SPANISH CREEK ASSESSMENT

REHABILITATION AND GRAVEL MANAGEMENT STRATEGY

Funded by CalFed Proposition 13

Feather River Coordinated Resource Management Group
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Introduction

A watershed assessment has been conducted that includes a comprehensive, community-based rehabilitation strategy for Spanish Creek that extends from the watershed headwater region to the outlet of American Valley. The final strategy focuses on the main-stem of Spanish Creek in American Valley.

Funding for this project has been provided in full or in part through an Agreement with the State Water Resources Control Board (SWRCB) pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) and any amendments thereto for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Spanish Creek, located in the upper Feather River watershed, has been subjected to intensive use for over 150 years. Impacts directly affecting the Spanish Creek watershed and its drainage system include hydraulic-placer mining, stream channelization, heavy livestock grazing, urban development (currently increasing), extensive timber harvesting, and the construction of an extensive road system. Quincy, located in American Valley, is the Plumas County seat.

American Valley is the naturally evolved floodplain of Spanish Creek. Extensive large-scale hydraulic mining in the mid to late 1800's led to the deposit of millions of cubic yards of coarse gravel and cobble adjacent to Spanish Creek and its tributaries upstream of the valley. The episodic release of these stored tailings has resulted in excessive deposition of this coarse material throughout the American Valley reach of Spanish Creek, resulting in accelerated bank erosion and enhanced flooding.

Hydraulic mining was invented to exploit the gravel contained in ancient river beds. Passage of the Sawyer Decision in 1884 resulted in the construction of several debris dams along the upper Spanish Creek stream channel and tributaries. Even though these structures held back large amounts of hydraulic outwash material, they began to fail in the early 1900's. Concurrent increases in urbanization led to the beginnings of channelization of Spanish Creek through American Valley. Spanish Creek was relocated toward the north side of the valley. Later, various public agencies continued that work in the mid-1900's and increased the size of the channel.

Gravel has been mined for years at the upstream end of American Valley. The operation was established to take full advantage of the natural tendency for gravel to deposit at that site. Initially, just enough gravel was harvested to prevent further aggradation of the channel. However, as community needs expanded, the operation began to overdraft the supply, contributing to ever-greater channel entrenchment (aka, gullying) and diminished gravel supply for downstream channel maintenance. In the past seven years, the amount of gravel extracted has been curtailed due to permitting requirements by the California Department of Fish and Game. As a result of the curtailment, more and more gravel is transported and deposited throughout Spanish Creek in American Valley. As is the case with many entrenched, low gradient streams, gravel is depositing as alternating point bars that intensifies channel meandering and bank erosion, damaging high value agricultural lands and public infrastructure facilities. Without intervention, the process will continue until a broad, new valley has formed at the new elevation with Spanish Creek inset into this new valley. Potentially, the entire American Valley could be affected.

In 1999, numerous landowners along Spanish Creek in American Valley began approaching the Feather River Coordinated Resource Management (FR-CRM) staff for assistance addressing their concerns of accelerated bank erosion. Given the above referenced conditions and history FR-CRM staff advised landowners to consider a holistic approach to the common problem while maintaining short-term solutions. To this end, the FR-CRM staff submitted this project to the CalFed Proposition 13 Watershed Program to develop the *Spanish Creek Watershed Assessment and Restoration Strategy*.

Project Goals

The long-term goals are (1) a stable, healthy channelway (entrenchment and stream channel); (2) a community with the capacity to collaborate and implement sound stream rehabilitation and watershed management practices; and (3) sustainable gravel transport and extraction technology that can be transferred to similar drainages.

The array of issues addressed by this project commonly exists throughout the Bay-Delta watershed. Developing solutions to these problems requires an understanding of historic and current activities that have led to the present condition.

Assessment

The FR-CRM collaborated with Dr. Jennifer Duan of the Desert Research Institute in Las Vegas to assess Spanish Creek using a dual approach. First, standard fluvial geomorphic (river features formed by running water) data were collected and analyzed. Existing channel morphological data and fluvial processes were compared with the degree of departure from pre-degradation conditions. Second, because of the high sediment supply, bedload quantity and size data was collected and, along with the morphological data was used to model sediment transport rates using a two-dimensional sediment transport rate model developed by Dr. Duan (EnSed2D). Finally, existing sediment transport rates were compared with rates affected by an array of bed and bank rehabilitation treatment techniques known to successfully treat streams in similar conditions.

These data, analyses and model results are presented in Appendix C. Previously, the FR-CRM successfully collaborated with Dr. Jennifer Duan to analyze the Ward Creek Project with the model, where it was tested for its predictive capabilities (Duan 2000).

The Drainage Basin

Spanish Creek is a tributary of the North Fork Feather River, via the East Branch North Fork Feather River, Map 1. The 202.1 square mile Spanish Creek drainage basin includes 71.2 square miles of Greenhorn Creek and 92 square miles of upper Spanish Creek, including Mill Creek and American Valley, Map 2. An average 55 inches of precipitation falls on the watershed annually. Greenhorn Creek and Spanish Creek combine at the mouth of American Valley. Spanish Creek begins in the Bucks Lake Wilderness and includes Silver Lake, Gold Lake, and Spanish Peak at 7017 feet elevation and Claremont peak at 6952 feet. The two lakes mark the heads where glaciers once were located. Spanish Creek flows 17.5 miles from its farthest headwater reach to the mouth of American Valley.

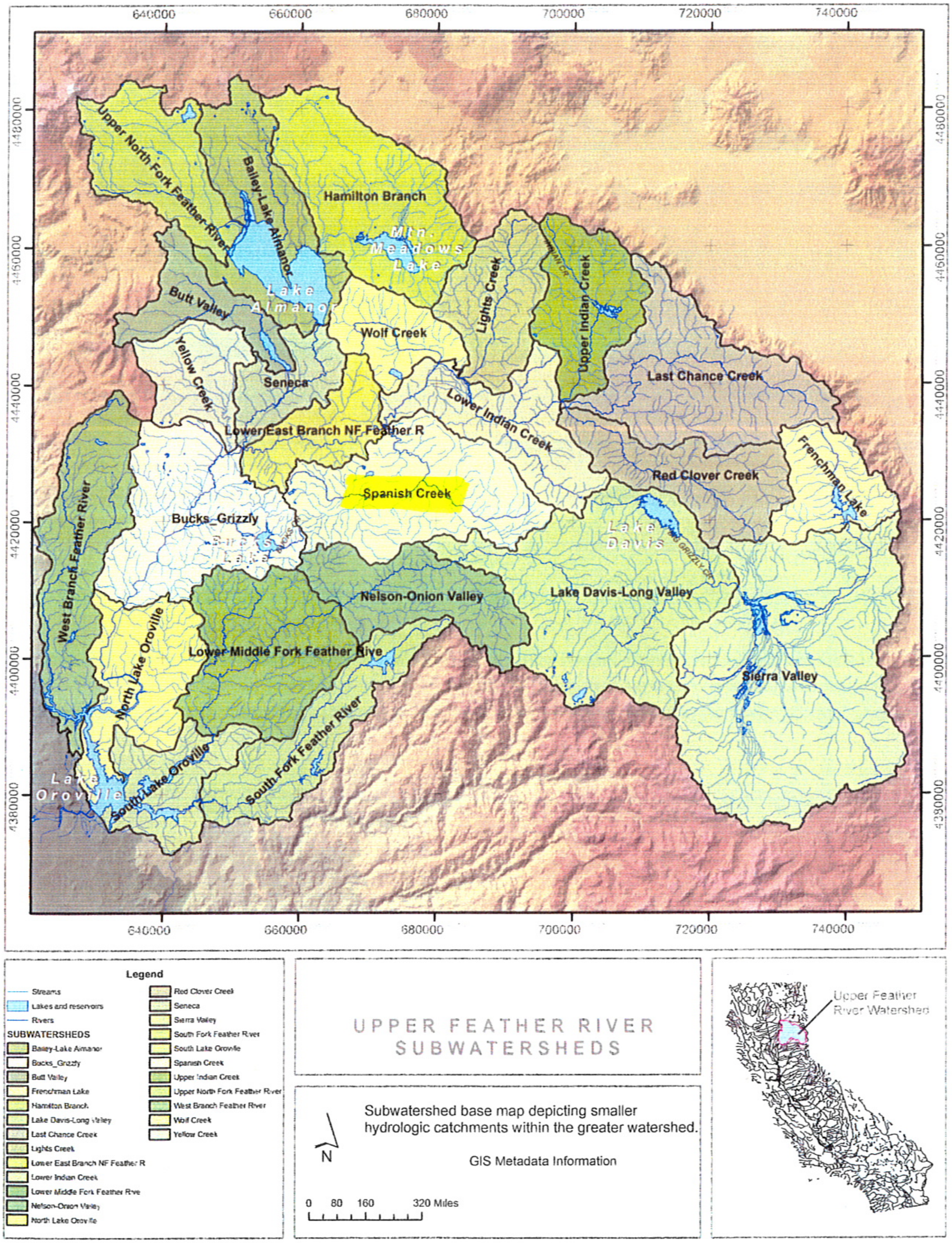
The primary streams of the upper Spanish Creek watershed are Mill Creek, Gansner Creek, the combined Meadow Valley and Rock Creeks, Silver Creek, the main stem of Spanish Creek, Pineleaf Creek, and Wapaunsie Creek, Map 3.

Most of these streams flow from the crest of the Sierra-Nevada Mountain Range, where the crest divides the Middle Fork Feather River from Spanish Creek along the southern watershed boundary and then divides the main North Fork Feather River from Spanish Creek along the western boundary. West of Meadow Valley is the 2,000- to 3,000-foot-high scarp of the east slope of the Sierra Nevada. It is clearly indicated by the eastward course of Spanish Creek and its tributaries (Durrell 1987).

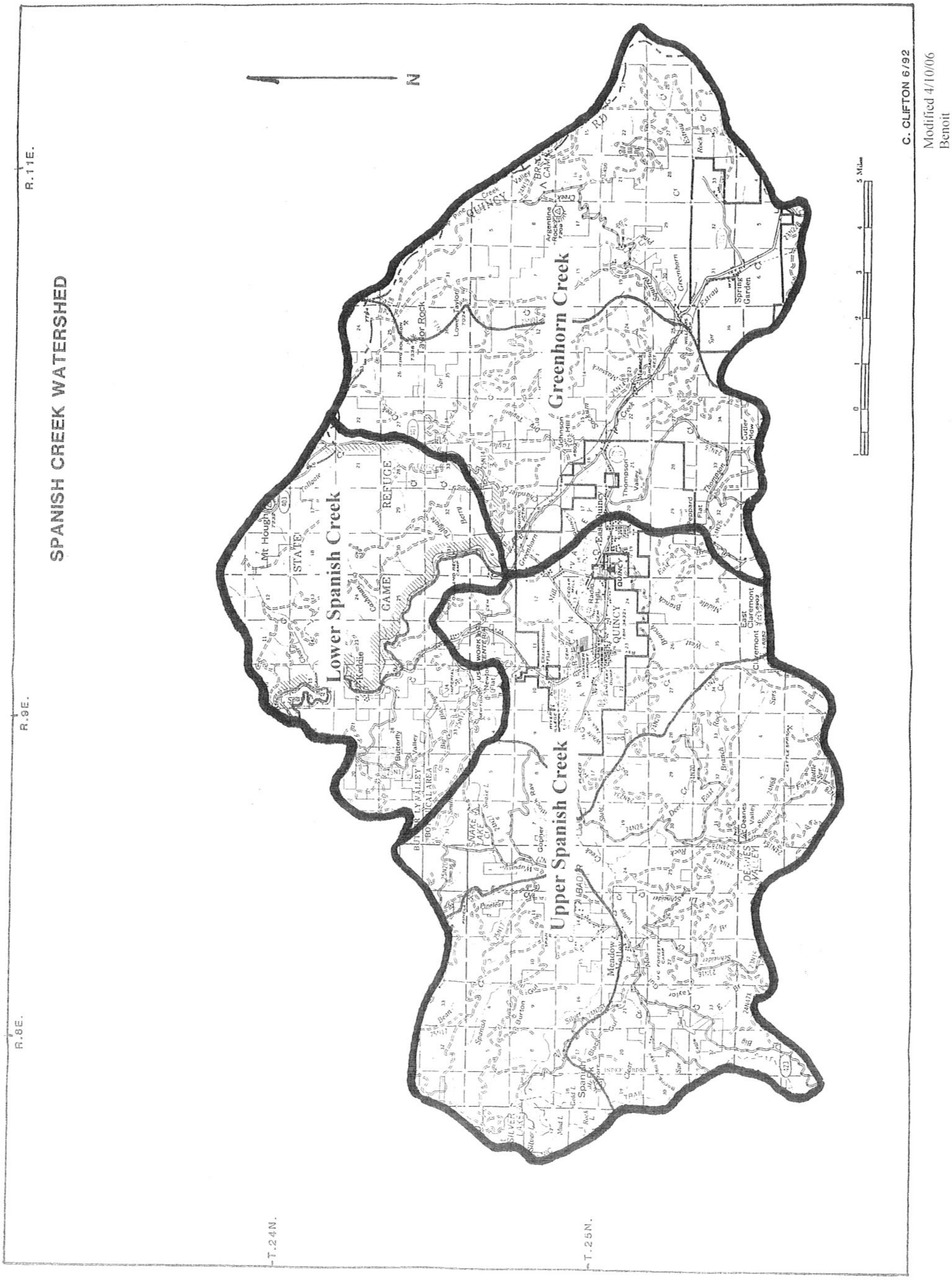
During the course of uplift of the Sierra Nevada, closed basins developed on crustal blocks depressed relative to the blocks adjacent to them. A lake occupied each closed basin. Within the upper Spanish Creek watershed, now extinct lakes occupied both American Valley and Meadow Valley. Each of these lakes finally drained as a result of infilling with sediment and erosion of the valley outlets. Meadow Valley is one of the few lake basins in the Feather River watershed that has eroded. The actual geologic history of Meadow Valley has yet to be studied (Durrell 1987).

