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LOWER KLAMATH RIVER TRIBUTARY DELTA STUDY

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U.S. Department of the Interior
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INTRODUCTION

The Klamath River and its tributary streams support runs of chinook salmon and steelhead that historically were much larger than they are today (USFWS 1979, CH2M Hill 1985). The reduction in fish abundance has been attributed to various causes, including land disturbance and sedimentation, over-harvest in the ocean, dam construction, and water diversion (USFWS 1979, Buer et al. 1981). One potential contributor to population declines that has been largely overlooked is the recent formation of gravel deltas where many lower river tributaries enter the Klamath. Fine sediments and gravels building up in the channel at the mouth of a stream could inhibit access to adult fish that are returning to spawn, and ultimately reduce survival and reproduction.

A late fall run of chinook salmon is known to utilize the lower Klamath River tributaries for spawning and rearing. These fish enter the main river in October and November after the stocks of fish that spawn upriver have moved through the area. Indian fishermen have traditionally viewed the downriver chinook as an important resource that provides a source of fresh fish late into the season. The fact that these fish spawn in streams near the traditional homes of the fishermen gives them added significance.

The lower river tributaries have changed considerably over the last century, according to numerous reports from elder Indian residents. Dense, old growth forest canopies have been removed from along the streams and road systems have been built high into many watersheds. The effects of these disturbances have been accentuated by major floods in the last three decades that have washed debris and sediments from the unstable hillsides, filling once-deep channels and pools and creating gravel deltas which project out into the Klamath River. While many barriers composed of logging debris have been removed with considerable effort by Indian, State, and Federal stream clearance crews, the accumulated sediments have remained largely unaffected. An observed lack of recovery in the low numbers of downriver chinook after this work suggests that the sediment and deltas may play a continuing role by restricting spawner access to the streams, particularly in years of low flows created by late rains or drought.

The Bureau of Indian Affairs contracted with Thomas R. Payne & Associates to examine the causes of delta formation, estimate their extent, evaluate the potential effect on spawner access, and recommend solutions as may be necessary.

STUDY SITES

Three streams out of approximately 20 lower Klamath River tributaries were selected for detailed examination after on-site consultation with representatives from the Bureau of Indian Affairs (Redding Office) and the U.S. Fish and Wildlife Service (Arcata Office). Roach Creek, Tectah Creek, and Bear Creek were judged to have deltas and physical characteristics typical of most tributaries between Weitchpec and the mouth of the Klamath (Figure 1). The watersheds of all three streams have been extensively logged.

ROACH CREEK

Roach Creek has a drainage area of 29.0 square miles, a mean annual precipitation of 80 inches, and is located 31.5 miles upstream of the mouth of the Klamath. Surveys have documented an abundance of suitable salmonid habitat in Roach Creek that is utilized by steelhead, chinook, and coho salmon (USFWS 1979, 1989). A boulder cascade at the base of a rock chute approximately one-third of a mile above the Klamath has been identified as a barrier to all upstream salmonid migration (USFWS 1979).

TECTAH CREEK

Tectah Creek drains 19.9 square miles, has a mean annual precipitation similar to Roach Creek (80 inches), and is 22 miles up the

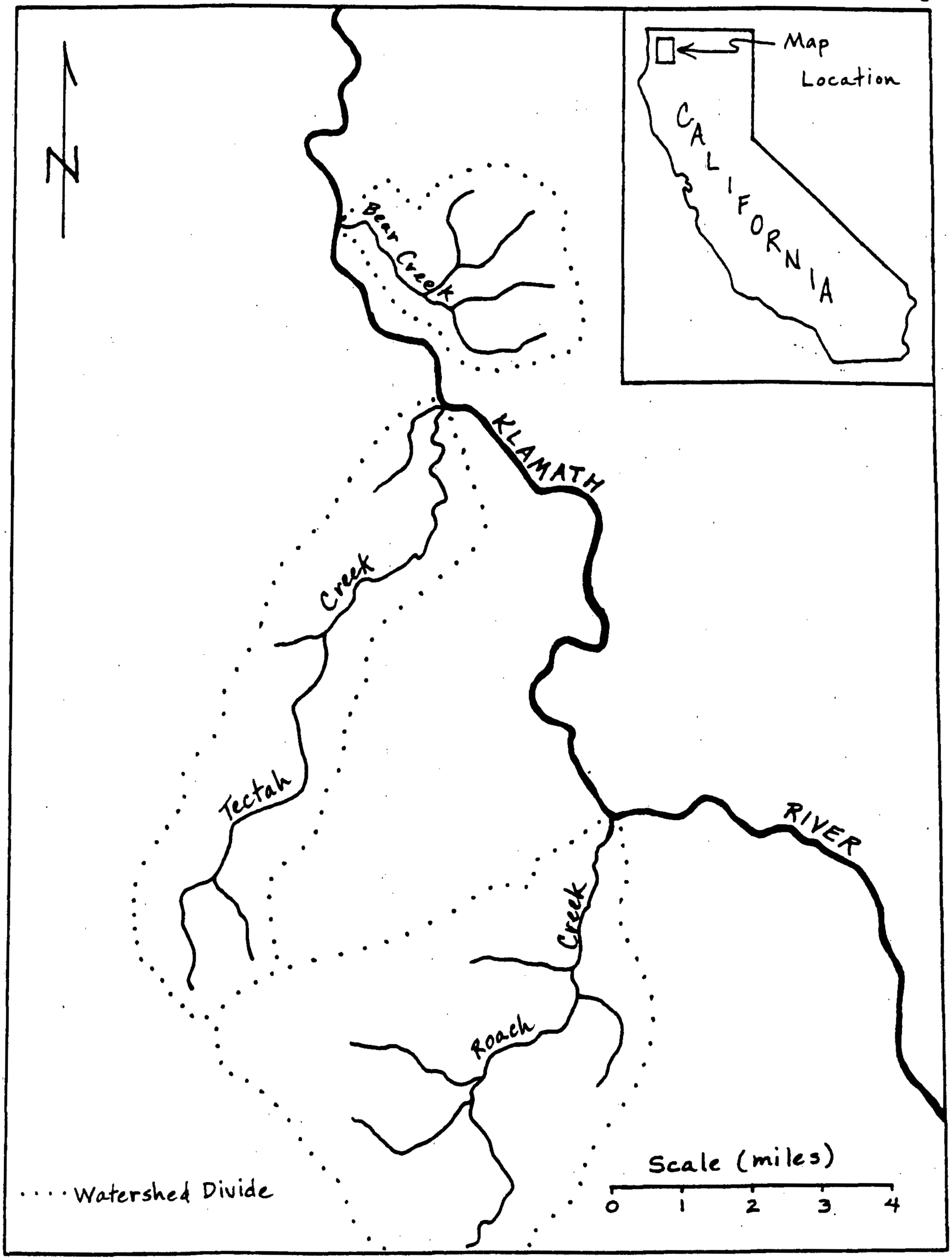

Figure 1. Location map of lower Klamath tributaries studied.

