Reconnaissance-Level Investigation of Sediment Sources and Channel Morphology, and Recommendations for Management, Pine Creek, Shoshone County, Idaho

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20 June 1996

INTRODUCTION

A series of high flows occurred in northern Idaho in 1996, the greatest of which were the floods of February 7-13th. Damage in Shoshone County was estimated at $5-7 million. On Pine Creek, some residents were evacuated, others were stranded by floodwaters (FEMA 1996). Existing levees failed to protect the town of Pine Creek from the floodwaters. In response to the flood damage, an Interagency Hazard Mitigation Team identified excessive bedload sediment and channel instability as contributors to flood problems in the region (FEMA 1996). Congress appropriated funds for channel works on Pine Creek to address problems of bedload deposition and channel instability.

PURPOSE AND SCOPE

The purpose of this study was to provide reconnaissance-level overview of geomorphic and hydrologic processes in the Pine Creek watershed based on a two-day site visit, to provide a preliminary and qualitative review of historical information, and to suggest management strategies at a conceptual level.

METHODS

Due to the reconnaissance level of our scope, we did not undertake any quantitative measurements in the field or office. Our priority was to place the watershed in its geomorphic and hydrologic setting, particularly to attempt to understand the nature and underlying causes of recent channel change.

We examined aerial photographs for various years from 1933 to 1991 (Table 1), from the collections of BLM, US Forest Service, and Shoshone County, as compiled for this study by BLM staff. These photographs were at various (unspecified) scales. Given the limited nature of our scope, we did not make measurements from the photographs or conduct mapping (e.g., using zoom-transfer stereoscope). We compiled sequential photo sets for three reaches, the Liberal King mine reach on the mainstem, a reach from the Calusa Creek confluence to the Langlois Creek confluence on the West Fork, and from the West Fork confluence upstream to the Hunter-Trapper Creek confluence on the East Fork (Figure 1). These reaches were selected as representative reaches based on knowledge of BLM staff and as sites that could be accessed by vehicle or foot. For those reaches we conducted a qualitative evaluation of channel change based on patterns on the aerial photography and from our field observations.

We also examined topographic maps, including the current USGS 7.5-minute quadrangle sheets, and the topographic base map (ca 1937) used in a geological report. BLM staff measured data points for a longitudinal profile from the topographic maps.

We reviewed two previous reports on Pine Creek flooding problems: 'Damage assessment for the West Fork of Pine Creek, Shoshone County, Idaho' by Geomax (1991), and a partial copy of 'Flood insurance study, Shoshone County, Idaho' by the Department of Housing and Urban Development (HUD 1979).

We conducted an aerial reconnaissance of the watershed by light aircraft, following most branches to the divide. In this reconnaissance, we looked primarily for sediment sources and pathways. We also shot oblique photographs of the channel at various points.

We spent two half-days in the field, examining the East and West Forks of Pine Creek. We concentrated our efforts in the West Fork because of the flooding problems experienced by homes in that drainage. We walked various sections of the mainstem West Fork and tributaries (Langlois, West Fork, Middle Fork, and Calusa Creeks).

BLM staff were extremely helpful in obtaining materials needed to conduct this study, providing background information, in measuring the longitudinal profile, and facilitating field work.

RESULTS

Watershed Setting

Pine Creek drains 79 square miles (mi^2) in the St. Joe Mountains, joining the South Fork Coeur d'Alene River at Pinehurst in Shoshone County, Idaho. Elevations range from 2160 ft at the confluence with the South Fork Coeur d'Alene River, to 6408 ft on Latour Peak on the west and about 5000 ft on the St. Joe Divide to the south. Annual precipitation ranges from 35 inches near Pinehurst to about 60 inches at the divide.

Pine Creek has two principal forks, which join about 6 miles upstream of Pinehurst (Figure 1). The West Fork drains 39.3 mi^2, with an average gradient of 1.5 percent in its main channel over the 5.5-mile reach from the Calusa Creek confluence to the East Fork confluence. Its principal tributaries are Ross Gulch, Langlois Creek, Middle Fork, and Calusa Creek. The West Fork is shown on the USGS 7.5-minute topographic map as the mainstem 'Pine Creek' up the to confluence of the Middle Fork, West Fork, and Calusa Creek, but to distinguish it from the East Fork, the term 'West Fork' is commonly applied to the entire channel down to the East Fork confluence. The town of Pine Creek was established on the lower portion of the West Fork floodplain (just upstream of the East Fork confluence) beginning in the 1940s.

The East Fork is the smaller fork, draining approximately 35 mi^2 (not measured), with an average gradient of 1.7 percent over the 3.9-mile reach from Masonia to the West Fork confluence. The basin is mostly uninhabited at present, although it contains many mine sites (including Masonia) reflecting intensive historical activity. Its principal tributaries are Highland Creek, Douglas Creek, Trapper Creek, and Hunter Creek.

Flood History

Pine Creek is ungauged, but the history of major floods as of 1979 was reconstructed from historical accounts and regional patterns by HUD (1979). Major floods occurred in 1894, 1896, 1917, 1933, 1938, 1964, and 1974. For northern Idaho, FEMA (1996) reported that disaster declarations were issued 13 times since 1956: 1956, 1957, 1960, 1961, 1962, 1963, 1964, 1972, 1974, 1976, 1980, 1984, and 1996. The 1996 flood has apparently been estimated by the U.S. Geological Survey as a 25-50 yr flood (Mike Stevenson, BLM, Coeur d'Alene, personal communication 1996).

Geomorphic Setting

The Pine Creek basin is underlain by Precambrian Belt Series metasedimentary rocks, which yield bedload sediments dominated almost entirely by quartzite. The basin is predominantly mountainous, with relatively little flat land available for settlement. Stream gradients are steep. In the upper watershed bedrock controls are locally important.

