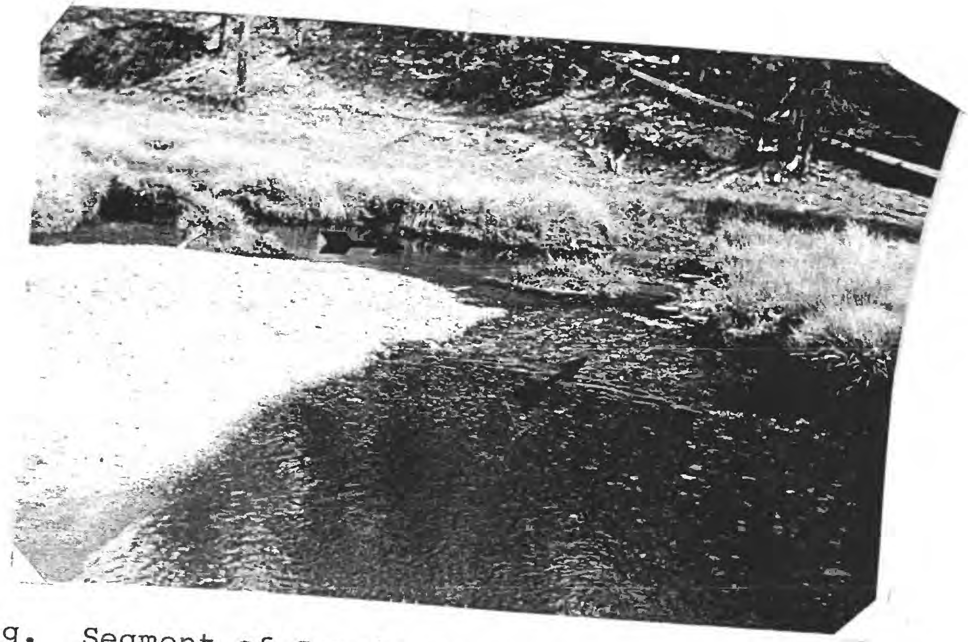
Figure 30.--Lower drainage, land use, and effects of log weirs on the streambed and banks, Summit Creek--Continued.



e. Bank erosion and channel enlargement along Summit Creek. Arrow shows direction of flow.

f. Erosion in Summit Creek caused by turbulent flow striking opposite bank at 90-degree angle. Arrows show directions of flow.

Figure 30.--Lower drainage, land use, and effects of log weirs on the streambed and banks, Summit Creek--Continued.



g. Segment of Summit Creek becomes abandoned as bank erosion and bed deposition continue. Arrows show directions of flow.

h. Undercut bank downstream of log weir along Summit Creek. Arrow shows direction of flow.

Figure 30.--Lower drainage, land use, and effects of log weirs on the streambed and banks, Summit Creek--Continued.

Significant findings include: (1) The identification of runoff cycles that may have directly affected sediment transport. Peaks of these cycles appeared to coincide with systematic changes in the hydraulic geometry of the Big Lost River at Howell Ranch (131205). Fluctuation in streambed elevations indicates that deposition occurred in the 1940's to mid-1960's during relatively dry periods. Sediment available for transport in the main channel apparently declined despite a relatively wet period that occurred in the 1970's. Adjustment of the channel bed toward a degradation trend is now (1981) constrained because of partially armored beds and drop structures. As a result of these constraints, lateral shifting and bank undercutting have occurred. Most notable is the increasing bedload of coarse sediment (per unit discharge) in the reach between Howell and Chilly. (2) Fine sediment that entered the reservoir apparently has been transported through the reservoir system because of its low trap efficiency. Reservoir surveys, observations of fence lines and tree stumps in the reservoir, and cesium-137 dating of the bottom sediments indicated that about 95 percent of the initial (1917) storage capacity still exists. Streambed elevations a short distance below the reservoir have degraded about 0.5 ft, as determined from gaging-station records.

Hydraulic geometry evaluations made in this study suggest that mean streamflow velocities are now slower and mean water depths are greater than during the past 20-30 years; therefore, whereas fine-grained sediment load may or may not have changed appreciably, coarse load per unit discharge may have decreased significantly within the Big Lost River system. This change is attributed to increased runoff and reduced coarse material available for transport. After initial degradation and meander adjustments, the rate of coarse sediment transport may be reduced and therefore would be less of a threat to reservoir life.