Although American Valley has not been studied, some of its features give us clues about its past. The lake resulted from damming by faulting of Spanish Creek. The prominent fault lies at the base of Grizzly Ridge between Spring Garden and Keddie. Thus the valley lies in what is referred to as the "Plumas Trench" (between the Sierra Nevada on

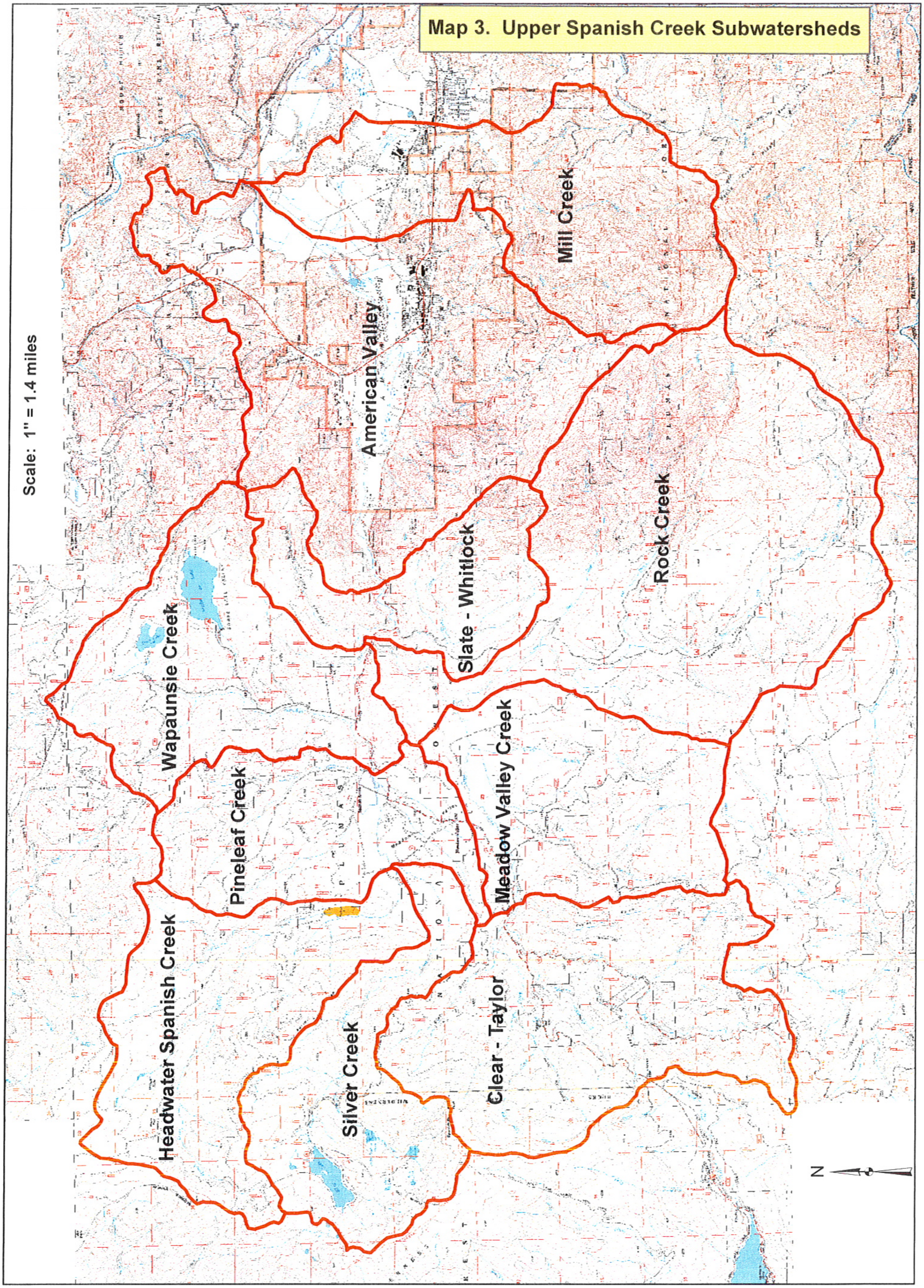
Map 1. Upper Feather River Subwatersheds



Map 2. Spanish Creek Watersheds



Map 3. Upper Spanish Creek Subwatersheds



one side and Grizzly Ridge and Keddie Ridge on the other is a relatively low strip of land, a depression, that extends from Sierra Valley near Calpine to American Valley). The hills in the valley are the tops of high fault-bounded blocks that stood as islands in the lake. The actual elevation of the lake shoreline is unknown but is estimated to be between 3440 and 3500 feet. Erosion of the valley outlet has progressed headward into the lake sediments by a distance of a few thousand feet and a depth of about 15 feet (Durrell 1987).

Geology. The primary types of rocks and deposits are granitic, volcanic and metavolcanic, ultrabasic intrusive (serpentine), and marine, lake deposits, and alluvium (Burnett 1962).

Relicts of early Tertiary (Eocene) rivers are referred to as a type of formation called Auriferous Gravel (meaning gold-bearing gravel). The term includes not only gravel, but beds of boulders, sand, and clay that are of middle Eocene age (approximately 50 million years old). Most deposits are present on the divides between the deep canyons of the modern rivers, where they rest on deeply weathered metamorphic and granitic rocks (Durrell 1987). Most of the auriferous gravels were deposited before the major period of volcanic activity in the Sierra Nevada. Many other gold-bearing gravel, however, were deposited in channels cut during the period of volcanic eruptions or in layers interbedded with the volcanic deposits (30 to 5 million years ago) (Bateman 1966).

Soils. Soils surrounding the valleys are primarily of the Skalan-Kistirn-Deadwood complex (Churchill 1988).

> The gently sloping to steep Skalan soils are on bouldery side slopes and near ridgetops. They are deep to very deep, moderately well drained, very gravelly loam soils.
>
> The moderately steep to very steep Kistirn soils are on concave drainages and steep, incised side slopes. They are very deep, well drained, very gravelly loam soils.
>
> The moderately steep to very steep Deadwood soils are on ridgetops and steep, barren southerly side slopes. They are shallow, moderately well drained very gravelly loam soils that are underlain by slightly fractured schists or shales.
>
> The Josephine soils are on northerly facing side slopes. They are deep, moderately well drained loamy soils.

Soils of the valleys are primarily of the Keddie-Massack-Forgay complex.

> The nearly level Keddie soils are on floodplains. They are very deep, poorly drained loamy soils that are subject to flooding.

The nearly level Massack soils are on floodplains. They are very deep, poorly drained, sandy soils subject to occasional flooding.

The gently sloping Forgay soils are on alluvial fans and terraces. They are very deep, somewhat excessively drained, extremely gravelly loam soils.

Land forming processes at work in Spanish Creek are soil erosion, landslides and slumps, mudflows, and stream channel erosion and sediment transport. Of these, mudflows and stream channel erosion and sediment transport are the most prevalent.

Mudflow is a general term for a process involving a flowing mass of predominantly fine-grained material possessing a high degree of fluidity. Debris flows also occur and involve a moving mass of rock fragments, soil, and mud (Bates, 1980). These processes generally occur during extreme storm events that saturate the watershed with water. Mudflows readily move into the nearest stream channel where downstream conveyance is enhanced.

Generally, soils in the watershed are moderately erodible on north facing slopes and highly erodible on south facing slopes (other factors include slope steepness and soil depth). Highly erodible or unstable conditions can be found on approximately 26% of the watershed, primarily where slopes are steep (Churchill, 1988). Though soil erosion occurs on specific sites, it is not considered a problem except where poor management or construction practices occur. The primary sources of sediment from soil erosion are roads, stream banks, construction sites, and mines sites.

Eroded material, whether its delivered to a stream or generated within a stream, is transported by stream channels to downstream reaches were the energy gradient is reduced and the eroded material drops out, forming deposits of coarse material within stream channels and fine material on floodplains and terraces.

Properties of Stream Channels. Figure 1 shows the longitudinal profile of Spanish Creek from its headwaters within the Bucks Lake Wilderness to the mouth of American Valley. Along the way, the slope and character of the channel changes from one that is steep and narrow, able to carry sedimentary material easily (the transport channel) to one that is nearly level and wide, where the sediment that has been transported from the upper watershed area settles (the response channel).

The deposition of sediment would have occurred from top to bottom in each of the two major valleys and, to a much lesser extent, within small valleys located in the various tributaries of Spanish Creek. Examples of these smaller valleys are: Snake Lake Valley and Smith Lake Valley on Wapaunsie Creek, and Deanes Valley on South Fork Rock Creek. A small, unnamed valley also appears at the head of Whitlock Ravine and several

