RECOMMENDATIONS FOR CHANNEL MANAGEMENT, PINE CREEK, SHOSHONE COUNTY, IDAHO

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Introduction

In response to damage from severe flooding in 1996 (FEMA 1996), Congress approved funding for channel restoration in the Pine Creek watershed (Figure 1). In addition, several projects have been approved and funded to prevent mine tailings from eroding into the stream, including stabilization in situ and removal to a repository site at the location of the Upper Constitution Mine.

This report follows on from an earlier reconnaissance-level investigation (Kondolf and Matthews 1996) to propose general approaches to management of these channels in light of what is known about the geomorphic controls on their behavior. Although some questions remain concerning basin hydrology, rates of sediment supply, the history and causes of channel destabilization (especially in the West Fork), some recommendations can be made now in time to be useful in planning and design of projects to be undertaken in fall 1996 and summer 1997. The window remaining for construction in 1996 is only 8-10 weeks, so in developing our recommendations, we have tried to identify projects that can be implemented this season and projects that require more planning and which may involve a longer construction period than available this fall.

Methods

We examined aerial photographs taken in August 1996, and further examined historical aerial photographs of the Pine Creek basin dating from 1933, 1937, 1956, 1965, 1975, 1984, and 1991. We walked the East Fork from the above the proposed repository site upstream of the Upper Constitution Mine to Denver Creek, noting channel conditions as a basis for conceptual design of channel stabilization projects (Matthews 1996). We also drove or walked accessible reaches of principal tributaries including Lower Gilbert Creek, Douglas Creek, Blue Eagle Creek, Highland Creek and its principal tributary Red Cloud Creek, lower reaches of Denver Creek, and lower reaches of Nabob Creek (Figure 2). Less accessible upstream reaches were viewed from a small airplane. We walked the West Fork through the leveed reach on BLM property downstream of County road bridge #2, and upstream beyond the Langlois confluence. Notes were taken of channel conditions on bluelines of enlarged 1996 aerial photographs (scale 1" = 200') provided by BLM staff. A total of 8 person-days were spent in the field in the Pine Creek watershed and in the BLM office in Coeur d'Alene reviewing relevant documents. We also examined other recently constructed channel restoration projects in Ninemile and Canyon Creeks.

We reviewed historical mine development and production figures as reported by Mitchell (1996) to document the relative timing of mine waste production (and its entry into tributary channels).

Field Observations of Sediment Sources, Sediment Delivery, and Channel Destabilization in the East Fork

Effect of Mine Wastes in Increased Sediment Yield

Nabob, Denver, Highland, and Gilbert Creeks all appear to be significant contributors of sediment to the East Fork, and all have mine sites with rock waste piles visibly contributing coarse sediment to the channels (Figures 2 for mine locations, Figure 6 for Highland Creek rock dumps, Figure 9 for Denver Creek rock dumps, and Figure 10 for rock dumps in Gilbert and Nabob Creeks). The implication is that the significantly increased sediment loads resulted from the uncontrolled introduction of mining sediment (Table 1).

Douglas Creek provides a useful comparison with Highland Creek. They are comparable in drainage area (6.3 vs. 5.0 mi^2), relief, basin aspect, and fire history, but they differ in two respects: the presence of sediment storage sites in downstream reaches of Douglas Creek (discussed below) and in mining history. The Douglas Creek basin has not been subject to mining or extensive road construction, while the Highland Creek basin has been heavily mined, involving removal of vegetation, construction of roads and industrial development, and most importantly, discharge of waste rock into the channel (Figure 6). Thus, Douglas Creek illustrates the sediment transport regime likely prevailing in Highland Creek prior to mining and the resultant increased sediment yield, although with a reach in which deposition is more likely before reaching the East Fork channel.

The 1996 floods were estimated to have a return period of 25-50 years (Mike Stevenson, BLM, Coeur d'Alene). Even in an undisturbed drainage basin, such a large, infrequent flood could be expected to transport a relatively large sediment load, as the threshold for erosion and transport of sediment from hillslopes to the channel (and remobilization of sediment in the channel) is exceeded. Our field observations indicate that upper reaches of Douglas Creek were actively transporting bedload and reworking channel deposits, but the channel remained narrow and stable, with fresh sediment deposits only in protected sites behind obstructions, low gradient reaches above controls, and spread out on wooded floodplains (Figure 4). Although no estimates of transport rates could be made, this pattern implies that while the transport rates during this large flood were high, they were not usually so and did not disrupt the integrity of the channel and floodplain configuration in alluvial reaches. As discussed below, most of this sediment was deposited in the alluvial reach before reaching the mainstem East Fork.

In contrast to Douglas Creek, the active, open channel of Highland Creek occupies most of the canyon bottom, with relatively little riparian vegetation remaining. The freshly deposited sediment varies in width, but is commonly 40 to 80 ft wide (Figure 5). We observed cedar stumps buried under aggraded sediment (typically about 2-ft thick) along the length of the Highland Creek channel downstream of mines, as illustrated about one-half mile upstream from the East fork confluence (Figure 5). The fresh channel deposits included a large fraction of dark Pritchard Formation lithologies, implying that much of this sediment was derived from mine rock waste dumps. In contrast, the channel upstream of the Highland-Surprise Mine is narrow (typically 10-

15 ft wide), with a continuous, dense riparian corridor along bank (Figure 5), similar to the channel of Douglas Creek.

The channel morphology and evidence of aggradation downstream of the mines indicates a greatly increased sediment load in Highland Creek. This increased sediment load has overwhelmed the sediment storage capacity of the valley bottom, and is being transported through the reach to the mainstem East Fork (Figure 5), forming an alluvial fan at the confluence.

Effect of Low-Gradient Floodplain Reach in Regulating Sediment Delivery to Main Stem

Douglas Creek flows through a flat alluvial valley (about 400 ft wide) extending for the lowermost 1.5 miles (valley length) above the East Fork confluence, while Highland Creek flows through a v-shaped valley (typically 150 ft wide or less) with fewer sites for intermediate sediment storage. We infer the gradient in the lower 1.5 miles of Douglas Creek is significantly lower than the comparable reach of Highland Creek, but relatively little difference is measurable on the 1:24,000 topographic map (with 40-ft contours), because the actual channel length is greater than that appearing on the map.

Trapper Creek also has a low gradient, floodplain reach above its confluence with the East Fork, but the sediment storage capacity of this reach appears to have been overwhelmed in 1996, and considerable bedload sediment reached the East Fork, based on the deposits and other field evidence at the confluence with the East Fork. The 1975 aerial photographs show a second channel along the right side of the alluvial bottomland of Trapper Creek, whereas the stream occupied only its left channel in 1996. This implies some reduction in opportunities for sediment storage in the alluvial bottomland so that the sediment load, whether natural or anthropogenically-increased, would pass through the alluvial reach more efficiently to reach the mainstem East Fork in 1996.