Klamath from the ocean. Fish surveys conducted by the USFWS have found chinook fry, steelhead fry and juveniles, and a few coho smolts (USFWS 1979, 1989). No migration barriers are present on lower Tectah Creek, although the lower mile is subject to intermittent flow conditions.

BEAR CREEK

The Bear Creek drainage, 18.5 miles upriver from the ocean, has an 8.9 square mile basin and a mean annual precipitation of 85 inches. There are few deep pools in Bear Creek and the lower reach of the stream is reported to go dry each summer. No fry or juvenile chinook were found during 1979 surveys by the USFWS (USFWS 1979), but small numbers of chinook, coho, and steelhead have been captured more recently (USFWS 1989).

METHODS

Field surveys of the three tributaries were conducted from October 1988 through February of 1989. On the first visit the dimensions of each delta were measured, stream channels through the deltas were mapped, and the streams were visually surveyed for barriers, spawning gravels, and the presence of fish. Reference bench marks were established and the profiles of the deltas and stream channels were surveyed. Water surface elevations of the tributaries and the Klamath River were recorded relative to the bench marks on all site visits. These measurements were used to calculate the discharge at which the Klamath River would cover the deltas. The number of wetted channels crossing each delta and the depth, velocity, and estimated discharge of each channel was recorded.

Aerial photographs taken in the years 1936, 1948, 1954, 1960, 1962, 1970, 1975, 1976, and 1983 were obtained and reviewed for evidence of watershed disturbance. The sizes of deltas in the three tributaries were measured from the photographs. Mean annual flow and mean annual peak flow for each creek were calculated from drainage areas and rainfall patterns using relationships presented in Humphrey (1976). Stream channel dimensions were estimated from regime equations (Chang 1988), resulting in width-to-depth ratios generally between 10-to-1 and 20-to-1. Manning's equation, utilizing a substrate roughness of 0.04 and a channel slope of 0.012 feet per foot, was used to calculate water velocities and depths associated with the mean annual and mean annual peak flows. Velocities required to lift and transport the size of gravels found on the deltas (measured by pebble counts) were estimated using the formulas in Simons and Senturk (1977).

RESULTS

ROACH CREEK

The delta on Roach Creek was found to be composed primarily of sand and gravel, with some cobble. In October of 1988 it was 426 feet wide along the Klamath River and extended upstream 410 feet. The delta is roughly triangular in shape and contains a large bed-rock protrusion along the south margin near the confluence of the delta and the Klamath River (Figure 2). The stream channel enters the Klamath River along the west edge of the delta and is not braided. Approximately 1000 feet upstream of the creek mouth migrating fish reach an impassable barrier consisting of rock cascades and chutes.

Flood History

Dates of the largest floods on streams representative of conditions on the study tributaries were compiled from U.S. Geological Survey stream gage records (Redwood Creek, Smith River, Blue Creek, and Willow Creek). Major floods since 1948 occurred in January 1953, December 1955, December 1964, January 1974, March 1975, December 1981, and February 1986. The largest event was December 1964 (100-year return period), the second largest March 1975 (25-year return period), and the third largest December 1955 (15-year return period). The remaining events had return periods of 5 to 10 years.

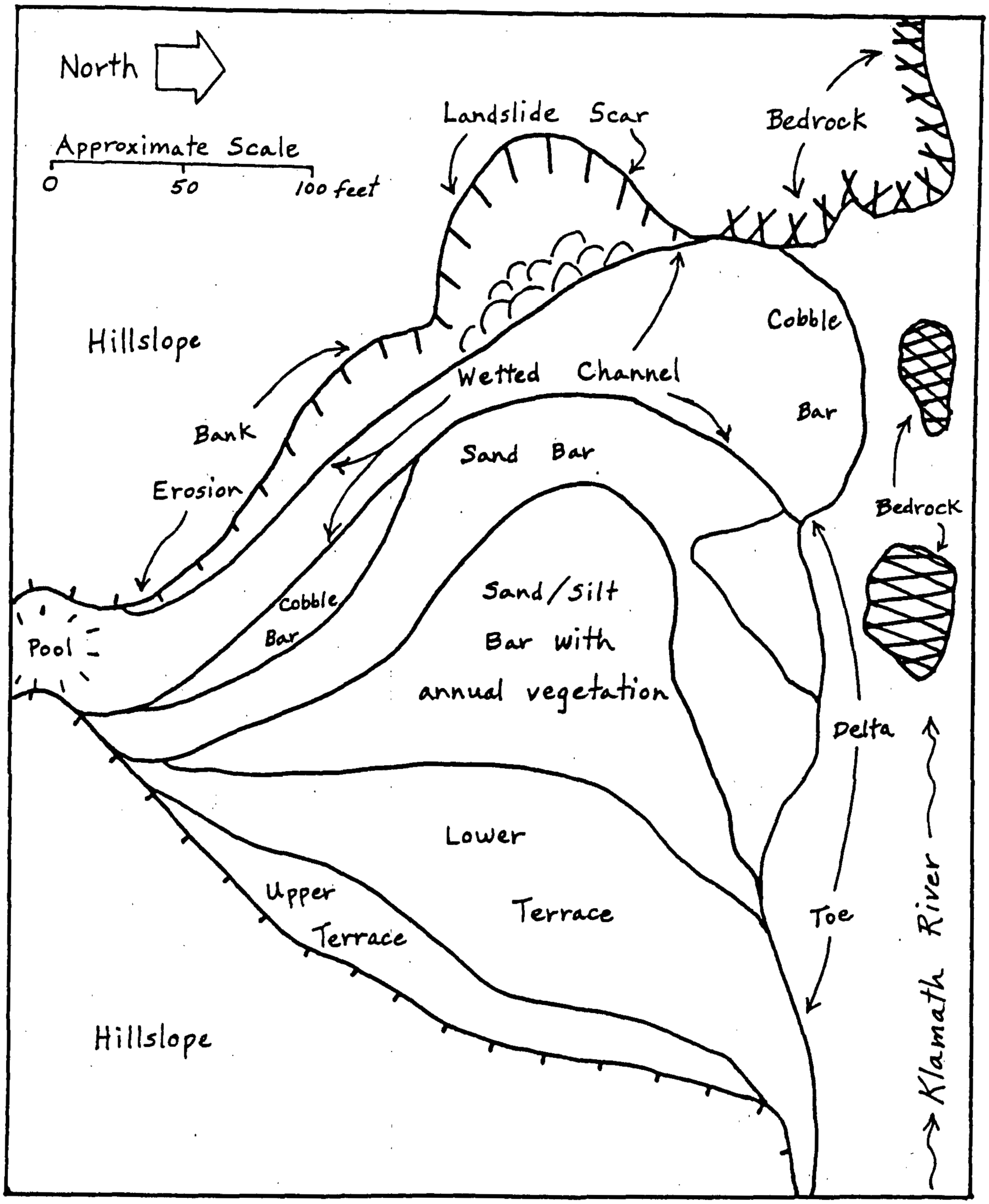

Figure 2. Sketch of Roach Creek Delta, February, 1989.

