UPPER DEER CREEK
ASSESSMENT
&
RESTORATION PLAN

FINAL DRAFT
3/23/06

FRIENDS OF DEER CREEK
&
NATURAL HERITAGE INSTITUTE

ACKNOWLEDGEMENTS

Many people provided valuable information and assistance in this Assessment and Restoration Plan. We would like to thank the CALFED Bay Delta Watershed Program for funding this project, and the California State Water Resources Control Board for grant management. We thank the late Professor Emeritus Luna Leopold for his practical river sense. We also thank Sue Sindt of NID, Friends of Deer Creek staff Marisha Finkler and Joanne Hild, and Jim Wofford.

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ACRONYMS

BLM	Bureau of Land Management
cfs	cubic feet per second
DO	Dissolved Oxygen
EPT	Ephemeroptera, Plecoptera, Trichoptera
FODC	Friends of Deer Creek
FDC	Friends of Deer Creek
NHI	Natural Heritage Institute
NID	Nevada Irrigation District
PG&E	Pacific Gas and Electric Company
USGS	United States Geological Survey

EXECUTIVE SUMMARY

Although Upper Deer Creek enjoys a number of enviable conditions, including perennial flow, low water temperatures, generally high levels of dissolved oxygen, and significant stretches of undeveloped riparian lands, Deer Creek is not as healthy or productive as it could be. The problems identified in this repot include: reduced peak flows; reduced frequency of substrate mobilization; infrequent inundation of floodplain habitat; residual mining deposits; reduced complexity and cover of riparian vegetation communities; prevalence of non-native riparian vegetation; excessive fine sediment deposits in certain reaches; excessive nutrient loads in certain reaches; non-point source pollution inputs; and sources of mercury and other heavy metal contamination from past mining activities.

Many actions are identified to address these problems such as increasing peak flows, regrading floodplain habitat, removing non-native vegetation and replanting with natives, reducing erosion from roads and other sources, reducing pollution from point and non-point sources, and remediation of sites contaminated with heavy metals. In addition, many topics requiring further study are also identified, including further flow monitoring and analysis, status of fishes and other aquatic biota, sources of fine sediment, sources of non-point pollution, and sources of heavy metal contamination and measures to reduce contaminant inputs and flows through the watershed.

Implementing the recommended actions would greatly enhance the health and productivity of Deer Creek. In addition, native flora and fauna would benefit and the influence of non-natives would be reduced. It is expected that with the human and scientific resources available to Friends of Deer Creek, combined with the support of partners such as the Bureau of Land Management, US Geological Survey, National Park Service, Nevada City, Nevada County and residents of the Deer Creek watershed, Deer Creek can thrive and gain recognition as an invaluable community resource.

CHAPTER I: INTRODUCTION

A. Problem Definition

The Deer Creek Watershed is located in Nevada County on the western slope of the northern Sierra Nevada region, with the last one hundred feet of the lower watershed occurring in Yuba County. Given the Deer Creek watershed's proximity to the Sacramento metropolitan area, its natural beauty and location below the snow line, it is experiencing rapid growth, particularly in the lower reaches. Unlike many urban and rural creeks in California, Upper Deer Creek enjoys many enviable conditions such as perennial flows, cool water temperatures, high levels of dissolved oxygen much of the year, and healthy cold-water fish populations. The Deer Creek of today, however, is significantly different from the Deer Creek that supported the hundreds of Native American residents for thousands of years, and the Deer Creek that greeted gold prospectors when they first arrived in the late 1840s. For example, three large dams and numerous small diversions now regulate flows and affect water quality and habitat conditions. In addition, Deer Creek suffers from the legacy of the gold mining era, from present day management of the river largely for water supply and from increasing urban encroachment. With this report, we intend to look at Upper Deer Creek in an integrated manner that addresses not only past and present uses of the creek, but also encompasses the value of the river as an ecosystem.

B. Project Goal and Objectives

The goal of the Upper Deer Creek Assessment and Restoration Plan is to develop a scientifically sound and implementable plan to improve the geomorphic and ecological function of Deer Creek from Scott's Flat Reservoir to Lake Wildwood (Figure 1). The reach of Deer Creek below Lake Wildwood was not included because that section was the subject of a separate study. This project is funded by the CALFED Watershed Program and is jointly implemented by Friends of Deer Creek (FODC) and Natural Heritage Institute (NHI). More specifically, the five objectives of the Upper Deer Creek Assessment and Restoration Plan are to:

- Develop a quantitative understanding of river hydrology, morphology, floodplain connectivity, and sediment transport;
- Assess sources of sediment and their impact on stream function;
- Assess creek health, including riparian vegetation composition and identify the relationship between riparian vegetation distribution and composition and geomorphic processes;
- Identify overall opportunities and constraints to restoration in upper Deer Creek; and
- Make recommendations regarding restoration goals, approaches and additional analysis.

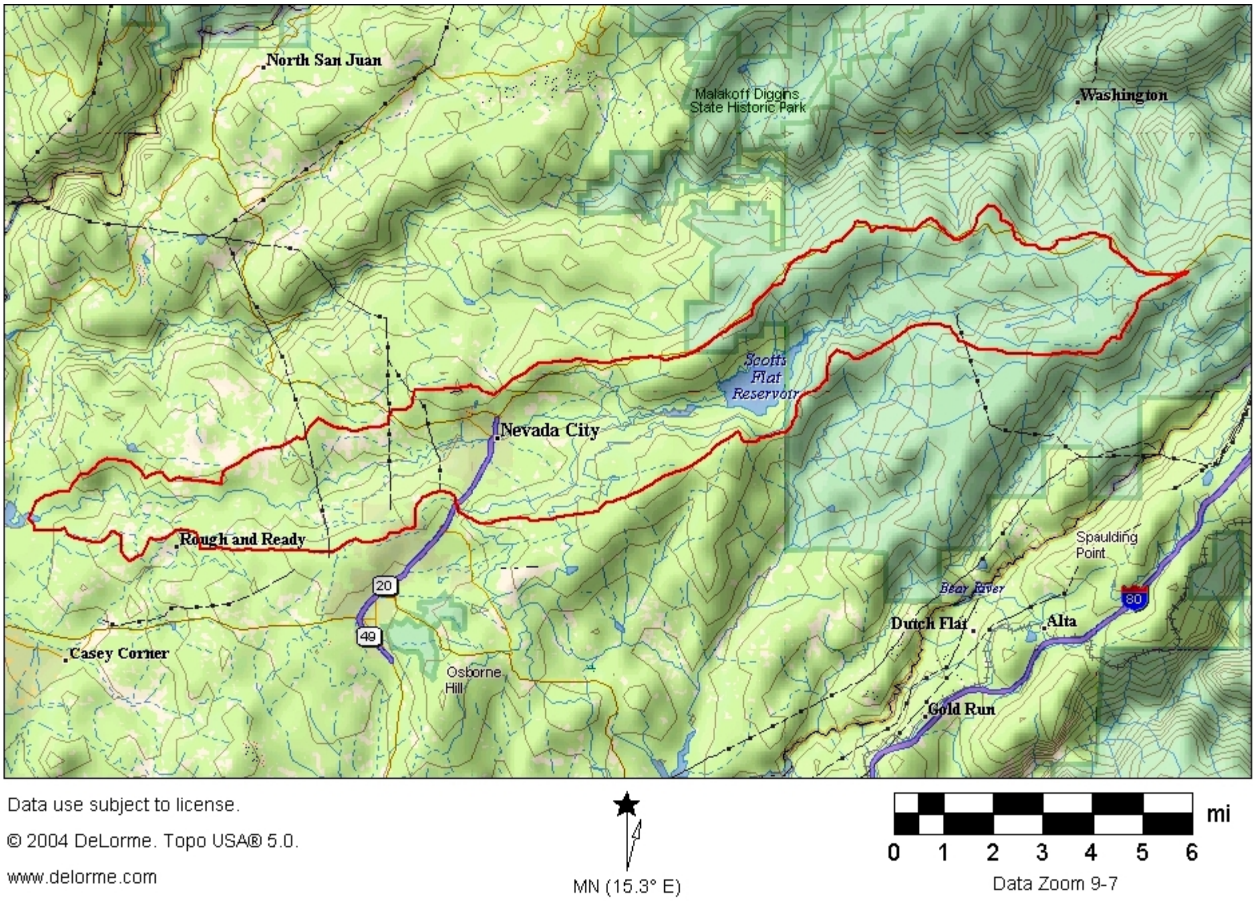

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Figure 1: Area of Focus within Deer Creek Watershed

C. Approach

The approach developed for the Assessment and the Restoration Plan involved a combination of desktop study, field observation and analysis. We began the Assessment with a flight over the Upper Deer Creek Watershed to provide a visual context for our work and to help us to preliminarily identify the distinct geomorphic reaches within the upper watershed.

Before initiating the Assessment, we spent a considerable amount of time developing a conceptual framework to guide the assessment, analysis, and planning. There is a significant body of literature focused on the form and function of alluvial rivers, and to a lesser extent, information on bedrock rivers. Deer Creek includes extensive reaches of bedrock and alluvial characteristics, and thus we needed to create a combined list of river attributes as guideposts for our analysis and restoration goals. These attributes are described in more detail in Chapter IV. In addition, we met with Professor Emeritus Luna Leopold who provided guidance and confirmed our approach.

In addition, the approach taken reflects a general consensus among assessment methodology sources on the importance of geomorphic processes to stream health. Understanding geomorphic processes and how they vary along Deer Creek is critical to any restoration plan because geomorphic processes drive the form of the creek channel and floodplains, which in turn influence in-stream and floodplain habitat, riparian vegetation, water quality, biota and many other important stream qualities (National Research Council, 1992). Thus, to restore and maintain healthy aquatic and riparian ecosystems successfully, restoration efforts must recreate the physical conditions necessary to support natural biotic communities (Gore, 1985; National Research Council, 1992). In addition, we hold that the design and implementation of a restoration program should be guided by an understanding of past changes, and should address the historical causes and course of channel degradation (Kondolf, 1995; Brookes and Sear, 1996).

Figure 2 illustrates the basic structure of a river system and the foundational role that river hydrology and morphology play. Key inputs, processes, and attributes that contribute to a healthy river (from McBain and Trush, 2004) include:

- channel morphology that is scaled to flow conditions;
- sediment supplies that are balanced with sediment transport capacity;
- frequent scour of bed surface and periodic scour of bed subsurface;
- channel migration (in alluvial sections);
- frequent floodplain inundation;
- self-sustaining diverse river corridor.

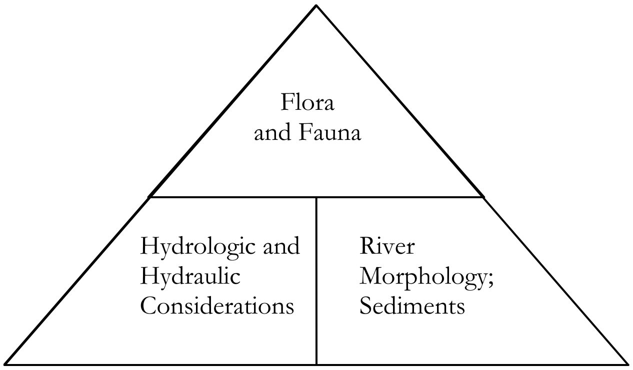


Figure 2: Basic Structure of a River System (Brookes and Shields, 1996)

Based on this approach, the Assessment and Restoration Plan included the components described below.

Historical Conditions

The limited historical information available related to the condition of Deer Creek was reviewed to attempt to describe the physical and ecological conditions of the creek prior to significant mining or development activities. This information was compared with existing conditions in Upper Deer Creek to better understand the gap between natural and present-day conditions. When discussing historical baselines in the context of a restoration plan, it is important to consider whether attempting to recreate "natural" conditions is always best for the health of the watershed, given other current constraints. Restoring native vegetation and reestablishing floodplain connectivity are examples of restoration actions that attempt to re-create historical conditions. However, reestablishing periodic drought-level summer flows to recreate historic conditions may be very detrimental to the health of the watershed, given other present-day stressors that we can't completely eliminate, such as urban runoff, increased nutrient and other pollutant inputs. Because the watershed has been highly modified, it is important to consider for any proposed restoration action whether attempting to recreate that historical condition is beneficial or detrimental to watershed health, given the reality of other stressors and constraints.

Hydrologic

Flow data from Nevada Irrigation District (NID) and USGS gauges, as well as data collected at gauges installed as part of the project were analyzed to begin to describe flows that could be considered "natural" or unimpaired by NID's water supply system, in addition to describing key hydrological patterns under current conditions.

Geomorphic

The geomorphic analysis first involved broadly classifying the distinct reaches of Deer Creek and characterizing the morphological channel types found along the majority of the study area. This included determining for several specific study sites the channel dimensions and stability, substrate characteristics, and the potential for channel-floodplain interaction.

Riparian Habitat

The riparian areas were surveyed to identify the major riparian species distribution and community structure.

Habitat Classification

The frequency and distribution of the major habitat types were determined, as well as the occurrence of large woody debris.

Water Quality

Data collected by Friends of Deer Creek on the chemical and physical water quality parameters, as well as macroinvertebrates, were analyzed.

Future Development

We considered the impact of probable future development on Upper Deer Creek, and reviewed the existing regulatory structure to determine their adequacy in controlling or mitigating these impacts. As a result of this Assessment, we were able to identify gaps in critical data, information, and analysis, as well as strategic areas for restoration, management changes, public outreach, education, and regulatory reform. The endpoint to which we gauged the steps necessary to get from the state of the river and the state of our knowledge today was FDC's vision that Deer Creek be "a healthy stream enjoyed by all, a watershed corridor full of wildlife and forests" (Friends of Deer Creek, 2004a).

CHAPTER II:
UPPER DEER CREEK:
SETTING, HISTORIC CONDITIONS, AND MODIFICATIONS

Figure 3: Deer Creek circa 1908, looking west from immediately downstream of Champion Mine. Note that channel is filled with gravels from mining activities.

A. Setting

Deer Creek's 83 square mile watershed reaches from an elevation of 150 ft at its confluence with the Yuba River approximately 20 miles east of Marysville up to approximately 5,000 ft at its highest point where it is wedged between the South Yuba and Bear rivers, approximately 10 miles east of Nevada City. The watershed is approximately 34 miles long and 2 to 4 miles wide. Like its northern cousins such as Butte, Chico and Battle creeks, the Deer Creek watershed rises in conifer forests at its upper elevations, passes through the mixed conifer-oak forests at its middle elevations and terminates in oak woodlands of the Sacramento Valley floor.

Deer Creek originates in Tahoe National Forest land, and then passes through a patchwork of private and Bureau of Land Management (BLM) landholdings, the town of Nevada City, and skirts the vicinity of Penn Valley before meeting the Yuba River below Englebright Dam. Higher elevations receive some of its approximately 60 inches of precipitation as snowfall, while lower portions of the watershed receive all of the 50 inches of precipitation as rainfall. The geology, slope and shape of the Deer Creek watershed reduce its capacity to naturally store winter precipitation. As a result, flows typically vary dramatically from highs of several hundred to thousands of cubic feet per second (cfs) in winter, to a low of less than ten cfs in summer.

The Nevada Irrigation District area encompasses some 280,000 acres mainly in Nevada and Placer Counties, including the vast majority of the Deer Creek watershed. NID sells raw water to residents in cities such as Nevada City and Grass Valley, in addition to farmers and residents in unincorporated county areas. NID operates more than 15 dams and diversions, and over 100 miles of canals and pipelines.

The majority of the watershed is privately owned. The watershed includes Scott's Flat Reservoir, Deer Creek Reservoir ("Lower Scotts Flat") and Lake Wildwood which serve as the major water-supply infrastructure. There are four water treatment plants located in the watershed including: Nevada City, Cascade Shores, Lake Wildwood, and Snow Mountain.

Although many residents in the watershed obtain their drinking water from private wells, the number of these wells is not known. In addition, the relationship between surface and groundwater is poorly understood.

B. Historic Conditions

Substantial information on the Deer Creek area became available after the influx of gold prospectors in 1848. However, few of these early sources specifically describe the creek. As a result, the historical condition of the creek can only be indirectly reconstructed from post-gold rush sources and analysis of documents and data describing more current conditions.

Flora and Fauna

The common names of mammals, birds, reptiles and fish species that were found in Nevada County before 1866 are listed below (Thompson and West, 1880):

Mammals:
Bear, cinnamon bear, panther, large yellow wolf, coyote, Indian dog, lynx, catamount, wild cat, mountain or civet cat, gray, black, silver and cross fox, fisher, badger, martin, weasel, mink, large striped skunk, small spotted skunk, large gray, ground, pine and flying squirrel, chipmunk, otter, raccoon, wood chuck, porcupine, gopher, mole, woodmouse, kangaroo rat, black-tailed deer and a small fur animal the size of a muskrat.

Birds:
Condor, king vulture, bald eagle, golden eagle, turkey buzzard, raven, crow, several kinds of hawk, road runner, several varieties of woodpecker, grouse, mountain and valley quail, pigeon, meadow lark, magpie, blackbird, flicker, robin, snipe, sand snipe, plover, curlew, red-winged black-bird, cross bill, linnet, cheewink, California canary, martin, swallow, blue crane or heron, sand hill crane, wild goose, Canada goose, wood, mallard, teal and dipper duck, mud hen, pelican, two varieties of humming birds.

Fish:
Salmon, salmon trout, brook trout, lake trout, perch, white fish, sucker, chub and two varieties of eels.

Reptiles:
Two kinds of rattlesnake, long striped, brown, pilot, green, purple, milk and waters snakes, four kinds of lizard, horned toad, common toad and frog. The vegetation species found in Nevada County at the time the influx of gold prospectors in the mid-1800s included the following (Dixon, 1905):

Trees:
Buckeye (*Aesculus californica*)
Wild nutmeg (*Tumioin californicum*)
Gray Pine (*Pinus Sabiniana Dougl.*)
Sugar-pine (*Pinus Lamertiana Dougl.*)
Yellow Pine (*Pinus ponderosa Dougl.*)
Hazel (*Corylus rostrata Ait. var. californica*)

Berries:
Manzanita (*Arctostapylos pungens*)
Snow-brush, sweet-brush, buck-brush (*Ceanothus integerrimus, Ceanothus cordulatus, Ceanothus velutinus*)
Strawberry (*Fragaria sp.*)
Thimbleberry (*Rubus glaucifolius*)
Service-berry (*Amelanchier pallida*)
Elderberry (*Sambucus glauca,* and *Racemosa L.*)
Chokecherry (*Prunus demissa*)
Wild plum (*Prunus sub-cordata*)
Gooseberry (*Ribes sanguineum Pursh.,.*)
Rose-hips (*Rosa pisocarpa*)

Roots, bulbs, grasses:
Small onion (*Allium parvum Kellogg)*
Broadstem onion (*Allium platycaule)*
Douglas's broadeia (*Brodiaea Douglasii)*
Brodiaea lacteal
Camassia esculenta
Reed Lily *Hastingsia alba*
Nevada Lewisia (*Lewisia nevadensis)*
Washington Lily (*Lilium washingtonianum Kellogg)*
American Bistort (*Polygonum bistortoides Pursh)*
Tar-weed (*Madia glomerata)*
California Compassplant (*Wyethia anugustifolia Nutt.)*
Horse-mint (*Mentha sp.*)
Mistletoe (*Phoreodendron juniperinum*)

Many of the fauna and flora listed in the identified sources that would have been found in the Deer Creek Watershed historically can still be found today. Although it is likely Deer Creek had populations of brook and rainbow trout, Deer Creek Falls located ¼ mile upstream from the confluence with the Yuba River is believed to be the historic and current upper limit of anadromous salmonids (Yoshiyama et. al., 2001). The fish community in stream reaches (not including reservoirs) now includes introduced brown trout (*Salmo trutta*). With the notable exception of wolf and grizzly bear and perhaps other mammal predators, most of the mammals present in the mid-1800s still occupy the watershed although likely not in the same densities as under pre-European, historical conditions. Because the sources of information on flora focused on plants that provided food, many other riparian species went unlisted. However, it seems reasonable to assume that the common native riparian species found today were also present historically, including (Faber and Holland, 1988):

Big leaf maple (*Acer macrophyllum*)
Box elder (*Acer negundo, subsp. Californicum*)
Toyon (*Heteromeles arbutifolia*)
California black walnut (*Juglans hindsii*)
Honeysuckle (*Lonicera hispidula var. vacillans*)
Sycamore (*Platanus racemosa*)
Cottonwood (*Populus spp.*)
Willow (*Salix spp.*)
Poison oak (*Toxicodendron diversilobum*)
California bay (*Umbellularia californica*)

Most plant species found historically can be found today, but numerous non-native invasives have been introduced to the watershed, such as Scotch Broom (*Cytisus scoparius*), Himalayan blackberry (*Rubus discolor*) and English ivy (*Hedera helix*). The latter two invasives have replaced native riparian vegetation in many areas and reduced habitat value for other native species.

Precipitation

A review of available rainfall data from the mid 1800's kept by the Yuba Canal Company indicates that the average annual rainfall for the Nevada City area has not changed significantly from what it is today. Figure 4 below shows the annual rainfall from 1967-2004 with an average of 58 inches per year, which is the same as the average in the mid 1800s. Rainfall is assumed to have been concentrated between the months of November and April, as it is today. The daily average rainfall is shown in Figure 5 below.

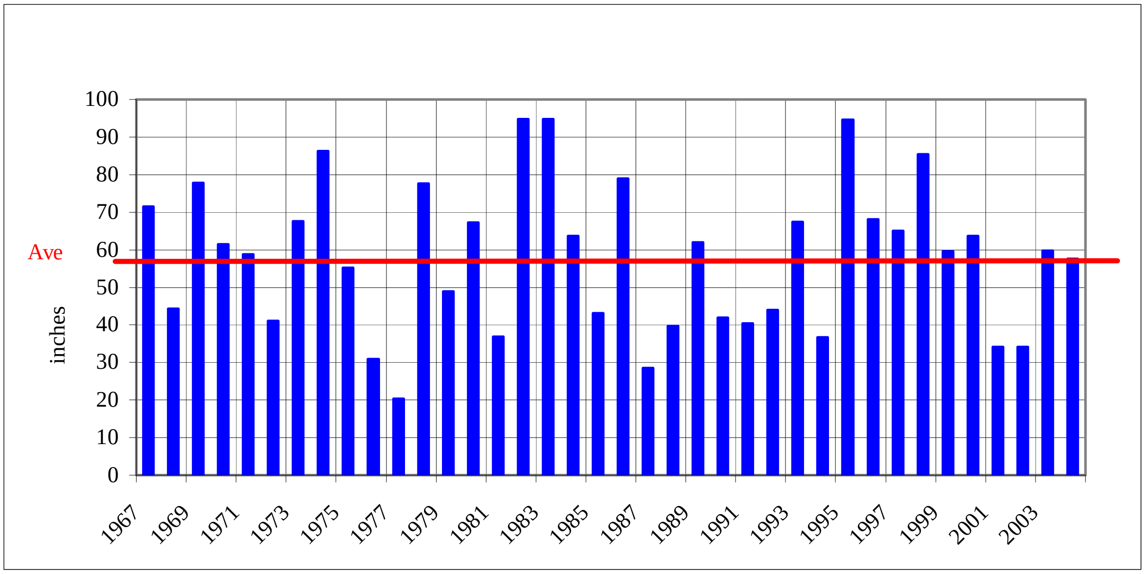


Figure 4: Annual Nevada City Precipitation, 1967 to 2004

Figure 5: Nevada City Average Daily Precipitation, 1967 to 2004

Hydrology

No information describing the hydrologic or geomorphic conditions of Deer Creek prior to extensive modification of the watershed was found. Because Oregon Creek, a tributary to the Middle Yuba River, is similar to the upper portions of the Deer Creek watershed in many respects (*e.g.,* size, shape, orientation, elevation and vegetation), it is a useful proxy to estimate Deer Creek flows under more natural conditions. USGS gauge 11409300 captures 23 mi^2 of the Oregon Creek watershed, similar to the 22 mi^2 area above the Scotts Flat reservoir. Since approximately 1970, NID has been estimating natural inflows from Deer Creek into Scotts Flat reservoir. Figure 6 shows average daily Oregon Creek and Scotts Flat inflows.

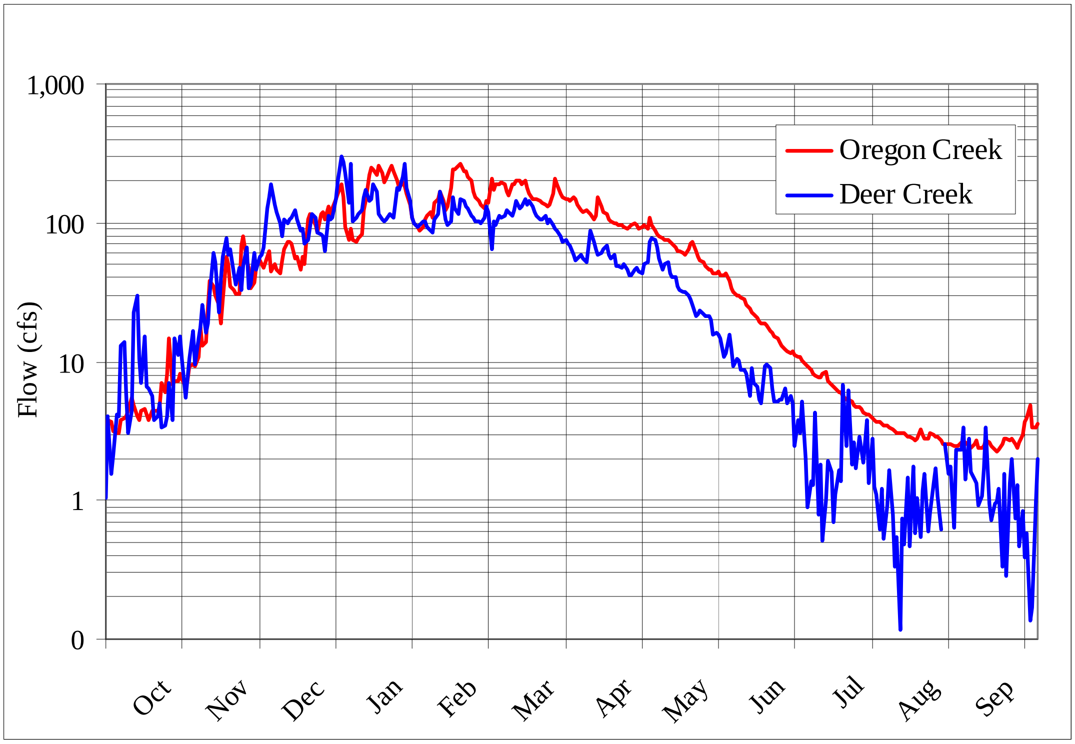


Figure 6: Average Daily Flows in Deer Creek (into Scotts Flat) and in Oregon Creek at Camptonville (USGS gauge 11409300 1967-2002)

One can see that the flows are fairly similar in magnitude and timing, with Oregon Creek exhibiting slightly higher flows from mid January through the summer months (Figure 6). Deer Creek appears to experience lower and more variable summer flows, but NID's method of estimating Deer Creek inflows is less accurate at lower flow levels.

C. Anthropogenic Modifications

The Deer Creek watershed has experienced a variety of human activities that have caused significant impacts to the landscape. Although the Native American residents undoubtedly affected the environment, it was the advent of hydraulic and placer gold mining that began a period of transformation of the landscape that continues today.

Mining

The discovery of gold in the Sierra foothills dramatically changed the land and waterscape in ways that we are still addressing. Compared to the present day population of Nevada City of approximately 3,000 people, in the 1850's, the population of Nevada City was roughly 5,000-10,000 people.

Extensive mining activities in the area affected Deer Creek geomorphology dramatically. As Figure 7 illustrates, Deer Creek produced approximately 25 million cubic meters of sediment (A), which is equivalent to removing almost 13 centimeters of material across the entire watershed (B) (James, 1999). The advent of hydraulic gold mining in the 1850's was followed by rapid and voluminous sediment production and widespread channel aggradation (James, 1999), particularly in the lower-gradient stretches of Deer Creek. While much of the material produced in 19th and 20th century mining has been distributed far downstream by now, significant amounts of sediment are likely still stored in the main channel and tributaries to Deer Creek. Certain lower-gradient reaches downstream of Nevada City appear to have experienced significant deposition of sediment many years ago.