Significant events influencing geomorphic processes in the basin include a fire in 1910 that reportedly burned primarily ridge-tops, a fire in 1924 that reportedly burned only the East Fork drainage, but which burned down to the channel, extensive grazing by 100,000s of sheep on ridge-tops from the 1920s to the 1950s, harvest of large cedars from the valley floors around the turn of the century, recent timber harvests (from the 1950s to present) on steep slopes primarily of the West Fork, intensive mining and discharge of tailings directly into stream channels primarily in the East Fork and its tributaries, and channelization works in the lower 2.3 miles of the West Fork. In addition to these events, the large floods reported above have been important agents for geomorphic change, transmitting the effects of human activities downstream.

Aerial Photograph Review

West Fork from Langlois Creek to Calusa Creek Confluence

In 1933, this reach had virtually no open channel upstream through the confluence of Calusa Creek. Floodplain surfaces were well vegetated despite that fact that the large cedars had been harvested by this time. Unfortunately, we do not know the date of the 1933 photographs, and the contrast is poor, as illustrated by the excerpt presented in Figure 2. Examination of the original aerial photograph print provides adequate resolution to identify features. The lack of open channel upstream of the Langlois confluence would indicate either a lack of prior large flood events, or a lack of large sediment inputs, or some combination of the two. These photographs predate the major flood in December 1933, which was the flood of record in the St. Joe River near Calder and the South Fork Coeur d'Alene River.

It is notable that downstream of the second county bridge, the channel was sinuous, flanked by extensive and mature riparian vegetation in many areas. Braid channels were evident in a number of areas, particularly upstream of the confluence of Ross Gulch, and an overflow channel is evident on the right bank floodplain through what is now developed land.

In 1957, the channel was somewhat more open at the confluence of Calusa Creek and at a number of points downstream (Figure 2). These changes are noticeable but small. However, beginning at a point about 1000 ft upstream of the Langlois Creek confluence, the channel is noticeably more open and has clearly visible meanders. The open channel continues downstream in essentially the same configuration as in 1933, although a left bank braid upstream of Ross Gulch was abandoned, and islands are newly visible at several points between Jackass Gulch and Ross Gulch.

The 1957 photos also show extensive logging on the southern slopes of Langlois Creek and in the Ross Gulch drainage. The slopes to the east of the channel have considerably greater tree cover than in 1933, presumably reflecting recovery from the 1910 and 1924 fires.

The 1968 photos show open channel the entire length downstream of the Calusa Creek confluence (Figure 2). In many locations, the channel is narrow, and the meanders appear to be migrating downstream. In several reaches, the channel has widened dramatically, presumably aggrading. This channel widening presumably reflects the effects of the December 1964 flood. These flood flows also jumped the main channel and flowed down the road along the west side of the valley for a distance of about 6,000 ft, rejoining the main channel at the confluence of Langlois Creek. Below the second county road bridge, channelization had been undertaken, but this work was evidently ineffective, as evidenced by channel widening and migration in a number of places.

In 1975, very little change is evident from 1968 conditions overall, but a number of specific changes from the 1974 flood are evident (Figure 2). For example, the 1974 flood flowed down the road and also through the wooded right bank floodplain about 2000 ft downstream of the Calusa Creek confluence. The channel margins of the open meander sequence of 1968 had been colonized by young riparian vegetation. At the Langlois Creek confluence, the main (right) channel appears to have become the less used channel and is more vegetated. Downstream of the second county road bridge, there was extensive damage to the levee system, including several new breakouts upstream of Ross Gulch. One new channel developed to the left of the main channel along the lines of the braid channel noted in 1933. This channel provided a straighter course for the river, and was used as the main channel when the levees were strengthened and rebuilt following the 1974 flood.

The rebuilding of the levees was undertaken by the US Army Corps of Engineers, and appears mostly complete by the 1975 photographs. Extensive logging is evident between Langlois and Ross Gulch. Logging roads cover virtually the entire slope on the north side of Langlois Creek, and the harvested slope of 1975 appears quite different from the well-treed slopes visible in 1968.

By 1984, the left channel flowing down the road (from the Calusa Creek confluence) appears to have been abandoned and flow had returned to the right channel, although it followed some new courses in the riparian zone (Figure 2). Channel widening had occurred and the meander pattern was altered from many tight meanders to fewer large wavelength meanders. In 1991, the channel had continued to widen, but in general showed little change from 1984 (Figure 2).

East Fork from West Fork Confluence to Highland Creek Confluence

In 1933, the active channel only partially occupied the alluvial valley bottom, and floodplain areas appear to be sparsely vegetated but are in distinct contrast to the open active channel (Figure 3). It is notable the that slopes have very little vegetation, presumably reflecting the effects of the 1924 fire (which reportedly burned to the valley bottom in the East Fork) and possibly the effects of sheep grazing.

In 1956, the channel had widened dramatically, with much of the sparsely vegetated floodplain areas visible in 1933 having become open gravel bars (Figure 3). The channel had straightened considerably. An alluvial fan is evident from Nabob Creek. Sediment delivery from other mined tributaries (such as Highland and Denver Creeks) is reflected by alluvial fans at the tributary mouths.

By 1968, only scattered remnants of floodplain areas remained (Figure 3). The active channel appears to migrate across most of the valley floor. In 1975, the channel appeared to continue to migrate across its bottom land from which virtually all vegetation had been removed. Tailings from mines are visible, and a widened part of Nabob Creek is evident some distance upstream.

By 1983, the channel had become braided, migrating back-and-forth across valley bottom (Figure 3). By 1991, a small amount of vegetation had become established at a number of locations, presumably reflecting the river's response to a lack of floods (Figure 3), and few other changes are evident.

Liberal King Reach

In 1933, the channel was sinuous and much narrower than the current channel, braided at the Liberal King mine, and flowed through an area along the left bank now occupied by tailings. Some gravel bars were open and unvegetated, but most were vegetated. The floodplain was vegetated, and appeared to contain some large trees.

