Stream Channel Analysis
North Fork Coeur d'Alene River Subbasin

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June 2007

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1.0 STREAM CHANNEL INTRODUCTION

This analysis estimates current and historical sediment loads entering the North Fork Coeur d'Alene River and evaluates channel responses, both currently and historically, to those inputs. Two gauged watersheds within the larger North Fork subbasin were studied in detail, the Big Elk Creek watershed, and the Little North Fork Coeur d'Alene River watershed above Burnt Cabin Creek. The channel analysis also examined the remainder of the North Fork subbasin, although in less detail.

Channel responses to disturbances can be complex and occur over long time periods. In particular, gravel and cobble sediment moves slowly as bedload and may take decades for sediment to travel through a watershed. Evidence was gathered to evaluate how the lower Little North Fork Coeur d'Alene River and the North Fork Coeur d'Alene River were processing their coarse sediment loads.

The Little North Fork above Burnt Cabin Creek was affected by legacy timber harvest practices such as splash damming and fluming, in addition to railroad logging. This was followed later by a dense network of logging roads and damage from culvert failures. Logging started later on the Big Elk Creek watershed, so its creeks' were not affected by the legacy practices. Big Elk Creek also has a dense network of logging roads. In both study watersheds, the channels responded to increased sediment load and riparian disturbance, becoming wider in the flatter, unconfined reaches. Sediment loads have decreased in both watersheds since the peak of logging activity and very few active sediment sources were identified. The stream channels have recovered to a large degree, although some problem areas remain in the upper Little North Fork watershed. The amount of sediment eroded from stream channels was estimated for both the historic conditions and current conditions.

The Prichard, Eagle, and Beaver Creek watersheds in the mining district were affected by mining, which started in the 1880s. Impacts included direct disturbance by dredging or mining of the floodplains, and coarse and fine sediment from tailing piles placed adjacent to the creeks. These creeks had a much larger and prolonged channel response to coarse sediment load, which is continuing with very little channel recovery.

No completely unmanaged reference reaches exist in the vicinity. Channels in the less-managed areas (largely unlogged and with few roads) in the upper North Fork HUC were impacted by large fires in 1910 (partly human-caused) and subsequent heavy sheep grazing. In addition, some small, unburned areas in the headwaters have been logged. There are long, unconfined, low-gradient valley segments of these less-managed streams that had a channel-widening response similar to the logged watersheds.

2.0 CHANNEL ANALYSIS METHODS

2.1 CHANNEL DATA COLLECTION

Channels with gradients below 1% and moderately-confined to unconfined valleys are the most likely to respond to excess coarse sediment supply by depositing sediment, becoming wider, and sometimes braiding. Channels in the 1 to 2% range are also sensitive to coarse sediment but the impacts are less likely to be visible on air photos. As an initial indicator of likely channel response, GIS-generated maps showing channel gradient class were generated. Channel profiles were plotted for the watersheds (Appendix 1). The channel gradient maps were used to select locations for historic air photo analysis, and to select channel segments in a variety of gradient classes for field work.

Existing information was gathered from various agencies and analyzed. United States Forest Service (USFS) cross-section surveys and related field data were gathered for Big Elk Creek, the Little North Fork above Burnt Cabin Creek and its tributaries, and less-managed streams in the burned, unlogged Tepee Creek watershed. One focus of cross-section analysis was to determine whether channel incision and enlargement had taken place, and whether channels are connected to their floodplains. No repeated cross-sections were found that could be reliably compared to earlier cross-sections. Cross-sections showing likely channel incision or active bank erosion were flagged for field checking to determine current conditions and causes.

Idaho Department of Environmental Quality's (IDEQ's) Beneficial Use Reconnaissance Program (BURP) data for tributary streams in the watershed were obtained. BURP photos and estimated percent bank erosion were utilized to identify additional sites with bank erosion and/or high coarse sediment load. Large Woody Debris (LWD) and pool counts were obtained from the BURP data and some USFS data sets.

A database of 122 channel cross-sections (including some repeated surveys) was compiled from USFS Coeur d'Alene District data, USFS PACFISH/INFISH Biological Opinion (PIBO) data summaries, and IDEQ BURP data summary sheets. For the latter two sources, the actual cross-sections were not available, but channel dimensions were provided as average values for typically three cross-sections per site. The Coeur d'Alene District data were entered into the database as individual cross-sections, and, in many cases, the actual cross-section plots were available. The Coeur d'Alene District data came from the Little North Fork, Big Elk Creek, the North Fork River along its entire length, and reference sites in the Tepee Creek watershed. The BURP and PIBO data were randomly distributed throughout the North Fork subbasin. Watershed Professionals Network (WPN) 2006 field data were later added to the channel database and provided to IDEQ (*Coeur d'Alene WPN channel database.xls*). The USFS provided 1999 resurveys for several 1992 cross-sections on the upper Little North Fork. Unfortunately, they used different benchmarks and it was not possible to confidently align them without the field notes.

Each cross-section site was coded as "managed" (dense road building and timber harvest in most of the watershed) or "less managed" (little or no timber harvest and few roads). The *less managed* areas all had early stand-replacing fires, which, in many cases, burned the riparian zones. Many but not all of them have a low density of roads, particularly in the valley bottoms. In at least some reaches, LWD reportedly was removed from the streams but we were not able to obtain a record documenting the affected reaches. The *less managed* designation also included watersheds that had some areas of timber harvest in the headwaters, but were mostly unaffected.

Scatter plots and linear regression were used to identify relationships between independent variables (channel gradient, Rosgen channel type, drainage area) and dependent variables such as bankfull width, entrenchment, and width: depth ratio. These graphs were used to identify similarities and differences between cross-sections from *managed* and *less managed* channels, with the intention of forming hypotheses on channel response that could be tested during field work.

2.2 Analysis of Historical Aerial Photographs and Maps

A time series of historical air photographs and the oldest survey maps were used to track changes in channel width and pattern. The earliest Government Land Office (GLO) survey maps and survey notes were obtained. The maps were compared with modern USGS topographic maps to determine locations where the North Fork had changed position since approximately 1905. Due to the small scale of the early maps, they were only usable for the lower North Fork reach, and part of the middle North Fork.

Historic photo analysis was completed for response reaches, which are the flatter, unconfined to moderately confined reaches where sediment is deposited in gravel bars. The analysis included response reaches of the North Fork River; the Little North Fork; Prichard, Beaver, Eagle, Tepee, Independence, and Trail Creeks; and Shoshone Creek at its mouth. In addition, photo analysis of smaller streams was completed using a stereoscope with magnification in the two detailed study areas, Big Elk Creek and the Little North Fork above Burnt Cabin Creek.

A series of historic aerial photos was used to determine relative changes in channel width and pattern, and to identify direct disturbances to the channels. Table 1 lists the map and photo sources used. Most areas were covered by the 1968 photographs, and complete photo coverage of the study area was available for 1996 and 2004. Many areas were missing the 1937 and/or 1983/1984 photographs. Very few 1975 aerial photographs were obtained for the response reaches.

Channel widths were not measured due to the time-consuming nature of making multiple measurements and scaling the aerial photographs. Instead, changes were described on Channel Disturbance Worksheets using Washington State's watershed analysis protocols. The symbols +, =, or - were used to indicate relative changes in active channel width (the combined width of channels and unvegetated gravel bars). The symbols were then transformed to a numerical scale to produce bar graphs showing the relative changes, with a value of 10 corresponding to the estimated pre-disturbance width and 13 indicating an extreme increase in width. If a channel had already become wider by the time of the first photographs, a value of larger than 10 was assigned.

2.3 CHANNEL FIELD WORK

Channel conditions were evaluated during two weeks of field work completed in August, 2006. Detailed data were gathered in the Big Elk Creek watershed and Little North Fork watershed above Burnt Cabin Creek. Field data were also gathered in response reaches of the mainstem North Fork, and lower Little North Fork to evaluate coarse sediment impacts downstream from sediment source areas. Reconnaissance-level inspections of bank erosion conditions and gravel bar abundance were completed in parts of the Tepee, Prichard, Eagle, Beaver, Graham, East Fork Steamboat, and Shoshone watersheds with an emphasis on visiting disturbed channel areas identified from the aerial photograph analysis. Some field checking of evidence of erosion in mine spoil piles areas along Prichard Creek was conducted; however, most mine impact areas on the smaller tributaries were on private property and were not inspected.

Table 1. Aerial photographs and maps used for historic channel analysis, in relation to large floods

DATE	TYPE	SCALE	SOURCE
1903-1908	Government Land Office (GLO) survey maps	1:31680	US BLM
12/15/33	High flow (48,200) at NF Coeur d'Alene River gage USGS 12413000		
1933 & 1935	Oblique low-elevation air photos	<<1:12000	USFS (from CD)
1937	B&W vertical air photos	1:20000	USFS (from CD)
4/15/38	High flow (40,400) at NF Coeur d'Alene gage USGS 12413000		
12/23/64	High flow (34,800) at NF Coeur d'Alene gage USGS 12413000		
1968	B&W vertical air photos	1:15840	USFS
1/16/74	Very high flow (61,000) at NF Coeur d'Alene gage USGS 12413000		
1975	Color air photos -- very limited coverage	1:24000	USFS
12/27/80	High flow (34,800) at NF Coeur d'Alene gage USGS 12413000		
2/21/82	High flow (38,800) at NF Coeur d'Alene gage USGS 12413000		
1983/1984	Color air photos	1:12000	USFS
2/9/96	High flow (56,600) at NF Coeur d'Alene gage USGS 12413000		
1996	Color air photos	1:15,840	USFS
2004	Color air photos	GIS 1m resolution	USDA NAIP
4/15/03	High flow (32,700) at NF Coeur d'Alene gage USGS 12413000		

The stream channel itself can be a major source of sediment if the channel incises below the level of its floodplain. Incision destabilizes the banks, which, in turn, can cause channel widening (Figure 1). Incision typically progresses upstream in the form of one or more headcuts. Eventually enough sediment is generated from upstream channel incision and bank erosion to cause deposition in previously incising downstream reaches. The deposited sediment forms a new floodplain entrenched within the former floodplain. The entire channel evolution progression from incision to restabilization may occur over several decades. Channel evolution stage was recorded at each field site visited and measurements were made to estimate the volume of sediment eroded. Channel stability was rated using the four-part classification of Henshaw (1999) based on the proportion and location of the eroding banks (Table 2).

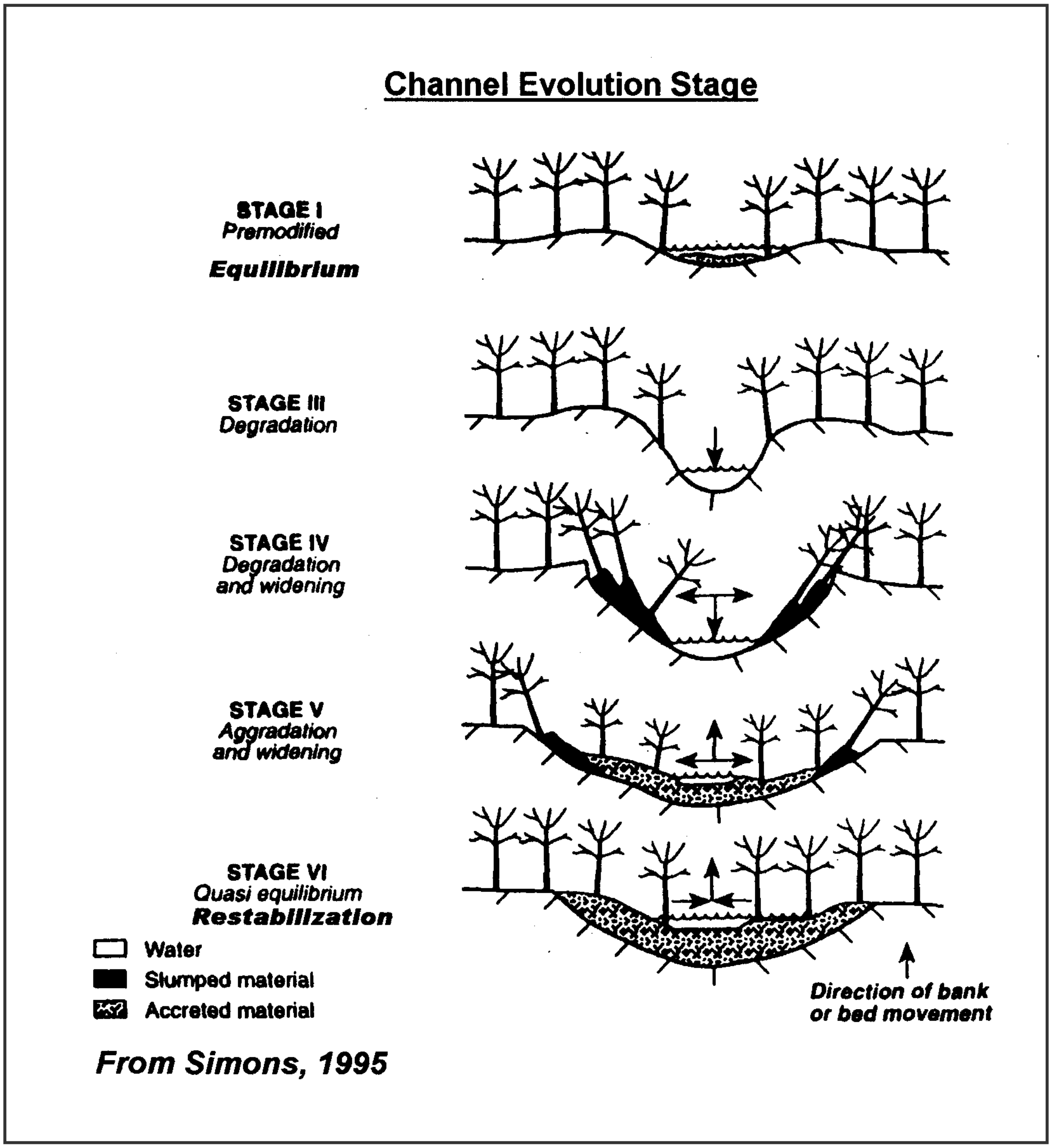


Figure 1. Channel evolution stages following incision (from Simons 1995)

Table 2. Channel stability class, modified slightly from Henshaw (1999)

STABILITY CLASS	CHARACTERISTICS
Stable	• Perennial vegetation to waterline • No raw or undercut banks (some erosion on outside of meander bends OK) • No recently exposed roots • No recent tree falls
Slightly Unstable	• Perennial vegetation to waterline in most places • Some scalloping of banks • Minor erosion and/or bank undercutting • Recently exposed tree roots rare but present
Moderately Unstable	• Perennial vegetation to waterline sparse (mainly scoured or stripped by lateral erosion) • Bank held by hard points (trees, boulders) and eroded back elsewhere • Extensive erosion and bank undercutting • Recently exposed tree roots and fine root hairs common
Completely Unstable	• No perennial vegetation at waterline • Banks held only by hard points • Severe erosion of both banks: eroded bank height >= 5 feet and/or landslides are common • Recently exposed tree roots common • Tree falls and/or severely undercut trees common
Armored Banks	• Stream banks and/or stream bed have been armored with riprap or other erosion-resistant materials

Terrace height and floodplain height above the streambed was measured with a laser level for rivers and larger streams, or a clinometer and rod for small streams. Bankfull width was measured with a tape for larger streams or a survey rod for small streams. Width between banks and terraces was measured with a rangefinder or tape. The width between intermediate grade breaks was estimated by eye. These data were later used to plot cross-sections showing channel shape, and to compute flood-prone width, entrenchment ratio, down-cut ratio, and the volume of sediment eroded by channel entrenchment. For river cross-sections, the bankfull channel was not usually surveyed in sufficient detail to calculate bankfull depth. Instead, bankfull depth was calculated based on drainage area using the regional bankfull geometry equations developed by the Forest Service, or using 1999 or later USFS cross-section data for a particular site. Bankfull dimensions were surveyed in the vicinity of some USFS 1992 cross-section sites along the Little North Fork and one site on the North Fork River. Our measured bankfull dimensions were in good agreement with the regional equation, but larger than the reported 1992 bankfull dimensions which apparently identified bankfull on a bar surface that was below the floodplain. Accordingly, the 1992 bankfull data set was not used in our analysis.

Other data that were recorded at most sample sites included gradient class (confirmed by clinometer or laser level if not obvious), valley wall confinement, gravel bar abundance and type, age and type of riparian vegetation on floodplain and terrace surfaces, channel pattern, LWD function and abundance, dominant and subdominant substrate size class in stream bed and banks, Montgomery-Buffington channel type, and Rosgen channel type.

Due to the large watershed area that needed to be covered, only a small number of pebble counts, LWD counts, and pool counts were made. Pebble counts in riffles did not include the stream banks. Pebble counts on bars were made in a consistent location at a point halfway between the upstream end of the bar and the bar apex. LWD and pool counts were made for a distance of the least 30 bankfull channel widths.

2.4 Channel Cross-Section Analysis

The channel cross-section data were analyzed to characterize the vertical component of channel response. Two dimensionless ratios were selected to identify vertical and horizontal movement of a channel relative to its floodplain. These ratios were calculated for WPN surveyed cross-sections and USFS cross-sections that extended far enough beyond the bankfull channel.

1. Entrenchment Ratio (Rosgen 1996) is flood-prone width divided by bankfull width. The flood-prone width is determined by locating the area that would be flooded by a flood two times higher than the maximum bankfull depth.

2. Down-cut Ratio was defined as terrace height above the bed divided by average bankfull depth. As many as three down-cut ratios were calculated for a given cross-section including the two stream banks, plus (if present) a higher terrace separated from the channel by an inset floodplain.

2.5 Channel Erosion Rate Calculations

Channel erosion rates for the two detailed-study watersheds were estimated for both historic and current conditions. Historic erosion was predominantly in the form of widespread channel entrenchment, whereas current conditions were evaluated on a more localized scale.

The magnitude of sediment production from channel incision and enlargement was calculated by comparing bankfull channel cross-section area (from field measurements and USFS surveys) with cross-section area between terraces. Channel erosion rates from Big Elk Creek and the upper Little North Fork were extrapolated to the remainder of the North Fork subbasin for the purpose of showing the relative order of magnitude of sediment contributions from each fifth-field HUC and from channel versus road sources. This extrapolation is based on limited or no field reconnaissance surveys, depending on the location. These estimates are far less accurate than the calculated erosion rates for Big Elk Creek and the upper Little North Fork.

2.5.1 Basis for Channel Erosion Rate Calculations

Studies in Mississippi found that a given stream reach will progress from initial incision to a state of quasi-equilibrium in 9 to 15 years (Schumm *et al*., 1984). If repeated events leading to incision occur, this progression can be interrupted by the upstream progression of new headcuts. Since incision proceeds upstream, an entire watershed will take much longer than 15 years to adjust to initial channel incision low in the watershed. For instance, studies in the Chaco Canyon area of New Mexico suggest an adjustment time of 50 to 100 years (Schumm *et al*., 1984). Henshaw (1999) studied Puget Sound, Washington lowland streams that had incised due to increased flood size from urbanization, and found they were likely to restabilize within one to two decades of constant land use.

Most of the North Fork surveyed tributary channels have incised along at least part of their lengths in response to direct channel disturbance by equipment, removal of LWD, flow increases, and/or narrowing of the floodplain by encroaching roads. The Big Elk and upper Little North Fork tributaries did not suffer a drop in base level of the trunk stream, but rather direct channel disturbance by equipment, removal of LWD, and much smaller flow increases than the urbanized example cited above. These factors caused incision in the steeper B and A channels and aggradation in the C-type channels at the bottom of each tributary. Most of the entrenched channels in the two study basins are in stages 5 to 6 with relatively stable banks, so incision is not a significant process under current conditions. Active channel incision is still occurring in parts of the Prichard-Eagle-Beaver mining district, in some tributaries of Trail Creek in the Tepee Creek watershed, and possibly in other creeks that were not field-checked.

2.5.2 Historic Channel Erosion Rates in the Big Elk and Upper Little North Fork Watersheds

Channel erosion rates were estimated for channels with gradients between 2 and 20%. Tributaries with gradients below 2% generally transport or deposit sediment, and are not normally a sediment source, although at times they may cut down through previous sediment deposits. Tributaries with gradients above 20% were assumed to convey so little flow that they accumulate colluvium and do not export sediment. Debris flows are rare in the North Fork subbasin.

For each slope class, the proportion of field-surveyed sites that were entrenched was multiplied by total channel length to obtain length of entrenched channels. The eroded cross-section area at each surveyed field site was calculated by subtracting undisturbed bankfull area from the entrenched channel area between terraces. For B-type channels, undisturbed bankfull area was calculated from drainage area using the USFS' regional bankfull geometry equations (U.S. Forest Service, 1999). For A-type channels, channel depth is greater due to form drag from large roughness elements, so bankfull area was estimated by multiplying the regional bankfull width by two times the regional bankfull depth which appeared appropriate based on Rosgen (1996) and observed bankfull dimensions in the field. The incised channels in our data set had cross-section areas 2 to 8 times larger than bankfull cross-section area. For each slope class, the average eroded area was multiplied by incised channel length to obtain eroded volume. Historic bank erosion was not calculated separately because it was included within the entrenchment calculations.

Channel entrenchment (incision followed by widening) was assumed to have occurred over a 30 year period. Although entrenchment of individual stream reaches probably occurred more rapidly, individual creeks and stream reaches were disturbed at different times as timber harvest proceeded and large storms occurred.

2.5.3 Current Channel Erosion Rates in the Big Elk and Upper Little North Fork Watersheds

Currently, the study watersheds have no ongoing channel incision, but there are areas with accelerated bank erosion. Since our field work occurred 10 years after the last major flood that would cause widespread bank erosion, sites rated Completely Unstable or Moderately Unstable were considered to have accelerated bank erosion (Table 2). Sites with Stable or Moderately Stable banks were considered to have natural, "background" erosion rates.

The only unstable steam reaches with accelerated erosion on Big Elk Creek were found near stream crossings. Recognizing that these zones become more extensive in the larger floods, which occur approximately once a decade, it was assumed that a 100 foot-long zone eroded the equivalent of 6 inches per decade for each of the 12 major stream crossings. A 2 foot bank height, based on field measurements, was used to develop these estimates.

In the upper Little North Fork, 15% of the surveyed sites with gradients of at least 2% had Unstable or Moderately Unstable banks. The majority of these sites were not associated with road crossings. We extrapolated the 15% rate of occurrence of Unstable or Moderately Unstable banks to all 2 to 20% channels. For larger channels with gradients between 2 and 8%, we used a typical bank height of 3 feet and 0.5 foot bank recession per decade. For smaller channels in the 8 to 20% range, we assumed a 1.5 foot high bank.

Current channel erosion was not calculated for reaches with channel gradients below 2%, using the same rationale as described above for historic erosion rates. C-type channels, with gradients less than 2%, are considered response reaches in which bank erosion is balanced by bar deposition. An exception was made for lower Iron Creek near the airstrip, where a low gradient reach continues to be severely-eroded by ATVs. The high banks have a 4-foot upper layer of fine sediment as well as at least 2 feet of gravel in the lower bank. The entire disturbed length visible on the 1996 air photo was assigned a 6 foot high bank and 1 foot of bank erosion per decade.

Our calculations were for accelerated erosion rate only. Total erosion rate is obtained by adding the accelerated erosion rates to the background erosion rate of 14.7 tons per square mile per year. This erosion rate (14.7 tons per square mile per year) is the middle value of sediment yield coefficients measured by the Forest Service in nearby Belt geology streams and used for WATSED modeling. It is also the rate used by IDEQ for the North Fork Coeur d'Alene TMDL (IDEQ, 2001).

2.5.4 Extrapolation to Other Parts of the North Fork Subbasin

Channel erosion rates from the detailed-study watersheds were extrapolated to other subbasins based on drainage area, not channel length. This assumes that drainage density is similar throughout the watershed, probably a reasonable assumption given the geology. The extrapolation is for erosion rates only -- no sediment delivery ratios were applied. Sediment yield at the bottom of the watershed would be lower due to sediment storage in upstream floodplains.

2.5.4.1 Logged areas

Each 6th-field HUC with timber harvest and roads was classified as less-disturbed or more-disturbed based on bank stability and sediment load observed during site reconnaissance, BURP site photos provided by IDEQ, historic and recent aerial photographs, and anecdotal information from the Forest Service. For less-disturbed HUCs, Big Elk Creek's unit erosion rate was multiplied by basin area to attain erosion rate in that HUC. More-disturbed HUCs were given a higher unit erosion rate from the upper Little North Fork. This procedure was done both for historic channel entrenchment and current bank erosion.

Bank erosion on the mainstem North Fork River downstream of Prichard Creek was measured by NRCS in 2000. No additional measurements of bank erosion extent were made. Interpretation of air photos indicated very little lateral movement of the river due to confinement by bedrock valley walls and revetments. The NRCS results are reported in the text, but were not added to the calculated bank erosion rates, which are for channels steeper than 2%.

The Prichard-Eagle-Beaver Creeks mining district currently has much higher erosion rates than the upper Little North Fork. We did not have enough field data to extrapolate confidently. These basins were assigned large multipliers of the Little North Fork rates. The resulting erosion rates should be viewed as a preliminary indication of large erosion rates of unknown magnitude.

At least 1000 tons per year of channel entrenchment, bank erosion, and valley wall erosion was estimated from the most obvious sediment sources during our brief reconnaissance in the mining district. Recognizing that the full current rate is far more, the mining district creeks were given a current bank erosion rate 3 times greater than the Little North Fork and a current channel entrenchment rate range of 1 to 10 times the historic channel entrenchment rate. In addition, the mining district creeks were given a historic erosion rate 5 times higher than the Little North Fork to reflect the greater length and severity of channel instability visible in air photos.

2.5.4.2 Burned, Unlogged Areas

For current conditions, unharvested areas with few or no roads were assigned the natural background erosion rate of 14.7 tons per square mile per year. This rate, developed by the US Forest Service, is based on sediment transport measurements in nearby watersheds and was used for the North Fork TMDL (IDEQ, 2001).

Some unlogged parts of Trail Creek, a tributary of Tepee Creek, currently have much higher erosion rates than the upper Little North Fork. At least six tributary creeks on the north side of Trail Creek have active channel entrenchment occurring at their downstream ends. Sufficient field data to extrapolate erosion rates for these areas with confidence was not available. Hence, a minimum of 600 tons per year was estimated based on field observations and a range of up to 10 times that figure was used as a placeholder to indicate a large sediment supply of unknown magnitude.

3. 0 CHANNEL RESULTS

3.1 CHANNEL CHANGES VISIBLE ON HISTORIC AERIAL PHOTOGRAPHS

Low-gradient, unconfined channels (response reaches) typically respond to excess coarse-sediment load by widening, depositing bars, straightening, and sometimes forming multiple channels (braiding). Large floods also can cause channel widening. Following passage of a sediment wave or large flood, the active channel gradually narrows and vegetation grows on the former gravel bars. When sediment load has decreased, the river will become more sinuous, bars will become smaller, and farther apart, and mid-channel grade bars will disappear. These changes can be readily observed on aerial photographs for all but the smallest streams.

The channel response analysis focused on major low-gradient, unconfined valley segments throughout the North Fork subbasin, as well as smaller tributaries in the two detailed study areas of Big Elk Creek and the Little North Fork above Burnt Cabin Creek. The upper North Fork HUC above Tepee Creek was not analyzed except near the Tepee Creek confluence.

Likely response reaches were viewed on a series of historic aerial photos (Table 1) to determine relative changes in channel width and pattern, and to identify direct disturbances to the channels. Very few response reaches had 1975 air photos, and many were missing 1968 and/or 1983/84 photographs. Bar charts depicting the relative changes in channel width were developed for the 39 reaches analyzed (Appendix 2).

Extreme width increases, avulsion channels, and continuous, wide gravel bars occurred in the Little North Fork, Shoshone Creek, Trail Creek (tributary of Tepee Creek), the North Fork above Tepee Creek and below the Little North Fork, Prichard Creek, and Eagle Creek (Table 3). Growth of bars where no bars previously existed was noted in some locations on the North Fork just downstream of Prichard Creek (Table 3). Less extreme, but significant, width increases occurred in Tepee, Independence, Big Elk, Beaver, Iron, and Burnt Cabin Creeks, the middle North Fork River in the vicinity of Miners -Brett-Wilson Creeks, and three reaches of the lower North Fork (Table 4).

Width increases occurred by 1937 or by 1968 in most response reaches. In many locations, avulsions were observed on the 1983/84 photos that presumably occurred during the 1974 or 1982 floods. An avulsion is a sudden switch to a new channel, often leaving a forested island between the old and new channels. Despite the avulsions, in many cases the 1983/84 active channel width stayed the same or decreased relative to 1968. Most response zones had narrowed by 1996 and stayed narrow since then. A few stream reaches either widened again or remained wide in the 1996 or 2004 photos.