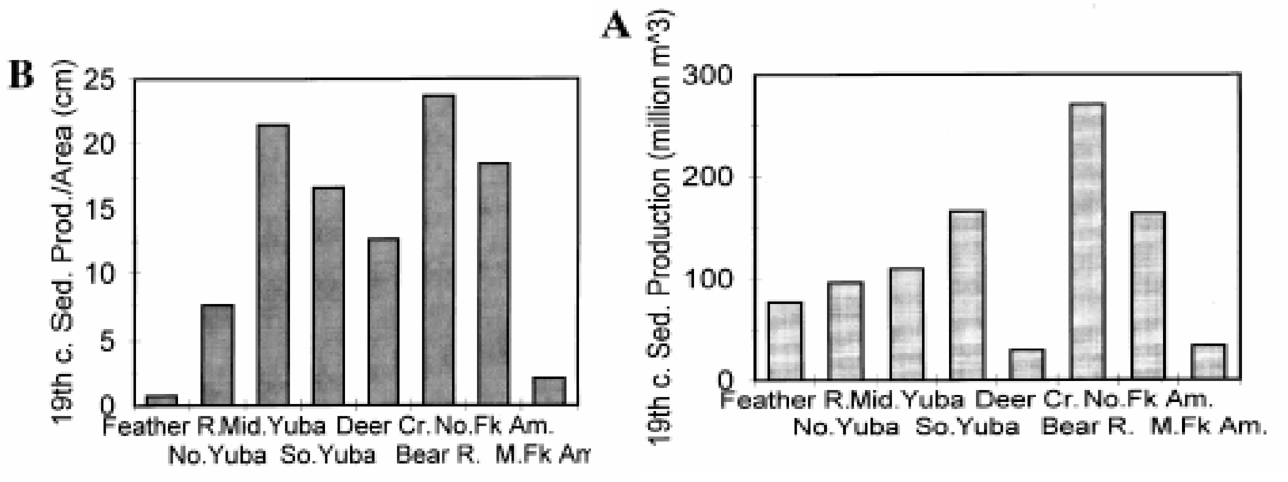
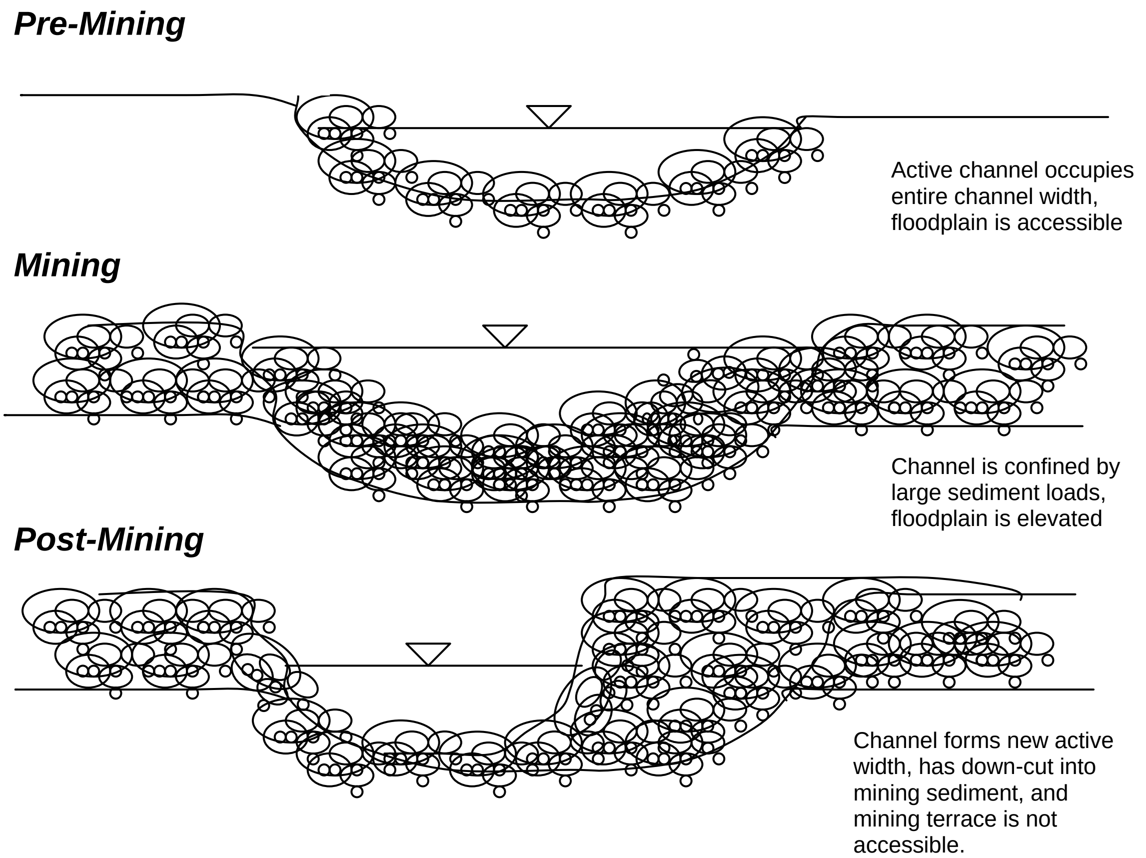


Figure 7: Amount and Depth of Sediment Produced During Mining Era (James 1999)

Since the cessation of mining and the construction of Scotts Flat dams, it appears the creek has eroded through these mining sediment deposits by as much as 20 feet in certain areas.

Below is a conceptual diagram (Figure 8) that illustrates the evolution of a Deer Creek cross-section from pre-mining through post-mining.



Active channel occupies entire channel width, floodplain is accessible

Channel is confined by large sediment loads, floodplain is elevated

Channel forms new active width, has down-cut into mining sediment, and mining terrace is not accessible.

Figure 8: A Conceptual Diagram of a Three Channel Cross-Sections: 1) Pre-Mining, 2) During the Mining Era, and 3) Post Mining

Dams, Flow Regulation and Diversions

Deer Creek serves as a key component of NID's network of canals, pipelines and natural channels that delivers water to its customers throughout the year. There are three large dams and reservoirs on Deer Creek, the characteristics of which are shown in Table 1. There are also numerous diversion dams on Deer Creek, as shown in Figure 9. These diversion dams serve NID's water distribution network.

Dam	Location	Owner	Year Built	Height
Scotts Flat Dam	RM 23	NID	1928	92
Deer Creek Dam (Lower Scotts Flat)	RM 21.5	NID	1948	175
Anthony House Dam (Lake Wildwood)	RM 3.9	Lake Wildwood Association	1970	75

Table 1: Large Dams on Deer Creek

Figure 9: Location of NID diversions on Deer Creek.

Deer Creek receives and transports natural runoff and 62,000 acre-feet of water imported from the South Yuba River through the South Yuba Canal, which enters Deer Creek through PG&E's Deer Creek Powerhouse upstream of Scotts Flat Reservoir. A portion of this imported water and natural runoff is diverted into the Cascade Canal and delivered to NID's water treatment plant south of Nevada City on Banner Mountain. The remaining flow is temporarily stored in Scotts Flat and Lower Scotts Flat reservoirs. The D-S Canal diverts water directly from lower Scotts Flat reservoir, and a portion of the D-S canal flow is also diverted into the Snow Mountain Ditch, which is delivered to areas north and east of Nevada City. NID releases water into Deer Creek to deliver water to the Newtown Canal, just downstream of Nevada City, and eventually the Tunnel Canal four miles upstream of Lake Wildwood (See also Appendix B for daily flow data for each of NID's canals).

NID operates its water supply system in two periods each year, a "winter season" typically from mid- October to mid-April, and an "irrigation season" typically from mid-April to mid-October. In late October each year, Scotts Flat reservoir storage levels usually reach their lowest and imports from the South Yuba typically have reduced to 35 cfs. NID begins to refill the reservoir during fall and early winter as natural runoff increases (See Figure 10). In wet years, Scotts Flat can fill as early as November, while in dry years Scotts Flat will not fill until as late as March, and sometimes only then with significant imports from the South Yuba (S. Sindt, pers. comm.).

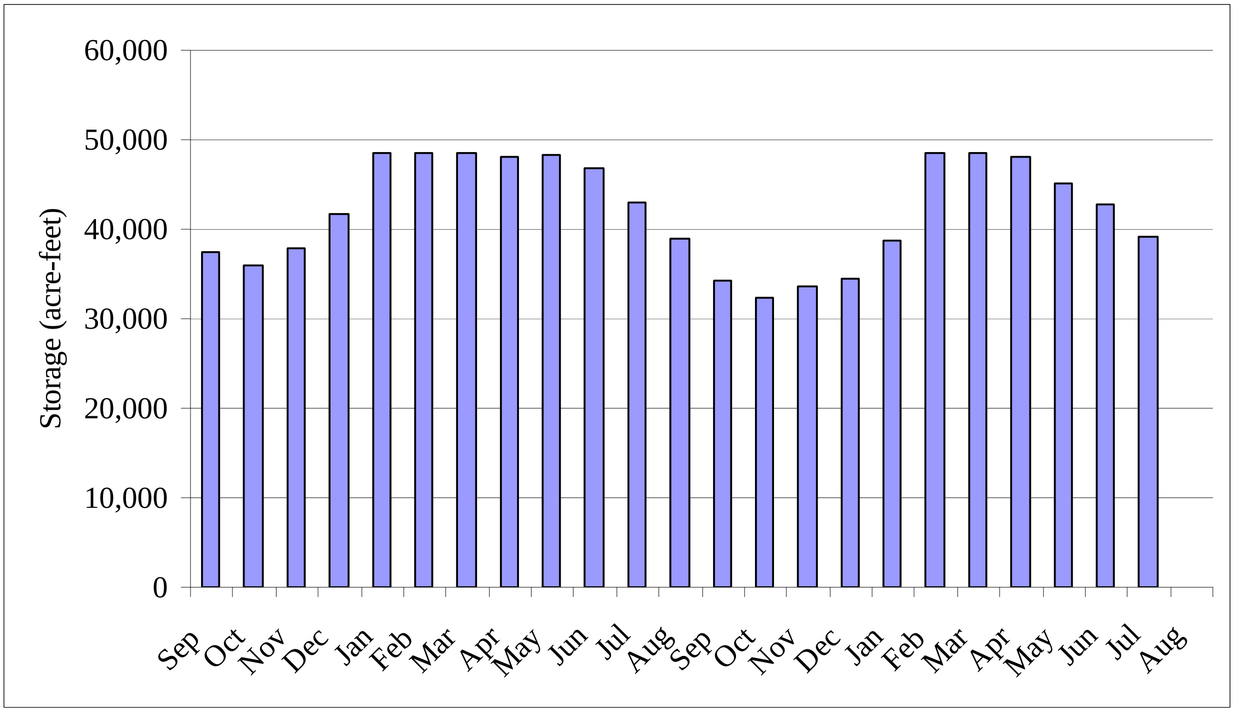


Figure 10: Typical End of Month Storage Levels in Scotts Flat Reservoir

As discussed in more detail below, NID's facilities and operations dramatically alter natural flows in Upper Deer Creek. Peak flow levels in winter are significantly reduced, and summer flow levels are increased. These modifications have important implications for Deer Creek geomorphology and ecology.

The hydrology of Deer Creek has changed dramatically compared to its historic pre-mining character. With the operation of PG&E and NID dams, diversions and inter-basin water transfers, Deer Creek no longer experiences the hydrologic variability it once did and a significantly greater amount of water flows through the system. The construction of Scotts Flat Dam in 1928 eliminated the sediment supply from upstream, which was likely unnaturally high as a result of hydraulic mining in Scotts Flat and above. With the reduced sediment supply, Deer Creek likely eroded its channel bed, which was unnaturally elevated as a result of the oversupply of sediments from hydraulic mining. Deer Creek is still responding to the mining activities of the previous two centuries.

Development

Between 1965 and 2001, the population in Nevada County nearly quadrupled, from 25,100 to 94,361 (Walker et. al., 2003), one fourth of which lives in the Deer Creek watershed. These approximately 25,000 residents live mainly in Nevada City, Lake Wildwood and the Penn Valley areas (Census Bureau, 2000). By 2050, the population is expected to increase to over 160,000 (Landis and Reilly, 2003), and the Deer Creek watershed will receive a portion of that growth. As discussed more fully below, development can cause significant changes to all aspects of a creek ecosystem.

Timber Harvest

Logging can cause significant adverse impacts to stream ecosystems. Timber harvests can affect aquatic systems by increasing the sediment load, decreasing coarse particulate organic matter and removing canopy cover which results in more extreme temperature fluctuations and a shift from a heterotrophic community to an autotrophic community. Historic photographs indicate that much of the land in the Deer Creek watershed was logged from the 1850s to the early 1900s (Figure 11).

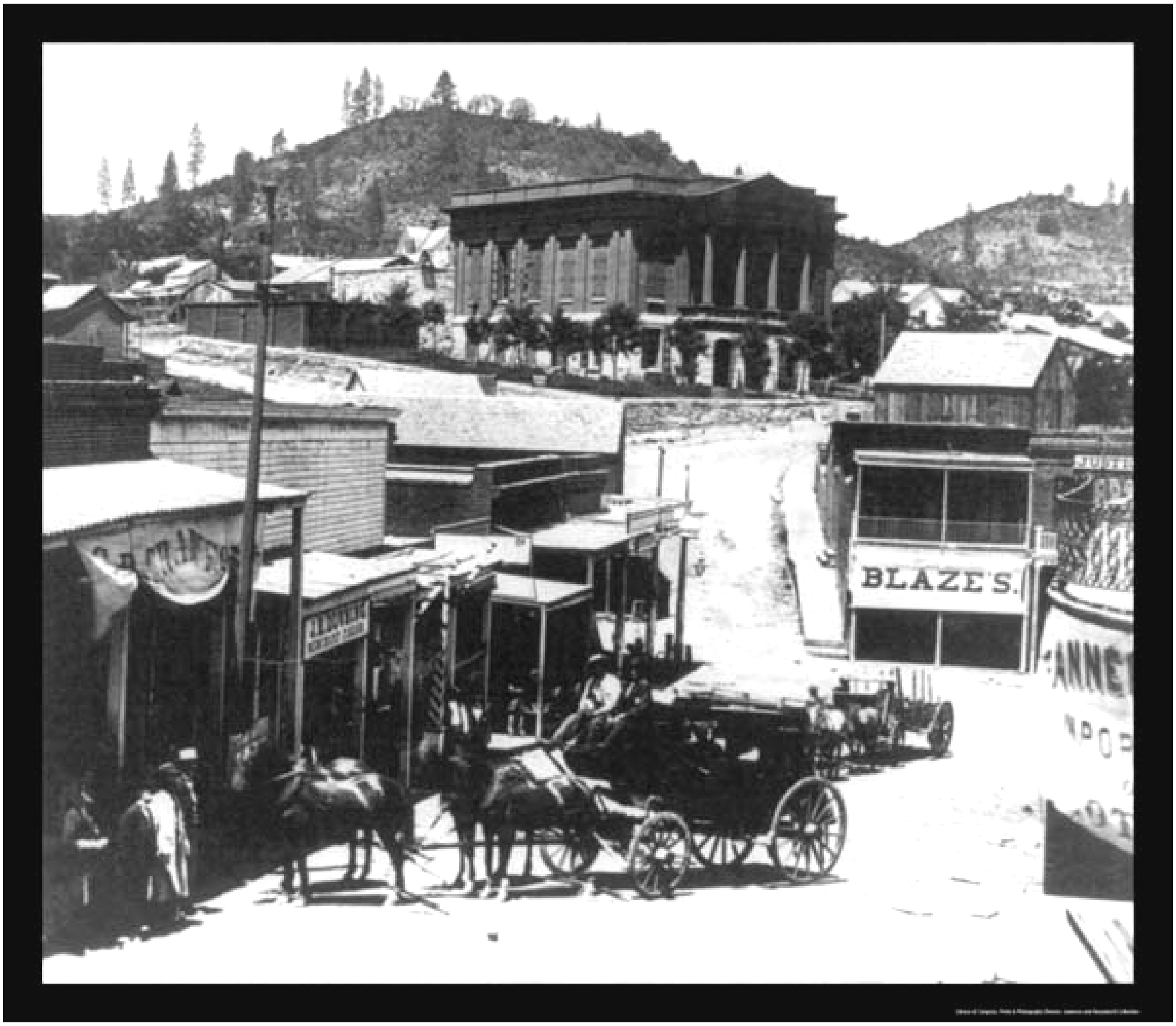


Figure 11: Photo of Nevada City and hills behind show extent of logging, circa 1890.

Since 1990, Nevada County has supplied each year less than 3 percent of the state's total timber harvest of between 1.5 and 3.0 million board feet (CA Board of Equalization, 2004). Typically less than 20% of the county's timber harvest has come from public lands. An analysis of recent aerial photos indicates that ongoing timber harvests in the Deer Creek watershed are primarily concentrated on Tahoe National Forest lands above Scotts Flat, although some logging is occurring on relatively small private parcels below Scotts Flat (Figure 12).

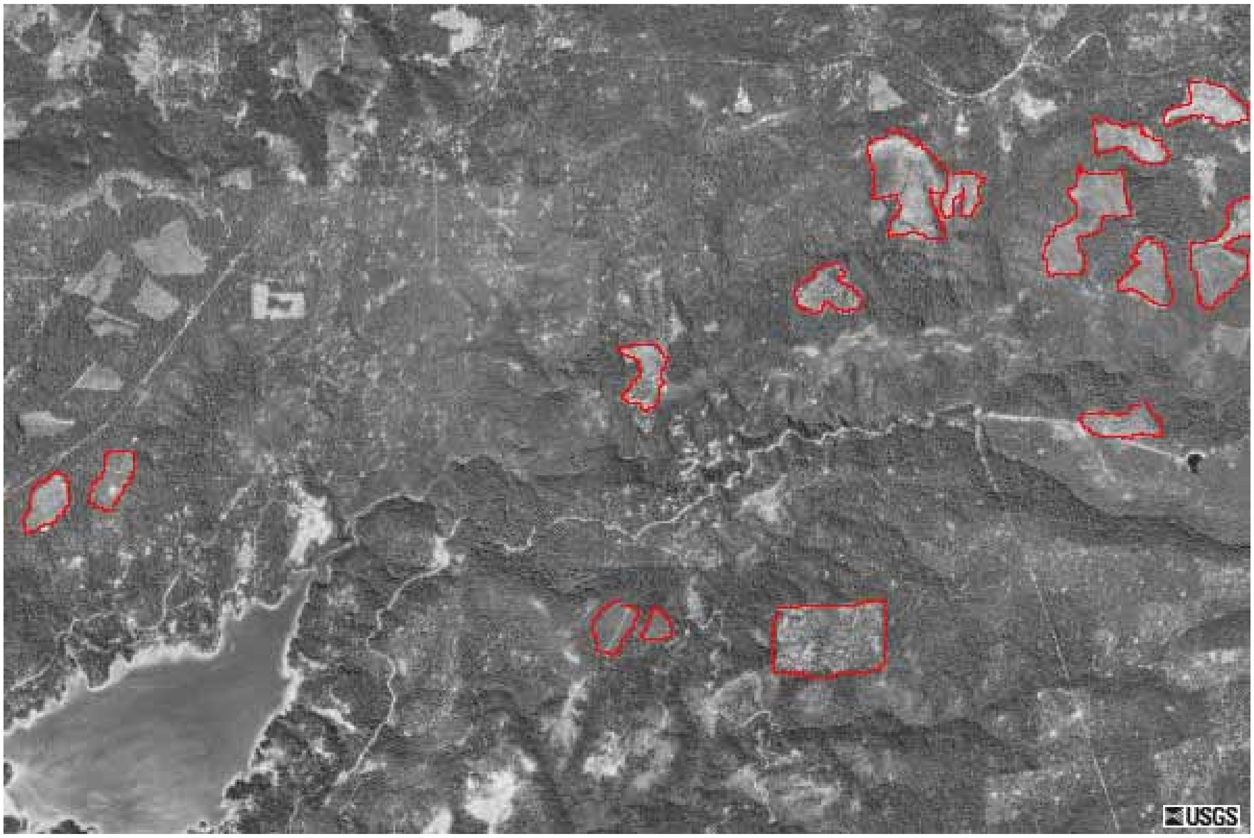


Figure 12: 1998 Aerial Photo Showing Recently Logged Areas above Scotts Flat

CHAPTER III:
UNDERSTANDING DEER CREEK HYDROLOGY

The following three chapters focus on understanding the hydrology, geomorphology, and ecology of Upper Deer Creek. For each of the sections, we describe the state of knowledge and gaps in our understanding. Data collected as part of our analysis and field assessment is included. These chapters provide a baseline for describing available data and understanding and also serving as the basis of our restoration and management recommendations.

A. Stream Flow Gauges

Only one real-time streamflow gauge exists on the mainstem of Deer Creek, located at river mile 0.4, below Lake Wildwood (see Figure 13). The period of record of this and other gauge data used in this report are shown in Table 2.

Gauge Number	Gauge Location	Period of Record
USGS 11418500	Deer Creek near Smartville (RM 0.4)	10/1/1911 – present
USGS 11409300	Oregon Creek near Camptonville (RM 5.1)	10/1/1967 – 4/21/2001
USGS 11409400	Oregon Creek (RM 3.4)	1/20/1969 – present
USGS 11409500	Oregon Creek near Hwy 49 (RM 0.4)	04/04/1911 – 01/20/1969

Table 2: Streamflow Gauges and Periods of Record

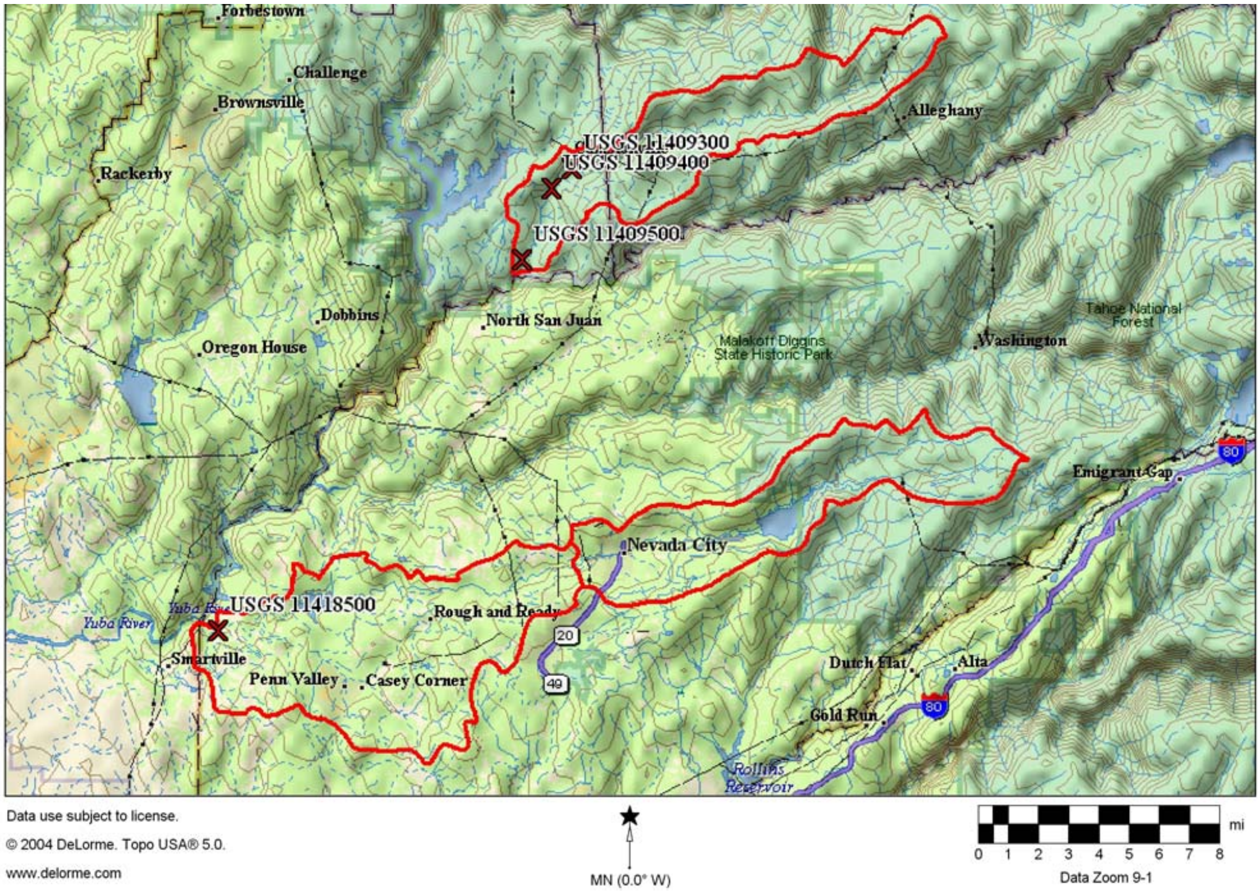


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Figure 13: Locations of USGS Streamflow Gauges on Deer Creek and Oregon Creek

As part of this project, two staff gauges were installed on Deer Creek, one located approximately 1.5 miles downstream of Nevada City at RM 16 (N39, 15', 22.9", W121, 2', 40"), the other located approximately 0.5 miles upstream of Nevada City at RM 17.8 (N39, 15' 50.5"; W121, 0' 40").

B. Variation in Flows

Hydrologic regimes play a significant role in determining the biotic composition, structure and function of aquatic and riparian ecosystems (Richter et. al., 1996). Intra-annual variation in flows is essential to lifecycle success of many aquatic and riparian organisms because it influences reproductive success, natural disturbance and biotic competition (Poff and Ward, 1990). Modification of hydrologic regimes can indirectly alter the composition, structure and function of aquatic and riparian ecosystems by changing the physical habitat characteristics such as water temperature, oxygen content, water chemistry and substrate particle size (National Research Council, 1992; Sparks, 1992). In this section, we analyze modifications to Deer Creek hydrology and their impact on ecosystem function.

Hydrologic regimes exhibit five fundamental characteristics:

- *Magnitude of flows* – can determine the availability and suitability of habitat;
- *Timing of flows* – can determine the life-cycle success or degree of stress or mortality of aquatic and riparian organisms;
- *Frequency of flow events* – can affect population dynamics by influencing reproduction or mortality events;

- *Duration of flow conditions* – may determine whether a certain life-cycle can be completed or the degree to which stressful effects such as inundation or desiccation accumulate;
- *Rate of change of flows* – can affect the stranding of certain organisms or the ability of plant roots to maintain contact with water in soils.

The higher portions of the Deer Creek watershed receive approximately 60 inches of precipitation each year while the lower elevations receive roughly 50 inches. Although a portion of the precipitation falls as snow each year, typically above 2500 ft, the hydrograph is dominated by rainfall events (see Figure 14).

