Humbug Creek Watershed Assessment and Management Recommendations

A pilot assessment of mining impacts and recommendations for action to improve water quality at Malakoff Diggins State Historic Park

THE SIERRA FUND

Thunder of Waters

They ripped and tore the gravel banks asunder
with powerful streams that rumbled like thunder.
A hundred hills were leveled by the blows
to smash millenniums of deep repose.

They crushed the face of nature in their lust
for gold, they reaped the shining dust.
They tore from gravel banks to ancient streams
to bring fulfillment to their gold-crazed dreams.

The havoc wrought displeased both God and man
and courts of law brought forth a mighty ban,
that stilled the giants, brought a calm surcease
to ancient hills that stood again in peace.

And God looked down upon the damaged sight
where man had gloried in his selfish might.
He planted tree and shrub for kindly shade
to heal the livid scars that man had made.

By Alvin Trivelpiece

Humbug Creek Watershed Assessment and Management Recommendations

Updated April 2015

Acknowledgements

The Humbug Creek Watershed Assessment and Management Recommendations Project was funded in part by the Sierra Nevada Conservancy Proposition 84 Grant Program, the Bella Vista Foundation, the Rose Foundation for Communities and the Environment, Teichert Foundation, the Giles & Elise G. Mead Foundation, and Patagonia. This work would not have been possible without the leadership of The Sierra Fund CEO Elizabeth "Izzy" Martin, and the in-kind contribution of many Working Group Advisors, most exceptionally Department of Parks and Recreation, the United States Geological Survey, Holdrege & Kull, the Center for Science in Public Participation, the South Yuba River Citizens League and the Department of Geological and Environmental Sciences at California State University, Chico.

Principal Author: Carrie Monohan, Ph.D. The Sierra Fund

Contributors: Mark Selverston, Sonoma State University
Jason Muir, Holdrege & Kull

Editors: Kerry Morse, The Sierra Fund
Rebecca Bushway, California State University, Chico
Karen Atkins, AmeriCorps Service Member

The breadth of this assessment would not have been possible without the dedicated work of California State University, Chico Department Chair Dr. David Brown and the Department's graduate and undergraduate students including: Harihar Nepal, David Demaree, Keith Landrum, Cameron Liggett, Susan Miller, Peter van Daalen Wetters, Travis Johnson, Elizabeth McElroy, and Alfred John Ward.

Special thanks to reviewers who greatly improved this document from an earlier manuscript including Dr. Charles Alpers, Jacob Fleck, and Jennifer Curtis of the United States Geological Survey; Tamara Sasaki, Cyndie Walck, and Daniel Shaw of California Department of Parks and Recreation; Randy Adams of California Department of Toxic Substances Control; Victor Izzo and Jeff Huggins of the Central Valley Regional Water Quality Control Board; John Hillenbrand of US EPA Region 9; Syd Brown, Kendra Zamzow, Rachel Hutchinson, Stephen McCord and Myfanwy Rowlands, and to who all attended The Sierra Fund's annual Working Group meetings throughout this project. Thanks also to American Rivers in Nevada City for generously lending their flow meter and YSI water quality meter for the initial stage of this project.

Table of Contents

List of Figures

List of Tables

ACHP	Advisory Council on Historic Preservation
ac	acre
AF	acre-feet
AIRFA	American Indian Religious Freedom Act
ARPA	Archaeological Resource Protection Act
As	arsenic
BLM	Bureau of Land Management
BMP	best management practice
BRL	Brooks Rand Labs
Ca	calcium
CABY	Cosumnes, American, Bear, and Yuba
CCR	California Code of Regulations
CALFED	California Bay Delta Authority
Cd	cadmium
CDPH	California Department of Public Health
CEL	Cranmer Engineering and Analytical Laboratory
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHHSL	California Human Health Screening Level
CHRIS	California Historical Resources Information System
Cl^-	chloride
cm	centimeter
CMS	cubic meter per second
CO_3^{2-}	carbonate
COC	contaminant of concern
CQ	critical question
Cr	chromium
CRLF	California red-legged frog
CSU	California State University
CTR	California Toxics Rule
Cu	copper
CUPA	Certified Unified Program Agencies
CWA	Clean Water Act
CVRWQCB	Central Valley Regional Water Quality Control Board
DFG	California Department of Fish and Game
DFW	California Department of Fish and Wildlife
DHg	dissolved mercury
DO	dissolved oxygen
DPR	California Department of Parks and Recreation
DTSC	California Department of Toxic Substances Control
DWR	California Department of Water Resources
EC	electrical conductivity
EIS	Environmental Impact Statement

Acronyms, Abbreviations, and Chemical Symbols

EPA	United States Environment Protection Agency
ESA	Endangered Species Act
F^-	fluoride
Fe	iron
ft	feet
FYLF	Foothill yellow-legged frog
g	gram
GIS	geographic information system
GPR	ground-penetrating radar
GPS	Global Positioning System
HCO_3^{1-}	bicarbonate
Hg	mercury
Hr	hour
Hz	hertz
in	inch
IRWMP	Integrated Regional Water Management Plan
K	potassium
kg	kilogram
km	kilometer
L	liter
LCT	Lake City Tunnel (outlet)
LiDAR	Light Detection and Ranging
LOI	loss on ignition
m	meter
MCL	maximum contaminant level
MeHg	methyl mercury
Mg	magnesium
mg	milligram
mi	mile
mm	millimeter
µg	microgram
µm	micrometer
Mn	manganese
MOU	Memorandum of Understanding
MRL	method reporting limit
Na	sodium
NAGPRA	Native American Graves Protection and Repatriation Act
NBT	North Bloomfield Tunnel (outlet)
NBGM Co.	North Bloomfield Gravel and Mining Company
NCRCD	Nevada County Resource Conservation District
ND	non-detect
NEPA	National Environmental Policy Act
ng	nanogram
NHPA	National Historic Preservation Act

Ni	nickel
NPDES	National Pollution Discharge Elimination System
NRHP	National Register of Historic Places
NTU	nephelometric turbidity units
OEHHA	Office of Environmental Health Hazard Assessment
OHP	Office of Historic Preservation
oz	ounce
Pb	lead
PCA	principal component analysis
PHg	particulate-bound mercury
ppb	parts per billion
ppm	parts per million
PRC	California Public Resources Code
PRG	preliminary remediation goal
Q	discharge
QA	quality assurance
QC	quality control
RL	laboratory reporting level
RWQCB	California Regional Water Quality Control Board
SHP	State Historic Park
SHPO	State Historic Preservation Office
SMARA	California Surface Mining and Reclamation Act
s	second
SO_4^{2-}	sulfate
SS	sampling sites
SWRCB	California State Water Resources Control Board
SYRCL	South Yuba River Citizens League
T	ton
THg	total mercury
TMDL	total maximum daily load
TSF	The Sierra Fund
TSS	total suspended sediment
UC	University of California
USC	United States Code
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WY	Water Year
WY 2012	time duration from October 2011 to September 2012
WY 2013	time duration from October 2012 to September 2013
XRD	x-ray diffraction
yd	yard
yr	year
Zn	Zinc
°C	degrees Celsius

Executive Summary

The Sierra Fund's (TSF) Working Group of Advisors, as part of the Reclaiming the Sierra Initiative, selected the Humbug Creek watershed for a watershed assessment including both environmental and cultural studies, and to provide management recommendations to remediate the environmental effects of legacy mining. The Initiative is a coordinated effort to address historic mining impacts in California. The Humbug Creek watershed includes Malakoff Diggins, once the site of California's largest hydraulic mine. The Malakoff Diggins hydraulic mine pit (Malakoff Diggins or the pit), within Malakoff Diggins State Historic Park (the Park), is a significant feature in the Humbug Creek watershed. The Park is managed by the California Department of Parks and Recreation (DPR). Mine-related discharge from the Park is currently regulated by a Waste Discharge Permit with the Central Valley Regional Water Quality Control Board (Order No. 76-258) (California Regional Water Quality Control Board (CRWQCB), 1976). Ongoing erosion from the Malakoff Diggins pit causes turbid surface water runoff containing particulate-bound metals to discharge to Humbug Creek, a tributary to the South Yuba River.

The Sierra Fund's Humbug Creek Watershed Assessment Project included studies to address critical questions regarding water quality, biotic conditions, and erosion in the Humbug Creek watershed. This project identified sources of deleterious sediment and metals from historic mining practices at the Park that impact water quality in the watershed. This document reports the findings of the project and recommends to DPR possible management actions to abate the chronic and ongoing degradation to water quality.

Findings

Studies to characterize the extent of water quality degradation found elevated levels of suspended sediment and metals (mercury, copper, lead, nickel, zinc, and iron). Specific findings include:

1. Humbug Creek contributes an estimated 500,000 kg (500 tons) of sediment and an estimated 100 g of mercury to the South Yuba River per year, during a dry or below normal year.

2. Malakoff Diggins via Diggins Creek is a major source of sediment, mercury, and other metals to Humbug Creek. (Malakoff Diggins pit water drains via Hiller Tunnel to Diggins Creek and then to Humbug Creek.)

    a. Mercury in Humbug Creek, below the confluence with Diggins Creek, is greater than 80% particulate-bound, rather than in dissolved form.

   b. Copper, nickel and zinc in Diggins Creek are primarily particulate-bound in the Hiller Tunnel discharge, rather than in dissolved form.

3. Shaft 5 (the Red Shaft) of the North Bloomfield Tunnel contributes elevated concentrations of mercury, nickel and zinc to Humbug Creek; however, the effective contribution is small because the discharge from the shaft is minimal (0.008 cms (0.03 cfs)).

4. As the walls of the Malakoff Diggins hydraulic mine pit continue to erode, material is deposited on the pit floor and is effectively filling in the pit. The vegetation that has established on the pit floor does not retain all the silts and clays, which continue to pass over the pit floor and create turbid water discharge with elevated concentrations of particulate-bound metals.

5. There are a number of physical hazards in the Park associated with the mine's access shafts and tunnel openings.

The Sierra Fund, recognizing the Park's unique historical status, its listing on the National Register of Historic Places and State Historic Park classification, proactively incorporated cultural resources and historic landscape components into the Humbug Creek Watershed Assessment. A registered professional archeologist (who had met the Secretary of the Interior's professional qualifications for archaeology) summarized the known cultural resources in the Park and reviewed proposed management recommendations for feasibility with respect to protecting and preserving the significant cultural values of the Park. Additionally, DPR is funding the first phase of a comprehensive Cultural Resources Inventory and Evaluation of the Park as a result of this assessment's findings.

Recommendations

The following management strategies are recommended for further study to address the issues raised by the Humbug Creek Assessment Project. Additional investigation is recommended to address data gaps and facilitate the selection and design of management strategies.

1. Sediment and metals discharge from the Malakoff Diggins hydraulic mining pit may be managed by:

   a. Constructing diversion ditches above the Malakoff Diggins pit to direct surface water around the pit, thereby reducing the amount of surface water flow over the pit walls, reducing sediment transport, and reducing surface water discharge out of the pit.

   b. Constructing a detention pond at the western end of the pit to detain storm water flows within the pit, to equalize pit discharge, and to settle and retain suspended solids. Construction of saddle dams on the southwestern pit rim would allow for long-term sediment retention as the pit accumulates sediment.

   c. Constructing a filtration outlet structure at the inlet to Hiller Tunnel with intent to filter sediment and particulate-bound mercury, copper, nickel, and zinc from the water discharge into Diggins Creek and subsequently Humbug Creek. Over time as sediments accumulate in the pit, the filtration outlet structure would need to be extended vertically.

2. Public exposure to water and metals discharge from Shaft 5 can be addressed by constructing a boardwalk to re-route the Humbug Creek Trail around Shaft 5. A long-term management strategy to treat the water and metals discharge at Shaft 5 would necessitate monitoring the outflow both at Shaft 5 and the North Bloomfield Tunnel outfall to determine permitting requirements.

3. Physical hazards associated with tunnel access shafts and openings can be managed by limiting public access, grading, and installing fencing and/or bat-friendly gates. It is recommended that bat-friendly gates be installed at the tunnel openings.

This project is a collaborative effort of TSF, TSF's Mining Toxins Working Group and DPR to assess and address the impacts of historic mining practices in the Humbug Creek watershed and to provide useful lessons for assessing and mitigating mine-related impacts in neighboring watersheds with similar mining legacies and water quality characteristics.

Introduction

There are an estimated 47,000 abandoned mines in California. Among those, roughly 5,000 present ongoing environmental hazards and the majority present physical hazards (California Department of Conservation (CDOC), 2000). A comprehensive inventory of abandoned mine features in California has not been completed nor have abandoned mines, identified as physical or environmental hazards, been prioritized for remediation. Despite the Department of Conservation's Abandoned Mine Lands Unit ongoing effort to inventory abandoned mine lands, in terms of its scale abandoned mine lands in California may be one of the longest-neglected environmental problems facing the state today.

Abandoned mine lands often present unique site-specific hazards that require individualized assessment and engineering of remediation techniques. Some important factors that determine which assessment and remediation techniques should be considered at given site are: 1) the range of historic mining and mineral processing activities that took place at the site, and 2) the current land ownership and land management status. Numerous abandoned mine sites share similar characteristics, such as distinctly turbid runoff from lands scarred by hydraulic mining where top soil was removed and erosion accelerated.

Most abandoned mines in California are on federal lands (67%), many are on private lands (31%) and some are on state and local government managed lands (2%) (CDOC, 2000). The funding available to assess and remediate a site is primarily determined by the land-owning entity. For example, private land owners are not eligible for USEPA Brownfields funding.

The Sierra Fund (TSF) has secured state funding from the Sierra Nevada Conservancy to assess and remediate state-owned, hydraulically mined lands in the Humbug Creek watershed that drain into the South Yuba River. A large portion of the Humbug Creek watershed is in the Malakoff Diggins State Historic Park (SHP), managed by the California Department of Parks and Recreation (DPR). It is considered a model watershed for addressing legacy mining impacts in California's headwaters because it is one of several watersheds that drain into the South Yuba River that are similarly affected by hydraulic mine runoff; others include Scotchman, Shady, and Spring Creeks. As a result, lessons learned from assessment and remediation on Humbug Creek will be applied to other sites whenever appropriate.

The Malakoff Diggins hydraulic mine was one of the largest such mines of the 19th century gold mining bonanza in California. Hydraulic mining debris from Malakoff Diggins was discharged through a nearly 2,000 m (8,000 ft) long drain tunnel (a tremendous feat of engineering in its own right) before entering Humbug Creek, a tributary to the South Yuba River.

Introduction

Currently, suspended sediment and heavy metals from the exposed and eroding historical mine workings, along with legacy mercury contamination from gold recovery operations, is mobilized by heavy rainfall to seasonally affect Humbug Creek and the South Yuba River. Humbug Creek itself is listed pursuant to Section 303(d) of the Clean Water Act (CWA) (USEPA, 2013a) as impaired for sedimentation/siltation, mercury, copper, and zinc. Copper and zinc are naturally occurring in the region and were exposed due to historic mining activities. Liquid elemental mercury was introduced in the gold mining and recovery process to capture gold, and millions of pounds of mercury were lost during mining operations in California (Churchill, 2000).

Sediment contaminated with mercury travels long distances and is deposited in stream and river floodplains as well as reservoir environments where it can be methylated and incorporated into the aquatic and terrestrial food chain (Singer et al., 2013). More than 96% of the total mercury loading to the San Francisco Bay-Delta comes from the streams and rivers of the Sierra Nevada and the Inner Coast Range (Wood, Foe, Cooke, and Louie, 2010). Source areas above reservoirs are a target for remediation of watershed-wide mercury pollution and stand to benefit thousands of miles of stream and river habitat. Source areas above reservoirs are specifically discussed as a mitigation strategy for mercury abatement in the Statewide Mercury Control Program for reservoirs (SWRCB, 2013c).

Project Purpose, Goals, and Objectives

The purpose of this assessment project was to identify recommendations for addressing water quality impairments and physical hazards in the Humbug Creek watershed that resulted from historic mining activities. The Sierra Fund launched this project in 2011 as a collaborative effort with the California Department of Parks and Recreation (DPR) and the Mining Toxins Working Group (Working Group) of technical advisors (see Appendix III, Working Group Members). Together, these project partners have worked to develop a comprehensive picture of the effects in the watershed, and helped craft Critical Questions and prioritize appropriate management recommendations to begin to address physical and chemical hazards at the Park, while bearing in mind the purpose and goals of the Park unit. The function of the Department of Parks and Recreation at Malakoff Diggins State Historic Park is to "preserve, restore, and reconstruct historic resources, and maintain and manage them in such a way as to perpetuate these values for the enjoyment and inspiration of the public in accordance with the declared purpose of the unit provide a historical environment in an appropriate natural setting that is representative of the height of hydraulic mining in northern California" (Department of Parks and Recreation (DPR), 1975).

The management recommendations are designed to honor the cultural and historical significance of Malakoff Diggins SHP and to improve water quality for California's treasured waterways. The experts in the Working Group helped to ensure that this project met rigorous scientific, environmental, and cultural sensitivity standards. The project's overall goals were to assess the

Humbug Creek watershed, provide management recommendations for the Park, and develop a model of collaborative planning that could be applied to other mining-impacted areas.

Using a comprehensive, science-based watershed assessment process, the project's objectives were to:

A. Compile existing knowledge of the ecosystem, habitat, cultural resources and natural conditions in the Humbug Creek watershed in a collaborative way with DPR; local, state, federal and tribal agencies; and local watershed groups.

B. Characterize and assess current water quality conditions in Malakoff Diggins SHP and Humbug Creek and evaluate their contribution to impairment of water quality conditions in the South Yuba River.

C. Evaluate and select the most effective and feasible management recommendations to improve water quality in Humbug Creek, congruent with the natural and cultural resource management objectives, policies, regulations, and mission of DPR.

D. Evaluate and select the most effective and feasible management recommendations to address the physical hazards related to the mine workings, congruent with natural and cultural resource management objectives, policies, regulations, and mission of DPR.

E. Identify critical data gaps and needed monitoring to inform remediation efforts.

F. Develop a project description, initial study, and environmental check list for the recommended management techniques and actions, and associated required permits.

Project Partners

The Sierra Fund has led this project since 2011, in close collaboration with the following partners:

- The California Department of Parks and Recreation (DPR), as the land management agency, has been the key project partner for compiling information on the watershed; providing cultural, natural and operations staff participation in meetings and review of all project activities and documents, which allowed for production of a feasible assessment and management recommendations plan; and providing access to Malakoff Diggins SHP.
- The California State University Chico, Department of Geological and Environmental Sciences (CSU Chico), has provided significant resources to this effort which has allowed the scope of the assessment to be much more comprehensive than it otherwise would have been. Under the direction of Adjunct Professor Dr. Carrie Monohan and Department Chair Dr. David Brown, several graduate students in the Department have conducted thesis projects at the site; these student projects have helped to accomplish significant portions of the assessment. Key findings from the graduate student research are included in the

assessment results section where appropriate. (See also Appendix I: CSU Chico Student Projects.)

- Mark Selverston (M.A., Registered Professional Archaeologist, Anthropological Studies Center at Sonoma State University) has helped ensure that archaeological and historical resources are considered during project planning and identification of management recommendations. He compiled a brief history of mining activity along Humbug Creek, as well as a list and map of known cultural resources, and relevant federal and state laws. In addition, he advised on potential cultural resources issues for each of the proposed management recommendations, and has contributed to this document.
- The South Yuba River Citizens League (SYRCL) has worked to promote community involvement through watershed educational tours and activities. SYRCL's science staff provided technical support for the project description and CEQA checklist.

The Sierra Fund's Mining Toxins Working Group

The Sierra Fund's Mining Toxins Working Group (Working Group) served as the technical advisors to the project and reviewers of this document. The Working Group includes a team of experts on historic mining and water quality issues, with representatives from the U.S. Geological Survey (USGS), Bureau of Land Management (BLM), US Environmental Protection Agency (USEPA), California State Water Resources Control Board (SWRCB), California Department of Toxic Substances Control (DTSC), local tribal leaders, and environmental consultants. These individuals are experts in their fields, and many have served as advisors to TSF's work since 2006. See Appendix III for Working Group members.

Figure 1. Working Group Members at Chute Hill Campground Overlook
The Sierra Fund working group members visited Malakoff Diggins State Historic Park on numerous field trips to scope assessment activities and recommendations. (Photo taken at Working Group field trip on November 15, 2011 by K. Morse.)

The Sierra Fund's Reclaiming the Sierra Initiative

The Sierra Fund is a nonprofit organization that works to address the most pressing needs of the Sierra Nevada region of California. Since 2006, The Sierra Fund's primary strategic campaign has been the "Reclaiming the Sierra" Initiative (the Initiative), which works to address the ongoing environmental, cultural and human health impacts of historic mining in the region. The Initiative's efforts are advised by the Working Group described above.

From its inception, the Initiative has worked to assess and raise awareness about the lasting effects of historic mining in California. In 2008, TSF released *Mining's Toxic Legacy,* the Initiative's first comprehensive report detailing the impacts of historic mining, data gaps, and recommendations for action. Subsequent technical studies conducted by TSF include the 2011 *Gold Country Angler Survey: A Pilot Study to Assess Mercury Exposure from Sport Fish Consumption in the Sierra Nevada* (Monohan, 2011a), and the 2010 *Gold Country Recreational Trails and Abandoned Mines Assessment: A Pilot Study to Assess Exposure Potential to Toxins from Mine Waste and Naturally Occurring Hazardous Substances* (Monohan, 2011b).

In the current phase of this Initiative, TSF is pursuing on-the-ground solutions to clean up physical and chemical hazards associated with historic mining activities and restore California's watersheds. The Working Group agreed that a site-specific pilot restoration project would be an effective way to coordinate strategies to address the many issues associated with historic mining contamination. After considering potential projects across the Sierra Nevada, the Working Group selected the Humbug Creek watershed as the best site for a model assessment and remediation project. The Humbug Creek watershed was the subject of investigation by the Department of Water Resources and the Nevada County Resources Conservation district in the late 1970's and early 80's. These efforts identified that Humbug Creek had significantly turbid runoff and was a major contributor of suspended sediment and metals, and led to the 303(d) listing of this water body as impaired under the CWA. Remediation of the site has the potential to result in major watershed benefits—and can serve as a model to address historic mining impacts at other sites.

A Model Project

In addition to improving water quality in the Humbug Creek watershed, the pilot project approach allows the Working Group to address several scientific, legal and regulatory challenges, while building relationships—all of which support the larger effort to address the impacts of historic mining in the Sierra Nevada. The collaboration of various agencies and experts is crucial to addressing the effects of legacy mining on watersheds, since the impacts are widespread and cross boundaries of state, federal and private properties. The Working Group collaborative process for identifying management recommendations and involving stakeholders will be a key model to address other legacy mining sites throughout the Sierra Nevada. Additionally, the Humbug Creek watershed presents scientific challenges to remediate water quality contamination that are primarily driven by storm events. The management recommendations and inclusive collaborative process developed by the Working Group will make planning and remediation of other legacy mining sites throughout the Sierra Nevada on public lands more efficient and cost-effective.

Project Funding

In 2011, the Humbug Creek Watershed Assessment and Management Recommendations project received base funding for a three year period from the Sierra Nevada Conservancy Proposition 84 Grant Program. The project's funding was supplemented by grants from the Bella Vista Foundation in 2011, 2012, and 2014, from the Rose Foundation for Communities and the Environment in 2012, from the Giles & Elise G. Mead Foundation in 2013, and from the Teichert Foundation in 2014. In addition to these grants, in-kind support of time and materials has been an invaluable contribution to this project. Patagonia has provided wet-weather sampling gear. In-kind support has been provided from many individuals and agencies, including TSF's Working Group advisors (see Appendix III). Within the Working Group, certain agencies and institutions have contributed staff time and other resources, particularly DPR, California Department of Toxic Substances Control, USEPA Region 9, and California State University, Chico.

Related Efforts

The Humbug Creek Watershed Assessment Project dovetails with a project on federal lands immediately adjacent to the project area. Just downstream of DPR's park boundary, BLM and USGS are working together to address the hydraulic mining debris on BLM lands along the banks of the South Yuba River at the confluence of Humbug Creek. Cleanup and Abatement Funds from the State Water Resources Control Board (SWRCB) have been received for that project. The BLM-USGS effort includes characterization of the material that has accumulated at the confluence. An evaluation of engineering options for stabilization of the material to reduce erosion and subsequent downstream contamination is planned by BLM, pending funding. The Humbug Assessment and Management Recommendations Project is supported by the fact that staff from USGS, BLM, USFS and SWRCB are engaged on mercury-related issues on the BLM-led project at the confluence, which is contiguous with the Malakoff Diggins State Historic Park.

Site Description

Study Area

Malakoff Diggins is one of the largest historic mine sites from California's 19th century mining heyday. The hydraulic mine pit is the most prominent feature of Malakoff Diggins State Historic Park (SHP), which is under the jurisdiction of California Department of Parks and Recreation (DPR) (California State Parks, 2010). Malakoff Diggins SHP is located in Nevada County, California, about 23 km (14 mi) northeast of Nevada City, and 100 km (63 mi) northeast of Sacramento (Cahill, 1979a) (Figure 3).

Figure 2. View of Malakoff Diggins Pit Looking West from the Chute Campground Overlook
The excavation left by hydraulic mining exposes Paleozoic-aged metamorphosed igneous and sedimentary rock. The pit is over a mile long, 1,000 ft wide in places, and up to 600 ft deep. The surrounding forest is primarily mixed conifer and oak woodland. The pit floor is vegetated by willows. There is a pond in the far west end of the pit. (Photo taken October 9, 2013 by C. Monohan.)

Malakoff Diggins SHP is located within the Humbug Creek watershed. Humbug Creek is a tributary of the South Yuba River. The Humbug Creek watershed is about 27 km^2 (6,700 ac) (Cahill, 1979b). The average annual precipitation is 101-152 cm (40-60 in) (California State Parks, 2010), which primarily falls between October and April (Cahill, 1979a). The Humbug Creek watershed discharges approximately 4,300,000 m^3 (3,500 AF) of water per year (Nevada County Resource Conservation District (NCRCD), 1979a). The Malakoff Diggins SHP contains about 14 km^2 (3,200 ac) of forest within the Ponderosa Pine Forest plant community, and is at 760 m (2,500 ft) to 1,000 m (4,000 ft) elevation (California State Parks, 2010). According to Cahill, "[t]he slopes and ridges surrounding the central Malakoff pit contain examples of pine forest, stands of black and live oak and manzanita, and open meadows. A number of areas that now contain dense stands of manzanita were probably once meadows or growths of pine that have been logged" (Cahill, 1979b).

The watershed supports a variety of wildlife. Birds observed at Malakoff Diggins SHP during an ecological study in 1975 included red-tailed hawk, northern flicker, western wood peewee,

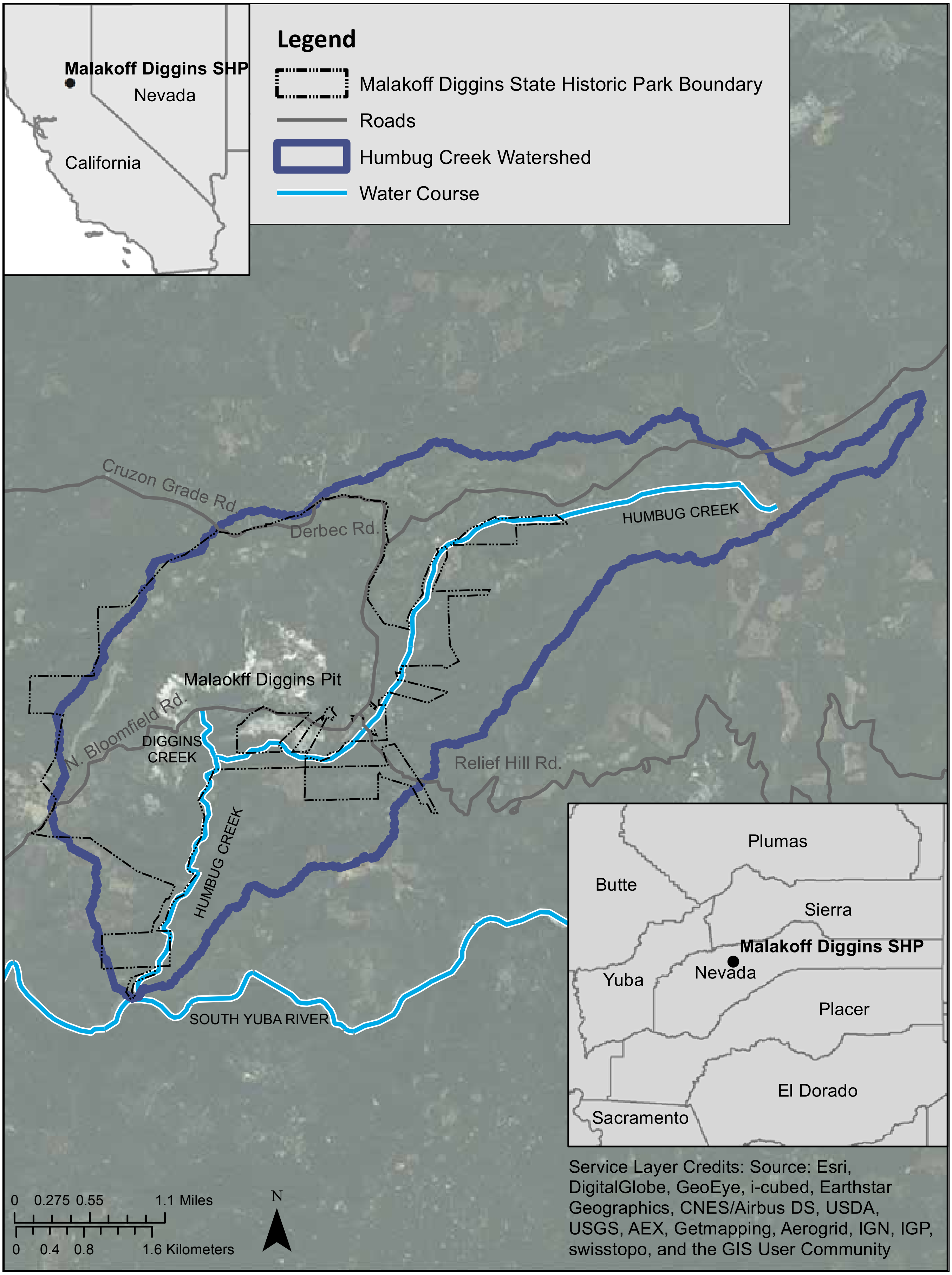


Figure 3. Site Location: Humbug Creek Watershed and Malakoff Diggins State Historic Park
Malakoff Diggins State Historic Park is in Nevada County, California.

Stellar's jay, mountain chickadee, Nashville warbler, orange-crowned warbler, oak titmouse, bushtit, Bewick's wren, Hutton's vireo, black-throated gray warbler, western tanager, purple finch, black-headed grosbeak, pileated woodpecker, spotted towhee, and many kinds of owls (Harding, 1977). Lukas (2002) described the Diggins areas as a healthy and diverse bird community that is becoming increasingly valuable as one of the most important sites for birds in the county. In addition to birds and small animals, the wild animal community includes black-tailed deer, coyote, bobcat, mountain lion, and black bear.

Sensitive or special status bird and amphibian species occur or may occur at Malakoff Diggins SHP. Willow flycatcher (*Empidonax trailii*) surveys by David Lukas in 2002 documented two unconfirmed willow flycatcher (*Empidonax trailii*) calls at Malakoff Diggins pit. Willow flycatcher is a State endangered species. Other California Department of Fish and Wildlife designated bird species of special concern documented by David Lukas and/or DPR biologists in Malakoff Diggins SHP were the yellow warbler (*Dendroica petechial*), yellow-breasted chat (*Icteria virens*), olive-sided flycatcher (*Contopus cooperi*), and California spotted owl (*Strix occidentalis occidentalis*). The California red-legged frog (CRLF) (*Rana draytonii*) is a Federal Threatened Species and a California species of special concern. CRLF is known to occur within a couple of miles of the Park and critical habitat is adjacent to the southern Park boundary. No protocol-level surveys for CRLF have been conducted at the Park. The Foothill yellow-legged frog (FYLF) (*Rana boylii*) is a California species of special concern. FYLF surveys were conducted in 1999 and 2000 found a scattered population of FYLF in Humbug Creek (California Department of Fish and Game, 2011; Yarnell and Larsen, 2000; Yarnell, 2005). DPR surveys in 2013 also found a scattered population and different life stages of FYLF. A reconnaissance fisheries survey completed in 1978 noted that due to sedimentation, fish populations in Diggins Creek were absent and found to be "fairly low" in Humbug Creek below the confluence of Diggins Creek "when compared to similar streams in the area not having the severe sedimentation problem" (NCRDC, 1978; Taylor, 1987).

The bedrock in the Malakoff Diggins area is Paleozoic-aged metamorphosed igneous and sedimentary rock (Department of Water Resources (DWR), 1987). Mio-Pliocene volcanic breccia and conglomerate (mudflows) overlie the Eocene auriferous gravel (Whitney, 1880; Saucedo, Wagner, and Martin, 1992). The auriferous gravel is part of a river channel deposit and contains boulders, pebbles and cobbles, and quartz gravels and sands (Saucedo et al., 1992). The bedrock basement is from the Paleozoic/Mesozoic (Saucedo et al., 1992). The bedrock is composed mainly of undifferentiated metasedimentary rocks consisting of argillite, phyllite, chert, conglomerate and breccia with some quartzite, clastic volcanic rock, and argillite matrix mélange (Saucedo et al., 1992).

Site Description

Summary of Mining, Management and Regulation in the Humbug Creek Watershed

Placer gold was discovered in modern stream gravels along Humbug Creek in 1851 or 1852, which led to a rush of gold prospectors to the area (Bean, 1867). The first wave of inexperienced miners dubbed the town "Humbug" due to the lack of easy stream placer gold (Gudde, 1975). A small party of more determined miners settled near the present town of North Bloomfield in 1853 and began opening up buried Tertiary placer gravel with shallow drifts, initiating a prosperous boom time for Humbug (Bean, 1867). Sluice and small-scale hydraulic ventures followed and by 1855 the community boasted a 24-stamp steam-driven mill (Gudde, 1975).

The North Bloomfield Gravel Mining Company (NBGM Co.) incorporated in San Francisco in August 1866 and continued to enlarge their holdings, acquiring the Malakoff claims in February 1867 (Deeds, 1867). The NBGM Co. acquired over 150,000 m^2 (1,500 ac) by 1870. The deed included a supply ditch, sluices, and flumes already on the diggins. The company headquarters and support buildings were established on the main road on the Malakoff claim, about 800 m (0.5 mi) west of North Bloomfield, and were quickly surrounded by hotels and dwellings that became known as Malakoff (Figure 4).

With the initial influx of miners, the Eureka Lake Company developed a water system to supply the San Juan Ridge, including the town of Humbug and the Malakoff Mine, which increasingly needed water for burgeoning placer ventures. More water was required after the NBGM Co. acquired the Malakoff claims and "developed a drain tunnel [Hiller Tunnel] from the mouth of the Virgin Ravine to drain them" (Bean, 1867). In 1870, the biggest setbacks to hydraulic operations continued to be access to water and drainage to run monitors and dispose of massive amounts of slurry debris, and NBGM Co. set about to develop engineering solutions.

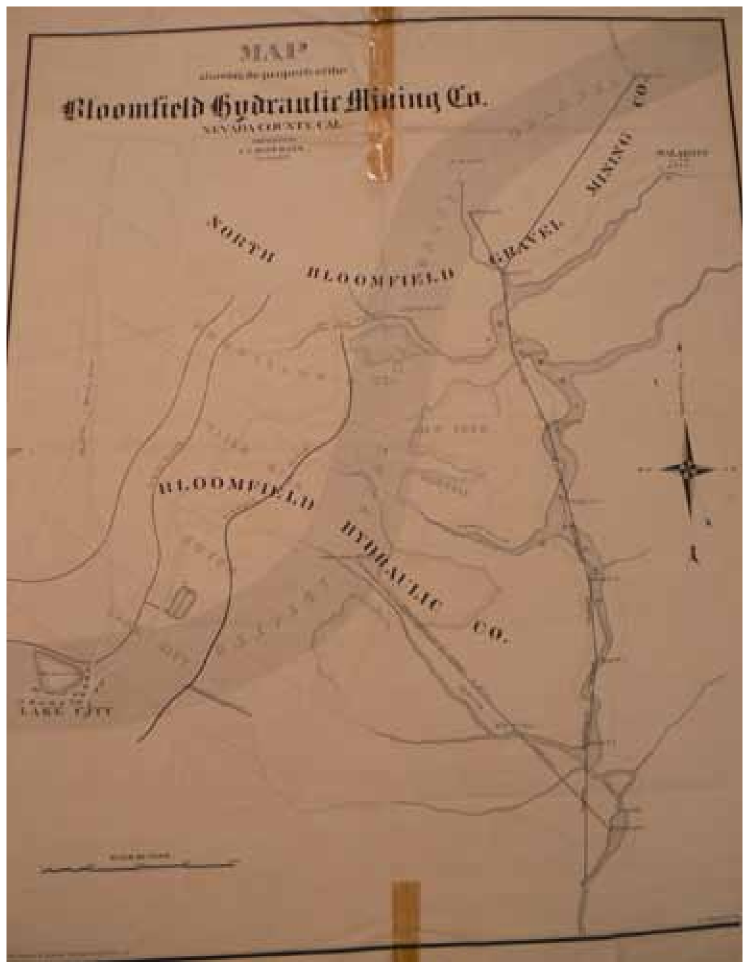


Figure 4. Map showing the Properties of the Bloomfield Hydraulic Mining Co.
This map, surveyed by C.F. Hoffmann in October 1872, shows the location of the New York claim Ravine and drainage to Humbug Creek, the Malakoff Village Site (Malakoff), and the proposed line for the Bloomfield Tunnel (also known as Lake City Tunnel). Additional historical features depicted on this map may warrant additional sampling for mercury source area identification. (Photo taken June 22, 2012 by D. Demaree.)

W. Hamilton Smith, Jr., a mine manager and noted mining engineer, led the development of innovative water supply and drainage solutions for the NBGM Co., most notably the North Bloomfield Tunnel. To supply water to the operations, Smith designed and built the first reservoir at Bowman Ranch and the ditch to the Malakoff Mine in 1870 (Jackson, 1967). More water required more drainage, and Smith engineered the 2.4 km (7,847 ft) North Bloomfield Tunnel constructed between 1872 and 1874, to drain the Malakoff Mine debris and water into Humbug Creek (Wyckoff, 1964). He is well-known for his innovative approach, which expedited construction by driving down eight shafts approximately 60 meters (200 ft) deep, spaced about 300 m (1,000 ft) apart, from which tunneling commenced in both directions, allowing work on 16 separate faces at once. The drain tunnel measured 2 x 2 m (7 x 8 ft), with small shafts 0.5 x 0.6 m (2 x 2 ft).

Hydraulic Mining

Twenty years after placer mining began in Humbug Creek, truly massive hydraulic operations commenced with the completion of the North Bloomfield Tunnel. A reporter from San Francisco visited the operation in 1879 and described the diggings as a great amphitheater, vaster in its circle than the stony base of the Coliseum (Jackson, 1967). Hydraulic mining used "monitors" to direct powerful jet streams of water to wash down hillsides in search of the ancient auriferous gravels. Seven monitors ran day and night. Water jets washed down the mountain side until debris clogged the drains, at which time 30 or 40 men descended into the pit to drill into the larger boulders and set "giant powder" before fleeing to a safe "block house" made of spent flume blocks. Once the debris was reduced sufficiently it was simply washed away; gold entrained in debris sank into cracks between wood blocks lining the sluices, flumes, and undercurrents, all of which were "charged" with quicksilver (mercury) which pulled gold out of the sediment.

Figure 5. Peak Hydraulic Mining Operations at Malakoff Diggins
Hydraulic mining monitors were used to direct powerful streams of water to wash down hillsides in search of gold bearing gravels. Seven monitors ran day and night. (Photo courtesy of California Department of Conservation, California Geological Survey Library.)

At Malakoff 15 flasks of mercury (a total of 520.50 kg (1,147.5 lb)) were added to sluices and undercurrents each run and sometimes scattered over the bank before it was washed so it worked its way down with the gravel into the sluices (Hanks, 1882). After a two- to three-week run, a systematic "clean up" occurred by which the water was halted and the sluice wood blocks removed so the amalgam and sediment could be collected and taken to the refinery where the mercury would be gassed off in a retort[1] leaving behind the gold.

Figure 6. Sluices on the Malakoff Diggins Pit Floor
Mine debris was washed into sluices that were laced with mercury to pull fine grained gold out of the sediment. The pit floor has a series of sluices which directed the slurry to the North Bloomfield Tunnel, the first 580 m (1,900 ft) of which was used as a tunnel sluice.

In addition to placing mercury into sluices and gravels, a tunnel sluice[2] was created by adding mercury by the flask-full to the first 580 m (1,900 ft) of the North Bloomfield Tunnel (Jackson, 1967). At the outlet of the North Bloomfield Tunnel, mine debris was discharged into an extensive series of flumes and mercury-laden undercurrents. These flumes and undercurrents eventually emptied into the South Yuba River at two locations, approximately 800 m (0.5 mi) and 200 m (700 ft) vertically below the mouth of the North Bloomfield Tunnel (Jackson, 1967). Between 1866 and 1900 about 20,000,000 m^3 (30,000,000 yd^3) had been processed in this manner, from which $3,500,000 in gold was extracted (Mac Boyle, 1919).

CESSATION OF MINING

Vast amounts water-borne debris from the Company's operation flowed down Humbug Creek to the South Yuba River and down to the Sacramento Valley, causing substantial property damage. Valley residents, mostly farmers, formed the Anti-Debris Association in response, culminating into the legal action *Woodruff vs. the North Bloomfield Gravel and Mining Company*. The findings for this case are commonly referred to as the Sawyer Decision and it effectively banned hydraulic mining in 1884, by prohibiting mining companies from sending debris downstream.

In an attempt to continue mining after 1884, the North Bloomfield Gravel and Mining Company invested in an elevator system that could dispose of debris in abandoned portions of the operation (Jackson, 1967). The old channels filled more quickly than they could be excavated, however, and the elevator was removed in 1899 (Stammerjohan et al., 1985). Not a single mine resumed hydraulic mining after 1900, and within the decade, monitors and penstock were either removed or lay scattered across forgotten mines (Jackson, 1967).

1 A retort is a vessel in which an amalgam (when mixed with gold, mercury dissolves the gold to form an amalgam that is 40-60 percent gold) is heated to volatilize the mercury and so separate it from the gold which retains its solid form (Interagency Minerals Coordinating Group (IMCG), 1996).

2 A tunnel sluice refers to a box shaped like a trough set into a sloping tunnel and in which a stream of water propels the sand and gravel away while the gold and other heavy minerals sink and are caught in riffles in the bottom of the box (IMCG, 1996).

In 1893, the U.S. Congress enacted the Caminetti Act to allow the resumption of hydraulic mining as long as the resulting debris was contained, and formed the California Debris Commission which undertook various efforts to address debris and flooding on the Yuba River and other streams. Englebright Reservoir downstream on the Yuba River is an example of the Debris Commission's efforts, though the dam was built in 1941, long after the NBGM Co. ceased hydraulic operations. Apparently the dam was built in anticipation of renewed mining efforts after the Great Depression, when the value of gold increased significantly.

In the 1920s, drift mining[3] occurred at Malakoff Diggins, and dragline dredging[4] began in 1941, both processes that use much less water than the original hydraulic mining process. The Innis Dredging Company had only operated a couple of years, when the War Production Board issued an order in 1942 shutting down most gold mining in the country as "non-essential" for the war effort (Lindström, 1990).

The North Bloomfield drain tunnel had already collapsed well before this time and the large hydraulic pit had substantially eroded. W. Kallenberger (1967), a longtime resident of the North Bloomfield area, recalled a massive landslide in the 1930s in which the entire west rim fell into the pit. In fact, he estimated that weathering had filled the pit to a depth of 20 m (70 ft) by about 1960.

Recent Management of the Humbug Creek Watershed

California Department of Parks and Recreation (DPR) acquired the idle property in the mid-1960s and created Malakoff Diggins State Historic Park (SHP). DPR nominated the Park to the National Register of Historic Places (NRHP) and the Malakoff Diggins-North Bloomfield Historic District was listed in 1973. Its recognition relied on the historic properties' association with the company and its famous Malakoff hydraulic mine, evident in the extensive mined-out pit, as well as the nearby Gold Rush community of North Bloomfield in which numerous well-preserved historic buildings still stood. The hydraulic pit was described in the nomination as "picturesque and monumental."

The California Department of Fish and Wildlife (formerly Department of Fish and Game) joined DPR in the early 1970s in determining that the hydraulic pit was responsible for turbid discharges into Humbug Creek and the South Yuba River, and that the turbid runoff was having an adverse effect on fish habitat. Best management practices (BMPs) were evaluated and the Central Valley Regional Water Quality Control Board (CVRWQCB) advocated for construction of a debris dam to retain fine-grained sediments within the pit. DPR requested an opinion from the California Attorney General in 1979 regarding the jurisdiction of water quality regulations. The Attorney General's 1980 opinion concluded that in setting or waiving discharge requirements for Malakoff

3 Drift mining uses underground mining techniques such as an adit or shallow shaft to extract gravel from rich alluvial deposits and move it to the surface for processing (IMCG, 1996).

4 Dragline dredging uses a power shovel with an excavator bucket or scoop attached by a cable to a hinged boom to extract submerged sediment and gravel from pits, canals, and trenches (IMCG, 1996).

Diggins SHP, the Regional Board "should and must consider all environmental factors, including the fact, if established, that action to control or eliminate silt from the discharge is inconsistent with the maintenance of the land as a state historic park" (Deukmejian, 1980). This situation of historical significance versus ongoing environmental degradation calls for a balanced approach to addressing abandoned hydraulic mine hazards while simultaneously maintaining the Historic District's ability to convey its nationally-recognized significance.

Malakoff Diggins SHP Mine Features

Malakoff Diggins SHP includes five distinct anthropogenic mining-related features created during the California Gold Rush: 1) the Malakoff Diggins hydraulic mine pit, 2) the Hiller Tunnel, which drains discharge from the pit into Diggins Creek, 3) the North Bloomfield Tunnel, 4) a series of access shafts associated with the North Bloomfield Tunnel, and 5) the Bloomfield Tunnel (of the Bloomfield Hydraulic Mine now called Lake City Tunnel) (Figure 7 on page 28). These features are described below:

1) The Malakoff Diggins hydraulic mine pit (also called the Pit, the Diggins, or the diggings) is about 2,000 m (6,800 ft) long, ranges from 300-1,200 m (1,000-3,800 ft) wide from north to south, and is 200 m (600 ft) deep in places (California State Parks, 2010). Hydraulic mining created steep unstable pit walls and left this large pit denuded of vegetation and it continues to be a source of sediment-laden runoff. The pit has a pond (approximately 850 m^2 (0.21 ac) in 2012) in its western half and willows grow on the pit floor. The pit receives water from drainages that flow into the pit from the north rim and from the eastern end of the pit. The forested area surrounding the pit is second-growth ponderosa pine with incense cedar, black oak, white fir and sugar pine, and white leaf manzanita is the dominant woody shrub (California State Parks, 2010). The pit currently drains into Hiller Tunnel.

2) Hiller Tunnel is believed to have been constructed either in the late 1850s by the Virgin Ranch Mining Company or in the late 1860s by the NBGM Co. founders. It is 170 m (557 ft) long. When NBGM Co. consolidated and increased operations, the Hiller Tunnel was replaced by the North Bloomfield Mine Tunnel (NBT), completed in 1874. After the NBT became blocked sometime around 1930, Hiller Tunnel once again became the primary discharge point for surface water from the pit, draining into Diggins Creek.