Sediment Yield from Unmined Drainages

In our field investigations, we observed the change in channel conditions upstream and downstream of mining related sediment inputs, and compared these upstream reaches with unmined channels. Our observations of the channels of the Upper East Fork, Gilbert Creek, Douglas Creek, Highland Creek, and the West Fork above the Calusa Creek confluence (Figure 3), all either unmined basins or at locations above the influence of mining sediment, indicate similar transport characteristics. All of these channels appear to show the passage of relatively high coarse sediment loads, clearly related to the 1996 floods. However, these steep channels typically remained very stable, with minor bank failures, bank toe scour, or reworking of previous flood deposits. In several cases, notably the West Fork above Calusa Creek and Gilbert Creek, small amounts of channel widening and reworking of what we have interpreted to be deposits from the 1974 flood, were observed. This interpretation is based on the presence of narrow vegetation stands in or adjacent to the channel of generally uniform size (implying similar ages), which contrast markedly with other streamside vegetation. The lack of obvious source areas for the sediment generated from these drainages also indicates that minor reworking of channel margins over long enough reaches may be the primary source for the sediment deposits observed in unmined tributary channels, typically deposited behind log jams or in low-gradient floodplain reaches. These volumes appear to be the product of an unusually high flow, and may reflect naturally high sediment yields from these areas on an infrequent and episodic basis. The bedload sediments of these channels are also quite consistent: all contain almost exclusively large fragments of quartzite.

In contrast to the upper, generally undisturbed basins just discussed, Trapper Creek produced large volumes of sediment, much of which was deposited near the confluence with the East Fork. The sources of the bedload sediment in Trapper Creek are not as obvious as on Highland Creek, as the basin was virtually unaffected by mining. However, the basin was burned earlier this century, higher elevations have been subject to timber harvest, and roads have been constructed through the basin, especially in higher elevations. It is unknown the degree to which these factors have changed runoff and sediment yield.

We observed at least four active hillslope failures, each of which could contribute substantial volumes of coarse sediment to the channel. The largest of these failures, downstream of the Hunter Creek confluence in the alluvial reach (Figure7), was also visible on 1975 aerial photographs. It is unclear the extent to which sediment delivery from these failures reflects high natural sediment delivery in an unusually wet year or the extent to which they reflect human activities.

Destabilizing Effect of Removing Bottomland Cedar Forest

We have hypothesized (Kondolf and Matthews 1996) that removal of the mature bottomland cedar forest in combination with increased sediment loads, allowed a geomorphic threshold to be crossed during moderate to large flood events (1917, 1933, 1938, 1964, 1974, and 1996), leading to destabilization of the alluvial valley floors. The increased sediment from mining activities has accelerated a change in the channel form from a narrow, sinuous, and stable channel in the early part of this century to the wide, braided, and shifting channel typical of current conditions. The East Fork reached this condition much more rapidly than the West Fork. Our analysis of aerial photographs indicates that the sequence was essentially complete on the East Fork after the 1964 flood. Much of the change had occurred by the 1956 photos, and by 1965 almost all stable floodplain surfaces seen in the 1933 photos had been eroded, leaving a wide unstable channel with virtually no vegetation. Much of this change probably occurred in the large 1938 flood, since available flow records from the St. Joe River at Calder (Table 2) show ~~that there were~~ no floods ~~in Pine Creek~~ with a recurrence interval greater than 10 years between May 1938 and November 1964, although with a greatly increased sediment load, even small to moderate storm flows may have been capable of transporting sufficient sediment to contribute to channel instability. Our review of historic mine production figures in Mitchell (1996) indicates that the bulk of ore production for almost all of the larger mines in the East Fork occurred between 1941 and 1952, spurred by wartime production needs. It is not certain how mine development, such as cutting tunnels and shafts, which would seem to generate most of the waste rock, is related to mine ore production. Certainly much of the mine development predates the bulk of ore production, and a large volume of waste rock is likely to have been available for transport during the flood of 1938.

One other significant difference between the East Fork and West Fork was the general removal of the large cedar stumps along the East Fork apparently in the 1950s and 1960s (Mike Stevenson, BLM, Coeur d'Alene, pers. comm. 1996). It is unclear to what extent removal of these stumps in the East Fork contributed to the propagation of instability, although field observations in the West Fork suggest that the stumps may provide some stability due to their large size and ability to trap other materials, often creating protected areas in which riparian vegetation may become established.

Discussion

The mine wastes have obviously played a key role in increasing bedload sediment transport and destabilizing channels and bottomland deposits. However, the coarse sediments in bed of Pine Creek consist primarily of white quartzite, most of which is probably derived from Revett and Burke Formations, which outcrop over most of the basin (Figure 8). The mine rock wastes are composed principally of the Pritchard Formation, which are predominantly dark-gray to black laminated argillites, but which include some massive white quartzite beds in the middle and near the top of the formation. The overwhelming dominance of white quartzite in the bed material of the East Fork implies that despite large inputs of rock wastes and concentrations of dark Pritchard Formation sediments near the point sources, these wastes do not constitute a large fraction of the sediment in the East Fork with increasing distance downstream of the point sources.

The extensive channel destabilization between 1933 and 1956, during a period of high influx of mine-derived sediment but relatively few large floods, implies that the mine-derived sediment served to destabilize the channel, and that much of the sediment transported downstream from unstable reaches was simply reworked from pre-existing bottomland deposits (most of which would have been white quartzite from the Revett and Burke Formations). This suggests that the progressive destabilization of the channel does not reflect the downstream translation of a wave of coarse sediment but rather propagation of channel instability, such that most of the sediment visible at one point in the channel is probably derived from erosion of bottomland deposits a short distance upstream.

This hypothesis is consistent with the observation that, where present, cedar stumps (relict from the forested bottomland predating 1900) are not buried by sediment as might be expected in the event of massive aggradation. Moreover, the increase in area of exposed, unvegetated, active channel did not progress downstream from the point sources of mine-derived sediment, but rather the reach downstream of Highland Creek began to destabilize before upstream reaches.

Management Implications

Because increased sediment yields have had a destabilizing effect on channel form in Pine Creek, leading to reworking of bottomland deposits and further instability, solution of instability problems requires a comprehensive approach involving treatment of source areas in addition to any channel modifications in affected downstream reaches. This is especially true in the East Fork, where mining sediment has significantly increased sediment delivery from tributaries.

On the East Fork, the reach below Highland Creek was destabilized earlier than upstream reaches, reflecting the delivery of increased sediment yields from Highland, Denver, and Nabob Creeks. Even with immediate action to control sediment sources, enough sediment is stored in the channels, and the transport rate of these coarse sediments is sufficiently slow, that the excess sediment is unlikely to flush for some time, probably decades. This makes the East Fork below the Highland Creek confluence more difficult to stabilize than reaches with less sediment influx.