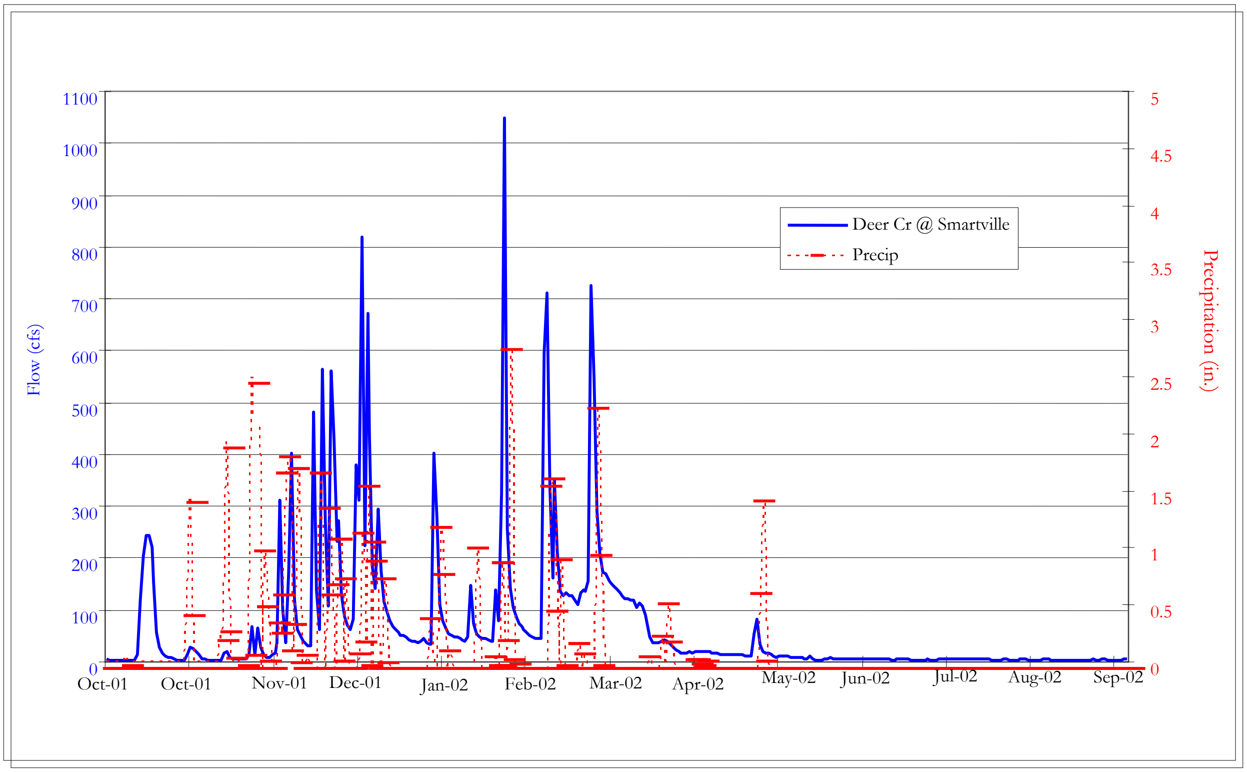

Figure 14: Water-Year 2001 Precipitation at Nevada City and Deer Creek Streamflow at Smartville (USGS 11418500)

Storms that cause rain to fall on snow typically generate the higher flows each year. For example, Figure 14 shows the highest flow in Water Year (WY) 2001 of 1050 cfs at Smartville (USGS 11418500) occurred in early February when 2.3 inches of rain fell on several inches of snow that had accumulated in the upper watershed above 3500 ft elevation.

Nevada Irrigation District estimates “natural” flow into Scotts Flat reservoir by monitoring reservoir storage levels, volume of imported water from the South Yuba River and water deliveries from Scotts Flat. Estimates are made on a daily basis, and monthly average flow estimates are shown in Figure 15.

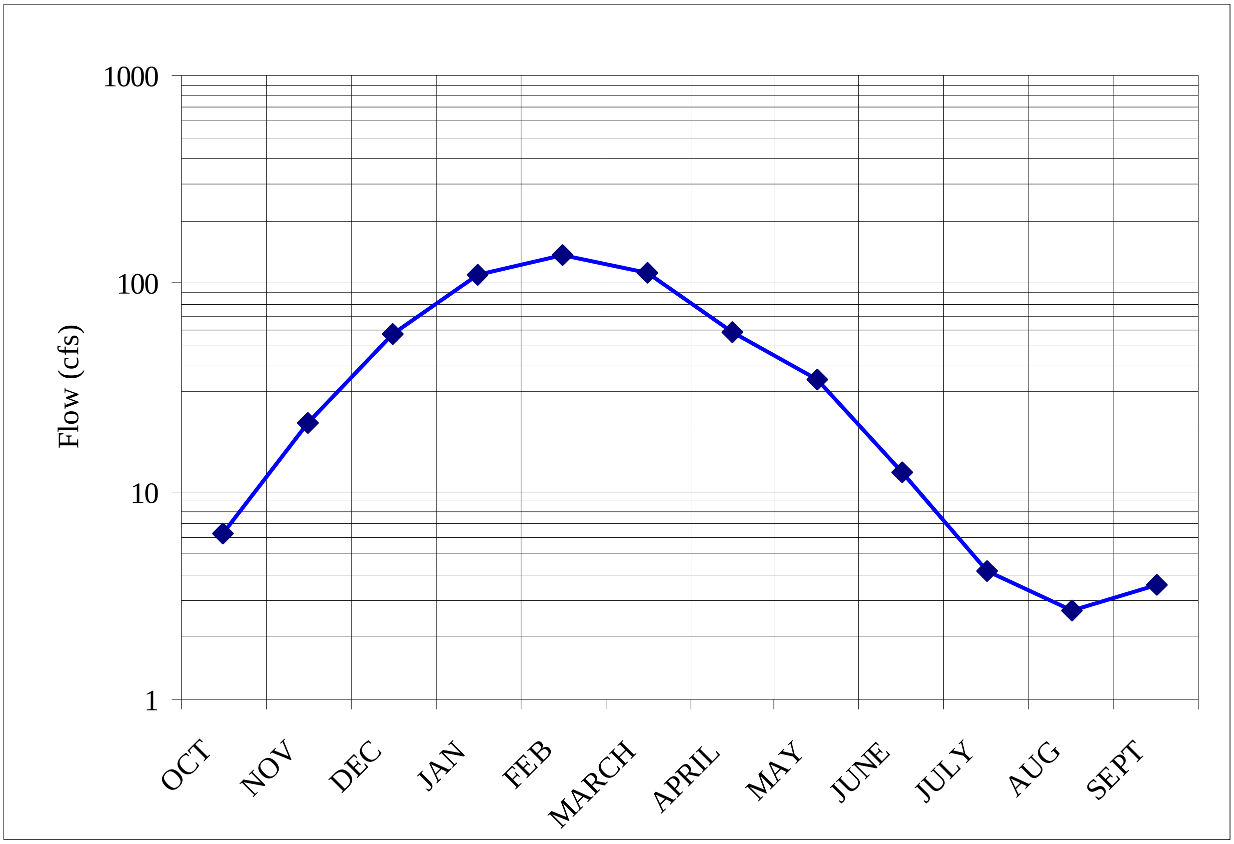

Figure 15: Average Monthly "natural" Flow into Scotts Flat Reservoir (NID data 1984-2004)

NID dams and water supply operations on Deer Creek substantially affect many of the fundamental characteristics of Deer Creek hydrology. Generally, the magnitude and frequency of flood flows in the 2-25 year recurrence intervals are reduced by the regulating effect of the two Scotts Flat reservoirs. Flood flows greater than the 25-year return interval appear not to be affected significantly by Scotts Flat. The magnitude of summer flows is higher and the duration longer and more consistent than would be experienced without the dams and water supply system.

In particular, the analysis of Upper Deer Creek hydrology focused on the magnitude and frequency of high flows and low flows. High flows were analyzed because peak flow events determine the geomorphic template of Deer Creek, and summer flows were analyzed because low flow conditions can have a significant impact on aquatic and riparian communities by creating ecological stressors or complete barriers to survival (*e.g.,* low dissolved oxygen, high water temperatures, and low water table).

High Flows

We analyzed the magnitude and timing of peak flood flows under current conditions, and under hypothetical conditions unaffected by NID dams. To determine the magnitude of current flood flows, a flood frequency analysis was performed of NID data related to occurrences of uncontrolled spill and controlled discharges from the Scotts Flat complex (NID, 2005). To determine the degree to which NID facilities and operations have altered flood flows, several methods were used to estimate the magnitude of flows that would be expected without dams on Deer Creek. Below is a summary of the five methods used.

1) Analysis of NID estimates of Deer Creek flows into Scotts Flat reservoir and data on uncontrolled spill and controlled releases from Scotts Flat

2) Flow estimates based on equations of Waananen and Crippen (1977) that predict flows based on watershed area, elevation and average annual rainfall and equations of Hedman and W.R. Osterkamp (1982) that predict flows based on the size of a stream's active channel

3) Estimates of runoff per watershed area based on surveys of the key tributaries and application of equations that relate channel geometry and area to estimated flood flows, *e.g.,*, the "Mannings equation" (Limerinos, 1898), Waananen and Crippen (1977) and Hedman and Osterkamp (1982). The results of this analysis are listed in Table 3

4) Analysis of USGS streamflow gauge records for Oregon Creek, used as a proxy for unimpaired Deer Creek flows in the Nevada City area. Oregon Creek and Deer Creek share many important characteristics

5) Analysis of USGS gauge records for Deer Creek near the confluence with the Yuba River

Methods 1 and 2 appear to be less accurate than methods 3, 4 and 5. Therefore, the Deer Creek Assessment and Restoration Plan relies on estimated flows using methods 3-5 to represent unaltered flood flows to compare with existing NID data as shown in Table 3.

Location	**Method/Source**	**2-yr** (cfs)	**5-yr** (cfs)	**10-yr** (cfs)	**25-yr** (cfs)	**50-yr** (cfs)	**100-yr** (cfs)
Releases from Scotts Flat	NID data	207	900	1,167	4,500	6,000	8,000
Estimated Inflow into Scotts Flat	NID data	600	1800	2500	n/a	n/a	n/a
Expected Flows out of Scotts Flat	Average of Methods 3, 4 and 5	1,286	2,248	3,189	4,838	7,390	9,366
Nev. City WWTP area = 32 mi^2	Average of Methods 3, 4 and 5	1,600	2,989	4,021	6,405	7,365	9,880
Smartville, area = 84.4 mi^2	USGS records, gauge no. 11418500	5,410	7,550	9,410	11,600	12,000	15,000

Table 3: Comparison of Peak Flows at Scotts Flat, Nevada City, and Smartville

Table 3 shows that Scotts Flat dam dramatically reduces flow levels for the 2-yr, 5-yr and 10-yr flood events. (A "2-yr flow" event is a flow of a magnitude that is statistically expected to occur once every two years based on the available flow record. A "5-yr flow" would be expected to occur once every five years, on average, and so on up to the 100-yr event.) It is not until the 25-yr flow that Scotts Flat releases fall within the range of estimates of inflow to Scotts Flat and expected unaltered flows. NID generally captures all inflow to Scotts Flat from approximately mid-November until Scotts Flat fills completely, which can be as late as March (S. Sindt, pers. comm.). Therefore, unless a flow event of significant magnitude occurs after Scotts Flat has filled, the contribution of flow from the watershed above Scotts Flat (25 percent of total watershed area) into Deer Creek is eliminated. The resulting reduction in peak flows would be most pronounced immediately below Scotts Flat, and would diminish progressively moving downstream as tributaries contribute unimpaired peak flows. The significance of reduced flood peaks is discussed below in Chapter IV.

Low Flows
Two methods were used to estimate low flows in Upper Deer Creek. The first employs NID's estimates of "natural flows," and the second uses Oregon Creek flow data as a proxy.

Method 1. Analysis of NID "Natural Flow" data – Since 1972, NID has estimated the amount of natural runoff it receives from upper Deer Creek into Scotts Flat reservoir by determining the increase in Scotts Flat storage that cannot be attributed to imports from the South Yuba River. These estimates are made approximately every day by monitoring the change of storage in Scotts Flat, the measured volume of transfers into the reservoir from the South Yuba River through the South Yuba Canal, and the releases from the Scotts Flat complex into the D-S Canal and also into Deer Creek. It is unlikely that this method produces accurate estimates of low flows. For example, NID data indicate inflows can remain zero for many days in summer, then jump up to 5 or 10 cfs for one or two days, then drop back to zero. These rapid pulses of flow do not correspond to rainfall events.

Applying this formula to the 30-plus years of data NID has collected suggests that under natural conditions Deer Creek flows at Scotts Flat that would have dropped to less than 5 cfs in most years, and less than 1 cfs in drier years (Figure 16), although these low flow estimates may have substantial error. It is likely that natural flows below Scotts Flat would have been higher than this as a result of contributions from numerous perrenial tributaries and a much larger watershed area.

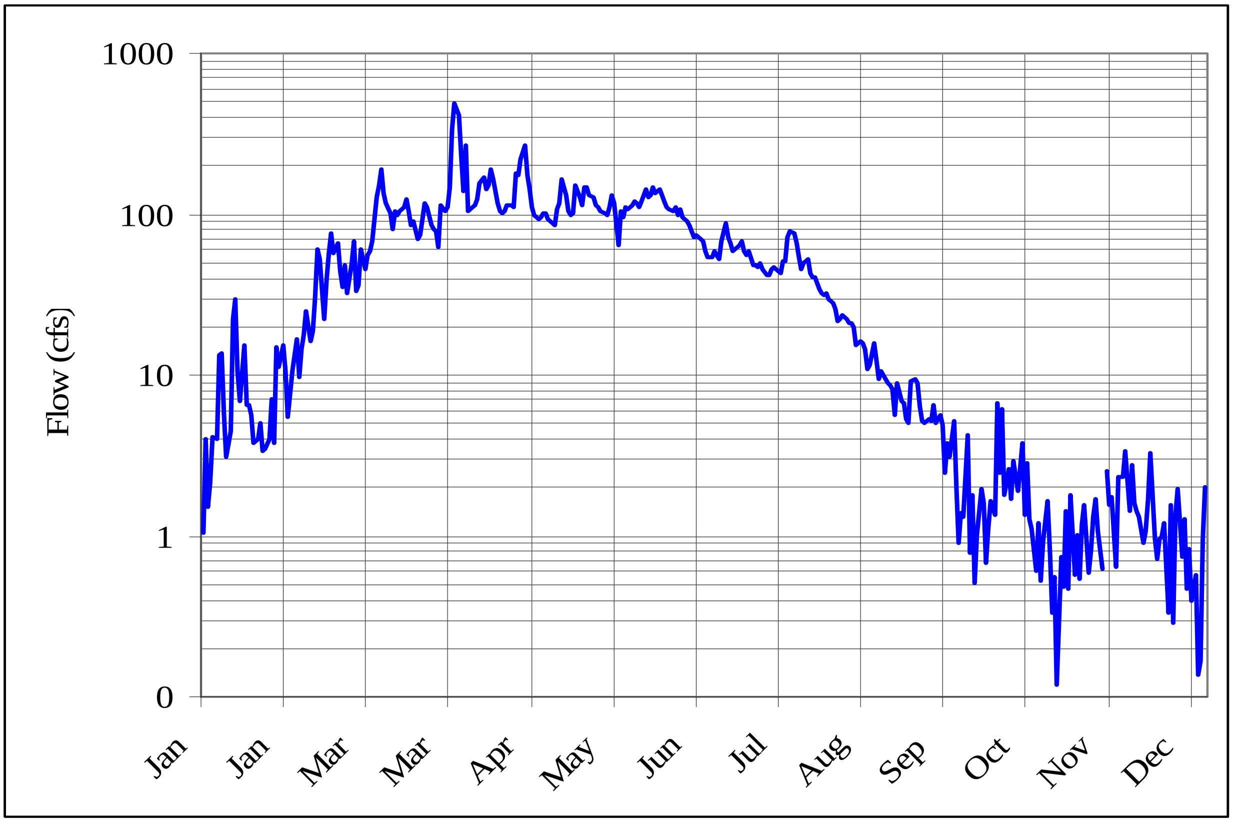

Figure 16: 30-year Average of NID Estimates of Natural Inflow into Scotts Flat

Because NID uses Deer Creek to deliver water from Scotts Flat to the Newtown and Tunnel canals, summer flows are artificially high. Between Scotts Flat and the Newtown Canal diversion dam (4.5 mi.) flows are approximately 20-30 cfs during the irrigation season, and from the Newtown Canal diversion to Tunnel Canal diversion dam (~8 mi.) flows typically do not drop much below 10 cfs between mid-April and mid-October. From here, NID diverts much of the flow into the Tunnel Canal. Summer flows in the approximately 4 mi. from the Tunnel canal to Lake Wildwood are approximately 4 cfs (S. Sindt, pers. comm.)

Method 2. Oregon Creek flows as proxy – Because Oregon Creek is so similar to the upper portions of Deer Creek, it is a useful proxy to estimate Deer Creek low flows in the upper quarter of the watershed under more natural conditions. USGS gauge 11409300 captures 23 mi^2 of the Oregon Creek watershed, similar to the 22 mi^2 area above the Scotts Flat Reservoir. Figure 17 below shows average daily flow levels for Oregon Creek at USGS gauge 11409300 over a 35-year period from 1967 to 2002. The 5th Percentile curve represents the lowest 5% of daily flows for each date averaged over the 35-year record, *i.e.*, 95% of flows for each day were above those in the 5th Percentile curve. The 50th Percentile curve is roughly equivalent to the average of flow value for that date over the 35-year period.

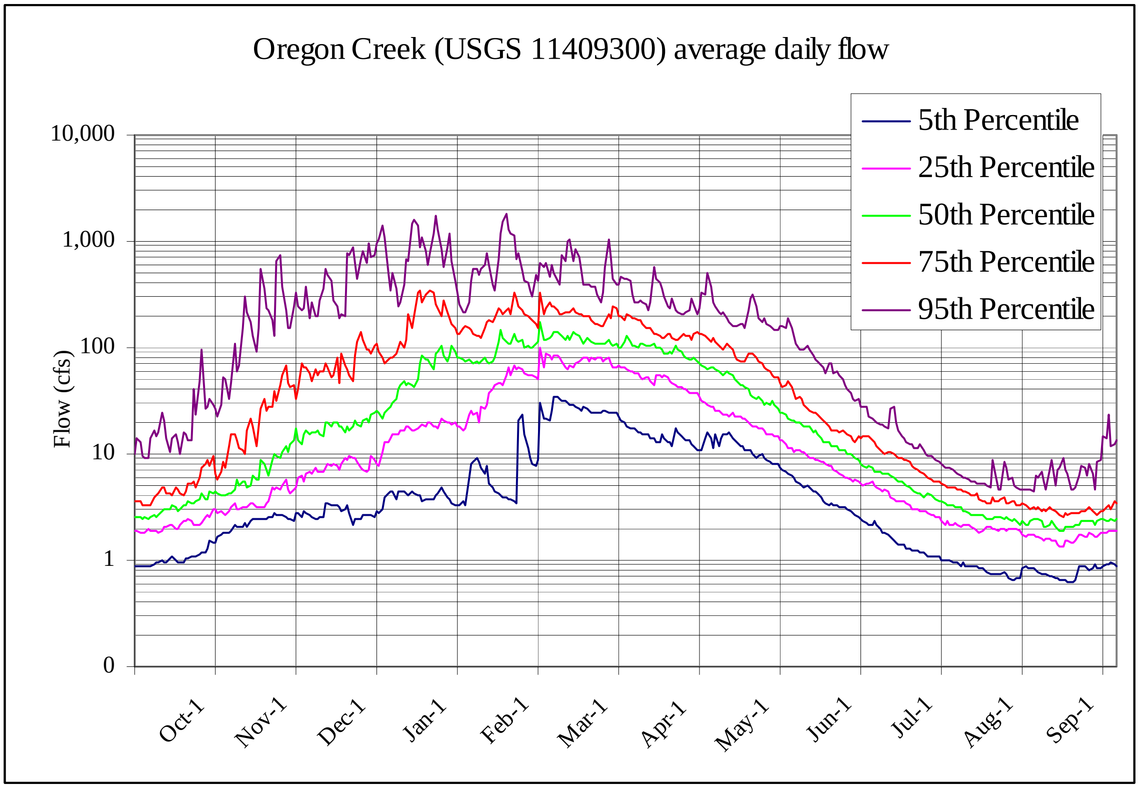

Figure 17: Oregon Creek Average Daily Flows at USGS gauge 11409300

One can see that from late August through early October, flows average approximately 2 cfs and it is not uncommon to experience flows below 1 cfs in drier years as evidenced by the 5th Percentile flow curve. Given that these figures represent averages over the 35-year flow record, it seems likely that surface flows occasionally reduced to a trickle in Oregon Creek in the driest years. The deeper pools, however, likely would not dry up even in the driest years. Even in average (50th percentile) and wetter years (75th percentile) flows routinely dropped to between 2-3 cfs in August and September. It seems reasonable to expect, therefore, that without NID's facilities and operations, Deer Creek above Scotts Flat would experience flows in the 2-5 cfs range during August and September in average years, less than 1 cfs in drier years, and occasionally no surface flow in critically dry years. Lower in the watershed, summer low flows were likely higher than those estimated for the Scotts Flat area of the creek.

As mentioned above, hydrologic conditions create stressors or even barriers for certain aquatic organisms. The high temperatures and low oxygen levels typically associated with low flow conditions in Deer Creek could play this role. However, the current state of the Deer Creek watershed could significantly exacerbate the strain on organisms in low flow conditions. Below Scotts Flat Deer Creek has few deep pools to mitigate the impact of low flows on aquatic life, since there is still so much mining debris in many areas of the channel. Elevated levels of nutrients in the water that result from wastewater treatment facility return flows or agricultural runoff promote excessive algal growth at low flows. Such algal blooms result in dramatic fluctuations in dissolved oxygen levels, with the possibility of periods with absolutely no oxygen in the water column. Such anaerobic conditions can kill all members of fish or macroinvertebrate populations. Under less disturbed conditions, it is likely that aquatic organisms could have endured low flow periods more easily.

C. Need for Further Study and Recommendations

In general, due to inadequate gauging, we have a very incomplete picture of the hydrology of Upper Deer Creek. Through various methods described above, we have been able to compile an initial understanding, but we have identified several needs for further study to better understand the hydrology of Upper Deer Creek. First, flow gauges should be installed in several locations on Deer Creek. Ideally, gauge sites would include:

- Above Scotts Flat to measure natural inflow;
- Above Willow Valley or Mosquito creeks to measure flows before inputs from these tributaries;
- Above Little Deer Creek and immediately below Nevada City to monitor runoff from the city;
- At two or more locations between Nevada City and Lake Wildwood to better understand tributary inputs; and
- On the major tributaries such as Little Deer Creek, Gold Run Creek, and Slate Creek.

If gauge sites had to be prioritized, the locations above and below Nevada City would be among the most important to install first.

Second, it would be useful to compare the timing, both seasonally and between years, of peak flows occurring in Oregon Creek and Deer Creek to better understand the impact of Scotts Flat on peak flows in Deer Creek. In addition, in order to understand the full range of natural flow variability within Upper Deer Creek, it would be useful to have automated hourly flow and precipitation loggers at several locations to determine rate of change of flows, duration, and magnitude, as well as to understand rainfall-runoff relationships.

While it is difficult to recommend exact flow levels that would help restore Deer Creek, general parameters for flow should incorporate elements of the natural flow regime, while taking into account ways to compensate for other present-day stressors that cannot be eliminated, such as urban runoff, increased nutrient and other pollutant inputs. Rapid growth of residential and urban development are predicted to continue, adding additional future stressors to the creek. A "restoration flow regime" would include some greater winter pulse releases to clean out the channel and maintain floodplain complexity, and *in the absence of the additional current anthropogenic stressors*, some moderately low summer flows through the whole watershed. The lower watershed, below Lake Wildwood, is listed under the Clean Water Act as impaired due to pH spikes from algae blooms caused by nutrient loading, low flows and high temperatures. With increasing demand for NID water, attempting to reduce summer flows in the upper watershed would likely have severe consequences for this highly stressed lower reach. Higher summer flows on upper Deer Creek, at least at the current level, may actually be a good thing for the mid section of Deer Creek, since they currently reduce temperatures, help dilute pollutants and control algae blooms, support cold water fish and a healthy macroinvertebrate population. Given the current and future anthropogenic stressors to Deer Creek biota, "restoring" the lowest natural flows would probably not be healthy for the creek. Flood flows, and their relationship to geomorphic function, are discussed in the following chapter.

CHAPTER IV:
UNDERSTANDING DEER CREEK GEOMORPHOLOGY

As mentioned in Chapter I, understanding geomorphic processes and how they vary along Deer Creek is critical to the Deer Creek Assessment and Restoration Plan because geomorphic processes drive the form of the creek channel and floodplains, which in turn influence in-stream and floodplain habitat, riparian vegetation, water quality, biota and many other important stream qualities

(National Research Council, 1992). To restore and maintain healthy aquatic and riparian ecosystems successfully, restoration efforts must recreate the physical conditions necessary to support natural biotic communities (Gore, 1985).

A. Geomorphic Attributes of Upper Deer Creek

It is important to recognize that Deer Creek exhibits reaches typical of a classic Sierra bedrock river, (McBain and Trush, 2004) and reaches characteristic of an alluvial river (Trush et. al., 2000). Steep, bedrock reaches are often followed by more gradually sloped reaches where significant alluvial features can be found for great distances (see Appendix C for maps of morphological types). A common misperception of bedrock rivers is that the channel morphology is static, and thus unaffected by changes to flow and sediment supply. But bedrock rivers are often dynamic depositional environments too. Deposition occurs within a confining, rigid bedrock framework that exhibits a bedrock template of pools and riffles.

This bedrock framework provides complex hydraulic controls that create diverse nested depositional features ranging from formations of large boulders to fine sand deposits. These depositional areas are important because the richness of biological communities in Sierra Nevada river ecosystems depends in part on the complexity created by these depositional features and processes. Sierra bedrock rivers have the following attributes of properly functioning bedrock river reaches (McBain and Trush, 2004):

1. Bedrock rivers exhibit nested depositional features;
2. Bedrock river ecosystems require variable annual hydrographs;
3. Episodic sediment delivery enhances spatial complexity;
4. Bedrock channel maintenance requires multiple flow thresholds;
5. Maintenance of depositional features is partially independent of bedload transport capacity;
6. Biological hotspots occur at highly depositional reaches;
7. Hydraulic pathways in the river corridor fluctuate seasonally and annually.

Several attributes of properly functioning alluvial river reaches have been identified that can help identify desired processes and develop management actions to restore or maintain healthy functions for Deer Creek. Trush et. al. (2000) identified 10 such attributes, the following seven of which are most relevant to the Deer Creek:

1. Each annual hydrograph component accomplishes specific geomorphic and ecological functions.
2. The channel bed surface is frequently mobilized.
3. Alternate bars must be periodically scoured deeper than their coarse surface layers.
4. Alluvial channels are free to migrate.
5. Floodplains are frequently inundated.
6. Large floods create and sustain a complex mainstem and floodplain morphology.
7. Diverse riparian plant communities are sustained by the natural occurrence of annual hydrograph components.

Each of these attributes is a function of the relationship between the hydrologic and geomorphic conditions of the river. The hydrologic patterns necessary to understand this relationship in Deer

Creek has been described above. The geomorphic assessment approach and results are described below.

B. Approach

The general approach taken to begin to understand the geomorphic aspects of Upper Deer Creek involves the following steps:

- Reach classification: using aerial video footage and analysis of topographic data, the distinct reaches of Deer Creek were identified and mapped based on longitudinal slope and valley width parameters.

- Channel Morphology typing: within each reach, the channel morphology and major habitat types were identified and mapped.

- Detailed surveys: within key reaches, locations that can serve as indicators of hydro-geomorphologic function and health were identified and surveyed in detail.

- Analysis of data collected in previous three steps.

C. Reach Classification

The purpose of classifying Deer Creek into distinct geomorphic reaches is to "permit [a] rapid inventory of large regions, provide a stratified geomorphological framework within which more detailed observations can be organized, and provide an initial basis for selecting restoration strategies" (Kondolf, 1995).

By analyzing aerial photos, topographic maps, and aerial video footage of the entire length of Upper Deer Creek, nine distinct reaches were identified between the confluence of the north and south forks of Deer Creek in the upper watershed and Lake Wildwood. Figure 18 below shows the reach divisions (see Appendix D for a detailed description of the reach classification analysis). Reach divisions correspond with significant slope breaks, adjusted slightly to allow easy identification in the field.