3) The North Bloomfield Mine Tunnel is 2,392 m (7,847 ft) long and was constructed from 1872-1874 to convey hydraulic mine debris away from the hydraulic mine workings in the pit and to process the mine debris as a tunnel sluice during peak operations (1874-1884). The North Bloomfield Tunnel is approximately 2.5 m high by 2.5 m wide (8 ft high by 8 ft wide), and was dug 60 m (200 ft) below the Hiller Tunnel through bedrock from the Malakoff Diggins pit to Humbug Creek. This tunnel is currently blocked and has very little discharge. The blockage likely occurred when Shaft 1 caved in, reported to be in the 1930's (Jackson, 1967), but blockages could exist in several places.

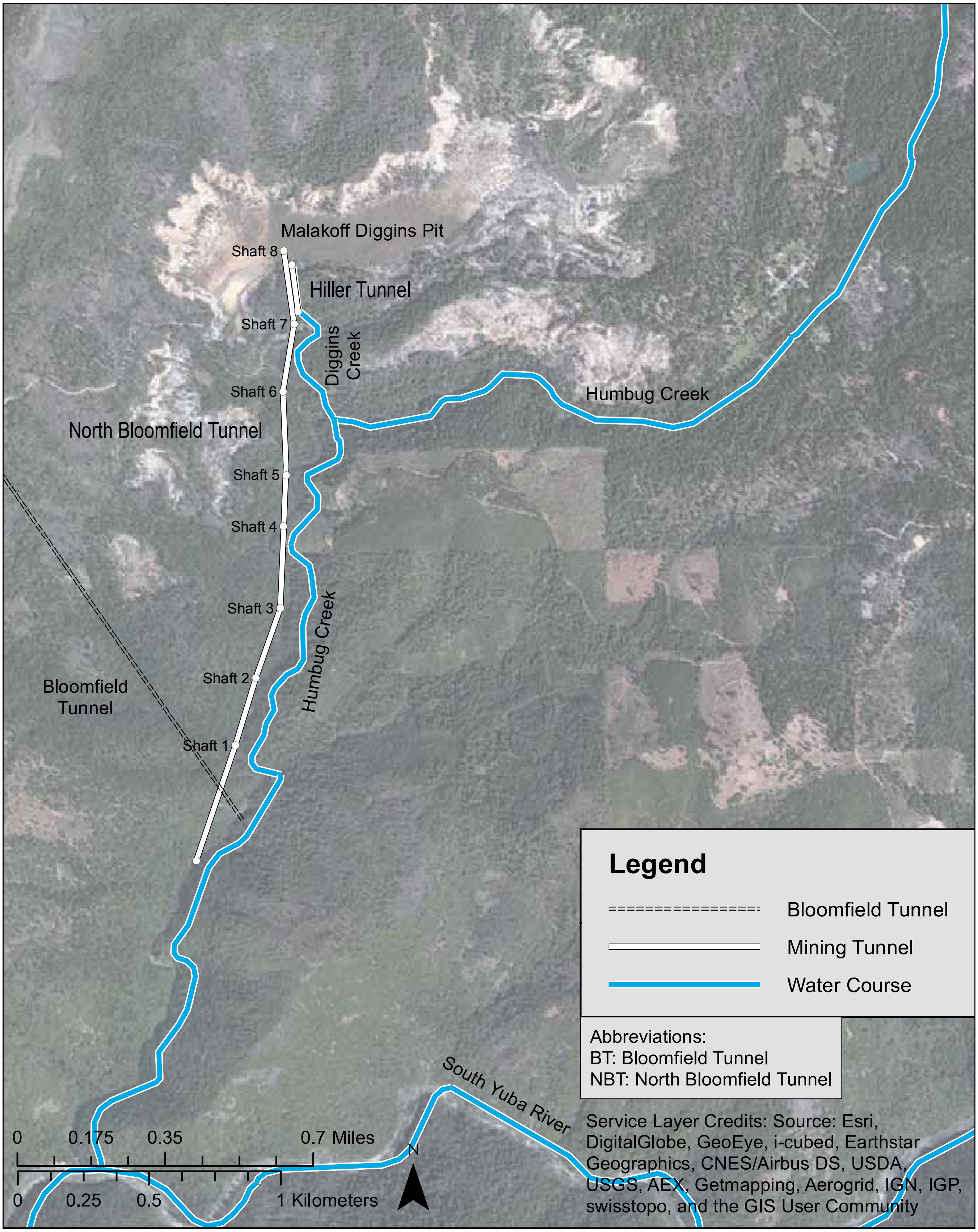


Figure 7. Humbug Creek Site Features – Mining Features
The main anthropogenic features include the Hiller, North Bloomfield and Bloomfield (also called Lake City) Tunnels. There are eight access shafts associated with the North Bloomfield Tunnel. Hiller Tunnel discharges into Diggins Creek which flows into Humbug Creek, a tributary to the South Yuba River. (Note: Shafts 2 and 4 are on the east side of Humbug Creek; the inaccuracy of their locations on this map is due to a projection discrepancy of +/-30 ft in the streams layer.)

4) There are eight access shafts associated with the construction of the North Bloomfield Tunnel at approximately 300 m (1,000 ft) intervals. The access shafts are labeled 1 through 8 with Shaft 8 being the tunnel inlet in the pit and Shaft 1 being the nearest access shaft to the tunnel outlet along Humbug Creek. Many of the access shafts hold standing water, one of which, the Shaft 5 (the "Red Shaft"), visibly discharges to Humbug Creek.

5) The Bloomfield Tunnel was constructed by the Bloomfield Hydraulic Company in the 1870s to service a placer mine located between Lake City and Malakoff Diggins. The tunnel is now referred to as the Lake City Tunnel because of its proximity to the now abandoned townsite. Its outlet opens to Humbug Creek just upstream of the North Bloomfield outlet. The extent and features of the tunnel (such as inlet and access shafts) are not currently known. The tunnel is blocked about 92 m (300 ft) from the outlet with quartz gravel, and there is a small amount of discharge to Humbug Creek, of clear water.

Water from the anthropogenic mining features in the Park discharges into a series of drainages and ultimately into the South Yuba River. Diggins Creek receives discharge from the Malakoff Diggins pit via Hiller Tunnel, and flows into Humbug Creek. It has been variously named historically as Virgin Ravine, Little Virgin Ravine, and Hillersheidts Ravine, as is noted on historical maps and archival documents (Bean, 1867). There is also an unnamed ravine that flows into Diggins Creek upstream of its confluence with Humbug Creek, which may be the New York Ravine (Bean, 1867). This ravine drains a mine-scarred area left by the Bloomfield Hydraulic Company to the west of the Malakoff Diggins pit. The extent of the mine features and history of this area west of the pit are not currently understood. Diggins Creek enters Humbug Creek approximately 1.5 miles upstream of its confluence with the South Yuba River.

Figure 8. Confluence of Humbug Creek and the South Yuba River: Summer and Winter
Humbug Creek enters the South Yuba River at the top left of the photo. In the summer there is no visible mixing zone (photo taken July 12, 2011 by C. Monohan), in the winter after a storm event the mixing zone is yellow (photo taken Feb 3, 2012 by C. Monohan). The South Yuba River appears clear above the Humbug Creek confluence. The turbid water continues at least ten miles downstream at Edwards Crossing. The mine debris deposit that was the subject of USGS research is in the foreground of the summer picture.

Figure 9. Access shafts Associated with the North Bloomfield Tunnel
There are eight access shafts that extend 250-440 feet below the surface to the horizontal North Bloomfield Tunnel. Some of them have standing water in them (Shaft 1, 2, 3, 4, 5 and 6) and some of them have collapsed or been filled in (Shaft 7 and 8). Shafts can present physical and chemical hazards. Shaft 5 and the North Bloomfield Tunnel outlet both have continuous discharge to Humbug Creek.

Watershed Assessment Activities

Scope

The scope of the Humbug Creek Watershed Assessment consisted of:

1. The cultural setting that would influence remediation design; and
2. Environmental impacts and impact sources that remediation would need to address, including:
    a. Water quality of discharge from mine features including the pit and access shafts,
    b. Biotic conditions in Humbug Creek, with respect to mercury methylation and incorporation into the food chain, and
    c. Erosion and depositional processes in the Malakoff Diggins pit, and the impact these have on water quality.

Figure 10. Hiller Tunnel Discharge at Low and High Flow
Hiller Tunnel is the only visible surface water discharge location of the Malakoff Diggins pit. It has year round flow, and discharges vast amounts of turbid water during storm events. (Photos taken on May 18, 2012 (dry season) and March 15, 2011 (wet season) by C. Monohan.)

Literature Review

With the help of CA Department of Parks and Recreation (DPR), an electronic library of all known documents about Malakoff Diggins and the Humbug Creek watershed was assembled, digitally scanned and cataloged. These documents included historic accounts of mining activities and prior assessment activities at the site (see Appendix V). Documents were scanned and provided to DPR and The Sierra Fund's Working Group advisors as a digital document library. The documents were reviewed and used to inform a data gap analysis that was instrumental in shaping the scope of this project's 2011-2014 cultural and environmental assessment activities in the Humbug Creek watershed.

In addition to historical documents, DPR provided hundreds of aerial photos of Malakoff Diggins and the Humbug Creek watershed dating back to 1941. These photos were scanned in high resolution for the document library, and for GIS analysis of selected photos to determine how the pit features have changed over time.

The literature review was expanded on a topic-by-topic basis by researchers and California State University (CSU) Chico graduate students. As the individual components of the assessment efforts matured, additional literature on the state of knowledge was collected by each researcher and graduate student. These documents were used to inform the development of the most appropriate and robust assessment methods. The literature at this point consists primarily of peer-reviewed scientific articles on studies that have used specific methods that may be pertinent to future management activities at Malakoff Diggins.

Cultural Assessment Literature Summary

The area around the Humbug Watershed is known to be rich in pre-historic indigenous cultural resources as well as more recent historic mining-related resources.

Registered Professional Archaeologist Mark Selverston, M.A., conducted a cultural resources records search and archival research for historical documents pertaining to Malakoff Diggins and the Humbug Creek watershed. All known resources have been integrated into a Geographical Information System (GIS) project and linked to a database, however, ground-truthing and new field surveys did not occur as part of this assessment. Sources of information included the North Central Information Center of the California Historical Resources Information System (CHRIS), U.S. Bureau of Land Management, DPR Sierra District archaeologist Denise Jaffke, DPR archives located at Empire Mine State Historic Park, primary and secondary sources at Doris Foley and Searls Historical Libraries, DPR volunteers Ross and Maiya Gralia, and other sources. The CHRIS is the repository for Nevada County's documented historic districts, sites, buildings, structures, and objects, as well as cultural resources studies. CHRIS archaeological data is confidential given the sensitive nature of these non-renewable deposits. Numerous studies have been carried out within and adjacent to Malakoff Diggins SHP. Other studies of portions of the Park that were not filed with the CHRIS were supplied by Denise Jaffke and incorporated into this study. Full citations of the studies are included in the references section of this document.

Studies Reviewed

The cultural assessment identified 19 reports regarding the cultural resources in the Malakoff Diggins SHP (Blanford, 1989; Felton, Porter, and Hines, 1979; Gilbert and Savitski, 1991; Gracyk, 2011; Gralia and Gralia, 2012a; Gralia and Gralia, 2012b; Hines, 1994; Hines and Rivers, 1994; Jaffke, 2005, 2006a, 2006b, 2007; Lindström, 1990; Payen, 1989; Stammerjohan, Wheeler and Hines, 1985; URS, 2004; Wheeler, 1987; White, 1991; and Zalarvis-Chase, 2004). Another five reports for adjacent properties discuss resources that cross into the Park, four of which are the result of timber harvest plans (Gillett, 1997; Ing, 1995; Whittlesey, 2002; and Willis, 2005) and the fifth an inventory of the USDA North Bloomfield Station (Rhoades, 1992). Additionally, DPR produced two other relevant reports, one a comprehensive compilation of archival information regarding Malakoff and the North Bloomfield Gravel Mining Company (Jackson, 1967) and the other a resource management plan that is a companion to the Felton et al. summary of resources (Porter, 1979).

Cultural Resources Inventories

Felton et al. (1979) conducted perhaps the most sweeping identification effort of the Historic District. They summarized earlier studies and added to the record many new prehistoric and historic-era resources, documenting 25 distinct sites. Their efforts were focused around North Bloomfield and the slopes north of the pit stretching over to Lake City. Their methodology did not involve a comprehensive survey strategy and cannot be considered a full survey. Neither did they attempt to address the hydraulic pit or the North Bloomfield townsite. However, subsequent studies did systematically inventory the same area north of the pit. In fact, the portion of the Park stretching from Lake City to the Derbec Mine and south to the town of North Bloomfield has been sufficiently examined, based on studies related to a recent forest fire fuel reduction undertaking (Gralia 2012a; Jaffke 2006a, 2007; URS 2004; Zalarvis-Chase 2004).

Malakoff Mine Pit

The hydraulic pit of the Malakoff Mine, a very large and complex historical site designated CA-NEV-551/H [5] has been the focus of four separate studies (Gilbert and Savitski 1991; Gralia and Gralia 2012b; Lindström 1990; and Stammerjohan et al., 1985). Stammerjohn, Wheeler, and Hines (1985) and Lindström (1990) specifically inventoried the pit and a large number of associated features, as well as developing substantial histories for the resource. Gilbert and Savitski (1991) focused on recording the historic dredge remains, and Gralia and Gralia (2012b) examined large metal objects

5 A backslash "/" is assigned to sites with both prehistoric and historic-era components, but in the case of the Malakoff hydraulic pit the / reflects an out-of-context bedrock milling boulder in the bottom of the pit. The site can be considered a strictly historic-era resource deserving of an H without the backslash.

present, including over 6,401 m (2,100 ft) of riveted iron pipe or penstock still *in situ*. While the Malakoff Mine pit has been intensively studied, a comprehensive site record organizing all of the identified features and artifacts associated with the enterprise at a landscape level is lacking.

Three studies in the Park consisted of archaeological investigations of a single, multi-component site (a site with both prehistoric and historic-era components), designated CA-NEV-356/H. The site is located on the edge of the pit rim and was observed upon discovery by Felton et al. (1979) to be badly slumping. Accordingly, Wheeler (1987), Payen (1989), and White (1991) all conducted excavations at the site, providing a substantial body of data regarding the prehistory of the Park.

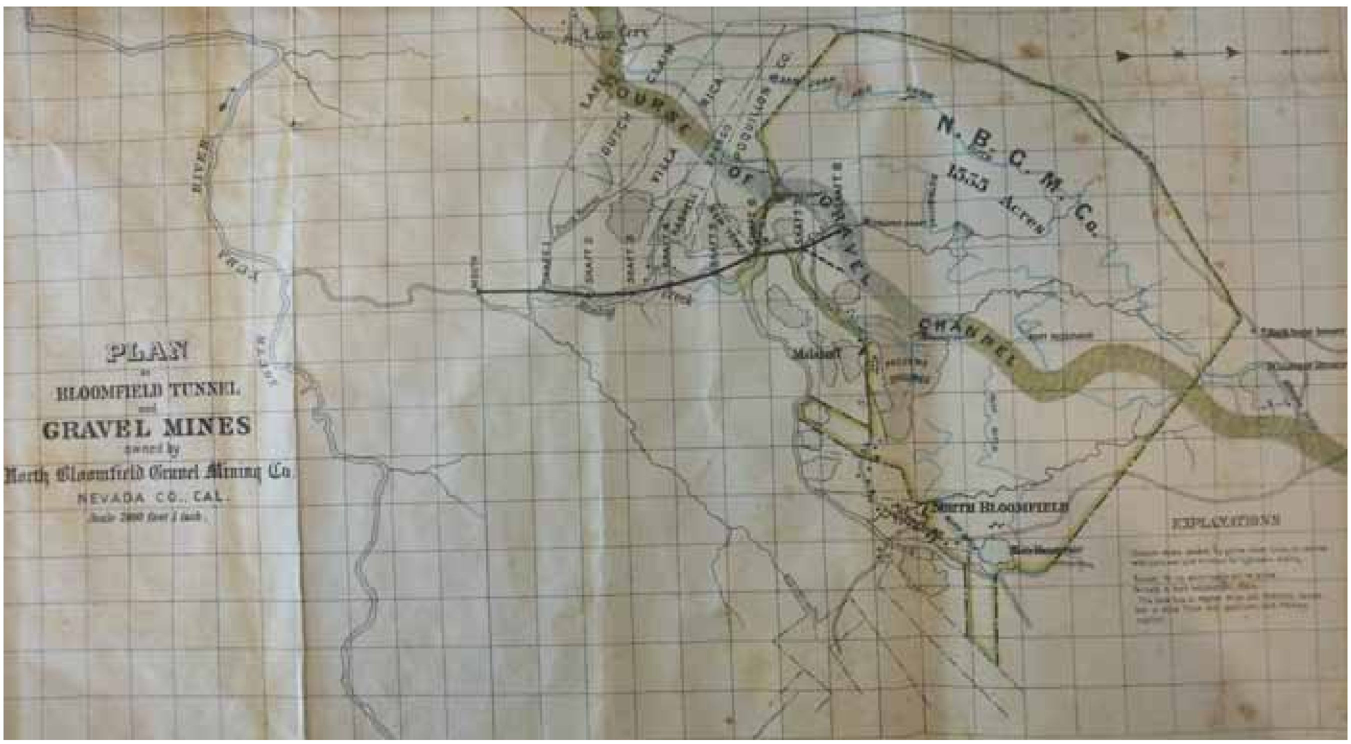


Figure 11. Plan of Bloomfield Tunnel and Gravel Mines
The North Bloomfield Gravel Mining Company created this map as part of a tabular statement and it was last updated in 1874. The map currently resides at the Society of California Pioneers. On it is visible the location of the historic town of North Bloomfield, the Malakoff Village, the North Bloomfield Tunnel and access shafts, Humbug Creek, the New York claim, the town of Lake City, and the course of auriferous gravels that the miners were excavating. (Photo taken June 22, 2012 by D. Demaree.)

North Bloomfield Town Site

The townsite of North Bloomfield has also been the subject of substantial study. Most of the resulting reports focus on specific elements of North Bloomfield. For example, the “Chinatown” part of town has been examined archaeologically (Blanford 1989; Hines and Rivers 1994). The barbershop is also the subject of a study, specifically for environmental compliance stemming from an electrical line project (Jaffke 2005, 2006b). Another compliance study limited in scope is Phil Hines’s (1994) survey for an outdoor educational facility. Lastly, Gracyk (2011) has recently prepared the most comprehensive report on the surviving components of North Bloomfield. She concludes the townsite is a significant Historic Vernacular Landscape and recommends it be considered as a district containing a town and settlement site. As with the pit, however, there is no single record tying all of the townsite elements together. Gracyk's report goes a long way in filling this gap.

Unsurveyed Areas

Some substantial portions of the Park have not been surveyed for cultural resources. Most notable is the hill slope east of Lake City and Humbug Creek from the South Yuba River almost all the way to North Bloomfield, as well as the stretch upstream from Blair Reservoir. Archival evidence indicates there are historic-era resources in these areas, such as the Bloomfield hydraulic mine and the North Bloomfield and Derbec drain tunnel portals, and presumably there are additional prehistoric sites as well.

Environmental Assessment Literature Summary

A variety of documents are included in the environmental literature review (Appendix V). The most relevant theses and dissertation documents, along with other studies about Malakoff Diggins and the Humbug Creek watershed are included in this section. These theses include G. Yuan's 1979 "The Geomorphic Development of a Hydraulic Mining Site in Nevada County, CA" (Stanford University) and D.H. Peterson's 1979 "A Study of Modern Sedimentation at Malakoff Diggins State Historic Park, Nevada County, California" (UC Davis). In addition to theses, a number of agency documents have been written for this site. The most useful of which, DWR's 1987 report "Erosion Control at Malakoff Diggins State Historic Park," summarizes the pioneering work conducted by the Nevada County Resource Conservation District (NCRCD) Water Quality Study, Phases I-IV. The most recent work in the Humbug Creek watershed is by USGS scientists including Dr. Charles Alpers and Jacob Fleck, both of whom serve on TSF's Working Group and are advisors to this assessment. USGS published a two-part report, "The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area" (Part 1) (Fleck et al., 2011) and "The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area" (Part 2) (Marvin-DiPasquale et al., 2011). These reports are instrumental in informing the scope of assessment activities described in this document.

The literature establishes that sediment from historic mining sites moves into the South Yuba River, and carries mercury with it. Mercury is known to move up the food chain into fish, and may pose a public health hazard to people who consume fish from downstream water bodies.

Yuan Thesis

Yuan studied the erosion of the pit's cliffs by examining historic photographs and comparing them to photographs taken at the time of her study (Yuan, 1979). From the photographs, cliff edges were estimated (Yuan, 1979). From the change in cliff edge, the rate of erosion was estimated to be 10,000-38,700 m^3/yr (13,100-55,600 yd^3/yr) of sediment, with an average of 20,000 m^3/yr (30,000 yd^3/yr) (Yuan, 1979).

Yuan described the gravels at Malakoff Diggins as decreasing in size going from the base of the cliffs to the top, with more weathered sediment near the top of edge of the Diggins (Yuan, 1979). Twenty-six soil samples were taken from varying heights along the 140 m (450 ft) cliff and the bottom of the cliff was estimated to be 39.9 m (131 ft) above the bedrock (Yuan, 1979). After sieving the material it was found that the upper portion of the pit contained 53% granules[6] and sand while the lower portion contained only 28% (Yuan, 1979). The lower portion contained more pebbles and cobbles while the upper portion contained fewer cobbles and pebbles (Yuan, 1979). X-ray diffraction analysis (XRD) to determine the mineralogy of the clay found it to be mainly composed of kaolinite (Yuan, 1979).

Peterson Thesis

Peterson conducted another erosion study around the same time as Yuan (Peterson, 1979). Peterson used multiple methods: 1) Aerial photos were used to estimate the cliff edge and calculate erosion; 2) plots were placed over the winter to look at the rate of erosion and deposition; 3) seismic refraction was used to look at the composition of the pit floor; and 4) grain size distribution curves for samples collected along the length of the pit were prepared. Peterson (1979) estimated an annual soil erosion rate of roughly 35,000 m^3/yr (45,000 yd^3/yr) within the hydraulic pit. He found that it was at least 30 m (100 ft) to bedrock in the pit. Peterson's grain size analysis of the pit floor indicated that large sediment (gravel size and larger) are retained in the pit and deposited on the pit floor near the source area, typically in the northeast portion of the pit, but that small sediment (silt and clay) did not settle on the pit floor but were transported out of the pit as suspended sediment in the Hiller Tunnel discharge. This is supported by the fact that roughness appears to be increasing in the pit floor with the establishment of vegetation in the pit, however fines still do not appear to settle out and continue to be discharged with surface flow out Hiller Tunnel.

Nevada County Resource Conservation District Studies

In 1978-9 DPR contracted with the NCRCD to design engineering recommendations pursuant to the CVRWQCB WDR 76-258 (CVRWQCB, 1976; NCRCD, 1979a). The Phase I study was a summary of existing information and development of a sampling and analysis plan for Phase II activities. The Phase II study included methods and data, and results for data collected in 1979 (NCRCD, 1979a). Water quality data were collected on total suspended solids, settleable solids, turbidity, and electrical conductivity during storm and non-storm events, and particle distribution was determined for some storm samples (NCRCD, 1979a). Monitoring included pH, dissolved oxygen, and hardness (NCRCD 1979a). Samples were taken of the Hiller Tunnel dischargeand tested for arsenic, cadmium, chromium, copper, iron, manganese, nickel, zinc, lead, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride and fluoride (NCRCD, 1979a).

6 The grain size for "granules" was not specified in the Yuan Thesis document. From the text it appears that granules were larger than silts and clay which (which were defined as less than 60 microns) but smaller than pebbles (which were not defined).

The NCRCD produced a series of phased reports relating to erosion and sedimentation problems at Malakoff Diggins SHP. The NCRCD used sediment concentrations in streams throughout the pit, at Hiller Tunnel, and Humbug Creek to calculate suspended load based on flow for individual storms. They noted that clay deposits in and around the pond may be periodically re-eroded by intense runoff events.

The Phase I Report reviewed policies relating to this study, natural resources and hydrology information for the study area and field survey methodology. Phase I concluded that in-depth study of erosion was needed to identify sources and create a management plan.

The Phase II Report discussed important physical features in the study area, monitoring methodology and field data collected during Phase II. The study concluded that water quality in Humbug Creek was severely degraded by large amounts of suspended silt from Diggins Creek during periods of high flow. As a result of the siltation, the trout fishery of Humbug Creek was severely impacted by destruction of spawning grounds, microhabitats, and possibly by reduction of the available food supply.

The Phase III Report included a discussion of data collected during Phase II for water quality programs, specifically: stream flow measurements, chemical constituents in the water, particle size distribution in runoff and in bedload, and precipitation for the area. The water quality parameters studied were pH, dissolved oxygen, hardness, discharge, particle size distribution, and precipitation. Samples were taken downstream of Hiller Tunnel and tested for metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Zn, Pb, Ca, Mg, Na, K), alkalinity (CO_3^{2-},HCO_3^-), and common ions (SO_4^{2-}, Cl^-, F^-) (NCRCD, 1979a). The largest instantaneous sediment load measured by NCRCD was measured on February 13, 1978 with 1,118 kg (2,464 lb) of sediment per minute at the outlet of Hiller Tunnel discharge with flow estimated to be 0.8 cms (30 cfs) (NCRDC, 1979b; DWR, 1987).

While the greatest discharge of suspended solids occurred during storm events, the amount of suspended solids discharged from the Diggins fluctuated, and consisted mainly of sand, silt and clay (NCRCD, 1979b). On January 16, 1979, samples from Humbug Creek had a suspended sediment concentration of 2 mg/L before joining with waters from Diggins Creek (which drains the Malakoff Diggins pit) and a suspended sediment concentration of 802 mg/L after joining Diggins Creek (NCRCD, 1979b). The conclusion of the Phase III Report states that "[t]remendous sediment loads, largely in the form of colloidal material, are transported from the Diggings area throughout winter. As a result, water quality is affected downstream in Humbug Creek and the South Yuba River. Sedimentation is a factor in the decline of fisheries in Humbug Creek" (NCRCD, 1979a). From the data collected, remediation options were proposed (NCRCD 1979b).

The Phase IV Report included a recommended best management practice to control sedimentation from Malakoff Diggings, a cost analysis and an implementation schedule (NCRCD, 1979b).

Department of Water Resources Report to Department of Parks and Recreation

The DWR report (1987) concluded that the two largest sources of sediment discharged to Humbug Creek from the Diggins are composed of exposed Tertiary auriferous gravel from the landslide deposits at the eastern end of the Diggins and from the cliffs throughout the Diggins and that landslides and cliff erosion would continue for hundreds or thousands of years at accelerated rates until the slope reached the angle of repose. The DWR report recommended reclaiming the mine by terracing and revegetation as "[t]he most effective method of eliminating the discharge of turbid water from the diggings in the shortest time possible…" At the same time, the report noted that "[s]uch a program would not preserve the historic aspects of the park, and the Department of Parks and Recreation has stated that this alternative is unacceptable." Consequently, the report also recommended "limited action alternatives" that included "stabilizing the landslides and rehabilitating the areas of gullying in the east and northeast portion of the diggings," revegetation and sediment barriers. Finally, the report recommended further studies of the impact of sediment discharge from the site using a more robust program of sediment discharge monitoring and of "the quality of fishery habitats [in the South Yuba River] and the possible effects of sediment discharge from Malakoff Diggins" (DWR, 1987).

USGS Studies

The U.S. Geological Survey (USGS) conducted mercury studies in 1999 and 2008 in the Yuba and Bear River watersheds, and continued to conduct research in 2013 in the Humbug Creek watershed. In 1999, they determined that fish in the Yuba and Bear River watersheds contained high concentrations of mercury, and in 2008 they learned that mercury from the Humbug Creek watershed is discharged to the South Yuba River, and that once mobilized, mercury can be transported long distances downstream where it can be methylated.

In 1999 the USGS conducted a pilot project in the South Yuba River, Deer Creek, and Bear River watersheds to study mercury concentrations in water, sediment, semi-aquatic and aquatic insects, amphibians, bird eggs, and fish (May, Hothem, Alpers, and Law, 2000). The study's report presented data from fish collected at five reservoirs and 14 stream sites, including two reference sites that had not been impacted by known historic gold mining practices.

- Of the 21 fish collected at Lake Englebright (the first reservoir downstream of Malakoff Diggins), 14 were smallmouth bass and two were largemouth bass. For the 14 smallmouth bass and three spotted bass collected in Lake Englebright, the mercury concentrations were above the 0.30 ppm screening value set by the Office of Environmental Health Hazard Assessment (OEHHA) (mean 0.63 ppm for smallmouth bass) while the two largemouth bass had mercury concentrations below the 0.30 screening value.
- Camp Far West Reservoir and Combie Reservoir in the Bear River watershed and Lake Englebright in the South Yuba Watershed had the highest mercury concentrations in tissues of upper-trophic level predatory fish, including largemouth, smallmouth, and spotted bass. Among all the bass species studied, 14 percent had mercury levels exceeding the FDA

regulatory action level of 1.0 ppm and 88 percent of the black bass exceeded OEHHA's 0.30 ppm screening value for mercury (May et al., 2000).

Consumption of mercury-contaminated fish is considered the primary route for human exposure to mercury (Shilling, White, Lippert, and Lubell, 2010) and people eating fish from streams and rivers in the Sierra Nevada foothills may be disproportionately exposed. In finding elevated concentrations of mercury in fish tissue in the Yuba and Bear River watersheds, the study provided confirmation of similar findings by Slotton, Ayers, Reuter, and Goldman (1997) which indicated that mercury present in the environment bioaccumulates in the food chain, specifically in fish tissue.

In 2008 the USGS tested the feasibility of using suction dredges to remove mercury from sediment. The study included:

Figure 12. South Yuba River at the Confluence of Humbug Creek, Looking Downstream
The hydraulic mining debris deposit is on the right side in the photo. This deposit continues to erode into the South Yuba River during storm events. It contains mercury that can be transported downstream and methylated. (Photo taken July 12, 2011 by K. Morse.)

- *Sampling at dredge site.* An area of the South Yuba River near the confluence with Humbug Creek was dredged (Fleck et al., 2010). Water samples were collected before, during, and after the dredging for analysis of total settleable solids, mercury, particulate mercury, and methylmercury (MeHg) (Fleck et al., 2010). Biota was tested for mercury bioaccumulation (Fleck et al. 2010). A tank experiment was conducted to see how long sediment remained suspended after disturbing the sediment (Fleck et al., 2010). Samples of unconsolidated material were taken from in and around the South Yuba River confluence and were tested for grain size and mineralogy (Fleck et al., 2010), and run through a series of tests in the laboratory, including placing them under varying oxidation-reduction conditions to observe the effects on mercury speciation (Marvin-DiPasquale et al., 2011).
- *Sediment source sampling.* Sediment samples were collected from the mouth of the North Bloomfield Tunnel and from one of the tunnel's access shafts[7] in the Humbug Creek watershed (Fleck et al., 2010). Total mercury was measured for each sample. The mercury in access shaft sediments was about 3,000 ng/g and mercury in tunnel sediments was much lower, at 100-500 ng/g (Fleck et al., 2010). The Quartz/Plagioclase ratios in the North Bloomfield Tunnel and access shaft were consistent with samples from the deposit

7 The access shaft that USGS sampled is referred to as Shaft 5 or the "Red Shaft" in this report because the shaft exudes a red precipitate.

at the South Yuba-Humbug Creek confluence, indicating that the source of the material at the confluence likely originated from Malakoff Diggins (Fleck et al., 2010).

The USGS studies concluded that mercury mobilized during storm events, or from suction dredge mining, is often bound to fine silts and clays and can stay in suspension for long periods of time and be transported long distances to locations where it can be methylated upon deposition, which contributes to the contamination of the food chain, and that sediment from Malakoff Diggins is contributing to the mercury contamination in the South Yuba River.

Gold Country Angler Survey

The Sierra Fund (TSF) conducted a pilot angler survey project to complement angler surveys conducted by the California Department of Public Health (CDPH) in the San Francisco Bay Area, by CDPH in the San Joaquin and Delta area, and by the Healthy Fish Coalition in the Sacramento River and the Delta. As part of The Sierra Fund's survey, in 2009 and 2010, 151 anglers were interviewed at 12 reservoirs and rivers in historic gold mining areas in the Sierra foothills that were listed as impaired for mercury under Section 303(d) of the CWA. The goals of the survey were: 1) to learn whether anglers were consuming the fish they caught, 2) to quantify their exposure to mercury in fish tissue, and 3) to gauge their awareness of the health hazards associated with consuming mercury in fish tissue. Of the 151 anglers surveyed, 47 percent reported that they intended to consume the fish caught the day they were surveyed (51 percent were catching and releasing), and of those, 73 percent reported that their families would also consume those fish (Monohan, 2011a).

Using regional values for mercury in the fish tissue of the different fish species consumed, TSF concluded that, while the majority of the anglers surveyed were not consuming sport fish at unsafe levels, nine percent were consuming MeHg in sport fish at levels exceeding the OEHHA safe eating guidelines. In order to define some of the underlying problems, TSF noted the lack of awareness among the anglers surveyed of health risks related to sport fish consumption, and the lack of posted fish consumption advisories at most of the survey locations where they were in effect. Consequently, TSF recommended increasing the funding for assessment and public education programs, and improving the collaboration among local, state, and federal agencies "to assess and address legacy mining issues in ways that will have a positive impact on water quality and supply, and human health" (Monohan, 2011a).

Summary of Literature on Sediment and Mercury Fate and Transport

Historic hydraulic mine sites are sources of sediment and mercury pollution to downstream watersheds. Trace metals form a weak bond with sediment by metal-solid interaction and the bioavailability of the metal depends upon the nature of the metal-solid interaction (Zhong and Wang, 2008).

Abandoned mines sites with high clay content and mercury contamination may have discharge with a stronger mercury-sediment bond, and therefore the potential distance mercury can travel during redistribution and mobilization of sediment during storm events can be great (Marvin-

DiPasquale et al., 2011). In addition, when mobilized mercury-contaminated sediment settles, it may be the source of MeHg production in depositional environments such as river pools, reservoirs and wetland habitats (Marvin-DiPasquale et al., 2011). Cycles of settling, remobilization, and re-deposition of mercury-contaminated sediments may continue to move sediment downstream, and pose a risk to fish, aquatic organisms and human health (Benoit, Gilmour, Riedel, and Riedel, 1998; Krabbenhoft et al., 1998; Covelli, Faganeli, Horvat, and Brambati, 1999; Gill et al., 1999; and Delongchamp, Ridal, Lean, Poissant, and Blais, 2009). It is therefore possible that mercury from the Malakoff Diggins site could travel long distances downstream where it can then become methylated and incorporated into the aquatic food chain. The literature supports the concept that Malakoff Diggins is an upstream source of mercury contamination to downstream waterways.

Critical Questions

Development of Critical Questions

The literature review provided background that allowed environmental research studies to target three categories for further investigation: Water Quality; Biotic Conditions; and Erosion, Deposition, and Sediment in the Pit.

Project partners and Working Group members selected and designed the wording of critical questions in each category in order to inform regulatory, restoration and remediation actions that need to be considered for the Malakoff Diggings SHP property. Assessment activities to address the critical questions were identified by Working Group members, and the methods and findings associated with addressing each critical question are discussed in greater detail in the following sections.

The Humbug Creek Watershed Assessment was designed to answer the following critical questions:

Water Quality Critical Questions

1) What is the annual sediment and mercury load in Humbug Creek? How much of that load is from storm events?

2) Is mercury in Humbug Creek transported primarily as particulate-bound mercury rather than in its dissolved form?

3) Is the quantity of suspended sediment in Humbug Creek directly correlated with mercury concentration in Humbug Creek?

4) Is Diggins Creek a source of sediment, mercury and/or other metals to Humbug Creek?

5) Are the mineral springs in the pit a source of heavy metals in the discharge of Hiller Tunnel?

6) Is shallow groundwater in the pit the source of heavy metal contamination in the Hiller Tunnel discharge?

7) What are the sources of mercury and suspended sediment in the pit?

8) Are mine tailings deposited in the southeast end of the pit a source of mercury in the discharge of Hiller Tunnel?

9) Is the water entering the pit free of mercury, copper, nickel, and zinc?

10) Is the North Bloomfield Tunnel contributing to degraded water quality in Humbug Creek?

11) Is Shaft 5 contributing to degraded water quality in Humbug Creek?

Biotic Sampling Critical Questions

12) Do the mercury concentrations in macroinvertebrates indicate that mercury is being methylated and incorporated into the aquatic food chain in Humbug Creek?

13) Do MeHg concentrations in macroinvertebrates from reaches of Humbug Creek downstream of Diggins Creek and/or Shaft 5 indicate that mercury is being methylated and incorporated into the aquatic food chain in Humbug Creek?

Erosion, Deposition and Sediment Conditions in the Pit Critical Questions

14) How are the pit rim, pond, and vegetation changing over time?

15) What is the depth to bedrock in the pit?

16) Is the pit filling in? Is it filling more rapidly than it was in 1979?

17) Are large particle sizes (gravels to sand) being retained closer to the source of erosion (assumed to be gullies in the east end of the pit) than during the 1979 Peterson study?

18) What are the erosional processes in the pit?

19) What is the annual sediment yield from the pit?

Methods

Environmental Assessment Methods

Dr. Carrie Monohan (Ph.D. in Forest Resources and Hydrology) conducted the environmental assessment activities with assistance from many individuals, including Dr. David Brown and CSU Chico graduate students Harihar Nepal, David Demaree, Keith Landrum, Susan Miller, Kathleen Berry-Garrett and Peter van Daalen Wetters (see Appendix I, CSU Chico Student Projects).

The physical and chemical conditions of major features in the Humbug Creek watershed were assessed using standard techniques in hydrology, water quality, geomorphology and ecology. The graduate student work was developed around the critical questions identified by the Working Group. The methods associated with the critical questions are presented in three general categories: water quality, biotic conditions and erosion and deposition in the pit. The critical questions are addressed individually in the Assessment Findings section.

The methods and results associated with individual critical questions can be found in greater detail in the Master's Thesis documents which are referred to at the end of each critical question section.

Water Quality

Water quality is covered in Critical Questions #1-11. This section covers methods to determine water quality in Humbug Creek, the mining pit, and the North Bloomfield Tunnel.

Critical Questions #1-4: Humbug Creek Water Sampling Locations

Research methods were established with the following specific goals:

- Produce a hydrograph and stage-discharge relationship for Humbug Creek using flow and stage measurements.
- Establish the relationship between turbidity and TSS in Humbug Creek.
- Determine the relationship of TSS and particulate-bound mercury (PHg) from TSS and mercury concentrations.
- Calculate the annual discharge, sediment and mercury loads in Humbug Creek, given the stage-discharge relationship, turbidity, and mercury concentrations.
- Determine the contributions from Diggins Creek and the pit to Humbug Creek.

Monitoring stations were established with these goals in mind. Water quality sampling sites were selected to provide information on sediment and metal loads into Humbug Creek, and to determine

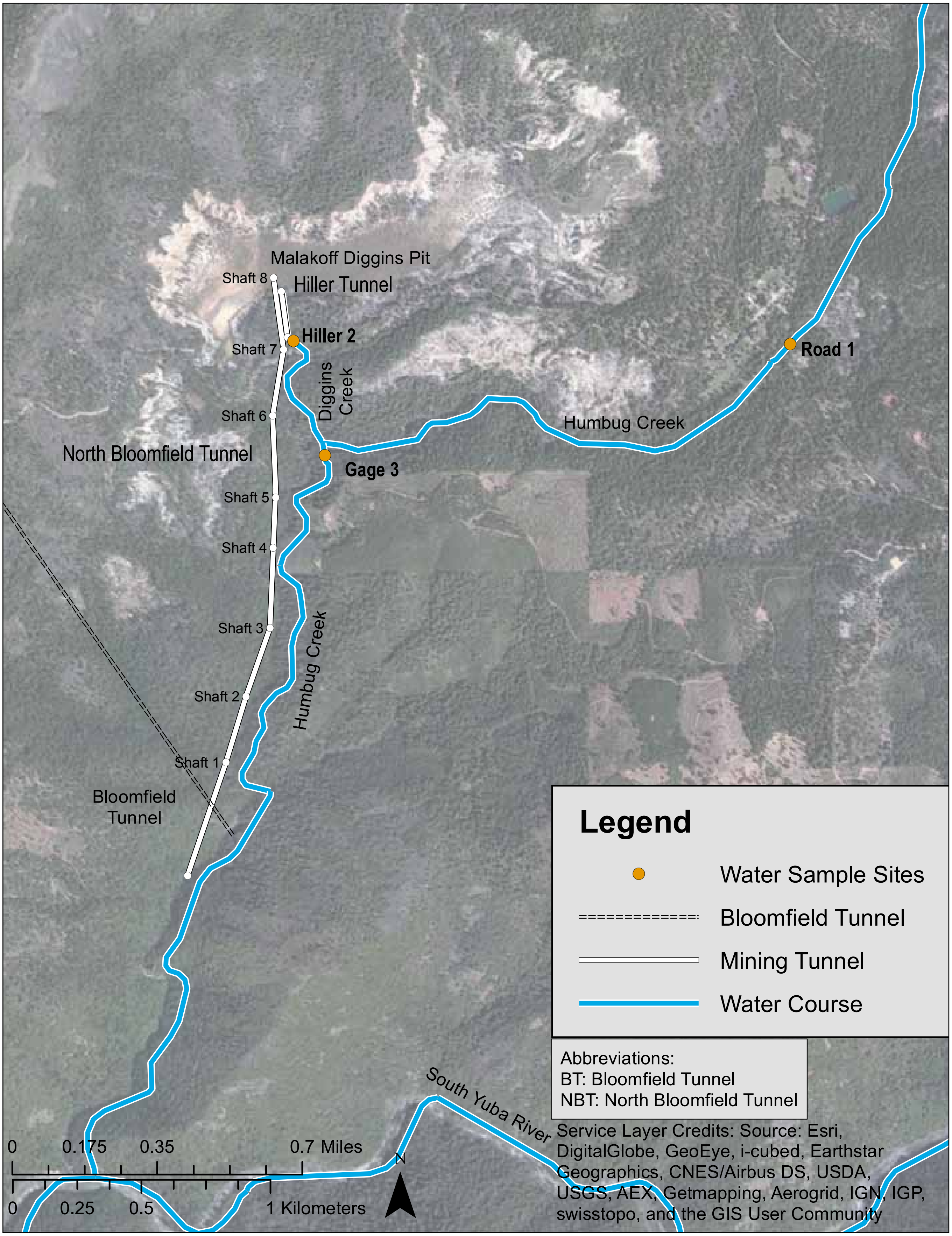


Figure 13. Humbug Creek Site Features – Water Quality Sample Sites
Three water quality sampling sites (Road 1, Hiller 2 and Gage 3) were sampled during the rising, peak and falling limbs of five storm events. A continuous monitoring station to measure stage and turbidity was set up at the Gage 3 site.

how much was contributed from Diggins Creek, which drains the hydraulic mining pit via Hiller Tunnel (Figure 13 on page 45). The study's three monitoring stations were:

- Road 1: Control location, Humbug Creek upstream of the confluence with Diggins Creek
- Hiller 2: Outlet of Hiller Tunnel in Diggins Creek
- Gage 3: Humbug Creek, thirty meters (100 ft) downstream from the confluence of Diggins Creek and Humbug Creek.

A continuous monitoring gage and an automated water sampler were installed at the Gage 3 site. The gage measured stage (SDI-12 Pressure Transducer) and turbidity (DTS-12 Turbidity Sensor) at 15 min intervals. Sampling specifications were programed into an automatic data logger (Forest Technology Systems (FTS) Axiom 700-H2 Datalogger) which obtained and stored data. The sampling plan was to take rising, peak and falling limb grab samples during three to five storm events to develop the regression relationships among turbidity, TSS and particulate-bound mercury.

The pressure transducer was installed in a 38 mm (1.5 in) PVC pipe with holes drilled in the side and no screen, which acted as a small stilling well of the meter, and is hereon referred to as stage. The turbidity meter's operational range was from 0-1,500 NTU (Forest Technology Systems (FTS), 2010). Grab samples were collected over the range of the turbidity meter's operational range and included the upper range of the meter (500-1,500 NTU) and when the turbidity meter had reached the extent of its operational range (>1,500 NTU). Samples were collected either by hand (grab samples) or were collected using an automated ISCO sampler (Teledyne ISCO 6712 Portable Sampler). During periods of high turbidity (March 2, 2012 and March 16, 2012 storm events), the automatic ISCO sampler was programmed to take water samples every four hours when the turbidity exceeded 900 NTU. The threshold 900 NTU was selected to represent the upper range of turbidity conditions while still ensuring that the meter was in a functional range of 900-1,500 NTU.

Figure 14. Gage Instruments in Humbug Creek at Gage 3 Site
The gage in Humbug Creek measured stage and turbidity every 15 minutes. The turbidity meter was installed at a 45° angle and can be seen as a black pipe on the left entering the creek, and the pressure transducer was installed vertically and can be seen in a PVC pipe next to a staff plate. (Photo taken February 17, 2012 (left) by C. Monohan and March 17, 2011 (right) by D. Brown.)

Figure 15. Gage Box at Gage 3 Site on Humbug Creek
The gage was installed November 11, 2011 and continues to operate at the time of this report (June 2014). The gage consists of a data logger (FTS systems), a turbidity meter (DTS-12 Turbidity Sensor), a pressure transducer (SDI-12 Pressure Transducer) and at times an ISCO sampler. (Photos taken March 12, 2012 (box), May 12, 2013 (logger), by C. Monohan.)

Critical Questions #1-4: Humbug Creek Hydrology

Hydrology was informed from the stage measurements of the continuous monitoring gage and from discharge, measured using a Marsh McBirney flow meter (Model 2000 with a top-setting wading rod). Discharge measurements were collected over a range of flow conditions to create a rating curve that could be used to estimate discharge from the pressure transducer readings during low flow and during storm events. The monitoring gage ran from December 15, 2011 to April 25, 2012 (128 days) in WY 2012.[8] The period from October 1, 2011 to December 15, 2011 and from April 26, 2012 to September 30, 2012 were considered to be periods of baseflow. The gage was reinstalled for WY 2013 on September 23, 2012 and operated until August 7, 2013 (318 days). The period from August 8 to September 30, 2013 was considered to be baseflow. During all baseflow periods the discharge was considered to be 0.08 cms (3 cfs) and there were no major storms during these periods. The gage was installed October 1, 2013 and as of the time of this

8 The 2012 Water Year is defined as October 1, 2011 through September 30, 2012

report is continuing to operate (June 2014). Water year 2012 was considered to be "below normal" and water year 2013 was considered to be "dry" according to the Sacramento Valley Water Year Type Index 40-30-30 (DWR, 2013).

Critical Questions #1-4: Humbug Creek Water Quality

Water samples were collected by the grab sample method during the rising, peak and falling limbs of the storm hydrographs at three water quality stations (Road 1, Hiller 2, and Gage 3) for four storms in WY 2012 and the rising and falling limbs for one storm in WY 2013. Grab samples were water samples collected by hand for constituents such as mercury concentration in the water that could not be measured using continuous monitoring techniques associated with turbidity and stage. Ultra clean hands methods were used for all grab samples (USEPA, 1996). The grab samples were collected from the water surface adjacent to the ISCO intake in a well-mixed area of the stream near the shore, right bank. The storms are referred to by the date that the peak flow occurred: the January 23, 2012 storm, February 13, 2012 storm, March 2, 2012 storm, March 16, 2012 storm, and December 2, 2012 storm (see Table 1 on page 48 for Storm Sampling dates).