Stabilizing steep, high-energy, coarse-grained channels is not an exact science, nor are one-time treatments likely to succeed (Acheson 1968, Smart and Thompson 1986, Klingeman, in press). An adaptive management approach, in which demonstration projects are undertaken to test different restoration techniques, is needed to develop an effective restoration program.

Management Approach

The management strategies recommended for the various reaches of Pine Creek reflect the differing geomorphic settings between the East Fork and West Fork drainages although they are based on two general principles: (1) control sediment sources and (2) stabilize channel deposits in place by channel restoration and re-establishment of the riparian forest. Controlling sediment sources involves treatment of mine waste inputs and prevention of continued lateral erosion of existing floodplain surfaces, both of which are contributing large amounts of sediment to the channels of Pine Creek. Channel restoration, where feasible, would involve bend stabilization using bio-technical revetment (logs, boulders, rootwads, and revegetation). In addition, there are immediate, short, intermediate, and long-term timeframes to be considered in the restoration of channel and floodplain stability in Pine Creek and management of the watershed. Immediate timeframes are those that should be considered for implementation in the remaining 8-10 weeks of this construction season, and deal with either unusual opportunities such as the salvage of plant materials from the repository site, or at critical sites where erosion is likely to occur this coming winter. Short-term projects include those that would be planned for construction in 1997. Intermediate considerations include replanting of cedar on the stabilized floodplain, since cedar typically require the shade provided by other riparian species in order to become established. Long-term aspects include consideration of land use management in tributary watersheds, such as timber harvest levels, which may impact restored floodplain areas due to sediment delivery.

East Fork Pine Creek

A number of projects are planned by the Bureau of Land Management to remove tailings, stabilize channels, and address sediment input from rock dumps in the East Fork drainage. Tailings will be removed from sites threatened by erosion and moved to a repository site near the Upper Constitution Mine. To our knowledge, the specific projects are now proposed are:

1. channel stabilization of lower Nabob Creek involving installation of about 60 rock weirs, including replacement of the undersized CMP under the County road with a larger box culvert.

2. removal of eroding tailings (from the Little Pittsburgh mine) on the mainstem near the Denver Creek confluence.

3. stabilization of rock dumps and tailings at the Highland-Surprise and Sidney-Red Cloud Mines, in the Highland Creek watershed.

4. removal of eroding tailings from the Douglas mill site on the right bank of the East Fork downstream of the Douglas Creek confluence.

5. removal of eroding tailings from the Constitution mill site on Upper East Fork upstream of the Gilbert Creek confluence.

The implementation of these projects should substantially reduce sediment inputs from mine wastes to the tributary channels at these locations, and, as a result, reduce cumulative sediment loads in the East Fork Pine Creek. Reduction in sediment loads will be a prerequisite to the recovery of floodplain stability in the lower reaches of the East Fork. However, the residence time for sediment already stored in the tributary channels will likely still extend to decades, arguing for intervention in the tributary channels to stabilize much of this sediment in place.

We examined a number of other sites identified by BLM staff as sources of coarse sediment to the channel, but for which no specific remedial actions have been proposed, evidently because of land ownership issues. These include the Star-Antimony and Nevada-Stewart mines on Highland Creek, all mines on Denver Creek, and that portion of the lower Constitution Mine on Gilbert Creek. Consideration should be given to treatment of these sites as well, since they will continue to contribute sediment to the channels and lengthen the likely recovery time of the system.

Repository Construction at Upper Constitution Site on East Fork

The construction of the repository at the Upper Constitution Mine will require extensive clearing of existing riparian forest, including many mature cottonwoods, as well as willows and alders. Since the repository is essential for other remedial work, BLM plans to implement its construction immediately. A wide range of riparian species are present at the proposed repository site, including cottonwoods, alders, willows, and dogwood. Removal of the riparian vegetation on the repository site presents an unusual opportunity to obtain plant materials for a demonstration project involving use of riparian vegetation for channel and floodplain stabilization. The management recommendations section below presents the conceptual framework for such a demonstration project along the East Fork, while Matthews (1996) presents the specific details on recommendations of use of salvaged plant materials.

West Fork Pine Creek

The West Fork Pine Creek upstream of the channelized reach beginning at the County Road Bridge #2 (also referred to as "Barney's Bridge"), presents a different condition that the East Fork. Here, the channel and floodplain are still in transition, as the instability continues to progress in each large flood event. As we have discussed, there are still outstanding questions regarding the cause of instability, which is apparently related both to high sediment loads resulting from human activities in the upper and tributary watersheds (fires, grazing, timber harvest, road construction, and hillslope failures) which in turn cause floodplain erosion and the introduction of additional sediment loads, to the natural sediment production during unusual floods, and to removal of the bottomland cedar forest. Because the West Fork still retains some floodplain structure, including remnant older cedar and scattered new cedar growth, much more extensive riparian vegetation, and most of the old cedar stumps, and because it has not experienced the massive increase in sediment supply from mining as in the East Fork, we believe that there is a greater likelihood of reestablishing a naturally stable channel configuration directly through channel reconstruction and revegetation. However, there is not yet sufficient information on which to base the channel design. More information is needed on channel geometry (both historically and current conditions), sediment sources, and discharge magnitudes. Therefore, we are only recommending minor actions in this area this season to reduce some of the most pressing erosion problems, while collecting the information necessary to design and construct a comprehensive project for this reach next year.

Mainstem Pine Creek -- Liberal King Reach

The channel management approach for the Liberal King reach on the mainstem Pine Creek, is constrained by potential damage to residences immediately adjacent to the channel, as well as the County road and associated bridges at the upstream and downstream limits of the project area. As a result, options are more limited, and an approach favoring more structural measures is likely warranted. Furthermore, this reach will still experience increased sediment loads for a number of years due to the extensive in-channel deposits upstream in both the West Fork, East Fork and their tributaries. The Bureau of Land Management intends to remove the tailings located on the left bank opposite the Liberal King mine this season, as soon as the repository has been completed, thus requiring restoration of the stream channel in the vicinity.

We conducted additional review of the historical aerial photographs of this reach to develop recommendations for restoration of channel stability. A sequence of aerial photos from

1933, 1937, 1956, 1965, 1975, 1984, and 1996 are shown in Figure 11. In 1933, the channel was generally narrow, sinuous, and braided in a number of locations. High flow channel scars between the channel and the County road are likely remnants of the 1917 flood or even earlier events. The channel flowed through an area along the left bank now occupied by tailings. Some gravel bars were open and unvegetated, but most were vegetated. By 1937, the channel had widened, migrated laterally in several locations, particularly on the outside of bends, and cut a new channel upstream of the lower bridge, apparently washing out the road. Most of these changes probably occurred in the December 1933 flood. 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 during 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.