By 1956, the channel had widened, with more unvegetated bars and fewer vegetated bars. The channel was less sinuous, and it had shifted to the east at Liberal King Mine, eliminating the braided channel downstream of the mine.

In 1965, the meanders downstream of the mine had greater amplitude and wavelength, with lateral migration into a partially vegetated (and thus formerly somewhat stable) floodplain surface. A new channel was cut (apparently during the December 1964 flood) to the west upstream of the Pine Creek highway bridge crossing, leaving a vegetated floodplain remnant as a island. Riprap had been placed to protect the highway. In 1968, the channel had shifted eastward against the hillslope downstream of Liberal King Mine, and the west braid at the island (upstream of the bridge) appeared to contain a large percentage of the flow. A junkyard was constructed on active flood deposits and occupied about 90 percent of the floodplain width at that point.

In 1975, the channel had widened upstream of the Liberal King Mine, with erosion of vegetated floodplain surface near the residence. The junkyard was eroded, and junk cars rearranged, by the 1974 flood. The main channel remained on the right side of the valley floor at the mine. Most flow was in the west braid at the island, with the channel directly adjacent to the highway riprap.

In 1983, some additional widening was evident, the braid upstream of the mine was more distinct, and the tailings pile was distinctly visible. What appeared to be an instream mine was operating downstream of the tailings pile.

In 1991, the active channel had shifted from the west channel to the east channel at the island upstream of the bridge. the west channel was filled with young vegetation. The channel continued to widen towards the residence on the left bank upstream of the mine and began to erode the tailings area.

Field Observations

It should be emphasized that our field observations were limited in scope to those areas readily accessible by foot in the short period of our field work, and did not involve any quantitative measurements. It was evident that significant changes had occurred in the study area since 1991. Based on our limited review of the recent hydrologic record, it appears that most of this change occurred during the various high flows of December 1995-April 1996.

West Fork from Langlois Creek to Calusa Creek Confluence

There has been considerable change in this reach since 1991, presumably mostly occurring in the floods of 1996. Aerial photographs for post-1996 flood conditions are not yet available, but from our overflight and field inspections it is clear that the channel has continued to widen and remove riparian vegetation, and appears to be highly unstable. We observed large, coarse-grained gravel and cobble bars with woody debris accumulations, braided channels, and undercutting of cedar stumps, all of which act to direct flows into streambanks or hillslopes where vegetation is undermined and additional sediment is entrained (Figure 5).

East Fork from West Fork Confluence to Highland Creek Confluence

There appears to have been relatively little change in this reach since 1991, and the channel has continued to shift rapidly back-and-forth across the valley bottom. Tributaries continue to deliver large volumes of sediment, most of which presumably occurred in the floods of 1996 (Figure 6). From our overflight and field inspections it is clear that the channel continues to be highly unstable. Unlike the West Fork which has stands of riparian vegetation that act to slow the progression of instability, the East Fork contains essentially no significant remaining areas of mature riparian vegetation. We observed large, coarse-grained gravel and cobble bars throughout the reach. There are very few cedar stumps remaining in the East Fork, and there are few other channel elements capable of constraining the channel migration.

Liberal King Reach

From our aerial overflight and ground observations, we observed that the channel had further eroded the left bank in 1996, entraining a vehicle behind a residence along the left bank. Several other vehicles are about to fall into the channel, and the residence is threatened if erosion of this bank continues(Figure 4). Riprap had been placed to protect the tailings temporarily until they could be relocated. The young vegetation in the west channel downstream was scoured and flow occupied both channels, and a meander had begun eroding into the island, undercutting mature riparian trees. Young vegetation remained on mid-channel bars upstream of the established island (Figure 4). Flood waters eroded a portion of the left bank at the junkyard and again entrained various vehicles (Figure 4), depositing them in the channel or on mid-channel bars just downstream.

DISCUSSION

Sediment Sources

On the East Fork, sediment sources are fairly obvious: mining-affected tributaries are contributing large sediment loads, as evidenced by large fans and recent road washouts, and mine tailings have been dumped directly into the main channel. This mining-related sediment has been produced and available to affect the channel since the turn of the century. Aerial photographs (Figure 3) indicate that much of the sediment had not reached the main channel until after 1933. This suggests that there was a lag between production of the sediment and its delivery to the main channel, which could be related to an apparent relative lack of large floods before 1933. Floods were reported only in 1894, 1896, and 1917, and their magnitude is unknown (HUD 1979).

On the West Fork, the sediment sources are less obvious. There is no one single source or activity that appears to dominate the sediment production and delivery. Instead, increased sediment delivery appears to be a combination of natural production during large flood events, increased runoff and accelerated erosion from timber harvest and road construction in steep tributary watersheds, and destabilization of the valley floor by harvest of large cedars and passage of high flows and increased sediment loads. Grazing and mining may also have contributed to increased sediment delivery, but it is difficult to assess the contribution of these factors.

Increase in Channel Instability Over Time

The East Fork already had an open channel by the time of the 1933 aerial photography, implying the channel was already accommodating increased sediment loads from mining by that time. However, the open active channel occupied only a portion of the bottomland, whereas today this open channel occupies virtually the entire bottomland. This increase in channel instability on the East Fork probably reflects a lag in delivery of sediment to the main channel, the loss of the stabilizing effects of the bottomland cedar forest, and possibly the crossing of a geomorphic threshold (discussed below).

On the West Fork, it is difficult to identify the active channel upstream of the Langlois Creek confluence in the 1933 aerial photography. It appears that the overflow at flood stage may have been accommodated by flowing through the mature cedar forest, with deposition of sediment within the forest. This pattern can be seen today in remnant forest areas along the mainstem West Fork upstream of Langlois Creek and on Langlois Creek itself above the West Fork confluence.