The mined watersheds -- Prichard, Eagle, and Beaver -- had the most severe, widespread, and persistent channel response to coarse-sediment load with relatively little recovery (see Section 3.4 for further discussion). Logged areas, such as Big Elk Creek and the Little North Fork, had fewer widened reaches than the mined watersheds and quicker recovery, with the exception of the reaches furthest downstream (see Sections 3.2 and 3.3 for further discussion). Some streams

Table 3. Locations and dates of extreme increases in active channel width (value of 13 on bar charts included in Appendix 2).*

Subbasin	Reaches with extreme width increases (value of 13 on bar charts in Appendix 2)	Date of Photo with Maximum Width
MANAGEMENT TYPE: LOGGED, DENSE ROAD NETWORK		
Little North Fork above Burnt Cabin	Little North Fork between Burnt Cabin and Hudlow Creeks	1968
	Little North Fork Coeur d'Alene River near Deception Creek	1968
	Little North Fork Coeur d'Alene River near Bootjack Creek	1983/84
	Little North Fork Coeur d'Alene River near Little Tepee Creek	1937
Lower North Fork (below Prichard)	North Fork Coeur d'Alene River just below Prichard Creek	1975
	North Fork Coeur d'Alene River below Little North Fork	1937
Prichard	Prichard Creek below Eagle	1937
	Prichard Creek above Eagle	1996
	Eagle Creek	1996
Shoshone (viewed only near mouth)	Shoshone Creek near mouth	1937
MANAGEMENT TYPE: BURNED, EARLY GRAZING, FEW OR NO ROADS		
Upper North Fork above Tepee (photos viewed only near Tepee Cr)	North Fork Coeur d'Alene River -- first few miles above Tepee	1937
Tepee	Trail Creek below Hamilton Creek	1983/84

* Note the historic channel analysis did not include most of the upper North Fork Coeur d'Alene River above Tepee Creek, nor smaller tributaries except Big Elk Creek and the upper Little North Fork Coeur d'Alene River watershed above Burnt Cabin Creek.

Table 4. Locations and dates of significant increases in active channel width (value of 12 on bar charts in Appendix 2).* Stream reaches listed in Table 2 above are not repeated in this table.

Sub-basin	Reaches with extreme width increases (value of 12 on bar charts in Appendix 2)	Date of Photo with Maximum Width
MANAGEMENT TYPE: LOGGED, DENSE ROAD NETWORK		
Little North Fork above Burnt Cabin	Little North Fork Coeur d'Alene River -- scattered areas between Tom Lavin and Solitaire Creeks	1996 or earlier
	Iron Creek	1968, 1983/84
	Burnt Cabin Creek	1937, 1968
	Little North Fork Coeur d'Alene River near Copper Creek	1937
	Little North Fork Coeur d'Alene River near Bumblebee Creek	1937, 1968
Lower North Fork (Below Prichard)	Beaver Creek below Trail Creek	1968, 1975
	North Fork Coeur d'Alene River near mouth	1937
	North Fork Coeur d'Alene River above Little North Fork	1968
	North Fork Coeur d'Alene River east of Grizzly Creek	1937
Middle North Fork (Above Prichard)	North Fork Coeur d'Alene River near Brett, Miners, and Wilson Creeks	1996 or earlier
MANAGEMENT TYPE: MOSTLY BURNED, EARLY GRAZING, FEW OR NO ROADS (SOME LOGGING IN HEADWATERS)		
Tepee	Tepee Creek near mouth	1996
	Tepee Creek downstream of Magee	1968
	Upper Independence Creek response zones	1937, 1968, 1983/84
	Independence Creek between Owl and Griffith creeks	1968, 1983/84, 2004
	Trail Creek near mouth	1968
	Trail Creek above Hamilton Creek	1983/84

* Note the historic channel analysis did not include most of the upper North Fork Coeur d'Alene River above Tepee Creek, nor smaller tributaries except Big Elk Creek and the upper Little North Fork Coeur d'Alene River watershed above Burnt Cabin Creek.

with early 20th-century burns, which had little to no logging and road building, had channel widening of a similar magnitude and timing as the densely-roaded, logged subbasins (see Section 3.5 for further discussion).

3.2 Big Elk Creek Channel Erosion and Conditions

Big Elk Creek drains an 11 mi.² watershed in the headwaters of the Tepee Creek watershed.

3.2.1 Big Elk Creek Land-Use History

The lowest mile of Big Elk Creek, east of First Creek, was part of the big burns of 1910-1919. The upper three quarters of the Big Elk watershed did not burn and was still unlogged in the 1930s. Dense, roadless, forest was apparent in the 1933 and 1937 photos west of First Creek. The valley-bottom meadows had patchy stands of trees a bit denser than today in some spots. As it does today, the meadow continued upstream well past the sharp bend in the creek. The forested part of Big Elk's watershed was part of the "Lost Block" which was logged over an extended period of time starting in 1925 (Russell, 1984). The Big Elk watershed was thus spared some of the more damaging "legacy" harvest practices that affected parts of the North Fork Coeur d'Alene watershed. Logging was well underway by 1968 (date of the next available air photographs), and a dense with network of roads was well developed.

3.2.2 Big Elk Creek Tributary Channel Erosion

This section describes erosion of *transport* channels, which have gradients above 2 percent and can generally transport eroded sediment downstream. The behavior of flatter, *response* channels is described in later sections.

3.2.2.1 Current Tributary Erosion

All the surveyed tributary creeks that deliver coarse sediment to Big Elk Creek had Stable, or at worst Slightly Unstable, banks with the exception of localized areas near culverts. Otherwise, bank erosion did not appear to be a current source of sediment beyond normal background rates. Downcutting also was not a current source of sediment at the sites surveyed, with the exception of a short reach of US Creek upstream from the 912 road crossing. The slight downcutting there may have resulted from installation of a much larger culvert that eliminated sediment blockage upstream from the road. The current accelerated channel erosion rate for the Big Elk watershed is estimated at about 70 tons per decade, equivalent to about 1 ton per square mile per year (Table 5).

Table 5. Historic and current channel erosion rates in the Big Elk Creek watershed

	Current Erosion	Historic Channel Erosion
Type of erosion	Primarily stream banks near culverts	Entrenchment of stream bed and banks
Volume		46,000 cubic yards
Accelerated erosion rate	7 tons/year	2500 tons/year assuming 30 years of erosion
Watershed area	11.6 mi.²	11.6 mi.²
Accelerated erosion rate per unit area	1 ton/square mile/year	220 tons/square mile/year if all entrenchment was due to management impacts
Background erosion rate	*14.7 tons/square mile/year*	

Figure 2. Forced bars (left) and LWD steps (right) in Big Elk Creek upstream of the 914 crossing.

Figure 3. US Creek (left), which has never downcut and a steep tributary to Big Elk Creek, upstream of US Creek, which downcut slightly and subsequently formed a new floodplain and restabilized.

Coarse sediment load appeared moderate in the upstream tributaries and upper Big Elk Creek. There were wood-forced gravel bars and sediment wedges upstream from LWD steps (Figure 2). This was partly an artifact of the relative abundance of LWD. Where there was no LWD, the creeks had a plane-bed channel without bars and the sediment load appeared lower. Channels steeper than 4 percent had abundant grade controls in the forms of LWD or boulder and cobble steps. These features provided significant roughness elements to dissipate energy and reduce erosion. These steeper tributary streams either never downcut (e.g., most of US Creek; Figure 3) or have formed a new floodplain and restabilized after downcutting (e.g., uppermost Big Elk Creek; tributary upstream of US Creek; Figure 3). The steeper tributaries are currently not entrenched to slightly entrenched. Although narrow, the valley bottoms are wide enough to allow floodplain development next to the small tributary streams. Floodplain connection no doubt contributes to the lack of current downcutting.

The channel analyst did not find any locations where roads parallel to streams encroached upon the floodplain enough to confine the major creeks. There was no trace of a spur road shown on the Forest Service B map going up US Creek from the 912 road. The creek had stable banks and numerous LWD steps and jams for at least 1000 feet upstream of the 912 road.

The surveyed creeks were not entrenched or slightly entrenched in 2006. Except for two of the steeper tributaries, all the surveyed sites had a low, frequently-flooded floodplain on at least one side. All surveyed sites had terraces that flooded during moderate-size floods. Only two sites had unflooded terraces close enough to the creek to measure. In the steeper channels, this lack of entrenchment or significant downcutting was clearly due to LWD or boulder steps that form grade controls. At the upper Big Elk Creek BURP site, which has a high terrace, the creek obviously downcut sometime in the past (perhaps in response to removal of wood during timber harvest, but possibly prior to human disturbance); it since has aggraded due to abundant LWD.

3.2.2.2 Historic Tributary Channel Erosion

Based on surveyed cross-sections, over half of the tributary channels in Big Elk Creek have incised in the past and then widened to evolution stage 5 (aggrading and widening) or 6 (restabilization). This process eroded an area between terraces that was 2 to 7 times greater than the bankfull channel area. The entrenched streams had 6 to 60 cubic feet of erosion per linear foot of channel. The total historic erosion from tributary channel entrenchment was about 46,000 cubic yards (Table 5). Some of this entrenchment may have occurred prior to timber harvest. Conservatively assuming it all occurred during a 30 year period following the greatest disturbance (1950s through 1970s, or 1960s through 1980s), the historic channel erosion rate was about 2500 tons per year, equivalent to about 220 tons per square mile per year. Confidence level in this erosion rate is only fair due to the low number of steeper headwaters streams that were visited.

3.2.3 Big Elk Creek Watershed Morphology and Sediment Routing

Gradient and valley confinement both progressively decline in the downstream direction (Figure 4). The headwater tributaries have narrow, steep valleys and cobble-dominated bedload sediment. These reaches transport sediment from upstream, and in some cases were a source of coarse sediment when entrenchment occurred. Downstream of the uppermost forks, Big Elk Creek's channel gradient drops to 5% and then progressively declines to about 1% below the major bend to the east shown on Figure 5. Surface sediment size downstream of the bend is predominantly very coarse to coarse gravel with small cobbles (Figure 6), but some large cobbles are transported all the way to the mouth of Big Elk Creek. Field-measured gradients were 0.5-0.6% downstream of the Leiberg-Magee Road Bridge.

The Big Elk valley is narrow in the headwaters, but widens to about 300 feet near US Creek. Continuing downstream, it narrows again at the sharp bend to the east, then widens to about 400 feet from below the bend to Big Gene Creek. The valley widens to more than 700 feet below Big Gene Creek. It narrows again from First Creek downstream to the mouth.

The combination of declining gradient and lower flood heights in a broad valley reduces the creek's ability to transport sediment. Given an ample supply of coarse sediment, sediment deposition zones occur wherever the sediment transport capacity declines abruptly. The uppermost sediment deposition zone in the creek occurs near US Creek and the next tributary downstream, where stream gradients are only 1 to 3% in between occasional LWD steps. Sediment delivery from steeper tributaries contributes to the presence of a deposition zone at this location.

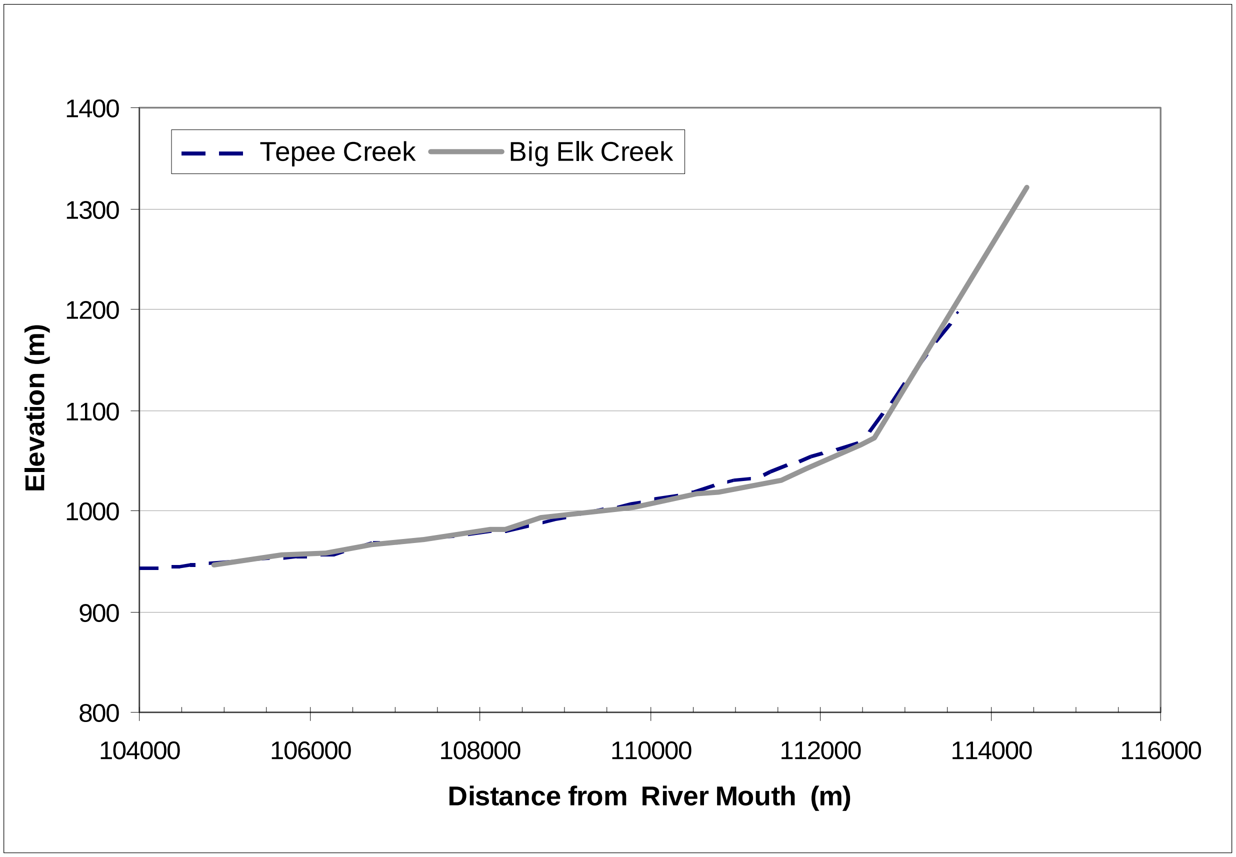


Figure 4. Profiles of Big Elk Creek and Tepee Creek.

Longer sediment deposition zones occur in the broad meadows below the bend. The sediment source for these zones is primarily Big Elk Creek itself, since tributary channels along the meadow deliver little or no coarse sediment. There is less large woody debris influence because the meadows are sparsely forested. Channel gradient is flat enough that meander bends, pools, and bars form even where large wood is absent.

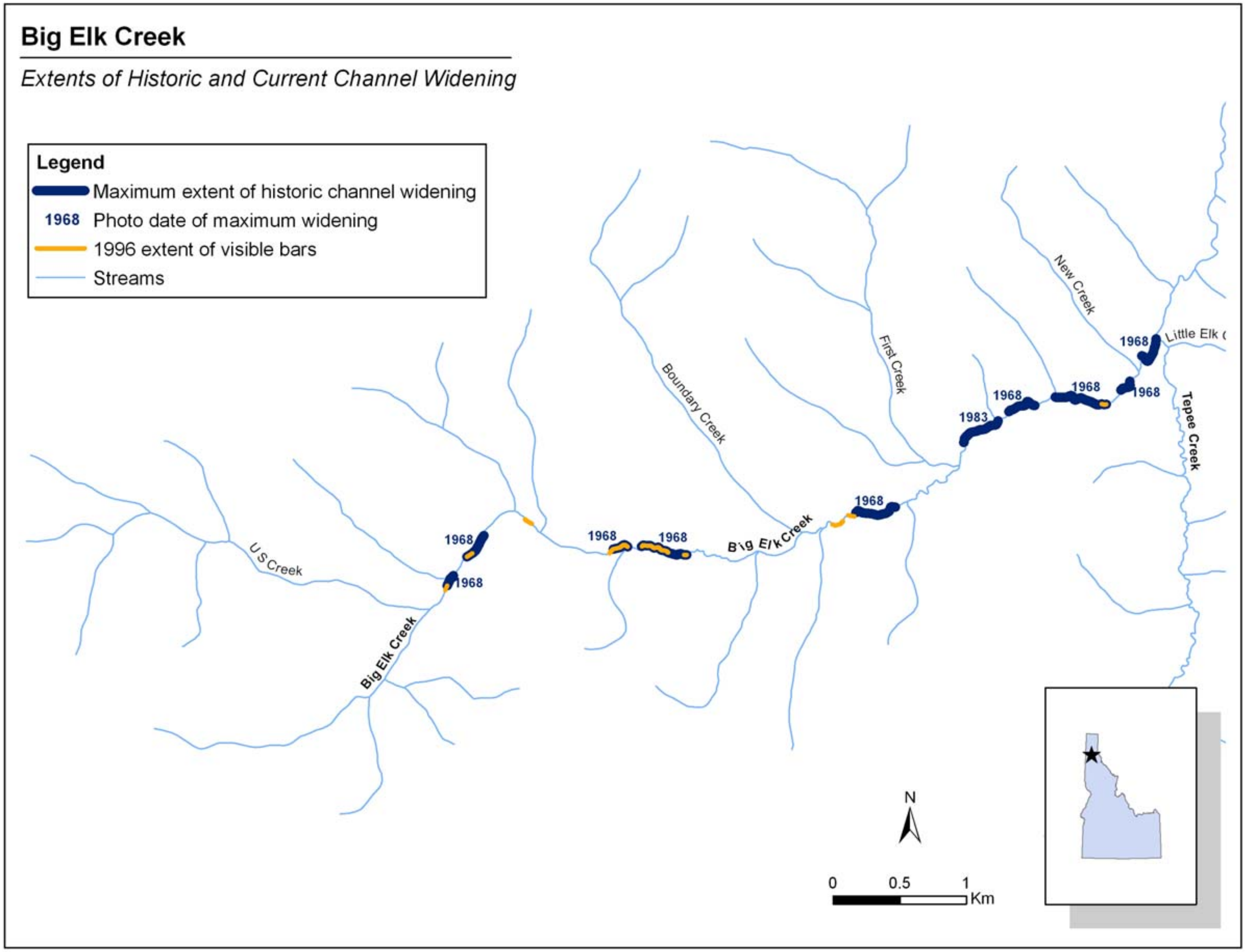


Figure 5. Extent of historic and current channel widening of Big Elk Creek mapped from aerial photographs.

Figure 6. Surface sediment size In Big Elk Creek downstream of the bend is predominantly very coarse to coarse gravel with small cobbles.

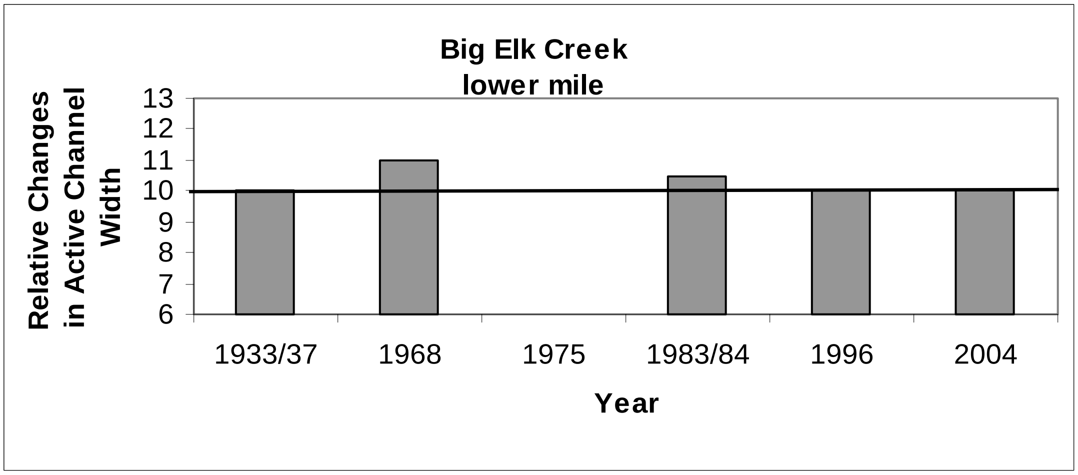
3.2.4 Big Elk Creek Downstream Channel Response to Sediment Load

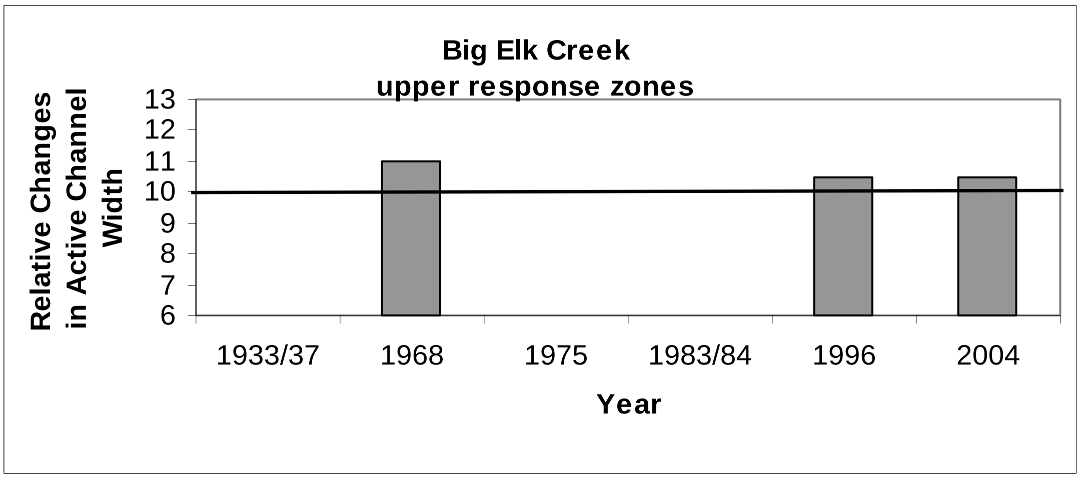
Aerial photographs of the full watershed were available only for 1968, 1996, and 2004. The available 1937 and 1983 photographs only covered the lowest 1 mile of Big Elk Creek. Big Elk Creek is so small as to be barely visible in the 1937 and 1968 black-and-white aerial photos, but visibility was good downstream of Boundary Creek due to the presence of the meadows.

In the 1937 photograph, gravel bars were visible in the lowest 3/4 mile of creek but not the next 1/4 mile. In 1968 and 1983, visible gravel bars went farther upstream and were wider and more extensive. Some areas near the mouth appeared straighter in 1968 due to dredging or bend cutoffs (indeterminate due to small size of photo). Relative to 1968, there were fewer bars present in 1983 (photo coverage lower mile only) and even fewer in 1996 (Figure 7). In 1996, the length of creek with visible bars was only 20 percent of the 1968 length in the response zone near US Creek (Figure 5). In 1996, bars were still present in about 80 percent of the 1968 length in the response zone below the large bend to the east, and less than 20 percent in the short response zone below Boundary Creek. Overall, channel length with visible bars in 1996 was 23 percent of 1968 length (Figure 7). The present distribution of gravel bars looks similar to the 1996 photo, and to the 1937 photo where available.

In the lower mile of Big Elk Creek, assuming 1937 conditions represent pre-disturbance width, the channel was widest in 1968, but the had returned to the pre-disturbance width by 1996 (Figure 5, Figure 7). The timing is less clear upstream due to lack of photos, but the channel in 1968 is clearly wider than in 1996 (Figure 7). The continued presence of visible gravel bars in upstream areas is probably due more to LWD-induced sediment storage than an excessive coarse sediment load.

Historic air photos were used to compare Big Elk Creek to surrounding watersheds. Channel responses in upper Tepee Creek above Big Elk Creek were similar in magnitude to the channel responses in Big Elk Creek (See section 3.5 for further discussion). No increase in channel width was apparent on the air photos in two small, unburned, unlogged Tepee Creek tributaries downstream of Big Elk Creek. Trail Creek, a much larger Tepee Creek tributary to the north, widened far more than Big Elk Creek and parts were still unstable in the 1990s (Section 3.5).





**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 7. Relative changes in active channel width of Big Elk Creek interpreted from aerial photographs.

Most of Trail Creek was burned and unlogged, but the headwaters had some logging and erosion-prone roads. Far more channel widening was apparent in Iron Creek (see Section 3.3), a logged Little North Fork tributary immediately west of Big Elk Creek with similar valley morphology.

In 2006, four out of five Big Elk Creek sample sites below the bend had a low sediment load and Stable banks. The fifth site, at a USFS cross-section site above Boundary Creek, had Moderately Stable banks and a moderately high sediment load.

The response zone upstream of the Leiberg-Magee Road Bridge provides a good example of the sediment-storage function of the meadows. This response zone had wide gravel bars in the 1968 photograph but no visible bars in the 1996 or 2004 photographs (1983 was missing). Our field visit in summer 2006 found this reach had a predominantly narrow, stable channel (Figure 8.), but there were some wider zones of bank erosion and collapse. These wider zones typically occurred at the outside of bends and had gravel bars too small to see on aerial photographs.

There were several abandoned channels on the floodplain, remnants of past avulsions (Figure 9). The most recently abandoned channel dead-ends at a gravel plug that is about 50 feet wide and a foot higher than the adjacent floodplain. The current, narrow channel is located over 35 feet southeast of the blocked former channel, and its bed is nearly 4 feet below the top surface of the gravel deposits. Apparently the creek easily cuts a new channel in the meadow when coarse sediment load exceeds the transport capacity of a particular stream reach and plugs the previous channel location. Excess coarse sediment (whether from upstream tributaries or from accelerated bank erosion during a large flood) tends to be stored in the meadow rather than transported downstream.

Figure 8. Predominantly narrow, stable channel in the meadows area of Big Elk Creek.

Figure 9. Avulsed channels in the meadows area of Big Elk Creek.

3.2.5 Big Elk Creek Channel Discussion

Big Elk Creek had a relatively small response to past management activities. Although most of the creek is flat and unconfined, bar growth and widening occurred in discrete areas rather than along the entire creek. The greatest amount of channel widening occurred in the 1960s and the response zones were shorter in the 1980s. Due to lack of photographs, it is unknown whether these response zones were active for decades or just occurred during the large floods that preceded each of the photo dates. In any case, Big Elk Creek's air photo response was subdued relative to Iron Creek to the west (a Little North Fork tributary with similar valley morphology) and the burned, unlogged streams to the north (Trail and Independence Creeks).

Big Elk Creek's subdued channel response is attributed to relatively few sediment sources, few roads along channels affecting channel structure, and unconfined stream valleys that allow flood flows to spread out. The modeled effect of roads on flood size is small. Several tributary streams deposit their sediment along the valley margins and deliver little or no sediment to Big Elk Creek. Forests have grown enough to supply LWD of a functional size to the tributary streams and the upper half of Big Elk Creek. As the amount of wood increases in the future, more forced bars and bends will occur. This trend may explain some new gravel bar areas visible on the 1996 photos that were not present in 1968. Meadows greatly restrict the wood supply along the lower part of Big Elk Creek, except where the creek has migrated next to the valley wall.

The current magnitude and location of coarse sediment deposits along Big Elk Creek appear normal for a steep, forested watershed. Active gravel-cobble bars occur in zones where gradient decreases and the valley becomes wider, often in association with LWD steps or jams. Reaches steeper than 1% without LWD had plane bed morphology with a straight channel and no bars or pools, despite the same loading of coarse sediment as adjacent LWD-rich reaches with gravel bars. The broad meadows of lower Big Elk Creek store a significant amount of the coarse sediment supply in the watershed, greatly reducing the coarse sediment load that reaches Tepee Creek.

3.3 Little North Fork above Burnt Cabin Creek -- Channel Erosion and Conditions

The Little North Fork Coeur d'Alene River has a 170 square-mile watershed and flows south, entering the North Fork River 5 miles from its downstream end. The detailed study area within the Little North Fork watershed is the 43 square-mile watershed upstream of Burnt Cabin Creek. Major tributaries, listed from the confluence with Burnt Cabin Creek upstream to the headwaters, include Cathart, Nicholas, Barney, Hudlow, Iron, Lewelling, Tom Lavin, Solitaire, Sob, and Honey Creeks (Figure 10).

3.3.1 Upper Little North Fork Land-Use History

Early timber harvest and road building was concentrated in the stream valleys of the Little North Fork and its tributaries. Some of the smaller streams were used as roads and skid trails, and flumes were used to transport logs down to the river. Most of the watershed above Burnt Cabin Creek was upstream of splash dams. There were two splash dams built in the first river mile upstream from Burnt Cabin Creek. Cathcart Dam was built in 1918 just downstream from Cathcart Creek. No Name Dam was built in 1919 a short distance upstream, above Beaver Creek (Russell 1984). The last log drive in the Little North Fork occurred in 1937, but that may have been further downstream because most of the lower dams were built in the late 1920s.