By 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. The 1996 photos and our field observations indicate that erosion of the left bank floodplain continued during the floods of February 1996. It is interesting to note that young riparian vegetation is becoming reestablished on certain gravel bars throughout the reach, much of which apparently survived the recent flood. BLM staff constructed a small berm upstream of the Liberal King mine, in order to divert flow into the old left channel and away from the tailings pile to enable removal to proceed this fall.

The channel stabilization project to be implemented should be based on creation of a more sinuous channel geometry, using significant structures to train the channel away from areas that would lead to additional damage or loss of property, and extensive revegetation. The bedrock outcrops are obvious locations for construction of channel bends, since these have performed that function historically and provide a means of dissipating energy without costly structure construction. Where possible, all existing riparian vegetation should be incorporated into the project design, and either left intact where its location complements the design or transplanted to a new location if the design channel passes through that area.

Management Recommendations

We present here our conceptual recommendations for various projects, follow-up studies and monitoring. The specific details including conceptual planform geometry, structure design and configuration, method and location of vegetation planting, and typical channel geometry are presented separately in Matthews (1996). As we noted in our previous investigation, we have more faith in efforts to train the stream using a bio-technical approach (Schiechtl 1980, Gray and Leiser 1982) incorporating natural materials rather than to control the channel with an extensive set of structural measures based on a uniform geometry and gradient. In rivers and streams that are aggrading or contain high sediment loads, such as those in New Zealand, use of structural measures (primarily riprap) is recommended for protection of critical areas and/or facilities, while wide, braided channels are trained using deflectors of various types and extensive vegetation plantings (Acheson 1968, Smart and Thompson 1986). We have been involved in the design and construction of restoration projects on the Carmel River using predominately riparian vegetation which have been quite successful in returning wide, unstable reaches to a stable, single thread configuration (Matthews 1990).

In contrast to this type of approach, many restoration projects have been undertaken using a greater reliance on structures (often of natural materials) and the incorporation of numerous grade control elements. Frequently, the restoration of riparian vegetation is often reduced to a secondary level well below the engineering of the specific structural elements. As a result, revegetation efforts are often unsuccessful. Several other concerns regarding these types of projects are: (1) the overall cost, since structures and large riprap are much more expensive to construct than replanting of riparian vegetation, (2) the approach that a certain pre-defined geometry is correct for the channel despite varying flows and sediment loads, and (3) the use of large numbers of structures may limit the ability of the stream to naturally adjust its geometry, which is important in maximizing habitat diversity. A common assumption seems to be that if the stabilizing structures are installed, the vegetation will reestablish itself naturally. This may be true in very limited locations along the low flow channel, where the necessary balance between adequate moisture to germinate seeds/maintain seedlings and scour during storms is achieved. The lack of riparian vegetation regeneration on many elevated surfaces indicates that these conditions are frequently not achieved, particularly in a disturbed channel and/or one with high sediment loads. The integration of riparian vegetation, with the minimum number and extent of structures may provide the most ecologically sound and cost-effective means of channel restoration (White 1979). Our observations of recently constructed stream restoration projects on Ninemile and Canyon Creeks indicate that revegetation efforts have been largely unsuccessful, although the numerous structures appear to be functioning as designed. Neither of these stream appears to have experienced high flows this season on the same magnitude as Pine Creek, perhaps due to higher elevations, and aspect differences.

The construction of a demonstration project will provide useful information on site specific revegetation techniques that is necessary to ensure the success of vegetation plantings, and which will be of critical importance for larger future projects.

EAST FORK

(1) *Demonstration Restoration Project on East Fork Pine Creek*

We recommend the implementation of a demonstration channel and floodplain restoration project on the East Fork Pine Creek using plant materials obtained from the site clearing at the proposed tailings repository. The location recommended is the reach from upstream of Douglas Creek to Highland Creek for the following reasons: (1) ready access from repository site, (2) lower sediment loads due to undisturbed tributary basins and planned project at Constitution site, (3) sections of road repaired after 1996 damage but not protected which would likely easily be eroded again, (4) higher probability of success for restoration strategy emphasizing bio-technical and riparian restoration techniques, (5) the need to repair damaged road upstream of Douglas Creek bridge to allow trucks hauling tailings to repository, and (6) baseflow from Douglas Creek. The demonstration project should be designed to incorporate various revegetation trials including stem vs. container plantings, fall vs. spring plantings, and size vs. success rates.

(2) *Treatment of Additional Sediment Sources in East Fork Tributaries*

There are a number of significant sediment sources on tributaries to the East Fork that are apparently not planned for treatment at this time, whether due to private property concerns or other access problems. We strongly recommend that efforts be made to incorporate these sources into future stabilization projects. For example, the lower reach of Gilbert Creek which contains a extensive rock dump from the lower Constitution site (Figure 10), is apparently not being planned for a stabilization project. However, a relatively small project could relocate the creek channel away from the eroding toe of the rock dump, creating a low terrace at the toe of the rock dump to catch materials and prevent it from reaching the channel.

(3) *East Fork Pine Creek downstream of Highland Creek*

This reach should have lower priority for restoration projects for several reasons: (1) it is subject to the highest sediment loads which will still be elevated for an extended period of time even with upstream restoration projects, (2) despite the high sediment loads, there has been some regeneration of riparian vegetation on bar surfaces in this reach, which remained stable in spite of the high flows of 1996, and (3) its makes more sense to treat the channel instability generally in a downstream progression.

(4) *East Fork Pine Creek Monitoring*

We believe that systematic monitoring of restoration projects is essential to their ultimate success, both in terms of evaluating their effectiveness, which can determine the most useful approaches, and for developing an understanding of the channel dynamics associated with restoration project implementation including determination of the causes of both success and failure. All too often, monitoring is either ignored or not carried through after changes occur. The incorporation of post-project monitoring into initial project planning provides the best approach (Kondolf and Micheli 1995). We recommend that monitoring on the East Fork consist of (1) a longitudinal profile and limited cross sections, (2) measurement of vegetation success and growth rates, and (3) streamflow monitoring at the Nabob Bridge, consisting of staff and crest gages, establishment of a stage-discharge relationship, and maintenance of annual peak discharge records.

WEST FORK

(1) *Channelized Reach Sediment Removal Project*

Shoshone County is currently removing sediment from the lower reaches of the West Fork of Pine Creek. They expect to continue working upstream throughout the fall, perhaps until streamflow begins. It is highly recommended that a longitudinal profile and cross sections be surveyed in the areas where sediment is removed. The change in volume in this reach will give a good estimate for the bedload transport rate of the West Fork, provided it can be related to a particular flow.

(2) *Levee Removal at Upstream End of Channelized Reach*

BLM staff has pursued conceptual implementation of this project with affected regulatory agencies at the local and federal level, all of whom were apparently supportive. Efforts should be made over the winter to coordinate the planning for implementation of this and an upstream project simultaneously. Information needed to design this project include detailed topography of the channel, levee, and floodplain areas and determination of some basic hydrology for the West Fork to allow for calculation of the frequency of overbank flow into the floodplain area.