The stage-discharge relationship was developed for the location of the gage site (Gage 3) on Humbug Creek downstream of the confluence with Diggins Creek. The stage-discharge relationship was developed to calculate the load of TSS and particulate-bound mercury in Humbug Creek.

Table 1. Storms Sampled in WY 2012 and 2013

Water Year /Storm	Start	End	Days Monitored (Storm or WY)
WY 2012	12/15/2011	4/27/2012	128
January 23, 2012	1/18/12 9:30AM	1/30/12 5:30PM	12
February 13, 2012	2/11/12 6:15PM	2/16/12 9:15AM	5
March 2, 2012	2/26/12 4:15PM	3/7/2012 4:15PM	10
March 16, 2012	3/12/12 7:15AM	3/26/12 2:45PM	14
WY 2013	10/1/12 12:00AM	3/7/13 1:30PM	158
December 2, 2012	11/27/12 2:30PM	12/14/12 2:30PM	17

The field meter turbidity data at the gage was regressed with the TSS data using simple linear regression in Excel (2007) and in R (3.1.0). Grab samples collected using the ISCO were analyzed for total suspended sediment (TSS) and turbidity at Cranmer Engineering, Inc. Grab samples collected by hand were analyzed for total suspended sediment (TSS) at Brooks Rand Labs. Unfortunately, the samples that went to Brooks Rand for analysis were not also measured for turbidity, and so the meter readings were used to generate a turbidity-TSS regression for the grab samples that were sent to Brooks Rand and to Cranmer. The regression of lab and field turbidity data has a R^2 of 0.84. The turbidity to TSS regression was made using the field meter turbidity readings and 16

TSS samples (n=16) (Brooks Rand Labs samples n=10, and Cranmer Lab samples collected by ISCO n=6).

Figure 16. Discharge Measurement at Road 1, Humbug Creek
Discharge was measured using the Marsh McBirney flow meter model 2000 with top-setting wading rod. (K. Landrum (left) and H. Nepal (right) in photo; photo taken on March 15, 2011 by C. Monohan.)

The field meter turbidity data at the gage was regressed with the particulate-bound mercury data using simple linear regression in Excel (2007) and in R (3.1.0). Duplicate 250 mL grab samples were sent for trace-level mercury analysis at Brooks Rand so that one sample could be filtered at the lab to remove particulate matter and one sample could be processed without filtering for total mercury analysis. The lab filtering, rather than field filtering, is a modification to EPA method 1669 which is considered appropriate as long as lab filtering takes place within the 48 hour hold time. Particulate-bound mercury was calculated by subtracting the dissolved mercury from the total mercury. Field filtering very turbid samples in storm conditions was not feasible. The mercury analysis was done on ten grab samples taken using ultra clean hands methods and on six samples collected using the ISCO using bottles for their first use.

For the January 23, 2012 storm event during rising, peak and falling conditions and during peak storm conditions on March 14, 2012, grab samples were analyzed for a suite of metals (aluminum, iron, manganese, barium, beryllium, chromium, copper, nickel, zinc and lead) from all three sites (Road 1, Hiller 2 and Gage 3) (n=4 at each site).

During the February 13, 2012 storm, grab samples were collected along Humbug Creek to assess the potential for other sources of contamination. The following sites were sampled: Humbug Creek at Road 1, Diggins Creek at Hiller 2, Humbug Creek at Gage 3, Bloomfield Tunnel outlet (BT) (Lake City Tunnel), Humbug Creek downstream of the BT, the North Bloomfield Tunnel outlet (NBT) and Humbug Creek downstream of the NBT. The sampling locations were selected by confluences and drainage from potential contributing areas and features (Figure 27 on page 67).

Error Analysis

There were three regressions for the Gage 3 site on Humbug Creek: 1) stage-discharge, 2) turbidity-TSS, and 3) turbidity-particulate-bound mercury (PHg). Each regression had an individual standard error associated with the fit of the regression. With the exception of fitting the turbidity-TSS and turbidity-PHg regressions through zero to eliminate negative values, the data were not transformed. In general, the instrument error was much larger than the standard error associated with the regression. The turbidity meter had accuracy of plus or minus 0.2 NTU between 0-500 NTU, and plus or minus 0.4 NTU for 500-1,500 NTU. For periods of the year when the meter was not in the water, baseflow conditions were assumed. For baseflow periods when the meter was not in the water the only error calculated was the standard error of the regression. Error was calculated as a percentage of the quantity measured and was assumed to be plus or minus 10% for discharge, plus or minus 14% for sediment load and plus or minus 25% for mercury load. The significant figures in the text for loads are limited to two significant figures and the actual precision of the load estimates and associated errors are reported in tables.

Critical Questions #5-6: Hiller Tunnel

To locate potential sources of metals to the Hiller Tunnel discharge, two mineral springs were sampled in the eastern corner of the pit during low water conditions (Figure 28 on page 71). The springs discharge perennially, although their contributions were not as evident during high water because this area of the pit floor was flooded. The surface flow from these springs contributes to the surface flow through the pit and into Hiller Tunnel. The springs were sampled on November 4, 2012 during low water conditions for pH, sulfate, cations (calcium, magnesium and sodium) and metals (aluminum, barium, iron, manganese, arsenic, copper, mercury and nickel).

To determine whether shallow groundwater in contact with mineralized gravel deposits was a source of metal contamination to the Hiller Tunnel discharge, four shallow borings were installed near the inlet of Hiller Tunnel (P-1 through P-4, see Figure 29 on page 73). P-1 was installed 20 m (60 ft) north of the entrance of Hiller Tunnel and was the boring closest to the Hiller Tunnel inlet. P-2 was installed approximately 60 m (200 ft) west of P-1 and captured flow from the direction of the pond. P-4 was installed 60 m (200 ft) east of P-1 and captured flow from the east side of the pit. P-3 was installed approximately 60 m (200 ft) north of P-1 and was more toward the middle of the pit than the other borings (Figure 29 on page 73).

The borings were installed on September 30, 2012, when conditions were dry, to a depth of 2 m (6 ft) using an 8 cm (3 in) diameter hand auger. The bottom 0.6 m (2 ft) of 5 cm (2 in) diameter PVC pipe was screened with premanufactured 0.05 cm (0.02 in) slots and sand was placed in the augured hole around the screen. End caps were attached compression-tight without screws or glue to avoid interference with pressure transducers or chemical issues, respectively. No centralizers were used and all materials were new upon installation. The area above the sand was backfilled and bentonite was used at the ground surface to limit surface water infiltration along the walls of the PVC pipe.

The depth to groundwater was measured and groundwater samples were analyzed for pH, conductivity, temperature, dissolved oxygen, and metals (aluminum, iron, arsenic, chromium, copper, lead, nickel, and zinc).

Critical Questions #7-9: Hydraulic Mining Pit

To determine the source of mercury and suspended sediment to the Hiller Tunnel, grab samples of surface water discharge were collected at various locations in the pit during the December 2, 2012 storm event (see Figure 28 on page 71). Discharge was measured using the velocity area method using a flow meter and the float method; discharge was difficult to measure in many of the small and often undefined drainages. Surface water quality sampling sites were selected in the hydraulic mining pit at locations that captured runoff from a feature of interest in the pit such as tailings piles or at a juncture of two drainages. The surface water sampling locations in the pit were selected to represent contributing areas above tributary junctions. Sampling locations were placed in strategic locations/junctures moving upstream from Hiller Tunnel. Grab samples collected at node locations were sampled for TSS and mercury (total and dissolved) (Figure 28 on page 71). The sites are described below:

- SS1 to SS4 are in drainages to the east of the Hiller Tunnel inlet that drain relic mine tailings on the south rim of the pit.
- SS5 to SS11 are in the actively eroding area of the east end of the pit. SS5 captures the spring discharge and SS11 is in an area that may capture drainage from placer tailings. SS6 and SS9 are background samples.
- SS12 to SS15 are background samples. SS12 and SS13 (northeast pit rim drainages) are in background locations, SS15 is a background location from a drainage that enters from the northwest end of the pit.
- SS18 to SS21 are near Hiller tunnel. SS18 is at the tunnel inlet, SS19 captures flow from the east end of the pit, SS20 captures flow from the west end of the pit, SS21 is at the tunnel outlet.

Figure 17. Surface Flow in the Malakoff Diggins Pit
Surface water samples were collected during the December 2, 2012 storm event from 20 locations in the pit during surface runoff. There were many areas where flow was unconfined and discharge was difficult to measure. (Photo taken December 2nd, 2012, by D. Brown of H. Nepal.)

Confirmation sampling in WY 2014 was conducted on both the water quality of the surface water entering the pit and on surface soil samples collected in the pit. The purpose of these additional sampling efforts was to confirm that water entering the pit was not bringing contamination into the pit and to quantify the contamination of the soil in the pit following the suspended sediment results.

Water samples were collected on February 9, 2014 during a storm event with surface water runoff. Samples were collected from surface water streams flowing into the pit along the pit Rim Trail and from Hiller Tunnel. The discharges of the streams entering the pit (R1-R8) were also measured. The samples were analyzed for total and dissolved metals. The samples were analyzed at Brooks Rand Labs for TSS, hardness, mercury, aluminum, arsenic, barium, beryllium, cadmium, chromium, copper, iron, magnesium, nickel, lead and zinc. The sample locations are displayed as R1-R8 in Figure 28 on page 71, along the pit Rim Trail where surface water enters the pit from the north during storm events.

Surface soil samples were collected on January 14, 2014 to determine if there were elevated levels of metals in the soil in the pit near where the surface water samples were collected during the December 2, 2012 storm. Fifteen sample locations were selected based on storm water sampling locations that indicated elevated levels of particulate-bound mercury during the December 2, 2012 storm event, and based on the archaeological information about where historical activities took place such as handling and storing mercury that occurred in the Malakoff Village location. A total of 15 surface soil samples were collected. To obtain surface soil samples, samplers wore gloves and used a plastic trowel to clear away any leaf litter. The trowel was used to shovel exposed soil into a sieve that was held above a sample jar. The sieve was 10 cm (4 in) in diameter and had a plastic frame with metal mesh with 0.3 cm (1/8 in) square holes. Samples were collected into acid-cleaned polyethylene jars. Occasionally, the plastic trowel was used to break particles apart to a size that would fit through the sieve. The jar was filled to the point of having at least 100 g (4 oz) of material. The sample jar was sealed in double plastic bags provided by the lab. To avoid cross-contamination the plastic trowel and sieve were cleaned between samples using 409 spray and paper towels. Samples were refrigerated until placed in a cooler with ice packs for shipping to the lab. They were analyzed at Brooks Rand Labs for arsenic, copper, mercury, nickel, lead and zinc. The locations of the confirmation surface soil samples are displayed as MC1-12 on Figure 29 on page 73.

Figure 18. Confirmation Soil Samples from the Malakoff Diggins Pit
Confirmation soil samples were collected from areas that had elevated concentrations of particulate-bound mercury in suspended sediment during the December 2, 2012 stormwater sampling day. (Photo taken January 14, 2014 by K. Atkins of C. Monohan.)

Critical Questions #10-11: North Bloomfield Tunnel

The North Bloomfield Tunnel access shafts were located using historical maps and GPS (Magellan Meridian Platinum v 4.06 WAAS Enabled NAM Land 1.03).

The outlet of the North Bloomfield Tunnel was located and water samples from 1,000 ft inside the tunnel were collected on March 9, 2012. The discharge from North Bloomfield Tunnel was measured on October 11, 2013. A preliminary investigation was conducted from the outlet of the tunnel to 300 m (1,000 ft) into the tunnel (distance measured by range finder) to determine the nature of the tunnel blockage. The tunnel contained an orange-red iron precipitate that accumulated to thigh-high sludge farther back into the tunnel. The tunnel blockage may have resulted from debris that entered from the access shafts as surrounding material collapsed, or from debris that may have entered when the North Bloomfield Road was constructed near Shaft 7 (likely near the existing road pull out for the Humbug Trailhead).

Standing water in North Bloomfield Tunnel access shafts (Shafts 1, 3, 5, 6) and the pit pond[9] were sampled on March 26, 2012, using a Sink Fast Bailer, 1L (Model # SF16x36SCW) manufactured by Aqua Bailer to collect water from the middle of the water column. Shafts 2 and 4 were located later and sampled on November 9, 2012. Tunnel and access shaft samples were analyzed for metals (arsenic, barium, chromium, copper, lead, nickel, and zinc) (BSK Labs) and total and dissolved mercury (Brooks Rand Labs). The discharge from Shaft 5 was measured on October 11, 2013.

The Bloomfield Tunnel (Lake City) portal was located and water samples were collected from the portal on February 13, 2013. The tunnel was explored and found to go back 90 m (300 ft) before being blocked by quartz gravel and sand. The direction of the tunnel was measured with a compass. The discharge from Bloomfield Tunnel was measured on October 11, 2013.

Figure 19. Collecting Water Sample from an Access Shaft Using a Bailer
Standing water in the North Bloomfield Tunnel access shafts was sampled by lowering a Sink Fast Bailer to the middle of the water column. The water was brought to the surface and transferred into containers provided by the laboratories. (Photo taken on March 9, 2012 by C. Monohan; D. Demaree and T. Johnson are depicted.)

Biotic Conditions

Critical Questions #12-13: Biotic Conditions

Macroinvertebrates, specifically water striders (*Gerridae*), were collected from three reaches of Humbug Creek using the Surface Water Ambient Monitoring Program (SWAMP) protocol and analyzed for MeHg at Brooks Rand Labs (Figure 38 on page 87).

9 Shaft 8 was assumed to be near the pit pond when it was sampled, but it was later determined more likely to be east of the Hiller Tunnel inlet.

The three 150 m (492 ft) reach sections were located in Humbug Creek: 1) upstream of the confluence with Diggins Creek at the Relief Hill Road crossing (Road 1), 2) 30 m (100 ft) downstream of the confluence at the gage location (Gage 3), and 3) downstream of the Shaft 5 discharge into Humbug Creek. (Additional macroinvertebrate data were collected as part of Susan Miller's CSU Chico thesis, but at the time of writing this report are not available.)

Figure 20. Macroinvertebrate Sampling, Humbug Creek
Water Striders (*Gerridae*) were collected from Humbug Creek. (Photo taken May 18, 2012 by C. Monohan; S. Miller depicted.)

Erosion & Deposition in the Pit

Critical Questions #14-19: Erosion and Deposition

Cliff edge erosion of the historic hydraulic mining pit at Malakoff Diggins was assessed using GIS. A series of historical aerial photographs of the pit from 1952 to 2012 were geo-referenced and compared over time to estimate the pit rim change from 1952 to 2012. Using aerial photographs from 1952 and 2012 the cliff edge was digitized and the amount of recession over time was measured to quantify surface area of material eroded over the 60-year time span. Subtraction of pit area in 1952 from that of 2012 revealed the total amount of area lost to erosion between the two photo periods.

Ground stakes installed by DPR in 2005 in the pit floor were used to estimate a deposition rate from 2005 to 2012. The stakes were installed in three transects perpendicular to flow in the alluvial aggrading portion of the northeast lobe of the pit. Stakes were also installed around the Diggins Loop Trail along the pit floor. The annual deposition rate was determined by comparing sequential measurements made from the top of the stakes to ground surface. Measurements were made at the time of installation in April 2005, and again in December 2005, December 2006, January 2008, and April 2013 (Figure 45 on page 93).

Cross sections of the pit floor deposits first measured using seismic refraction by Peterson in 1979 were re-located using GPS and a follow-up seismic survey was conducted using a Bison Series 5000 Digital Instantaneous Floating Point Signal Stacking Seismograph with 14 Hz geophones and sledge hammer impact. Peterson (1979) used three transects in a seismic refraction survey to estimate depth to bedrock in the Malakoff Diggins pit. Peterson's transects were located in the upper northeast portion of the pit in a northeast-southeast direction, in the middle of the pit in a northeast-southeast direction and in the western portion of the pit also in a northeast-southeast direction, dividing the pit floor into four sections (Figure 43 on page 91).

To determine whether large particles (gravel to sand) were being retained closer to the source of erosion, pit floor samples were collected of the top 0-30 cm (0-12 in) in a longitudinal profile of the pit from the same locations that Peterson (1979) collected samples (Figure 47 on page 97). They were analyzed for grain size variation along the pit floor using a standard shaker table analysis (sieve sizes 2 mm, 1 mm, 500 µm, 250 µm, 125 µm, 63 µm) and using a laser diffraction analyzer at USGS labs for grain sizes 2 mm-0.375µm (Beckman Coulter LS 13 320 Particle Size Analyzer with the Aqueous Liquid Module).

The erosional processes of the cliff walls and gullies were measured using both direct field measurements and GIS remote sensing technologies. The direct field measurements include erosion bridges as well as deposition stakes and trail markers. Direct field erosion measurements were made using a 1 meter erosion bridge to find relative soil elevation change at locations throughout the pit (Blaney and Warrington, 1983). An erosion bridge is a 1 meter-long carpenter's level spanning two rebar pins above the soil surface with measurements made at intervals of 50 mm (2.2 in) by thin aluminum rods. The change loss/gain of elevation represents the magnitude of erosion or deposition, and creates a soil contour profile which can be repeated and held against the previous measurement at that location (Ypsilantis, 2011).

Erosion bridges were installed in seven representative areas of the pit on actively eroding slopes or cut faces throughout the pit in order to quantify erosional/depositional elevation changes for the different soil types and slope ranges (Erosion Plots 1-7, Figure 52 on page 103). Each plot was representative of a dominant erosion process within the zone of depletion, zone of translocation, or zone of accumulation within the individual slope (Selby, 1993). These areas' primary erosion processes were rainsplash, frost wedging, sheetwash and rilling.

The results of these erosion measurements and GIS analyses of representative units were combined to calculate an annual sediment yield from the pit. Representative units were defined as areas of similar morphology and were delineated through observations within the pit and related to areas on the map image using landmarks, such as individual gullies or landslides as reference markers. Multiplying elevation change by the area of similar slope and soils type yields a volume of sediment eroded for that area.

Figure 21. Erosion Bridges in the Malakoff Diggins Pit
Erosion bridges were used to measure cliff wall rilling volume at seven representative locations. 50 mm aluminum bars were placed in a modified 1 meter level that spanned two rebar pins. (Photo taken February 14, 2013 by J. Howle; K. Landrum depicted.)

Assessment Findings

Assessment findings are organized according to the 19 critical questions (CQs) identified by project partners. The discussion of findings for some questions are grouped, as follows:

Water Quality

- CQ1: What is the annual sediment and mercury load in Humbug Creek? How much of that load is from storm events?
- CQ2 & 3: Is mercury in Humbug Creek transported primarily as particulate-bound mercury rather than in its dissolved form? Is the quantity of suspended sediment in Humbug Creek directly correlated with mercury concentration in Humbug Creek?
- CQ4: Is Diggins Creek a source of sediment, mercury and/or other metals to Humbug Creek?
- CQ5: Are the mineral springs in the pit a source of heavy metals in the discharge of Hiller Tunnel?
- CQ6: Is shallow groundwater in the pit the source of heavy metal contamination in the Hiller Tunnel discharge?
- CQ7 & 8: What are the sources of mercury and suspended sediment in the pit? Are mine tailings deposited in the south east end of the pit a source of mercury in the discharge of Hiller Tunnel?
- CQ9: Is the water entering the pit free of mercury, copper, nickel, and zinc?
- CQ10 & 11: Is the North Bloomfield Tunnel contributing to degraded water quality in Humbug Creek? Is Shaft 5 contributing to degraded water quality in Humbug Creek?

Biotic Sampling

- CQ12 & 13: Do the mercury concentrations in macroinvertebrates indicate that mercury is being methylated and incorporated into the aquatic food chain in Humbug Creek? Do MeHg concentrations in macroinvertebrates from reaches of Humbug Creek downstream of Diggins Creek and/or Shaft 5 indicate that mercury is being methylated and incorporated into the aquatic food chain in Humbug Creek?

Erosion, Deposition and Soil Conditions in the Pit

- CQ14: How are the pit rim, pond, and vegetation patch changing over time?
- CQ15: What is the depth to bedrock in the pit?
- CQ16: Is the pit filling in? Is it filling more rapidly than it was in 1979?
- CQ17: Are large particle sizes (gravels to sand) being retained closer to the source of erosion (assumed to be gullies in the east end of the pit) than during the 1979 Peterson study?
- CQ18: What are the erosional processes in the pit?
- CQ19: What is the annual sediment yield from the pit?

Flow and discharge

From the monitoring gage data and flow measurements, a continuous hydrograph was developed. The volume of water released over a water year (WY) was calculated as 4,900,000 kL (4,000 AF) discharged from Humbug Creek in WY 2012, and 3,900,000 kL (3,200 AF) discharged over the 2013 WY. Baseflows were common through the summer and fall months (May-October).

The pressure transducer was removed on April 26, 2012 and reinstalled September 23, 2012. There were no storms during this period and baseflows were assumed to be 0.09 cms (3 cfs). (Baseflows measured in 2013 ranged from 0.06 to 0.11 cms (2 to 4 cfs).) Peak flows in WY 2013 were 0.9 ± 0.09 cms (32 ± 3 cfs) in the March 16, 2012 storm, and 1 ± 0.09 cms (40 ± 3 cfs) in the December 2, 2012 storm (Figure 22).

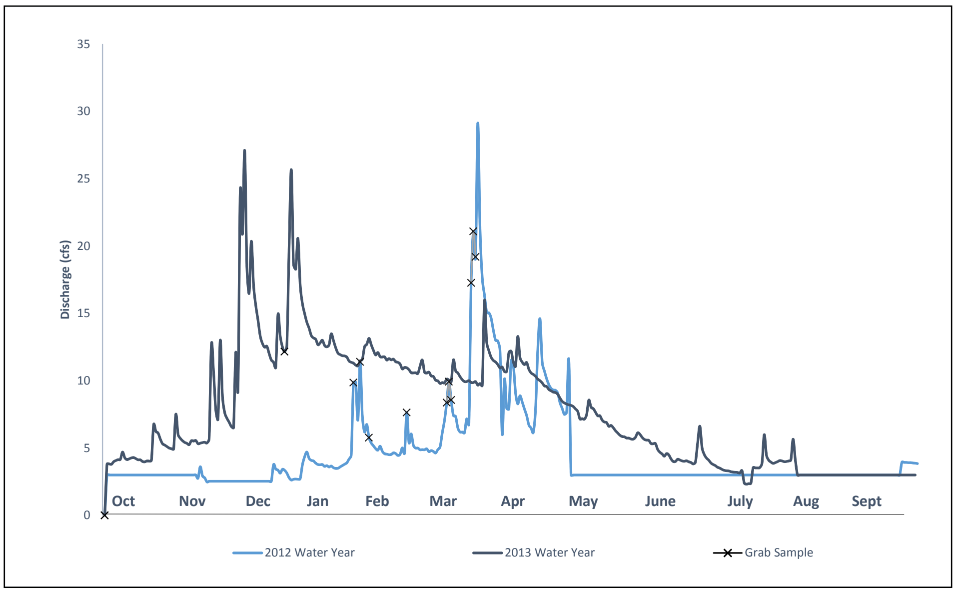


Figure 22. Humbug Creek Hydrograph
The discharge at the Gage 3 site on Humbug Creek from daily flows taken at 3:15 pm are displayed for Water Year 2012 and 2013. The dates on which water quality samples were collected from Gage 3 are marked with an x. Low water periods when the pressure transducer was not in the water are assumed to be a baseflow (3 cfs).

A stage-discharge relationship was developed using the statistical program "R" (R Core Team, 2014) and nine paired pressure readings and discharge measurements collected over the range of 0.06 – 0.51 cms (2-18 cfs) during the water years (WY) 2012, 2013 and 2014. The pressure readings were adjusted for March 26, 2012-April 27, 2012 due to sediment that entered the meter casing during the large spring storm events in late WY 2012 and

What is the annual sediment and mercury load in Humbug Creek? How much of that load is from storm events?

Findings

The annual sediment load in Humbug Creek is estimated to be at least 500,000 kg/yr (500 tons/yr), and the annual mercury load is at least 100 g/yr (0.25 lb/yr). At least half of the annual sediment and mercury load in Humbug Creek is from episodic production during storm events.

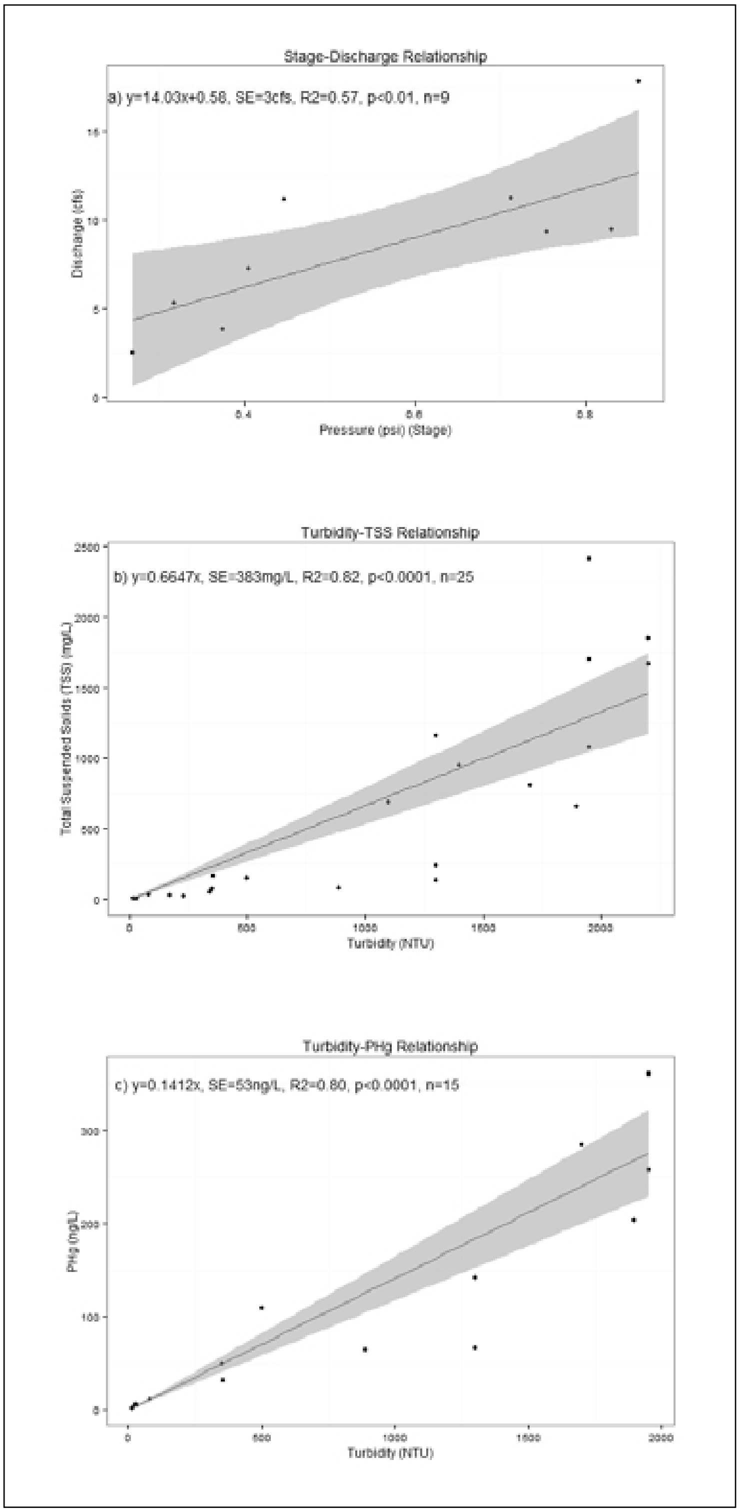


Figure 23. Regression Relationships for Humbug Creek
Three regression relationships were found for the Gage 3 sample site on Humbug Creek: Stage-Discharge Relationship, Turbidity-TSS Relationship and Turbidity-Particulate-Bound Mercury Relationship.

surrounded the pressure transducer. As a result 0.46 psi was subtracted from the meter's pressure readings. When the meter was reinstalled in October 2012 the pressure readings were also adjusted for the entire WY 2013 (by adding 0.169 psi) because the meter was elevated by some sediment in the casing. Both of these adjustments served to make the hydrograph of baseflow readings comparable among water years and after the storm events. The adjusted pressure readings were used to make the stage-discharge relationship (Figure 23).

The stage-discharge relationship was used to develop a rating curve at the Gage 3 location on Humbug Creek. The linear equation that describes this relationship has an R^2 value of 0.57, $p<0.01$, n=9. The standard error of 0.085 cms (3 cfs) was used to calculate the error of the regression equation. Discharge estimates outside of this range are based on a linear extrapolation and are considered to be less accurate the farther they are from this range.

Turbidity, TSS and PHg relationships

Turbidity and TSS in Humbug Creek correlated well (R^2 =0.82, $p<0.0001$, n=25, see Figure 23). During baseflow conditions, turbidity was typically less than 3.0 ± 0.1 NTU; however, during storm events turbidity regularly exceeded 1,600 NTU, the operational range of the gage. For annual load calculations during baseflow periods when the meter was not in the water, a turbidity of 1.5 NTU was assumed. The turbidity-TSS relationship combined with stage-discharge allowed sediment loads to be calculated.

Key Findings for Turbidity and TSS:

- On March 16, 2012, the highest TSS measurement from a grab sample was 2,410 mg/L, which led to a calculation of 2 kg (5 lb) of sediment per second moving through Humbug Creek as an instantaneous sediment load.[10] The flow rate was approximately 0.9 cms (32 cfs). (The turbidity reading for the measurement was over the meter's capacity and read 1,949 NTU.)
- On December 2, 2012 the peak instantaneous sediment load was estimated at 1 kg (3 lb) of sediment per second. This is an estimate, as no grab samples were collected to verify TSS. The peak discharge was calculated to be 1 cms (40 cfs) with an estimated turbidity of 1,949 NTU (meter reading outside of operational range) and a calculated TSS of 1,296 mg/L. This calculation is likely an underestimate because it is a turbidity reading that is outside of the meter's range.
- The largest storm in the 2012 WY was the March 16, 2012 storm lasting 14 days with an estimated sediment load of 240,000 kg (240 T) moving through Humbug Creek over that period, approximately 17,000 kg/day (17 T/day).
- The second largest storm in the 2012 WY was January 23, 2012 which was 12 days long and had a sediment load of 66,000 kg (66 T), approximately 5,500 kg/day (5 T/day).
- The largest storm in the 2013 WY was the December 2, 2012 storm lasting 17 days with an estimated sediment load of 270,000 kg (270 T) moving through Humbug Creek over that period, approximately 16,000 kg/day (16 T/day).

The regression of TSS and turbidity using grab samples enabled TSS to be calculated continuously for turbidity measured from 0-900 NTU and allows for peak storm conditions to be estimated for 900-1,500 NTU. For example, the peak turbidity meter reading for the March 16, 2012 storm of 1,949 NTU was used to calculate an instantaneous sediment load using the turbidity-TSS relationship. Using the turbidity-TSS relationship, the sediment load is calculated to be 20 kg/s (2.57 lb/s), 54% of the measured value from grab samples. Thus, it appears that meter readings in the upper range underestimate the actual turbidity by at least 46%. In other words, because there is both a meter reading and grab sample for this storm event it was

10 The NCRCD sample collected at Hiller Tunnel was considerably closer to the pit than The Sierra Fund samples that were collected at the Gage 3 site on Humbug Creek, 30 m (100 ft) downstream of the Humbug Creek and Diggins Creek confluence.

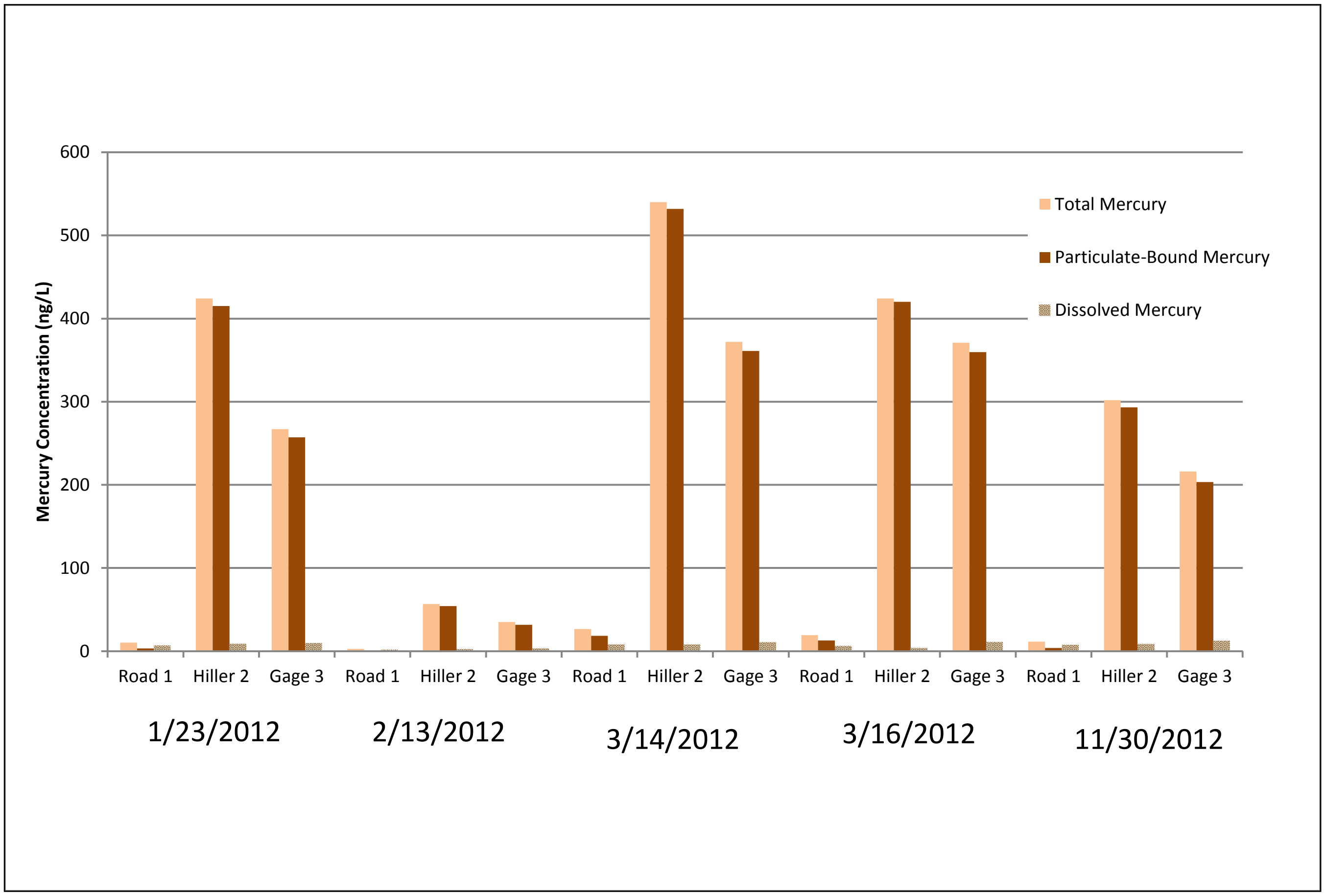


Figure 24. Mercury Forms in Humbug Creek during Storm Events
Water quality sampling site data for five storm events at the Road 1, Hiller 2 and Gage 3 sites. Hiller Tunnel contributed mercury to Humbug Creek during all storm events. The primary form of mercury was particulate-bound.

clear that the meter readings in the upper range underestimated the actual turbidity by at least 46%. This example demonstrates the value of having a turbidity-TSS relationship for continuous data but also demonstrates the limitations of this relationship at the upper range of the meter and the importance of taking grab samples during peak storm conditions to develop the relationship.

Similar to the turbidity-TSS relationship, the mercury analysis of grab samples was used to develop a turbidity-particulate-bound mercury relationship (R^2=0.80, $p<0.001$, n=15). In WY 2012 the largest storm, March 16, 2012 (14 days long), had a mercury load of 52 g; the January 23, 2012 storm (11 days long) had a mercury load of 14 g. The highest concentration of total mercury collected from Humbug Creek was in a grab sample collected on March 16, 2012 with 371 ng/L total mercury. There were approximately 0.85 cms (30 cfs) in Humbug Creek at the time that this sample was collected. The calculated instantaneous particulate-bound mercury load was 42 mg/min of mercury (Figure 24 on page 60).

Key Findings for Sediment Loads:

- The sediment load for Humbug Creek during the 2012 WY (365 days) was 474,000 kg (474 T). The sediment load for Humbug Creek for the 2013 WY (365 days) was 570,000 kg (570 T).
- The sediment load for the 2012 WY was primarily from storm events (70%).
- The annual sediment load is approximately 500,000 kg/yr (500 T/yr) of sediment from Humbug Creek during the two years monitored (WY 2012 and 2013). This sediment load calculation is likely to be an underestimate because it reflects two low water years, and only the suspended sediment load and not the bed load was calculated (Table 2).

Similar to the annual sediment load, the annual mercury load was made up primarily from storm events (70%). In WY 2012 the largest storm, March 16, 2012 (14 days long), had a mercury load of 51 g and the January 23, 2012 storm (11 days long) had a mercury load of 14 g. The annual mercury load is at least 100 g of particulate-bound mercury per year from Humbug Creek

Table 2. Humbug Creek Watershed Annual Loads and Storm Event Loads for WY 2012 and 2013

Time Period	Duration (Days)	Discharge (AF)	Error (AF) ±	Sediment Load (ton)	Error (ton) ±	Sediment Load (ton/day)	Mercury Load (g)	Error (g) ±	Mercury (g/day)
Total WY 2012	365	4,178	418	474	66	1	101	25	
Low Water, Fall	75	446	45	0			0.12		
Meter	128	2,804	280	473	66		100	25	
Low Water, Summer	156	928	93	1			0.24		
WY 2012 Storms									
January 23rd	12	172	17	66	9	6	14	4	1
February 13th	5	53	5	4	1	1	1		
March 2nd	10	129	13	22	3	2	5	1	
March 16th	14	466	47	243	34	17	52	13	4
WY 2012 Percent Storm		20%		71%			71%		
Total WY 2013	365	3,211	321	571	80	2	121	30	
Meter	158	2,890	289	567	79		121	30	
Low Water, Summer	54	321	32	4	1		0		
WY 2013 Storms									
December 2nd	17	547	55	269	38	16	57	14	3
WY 2013 Percent Storm		17%		47%			47%		

Notes:

Baseflow was estimated based on low water seasons (spring and fall 2012, summer 2013) when meter was not in place

Error was calculated as a percent of the quantity measured; it was assumed to be 10% for discharge, 14% for sediment load and 25% for mercury.

What is the annual sediment and mercury load in Humbug Creek? How much of that load is from storm events?

Findings

The annual sediment load in Humbug Creek is estimated to be at least 500,000 kg/yr (500 tons/yr), and the annual mercury load is at least 100 g/yr (0.25 lb/yr). At least half of the annual sediment and mercury load in Humbug Creek is from episodic production during storm events.

during the two water years monitored. This mercury load calculation is likely an underestimate because it reflects only part of the water year and was calculated for two below-normal water years.

Key Findings for Turbidity and PHg Relationship:

- Based on the turbidity-PHg relationship, the annual mercury load was estimated to be 100 g of mercury for Humbug Creek during the 2012 WY and 120 g for the 2013 WY.
- Similar to the annual sediment load, the annual mercury load was made up primarily from storm events (70%). The annual mercury load is at least 100 g of particulate-bound mercury per year from Humbug Creek. This mercury load calculation is an underestimate because it reflects below normal water years and because it was calculated only for suspended load.

Particulate-Bound and Dissolved Mercury

At each sampling event, samples were collected for analysis of filtered (dissolved) mercury and total mercury. Particulate-bound mercury was calculated by subtracting the dissolved mercury from the total mercury. At the Road 1 site (Humbug Creek upstream of the Hiller Tunnel discharge), 32% of the total mercury was particulate-bound. However, below the Diggins Creek confluence, the dominant form is particulate-bound: 88% of total mercury at Hiller 2 on Diggins Creek was particulate-bound, and 79% of total mercury was particulate-bound at Gage 3 (Figure 24 on page 60 and Table 3 on page 64).

These percentages are averages across 10 sampling events for each site, spanning both baseflow and storm conditions. The percentage of particulate-bound mercury to total mercury increases during storm events because of the strong correlation between particulate-bound mercury and TSS.

For all mercury samples collected in Humbug Creek at the Gage 3 site (n=10 hand-collected grab samples and n=6 ISCO-collected samples) total mercury averaged 84% particulate-bound mercury. This average included non-storm conditions. The highest mercury concentration collected from Humbug Creek at Gage 3 was measured on March 16, 2012 during a large storm event (371 ng/L) and had 97% particulate-bound mercury (Figure 24 on page 60). The high percentage of particulate-bound mercury during a storm event has implications for mercury transport from Malakoff Diggins to downstream reaches in Humbug Creek and the South Yuba River because mercury-enriched clay particles travel long distances once mobilized.

The California Toxics Rule (CTR) human health criteria (one-per-million risk of cancer) for consumption of water and aquatic organisms is 50 ng/L dissolved mercury. Samples collected from the Hiller Tunnel outlet and from Humbug Creek downstream of the Hiller Tunnel did not have concentrations of dissolved mercury that were above 50 ng/L even during storm events (January 23, February 13, March 2, March 16 and December 2, 2012). However, the concentrations of total mercury ranged between 200 - 500 ng/L at Hiller 2 and Gage 3 sites during storm events. The identification of sources of mercury is important for the Statewide Mercury Control Program for mercury in reservoirs and upland hydraulic mine sites where mercury was used should be considered to be potential sources.

The level of sediment contamination for turbid water samples can be determined by the concentration of particulate-bound mercury (ng/L) divided by the concentration of sediment (mg/L), resulting in the ng/mg ratio of mercury concentration in ppm. The average concentration of mercury in

CQ2: Is mercury in Humbug Creek transported primarily as particulate-bound mercury rather than in its dissolved form?

CQ3: Is the quantity of suspended sediment in Humbug Creek directly correlated with mercury concentration in Humbug Creek?

Findings

CQ2: At the Humbug Creek control site (Road 1), mercury was primarily in the dissolved form, but at the confluence with Diggins Creek (Hiller 2) and below the confluence (Gage 3), the majority of the mercury was in the particulate-bound form. Mercury below the pit drainage is primarily transported in particulate-bound form.

CQ3: The particulate-bound mercury is highly correlated with total suspended sediment in Humbug Creek at Gage 3 site (R^2=0.80, n=15, $p<0.0001$).

suspended sediment in Diggins Creek was 0.29 ng/mg (0.29 ppm) (Hiller 2 site), in Humbug Creek was 0.37 ng/mg (0.37 ppm) (Gage 3 site), and at the Road 1 site was 0.62 ng/mg (0.62 ppm). It is interesting to note that Road 1, the background sampling site, had a higher concentration of mercury in suspended sediments than Hiller 2 or Gage 3, however this is not unexpected as Road 1 has low suspended sediments as it is upstream of where Diggins Creek discharge enters Humbug Creek (particulate-bound mercury divided by a low TSS results in a larger concentration of mercury per suspended sediment particle.)

These values are far below the preliminary remediation goal (PRG) for mercury in residential soil which is 23 mg/kg (ppm). The suspended sediment mercury concentration found in Humbug and Diggins Creek by USGS Fleck et al. (2010) was 0.3 ng/mg (ppm). These values are within the range described by Bouse et al. (2010) who characterized hydraulic mining debris deposited in the San Francisco Bay as having a mercury concentration of 0.45 ng/mg (ppm). This supports the theory that many hydraulic mine sites where mercury was used may have mercury-contaminated sediments in the range

Table 3. Humbug Creek Water Quality Data

Site	Date Sampled	Discharge (cfs)	Total Mercury (ng/L)	PHg (ng/L)	Dissolved Mercury (ng/L)	% PHg	TSS (mg/L)	PHg in Suspended Sediment (ng/mg) (ppm)	Al (mg/L)	Fe (mg/L)	Mn (mg/L)	Ba (ug/L)	Be (ug/L)	Cr (ug/L)	Cu (ug/L)	Pb (ug/L)	Ni (ug/L)	Zn (ug/L
Reporting Limit			*0.8*		*0.8*		*3*		*0.05*	*0.05*	*0.01*	*5*	*0.5*	*0.5*	*0.5*	*0.5*	*1*	*10*
Detection Limit			*0.3*		*0.3*		*0.5*		*0.023*	*0.023*	*0.0045*	*2.3*	*0.18*	*0.28*	*0.18*	*0.2*	*0.3*	*5*
Road 1	1/20/2012	1.21	3.31	0.86	2.45	26%	1.1	3.0	ND	0.05	ND	29	ND	0.58	0.77	ND	19	ND
	1/23/2012		10.40	3.27	7.13	31%	4.4	2.4	0.43	0.55	ND	25	ND	0.82	3.1	ND	7.5	ND
	1/27/2012	1.92	2.44	0.53	1.91	22%	0.6	4.1	ND	0.11	ND	23	ND	ND	1	ND	11	ND
	2/13/2012		2.71	0.79	1.92	29%	1.0	2.7										
	3/1/2012		1.91	0.10	1.81	5%	0.4	4.8										
	3/2/2012	1.65	2.11	0.28	1.83	13%	0.3	7.0										
	3/14/2012	35.22	26.70	18.53	8.17	69%	55.2	0.5	1.2	2.8	0.09	40	ND	1.3	7.1	0.74	12	ND
	3/16/2012		19.30	12.92	6.38	67%	19.3	1.0										
	11/30/2012		11.40	3.93	7.47	34%	8.4	1.4										
	12/10/2012		1.98	0.41	1.57	21%	1.0	2.0										
Road 1 Averages						32%		2.9	2									
Hiller 2	1/20/2012	0.23	7.12	4.31	2.81	61%	33.3	0.2	0.13	9.4	1.4	64	ND	0.86	2.6	0	48	22
	1/23/2012		424.00	415.04	8.96	98%	1630.0	0.3	20	34	0.58	190	1.8	65	93	23	81	110
	1/27/2012	0.53	15.00	12.76	2.24	85%	54.9	0.3	0.7	3.6	1.2	68	ND	2.7	3.9	0.74	47	16
	2/13/2012		56.7	54.21	2.49	96%	281.0	0.2										
	3/1/2012		7.76	5.68	2.08	73%	24.6	0.3										
	3/2/2012	2.05	9.5	7.69	1.81	81%	34.3	0.3										
	3/14/2012		540.00	531.79	8.21	98%	2940.0	0.2	22	39	0.52	230	2.4	76	130	30	110	130
	3/16/2012		424.00	420.17	3.83	99%	930.0	0.5										
	11/30/2012		302.00	293.25	8.75	97%	449.0	0.7										
	12/10/2012		13.70	12.35	1.35	90%	31.3	0.4										
	2/9/2014		500.00	495.72	4.28	99%	2560.0	0.2	26,900	36,700				92	136	38	109	158
Hiller 2 Averages						89%		0.3	0.1									
Gage 3	1/20/2012	5.84	6.09	3.24	2.85	53%	9.7	0.6	0.05	1.6	0.57	50	ND	0.53	1.3	ND	23	ND
	1/23/2012	14.67	267.00	257.22	9.78	96%	1080.0	0.2	11	18	0.37	120	1.2	39	57	15	56	68
	1/27/2012	5.84	6.55	5.84	0.71	89%	6.8	1.0	0.2	0.59	0.21	38	ND	0.97	1.5	ND	14	ND
	2/13/2012	7.17	35.00	31.75	3.25	91%	166.0	0.2										
	3/1/2012	6.11	7.64	4.51	3.13	59%	4.9	1.6										
	3/2/2012	7.47	13.70	11.25	2.45	82%	39.6	0.3										
	3/14/2012	23.72	372.00	361.00	11.00	97%	1700.0	0.2	15	26	0.39	170	1.7	56	92	21	79	95
	3/16/2012	30.24	371.00	359.70	11.30	97%	2410.0	0.2										
	11/30/2012	2.53	216.00	203.50	12.50	94%	659.0	0.3										
	12/10/2012	2.53	4.37	1.37	3.00	31%	5.7	0.8										
Gage 3 Averages						79%		0.5	0.4									

ND were found for Antimony (RL 0.5 ug/L), Arsenic (RL 2.0 ug/L), Cadmium (RL 1.0 ug/L), Selenium (RL 2.0 ug/L), Silver (RL 0.25 ug/L), and Thallium (RL 1.0 ug/L).
Hardness as CaCO3 was 65.90 mg/L on 2/9/2014

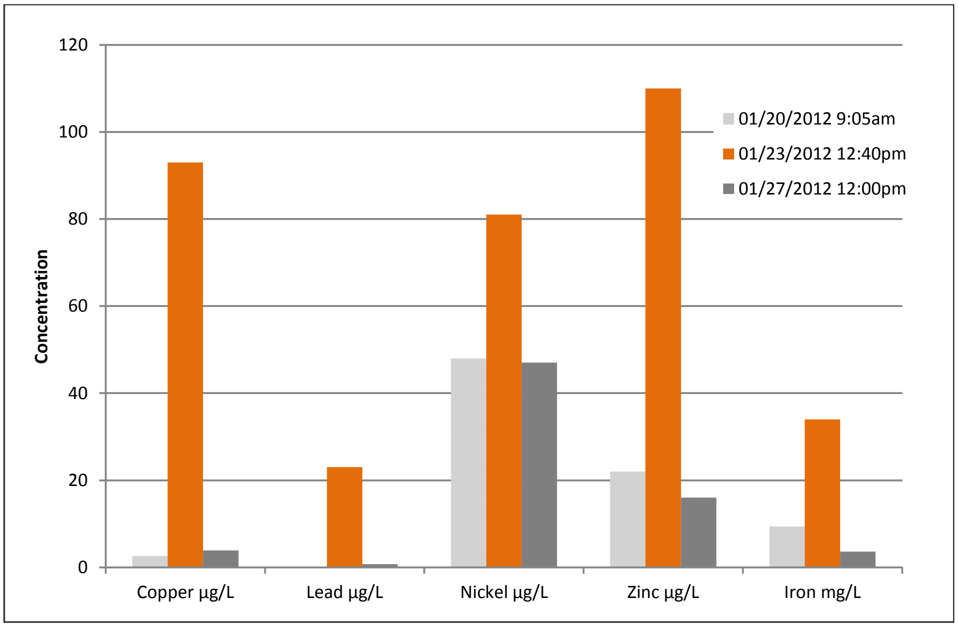


Figure 25. Metals in Hiller Tunnel Storm Event Discharge, January 2012 Storm
Samples were collected at Hiller Tunnel during the rising, peak and falling limbs of the January 23, 2012 storm event. The total metals concentration increased with discharge and decreased with discharge. The peak concentration of total copper was 93 µg/L, the peak concentration of total lead was 23 µg/L, the peak concentration of total nickel was 81 µg/L, the peak concentration of total zinc was 110 µg/L and the peak concentration of total iron was 34 mg/L.

of 0.3 ppm. These concentrations do not exceed the PRG, but these sites may be an ongoing source of mercury that can become methylated in downstream reaches.