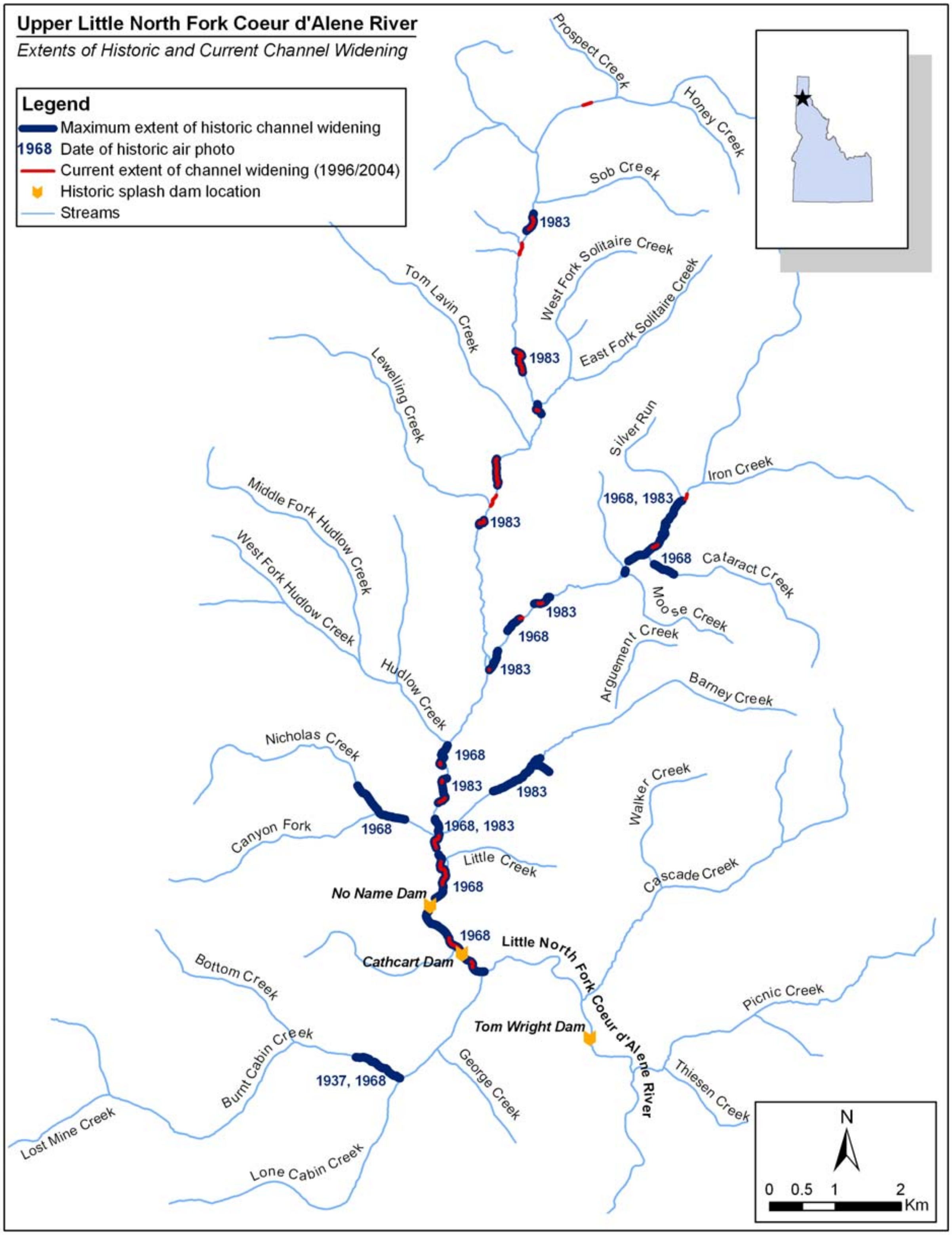


Figure 10. Extent of historic and current channel widening of the Upper Little North Fork Coeur d'Alene River mapped from aerial photographs.

The review of air photos indicates that riparian harvest along the Little North Fork had progressed up to about Lewelling Creek by 1933, and up to Honey Creek by 1968. By 1968, there was a dense network of logging roads on the hillsides, but many areas remained that were not logged. More road building, skid trail building, and timber harvest occurred in the 1970s and 1980s. LWD was removed from stream channels through the 1980s, according to USFS biologist Ed Lider.

3.3.2 Upper Little North Fork Tributary Channel Erosion

This section describes erosion of *transport* channels, which have gradients above 2% and can generally transport eroded sediment downstream. The behavior of flatter, *response* channels is described in later sections.

3.3.2.1 Current Channel Erosion

Most locations surveyed had Stable, or, at worst, Slightly Unstable banks in summer 2006, which was a decade after the last major flood. In most locations, bank erosion or channel downcutting did not appear to be a current source of sediment beyond normal background rates. Banks were Moderately Unstable or Unstable at 15% of the surveyed sites, which were considered to be eroding faster than the natural background rate. Most of the eroding sites were in the Iron Creek drainage and had either severe current road encroachment, direct channel disturbance by old roads, or ongoing ATV use (Figure 11). Moderately unstable banks were observed in Canyon Fork Creek upstream of Nicholas Creek, associated with flow deflection by LWD and a high sediment load from unknown sources upstream.

Figure 11. Disturbance of the channel and banks of Iron Creek near the airstrip by ATVs.

Table 6. Historic and current channel erosion rates in the Little North Fork Coeur d'Alene River watershed above Burnt Cabin Creek

	Current Erosion	Historic Channel Erosion
Type of erosion	Primarily stream banks	Entrenchment of stream bed and banks
Volume		260,000 cubic yards
Accelerated erosion rate	360 tons/year	14,000 tons/year assuming 30 years for observed erosion
Watershed area	43.2 mi.^{2}	43.2 mi.^{2}
Accelerated erosion rate per unit area	8 ton/square mile/year	330 tons/square mile/year if all entrenchment was due to management impacts
Background erosion rate	*14.7 tons/square mile/year*	

The current rate of accelerated bank erosion in the watershed upstream of Burnt Cabin Creek, including the few areas still downcutting, was estimated at about 360 tons per year. The unit rate of bank erosion is about 8 tons per square mile per year (Table 6).

In 2006, the coarse sediment load in most tributary channels appeared low to moderate. Most streams had few or no bars and cobble-dominated beds with little gravel. This appears to contradict the results of the RSI surveys done in 1992, either because most of the gravel has since moved through the system or because we did not visit the same sites (locations were not available).

Coarse sediment load appeared high on Canyon Fork Creek upstream of Nicholas Creek (a known RSI site) and on the west fork of Moose Creek. Most coarse sediment from these particular tributaries does not reach the Little North Fork. Iron Creek at and downstream of the airstrip had a high fine and coarse sediment load, attributed to erosion of the streambed and banks where numerous ATV trails cross the channel (Figure 12)

Figure 12. Fine sediment from ATV erosion in Iron Creek near its mouth

Riparian trees along most creeks are large enough to provide LWD to the streams. There is a fair amount of functional large woody debris in the channels. The logs store sediment and form steps in steep headwaters streams (Rosgen A channels). In moderately-sloping B channels, fallen trees cause bank erosion and channel migration in addition to forming bars and pools. The B and C channels along parts of lower Iron Creek have less LWD. These areas lack a riparian forest due to wetland meadows or are dominated by young successional stages of willow shrubs on former gravel bars.

3.3.2.2 Historic Channel Erosion

We found old plank roads in and along two steep tributaries in the Iron Creek watershed: the west fork of Moose Creek and nearby Cataract Creek. As a result, the surveyed reaches of these creeks had very few steps in the channels to provide grade control. These channels were either currently or formerly unstable and had poorly-defined or multiple channels. In contrast, no evidence of old roads was found in the steep tributaries in the Lewelling and Tom Lavin drainages. These drainages had stable LWD and boulder/cobble steps, which provide significant roughness elements to dissipate the energy of the flow (Figure 13). We were unable to sample enough other creeks to determine what is typical for other drainages.

Figure 13. LWD provides grade control in steep headwaters of Lewelling Creek (left). Evidence of former downcutting is found in some of the tributaries, such as the site on Lewelling Creek pictured on the right where an old stump was found on an entrenched floodplain.

Entrenchment occurs when the stream bed degrades to the point where floods can no longer access the floodplain regularly. Causes of entrenchment on the Little North Fork could include increased flood discharge, removal of channel LWD for harvest or to facilitate log drives, and road encroachment of the floodplain that significantly deepens flows. The very large 1974 flood reportedly caused widespread scour and deepening of second and third order channels (USFS, 1974).

The cross-section shape of many of the streams provides evidence of former downcutting (Figure 14). Two sites with unstable banks still had narrow, entrenched channels (Stage 4, Figure 1). In one case, road encroachment prevented the channel from widening enough to deposit sediment. Most entrenched streams have since widened to stage 5 or 6, in which aggrading or restabilized channels have bars and/or floodplains within a narrow valley (Figure 14). This narrow valley is inset within higher terraces formed by the former floodplain. On the Little North Fork tributaries, the eroded cross-section area between terraces was 3 to 8 times larger than the bankfull channel area prior to downcutting. The entrenchment process eroded a large amount of sediment that moved downstream.

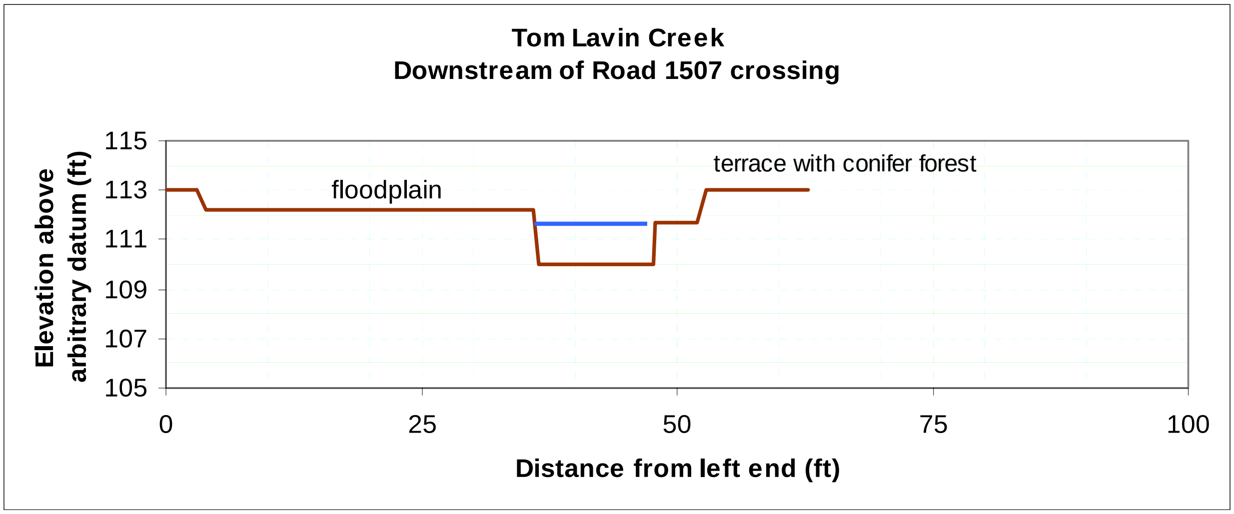


Figure 14. 2006 cross-section of Tom Lavin Creek below the Road 1507 crossing, showing a floodplain that formed within the entrenched terrace. Prior to entrenchment, the bankfull channel was higher and the current terrace flooded nearly every year.

Coarse sediment load was far higher previously, when the creeks were actively downcutting and widening, or had active roads down the channels. Based on surveyed cross-sections, currently-stable channels that downcut in the past had 5 to 125 cubic ft of erosion per linear foot of stream. Our sampling suggests this occurred on more than two thirds of tributary channels steeper than 2%. Historic channel entrenchment eroded about 260,000 cubic yards of sediment. Some of this entrenchment may have occurred prior to timber harvest, but most probably occurred either during early logging in the splash-dam era or during the peak of the road building/logging of the 1960s through 1980s. Major flood events may also have contributed to the current condition. Conservatively, assuming that all the entrenchment occurred during a single 30-year period as a result of timber harvest activities, the estimated historic erosion rate is about 14,000 tons per year. The equivalent unit rate is 330 tons per square mile per year (Table 6). If half the erosion occurred during early logging and half in the mid-20th century, the historic rate would be half as large. Confidence level in the erosion rate is moderate due to the number of headwaters streams that were not visited.

3.3.2.3 Tributary Erosion Summary

As of summer 2006, tributaries above Burnt Cabin Creek were no longer delivering much coarse sediment to the Little North Fork. Channel erosion rates were greatly reduced compared to estimated inputs decades earlier, when many tributaries were incising or were directly disturbed by roads or flumes. Most of the currently-eroding channels discovered during field work were in the Iron Creek watershed. Canyon Forks Creek above Nicholas Creek also had a high sediment load but the source was not explored.

3.3.3 Upper Little North Fork Watershed Morphology and Sediment Routing

The gradient of the Little North Fork gradually decreases downstream (Figure 16), from over 1.5% in the headwaters, to between 1.0 and 1.5% upstream of Iron Creek. River gradient drops to below 1% downstream from Iron Creek, to less than 0.7% downstream of Hudlow Creek, and less than 0.5% in the final mile upstream of Burnt Cabin Creek.

The river valley is wide relative to the river's width in most of the study area, so the unconfined channel can migrate across the valley floor. Channel migration processes tend to be most active in channels with a gradient less than 1%, but steeper channels can also migrate in response to inputs of LWD or coarse sediment.

The dominant and subdominant grain sizes on the river bed upstream of Burnt Cabin Creek are small cobble and coarse gravel, respectively. Maximum particle size was typically large cobble and did not decrease with distance downstream. We had too little data on median sediment diameter to identify any trends.

Watershed morphology determines the coarse sediment delivery potential of each tributary to the Little North Fork (Table 7). Iron, Barney and Solitaire creeks have steep headwaters but their broad, gently-sloping lower valleys store much of the coarse sediment load, thereby reducing sediment delivery to the Little North Fork. In addition, coarse sediment from many of Iron Creek's lower tributaries does not reach Iron Creek but drops out in alluvial fans on the valley edge, similar to Big Elk Creek.

Hudlow, Cathcart, and Canyon Forks Creeks are moderately steep in their lower reaches, but they deliver sediment into abandoned river channels on the west side of the Little North Fork's floodplain. They drop their coarse sediment load on the valley edge, and little or no coarse sediment gets as far as the Little North Fork (Figure 15). These creeks deliver coarse sediment directly to the river only when channel migration moves the river to the west side of the valley. This situation may occur soon on Canyon Forks Creek as the river is moving west at that location. However, Canyon Forks Creek also has numerous beaver dams between Nicholas Creek and the mouth, so its sediment delivery is low except following major floods that destroy the beaver dams.

Only Tom Lavin, Sob, Lewelling and probably Honey Creeks remain steep and deliver most of their coarse sediment directly to the Little North Fork. These creeks have no significant sediment storage zones and are steep and confined, allowing them to deliver large cobbles all the way to the Little North Fork (Figure 15). Burnt Cabin Creek, which enters just below the detailed study area, also delivers its coarse sediment load directly to the Little North Fork.

Figure 15. Tributaries differ in ability to deliver coarse sediment to mainstem. Hudlow Cr. (left) flows down a channel on Little North Fork floodplain where the creek deposits its sediment load. Sediment will be stored on the floodplain until the mainstem migrates to the depositional area. Other tributaries, such as Iron Creek, pictured on the right, store sediment in their own floodplains and do not deliver much sediment to the mainstem.

Table 7. Tributary coarse sediment delivery potential to the Little North Fork Coeur d'Alene River, reflecting the relative proportion of a tributary's coarse sediment that reaches the river instead of being deposited upstream. This table does NOT show the amount of sediment produced by each tributary.

	TRIBUTARY MORPHOLOGY / SEDIMENT DELIVERY TO RIVER			
CREEK	**Steep, narrow valley; direct delivery to river HIGH**	**Broad, flat valley below steep segments MODERATE**	**Beaver dams LOW SPORADIC**	**Tributary ends in abandoned channel on river floodplain NONE**
Honey	X			
Sob	X			
Solitaire		X		
Cathcart			X	X
Tom Lavin	X			
Lewelling	X			
Iron		X	X	
Hudlow				X
Barney		X		
Canyon Forks			X	X
Burnt Cabin	X			

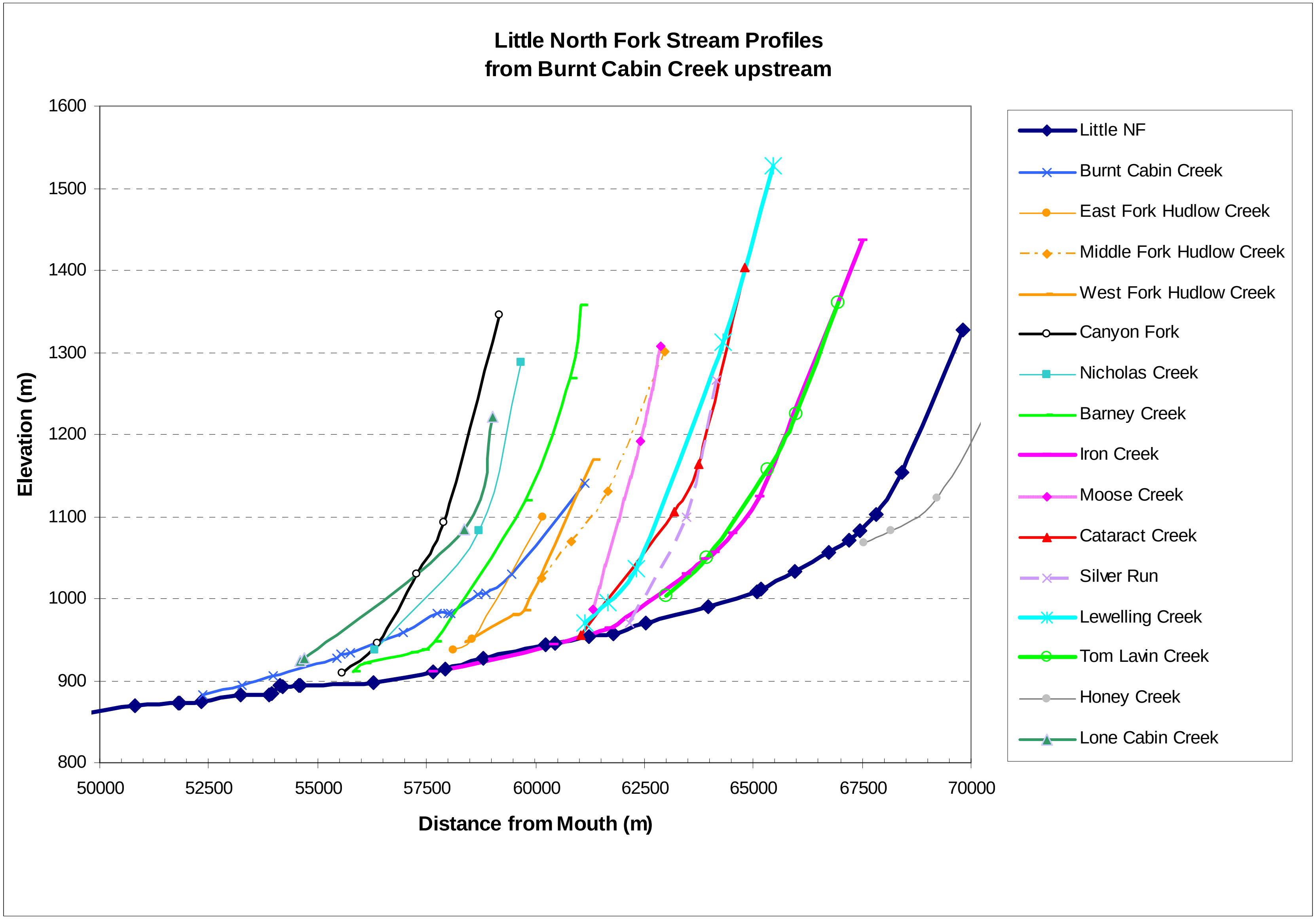


Figure 16. Profiles of the Little North Fork Coeur d'Alene River and its tributaries upstream from Burnt Cabin Creek.

There were no unvegetated alluvial fans on the Little North Fork at tributary junctions, but a low, split-channel area of former gravel deposits was observed at the mouth of Tom Lavin (Figure 17) and Lewelling Creeks. The river easily absorbs coarse sediment from the tributaries due to their small size.

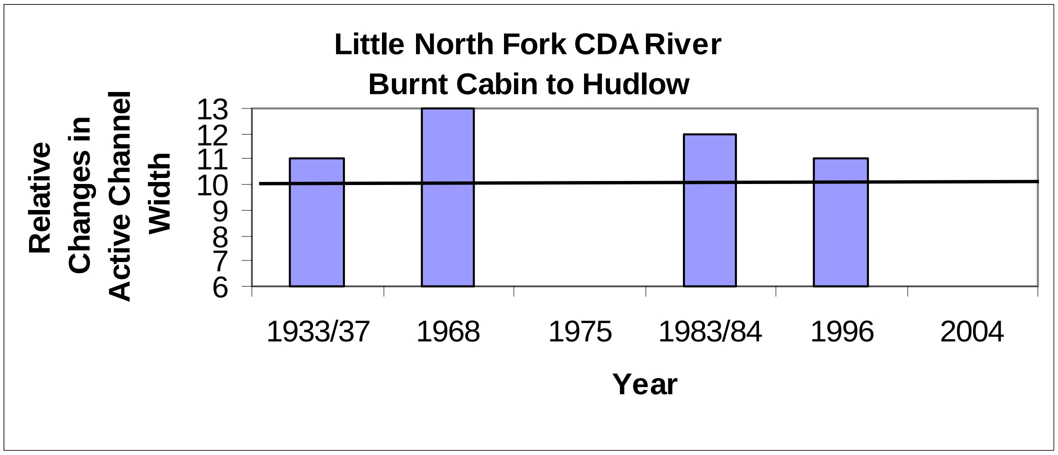
Figure 17. Split channel at mouth of Tom Lavin Creek.

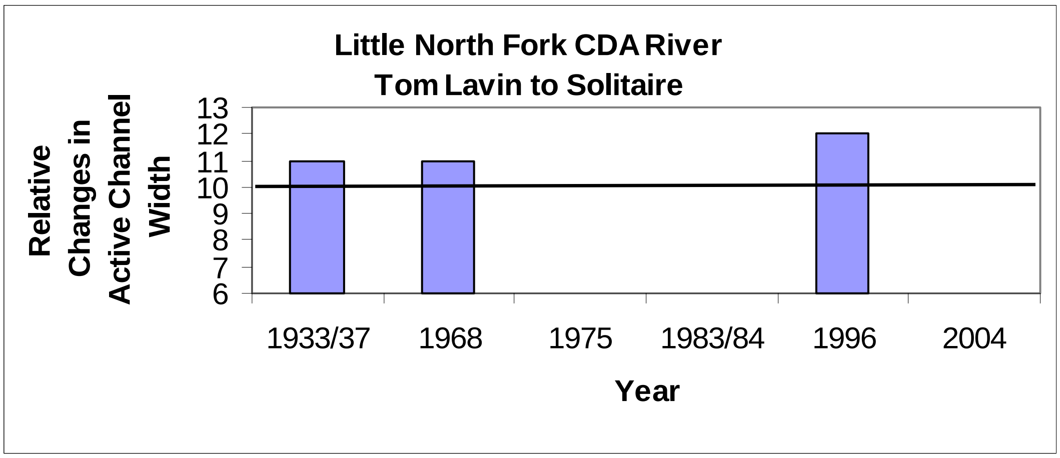
3.3.4 Little North Fork Channel Response to Coarse Sediment Inputs and Riparian Timber Harvest

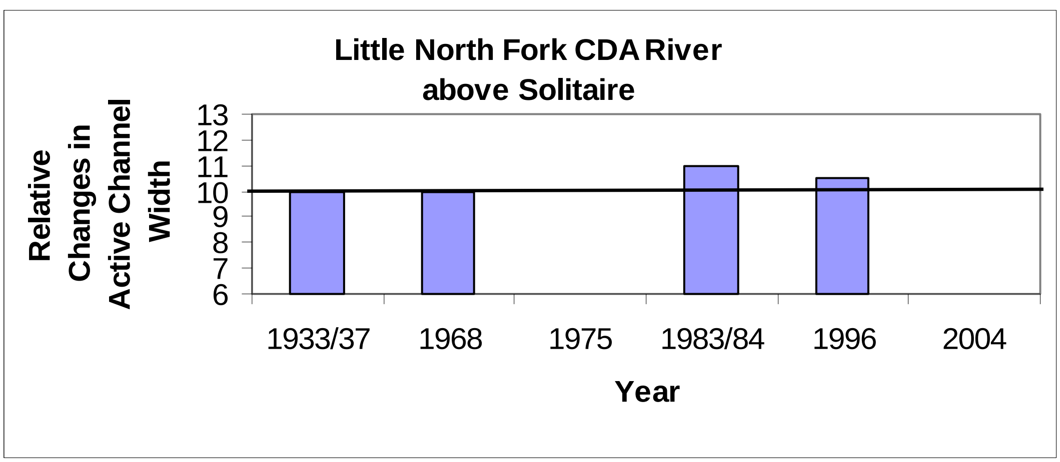
3.3.4.1 Changes in Channel Width and Pattern

The Little North Fork upstream of Burnt Cabin Creek responded to the combination of increased tributary sediment delivery and riparian timber harvest by widening, depositing large gravel in bars, a minor amount of braiding, and in some cases jumping to another part of the floodplain (avulsion). These response zones were unconfined, low gradient segments of the Little North Fork, Iron Creek, Canyon Fork Creeks, Nicholas Creek, and Barney Creek.

The Little North Fork tributaries upstream from Burnt Cabin Creek, and the Little North Fork River itself upstream of Solitaire Creek, were narrow and barely visible in the 1930s photographs. Downstream of Solitaire Creek, the Little North Fork had a few, relatively narrow bars mostly near the downstream end. By 1968, many river reaches downstream of Hudlow Creek had wide gravel bars and active channel migration (Figure 18, Figure 19). The tributary creeks with broad, gently-sloping valleys had widened by 1968. The widening response continued into the 1980s. The rivers and creeks were much narrower by 1996, with the exception of Iron Creek and some scattered response zones in the river upstream from Tom Lavin Creek; no channel response in Hudlow and Lewelling Creeks was apparent throughout the period of photographic record.







**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 18. Relative changes in active-channel width in 3 reaches of the Little North Fork Coeur d'Alene River above Burnt Cabin Creek.

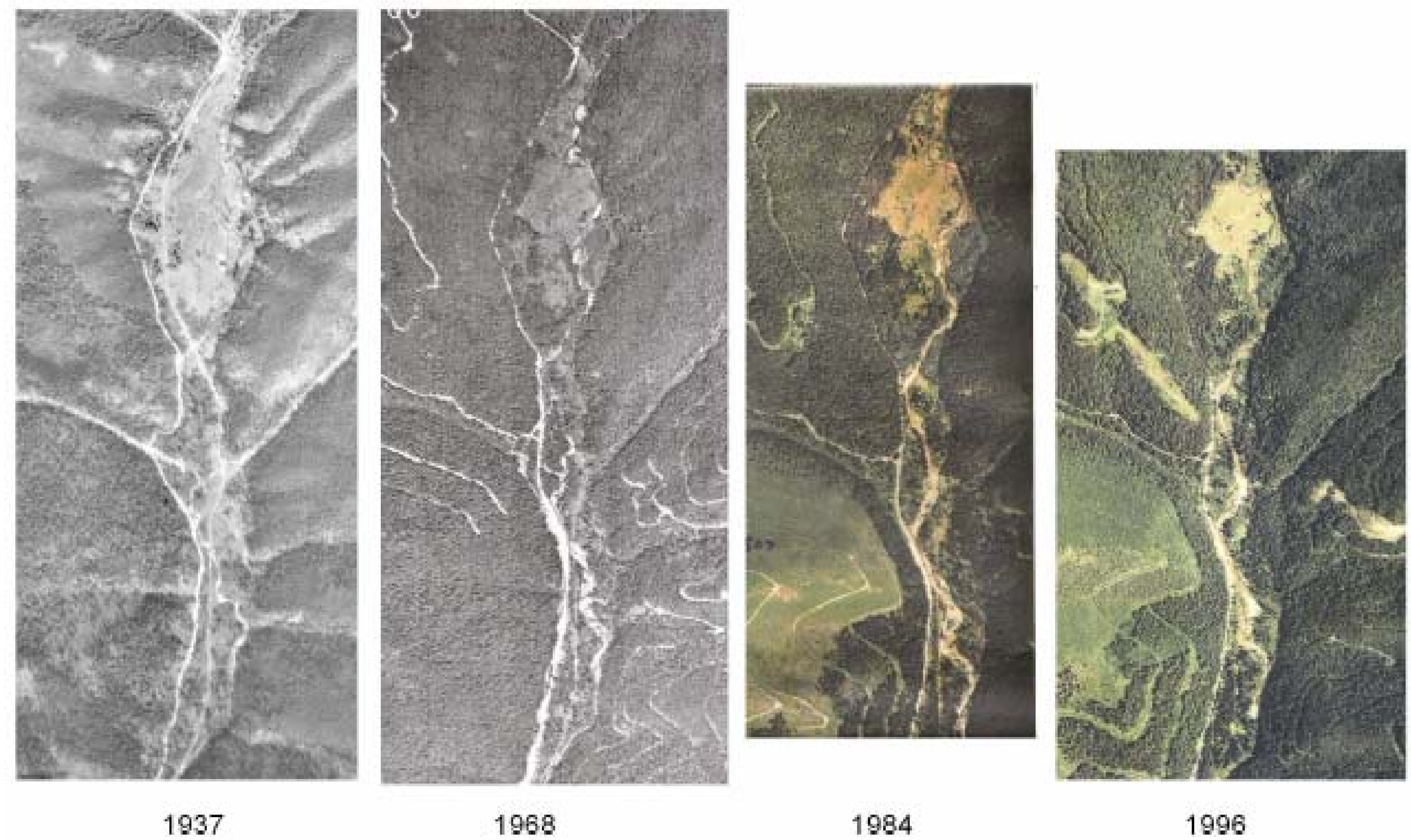


Figure 19. Air photos of Little North Fork Coeur d'Alene River upstream of Burnt Cabin Creek showing wide channel in 1968 followed by narrowing of the channel in 1984 and 1996. Canyon Fork enters at left.