Photographic History

1936 (July): No delta is present. The creek bed is barely visible and little sediment deposition is exposed. There is no evidence of road construction or logging activity in the watershed.

1948 (June): A very small sediment deposit (50 by 150 ft) is visible at the mouth of the creek. The Klamath River main channel is flowing against the south bank (mouth of Roach Creek). Very little sediment is visible in the stream channel. No evidence of roads or logging is visible.

1954 (July): A small sediment deposit is present (80 by 300 ft). The photographs show no logging or roads present, at least in the north half of the basin.

1962 (August): A large delta has formed in the mouth of Roach Creek with dimensions of 240 by 400 ft. Extensive sediment deposits are visible in the lower 5000 feet of the creek. A portion of the basin has been logged and a system of roads constructed. The main creek channel is flowing on the west side of the delta.

1975 (May): The delta is 550 ft wide by 500 ft long, twice the width of 1962. Extensive sediment deposits are visible in the lower sections of the creek. The creek channel crosses near the center of the delta. New areas of logging are present in headwater areas. Older cut units in the north half of the basin have become revegetated.

1976 (July): The main Klamath River is at a very low stage, revealing a delta on Roach Creek that protrudes into the River. Dimensions of the delta are 700 by 900 feet. The creek channel is again located on the extreme west side of the delta. Extensive sediment deposits are visible throughout the creek.

1983 (August): The delta has dimensions of 500 ft by 500 ft and appears similar to the 1989 condition. The creek channel is on the east side of the delta. Logging activities in the north portion of the basin are less obvious than in previous years.

The photographic record shows that Roach Creek prior to logging and several major storm events had very little sediment in the channel and only a small delta at its mouth. After logging and severe flooding, a very large delta formed and abundant sediment was being stored and transported within the stream. The stream channel at the mouth of the creek is very unstable and migrates between the east, west, and center of the delta.

TECTAH CREEK

Tectah Creek has a delta composed principally of gravels and sand. In October of 1988 it measured 303 feet along its boundary with the Klamath River and extended 395 feet upstream (Figure 3). A small pool of water (3 by 8 ft) was present near the upper end of the delta although the stream itself was dry. The pool contained numerous yearling steelhead and some coho fry. A large bedrock outcrop projecting into the Klamath River just upstream of the delta protects the sediment deposits from all but the highest main river flows. The dry stream channel showed signs of previous braiding. Following a rainstorm in November 1988, three active channels were observed at the mouth, two of which carried approximately 45% of the total discharge (20 cubic feet per second) each, and a third about 10%.

Photographic History

1936 (July): No delta is visible. Some sediment deposits are present in the last few thousand feet of the channel. Stream discharge is continuous to the Klamath River. The main channel of the Klamath is located on the south bank next to the mouth of the creek. No logging or roads are visible.

1948 (June): A delta with dimensions of 200 ft wide by 200 ft long is present. No logging activities are visible in the watershed. No

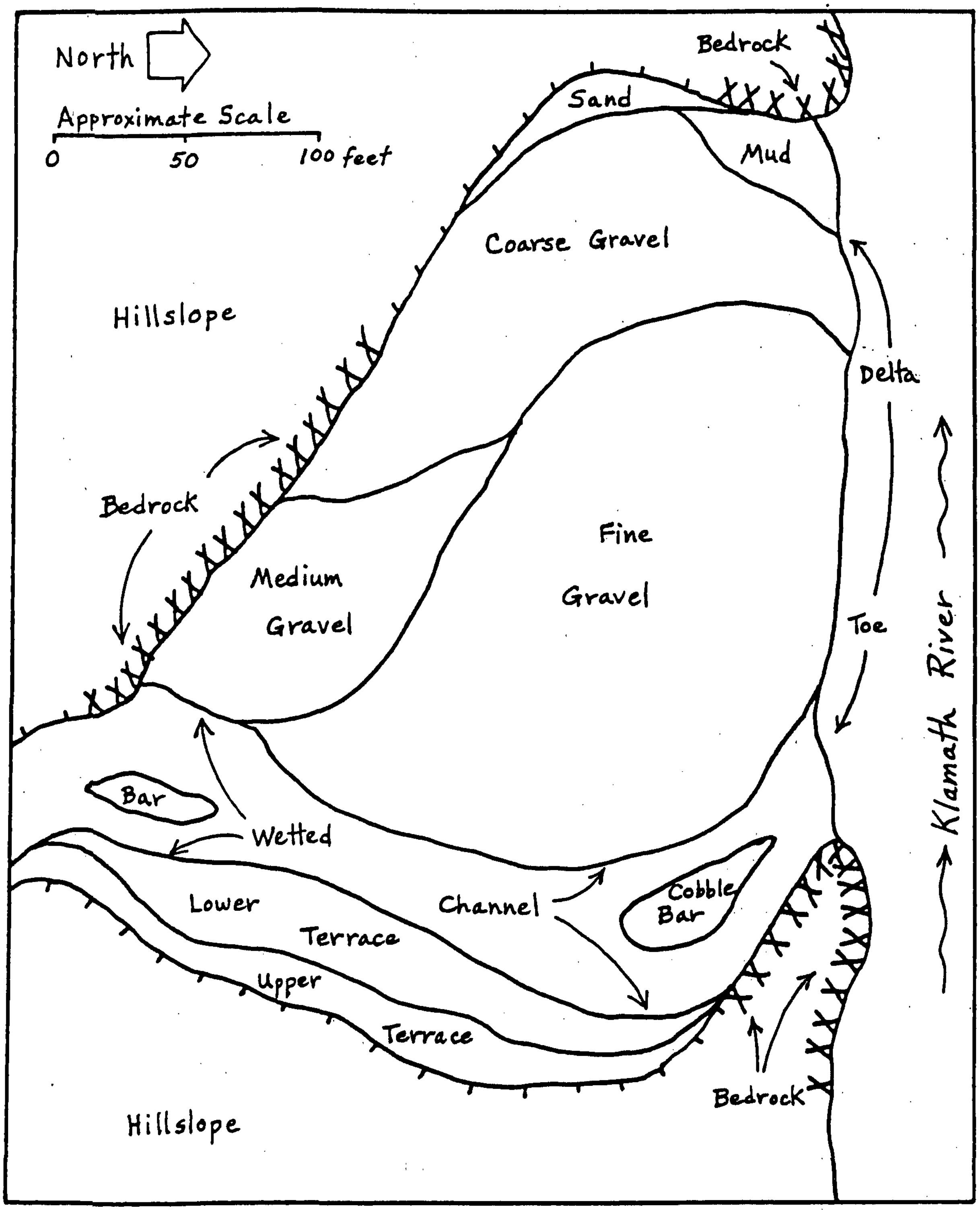

Figure 3. Sketch of Tectah Creek Delta, February, 1989.

sediment is visible in the creek above the delta.