This implies that the cedars and other vegetation were sufficient to stabilize the channel under pre-disturbance conditions, but that the combination of the loss of the mature cedars and decay of their roots (reduction in resistance to erosion) and increase in sediment load (increase in potential erosion and instability) caused these channels to cross a geomorphic threshold and to adopt an unstable, braided pattern. Loss of riparian vegetation has been implicated in causing channel instability in other rivers (e.g., Kondolf and Curry 1986). In areas of uneroded floodplain with remnant cedar stumps, the density of stumps suggests a dense forest of cedar trees, which would probably have formed a cohesive unit, increasing bank and floodplain resistance to erosion, dissipating flood energy, and providing sites for sediment deposition. The cedar stumps probably continue to exert some stabilizing influence for small areas, but the overall effect of the bottomland forest has been lost.

The potential instability of these channels is indicated by its position on the braided/meandering field of Leopold et al. (1964), on which braided and meandering channels are plotted against channel slope and bankfull discharge (Figure 7). For the East and West Forks, the gradients are 1.5 percent and 1.7 percent respectively. The bankfull discharge is unknown, and references with which the 2-yr flood (a potential surrogate discharge) could be estimated using regional relations are unavailable to us, except for the relations for the Salmon River drainage developed by Emmett (1975) and reflecting annual average precipitation of only about 20 inches. Nonetheless, if we assume that the bankfull (or 2-yr discharge) lies between 500 to 1,000 cubic feet per second (cfs), it is clear that both forks of Pine Creek plot well within the braided and straight channel range.

Effects of Channelization

The channelization of the lower 2.3 miles of the West Fork Pine Creek in 1965 and 1974 has complicated the task of reestablishing channel stability. The natural functioning of the floodplain in this area has been eliminated, and the narrow channel acts as a conduit for flow and sediment until it reaches the obvious hydraulic control at the first bridge over the West Fork (the 'Barkerville Bridge') and the bedrock outcrop just downstream. Floodplains act as dissipators of energy by their relatively high roughness values, and provide storage areas for both floodwater and the sediment carried by these flows. Currently, once flow and sediment enter the channelized reach at the second County Road bridge, there is little opportunity for sediment storage and/or a reduction in stream energy. Unfortunately, the town of Pine Creek could hardly have been located in a worse place, as the West Fork goes through a narrow constriction before joining the East Fork. This area has probably always acted as a hydraulic control at high flows, forcing the deposition of sediments to form a wide floodplain just upstream.

Channelization, typically straightens and narrows the channel and increases the gradient, forming a smoother, steeper channel that dissipates less stream energy and thus typically increases flow velocity. The increased velocity is capable of transporting larger grain sizes and more sediment. This may lead to the migration of a knickpoint upstream. It is not clear, without profile surveys, whether this has been a contributing factor in the channel instability upstream of the channelized reach, as the tendency towards downcutting may be overwhelmed by the increased sediment delivery.

Conclusions and Recommendations

It should be emphasized that our conclusions are based on a brief (2-day) reconnaissance of the Pine Creek watershed and readily available historical information. Some of our preliminary interpretations may require modification based on more thorough work. Given the complexity of the processes here and likely cost of engineering measures to address flooding and channel instability, a thorough historical geomorphic study (Kondolf and Larson 1995) should be undertaken before resources are committed to proposed solutions. In addition, restoration design at specific sites will require accurate site specific information such as detailed channel topography, bed and bank material size, hydraulic modelling (if appropriate), and information on depth to groundwater during dry season. Another task is compilation of all previous relevant work and existing information, such as the US Army Corps of Engineers hydrologic and hydraulic study referred to on p.25 in HUD (1979), the details of the HEC-2 model used in the flood insurance study (HUD 1979), and flow records for comparable and nearby drainages as a basis for estimating flows on Pine Creek.

Elements in this historical study should include quantitative analysis of historical aerial photographs and historical maps, inventory of sediment sources, detailed longitudinal profile, resurvey of cross sections surveyed for the flood insurance study (HUD 1979), interviews with long-term residents, location and reoccupation of old ground photographs, resurvey of channel cross sections at bridges for comparison with channel geometry at time of construction, and analysis of field geomorphic and vegetative evidence for former channel conditions (Kondolf and Larson 1995).

Based on the evidence presented here, we hypothesize that a geomorphic threshold was exceeded in East Fork first, the West Fork later, as a result of decreased bank and floodplain stability resulting from loss of the floodplain forest, and increased sediment loads and a number of large flow events in the last fifty years. Unfortunately, given the changes in sediment delivery resulting from various watershed changes (mining, grazing, timber harvest, and road construction) and remobilization of channel and floodplain stored sediment, restoration measures cannot be successfully planned without accounting for how future sediment delivery is likely to affect project sites. Moreover, there is a lag time inherent in this system: coarse sediment moves through the alluvial reaches of a river system slowly (reflecting the infrequency of floods capable of transporting the coarse fraction), so a potentially long period would be required to flush it through the channels. The potentially long wait necessary for flushing the sediment is an argument for undertaking measures to stabilize the deposits in place. The potential impairment of flood control infrastructure from the movement of large volumes of sediment into downstream reaches of Pine Creek near Pinehurst (with its more extensive floodplain settlements at risk) also argues for stabilizing deposits in place upstream.

A wide range of management approaches is possible, ranging from buy-out of residents in the West Fork and allowing the channel to evolve over a long period of time, to intensive and expensive channel stabilization and sediment source reduction measures, as well as intermediate level interventions. Because we infer a geomorphic threshold has been crossed, and because accelerated sediment delivery is ongoing, it is unlikely that the channels will 'heal' themselves in the near future. The various reaches have different constraints, and thus different options available. In the paragraphs below, we present various options for different reaches. Ultimately, the choice of specific options for various reaches should be made utilizing a comprehensive planning approach, based on sound scientific understanding of the controlling processes, and reflecting the needs of the stakeholders and the resources required for the long term success of the program. Any program that involves engineered structures to protect property should also have a cost-benefit analysis completed that incorporates the long-term maintenance costs of attempting to control river behavior in such an unstable system.