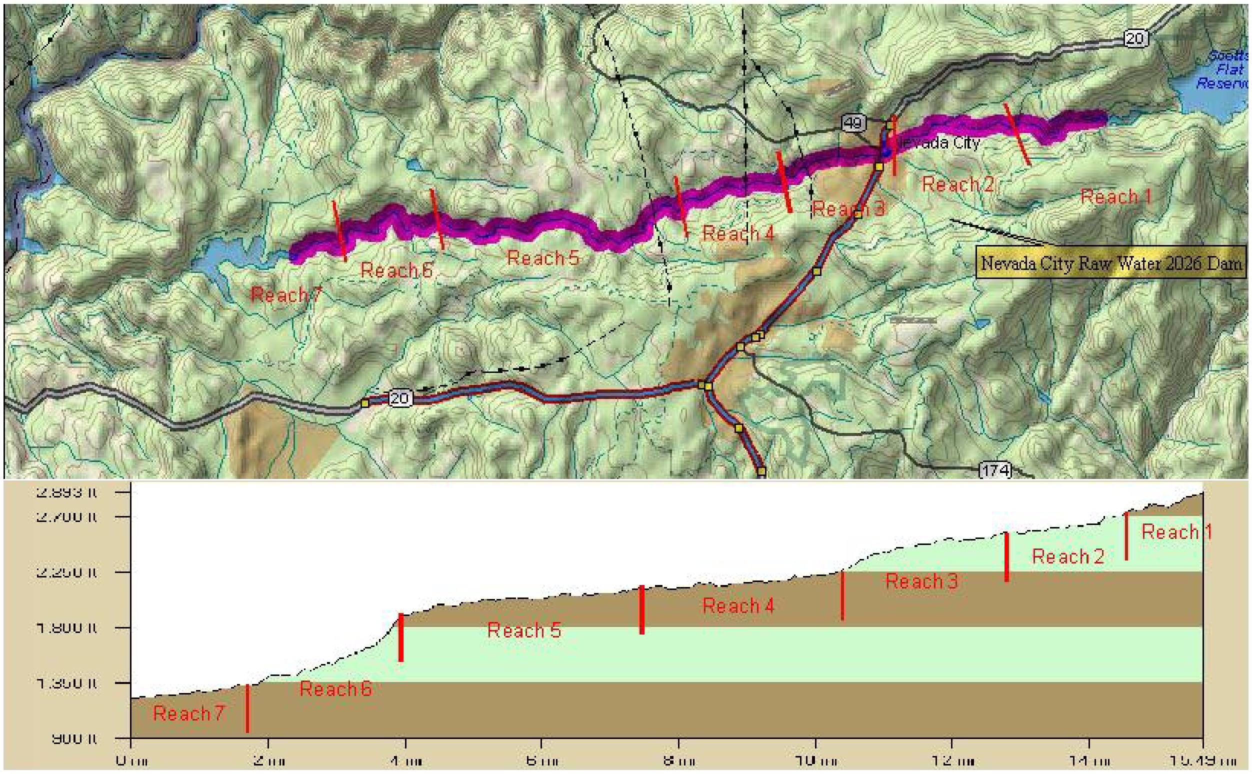

Figure 18: Plan View of Reach Divisions along the Mainstem of Upper Deer Creek

We identified seven reaches described below:

Reach 1: Lower Scotts Flat Reservoir to Willow Valley Creek

- Upstream Elevation: 2884 ft
- Downstream Elevation: 2624 ft
- Change in Elevation: 260 ft
- Linear Distance: 9030 ft
- Average Slope: 0.028

Reach 2: Willow Valley Creek to Little Deer Creek

- Upstream Elevation: 2624 ft
- Downstream Elevation: 2475 ft
- Change in Elevation: 149 ft
- Linear Distance: 11460 ft
- Average Slope: 0.013

Reach 3: Little Deer Creek to Providence Mine Road

- Upstream Elevation: 2475 ft
- Downstream Elevation: 2182 ft
- Change in Elevation: 293 ft
- Linear Distance: 11040 ft
- Average Slope: 0.027

Reach 4: Stocking Flat to Little Deer Creek Lane

- Upstream Elevation: 2182 ft
- Downstream Elevation: 2108 ft
- Change in Elevation: 74 ft
- Linear Distance: 10670 ft
- Average Slope: 0.0069

Reach 5: Little Deer Creek Lane to Tunnel Ditch

- Upstream Elevation: 2108 ft
- Downstream Elevation: 1940 ft
- Change in Elevation: 168 ft
- Linear Distance: 16740 ft
- Average Slope: 0.010

Reach 6: Tunnel Ditch to Paddy Flats

- Upstream Elevation: 1940 ft
- Downstream Elevation: 1330 ft
- Change in Elevation: 610 ft
- Linear Distance: 14100 ft
- Average Slope: 0.043

Reach 7: Paddy Flats to Wildwood Reservoir

- Upstream Elevation: 1330 ft
- Downstream Elevation: 1216 ft
- Change in Elevation: 114 ft
- Linear Distance: 8450 ft
- Average Slope: 0.013

D. Channel Morphology Typing

Within each of the reaches described above, we determined the channel morphology type as part of our field assessment. The most appropriate classification system for channel type morphology for Upper Deer Creek is the Montgomery-Buffington classification of channel-reach geomorphology in mountain drainage basins (Montgomery and Buffington, 1997), which offers a "process-based framework within which to assess channel condition and response potential." Mountain drainages exhibit seven channel morphologies: colluvial, bedrock, cascade, step pool, plane bed, pool riffle, and dune riffle. The classifications are represented in the schematic plan form and idealized long profile below.

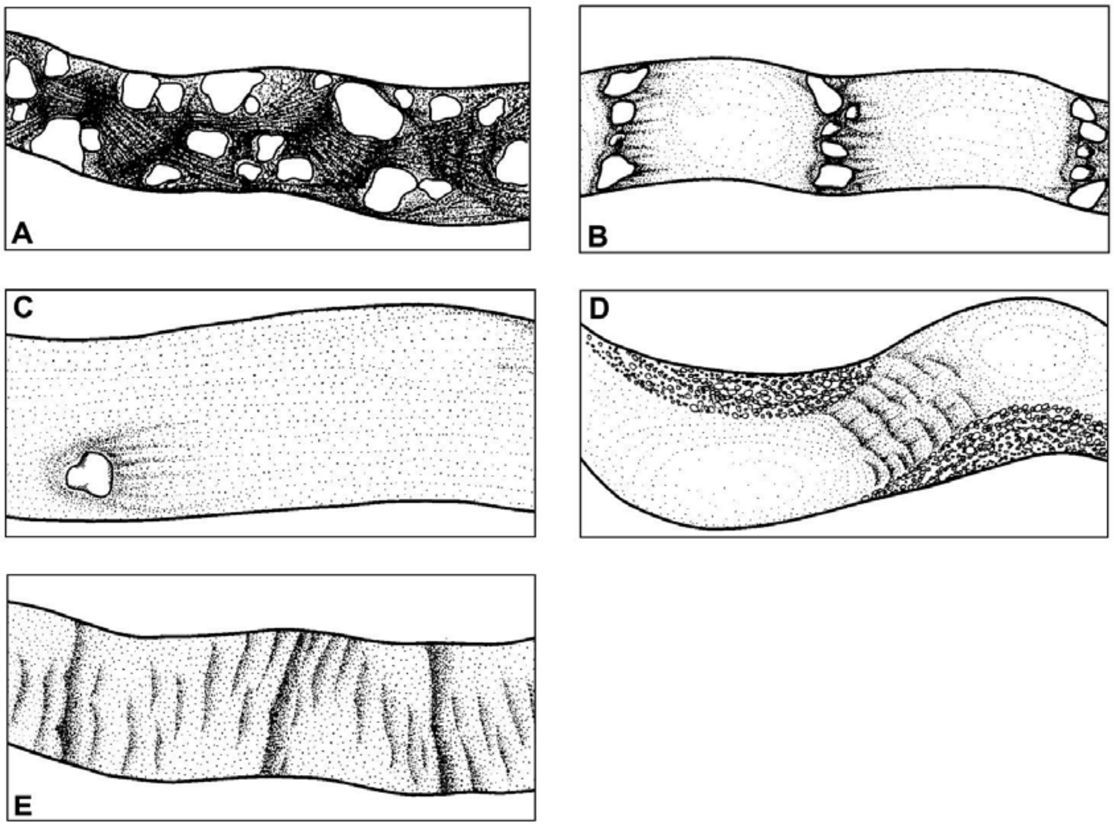

Figure 19: Schematic Plan Form of Mountain Stream Channel Classifications: A) Cascade; B) Step Pool; C) Plane Bed; D) Pool Riffle E) Dune Riffle (Reprinted from Montgomery and Buffington, 1997).

Examples of these channel types on Upper Deer Creek are shown in Figures 21 – 24. Note that Upper Deer Creek does not feature Dune Riffle habitat, Type E.

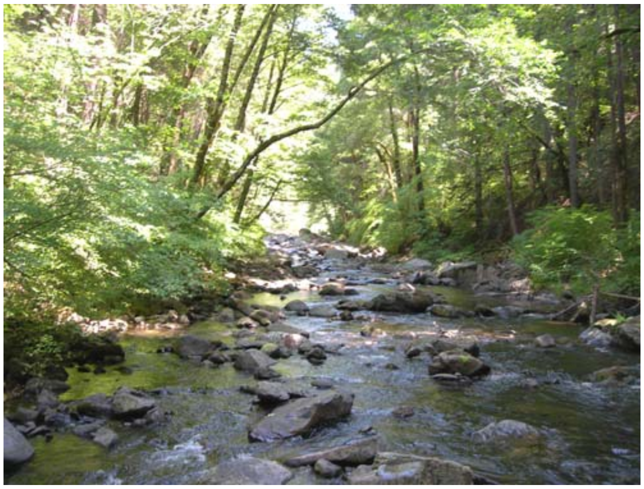

Figure 20: Example of a cascade reach (Type A), one mile below Scotts Flat

Figure 23: Example of a riffle pool reach (Type D), ½ mile above Bitney Springs Road

Figure 21: Example of a step pool reach (Type B), ¼ mile below Scotts Flat

Figure 24: Bedrock reach, ¾ mile below Scotts Flat

Figure 22: Example of plane bed reach, (Type C), ¼ mile above Bitney Springs Road

E. Sediment Supply

The design and implementation of a restoration program should be guided by an understanding of past changes, and should address the historical causes and course of channel degradation (Kondolf, 1995; Brookes and Sear, 1996). It is important to clarify that in the discussion of geomorphology here, the term "sediment" means alluvium in general, including cobbles, gravels and fines. While excessive fine sediment loading to creeks from soil disturbance is a common water quality problem and a concern for Deer Creek, a healthy variety of sediment/alluvium, as discussed below, is an important characteristic of a healthy watershed.

Before the mining era in larger mountain channels such as Deer Creek, alluvium collected in reaches of gentle gradient while steep reaches were floored by bedrock and large boulders. These channels stored relatively little sediment, so the rate of material coming from the hillslopes controlled pre-mining sediment volumes available for transport or deposition in Deer Creek (James, 2004). Sediment yields and the distribution of alluvium in such basins depend on the balance between hillslope sediment production and channel transport capacity (Montgomery et al., 1996).

Prior to European disturbances, the power of Deer Creek in the upper reaches would likely have been sufficient to carry most of the sediment supplied to the creek by hillslope process, so channel-beds were dominated by coarse channel lags, bouldery colluvium, and bedrock. From 1848 through the 1930s the Deer Creek watershed was the focus of significant mining activities that produced 25 million cubic meters of sediment. Over a relatively short period of time during hydraulic mining (1848- 1885), channels in and below the mines were converted from colluvial-supply systems to alluvial streams with abundant stores of relatively fine alluvium (James, 2004). Through time, Deer Creek shifted from a supply-limited to a transport-limited system in response to the introduction of massive volumes of mining sediment.

Based on studies of the Bear River and other Sierra rivers, much of the sediment from the mining era has been transported out of the mainstem portions of Deer Creek and other systems by now (James, 1999). This is not true of all significant rivers or tributaries, such as Greenhorn Creek on the Bear River. In addition, there are still significant deposits of sediment produced by mining along Deer Creek that continue to supply sediment to the system.

One such deposit is a terrace that is immediately downstream of the former Champion and Providence mines where the high-gradient reach (5% slope) that flows through Nevada City becomes more gradual. The terrace sits 12-25 ft above the current channel elevation (Figure 20 below). It seems likely that during the mining era, sediment supply surpassed sediment transport capacity and the channel aggraded in this reach by at least 15 feet. After the end of the mining era and the reduction in sediment supply, Deer Creek has cut down through the mining deposits to bedrock in some locations. Although much of the mining sediments has been transported out of this and similar reaches, a portion remains in the terraces and will only be transported as Deer Creek migrates laterally into the banks of the deposits. Significant channel downcutting, another way to transport sediment, will be limited due to the location of exposed bedrock.

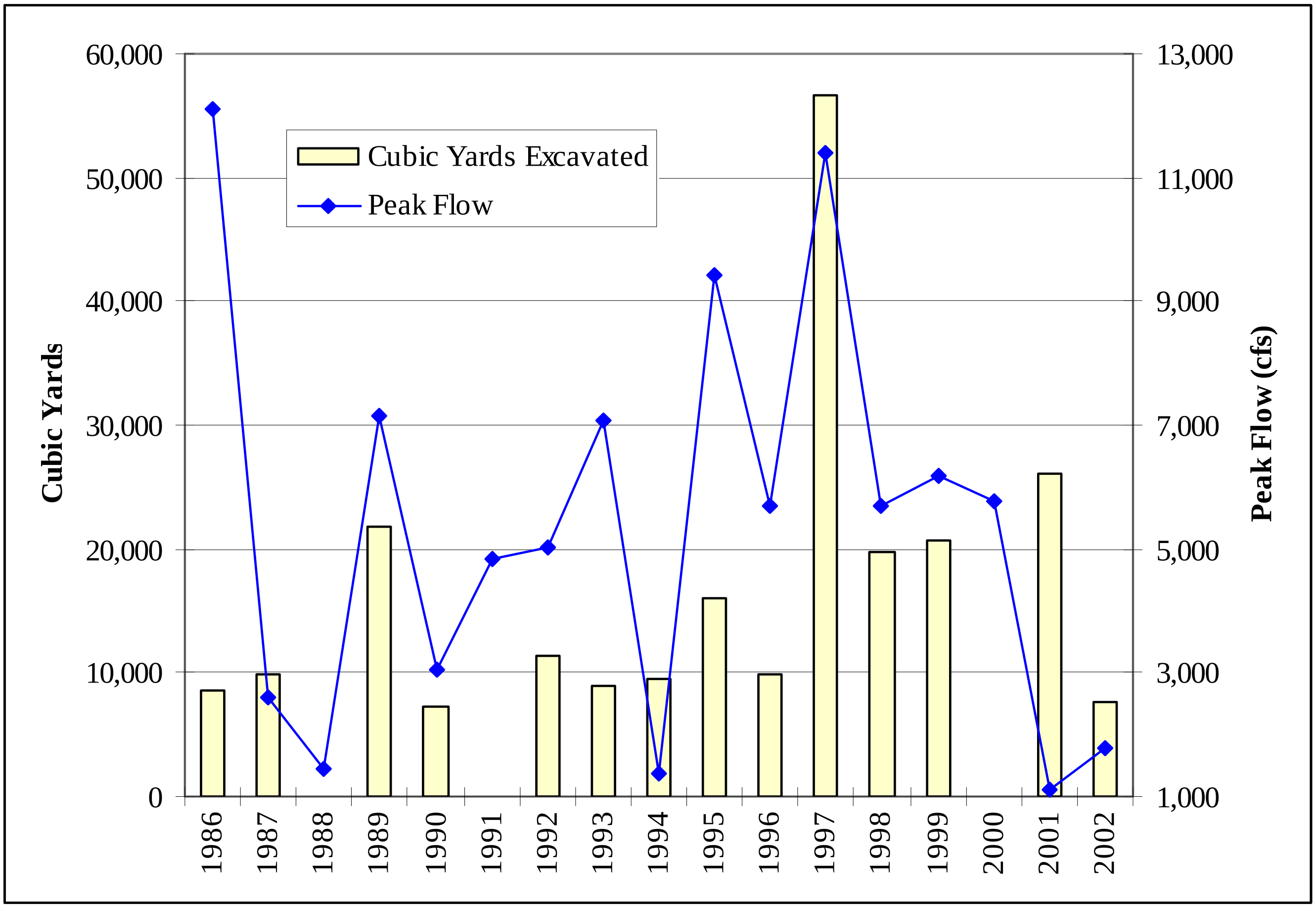

Figure 25: Amount of Sediment Excavated from Lake Wildwood compared to Peak Flows on Deer Creek at the Smartville Gauge (USGS 11418500)

The amount of sediment currently transported by Deer Creek can be estimated by examining records of sediment excavated from Lake Wildwood. Figure 25 shows the volume of annual sediment excavated from Lake Wildwood since 1986. The average volume excavated each year is 12,300 yd^3. It is possible, however, that Lake Wildwood managers do not remove completely the sediment that is transported into the reservoir. The area of excavation is focused on the upstream end of the reservoir, and the finest material might be transported beyond the typical zone of excavation, particularly during the extreme flood events. Thus, these excavation data likely underestimate the amount of sediment transported by Deer Creek.

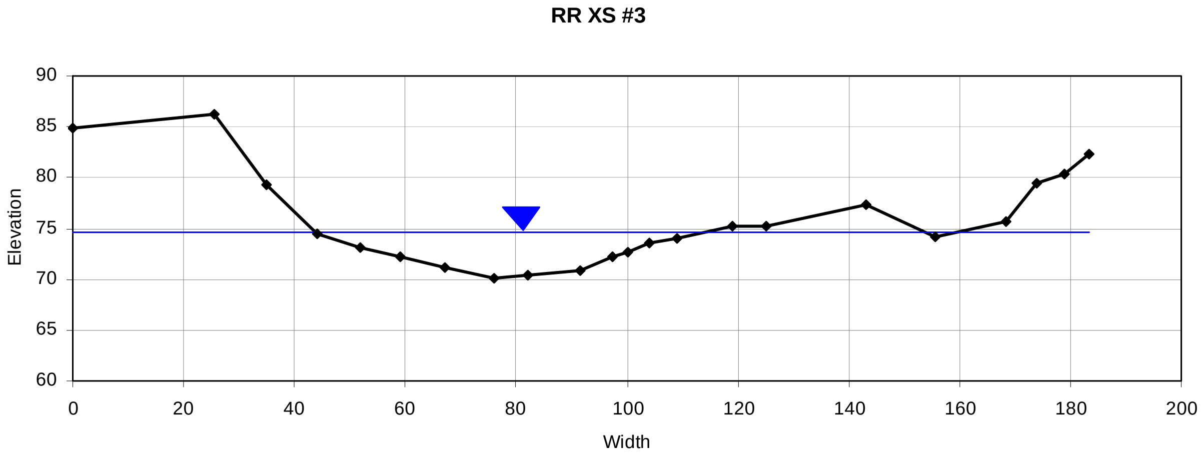

Figure 26: Channel Cross-Section Showing Elevated Terrace of Mining Debris, River Left

Lake Wildwood is approximately 15.5 miles downstream of Scotts Flat, and the watershed area between the two dams is approximately 36 mi^2. The average sediment yield therefore is 342yd^3/mi^2 each year, or approximately 764 tons/mi^2/yr. The maximum amount of sediment transported in one year occurred in 1997 when Deer Creek transported 56,000 yd^3, or 1555 tons/mi^2, enough sediment to cover the 36 mi^2 portion of the watershed to a depth of 0.6 in. By contrast, during the 19th century hydraulic mining era, the Deer Creek drainage produced enough sediment to cover the watershed in 4.7 inches of sediment (Heur, 1891; Gilbert, 1917 in Allan, 1999). The average sediment yield rate of 764 tons/mi^2 is less than the average yield rate estimated for California of 1,300 tons/mi^2 (Dunne and Leopold, 1978). The USGS estimated that the Yuba River sediment yield is approximately 970 tons/mi^2/yr (Snyder et. al., 2004). Sediment transport in the Yuba River is also affected by residual stores of sediment generated during the mining era.

However, the climate, unstable bedrock, rate of geologic uplift and land use within California's watersheds produce the highest yields of sediment in the country and some of the highest in the world (Mount, 1995). Moreover, several reaches of Deer Creek suffer from significant depositions of fine grained material that has buried gravels that would otherwise support important macroinvertebrate populations. See maps in Appendix C for locations of these areas.

Influence of Scotts Flat on Sediment Supply

Primary changes caused by dams include a reduction in the river's sediment load as well as an alteration of the flow regime. Typical changes in the flow regime include a reduction in the magnitude of peak flows and a possible increase in the magnitude of low flows. Such artificially introduced changes may trigger an adjustment by the river as it attempts to re-establish an approximate equilibrium between the channel and the discharge and sediment load being transported (Kondolf, 1997; Juracek, 1999).

Figure 27: Bedrock Outcropping Below Scotts Flat

In general, rivers downstream from dams initially adjust by channel degradation. Typically, a river will scour, and thus lower, its channel bed as the sediment-depleted water emerging from the dam attempts to replenish its sediment load. Typically, channel degradation initiates near the dam following closure and eventually may migrate a considerable distance downstream (Williams and Wolman, 1984). Deer Creek is an exception to this rule because a series of bedrock outcroppings occurs approximately 500 feet below Lower Scotts Flat (Figure 27), thus limiting its ability to adjust.

Below Scotts Flat, current sources of sediment are limited to bed and bank erosion and input from the tributaries. Similar to many studies of rivers downstream of dams, stream surveys we conducted including pebble counts indicated that Scotts Flat has caused the channel substrate in the first 1.5 miles below the dam (until the confluence with Willow Valley Creek) to become larger than sediments found in similar reaches further downstream and above the dam. The average diameter of channel substrate below the dam is 100mm, whereas at a location of similar channel slope three miles downstream, below the confluences of three significant tributaries, the average diameter is 47mm. Above the dam, the D_{50} is 55mm. In addition, the substrate immediately below the dam is largely angular, suggesting the sediment comes from the nearby hillslopes and the creek has had little chance to abrade the sharp edges. At the survey site three miles downstream, the sediment shape is significantly more rounded, indicating the substrates has been worked by the creek to a greater degree (see Figure 24). This is a common effect of dams (Grant et. al., 2003). Clearly, the dams have altered the channel substrate size and shape.

Figure 28: Substrate Immediately Below Scotts Flat (L), and 3 miles Downstream (R)

F. Bank Stability

The stability of the banks of Deer Creek was evaluated on two levels. Aerial photographs were evaluated to determine the history of large-scale channel movements, and local channel stability was evaluated using the methodology described by Johnson et al 1998 as part of our field assessment. Stable banks were characterized by the presence of boulders, rocks, or rooted vegetation that reduces the bank's susceptibility to erosion, while unstable banks were characterized by the presence of exposed raw dirt, lack of rooted vegetation, steep sloped banks, undercuts, and often slumping banks (See Appendix E for a full description of the methodology used). Below are photographs of both stable and unstable banks on Deer Creek.

Figure 29: Example of unstable bank.

Figure 30: Example of stable bank.

The survey of local-scale bank conditions indicated that much of the creek has moderate to good bank stability, while certain locations suffer from poor bank stability conditions. Bank stability ratings started below Scotts Flat Dam. Reach 3 rated the highest for bank stability with an average of 6 measurements and rated a category 3.5 which is described as slightly unstable to stable (see Appendix E for details). This reach primarily had well rooted vegetation, such as large trees and shrubs down to the streams edge and only some areas showed signs of minor erosion. In general, reach stability decreased with down stream progression. Reach 4, was rated as a 2.76 and can be described as moderately unstable to slightly unstable. This reach had bank undercutting and less vegetation down to the stream edge. Reach 5 was the least stable reach, classified as a 2.15 and can be described as moderately unstable. This reach had extensive undercutting and erosion. Reach 6 and 7 do not conform to the general trend of progressively less stable banks with downstream progression, instead reach 6 rated 2.37 and reach 7 rated 2.83, slightly unstable to stable. One explanation for this sudden change in trend is that the banks were less steep and more in contact with the floodplain in these lower reaches, and therefore destabilization processes were more difficult to detect during summer high flows, when this study was conducted. See Appendix E for a map of areas along Upper Deer Creek with unstable bank conditions.

Aerial photographs show that in the alluvial reaches, Deer Creek has experienced significant adjustments as a result of large flow events. For example, in Figure 35 below, the 1997 flood caused the reach below Providence Mine Road to shift more than 150 feet in several locations.

G. Sediment Transport

As mentioned above, several attributes of healthy, functioning rivers are a function of sediment transport and deposition dynamics, including in bedrock reaches. These attributes include:

- Bedrock rivers exhibit nested depositional features.
- Episodic sediment delivery enhances spatial complexity.
- Biological hotspots occur in reaches with significant deposits, gravel bars and floodplain habitat.

And in depositional reaches:

- The channelbed surface is frequently mobilized.
- Alternate bars must be periodically scoured deeper than their coarse surface layers.
- Alluvial channels are free to migrate.
- Diverse riparian plant communities are sustained by the geomorphic effect of natural annual hydrograph components.

It is important therefore to understand the sediment transport and deposition dynamics of Deer Creek to determine whether the attributes of a healthy creek are being sustained. Low flows, even though they occur most of the time, transport relatively minor amounts of bedload sediment because the bedload transport rate is near zero. Very large flood flows, although having the highest transport rates, account for relatively minor amounts of bedload sediment because high flows occur infrequently and are generally of short duration. Consequently, the largest proportion of the total bedload is transported by flows around the peak of the total bedload transport curve (i.e., the effective discharge). In many rivers, bankfull discharge approximates effective discharge.

Conceptually, the required maintenance flow regime begins at a discharge at which gravels making up the bed of the channel begin to move and includes all flows up to and including the 25-year flow.

This range of flows should sustain the attributes of healthy functions listed above, including: mobilize the channelbed sediment, scour alternate bars deeper than their coarse surface layers, scour vegetation from the channel, partially inundate the floodplain, and provide high flow functions needed to sustain streamside vegetation (Schmidt and Potyondy, 2004).

For the purpose of evaluating whether current flows are of sufficient magnitude to sustain the healthy river attributes, it was assumed that mobilization of the median sized sediment (D50) would represent mobilization of some portion of the bed. It was assumed that the mobilization of the D84 sized sediment would represent mobilization of the channel bed as a whole.

Sediment supply thresholds were evaluated using a combination of field observation and calculations. Field data were collected at six sites (Figure 25). Data were collected at each site generally according to the methods described in Harrelson *et. al.,*(1994) and included channel cross sections, longitudinal profile, channel substrate size, high-water marks and water surface elevations. Channel substrate size was determined by pebble counts (Wolman 1954).

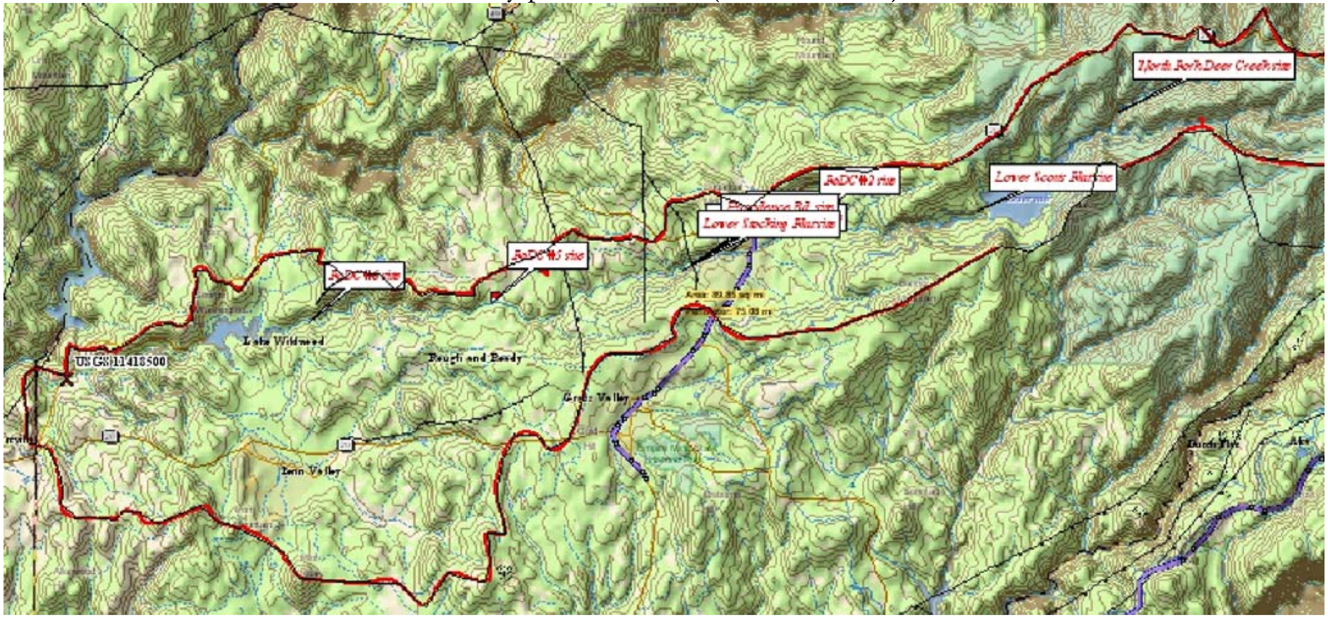

Figure 31: Location of Survey Sites

Appendix F contains the particle size distribution curves, cross-sections and longitudinal profiles for each of these sites.