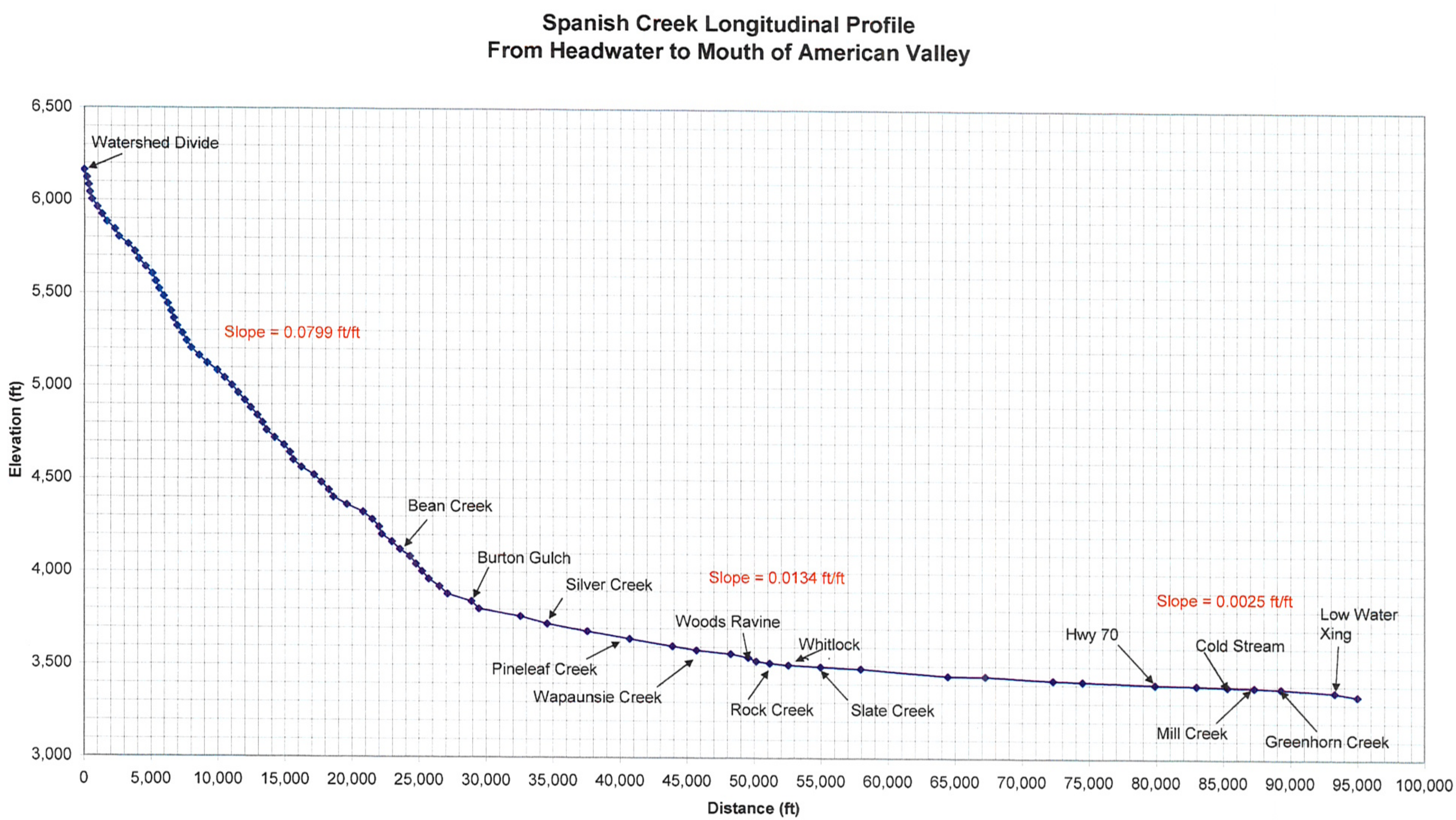

Spanish Creek Longitudinal Profile
From Headwater to Mouth of American Valley
Elevation (ft)
Distance (ft)
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
55,000
60,000
65,000
70,000
75,000
80,000
85,000
90,000
95,000
100,000
Watershed Divide
Slope = 0.0799 ft/ft
Bean Creek
Burton Gulch
Silver Creek
Pineleaf Creek
Wapaunsie Creek
Woods Ravine
Slope = 0.0134 ft/ft
Whitlock
Rock Creek
Slate Creek
Hwy 70
Slope = 0.0025 ft/ft
Cold Stream
Mill Creek
Greenhorn Creek
Low Water
Xing

Figure 1.

very short depositional stream-reaches are located at various locations on most of the other tributary channels.

Because of their weight, coarse bedload material (boulders, cobbles, and gravel) deposit first, beginning at the head of these valleys and depositional stream reaches, followed downstream by smaller and smaller material sizes until only the smallest sizes (sand, silt and clay) are available to deposit on the larger meadow surfaces.

Because of the stream reduced stream gradient in the valleys, the ability of the stream to transport the coarse portion of the load decreases. The stream channel is forced to become much more sinuous and meandering is the norm. Coarse bedload material deposits on the inside of meander bends, forming point bars. Bar deposition in turn diverts the stream around the bar toward the opposite bank, causing erosion and lateral migration of the channel (Collins, 1990). When all is in balance (dynamic equilibrium), the amount of material eroded from the outside of the meander bend equals the amount of accretion on the inside of the bend.

The sinuous pattern that develops is a product of the sediment load, sediment size, and energy of streamflow (independent variables) delivered to the system at that location. The sinuous pattern includes riffles and pools and their spacing. Changes in any one of the independent variables causes the entire system to rebalance, deepening, widening, straightening, etc. Aquatic and riparian habitats can be damaged or lost, water quality can degrade, and groundwater tables can drop.

Climate and Precipitation Patterns. Precipitation falls primarily as snow above 6000 feet and a mixture of snow and rain below that elevation. The average annual precipitation varies from 35 to 90 inches (Map 4), yielding from 16 to 65 inches of average annual runoff. Most of the precipitation is generated during winter frontal disturbances enhanced by orographic uplift as storm systems move into the area from the Pacific (Harris, 1981). Since Spanish Creek is east of the Sierra Nevada crest, a moderate rain-shadow effect occurs, leaving Spanish Creek with less precipitation than its counterparts west of the crest, but more frequent summer thunderstorm activity occurs.

Approximately 51% of the average annual precipitation falls during December, January and February. Summer months receive approximately 3%, Figure 2. Spring and summer base flows primarily depend on the accumulation of snow at the higher elevations and the recharge of groundwater at all elevations.

Runoff. Average annual runoff amounts range from 16 inches in American Valley to as much as 65 inches along the crest of the Sierra. Because much of the precipitation falls as snow, the primary runoff months occur during the spring with 62% running off during the months or March through May. The low flow months of July through October see only 3% of the total, Figure 2.

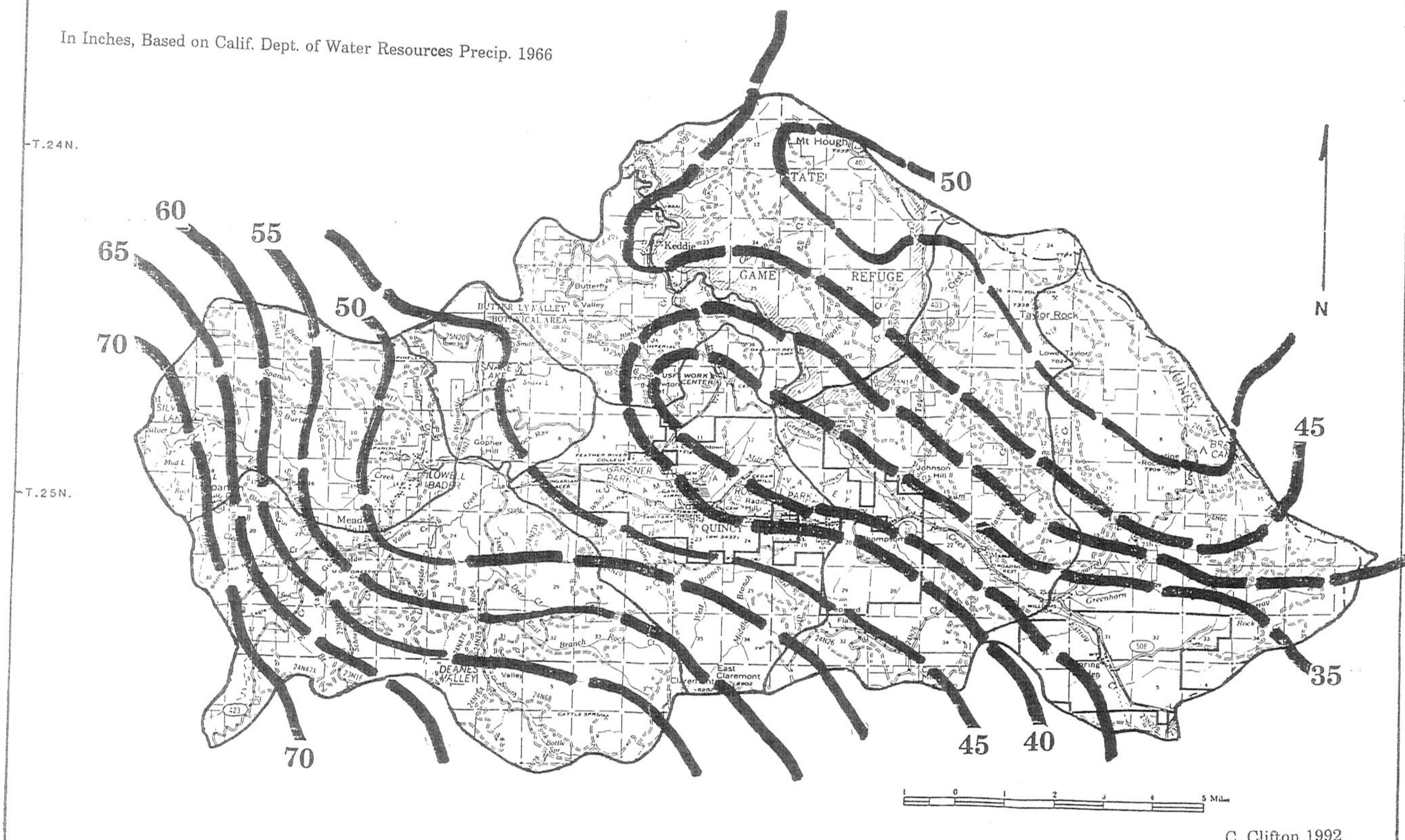
Map 4.