1954 (July): A delta 200 feet wide by 250 feet long is present. Some sediment is visible in the lowest 2000 ft of the channel. The 1954 photo index map shows only minor logging in the basin since 1948 (less than 2 percent of the area).

1960 (August): Delta dimensions are 300 feet wide by 200 feet long, similar to 1954. There are no visible changes in the creek or watershed following the December 1955 flood.

1962 (August): Delta dimensions are similar to 1960. There are no obvious changes in creek appearance. New logging has occurred in the western portion of the basin which may have begun in the late 1950's.

1970 (July): Delta dimensions have increased to 350 feet by 450 feet, with the creek channel near the center. The delta extends 100 feet into the Klamath main channel. The volume of sediments stored in Tectah Creek above the delta appears to have increased to double the amount present in 1962. The south and west portions of the basin have been extensively roaded and logged.

1975 (May): Delta dimensions are 500 feet by 500 feet. Extensive areas of sediment deposits 100 to 300 feet wide are visible for two miles upstream. The creek channel crosses the delta on the west side. New logging activities have extended into east side of the basin.

1976 (July): Low flow on the Klamath River has exposed a delta with dimensions of 700 feet by 700 feet, an increase which may be due to greater exposure created by lower Klamath River flows. The creek channel is located on the far west side of the delta. Old and new logging activities are visible in most of the basin, with the exception of the north end.

1983 (August): Delta dimensions are reduced to 400 feet by 400 feet.

Timber harvest units and roads, both old and new, cover nearly all of the drainage. Sediment deposits in the channel are less visible, evolving into vegetated terraces. At least ten active slope failures appear to be delivering sediment to the creek.

The delta on Tectah Creek, similar to Roach Creek, has evolved to a large size from flooding following watershed disturbance. Major changes did not appear to result from flooding until after logging and road construction. Sediment storage in the stream channel increased along with the delta and contributed to the intermittent flow characteristics of the lower stream. The channel across the delta is also unstable and changes unpredictably from year to year.

BEAR CREEK

Bear Creek has a delta made up of gravels and small and large cobbles. The true size of the delta is difficult to define because Bear Creek discharges into the Klamath River over a large main river gravel bar. That portion of the gravel bar that had been obviously affected by flow from the tributary was 274 feet long and extended 278 feet upstream (Figure 4). There was no stream flow present in October 1988, although a braided pattern of dry channels was evident. Following increased flows in November, a split channel was observed at the mouth of the creek, with the majority of flow in one main channel. Pools were infrequent and shallow throughout the lower mile of the stream.

Photographic History

1936 (July): The Klamath River bar is 250 feet wide on the east side of the river. A delta is not visible at the mouth of Bear Creek. Little sediment is present in the creek channel. No evidence of logging activity is visible.

1948 (June): Bear Creek apparently has a delta with dimensions of 250 feet by 250 feet on top of the Klamath River bar. The main stream

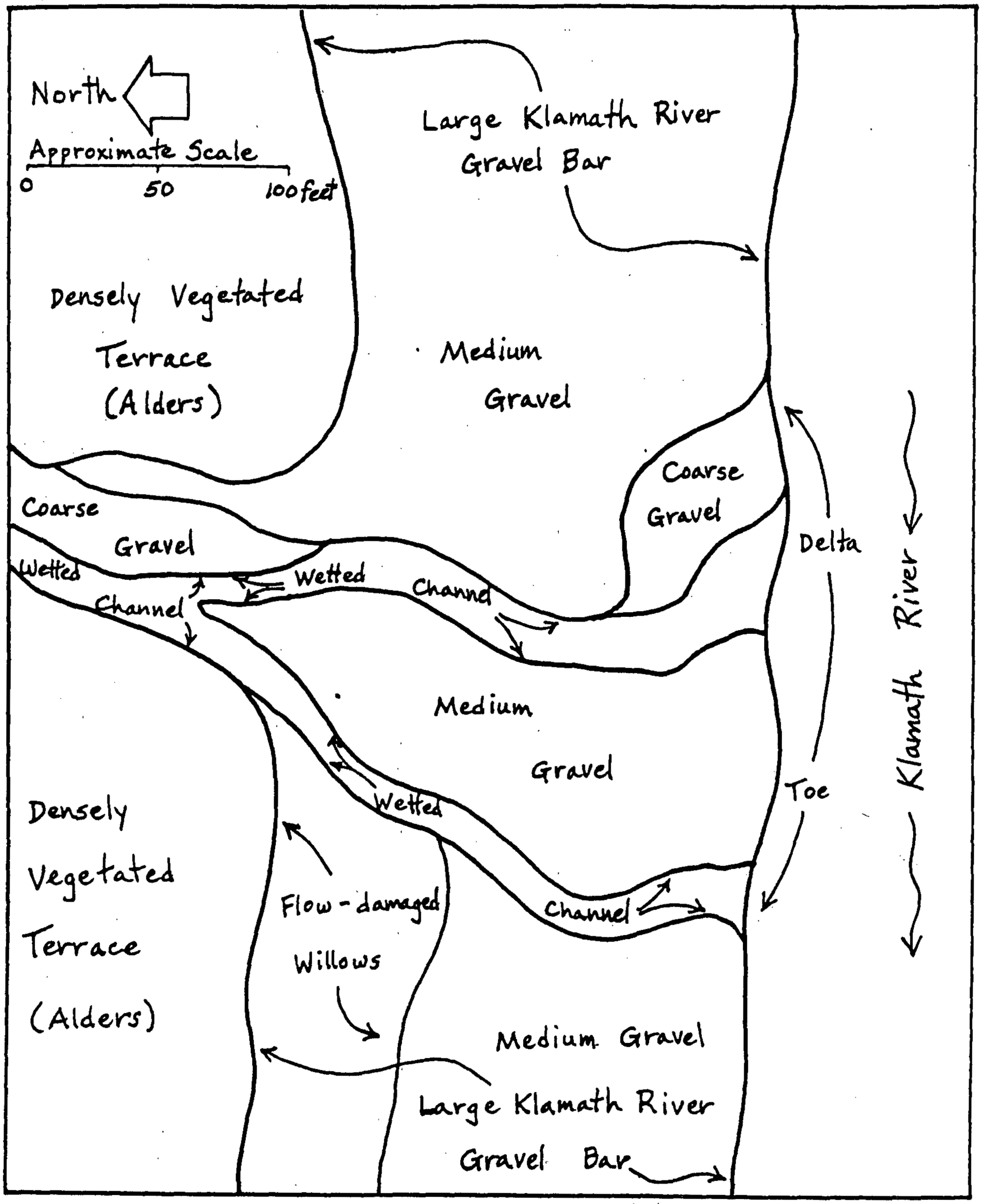

Figure 4. Sketch of Bear Creek Delta, February, 1989.

channel crosses in the center. Sediment in the creek channel extends upstream for 750 ft. No evidence of logging is visible.