The longest response zones on the Little North Fork upstream from Burnt Cabin Creek occurred downstream of Hudlow Creek where the gradient decreases to less than 0.7% .

The greatest length and amplitude of channel widening in these areas and the tributary creeks occurred in the 1968, or in fewer cases the 1983/84, photographs (Figure 20). 1975 photos were not available upstream of Burnt Cabin Creek, but downstream of Burnt Cabin Creek the response zones were generally narrower in 1975 than in 1968 and 1983. By 1996, the response zones had shrunk to less than one third of their former length. The remaining areas of active gravel bars had narrowed. No significant channel migration occurred between the 1996 and 2004 air photos and the active gravel bars remained the same or narrowed (indeterminate due to grass growth on bars in the 2004 photos).

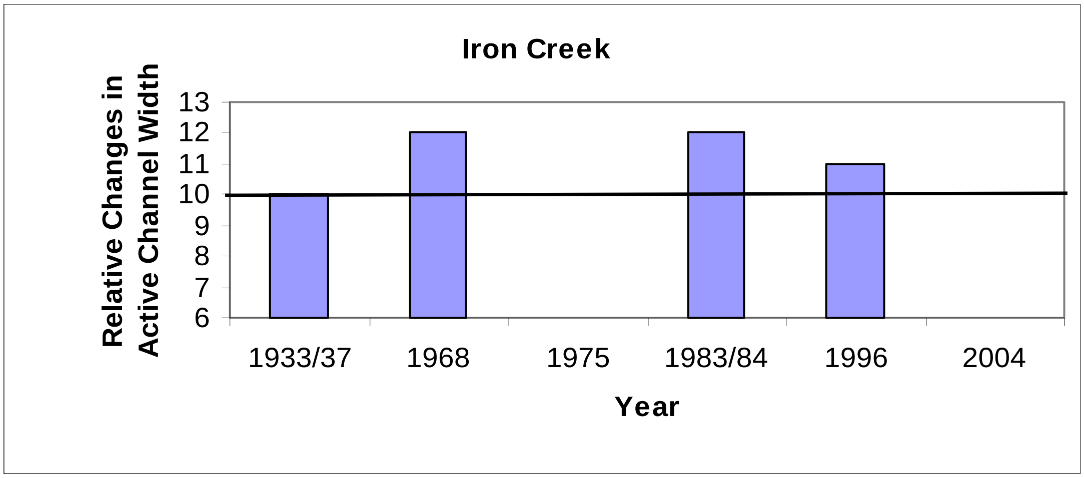
Channel widening on the Little North Fork occurred later upstream of Iron Creek, either due to later riparian and hillside harvest, or in some locations sediment deposits caused by LWD jams. The maximum channel response occurred in 1983 or 1996. By 1996, about 10 formerly narrow areas of the river between Iron and Sob Creeks had widened. Upstream of Sob Creek, the river widened by 1983/84 and narrowed again by 1996.

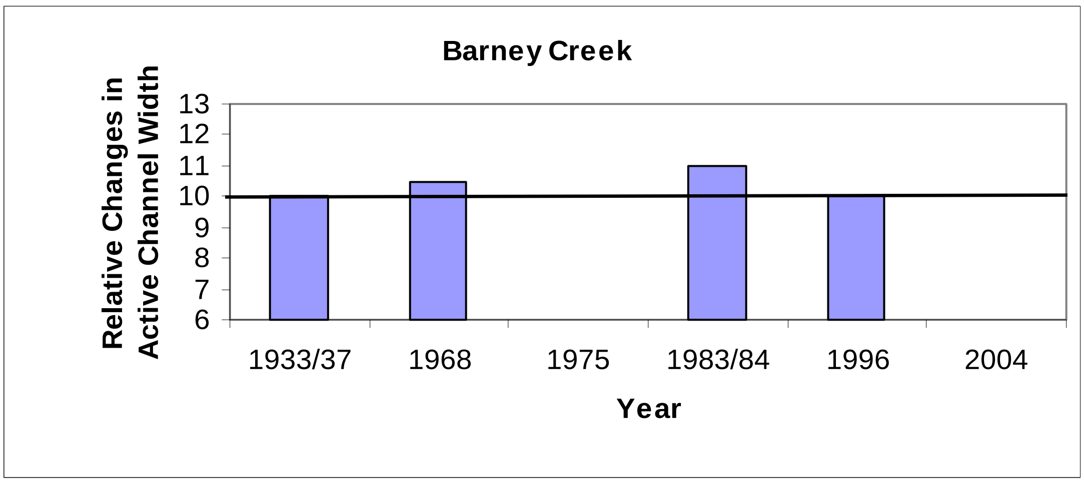
3.3.4.2 Channel Cross-section Changes in Response to Coarse Sediment Load

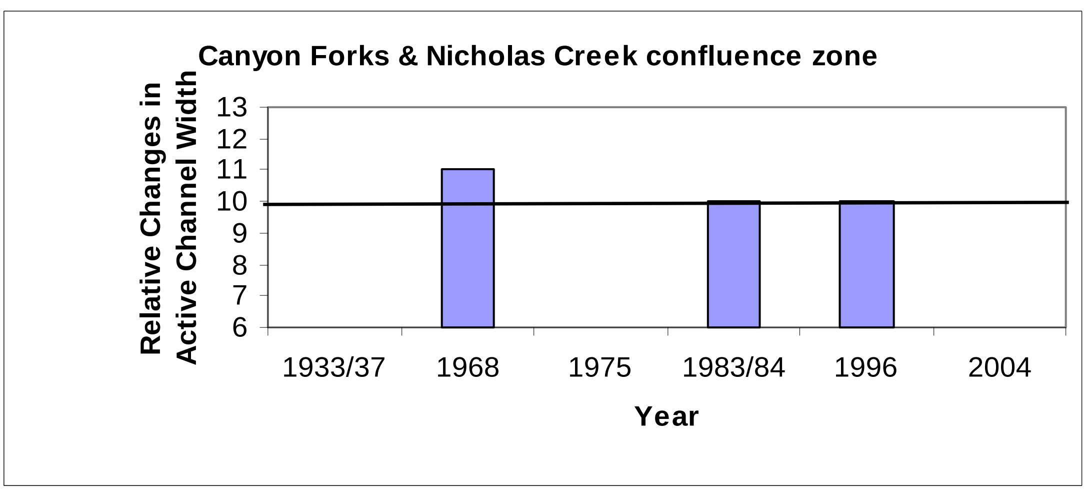
Field work and cross-section analysis were used to assess how the Little North Fork has processed the large amount of coarse sediment that caused channel widening in the mid-20th-century. The abundance of coarse sediment compared to a channel's transport capacity is expressed by adjustments of channel geometry. When more coarse sediment enters a reach than the channel can transport, the bed rises (aggrades) and the channel becomes wider and shallower. In extreme cases, the channel becomes perched above the adjacent floodplain, multiple channels develop (braiding), or the channel may jump (avulse) to a lower part of the floodplain. Once sediment supply drops, the channel narrows and deepens resulting in slight entrenchment.

The Little North Fork is generally slightly entrenched to unentrenched from Burnt Cabin Creek to Solitaire Creek. Slight entrenchment is normal for C-type channels whereas braided channels are not entrenched at all (Rosgen, 1996). In a reach that formerly had large active sediment deposits, slight entrenchment within those deposits indicates some recovery following passage of a sediment wave. An unentrenched cross-section (defined here as floodprone width > four times the bankfull width) indicates the channel has yet to recover from sediment deposition.

A low floodplain was present in 14 of 15 sites along the Little North Fork upstream of Burnt Cabin Creek. Low terraces subject to flooding in moderate events occurred in 9 of the 15 sites. In two locations, these intermediate terraces were adjacent to the river and the lower floodplain behind them, indicating a perched condition due to sediment deposition (Figure 21, Figure 22). More commonly, the intermediate terraces were farther from the river beyond the low floodplain and had vegetation varying from alders to 8-inch through 2-foot diameter conifers which grew up after downcutting.







**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 20. Relative changes in active-channel width for Iron, Barney and Nicolas/Canyon Forks Creeks, the three tributaries above Burnt Cabin Creek that widened visibly in historic air photos.

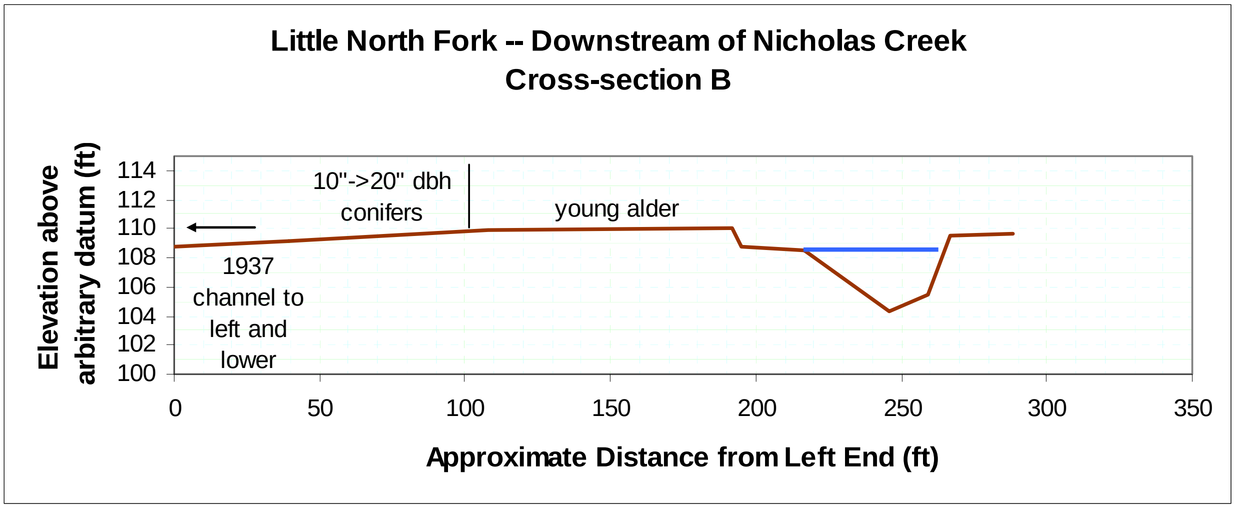


Figure 21. Cross-section B on the Little North Fork downstream of Nicholas Creek, showing the river still perched above the floodplain in gravel deposits dating to the 1960s through 1980s. Seventy (70) percent of active channel area is covered with gravel bars.

Figure 22. Photos of the perched channel located at cross-section B on the Little North Fork downstream of Nicholas Creek. Seventy (70) percent of active channel area is covered with gravel bars.

In at least one location, the river was perched but has recently jumped back into a lower, pre-disturbance channel leaving sediment deposits behind on the floodplain (Figure 23, Figure 24). It is likely that the upstream channel shown in Figure 21 will soon do the same thing, since LWD recruited by bank erosion is likely to block the present channel and force an avulsion.

A higher, older terrace with mature, second-growth conifers was observed in several locations. The high terrace between Burnt Cabin and Cathcart Creeks is 8.5 feet above the riverbed. In the vicinity of Barney Creek, it is 7 feet above the riverbed, and it is 6 feet high near Lewelling Creek. The lateral migration that created a wide floodplain below the terrace would have taken decades to occur.

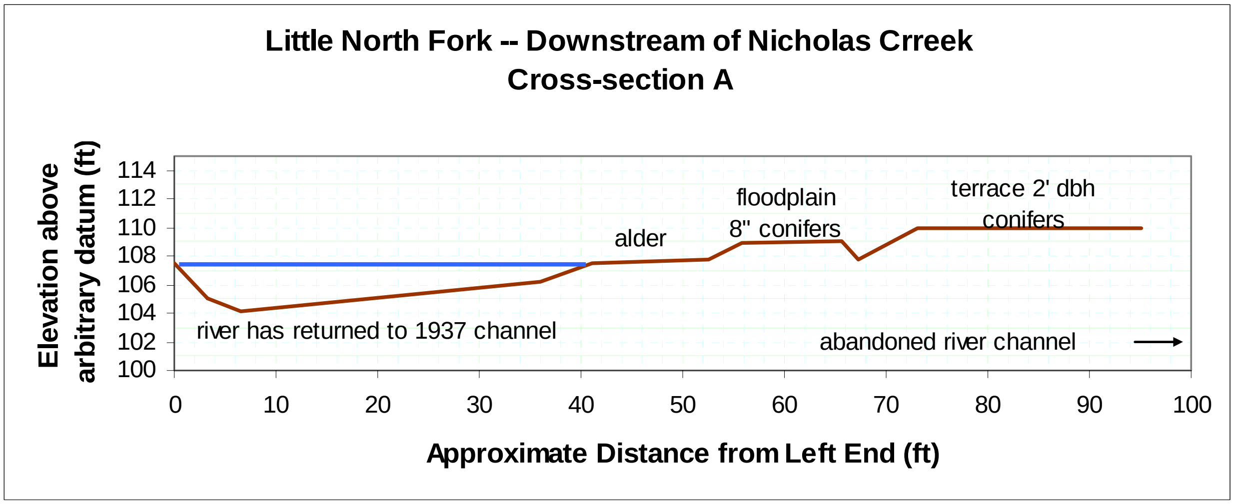


Figure 23. Cross-section A on the Little North Fork downstream of Nicholas Creek. Cross-section A is downstream from cross-section B. Here the river jumped back to its 1937 location, leaving wide gravel deposits behind on the floodplain. Only 5% of active channel area is covered with gravel bars.

Figure 24. The original lower channel at cross-section A on the Little North Fork downstream of Nicholas Creek was occupied in 1937 and has recently been reoccupied. Roughly 5% of its area is in bars.

In these cases where the channel is entrenched into older alluvial terraces, downcutting could have been caused by removal of LWD or splash damming, or even by climate change prior to human disturbance. Only one moderately-entrenched river reach was observed during field work. This reach was in the vicinity of Tom Lavin Creek where the river is entrenched between an old, sloping terrace and the valley wall.

Interestingly, there was no apparent difference in entrenchment or river appearance below the splash dams in the first mile above Burnt Cabin Creek. The river there was only slightly entrenched, having one to two levels of low floodplain and a high terrace on the valley margin (Figure 25, Figure 26). Splash damming has been known to cause extensive bank erosion (Russell, 1984). Apparently damage to the banks along with an abundant sediment load from upstream caused enough sediment deposition to counteract any initial downcutting that was caused by floods released by the dams.

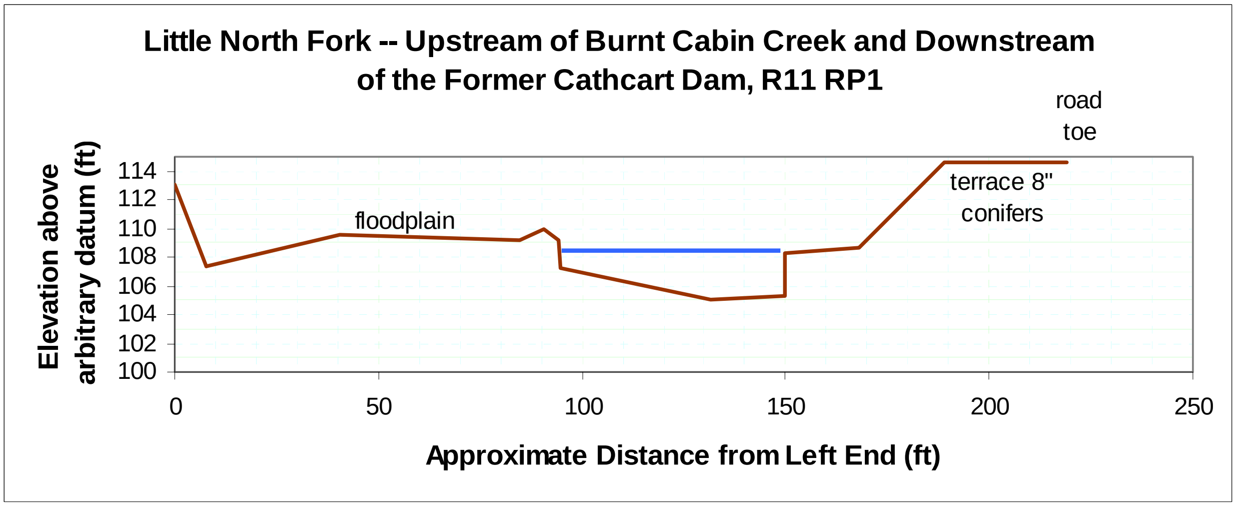


Figure 25. Cross-section on the Little North Fork, depicting the slight entrenchment of the river in a 100-foot wide floodplain below Cathcart splash dam. There is a higher terrace on the right side of the valley. This section of river has a low gradient and few gravel bars.

Figure 26. Little North Fork above Burnt Cabin Creek.

3.3.4.3 Bank Stability, LWD, and Sediment Storage on the Little North Fork Coeur d'Alene River

Most river reaches surveyed in summer, 2006 had Stable to Slightly Unstable banks. There were long, stable reaches with no bank erosion. These stable reaches were relatively straight with few pools or bars, and little to no LWD. Sediment load appeared low in these reaches due to lack of gravel bars. Coarse sediment is transported efficiently downstream with little exchange of sediment between the river and floodplain.

The long, stable reaches were interspersed with shorter active zones that had gravel bars, discontinuous eroding banks, meander bends, and in some cases LWD jams. Eroding banks were associated either with bars and bends, or (upstream from Iron Creek) with LWD jams. Coarse sediment load appeared moderate in these active zones because of gravel bars caused by the channel bends and LWD jams. Although sediment abundance appeared higher than in the straight reaches, the straight reaches probably carry at least as much coarse sediment as the active zones.

Most bank erosion currently occurring along the Little North Fork is not a net source of coarse sediment because erosion on the outside of one bend is balanced by bar deposition on the inside of the next bend downstream. Channel migration either redistributes coarse sediment with no net change in volume or bar height, or it stores sediment in the floodplain if there is net aggradation while it occurs, or if the river avulses to a lower, former channel location (for example, Figure 23). One location that has been a net source of sand and fine gravel is a 7- foot high terrace on the outside of a bend at the mouth of Barney Creek. Air photos show this bend has eroded very slowly since 1996.

Conifers along much of the Little North Fork upstream from Burnt Cabin Creek have grown large enough to provide functional-sized large woody debris. LWD that piled up behind bridges in the 1996 flood was harvested and added back to the river by the USFS (Ed Lider, pers. comm.). Channel migration erodes banks and undercuts trees that topple into the river. There is abundant functional wood upstream of Tom Lavin Creek, where the river is less than 20 feet wide (Figure 27). Downstream of Tom Lavin Creek, reaches with channel-spanning logjams and high LWD density alternate with long, wood-free reaches with plane bed morphology. The LWD jams cause significant coarse sediment storage in the form of bars, and also sediment wedges that extend hundreds of feet upstream and raise the streambed by 3 to 5 feet. There are fewer channel-spanning jams downstream of Iron Creek because the river widens to greater than 40 feet. There are probably no LWD jams below the confluence of Canyon Forks Creek.

Some riparian areas upstream of Burnt Cabin Creek remain unforested. There are grass meadows on some older floodplain surfaces, maintained by grazing and camping disturbance. The active response zones of the 1960s through 1980s have been colonized by willows or young trees and will ultimately grow into trees large enough to provide functional LWD.

Figure 27. Functional wood contributes to the storage of sediment storage upstream of Tom Lavin Creek (top). Sediment storage by LWD is intermittent in middle reaches: example near Lewellyn Creek (middle pictures). Sediment storage by LWD is rare downstream of Iron Creek (channel width effect) (bottom picture).

3.3.4.4 Channel Response Zones on the Little North Fork Downstream of Burnt Cabin Creek

Although the Little North Fork downstream of Burnt Cabin Creek was not part of the detailed study area, historic photos were reviewed to investigate the downstream movement of the coarse sediment load. Five response zones downstream of Burnt Cabin Creek were identified from aerial photographs. From upstream to downstream, these reaches are near Deception, Bootjack, Copper, Little Tepee, and Bumblebee Creeks. All five response reaches had very active channel migration and avulsions indicating high sediment load (Figure 28, Figure 29).

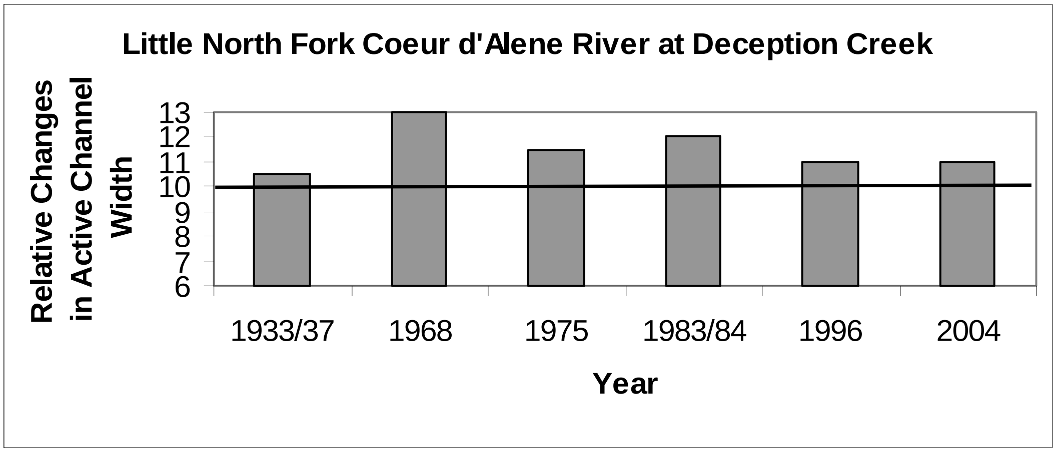
The disturbance timing in the Deception Creek response reach was similar to the timing in the reach from Burnt Cabin to Hudlow Creeks, which are located upstream. The maximum observed width in each of these reaches was observed in the 1968 photos. A small, second peak was observed in the 1983/84 photos, which followed some major avulsions. A splash dam was built in the middle of this reach in 1929 and the three upstream dams were built from 1915-1919, yet in 1937 the reach was relatively narrow suggesting little impact on channel width from operations of the dams.

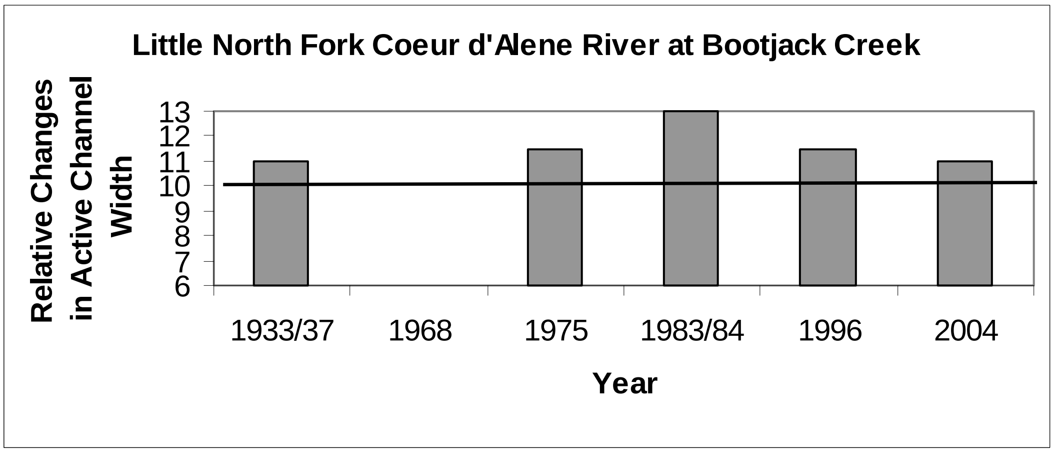
The response reach near Bootjack Creek was wider in 1983/84 than in subsequent years, but the timing is difficult to determine because the 1968 photos and part of the 1975 photos were missing. Large, recent avulsions were visible in the 1975 and 1983/84 air photos. This response reach was just below the Delaney dam, which was built in 1929, yet the river was narrower in the 1937 photos.

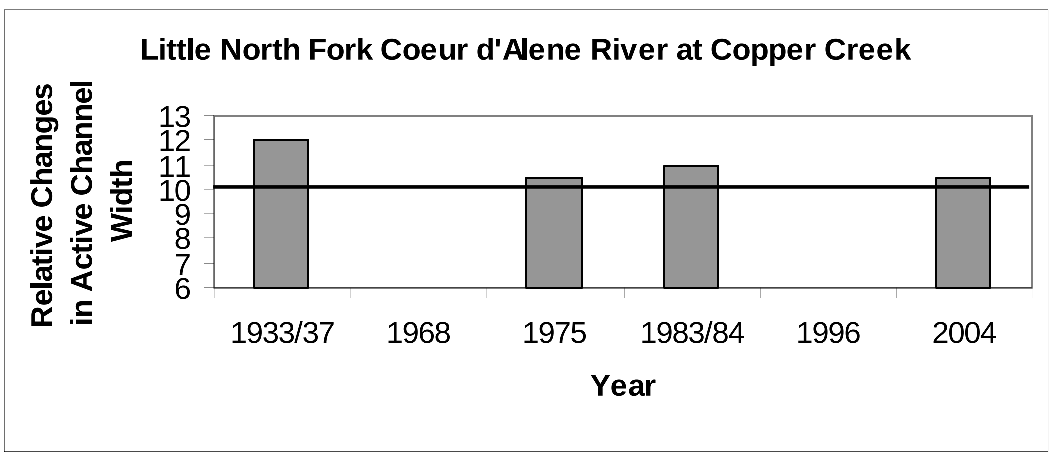
The Little Tepee Creek response reach was quite a few miles downstream from the Breakwater dam. Relative to 1937, the channel was much narrower in the 1968 through 1984 photos, although it had multiple avulsions and the upper half was in a completely different location in 1937. More avulsions and additional channel widening occurred between 1984 and 2004.

The Bumblebee Creek reach, near the downstream end of the Little North Fork, had wide active bars in both 1937 and 1968, but was straighter in 1968. The reach was much narrower in the photos from 1975 on, with a smaller increase in channel width in 1983/84 at the downstream end of the reach.

Four of the five response reaches downstream of Burnt Cabin Creek have largely recovered. Wide active bars remain along only one-third of the former active length. The longest response reach, near Little Tepee Creek, is only partially recovered. More than half its length still has large gravel bars and some areas are still braided. Several avulsions, major bend growth, and channel widening occurred between 1984 and 2004 in the Little Tepee Creek response reach. The 1996 photos were not examined to identify possible tributary sediment sources.

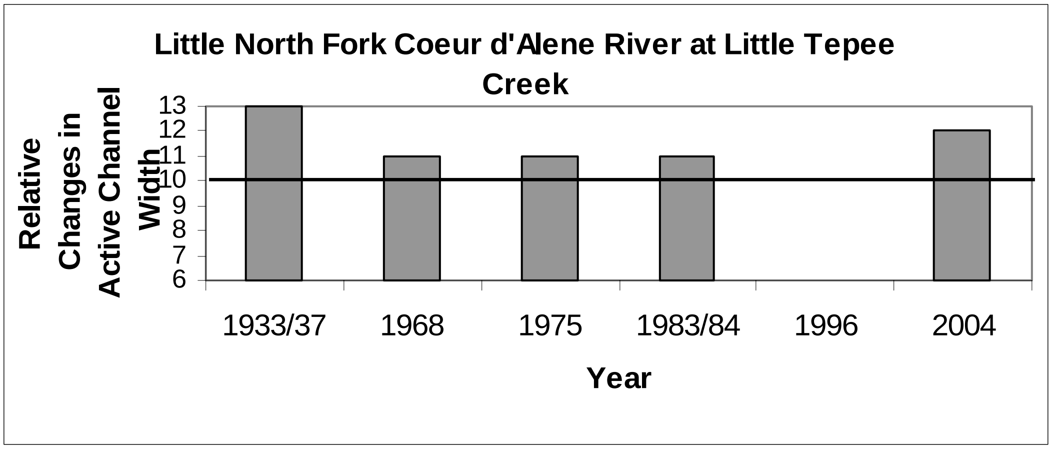


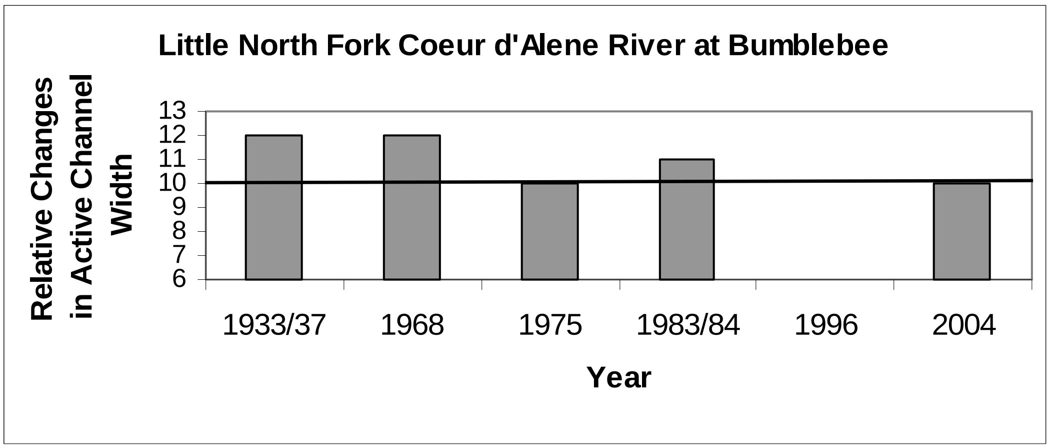




**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 28. Relative changes in active channel width in Deception, Bootjack and Cooper Creek response reaches on the Little North Fork Coeur d'Alene River downstream from Burnt Cabin Creek, interpreted from aerial photographs.