Isohyetal Map

SPANISH CREEK WATERSHED

Average Annual Percipitation

In Inches, Based on Calif. Dept. of Water Resources Precip. 1966



C. Clifton 1992

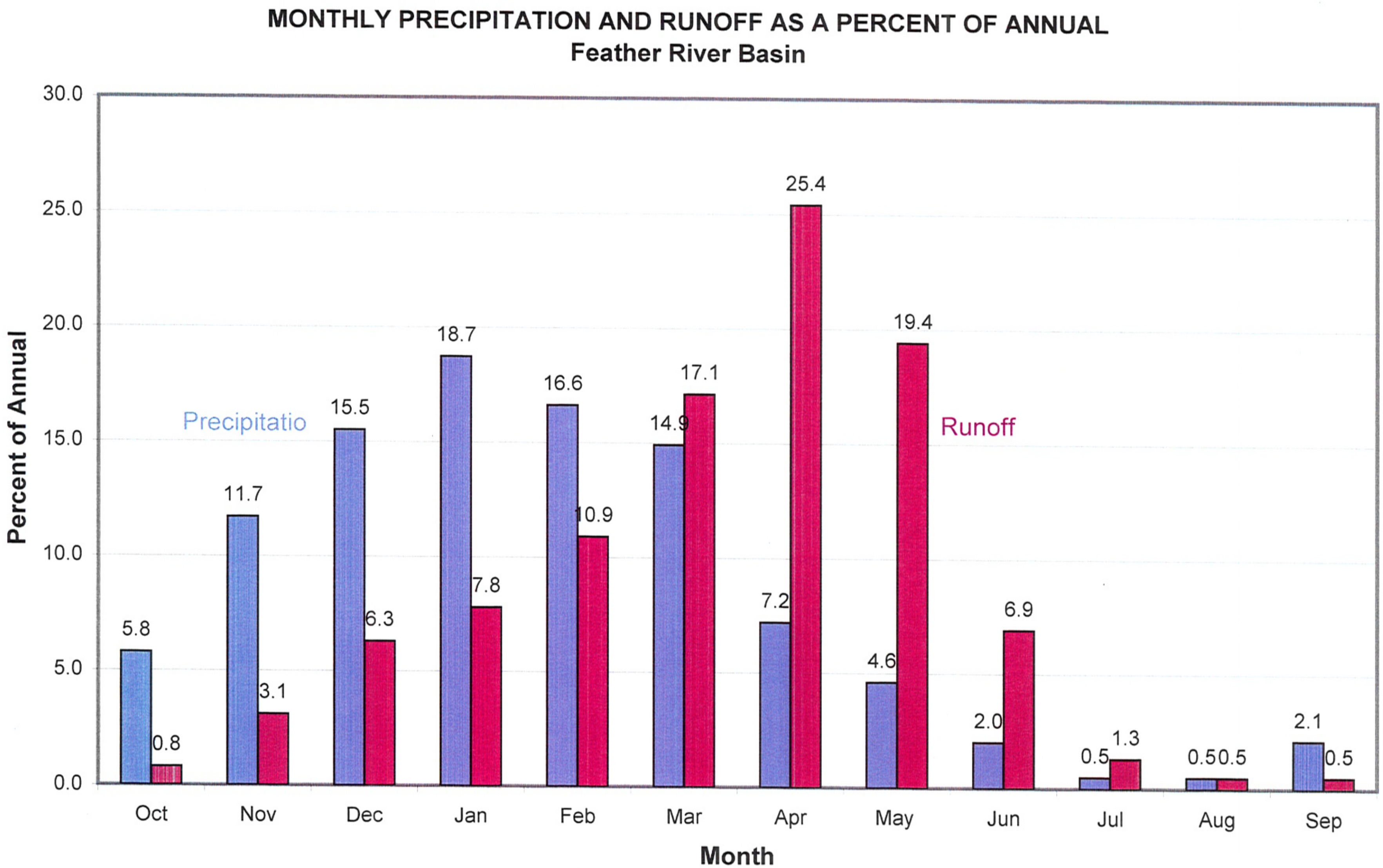
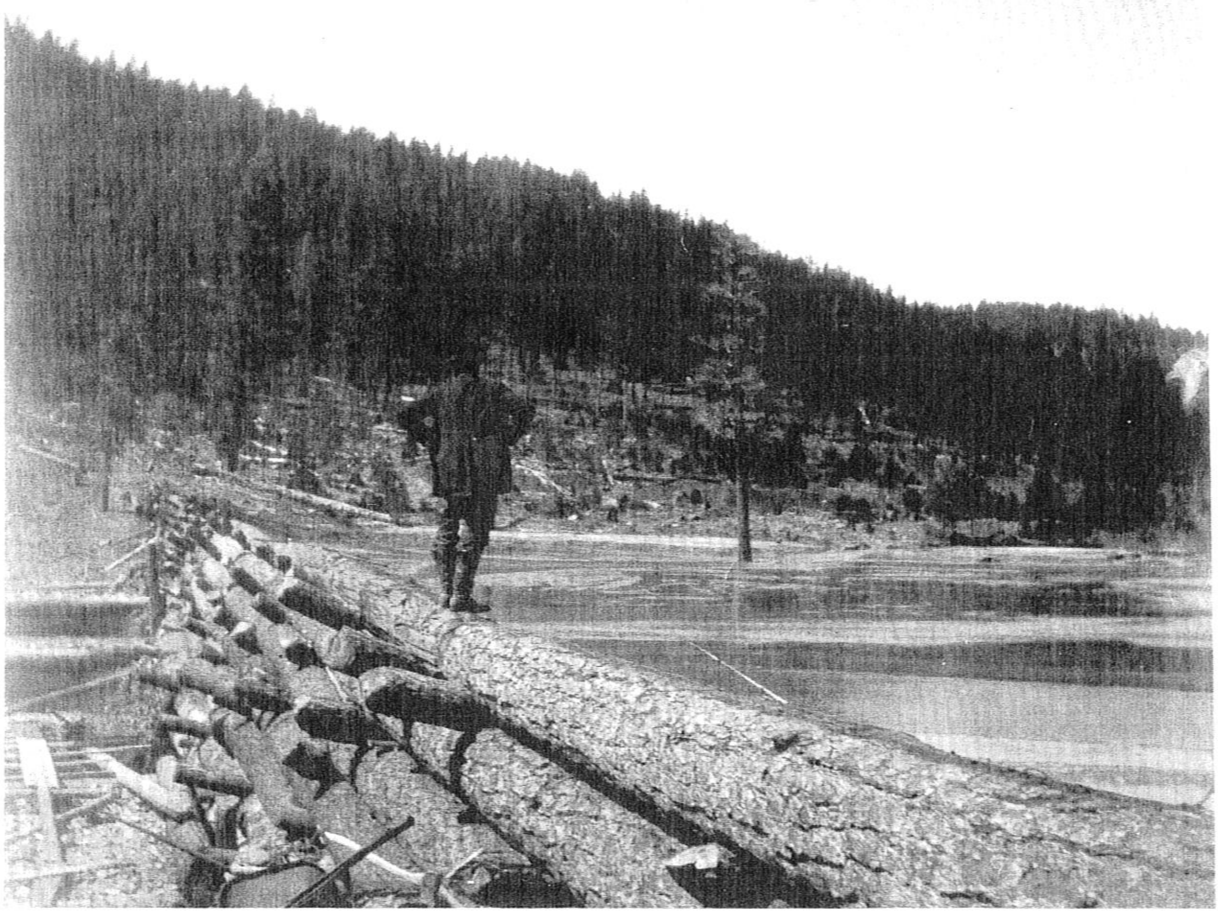

MONTHLY PRECIPITATION AND RUNOFF AS A PERCENT OF ANNUAL
Feather River Basin
Percent of Annual
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Precipitatio
Runoff
5.8
0.8
11.7
3.1
15.5
6.3
18.7
7.8
16.6
10.9
14.9
17.1
7.2
25.4
4.6
19.4
2.0
6.9
0.5
1.3
0.50.5
2.1
0.5
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month

Figure 2.

Figure 3. Log Crib Dam on Spanish Creek at Green's Flat

Figure 5. Sediment Deposit Behind Log Crib Dam at Green's Flat



The long-term stream gage on Spanish Creek, located downstream of American Valley and below the confluence with Greenhorn Creek at Keddie, has been in operation 72 years, since 1934 (USGS 11402000). The Feather River CRM has operated a stream gage on Spanish Creek at the footbridge next to Gansner Park since 2001. Various other stream gages are and have been operated, as gage plates for short periods of time. One of those is Mill Creek near Quincy (USGS 11401940).

Examining the flood that occurred January 1, 1997 (the highest flood on record) at the Spanish Creek stream gage site at Keddie, the flood peaked at 22,100 cubic feet per second and was determined to have a return interval of 40 years (annual probability of occurrence of 2.5%). The estimated peak discharge at Gansner Bridge for that flood was 10,604 cfs. Reviewing the flood that peaked on December 31, 2005, it is estimated to have a 10-year return interval, or 10% annual probability of occurrence. The flood peaked at Keddie at 13,500 cfs and at Gansner Bridge it peaked at 5,221 cfs.

We have concluded that, generally, 60% of the streamflow at the Keddie stream gage comes from the Upper Spanish Creek watershed and 40% from the Greenhorn Creek watershed, Appendix A.

History, Land Uses, and Sediment Sources

The existing conditions giving rise to the need for this watershed analysis are a result of four primary impacts: mining, roads, timber harvesting and wildfires. Livestock grazing is of minor importance. Approximately 60% of the watershed has been impacted, affecting soil quality, water quality, aquatic and riparian habitats, groundwater tables, flooding and droughts (Benoit 1987).

Mining. The California gold rush began in 1848 with crude mining at Bidwell Bar on the Feather River. Small stream placer mining, working along the stream channels, occurred in 1849 and 1850. The early 1850's saw an increase in the scale of mining with more digging and more concentrated efforts. Companies formed and rivers began to be re-channeled so that riverbeds could be mined. Large, stable gravel-bars were heavily excavated and tunnels were dug into hillsides to access additional gravels.

From the mid to late 1850's, miners expanded into all of the Sierras. The upper reaches of the Feather River, including Spanish Creek, were found to be rich in free gold. Water was diverted into ditches and allowed to wash across the diggings then back to the streams (booming). This was the precursor to hydraulic mining.

The hydraulic mining of old river deposits found in beds on mountain slopes and ridges began in the late 1850's, spread fast, and was uncontrolled until 1884, when the Sawyer Decision limited hydraulic mining and the release of the outwash material (slickens) into streams and rivers. Many of the major hydraulic pits discontinued operation.

From 1884 to 1900, most mining turned to drift mining, where miners followed buried gravels. Some hydraulic mining continued, especially in Spanish Creek and its tributaries. Large log-crib dams were constructed in Spanish Creek and several of its tributaries to contain the hydraulic outwash material, Figure 3. Much of the material contained by these dams (boulders, cobbles and gravels) is still evident today within Spanish Creek upstream of Meadow Valley in Bean Creek (Green Flat and Spanish Ranch), in Wapaunsie Creek near Gopher Hill and in Spanish Creek from Wapaunsie Creek downstream to American Valley. Other known locations of these dams were Rock Creek and Slate Creek. These areas were mapped by the Forest Service in their Plumas National Forest Soil Resource Inventory as dumps, mines and riverwash.

Bucket dredging was developed in the Oroville area in the early 1900's and spread to upstream areas, including Meadow Valley. Following World War I, mining resumed in earnest at most previously worked mines (James, 1987).

Today, gold mining is conducted mostly on a small scale in the Spanish Creek drainage, usually in previously worked areas. Gravel mining of the old mine outwash material, transported downstream and deposited as gravel-bars, has been intensive up until late. Much of this mining has been curtailed due to concerns that it is negatively affecting the recovery of streams and riparian areas. A small amount of off-channel gravel mining continues at Green Flat near Meadow Valley.

Roads. Historically, roads were located next to or within meadows and streams because these were the easiest locations for their establishment, given the technology of the day. Many of these roads are still in use today. Those in most use have been expanded, further encroaching on streams and meadows. Some of these roads, however, are being moved upslope and the original roadbed obliterated.

Roads and road-like features (skid trails and landings) cover a significant portion of the watershed, cumulatively contributing a large amount of fine sediment (sand, silt, and clay) to stream channels. See Clifton 1992 for an in-depth analysis of roads in the Spanish Creek watershed. Within the entire Spanish Creek watershed, an estimated 98% of all the fine sediment flowing to streams comes from roads (51%) and stream channels (48%). An estimated 232,500 tons of sediment reaches the Rock Creek reservoir annually from Spanish Creek. This amounts to 1,184 tons per square mile, or an average of 112,480 tons per year from upper Spanish Creek watershed alone, approximately half from roads (SCS 1989).

Timber Harvesting and Wildfires. Logging began soon after the arrival of the miners. By the late 1800's and early 1900's Steam Donkeys and railroad transportation greatly facilitated logging and timber clearcutting became the preferred logging technique (James, 1987). By the 1950's, tractor logging had replaced railroad logging, allowing steeper terrain to be accessed. Many intermittent and ephemeral stream channels were used as pathways to drag logs to landings, which were located within or next to these same stream channels.

Native Americans began setting fires to effect a change in the vegetation around AD 500 – 1000. Many mountain valleys and canyons were subject to burning (James, 1987). Large destructive wildfires are a more recent phenomenon and are attributed to the accumulation of logging slash and the natural buildup of vegetation caused by over 80 years of wildfire suppression. Naturally occurring fires and those set by Native Americans were frequent and generally of low intensity, rejuvenating riparian and upland plant communities (Clifton 1992).