(3) *Channel Restoration in the reach Upstream of County Road Bridge #2*

1996 Efforts: Given the short remaining construction season, we recommend that only minor construction efforts be made in this reach this year. The priority should be towards reducing sediment inputs both from continued hillslope failures and major erosion of floodplain surfaces. Limited channel relocation away from the toe of hillslope failures (2 locations) and removal and/or realignment and anchoring of large woody debris from locations causing flow deflection and erosion to locations acting to stabilize eroding banks, are the recommended actions for this season.

1997 Project: With more lead time to develop the information necessary for a comprehensive stabilization design, we recommend planning for implementation of a large scale project in the West Fork in the summer/fall of 1997. This work would be done in conjunction with the levee removal process, which would provide a source for fill materials, riprap, and some plant materials that would be needed for project construction.

(4) *West Fork Pine Creek Monitoring*

A similar monitoring program to the East Fork should be implemented which includes longitudinal profile and cross section monitoring, and streamflow monitoring at the Ross Gulch bridge with staff and crest stage gages. Other elements would be included once a project was undertaken on the West Fork.

MAINSTEM PINE CREEK

(1) *Liberal King Reach Stabilization Project*

1996 Project: providing the tailings are removed from this site this season, a channel restoration project will need to be implemented for this reach. We recommend that structures and vegetation be installed to prevent any further lateral erosion of the left bank floodplain and to reestablish a more stable geometry.

1997 Project: any work not able to be completed during the 1996 season, and the implementation of more extensive riparian vegetation planting throughout the project area.

(2) *Streamflow Monitoring*

We recommend that a continuous streamflow monitoring station be installed on the mainstem Pine Creek. The lack of streamflow records hampers our ability to analyze changes in channel conditions and precludes even the most basic of hydrologic analyses. Given the long-term nature of any comprehensive restoration program such as will be necessary on Pine Creek and the likely levels of expenditure for restoration compared to the relatively small initial investment in equipment and the small cost of annual station operation and record computation, establishment of such a monitoring station is completely warranted. We recommend a continuous station on the mainstem combined with manual stations on both the East Fork and West Fork which will allow the relative importance of runoff from each subbasin to be documented.

Report Limitations

This report, while more extensive in certain recommendations than our previous reconnaissance-level investigation, does not purport to be a design document and is not intended for the purposes of project construction. Such work should be based on detailed designs prepared under the guidance of a registered civil engineer. W.V. Graham Matthews and G. Mathias Kondolf provide their findings, conclusions, and recommendations 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.

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TABLE 1

BASIN AND SEDIMENT YIELD CHARACTERISTICS OF SELECTED EAST FORK PINE CREEK TRIBUTARIES

TRIBUTARY	DRAINAGE AREA (mi^2)	MAXIMUM ELEVATION (feet)	RELIEF (feet)	NUMBER OF LARGE MINES	TOTAL REPORTED PRODUCTION$_3$ (tons)	HILLSLOPE FAILURES$_{10}$ (N or Y) and (#)	ALLUVIAL FAN AT CONFLUENCE (N or Y)
Nabob Creek$_1$	0.9	4700	2220	1	139,213$_4$	N	Y
Denver Creek$_1$	1.2	4889	2330	3	826,733$_5$	N	Y
Highland Creek$_1$	5.0	6297	3690	3	518,691$_6$	N	Y
Red Cloud Creek$_2$	1.12	4889	1920	1	495,848$_7$	N	Y
Blue Eagle Creek$_2$	0.88	4920	2240			N	N
Dry Gulch$_2$	0.81	5370	2640			N	N
Douglas Creek$_1$	6.3	6188	3430			N	N
Gilbert Creek$_2$	0.84	5426	2530	1	332,680$_8$	N	Y
Upper East Fork$_2$	3.5	5472	2570	1	332,680$_9$	N	Y$_{11}$
Trapper Creek$_2$	7.0	5626	3130			Y (4)	Y
Hunter Creek$_2$	3.96	5626	2980			N	N

Notes:
1. Source: unpublished data, BLM, Coeur d'Alene
2. Measured from 1:24,000 scale topographic map
3. Source: Mitchell (1996)
4. Nabob Mine
5. Hilarity mine, Little Pittsburg mine, and 1/2 of Sidney mine.
6. Highland-Surprise mine (other mines without production records: Star-Antimony and Nevada Stewart)
7. 1/2 Sidney mine
8. 1/2 Constitution mine
9. 1/2 Constitution mine
10. Based on aerial and field reconnaissance
11. Large gravel bars behind 2 culverts at road crossings

TABLE 2

ST. JOE RIVER at CALDER, ID

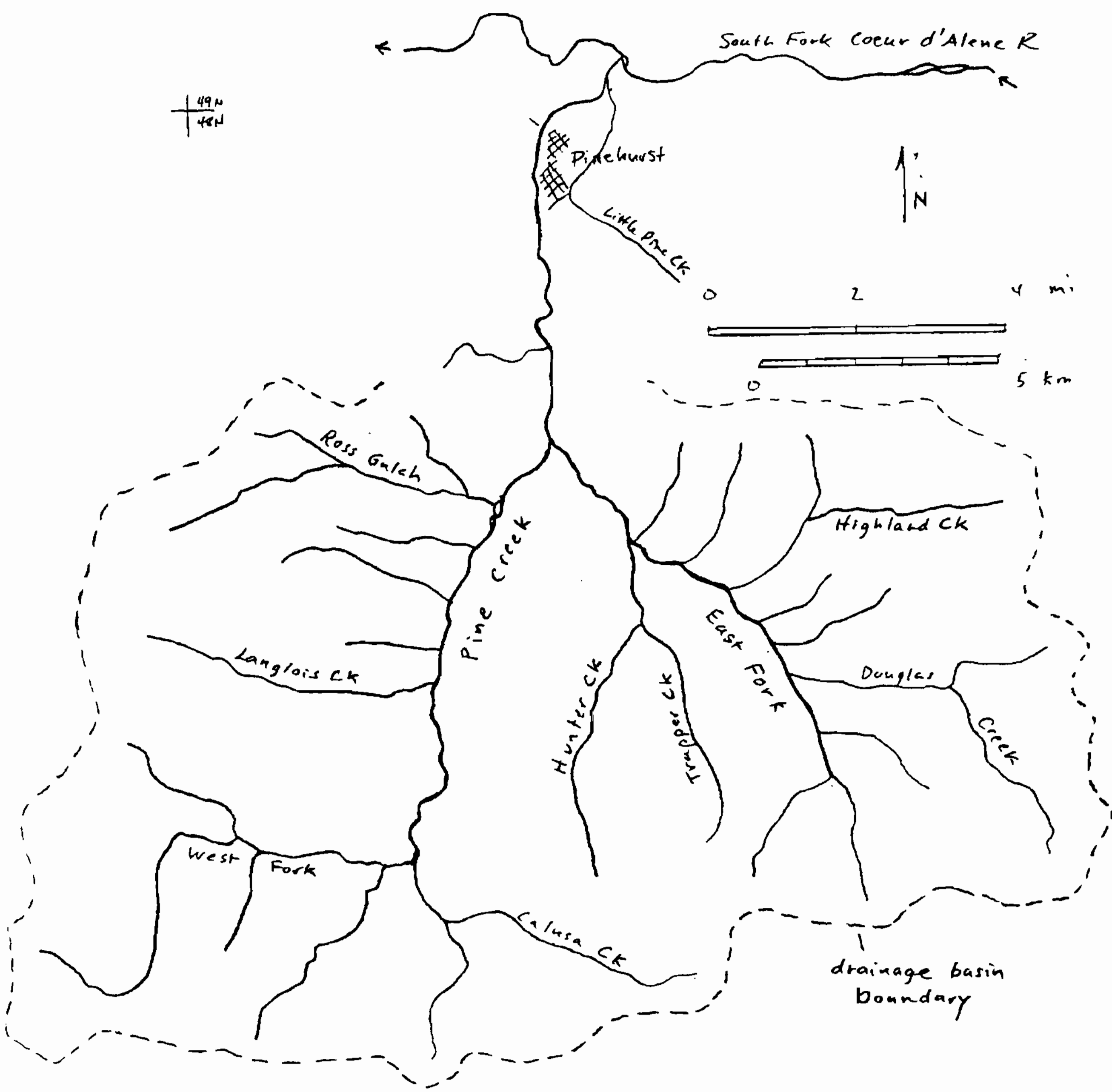
Annual Maximum Peak Discharge and Flood Frequency Analysis