Key Findings:

- Mercury during baseflow and storm events below the Malakoff Diggins discharge is primarily in particulate-bound form, with storm events having more particulate-bound mercury than baseflow.
- Although total mercury can reach high concentrations, dissolved mercury in water is below the regulatory level of concern.
- Although TSS and total mercury can reach high concentrations, mercury in suspended sediment is well below residential preliminary remediation goal concentrations.

CQ2: Is mercury in Humbug Creek transported primarily as particulate-bound mercury rather than in its dissolved form?

CQ3: Is the quantity of suspended sediment in Humbug Creek directly correlated with mercury concentration in Humbug Creek?

FINDINGS

CQ2: At the Humbug Creek control site (Road 1), mercury was primarily in the dissolved form, but at the confluence with Diggins Creek (Hiller 2) and below the confluence (Gage 3), the majority of the mercury was in the particulate-bound form. Mercury below the pit drainage is primarily transported in particulate-bound form.

CQ3: The particulate-bound mercury is highly correlated with total suspended sediment in Humbug Creek at Gage 3 site (R^2=0.80, n=15, p<0.0001).

Is Diggins Creek a source of sediment, mercury and/or other metals to Humbug Creek?

Findings

Diggins Creek is a source of sediment, mercury, copper, lead, nickel, zinc, and iron to Humbug Creek during storm events. Humbug Creek has lower levels of these metals upstream of Diggins Creek (Road 1) and significantly higher levels downstream of the confluence with Diggins Creek (Gage 3) during storm events. Additional sampling of metals in the total and dissolved form confirmed that the metals in the Hiller Tunnel outlet discharge are primarily in the particulate-bound form. Additional sources of sediment and heavy metals to Humbug Creek may exist.

During the February 13, 2012 storm, (peak discharge of 0.3 cms (10 cfs) and turbidity of 350 NTU at Gage 3), samples were collected between the hours of 9:30 am and 12:30 pm from a series of stations in an effort to identify sources of sediment and mercury to Humbug Creek. Sampling sites were located at and below potential sources: Humbug Creek at Road 1, Diggins Creek at Hiller 2, Humbug Creek at Gage 3, Bloomfield Tunnel (Lake City Tunnel) outlet (BT), Humbug Creek downstream of the BT, the North Bloomfield Tunnel outlet (NBT) and Humbug Creek downstream of the NBT (Figure 26 on page 66 and Figure 27 on page 67).

This series of samples clearly indicated that the primary form of mercury in Diggins Creek and in Humbug Creek below Diggins Creek was particulate-bound mercury (87-95%) and that the primary source of sediment and particulate-bound mercury was from Diggins Creek, which drains Malakoff Diggins. The Lake City and the North Bloomfield Tunnels, which discharge very small amounts to Humbug Creek, did not contribute significantly to the total or particulate-bound mercury in Humbug Creek.

The conditions of February 13, 2012 were compared to the conditions during other storm events. The concentration of particulate-bound mercury at Road 1, Hiller 2 and Gage 3 were compared to storm samples from January, 23 2012; February 13, 2012; March 14, 2012; March 16, 2012 and November

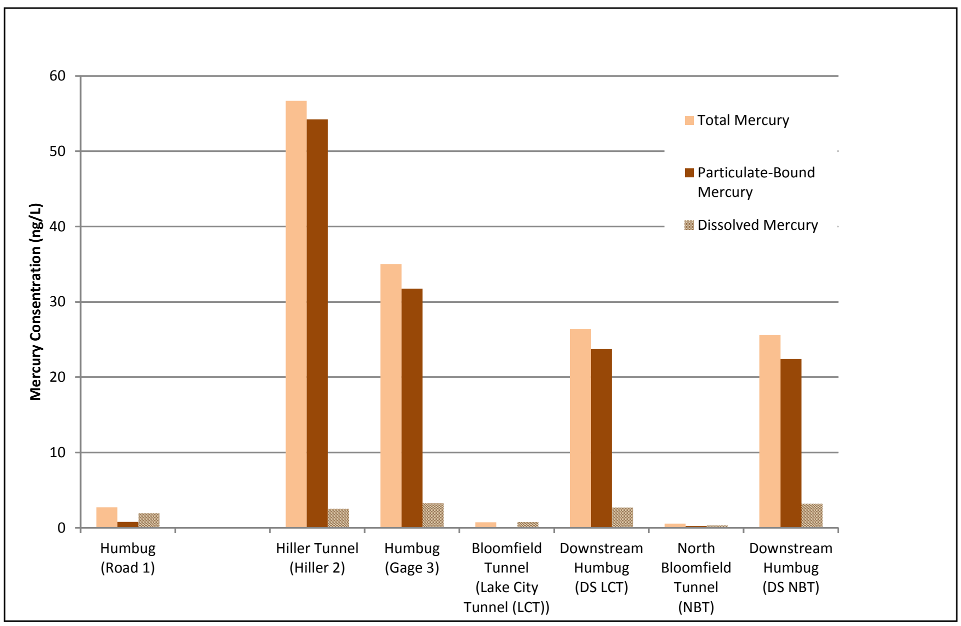


Figure 26. Mercury Sources in Humbug Creek, February 13, 2012
Samples taken on a single day (February 13, 2012) following a mild storm event, from the most upstream water quality sampling site (Road 1) and working downstream to below the North Bloomfield Tunnel outlet (DS NBT). The largest contribution of mercury to Humbug Creek was from the Hiller Tunnel (Hiller 2). Samples were also collected from inside the Bloomfield (Lake City) and North Bloomfield Tunnels.

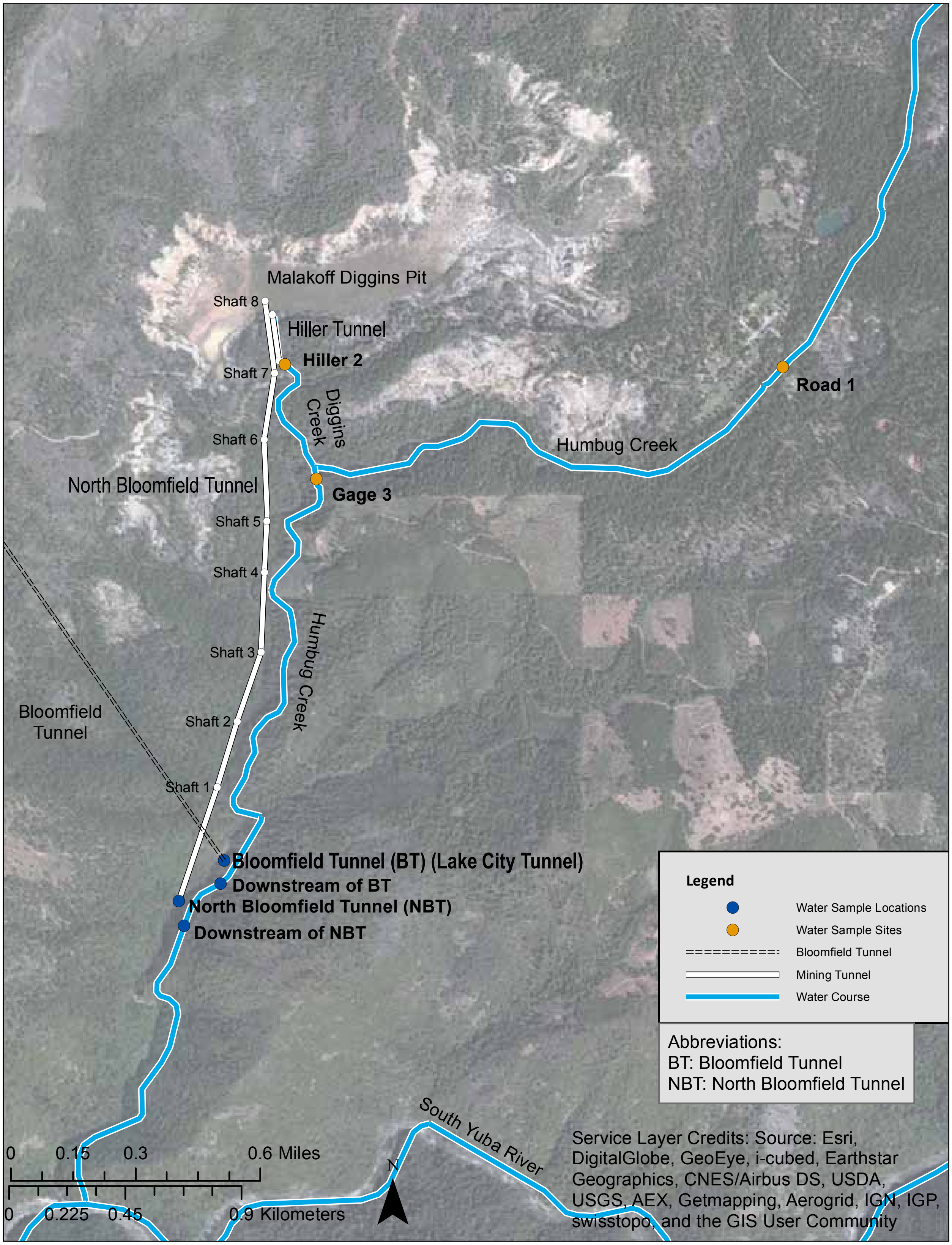


Figure 27. Humbug Creek Site Features – Water Quality Sample Sites and Additional Sample Locations
The water quality sampling locations included three sampling sites (Road 1, Hiller 2 and Gage 3), as well as additional locations that were sampled one time on February 13, 2012 to look for additional mercury sources; these included water quality sampling locations at the Bloomfield Tunnel (also called Lake City), Humbug Creek downstream of the Bloomfield Tunnel, the North Bloomfield Tunnel, and Humbug Creek downstream of the North Bloomfield Tunnel.

Table 4. Discharge and Metals in Malakoff Diggins Pit Inflow and Outflow, February 9, 2014 Storm

Site	Discharge (cfs)	TSS (mg/L)		Hardness (mg eq CaCO3/L)	Hg (ng/L)	Al (µg/L)	Ca (µg/L)	^{52}Cr (µg/L)	^{63}Cu (µg/L)	^{57}Fe (µg/L)	Mg (µg/L)	^{60}Ni (µg/L)	Pb (µg/L)	^{66}Zn (µg/L)
Primary Regulatory Levels					50^{**}	1000^{*}	5^{*}	180^{**}	9^{**}			100^{*}	15^{*}	120^{**}
Secondary Regulatory Levels										$300^{\#}$	$50^{\#}$	$12^{\#\#}$	$2^{\#\#}$	$5000^{\#}$
Hiller	46.5	2560	Total	65.90	500.00	26,900.00	13,000.00	91.80	136.00	36,700.00	8,120.00	109.00	37.80	158.00
			Dissolved	17.70	4.28	52.70	3,680.00	0.53	2.19	34.70	2,060.00	8.14	0.07	3.42
R1	0.4169	2.5	Total	12.60	11.50	1,160.00	3,100.00	0.53	2.64	589.00	1,190.00	0.42	0.25	1.09
			Dissolved	12.60	9.43	544.00	3,090.00	0.53	2.07	282.00	119.00	0.42	0.15	0.71
R2	0.1033	2.4	Total	19.50	21.50	4,030.00	4,760.00	3.22	4.30	1,440.00	1,840.00	1.50	0.57	3.43
			Dissolved	18.50	13.50	1,300.00	4,540.00	0.77	3.08	709.00	1,740.00	0.65	0.28	1.86
R4	1.9671	6.1	Total	13.60	11.90	1,960.00	3,250.00	0.62	2.42	1,270.00	1,320.00	0.43	0.41	1.93
			Dissolved	13.20	6.56	916.00	3,150.00	0.53	1.88	590.00	1,300.00	0.42	0.20	1.46
R5	0.1548	11.3	Total	17.60	9.40	2,080.00	4,490.00	1.39	2.53	1,500.00	1,550.00	0.54	0.60	2.23
			Dissolved	15.80	5.42	491.00	3,990.00	0.53	1.51	343.00	1,410.00	0.42	0.13	5.92
R7	0.3173	3.1	Total	12.70	8.06	292.00	3,140.00	0.53	2.00	149.00	1,180.00	0.42	0.11	0.63
			Dissolved	11.70	5.98	102.00	2,900.00	0.53	1.73	39.20	1,090.00	0.42	0.06	0.63
R8	0.71635	4.1	Total	13.00	12.70	565.00	3,060.00	0.53	2.07	389.00	1,300.00	0.42	0.18	0.82
			Dissolved	12.30	5.40	52.60	2,870.00	0.53	1.32	14.70	1,240.00	0.42	0.06	0.39

Regulatory sources for dissolved metals: MCL CDPH*; CTR CCC**; CDPH$^{\#}$; and PHG OEHHA$^{\#\#}$

30, 2012. For all storm events the majority of the total mercury was made up of particulate-bound mercury and only a small portion was in dissolved form (Figure 24 on page 60).

The concentration of particulate-bound mercury in Humbug Creek increased on average 18-fold after Diggins Creek entered Humbug Creek, relative to concentrations at the Road 1 site (Figure 24 on page 60). Hiller Tunnel outlet discharge calculations are limited because there was no gage installed at Hiller Tunnel and it was dangerous to measure discharge during storm conditions. As a result, the concentrations are compared rather than the loads.

The contribution of Hiller Tunnel outlet discharge to metals in Humbug Creek was assessed during the January 23, 2012 storm event. The total concentrations of copper, lead, nickel, zinc, and iron were measured on January 20, 23, and 27, 2012 (the rising, peak and falling limbs of the storm event). Hiller Tunnel outlet discharge was measured again for these metals on February 9, 2014 for total and dissolved forms. The Hiller Tunnel outlet discharge had 93 µg/L total copper, 23 µg/L total lead, 81 µg/L total nickel, 110 µg/L total zinc and 34 mg/L total iron during peak storm conditions on January 23, 2012, while the concentrations were lower on both the rising and falling limbs of this storm. Other metals (antimony, arsenic, cadmium, selenium, silver and thallium) were below the method reporting limit (MRL)[11] (Figure 25 on page 65).

Similar to sediment and mercury, the concentrations of other metals from the Hiller Tunnel outlet increased as discharge increased and decreased as

11 MRLs are: antimony 0.5 µg/L,, arsenic 2.0 µg/L, cadmium 1.0 µg/L, selenium 2.0 µg/L, silver 0.25 µg/L, and thallium 1.0 µg/L

discharge returned to baseflow. Copper, like mercury, follows the hydrograph. At the peak of the storm (January 23, 2012), the Hiller Tunnel outlet discharge had a total copper concentration of 93 µg/L, but concentrations of 2.6 and 3.9 µg/L three days before and seven days after the storm event, respectively. This indicated that copper, like mercury, was likely in a particulate-bound form because the concentration goes down with discharge and turbidity. Additional sampling for dissolved metals at the Hiller Tunnel outlet discharge confirmed that metals in the Hiller Tunnel discharge are in particulate-bound form.

Total and dissolved metals were analyzed from the Hiller Tunnel outlet discharge collected on February 9, 2014 (Table 4 on page 68). The discharge from the Hiller Tunnel outlet was measured to be 1.3 cms (46 cfs) at the time of sampling. Total metals for mercury, arsenic, barium, beryllium, aluminum, chromium, copper, iron, magnesium, nickel, lead, nickel and zinc were elevated compared to the concentration of dissolved metals.

The CTR threshold for dissolved copper is 9 µg/L, and Hiller Tunnel discharge reached 136 µg/L total copper during the February 9, 2014 sampling event, but the dissolved concentration for copper was only 2.19 µg/L. The CDPH threshold for dissolved lead is 15 µg/L, and the Public Health Goal is 2 µg/L. The Hiller Tunnel discharge had a total lead concentration of 37 µg/L during the February 9, 2014 sampling event and had 0.068 µg/L dissolved lead. The CDPH threshold for dissolved nickel is 100 µg/L, with a California Office of Environmental Health Hazard Assessment (OEHHA) benchmark value of 12 µg/L. The Hiller Tunnel discharge had a total nickel concentration of 109 µg/L during the February 9, 2014 sampling event, but only 8.14 µg/L dissolved nickel. The CDPH threshold for dissolved iron is 300 µg/L. The Hiller Tunnel discharge had a total iron concentration of 36 mg/L (36,000 µg/L) during the February 9, 2014 sampling event, but only 34.7 µg/L dissolved iron.

Two unnamed ravines that originate from the historic New York Claim enter Diggins Creek from the west downstream of Hiller Tunnel before Diggins Creek enters Humbug Creek. These unnamed ravines have discharge during large storm events and they may be additional sources of sediment and heavy metals to Humbug Creek. On March 14, 2012 these ravines had runoff. The first Ravine with the footbridge nearest the North Bloomfield Rd on the Humbug Trail, had 0.283 cms (10 cfs) and a pH of 5.15. The second ravine that does not have a footbridge and is also on the Humbug trail had 0.042 cms (1.5 cfs) and a pH of 2.5. The source and contribution of these unnamed ravines to Diggins Creek and to Humbug Creek is an area for additional investigation.

Is Diggins Creek a source of sediment, mercury and/or other metals to Humbug Creek?

Findings

Diggins Creek is a source of sediment, mercury, copper, lead, nickel, zinc, and iron to Humbug Creek during storm events. Humbug Creek has lower levels of these metals upstream of Diggins Creek (Road 1) and significantly higher levels downstream of the confluence with Diggins Creek (Gage 3) during storm events. Additional sampling of metals in the total and dissolved form confirmed that the metals in the Hiller Tunnel outlet discharge are primarily in the particulate-bound form. Additional sources of sediment and heavy metals to Humbug Creek may exist.

Are the mineral springs in the pit a source of heavy metals in the discharge of Hiller Tunnel?

Findings

The two springs' waters are acidic and contribute to the discharge at Hiller Tunnel outlet. However, the metals concentrations in the springs' waters were not high enough in concentrations to consider the springs to be a significant contributing source of the metals to Humbug Creek, and especially not during storm events when precipitation-driven surface runoff dominates the pit discharge.

Two mineral springs, known as Red and Green Bubble, in the Malakoff Diggins hydraulic mining pit were sampled (Figure 28 on page 71). The pH of both springs' waters was low and the sulfate level was high. Total metal concentrations were slightly elevated, with concentrations higher in Red Spring than in Green Bubble Spring.

The total metal concentrations that were found in the Hiller Tunnel outlet discharge, including copper, lead, nickel, zinc, and iron, were not elevated in the mineral springs with the exception of zinc and iron. Total copper was low in the Red Spring (7.4 µg/L) and was not detected in the Green Bubble Spring (RL 2.3 µg/L), and ranged from 3 - 136 µg/L in the Hiller Tunnel outlet. Total nickel was elevated in both springs (at 37 µg/L in the Green Bubble Spring and 82 µg/L in the Red Spring), and ranged from 47 - 110 µg/L at the Hiller Tunnel outlet during storm events. Lead and zinc, although elevated in the Hiller Tunnel discharge, were not detected in the mineral springs (lead MRL at 2.3 µg/L, zinc MRL 23 µg/L) (Table 5 on page 70).

Table 5. Malakoff Diggins Pit Springs Water Chemistry

Constituent	Green Bubble Spring	Red Spring
pH	2.4	3.88
Sulfate as SO4 (µg/L)	7,000	9,400
Total Metals		
Aluminum (mg/L)	150	540
Barium (µg/L)	95	96
Calcium (µg/L)	880	1,400
Iron (mg/L)	ND	6.3
Magnesium (µg/L)	590	880
Manganese (µg/L)	42	210
Sodium (µg/L)	1,500	1,800
Arsenic (µg/L)	ND	2.9
Copper (µg/L)	ND	7.4
Mercury (ng/L)	0.54	1.15
Nickel (µg/L)	37	82

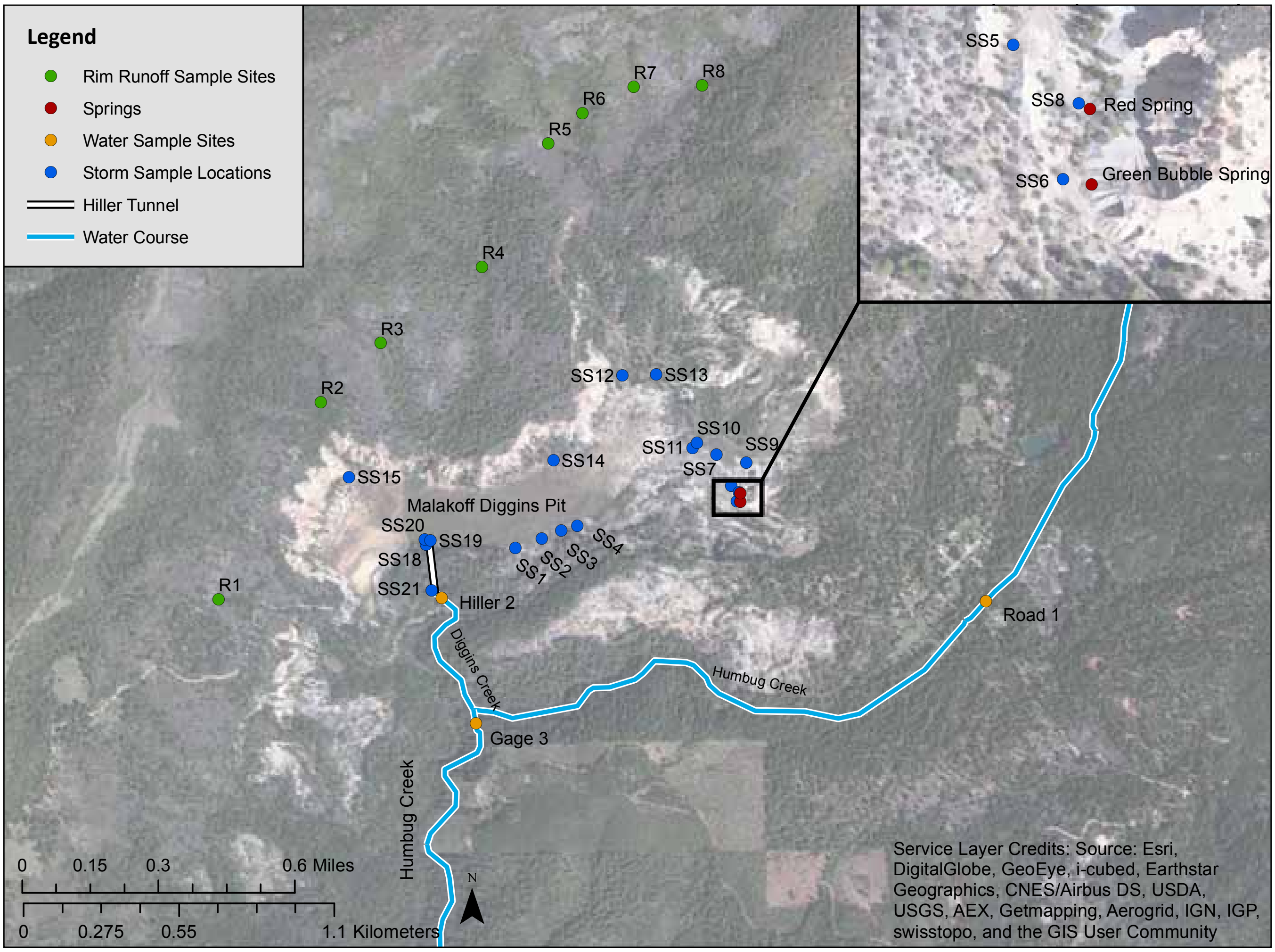


Figure 28. Malakoff Diggins Pit Springs and Stormwater Sample Sites
This map includes the sampling sites along the pit rim (R1-R8), the location of the springs in the pit, and the water quality sampling locations (SS1-SS20) that were sampled during the December 2, 2012 storm event during a three hour window.

Is shallow groundwater in the pit a source of heavy metal contamination in the Hiller Tunnel discharge?

Findings

Total metals are at increased concentrations in the subsurface groundwater near the inlet to Hiller Tunnel, but more research is needed to determine the cause of and significance of these concentrations to surface water discharge from the pit.

Four piezometer boring sites near the inlet of Hiller Tunnel were dug to reach shallow groundwater, and sampled five times (sampling dates November 4, 2012; December 2, 2012; February 9, 2013; March 9, 2013; and March 22, 2013) for total metals including aluminum, iron, arsenic, chromium, copper, lead, nickel, and zinc (Figure 29 on page 73).

The bore groundwater samples were only analyzed for total metals, and cannot be utilized to determine if regulatory limits, which are based on dissolved concentrations, have been exceeded. They do provide useful information, however, and where total metal concentrations are elevated, follow up samples are recommended to be collected and analyzed for dissolved concentrations. Total copper, nickel and zinc were all elevated at boring P-3 when compared to regulatory limits for dissolved metals (Figure 30 on page 74).

Temperature, conductivity, dissolved oxygen and pH were measured in-situ in the borings during all five water sampling events and at five additional times (October 13, 2012; November 5, 2012; November 10, 2012; November 21, 2012; December 3, 2012; December 15, 2012; January 12, 2013; February 10, 2013; March 2, 2013; and March 10, 2013) (Table 6 on page 75). Temperature averages were 8-11 ˚C. Sites P3 and P4 had a similar temperature range (6-11 ˚C and 6-13 ˚C), while P1 had a wider temperature range (2-12 ˚C) and the temperatures in P2, which received water from the pond, did not change much over the year (10-12 ˚C). Conductivity was generally in the range of 0.3 to 1.5 mS/cm^2. Site P3 was on the high end of the range (1 to 1.6 mS/cm^2) while site P2 had a narrower range and at the low end (0.3 to 0.7 mS/cm^2). Dissolved oxygen (DO) generally ranged from 1-6 mg/L over the five sampling events, except at P3, where DO ranged from 4-7 mg/L. No samples exceeded 60% DO.

All of the borings had an average pH between 6.3 and 6.6, which is slightly acidic. However, the pH range for P1 was wider than the others. There was a single reading of pH 3.6 in boring P-1 on December 3, 2012 during a significant rain event (Table 6 on page 75). Visual observations suggest that there may have been reducing conditions in the sediment in the pit near the inlet to the Hiller Tunnel; the upper layer of mud is red (oxidized iron) but beneath the surface it there is a black (reduced iron) layer. If reduced iron (or aluminum) in sediment or groundwater was flushed into an oxidized zone (during a precipitation event), it could cause the pH to drop:

$$Fe(2+) + 3H2O \rightarrow Fe(OH)_3 + 3H+$$

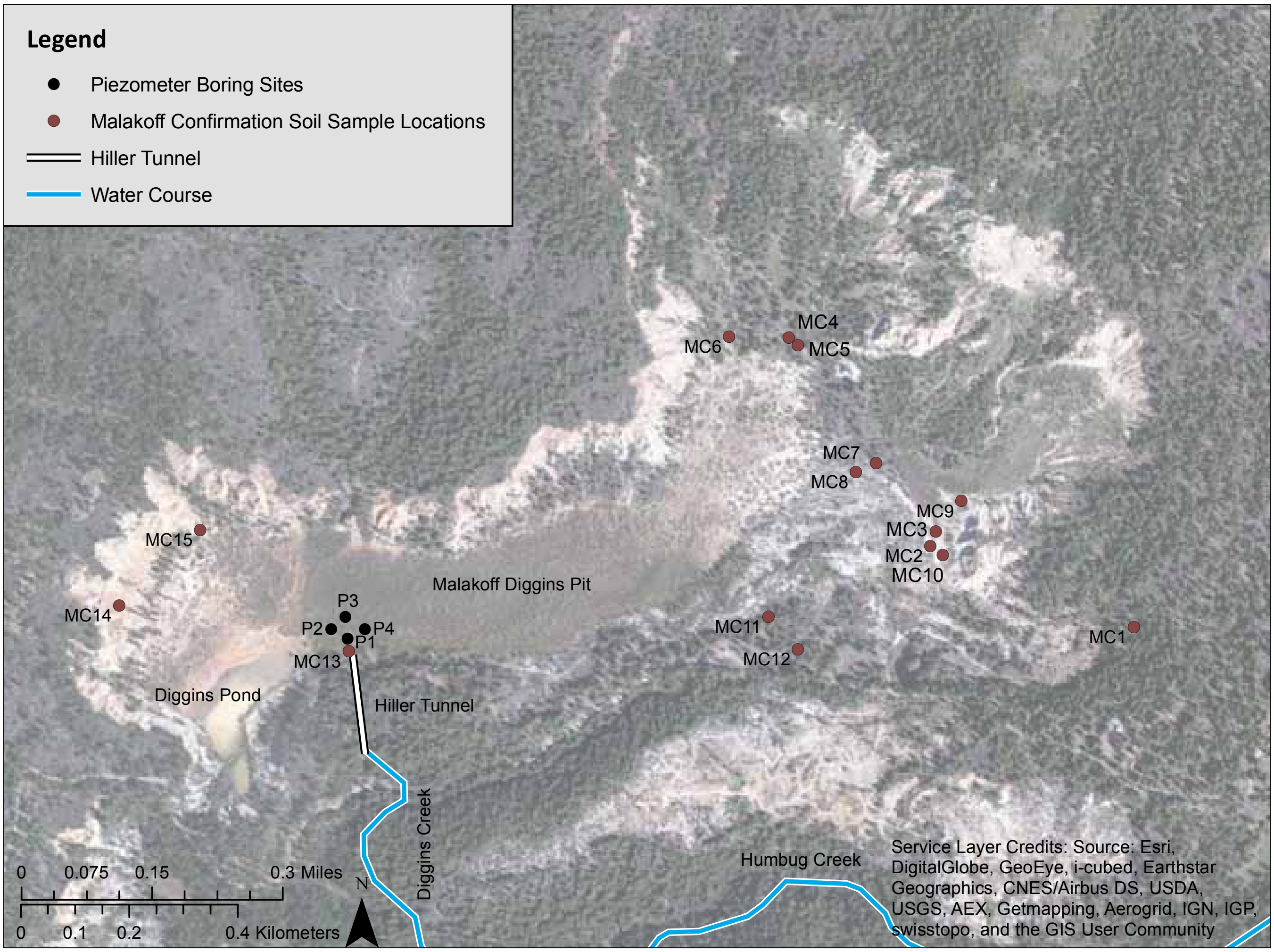


Figure 29. Malakoff Diggins Pit Confirmation Soil Sample Locations and Boring Sites
Confirmation soil samples were collected from locations in the pit that had elevated concentrations of PHg in suspended sediment during a storm event, and from locations where mercury was stored historically at the Malakoff Village site (MC11 and MC12). The boring locations (P1-P4) are at the inlet to Hiller Tunnel.

The degree to which the subsurface water quality in the pit is contributing to the surface water quality in Hiller Tunnel discharge is still unclear. The subsurface flow paths determined by water level loggers installed inside the borings and Principal Component Analysis (PCA) of water chemistry similarities between the borings indicate that there are three separate flow paths: (1) one comes from along the south side of the pit and affects P-4, (2) another comes from Diggins Pond and P-2 (and possibly P-1), and (3) the last comes from the north side of the pit and affects P-3. P-3 had distinctly different patterns of metal concentrations and conductivity from the rest of the borings. Metal concentrations increased during the period that measurements were collected in P-3. However, it is interesting to note that the groundwater samples collected during a peak storm event on December

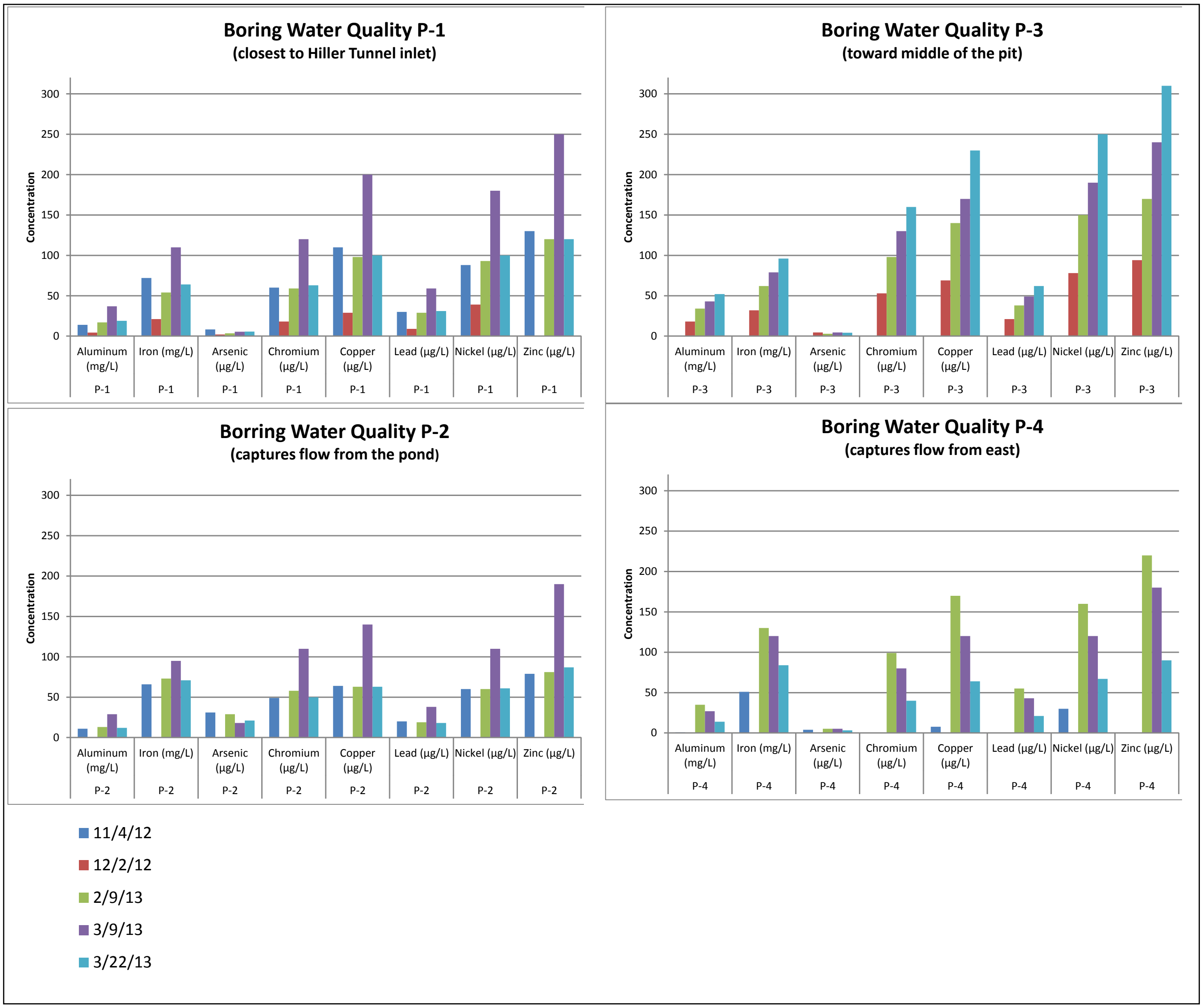


Figure 30. Shallow Subsurface Water Chemistry at Boring Sites in the Malakoff Diggins Pit
Water quality samples were collected from four shallow borings near the inlet of Hiller Tunnel on five different dates. Arsenic was above 10 µg/L in P-2 during all sampling dates (18-31 µg/L arsenic). Copper was greater than 100 µg/L in all borings during at least one of the sample dates.

3, 2012 had some of the lowest concentrations of metals for all borings compared to samples taken from the borings during low water conditions, which could suggest dilution.

For more detail on the boring water chemistry and analysis see David Demaree's thesis *Subsurface Waters at Malakoff Diggins: Pit, North Bloomfield Tunnel and Hiller Tunnel*, Fall 2013.

Table 6. In-Situ Measurements from Borings in the Malakoff Diggins Pit

Site	Date Sampled	T (°C)	EC (ms/cm^2)	DO (%)	DO (mg/L)	pH	H_2O Depth (ft)
P-1	10/13/2012	12.41	1.225	34.3	3.42	6.74	8.12
	11/5/2012	11.58	0.492			5.72	
	11/10/2012	11.24	0.537	44.5	4.65	7.48	
	11/21/2012	10.23	0.505	22.2	2.57	6.10	
	12/3/2012	9.35	0.509	19.7	2.23	3.62	
	12/15/2012	8.48	0.489	54.0	6.05	6.84	
	1/12/2013	5.99	0.63	24.9	3.05	6.82	
	2/10/2013	5.44	0.411	29.1	3.56	6.41	
	3/2/2013	2.16	0.392	38.1	4.66	6.03	
	3/10/2013	5.53	0.396	9.5	1.19	7.24	4.34
P-1 Averages		8.24	0.560	31	3.49	6.30	6.23
P-2	10/13/2012	11.65	0.689	18.7	2.02	6.11	5.86
	11/5/2012	11.67	0.321			5.40	
	11/10/2012	10.8	0.317	55.4	6.45	9.19	
	11/21/2012	10.91	0.315	16	1.72	6.58	
	12/3/2012	10.7	0.317	21.4	2.34	5.52	
	12/15/2012	10.51	0.317	37.2	4.07	7.22	
	1/12/2013	10.3	0.392	21.5	2.41	7.55	
	2/10/2013	9.86	0.256	21.4	2.41	5.86	
	3/2/2013	9.82	0.255	28.1	3.15	6.10	
	3/10/2013	9.84	0.261	24.5	2.74	6.38	3.2
P-2 Averages		10.61	0.34	27.13	3.03	6.59	4.53
P-3	10/13/2012	*(no water in boring)*					
	11/5/2012						
	11/10/2012						
	11/21/2012	10.59	1.375	44.3	4.96	6.23	
	12/3/2012	9.86	1.61	37.7	4.17	6.84	
	12/15/2012	8.69	1.509	58.2	6.66	7.18	
	1/12/2013	6.54	1.656	52.3	6.3	6.87	
	2/10/2013	6.21	1.084	45	5.51	6.03	
	3/2/2013	6.62	0.998	32.8	3.97	6.26	
	3/10/2013	6.52	1.124	30.3	3.68	6.63	3.62
P-3 Averages		7.86	1.34	42.94	5.04	6.58	3.62
P-4	10/13/2012	12.73	1.483	12.7	1.3	6.04	7.01
	11/5/2012	11.58	0.49			5.72	
	11/10/2012	10.4	0.279	33.2	3.51	7.8	
	11/21/2012	10.12	0.38	15.2	1.68	6.12	
	12/3/2012	9.44	0.337	45.35	5.02	5.81	
	12/15/2012	8.72	0.359	38.1	4.36	6.54	
	1/12/2013	7.22	0.437	28.7	33.5	6.71	
	2/10/2013	6.45	0.271	36.7	4.41	6.2	
	3/2/2013	6.56	0.264	24.2	2.96	6.03	
	3/10/2013	6.38	0.261	26.2	3.07	6.35	4.11
P-4 Averages		8.96	0.46	28.93	6.65	6.33	5.56

Is shallow groundwater in the pit a source of heavy metal contamination in the Hiller Tunnel discharge?

Findings

Total metals are at increased concentrations in the subsurface groundwater near the inlet to Hiller Tunnel, but more research is needed to determine the cause of and significance of these concentrations to surface water discharge from the pit.

What are the sources of mercury and suspended sediment in the pit?

Is the source of mercury in the discharge of Hiller Tunnel the mine tailings deposited in the south east end of the pit?

Findings

The largest loads of suspended sediment and particulate-bound mercury in the pit were areas with the highest discharge coming from the north rim of the pit (SS15 and SS12). Additional sources of mercury were in the eastern end of the pit (SS13 and SS5), in the southeastern portion of the pit (SS8, 9 and 10), in the mine tailings piles (SS4), and the Malakoff Village Site (MC 11 and 12). However, there are likley additional mercury sources in the pit.

Suspended sediment, particulate-bound mercury (PHg) concentrations, and loads were compared across 20 sites in the pit to determine potential source(s) of sediment and mercury during a large storm event (December 2, 2012). The sites were located near possible old mine tailings, at the east end of the pit, along the north rim of the pit, and near Hiller Tunnel (Figure 28 on page 71 and Table 7 on page 77).

The four sites at the south rim of the pit (SS1-SS4, see Figure 28 on page 71) were expected to capture drainage from possible historic mine tailings. These sites had high particulate-bound mercury concentrations (as much as 150 ng/L), but were not considered large sources because of the low discharge flowing from these sites, less than 0.08 cms (3 cfs).

The seven sites at the east end of the pit (SS5-SS11) included runoff from the springs, and the edge of the tailings piles captured by Sites 1-4 (SS1-SS4). Sites SS8, SS9 and SS10 all had relatively high concentrations of particulate-bound mercury and contribute to the load at the outlet. While Site 9 (SS9) had elevated concentrations of particulate-bound mercury (956 ng/L), the discharge was low (4 cfs), and this area may be a major source of suspended sediment and particulate-bound mercury to the Hiller Tunnel discharge.

The three sites that drained the north rim of the pit (SS12, SS13, and SS15) were selected as background sites. However, sites SS12 and SS15 were the largest contributors of particulate-bound mercury to the pit. The pond receives water from SS12 (PHg 92 ng/L, discharge 1.25 cms (44 cfs)) and SS15 (PHg 776 ng/L, discharge 0.34 cms (12 cfs)). One third of the particulate-bound mercury coming from the pond may have originated from SS15 (9,000 ng/s PHg) along with one fourth of the sediment (7,000 mg/s TSS). This is consistent with the groundwater results in the borings P1-P4, in which P3 had higher metal concentrations. This could be explained by the fact that historic mining practices sometimes included direct application of mercury to the cliff walls and ground sluices along the pit rim (Jackson, 1967).

The four sites near the Hiller Tunnel inlet (SS18-SS21) represented the cumulative discharge from the pit since Hiller Tunnel is the only visible drainage for surface runoff from the pit. The four sites in the vicinity of Hiller Tunnel were expected to have high suspended sediment and particulate-bound mercury. Site SS20 represented drainage from the west side of the pit, including overflow from the pond. Drainage from the pond contributed the greater part of the flow (SS20).

Table 7. PHg and Suspended Sediment Loads within the Malakoff Diggins Pit, December 3, 2012 Storm

Site			PHg (ng/L)	PHg Load (ng/s)	% PHg Load to the Outlet	TSS (mg/L)	TSS Load (mg/s)	% TSS Load to the Outlet	Discharge (cfs)	PHg in Suspended Sediment (ng/mg) (ppm)
South Side of the Pit		SS1	32.80	8.75	0.03%	111.0	29.6	0.04%	0.28	0.3
		SS2	150.41	249.08	0.96%	342.0	566.4	0.76%	1.66	0.4
		SS3	141.20	378.41	1.45%	374.0	1,002.3	1.34%	2.68	0.4
	Tailings	SS4	67.80	116.95	0.45%	34.5	59.5	0.08%	1.73	2.0
East End of the Pit	Springs	SS5	115.20	663.09	2.54%	5.4	31.1	0.04%	5.76	21.3
		SS6	21.24	126.80	0.49%	88.5	528.3	0.71%	5.97	0.2
		SS7	42.89	162.70	0.62%	243.0	921.8	1.24%	3.78	0.2
		SS8	46.16	1217.70	4.67%	198.0	5,223.2	7.01%	26.38	0.2
		SS9	956.70	1138.47	4.37%	2,960.0	3,522.4	4.73%	1.20	0.3
		SS10	889.40	3589.08	13.76%	1,400.0	5,649.6	7.58%	4.03	0.6
	Tailings	SS11	8.39	9.32	0.04%	8.1	9.0	0.01%	1.09	1.0
North Side of the Pit	East Rim into Pit	SS12	92.70	4112.50	15.77%	541.0	24,000.7	32.20%	44.36	0.2
	Tailings	SS13	33.20	51.38	0.20%	3.6	5.6	0.01%	1.55	9.2
	West Rim into Pond	SS15	776.30	9160.34	35.13%	593.0	6,997.4	9.39%	11.80	1.3
Near the Hiller Tunnel	Inlet	SS18	347.10	10343.58	39.67%	478.0	14,244.4	19.11%	29.81	0.7
	East	SS19	579.80	3620.85	13.89%	1,180.0	7,369.1	9.89%	6.25	0.5
	Pond Drainage	SS20	215.41	20270.08	77.73%	342.0	32,182.2	43.18%	94.11	0.6
	Outlet	SS21	276.80	26046.88	99.88%	792.0	74,527.2	100.00%	94.11	0.4

The pond was a major contributor of suspended sediment and particulate-bound mercury to the Hiller Tunnel during storm runoff, and the north rim of the pit was a major contributor to the pond. If the water stayed in the channel/preferential flow path along the North Rim it could be contributing to suspended sediment and particulate-bound mercury at SS20. Considering the discharge from the Hiller Tunnel to be the sum total of suspended sediment from the pit (74,000 mg/s), almost half (47%) of the suspended sediment came from the pond side of the pit (SS20, 32,000 mg/s). Likewise, considering the discharge from the Hiller Tunnel to be the sum total of particulate-bound mercury from the pit (26,000 ng/s), more than three quarters (77%) of that came from the pond side of the pit (SS20), 20,000 ng/s (Table 7 on page 77 and Figure 31 on page 78).