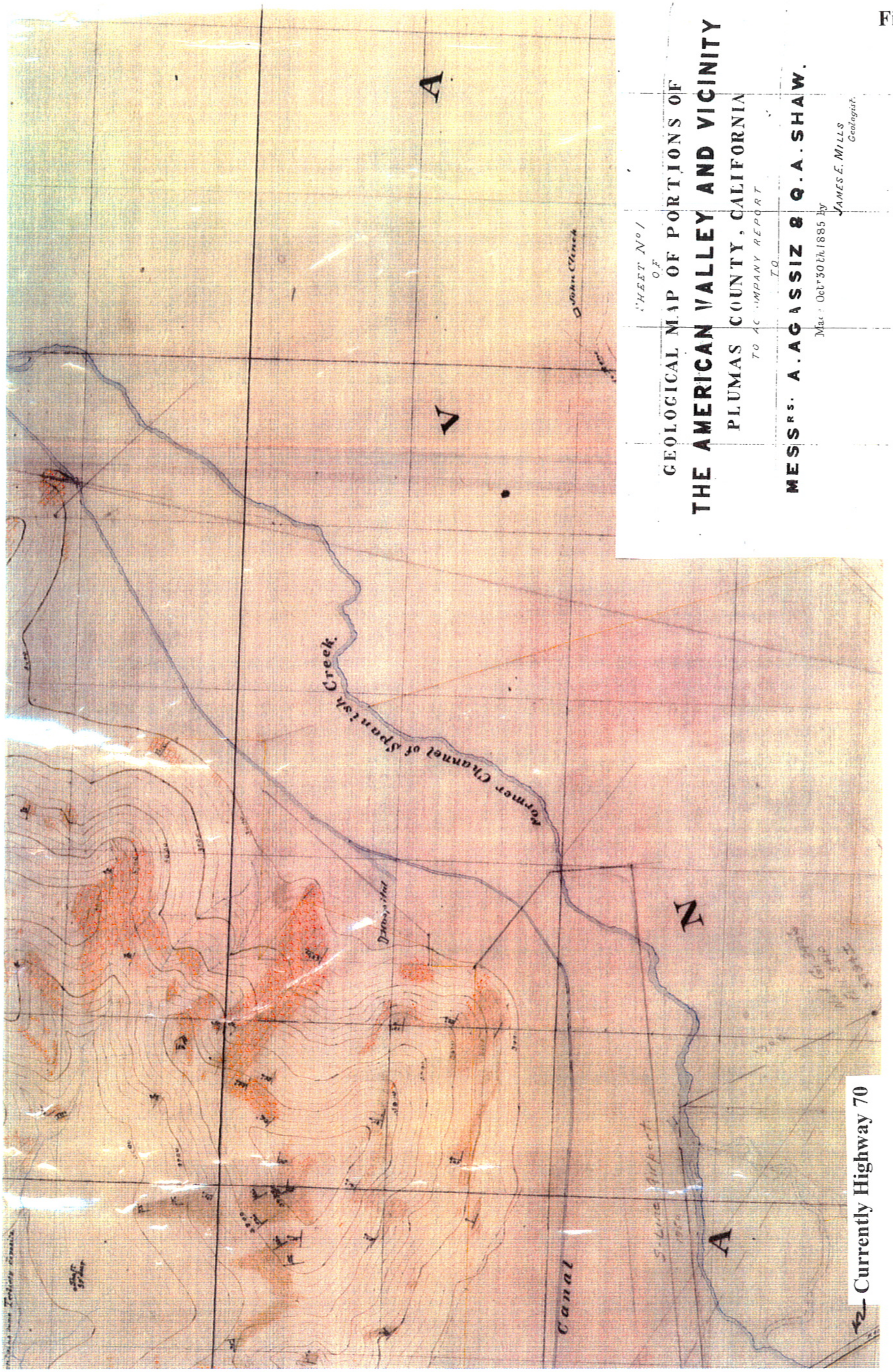
Large wildfires not only affect the hydrology of the burned area but also the potential erosion of mountain slopes and stream channels, temporarily increasing sediment to stream channels. Large runoff events immediately following a destructive wildfire can also affect potential slope instability and the occurrence of mudflows.

<u>Livestock Grazing</u>. Soon after the California Gold Rush, horses and then cattle were brought in to provide transportation and food, grazing many of the meadows. Most of the meadows were wet and were drained to allow more access by livestock and then irrigated for hay crops (James 1987). Beaver that survived the heavy trapping during the first half of the nineteenth century were now treated as pests to be exterminated. The beneficial effects of beaver on the hydrology of the watershed were almost eliminated (Bailey 2003). By the later 1800's and early 1900's, intensive sheep grazing in the upland areas and high meadows and intensive cattle grazing in the large valley meadows severely damaged stream and riparian areas. By 1920 the upland areas were seriously eroding and most of the principal meadows were deeply gullied (James 1987 and Hughes 1934). The degradation of stream channels in the valleys and meadows of Spanish Creek was probably initiated by channel diversions and the construction of drainage ditches and exacerbated by overgrazing and intensive mining.

<u>Coarse Sediment and Streamflow</u>. Before the passage of the Sawyer Decision, hydraulic outwash material was washed directly to stream channels. The streams attempted to transport this overload of material downstream, but usually lacked sufficient stream power to move it and the channels aggraded (filled in), causing frequent flooding within the valleys. To alleviate this problem, ditches were constructed to carry the water and sediment within a narrow, deep channel. The most notable is the current Spanish Creek channel (Figure 4), where it enters American Valley, skirts along the valley's north edge, finally returning to its natural channelway downstream of the confluence with Greenhorn Creek (also channelized) where a natural bedrock, valley constriction is located. In Meadow Valley, Spanish Creek flows in a trench that is located near the center of the valley and ends at a similar bedrock constriction.

After the passage of the Sawyer Decision in 1884, hydraulic outwash material was collected behind large log-crib dams (Figure 5) that have since deteriorated, releasing

Figure 4.



SHEET No 1 OF
GEOLOGICAL MAP OF PORTIONS OF
THE AMERICAN VALLEY AND VICINITY
PLUMAS COUNTY, CALIFORNIA
TO ACCOMPANY REPORT TO
MESSRS. A. AGASSIZ & Q. A. SHAW.
Made Octr 30th 1885 by
JAMES E. MILLS
Geologist.
A
V
N
A
Former Channel of Spanish Creek.
Canal
Quincy
Currently Highway 70

massive amounts of coarse material to move downstream. Much of that material is not only visible within Spanish Creek between Meadow Valley and American Valley, but it is contributing to the aggradation of the channel in many locations and the formation of the large gravel bars that extend through the length of Spanish Creek in American Valley.

Where bedload material (boulders, cobbles, and gravels) once deposited at the head of the valleys, it is now transported through the valleys, forming and maintaining gravel bars and islands along the way. Where once streamflows spread over a wide area, depositing finer and finer sized material, it is now concentrated within man-made trenches that have enlarged over the years and continue to widen today.

Spanish Creek is attempting to develop an inset channel and floodplain within the existing entrenchment (a.k.a. gully) at the current, lower elevation. The morphology of this inset stream channel is adjusting to both the bedload and the streamflow delivered to it. As gravel mining has ceased at the head of the valley, more bedload material has begun moving downstream and the bars and islands are believed to be increasing in size. As bedload material travels along the bed of the stream channel and up onto bars on the inside of bends, the main thread of the river is forced against the concave, outside channel banks (Figure 6), causing undermining and collapse (Collins 1990). This process continues until the stream has developed the channel and floodplain that are in dynamic equilibrium with streamflow, sediment load and sediment size. Much of Spanish Creek in American Valley has little to no floodplain, resulting in deep, powerful flood flows that apply tremendous stress to the banks of the entrenchment, especially along the outside of bends.

Socio-economic Aspects (*treatment constraints*). Originally, the floor of American Valley was the broad floodplain of Spanish Creek. The main channel of Spanish Creek in the valley was located approximately where Clear Stream is today, Figure 5. This floodplain was abandoned, except during times of extreme flood events, after Spanish Creek was relocated to its present location and as the new channel cut into the highly erodible soil material of the valley.

Elizabethtown, the original gold rush town in American Valley was occupied from 1852 to 1858. Quincy became the county seat in 1854, after which Elizabethtown dwindled and was eventually dismantled. The town site was eventually buried by 4 to 12 feet of hydraulic mining outwash material (Elliott 1997). Quincy occupies the foot slopes and alluvial fans at the edge of the American Valley meadow floodplain. Today, the community has expanded out onto the meadow with a network of roads and stream crossings, Feather River College facilities, the River Ranch RV Park, the Quincy Airport and associated industrial buildings, the Quincy Community Services District office and facilities, residential houses, and various ranches. These all constrain Spanish Creek to remain in its present location and incised condition. This means that the entrenched channel's ability to convey most of the floodwaters should be maintained. It does not mean that the channel should degrade or enlarge further.

There is a small levee system constructed along the existing Spanish Creek entrenchment to help contain extreme flood flows. That levee system is probably a remnant and enhancement of the original ditch construction. A tree ring survey of pine tree stumps located on the levee upstream of Highway 70 showed that the trees were at least 80 to 100 years old (Benoit 1990). These trees probably germinated on the ditch levee soon after construction. What's left of the levees extends from about 5000 feet upstream of Highway 70 to about 3000 feet downstream of the highway.

Upstream of the highway, homes are slowly being constructed on the Spanish Creek terrace, former floodplain, south of Spanish Creek, and the Feather River College facilities and the RV Park are on the north side of the creek. The college is just downstream of what was Spanish Creek Aggregate, which mined gravel at the head of American Valley.

Spanish Creek Road, the access route for the Quincy Community Services District, is located on the downstream section of the levee. Industrial buildings line the airport airfield and Spanish Creek Road, protected by the 4 foot high levee. Beskeen Lane runs along the hillslope on the opposite side of the creek from Spanish Creek Road and provides access to several homes and a historic graveyard. To protect the two roads, little channel expansion can be tolerated through this reach. Immediately downstream of the two roads is the Quincy sewage treatment facility and ponds, further constraining the channel to its existing location and width.

Downstream of the sewage treatment ponds are mostly large ranches and the confluence with Greenhorn Creek. The bedrock constriction at the mouth of the valley causes large flood events (average recurrence interval of 9.5 years) to pond onto these ranches. The recent flood (12/31/2005) was deemed to have a recurrence probability of 10% per year (10-year frequency). It flooded the Bengard Ranch (north side of Spanish Creek) to a depth of about 2 feet, spilling onto the ranch about 8000 feet upstream from the mouth of the valley. The Pourcho Ranch is located on Spanish Creek immediately downstream of the confluence with Greenhorn Creek. The recent flooding there reached a depth of 4 to 5 feet.

Encroachment onto the historic floodplain with residential structures, industrial buildings, etc. will probably continue. Several attempts have been made to gain permits for the construction of a golf course and attendant buildings and roads. No doubt ranching will continue with the diversion of Spanish Creek water to irrigate the pastures. The isolated wetlands that still remain throughout the valley will probably limit growth in those areas.

Desired Condition

Given the condition and processes described above and given the listed constraints, the following desired condition statements are made:

1. Sediment production, transport, and deposition are commensurate with a properly functioning stream system.
2. Spanish Creek is in proper functioning condition, including its aquatic and riparian habitats.
3. The stream channel from the head of American Valley to past the Quincy Community Services District plant is able to convey most floodwaters with no significant aggradation or degradation.
4. The entire channel through American Valley is in proper functioning condition, including rehabilitated aquatic and riparian habitats.
5. Water temperatures do not exceed 68° F except for short durations of time.

Rehabilitation Strategy

The two primary components of this strategy are (1) sediment/gravel management and (2) stream channel rehabilitation. The two components should work together in a synergistic manner to reduce erosion and the production of sediment, enhance stream channels and riparian areas, and, where necessary, maintain the channels' ability to convey floodwaters.

Gravel Management

An oversupply of gravel is delivered to Spanish Creek from sites impacted by large gold mining operations. Additionally, the channelization of Spanish Creek in both Meadow Valley and American Valley and subsequent degradation of those channels is also contributing large amounts of sediment. The channeling of Spanish Creek has transformed it from one that captured and stored sediment to one that now readily transports sediment through the valleys, temporarily storing it as large gravel bars. These gravel bars, especially the bars that form at meander bends (point bars), force streamflows against the opposite channel bank, accelerating erosion along those banks, further accentuating the bend.

To reduce the amount of sediment entering and moving through the valleys, a sediment/gravel management plan is proposed that consists of (1) reducing erosion of and delivery from high priority sediment sources and (2) removing gravel from the stream channel at designated locations and at appropriate rates.

1. Erosion and Sediment Delivery.

Table I below lists the 9 subwatersheds of the Upper Spanish Creek Watershed (Map 3) and, from previous studies (Churchill 1988; James 1988; Wills 1988; SCS 1989; Clifton 1992), the primary erosion/sediment sources located within each. Each subwatershed is also ranked according to the following criteria, listed in order of importance:

1. Infrastructure or private structures at high risk of damage from continued lateral migration of the incised stream channel.
2. Significant sediment sources.
3. High landowner interest and willingness to participate in a long-term program.
4. Good potential to meet desired conditions.