Water Year	Peak Discharge Annual Maximum (cfs)
1911	14400
1912	15700
1921	17400
1922	17600
1923	13600
1924	13100
1925	17200
1926	11500
1927	18000
1928	16600
1929	9360
1930	8510
1931	8790
1932	17400
1933	19600
1934	53000
1935	13400
1936	20000
1937	12700
1938	46000
1939	13800
1940	8140
1941	5280
1942	10400
1943	14800
1944	5470
1945	15500
1946	15200
1947	23600
1948	23700
1949	19200
1950	18400
1951	17200
1952	16200
1953	13600
1954	20400
1955	18200
1956	20600
1957	16700
1958	14000
1959	15200
1960	13500
1961	15500
1962	16600
1963	7200
1964	19100
1965	30400
1966	14400
1967	18200
1968	14000
1969	16600
1970	14700
1971	23000
1972	21600
1973	6500
1974	33000
1975	16600
1976	21600
1977	6730
1978	18600
1979	21000
1980	12800
1981	24600
1982	23800
1983	12700
1984	14400
1985	14300
1986	14800
1987	13300
1988	12700
1989	14200
1990	11100
1991	24000
1992	6980
1993	13900
1994	8970
1995	21000

Rank	Peak Discharge Annual Maximum (cfs)	Water Year	Weibull Plotting Position	Recurrence Interval (years)
1	53000	1934	0.013	78.00
2	46000	1938	0.026	39.00
3	33000	1974	0.038	26.00
4	30400	1965	0.051	19.50
5	24600	1981	0.064	15.60
6	24000	1991	0.077	13.00
7	23800	1982	0.090	11.14
8	23700	1948	0.103	9.75
9	23600	1947	0.115	8.67
10	23000	1971	0.128	7.80
11	21600	1972	0.141	7.09
12	21600	1976	0.154	6.50
13	21000	1995	0.167	6.00
14	21000	1979	0.179	5.57
15	20600	1956	0.192	5.20
16	20400	1954	0.205	4.88
17	20000	1936	0.218	4.59
18	19600	1933	0.231	4.33
19	19200	1949	0.244	4.11
20	19100	1964	0.256	3.90
21	18600	1978	0.269	3.71
22	18400	1950	0.282	3.55
23	18200	1955	0.295	3.39
24	18200	1967	0.308	3.25
25	18000	1927	0.321	3.12
26	17600	1922	0.333	3.00
27	17400	1921	0.346	2.89
28	17400	1932	0.359	2.79
29	17200	1925	0.372	2.69
30	17200	1951	0.385	2.60
31	16700	1957	0.397	2.52
32	16600	1928	0.410	2.44
33	16600	1962	0.423	2.36
34	16600	1969	0.436	2.29
35	16600	1975	0.449	2.23
36	16200	1952	0.462	2.17
37	15700	1912	0.474	2.11
38	15500	1945	0.487	2.05
39	15500	1961	0.500	2.00
40	15200	1946	0.513	1.95
41	15200	1959	0.526	1.90
42	14800	1943	0.538	1.86
43	14800	1986	0.551	1.81
44	14700	1970	0.564	1.77
45	14400	1911	0.577	1.73
46	14400	1966	0.590	1.70
47	14400	1984	0.603	1.66
48	14300	1985	0.615	1.63
49	14200	1989	0.628	1.59
50	14000	1958	0.641	1.56
51	14000	1968	0.654	1.53
52	13900	1993	0.667	1.50
53	13800	1939	0.679	1.47
54	13600	1923	0.692	1.44
55	13600	1953	0.705	1.42
56	13500	1960	0.718	1.39
57	13400	1935	0.731	1.37
58	13300	1987	0.744	1.34
59	13100	1924	0.756	1.32
60	12800	1980	0.769	1.30
61	12700	1937	0.782	1.28
62	12700	1983	0.795	1.26
63	12700	1988	0.808	1.24
64	11500	1926	0.821	1.22
65	11100	1990	0.833	1.20
66	10400	1942	0.846	1.18
67	9360	1929	0.859	1.16
68	8970	1994	0.872	1.15
69	8790	1931	0.885	1.13
70	8510	1930	0.897	1.11
71	8140	1940	0.910	1.10
72	7200	1963	0.923	1.08
73	6980	1992	0.936	1.07
74	6730	1977	0.949	1.05
75	6500	1973	0.962	1.04
76	5470	1944	0.974	1.03
77	5280	1941	0.987	1.01

Notes: Data from EarthInfo Peak Values CD-ROM and USGS records for 1995 Water Year