The sediment transport estimates are based on the investigations of Sagan and Bagnold (1975) and Leopold, Wolman and Miller (1964). The approach is based on observations of the mobilization of channel substrate as a function of water depth and channel slope. The details of the estimates are provided in Appendix E.

Site No.	Site name	Frequency D50 mobilized (yrs) (1 - 2 yrs is ideal)	Frequency D84 mobilized (yrs) (5 – 10 yrs is ideal)	Frequency floodplain is inundated (yrs) (1 – 2 years ideal)
1	Scotts Flat	2 - 5	25 – 50	no floodplain
2	FDC #2	10	50 - 100	10
3	NC WWTP	1	5 – 10	no floodplain
4	Providence	2 – 5	100	10 - 25
5	Upper Stocking	1 - 2	50 – 100	10 - 25
6	Lower Stocking	5 – 25	50 – 100	5 - 10
7	FDC #5	2 – 5	10 – 25	2 - 5
8	FDC #6	10 – 25	50 – 100	no floodplain

Table 4: Summary of Substrate Mobilization and Floodplain Inundation Frequencies

Table 4 indicates that at the majority of sites, three of the key attributes of good geomorphic function (*i.e.,* D50 is mobilized every 1-2 yrs, D84 is mobilized every 5-10 years and the floodplain is inundated every 1-2 years) are accomplished much less often than is considered necessary for a properly functioning river. With the exception of the Nevada City Wastewater Treatment Plant, where D50 and D84 material would be expected to be mobilized at the ideal frequency, and the Upper Stocking Flat location, where D50 sediments would be mobilized at a good frequency, none of the other sites achieve the desired frequency for any of the three attributes. Only at the FDC #5 site does the floodplain get inundated relatively close to the ideal frequency.

The low frequency with which substrates are mobilized and floodplains are inundated reduces the health and productivity of Deer Creek. The low frequency of these events is caused by three factors. First, as described above, Scotts Flat dam reduces the magnitude of flows for floods in the 2 – 25 year frequencies. Second, like other dams, Scotts Flat eliminates the supply of sediment from the upper watershed which results in the coarsening of sediment downstream of the dam, which results in higher flows being required to mobilize the dominant substrate in the channel. Third, residual debris from the mining era remains at many locations in terraces above the stream channel.

To address the problem associated with mobilizing substrates, two methods could be used. First, releases from Scotts Flat could be increased during certain storm events to reach mobilization thresholds. During 2-year events, flows would need to be increased by at least 400 cfs, and for 10-year events flows should be increased by at least 1000cfs. Second, certain reaches with significant riffle habitat could be "mechanically mobilized," a strategy used in restoration efforts below dams on salmon-bearing streams. Mechanical mobilization involves using tractors pulling implements that rip up the top layer of gravel bars to facilitate mobilization when significant flow events occur.

To address the problem associated with loss of sediment supply, gravels could be introduced below Scotts Flat Dam. Supplementation of gravels would reduce the dominant size of channel substrates, which would reduce the flows at which substrates would be mobilized. Adding gravel would also provide additional trout spawning habitat if sized appropriately.

To address the problem associated with the infrequency of floodplain inundation, two approaches could be employed. First, during storm events releases from Scotts Flat could be increased enough to inundate floodplains on an average frequency of once in two years. The level of flow increase required would range from 500 cfs to 4,000 cfs depending on location. At locations requiring increases of more than 1000 cfs, floodplains are likely artificially elevated as a result of residual mining debris. They have essentially become terraces,S abandoned as the river cut down through mining deposits. In these reaches, the river channel will likely have to be reshaped using heavy equipment to create a channel that reflects the altered hydrology and sediment supply of today. This approach has been used on the Trinity River, which has a mining and dam building history not unlike Deer Creek. On the Trinity, managers regraded significant areas of abandoned floodplain terraces down to elevations that are now flooded on a regular basis.

H. Floodplain Connectivity

As described above, one of the attributes of a healthy river is "floodplains are frequently inundated" (Trush et al, 2000). These floodplains are also the engines of biological activity in river systems. Flooding of riparian areas delivers much needed sediment and nutrients to the floodplain, scours and prepares the floodplain surface for pioneer species, provides rearing habitat for key fish species, and delivers nutrients back into the main channel. The frequency, timing, and quantity of flooding have profound impacts on the type of vegetation and habitat that exist in the riparian areas. Ideally, rivers alluvial in California would experience over bank flooding every 1-2 years. Whether or not this occurs is a function of the shape, size, and roughness of the channel, and the stream hydrograph, both of which have been altered in Deer Creek. Hydraulic mining added massive amounts of sediment into Deer Creek that are still stored in its channel and floodplains (See Figure 32, below). The upstream dams have attenuated the 2-25 year floods, reducing the frequency of high flow events that provide enough water to access the floodplains.

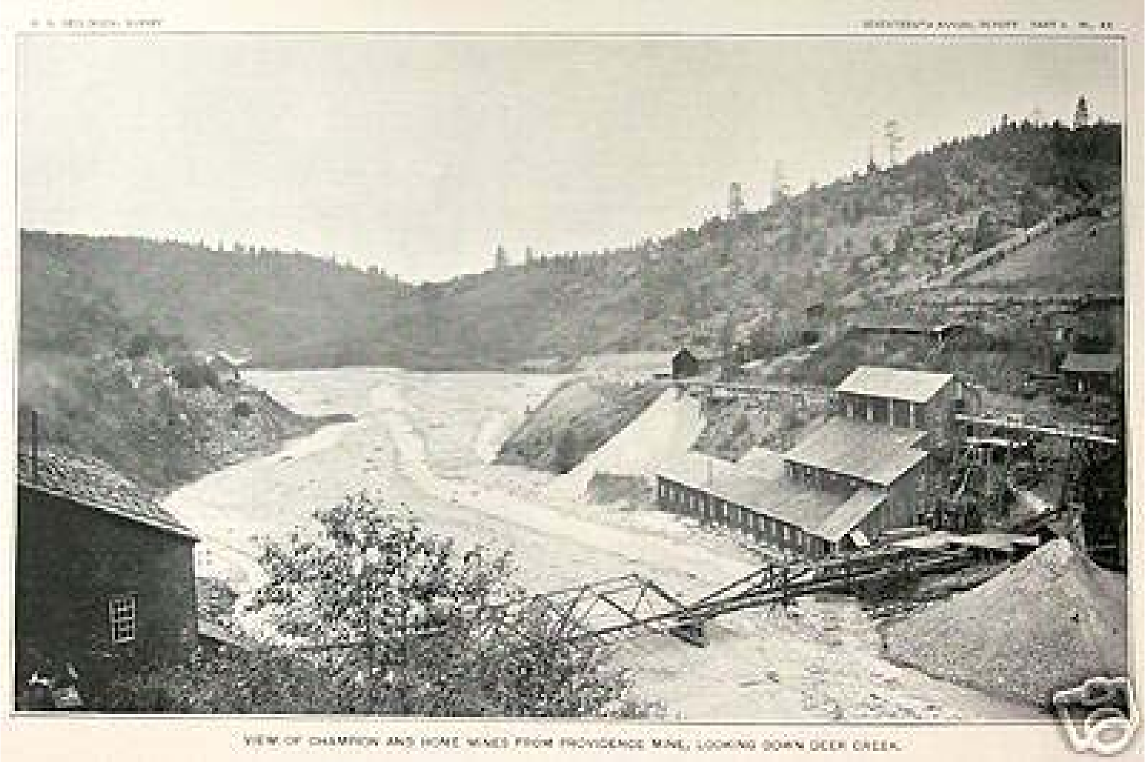

Figure 32: Massive amounts of sediment filled the Deer Creek channel at the height of the mining era. This photo is of Champion Mine, 1.5 miles West of Nevada City, circa 1880.

Given these alterations, we examined the frequency of floodplain inundation by surveying several cross sections along the river and comparing that with the likely high flow events of varying return intervals. By examining aerial photographs and surveying the creek from the overflight, we were able to identify most of the likely floodplains in the study area. We chose the cross-sections (in part) to provide a reasonable representation of the floodplain types in Deer Creek.

Figures 33 through 41 show the cross sections plotted with estimates of the water surface levels of the 2-year (blue line) and 10-year (red line) flood events.

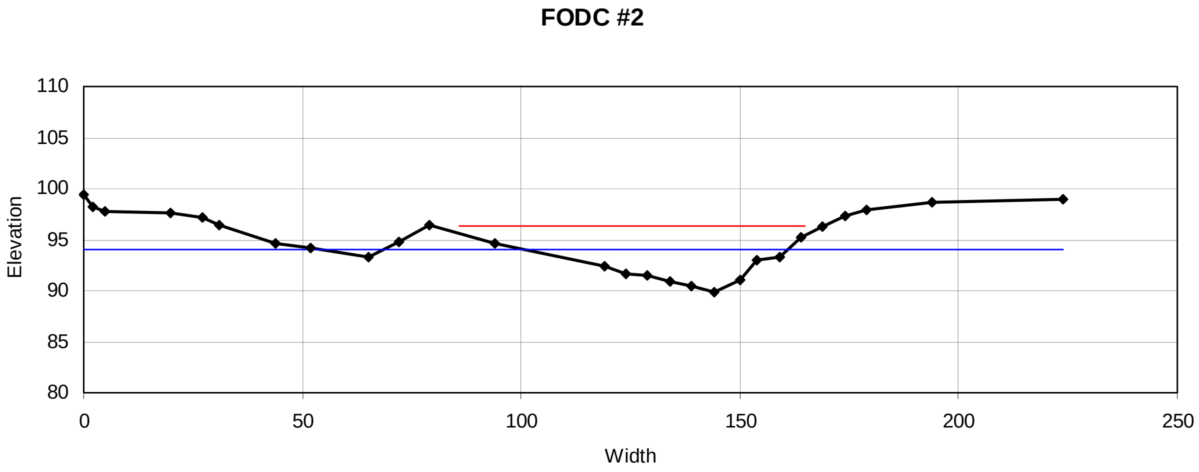

Figure 33: Cross-sections showing the estimated water surface elevation during a 2-year (blue) and 10-year flood event (red) at the Friends of Deer Creek Monitoring Site #2

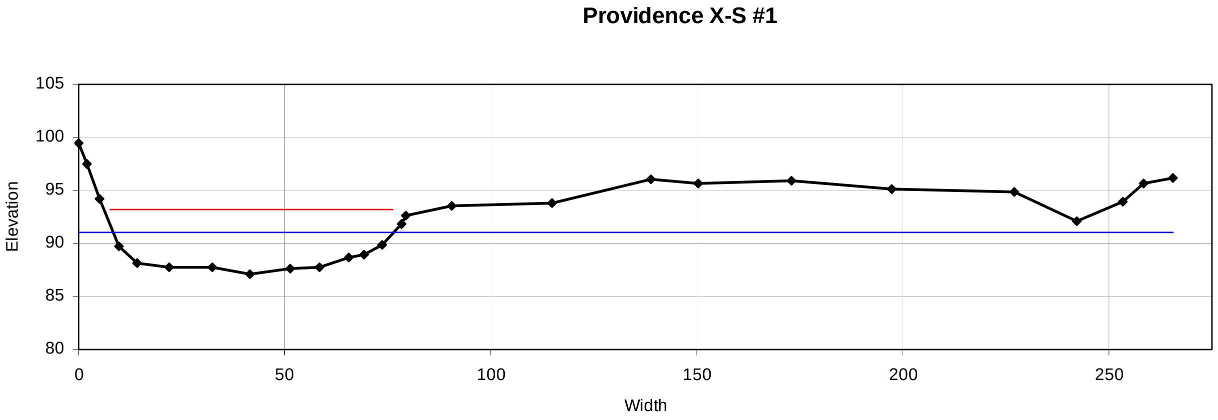

Figure 34: Cross-sections showing the estimated water surface elevation during a 2-year (blue) and 10-year flood event (blue) at the Providence Road reach cross section #1

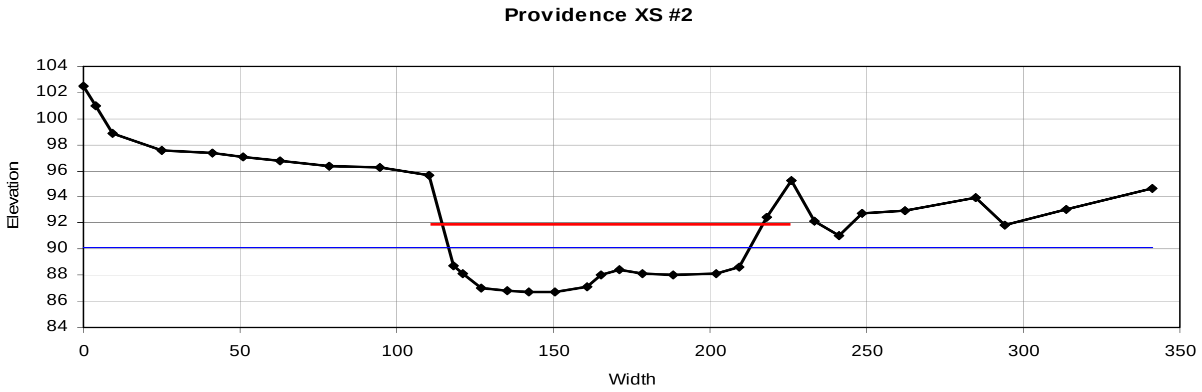
Providence XS #2

Figure 35: Cross-sections showing the estimated water surface elevation during a 2-year (red) and 10-year flood event at the Providence Road reach cross section #2

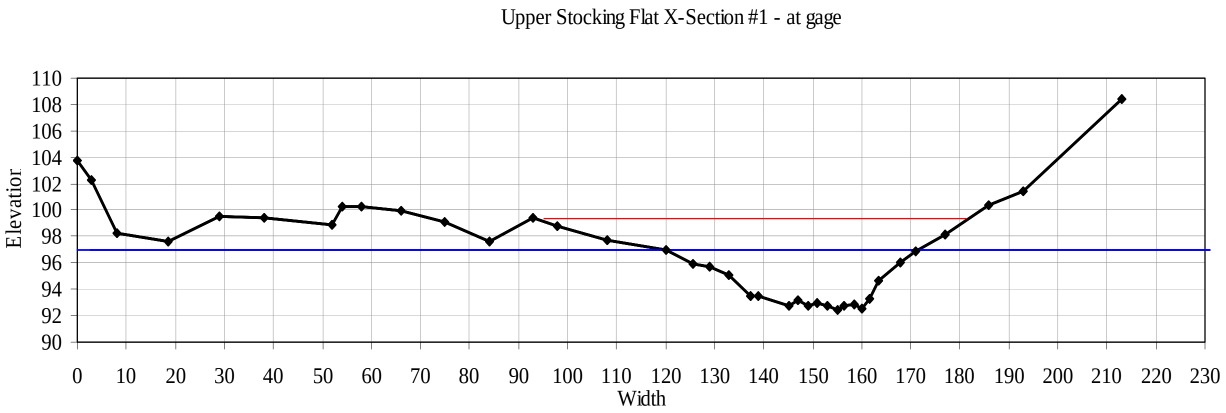
Upper Stocking Flat X-Section #1 - at gage

Figure 36: Cross-sections showing the estimated water surface elevation during a 2-year (blue) and 10-year flood event (red) at the Upper Stocking Flat reach at cross section #1

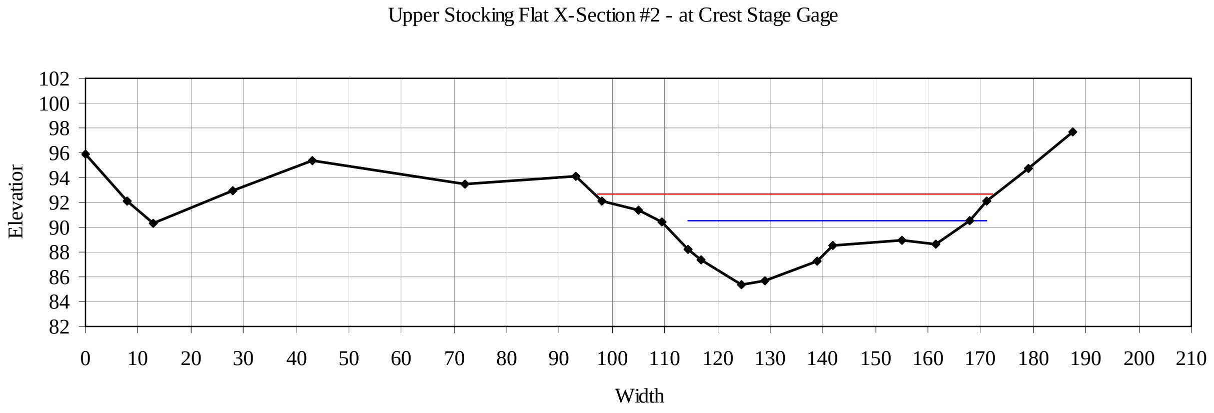
Upper Stocking Flat X-Section #2 - at Crest Stage Gage

Figure 37: Cross-sections showing the estimated water surface elevation during a 2-year (blue) and 10-year flood event (red) at the Upper Stocking Flat reach at cross section #2

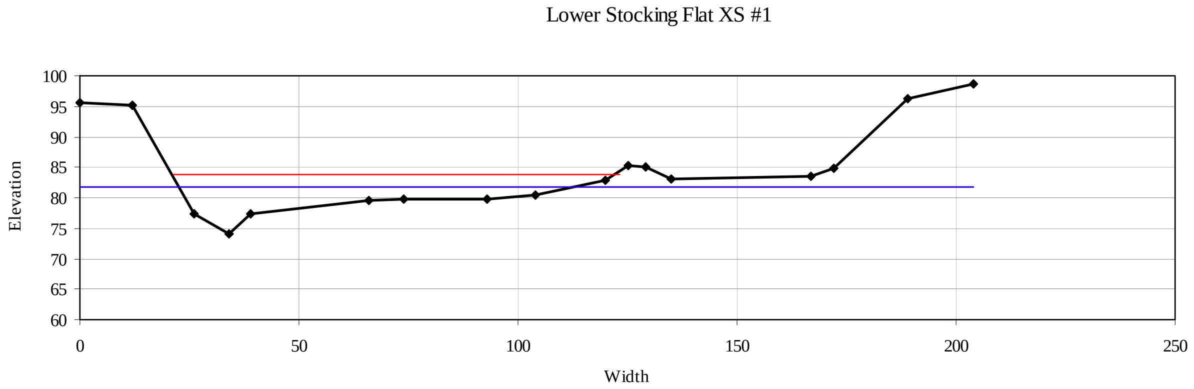

Figure 38: Cross-sections showing the estimated water surface elevation during a 2-year (blue) and 10-year flood event (red) at the Lower Stocking Flat reach at cross section #1

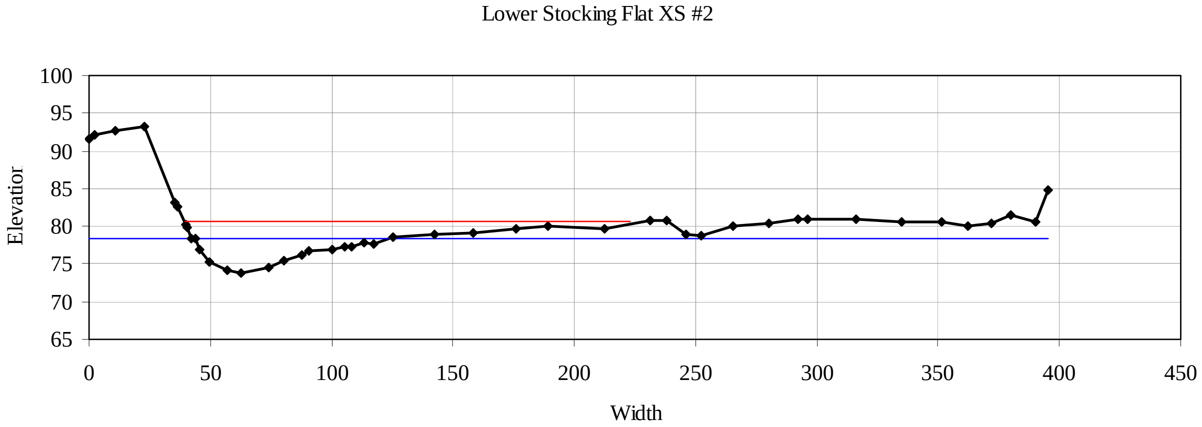

Figure 39: Cross-sections showing the estimated water surface elevation during a 2-year (red) and 10-year flood event at the Lower Stocking Flat reach at cross section #2

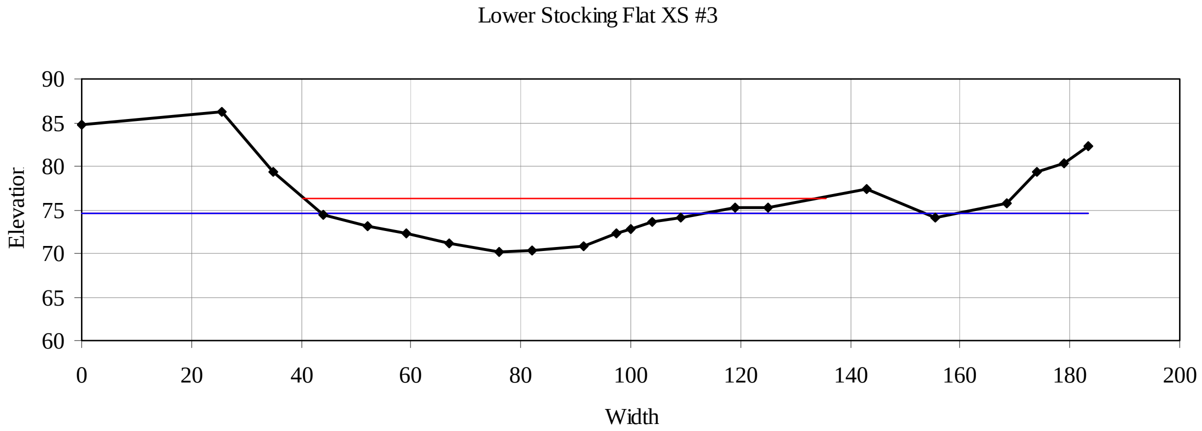

Figure 40: Cross-sections showing the estimated water surface elevation during a 2-year (blue) and 10-year flood event (red) at the Lower Stocking Flat reach at cross section #3

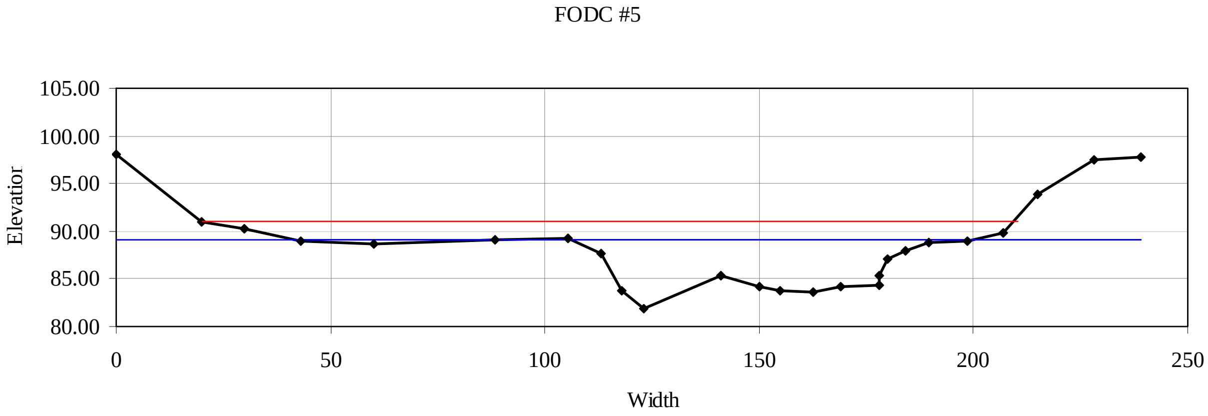

Figure 41: Cross-sections showing the estimated water surface elevation during a 2-year (blue) and 10-year flood event (blue) at the Lower Stocking Flat reach at cross section #3

Location	Flow to Inundate Floodplain (cfs)	Return Interval (years)	Adequate Return Interval?
FODC 2	2100	50	No
Providence XS #1	3600	50	No
Providence XS #2	5800	100	No
Upper Stocking XS#1	1976	2	Yes
Upper Stocking XS#2	3250	50	No
Lower Stocking #1	4026	50	No
Lower Stocking #2	2525	20	No
Lower Stocking #3	3250	35	No
FODC #5	1200	2	Yes

Table 5: Frequency of Floodplain Inundation

The figures and table show that, with the possible exception of Lower Stocking Flat #1 and FODC #5, the estimated 2-year flows do not inundate the adjacent floodplains. The result is abandoned floodplain terraces that are not appropriately prepared, seeded, and inundated by frequent small floods. In mountain streams, where so much of the biotic activity occurs in these depositional reaches and occasional large floodplains, it is critical that the floodplains be functioning properly. The resulting riparian conditions are described below in the Vegetation Encroachment and Riparian Vegetation sections.

Vegetation Encroachment

In the winter of 1998, flows in Deer Creek likely exceeded the Q100 flood (100-year flood flows). As a result, many of the floodplain surfaces were inundated and cleared of vegetation, and in some cases, the stream avulsed into a new channel. Figure 34 below shows "Rich's Reach" in an August 1998 aerial, and an October 2004 oblique aerial. The August 1998 photo includes a GIS overlay of the stream course based on pre-flood conditions.

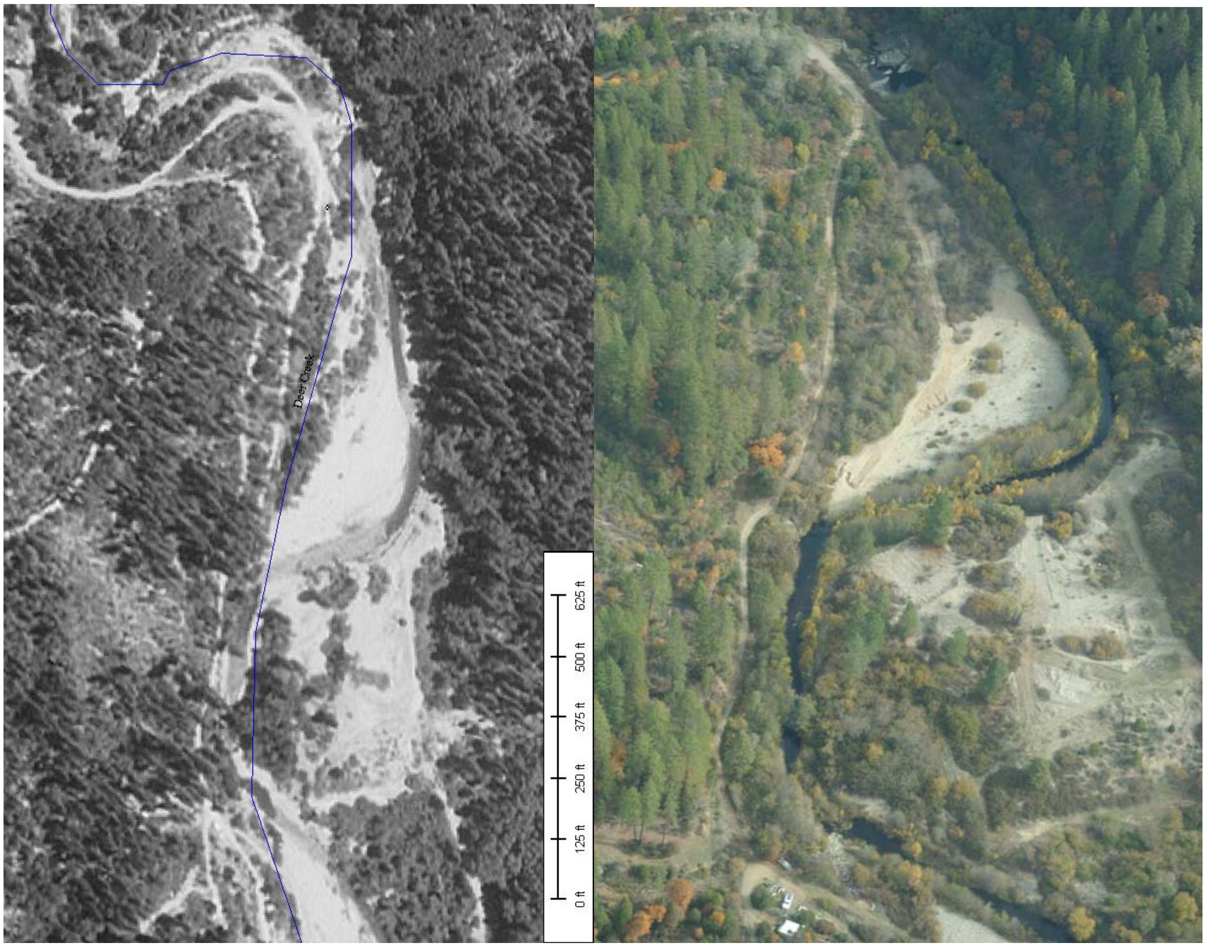

Figure 42: Aerial of Lower Stocking Flat in August 1998 (left) and Oblique Aerial of Lower Stocking Flat in October 2004 (right)

The blue line in the photo on the left indicates the previous stream course before the 1997 flood redirected the channel. Note in the photo on the right the development of a narrow band of willows and white alders along the margin of the stream and the dearth of vegetation in the interior section of the floodplain.