1954 (July): A delta is not obvious but probably covers the width of the Klamath River bar (350 ft). No flow or creek channel is visible. Minor sediment deposits are present in the creek channel for 2000 feet upstream. No logging activities are visible in the basin.

1962 (August): The Klamath River main channel is on the east side. Delta dimensions are 400 feet wide by 300 feet long. Sediment deposits are visible in the creek channel for 7000 feet upstream. Logging roads and cut units are evident in the western half of the basin.

1975 (May): High flows in the main Klamath cover all but 200 feet of the main river bar on the east side. Delta dimensions are 250 ft by 250 ft with the creek channel along the south side. Sediment deposits are visible in the creek channel for over 7000 ft upstream. Roads and clearcut units cover over half of the basin.

1976 (August): Low flows in the Klamath expose a delta of 375 feet by 525 feet. The stream channel is in the middle of the delta. Extensive sediment deposits cover the channel upstream of the delta, as in the May 1975 photo.

1983 (August): The delta is the same width as the Klamath River bar on the east side of the river (280 ft). Revegetation of clearcut units is visible. Sediment deposits in the channel are becoming vegetated but are still visible for 5000 ft upstream. Three active debris avalanches are visible near the creek and on logging roads.

Unlike Roach and Tectah Creeks, sedimentation in Bear Creek is greatly affected by a Klamath River gravel bar. Delta size, as well as stored sediment in the lower reaches of Bear Creek, responds not only to the volume of sediment coming out of the Bear Creek watershed but also to phase changes of the Klamath gravel bar. When the Klamath bar grows, the base level of Bear Creek is elevated, resulting in delta growth, sediment deposition, and channel braiding. Conversely, erosion of the Klamath bar will cause downcutting in the Bear Creek delta and consolidation of the channel. Because of the interaction between Bear Creek and Klamath River processes, future changes in the Bear Creek delta are difficult to predict and are unlikely to be similar to changes in the Roach and Tectah Creek deltas.

Sediment Transport

Mean annual flow and mean annual peak discharges for each study stream were calculated and are presented with the flow and velocity at 0.5 ft depth (assumed minimum depth for migration) in Table 1. These data, combined with the erosional and transport velocities presented in Table 2, indicate that only particles larger than cobble would not be moved by flows present in normal water years. Nearly all sediment comprising the deltas would be readily transported by annual average peak flows.

Table 1
Representative Creek Flows, Velocities, and Basin Data

	Mean	Average Peak		0.5 ft Depth		Drainage	Mean Annual
	Flow (cfs)	Flow (cfs)	Vel. (ft/sec)	Flow (cfs)	Vel. (ft/sec)	Area (sq mi)	Precip. (in)
Bear	43	710	9	10-20	2-4	8.9	85
Tectah	83	1244	10	10-20	2-4	18.7	80
Roach	128	1855	11	10-20	2-4	29.0	80

Table 2
Initiation and Transport Velocities

Grain Size	Erosion Initiation	Minimum Transport
Very Find Sand	0.5-1.5 ft/sec	0.05 ft/sec
Course Sand	1.0-2.0 ft/sec	0.3 ft/sec
Medium Gravel	3.0-5.0 ft/sec	2.0 ft/sec
Small Cobbles	10-15 ft/sec	6.0 ft/sec

Change in Delta Size

Figure 5 shows the change in size over time of the selected tributary deltas. Areas were calculated from measurements made on the series of sequential aerial photographs and from field data collected during the study. The Roach and Tectah Creek deltas have behaved very similarly, showing a slow growth up until the major floods of 1964 and 1975, after which the deltas had nearly tripled in size. Subsequent photographs indicate that the Roach and Tectah deltas have become significantly reduced in size, most likely due to high flows and sediment transport in the Klamath River since that time. Because the Bear Creek delta is incorporated into a lateral bar of the Klamath, its size is largely determined by the flow and sediment transport of the main river rather than just by deposition of material from Bear Creek. Although there have been some changes since the 1950's, the size of this delta has remained relatively stable.

Delta Inundation

Measurements of the Klamath River water surface elevation and previous high water marks were made at the mouths of the three deltas. These measurements allowed development of Klamath River stage-discharge rating curves specific to each delta. By overlaying the rating curves onto longitudinal profiles of the stream channels drawn