FIGURE 1
PINE CREEK WATERSHED



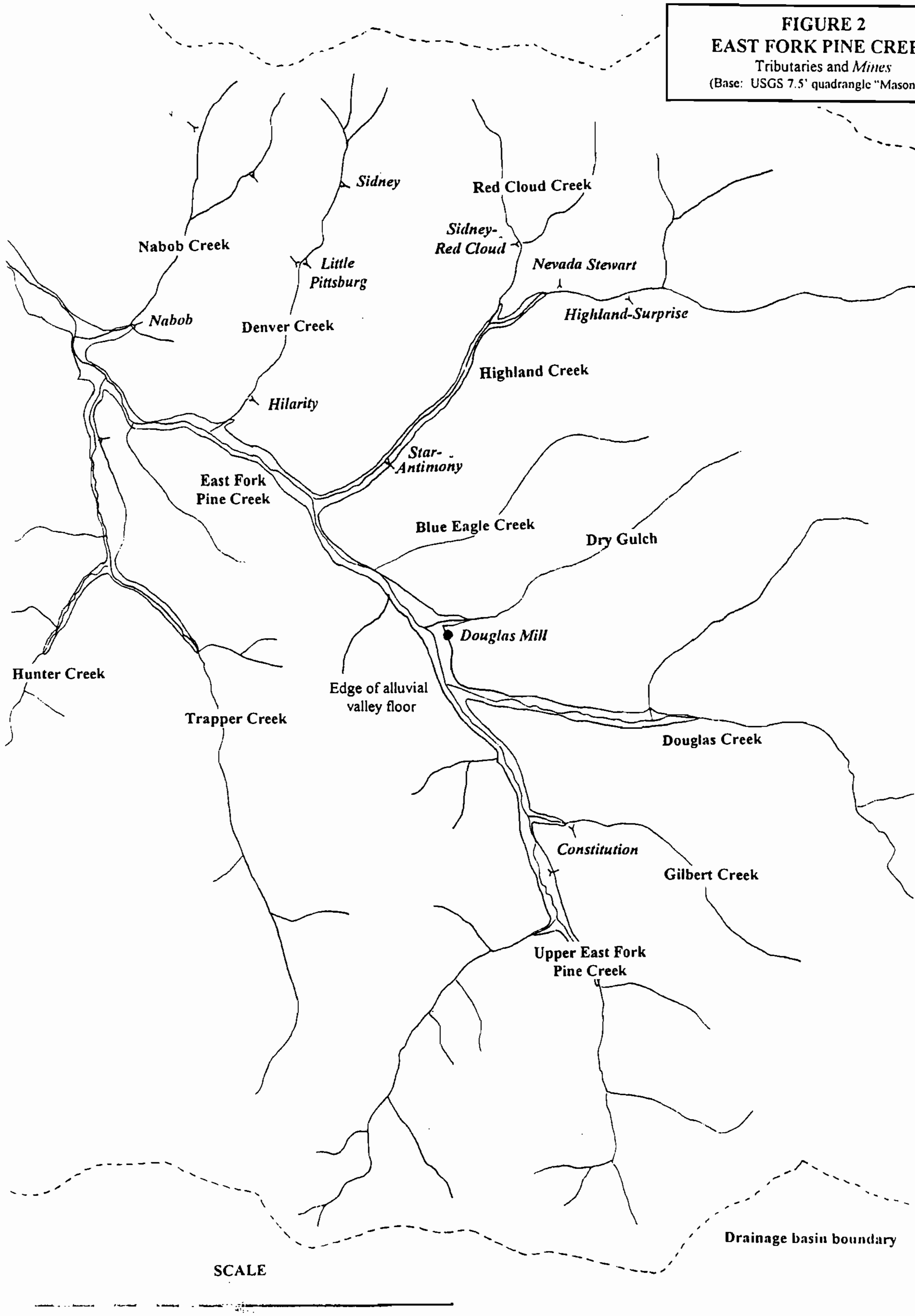


FIGURE 2
EAST FORK PINE CREEK
Tributaries and *Mines*
(Base: USGS 7.5' quadrangle "Masonia")

FIGURE 3
STABLE CHANNELS IN UPPER EAST FORK AND WEST FORK BASINS UPSTREAM OF ANY MINING SEDIMENT INFLUX

Top: view of upper East Fork of Pine Creek upstream from proposed repository site at the Constitution mine. Channel remained stable during 1996 floods. Bottom: view upstream of West Fork Pine Creek above confluence of Middle Fork.

FIGURE 4
PHOTOGRAPHS OF DOUGLAS CREEK

Top: oblique aerial view of sediment deposits in lower gradient alluvial reaches of Douglas Creek. Bottom: view of stable, undisturbed channel of Douglas Creek about 1000 feet upstream confluence with East Fork.

FIGURE 5
PHOTOGRAPHS OF HIGHLAND CREEK
Channel impacted by mine wastes and
in undisturbed upstream reach

Top: view of sediment deposits and wide, open channel along lower Highland Creek about 1000 feet upstream confluence with East Fork. Bottom: view of partly buried cedar stumps showing aggradation of creek channel.

Top: view of undisturbed reach of Highland Creek just upstream of Highland-Surprise mine. Note narrow channel with dense riparian lining the banks. Bottom: oblique aerial view of lower Highland Creek and confluence with East Fork Pine Creek. Note sediment deposits and lack of streamside vegetation.

FIGURE 6
PHOTOGRAPHS OF HIGHLAND CREEK
Mine rock dumps directly contributing sediment to creek channel

Top: view of large rock dump at Sidney-RedCloud mine on Red Cloud Creek. Bottom: view of rock dump at Star-Antimony mine on Highland Creek about 2000 feet upstream of confluence.

Top: view of eroding rock dump upstream of main mine buildings at the Highland-Surprise mine. Bottom: view upstream of lower rock dump below main mine buildings at the Highland-Surprise mine.

FIGURE 7

PHOTOGRAPHS OF TRAPPER CREEK

Hillslope failure and floodplain sediment storage

Top: oblique aerial photograph of Trapper Creek showing sediment deposits from 1996 floods in braided channels of alluvial reach. In 1975, another flood channel occupied the right side of the floodplain, where the trailers are currently located at the upper center of the photo. Bottom: oblique aerial photograph showing large hillslope failure downstream of Hunter Creek confluence.

FIGURE 8
GENERALIZED GEOLOGIC MAP OF THE PINE CREEK WATERSHED
After Jones (1919)