Each implemented BMP structure probably will alter the local flow regime in and along the Big Lost River. Local channel hydraulics may be altered drastically, which would lead to an increase in coarse load transport. For example, when lateral erosion and channel adjustments are prevented by gabions, stream energy is redirected to the bed, as well as to the base of the outside bank at meanders. In addition, flow from a curved bank protected by gabions may be deflected to an unprotected bank downstream, increasing the erosion rate. Thus, although the intent of a structure is to halt bank erosion, excess flow energy may be dissipated downstream on the unprotected beds and banks.

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GLOSSARY OF TERMS

Terms related to streamflow, erosion, sediment, and other hydrologic data as used in this report are defined below. A more complete list of terms is given by the U.S. Geological Survey (1977), and some of the following definitions are taken wholly or partly from that report.

alluvial flood-plain channels - small, narrow, cutting channels on the flood plain formed by overbank flow during floods, usually originating upstream from an obstruction in the main channel.

aggradation - progressive raising of a channel bed by accumulation of sediment eroded and transported from other areas.

armoring - coarsening and sorting of surface bed material resulting in an increase in mean particle size as finer material is swept away.

bank failure - downward slipping and displacement of masses of bank material, caused where flowing water cuts away the supporting base of the bank.

chemical weathering - decomposition of rocks and soils by chemical reactions such as hydrolysis, hydration, oxidation, carbonation, ion exchange, and solution.

cutbank - a steep, bare slope formed by lateral erosion of a stream.

debris jam - large, mobile accumulations of logs, brush, and other organic materials in the stream, usually transported by flotation during high flows.

degradation - progressive lowering of a streambed by removal of sediment from the boundary.

deposition (fill) - mechanical or chemical processes through which sediment accumulates.

drop structure - a vertical concrete structure across the stream that controls channel slope by preventing scour upstream of the structure.

erosion - wearing away of the land surface by detachment and movement of soil and rock fragments through the action of moving water and other geological agents.

Froude number - a dimensionless numerical quantity used as an index to characterize the type of flow in a stream. The number represents the ratio of inertial to gravitational forces.

gabion - a specially designed basket, cylinder, or box of corrosion-resistant wire encasing rock and other coarse aggregate commonly placed in tiers against a bank for protection against bank cutting and erosion.

mass wasting - failure and downslope transport of a mass of soil and rock materials as a result of gravitational forces.

mechanical weathering - decomposition of rocks and soils by frost action, absorption of water, and temperature changes.

particle-size distribution - frequency distribution of the relative amounts of particles in a sample that are within specified size ranges, or a cumulative frequency distribution of the relative amounts of particles coarser or finer than specified sizes. Relative amounts usually are expressed as percentages by mass.

recurrence interval (return period) - average interval of time within which the given flood will be equaled or exceeded once. The recurrence interval is the reciprocal of the probability of the given flood magnitude being equaled or exceeded in any one year.

riffle - natural shallows or other expanse of shallow bottom extending across a streambed over which the water flows swiftly in undulating waves.

riprap - large, broken rock fragments piled together irregularly in a dense border along a stream to prevent bank erosion by the flowing water.

scour - enlargement of a flow section by removal of boundary material through the action of fluid in motion.

sediment - (1) particles derived from rocks or biological materials that have been transported by a fluid, (2) solid material (sludges) suspended in or settled from water.

sediment discharge - the mass or volume of sediment (usually mass) passing a stream transect in a unit of time. The term may be qualified, for example, as suspended-sediment discharge, bedload discharge, or total sediment discharge.

sedimentation - a broad term that pertains to the five fundamental processes responsible for the formation of sedimentary rocks: (1) weathering, (2) detachment, (3) transportation, (4) deposition (sedimentation), and (5) diagenesis; and to the gravitational settling of suspended particles that are heavier than water.

sinuosity - ratio of the length of the channel or thalweg to the down-valley distance.

weir - a small dam in a stream designed to raise the water level or divert flow through a desired channel. The structure may contain a notch through which the low flow discharges.