In general, we would have more faith in efforts to train or influence the river rather than those that seek to control the river, because the latter involve considerably greater commitment of resources and tend to work against the river rather than with it.

West Fork Road Bridge No. 1 (The 'Barkerville Bridge")

The hydraulic model used in the HUD (1979) analysis indicated that the existing levees provide only about 50-year protection to the floodplain development. This model (HEC-2) cannot take into account sediment deposition or debris clogging of bridge openings, and may therefore indicate a greater level security that actually exists with the upstream conditions which provide such a high sediment and debris load. Any program to maintain the existing structures (channel, levees, and bridge) will have high long-term costs given the instability of the channel upstream.

Continue Gravel Mining. We understand that until the early 1990s, aggraded gravel was removed from the depositional reach under and upstream of this bridge on an annual or as-needed basis under auspices of Shoshone County. Excavation of gravel from the channel helps to maintain channel capacity at least for moderate floods. However, during large floods it is possible that even a recently dredged channel can aggrade enough to cause overtopping of the adjacent levees, or at least cause debris clogging of remaining bridge opening with similar consequences to the February 1996 event. If gravel is to be removed, the excavation should not exceed the depth of the design channel. This depth has been estimated at 8 ft under the bridge, and appears to diminish upstream towards Ross Gulch bridge.

Raise Bridge and/or add channel capacity. If the bridge were raised several feet and/or if the channel capacity were increased in the vicinity of the bridge, the likelihood of bridge failure or overtopping would be greatly reduced, and the consequences of sediment aggradation under and upstream from the bridge would be lessened. The cost of work, such as bridge replacement, is high and may not be justified on economic grounds.

Remove Bridge and install concrete ford. An approach frequently used in areas that experience high sediment and debris loads and where high flows are of short duration or occur when access is not necessary, involves installation of a concrete ford instead of a bridge. With a ford, there is no obstruction to the passage of sediment or debris, and cleanup only involves removal of any sediment accumulated on the concrete surface. The bridge upstream near Ross Gulch could be available for access for local residents, and is in an area with much lower risk of failure.

Remove and/or setback levee on left bank. A more extreme option would be to either remove the left bank levee, or at least relocate it away from the existing channel to allow substantially more channel capacity. This would involve buy-out and/or relocation of a number of structures in this part of the floodway. It would also involve modifications or removal to the bridge.

West Fork Channelized Reach

Channelization of the lower 2.3 miles of the West Fork of Pine Creek has eliminated energy dissipation, flood storage, and sediment deposition functions of natural floodplains. Sediment entering the channelized reach has no opportunity to deposit until affected by backwater near the Barkerville Bridge, where its deposition threatens the functioning of the bridge and flood control levees.

Remove upstream right bank levee on BLM land. The section of the levee from the County Road bridge #2 downstream about 3000 feet serves little purpose except to isolate a significant amount of floodplain from interaction with the stream channel. There are no structures protected by this stretch of levee. This area of floodplain could be allowed to store both water and sediment by lowering of the levee sufficiently to allow overbank flow during moderate storm events. A section of tie-back levee would need to be constructed upstream of the first residence to prevent outflanking of the remaining levee, although this could be done using riprap removed from the existing structure. The lowermost 2 to 3 feet of riprap, up to a point level with the adjacent floodplain, could be retained to constrain the lateral migration of the channel while allowing overbank flow. Reducing the length of the channelized reach could result in less sediment reaching the downstream bridges, particularly when implemented in conjunction with an upstream stabilization program.

Remove the right bank levee downstream to Ross Gulch. A more extensive option that the one above, this would involve removal of about 7000 feet of levee from County Road bridge #2 downstream to Ross Gulch, which is the start of the more densely developed right bank floodplain. There are several homes in the area where the levee would be removed, and these would either need small ring levees or some other form of protection. This option would remove over 60% of the existing channelized reach, thereby allowing a functioning floodplain in all but the lower 4000 feet of the West Fork.

Remove large woody debris from channel or secure along banks. Large woody debris stored in the active channel has the capability of being mobilized during high flows and causing clogging problems at bridge openings downstream. Large trees that have been eroded upstream and deposited on gravel bars in the channelized reach should be removed or secured using cable and/or riprap along unstable banks.

Plant riparian vegetation along the toe of the levee. Where the channelized reach is sufficiently wide to allow planting of a narrow band of riparian trees at the toe of the levee, vegetation growth will act to reduce velocities against the riprap, and thus reduce the possibility of failure during large storm events. The US Army Corps of Engineers does not currently allow vegetation on the channel side slope or top of the levees they maintain. The benefits of the vegetation can be seen along the toe of the right bank levee downstream from Ross Gulch bridge. Here the vegetation absorbed much of the impact from high velocity flow while protecting the riprap slope of the levee.

West Fork Upstream to Calusa Creek Confluence.

This reach of the creek appears to provide much of the sediment and debris load that affects downstream areas. The continued cycle of progressive instability is likely to have adverse consequences downstream, not to mention the loss of riparian habitat in the reach. Undertaking a stream restoration program in such an unstable environment is not simply a matter of installing structures and planting vegetation. A ongoing program will be necessary to achieve long-term success. Failures will undoubtedly occur, but with proper monitoring and evaluation, the lessons learned will improve future efforts. The restoration concept should focus on stabilizing in-place sediment deposits and reducing the lateral migration of the channel into streambanks and hillslopes from which additional sediment is contributed to the creek.