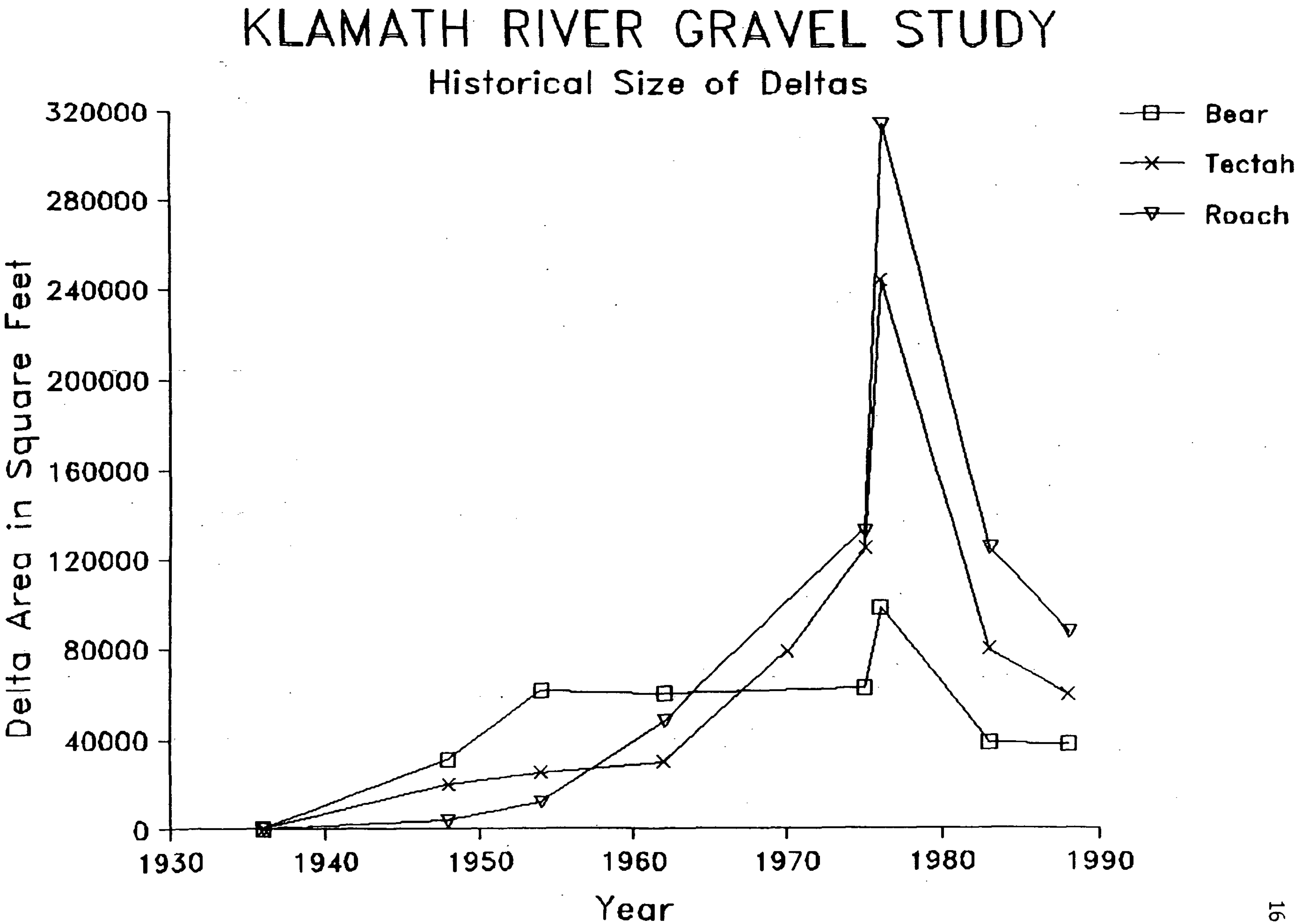

Figure 5. Historical changes in delta size for Bear, Tectah, and Roach Creeks, 1936-1989.

from field surveys, the discharge at which the Klamath River would inundate the deltas can be determined. Figures 6, 7, and 8 show the profiles of Roach, Tectah, and Bear Creeks and the stage of the Klamath River at 5,000, 10,000, 15,000, and 20,000 cfs. On all three streams a Klamath flow of 10,000 cfs covers the steepest parts of the stream channels where they cross the deltas and 15,000 cfs completely inundates the channels and the deltas.

A review of the discharge records for the Klamath River near Klamath was done to determine the earliest dates each fall that fish access over the deltas is likely to be facilitated by inundation. For the period 1967 through 1987, mean daily Klamath River flows exceeded 10,000 cfs by late October in 40 percent of the years, and by mid-November in 80 percent of the years. Mean daily flows exceeded 15,000 cfs by late October in 35 percent, and by mid-November in 75 percent of the years in this period.

DISCUSSION

Deltas are the result of the deposition of sediments by streams and are formed when the tributary watershed delivers sediments in amounts greater than the main river stream can effectively remove. Deltas form at mouth of a stream because of the change in gradient between the tributary and the main river. Accelerated erosion within the watershed of a tributary (often a result of logging and road construction in unstable terrain) increases the amount of sediment available for transport and delta deposition. The ability of a main river to effectively transport tributary sediments further downstream is a function of flow rate, sediment load, shape of the confluence, and timing of flood peaks of the tributary relative to those of the main river.

From our field studies and examination of aerial photographs, it is clear that delta formation and changes in delta size for the study streams have been the result of complex interactions between watershed disturbances, tributary erosion rates, major storm events, and

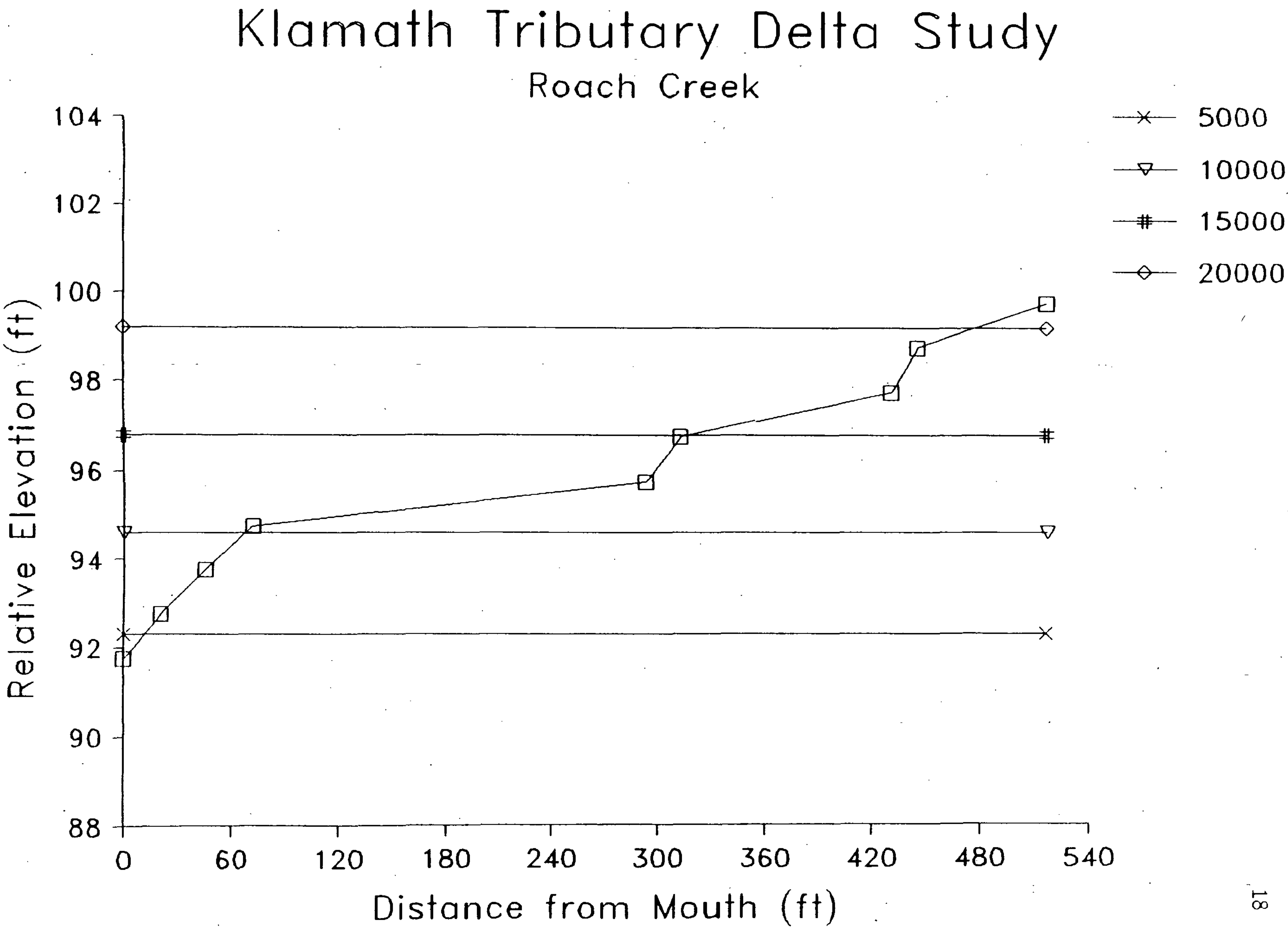

Figure 6. Klamath River inundation elevations on Roach Creek delta at several Klamath flow rates.