Table 1. A Ranking of the Upper Spanish Creek Subwatersheds

Subwatershed Name	Area (mi^2)	Primary Sediment Sources	Priority Rank
American Valley	15	Incised stream channels; in-stream sediment deposits (gravel bars)	1
Mill Creek	9	Incised stream channel; channel clearing	2
Wapaunsie Creek	8	Incised stream channels; in-stream sediment deposits; Gopher Hill Mine Complex; historic mine tailings; roads	2
Slate - Whitlock	5	Gopher Hill Mine Complex; Hungarian Placer Mine; Woods Ravine; historic mine tailings; Slate Creek mine tailings; roads	2
Rock Creek	17	Incised stream channels; Deanes Valley; roads	7
Meadow Valley Creek	7	Incised stream channels; in-stream sediment deposits; roads	4
Clear Creek – Taylor Gulch	11	Incised stream channels; in-stream sediment deposits; historic mine tailings; unstable slopes; roads	5
Meadow Valley – Pineleaf Creek	6	Incised stream channels; in-stream sediment deposits; historic mill site; historic placer mine tailings; roads	3
Silver Creek	6	Incised stream channel; loss of in-channel storage for natural sediment supply	6
Spanish Creek Headwater	8	Incised stream channels; Bean Hill Mine Complex; Greens Flat; roads	3

Initially, this plan will focus on Spanish Creek within the highest priority subwatershed, American Valley. Other subwatershed potential treatment areas will be a part of this plan as projects develop that will aid in meeting the desired condition for Spanish Creek in American Valley. This plan can be expanded as funds and priorities develop. Priority project areas not currently included in this plan but which would significantly reduce sediment to Spanish Creek, helping to meet desired conditions, are as follows:

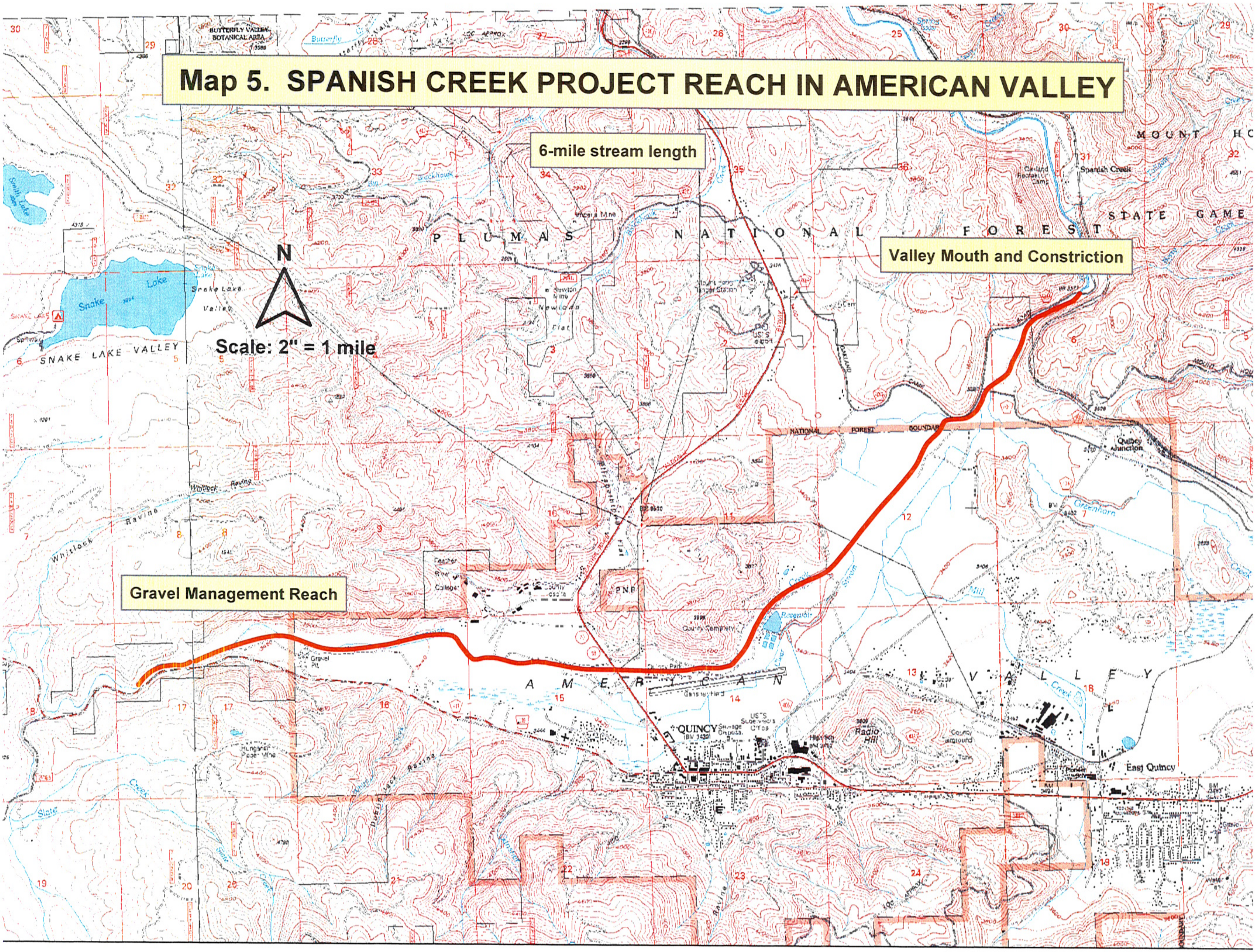
1. Bean Creek (Bean Hill Mine Complex).
2. Greens Flat on Spanish Creek at the head of Meadow Valley.
3. Spanish Creek through Meadow Valley.
4. Silver Creek in Meadow Valley.
5. Meadow Valley Creek through Meadow Valley.
6. Wapaunsie Creek at Gopher Hill.
7. Woods Ravine at Gopher Hill.
8. Spanish Creek and adjoining tailings deposits at Gopher Hill.

2. Gravel Removal. Active gravel management would take place on Spanish Creek at the head of American Valley, Map 5. Its location is based on fluvial geomorphic principles governing sediment transport and deposition evaluated in the EnSed2D computer model developed by Dr. Jennifer Duan and modified for this study (Duan 2006). Jen Weller, Graduate Student at the University of Nevada, Reno, conducted research necessary to adjust and calibrate the model for Spanish Creek (Weller 2005).

EnSed2D is a depth-averaged, two-dimensional hydrodynamic flow model, a sediment transport model, and a bank erosion model. It is also used to predict bed aggradation and degradation. The model accurately predicts that the highest bedload transport occurs in the channel reaches upstream of American Valley and that transport is significantly reduced in the downstream reaches, Appendix C. "*It is very likely that bed aggradation will mainly occur at the middle reaches, where there is a significant reduction in channel slope. The excessive bedload from upstream mountain reaches will be deposited at the middle reaches after the "Devil's Elbow" because of the reduced transport capacity in the American Valley. The lower reach will experience some aggradation or incision depending* [on the amount of] *bedload transported to this reach*" (Weller 2005, pp 82 & 83).

Parameters used by us and the modelers to locate gravel management sites include:

- The rate of replenishment from upstream.
- Ability to maintain stable streambed elevations.
- Historical patterns of sediment transport, bar formation, and bank erosion.
- Prediction of the local effects of gravel removal on bed elevation and on the stability of banks and bars and the desirability or acceptability of anticipated effects.



Map 5. SPANISH CREEK PROJECT REACH IN AMERICAN VALLEY
6-mile stream length
Valley Mouth and Constriction
Gravel Management Reach
N
Scale: 2" = 1 mile
PLUMAS NATIONAL FOREST
AMERICAN VALLEY
QUINCY
East Quincy
Snake Lake
SNAKE LAKE VALLEY
Radio Hill
STATE GAME
MOUNT H
Spanish Creek
BUTTERFLY VALLEY BOTANICAL AREA
NATIONAL FOREST BOUNDARY

We recommend that two designated gravel management sites be located as follows (Map 6):

1. The large gravel bar located approximately ¾ mile upstream of the head of American Valley. It is easily accessed from Bucks Lake Road using an existing road with a locked gate.
2. The former "Spanish Creek Aggregate" site located at the head of the valley and extending to the entrenchment bend at Feather River College. The reach is approximately 1.5 miles long.

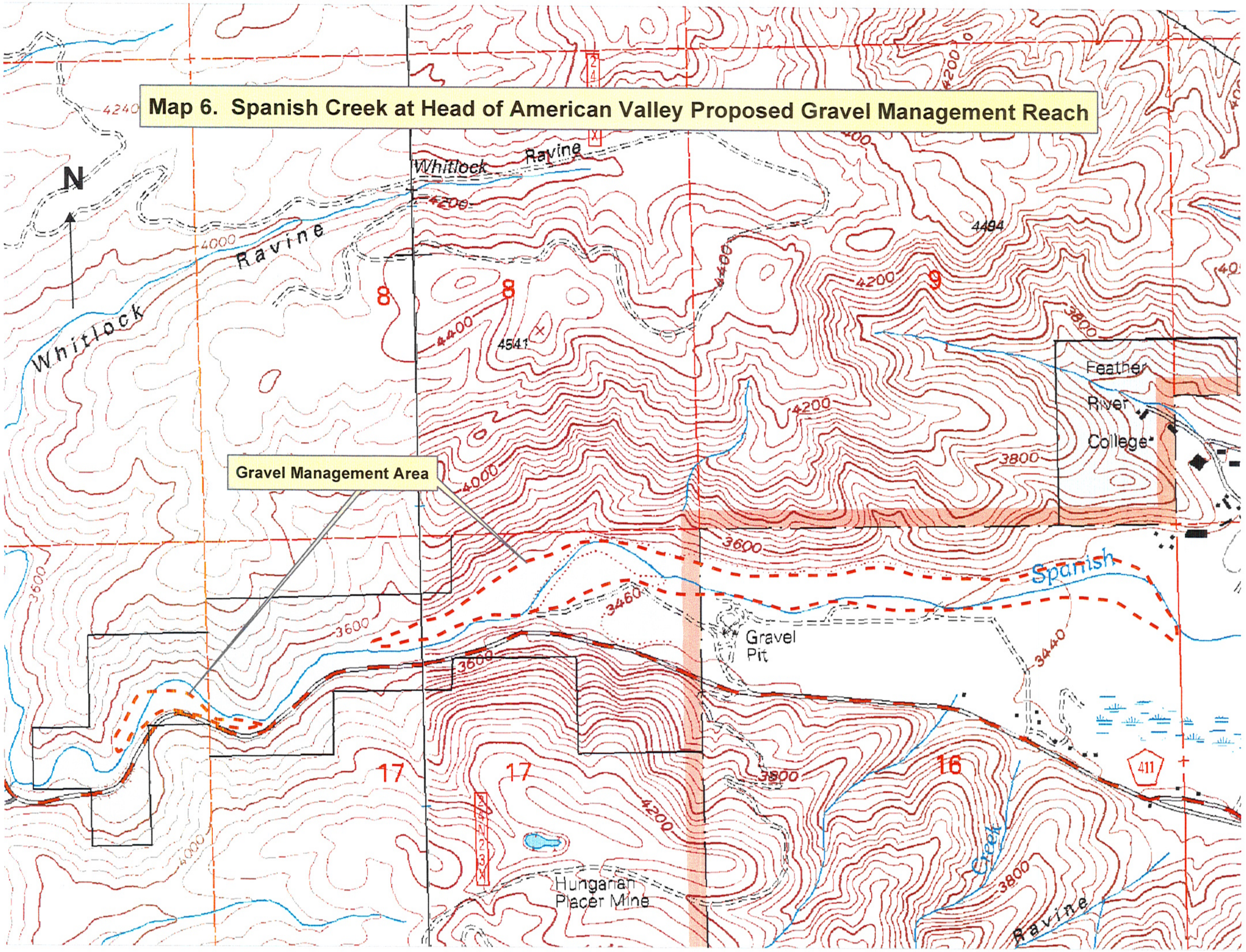
General Operating Plan. The gravel management reach will be managed to maintain areas where bedload can deposit and removal will not damage the recovery of the stream channel. The alignment of Spanish Creek would be designated and all heavy equipment kept from the active channel area, except for designated crossings. Gravel would be removed as deemed necessary, not to exceed once a year. The methods for extracting gravel must not interfere with the integrity of the stream channel and its floodplain functions. Gravel excavation will not lower elevations below the stream bankfull elevation (as determined by cross-sectional surveys and annual monitoring results).