Bank and floodplain stabilization program. The program should involve utilizing as much on-site material as possible, developing bio-technical bank protection designs that incorporate logs, cedar stumps, and boulders. The design could use a series of hard points to direct flows away from unstable banks and to train the creek into a sinuous single thread channel. The hard points may at times be continuous along a bank, but more often would act as deflectors (also known as spurs, groins, dikes or barbs), periodically placed. The structures will create areas where riparian plantings will have the highest probability for success. These structures could also be located to maximize the benefit from existing remaining riparian vegetation. In the long-term, the most important component of such a program will be the successful restoration of a dense riparian zone on the stabilized gravel bars and rebuilt floodplains. In those areas of the channel that do not have perennial flow, the depth necessary for riparian plantings to have access to continuous moisture must be determined. It is beyond the scope of this reconnaissance-level investigation to provide any specific design information.

East Fork Pine Creek

Heavy sediment loads from mines and mining-affected tributaries have destabilized this reach to a greater extent than the West Fork has been affected. Thus, stabilization approaches must address sediment sources. Design of structures in the active channel must recognize that the active channel is prone to migrate across the valley bottom; structures may encourage the channel to stay in one location, but they should be designed so as not to be vulnerable to outflanking. Elevations of remnant cedar stumps suggest that aggradation in the channel has been limited, but the potential for burial of structures by sediment must be investigated before substantial investments are made. No structures are threatened (except the road), so the primary goal of stabilization here would be to reduce sediment loads to populated downstream reaches.

Stabilize mine tailings in tributary channels. The success of a restoration program on the East Fork will depend to a significant degree on the amount of sediment that is generated by the major tributaries. Efforts should be made to stabilize in place, as much of the sediment stored in or adjacent to the tributary channels. This work would likely involve construction of check dams and other grade control type structures at appropriate locations along the tributary channels. Vegetation should be planted to stabilize sediments where feasible.

Channel and floodplain stabilization program. A similar program to that described for the West Fork could be undertaken along the East Fork. There is much less on-site material available for use in bio-technical structures, and it would appear that riprap and/or gabion deflectors and grade control structures would be necessary. Grade control structures are an effective, but expensive option. Such structures have been utilized successfully in many environments with high sediment loads. Given that the East Fork is more unstable than the West Fork, a demonstration project to test various techniques may be useful before committing large amounts of resources. All restoration projects have a variety of techniques available, with significant trade-offs between risk and cost. Those methods with the greatest risk emphasize vegetation plantings and few structures, and as a result, cost substantially less. Engineered structures have less risk, but cost many times what vegetative solutions do.

Mainstem Pine Creek, Liberal King reach.

Several residences are threatened with erosion in this reach, which appears to be caused by the deposition of mid-channel bars and channel braiding from sediment generated upstream that is beyond the capacity of the channel in this reach to transport. In addition, mine tailings are threatened by lateral migration of the channel. Erosion of the tailings would have downstream water quality impacts.

Channel stabilization. The tailings need to be removed before the next high flow season, after which a stabilization program could be implemented to reestablish a channel more capable of carrying significant sediment loads without the creation of mid-channel bars and resulting lateral instability. The project would also protect the existing residences from further property loss, and train the channel to exit the project reach through the County Road bridge downstream with a more stable alignment. Such a project would involve channel grading, installation of riprap deflectors and extensive riparian revegetation.

REPORT LIMITATIONS

The reader should bear in mind that this report is a reconnaissance-level investigation, based on two days of work, and does not purport to be a design document. G. Mathias Kondolf and W.V. Graham Matthews provide their findings, recommendations, and conclusions after preparing such information in a manner consistent with that level of care and skill ordinarily exercised by members of the profession practicing under similar conditions in the fields of hydrology and fluvial geomorphology. This acknowledgment is in lieu of all other warranties either expressed or implied.

REFERENCES CITED

Emmett, W.W. 1975. The channels and waters of the upper Salmon River area, Idaho. *US Geological Survey Professional Paper 870-A*.

FEMA (Federal Emergency Management Agency). 1996. Hazard mitigation report with early implementation strategy, northern Idaho flooding of 1996. Report No. FEMA-1102-DR-IDAHO.

Geomax. 1991. Damage assessment for the West Fork of Pine Creek, Shoshone County, Idaho. report to BLM by Geomax, Bozeman, Montana.

HUD (Department of Housing and Urban Development). 1979. Flood insurance study, Shoshone County, Idaho, unincorporated areas. March 1979.

Kondolf, G.M., and R.R. Curry. 1986. Channel erosion along the Carmel River, Monterey County, California. *Earth Surface Processes and Landforms*, 11:307-319.

Kondolf, G.M., and M. Larson. 1995. Historical channel analysis and its application to riparian and aquatic habitat restoration. *Aquatic Conservation*. 5:109-126.