The 1997 flood moved the stream in Lower Stocking Flat southward in this reach and cleared the floodplain surface of all woody vegetation. In the six years between photos, the major change is the growth of willows and white alders along the margins of the stream. In a properly functioning system, we would expect to find a wider swath of riparian vegetation covering the entire floodplain. There are two reasons the floodplain is not functioning properly. First, this reach experienced deep deposits of mining debris, and significant amounts of mining sediments remain. As can be seen in Figures 31 – 33, the left side of the channel (right side in photos) has abandoned terraces between 10-15 feet above the channel. This elevated floodplain surface prevents riparian vegetation from establishing because groundwater us too deep. On the right side of the creek (left side of photos), although the floodplain elevation is relatively close to the channel, the attenuation of flood flows prevents the floodplains from being inundated frequently. With a natural hydrograph, flows would likely have covered the floodplain in three of the past six years, preparing the surface, depositing silt, and distributing seed sources. The absence of vegetation across the entire floodplain implies that high flows are not inundating the surface, or if they are, it is not for a long enough period of time. Upper Stocking Flat (Figures 29-30) exhibits the same general problems.

As described above in the hydrology section, summer flows in Deer Creek are likely higher than they would have been under the natural hydrograph. These higher summer flows could be promoting a narrow band of extremely hearty riparian vegetation. This overly dense band of vegetation may be encroaching on the stream channel, preventing small floods from accessing the flood plain and focusing more of the stream's energy in the channel, causing incision rather than lateral erosion. This pattern is repeated several times in reaches 5 though 7 and its implications could affect floodplain health and function in much of the creek.

Need for Further Study

In order to better understand the function of floodplains in Deer Creek, it is essential to collect better hydrologic data. In addition to a recording stream gauge, we recommend that Stocking Flat be monitored for overbank flooding (timing, frequency, extent, duration), and changes in geomorphology and vegetation. The reach is accessible and has three monumented cross sections.

To advance geomorphic restoration goals, more investigation is needed into the extent that floodplain problems are caused by historic mining practices or other factors, and the opportunities and constraints on removing hydraulic debris terraces to restore floodplain connectivity. Additionally, while gravel supplies have been depleted in the bedrock section just below lower Scotts Flat dam, the lack of channel downcutting and difficulty of access make gravel augmentation a low priority. However, with the likelihood of continued rapid growth causing more soil disturbance in the watershed, fine sediment levels should be monitored over time and erosion control Best Management Practices incorporated into development guidelines to insure that fine sediments levels do not become serious water quality concerns.

CHAPTER V:
UNDERSTANDING DEER CREEK: RIVER ECOLOGY

In this chapter, we focus on water quality and riparian vegetation as a key aspect of the river health. In addition, we briefly discuss species of concern and wetland habitat. In Chapter II, we have also discussed the historic flora and fauna and how it likely differs from current conditions.

A. Water Quality

Temperature and Dissolved Oxygen

Several Deer Creek water quality parameters in historic times likely differed significantly from current conditions. For example, FDC monitoring data show that current water temperatures remain relatively cold (<20ºC), and dissolved oxygen (DO) concentrations at or near saturation levels from below Scotts Flat nearly to Lake Wildwood for much of the summer. Historically, summer flows would have been lower than today for the reasons discussed above, and therefore ambient air temperatures would have influenced water temperatures more dramatically. This would have resulted in higher daily peak and daily average temperatures, and greater daily temperature swings during the summer.

Because of the decreased solubility of oxygen in warmer water, average DO levels in summer likely would have been lower in general than today. In addition, warmer temperatures might have allowed more algal growth, which in turn would have produced more extreme daily swings in DO associated with higher oxygen production during the day and greater respiration at night. Increased algal growth will also increase daily shifts in dissolved CO_2. Because of the interdependence of CO_2 concentration and pH, pH readings for upper Deer Creek likely varied more on a daily basis historically than today. Given other current stressors on aquatic organisms, we do not recommend attempting to re-create low DO levels.

Nutrients and Conductivity

Historic nutrient levels were likely similar to today's concentrations, at least in the upper reaches of the creek. FDC monitoring data indicate undetectable levels of phosphates and nitrates at the most upstream monitoring sites 1-3, and low levels at sites 4 – 6 from below the Nevada City wastewater treatment plant to above Lake Wildwood[1]. It is possible that naturally occurring nutrients that were historically transported from the upper watershed are now trapped in Scotts Flat reservoir to some degree. Historical conductivity values were likely similar to current levels between Scotts Flat and the Nevada City treatment plant because FDC monitoring results indicate low conductivity which is typically reflective of unpolluted waters. Below the Nevada City treatment plant, however, conductivity begins to increase and may reflect effluent from the plant and other inputs below Nevada City.

Macroinvertebrates

FDC monitoring data indicate moderately high taxa richness, EPT (Ephemeroptera, Plecoptera, Trichoptera) indexes and significant percentages of sensitive species throughout much of the study area, reflecting a generally cold, clean, and fast moving stream. The health indicators reveal the gradual degradation of the habitat as one moves downstream where more impacts occur. Because historic water quality parameters such as temperature, DO, CO_2, and pH were different and more seasonably variable than current conditions, it is likely that the macroinvertebrate community differed from current conditions as well. The historic community likely had lower EPT indexes and a greater percentage of species more tolerant of higher and variable temperatures, lower average DO levels and more seasonably variable flow conditions. Overall, macroinvertebrate productivity might have been higher in the past because consistently cold temperatures of today can reduce metabolism and growth rates, while pre-mining, pre-dam channel substrates and healthier riparian ecosystems of the past most likely provided more and better habitat for macroinvertebrates. However, in any year that summer flows became intermittent, the productivity of aquatic organisms of all types would decrease in all stretches where surface water disappeared.

Macroinvertebrate community health would most likely increase with habitat restoration within the creek channel and riparian zone. Riparian vegetation in the watershed needs to be protected, with non-native species replaced with natives. Restoration which targets areas with greatest erosion and implementing erosion control Best Management Practices would help prevent the fine sediment deposition so detrimental to the macroinvertebrate's ability to obtain adequate amounts of oxygen

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[1] Below Lake Wildwood, monitoring data clearly indicate a significant increase in nutrient levels resulting from outfall from the treatment plant and perhaps the lake as well. Low summer flows due to water diversions exacerbate the problem, contributing to high temperatures, algae blooms and fluctuations in pH that kill aquatic organisms.

and their ability to attach to the substrate. In some areas, especially below the Scotts Flat dam where sediments inputs from above have been halted, the addition of gravels and cobbles may be necessary to improve macroinvertebrate habitat.

Deer Creek macroinvertebrates need to be studied for a longer periods to better understand the effects of flow, water temperature, erosion, metal contamination and other factors on the health of the community.

Mining and Heavy Metal Contamination

The rich gold-bearing veins of Nevada County made it the largest lode mining area in California. Hundreds of hydraulic and hardrock gold mines were located in the Deer Creek watershed, with 16 major mines in the immediate vicinity of Nevada City. It is clear from historical records and preliminary research that tailings from these mines are likely to contain high levels of toxic heavy metals, including mercury, arsenic and lead, and may pose significant risks to public health.

Mercury, a powerful neurotoxin, was used to amalgamate gold in both hydraulic and hardrock (lode) mining. Mercury accumulates in aquatic food chains, posing risks to human health through consumption of contaminated fish. It has been estimated that 30 million pounds of mercury, imported from mines in the Central California coastal range, was utilized in the process of extracting gold in the Sierra Nevada. Annual mercury losses at mine sites ranged from 10 to 30 percent of the amount used to recover gold, with an estimated total loss of 13 million pounds of mercury into the environment (Alpers and Hunerlach, 2000).

Mercury was used in gold processing in the Deer Creek watershed. A 1999 study by the USGS investigated mercury contamination in Sierra Nevada streams, including sampling at three sites on Deer Creek (May et. al., 1999). Brown trout and rainbow trout collected from Deer Creek were found to have generally much lower mercury concentrations than the bass and catfish collected from the reservoirs in the Deer Creek, South Yuba and Bear River watersheds. Trout are primarily insectivorous species and they were collected mostly from streams that are less likely to be mercury methylation sites than the reservoirs. Nevertheless, trout sampled from Little Deer Creek in the study showed some of the highest mercury concentrations for trout in the South Yuba, Deer Creek and Bear River watersheds. They had values greater than 0.30 ppm, the Office of Environmental Health Hazards Assessment's screening value, as shown in Figure 43, below. Mercury concentrations in Deer Creek fish did not exceed the Food and Drug Administration's 1.0 ppm action level for regulating mercury concentrations in commercial fish, but it is possible that the measured levels are affecting fish productivity and health, as well as the health of wildlife or humans who regularly consume these fish.

Based on the results of the USGS study, Scotts Flat Reservoir and Little Deer Creek were both listed on California's 303 (d) list under the Clean Water Act as having impaired beneficial uses due to mercury contamination. Additionally, a county-level Interim Public Health Notification (Nevada County Department of Environmental Health, 2000) and a draft fish consumption advisory (OEHHA, 2003) were placed on these waterbodies.

Arsenic contamination in Deer Creek is associated with arsenopyrite mineralization in gold-bearing veins that were mined and processed to extract gold. Arsenic is a carcinogen that can affect humans and wildlife when inhaled in dust or ingested in water or soil. Mill tailings, waste rock, and exposed soils from Deer Creek mine sites are likely to be significant sources of arsenic contamination, as evidenced by high arsenic levels found in several tailings areas. According to the Bureau of Land Management, processing of arsenopyrite ores resulted in the concentration of arsenic levels 100 to 1000 times greater than background levels at certain mine sites.

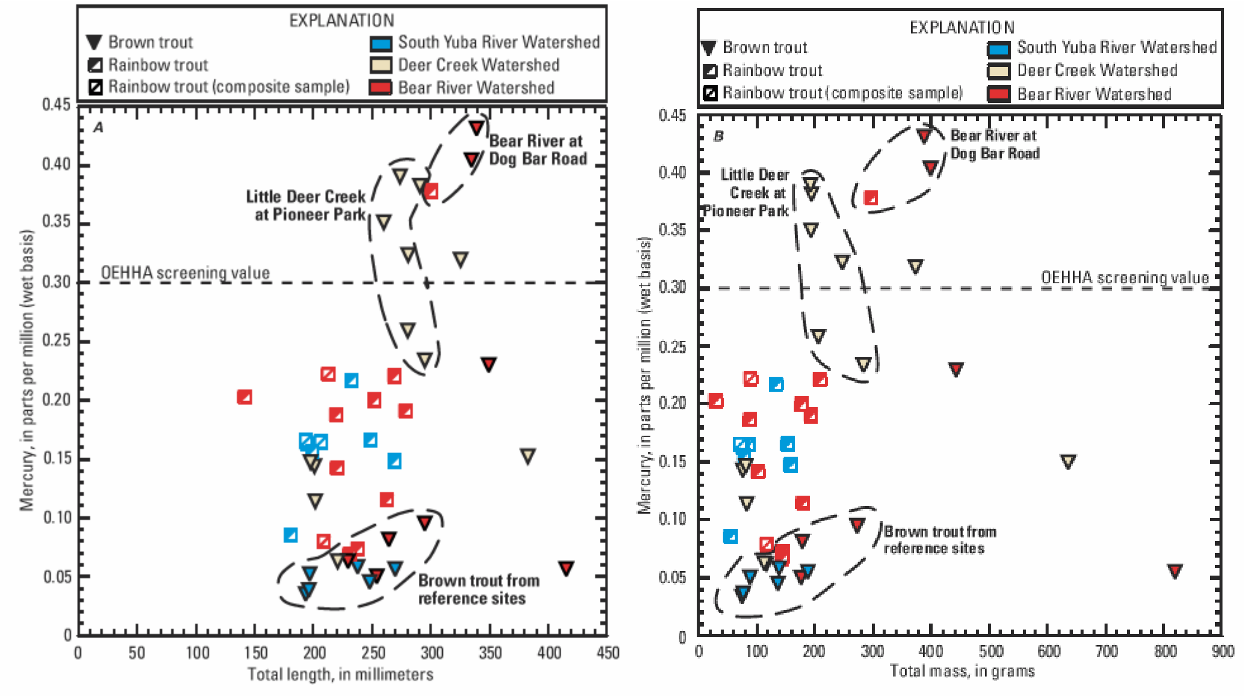

Figure 43: Mercury concentration for stream fish samples collected from the South Yuba River, Deer Creek, and Bear River. *A* in relation to total length, and *B* in relation to total mass. Dashed horizontal line at mercury concentration of 0.3 ppm represents a screen level value provided by the Office of Environmental Health Hazard Assessment. (From May et. al., 1999.)

Other heavy metals that were naturally co-occurring in the lode gold formations, and are likely to be elevated in the tailings include lead, chromium and antimony. Galena, or lead sulfide, contained small amounts of silver, and the lead was heavily concentrated in the process of silver extraction. Lead toxicity affects the nervous system and may cause developmental problems or brain damage. Chromium was found in Chromite ore and oxidized to Chromate. Chromate toxicity produces dermal ulceration and serious respiratory problems if inhaled, including bronchogenic carcinoma. Antimony is listed by the US EPA as a known/potential carcinogen, which may also cause abdominal sickness or respiratory problems if inhaled in dust.

Intense growth pressure in the Nevada City area has slated for development many old mine sites and soils with potentially high levels of arsenic and other toxic metals. However, no systematic assessment of contamination has been conducted for these areas, and the impacts of soil disturbance associated with development create a present-day concern for water quality and human health. The location of contaminant sources, and feasibility of remediation have yet to be evaluated in much of the watershed, and more studies are needed to locate heavy metal sources for effective remediation and implementation of protective measures. Identification and remediation of heavy metal sources in the watershed is a high priority for Deer Creek restoration.

B. Riparian Vegetation

Riparian zones are some of the most productive and structurally diverse habitats in the Sierra Nevada. The health and condition of the riparian zone is a function of underlying geology, soils, the stream hydrograph, and of terrestrial activities such as human management or grazing. Healthy riparian zones exhibit the attributes described in the Table 6 (reproduced from Kondolf et al, 1996).

General Attribute	Specific Attributes	References
Moisture availability	Shallow water table supports phreatophytes Evapotranspiration, shading increase humidity	California State Lands Commission 1993
	Moist environments for amphibians, reptiles	Reynolds et al. 1993; Jennings 1996
Structural complexity	Vegetation provides cover for wildlife, birds Multiple plant canopies create multiple niches	Krzysik 1990
	Seasonal changes in deciduous vegetation	Reynolds et al. 1993
Periodic disturbance	Floods disrupt existing organisms, providing opportunities for pioneer species	Resh et al. 1988; Sparks et al. 1990; Junk et al.1989
Linear nature	Edge effect: terrestrial-aquatic ecotone	Schimer and Zalewski 1992
	Riparian zones serve as wildlife migration corridors	Thomas et al. 1979
Food resources	Diverse vegetation yields diverse foods	Cross 1988
	Diverse habitat harbors diverse prey Open water available for wildlife	Raedeke et al. 1988
Microclimate	Shaded, cool, moist in summer Protected in winter: overwintering habitat	Raedeke et al. 1988
Influences on aquatic habitat	Shading moderates water temperatures Shading moderates algal growth	Brown 1969
	Plant materials and insects fall into stream, adding chemical energy and nitrogen	Cummins et al. 1989; Knight and Bottorff 1984
	Riparian zone "buffers" stream from upland	Erman and Mahoney 1983; Mahoney and Erman 1984
	Riparian vegetation stabilizes stream banks	Kondolf and Curry 1986

Table 6: Ecological Attributes of Riparian Areas

In support of the Upper Deer Creek Restoration Plan's efforts to assess overall creek health, including riparian vegetation composition and to identify the relationship between riparian vegetation distribution and composition and geomorphic processes, we developed a riparian condition rapid assessment methodology implemented during a stream walk/float down Upper Deer Creek during July and August 2005.

NHI's initial riparian condition assessment is necessarily rapid and coarse. We designed it to provide a summary understanding of riparian health along Upper Deer Creek. We based our methodology on modified versions of existing riparian zone surveys (USEPA, 1997; Fateman and Yin, 2002, SFEI, 1996). For each riparian sample location, we measured those attributes described in the text and Table 7 below.

General Attribute	Measured Attribute
Moisture availability	None
Structural complexity	Dominant species of upper canopy (trees), lower canopy (shrubs), and percent cover of groundcover (grasses and forbes). Average height of canopies and ground cover
Periodic disturbance	Floodplain terrace height as an indicator of floodplain accessibility and disturbance
Linear nature	Average width of riparian zone
Food resources	Percent non-native
Microclimate	Percent canopy cover over riparian zone
Influences on aquatic habitat	Percent canopy cover over stream

Table 7: Measured Ecological Attributes of Upper Deer Creek Riparian Areas

Transects are 50 feet wide and as deep as the active riparian area. We identified the active riparian area as the zone adjacent to the stream that either had typical riparian vegetation or appeared to be within the likely floodplain during an overbank flood event. In some rare cases, we included abandoned floodplains in the riparian zone if new floodplains had not fully developed. We endeavored to have at least two transects per geomorphic sub-reach. We located these transects in three ways:

1) At existing cross-sections;
2) In areas that appeared to be representative of the sub-reach;
3) Randomly at locations out of sight (e.g., around the next bend)[2]

At each transect, we identified the location (lat/long) and the approximate distance from the top of bank to the end of the riparian zone. We recorded 62 transects in reaches 3-7 of the study area. Each transect included separate observations for right bank and left bank, resulting in 124 transect observations. We summarize the findings below.

Structural Complexity

To measure structural complexity, we identified the dominant species in the upper canopy (trees), lower canopy (shrubs), and identified the presence of groundcover (grasses and forbes). For upper and lower canopy, we estimated the average height of the canopy. For the upper canopy, lower canopy, and groundcover we estimated the percent cover of the canopy (in five categories <20%; 20-40%, 40-60%, 60-80%, >80%).

The upper and lower canopies of the riparian vegetation in Deer Creek are dominated by white alders and willows. The upper reaches of the study area (upstream of Nevada City) are primarily white alder and dogwood or white alder and willow mixes. The lower reaches are primarily white alder and willow, or mixed willow. This variation is probably due to the difference in stream

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[2] Ideally, all the transects would have been located randomly, but as we were establishing the geomorphic sub-reaches simultaneously, time did not permit us to wait for a full reach to be established before selecting transect locations.

geomorphology. The reaches downstream of Nevada City are less steep and more depositional in nature, giving some advantage to willows. The riparian areas upstream of Nevada City (at boundary between Reach 4 and Reach 5) are steeper, smaller, more shaded by hill slopes, and rockier, which favors dogwood. The white alders perform well in both settings.

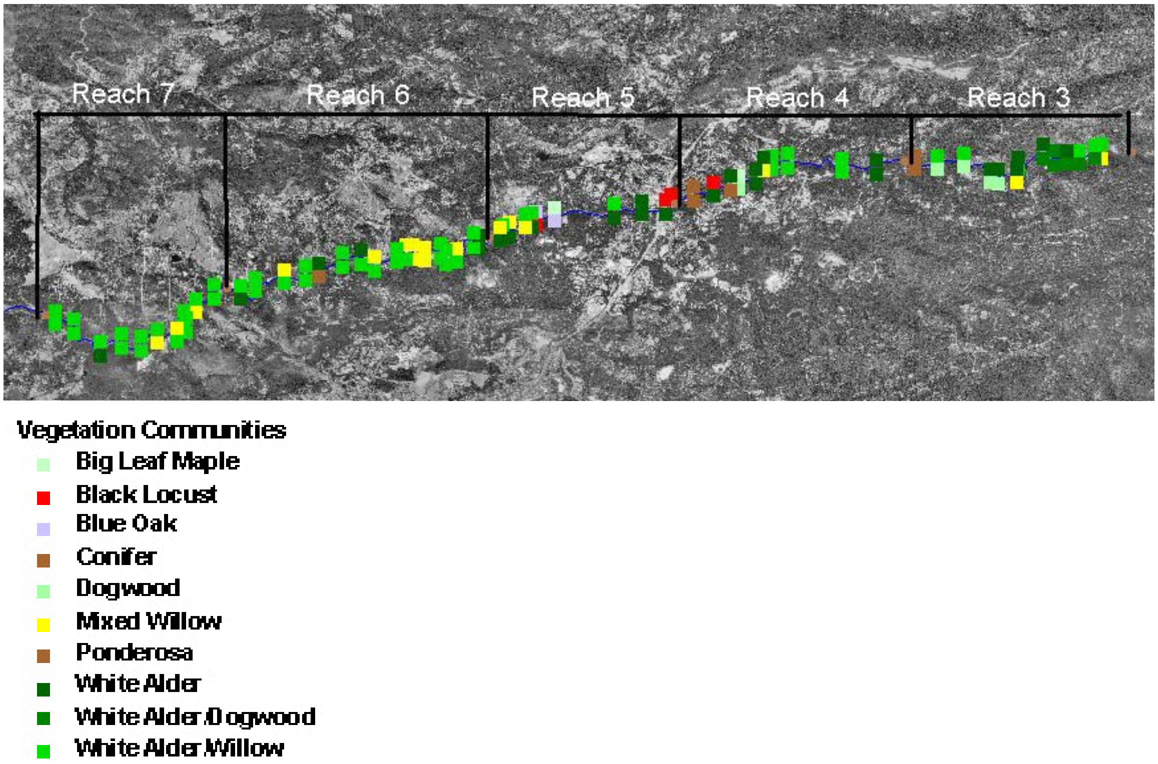


Figure 44: Map of Dominant Riparian Species along Upper Deer Creek

White alder, dogwood, and willow dominate above Nevada City (reaches 3 and 4) and white alder and willow dominate below Nevada City (reaches 5-7). Figure 43 also shows some transects dominated by ponderosa pines. Ponderosa are not typical riparian trees and thrive in drier substrate. In the lower reaches of the study area, the dominance of ponderosas indicates abandoned and inaccessible floodplain terraces. In the upper reaches, it results from the narrowness of the riparian areas (as a result of the narrowness of the creek valley). The zones are so narrow that upland species are very close to the edge of the stream.

Periodic Disturbance

Terrace height above bankfull elevation served as a rough indicator of the frequency of periodic disturbance. When combined with the hydrologic and geomorphic analysis at the established cross sections, terrace height gave a rough sense of the frequency of inundation. If terrace height varied, we reported a range of elevations above bankfull.

As a rough indicator of frequency of disturbance, we estimated in the field the height of the floodplain above bankfull discharge. In an undisturbed system, the bankfull discharge approximates a flow magnitude expected to recur every 1.5 to 2 years. It would be unlikely that the 2-year flow would be able to access a floodplain that was perched 5 or more feet above bankfull. Figure 44 displays those transects where the floodplain was 5 or more feet above bankfull discharge. The red dots in the figure below highlight those floodplain surfaces that are likely not inundated every 1-2 years. This absence of frequent inundation and periodic disturbance could hinder the function of riparian areas at these sites.

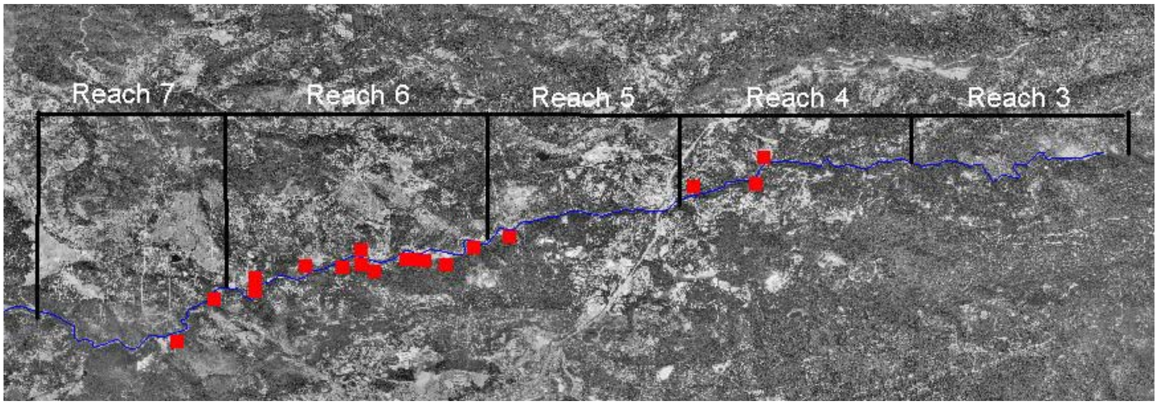


Figure 45: Location of Flood Terraces 5 feet or Higher above Estimated Bankfull Discharge

Although this is a very coarse measurement, the prevalence of these abandoned floodplains in reaches 6 and 7 with significant residual mining debris deposits indicates that the loss of floodplain function may be widespread in Deer Creek in other depositional areas (see discussion of floodplain accessibility above).

Linear Nature

We approximated the width of the riparian area (distance from bankfull to the furthest point of the riparian zone). We reported distances greater than 100 feet as >100.

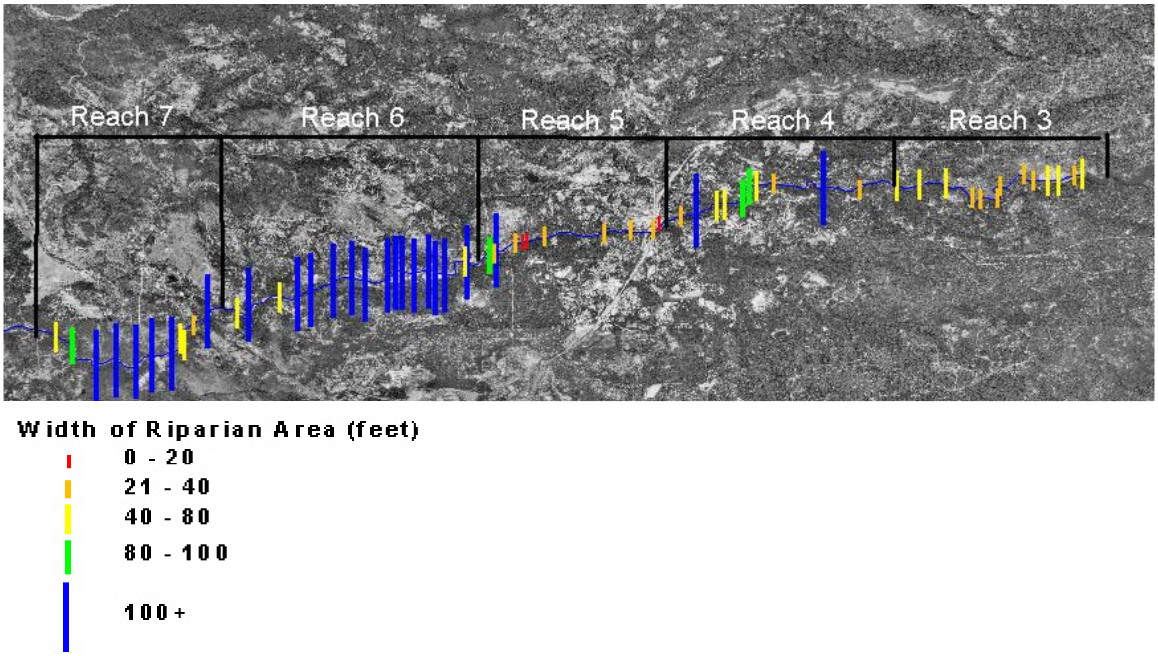


Figure 46: Width of Riparian Area

Figure 45 displays the varying width of the riparian area. As would be expected, the widths are greater in the lower, less steep, and more depositional reaches of the study area (reaches 5, 6, and 7) and smaller in the steeper reaches (3 and 4).