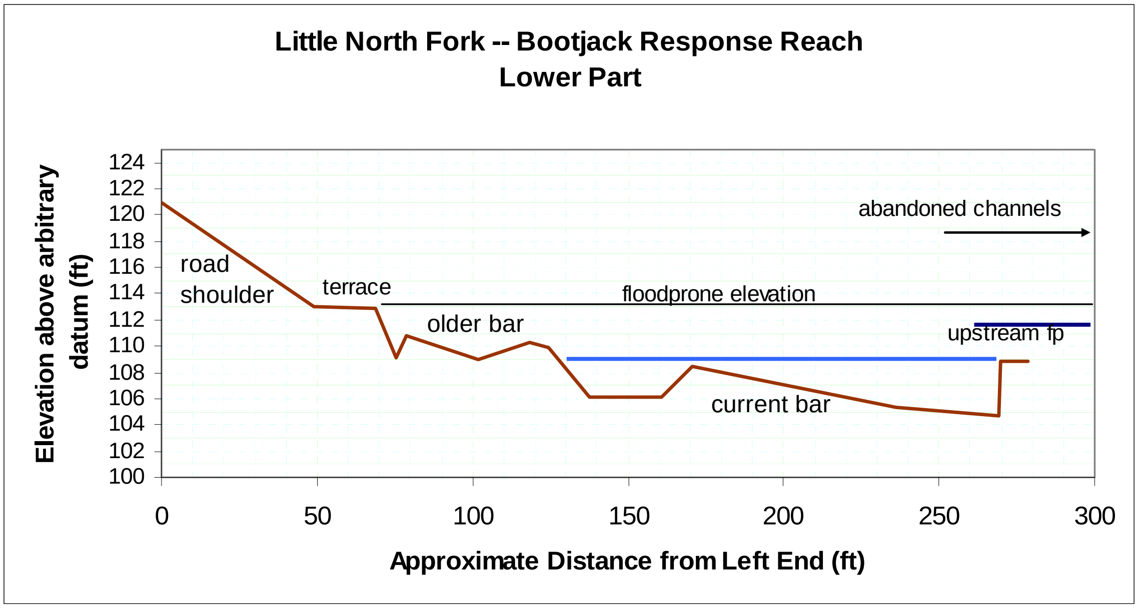
**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 29. Relative changes in active channel width in Little Teepee and Bumblebee reaches on the Little North Fork Coeur d'Alene River downstream from Burnt Cabin Creek, interpreted from aerial photographs. Bumblebee is farthest downstream near the mouth of the river.

The three lower response reaches differed from upstream by becoming wider earlier in the photo sequence. The maximum width of channel was observed in the 1937 photos; however, each reach behaved differently in subsequent years.

The Copper Creek response reach was directly above the Breakwater splash dam, which was built in 1928 at the lowest location in the watershed. It was part of a system of dams that backed water up for 8 miles. The 1933 flood picked up all the logs in the river and "lodged it tight" for half a mile upstream of Breakwater Dam (Russell, 1984). The log drives possibly continued as late as 1937 although the location is unclear. The 1968 photos were missing for the Copper Creek response reach. The channel was narrower in nearly all the photos from 1975 though 2004, although a slight increase was observed in the 1983/84 photos.

Limited field surveys were conducted in some of the affected reaches. Entrenchment and downcutting have occurred in at least some parts of the Bootjack and Little Tepee response



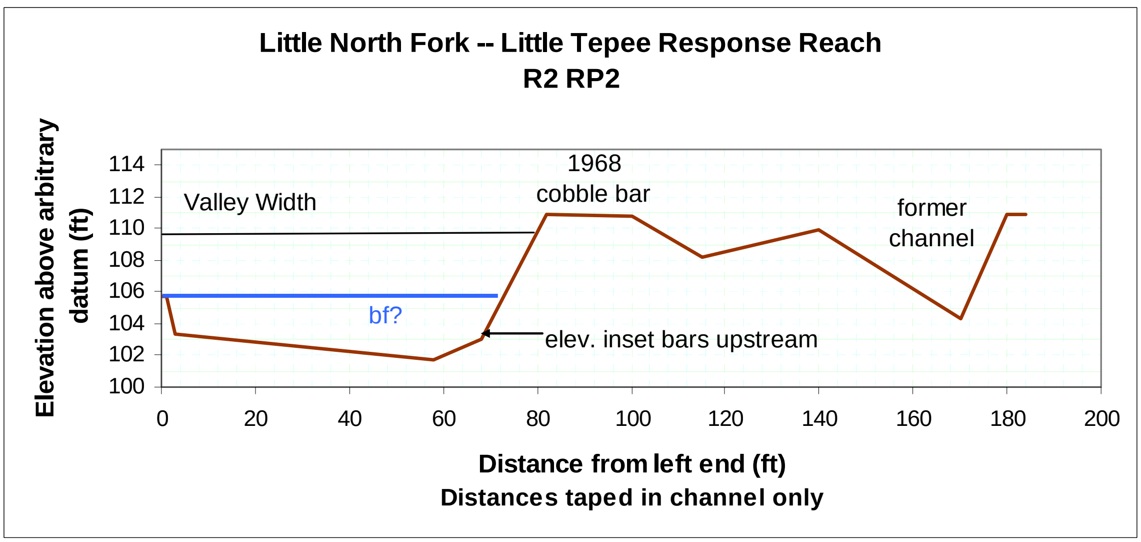


Figure 30. 2006 cross-sections of the Little North Fork near Bootjack and Little Tepee Creeks, depicting how the river has downcut through terrace deposits of coarse sediment.

reaches which appeared narrowed in the air photos (Figure 30). Little or no vertical change is apparent at the downstream extent of the Bumblebee response reach, based on cross-section data. The river now appears to be transporting the incoming sediment load from upstream rather than depositing it. This indicates a declining sediment load, but clearly parts of these long response zones are still choked with sediment.

The Little North Fork downstream of Burnt Cabin Creek is too wide for channel-spanning LWD jams to form, and probably too wide and deep for most of the available LWD to form stable accumulations. No LWD jams were observed in the air photos or limited field observations. In addition, the response reaches have extensive riparian areas that are unforested or have young riparian forests. These areas are unlikely to produce mature riparian forest or deliver LWD to the river for decades. This is a legacy of the broad, former gravel flats in the response zones, as well as frequent inundation of the floodplain in areas where sediment deposition has kept the channel from entrenching.

3.3.5 Little North Fork Discussion and Sediment Routing

Most tributaries above Burnt Cabin Creek are not currently delivering much coarse sediment to the Little North Fork River. Sediment delivery is down significantly from the peak logging periods in the early- and mid-20th century. Some problem areas associated with roads or early harvest practices remain, notably in Iron Creek. The forest has regenerated to a point where clear cuts no longer increase peak flows during rain-on-snow floods, although dense road networks are still increasing the magnitude of floods a small amount. The flood energy to erode and transport coarse sediment has likely diminished since the peak of road building and timber harvest.

Most of the formerly-wide channels have healed significantly in response to the lower sediment load and regrowth of riparian forests that stabilized stream banks, but some areas are still not entrenched and will take more time to convert back to a slightly entrenched, meandering channel. Due to their low gradient and broad floodplain, the response reaches are still transport-limited even though the sources of coarse sediment from upstream have diminished. These reaches contain an abundant supply of coarse sediment in the river bed and floodplain. The amount of coarse sediment moving downstream through these reaches is limited by the river's ability to transport sediment, not by the supply of sediment from upstream.

The response reach near Little Tepee Creek was the only response reach in the whole Little North Fork watershed that widened significantly between 1983/84 and 2004. Further investigation is needed to determine whether this represents movement of a sediment wave from the next two reaches upstream (which were widest in the 1983/84 and 1968 photos, respectively), a response to sediment supply from local tributaries in the 1996 flood, or some other factors. We did not look at 1996 photos downstream from Burnt Cabin Creek, or look at any tributaries downstream from Burnt Cabin Creek, so these suggestions are speculative.

Low gradient rivers such as the Little North Fork process coarse sediment relatively slowly. Sediment waves move down the channel at a rate of approximately 21 bankfull channel widths per year in the maritime Pacific Northwest, but limited evidence suggests that they may move up to twice as fast in areas with prolonged snowmelt floods (Beechie, 2001). Long reaches of the Little North Fork below Burnt Cabin Creek are narrow, which would also encourage faster bedload velocity. For the Little North Fork, sediment would move about 0.1-0.2 miles per year upstream from Burnt Cabin Creek. It would does take about 25-50 years for gravel from Iron Creek to move down the river as far as Burnt Cabin Creek. Between Burnt Cabin Creek and the mouth of the Little North Fork, Beechie's relationship suggests a bedload velocity of 0.3-0.6 miles per year, which would take about 40-80 years.

Applying these travel times to known peaks of sediment loading upstream, sediment from legacy logging in Burnt Cabin Creek in the 1930s would have reached the Little North Fork River mouth at the earliest in the 1970s, but maybe not until the 2010s. The early channel response of the lowest reaches of the Little North Fork is probably representative of erosion in the watershed below Burnt Cabin Creek. The sediment that caused the peak channel response in the 1960s in the area above Burnt Cabin Creek might just now be starting to arrive at the mouth of the Little North Fork. However, that sediment pulse would be attenuated from traveling such a long distance. It is from a relatively small portion of the watershed's drainage area, so the bulk of the sediment may already have moved downstream or been put into floodplain storage.

The results show no evidence of a single sediment wave that has moved downstream over time. Had that been the case, maximum widening would have occurred first upstream and then moved downstream over time while the upstream locations narrowed. The amount of entrenchment does not vary systematically downstream either. Although most areas have narrowed, some areas are still not entrenched. It seems likely that pulses of sediment from tributaries have entered the Little North Fork at least several times -- during the early logging decades dominated by flumes and splash dams, during the height of road-building and tractor logging as documented by USFS reports for the 1964 and 1975 floods, and smaller pulses from culvert and road failures in the 1983/84 and 1996 floods.

In addition to coarse sediment, loss of riparian trees that protect banks is a factor. Riparian harvest also seems to have affected the timing of channel response in the uppermost reaches of the Little North Fork, and the Copper Creek response reach was very likely destabilized by the large 1933 logjam above Breakwater Dam.

Bank erosion is partly event-driven, since higher shear stresses are exerted on the bed and banks during larger floods. However, greater rates of bank erosion and channel widening can occur if coarse sediment supply is high. In these situations, gravel bar deposition can force flow laterally towards the banks. Banks generally become more stable once a sediment wave has passed, and the gravel bars left behind become vegetated. The 1974 and 1996 floods were larger than the 1964 and 1982 floods (at least on the mainstem North Fork River, although the Little North Fork may have differed) yet the response reaches tended to be wider in photos that followed the smaller floods. This seems a surprising result for 1974 given the reported damage from that flood, but the 1975 photos were missing upstream of Burnt Cabin Creek so the effect of the 1974 flood in that area is unknown. The relative lack of channel response in photos taken the year after the 1996 flood, combined with 2006 field evidence, strongly indicates that sediment loads have decreased from their peak.

3.4 PRICHARD, EAGLE AND BEAVER CREEKS

Prichard, Eagle, and Beaver Creeks, located in the southeast part of the North Fork subbasin, are part of the Coeur d'Alene mining district. This report section addresses channel responses to sediment in those creeks as well as channel response of a short length of the North Fork River just downstream from Prichard Creek. The *Sediment Source Technical Report* contains information on estimated historic and current sediment loads.

Prichard Creek drains a 123 square mile watershed and flows west into the North Fork River. Eagle Creek, its major tributary, has two forks. It drains a 45 square mile watershed and enters Prichard Creek from the north about 3 miles upstream from its mouth. Beaver Creek drains a 42 square mile watershed and enters the North Fork about 2 ½ miles downstream from Prichard Creek. The lower reaches of all three creeks have broad, unconfined valleys with channel gradients less than 1%. Slightly steeper response reaches in the 1-2% range continue for miles upstream. The creeks are fed by steep gulches.

3.4.1 Mining District Land-use History

Mining got underway in the late 1800s. The first Government Land Office (GLO) survey map in 1908 delineates dozens of mining claims in Prichard Creek. Upstream from Eagle Creek, nearly the entire valley bottom was dredged with floating dredges from 1917 to 1926. Gravel was dredged to a depth of up to 69 feet above the Murray Bridge. Prichard Creek was relocated next to the south valley wall, held there by cobble dredge spoils.

Underground mines in the headwaters of tributary creeks operated primarily from the 1920s to the 1960s. Tailings from these mines were left next to the creeks. Most of the gulches and draws had roads up them to access the mines. Some placer mining with excavators and hydraulic dredges (seen on Trail Creek, a tributary of Beaver) still occurs along creeks today.

Mining claims along the first mile of the lower North Fork River downstream of Prichard Creek were also mapped in the 1908 GLO survey. However, no evidence of mining appeared in the 1937 air photos, and we did not see any dredge spoils on the valley floor.

3.4.2 Mining District Coarse Sediment Sources

Mining-related sediment sources include tailings piles (not investigated by WPN), dredge spoils, valley-wall landslides where Prichard Creek is pinned against the valley wall by dredge spoils, and banks of soil disturbed by excavators and dredges (Figure 31). Sediment from early mining activities is still making its way downstream. The East Fork of Eagle Creek, Butte Gulch on Prichard Creek, Trail Creek, and numerous gulches on the east side of Beaver Creek appear to be active sources of sediment. The west-side tributaries of Beaver Creek looked stable on air photographs and were apparently not mined. Many of the creeks and gulches are privately owned or have private mining claims and are not accessible by the public.

Old roads go up nearly every gulch in the mining district. The roads removed riparian vegetation and structure, leading to bank erosion and downcutting, and tended to capture the creeks. For example, the tributary that enters Eagle Creek just below the forks looked gullied in the 1937 photo and was still unstable and eroding in 2006 despite some restoration efforts.

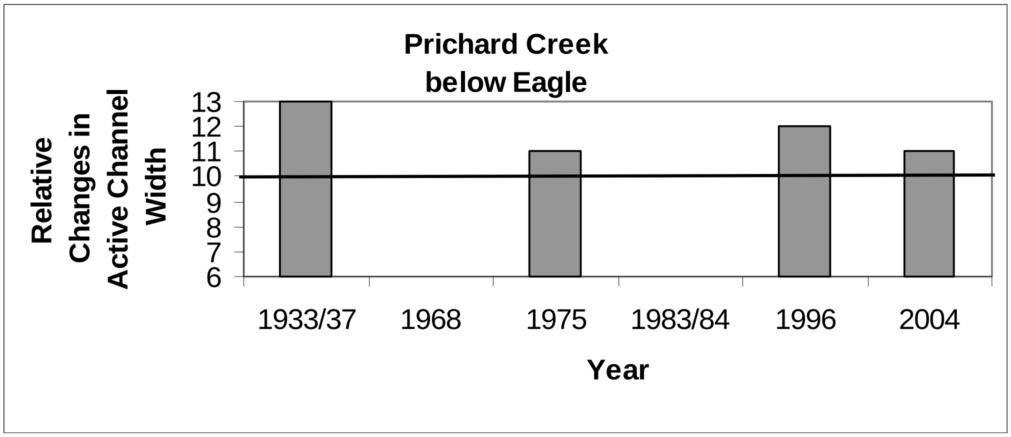
Figure 31. Dredge spoils confining Prichard Creek and valley wall landslides delivering to the creek.

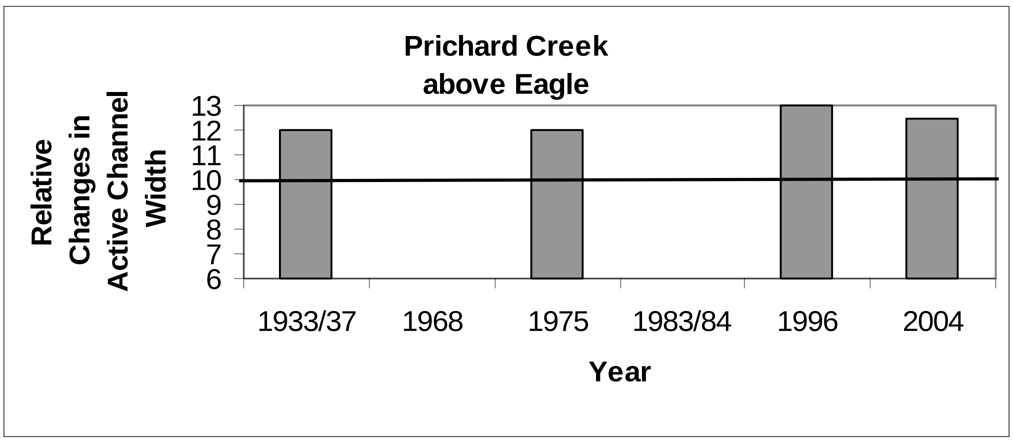
3.4.3 Mining District Channel Response

The channels with the greatest increase in width in response to sediment loads in the North Fork subbasin are found in Prichard, Eagle, and Beaver Creeks. The overall proportion of affected channels was also greatest in these creeks. The creeks have recovered very little; most reaches were still wide and unstable in 2006. The lower gradient reaches of these creeks are largely steeper than the response reaches elsewhere in the North Fork subbasin; hence, would be expected to recovery more quickly over time. (A hand-drawn map of response zones will be transmitted to IDEQ with the final report.)

The mainstem creeks, including the lower parts of West Fork and East Fork Eagle, widened along nearly their entire length including confined sections (Figure 32, Figure 33, Figure 34). Many reaches became braided, and those that did not changed from straight, narrow channels to meandering channels with large bars (Figure 35). These responses were already extreme in the 1930s with the exception of lower Beaver Creek (we had no 1930s photos of Beaver Creek above Delta). In mainstem Eagle and the lower tailings reach of Prichard, sediment deposits were deep enough to cause the creek to run subsurface in summer (Figure 36). These conditions still persisted in 2006.

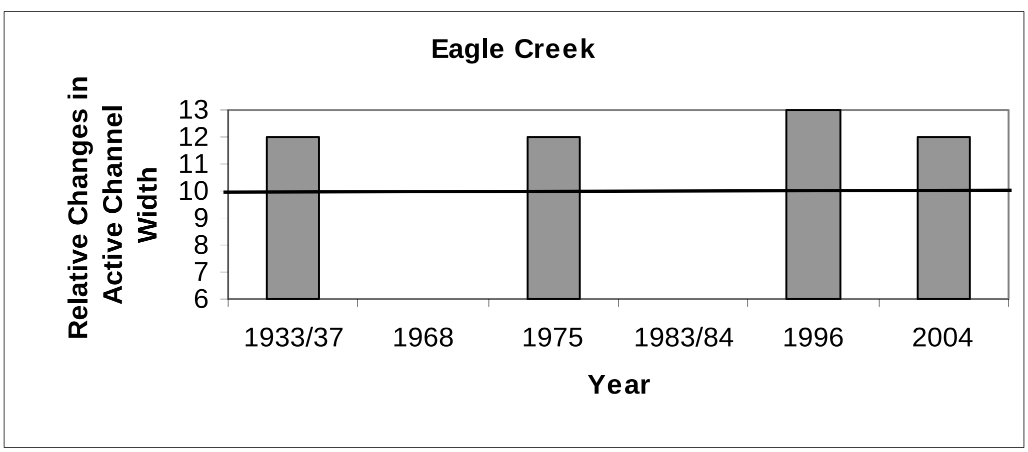
Three quarters of the historic response areas still remain excessively wide and many of them still braided (Figure 37, Figure 38). Prichard Creek downstream of Eagle Creek narrowed by 1975 but was wider again by 1996. Some steeper and more confined reaches of Prichard Creek had narrowed by 1996 or 2004, indicating a diminished sediment load. Field inspection indicated that downcutting has occurred and some bends have been cut off resulting in a straighter, single-thread channel in these zones (Figure 39, Figure 40). Stream banks were moderately unstable to unstable in most places we inspected, although the BURP sites had stable to moderately stable banks.





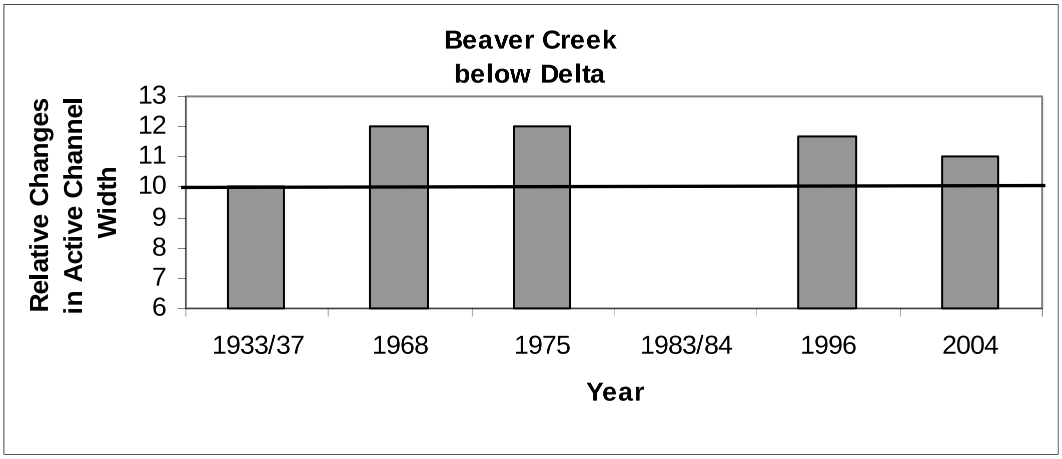
**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 32. Relative changes in active channel width of Prichard Creek interpreted from aerial photographs.



**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 33. Relative changes in active channel width of Eagle Creek and its lower forks, interpreted from aerial photographs.



**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 34. Relative changes in active channel width of Beaver Creek interpreted from aerial photographs.

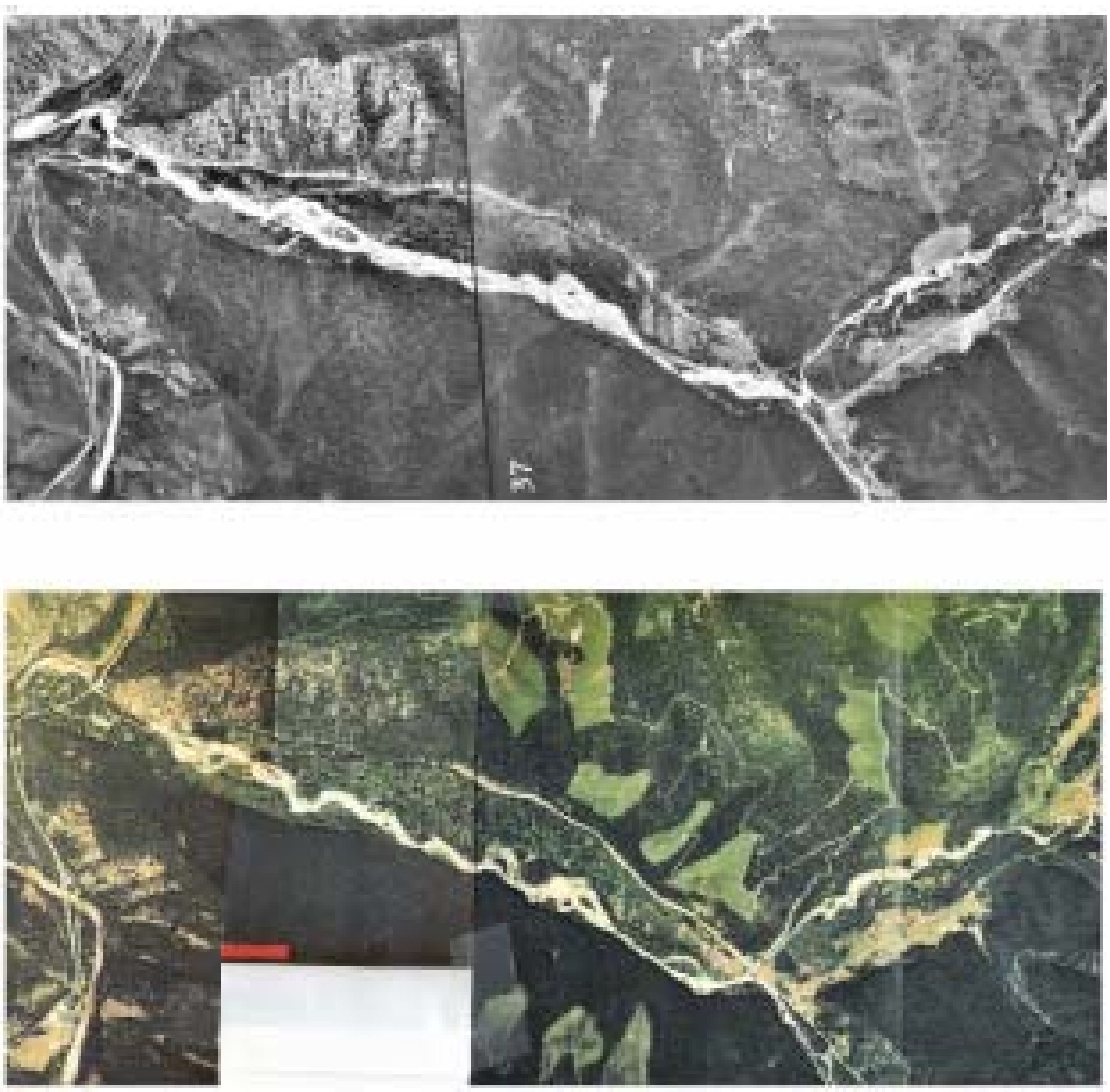


Figure 35. 1937 and 1996 air photos showing lower Prichard Creek and Eagle Creek.

Figure 36. Areas where the stream runs subsurface due to high volumes of deposit along the lower dredge spoils in Prichard Creek upstream of the confluence with Eagle Creek (left) and in Eagle Creek, downstream of the forks (right).

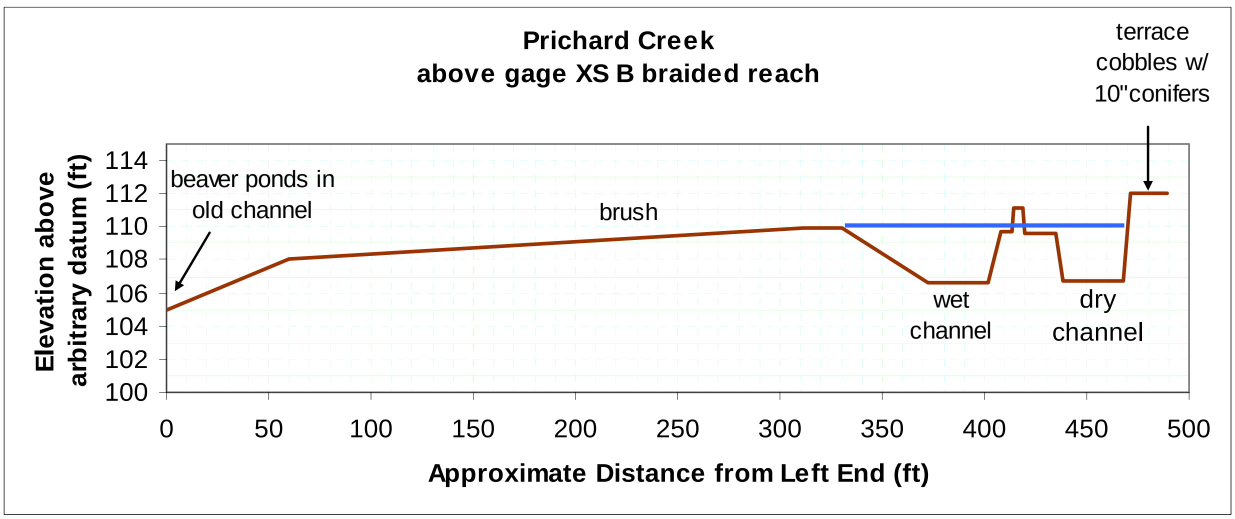


Figure 37. Year 2006 cross-section depicting a braided reach of Prichard Creek downstream of Eagle Creek. The active channel in the braided reach is over 400 feet wide.