The major contributor to the suspended sediment in Hiller Tunnel was the flow from the pond which received water from SS15 and SS12, both of which entered the north rim with large amounts of water and therefore stream power to transport sediment. Furthermore, 74,000 mg/s of suspended sediment was measured in the sample from the Hiller Tunnel outlet (SS21), but only 14,000 mg/s was measured from the Tunnel inlet (SS18).

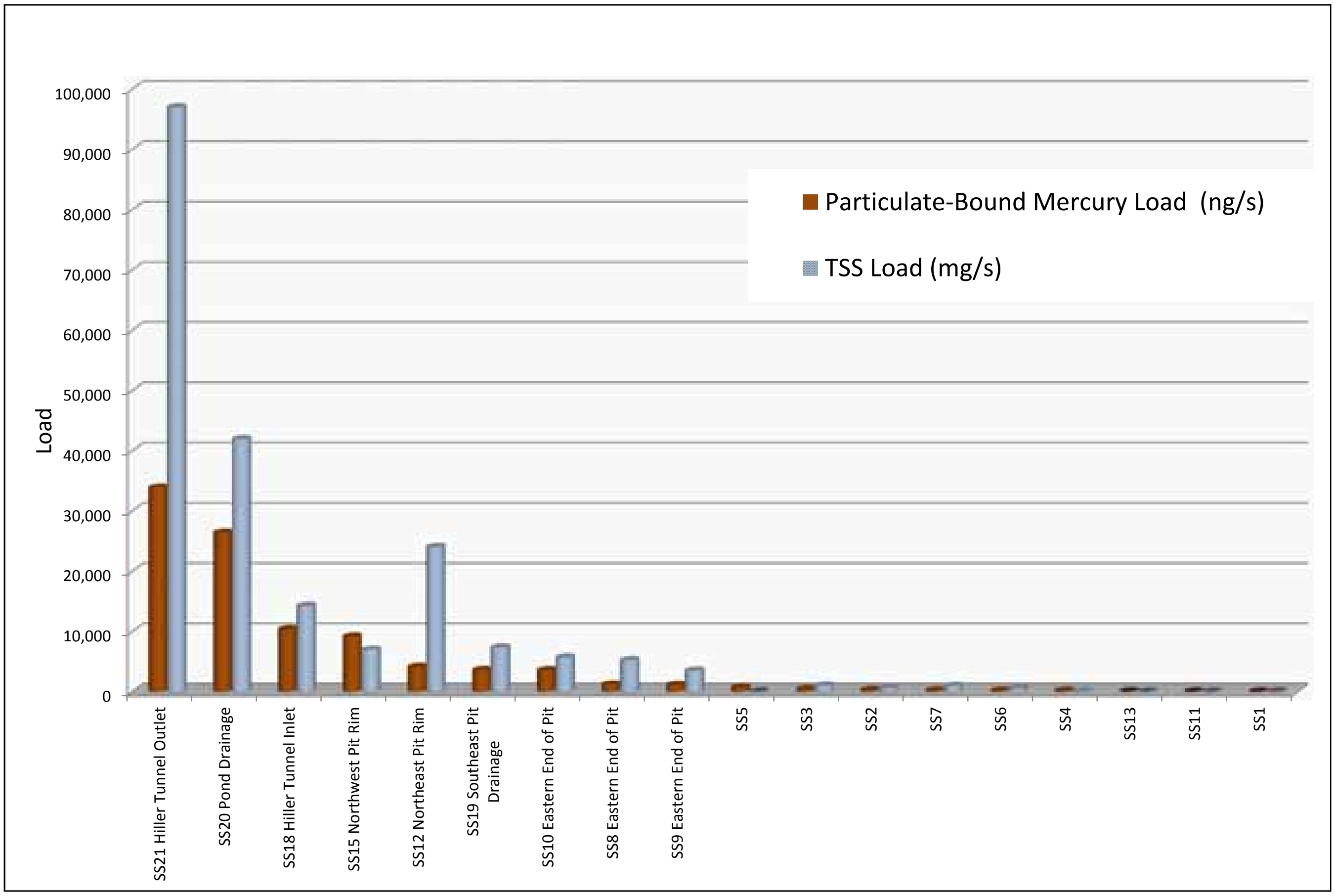


Figure 31. Particulate-Bound Mercury and TSS Loads in Malakoff Diggins Pit and Discharge
Water quality samples of surface water runoff at 20 locations throughout the pit over a three hour period were collected during a peak storm event on December 2, 2012. The discharge was measured at the time of sample collection and the particulate-bound mercury load and TSS load were calculated.

Similarly, 26,000 ng/s of particulate-bound mercury was in the discharge from Hiller Tunnel, but only 10,000 ng/s was in the inlet sample. This indicates that Hiller Tunnel may be a source of mercury. This is supported by the fact that samplers encountered people scrapping the tunnel bottom for gold-mercury amalgam on October 14, 2012 during low flow conditions, which means people have found mercury and gold in the cracks at the bottom of the tunnel (McElroy, 2012). In addition, the energetic transport of clasts through the tunnel could desegregate the clasts into their finer component particles, increasing the PHg concentration.

The concentration of particulate-bound mercury (ng/L) was divided by the concentration of suspended sediment (mg/L), to get a ng/mg (ppm) measurement of mercury in the suspended sediment, as was done when comparing mercury concentrations in water samples to PRGs. The sampling

Table 8. Soil Confirmation Sampling in the Malakoff Diggins Pit

Constituent		As (ppm)	Cu (ppm)	Hg (ppb)	Ni (ppm)	Pb (ppm)	Zn (ppm)	% Total Solids
CHHSL	*Residential*	*0.07*	*3,000*	*18,000*	*1,600*	*80*	*23,000*	
	Commercial	*0.24*	*38,000*	*180,000*	*16,000*	*320*	*100,000*	
SS Sample Location	*Confirmation Sample Location*							
	1			261				15.55
SS5	2	3.22	6.95	16.1	2.67	1.74	8.65	94.11
	3	7.57	29.7	107	43	11.3	51.1	73.44
	4			33.5				88.01
SS13	5			14.6				77.66
SS12	6			32.1				89.61
SS10	7			15.6				73.54
SS11	8			21.3				89.39
SS9	9			7.58				86.16
SS8	10	3.13	9.28	36.4	12.6	3.62	17.5	75.87
	11			**4,160**				94.27
	12			**6,330**				83.11
SS18	13			136				28.83
	14			25.8				75.71
SS15	15			25.2				94.36

Note:
Confirmation sample locations were selected to coincide with SS sample locations collected during storm events and from archeological features.

sites with the highest concentration of mercury in sediment were: SS5 (21.33 ppm) where the mineral springs were located in the east end of the pit; SS13 (9.22 ppm) near the north rim, perhaps where mercury was applied to ground sluices during the time of the bucket line dredge operations (Jackson, 1967); and SS4 (1.97 ppm) where there was perhaps processing of tailings after the Sawyer Decision (Figure 28 on page 71).

For more detail on the sediment and mercury transport in the pit see Harihar Nepal's thesis *Sediment and Mercury Loads and Sources at Humbug Creek from Malakoff Diggins*, Fall 2013.

Sediment samples were collected near sites that had elevated concentrations of mercury in suspended sediments, specifically SS5, SS8, SS9, SS10, SS11, *What are the sources of mercury and suspended sediment in the pit?*

Is the source of mercury in the discharge of Hiller Tunnel the mine tailings deposited in the south east end of the pit?

Findings

The largest loads of suspended sediment and particulate-bound mercury in the pit were areas with the highest discharge coming from the north rim of the pit (SS15 and SS12). Additional sources of mercury were in the eastern end of the pit (SS13 and SS5), in the southeastern portion of the pit (SS8, 9 and 10), in the mine tailings piles (SS4), and the Malakoff Village Site (MC 11 and 12). However, there are likley additional mercury sources in the pit.

SS12, SS13, SS15, and SS18. The confirmation sediment samples did not have elevated concentrations of mercury (Table 8 on page 79). There is still the possibility that there are mercury sources between the pit floor samples (SS15, SS12 and SS13) and the rim samples R2 and R5 (Figure 29 on page 73). This seems plausible considering that the pit walls were where the most recent hydraulic mining and mercury applications took place (Jackson, 1967).

Additional mercury sources may also exist. For example two soil samples taken from the old Malakoff Village Site along the south rim of the pit (Malakoff Confirmation soil samples 11 and 12) (Figure 29 on page 73, Table 8 on page 79), had 4,160 ng/g (4.16 ppm) and 6,330 ng/g (6.33 ppm) total mercury. This indicates that additional source areas for mercury need to be investigated and it is recommended that investigation be coordinated with the archeological findings on how and where mining operations that used mercury took place in the watershed. It is also recommend that additional samples be collected to identify locations that contribute to the particulate-bound mercury concentrations.

Figure 32. Malakoff Village Site
Confirmation samples collected from the Malakoff Village site found mercury at 4,160 ng/g (4.16 ppm) and 6,330 ng/g (6.33 ppm) in the soil at locations where mercury was stored (approximate location of the office) and where it was applied nearby. Future soil samples should be guided by an archeologist's understanding of historic mining operations. (Photo taken in 2013 by M. Selverston.)

Confirmation sampling in WY 2014 of streams that flow into the pit from the North Rim (R1-R8, Figure 28 on page 71) did not have elevated levels of suspended sediment, particulate-bound mercury, or other metals (Table 4 on page 68). Storm runoff at the pit rim sampled from the Rim Trail did not have significant concentrations of zinc, lead, nickel, copper, or chromium. All incoming pit rim runoff samples contained low mercury (<25ng/L), however, R2 had more total and dissolved mercury than any of the other rim sites, (THg 21.5ng/L, dissolved Hg 13.50ng/L) (Table 4 on page 68). This further suggests that water coming into the pit was not bringing contaminants in, but was picking up both particulate-bound mercury and TSS from the cliff as it approached the pit floor.

Is the water entering the pit free of mercury, copper, nickel, and zinc?

Findings

Confirmation sampling of eight streams that run into the pit from the north rim during storm events did not have elevated levels of total or dissolved mercury, copper, nickel or zinc.

Is the North Bloomfield Tunnel contributing to degraded water quality in Humbug Creek?

Is Shaft 5 contributing to degraded water quality in Humbug Creek?

Findings

The North Bloomfield Tunnel has elevated total metal concentrations of mercury, nickel and barium. The outlet of the tunnel and Shaft 5 are the only known discharge locations to Humbug Creek. The amount of discharge from these locations is low, less than 0.002 cms (0.08 cfs).

The elevated levels of mercury, arsenic, nickel, and zinc from Shaft 5 are most likely contributing to degraded water quality in Humbug Creek. However, the effective contribution to Humbug Creek is small because the discharge rate is low.

A conceptual model of the North Bloomfield Tunnel, its blockage(s), and discharge was created using the tunnel and shaft alignments depicted on historic maps, current water level elevations and the depth of standing water, discharge locations and water chemistry data as indicators of current conditions (Figure 34 on page 83).

The mouth of the NBT and access shafts were sampled for total metals, total mercury and dissolved mercury (except Shafts 2 and 4 which were only sampled for total mercury).

The metal concentration data were compared across all access shafts. All of the access shafts had total mercury concentrations less than 30 ng/L except Shaft 5 (the Red Shaft), which had a total mercury concentration of 2,270 ng/L and a dissolved mercury concentration of 0.51 ng/L. The sediment surrounding the Shaft 5 was sampled by USGS on January 13, 2009, and had a concentration of total mercury in the sediment of 2,520 ng/g (ppb) (Fleck et al., 2010) (Figure 37 on page 85).

Figure 33. Shaft 5 Discharge to Humbug Creek
Shaft 5 is the only access shaft that has discharge to Humbug Creek as surface flow.

Shaft 5 is the only airshaft that has water upwelling out of the shaft and into Humbug Creek as surface flow. The quantity of flow coming out of Shaft 5 was measured as 0.0008 cms (0.03 cfs). The discharge coming from Shaft 5 appeared to be relatively constant throughout the year, but no continuous monitoring was done to confirm this. Shaft 5 had the highest total arsenic concentration (5 μg/L) of the access shafts, which is half of the USEPA primary MCL for dissolved arsenic (10 μg/L). It had the highest total zinc at 150 μg/L, which is well below the CDPH MCL (5,000 μg/L) but above the CTR chronic aquatic life criteria of 120 μg/L. Shaft 5 had the highest total nickel (180 μg/L) which exceeds the CDPH primary MCL for dissolved nickel (100 μg/L) (Figure 36 on page 84).

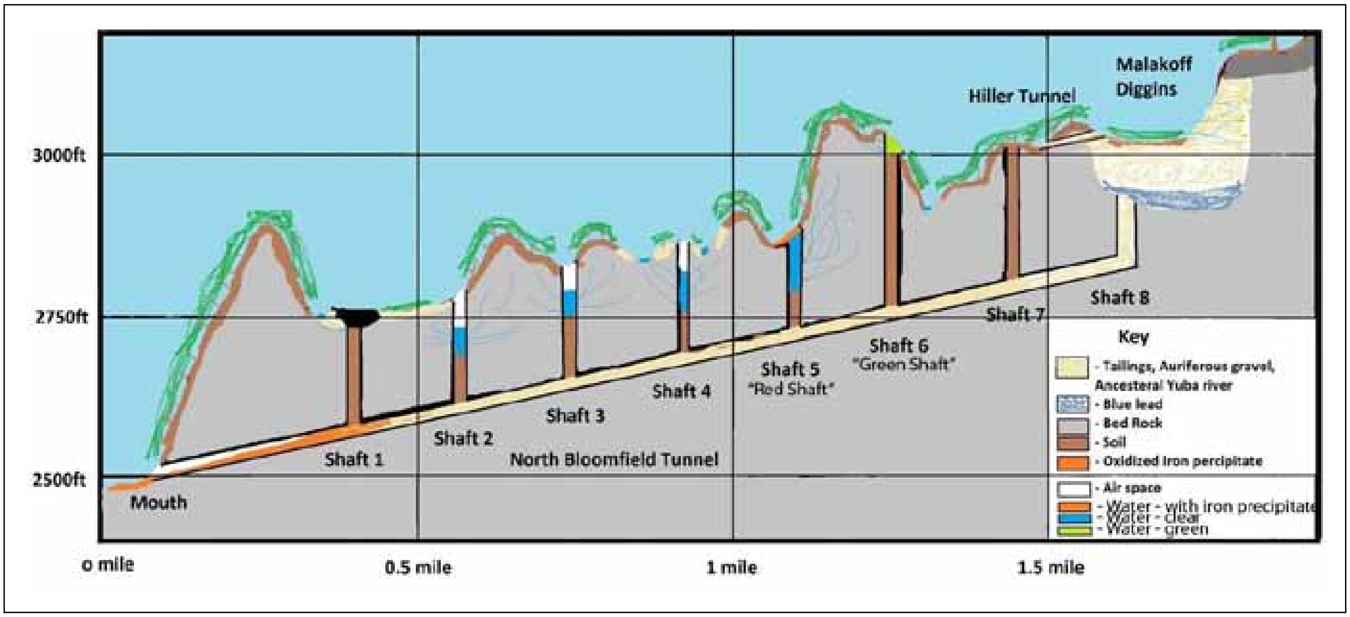
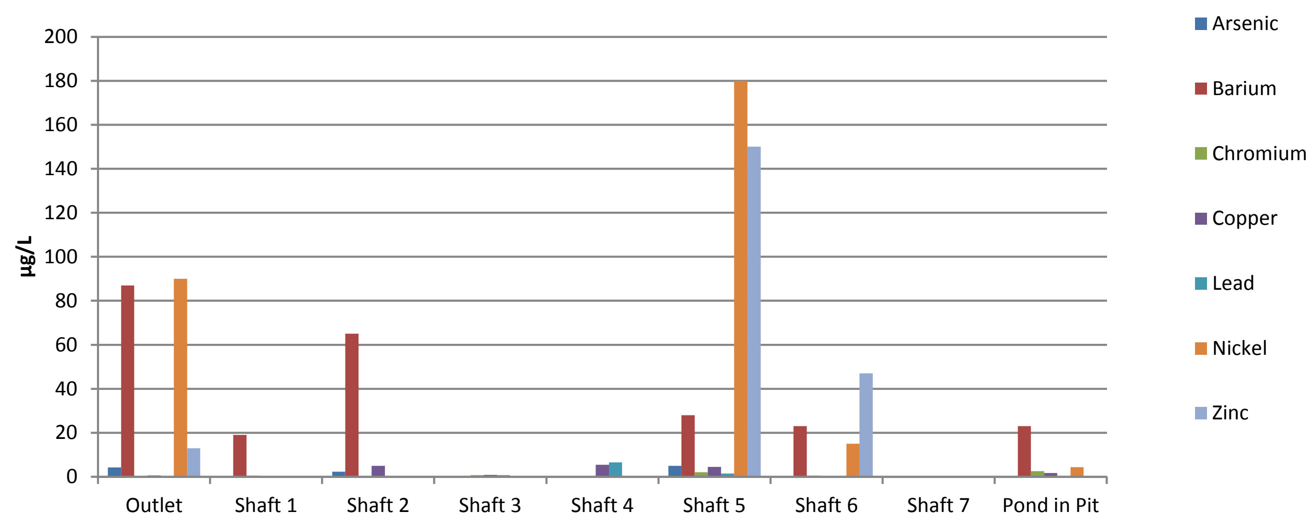


Figure 34. North Bloomfield Tunnel Conceptual Model
The conceptual model represents the condition of the North Bloomfield Tunnel and its various features based on current understanding.

Figure 35. North Bloomfield Tunnel Outlet
The North Bloomfield Tunnel is 7,847 feet long, and extends from the Malakoff Diggins pit to Humbug Creek. It currently has very low discharge to Humbug Creek. The outfall is approximately 8 ft high by 8 ft wide. It was used to convey material away from the pit and emptied into a series of undercurrents that captured material from the outfall and transported it to the South Yuba River. The North Bloomfield Tunnel is currently blocked in an unknown location. (Photo taken November 13, 2013 and March 12, 2012 by C. Monohan; T. Johnson depicted in photo.)



Constituent	Outlet	Shaft 1	Shaft 2	Shaft 3	Shaft 4	Shaft 5	Shaft 6	Shaft 7	Pond in Pit
Arsenic (μg/L)	4.2	ND	2.3	ND	ND	5	ND		ND
Barium (μg/L)	87	19	65	ND	ND	28	23		23
Chromium (μg/L)	ND	0.53	ND	0.75	ND	2.1	0.52		2.5
Copper (μg/L)	0.6	ND	5	0.81	5.4	4.5	ND		1.7
Hardness as $CaCO_3$ (mg/L)		45		35		160	160		5.8
Iron (mg/L)		2.4	0.21	0.46	2.8	40	18		2
Lead (μg/L)	ND	ND	ND	0.69	6.5	1.5	ND		ND
Nickel (μg/L)	90	ND	ND	ND	ND	180	15		4.3
Zinc (μg/L)	13	ND	ND	ND	ND	150	47		ND

Figure 36. Total Metals in North Bloomfield Tunnel Features
The access shafts, outlet and pond in the pit were sampled for hardness and total metals including As, Ba, Cr, Cu, Pb, Ni, Zi, and Fe. The results are displayed as a bar chart except for Fe and Hardness, which are included in the table only.

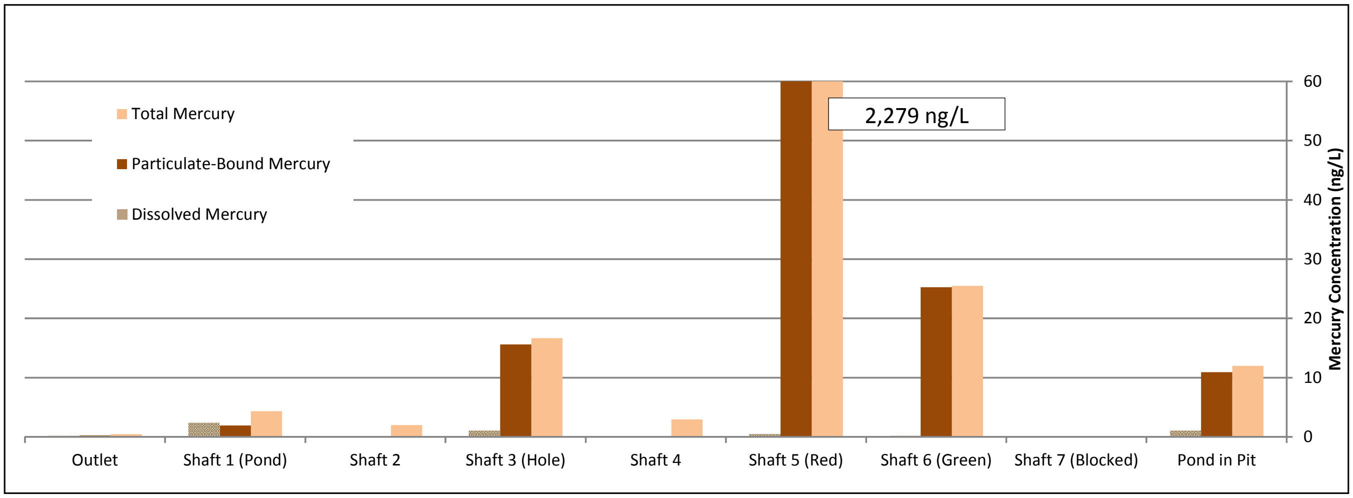


Figure 37. Mercury in North Bloomfield Tunnel Features
Standing water in Shaft 5 had a total mercury concentration of 2,270 ng/L. Discharge from the NBT outlet had a total mercury concentration of 0.49 ng/L. The outlet and Shaft 5 both had discharge to Humbug Creek, while the other access shafts did not appear to have discharge. The primary form of mercury at all features was particulate-bound, the exception being Shaft 1.

The outlet of the North Bloomfield Tunnel has a small continuous discharge measured to be 0.002 cms (0.08 cfs) that does not appear to change throughout the year, but no continuous monitoring was done to confirm this. The sample collected from the outlet of the North Bloomfield Tunnel had elevated levels of total barium (87 µg/L) and total nickel (90 µg/L). The total nickel concentration was below the CDPH MCL, but it is possible that the CTR chronic aquatic life criterion (CCC) of 52 µg/L for dissolved nickel may be exceeded.

Do the mercury concentrations in macroinvertebrates indicate that mercury is being methylated and incorporated into the aquatic food chain in Humbug Creek?

Do the macroinvertebrates in reaches of Humbug Creek downstream of Diggins Creek and/or Shaft 5 indicate that mercury is being methylated and incorporated into the aquatic food chain in Humbug Creek?

Findings

Mercury is being methylated and incorporated into the aquatic food chain in Humbug Creek Watershed. Reaches below Diggins Creek (Reach 2) and the Red Shaft (Reach 3) did not have greater concentrations of methymercury in water striders (*Gerridae)* than Reach 1.

In order to learn about the extent of the impact of mercury from Diggins Creek and from Shaft 5 to the Humbug Creek ecosystem, macroinvertebrate methylmercury studies were conducted.

To determine if mercury in Humbug Creek was being incorporated into the aquatic food chain, water striders (*Gerridae*) were collected from three different reaches in Humbug Creek (Figure 38 on page 87). The hypothesis was that striders from the background reach (Road 1/Reach 1) would have lower mercury concentrations than those from the reach downstream of the confluence with Diggins Creek (Gage 3/Reach 2) and/or the reach downstream of the Shaft 5 discharge (Reach 3).

The highest concentration of MeHg in water striders was found in Reach 1. The sample from this reach had the fewest number of individuals (n=5). The concentration of MeHg was 219 ng/g (wet weight) whereas the concentration of the samples in Reaches 2 and 3 were 158 and 154 ng/g (wet weight) respectively. Multiplying the concentration of MeHg wet weight to the total wet weight per sample, the body burden of the individual at each site was calculated. The body burden at Reach 1 was 13 ng/individual and at Reaches 2 and 3 it was 9.2 and 8.8 ng/individual, respectively (Table 9 on page 87).

These results confirmed that mercury is methylated in the Humbug Creek watershed, which means that mercury is contaminating the aquatic food chain. These results also indicated that *Gerridae* in the upper reaches of Humbug Creek had a greater body burden of MeHg than those in the lower reaches. One explanation for this unexpected result is that the lower reaches of Humbug Creek may have more individuals and therefore greater biodilution. In addition, the greater concentration of dissolved mercury in the upper reaches of Humbug Creek at Road 1 may indicate a greater methylation potential, whereas the primary form of mercury below Diggins Creek is in the particulate-bound form. It is recommended that the source of the dissolved mercury upstream of Road 1 sampling site be investigated.

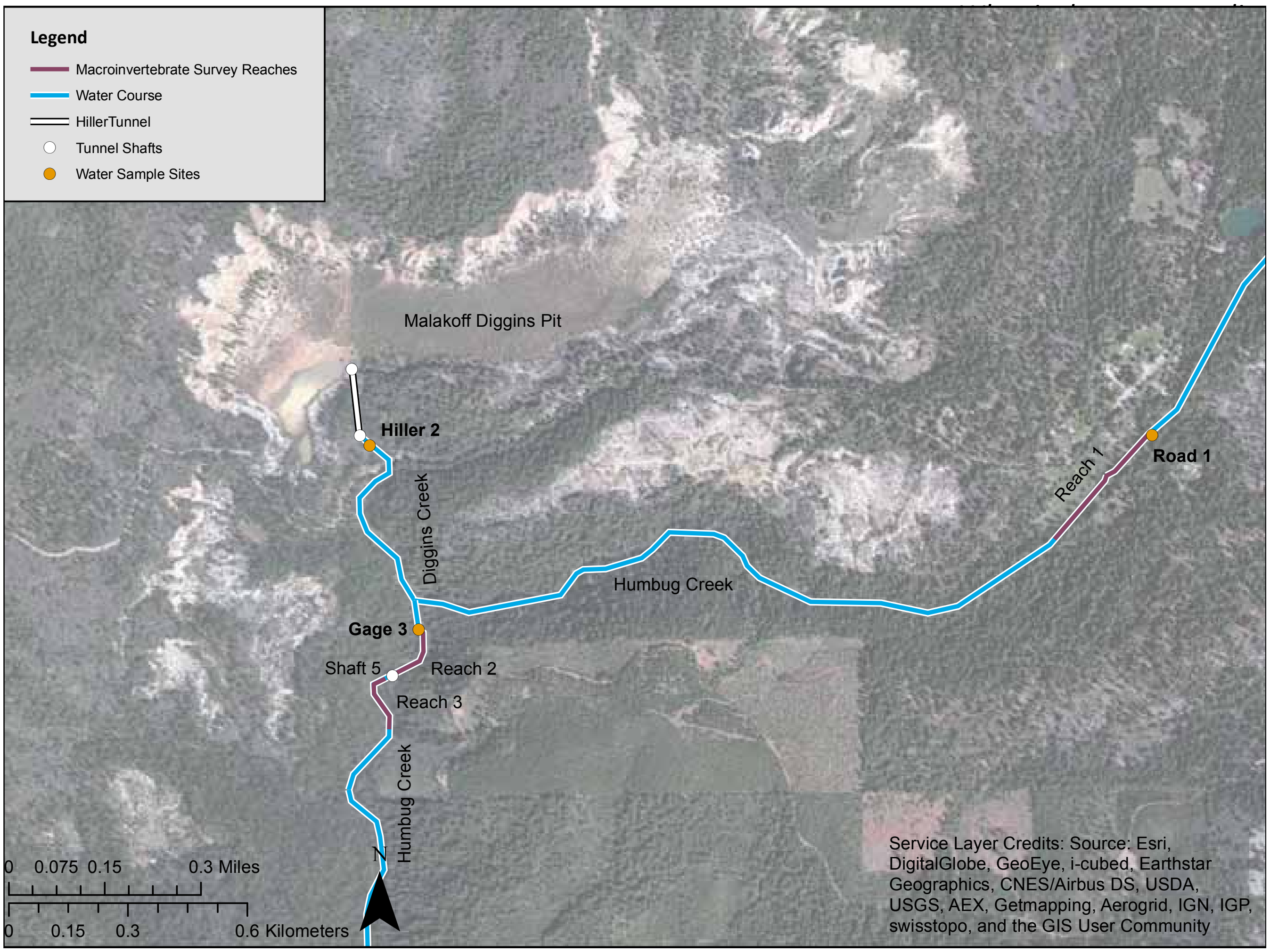


Figure 38. Humbug Creek Macroinvertebrate Survey Reaches
Water striders (*Gerridae*) were collected from three different reaches in Humbug Creek.

Table 9. Mercury in *Gerridae* (Water Striders) in Humbug Creek

Sample Location		Wet MeHg (ng/g)	Number of Individuals (n)	Total Weight (g)	Wet Weight (per n)	Total Dry Weight (g)	Dry Seight (g/n)	Wet-Dry Seight (per n)	Body Burden (ng MeHg/n)
Reach 1	Road 1	219	5	0.290	0.058	0.103	0.021	0.037	12.7
Reach 2	Gage 3	158	20	1.170	0.058	0.405	0.020	0.038	9.2
Reach 3	Shaft 5	154	21	1.201	0.057	0.420	0.020	0.037	8.8

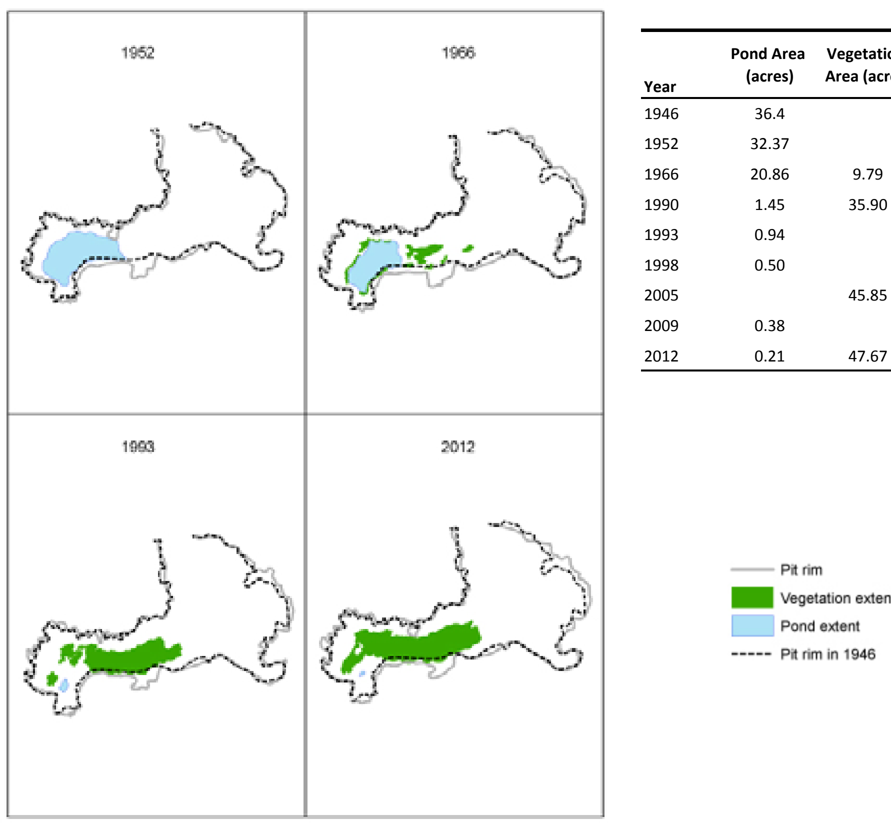
How are the pit rim, pond and vegetation changing over time?

FINDINGS

The pit is growing in size as the pit walls continue to erode. The pond is shrinking in size and the vegetation patch on the floor of the pit is growing in size.

In order to quantify the changing size of the pit and the average annual sediment load, historical aerial photos from 1952 were compared to contemporary 2012 images using ArcGIS, with fixed geologic and anthropological features as georeference points (Kirchner, 2002). The pit rim edge was traced using a 1952 aerial image and was compared to the pit rim edge traced from a 2012 aerial image. Subtraction of pit area in 1952 from that of 2012 revealed the total amount of area lost to erosion between photos. The difference between these two images indicated that the pit had grown in size by almost 100,000 m^2 (25 acres) by pit rim erosion processes (Figure 41 on page 89).

Similarly, the area of the pond and the area of the vegetation (willow patch) in the pit were compared between 1952 and 2012. The pond has become smaller and the vegetation patch has grown larger (Figure 39 on page 88). The pond was 130,000 m^2 (32 ac) in 1952, shrunk to 4,000 m^2 (1 ac) by 1990, and was 800 m^2 (0.2 ac) in 2012. The vegetation patch was 40,000 m^2 (10 ac) in area in 1966, grew to 140,000 m^2 (35 ac) by 1990, and was 192,226 m^2 (47 ac) in 2012.



Year	Pond Area (acres)	Vegetation Area (acres)
1946	36.4	
1952	32.37	
1966	20.86	9.79
1990	1.45	35.90
1993	0.94	
1998	0.50	
2005		45.85
2009	0.38	
2012	0.21	47.67

Figure 39. Pond and Vegetation Changes in Malakoff Diggins Pit
Aerial images from 1946, 1966, 1993 and 2012 were georeferenced into GIS and the topographical signature of the pond and the vegetation patch were compared over time.

Figure 40. Malakoff Diggins Pond
The pond in the Malakoff Diggins pit is in the far west end of the pit. It drains to Hiller Tunnel. The pond is clear in the summer and turbid during the rainy season. (Photo taken on November 9, 2011 (dry) and April 6, 2012 (wet) by C. Monohan.)

The visual changes of the pit rim over time and of the pond and vegetation patch are striking, but quantification of these changes is limited by the two dimensional images available for use. In order to make volume estimates, particularly useful for calculating erosion rates, a three dimensional image of the pit is needed either by conducting airborne LiDAR for the site or creating a 0.6 m (2 ft) contour topographical map from a traditional flyover.

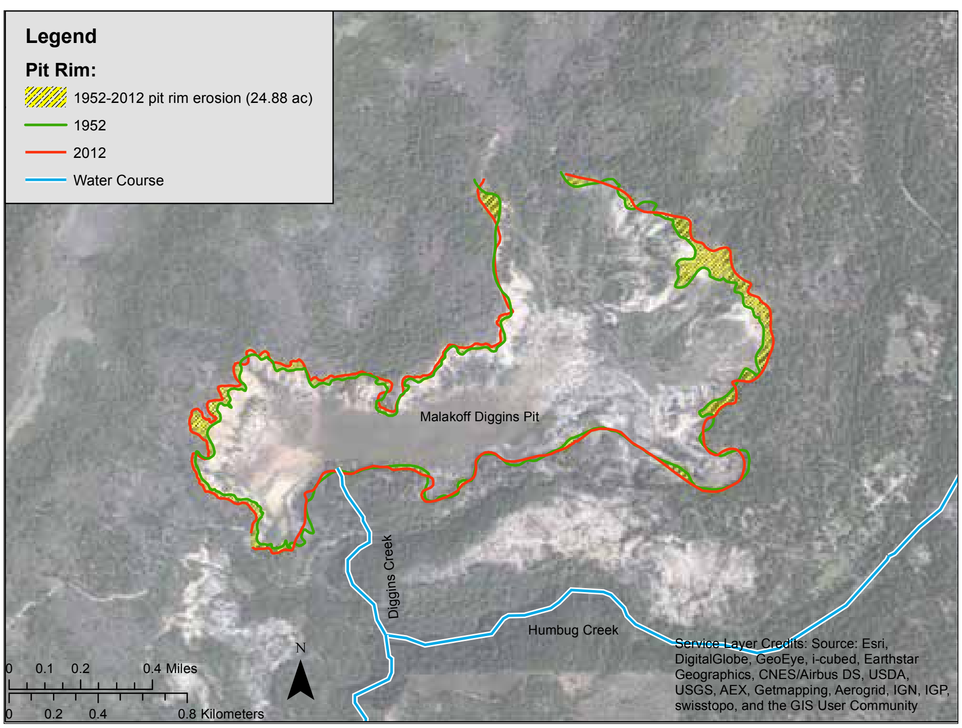


Figure 41. Malakoff Diggins Pit Rim Erosion
Aerial images from 1952 and 2012 were georeferenced and compared in GIS to determine the change in pit rim surface area over time. A volume estimate was made from the surface area difference.

What is the depth to bedrock in the pit?

Findings

Current understanding of the depth to bedrock is based on seismic surveys conducted in 1979 when there was an estimated 30.5 m (100 ft) of sediment in the pit. Presumably the pit is filling in and the depth to bedrock has increased. A new depth to bedrock estimate was not measured using seismic methods, but the depth to shallow ground water (saturated zone) was 3.7 m (12 ft).

To determine the depth to bedrock in the pit, the locations where seismic surveys were conducted in 1979 were relocated and the surveys were replicated (Figure 43 on page 91). The average depth to bedrock in the pit was estimated to be 30.5 m (100 ft) by Peterson in 1979. Peterson concluded that the bedrock of the pit was overlain by 30.5 m (100 ft) of unconsolidated sediment, the upper 10 m (33 ft) of which were deposited since 1917.

To replicate these surveys, a Bison Series 5000 Digital Instantaneous Floating Point Signal Stacking Seismograph was used. Unfortunately, due to poor acoustic connectivity in the sediments, presumably caused by the number of willow trees and their massive root systems, the seismic surveys were noisy and did not reach bedrock. The surveys did however locate what is likely the subsurface water table at Transect 1 in the most northeast corner of the pit where willow establishment is still sparse (Figure 43 on page 91). The water table was defined by two contacts between strata having velocity contrasts, commonly referred to as refraction.

The seismic survey was conducted at the same location on two different dates with two different geophone spacings. In one case, using a 0.9 m (3 ft) spacing for the geophones, the contact depth was 4.11 m (13.5 ft) deep. (The upper unit had a velocity of 339 m/s, consistent with unsaturated sand, and the lower unit had a velocity of 1,565 m/s, consistent with saturated sand.) In the second case, using a 9.1 m (30 ft) spacing for the geophones, the contact depth was at 3.7 m (12 ft). (The upper unit had a velocity of 479 m/s, consistent with unsaturated sand, and the lower unit had a velocity of 1,135 m/s, consistent with saturated sand.) It is clear that neither of these surveys reached the depth to bedrock. However, the saturated zone in the pit during the dry season is a useful tool to understand the hydrologic function of the pit.

Figure 42. Seismic Surveys in the Pit
Seismic surveys were conducted at the same locations in the east end of the pit where Peterson conducted seismic surveys in 1979. The vegetation made it difficult to register a contact with bedrock, and some transects were not accessible because of dense vegetation growth on the pit floor. (Photo taken on September 22, 2012 by C. Monohan; D. Demaree and C. Liggett are depicted.)

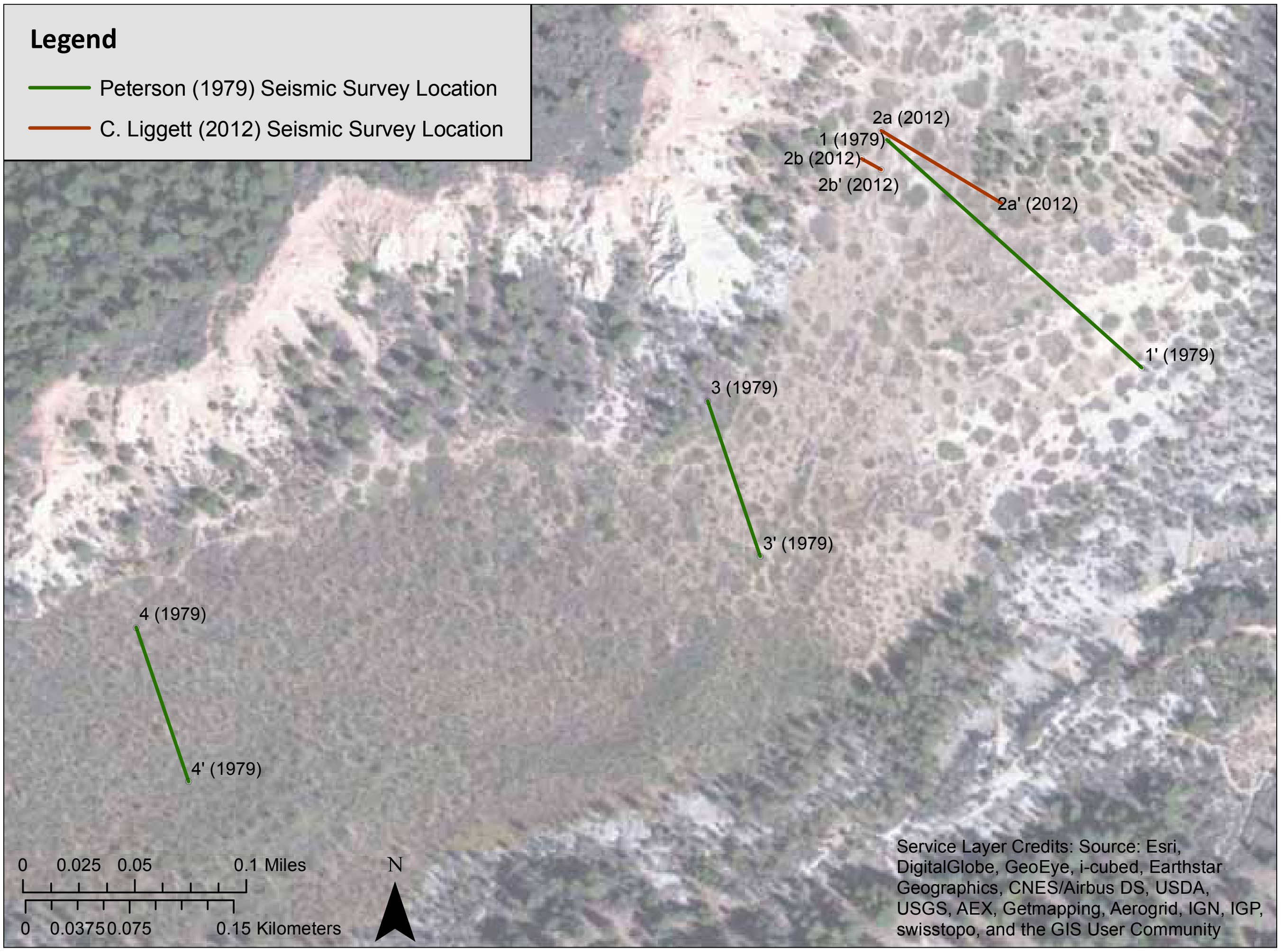


Figure 43. Malakoff Diggins Pit Seismic Survey Locations
Surveys completed by Peterson in 1979 were recreated in 2012 by C. Liggett. Seismic surveys in 1979 detected the distance to bedrock to be 100 feet and seismic surveys in 2012 detected the distance to the shallow ground water table to be 12 feet. Dense vegetation prohibited the replication of the seismic survey for Peterson's transects 3 and 4.

Is the pit filling in? Is it filling in more rapidly than it was in 1979?

Findings

The Malakoff Diggins pit is continuing to fill in at a current rate of 0.04 m/yr (0.13 ft/yr), which is less than the rate estimated for the 1883 to 1979 period of record. The total deposition volume estimated for the entire area of the pit is 12,000 m^3/yr (420,000 ft^3 /yr). Assuming this estimate is valid, the pit is filling in more slowly than it was prior to 1979, likely due to the pit walls becoming less vertical.

Trail markers and stakes installed throughout the pit floor by DPR in the spring of 2005 were used to measure deposition (Figure 45 on page 93). The annual deposition rate was determined by comparing sequential measurements made from the top of the stakes to the ground surface (Schumm, 1964). Measurements were made at the time of installation in April 2005, and again by DPR in December 2005, December 2006, and January 2008, and were repeated as a part of this study in April 2013, and September 2013.

Figure 44. Deposition in the Pit
Trail markers installed by DPR were used as deposition stakes markers throughout the pit. The old trail markers were measured in 2005 when new trail markers were installed. (Photo taken October 29th, 2013 by J. Howle; C. Alpers depicted for scale.)

Deposition stakes in the alluvial deposits of the pit floor measured an aggradation of 47.5 mm (1.87 in) per year (± 4.5 mm), when all measurements were averaged over the 8 years of record. The mine pit floor depositional area is made up of different source areas and associated depositional plains/colluvial deposits. The pit floor was divided into four sections containing deposition associated with these separate sources, each having a different deposition rate. The area of each depositional zone was measured using the GIS ArcMap 10 area measure tool on the aerial maps. The volume for each depositional zone was then found by multiplying average elevation change of the stakes and posts contained in each zone by its area. The pit floor and the measurements were averaged by individual areas for a volume calculation (Figure 46 on page 94). The findings of the four process based areas are as follows:

East

There are four stake transects placed by DPR in the alluvial plain where streams draining gully networks converge and braid together in an alluvial plain with a 10 degree slope. The average deposition over the 8-year period in the east side of the pit floor zone was measured at 53 mm/yr, ±6 mm. This area was measured using the ArcMap 10 area measure tool. The area

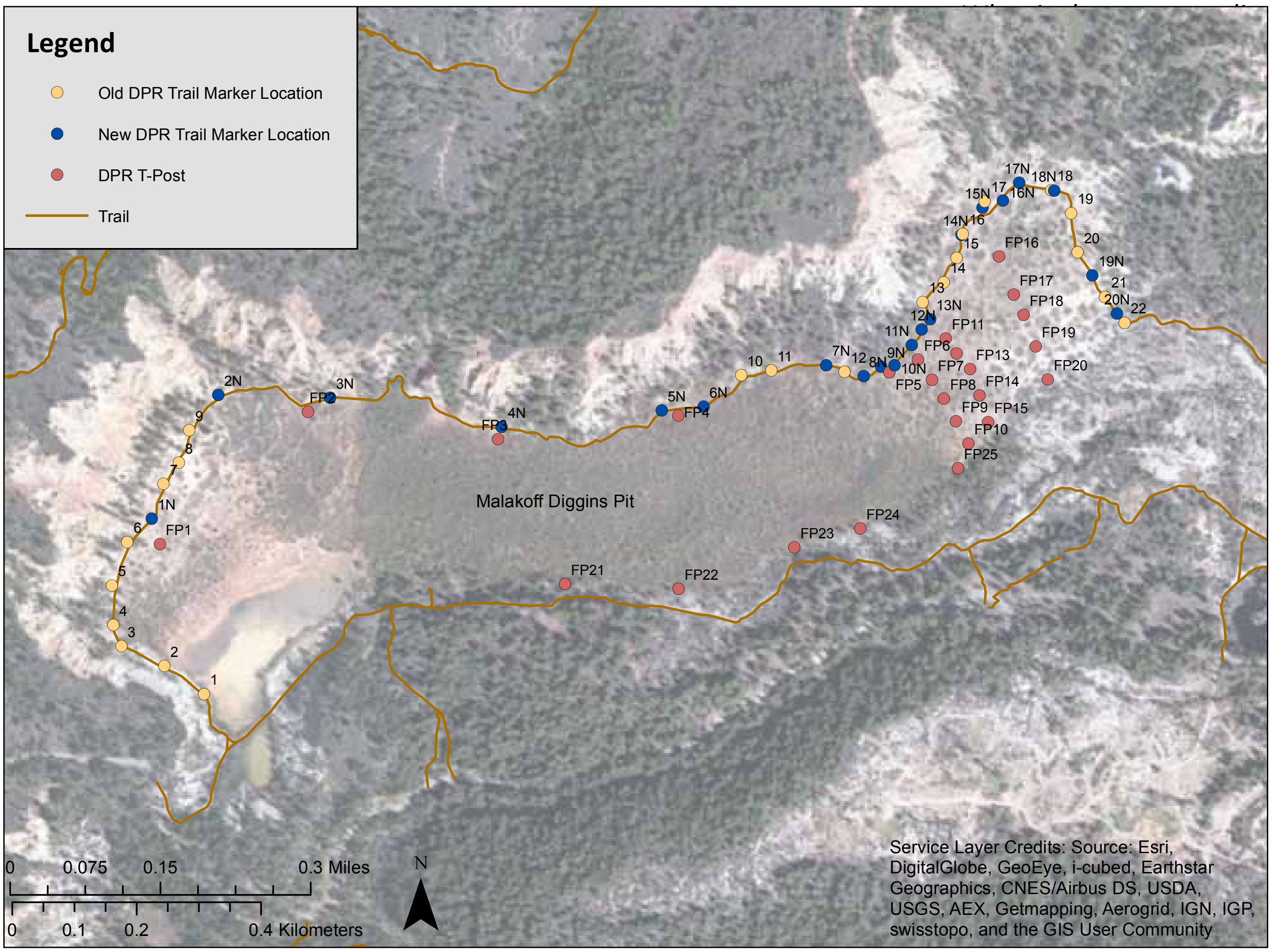


Figure 45. Sediment Deposition Monitoring Sites in the Malakoff Diggins Pit
Monitoring ground stakes included old and new trail markers and T-Posts installed by DPR. At these location, the distance from the top of the deposition stake to the ground surface was measured in April 2005, December 2005, January 2008, April 2013 and September 2013.

was found to be 83,290 m^2. Annual volume of deposition over the eight year period in this area was then calculated as 4,401 ±28 m^3/yr.