One of the attributes of mountain stream is that depositional areas are biologic hotspots. These wider riparian areas are also indicators of where we can expect increased biotic activity and increased sensitivity to stresses on the stream. If the study area had extended further downstream into the very steep Reach 8, we would have seen a subsequent decrease in riparian zone in that reach.

Food Resources/Non-Natives

As a very rough indicator of potential food resources for native aquatic species, we estimated the percent of non-native vegetation species in the upper and lower canopies and noted non-native ground covers in the field notes.

Figure 46 shows the location of transects that had greater than 20 percent of either canopy (upper or lower) consisting of non-native species. The map shows a remarkable increase in presence of non-natives near and downstream of Nevada City. This indicates the role that humans play in the spread of non-natives. While some of these are ornamental trees in back yards (centering on the urban reach near Nevada City) most of the non-natives in the upper and lower canopies were black locust trees.

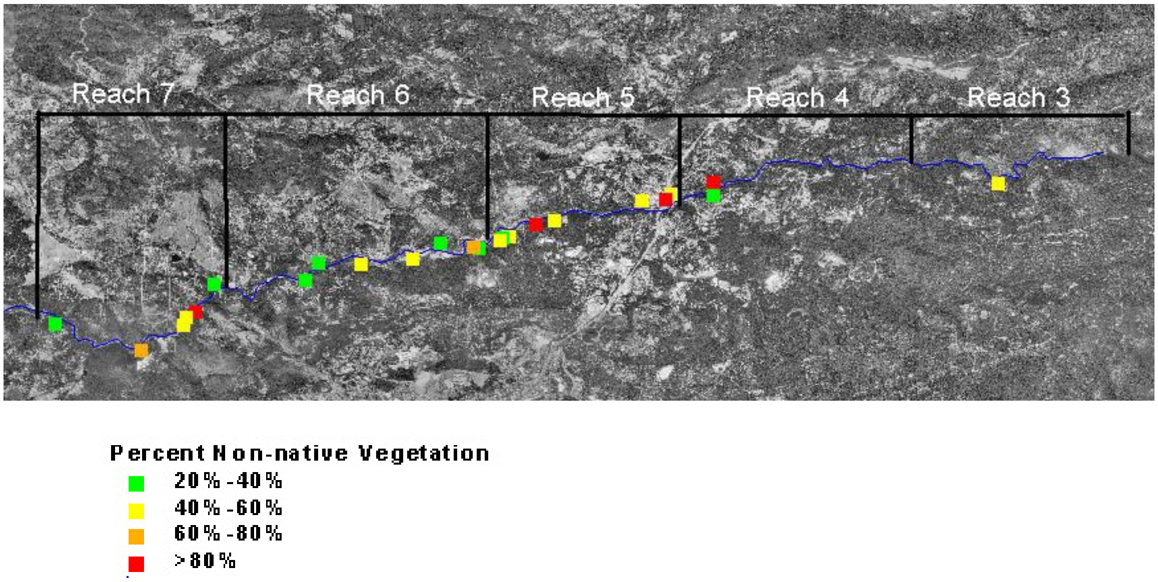


Figure 47: Percent Non-Native Vegetation

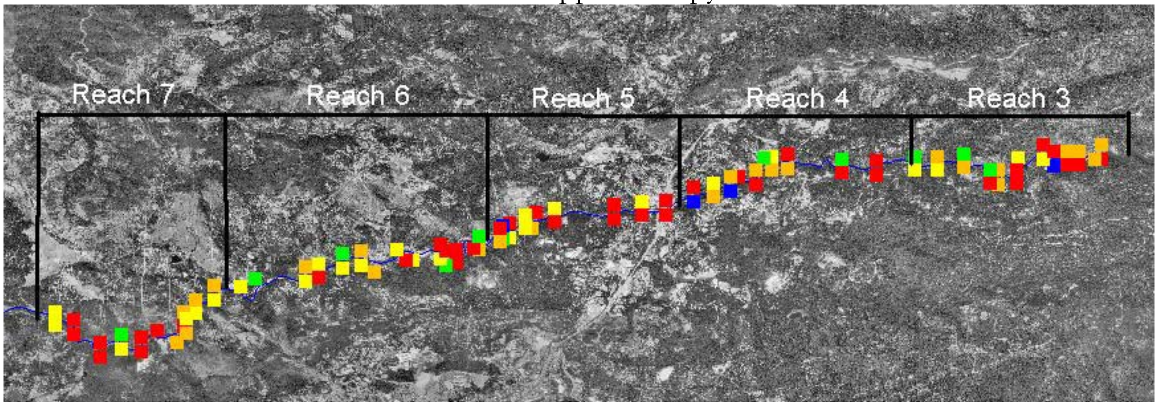
The figure above shows all transects with more than 20 percent non-native vegetation in either the upper or lower canopy. Non-natives increase significantly in and downstream of Nevada City (lower reach 4 through reach 7). Though not quantified (and thus not displayed in map), much of the groundcover from Reach 4 downstream is the invasive Himalayan blackberry. Upstream of Reach 4, native blackberry seems to out compete the Himalayan blackberry. Whether this is a function of riparian conditions, elevation, or other factors is unknown.

The most problematic and invasive non-native plant species found along Deer Creek include:
Scotch Broom (*Cytisus scoparius*)
Himalayan blackberry (*Rubus discolor*)
English ivy (*Hedera helix*)
Black Locust (*Robina spp.*)
Vincus (*Vinca spp.)*

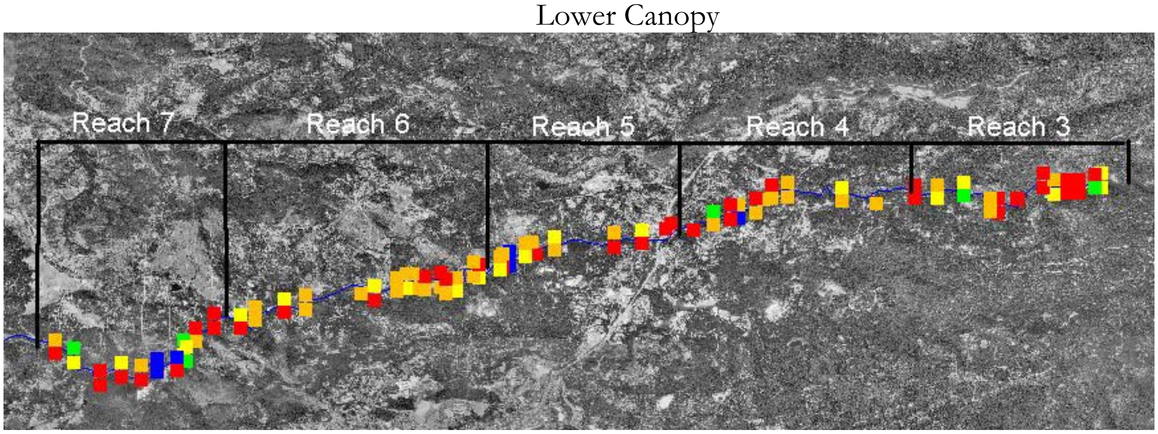
Microclimate

Percent canopy cover over the riparian area served as an indicator of microclimate and the riparian vegetation's ability to cool and shade the riparian zone. For the upper canopy, lower canopy, and groundcover we estimated the percent cover of the canopy (in five categories <20%, 20-40%, 40-60%, 60-80%, >80%). Figure 47 displays the percent cover of the upper canopy, lower canopy, and gaps in the canopy, (from top to bottom). The lower map shows only those areas where both the upper and lower canopy provide less than 20% cover, providing little structural complexity and leaving the ground cover exposed to sunlight and heat and subsequent evapotranspiration. These represent 20% of the total transects recorded. These are potentially areas that deserve some restoration or remedial action to improve the structural diversity and establishment of microclimates in the riparian zone. Several of these areas are centered around Nevada City.

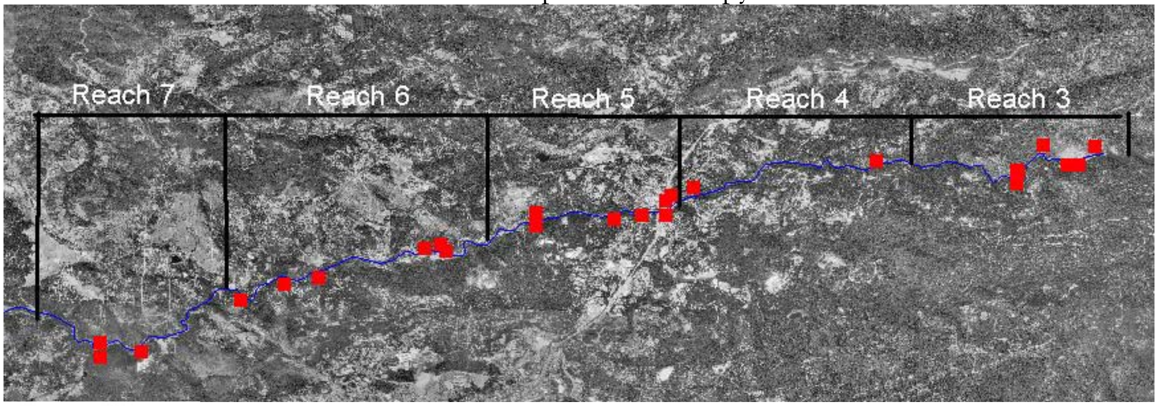
Upper Canopy



Lower Canopy



Gaps in the Canopy



Percent Cover

- 🟥 <20%
- 🟧 20%-40%
- 🟨 40%-60%
- 🟩 60%-80%
- 🟦 >80%

Figure 48: Percent Canopy Cover of Riparian Zone

Upper Deer Creek exhibits a diversity of canopy cover amounts. The top two maps do not exhibit any strong spatial trend. The lower map highlights those areas lacking either upper or lower canopy. While distributed across the entire study area, there is a cluster of gaps in the canopy surrounding Nevada City (at boundary between Reach 4 and 5).

Influences on Aquatic Habitat

Percent canopy cover over the stream served as an indicator of the riparian zones' ability to shade and to provide nutrient inputs into the stream channel. For canopy cover over the stream, we took spectral densiometer readings from the middle of the stream. Riparian zone width served as an indicator of the zones' ability to buffer the stream from upland influences.

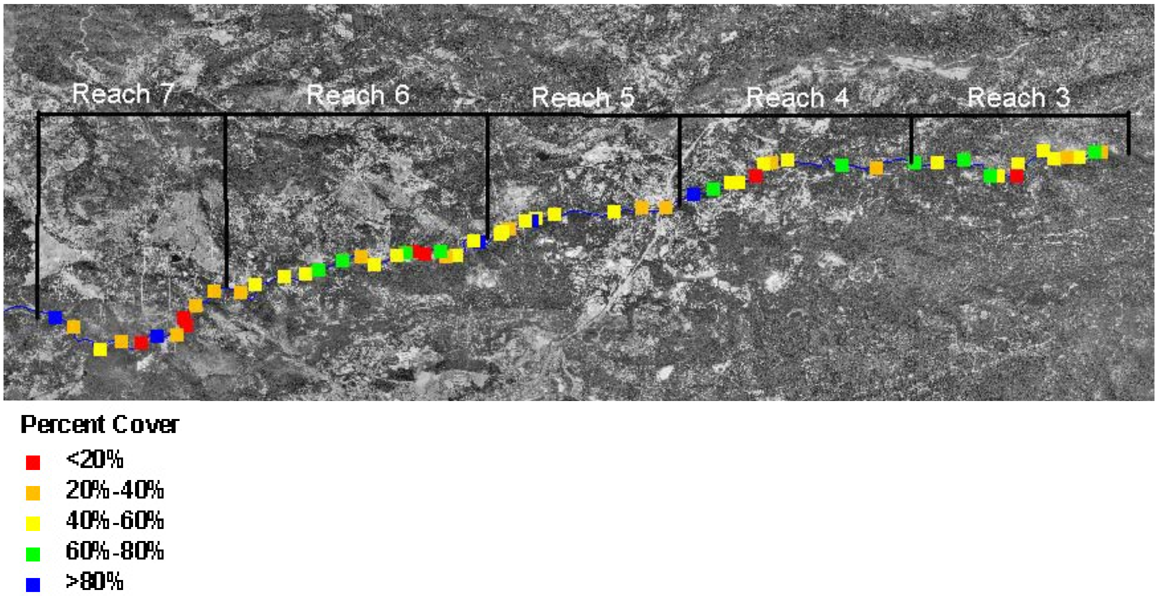


Figure 49: Percent Canopy Cover Mid-stream

Figure 48 summarizes the results of our spectral densiometer readings taken from the middle of the creek. The figure illustrates a very slight downstream trend toward decreasing canopy cover in the middle of the stream. This likely results in part from the slight increase in stream width as the contributing drainage area and runoff increase. Figure 48 above also summarizes the riparian width measurements. The areas with wider, active riparian areas provide a greater buffer to upland stresses.

Summary Comments on Riparian Vegetation in Upper Deer Creek

The conditions of the riparian zone are a function of the hydrograph, mining history, sediment availability, the resulting geomorphology, and seed sources. Our assessment describes a riparian zone that is in reasonably good health. The riparian zone offers structural diversity, a mosaic of vegetation types, significant shading of the creek and floodplains, and varied width and complexity. However, there are pressing issues. We have identified the three most pressing issues regarding the riparian conditions as: loss of floodplain accessibility (discussed above), invasive non-native species, and loss of lower canopy cover (and on a limited reach, the riparian zone entirely) in the proximity of Nevada City.

Invasive species are most prevalent in and below Nevada City. This is consistent with the pattern of human development in the watershed. Most of the upper and lower canopy invasive specimens are black locust. Himalayan blackberry dominates much of the ground cover in the study reach. Unchecked, these invasive species could out-compete native species, distorting the river's natural wildlife and habitat. Non-native vegetation does not provide the habitat and food values provided by natives, which could result in lower productivity of native fauna, or the local extirpation of natives.

In the reach upstream of Nevada City, where backyards extend down to the creek edge, the lower canopy is deficient. It appears as if most landowners prefer tall trees for shading but clear the lower canopy and ground cover because is interferes with views of and access to the creek. This clearing reduces the structural complexity of the riparian zone and limits its ability to buffer the creek from upland runoff. Educational outreach could be conducted with landowners in this zone to educate them about the importance of controlling invasive species, the benefits of lower canopy riparian vegetation, and the protection this affords their property during floods.

C. Wetlands

In mountain streams, wetlands and riparian areas contribute significant biotic productivity to the ecosystem. The section above described the conditions of the riparian zones. Though we did not perform a systematic survey or assessment of freshwater wetlands along Deer Creek, in our creek survey and overflight, we did notice an absence of these habitats. We identified only one freshwater wetland that was not directly associated with the riparian zone of the mainstem of Upper Deer Creek. This wetland occurs near the Providence Mine Road cross sections in Upper Stocking Flat where Woods Ravine empties out of the hillside and into Deer Creek. Water pools at this location and forms a small freshwater wetland. This wetland appears to have been once significantly larger (probably 4-5 acres), but Woods Ravine was channeled and now runs parallel to the Creek for some distance before joining the creek. Undoubtedly there are more outside of our study area, but it still appears that there are fewer than expected. In its natural state, we may have expected more wetlands in the system. In early aerial photos, it appears that the area now under Scotts Flat reservoir was a large, flat terrace and may have been the largest wetland in Upper Deer Creek prior to when mining activity commenced.

D. Need for Further Study

More effort should be given to mapping and studying wetlands as they are a critical component of the hydrologic and biologic systems operating in the Deer Creek watershed. Restoration of wetlands is important for ecosystem health, but must be conducted with caution in this heavily-mined region. Mercury, used in extracting gold, is known to methylate (convert to a bioavailable form) at an increased rate in most wetlands. Because of the likelihood of residual mercury contamination from historic mining activities, mercury levels and inputs to a proposed wetland area should be characterized, and a strategy to address methylation potential developed before wetland restoration is pursued. Further studies on the extent and magnitude of heavy metal contamination are recommended.

In addition, more studies are needed on the fauna of the watershed, including the condition of indicator species, endangered, threatened or species of concern in the watershed. Strategies should also be identified to protect or improve the habitat of these species. Friends of Deer Creek also plans to conduct further studies to map the distribution of the most important invasive plant species, and focus efforts on maintaining these edges and preventing further spread. Additional water quality studies are also needed to understand the causes of algal blooms and bacterial contamination in the watershed that affect the ecology and health of the Creek. Ongoing water quality monitoring is needed to evaluate the effectiveness of restoration and adaptive management actions.

CHAPTER VI:
FUTURE DEVELOPMENT AND ITS IMPACT

While the previous chapters focused on historic and current conditions, this chapter begins to look to the future by predicting what the future impacts will be on Deer Creek based largely on urban and residential development. In addition, we look at the existing and planned regulatory context and analyze whether or not it is adequate to mitigate these future impacts.

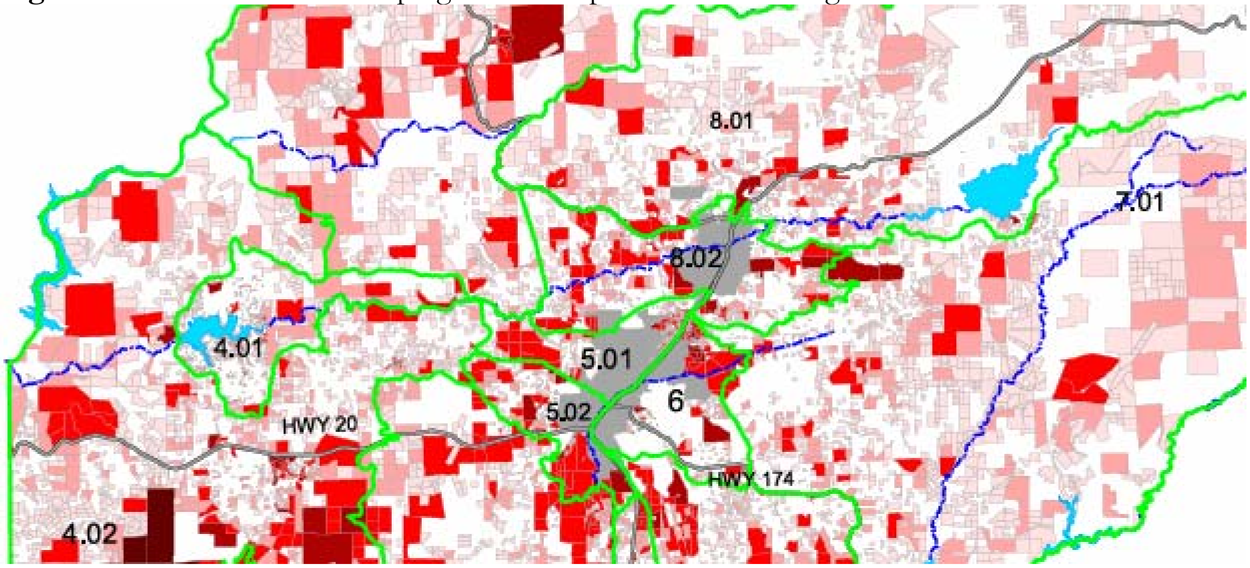
A. Future Population

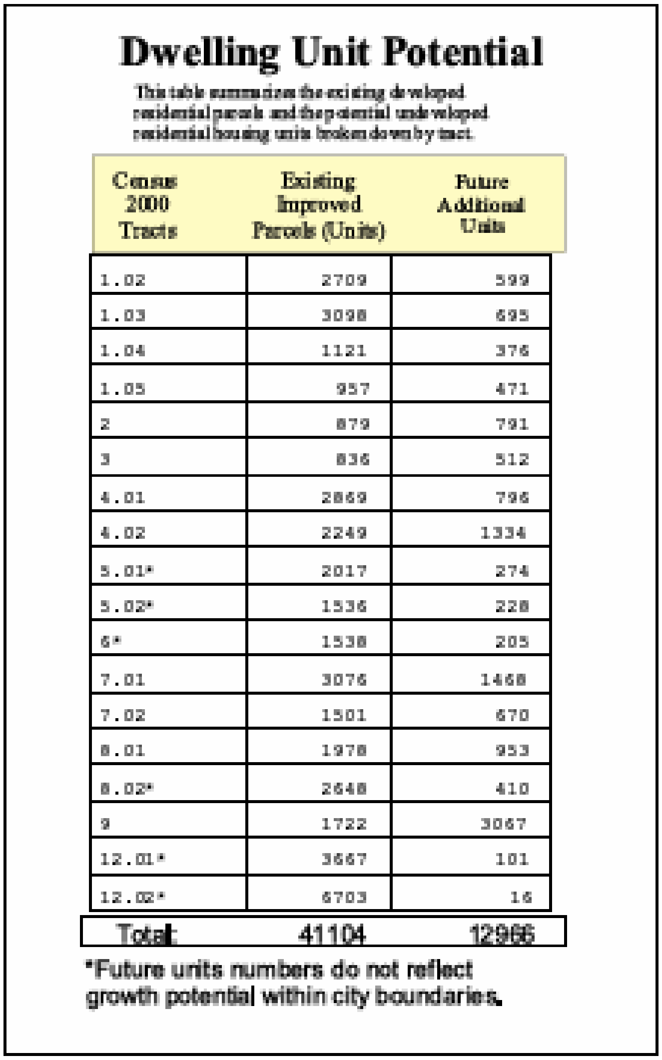
Between 1965 and 2001, the county's population nearly quadrupled, from 25,100 to 94,361 (Walker et. al., 2003), and by 2050, the population is expected to increase to over 160,000 (Landis and Reilly, 2003). The Deer Creek watershed will receive a portion of that growth. More than one fourth of the Nevada County population lives in the Deer Creek watershed. These approximately 25,000 residents live mainly in Nevada City, Lake Wildwood and Penn Valley (Census Bureau, 2000). As discussed more fully below, development can cause significant changes to all aspects of a creek ecosystem.

B. Future Development

The Nevada County Planning Department tried to estimate the number of parcels and dwellings that could be created given current zoning. The county identified dozens of parcels in the Deer Creek Watershed that could be developed further, either by building on an existing parcel, or splitting a parcel and building dwellings on the newly created parcels (see Figure 49). Some parcels could be split into two, whereas others could be split into 5 or more. Although it is not possible to tell exactly how many of these parcels are within the watershed, a conservative estimate would be that at least 1500 new dwellings could be constructed on new or existing parcels. There is a concentration of parcels with development potential in the Penn Valley area, but parcels are scattered throughout the watershed. If an average of three persons occupy these new dwellings, the population in the Deer Creek Watershed could increase by at least 20 percent to 30,000.

Figure 50: Potential for developing additional parcels and dwelling units.





Dwelling Unit Potential

This table summarizes the existing developed residential parcels and the potential undeveloped residential housing units broken down by tract.

Census 2000 Tracts	Existing Improved Parcels (Units)	Future Additional Units
1.02	2709	599
1.03	3098	695
1.04	1121	376
1.05	957	471
2	879	791
3	836	512
4.01	2869	796
4.02	2249	1334
5.01*	2017	274
5.02*	1536	228
6*	1538	205
7.01	3076	1468
7.02	1501	670
8.01	1978	953
8.02*	2648	410
9	1722	3067
12.01*	3667	101
12.02*	6703	16
Total	41104	12966

*Future units numbers do not reflect growth potential within city boundaries.

N
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Created by Nevada County GIS Division
mark-tomich2.apr
7/12/04

2 0 2 Miles

Legend

- 🟩 Census 2000 Tracts
- ╱╲ Highway
- 🟦 Large Lakes
- ☐ County
- ⬜ City Boundaries

Potential Units per Parcel

- 🟥 1 (10,390 Total)
- 🟥 2 - 4 (1,734 Total)
- 🟥 5-25 (714 Total)
- 🟥 26 - 100 (99 Total)
- 🟥 > 100 (29 Total)

C. Water Resource Development

As population increases in Nevada County, including the Deer Creek watershed, NID will be required to serve new residents and existing customers in its service territory. Because NID uses Deer Creek below Scotts Flat to deliver water to several of its service canals (*i.e.,* Newtown and Tunnel canals), Deer Creek will likely continue to serve its delivery function – unless NID were to replace Deer Creek as a water delivery channel with a pipeline(s) or another canal(s), or if demand served by the Newtown or Tunnel were to dramatically decrease. These events are unlikely to happen in the foreseeable future. However, as water demand increases, it is possible that NID will be forced to deliver water more efficiently, which could include reducing flows in Deer Creek to the very minimum necessary for deliveries. This is particularly important for denser developments (four major dense developments are currently proposed around Grass Valley, to be supplied by NID water from Deer Creek), which will rely on NID instead of wells for water supply, and will add many more people/area and dramatically increase water demand. This might be counteracted by decreased agricultural demand as farm and ranchland is converted to residential and commercial uses. This anticipated growth could cause some reduction below lower Scotts Flat, where water is diverted to Grass Valley in the D-S Canal, but flows would likely remain elevated to the Newtown and Tunnel canals. However, in lower Deer Creek, where low summer flows are already exacerbating algae blooms and causing significant water quality degradation, increased upstream diversion could have severe consequences.

D. Climate Change

Climate change will drive the future amount, location, and timing of precipitation and snowmelt for California. The impacts of these changes are already being documented, including an increase in the number and severity of major storm events. Impacts of climate change on the Sierra Nevada region are predicted to include: a higher snowline, an increase in runoff and sediment from winter rain events, shifting shrubland to higher elevation areas, increasing number of thunder and lightning storms, and additional stress on trees (Wilkinson 2002). As air temperatures increase with climate change, Deer Creek water temperatures are expected to increase as well, although not necessarily as much as air temperatures. If climate change were to alter precipitation and runoff patterns severely enough to prevent NID from making full deliveries to its customers, it is possible that flows in Deer Creek would be reduced in proportion to the decreases in deliveries to customers served by the Newtown and Tunnel canals (see discussion above).

E. Implications for Upper Deer Creek

To accommodate for the growth in the County, land currently in open space, agriculture, grazing, or private timber harvesting will be converted to residential or commercial use. Urbanization and development modifies both the amount and timing of runoff into the creek and the quality of water entering the creek. In both cases, the main driver of change is an increase in impervious surfaces such as paved roads, parking lots, and buildings and storm drains. An increase in impervious surfaces decreases infiltration and increases runoff. Figure 50 illustrates the relationship between percent impervious surface and the fate of rainfall. The illustrations (Figure 50) provide a quantitative description of infiltration versus runoff across a continuum of development, while the graph displays the resulting impact on the magnitude of flood peaks and the duration of the lag-time.

This exponential change in infiltration rates that occurs as lands are converted from natural cover to impervious surface has profound effects on local hydrology. In essence, as the Deer Creek watershed continues to develop, rainfall will be transported more rapidly into the stream channels, resulting in shorter lag-times and higher peaks. Since less water infiltrates into the ground, less is stored as groundwater and less released as base flow during low flow times of the year, such as summer.