Figure 38. Photos of a braided portion of Prichard Creek downstream of Eagle Creek.

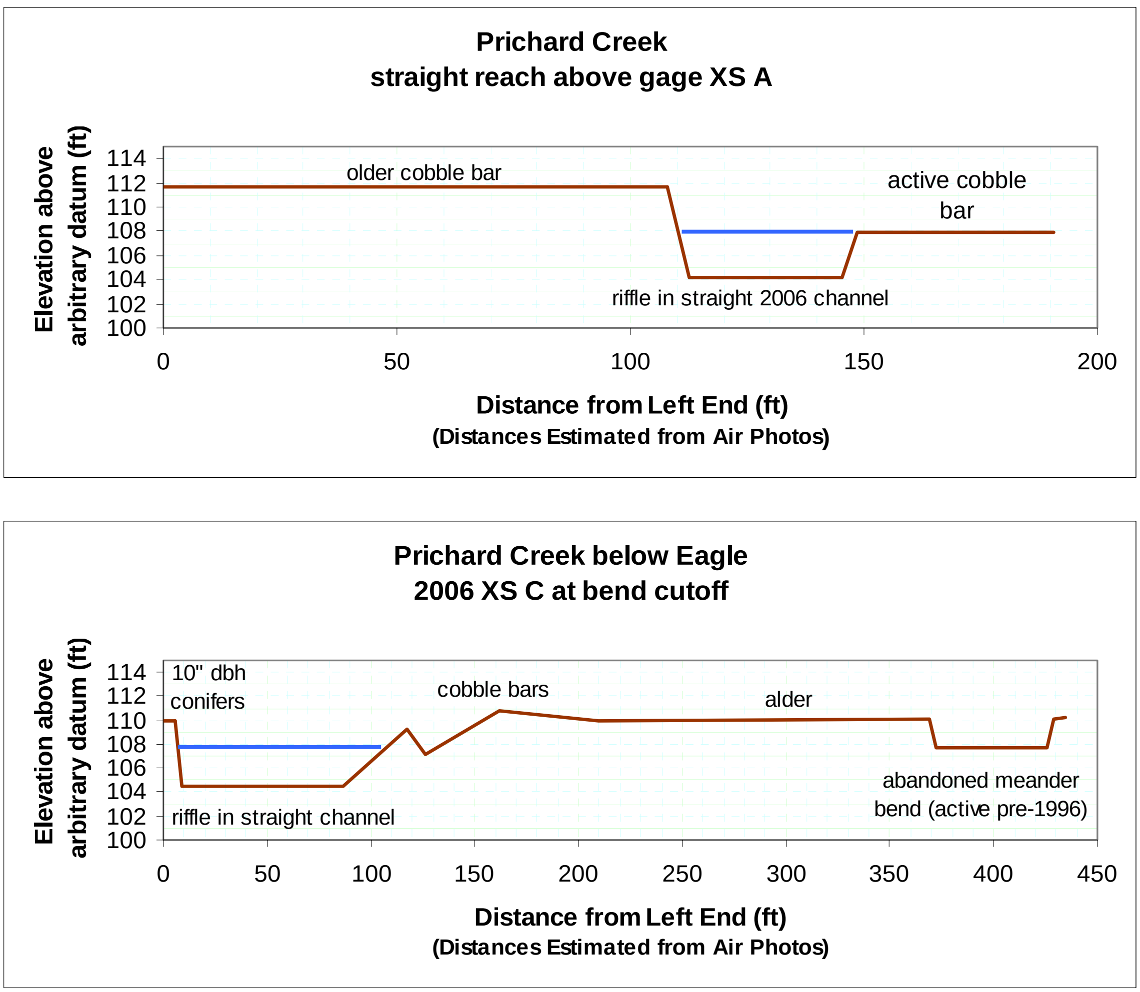


Figure 39. Year 2006 cross-sections depicting recent downcutting in narrow-valley sections of Prichard Creek downstream of Eagle Creek.

Figure 40. Photos of recently downcut areas in Prichard Creek downstream of Eagle Creek.

Channel response occurred later in Beaver Creek. The mainstem of Beaver Creek downstream of Trail Creek was cleared for farming but the creek was still narrow in 1933. (There were no 1930s photos upstream of Trail Creek.) By 1968, long reaches of the creek had widened both upstream and downstream of Trail Creek, and there were reaches with two channels where avulsions had occurred. This condition continued through at least 1975, with some short areas starting to recover in the last decade. Many of the east-side tributaries still are overloaded with sediment near their downstream ends. There were no changes visible on air photos in the North Fork River downstream of Beaver Creek, probably due to the creek's small size.

The 1937 air photos of the mouth of Prichard Creek show two wide bars in the river just downstream of the sediment-laden creek. These bars were wider than the narrow, alternating bars that are typical for this reach of the river. Bar growth continued downstream and laterally through 1968 and 1975, pushing the river to the opposite bank and causing bank erosion. No additional bar growth has occurred since 1975, and higher parts of the bars have become vegetated. The river has incised through the 1975 deposits (Figure 41). Bar deposition is still occurring at a lower elevation.

Figure 41. Mouth of Prichard Creek where the stream is downcutting through former deposits.

3.5 CHANNEL RESPONSE AND SEDIMENT LOAD IN BURNED, LESS-MANAGED PARTS OF THE NORTH FORK COEUR D'ALENE RIVER WATERSHED.

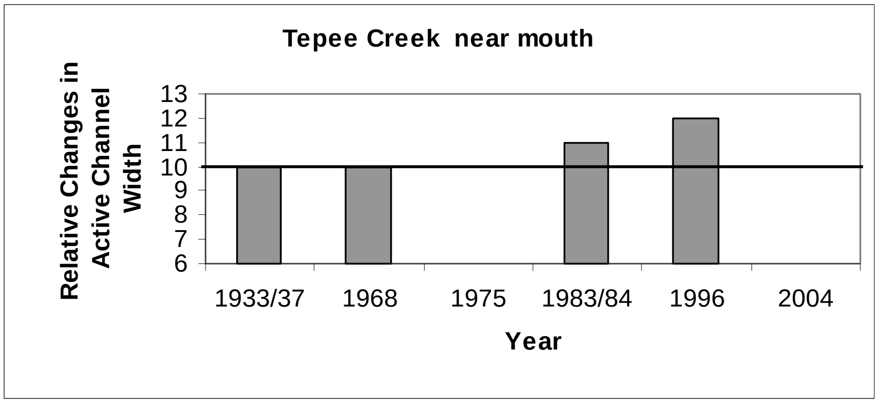
This report section is based primarily on air photo analysis of response reaches in the Tepee Creek watershed, a few USFS cross-sections, and very limited field reconnaissance along Tepee Creek and Trail Creek. The Sediment Source Technical Report and spreadsheets provide additional information regarding the estimated historic and current sediment loads that were extrapolated from the two study watersheds. The Excel channel database contains information on some of the tributaries.

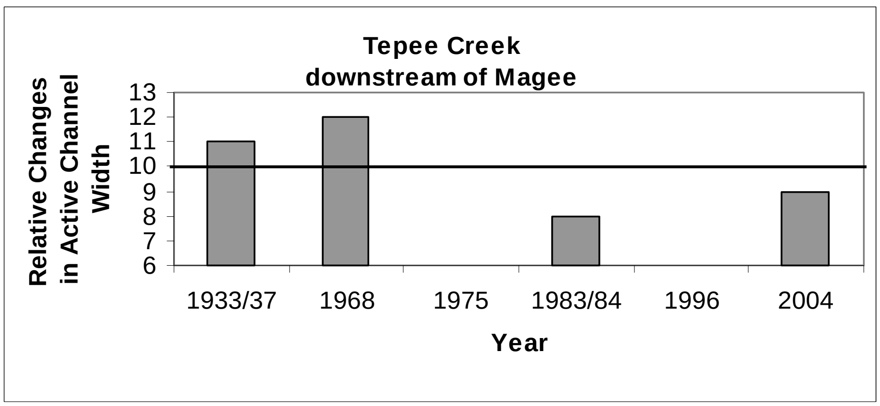
The two watershed areas that were mostly burned by the 1910 fire, Tepee Creek and upper North Fork above Tepee Creek, had a significant amount of channel widening despite their relative lack of roads and timber harvest (Figure 42). Possible natural causes include a high natural supply of coarse sediment and the long, flat, unconfined valleys that cause sediment to deposit (Figure 43). Long reaches of Trail, Tepee, Independence, and Big Elk Creeks have gradients of 0.5 % or less. Man-made causes include removal of riparian vegetation and channel structure in the response reaches, soil erosion after the 1910 fire and subsequent sheep-grazing, and erosion from logged and/or roaded areas in the unburned headwaters of some of the creeks.

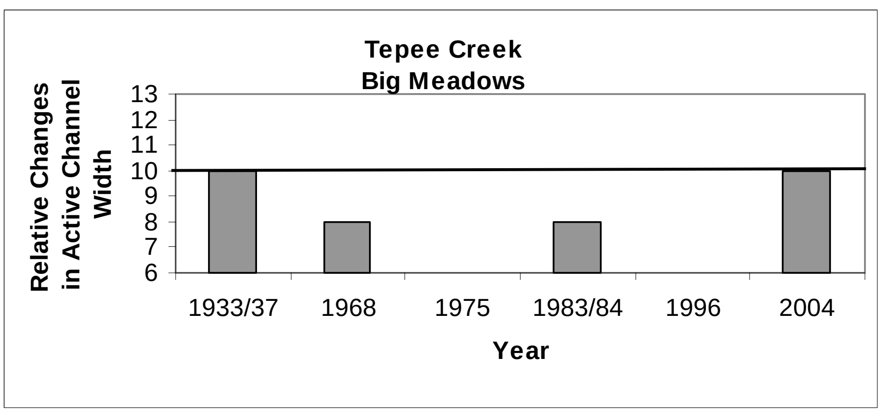
Outcrops of Belt Group rocks along Tepee Creek (and probably throughout the North Fork subbasin) contain crumbly layers of gravel and cobbles that fall into the stream when undercut during flooding. The high natural supply of coarse sediment in the North Fork subbasin is best illustrated at Settlers Grove of Ancient Cedars, an old-growth forest in the headwaters of West Fork Eagle Creek. Gravel with cobbles forms large bars in the creek, and coarse sediment is also exposed on the forest floor (Figure 44).

Unconfined, low gradient channels are known to widen when there is no riparian forest to provide bank stability. Several factors may have reduced riparian stability:

- ◊ The 1910 fire probably burned many of the riparian trees.
- ◊ The valley bottoms of Independence Creek, Trail and Tepee Creeks were reportedly bulldozed in the 1930s to remove *Ribes* (gooseberry) shrubs (USFS, 1997). The lower 3 miles of Independence Creek were cleared between the 1935 and 1937 air photographs. Bulldozing of other areas must have occurred after the 1930s photographs, so the extent of disturbance is unknown.
- ◊ Large wood was pulled out from Independence Creek by bulldozer in the 1950s to improve fish passage (USFS, 1997), and this practice may have occurred in additional streams in the burned subbasins.
- ◊ Timber was salvaged after the 1910 fire and transported down some creeks in "log drives". This occurred in 1910-1912 in the lower 4 miles of Independence Creek, Tepee Creek "down from Magee", and the North Fork River from above Cathedral Rocks (Russell, 1984). A 1926 log drive in Spruce Creek, a tributary of the upper North Fork River, ran out of water due to shallow banks.







**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 42. Relative changes in active channel width of Tepee Creek interpreted from aerial photographs.

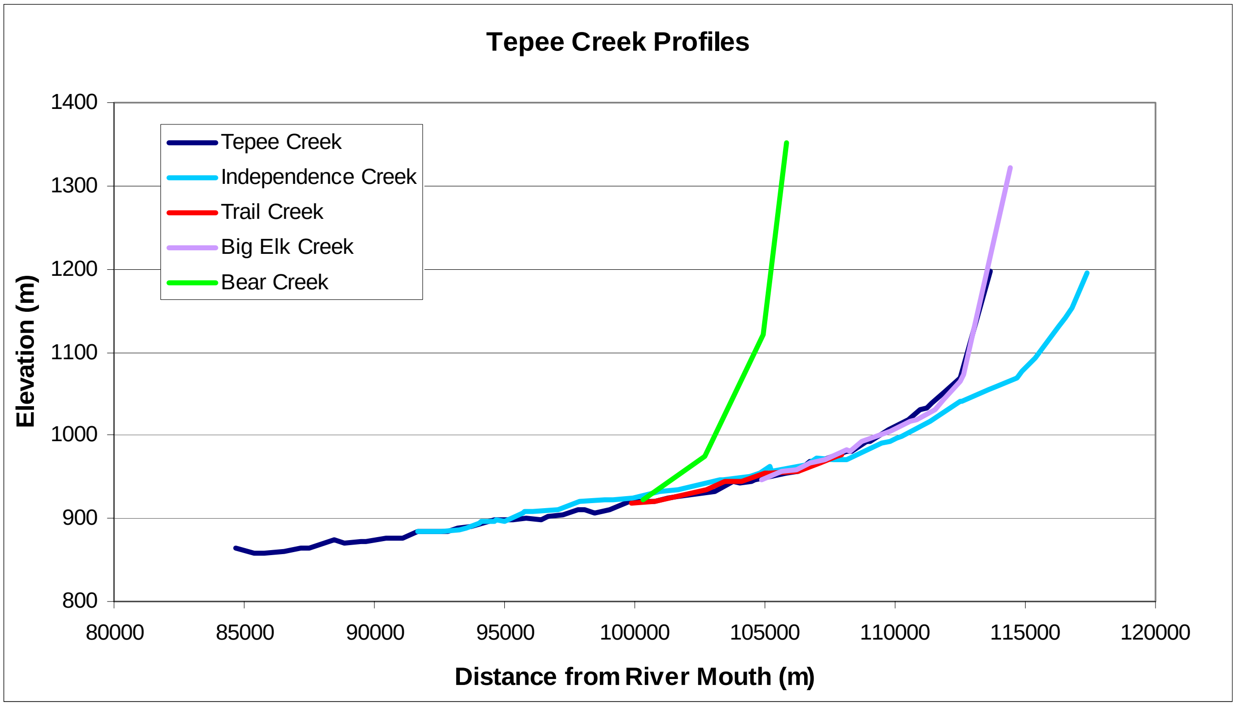


Figure 43. Channel profiles of Tepee Creek and some of its tributaries.


Figure 44. Gravel bars and gravelly floodplain soil in an undisturbed, old-growth cedar forest in Settlers Grove, West Fork Eagle Creek.

◊ Heavy grazing by sheep occurred within at least parts of the burned areas in both the Tepee and upper North Fork watersheds from the 1910s through the 1930s. There were low levels of cattle, sheep, and horse grazing in Tepee and Trail Creeks in the 40s through 50s, and on Independence Creek in the 1940s through 1960s. The Forest Service has had no grazing allotments in any of these basins since then (Sherri Lionberger, USFS, phone call 5/18/07).

◊ Two reaches of Tepee Creek near Magee were narrowed by channelization. One reach was later restored to a meandering channel by the Forest Service.

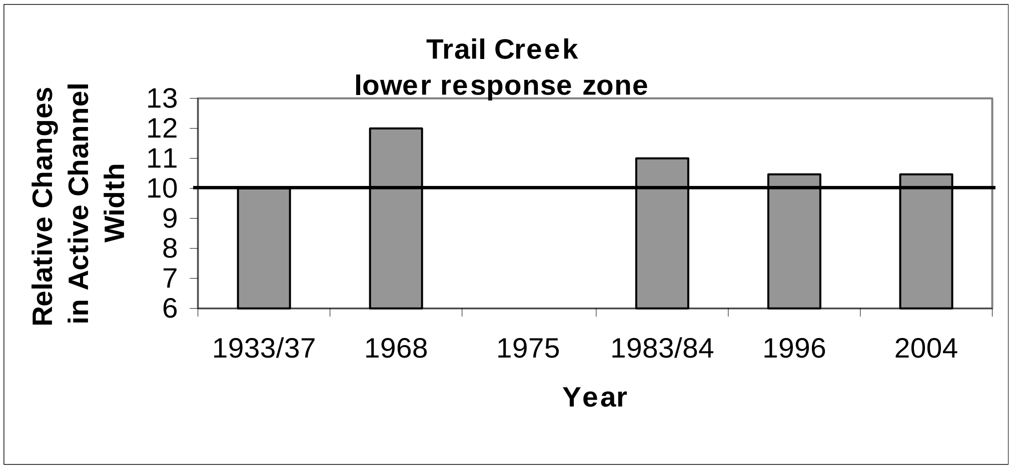
Sediment loads to the creeks were probably elevated for a least a few years following the 1910 fire. Rill and gully erosion could have occurred from rainfall on bare slopes. Tributary channels may have incised after the fire removed riparian vegetation and increased runoff rates. Sheep herds may have worsened erosion and runoff rates.

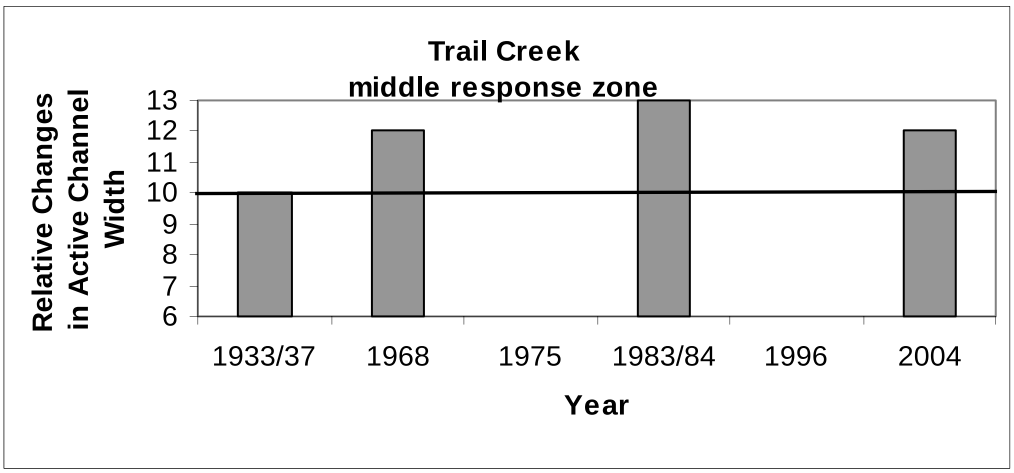
The North Fork River upstream of Tepee Creek was analyzed only at its downstream end using the same photos that covered the Tepee Creek confluence. The channel was very wide in 1937 and then narrowed before widening again by 2004. Several of the unlogged tributaries to the upper North Fork appeared to have a high coarse sediment load in 2003 ground photos at some of IDEQ's BURP sites, including Deer Creek.

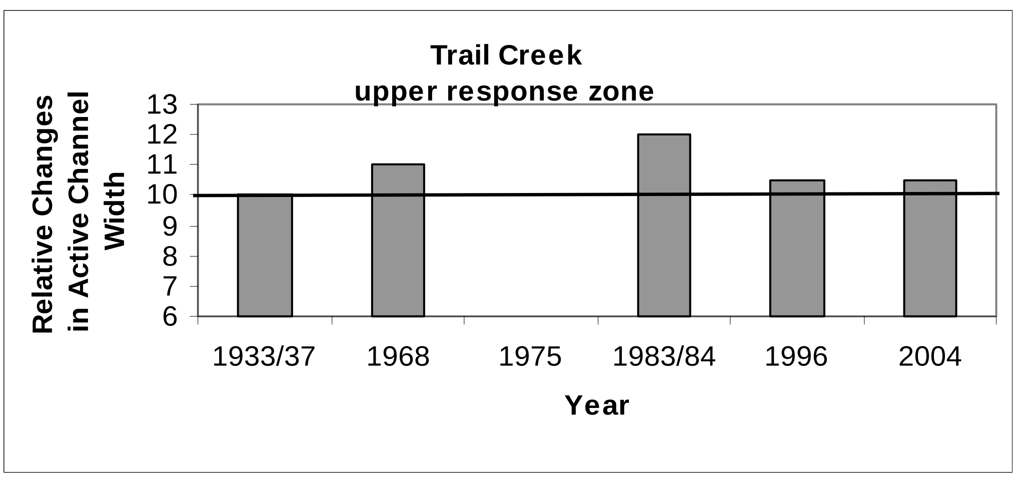
The timing of channel response was later on the lowest reach of Tepee Creek, which was widest in 1983 and 1996. Tepee Creek, Trail Creek, and most of Independence Creek were fairly narrow with scattered bars in the 1930s photos that predated the *Ribes* bulldozing. How this compared to pre-burn conditions is unknown. The response reaches had widened by 1968.

Channels in Trail Creek, another major tributary to Tepee Creek, were significantly wider by 1968 and later (Figure 45). Potter and Stewart creeks in Trail Creek's headwaters were not burned but were logged. Floods in the 1970s, 1980s, and 1990s washed out a number of logging roads that contributed sediment (Ed Lider, USFS, e-mail 2/2/07). Flood-damage summary reports by the USFS referred to mudflow and mud slides in Potter Creek in 1974 and unspecified damage in the 1964 flood. Channel incision is a current sediment source in the lower reaches of several unlogged tributaries farther downstream (Hamilton, Dresser, Bear, and 2 small ravines) and possibly other locations. In the 1996 flood, Hamilton Creek aggraded 2 to 3 feet between Trail Creek and the 436 road crossing, which washed out and contributed some sediment in addition to the channel downcutting upstream (Ed Lider, 2/2/07). The cause and extent of channel downcutting require additional investigation, but it could be a significant sediment source.

Downstream of Hamilton Creek, Trail Creek became wider and braided by 1968 and was slightly wider and more braided by 1984. The 1996 photo was missing, but in 2004 the channel was nearly as wide as 1983 and major avulsions had relocated a mile of Trail Creek to a different part of the valley. It seems likely that the avulsions were caused by the large coarse sediment load from Hamilton and Dresser creeks. Other factors that cause instability in this reach are the declining gradient which causes the sediment influx from upstream to deposit, and an increasing population of beavers may also have played a role (Ed Lider, 2/2/07). The other two response zones on Trail Creek had both narrowed by 1996. The lower response zone of Trail Creek







**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 45. Relative changes in active channel width of Trail Creek interpreted from aerial photographs.

reached maximum width in the 1968 photo, then narrowed. The upper response zone in Trail Creek widened slightly in 1968 and reached maximum width in 1983/84. Since then it has narrowed but still remains slightly wider than in 1937.

Independence Creek had no unburned areas that were subjected to timber harvest. No current sediment sources are known for Independence Creek, but there may be downcutting channels similar to those found on Trail Creek. Evidence of past downcutting is indicated in the Forest Service cross-sections on Emerson Creek (a tributary that enters Independence Creek. upstream of the lowest response reach). The lowest reach had widened by 1968 and the disturbed area lengthened by 1983/84. The reach had mostly recovered by 1996 and had returned to 1933 width by 2004 (Figure 46). In the middle response reach between Owl and Griffith Creeks, Independence Creek widened by 1968 and has remained wide since then. The upper response zones above Griffith Creek were already wide by 1933 and remained that way through 1983/84, then narrowed somewhat by 1996.

The logged area in the headwaters of Tepee Creek, which includes Big Elk Creek, was relatively stable and had a subdued channel response (Section 3.2). The mouths of burned, unlogged tributary creeks to Tepee Creek downstream from Big Elk Creek appeared to have a low sediment load in summer 2006.

To summarize, some response reaches of streams in the burned parts of the Tepee Creek watershed widened, similar to parts of the watershed that were logged and subjected to dense road building. The watershed geology supplies coarse sediment to the streams. In addition, the burned areas are not pristine and had early disturbances to their riparian zones and uplands that contributed sediment and destabilized the banks of response channels. Trail Creek has some known erosion areas that have provided sediment to the stream in 1996 or more recently.

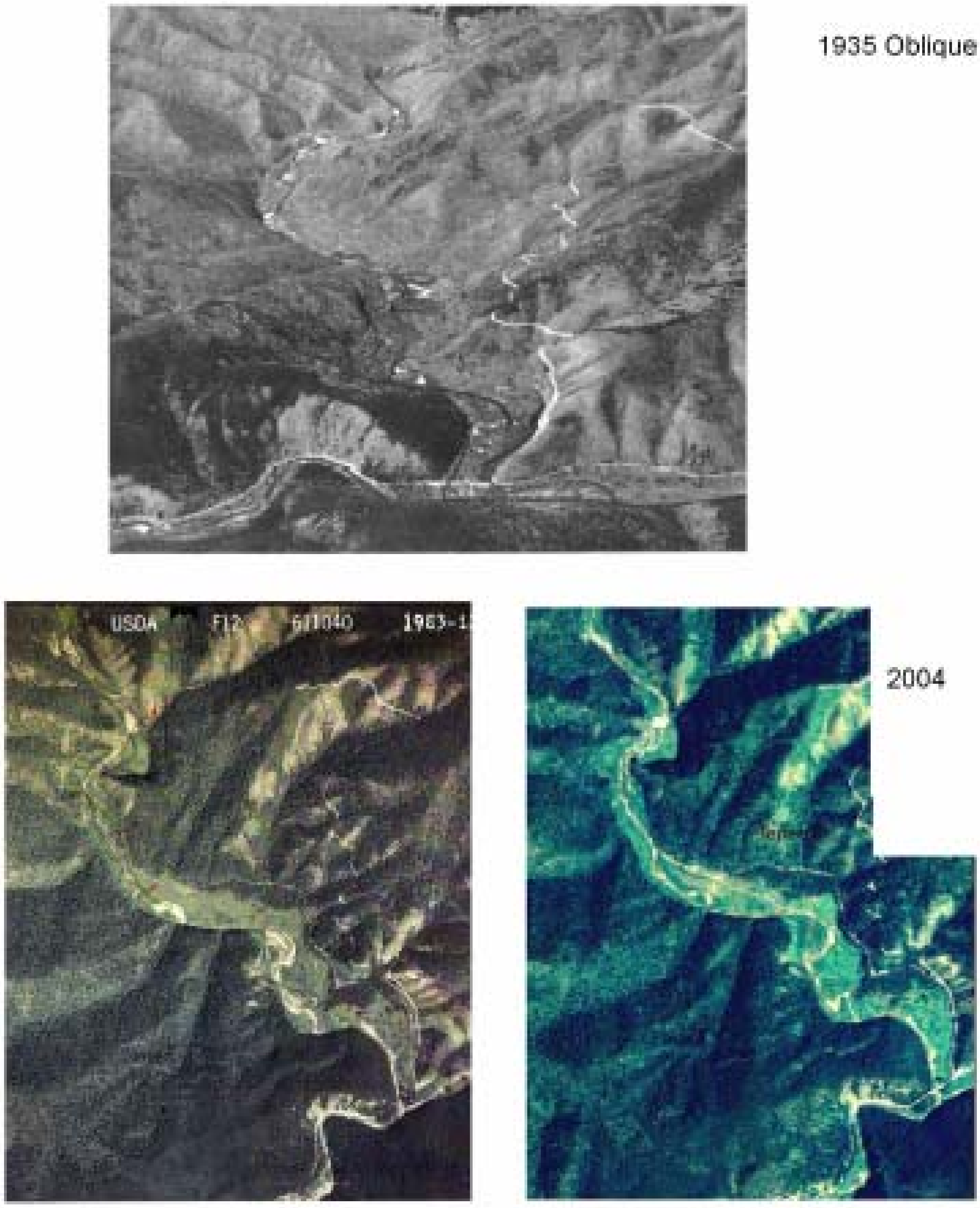


Figure 46. Air photos of lower Independence Creek showing channel widening in 1983 (lower left photo) compared to 1935 (oblique) and 2004 (lower right) photos.

3.6 CHANNEL RESPONSE AND SEDIMENT ROUTING DOWN THE NORTH FORK COEUR D'ALENE RIVER

3.6.1 Topographic Summary

Tepee Creek occupies a flatter valley that is a continuation of the middle North Fork valley. The other major tributaries are steeper than the North Fork (Figure 47). The North Fork River flattens gradually downstream with a concave profile. The river gradient is typically between 0.6 and 0.8% upstream from Tepee Creek. The gradient averages 0.3% between Tepee and Prichard Creeks, but the reduced gradient is compensated for by increased discharge that keeps sediment moving downstream. Downstream of Prichard Creek, the average gradient is less than 0.2%, becoming very flat in the reach below the Little North Fork Coeur d'Alene River where most of the coarse sediment load is forced to deposit.