North

The northern cliff wall of the pit erodes down onto the plain of the floor while the streams both erode and deposit material along the toe of the slope at a right angle to the cliff face and its deposition. The area of the north deposition zone was measured as 79,560 m^2. Using measurements of trail markers over the eight year monitoring period, the average deposition in this zone was found to be 54 mm/yr ±10 mm. Multiplication of the measured values yielded a volume of material deposited in the area of 4,295 ±807 m^3/yr.

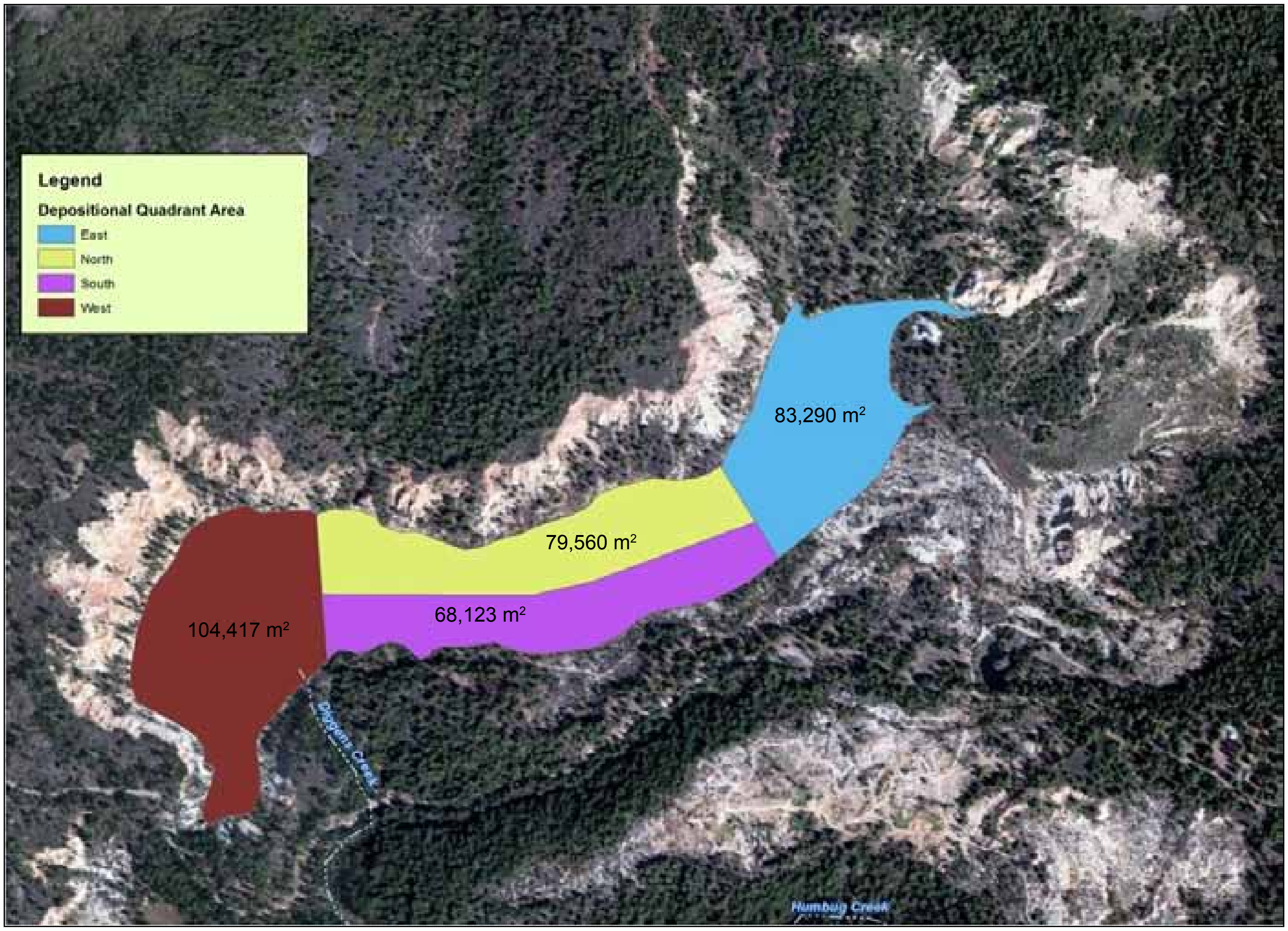


Figure 46. Depositional Area and Volume of the Malakoff Diggins Pit Floor
The pit floor was divided into separate polygons in GIS and the depositional stakes that were in each quadrant were used to measure deposition volume over time.

Table 10. Deposition Volume Caluclations

Quadrant	Area (m^2)	Total Deposition over 8 yrs (mm/yr)	Average Deposition Rate (mm/yr)	Average Annual Volume (m^3/yr)
East	83,290	422.80	52.85	4,402
North	79,560	431.90	53.99	4,295
West	104,417	210.00	26.47	2,764
South	68,123	146.30	18.29	1,246
Total Deposition (m^3/yr)				**12,707**

West

The westernmost cliffs of the pit deposit directly into the remaining small pond. As the depositional plain builds below the cliffs, the area of the pond is encroached upon with alluvium. Using ArcGIS, the area of this depositional zone was measured at 104,417 m^2. Using trail markers on the alluvial slope, the average annual deposition was measured at 26 mm/yr ±7 mm. The average annual volume of deposition in the west zone was calculated as 2,763 ±20 m^3/yr.

South

The southern depositional zone is the flat plain adjacent to tailings rock piles and vegetated native soil hillsides along the south rim of the pit. It is downslope from the east depositional zone. Hill slopes here contribute smaller amounts of sediment due the fact that they are not as tall and are more protected by vegetation, and contain a higher fraction of coarse material as waste rock evidenced by hummocks and rock piles. As a result, only a few areas of cliff face exist along the south side of the pit. Most of the material deposited in the south quadrant of the pit floor likely originated from the east, as the main channel runs along, and actively deposits in the vegetation at the south side of the pit floor. The area of this zone was measured using ArcMap as 68,123 m^2. The annual deposition rate in the southern quadrant was found to be 18 mm/yr ±5 mm. The average annual volume of deposition in the quadrant was calculated as 1,246 ±34 m^3/yr.

The volumes of all four depositional zones were added together to find the total volume deposited in the pit floor (Table 10 on page 94). The total estimated volume of sediment deposited on the pit floor per year was 12,707 m^3/yr.

Using this rate to estimate annual deposition in the pit from 1979 to 2013, the depth to bedrock has increased by at least 1.5 m (5.0 ft) over 34 years, making the total depth to bedrock at least 31.5 m (105 ft) when added to Peterson's estimate of 30 m (100 ft) made in 1979. This estimate assumes that the average measurement made over eight years adequately represents the entire pit.

Presumably the pit was at its deepest point when hydraulic mining ceased in 1883 and it filled in to 30 m (100 ft) deep by 1979. The upper 10 m of this sediment was deposited after 1917 at an average rate of 47,550 m^3 per year (Peterson, 1979). The rate of deposition was higher in the past. These are rough estimates and they are extrapolated over the entire pit, however, they are within the range of estimates made by others of the volume of sediment deposited in the pit which range from 5,000 to 48,000 m^3/yr (6,500 to 62,000 yd^3/yr) (Peterson, 1979).

For more information on the deposition stakes, their analysis and pit deposition rates see the thesis by Keith Landrum *Quantifying Surficial Processes in Malakoff Diggins, A Historic Hydraulic Mine* (2014).

Is the pit filling in? Is it filling in more rapidly than it was in 1979?

Findings

The Malakoff Diggins pit is continuing to fill in at a current rate of 0.04 m/yr (0.13 ft/yr), which is less than the rate estimated for the 1883 to 1979 period of record. The total deposition volume estimated for the entire area of the pit is 12,000 m^3/yr (420,000 ft^3 /yr). Assuming this estimate is valid, the pit is filling in more slowly than it was prior to 1979, likely due to the pit walls becoming less vertical.

Are large particle sizes (gravels-sand) being retained closer to the source of erosion (assumed to be gullies in the east end of the pit) than during the 1979 Peterson study?

Findings

The particle size distribution of the pit floor indicates that the larger grain sizes (gravel-sand) are being retained in the pit closer to the source area of erosion in the east, and that fine silts and clays are being transported through the pit and discharged at Hiller Tunnel.

Sediment samples (Figure 47 on page 97) were collected to determine the particle-size distribution along the length of the pit. In order to evaluate how the particle-size distribution of the pit may have changed over time, results of this analysis were compared to similar analyses performed in 1979 by Peterson.

Sediment at the pit floor was coarser at the east end, and finer toward the west (Table 11 on page 97). Sediments deposited near the inlet to Hiller Tunnel have become finer over time, having a finer median D_{50} at the surface (0-24 cm) than at depth (131-132 cm). This change in particle size distribution has likely occurred as a result of the increased roughness on the pit floor, caused in part by the increased density and size of the vegetation patch.

As the size and density of the vegetation patch increases, sediment carried to and deposited at the inlet to Hiller Tunnel will be even finer. This will result from progressively finer sediment being retained within the vegetation. It must be emphasized that the vegetation patch is only a partial mitigation to suspended sediment in Hiller Tunnel; vegetation alone is not sufficient to inhibit the transport of fine silts and clays.

For more detail on the sediment deposition patterns in the pit and effect of the vegetation on discharge see Cameron Liggett's thesis *Particle-Size Distribution Analysis and Sediment Deposition on the Pit Floor at Malakoff Diggins State Historic Park*, Spring 2014.

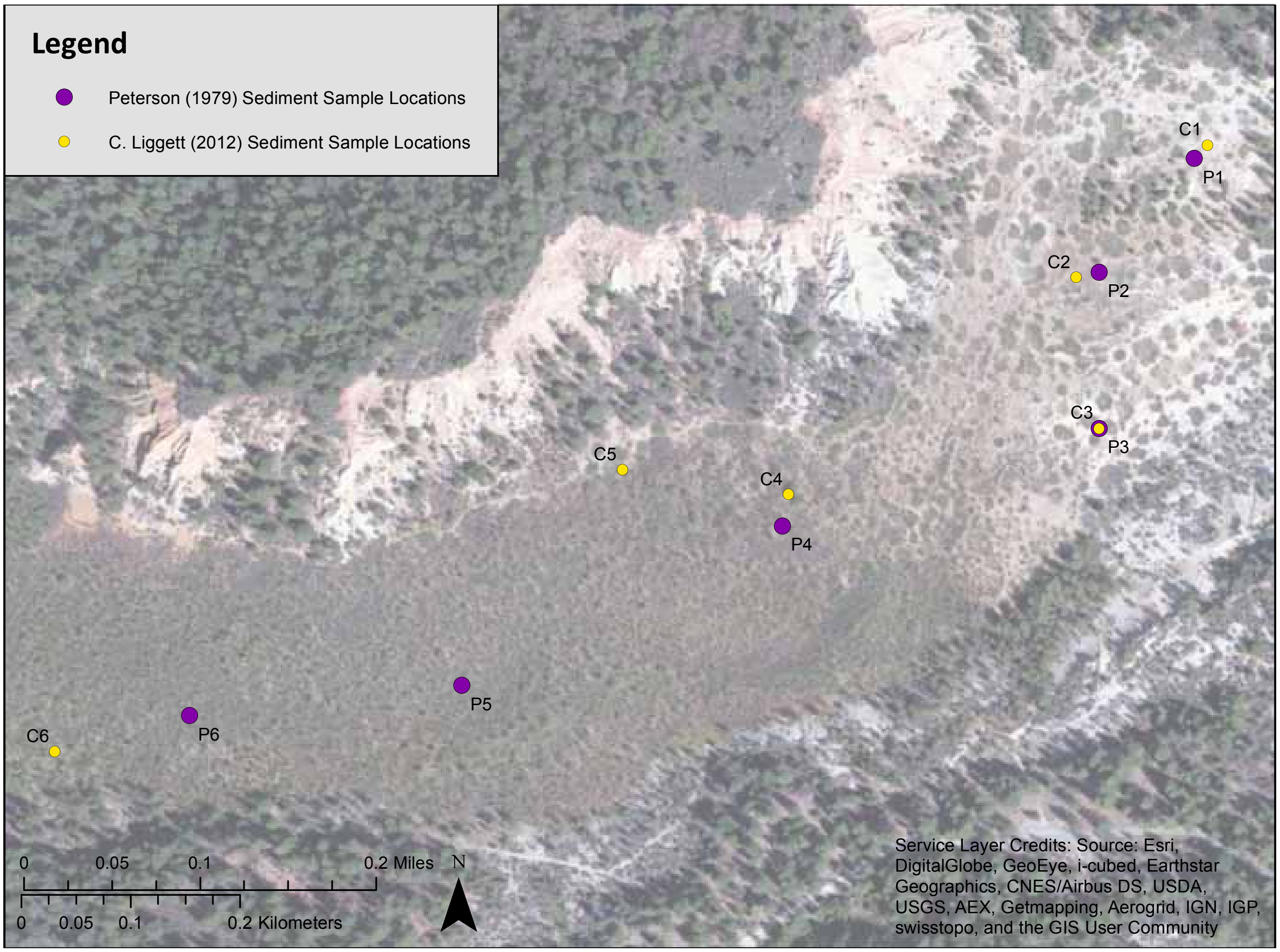


Figure 47. Malakoff Diggins Pit Particle Size Distribution Sample Locations
Surface samples were collected in 1979 by Peterson and in 2012 by C. Liggett and were analyzed for grain-size distribution. D50 decreased from the east (source area) to the Hiller Tunnel outlet. This indicates that finer particles are being transported farther from the source in the east end of the pit even as the pit floor vegetation has established.

Table 11. Particle-Size Distribution in the Malakoff Diggins Pit

Sample Location	D_{50} Values (µm)	
	Liggett (2012)	Peterson (1979)
1	890,6800,800	610
2	130, 440, 130	840
3	300, 160, 190	570
4	80, 30, 69	620
5	66, 32, 26	350
6	19, 17, 12	

What are the erosional processes in the Malakoff Diggins pit?

Findings

The erosional processes in the Malakoff Diggins pit include landslides, rilling, ice wedging, dry ravel, rainsplash, surface wash and overland flow.

There are a number of erosional processes taking place within the pit which overlap both spatially and temporally. Each processes of erosion, including location, extent of conditions, and how it takes place within the pit will be described separately for clarity.

Landslides as a major contributor of sediment of all sizes

Along the northeast side of the pit, landslides of various sizes and age have greatly contributed to erosion (Peterson, 1979). Recurring landslides dominate the morphology in the east end of the pit. Older landslides are evidenced by large downslope deposits which are now stable, vegetated by various stages of vegetative succession, and are bisected by deep gullies. The complex landslides appear to be related to clay interbeds at 990 m (3,250 ft) and associated localized visible seeps (DWR, 1987). The headscarps of the landslides continue to migrate upslope, with their arcutous concave shape concentrating flows, and delivering large amounts of sediment into gullies below. Gullies continue to mobilize and transport material from the clay-rich landslide deposits, and are a major source of fines within the pit (NCRCD, 1979b). Landslide deposits in the east of the pit are dissected by deep gullies. The walls of these gullies have multiple small failures which fall into the main channel and are washed downstream. Large volumes of disturbed material in an area with high amounts of overland flow create accelerated rates of erosion (Selby, 1993). At the mouth of these gullies, on the edge of the pit floor, are significant deposits of cobble and gravel fining downstream. Numerous clayballs of cobble size are visible here. Peterson performed a point count of clasts in this area and found that "35 to 45 percent of the cobble sized material was composed of clay transported as clayball fragments" (Peterson, 1979).

Figure 48. Landslides along the Malakoff Diggins Pit Rim
Landslides reoccur periodically along the eastern cliff rim. Inset photo: Comparing a photo of a recent landslide to the existing landscape near the Chutte Hill Campground overlook. (Photo taken on November 15, 2011 by C. Monohan)

Figure 49. Riling of Cliff Walls at Malakoff Diggins
Inter-rill erosion occurs on cliff walls. Rills mobilize sediment and cut into the hillside, forming gullies. A network of rills and gullies accept and transport material from steep slopes toward the pond and Hiller Tunnel. (Photos taken on April 16, 2012 and March 15, 2011 by D. Brown.)

Ice wedging/frost heave, and dry ravel

Occurring throughout the pit, frost heaving and subsequent dry ravel have been widely observed during winter months within the walls of the pit (Landrum, 2014). The growth of frost columns or needle ice lifts the upper surface material by as much as 3 cm. As the ice melts, the lifted layer appears "fluffed up" on the surface, allowing gravity to move the loose material downhill as dry ravel (Peterson, 1979). The loose material fills gullies and deposits scree cones at the base of hillsides, where it can be easily re-mobilized during rain events (Selby, 1993). Peterson noted that this erosional process did not contribute substantial volumes of material to overland flow within the pit (Peterson, 1979). However, observations in 2012/2013 show that material lost due to frost wedging was temporarily stored mid-slope within rills and gullies. This storage in the upper area of accumulation and reworking is prone to mobilization by subsequent storms.

Rainsplash and surface wash erosion

Rainsplash at the upper reaches of slopes mobilized fine sediment for transport by overland flow. Peterson (1979) noted that the "belt of no erosion" (Horton, 1945) at the upper reach of slopes is non-existent within the pit. This may be due to the extreme angle of the cliffs at the pit edge or a process of overland flow entering the pit from above. Surface flow and rainsplash are the dominant erosion processes (DWR, 1987). The coarse sediment of the pit walls was particularly susceptible to erosion by rainsplash and sheet flow, while the clay interbeds were much more cohesive (Peterson, 1979). Rainsplash influenced not only the upper reaches of the pit but any areas which were not armored by organic matter, vegetation, rock, or cohesive layers. Most of the area of the pit remains completely denuded by the original mining operations and ongoing erosion, evident in aerial photos. Areas of bare mineral soil throughout the pit continue to be impacted by rainsplash and sheet wash.

Figure 50. Overland Flow along the Malakoff Diggins Pit Floor
Areas of bare mineral soil continue to be impacted by rainsplash and sheetwash. The pit floor in the east end of the pit shows surface flow accumulation (upper panel) surface flow accumulates significantly moving west toward Hiller Tunnel (lower panel). (Photos taken on March 17, 2011 by D. Brown.)

Rills and overland flow

Inter-rill erosion due to sheet flow and rainsplash occurred on coarse grained sediment, as was evidenced by pebbles on soil pedestals. As sheet flow becomes deeper and more turbulent, rills began to form. Rills mobilized more sediment as they cut into the hillside with increasing power. Convergences of overland flow as rills lead to deeper, more erosive flow, where the depth of flow within the rill increased the rate of incision. In addition, overland flow in the form of rills received sediment mobilized from rain splash. Direct observation of turbid runoff from sheet flow and rills on the pit walls confirmed the contribution of sediment to clear streams originating outside of the pit (NCRCD, 1979a). This suggests that cliff areas contribute a substantial amount of sediment to overland flow within the pit (NCRCD, 1979a). As sheet flow washed material down from the walls, the network of rills and gullies accepted and transported material from steep slopes toward the pond and Hiller Tunnel (DWR, 1987).

Gullies

As rills expanded and converged, gullies formed downstream. These gullies further incised, carrying mobilized sediments of larger sizes. Headcutting of gullies due to plunge pool action and seepage at cut faces deepened gullies as they migrated upslope. The deepening of gullies further accelerated erosion by over steepening slopes and undercutting banks, leading to mass wasting of gully sides directly into the stream where it was easily transported

Figure 51. Gullies Form along Cliff Walls at Malakoff Diggins
Gullies incise into the hillside as headcuts migrate upslope, oversteepening slopes and causing accelerated erosion, leading to mass wasting of gully walls. (Photo taken April 6, 2012 by C. Monohan.)

What are the erosional processes in the Malakoff Diggins pit?

Findings

The erosional processes in the Malakoff Diggins pit include landslides, rilling, ice wedging, dry ravel, rainsplash, surface wash and overland flow.

(Selby, 1993). All contributing streams within the pit exited gullies at the pit floor before reaching the pond and Hiller Tunnel.

Deposition in the pit floor

Overland flow was the chief mechanism of transport for large amounts of sediment from cliff walls to the bottom of the pit, as it moved toward the outlet at Hiller Tunnel. As the gradient of the streams decreased, so did stream velocity, allowing the larger coarse material to settle in alluvial fans. Along the eastern edge of the pit floor, three or more streams converge in a large braided alluvial fan, depositing increasingly finer sediment westward toward Hiller Tunnel. The interface between the pit floor and the steep walls of the pit was characterized by numerous alluvial fans associated with gullies and large rills as they deposited the coarse bedload. The low-lying flats with vegetation and ponding were depositional in nature. An alluvial fan at the confluence of 3 or more channels on the east side of the pit floor has aggraded considerably since 1946, extending westward into the pond area (DWR, 1987). The pond was nearly full of sediment and vegetation, and has aggraded to a level at or above the inlet to Hiller Tunnel. This may have increased the sediment load and bedload out of Hiller Tunnel, especially during high flows (DWR, 1987).

What is the annual sediment yield from the pit?

Findings

The present day sediment budget from the pit was estimated as the sum of the pit rim erosion (10,906 m^3) calculated from pit area change and rilling, measured with erosion bridges, (9,117 m^3) minus the deposition on the pit floor, measured from the stakes, (12,707 m^3). The difference was the estimated sediment yield discharged from Malakoff Diggins mining pit (7,316 m^3/yr).

Pit Rim Erosion

To quantify the contribution to the annual sediment load from the pit rim retreat, the change in area from 1952 to 2012 in the pit rim area was divided into multiple polygons to represent individual landslide complexes and gullies. Rim retreat was assumed to be a function of erosion parallel to slope. The crown of most failures around the rim are arcuate, although recession due to block failure and surface erosion have left irregular recession in some places. The geometrical dimensions and method for calculating an estimated volume are taken from Cruden and Varnes (1996) (Wieczorek, Jakob, Motyka, Zirnheld, and Craw, 2002). The geometry of each polygon was measured using ArcGIS, allowing for the calculation of volume using a semi-elliptical cone shape for each mass wasting scar. To represent the shape of observed slide scars that are one quarter of an ellipse in area, or crescent shaped, 1/12 was used as an operator in place of 1/3 for a true cone. The 33 polygons were individually calculated for their volume, and summed to create a total volume lost from pit rim erosion over the 60 year span. Dividing the volume lost by 60 years yielded the average amount of material lost annually.

The equation below shows the operations, where L=length of slide from toe to rim, W= width at the rim, and D= estimated depth of the failure plane. The depth or thickness of each landslide was more difficult to estimate, since the GIS data could not be accurately measured in the vertical elevation (Z dimension).

Equation 1:

$$\left(\frac{\Sigma\left(\frac{1}{12}\right)\pi D\,W\,L}{(60)}\right) = (V_t)\text{total volume lost to pit rim expansion 1952} - 2012$$

The length of the perimeter of the polygons was measured as 11,248.8 m. Dividing the perimeter of the long, narrow polygons in half yields the approximate length of the area eroded i.e., just the top half of a circular polygon feature. Assuming that the erosion was parallel retreat, the total volume of material eroded at the pit rim between 1952 and 2012 was 654,361.61 m^3. Dividing the total volume by 60 years, the average annual volume of material lost from the pit rim was found to be 10,906 m^3/yr.

$$\frac{654{,}361\ m^3}{60\ yrs} = \mathbf{10{,}906\ m^3/yr}$$

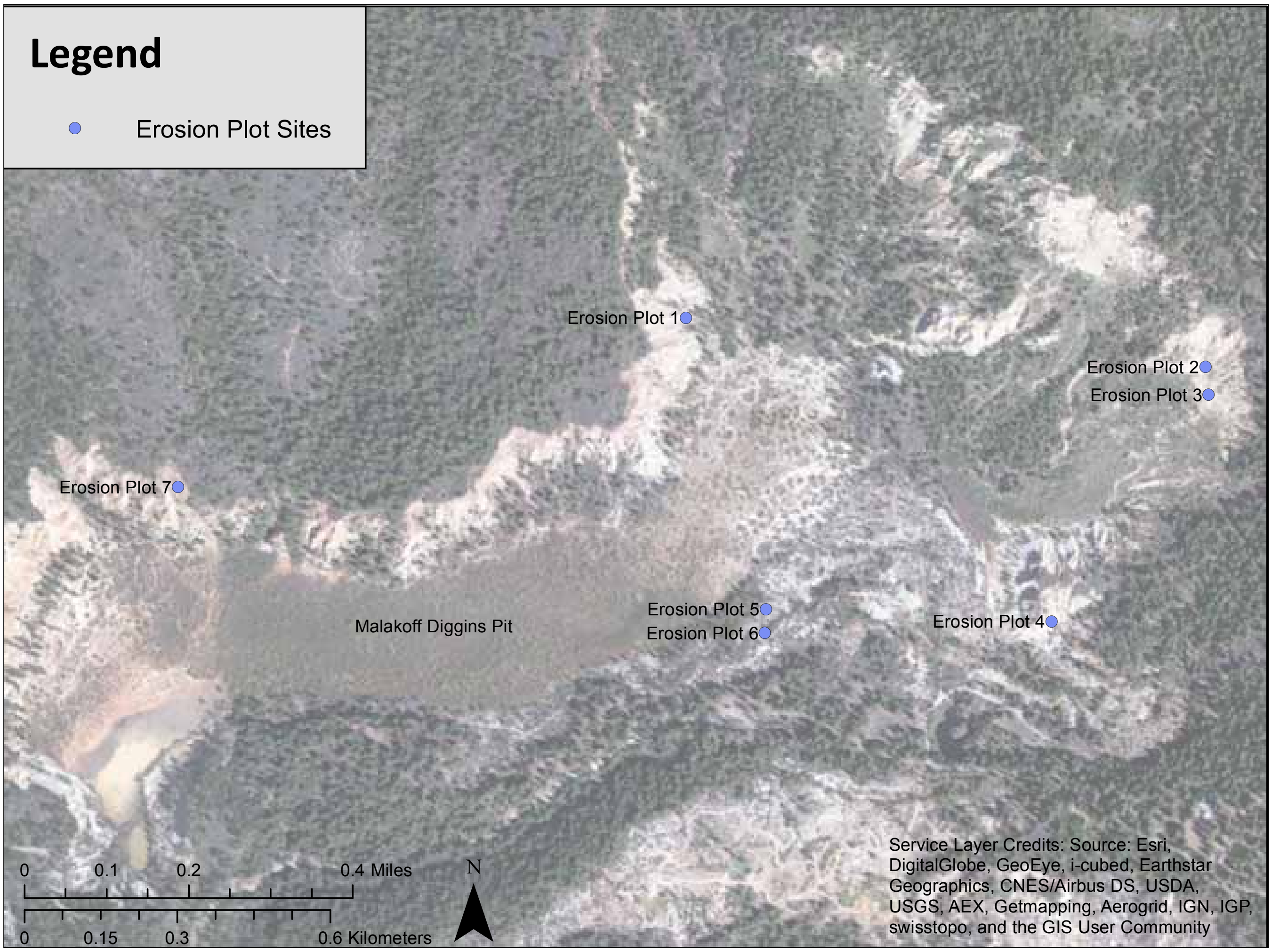


Figure 52. Malakoff Diggins Pit Erosion Plot (Erosion Bridge) Sites
Erosion bridges were used to measure cliff wall erosion in seven locations throughout the pit.

Table 12. Volume Calculations from Erosion Plots and Area Polygons

Erosion Plot Name	Polygon Area (m^2)	Elevation Change (m)	Volume Change (m^3)
1	51,998	-0.0242	-1,256
2	13,284	0.0131	174
3	44,884	-0.0293	-1,313
4	38,911	-0.0245	-952
	73,739	-0.0245	-1,804
5	32,201	0.0074	239
	9,101	0.0074	68
6	39,041	-0.0485	-1,893
	26,698	-0.0485	-1,295
	10,843	-0.0485	-526
	10,567	-0.0485	-513
7	18,078	-0.0016	-29
	7,275	-0.0016	-12
	3,030	-0.0016	-5
Total Volume Change (m^3)			-9,117

Cliff Face Erosion

To quantify the contribution to the annual sediment load from cliff face erosion, erosion bridges were installed in October of 2012, and monitored throughout the water year as erosion took place. An erosion bridge is a 1 m (3 ft) level spanning two rebar pins above the soil surface with measurements made at intervals of 50 mm by thin aluminum rods. The erosion bridge was constructed of a 1 m (3 ft) carpenter's level flush-mounted to a wooden clamp brace with holes drilled at 50 mm for measurement rods. The clamps have marks at 1 meter to ensure accurate and consistent mounting to the rebar pins. Rebar pins were installed level with one another at seven locations on the pit walls where primary surface erosion occurs (Blaney and Warrington, 1983). The pins remained undisturbed in the ground at each location for the duration of the study, and were covered with safety caps which were painted grey to minimize visual impacts. The horizontal bubble of the level was used to monitor and adjust for any changes in the level of the rebar pins during the study. The change (loss/gain) of elevation represents the magnitude of erosion or deposition, and creates a soil contour profile which can be repeated and held against the previous measurement at that location (Ypsilantis, 2011).

Once the winter rains began, measurements were made intermittently following major precipitation events. These measurements showed how events of varying magnitude affect erosion at each location (Figure 52 on page 103). The final measurements were made at the end of September 2013. The annual erosion rate for each plot was determined by comparing the sequential measurements from the datum (erosion bridge) to the ground surface. Quantitative elevational change measurements of the substrate surface represent erosion caused by surficial processes such as rainsplash, sheetwash, ice wedging, dry ravel, and rilling (Sirvent, Desir, Gutierrez, Sancho, and Benito, 1997).

During the study period of 2013 the average soil elevation change measured by the seven erosion bridges was -15.35 mm (+/- 8.41 mm). As shown by the standard error, a wide range of erosion values were measured. Erosion affected individual monitoring plots quite differently, from extremely high erosion rates to deposition. Some locations had erosion, midwinter deposition, then erosion again in spring. In addition, the contour profile measurements created by the multiple rods across the erosion bridge recorded the creation and destruction cycle of rills at many locations.

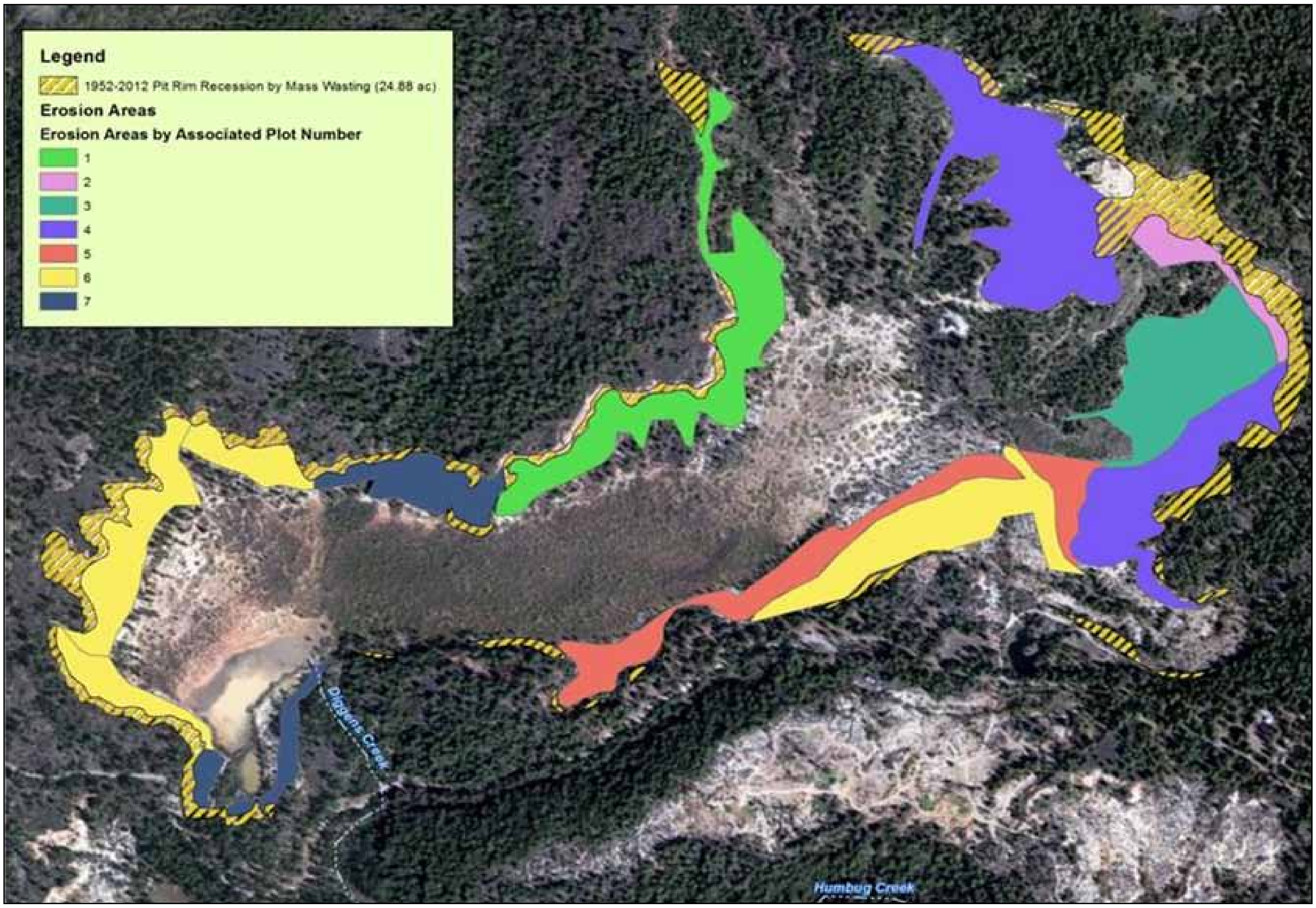


Figure 53. Erosional Areas of the Malakoff Diggins Pit Walls
The pit walls were divided into separate polygons in GIS and erosion bridges in each quadrant were used to measure erosion volume over time.

Erosion results showed a wide variation between plots, and throughout the year. Observations and results revealed the episodic nature of erosion at Malakoff Diggins. Oversaturation of soil led to mass wasting failures. Mass failures were initiated by the continued oversteepening of the translocational and depletion zones of the concave slopes by gullies. Measurements at erosion plots identified slopes within gully complexes such as Plots 1, 4, and 6 as having the highest erosion rates (Table 12 on page 103). Erosion plots located on colluvial deposits such as Plots 2 and 7 measured much lower erosion rates and even deposition as above slopes contributed material by slumping, creep, and dry ravel. Furthermore, soil structure appeared to play an important role in cohesion. Sites with large sand, gravel and cobble lost the most elevation to erosion, where sites dominated by clay such as Plot 7 eroded very little comparatively.

What is the annual sediment yield from the pit?

Findings

The present day sediment budget from the pit was estimated as the sum of the pit rim erosion (10,906 m^3) calculated from pit area change and rilling, measured with erosion bridges, (9,117 m^3) minus the deposition on the pit floor, measured from the stakes, (12,707 m^3). The difference was the estimated sediment yield discharged from Malakoff Diggins mining pit (7,316 m^3/yr).

Average values of soil elevation change from erosion bridge plots were applied to areas of similar morphology and slope to quantify the volume eroded for the area measured. Values of areas measured using ArcGIS are in Table 12 on page 103 and the areas are visible on the map in Figure 53 on page 105. Table 12 on page 103, the area of each polygon and the elevation change measured by each erosion bridge are multiplied to get a volume estimate of erosion. These volume estimates are added together to get a total annual sediment load from erosion plots, which represent sheetwash and rilling, of 9,000 m^3/yr.

Annual Sediment Yield

Annual sediment yield from the pit was calculated by adding the volume eroded by pit rim recession of 10,906 m^3 to the volume contributed by sheetwash and rilling measured with erosion bridges of 9,117 m^3 , and subtracting the 12,707 m^3 volume of deposition in the pit floor measured with posts and stakes. The estimated total annual sediment yield calculated for the Malakoff Diggins mining pit was 7,316 m^3/yr. Most of the soil lost was in the form of fine clays suspended in the runoff, as the vegetative flats and pond trapped all of the coarse, and some fine material. Fine suspended clay particulates directly impact Humbug Creek.

Additional data are needed to create a more precise estimate of sediment yield. Many areas of the pit were not directly measured, and data from only one erosion bridge was applied to large morphologically similar areas nearby which may not have the same erosional characteristics as those measured. Additionally, the measurements made in 2013 were not adequate to cover the large area and multitude of terrains and substrates which erode at different rates. The seven small erosion plots were not able to measure all of the slopes or even fully characterize erosion on the slopes where they were located. Data of erosion was only gathered for one year, far too short a timeframe to prove definitive trends relating the erosional processes observed and measured to deposition below. Nonetheless, measurements of this study provide an estimation of the erosion associated with rill and inter-rill erosion.

For more detail on the erosion processes in the pit and analysis see Keith Landrum's thesis *Quantifying Surficial Processes in Malakoff Diggins, A Historic Hydraulic Mine*, Summer 2014.

Summary of Findings

Cultural Resources Findings

Malakoff Diggings Historic District is listed on the NRHP for its important association with California gold mining generally, and the North Bloomfield Gravel Mining Company and precedent-setting environmental law specifically. The California Attorney General concluded that "the SWRCB and the Regional Water Quality Control Boards were legally obligated, in formulating water quality control policy and waste discharge requirements, to consider the effects of waste discharge on factors of the environment … (meaning) the physical conditions which exist within the area that will be affected by a proposed project, including … objects of historic or aesthetic significance" (Deukmejian, 1980). The Historic District contains 15 listed buildings and a notable landscape in the form of the Malakoff Mine (Malakoff Diggins hydraulic mine pit). Many historic-era resources have been identified but not evaluated for inclusion in the Historic District, many of which are likely eligible for listing as contributors. There are prehistoric sites in the Park that are potentially eligible for NRHP listing for their individual contributions, as well. DPR has indicated their intention to update the NRHP nomination following planned cultural resources inventory and evaluation phases.

The prevailing resource in the Park is, of course, the Malakoff Diggins Historic District itself. The original nomination for this historic property is limited in scope, however, and makes no mention of many other known cultural resources. This assessment identified documentation of 203 cultural resources located within the Historic District. Another 24 sites are located near the Park. The location of all identified resources has been added to a Geographical Information System (GIS) database file and is available for consideration during planning. Given the sensitivity of archaeological resources, this map and specific site locations are confidential.

The total number of sites in the Park consists of 170 historic-era resources, 21 prehistoric sites, and 12 multi- or dual- component sites that contain elements from both periods. With the exception of the massive hydraulic pit site, these resources have not been formally evaluated for their potential contributions to the Historic District, which relied on 15 buildings in North Bloomfield and the Malakoff Mine landscape, nor have they been evaluated for their individual historical significance. A large number of these identified resources should be considered part of the Malakoff Mine Complex, CA-NEV-356/H. DPR also nominated several of the prehistoric sites as an archaeological district, but that nomination was returned by the National Park Service for additional information which was never furnished. Accordingly, the prehistoric resources do not constitute a nationally recognized historic district, nor are they components of the Malakoff Diggins Historic District. However, they must be evaluated on their own merits against the National Register Criteria for

Consideration prior any disturbance. For all intents and purposes the multicomponent site on the edge of the pit that was the subject of three excavations should be considered eligible for listing on the NRHP, since it was excavated to preserve its significant values before they eroded down into the pit. The site's data potential may be determined exhausted, however.

Historic-era resources are far more numerous in the Historic District. However, 132 of them are rather simple resource types such as ditches, old roads, utility poles, fence lines, a bridge, and small artifact deposits or even a single item. Some of these are well known, such as the Bowman, Union, Irwin, and Milton ditches (Felton et al., 1979). The remaining 38 sites and historic-era components of the 12 multi-component sites vary widely in complexity from the sprawling Malakoff Mine Complex to the ruins of a single dwelling. The North Bloomfield Chinatown, portions of Lake City, the Derbec Mine, and other elements of the mining and settlement fabric are among these. Many of these known sites may upon further scrutiny be determined to be elements of the same system and redefined accordingly. The buildings and other town elements are not included in this count because of the way standing architecture is distinguished from archaeological resources. Gracyk's (2011) report does an excellent job summarizing all of the intact components into a single document.

The Park contains 33 documented prehistoric resources and probably more that have yet to be identified. Several of these sites were found in the 1950s and 60s, and later investigations failed to relocate seven of them. Documented sites generally consist of scatters of ground and chipped stone and/or bedrock milling on spring-fed slopes above the pit, along Slaughterhouse Ravine, north of town, and the Martin Ranch area. Rock art in the form of a small petroglyph has been identified at one site, which is uncommon. Archaeology at CA-NEV-356/H demonstrates that prehistoric occupation in the Park began at least 2,500 years ago, based on radio carbon dating and obsidian hydration. Another site in the Park, CA-NEV-93/H, contains worked bottle glass, indicating occupation during the historic-era. A memory map made by Maxine Ivey Johnson now on display at North Bloomfield, depicts a few teepee-like structures as the homes of "Maggie the Squaw" and "Old Webb" along Blair Ditch, reinforcing the fact that the Native community continued to live on their ancestral lands well into the historic era.

Maps of the cultural resources will improve understanding of potential metals source areas, both within and outside of the pit. A map which shows historic mines and processing sites upslope of the diggings and Humbug Creek can be used to determine additional potential source areas. A series of historic maps that represent various phases of historic workings, that show the layout of operations, sluices, flumes, tunnels, drifts, dragline operations, dredging locations, tailings, and town sites and assay offices should be generated. This map information can be used to guide additional sampling for mercury sources.

Summary of Findings

Environmental Assessment Findings

Historic hydraulic mining in and around Malakoff Diggins SHP has resulted in turbidity and particulate-bound metals problems in Humbug Creek. While considerable data were previously available about turbidity, this study provided significant additional information regarding sediment transport and the sources and fate of heavy metals. The findings of this study support the development of management recommendations for both sediment and heavy metals, and offer a path ahead within the current regulatory framework.

Key studies were performed by Yuan (1979), Peterson (1979), DWR (1987) and NCRCD (1979a,b). Review of these and other previous studies, as well as the findings of the present environmental assessment, yields the following key findings:

Historic Mining Operations and Pit Features

- From 1886 to 1900, an estimated 30,000,000 m^3 (39,000,000 yd^3) of overburden soil and Tertiary gravels were hydraulically displaced during the historic mining operations. Of this total mined volume, an estimated 22,000,000 m^3 (29,000,000 yd^3) were discharged from the hydraulic pit (Jarman, 1927).
- The hydraulic pit measures approximately 2,000 m (7,000 ft) long, and up to approximately 900 m (3,000 ft) wide. The northern, eastern and western pit walls range from approximately 60 to 150 m (200 to 500 ft) tall.
- The pit floor is a broad, gently sloping alluvial plain that measures approximately 1,000 m (4,000 ft) long and 150 to 300 m (500 to 1,000 ft) wide, comprising approximately 300,000 m^3 (75 ac). The central portion of the pit floor, comprising approximately 40 acres, supports significant vegetation.

Precipitation and Runoff

- Annual precipitation is approximately 160 cm/yr (62 in/yr), and 86 percent of this typically falls during November through April. The pit and its contributory drainage area measures approximately 5 km^2 (1,220 ac). Annual runoff from the pit and its contributory area was previously estimated to be 4,000,000 m^3 (3,000 AF) (NCRCD, 1979a).
- Annual runoff from the pit observed during the present study was approximately 4,933,927 m^3 (4,000 AF) for WY 2012 and 3,700,446 m^3 (3,000 AF) for WY 2013.
- NCRCD (1979a) estimated a 10-year, 24-hour peak flow rate of 20 m^3/sec (704 cfs). MacDonald (1989) estimated the 10-year, 24-hour flow to be 10 m^3/sec (350 cfs), and estimated that retention of such a storm would require 800,000 m^3 (30 million cubic feet), or approximately 900,000 m^3 (700 AF), not including provisions for freeboard and sediment retention.

Erosion

- Yuan (1979) compared historical photographs of the northern pit cliffs taken over a 69-year period and estimated an average erosion rate of 8.9 cm/yr (3.5 in/yr.). This estimate of hillside retreat did not consider mass wasting from the landslides in the eastern end of the pit. Landsliding and hillside retreat is expected to continue, particularly in the unstable eastern portion of the pit, which will continue to increase the pit size and to release sediment. From 1952 to 2012, the pit area increased by approximately 100,000 m^2 (25 ac) due to pit rim erosion (Figure 41 on page 89). Assuming that the erosion is parallel retreat, the total volume of material eroded at the pit rim between 1952 and 2012 was 650,000 m^3. Dividing the total volume by 60 years, the average annual volume of material lost from the pit rim was found to be 11,000 m^3/yr.
- Peterson (1979) estimated an annual soil erosion rate of roughly 35,000 m^3/yr (45,000 yd^3/yr) within the hydraulic pit. Peterson generally agreed with Yuan's (1979) findings regarding hillside retreat, which yielded 20,000 m^3/yr (30,000 yd^3/yr) erosion on average, and Peterson (1979) estimated that mass wasting from the eastern landslides would yield 11,000 m^3/yr (15,000 yd^3/yr) on average in addition to Yuan's (1979) estimate.
- Data obtained by DWR (1987), Peterson (1979) and NCRCD (1979a) indicate that much of the fine-grained sediment originates from erosion of the eastern landslide deposits. Peterson (1979) estimated that nearly three quarters (estimated 15,000 yd^3/yr) of the fine soil fraction originates from the unstable eastern end of the pit, while the remainder (estimated 4,000 m^3/yr (5,000 yd^3/yr)) originates from other portions of the pit.
- Peterson (1979) anticipated that much of the coarse fraction of eroded material (sand and larger particle sizes, as well as clasts of fine-grained particles; estimated 19,000 m^3/yr (25,000 yd^3/yr)) would tend to be deposited on the pit floor, while much of the fine fraction (silt and clay; estimated 16,000 m^3/yr (21,000 yd^3/yr)) would tend to leave the pit via Hiller Tunnel.
- The present study indicates that as the pit walls continue to erode, the pit is growing in size, the pond is shrinking in size, and the vegetation patch on the pit floor of the pit is growing in size.
- Not all of the fine silts and clays that make up the majority of the turbid discharge from the pit are retained by the vegetation that has established on the pit floor.