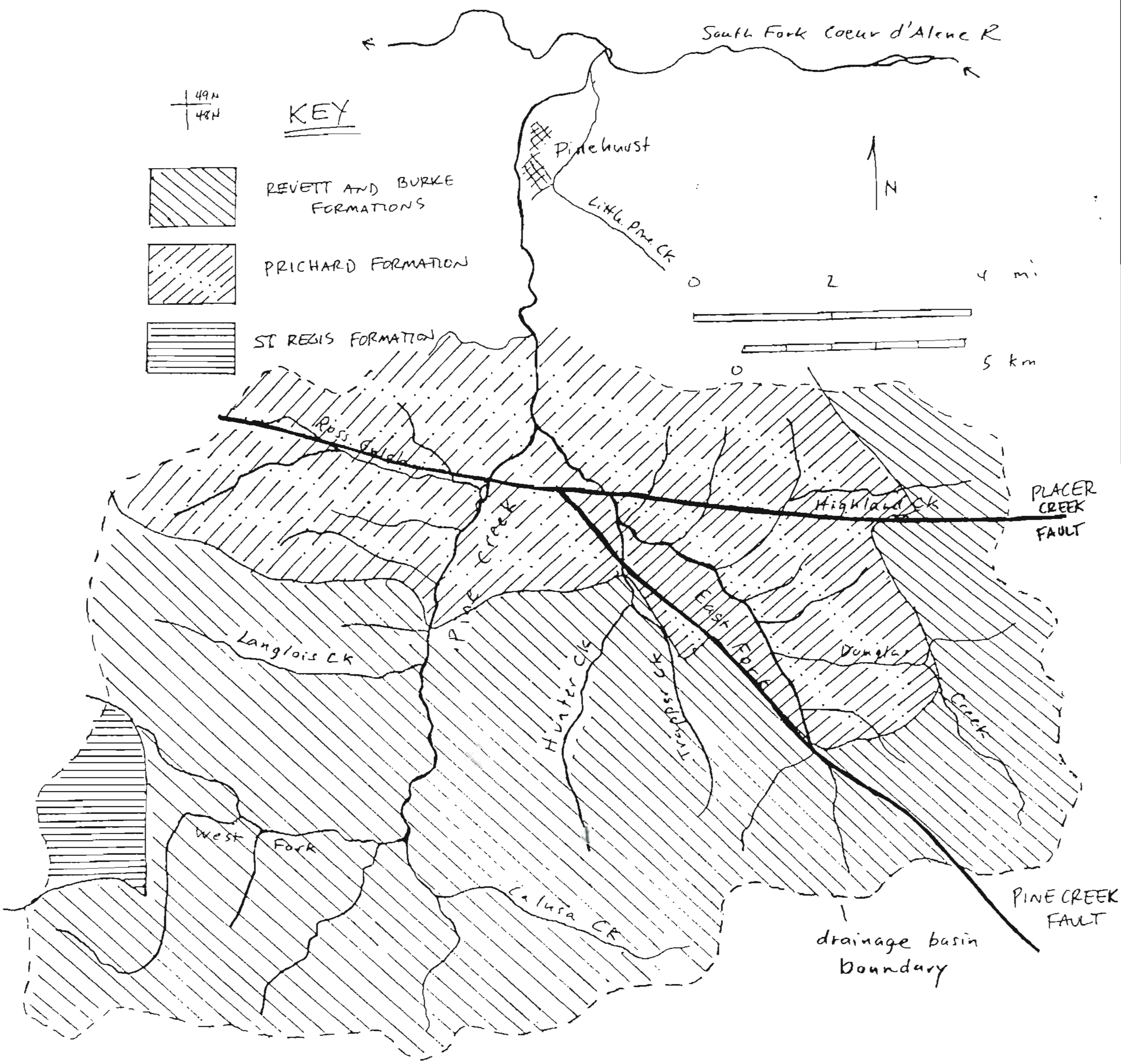


FIGURE 9
PHOTOGRAPHS OF DENVER CREEK
Effects of mining sediment on stream channel

Top: oblique aerial photograph of Little Pittsburg mine on Denver Creek showing sediment deposits behind building, erosion, and rock dump downstream. Building to left of center is same as one shown in lower photo. Bottom: view to collapsing mine buildings, trapping sediment.

Top: view of erosion and sediment deposition downstream of Hilarity mine on Denver Creek. Toe of rock dump is visible on left. Bottom: view upstream of sediment choked channel of Denver Creek near confluence with the East Fork Pine Creek.

FIGURE 10
EAST FORK AND TRIBUTARIES
Effects of mining sediment on stream channels

Top: view upstream along Gilbert Creek showing rock dump from Constitution mine. Channel is along toe of slope, behind alders. Bottom: view of leachate from rock dump on Gilbert Creek.

Top: view of erosion of tailings at Douglas Mill on mainstem of East Fork Pine Creek. Bottom left: view downstream along Nabob Creek showing channel erosion from 1996 floods. Note riprap on right bank protecting capped tailings pond. Bottom right: eroding rock dump at Nevada Stewart mine on Highland Creek.

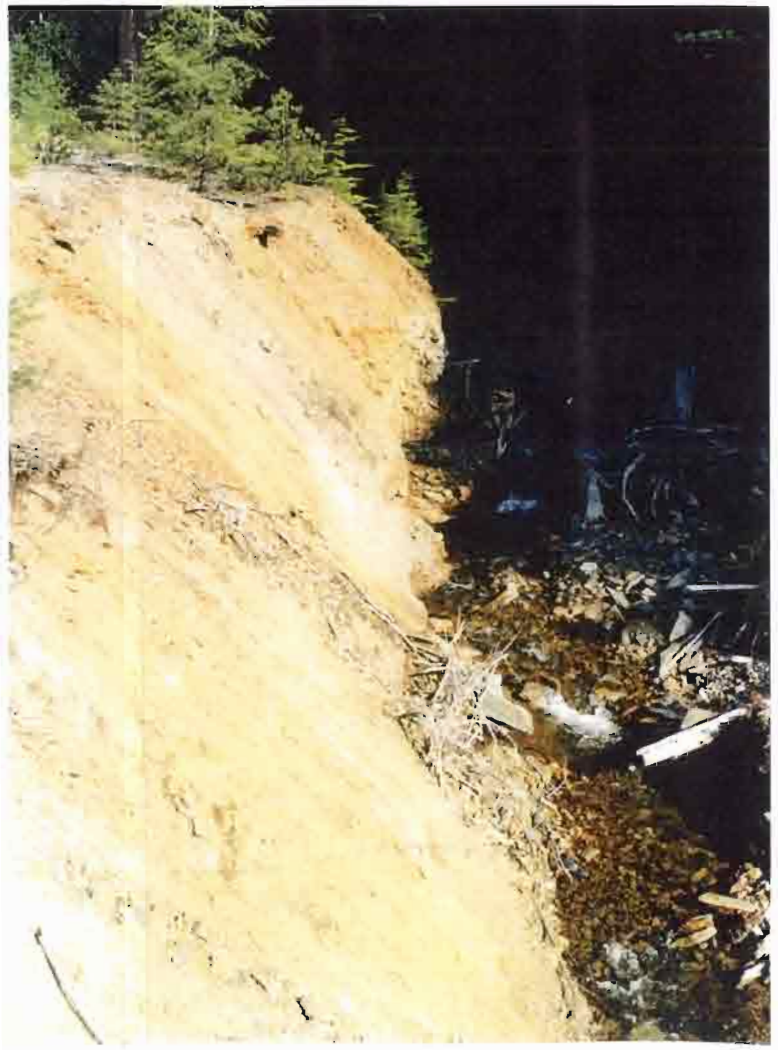


FIGURE 11
LIBERAL KING REACH -- MAINSTEM PINE CREEK
Sequential historic aerial photographs