Responsible Parties. The party or parties responsible for removing gravel will be the respective owner(s) of the property from which gravel is to be removed. Gravel removal will take place in consultation with the Spanish Creek Technical Advisory Committee (TAC). This committee would meet approximately once a year to review all data and information and to formulate recommendations for future gravel removal.

Permit Process. The purpose for removing gravel from the Spanish Creek gravel management zone will be to maintain the function of floodplains and to reduce the risk of magnifying gravel-bars within downstream reaches, thereby maintaining the stream channel in an at-grade state (neither aggrading nor degrading) and minimizing erosion stresses against channel banks. An exemption will be sought from the State Mining and Geology Board that would allow excavation and grading for the purpose of repairing and restoring floodplains and their connection with the active stream channel and because it is an integral part of rehabilitating the Spanish Creek channel.

Other permits will be obtained, as required, including those required by the Clean Water Act, Sections 401 and 404, and Stream Alteration Agreements from the California Department of Fish & Game.

Estimated Cost. An annual inspection of the gravel collection/extraction areas would be required to assess compliance with the General Operating Plan. The inspection would focus on specific requirements and attributes, such as extraction elevation, channel alignment, gravel accumulations above bankfull elevation, damage to the stream channel and floodplain from the extraction activities, and general success of the program. It is expected that the FR-CRM staff and California Department of Fish & Game personnel


Map 6. Spanish Creek at Head of American Valley Proposed Gravel Management Reach
N
Gravel Management Area
Whitlock Ravine
Whitlock Ravine
Feather River College
Spanish
Gravel Pit
Hungarian Placer Mine
Creek
Ravine
4541
4484
411
8
8
9
16
17
17

would perform these inspections with the property owners and gravel operators. An annual inspection report would also be produced. The estimated cost to conduct the inspection and write the report is $500 per year.

Spanish Creek Bank Treatment and Channel Enhancement

Because the Spanish Creek channel has been confined to a constructed channelway along the north side of the valley and that channelway has incised, little flooding now occurs on the valley floor and few floods exceed the capacity of the incised channelway. Spanish Creek is still a free flowing stream and persists in establishing a stream channel that is in dynamic balance with the sediment load delivered to it and a floodplain that is also in balance with the load and with the amount of water in transport.

Flows in excess of what is needed to move the sediment load should flow out onto this floodplain, spreading floodwaters and keeping the depth of flow in the channel to that needed to transport the sediment load. Existing conditions don't allow most floodwater to spread and so the depth of flow in the channel exceeds that required to transport the load delivered to it. This excess flow depth is applying excessive flow forces against the bottom and banks, but because the bottom is at or near the old American Valley lakebed material, downward scour is reduced and lateral erosion increased. Scour into the lakebeds is occurring (Figure 7) and extends from the mouth of the American Valley to just upstream of the Highway 70 Bridge.

The bottom of this section of channel is covered with a veneer of gravel and few energy-dissipating features (pool-drops and meander bends) exist. Some misplaced features have been constructed that are helping to dissipate flow energy, but in most cases flows are being misdirected into adjoining banks where active erosion is occurring. In each case, flow velocities are increased, mostly dissipating the increased energy in a horizontal plane.

One of the primary attributes of the technology proposed in this strategy is that streamflow energy would be dissipated on a more vertical plane and incrementally. The establishment of vegetation around and between the proposed features is vital to their long-term success. It also helps meet the desired condition of healthy riparian areas. Two primary treatment techniques are proposed for Spanish Creek in American Valley. These are:

1. Boulder Vanes (with energy dissipating pools) on meander outcurves, Figure 8.
2. Channel Constrictions (with energy dissipating pools) between the bends and at morphologically sequenced locations, Figure 9.

Again, these techniques include a lot of vegetation plantings. Vertical banks would also be laid back and vegetated, as shown in Figure 10. Along with a dense mat of roots to help stabilize banks, vegetation creates a dense layer of stems against the banks,

Figure 6. Channel Bend and Point Bar

Figure 7. Exposed Lakebeds and Alluvial Sediment in American Valley

Figure 8. Boulder Vane

Figure 9. Boulder Channel Constriction

Figure 10. Bank Treated with Boulder Vanes, Sloped Back and Vegetated

1 *Pre-project, Wolf Creek* 1999

2 *Post-project, Wolf Creek* 2000

3 Wolf Creek 2004

eliminating most bare soil areas, reducing flood flow velocities along the treated banks to near zero, and stabilizing the steeply sloped soil mass with deep roots.

These treatment techniques have been shown to be effective in entrenched stream channels. Past experiences by the FR-CRM have demonstrated the weaknesses of other techniques in these environments and the strength of the treatments proposed here (Wilcox 2001).

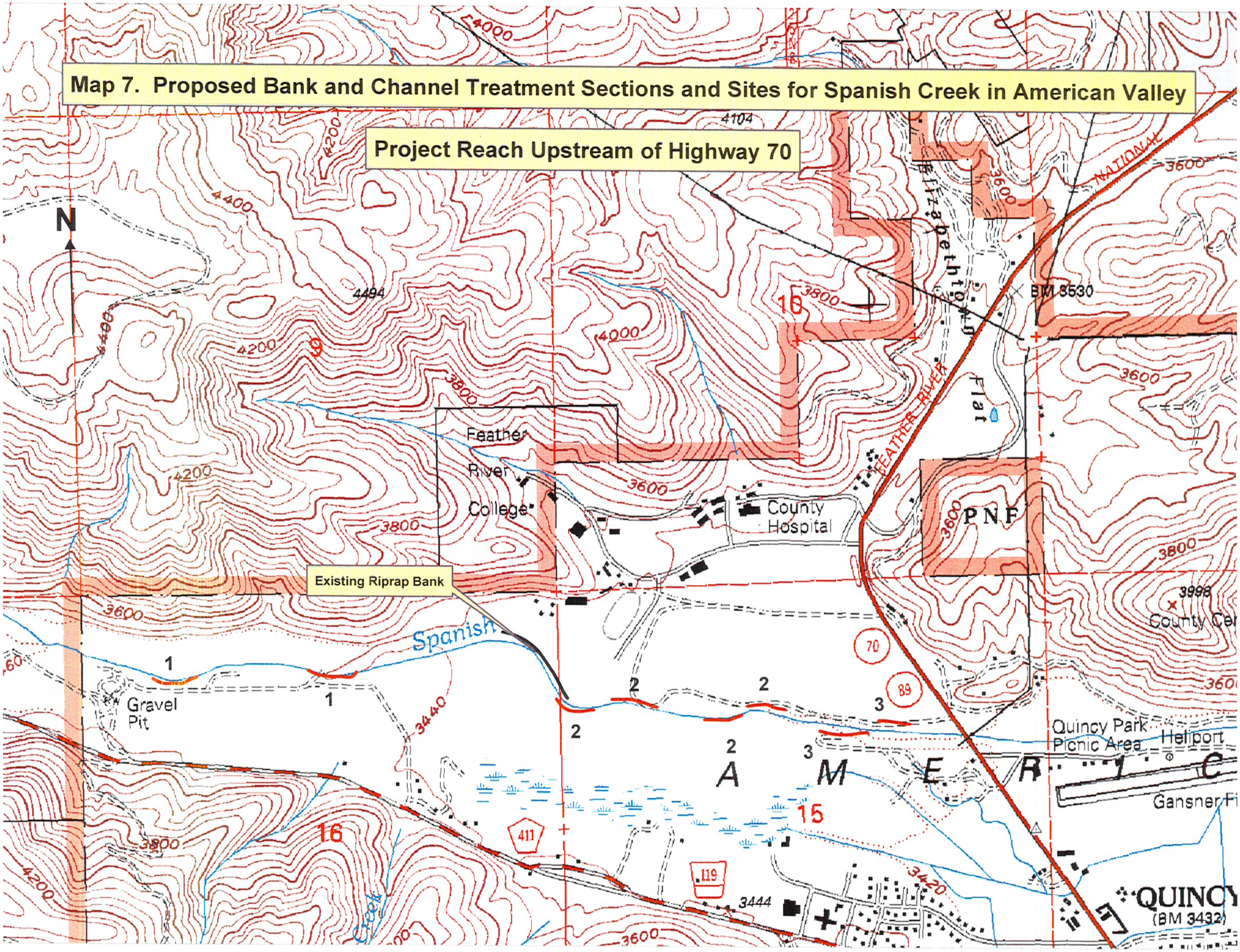
The EnSed2D model was applied to the proposed techniques with positive results. Primarily, the model demonstrated that the proposed channel treatment techniques would not cause channel aggradation or degradation, but that the channel would maintain its existing flow capacity (one of the desired conditions).

The gravel management proposal and the channel treatment proposals are expected to work together to:

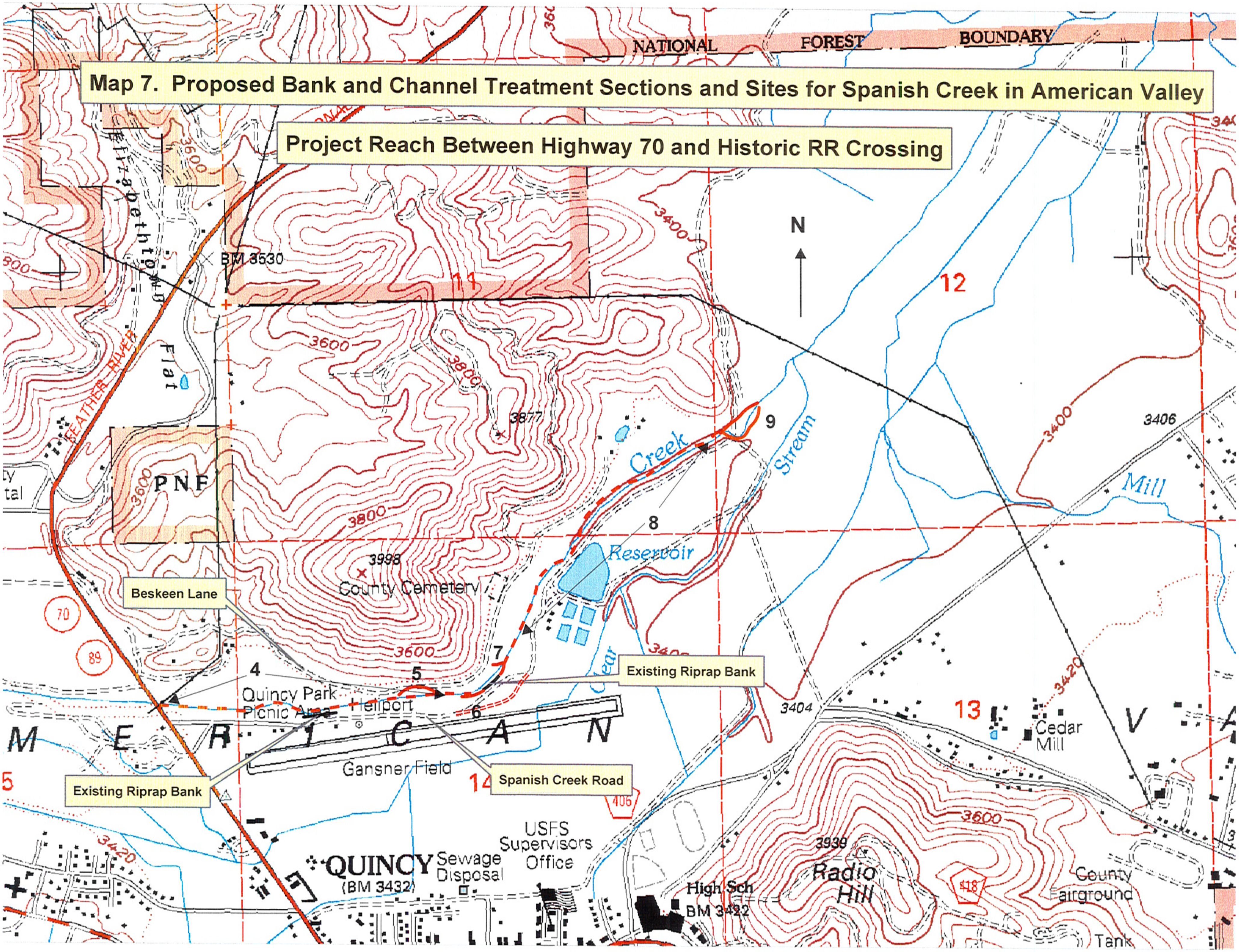
- Reduce the sediment load now being transported through American Valley.
- Reduce the development of the depositional bars.
- Reduce erosive forces against the channel banks.
- Improve water quality.
- Improve aquatic and riparian habitats.