Sediment Deposition

- Considering the erosion rate 35,000 m^3/yr (45,000 yd^3/yr) estimated by Peterson (1979), and conservatively assuming that all of the eroded material is retained in the hydraulic pit, the floor of the pit would gain one foot in elevation every 12 years. In reality, not all of the sediment is retained in the pit, and the retained sediment is not uniformly distributed between the alluvial fans at the base of the slopes, the upper pit, and the lower pit.

- As a result of sediment accumulation in the pit, DWR (1987) observed that the pond size in 1987 was approximately one-tenth of its size in 1952. Enough deposition has occurred in the braided stream channels of the pit floor that the elevation of the alluvium at Hiller Tunnel is higher than the tunnel inlet, creating a potential physical hazard at the tunnel inlet. Surface water now flows directly into the tunnel inlet, rather than through the remnant diggings pond. Figure 39 on page 88 depicts the increase in vegetation and reduction in pond area from 1952 through 2012.
- Peterson (1979) used seismic refraction techniques to estimate that the pit floor contained approximately 100 ft of sediment. The upper third of this sediment is believed to have been deposited since 1917. Using topographic maps prepared by Hammon Engineering Company (1917) and USGS (1949), Peterson (1979) observed that the pit floor elevation rose from 3,000 ft to 3,040 ft during the 32-year period between 1917 and 1949, resulting in an average deposition rate of roughly 47,000 m^3/yr (62,000 yd^3/yr). This estimated historical deposition rate is higher than Peterson's estimate of the 1979 deposition rate (34,000 m^3/yr). It is not surprising that the sedimentation rate is gradually decreasing with time.
- Peterson (1979) found that much of the fine sediment is contained in larger clasts that would tend to remain on the east side of the pit, or would tend to settle more quickly in water than would their component silt and clay particles. A point count of clasts carried into the floor of the diggings by the principal drainages through the landslide areas showed that 35 to 45 percent of the cobble sized material was composed of clay that was transported as clayball fragments. In general, the conceptual design of sediment retention basins by NCRCD (1979b) and others considers particle size distribution based on suspended sediment exiting Hiller Tunnel, and generally does not consider the upstream particle size distribution. The energetic transport of clasts through the tunnel would tend to desegregate the clasts into their finer component particles, which have longer settling times.
- The present study, using deposition markers, indicated that the pit is filling in and the depth to bedrock has increased since the surveys were first conducted in 1979.
- The present study identified sources of suspended solids by the sampling of waterways within the pit during storm events and also by measurement of sediment deposition at stake locations. The present assessment found that sediment deposition in the northeast alluvial fan takes place at approximately 0.04 m/yr (0.13 ft/yr), based on data from 35 stake locations measured from 2005 to 2012. Conservatively assuming that the elevation of the entire pit floor increases 0.04 m/yr (0.13 ft/yr) would yield a deposition rate of 12,000 m^3/yr (16,000 yd^3/yr). This estimated deposition rate is lower than the previous estimate (19,000 m^3/yr) by Peterson (1979), as well as the historical deposition rate (47,000 m^3/yr) estimated by Peterson (1979).

- The particle size distribution along the length of the pit information collected by the present study indicates that the source of coarse sediments is in the east end of the pit and that progressively finer sediments are deposited on the pit floor in the direction of Hiller Tunnel.

Sediment and Metals Discharge

- Peterson (1979) estimated sediment discharge rates of 9,400 to 16,400 m^3/yr (12,300 to 21,500 yd^3/yr). These estimated rates were based on data obtained from NCRCD (1979a), assuming that approximately half to nearly all of the eroded silt and clay is discharged from the pit.
- Based on flow and suspended solids data collected during one storm event, Cranmer Engineering Inc. (NCRCD, 1979a) estimated that sediment discharge from Hiller Tunnel was 5,000 m^3/yr (6,000 yd^3/yr).
- Based on stream flow and suspended solids data obtained during the present assessment, sediment load in Humbug Creek was estimated to be approximately 500,000 kg/yr (500 T/yr) during 2011 and 2012. Precipitation in WY 2012 and 2013 was below average, and at least half of the sediment load was discharged during one storm event. Considering the frequency and magnitude of storm events for an average year and an above-average year, sediment discharge rates may range from 765 to 2,300 m^3/yr (1,000 to 3,000 yd^3/yr).
- DWR (1987) concluded that a significant amount of sand-size sediment appears to be discharged from the pit, indicating that the service life of the detention basin proposed by NCRCD (1979b) may not be as long as originally expected. Bedload sampling is required to determine the contribution of bedload to sediment and mercury transport.
- The present assessment identified elevated concentrations of sediment, mercury, copper, lead, nickel, zinc and iron in water discharged from the hydraulic pit via Hiller Tunnel. The metals are associated primarily with suspended sediment. Humbug Creek has lower levels of these metals upstream of Diggins Creek (Road 1) and significantly higher levels downstream of the confluence with Diggins Creek (Gage 3).
- The present study estimates the annual mercury load to be 100 g (0.25 lb) per year during the relatively dry years of 2012 and 2013. Considering that mercury loading is proportional to sediment loading, the mercury load during an average and above-average year, as described above, may range from 250 to 500 g/yr.
- The present study's observations were made during two years with below-average rainfall but included data from five storm events. During the study period, over half the annual sediment and mercury load in Humbug Creek was from storm events.
- The source of a majority of the water quality impairment in Humbug Creek is from runoff from Malakoff Diggins pit during storm events, via Diggins Creek. The source of

heavy metals contamination in the Malakoff Diggins pit is predominantly associated with suspended sediment transport. The tributaries that enter the pit from the north rim were not a sources of contamination to the pit, as the water was low in total and dissolved metals and suspended sediment. The majority of the mercury in Humbug Creek (Gage 3) and in Diggings Creek (Hiller 2) was in particulate-bound form, not in the dissolved form.

- Particulate-bound mercury concentrations detected in surface water in Humbug Creek were greater than 50 ng/L during all observed storm events. The particulate-bound mercury discharge from Hiller Tunnel is significant and may be transported long distances to environments where the mercury can be methylated and thereby introduced into the aquatic food web (Marvin-DiPasquale et al., 2011).
- Macroinvertebrate sampling conducted as part of the present study in Humbug Creek confirmed that mercury is being methylated and is being incorporated into the local aquatic food web.
- The present study indicates that discharge from the North Bloomfield Tunnel outlet and one of the access shafts (Shaft 5) has elevated concentrations of metals. Elevated levels of mercury, arsenic, nickel, and zinc in the water from Shaft 5 have the potential to degrade water quality in Humbug Creek and also present a risk of direct exposure to Park visitors. However, the discharge rates from the North Bloomfield Tunnel outlet and Shaft 5 are low.

Implications of Findings

The fact that particulate-bound mercury is the predominant form of mercury coming from the Malakoff Diggins pit suggests that efforts to reduce suspended sediment will also reduce the transport of particulate-bound mercury and contamination of downstream reaches.

As described above, sediment is discharged from the hydraulic mining pit to Humbug Creek via Diggins Creek, primarily during storm events, resulting in high levels of silt and clay that cause extremely high turbidity in Humbug Creek. Better understanding of pit erosion and deposition processes may help to identify sources of silt and clay that can be targeted for erosion control techniques. The pit walls are part of the historic signature of this landscape. Although they continue to erode and expand the pit, abating this expansion is unlikely to be successful because of the scale of the problem and the cultural significance of the cliffs.

The findings of this assessment suggest that the Malakoff Diggins pit discharge at Hiller Tunnel be a priority for remediation activities. The recommended management method is the retention of storm water discharge within the pit so that it can be allowed to settle and possibly be filtered. Surface water that enters the pit from above does not have elevated levels of mercury or other metals and flow could be diverted to nearby waterways, thereby reducing surface water flow entering the pit, the erosion rate of the pit rim, and the sediment load.

Additionally, it is recommended that: 1) water quality at the North Bloomfield Tunnel outlet and Shaft 5 be assessed to determine seasonal trends, and to facilitate the evaluation of permitting mechanisms and management strategies; and 2) the physical hazards associated with the open mine features be addressed.

Conceptual Model of Sediment and Heavy Metals

Based on the key findings of this assessment, a conceptual model was developed to describe the fate of sediment in the Malakoff Diggins hydraulic pit. The conceptual model, presented as Figure 54 on page 116, considers the primary sediment sources within the pit, the transport of sediment within the pit, and its eventual retention or discharge. The purpose of the model is to illustrate what estimates are presently available, and what additional data are needed. As discussed above, the past and current estimates of sediment deposition and sediment discharge indicate that the annual rates of deposition and discharge have been decreasing over time. As discussed in the Data Gaps section of this report (below), additional monitoring of discharge, suspended sediment load and bedload is required to further characterize the relationship between precipitation, runoff and sediment transport, and to assess the partitioning of sediment within the hydraulic pit.

In addition to sediment release from the pit, the present assessment considers the release of heavy metals. Above certain concentrations, heavy metals may present risks to human health or to the environment. Management strategies selected to reduce sediment release from the hydraulic pit will need to be compliant with regulations that apply to these heavy metals. Therefore, it is appropriate to consider these metals as part of the conceptual model. Constituents of potential concern, exposure pathways and potential targets are discussed below.

1) CONSTITUENTS OF POTENTIAL CONCERN

Heavy metals and metalloids are considered as constituents of potential concern (COPCs) based on the site's history of gold mining. Naturally elevated concentrations of metals such as copper, lead, nickel, zinc and iron are commonly associated with hard rock (lode) gold deposits, and less commonly associated with placer gold deposits such as those mined from the Malakoff Diggins hydraulic pit. These metals are likely to occur naturally within the pit sediment at ambient (background) concentrations. Although the metals have been detected in surface water discharge, their presence in surface water is likely associated with suspended sediment concentrations rather than dissolved concentrations in the water itself.

Mercury is also present in suspended sediment discharged from the hydraulic pit. Unlike the other metals mentioned above, mercury was historically imported by the mining industry for gold recovery, and generally does not occur naturally at significant levels in this region. Historical import of mercury by the mining industry is not the only source of mercury in the environment. Elemental mercury can volatilize to the atmosphere and remain airborne for more than a year, being transported long distances before returning to earth by wet or dry deposition (USEPA, 1997). USEPA (2006) estimates that 83 percent of the mercury deposited in the United States originated outside of the United States.

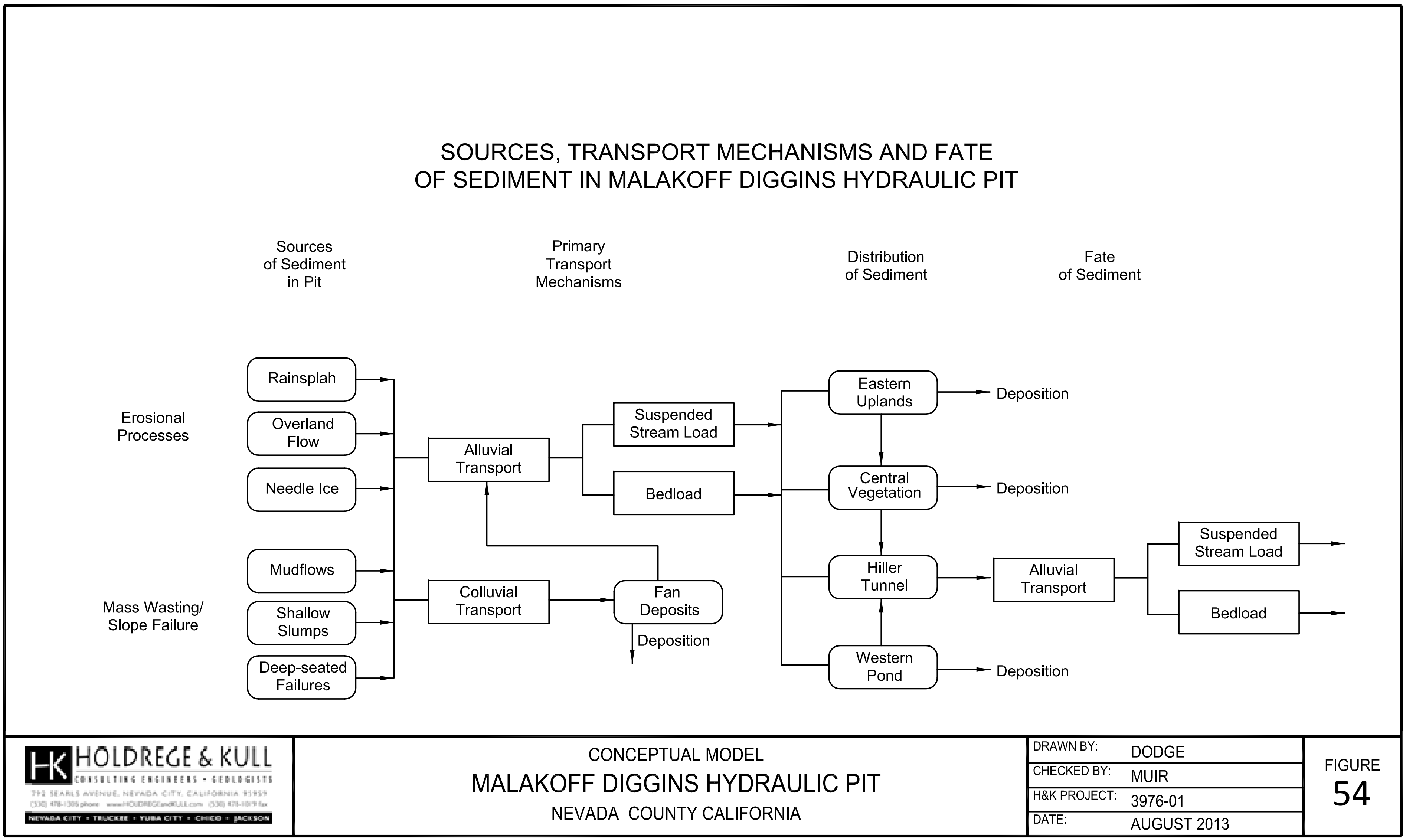


Figure 54. Conceptual Model of Sediment Source, Fate and Transport in the Malakoff Diggins Pit
Erosional processes, transport mechanisms, and the distribution and fate of sediment in the pit result in deposition on the pit floor or discharge of sediment through Hiller Tunnel as suspended sediment and bedload.

In saturated, anaerobic environments, inorganic mercury may be consumed by organisms and converted into organic mercury. Mercury in the water column (both inorganic and organic) is predominantly bound to organic matter, either to dissolved organic carbon or to suspended particulate matter (USEPA, 1997), resulting in a common positive correlation between total suspended solids (TSS) and mercury in water.

Methylation and biomagnification of mercury, as described by Alpers, Hunterlach, Hothem, and May (2005), are current topics of study in the South Yuba River watershed, of which Humbug Creek is a part. According to Alpers et al. (2005), "[t]he concentration of MeHg generally increases by a factor of ten or less with each step up the food chain, a process known as biomagnification. Therefore, even though the concentrations of Hg(0), Hg(II), and MeHg in water may be very low and deemed safe for human consumption in drinking water, MeHg concentration levels in fish, especially predatory species such as bass and catfish, may reach levels that are considered potentially harmful."

Figure 55. Identifying Mercury Sources
Humbug Creek is a source of mercury-contaminated sediment to the South Yuba River, and identifying sources in the headwaters and remediating them at the source can protect miles of downstream habitat. (Photo taken on March 23, 2012 by C. Monohan.)

Humbug Creek has been placed on the CWA Section 303(d) list by the SWRCB (State Water Resources Control Board (SWRCB), 2013a) as impaired for sedimentation, mercury, copper and zinc. Pursuant to the CWA, the development of Total Maximum Daily Load (TMDL) limitations is anticipated for these constituents in Humbug Creek.

2) SOURCE IDENTIFICATION

A source is defined as any area where a hazardous substance has been deposited, as well as any soil that has been contaminated. The following sources have been identified:

- The present assessment has identified sediment within the Malakoff Diggins hydraulic pit as a primary source of mercury within the Humbug Creek watershed, and mercury within the North Bloomfield Tunnel as a secondary source.
- The Malakoff Diggins hydraulic pit discharges surface water and sediment to the Creek via Hiller Tunnel. The tunnel itself generally does not retain sediment due to the seasonal high flows from the diggings. The discharge of surface water via Hiller Tunnel is perennial, but the discharge of sediment from Hiller Tunnel takes place primarily during higher flows experienced in the rainy season.

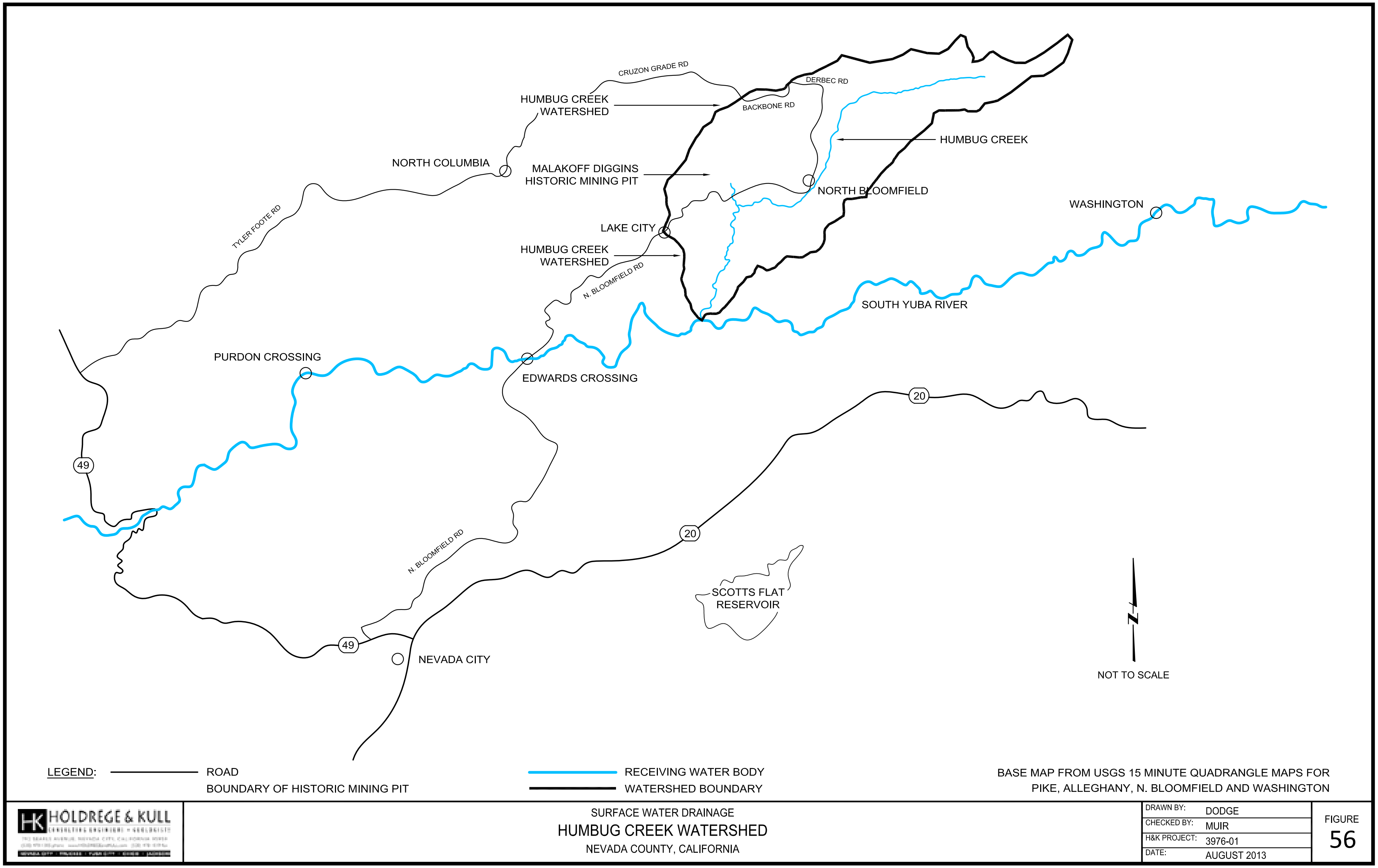


Figure 56. Regional Surface Water Drainage Area
Humbug Creek is a tributary to the South Yuba River.

- The North Bloomfield Tunnel historically conveyed water and sediment from the mine, although an apparent mid-tunnel blockage has resulted in discharge from its upper vertical shafts. Analysis of grab water samples from the tunnel outlet and from a vertical access shaft (Shaft 5) has identified mercury in discharge associated with the North Bloomfield Tunnel.
- Diggings associated with the Lake City hydraulic mine, although not located within the surface water drainage boundary of Humbug Creek, historically drained to Humbug Creek via the Bloomfield Tunnel (Lake City Tunnel). Although the Bloomfield Tunnel is not expected to be a significant source of mercury to Humbug Creek, the present connectivity of the Lake City diggings to Humbug Creek via the Lake City Tunnel is not known.
- Historical mineral survey plats (Bureau of Land Management (BLM), 2011) identify several other placer gold mining claims within the watershed, such as those in the Colorado Hill area located immediately south of the Malakoff Diggins pit, below North Bloomfield Road. Although these potential mercury sources are not expected to be significant, they have not been characterized, and no record of past characterization has been encountered.
- Mercury within sediment in Humbug Creek has not been assessed; however, its contribution to the total mercury load in Humbug Creek is expected to be small in comparison to the seasonal discharge from the Malakoff Diggins mining pit. Peterson (1979) found clay veneers as thick as 4 mm (0.16 in) on boulders in Humbug Creek, indicating that some fine-grained sediment is deposited before reaching the South Yuba River. However, the vast majority of the sediment passes through Humbug Creek.

Historical sources of mercury in the watershed include mining (predominantly placer) and related gold extraction processes. Other heavy metals tend to originate from mineralized lode gold deposits, which are generally not expected to be abundant within the watershed.

Loss of mercury by historical hydraulic placer gold mining operations is described by Alpers et al. (2005): “[t]o enhance gold recovery from hydraulic mining, hundreds of pounds of liquid mercury (several 76 lb flasks) were added to riffles and troughs in a typical sluice. Mercury use in sluices varied from 0.1 to 0.36 lb/ft^2. A typical sluice had an area of several thousand square feet; several hundred pounds of mercury were added during initial start-up, after which several additional 76 lb flasks were added weekly to monthly throughout the operating season. Under average conditions, the annual loss was about 25 percent (Bowie, 1905). Assuming a 10- to 30-percent annual loss rate, a typical sluice lost several hundred pounds of mercury during the operating season (Hunerlach, Rytuba, and Alpers, 1999).”

Mercury concentrations in surface water tend to correlate well with surface water TSS concentrations, as fine sediment is re-suspended in the water column during storm events. Therefore, sediment retention for low-recurrence, high-flow storm events is considered important to reduce downstream mercury transport.

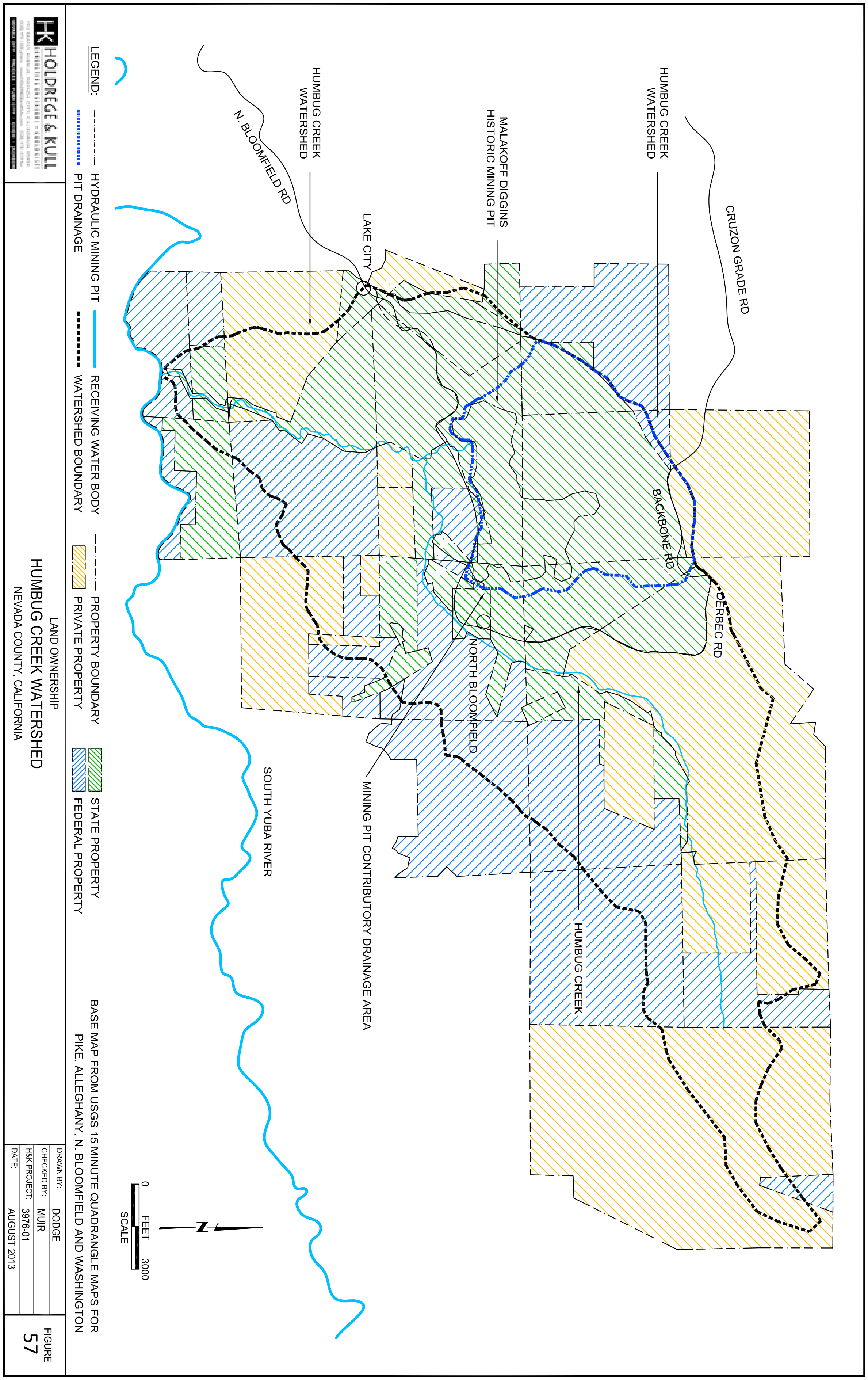


Figure 57. Land Ownership in the Humbug Creek Watershed

Land ownership in the Humbug Creek watershed includes private, state and federal landowners.

3) PATHWAY IDENTIFICATION

Potential exposure pathways include contaminant transport via the food chain, soil exposure, surface water migration, groundwater migration, and air migration. Exposure pathways pertain to both present land use and anticipated future land use.

The exposure pathway of greatest concern for MeHg is the consumption of fish, although exposure can also occur through inhalation or dermal exposure. The primary route of exposure to inorganic mercury is through ingestion. Inorganic mercury compounds may also be absorbed through the skin, although at much lower levels than through ingestion (ASTDR, 1999).

4) TARGET IDENTIFICATION

Targets may consist of people, sensitive environments, fisheries, and resources that could potentially be affected by contamination sources. Potential targets are discussed below by exposure pathway.

Surface Water Potential Targets

The surface water drainage pathway within and downstream of the Humbug Creek watershed is depicted on Figure 56 on page 118. Drinking water sources, fisheries, and recreational uses have been identified downstream of the site. The Basin Plan (California Regional Water Quality Control Board (CRWQCB), 1998) lists the following beneficial uses for the Yuba River:

- Municipal and domestic supply;
- Agricultural supply: irrigation and stock watering;
- Hydropower generation;
- Water recreation: contact, canoeing and rafting, and other non-contact recreation;
- Freshwater habitat: warm water ecosystems (below Englebright Reservoir) and cold water ecosystems (above Englebright Reservoir);
- Migration: warm and cold water ecosystems (both below Englebright Reservoir);
- Spawning: warm water ecosystems (below Englebright Reservoir) and cold water ecosystems (above Englebright Reservoir); and
- Wildlife habitat.

Groundwater Pathway Potential Targets

Although the site is not expected to have a significant impact on local groundwater, there is potential for groundwater impact via infiltration from the pit, or via the partially plugged water conveyance tunnel (the North Bloomfield Tunnel).

Soil Pathway Potential Targets

The hydraulic pit and lower Humbug Creek, downstream of the pit, are located predominantly within the Malakoff Diggins State Historic Park, and surrounded by federal and private land, as depicted on Figure 57 on page 120. Although the hydraulic pit and lower Humbug Creek do not support a resident human population, current and future land use includes recreational activity such as hiking and camping. Soil pathway potential targets include human and ecological receptors. In general, human exposure via soil pathways is not expected to be significant based on the exposure frequencies associated with recreational land use and the identified soil metals concentrations in the hydraulic pit.

Air Pathway Potential Targets

Recreational site visitation may result in exposure via the air pathway. Disturbance of surface soil on trails may contribute to onsite exposure via the air pathway. In general, human exposure via air pathways is not expected to be significant based on the recreational land use and the identified soil metals concentrations in the hydraulic pit. The nearby resident population is generally not located near enough to the site for offsite exposure via the air pathway to be considered likely.

Figure 58. Soil Pathway Targets
Recreational trails traverse mine-impacted landscapes throughout Malakoff Diggins State Historic Park. (Photo taken on October 29, 2013 by J. Howle.)

Recommendations

This section presents a preliminary engineering evaluation of management strategies, and provides recommendations for the most promising alternatives. The engineering evaluation is based on the findings of the present assessment and the results of previous studies. This section was prepared by Jason Muir, PE, GE, Principal Engineer at Holdrege & Kull Consulting Engineers and Geologists. Mr. Muir has 19 years of experience with characterization and mitigation of mining impacts under the oversight of the Cal/EPA, DTSC and the Regional Water Quality Control Boards. Mr. Muir also prepared significant sections of the summary of findings and the conceptual model presented above. The findings of this watershed assessment indicate that strategies are necessary for:

1) Management of sediment and metals discharge from the Malakoff Diggins hydraulic pit,

2) Management of water and metals discharge from the North Bloomfield Tunnel, and

3) Management of physical hazards associated with the North Bloomfield Tunnel.

Guiding Principles

The evaluation considers these guiding principles:

- Adaptive management strategies are necessary to address environmental and physical hazards while complying with Park management objectives.
- Additional monitoring is necessary to inform the final remedial design.
- Cultural resources inventory and evaluations are necessary to determine whether the final remedial design will result in an adverse effect to significant cultural resources and, if so, inform the development of appropriate treatment measures.
- The precautionary principle is used: action is recommended now to address the immediate needs while performing the additional monitoring.

Organization of this Evaluation

The following sections describe:

- The framework of water quality laws and regulations;
- Evaluation of management strategies and recommendations for the most promising alternatives; and
- A data gaps analysis, which is intended to guide further study and to facilitate remedial design.

Regulatory Framework

This section describes potentially applicable water quality objectives and permitting mechanisms for management strategies related to the protection of water quality, however there are additional laws, regulations, and agency policies that apply to actions taken in the Park. The regulatory framework governing protection of water quality is described in the *Policy for Implementation of Toxic Standards for Inland Surface Waters, Enclosed Bays and Estuaries of California*, also known as the State Implementation Policy (SWRCB, 2005). Pursuant to state and federal regulation, the following water quality objectives and criteria are potentially applicable:

1. Federal water quality criteria set forth in the National Toxics Rule (NTR) (United States Environmental Protection Agency (USEPA), 1993) and in the CTR (USEPA, 2000), which is promulgated by the USEPA in 40 CFR 131.38.
2. Water quality objectives from the Basin Plan established by the California Regional Water Quality Control Board, Central Valley Region (CRWQCB, 1998), including Maximum Contaminant Levels (MCLs) specified in Title 22 of the California Code of Regulations (22 CCR), which are incorporated by reference into the Basin Plan;
3. USEPA ambient water quality recommended criteria and other criteria commonly used by the Regional Water Quality Control Board to interpret narrative objectives in the Basin Plan, such as OEHHA fish consumption benchmarks, federal and state antidegradation requirements, and waterway-specific benchmarks.

Common regulatory benchmark concentrations are listed in Table 13 on page 125. Peak measured values are compared to selected benchmark values in Table 14 on page 125. Regulations and permitting mechanisms are described below.

1) CALIFORNIA TOXICS RULE

The USEPA (2000) promulgated ambient water quality criteria for priority toxic pollutants in California inland surface waters, enclosed bays and estuaries under the CWA. These standards, known as the CTR, were codified in Title 40 of the Code of Federal Regulations (CFR), Part 131.38. The CTR established a human health criterion (HHC) for mercury of 50 ng/L for the ingestion of water and fish, and 51 ng/L for the ingestion of fish only. Due to the large biomagnification factor used to calculate the HHC, the contribution of ingesting water is not significant in comparison to the contribution of fish consumption (USEPA, 2000). Regulatory action is often driven by MeHg concentrations in fish, as discussed below, rather than these CTR criteria for mercury in water.

Table 13. Common Regulatory Benchmarks for Metals in Water

Constituent	Method	Target MDL	Typical Target MDL	Benchmark Values													
				Primary MCL	source	Secondary MCL	source	PHG	source	IRIS RfD	source	SNARL	source	CTR	source
Aluminum (µg/L)	EPA 6020, M200.7 ICP	0.03	30	1000	CDPH	200	CDPH	600	OEHHA	ne	--	ne	--	ne	--
Antimony (µg/L)	EPA 6020, M200.8 ICP-MS	0.0004	0.4	6	CDPH	ne	--	20	OEHHA	2.8	USEPA	6	USEPA	14	D1
Arsenic (µg/L)	EPA 6020, M200.8 ICP-MS	0.0001	0.54	10	USEPA	ne	--	0.004	OEHHA	2.1	USEPA	ne		150	B2
Barium (µg/L)	EPA 6020, M200.8 ICP-MS	0.0001	0.3	1000	CDPH	ne	--	2000	OEHHA	1400	USEPA	1400	USEPA	ne	--
Cadmium (µg/L)	EPA 6020, M200.8 ICP-MS	0.0001	0.2	5	CDPH	ne	--	0.04	OEHHA	3.5	USEPA	5	USEPA	2.2	B2
Chromium (µg/L)	EPA 6020, M200.8 ICP-MS	0.0001	0.4	ne	--	ne	--	ne		10500	USEPA	ne	--	180	B2
Cobalt (µg/L)	EPA 6020, M200.8 ICP-MS	0.00005	0.5	ne	--	ne	--	ne		ne	--	ne	--	ne	--
Copper (µg/L)	EPA 6020, M200.8 ICP-MS	0.0005	3	1300	CDPH	1000	CDPH	300	OEHHA	ne	--	ne	--	9	B2
Iron (µg/L)	EPA 6020, M200.8 ICP-MS	0.02	20	ne	--	300	CDPH	ne		ne	--	ne	--	ne	--
Lead (µg/L)	EPA 6020, M200.8 ICP-MS	0.0001	0.1	15	CDPH	ne	--	2	OEHHA	ne	--	ne	--	2.5	B2
Manganese (µg/L)	EPA 6020, M200.8 ICP-MS	0.005	5	ne	--	50	CDPH	ne		980	USEPA	300	USEPA	ne	--
Mercury (µg/L)	EPA 7470A, M245.1	0.0002	0.2	2	CDPH	ne	--	1.2	OEHHA	ne	--	2	USEPA	0.05	D1
Nickel (µg/L)	EPA 6020, M200.8 ICP-MS	0.0006	2	100	CDPH	ne	--	12	OEHHA	140	USEPA	100	USEPA	52	B2
Silver (µg/L)	EPA 6020, M200.8 ICP-MS	0.0001	0.7	ne	--	100	CDPH	ne		35	USEPA	100	USEPA	3.4	B1
Thallium (µg/L)	EPA 6020, M200.8 ICP-MS	0.0001	0.1	2	CDPH	ne	--	0.1	OEHHA	0.6	USEPA	0.5	USEPA	1.7	D1
Vanadium (µg/L)	EPA 6020, M200.8 ICP-MS	0.0002	0.4	ne	--	ne	--	ne		63	USEPA	ne	--	ne	--
Zinc (µg/L)	EPA 6020, M200.8 ICP-MS	0.002	2	ne	--	5000	CDPH	ne	--	2100	USEPA	2000	USEPA	120	B2

CDPH = California Department of Public Health, OEHHA = California Office of Environmental Health Hazard Assessement, CTR = California Toxics Rule, IRIS = USEPA Integrated Risk Information System, IRIS RfD = Reference Dose as a Drinking Water Level, MCL = Maximum Contaminant Level, MDL = method detection limit, ne = not established, PHG = Public Health Goal, RL = reporting limit, SNARL = Suggested No-Adverse-Response Level, USEPA = United States Environmental Protection Agency

Table 14. Selected Benchmark Values

Parameter	Units	Peak Measured Value			Background Value	Example Benchmark Values			
		Hiller Tunnel Outfall	Shaft 5	NB Tunnel Outfall		Drinking Water	source	Fish and Ag	source
TSS	mg/L	**2940**	--	--	55	--	--	**450**	Narrative Chemical Constituents Objective (Ag)
Copper	ug/L	**130**	4.5	0.6	7	**1300**	CDPH Primary MCL	**9**	CTR Criterion Continuous Concentration
Iron	ug/L	**39000**	--	--	2800	**300**	CDPH Secondary MCL	--	--
Lead	ug/L	**30**	1.5	<1	0.7	**15**	CDPH Primary MCL	**2.5**	CTR Criterion Continuous Concentration
Mercury	ug/L	**540**	0.06	<0.001	27	**2**	CDPH Primary MCL	95%	Reduction of existing input, Cache Creek TMDL
Nickel	ug/L	**110**	**180**	**90**	12	**100**	CDPH Primary MCL	**52**	CTR Criterion Continuous Concentration
Zinc	ug/L	**130**	**150**	13	<10	**5000**	CDPH Secondary MCL	**120**	CTR Criterion Continuous Concentration

Notes:
CDPH = California Department of Public Health
CTR = California Toxics Rule
MCL = Maximum Contaminant Level
TSS = Total suspended solids
TMDL = Total Maximum Daily Load

CTR values for copper, lead, nickel and zinc (9, 2.5, 52 and 120 µg/L, respectively) are Criterion Continuous Concentration (CCC) values, which are based on the concentration to which aquatic life can be exposed for four days without deleterious effects. No CTR value is listed for iron.

The CTR human health criteria are meant to be applied at stream flows equal to or greater than the harmonic mean flow (40 CFR 131.38). The harmonic mean flow is a statistical value that can be calculated if sufficient stream-flow measurements are available. The harmonic mean flows are typically lower than the arithmetic mean flow. To investigate the degree of this difference, stream-flow data from 60 rivers across the country were evaluated by Lewis Rossman (Rossman, 1990). Rossman (1990) reports that on average, 7 day harmonic mean design flows were 2% lower than the arithmetic mean flows and 30 day harmonic mean design flows were 5.6% less than arithmetic mean flows. Therefore, sampling when flows exceed the annual arithmetic mean will typically indicate that the flows also exceed the harmonic mean, as is required by the CTR.

2) FISH CONSUMPTION BENCHMARKS

The USEPA (2001) established a MeHg ambient water quality criterion of 0.3 mg MeHg per kg of fish tissue (mg/kg) wet weight pursuant to the Section 304(a) of the CWA. This water quality criterion is the maximum allowable MeHg concentration in freshwater and estuarine fish and shellfish tissue that the USEPA considers necessary to protect consumers of fish and shellfish among the general population (USEPA, 2006).

The OEHHA established a screening level of 0.3 mg/kg to identify concentrations that may be a human health concern for frequent consumers of fish (Office of Environmental Health Hazard Assessment (OEHHA), 1999; DWR, 2007).

3) AQUATIC LIFE BENCHMARKS

The USEPA (2013d) recommends freshwater acute and chronic MeHg criteria of 1,400 ng/L and 770 ng/L, respectively. The acute criterion is an estimate of the highest concentration of MeHg in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The chronic criterion is an estimate of the highest concentration of MeHg in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. These aquatic life criteria are intended to be protective of the vast majority of aquatic communities (USEPA, 2013d). The USEPA does not provide a recommendation for an inorganic mercury criterion in ambient water.

4) DRINKING WATER BENCHMARKS

Federal and state drinking water regulations are based on inorganic mercury toxicity (OEHHA, 1999). The OEHHA is required to assess risk and adopt Public Health Goals (PHGs) for contaminants in drinking water based exclusively on public health considerations in accordance with the California Safe Drinking Water Act of 1996. The PHG for inorganic mercury (1.2 µg/L) in drinking water was established by OEHHA in 1999 and was re-evaluated and supported in 2005. PHGs for copper, lead and nickel are 300, 2 and 12 µg/L, respectively. No PHG values are listed for lead or zinc.

The CDPH establishes maximum contaminant levels (MCLs) for chemicals in drinking water to protect against the risk of adverse health effects, considering non-risk issues such as the feasibility of water treatment. The current mercury MCL is 2 μg/L. Although inorganic mercury is the dominant mercury species in the water column, analysis of total mercury concentration is typically performed to determine compliance with the standard. Primary (health based) MCL values for copper, lead, and nickel are 1,300, 15 and 100 μg/L, respectively. No primary MCL values are established for iron or zinc; secondary (aesthetic) MCL values for iron and zinc are 300 and 5,000 μg/L, respectively.

5) NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM

The National Pollution Discharge Elimination System (NPDES) is a program authorized by the CWA and administered by the Regional Water Quality Control Board to regulate point sources that discharge pollutants into surface water bodies. Point sources include but are not limited to factory pipes and mine tunnel portals.

One example of NPDES permitting is the Industrial Storm Water General Permit (Order 97-03-DWQ). The Industrial General Permit is an NPDES permit that regulates discharges associated with ten broad categories of industrial activities, and requires the implementation of management measures to achieve the “best available technology” (BAT) that is economically achievable, as well as the “best conventional pollutant control technology” (BCT). Draft effluent limitation guidelines associated with a proposed permit update (SWRCB, 2013b) lists a peak (one-day) TDS limitation of 450 mg/L, which is equal to a water quality objective set forth in the Basin Plan to protect agricultural uses, in the absence of information supporting a less protective limitation. The proposed limitations do not necessarily apply to a legacy site such as the Malakoff Diggins hydraulic pit. Limitations on turbidity (e.g., 250 NTU) are also set forth in the general permit.

The Industrial Storm Water General Permit, as described above, may be the most efficient permitting mechanism for management strategies related to sediment control in the Malakoff Diggins hydraulic pit. However, some discharges from the site may also be subject to the requirements of a more complicated, site-specific NPDES permit. A site-specific NPEDS permit would allow the regulated discharge of a specified amount of a pollutant into a receiving water body, provided that it complies with applicable laws, regulations and policies, including the federal and state antidegradation policies, as described below.

Federal Antidegradation Policy

The federal antidegradation policy, originally adopted in 1975, is expressed as a regulation in Title 40 of the Code of Federal Regulations, Section 131.12 (40 CFR 131.12). The federal policy requires that “water quality shall be maintained and protected.” More specifically, the federal regulation requires states to develop and adopt a statewide antidegradation policy and identify the methods for implementing such a policy. The state antidegradation policy and implementation methods are required, at a minimum, to ensure that existing water uses and the level of water quality necessary to protect these uses be maintained and protected. Where water quality exceeds the levels necessary to support beneficial uses, measures are to be taken to ensure that water quality is maintained and protected, unless the State finds that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located.

Water bodies can be classified in three tiers of antidegradation protection, pursuant to the provisions of the federal antidegradation policy, although the tiers were not specifically named in the federal policy. The tiers and the corresponding provisions of 40 CFR 131.12 are summarized below.

- Tier I: Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
- Tier II (High Quality Waters): Where the quality of water exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality must be maintained and protected unless the State finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the State is required to assure water quality adequate to protect existing uses fully. Further, the State is required to assure that the highest statutory and regulatory requirements are achieved for all new and existing point sources and all cost-effective and reasonable best management practices are used for nonpoint source control.
- Tier III (Outstanding National Resource Waters): Where high quality waters constitute an outstanding national resource, such as waters of National and State parks and wildlife refuges and water of exceptional recreational or ecological significance, that water quality must be maintained and protected.

Additional guidance pertaining to the federal antidegradation policy can be found in:

- "Guidance on Implementing the Antidegradation Provisions of 40 CFR 131.12" (United States Environmental Protection Agency, Region 9 (USEPA, 1987). This document provides general program guidance for states in Region 9 on developing procedures for implementing antidegradation policies. This document is appended to APU 90-004.
- "Tier 2 Antidegradation Reviews and Significance Thresholds" (USEPA, 2005). This memorandum provides technical recommendations to USEPA regions pertaining to the lowering of water quality in high quality waters.

The purpose of Tier 2 protection, according to USEPA (2005), "is to maintain and protect high quality waters and not to allow for any degradation beyond a de minimis level without having made a demonstration that such a lowering is necessary and important." To quantify this de minimis level, USEPA (2005) considers the “available assimilative capacity,” which is defined as the difference between the applicable water quality criterion for a specific water quality parameter and the ambient water quality of that parameter, where ambient water quality is better than the water quality criterion. A “significance threshold value” of ten percent (10%) of the available assimilative capacity is set forth for non-bioaccumulative chemicals of concern. Discharges that would reduce the assimilative capacity of a water body by greater than ten percent of its baseline assimilative capacity would typically require a full Tier 2 antidegradation review. Where there are multiple or repeated increases in discharges, a cumulative cap on the reduction of the assimilative capacity of a water body may be considered.

State Antidegradation Policy

The state antidegradation policy, “Statement of Policy with Respect to Maintaining High Quality of Waters in California” was issued by the SWRCB in 1968 as Resolution 68-16 and predates the federal policy. As stated in the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins (CRWQCB, 1998), the SWRCB has interpreted Resolution No. 68-16 to incorporate the federal antidegradation policy. Resolution No. 68-16 states, in part:

- Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies.
- Any activity that produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practical treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained.

To obtain an NPDES permit, a facility owner typically submits an application to the Regional Water Quality Control Board. The application must contain data characterizing the discharge rates and the chemical characteristics of the discharge and the receiving water. A simple antidegradation analysis may suffice if the following conditions are met:

1. The reduction of water quality is spatially localized or limited with respect to the water body, e.g., confined to the mixing zone;
2. The reduction of water quality is temporally limited and will not result in any long term deleterious effects on water quality, e.g., will cease after a storm event is over;
3. The reduction of water quality is not considered significant;

4. The activity causing the reduction in water quality has been adequately subjected to environmental and economic analyses under the California Environmental Quality Act (CEQA) or by other supporting information.

If there is a substantial increase in mass of pollutants discharged, or if there is mortality or significant impairment of growth or reproduction of resident species, a complete antidegradation analysis is typically required. Antidegradation analysis generally includes:

1. Comparison of receiving water quality to the water quality objectives applicable to the water body, including site-specific objectives if available, and considering the beneficial uses for the water body set forth in the applicable Basin Plan. Baseline water quality is defined as the best water quality of the receiving water that has existed since the Antidegradation Policy was established in 1968. If poorer water quality was permitted, the baseline water quality is defined as the most recent water quality resulting from the permitted action.

2. Balancing of the proposed action against public interest. Reduction in water quality is generally not permitted unless the reduction in water quality is offset by public benefit. Examples of social and economic parameters that could be affected typically include employment, housing, community services, income, tax revenues and land value. The reduction in water quality must be consistent with maximum public benefit, must not unreasonably affect actual or potential beneficial uses, and must not cause water quality to fall below the water quality objectives prescribed in the Basin Plan. Feasible alternative control measures, which may reduce, eliminate or compensate for negative impacts of the discharge, must be evaluated.