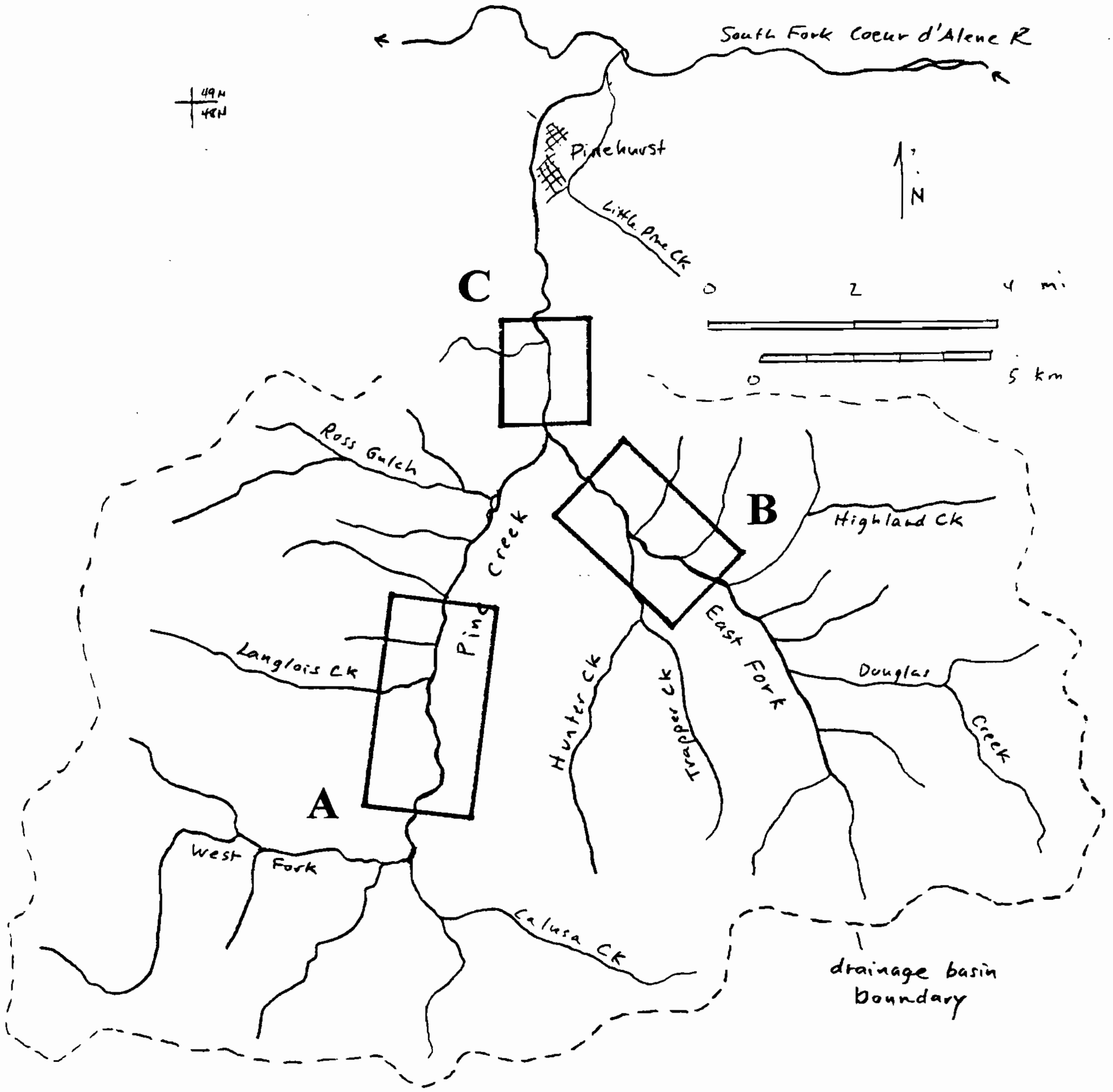
Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman & Sons, San Francisco.

TABLE 1

List of Aerial Photographs Used in this Study
(Scales varied and were not determined)

YEAR	DATE	AGENCY	NOTES
1933	No Record	ASCS ?	Coverage not complete for upper reaches, some enlargements available from Shoshone County
1956-57	Sep 1956 Aug 1957	ASCS ?	
1965	No Record	No Record	
1968	July	ASCS ? USGS?	9 x 9 prints and enlargements available. Flight ETM
1975	Sep	No Record	Small scale
1981	No Record	USDA	
1983-84	Aug 1983 Jul 1984	USDA	Identifier No. 611040
1991	Sep	USDA-F	Identifier No. 611040

FIGURE 1
Pine Creek drainage basin, showing reaches selected for more detailed aerial photo analysis.

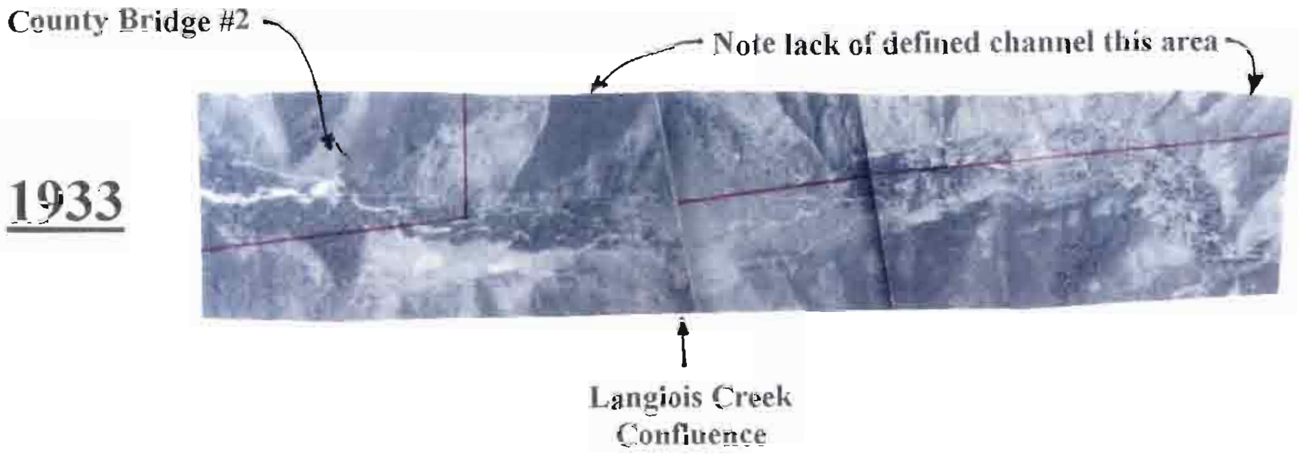


A. West Fork between Calusa Creek confluence and Langlois Creek confluence
B. East Fork between Douglas Creek confluence and West Fork confluence
C. Liberal King mine reach.

FIGURE 2

Historical vertical aerial photographs of the West Fork Pine Creek from a point downstream of the Calusa Creek confluence to County bridge #2 downstream of the Langlois Creek confluence

1933



1956

Some channel widening, particularly downstream Langlois Creek confluence. Still lack of defined channel in most of the reach upstream of that point.