Proposed Treatments and Priority Ranking. Treatment proposals would use naturally occurring materials like whole trees, boulders, living vegetation, and existing stream channel and valley bends, bars, and bedrock outcrops. Treatment proposals would be designed to work with the energy of flowing water to maintain a balance between stream discharges and flow velocities to minimize the stress of streamflow against channel banks, bottom, and project features. The proposed treatments would include:

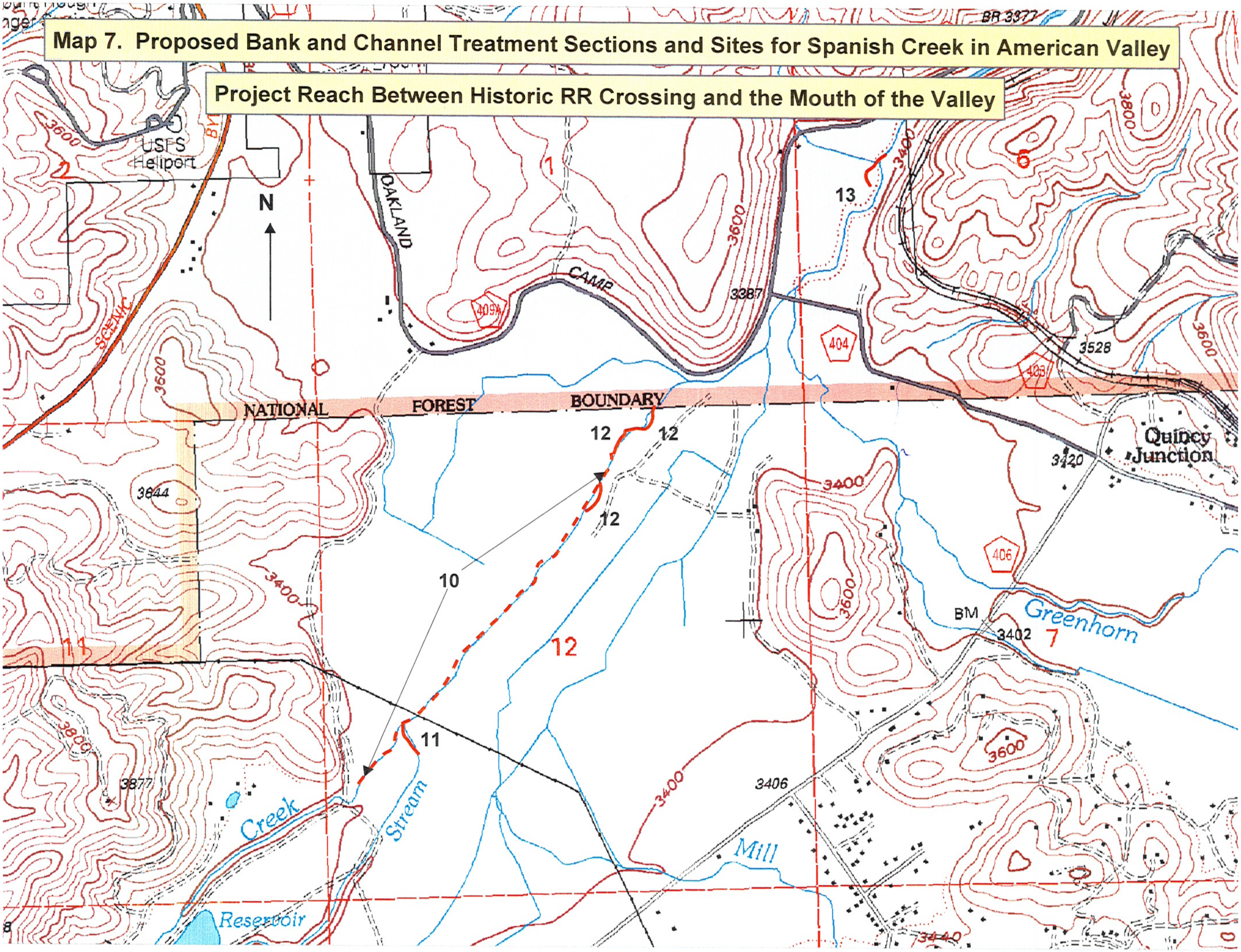
1. Sloping and vegetating vertical banks to improve floodplain capacities and reduce flow velocities against channel banks.
2. Installing boulder or log "vanes" to deflect the center of streamflow away from channel banks and to enhance the distribution and dissipation of streamflow energy.
3. Installing boulders, tree boles with root wads, and live vegetation to help regulate stream flow velocities and establish riffles and pools to enhance aquatic habitats.
4. Where needed and possible, allowing further recession of channel banks to increase floodplain capacities.
5. Removing, replacing, or modifying existing in-channel and bank structures that are causing channel and streamflow instability.
6. Controlling bank erosion using biotechnical erosion control techniques (NRCS 1996).



Map 7. Proposed Bank and Channel Treatment Sections and Sites for Spanish Creek in American Valley
Project Reach Upstream of Highway 70
N
Existing Riprap Bank
Spanish
Feather River College
County Hospital
Elizabethtown Flat
FEATHER RIVER
NATIONAL
PNF
BM 3530
Gravel Pit
Quincy Park Picnic Area
Heliport
AMERICA
QUINCY
(BM 3432)
1
1
2
2
2
2
3
3
70
89
411
119
4494
4104
3444
3998



Map 7. Proposed Bank and Channel Treatment Sections and Sites for Spanish Creek in American Valley
Project Reach Between Highway 70 and Historic RR Crossing
NATIONAL FOREST BOUNDARY
N
BM 3530
Flat
PNF
FEATHER RIVER
3877
3998
County Cemetery
Creek
Stream
Reservoir
Mill
3406
3404
Beskeen Lane
Quincy Park
Picnic Area
Heliport
Existing Riprap Bank
Existing Riprap Bank
Spanish Creek Road
Gansner Field
4
5
6
7
8
9
11
12
13
14
M E R I C A N V
Cedar Mill
QUINCY
(BM 3432)
Sewage Disposal
USFS Supervisors Office
High Sch
BM 3422
Radio Hill
3939
County Fairground
Tank
70
89


Map 7. Proposed Bank and Channel Treatment Sections and Sites for Spanish Creek in American Valley
Project Reach Between Historic RR Crossing and the Mouth of the Valley
N
USFS
Heliport
OAKLAND
CAMP
409A
404
405
406
NATIONAL
FOREST
BOUNDARY
Quincy
Junction
Greenhorn
Creek
Stream
Mill
Reservoir
BM
3402
3420
3528
3387
3406
3644
3877
3600
3400
3800
3440
BR 3377
SCENIC
10
11
12
13

Map 7 shows the location of the different proposals with the existing features and the table below lists each project, their projected costs, and priorities (See Appendix B, Project Concept Description).

Table 2. Proposed Channel Treatments, Priority and Cost Estimates

Map Number	Priority	Treatment Proposal	Estimated Cost
1	Moderate	1, 2 & 6	$80,000
2	Moderate	1, 2 & 6	$100,000
3	High	1, 2 & 6	$30,000 (funded)
4	Moderate	3, 4 & 6	$90,000
5	High	1, 2 & 6	$50,000
6	High	1, 2, 6 & relocate 650 ft of Spanish Creek Road	$100,000
7	High	1, 5 & reconstruct water diversion intake	$50,000
8	Moderate	1, 2, 3, 4 & 6	$160,000
9	High	1, 5, 6	$20,000
10	Low	3, 4 & 6	$100,000
11	High	Grade-drop structure	$80,000
12	Moderate	1, 2 & 6	$50,000
13	Moderate	1, 2 & 6	$40,000

The total estimated cost for treating channel banks and enhancing channel morphometry is $900,000 to $1,000,000. The high priority projects, excluding the Dyrr Bank, would cost an estimated $300,000. These costs include those associated with all surveys, final designs, environmental studies, and permits.

Program and Project Monitoring and Adjustments

The effects of removing excess gravel from the stream system and installing stabilizing treatments on channel aggradation, degradation, and widening would be monitored and assessed annually. Program adjustments would be based on monitoring results so that program objectives continue to be met or are adjusted to meet changes in condition and new information.

Gravel Management Monitoring Plan

To characterize the supply of gravel to downstream reaches and to assess the effects of gravel removal, the interaction of sediment production and transport with river-channel morphology will be monitored. A combination of observation and field measurements using aerial photographs, gages, and cross-section measurement sites will be used.

Eight project reaches have been delineated and the effects to each reach and to downstream reaches would be monitored by establishing 1 permanent cross-section measurement site per reach along with 2 gage sites per reach. Low elevation aerial photographs would be taken to help assess the overall health of the project reaches. Data and information would be analyzed immediately after collection. The following table describes each monitoring parameter:

Table 3. Gravel Management Monitoring Parameters and Schedule

Parameter	Monitoring Element	Monitoring Frequency	Responsibility
Gravel Extraction Records	Cubic yards; tons	Annually	Aggregate extractor
Cross-section Survey	Channel W/D; D_{50}: floodplain width; gravel-bar accretion; bank recession	5 years	Spanish Cr TAC
Gage	Channel bed elevation	5 years	Spanish Cr TAC
Aerial Photographs	Channel migration patterns; bank recession	10 years	Spanish Cr TAC

* High streamflow years may require more frequent monitoring.

Stream Channel and Riparian Monitoring Plan

Performed in conjunction with the Gravel Monitoring Plan, monitoring the stream and riparian areas will focus on specific project sites and stream sections. This plan will focus on both site-specific success and maintenance needs and on overall program objectives. Periodic reviews of the collected data will help determine project enhancement or modification needs. Data and information will be analyzed immediately after collection. The following table describes each monitoring parameter:

Table 4. Stream and Riparian Monitoring Parameters and Schedule

Parameter	Monitoring Element	Monitoring Frequency	Responsibility
Photograph Points	Vegetation response; channel/bar stability	Biannually for 10 years	Spanish Cr TAC
Water Quality	Water temperature; suspended sediment	Biannually for 10 years	Spanish Cr TAC
Project-site Stability	Structure durability; vegetation recovery, canopy cover	Biannually for 10 years	Spanish Cr TAC
Habitat Durability	Riffle-pool frequency; aquatic insect diversity (DPT)	Biannually for 10 years	Spanish Cr TAC

Monitoring Cost Estimate. Five stream channel reaches have been identified and would be monitored. Each reach is projected to require at least one day collecting the appropriate data and conducting the assessment of the data. The initial establishment of the data points and measurements will cost approximately $12,000. Subsequent monitoring and assessment costs are estimated at $5,000 for each monitoring period.

The Spanish Creek Technical Advisory Committee (TAC). The Spanish Creek TAC was established to oversee the rehabilitation of Spanish Creek. Its members include FR-CRM staff, management committee members, State, Federal and local agency engineers, hydrologists and other natural resource specialists, Plumas County and all landowners with property along Spanish Creek affected by this strategy. This committee would meet approximately once a year to review all data and information and to formulate recommendations for future gravel removal, stream rehabilitation and other needs. The TAC is an integral part of the FR-CRM, working directly for the Management Committee.

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