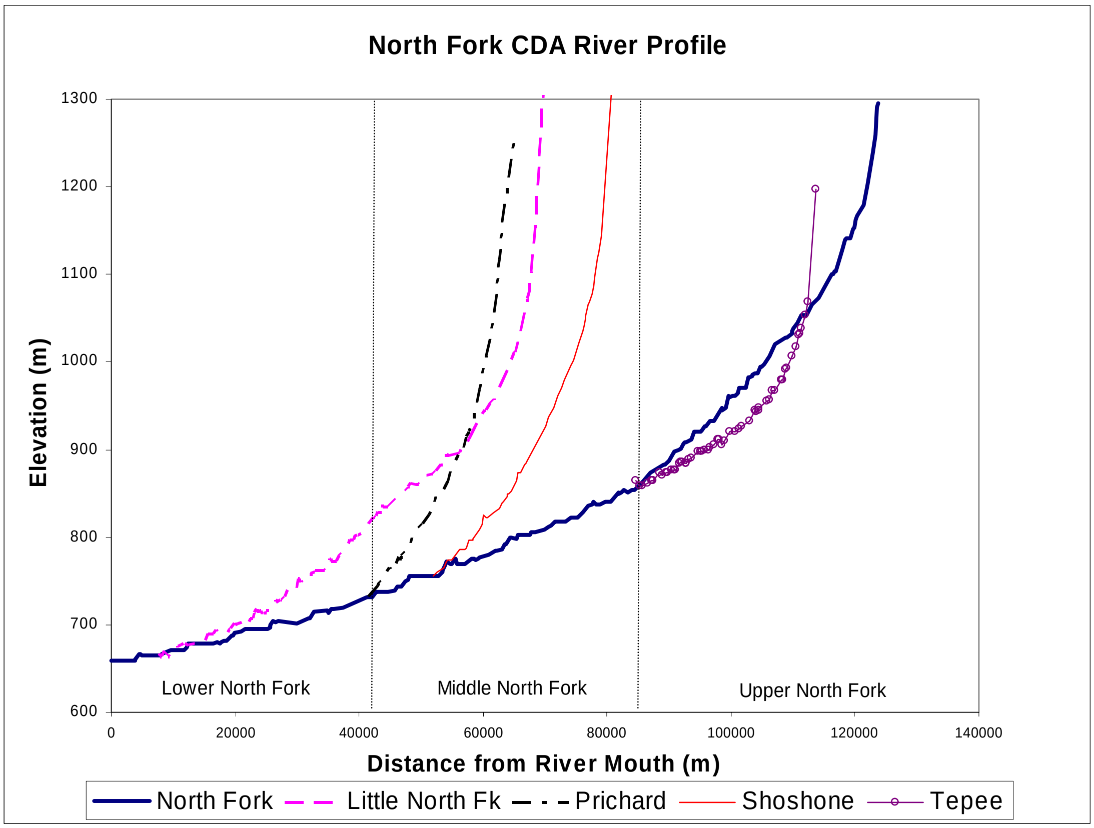


Figure 47. Profile of the entire North Fork Coeur d'Alene River and its major tributaries

3.6.1 Bedload Sediment Waves and Estimated Downstream Travel Time

Low gradient rivers such as the North Fork Coeur d'Alene River process coarse sediment relatively slowly. Sediment waves move down channels at a rate of approximately 21 bankfull channel widths per year in the maritime Pacific Northwest, but limited evidence suggests that they may move up to twice as fast in areas with prolonged snowmelt floods (Beechie, 2001). The middle reach of the North Fork River is narrow, which would encourage faster bedload velocity. Coarse sediment would move about 0.7-1.4 miles per year using a typical bankfull width (the higher estimate is two times faster than Beechie's formula), taking about 20 to 41 years to travel down-river from Tepee Creek to Prichard Creek. It would take about 16 to 33 years for gravel to travel from Prichard Creek to the river mouth. Altogether, it would take up to 74 years for a sediment wave to move from Tepee Creek to the mouth of the river.

Coarse sediment has entered the North Fork River at multiple times from multiple locations, so there is no single sediment wave. Incomplete air photo evidence suggests that, at a minimum, sediment waves reached the Tepee Creek-North Fork confluence in the 1930s and again in the 1990s/2000s. Prichard Creek has been a consistently large source of coarse sediment to the lower North Fork River since the 1930s or earlier. The lower portion of Prichard Creek was once again wider in the 1996 photos. As described in Section 3.4.3, anomalously large gravel bars had formed in the first mile downstream from Prichard Creek by 1937 and grew to their greatest height and width by 1975, but there was still active bar deposition occurring there in 2006. Sediment from Prichard Creek was added to any sediment waves moving down the middle North Fork. Sediment export from the Little North Fork River may have peaked in the 1930s through 1960s, although additional sediment is still making its way downstream (see Section 3.3.4).

Sediment-export timing from the numerous, steeper tributaries is harder to judge. Most tributaries are steep and narrow and have no response reaches that reflect the timing or magnitude of sediment delivery. There were probably large pulses of sediment following the first wave of early logging activity, fires, and subsequent floods in the 1930s. Pulses of sediment would have entered the watershed during and after major flood events in the 1960s, 1970s, and to a lesser extent 1980s and 1990s. The quantity of sediment would have been dependent upon the timing of road-building and logging in each drainage.

Shoshone Creek, a major tributary to the middle North Fork River, has an unconfined response reach at its mouth. Its behavior may provide an indication of the timing of sediment delivery from other tributaries. The last log drive out of Shoshone Creek was in 1923, and by 1933 the lower half mile of the creek had a very wide, braided channel. In 1975, it was braided in fewer locations and somewhat narrower. The creek narrowed a little more in 1996 but had active bars and a recent avulsion. It narrowed still more by 2004, and former gravel bars were revegetated with willows. Although on a downward trend, the sediment load appears to have remained high at least through 1996.

Graham Creek is a small tributary of the lower North Fork that was logged and then burned prior to the 1937 air photo. The downstream end of the creek was braided in 1975. The coarse sediment load in 2006 still appeared moderately high and there was evidence of prior channel entrenchment.

Cougar Gulch, a larger tributary of the lower North Fork, had a small, active sediment fan in 2006 on the river's edge, protected from the river flow by the backwater from a revetment. An eroding, 5 foot high bank was documented in photos taken in 2004 at IDEQ’s upstream BURP site that may indicate channel downcutting. Sediment loads appeared low in Steamboat Creek. No other lower North Fork tributaries were visited by the channel analyst.

Using the bedload sediment travel times from above, a sediment wave that reached the Tepee Creek-North Fork confluence in the 1930s would have reached Prichard Creek sometime between the 1950s and 1970s. That same sediment wave would then have reached the river mouth near Enaville in the 1970s at the earliest, but using the slower bedload velocity rate it could just be arriving there now. Gravel that entered the river from Prichard Creek in the 1930s would possibly have reached the river mouth between the late 1940s and the early 1970s. The peak of sediment export from Prichard Creek in the 1970s would have reached the river mouth between the early 1990s and late 2000s.

3.6.2 Middle North Fork Coeur d'Alene River Channel Response

The valley of the middle North Fork River is fairly narrow upstream from Prichard Creek. Long, confined reaches with valley widths less than 200 or 300 feet alternate with short, unconfined reaches from 700 to over 1000 feet wide. Channel migration is generally constrained by bedrock valley walls that lock the river bends in place. The river is straight to sinuous, and many of the river's bends are caused by bends in the valley wall. The channel pattern in the early 1900s was very similar to today in most of the middle North Fork, based upon comparison of recent USGS topographic maps with the original Government Land Office (GLO) survey (Table 8). This reach has 1 or 2 roads along the edge of the river valley, as well as multiple bridge crossings that pin the river in place.

In the confined reaches that dominate the middle North Fork River, flow is fast and deep enough that coarse sediment moves through the reach without accumulating. In less-confined reaches where there is room for the river to deposit sediment, a mostly-subdued response to the coarse sediment load moving through is indicated in the air photos. Most of the bars stayed a similar size and shape, controlled by local hydraulics rather than the sediment supply. Air photos indicate that the active-channel width and/or bar activity at some sites increased between 1968 and 1996, and then narrowed again by 2004. Very few air photos could be located for the period between the 1970s and 1980s; hence little information regarding sediment changes in that time frame is available.

The longest response reach begins several miles downstream from Tepee Creek and extends from Wilson Creek through Miners Creek. It had multiple floodplain channels in the 1930s indicating a history of prior avulsions, but all the river flow was in a main channel on the west side of the valley. In 1968, two long channels on each side of the valley shared the river flow equally, but the overall bar area was slightly lower. By 1996, the west channel had been (recently?) abandoned and was plugged with sediment at the upstream end, and the east channel had developed new wide, active bars. A few miles farther downstream, the Big Hank Meadows area also increased in width and channel migration activity by 1996. Active channel width decreased in both areas by 2004.

Two cross-sections were surveyed in 2006 in the Miners-Wilson reach to look for vertical change in river deposits of different ages. The upstream cross-section was located in a depositional zone upstream from the avulsion and includes a mid-channel bar that was probably reworked in the 1996 flood (Figure 48, Figure 49). The cross-section showed that the river had downcut 2 feet since 1996, and had downcut 4 feet below an older terrace that had recently-burned forest on it in the 1930s. This terrace had once been an active gravel bar since it was composed of gravel-cobble sediment. Cross-section B was located downstream and crossed both avulsion channels (Figure 50). The evidence for vertical change at XS B was indeterminate. Although the east river channel is lower than the abandoned west channel, the most-probable bankfull indicators on the east and west channels had similar elevations.

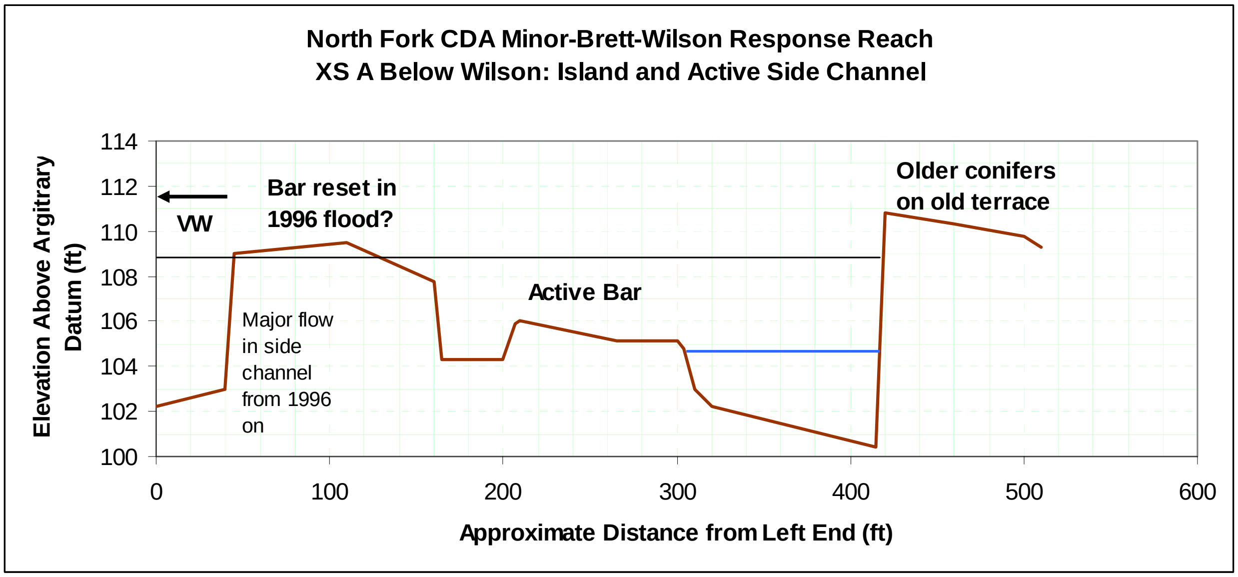


Figure 48. Year 2006 cross-section on the Minor-Brett-Wilson response reach located in a depositional zone.

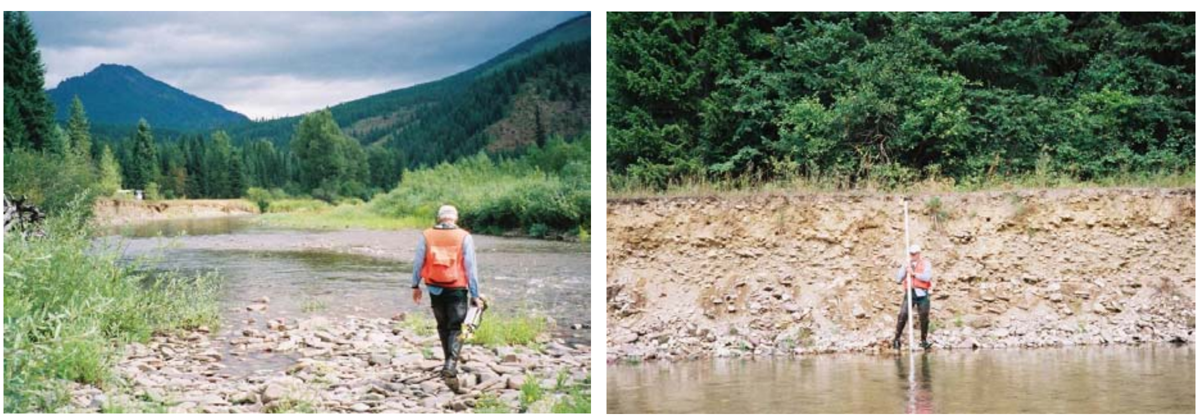


Figure 49. Response reach near Minor-Brett Wilson, cross-section A with mid-channel bar in view (left) and downcutting at the left end of the cross-section below an older terrace (right).

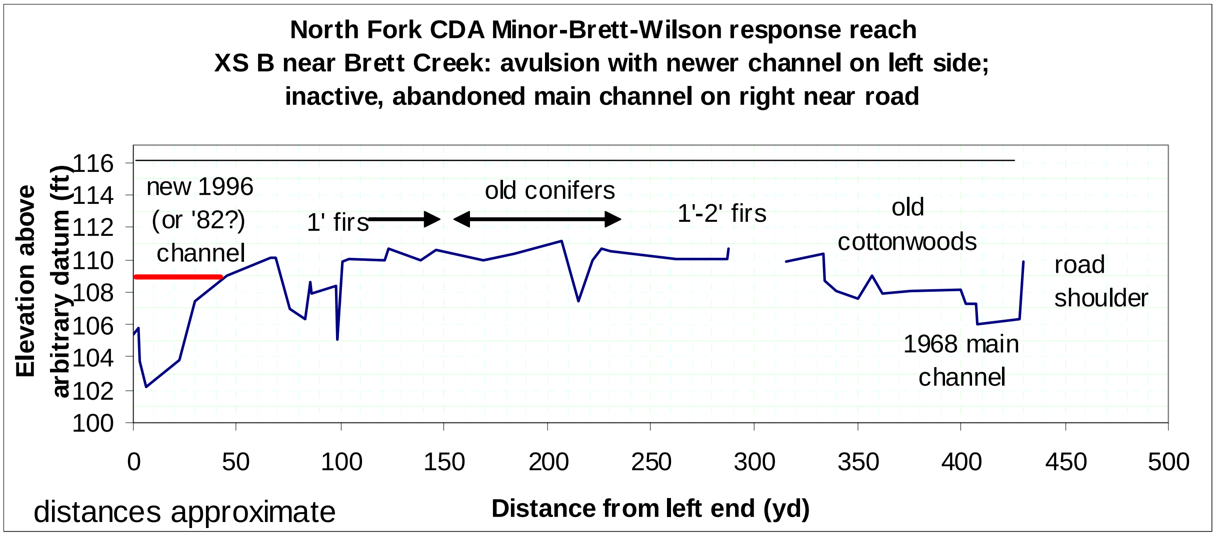


Figure 50. Year 2006 cross section B at Minor-Brett-Wilson response reach.

Much farther downstream, river bed elevation at the USGS gage a short distance upstream of Shoshone Creek has held fairly steady since 1954. The river bed was 0.4 foot lower from the late-1970s through mid-1990s, but then it rose again to the same elevation as before (Figure 51). Stream gages are normally sited in stable reaches that do not accumulate sediment, and that seems to be the case for this gage. A 2006 pebble count at the gage found bed sediment slightly finer (D_{50} 58 mm, D_{84} 105 mm) but essentially similar in size to 1992 pebble counts that were completed upstream and downstream from the gage (D_{50} 64-78 mm, D_{84} 120-150 mm). There is no convincing evidence of significant fining that would accompany a sediment wave. There were no earlier pebble counts available.

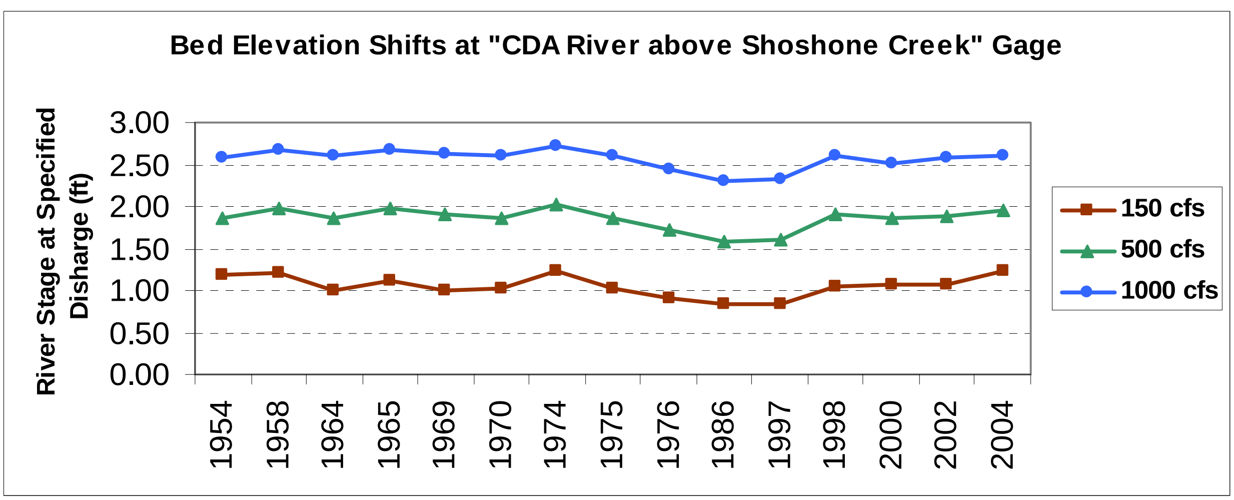


Figure 51. Bed elevation shifts at “CDA River above Shoshone Creek” gage. River stage is plotted at three discharge levels.

Table 8. Government Land Office surveys of the North Fork Coeur d'Alene watershed: dates, coverage, and comparison of river patterns

Township & Range	Map order (from River Mouth)	Date of Original GLO Surveys	Follow up Surveys New River course	Water Features Shown	N Fork subbasin	N Fork river detail and Accuracy[1]	Comparison with USGS Topo Maps Remarks[2]
T51NR4E	7	1908		N FORK CDA	Middle N Fork, Shoshone	Good	River pattern unchanged, valley wall control
T51NR3E	8	1903-1909		N FORK CDA	Middle N Fork	Good	River pattern unchanged, valley wall control
T52NR2E		1904		Tepee Cr.	Tepee	N/A	
T52NR3E W1/3	9	1904		N FORK CDA	Middle N Fork	Poor	Simplified river channel, inaccurate location
T52NR3E E2/3		1939			Shoshone, MNF	N/A	Shows road to Pond Peak
T49NR1WSE1/4		1891		4th of July Cr.		N/A	
T49NR1W rest		1903		4th of July Cr.		N/A	
T49NR1E	1	1885		N FORK CDA	Lower N Fork, Little N Fork	Poor	Good detail of mainstem CDA River; poor detail of first 0.3 miles of N Fork
T49R2E not 30-31	3	1904	1972 Sec 18-19	N FORK CDA	Lower N Fork, RM 3, upstream	Good	Channel migration evident sec 4, 17-19; sec 8 wider in GLO with more side channels
T49NR2E Sec 30-31	2	1891		N FORK CDA	Lower N Fork RM 0-3	Poor	Simplified river channel not surveyed, just drawn in
T50NR1W		1905		Wolf Lodge Cr		N/A	
T50NR1E		1905		Little N FORK	Little N. Fork	N/A	Shows trail to Cataldo, mainstem CDA River
T50NR2E	4	1903-1905		N FORK CDA, Cougar, Steamboat	Lower N Fork	Good	River pattern unchanged, valley wall control. Sec 24 wider in GLO map
T50NR3E	5	1904-1905	1983 Sec 29 & 25	N FORK CDA	Lower N Fork	N/A	Most of reach was valley wall control except wider w/channel migration Sec 22, 25, 36. Long side channel in section 25 is gone in topo map
T50NR4E	6	1905-1908	1981 Sec 10	N FORK CDA, Pritchard, etc.	Middle N Fork, Pritchard, Little N Fork	Good	River pattern similar, mostly valley wall control. GLO does not show section 10 channel shown on later topo map. Shows numerous mining claims Prichard Cr. and 1st N. Fork meander bend downstream of Prichard, placer mined?

[1] Accuracy, river detail, and pattern were compared with USGS 7.5 minute topographic maps, scale 1:24,000, based on 1985-1996 air photos (Forest Service B maps)

[2] GLO maps for townships north of 52N were not obtained due to the small size of the North Fork Coeur d'Alene River

Downstream of Lost Creek, which is the first major tributary downstream of Shoshone Creek, the number and size of the rare, small, mid-channel bars were slightly higher in 1975 and 1996 than in 1937 or 2004.

To summarize, response reaches in the first 10 miles downstream from Tepee Creek increased in active-channel width through 1996 and then decreased by 2004. There is some evidence of later incision which would be consistent with passage of a sediment wave that originated from Tepee Creek. An earlier sediment wave from the upper North Fork River that reached the Tepee Creek area in the 1930s would have already passed downstream to Prichard Creek by the 1960s or 1970s. That does coincide with the additional bars visible in the 1975 photos downstream of Lost Creek; however, it is not clear whether the additional bars were due to a sediment wave or simply the extremely large 1974 flood. Given the long gaps between photos and the low number of response zones, it was not possible to track sediment waves down the middle North Fork Coeur d'Alene River with any degree of certainty.

3.6.3 Lower North Fork Coeur d'Alene River Channel Response

3.6.3.1 Sediment Deposition and Changes in Sediment Size

The North Fork River gage at Enaville had to be moved ¼ mile downstream in 1989 or 1990 due to excessive gravel deposition at the original gage site (Kevin Kerlin, USGS Post Falls office, phone call, 2/23/07). River bed elevation at the new gage site increased about 1 foot in the 1996 flood and has since declined slightly (Figure 52). There were no repeatable cross-sections elsewhere on the river to assess vertical changes.

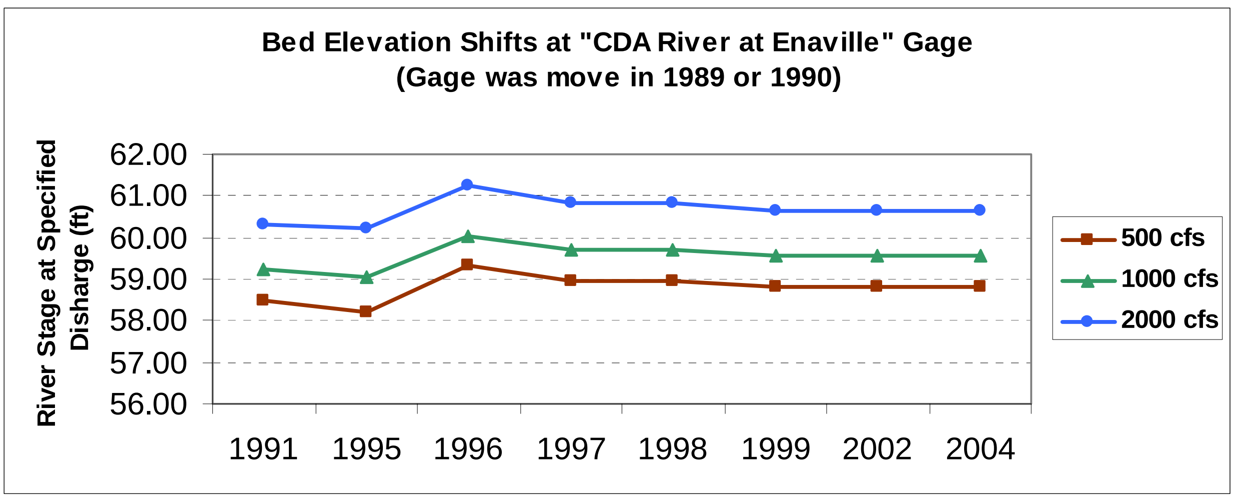


Figure 52. Bed elevation shifts at "CDA River at Enaville" gage. River stage is plotted at three discharge levels

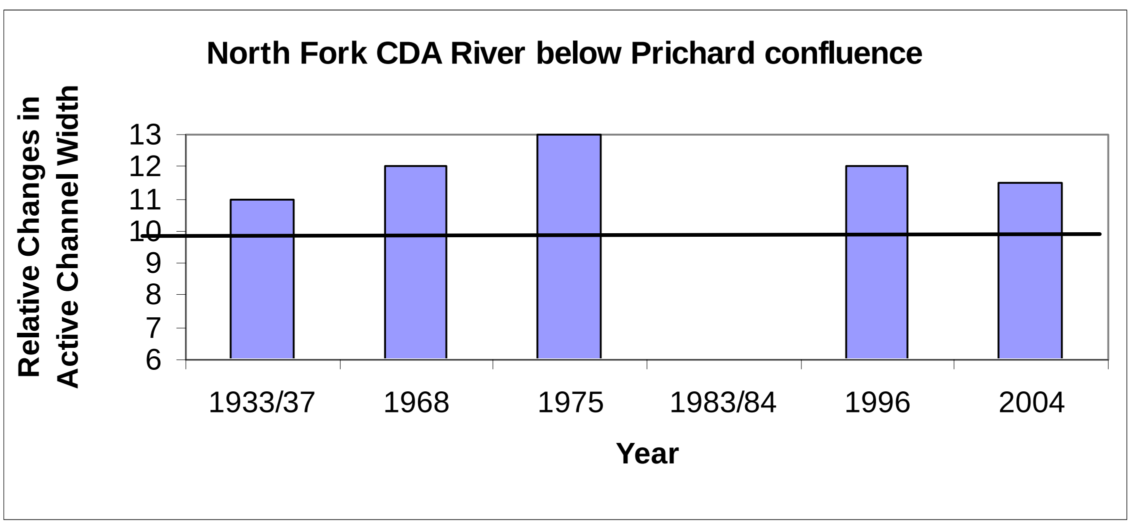
Due to the declining gradient, the river bed material becomes progressively finer downstream in the last few miles. Most of the large cobbles drop out upstream from RM 8. Bar sediment a short distance above the Little North Fork River mouth has a surface texture of small cobbles and gravel (D50 71 mm, D84 130 mm). The Little North Fork adds a large amount of coarse sediment of a similar size (D50 68 mm, D84 102 mm) just where the gradient flattens even more.

Most of the remaining, smaller cobbles drop out near the Little North Fork, upstream from the USGS gage at Enaville. At the gage (located at the bridge farthest downstream), the bar sediment is gravel with a D50 of 27 mm and D84 of 47 mm.

Much farther upstream, a USGS gage was located for a few years in the 1940s in a narrow section of the North Fork River downstream of Beaver Creek. A pebble count was made at that location following a large flood in 1948, but its precise location relative to three cross-sections was not stated (Barnes, 1967). At that time, the median diameter (D50) of the substrate material was 103 mm and the D84 was 650 mm. The bed was dominated by cobbles with areas of bedrock and boulders. A 1992 pebble count by the USFS 100 to 600 feet upstream from the 1948 pebble count (1948 location was not specified) found a similar, but slightly finer bed with boulders (D50 83 mm, D84 420 mm). The differences could be explained by local hydraulics or different protocols for sampling bedrock and banks. Relative to the cobble-gravel bed upstream near the Shoshone gage, this is clearly a much faster transport reach where finer sediment would not deposit except in local pockets affected by hydraulics. In 1991, the USFS conducted a pebble count at this gage (USFS, 1992). The sample was 25% sand, indicating that the gage was located in one of the anomalous areas where fine material could accumulate.

3.6.3.2 Channel Response on Historic Air Photos

Gravel bar growth and bar height in the North Fork River downstream of Prichard Creek was greater in the 1975 photo than in 1937, 1996, and probably 1968 (Figure 53, Figure 54).



**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

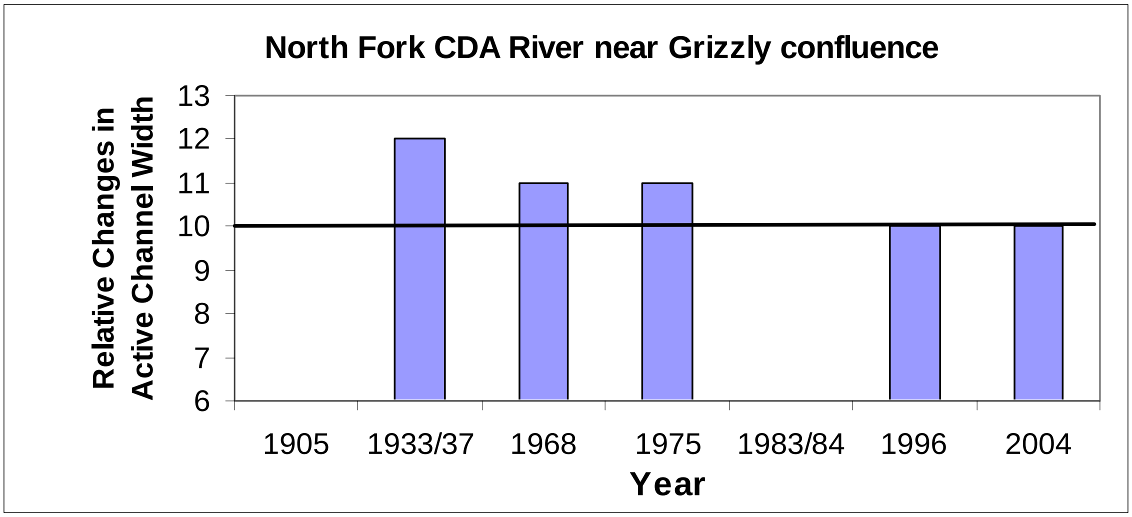
Figure 53. Relative changes in active channel width of the North Fork Coeur d'Alene River downstream of the confluence with Prichard Creek as interpreted from aerial photographs.