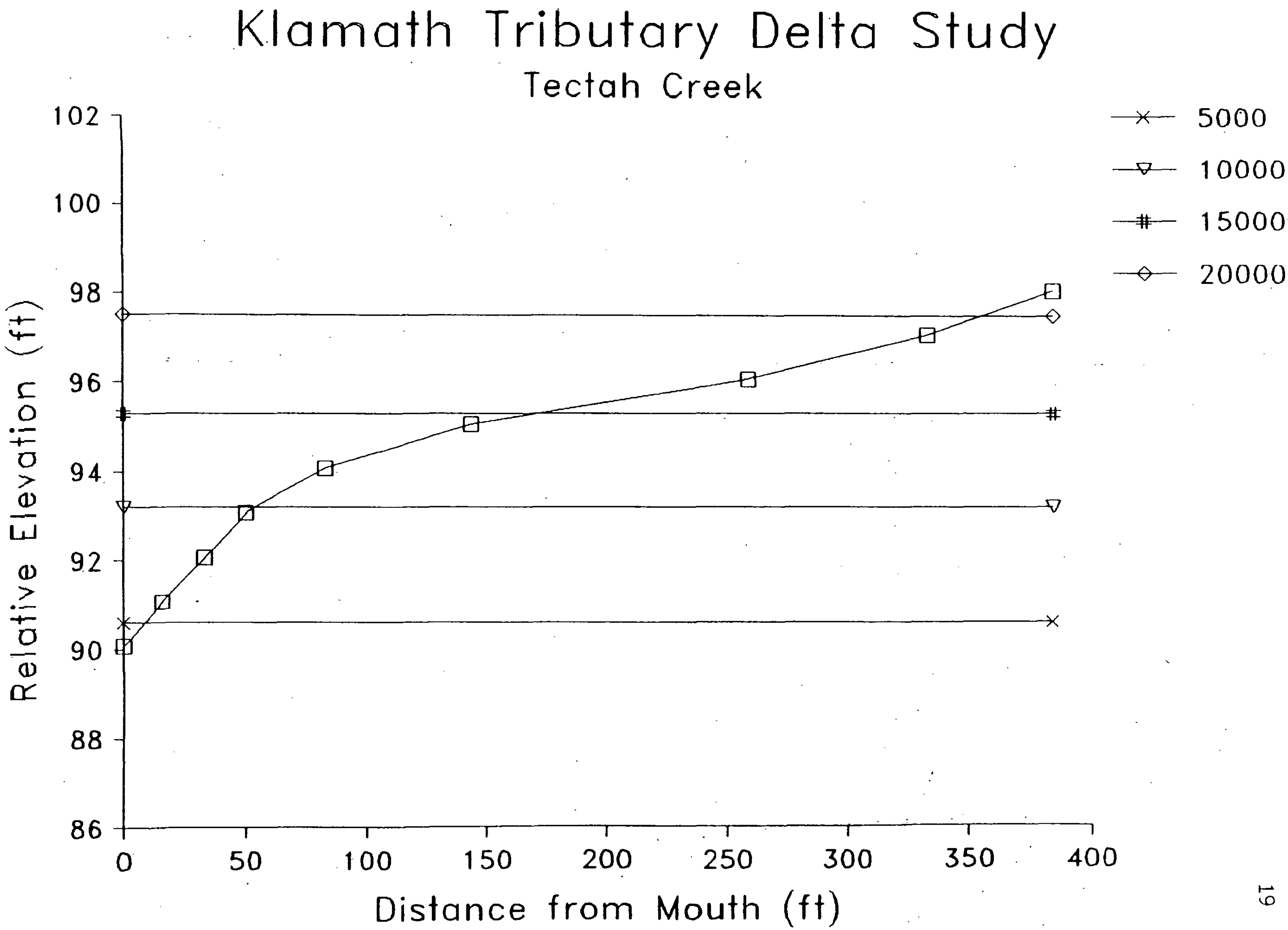

Figure 7. Klamath River inundation elevations on Tectah Creek delta at several Klamath flow rates.