1968

Channelized reach downstream of County Road Bridge #2. Effects of 1964 flood evident in channel widening. Note flood channel cut following road along upstream of Langlois Creek confluence.

1975

Generally little change from 1968, despite passage of large 1974 flood. Most of flow appears to have been down left channel. Right channel meanders are revegetating opposite Langlois Creek confluence.

1984

Most flow appears to have returned to the right channel. Channel continues to widen in many places. New channel cut through riparian along right side of valley bottom upstream of Langlois Creek.

1991

Left channel now appears abandoned. Main channel continues to widen throughout reach.

FIGURE 4
1968 vertical aerial photograph and 1996 oblique aerial photographs of the
Mainstem Pine Creek in the vicinity of Liberal King Mine

1968

Note much narrower channel upstream of Liberal King mine, compared to present conditions. Car junkyard occupies most of floodplain, including much of active channel. Channel at downstream island is directly against road riprap.

Channel has widened substantially upstream mine. Deposition of mid-channel bar is deflecting flows towards residence on left bank. Vegetation is beginning to establish on center of bar. Tailings protected by temporary riprap to prevent erosion at low to moderate flows. Downstream translation of meander will likely outflank tailings and riprap.

Erosion continues at junkyard. Entrained vehicles are visible on mid-channel bar downstream.

Vegetation becoming established on mid-channel bar, upstream of older island. Vegetation on 1968 channel adajcent to highway is being eroded as meanders translate downstream.

FIGURE 5
1996 oblique aerial photographs and ground photos of the West Fork Pine Creek in the vicinity of the Langlois Creek confluence

View downstream of the confluence of Langlois Creek and vicinity. Wide, shifting unstable channel occurs throughout this reach. One site of hillslope erosion is visible where channel impinges on right side of valley.

View of channel just upstream of Langlois Creek confluence. New channels were cut through riparian vegetation during floods of 1996.

View downstream from confluence of Langlois Creek. Woody debris has been deposited on large gravel bars, assisting in creating blockages and diverting flow towards the streambanks.

Typical view upstream of confluence of Langlois Creek. Large cedar stumps are being slowly eroded and floodplain material remobilized.

FIGURE 6
1996 oblique aerial photographs and ground photos of East Fork Pine Creek and tributaries

View upstream along the East Fork to the confluence of Nabob Creek. Channel shifted across active floodplain during the three storm events in Water year 1996. Remnants of riparian vegetation visible on islands and along margins of channel.

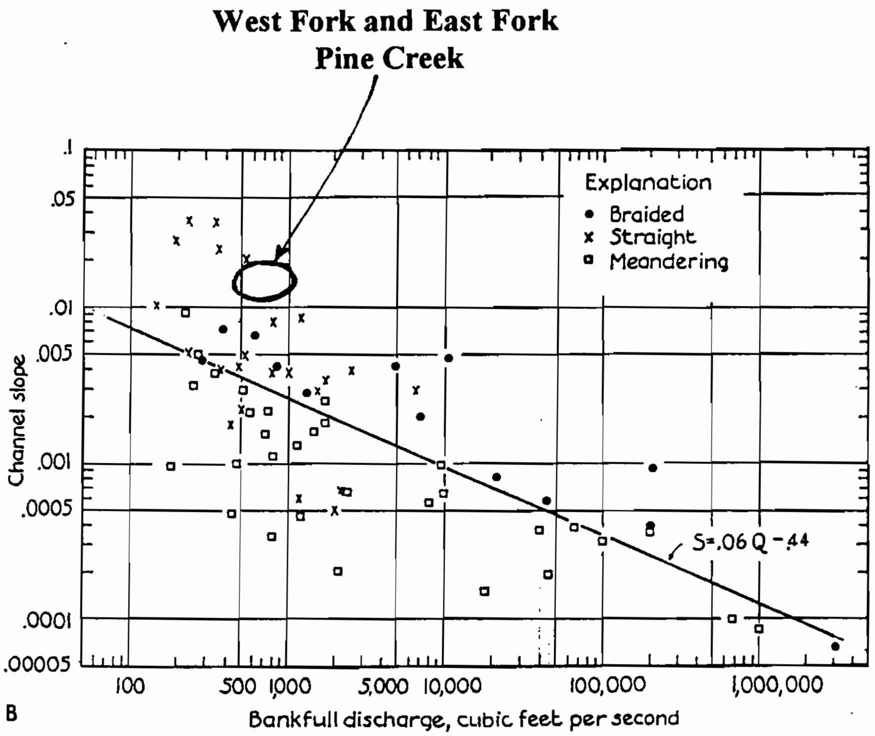
View of sediment fan at confluence of Nabob Creek. Culvert was clogged by large influx of sediment, and overtopped road.

View of Highland Creek confluence. County Road acted as debris dam after undersized culvert clogged. Creek finally washed out road. Note large amount of stored sediment in creek channel upstream.

View upstream of confluence of Highland Creek and washed out County Road. Large tributary sediment input is probably the major factor in the instability of the East Fork channel.

FIGURE 7

Comparison of Pine Creek with Braided/Meandering Planform Relationship to Bankfull Discharge after Leopold et al. (1964)



(From Leopold, et al. 1964)

The gradient of West Fork Pine Creek in its alluvial reach is .015, while the gradient of the East Fork Pine Creek is .017. Although the bankfull discharge is not known, the U.S. Army Corps of Engineers, as reported by HUD (1979), computed the 10-year storm flow for the West Fork as 2255 cfs. Bankfull discharge is commonly found to have a recurrence interval of from 1.5 to 5 years. Based on the COE calculations, bankfull discharge would likely be in the range of 500-1000 cfs. This area is shown on the channel slope versus bankfull discharge from Leopold et al. (1964) above. The West and East Forks plot well into the braided field, indicating that in the absence of bank stabilizing factors such as a dense riparian forest, these channels would likely have a braided pattern.