Figure 54. Bars in North Fork below Prichard Creek were at their greatest magnitude in the 1975 photos. There has been some channel downcutting since, but the bars are still active.

The response reach east of Grizzly Creek had an island-braided pattern with wide bars in the 1930s. It gradually changed to a meandering pattern with narrow bars by 1996 (Figure 56, Figure 55). This is the only place on the lower river that still has unrestricted channel migration and floodplain connection, though it was narrowed by roads at the downstream end. These changes indicate a decline in sediment load. A oxbow cutoff shortly before 2004 led to formation of new gravel bars and side channels, but the active-channel width is still much narrower than in the 1930s (Figure 57, Figure 58).

The original GLO survey map indicates that some reaches in the lowest 8 miles of river were considerably wider in 1905 than present, and contained islands and side channels (Figure 59*)*. By 1937, road construction had cut off larger portions of the floodplain including meander bends, bars, and side channels (Figure 60).

Figure 55. 1937 (top) and 1996 (bottom) photos of Lower North Fork Coeur d'Alene River at Grizzly Creek. Not the change from a braided to meandering pattern.



**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 56. Relative changes in active channel width of the North Fork Coeur d'Alene River near the confluence with Grizzly Creek as interpreted from aerial photographs.

Figure 57. North Fork Coeur d'Alene River near the confluence with Grizzly Creek in 2006, 2 years after an oxbow was cutoff.

Figure 58. Oxbow on the North Fork Coeur d'Alene River near the confluence with Grizzly Creek in 2006, 2 years after it was cutoff by the mainstem.

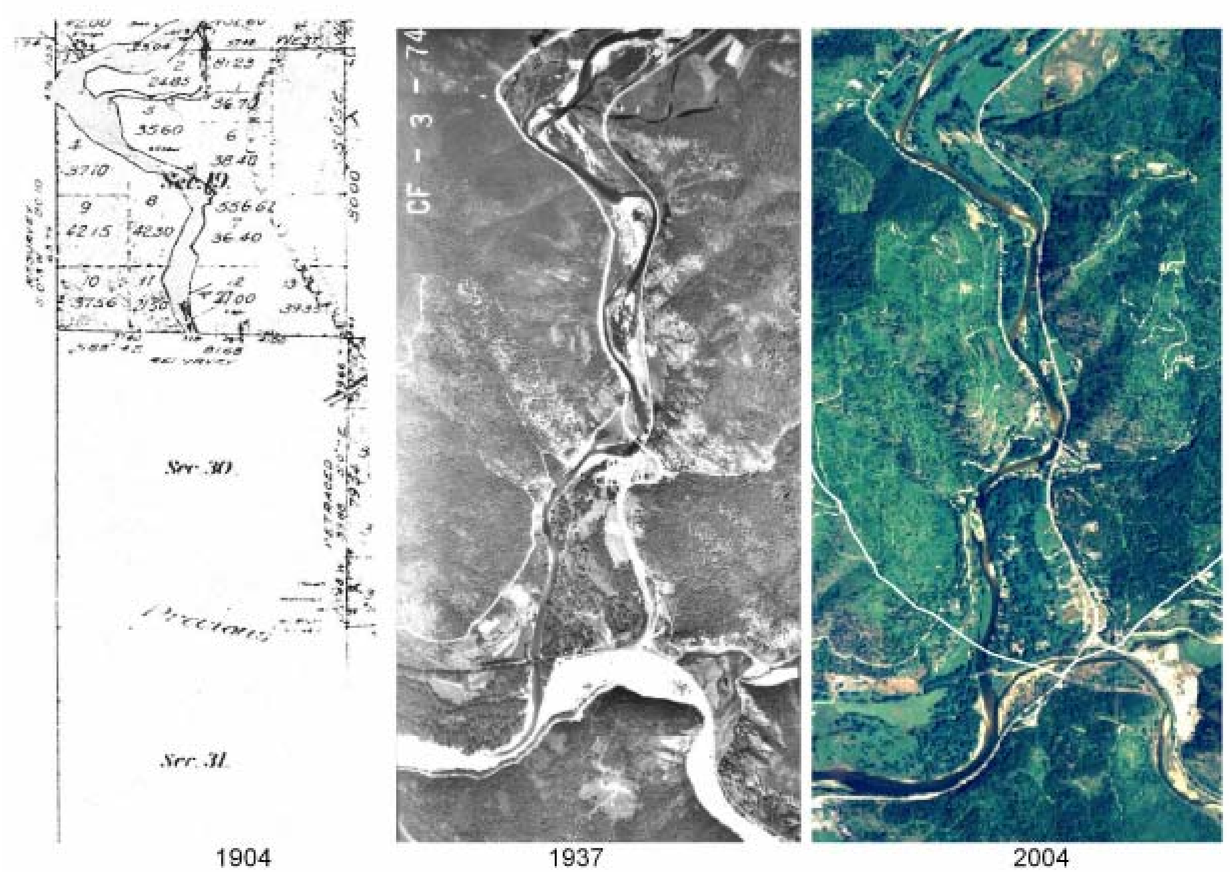
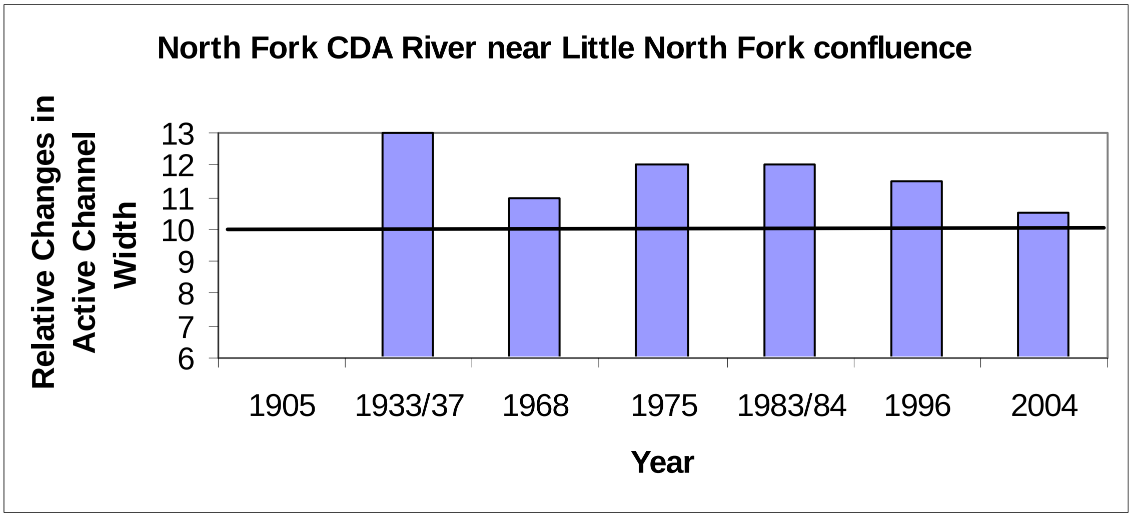


Figure 59. GLO map and air photographs of the North Fork Coeur d'Alene River upstream of the river mouth, showing progressive decline in widths following road construction.

Figure 60. The lower Coeur d'Alene River typically has few gravel bars and armored banks along roads.

Numerous broad, active gravel bars, braiding, and wooded islands along the lower river are apparent in the 1937 air photos. Subsequent channel response to the sediment load from upriver and the Little North Fork has been dampened by bank armoring. Active-channel width had declined almost everywhere by 1968 (Figure 61). There were minor areas of bar growth and channel shifting in the 1975 and 1983/84 photos, including a small avulsion, but the river shifted around within the same, narrow corridor.

The reach downstream of the Little North Fork had the most bars and the greatest amount of channel migration in all years that air photos were available (Figure 62). (There was evidence of gravel mining at two locations, but the gravel pits were small relative to the size of the river.)



**A value of 10 represents assumed pre-disturbance width. Active channel width includes gravel bars as well as the wetted channel. Years without bars on the graph did not have aerial photos.*

Figure 61. Relative changes in active channel width of the North Fork Coeur d'Alene River near the confluence with the Little North Fork as interpreted from aerial photographs.

Figure 62. North Fork CDA River upstream of the Little North Fork gravel deposition zone.

The upstream part of the response reach above Milepost 6 widened between 1937 and 1968. Active channel switching and an island-braided pattern with wide gravel bars were maintained through 1996. By 2004, all the response reaches in the lower 8 miles had become narrower.

3.6.3.3 Discussion of Factors Affecting River Channel Response

The effects of coarse sediment load and riparian disturbance from repeated log drives down the river are apparent in the earliest air photos from the 1930s. In Russell (1984), old timers recount "The log drives tore the banks down and caused the river to change course in some places and widen out and become shallow." Before 1910, the "river was narrow like a flume, 8-10 feet deep around Enaville and Linfer in the summer". Specific log drives down the North Fork referred to in Russell (1984) occurred from 1910 through 1927, with a last drive from Steamboat Creek in 1943. Some of the larger tributaries also had splash dams, including Steamboat and Lost Creeks.

The increased bar growth observed in 1975 downstream of Prichard Creek could be the expression of the coincidental arrival of a sediment wave from Prichard Creek and a sediment wave moving down the middle North Fork (originating near Tepee Creek in the 1930s) if the sediment travel rate was slower than predicted by the Beechie equation (see Section 3.6.1). The sediment wave travel times suggests that wide gravel bars in the 1930s near Grizzly Creek probably came from pre-1930s mining and logging in Prichard Creek or other nearby tributaries.

The river's flatter response reaches near the Little North Fork confluence were expected to respond to increased coarse sediment load by large-scale widening and braiding. The maximum active-channel width in 1937 photos below the Little North Fork is consistent with arrival of a sediment wave from the Little North Fork by the 1930s, if not earlier. There was little new bar deposition in the 1964 and 1974 floods despite likely arrival of additional sediment waves from the Little North Fork and North Fork. The dampened response is explained by widespread bank armoring which prevented the river from migrating and forming new bars. In the decades between the floods of the 1930s and 1964, the higher parts of former gravel bars had become forested which reduced active width. In addition to the obvious roads, revetments to protect private property had been built closer to the river but were not visible in the air photos.

The reduced channel width observed in the 2004 photos could reflect reduced sediment load since much of the sediment has likely arrived at the lower river by now. However narrower channels were present almost everywhere in the watershed in 2004. This is partly due to the length of time that elapsed since the last sizable flood rather than reduced sediment load. New pulses of bedload sediment and subsequent channel response will likely occur during and following the next flood.

The North Fork River's valley broadens intermittently starting about 4 miles downstream of Beaver Creek and the gradient gradually decreases in the downstream direction. Both of these factors tend to promote deposition of coarse sediment, yet there is very little expression of this in the historic air photos because there are very few locations where the river can migrate laterally in response to gravel bar deposition.

Valley morphology and works of man both contributed to the lack of channel migration. Many river bends are pinned against the valley wall. Since bank erosion usually occurs on the outside of a bend, the valley walls (or the armored roads next to them) hold the bends in place and stabilize the channel. By 1937, roads had artificially confined the river in wider sections of the valley. Road embankments have narrowed not only the channel migration zone but also the floodplain. Lack of channel migration reduces sediment storage in the floodplain, and the narrow floodplain increases stream power and sediment transport rates. The restricted floodplain causes more of the coarse sediment to be transported downstream to the Enaville area.

The river's inability to move laterally is undoubtedly causing faster rates of vertical deposition in the lower 8 miles of the river, where the declining gradient forces coarse sediment to deposit. This part of the river has some small braid bars and more eroding banks than upstream, symptoms of sediment deposition and the river's attempt to create a wider meander belt.

Bank erosion on the mainstem North Fork River downstream of Prichard Creek was measured by NRCS in 2000 (Sampson, 2000). Fourteen Percent (14%) of the 24.3 miles of channel were eroding, with an estimated erosion rate of 1,149 tons per year. This rate of bank erosion is to be expected under natural conditions on such a low gradient river, and is not a net source of sediment because an equal or greater amount of sediment is deposited nearby.

Bank armor protects the roads wherever they come close to the river. Armor protecting a gas pipeline also constricts the river near the Little North Fork. At least 6,100 linear feet of river bank has been protected by NRCS projects constructed in cooperation with local landowners to protect private land (Table 9). These private projects tend to constrain the river in the few locations where channel migration could still occur, precluding formation of new side channels and LWD recruitment. More than half of the NRCS projects were built in 1997 following the large 1996 flood. Others were built in the 1970s following the larger 1974 flood. The list of NRCS projects from the 1970s and earlier (Table 9) may be incomplete (Kim Erk, NRCS, personal communication). Frequently-flooded houses near Enaville were bought out by FEMA following the 1996 flood, removing the impetus for future bank protection projects in that area. However, the recent trend of summer-season RV parks near the river may result in an increase in bank armoring.

The wide, flat floodplains near the mouth of the lower North Fork River reportedly had multi-thread channels with large cottonwood forests; although the 1905 GLO map does not identify which islands were forested and which were bare gravel. Recent temperature research on the lower Coeur d'Alene River has found that side channels are colder than the river (Ed Lider, USFS, phone call 2007) and may provide important summer refuge habitat for fish.

LWD levels are visibly higher in the response reach east of Grizzly Creek than the rest of the river due to recruitment of riparian trees by active channel migration. There are enormous old-growth cedar stumps on the floodplain nearby.

Logs were moved downstream during the spring floods, and commonly got stuck in the sloughs and channels of the floodplain. In the late 1800s a log drive got stuck in the vicinity of Cedar Creek and caused a mile-long logjam (Russell, 1984). The 1905 GLO survey map included a long side channel in this vicinity. The side channel was obliterated before 1937 by a major road, and since then the river has had a narrow, single channel.

Table 9. Bank stabilization projects on private land. Information provided by NRCS Coeur D'Alene office December 2005.

LENGTH (ft)	NAME	YEAR	PROJECT TYPE	PROJECT GOALS
1000	Lightener Draw	1997	LWD debris removal	remove flow obstruct
800	North Fork CDA River	1974	rock, bank stabilization	bridg protect
175	North Fork CDA River	1975	log revetments+ riprap	bank stabilization
300	North Fork CDA River	1975	rock riprap	bank stabilization
350	North Fork CDA River	1978	gabions	bank stab
250	North Fork CDA River	1985	log revetments+ riprap	bank stab
400	North Fork CDA River	1997	bank stabl, riprap	bridg protect
700	North Fork CDA River	1997	cleanup	debris removal
200	North Fork CDA River	1997	riprap bank stabilization	road protect
300	North Fork CDA River	1997	barbs, riprap, debris removal	protect homes
200	North Fork CDA River	1997	riprap bank stabilization	protect homes
2000	North Fork CDA River	1997	5 barbs	bank stab
75	North Fork CDA River	1997	1 barb	bank stab
800	North Fork CDA River	2003	stream barbs, veg, grading	bank stab
250	North Fork CDA River	2006	bank stab, veg	wildl hab
55	Pritchard Creek	1997	culvert repair, riprap	culvert repair, bank stab
300	Thomas Creek	1997	4 log drop struct, grade control, culvert	reestablish gradient, pool,
2640	Tributary Creek	1981	capping	mine tailing stabil
50	West Fork Eagle Creek	1997	debris removal	remove log jam
75	Yellow Dog Creek	1985	gabions, debris removal	bank stab

3.7 Estimated Channel Erosion Rates

Channel erosion rates from the upper Little North Fork River and Big Elk Creek were extrapolated to the rest of the North Fork subbasin using the methods described in section 2.5.4. These rates are more speculative than the rates for the two watersheds that were studied in detail. The extrapolation was completed for the purpose of identifying the relative magnitudes of erosion types and source areas. The channel erosion rates were combined with other types of erosion reported in the *Sediment Source Technical Report*.

The peak rate of channel entrenchment may have been as high as 400,000 tons per year if all channel entrenchment occurred within a 30 year period (Table 10). If the same volume of erosion occurred in two separate 30-year periods, such as the early 20th century logging using water-based transport followed by the 1970s-era logging with extensive road building, the rates would be approximately halved. The contribution of fire and grazing to erosion and/or channel entrenchment in the northern watersheds is unknown and has not been estimated. These burned watersheds were clearly a large sediment source of some magnitude.

Current channel entrenchment appears to be limited to just a few watersheds, most notably in the mining district. The current erosion rate due to entrenchment is estimated at 3,000 to 30,000 tons per year, which is 1 to 2 orders of magnitude lower than historic peak rates.

The estimated bank erosion rate for the total watershed is about 6,600 tons per year (Table 11). This is equivalent to about 7 tons per square mile per year and is in addition to the background erosion rate of 14.7 tons per square mile per year.

Total current channel erosion from bank erosion and entrenchment, combined, is estimated at between 10,000 and 37,000 tons per year. These rates do not include natural background erosion.

Table 10. Channel entrenchment erosion rates by 6th-field HUC for historic and current conditions in the North Fork Coeur d'Alene River watershed.

6th-field HUC	6th-field HUC Name	GIS Area (sq mi)	Historic Peak Rate of Channel Entrenchment[1] (tons/yr)	Estimated Range of The Current Rate of Channel Entrenchment (tons/yr)
1701030101	NF Coeur d'Alene River above Tepee Cr (burned/grazed)	95	unknown	unknown
	NF Coeur d'Alene River above Tepee Cr (logged)	7	1,500	assumed low
1701030102	Tepee Cr (burned/grazed)	114	unknown	600 to 6,000 (Trail Creek)
	Tepee Cr (logged)	30	7,400	assumed low like Big Elk
1701030103	Middle NF Coeur d'Alene River above Prichard Cr	123	29,800	assumed low
1701030104	Shoshone Cr	69	22,800	assumed low
1701030105	Prichard Cr (mined and logged)	98	161,900	1,600 to 16,000 (1 to 10% of peak rate)
1701030106	Lower NF Coeur d'Alene River below Prichard Cr	189	102,100	700 to 7,000 (Beaver Creek) (1 to 10% of peak rate)
1701030107	Little NF Coeur d'Alene River	170	56,200	low
17010301	**TOTAL North Fork Coeur d'Alene River Watershed**	**896**	**381,800 + unknown amount from burned areas**	**3,000 to 30,000**

[1/] Rates assume a 30 year period of entrenchment; rates could be considerably reduced if erosion occurred over a longer period of time

Note: Rates were extrapolated from Big Elk Creek and the Upper Little North Fork Study Areas based on drainage area only. No sediment delivery ratios have been applied. Rates in the table do not include natural background erosion.

Table 11. Current bank erosion rates by 6th- field HUC in the North Fork Coeur d'Alene River watershed.

6th-field HUC	6th-field HUC Name	GIS Area (sq mi)	Current Bank Erosion Rate (tons/yr) Rounded to Nearest 10
1701030101	NF Coeur d'Alene River above Tepee Cr (7 sq. mi. logged)	102	10
1701030102	Tepee Cr (30 sq. mi. logged)	144	80
1701030103	Middle NF Coeur d'Alene River above Prichard Cr	123	290
1701030104	Shoshone Cr	69	550
1701030105	Prichard Cr (mined and logged)	98	2960
1701030106	Lower NF Coeur d'Alene River below Prichard Cr	189	1300
1701030107	Little NF Coeur d'Alene River	170	1360
17010301	**TOTAL North Fork Coeur d'Alene River Watershed**	**895**	**6550 (~6,600 tons/year, ~7 tons/sq mi/yr)**

Note: Rates in the table do not include natural background erosion. Bank erosion rates extrapolated from big Elk Creek and Upper Little North Fork Study areas based on drainage area and not channel lengths. No sediment delivery ratios have been applied.

4.0 SUMMARY

Many low-gradient channels in the North Fork subbasin responded to large inputs of coarse sediment (as well as loss of riparian trees) by depositing large gravel bars, becoming wider, and braiding or changing course. Inspection of historical air photographs dating from the 1930s through 2004 found that most channel-widening responses occurred in the 1930s through 1980s. The width of most channels was reduced by 1996 and the length of disturbed channels had decreased greatly. Previously-widened channels became even narrower between 1996 and 2004. The historical increase in channel width was extensive in both the logged and roaded part of the watershed and the portions that were burned but not logged or roaded.

Prichard, Eagle, and Beaver Creeks in the Coeur d'Alene Mining District had the most severe and persistent channel response to high sediment load. Many stream reaches remain over-widened and braided, and have long reaches with eroding banks. Parts of Prichard Creek have been pushed next to the valley wall by dredge spoils, resulting in occasional valley-wall landslides as well as erosion of the spoils piles. Portions of Prichard and Eagle Creeks go dry in the summer due to the large volume of coarse sediment that has filled in their channels.

Channel conditions in the logged portions of the subbasin where no mining has occurred were investigated in Big Elk Creek and the upper Little North Fork River, with limited field reconnaissance elsewhere. Most tributary channels currently have mostly-stable banks and low to moderate sediment load. Most streams are connected to their floodplain, which reduces erosion rates, and most of the steeper streams now have large woody debris that stabilizes the channel. Many channels steeper than two percent showed evidence of previous entrenchment. Deepening and widening of entrenched channels was formerly a large sediment source.

The Tepee Creek and upper North Fork River watersheds burned in the early 20th century so they had little logging or road-building. Many low-gradient channels in these basins widened in the 1930s or later, with a similar scale of response as the logged watersheds. Although most of the affected reaches have narrowed, some still remained excessively wide and have switched channels in the 1990s or later. These basins were far from pristine. In addition to removal of vegetation by fires, parts were heavily grazed with sheep up until the 1930s, and log drives occurred in some of the larger streams to remove burnt timber. The current sediment load at the lower ends of most Tepee Creek tributaries appeared to be low; however some Trail Creek tributaries have high erosion rates and are undergoing channel entrenchment.

The local geology appears to supply a relatively high volume of cobbles and gravel to the streams. Coarse sediment enters the streams from streamside cliffs that are undermined at the toe by the stream. The old-growth cedar forest in Settlers Grove on the West Fork Eagle Creek has large gravel bars in the creek, and coarse gravel and cobbles are visible on the floodplain surface between the cedar trees.

Although many of the smaller stream channels have recovered well from past disturbances, some reaches of rivers and larger creeks still remain overloaded with sediment. Large woody debris is rare in the larger channels. In many cases, the low abundance of instream wood is having a greater effect on the low number of pools than is the excess supply of coarse sediment. Coarse sediment moves downstream fairly slowly, taking the better part of a century to travel from upper reaches of the watershed to the river mouth. The remaining river reaches that still have an excess coarse sediment supply are for the most part responding to sediment generated far upstream many decades earlier.

5.0 RECOMMENDATIONS

The recommendations for channel modifications discussed in this section focus only on in-channel or channel adjacent projects and do not address roads or other upslope sediment sources. Recommendations provided in the *Sediment Source* report will result in additional reductions of sediment inputs to streams.

Current channel sources of coarse sediment are concentrated in specific subbasins (Table 12). Sediment source reduction efforts will be most effective if they are concentrated in these locations. Culvert replacements or other remedial road work on tributaries will have maximum benefits if the work is focused on streams that deliver coarse sediment directly to larger channels (see examples in Big Elk Creek and upper Little North Fork chapters). Although work on streams that deposit their coarse sediment on valley margins would produce local erosion-control benefits, it would not reduce the coarse sediment load of downstream waters.

Table 12. Ongoing sediment sources identified during 2006 channel analysis. Other sediment sources likely exist in areas that were not field-surveyed.

Location of known current sediment sources	Description
Prichard Creek	Miles of creek are pinned between dredge spoils and valley wall, erodes both (valley wall landslides)
Beaver tributaries, perhaps elsewhere in mining district	Placer mining by bulldozer or hydraulic methods, next to streams
Prichard-Eagle-Beaver tributaries	Roads up narrow gulches, creek erodes fill or gullies the road surface
Prichard-Eagle-Beaver subbasins	Mine tailings piles eroded by creeks (remediation underway by BLM, other agencies)
North Fork Coeur d'Alene River along Old River Road	Road fill erosion due to 1) road bed is several feet below flood level, and 2) undersized riprap
Trail Creek upper tributaries (Tepee Cr. subbasin)	Former road washouts and slides on Potter and Stewart Creek during large floods including 1996; current status unknown
Trail Creek lower tributaries (Tepee Cr. subbasin)	Channel incision and bank erosion
Cougar Gulch -- extent unknown	Bank erosion and possible channel incision
Iron Creek near airfield	ATV traffic across creek erodes fine and coarse sediment from streambed and banks

5.1 Coeur d'Alene River tributaries in the Mining District

The following recommendations apply to the streams affected by mining. Note, the mining district effects are also addressed in a separate TMDL for metals. These recommendations are not intended to supersede any recommendations addressing metals which were developed in that TMDL.

- Pull back spoils piles along Prichard Creek enough to reestablish a floodplain, ideally at least 200 feet wide. Establishing a floodplain will reduce stream power and sediment transport rates. Relocate the creek away from the valley wall and the base of the spoils piles using barbs and revegetation.
- Move other creeks away from mining debris where possible. Armor banks where moving the creeks is not feasible.
- Shut down and remediate placer mining operations that cannot be isolated from tributary creeks.
- Plant riparian revegetation (and minimize livestock effect on riparian vegetation if applicable) along eroding reaches of lower Beaver Creek.
- Construct new channels through seasonally dry reaches of the mainstem creeks (Prichard, Eagle, and Beaver) that have completely filled in with coarse sediment. This should be undertaken only after the upstream sediment supply has been significantly reduced. An approach using riparian vegetation, LWD, and limited armoring to train the channel (for instance barbs directing the channel away from high, erodible banks) may prove both useful and cost-effective (Matthews and Kondolf, 1996).
- Remove road fill and repair road-related erosion in narrow tributary gulches.

5.2 Larger Rivers and Streams

The following recommendations apply primarily to the larger rivers and streams. They address the legacy effects of past coarse sediment inputs, riparian harvest, and early log transport down waterways. These recommendations are primarily intended to mitigate negative effects on beneficial use by aquatic species. If widely implemented, they would also eventually reduce bank erosion and promote sediment storage in floodplains.

Excessive coarse sediment has been shown to reduce pool volumes, therefore reducing the quantity and quality of fish habitat. Coarse sediment load will likely remain high along the mainstem Little North Fork and mainstem North Fork Rivers for at least several more decades due to the slow downstream movement of coarse sediment. Large Woody Debris of sufficient size to form jams increases the depth and number of pools in pool-riffle channels with gradients less than 1%.

Although coarse sediment loads have declined in most streams, long reaches of the larger tributaries have smooth, featureless channels that lack pools and LWD (e.g., Steamboat and Shoshone Creeks). Streams with gradients in the 1 to 3% range tend to have plane-bed morphology (long, featureless riffles) in the absence of LWD, but will form pools if LWD is added.

Add Large Woody Debris (LWD). LWD placement should include trees with rootwads that are large enough to function as stable single logs or key members in jams. These key members will then rack up smaller LWD that floats in from upstream, in time forming new jams. LWD that piles up on bridge piers during floods could be redistributed in stream channels that lack functional wood. We noted that many Forest Service restoration projects in the watershed used small logs about the diameter of a telephone pole, without rootwads. In most cases these logs were too small to produce any beneficial effect on channel morphology. Log diameter and length should be selected based on bankfull channel dimensions and be large enough to remain in the channel reach being treated. LWD placement will be most feasible in smaller streams with good road access, or in conjunction with other sediment source control projects such as road removal.

Encourage the development of major riparian forests in areas upslope of the normal flood level that are currently vegetated with willows or grass. A system-wide increase in channel LWD levels will only occur once mature riparian forests have been reestablished. This has already occurred along many tributary creeks and upper reaches of the Little North Fork River, but many lower reaches have grass or willow flats next to the stream. Channels vegetated with large trees are better able to resist bank erosion and have lower width:depth ratios, which improves shading and lowers water temperature. Care should be taken to ensure that planting areas are not within the annual or frequent flood zone, where trees may be torn out in high flows or be drowned.

Discourage clearing or bank armoring near channels by enforcing adequate riparian buffer zones. Bank armoring prevents channel migration and prevents establishment of forest on the banks. Channel migration stores sediment in the floodplain and recruits LWD into the channel. Prior to extensive road building and bank armoring, the lower North Fork River had channel migration zones that recruited large cottonwoods and cedar trees. Narrow buffer zones increase the likelihood of riparian clearing and bank armoring to protect developed property.

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