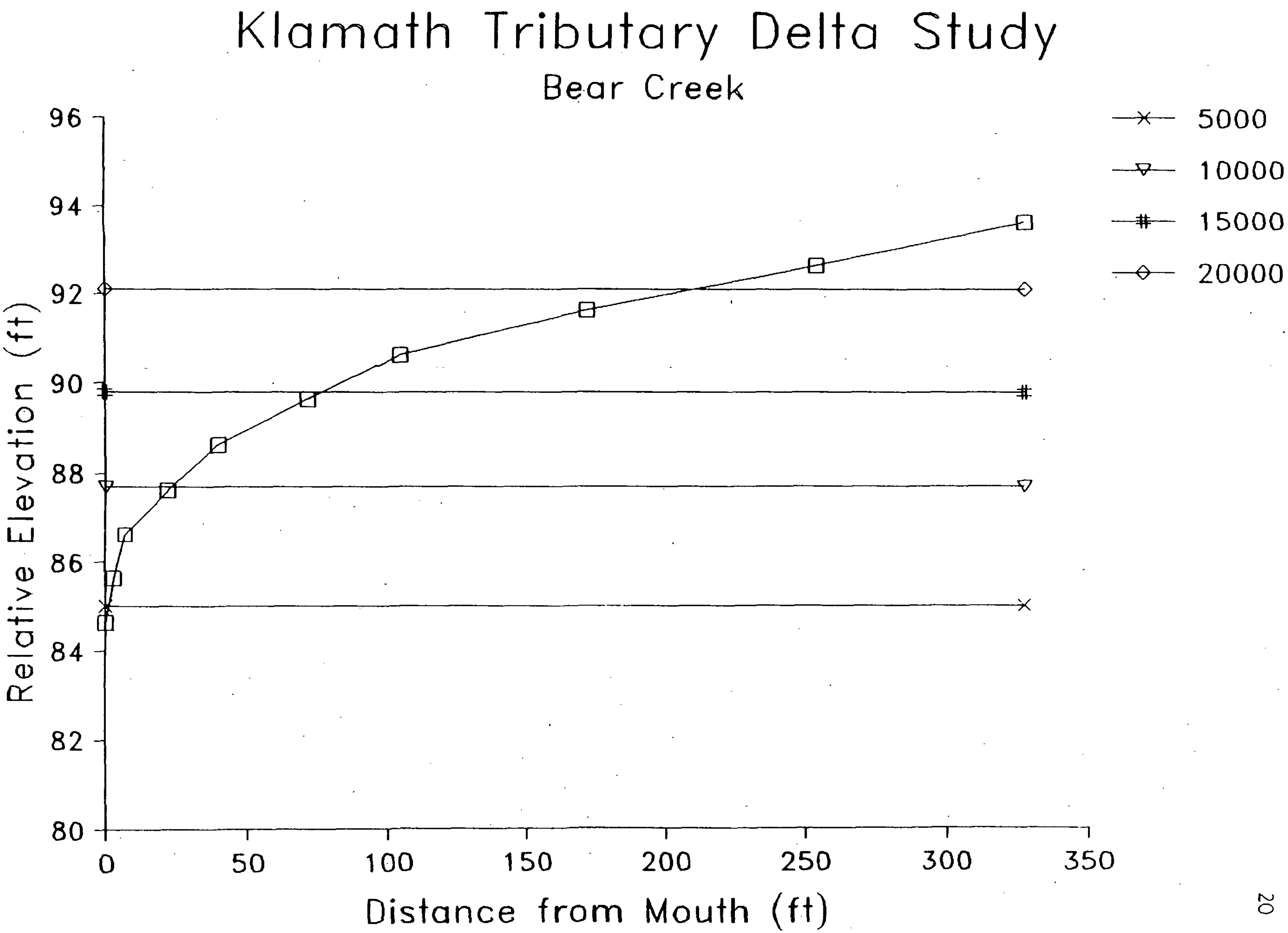

Figure 8. Klamath River inundation elevations on Bear Creek delta at several Klamath flow rates.

Klamath River flood stages. Short (1987) and Madej (1987) have demonstrated that some logging practices combined with major storm events could result in catastrophic volumes of sediment in streams. Ziemer (1981) has shown that there appears to be a critical time period of diminished soil shear strength after logging (between root decay of harvested trees and recovery of mature vegetation) when land is particularly susceptible to landslides during prolonged, high intensity rainstorms. Considering possible variations due to rainfall, geology, tree species, and aspect, Roach, Tectah, and Bear Creeks are likely to still be within this critical time period.

Although watersheds generally recover from land disturbances which cause surface erosion in about 10 years, other factors such as debris avalanches near stream channels, poorly constructed and maintained roads, abandoned roads, and channel sediment storage can continue to produce high sediment loads for decades (Madej 1987; Hagans and Weaver 1987). For these reasons, none of the study streams can be considered "stable" in the long term. Recurring large floods are likely to result in phases of delta growth and recovery, but probably to a lesser extent than in the past. Future delta configurations will be largely determined by the continued supply of sediment from the tributary watersheds. Over a 20 to 30 year time frame, the deltas are generally likely to decrease in size to pre-1954 dimensions as floods remove the channel-stored sediments (assuming no additional land disturbances). In Tectah Creek, the presence of numerous active debris avalanches may delay recovery until the features stabilize.

Field reconnaissance, aerial photography, and hydraulic calculations clearly indicate that the stream channels crossing the deltas are quite unstable and will frequently change location. Given the nature of the channel material (i.e. easily transported sand and gravel) and the geomorphic reasons for delta formation (decreased stream gradient and sediment deposition), this instability is expected to cause channel migration each year and even after storms within each year. With Klamath River flows of 15,000 cfs or more (that inundate the deltas) and high flows in the tributaries, any manmade channels, structures, or other alterations made to improve fish passage would be rapidly covered with sediment. During periods of low flow in the Klamath and moderate to high flows in the tributaries, erosion or lateral migration of the stream channel is likely to undermine or abandon any improvements.

Our observations of the deltas also suggest that fish access to these tributaries is more limited by the timing and extent of rainfall than by the physical characteristics of the deltas. In October of 1988, Roach Creek had water flowing at its mouth (estimated at less than 0.5 cfs) while Bear Creek and Tectah Creeks were dry for approximately one mile upstream. Following a major storm in November of 1988, all three streams had flows in excess of 15 cfs. At Tectah Creek, detritus hanging in riparian vegetation showed that the entire delta had been inundated during and after the storm. By December the main river had receded enough to re-expose all the deltas. Even though each stream had cut new channels and some were more braided than others, in no case would adult salmonids have been physically denied access.

Flow records between 1966 and 1978 for Blue Creek, a 120 square mile basin which enters the Klamath River just downstream of Bear Creek, were examined to determine typical starting dates for increased tributary stream flow. The earliest date for significant flow to occur in the lower Klamath watersheds was October 17, and the average date was the first week in November. In view of the timing of Klamath flows, tributary channel alteration could be of some value to migrating fish if the first fall rains increase tributary flow but do not raise the Klamath. For the range of flows and velocities calculated for the study streams, average annual flows would cause rapid erosion, downcutting, and lateral channel migration within the sands and gravels of the deltas. Artificial or improved channels constructed on the deltas would be relatively stable only if the channels had predominantly cobble beds. The channels would be re-worked by higher flows nearly every year, except in extreme drought years such as 1977.

Bear Creek differs from Tectah and Roach in that the stream presently empties into the Klamath by flowing across a major Klamath River gravel bar. As such, the configuration of the Bear Creek delta is subject to instabilities not only from its own sedimentation, but also to that of the Klamath. Physical alteration of such a site is especially likely to be ineffective due to the larger-scale processes that affect the main river bar.

CONCLUSIONS

Construction of man-made structures to develop or maintain channels for fish migration across the deltas of the study streams would only be at best a temporary solution. The mobility of gravels in the deltas would allow the streams to rapidly erode or abandon any physical alterations. Even if structures had been present on Bear and Tectah Creeks in the fall of 1988, they would not have provided access to the streams any earlier than became available after the fall rains because the tributaries were dry before that time. Other solutions, such as delta excavation and disposal, would be very expensive and ineffective due to the volume of sediments stored in the tributaries that would allow the deltas to quickly rebuild. The deltas now appear to be eroding naturally and should ultimately stabilize at a smaller size, depending on the nature of continued watershed disturbances and the severity of natural floods.

In years when sufficient stream flow is available above the deltas to sustain spawning salmonids and access is difficult or restricted due to channel braiding, selective application of light explosives, suction dredging, or hand labor could temporarily consolidate braided flow into a single, deeper channel. Application of these methods should be based upon site-specific evidence that spawning adults are unable to negotiate the delta and that upstream habitat is available in sufficient quantity and quality to ensure the survival of spawners after they gain access.

RECOMMENDATIONS

1. A monitoring program should be established that would annually check the condition of all deltas and track the flow of the tributaries and the Klamath River beginning with the first significant storms in late September or October. In years when the stage of the Klamath is low, tributary flow is reaching the river, and channels across the deltas are shallow and braided, corrective action could be taken on a site-specific basis.

2. Tributary watersheds should be surveyed to identify and quantify major existing and potential sources of sediment and remedial actions should be devised in cooperation with landowners and land managers as a long-term solution to the problem of delta formation.

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