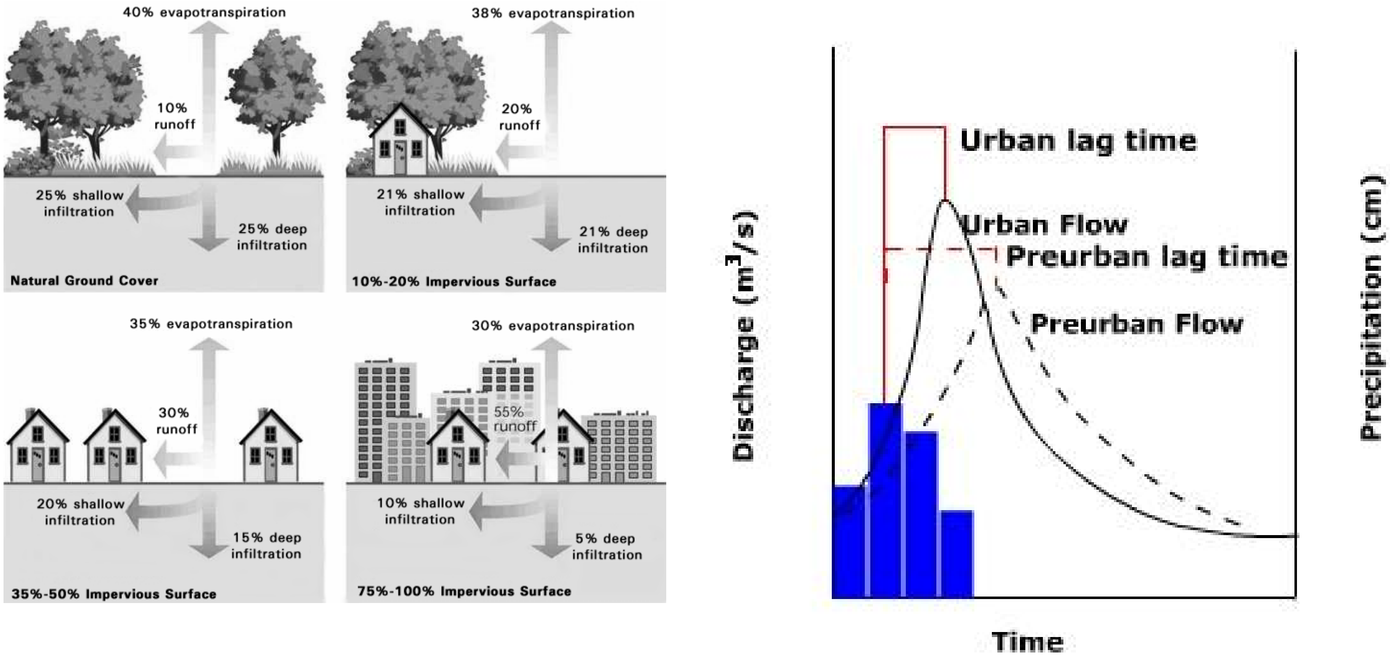

Figure 51: Effect of Urbanization on Hydrologic Processes

Infiltration into the ground also serves to cleanse the water before it enters the stream channel as depicted in Figure 51. Under natural conditions, riparian and wetland vegetation along Deer Creek also filter out many potential pollutants. Research demonstrates that higher levels of surface water toxicity are generally associated with watersheds containing more developed land surface and less open space (Skinner et al., 1999).

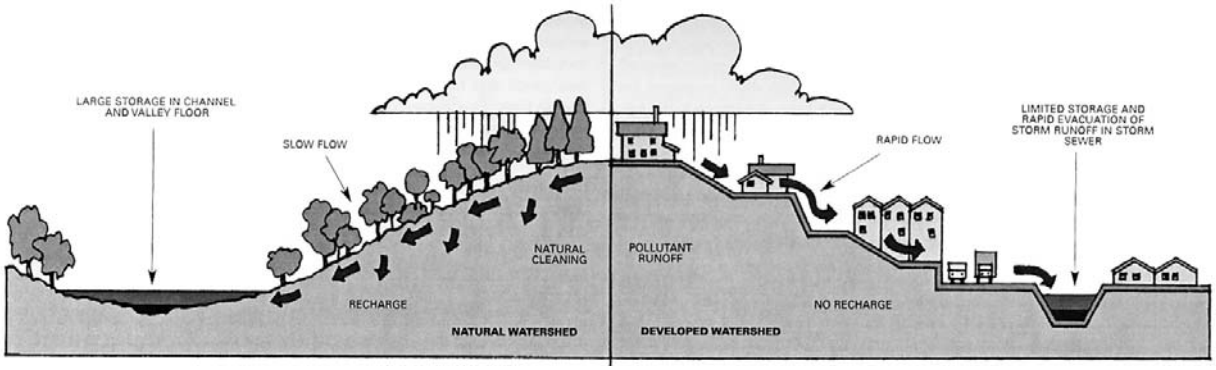

Figure 52: Effect of Urbanization on Groundwater Recharge and Water Quality

Contaminants such as pesticides, heavy metals (including Cd, Cr, Cu, Pb, Ni, and Zn), dioxin, and n-nitroso compounds are common constituents in stormwater in developed watersheds and have been correlated with developmental toxicity in a variety of aquatic organisms (Wisk and Cooper, 1990; Pillard, 1996; Skinner et al., 1999; Wenning et al., 1999). Developed watersheds also contribute runoff from septic systems, yard care products, automotive exhaust and oils, and other constituents commonly found in urban environments. Research indicates that the impacts of polluted runoff may be especially significant if contaminated surface waters empty into an enclosed area such as a bay, estuary, or reservoir (Katznelson et al., 1995). Thus, increases in polluted runoff from the Deer Creek watershed could inflict large and potentially irreversible ecological harm to bodies of water downstream. Urbanized streams typically incise, exhibit greater concentrations of fine sediments, and higher primary production, including harmful algal blooms, as a result of greater nutrient availability.

E. Regulatory Context

Several sate and federal laws and regulations form the regulatory framework governing Deer Creek. The three most important include the federal Clean Water Act, and the state Basin Plan and Fish & Game Code. The Basin Plan, administered by the Regional Water Quality Control Board-Central Valley Region recognizes that Deer Creek is used as a municipal and domestic drinking water supply, and also recognizes the following beneficial uses:

- agricultural irrigation
- hydropower generation
- agricultural stock watering
- non-contact water recreation
- body contact water recreation
- warm freshwater aquatic habitat
- groundwater recharge and freshwater replenishment
- cold freshwater aquatic habitat
- warm fish migration habitat
- cold fish migration habitat
- warm spawning habitat
- cold spawning habitat
- wildlife habitat

In general, the Basin Plan requires that these beneficial uses be protected in perpetuity, but the plan provides little guidance on the priority of the various uses or how to resolve disputes when beneficial uses seem in conflict.

Several sections of the Clean Water Act establish water quality standards that must be met, including both numerical and narrative standards. Section 401 requires that any action requiring a section 401 certification be required to meet all federal and state water quality standards, including protecting all beneficial uses as defined by the Basin Plan. Section 303 requires that water bodies be assessed for compliance with a list of water quality standards, and if found out of compliance a plan must be developed that will bring the water body into compliance. This plan is known as the Total Maximum Daily Load, or TMDL. As mentioned above, Scotts Flat and Little Deer Creek have been designated non-compliant for mercury and listed under California's 303(d) list. This listing will eventually result in a TMDL being developed to address the problem.

Additional investigation is needed into the regulatory opportunities and constraints on maintaining healthy flows in the entire Deer Creek watershed, especially in the lower sections below NID's major diversions and Lake Wildwood Reservoir, and mechanisms for increasing summer flows in this section to improve watershed health.

CHAPTER VII: RESTORATION OBJECTIVES AND RECOMMENDATIONS

In this chapter, we combine information from our previous analysis and assessment, including the field assessment and analysis of future conditions to identify priority restoration, management, education, and regulatory reform goals and objectives, and associated actions. We begin with a conceptual model to illustrate how proposed restoration actions are related to historic and present-day forces and effects.

A. Restoration Conceptual Model

This conceptual model incorporates the *Forces* that have left a legacy in the Deer Creek watershed, connects them to the *Effects* that they had, and then demonstrates the *Restoration* actions that would mitigate these effects.

As discussed in this assessment and plan, hydraulic mining altered the channel morphology of Deer Creek. The increased sediment load to the stream caused the channel to aggrade where mining debris accumulated in low gradient reaches. The effect of the increased sediment load can be partially mitigated if flood flows are allowed to return the channel back to a state of equilibrium over time. But this will likely require many decades in areas where the mining debris sits in terraces far above the creek channel, and may require mechanized removal of terraces and floodplain regrading. Mining has also introduced a number of heavy metal contaminants to the stream including mercury, which was used to extract gold from sediments and hard rock. Restoration from the effects of mercury contamination may include removal or stabilization of accumulated mercury laden sediment.

The NID water supply system has dramatically altered Deer Creek. Dams have altered the flow regime by reducing the magnitude and frequency of peak flows that are necessary to maintain channel morphology and habitat diversity and health. NID's deliveries during the irrigation season also create a colder, faster moving stream than would otherwise occur, but this partially mitigates water quality degradation and supports a healthy macroinvertebrate population under current conditions. In addition, dams prevent the movement of sediment downstream, and aquatic biota from moving in either direction. To mitigate the effects of dam control, releases that mimic more natural flow regimes should be considered, such as pulse releases during the winter that mimic 2-10 year flood flows. While gravel supplies have been depleted in the bedrock section just below lower Scotts Flat dam, the lack of channel downcutting and difficulty of access make gravel augmentation a low priority. However, with the likelihood of continued rapid growth causing more soil disturbance in the watershed, fine sediment inputs from anthropogenic erosion need to be controlled.

Development in the Upper Deer Creek Watershed, particularly around Nevada City, has resulted in reduced canopy cover and loss of riparian habitat, an increase in invasive species, and an increase in impervious surfaces. These influences modify the amount and timing of runoff, creating a shortened lag-time and degraded water quality. To mitigate the effects of urbanization, the removal of non-native vegetation and replanting of native vegetation should be encouraged, as well as runoff and erosion control mechanisms.

Timber was harvested heavily in the late nineteenth century from Deer Creek watershed, however, logging in the headwaters and private parcel logging continue to the present day. Logging generally reduces habitat for wildlife, degrades water quality by increasing fine sediment loads to the stream and increases runoff from impervious surface where heavy machinery has compacted the ground. However, some selective logging or thinning may enhance spatial variability and habitat complexity, as well as mitigate the impacts of catastrophic wildfires from historical fire suppression. Careful planning for wildlife habitat preservation and erosion prevention should be incorporated in timber harvest or thinning plans. Managing sediment control during logging operations will help alleviate the impacts to the aquatic environment.

Invasive species reduce habitat for native wildlife and reduce effective riparian buffers. Removal of invasive species, replanting of native species and education to prevent spread of invasives will help mitigate the negative effects.

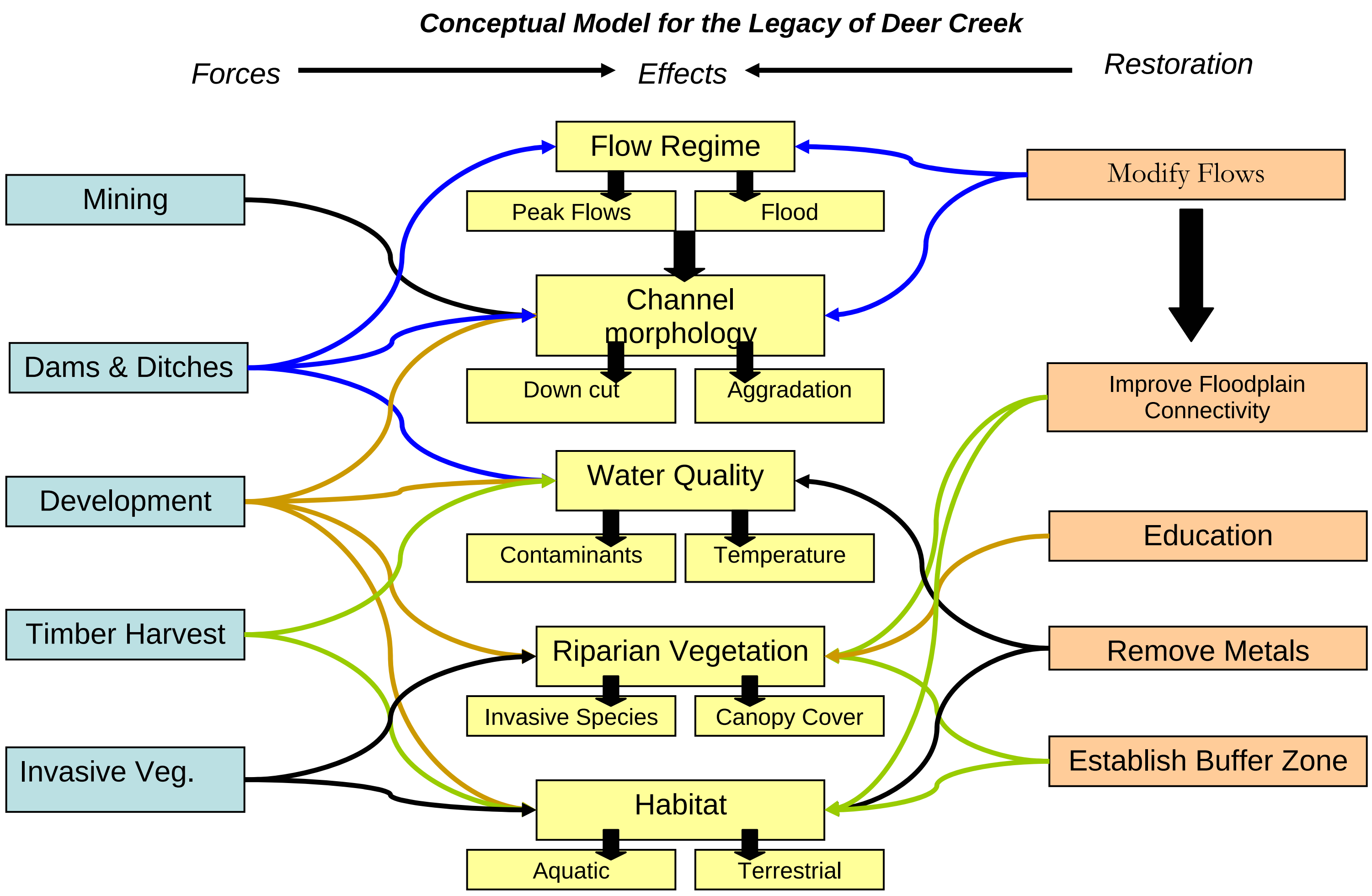

Figure 53: Conceptual model for Deer Creek restoration efforts.

B. Upper Deer Creek Restoration Goals and Recommended Actions

Based on the assessment and analysis of the various aspects of Deer Creek described in this report, several actions can be recommended to address identified problems that prevent Deer Creek from being as healthy and productive as it can be. To be clear, these suggested actions do not amount to a call to return the creek conditions that would have been found before mining and water infrastructure development. Indeed, that would be impossible, and not necessarily advisable. For example, recreating "natural flows" in the summer would require reducing current flow levels significantly from July through October. Reproducing such flows would be difficult, if not impossible, given the role that Deer Creek plays in NID's water delivery system. In addition, mimicking low summer flows for extended periods might not be advisable under current circumstances, *e.g.,* higher nutrient loads from wastewater treatment, non-point source pollution, reduced riparian forest cover, excessive fine sediment inputs and the persistence of heavy metals from mining. Such present conditions would likely amplify the level of stress to aquatic organisms caused by otherwise natural effects of low flows, *e.g.,* higher water temperatures, lower DO, greater algal growth and less available aquatic habitat. However, experiments with short-term reductions in summer flows might be considered to determine whether native biota would benefit from a period of conditions more similar to conditions under which they evolved (Power et. al., 1996). A suggestion to consider short-term, experimental low flows in Upper Deer Creek – above Lake Wildwood only – is included in the recommendations.

Described below are recommended actions to improve the health and productivity of Deer Creek organized into several broad categories. Included also are several recommendations of additional research, as well as actions to promote science-based management and to foster a stewardship ethic. These recommendations reflect input provided by Friends of Deer Creek staff and directors. In addition, a table is provided that summarizes these recommendations in addition to the associated issues, objectives, problems and current constraints.

Improve Flow Characteristics and Geomorphic Function

- Re-establish more frequent disturbance and inundation of riparian areas increased flood flows during certain storms to create higher flows for 2, 5 and 10 year flood events.
- Regrade large, abandoned floodplain terraces to elevations that will flood at proper intervals, (beginning with BLM-owned land in Providence Road reach) and with willing landowners in the Stocking Flat area. Closely monitor these floodplain areas for frequency, depth, and duration of inundation and subsequent vegetation response.
- Continue to monitor and analyze flows necessary for geomorphic function and aquatic health.

Restore and Protect Riparian Habitat

- Establish to the extent possible, a natural buffer zone along the river through land acquisitions, conservation easements and building ordinances.
- Consider short-term, experimental periods of lower flows in late summer or early fall months from Scotts Flat to Lake Wildwood to determine if native biota would benefit from these conditions.
- Introduce a comprehensive natural habitat educational program to encourage the growth of native species and discourage non-native plants. Map distribution of priority invasives, and work with landowners to control boundaries and prevent further takeover by invasives.
- Remove priority invasive non-native species from riparian zones.

- Work with private landowners to plant native groundcover and lower canopy vegetation in riparian areas in and around Nevada City.
- Support the development of forest fire protection guidelines that maintain ecological balance and protect water quality.
- Support educational and recreational access to Deer Creek to improve public awareness and promote stewardship.
- Engage the community in all aspects of watershed protection and restoration. Educate the public about how restoration improves biological diversity, and why this is important.

Restore and Protect Fisheries and Priority Species

- Assess health of fish populations of Deer Creek.
- Identify additional priority/indicator species and associated habitat types to be protected.
- Assess the health of indicator species and their food webs and habitats.
- Develop and implement protection measures for these species.
- Conduct a feasibility analysis to consider applying a stringent river corridor overlay districts to current zoning requirements.
- Restore salmon and steelhead runs in lower Deer Creek.

Reduce Erosion

- Further assess sediment delivery from roads, logging and developments.
- Identify priority areas for erosion control.
- Develop strategies for reducing erosion and sediment loading to the creek.
- Develop Best Management Practices guidelines for preventing erosion from development.
- Support the development of scientifically-sound zoning and building regulations that protect creek health.

Reduce Adverse Effects of Mercury/Heavy Metals

- Identify and priority heavy metal contamination sources, analyze remediation options, and implement remediation measures.
- Reduce mercury and arsenic methylation and bioavailability in the watershed.
- Reduce mercury transport through DC watershed.

Reduce Nutrient, Bacterial and Stormwater Pollution

- Monitor the impacts of wastewater treatment discharge.
- Replace wastewater chlorination treatment with contaminant-free alternatives.
- Locate problem sources for nutrients and bacteria through nutrient, algae and bacteria studies.
- Design and implement appropriate contaminant reduction solutions.
- Assess and work toward the reduction of nutrient and bacterial contamination from septic systems.
- Support implementation of the Regional Board's new septic system pollution reduction guidelines.
- Assess and reduce pollutant delivery from stormwater runoff and other non-point sources.

Promote Science-Based Management

- Continue to refine our understanding of natural flow regimes in Deer Creek through installation of flow meters and analysis of historical data.
- Continue to collect scientifically rigorous and defensible monitoring data as a basis for evaluating progress toward restoration goals and the effectiveness of water quality improvement efforts.

- Implement marked rock experiments to provide empirical data to compare to sediment transport model results.
- Map and monitor non-riparian freshwater wetlands in the watershed.

Increase Stewardship through Access and Education

- Increase Deer Creek's visibility and inspire community stewardship through the design and construction of a loop trail around Upper Deer Creek that follows the Rough and Ready Ditch on the river left and the Newtown Ditch on river right and crosses Deer Creek with a pedestrian bridge above Lower Stocking Flat on BLM land. Link this trail with existing trails such as the Rotary Trail and the trail to Pioneer Park. Connect this trail system with downtown Nevada City to promote town-centered planning and local economic development. To develop this trail system, work with the Nevada County Land Trust to assess and acquire key parcels and trail easements.
- Provide interpretive signage that explains the history, ecology, and restoration of Upper Deer Creek, including the important cultural role that Chinese Americans played in the area.
- Foster education and river awareness programs that include materials explaining how restoration and protection improves biological diversity, and why this is important.
- Expand public education efforts on non-point source pollution prevention, including storm drain stamping, and disseminate Best Management Practices guidelines for preventing erosion from development.
- Assess and communicate public health risks to the community regarding heavy metals.
- Develop partnerships with Neighborhood Associations around Deer Creek to develop and disseminate information.

Table 8: Summary of Deer Creek Issues/Objectives, Problems and Recommended Actions

Issue/Objective	Current Problem	Current Constraints	Recommended Actions
Flows and Geomorphic Function			
Unaffected flood peaks	Dams attenuate flood peaks	Scotts Flat storage operations	High flows at 2, 5, 10 yr intervals
Low summer flows	Water supply elevates summer flows	NID water delivery obligations	Experimental short-term low flow
Sediment supply uninterrupted	Dams interrupt sediment transport	Scotts Flat dam will remain	Gravel, cobble supplementation
Frequent channel forming flows	Dams attenuate flood peaks	Scotts Flat storage operations	High flows at 2, 5, 10 yr intervals
Floodplain regularly inundated	Dams attenuate flood peaks Floodplains unnaturally perched	Scotts Flat storage operations Large amounts of mining debris	High flows at 2, 5, 10 yr intervals Regrade floodplains and channels
Riparian Habitat			
Undisturbed riparian corridor	Interrupted native riparian zone	Existing and future development	Buffer zones, conservation easements Educational program for residents on crk Improve forestry operations Fire guidelines to protect water quality
Native riparian species only	Widespread distribution	Vast seed bank	Map priority non-natives Replace non-natives with natives
Restore Fisheries, Priority Species	Non-natives introduced	Little known about Deer Creek fishes	Assess fish populations Identify additional priority species Assess health of indicator species Develop/implement protection actions Analyze feasibility of est. river corridor Restore salmonids in lower Deer Creek.
Erosion			
Erosion from undisturbed soils	Sediment from roads, development, timber	Roads and development continue	Identify priority roads, developments Implement erosion control measures
Mercury and Heavy Metals			
Metals occurred in undisturbed soils	Contamination from mine waste sites Stream substrates contaminated	Broad distribution of contamination	Identify priority contamination sources Reduce Hg methylation/bioavailability Reduce Hg transport through watershed
Nutrient, Stormwater Pollution	Stormwater runoff	Urban surfaces to increase	Minimize hard surfaces in development Reduce pollution from stormwater
	Effluent from wastewater treatment	Wastewater facilities will remain	Ensure wastewater does not degrade

Promote Science-Based Management	Certain gaps in understanding creek	Resources to conduct science	Refine understanding of flows Collect monitoring data Implement marked rock experiments Map and monitor wetlands
Increase Stewardship through Access and Education	Inadequate access to, appreciation for, Deer Creek	Few opportunities to interact with Deer Creek	Construct trails Provide interpretive signage Foster education programs Educate on non-point pollution Communicate health risks of metals Partner w/neighborhood associations

C. Conclusion

Although Upper Deer Creek enjoys a number of enviable conditions, including low water temperatures, generally high levels of dissolved oxygen, and significant stretches of undeveloped riparian lands, Deer Creek is not as healthy or productive as it could be. The problems identified in this repot include: reduced peak flows; reduced frequency of substrate mobilization; infrequent inundation of floodplain habitat; abandoned terraces of residual mining deposits; reduced complexity and cover of riparian vegetation communities; prevalence of non-native riparian vegetation; excessive fine sediment deposits in certain reaches; excessive nutrient loads in certain reaches; non-point source pollution inputs; and sources of mercury and other heavy metal contamination from mining activities.

Many actions are identified to address these problems such as increasing peak flows, regrading floodplain habitat, removing non-native vegetation and replanting with natives, reducing erosion from roads and other sources, reducing pollution from point and non-point sources, and remediating sites contaminated with heavy metals. In addition, many topics requiring further study are also identified, including flow patterns, status of fishes and other aquatic biota, sources of fine sediment, sources of non-point source pollution, and sources of heavy metal contamination and measures to reduce contaminant inputs and flows through the watershed.

Implementing the recommended actions would greatly enhance the health and productivity of Deer Creek. In addition, native flora and fauna would benefit and the influence of non-natives would be reduced. It is expected that with the human and scientific resources available to Friends of Deer Creek, combined with the support of partners such as the Bureau of Land Management, US Geological Survey, National Park Service, Nevada City, Nevada County and residents of the Deer Creek watershed, Deer Creek can thrive and gain recognition as a priceless community resource.

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Appendix E

Bank Stability

Definition: Stable banks are characterized by the presence of rooted vegetation that reduces the bank's susceptibility to erosion, while unstable banks are characterized by the presence of exposed raw dirt, lack of rooted vegetation, steep sloped banks, undercuts, and often slumping banks.

Method: Determine the category of bank stability along the entire reach and for the left upstream bank and the right upstream bank at each riparian vegetation transect.

Along entire reach: The objective is to calculate the percent of streambank that is stable. Assess the entire vicinity of the reach as defined by the geomorphic survey. Use the scale below to assess the degree of stability/instability, note % of category. The sample area includes the portion of the streambank that is above the ordinary low water line. The measurement extends up to the first flat, depositional feature located at bankfull or up to twice the bankfull elevation. Make sure that you are measuring the bank and not the floodplain.

For transects: Use the scale below to assess the degree of stability/instability and check it off on your data sheet for the both the left and right bank. The stability plot is 4 feet wide (2 feet on either side of the transect line) and perpendicular to the streambank (not stream channel). The sample area includes the portion of the streambank that is above the ordinary low water line. The measurement extends up to the first flat, depositional feature located at bankfull or up to twice the bankfull elevation.

Category	Type	Description
4	Stable	Vegetation other than just grasses down to the ordinary low-water line No raw or undercut banks No recently exposed roots No recent tree falls
3	Slightly Unstable	>50% of bank vegetated to ordinary low-waterline Some scalloping of banks Minor erosion or bank undercutting Recently exposed tree roots rare, but present
2	Moderately Unstable	<50% of bank vegetated to ordinary low-waterline Bank held mainly by hard points, and eroded bank elsewhere Extensive erosion and bank undercutting Recently exposed tree roots and fine root hairs common
1	Completely Unstable	No vegetation (other than grasses) at waterline Bank held only by hard points Severe erosion of banks on outside bends and on both banks of straight stretches Recently exposed tree roots common Tree falls and/or severly undercut trees common Massive bank slumping, large silt deposition, exposed raw dirt
1	Armored Banks	Banks held by placed structures such as riprap, retaining walls, etc

Definitions
Vegetation cover = perennial vegetation cover (moss is not perennial)
Ordinary low water line = the bottom or "toe" of the bank slope
Hard points = trees and boulders
Signs of erosion = crumbling, unvegetated banks, exposed tree roots, deposition, bank sloughing, erosion scars, slump blocks

Comments
Note any local factors that might affect stability, roads, development, bends, obstacles, etc

Trash

Methods: For each reach score the amount of small and large trash, tally using sets of 5

Definitions
Small = size that one person can remove easily – plastic, glass, metal, fabric, rubber, misc
Large = size requiring multiple people, trips, machinery to remove) – appliances or furniture, tires, cars or car parts, construction debris (concrete, rebar, bricks, wood, shingles), filled garbage bags

Comments
Note obvious dump sites, and note right or left bank

Small Diversions or Outfalls

Methods: Note number of diversion pipes and outflow pipes per reach

Definitions
Diversion pipe = DP
Outflow pipe = OP
Outflow pipe flowing = OPF

Comments
Note quality of water (soapy, green, etc) and odor (if any) of outflow

Road/Trail Crossing

Method: Note number of trail or road crossings for each reach

Definitions
Trail = T (4T = 4 trail crossing for that reach)
In-stream Road Crossing = IRC
Culverted Road Crossing = CRC
Bridged Road Crossing = BRC

Comments
Note if creek is constrained by crossing

Development

Method: Note number of houses or major structures (garages, large outbuildings) visible within 200 feet of creek within each reach, tally in sets of five

Comments

Note if houses or major structures are in the floodplain

Other

Comments

Note fencing along the creek in the riparian zone, estimate height and length