The data presented in the NPDES permit application are used by the Regional Water Quality Control Board staff to develop a draft permit containing effluent limits that are considered protective of water quality standards, as well as requirements for monitoring and reporting, facility-specific special conditions, and standard conditions. The draft permit undergoes pubic review prior to issuance of the final permit.

6) GENERAL PERMIT FOR DISCHARGES OF STORM WATER ASSOCIATED WITH INDUSTRIAL ACTIVITIES

The State Water Board's Industrial Storm Water General Permit Order 97-03-DWQ (General Industrial Permit) regulates discharges associated with 10 broad categories of industrial activities. The General Industrial Permit requires the implementation of management measures that will achieve the performance standards of best available technology economically achievable (BAT) and best conventional pollutant control technology (BCT). The General Industrial Permit requires the development of a Storm Water Pollution Prevention Plan (SWPPP) and a monitoring plan. Through the SWPPP, sources of pollutants are to be identified and the means to manage the sources to reduce storm water pollution are described.

7) WATERWAY-SPECIFIC BENCHMARKS

When federal standards appear to be over-protective or under-protective of the designated uses for a specific water body, the Regional Water Quality Control Board may develop site-specific water quality criteria. The CWA 303(d) list of impaired water bodies contains such site-specific water quality criteria. As mentioned above, Humbug Creek has been placed on the CWA Section 303(d) list by the SWRCB (SWRCB, 2013a) as impaired for sedimentation, mercury, copper and zinc. Pursuant to the 303(d) listing, waterway-specific TMDL limitations are to be developed for these constituents in Humbug Creek.

The Regional Water Quality Control Board uses the USEPA MeHg water quality criteria (and the OEHHA screening level) of 0.3 mg/kg in fish as a benchmark value to determine whether a surface water body should be listed (SWRCB, 2013a). Although listing of the South Yuba River has been recommended by the Regional Water Quality Control Board, and SWRCB staff have recommended approval by the State Board, site-specific values for the South Yuba River are not expected until 2021 (SWRCB, 2013a).

As an example of site-specific benchmark values for another water body, a MeHg limit of 0.14 ng/L was established for the water in Cache Creek based on potential fish consumption by humans. Methylmercury limits in trophic level 3 and 4 fish of 0.12 mg/kg and 0.23 mg/kg wet weight, respectively, were established for Cache Creek, and a reduction of total mercury discharge by 95% is required for individual upstream mine sites (California Regional Water Quality Control Board (CRWQCB), 2005).

Preliminary Engineering Evaluation

This preliminary engineering evaluation assesses the feasibility of selected management alternatives, focusing on effectiveness, constructability, cost, and administrative feasibility. No engineering design was conducted as part of this evaluation. The purpose of the evaluation is to provide an overview of the alternatives within the present regulatory framework, considering applicable federal, state and local environmental laws, regulations and standards, as described above.

Preliminary ranking criteria for the following management strategies are presented in Table 15. The most promising management strategies are sometimes a combination of individual strategies, and may involve other strategies that have not yet been identified. For completeness, the “No Action” alternative is also considered.

Table 15. Preliminary Ranking Criteria for Management Alternatives

Alternative	Aesthetic Impacts			Cultural Impacts			Maintenance Needs			Effectiveness			Initial Costs			Long Term Costs		
	High	*Mod*	*Low*	*High*	*Mod*	*Low*	*High*	*Mod*	*Low*	*High*	*Mod*	*Low*	*High*	*Mod*	*Low*	*High*	*Mod*	*Low*
1) Hydraulic Mining Pit- Management of Sediment and Metals Discharge																		
A. No Action			X			X			X			X			X	X		
B. Divert Surface Water Inflow to Hydraulic Pit		X		X				X			X		X				X	
C. Stabilize Hydraulic Pit	X			X			X			X			X			X		
D. Retain Sediment in Hydraulic Pit		X			X			X		X				X			X	
E. Dewater Hydraulic Pit		X		X			X			X			X				X	
F. Treat the Discharged Water		X				X	X			X			X			X		
2) Shaft 5 (Red Shaft) and North Bloomfield Tunnel Outfall- Management of Water and Metals Discharge																		
A. No Action			X			X			X			X			X	X		
B. Plug Shaft			X	X					X		X				X			X
C. Apply Discharge to Land			X	X				X		X				X			X	
D. Treat the Discharged Water		X				X	X			X			X				X	
3) Tunnel and Access Shafts- Management of Physical Hazards																		
A. No Action			X			X			X			X			X	X		
B. Fence Hazardous Features		X				X		X		X					X			X
C. Plug Hazerdous Features		X		X					X	X					X			X
D. Install Bat-Friendly Gates			X	X					X	X					X			X
E. Reroute Trail Segments		X			X		X				X		X					X

1) Management of Sediment and Metals Discharge from Hydraulic Mining Pit

Management strategies to reduce sediment discharge from the hydraulic pit can be grouped in two categories: erosion control and sediment retention. Six alternative strategies were considered for management of sediment and metals discharge from the Malakoff Diggins hydraulic pit:

A. No Action

B. Divert Surface Water Inflow around the Hydraulic Pit

C. Stabilize Hydraulic Pit

D. Retain Sediment in Hydraulic Pit

E. Dewater Hydraulic Pit

F. Treat the Discharged Water

Strategies B and C pertain to erosion control, while strategies D, E and F pertain to sediment retention.

Option 1A: No Action

Proposed Action

Under the "No Action" alternative, surface water, sediment and associated heavy metals would continue to discharge from the Malakoff Diggins pit. Although sediment deposition rates appear to be gradually slowing over time, considering the pit's large size and the instability of the pit walls, erosion from the pit is expected to continue for hundreds of years. Sediment deposition within the pit is altering the gradient of the pit floor, and appears to be causing a physical hazard at the Hiller Tunnel inlet. Erosion and discharge rates from the pit may increase in the future as a result of slope instability and/or climate change.

Discussion

Unmanaged discharge of sediment and associated heavy metals from the Malakoff Diggins pit would not be in accordance with current environmental regulations and is therefore not considered administratively feasible. The Park is currently regulated by a Waste Discharge Permit with the Central Valley Regional Water Quality Control Board (Order No. 76-258) and Parks is currently paying an annual Waste Discharge fee (CRWQCB, 1976).

Data Gaps

Additional information regarding slope stability within the pit is required to predict future sediment discharge rates. Additional information on metal sources or hot spots is also needed to refine sediment abatement remediation methods.

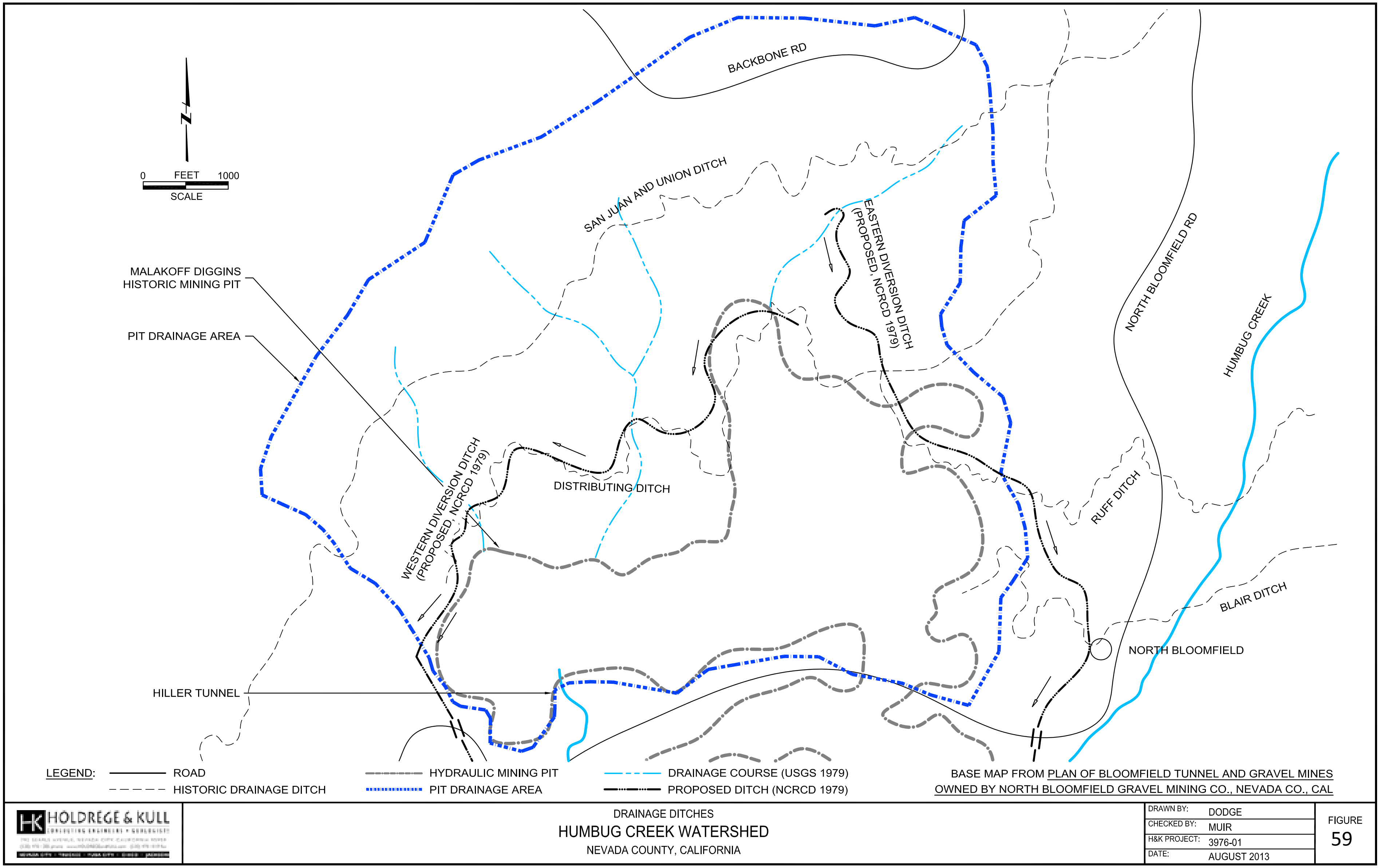


Figure 59. Proposed and Historical Drainage Ditches

The proposed ditches that would divert water from the pit rim around Malakoff Diggins Pit are depicted, as are historical ditch locations.

Option 1B: Divert Surface Water Inflow to Hydraulic Pit

Proposed Action

Diversion ditches may be employed to capture surface water runoff from the drainage courses above Malakoff Diggins pit and to convey the surface water around the pit, thereby reducing the amount of water eroding the pit walls and transporting sediment and sediment-bound metals from the pit. Alternatively, overside drains may be used to capture surface water at key locations above the pit and to direct the water over the slopes and through the pit in closed pipe collectors or armored swales.

Discussion

The Malakoff Diggins hydraulic pit measures approximately 340 ac, and its contributory drainage area (including the pit) measures approximately 3 km^2 (1,200 ac). The pit and its drainage area are depicted on Figure 56 on page 118. NCRCD (1979b) provided a preliminary design and cost estimate for construction of two diversion ditches (east and west) above the hydraulic pit. The eastern ditch would drain to the east along the 1,036 m (3,400 feet) elevation contour line, and the western ditch would drain to the west from approximately 1,097 m (3,600 feet) in elevation. The ditches may follow segments of historical water conveyance ditches. The approximate alignments of the historical ditches and proposed ditches are depicted on Figure 59 on page 134.

The diversion ditches considered by NCRCD (1979b) measure approximately 5,120 m (16,800 ft (3.2 mi)) in total, from their origin above the hydraulic pit to the existing culverts beneath North Bloomfield Road. A typical ditch section would be 0.6 to 1.2 m (2 to 4 ft) deep and approximately 8 to 6 m (20 ft) wide at crest height. In addition, a berm on the downslope side of the ditch would need to be wide enough to allow for maintenance access, and may be two meters (eight feet) wide or greater. A typical cross section is depicted on Figure 60 on page 136.

The diversion ditches would decrease the contributory drainage area by approximately half, and would decrease pit run-on by approximately 10 percent. NCRCD (1979b) estimated that the two diversion ditches would decrease downstream sedimentation by 15 to 30 percent, at a cost of $547,800 (1979 dollars), or $1,763,000 current dollars (United States Department of Labor, 2013). The ditches would also require periodic maintenance. Although the ditches do not represent a complete solution, they could be considered in combination with sediment retention strategies.

The proposed ditches may follow segments of historical water supply ditches, including the "Ruff Ditch" and "Distributing Ditch," which are also depicted on Figure 59 on page 134. The approximate alignment of the historical ditches is based on *Plan of Bloomfield Tunnel and Gravel Mines Owned by North Bloomfield Gravel Mining Co., Nevada Co., Cal.* (Tabular Statement, NBGM Co., May 23, 1874), a copy of which was obtained from the Searls Historical Library in Nevada City, California. In addition to the historical ditches, prehistoric features have also been identified in the vicinity of the proposed ditch alignments. Significant cultural resources will need to be assessed and avoided or treated during design and construction.

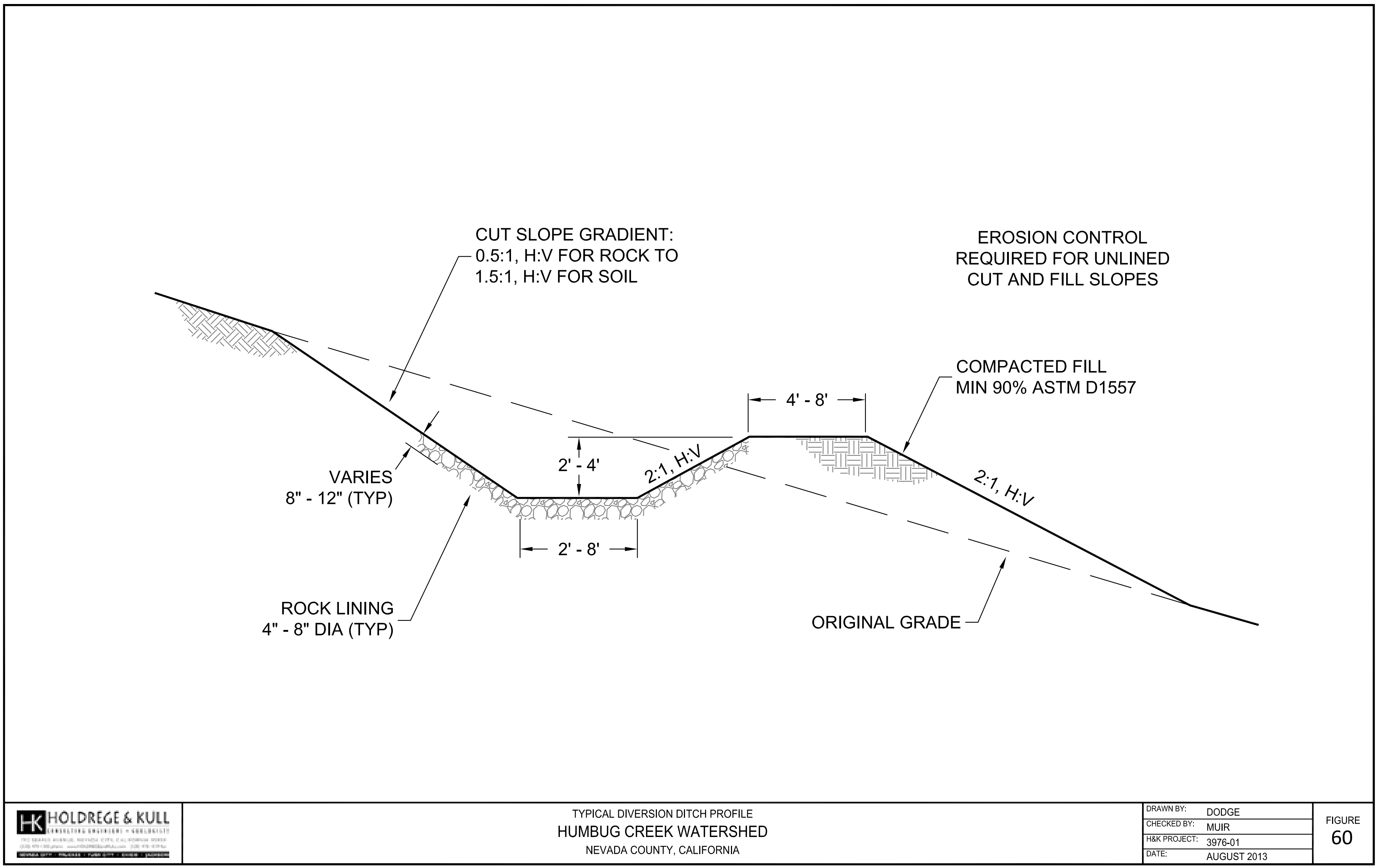


Figure 60. Typical Diversion Ditch Profile

The proposed ditches that would divert water from the pit rim around Malakoff Diggins Pit could be constructed to resemble this typical diversion ditch profile.

The primary function of the proposed ditches is to divert storm water around the hydraulic pit from ephemeral drainage courses above the pit, thus reducing erosion by reducing surface water flow over the pit walls, and reducing sediment transport by reducing the surface water flow out of the pit via Hiller Tunnel. The ditches proposed by NCRCD (1979b) were to be lined with rock to prevent erosion, and water lost from infiltration through this permeable ditch lining would tend to contribute to subsurface seepage into the hydraulic pit. It is recommended that a less permeable ditch lining be considered to reduce seepage in key segments of the ditch above unstable portions of the pit.

Data Gaps

The discharge in the drainages would need to be quantified to design water conveyance structures. Depending on the size and configuration of the conveyance structures and their installation, adverse impacts to the historical value of the area surrounding the pit could likely be avoided or mitigated. The previous estimate of sediment retention resulting from surface water diversion NCRCD (1979b) would need to be re-evaluated based on updated hydrograph data. The project area would have to be defined and cultural resources considered. Impacts due to decreased water input to vegetation and associated wildlife habitat will also need to be evaluated.

Option 1C: Stabilize Hydraulic Pit

Proposed Action

The steep pit walls are subjected to headwall and gully erosion, hydrostatic pressures from seepage, mass wasting, and progressive slope failure. Pit stabilization techniques may include recontouring, mechanical slope stabilization, pit wall dewatering, erosion control, sediment retention and revegetation.

Discussion

Recontouring of the pit walls would essentially constitute reclamation of the mining pit. The current un-reclaimed pit serves as an example of historical mining practices that were conducted in the absence of environmental stewardship. The historical value of the mining pit, as well as the high cost of reclamation, are factors to be considered while evaluating alternatives for pit stabilization. Re-contouring and stabilization of the entire 1.3 m^2 (330 ac) mining pit is not considered economically feasible and would not be consistent with Park objectives. Less invasive, but potentially less effective stabilization techniques include the installation of horizontal dewatering wells and revegetation of the pit walls.

Revegetation would typically require soil amendment and planting, and would serve to retain soil on slopes. Revegetation of the northeastern portion of the pit would promote native vegetation which could increase the roughness of the pit floor to hold eroded alluvium in the pit. The northeastern lobe of the pit floor is currently the least vegetated area of the pit and also features the most actively eroding pit walls. Revegetation may be inconsistent with Park objectives if it will

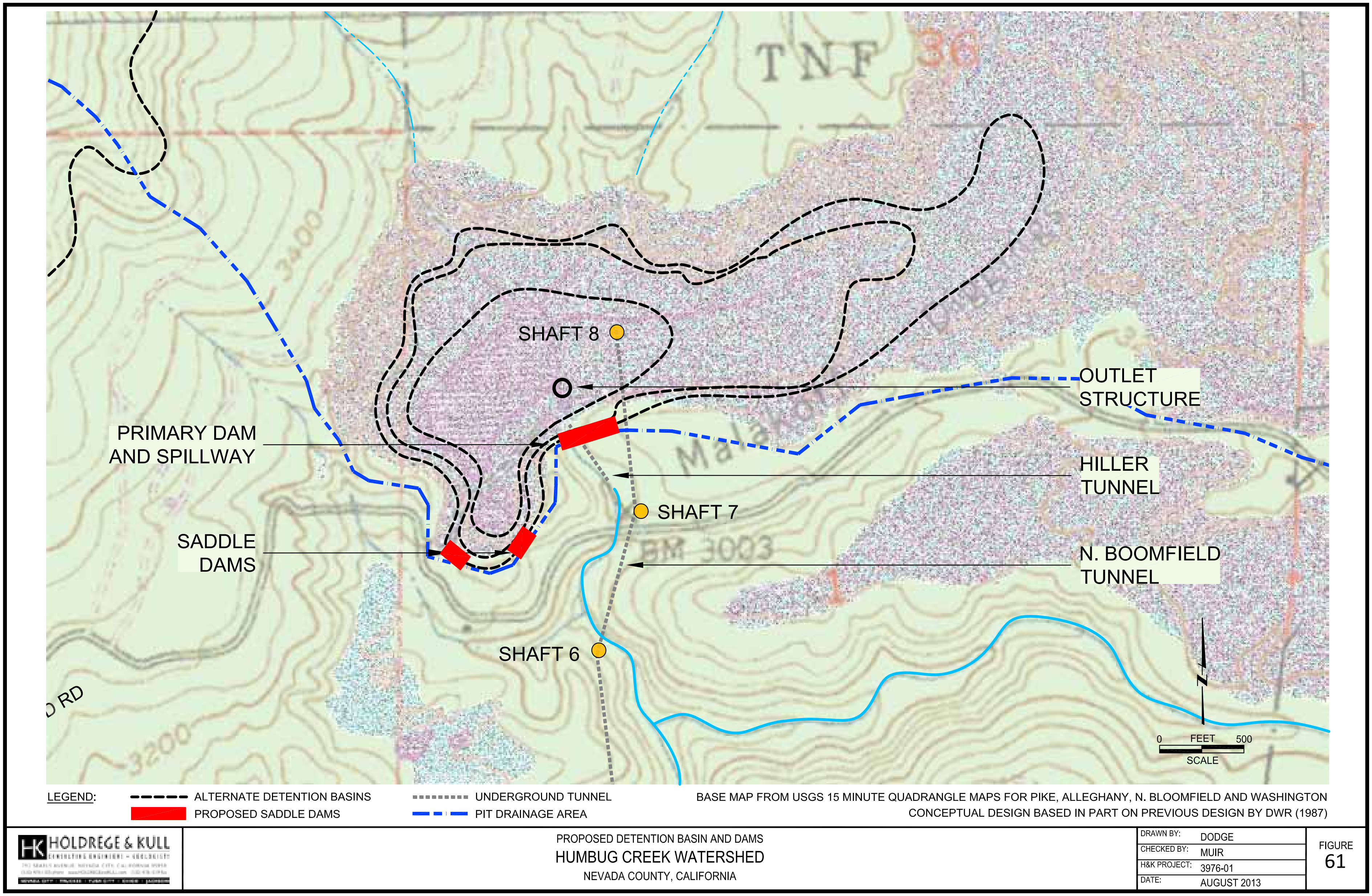


Figure 61. Proposed Detention Basin and Dams
The proposed detention basin in the Malakoff Diggins pit could include three reinforced dam wall structures, called saddle dams.

lessen the cultural integrity of the pit. Revegetation of certain portions of the pit, however, may be an option if they are not culturally important locations.

A pilot stabilization project may be considered to test specific stabilization strategies such as dewatering and revegetation, and possibly to preserve specific Park features above an unstable slope. A pilot project may incorporate interpretive features, to demonstrate to Park visitors why reclamation is important in the context of mining.

A typical pilot project may be located in an area of shallow slope failure and may be approximately 20,000 square meters (five acres) that no longer contributes to the historic character of the pit, comprising a 200m (500 ft) segment of the pit wall. Based on typical unit costs for reclamation, reclamation of a typical pilot area may cost $250,000, including dewatering, revegetation and routine maintenance for five years. Costs would be less for a relatively stable, flat-lying project area, where only revegetation, surface water routing and erosion control are necessary. Costs could exceed $250,000 for steep, unstable cliff areas.

Data Gaps

Outstanding questions about revegetation include the type of soil amendments and what type of plants would make revegetation successful. The project area would have to be defined and cultural resources considered.

The cost of landslide stabilization would depend upon the depth of the failure plane, some of which were identified by Peterson (1979). MacDonald (1989) acknowledged that areas with deep-seated failure planes may destabilize adjacent areas with shallower failure planes by removing lateral support. Therefore, it is necessary to investigate slope stability prior to siting a pilot project for slope stabilization and revegetation.

Option 1D: Retain Sediment in Hydraulic Pit

Proposed Action

A detention pond would be designed and constructed to detain storm water flows within the pit, to equalize pit discharge, and to settle suspended solids.

Discussion

Detention ponds have been constructed at many sites owned by the Forest Service (Tahoe National Forest) in this region. The ponds must be appropriately sized to settle fine silts and clays during the design storm events. Over time, the pond's effectiveness would tend to diminish as a result of lost capacity due to sediment retention. A detention pond within the Malakoff Diggins pit would modify and add features to a known historical property that has important visual values and may be inconsistent with Park objectives. The specific values will need to be considered in light of specific design and suitable treatments for the loss of any significant values will need to be considered.

Sediment retention strategies involve the construction of sediment traps or detention basins and additional treatment such as the addition of chemical flocculants to remove clay-sized suspended

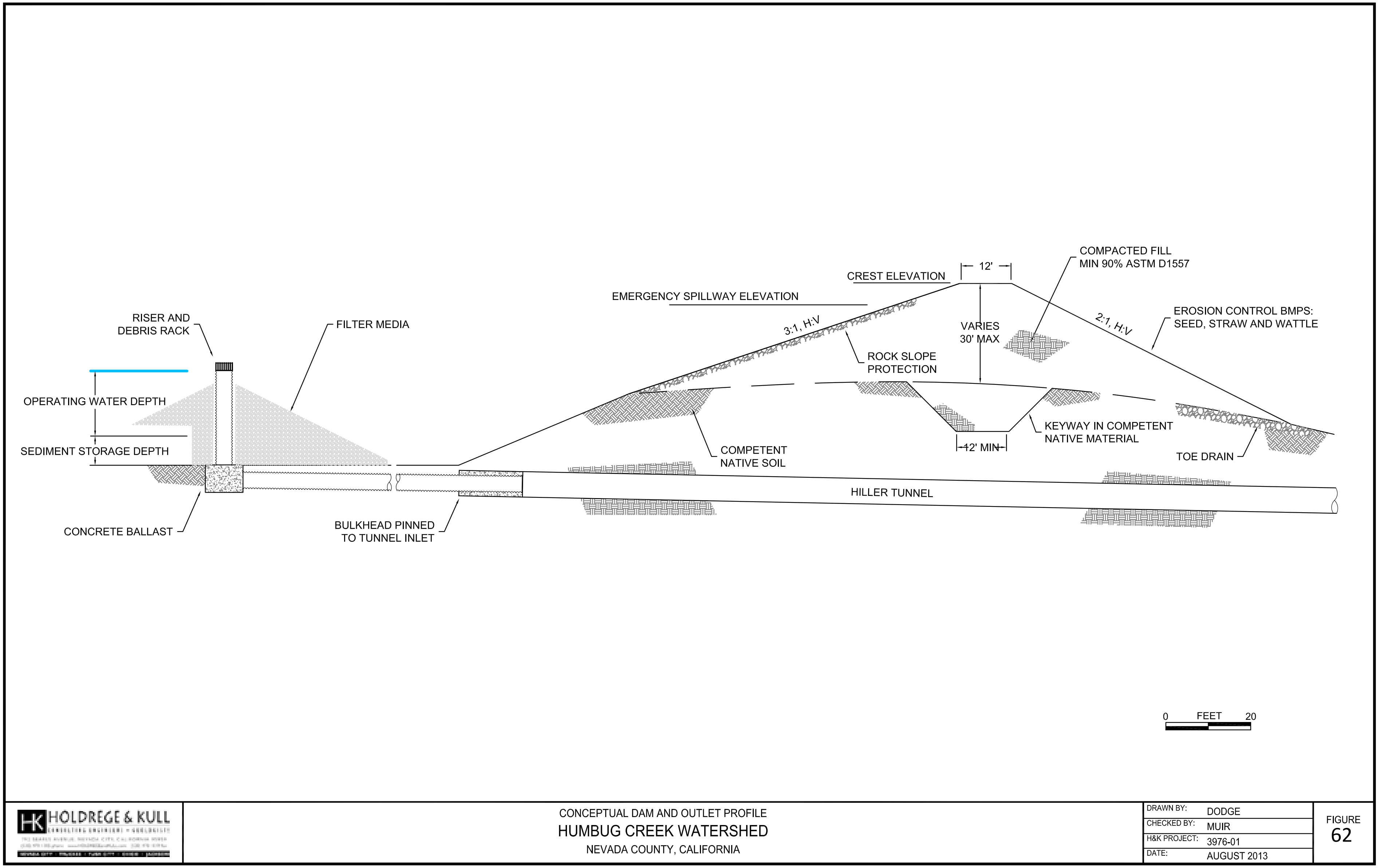


Figure 62. Conceptual Dam and Outlet Profile
Conceptual Dam and Outlet Profile. The proposed detention basin and outlet structure includes a standpipe and filter media that would serve to filter water before allowing the water to flow out the Hiller Tunnel.

solids. Primary design considerations are (1) the large basin size and/or mechanical filtration rates required by winter storm flows and spring snowmelt, (2) the potential detrimental effect that a large pond may have on the stability of adjacent pit slopes, and (3) whether sediment removal is necessary as an ongoing maintenance task, regardless of whether the sediment is settled or filtered.

Figure 63. Malakoff Diggins Pit, Flooded, 1954
This photo demonstrates the changing nature of the Malakoff Diggins pit over the last century. A water and sediment detention structure near the inlet of Hiller Tunnel may return the pit to similarly flooded conditions. (Photo by Alma Lavenson; courtesy of The Bancroft Library, University of California, Berkeley; BANC PIC 1987.021:285-PIC.)

DWR (1987) proposed the construction of a large sediment detention basin occupying the entire western and central segments of the pit floor (Figure 61 on page 138). A saddle dam and two wing dams would be constructed to allow the retention of surface water throughout the rainy season without discharge. Despite the surface water retention, suspended solids would tend to be discharged during dry-season release from the basin. Cost was estimated to be $282,500 in 1987 dollars, or $581,000 in 2013 dollars. This cost does not include periodic removal of sediment from the detention basin, should sediment removal be required.

MacDonald (1989) recommended the construction of small settling basins and passive, in-stream chemical flocculation. MacDonald recommended that the settling basins be designed to hold runoff from the 10-year, 24-hour design storm, which may not be consistent with current regulations requiring the detention of larger, less frequent storm events. These larger storm events are expected to contribute significantly to sediment release from the hydraulic pit.

If sediment must be removed to maintain basin capacity, typical dredging costs are $13/m^3$ ($10/$y^3$). Grading for equipment access, disposal site preparation and equipment mobilization may cost $50,000 to $100,000. Based on the recently estimated rate of sediment deposition 7 m/yr (0.23 ft/yr), the western 80,000 square meters (20 acres) of pit floor may collect 8,000 m^3/yr (10,000 yd^3/yr) of sediment, and another 4,000 m^3/yr (5,000 yd^3/yr) may be discharged. Thus, dredging for basin maintenance may be $100,000 per year, assuming dredge spoils can be placed within the pit.

Current sediment deposition rates indicate that retention is feasible. Furthermore, management strategies for sediment retention are proposed that avoid the need for routine sediment removal (dredging), and incorporate safety features for the Hiller Tunnel inlet and outlet. This may be accomplished by employing a filtering outlet structure that can be extended vertically as sediment is deposited. A profile and conceptual details of the outlet structure are depicted on Figure 62 on

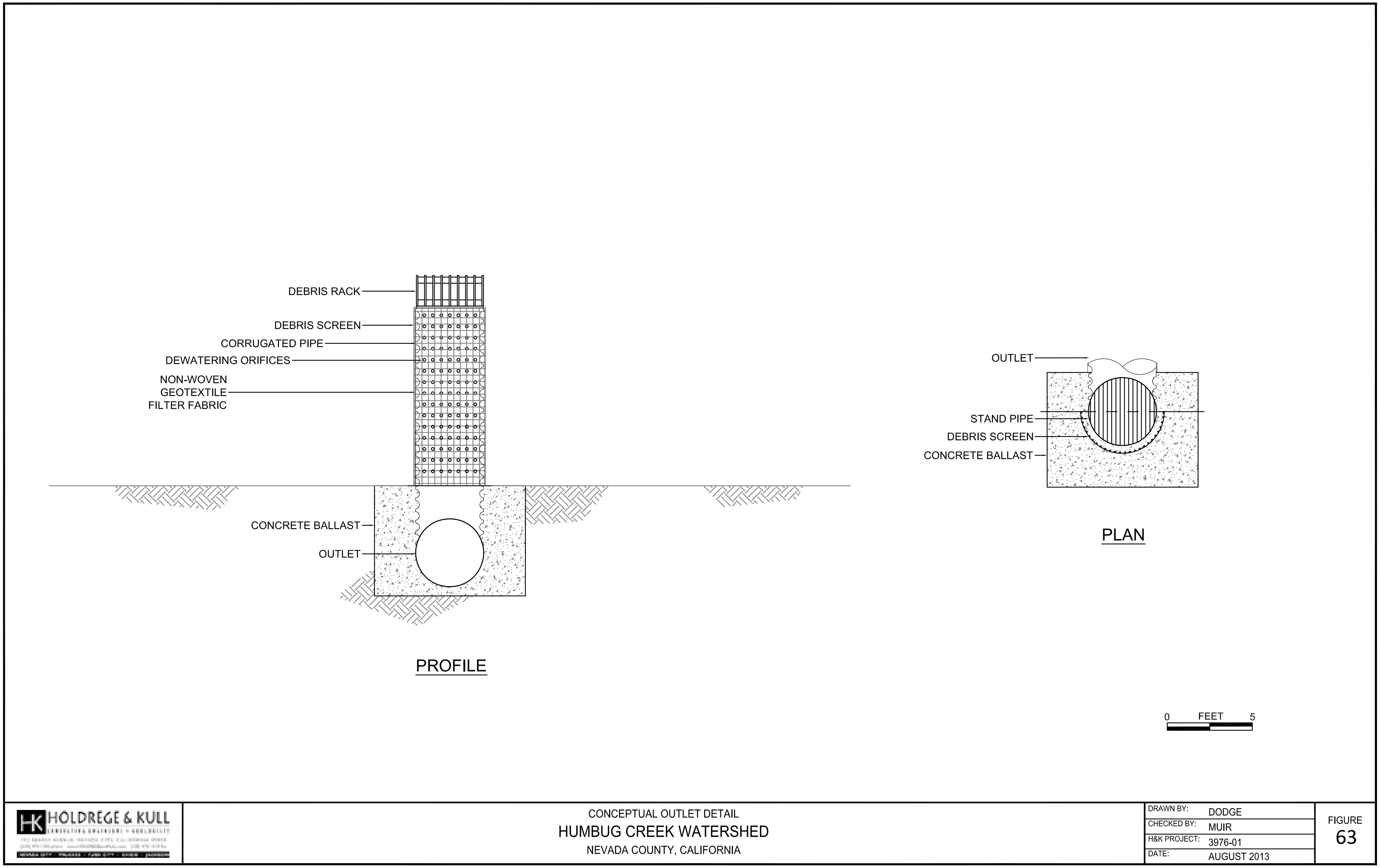


Figure 64. Conceptual Outlet Detail
Standpipe and filter media detail includes a debris rack covering the top of the pipe, and a series of layered filter screens along the length of the standpipe including a geotextile fabric and debris screen.

page 140 and in Figure 64 on page 142, respectively. Saddle dams are recommended to allow for long-term sediment retention capacity as the basin fills with sediment over the years. A dam plan and profile are depicted on Figure 62 on page 140.

Data Gaps

The water flow paths in the pit would need to be mapped and quantified to inform this management strategy. Additional monitoring of flow, suspended sediment and bedload is required above and within the hydraulic pit. A survey of the pit is required so that the design can be based on accurate pit topography. Infiltration rates must be established for design of the detention basin outlet structure. More information is needed regarding particle size above the Hiller Tunnel inlet. Determination of the capacity of the detention pond before it reaches the existing saddle height and the additional capacity added to the detention pond with the southwest rim saddle dams is needed.

Adverse impacts to the historical and biological values of the hydraulic pit and its components would need to be considered.

Option 1E: Dewater Hydraulic Pit

Proposed Action and Discussion

One option to reduce discharge of turbid water to Humbug Creek from Hiller Tunnel would be to dewater the pit using a subsurface infiltration gallery or a group of dewatering wells. The intercepted subsurface water, which would be relatively sediment-free, would be discharged to Humbug Creek via Miner's Creek or another suitable surface water course.

This alternative has an obvious technical limitation related to the limited discharge capacity of a subsurface dewatering system, and the need for retention and equalization of storm flows. In the absence of electrical power to the hydraulic pit, the dewatering system would need to function passively, likely requiring a siphon or deep horizontal borings through bedrock. There is an elevation difference of up to 27 m (90 ft) between the pit floor and the nearest surface water drainage, Miner's Creek.

Data Gaps

A number of uncertainties and critical information gaps would need to be addressed before this alternative can be evaluated. In addition, the watershed assessment has identified low pH and high dissolved metals in shallow subsurface seepage, which should not be introduced to surface waters as a result of dewatering. Potential negative impacts of dewatering on the pit's existing vegetation would need to be considered. Depending on the size and configuration of the pit siphon and its installation, adverse impacts to the historical value of the pit itself could likely be avoided or mitigated. The project area would have to be defined and inventoried for cultural and biological resources as a first step. It is recommended that a pilot study to determine the filter capacity and its effectiveness at removing the very fine sediment be considered.

Option 1F: Treat the Discharged Water

Proposed Action and Discussion

Additional information is required regarding dissolved metals concentrations in surface water in the hydraulic pit to evaluate whether treatment of water is worthy of consideration. Active water treatment (water treatment facility) to remove metals from surface water in the hydraulic pit is considered a potentially expensive management alterative. No electrical power is currently available in the hydraulic pit. Passive treatment (flocculants and settling) may be less expensive but would require significant alteration of the pit floor.

2) Management of Water and Metals Discharge from North Bloomfield Tunnel

The North Bloomfield Tunnel extends from the Malakoff Diggins pit and is partially blocked. The tunnel has eight access shafts (Shafts 1 through 8) and a tunnel outfall (outlet). Locations are depicted on Figure 65 on page 146. Table 16 on page 145 includes elevations and physical conditions for each portal. Shafts 1 through 6 and the tunnel outfall are depicted in Photos 1 through 7. Shaft 7 has not been identified and is apparently collapsed. Shaft 8 is located beneath the sediment in the mining pit.

Elevated metals concentrations have been detected in discharge from the North Bloomfield Tunnel at two locations: access shaft 5 and the North Bloomfield Tunnel outfall. The flow rates of the discharges are relatively low and do not appear to increase significantly during the rainy season. Four alternative strategies are considered for management of water and metals discharge from the North Bloomfield Tunnel and its access shafts:

A. No Action

B. Plug

C. Apply the Discharge to Land

D. Treat the Discharged Water

Option 2A: No Action

Proposed Action and Discussion

No discharge has been observed from Shafts 1, 2, 3, 4, 6, 7 and 8 and therefore no action is proposed at these locations. Discharge from Shaft 5 and the North Bloomfield Tunnel outlet would continue.

Option 2B: Plug

Proposed Action

The existing point source discharges at Shaft 5 and the North Bloomfield Tunnel outfall may be eliminated if the shaft is plugged. (Shafts 2, 3 and 4 may also be plugged, but not to eliminate

Table 16. North Bloomfield Tunnel and Access shafts

Feature	Discharge Estimate[1] (gpm)	Location		Elevation			Portal Condition			Management Strategies	
		Lat. (°N)	Long. (°W)	Ground Surface (ft)	Water Surface (ft)	Blockage Elevation (ft)	Open	Col-lapsed	Sub-merged	Environmental Hazards	Physical Hazards
Tunnel Outfall	10	39° 20.923'	120° 55.591'	2,504	2,504	na	X			Monitor / Permit	Bat gate
Shaft 1	none	39° 21.159'	120° 55.481'	2,758	2,751	2,746			X	not identified	not identified
Shaft 2	none	39° 21.296'	120° 55.423'	2,798	2,754	2,682	X			not identified	Fence and post / plug
Shaft 3	none	39° 21.439'	120° 55.354'	2,849	2,821	2,791	X			not identified	Fence and post / plug
Shaft 4	none	39° 21.591'	120° 55.341'	2,862	2,817	2,698	X			not identified	Fence and post / plug
Shaft 5	2	39° 21.730'	120° 55.329'	2,883	2,883	2,807			X	Monitor / Permit	Fence and post
Shaft 6	none	39° 21.884'	120° 55.333'	2,960	2,957	2,956			X	not identified	Fence and post
Shaft 7	none	39° 22.023'	120° 55.300'	3,015	unknown[2]	na		X[4]		not identified	not identified
Shaft 8	none	39° 22.173'	120° 55.322'	3,022	unknown[3]	na		X[4]		not identified	not identified

Notes:
1 Based on dry season observation.
2 Mapped location of Shaft 7 is north of N. Bloomfield Road.
3 Mapped location of Shaft 8 is near Hiller Tunnel entrance in hydraulic pit floor.
4 Shaft portal was not identifed at mapped location; therefore, collapse is assumed.

References:
Plat of the Bloomfield Hydraulic Mine, Hoffman, September 1873
Plan of Bloomfield Tunnel and Gravel Mines Owned by North Bloomfield Gravel & Mining Co., Nevada Co., Cal., undated

discharge, rather to mitigate a physical hazard, see Option 3B.) Typical plug installation is estimated to be $12,000 to $15,000.

Discussion

Plug installation is not considered technically feasible for Shaft 5 or for the North Bloomfield Tunnel outfall based on the potential effects of hydrostatic pressures on the blockage in the main tunnel. Installation of a foam or concrete plug may not be suitable in instances of wildlife habitation. Installation of plugs may be inconsistent with Park objectives.

Data Gaps

Engineering studies would be required to evaluate geotechnical stability and potential hydrostatic pressures. With respect to historical resources, a determination of adverse effect would need to be conducted. The nature of the fractured bedrock around the shaft would need to be investigated to ensure that plugging would not result in seepage of water of similar quality nearby the plug.

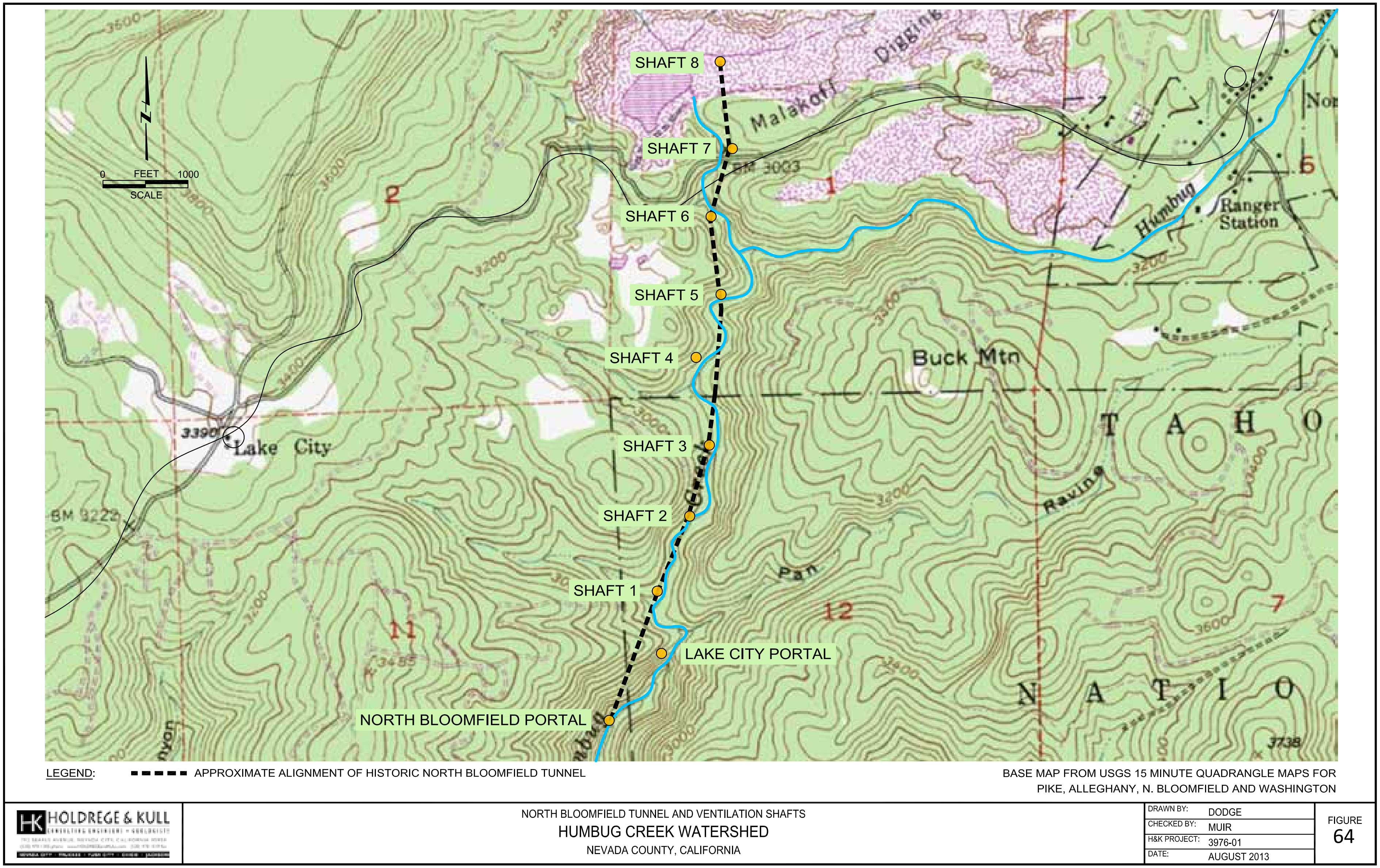


Figure 65. North Bloomfield Tunnel and Access Shafts

The North Bloomfield Tunnel is 7,846 ft long and it has eight access shafts that are approximately 1,000 ft apart. The access shafts extend from 250-400 ft from the surface to the tunnel and were used to facilitate construction and operation of the tunnel.

Option 2C: Apply Discharge to Land

Proposed Action

The existing point source discharge at Shaft 5 and/or the North Bloomfield outfall may be applied to land, provided that the land application does not result in other adverse environmental effects.

Discussion

Permitting of the point source discharge would be required for land application, and the application area would require routine monitoring to document that the land application complies with the permitting requirements. Although the discharge flow rate is low, elevated metals concentrations in the discharge may conflict with applicable water quality objectives.

Flow measurement and monitoring are recommended for Shaft 5 and the North Bloomfield Tunnel outfall to determine permitting requirements. Quarterly flow measurement, surface water sampling, laboratory analysis and reporting for a period of one year at Shaft 5 and the North Bloomfield Tunnel outfall is estimated to cost $8,000. Recommended monitoring parameters are listed in Table 17 on page 147.

Table 17. Additional Monitoring Parameters

Constituent	EPA Method	Target MDL (mg/L)
Calcium, dissolved	M200.7 ICP	0.2
Magnesium, dissolved	M200.7 ICP	0.2
Sodium, dissolved	M200.7 ICP	0.3
Potassium, dissolved	M200.7 ICP	0.3
Chloride, dissolved	M325.2	1
Bicarbonate, dissolved	M2320B-Titrametric	2
Carbonate, dissolved	M2320B-Titrametric	2
Total alkalinity, dissolved	M2320B-Titrametric	0.2
Nitrate/Nitrite (as N), dissolved	M353.2	0.02
Silica, dissolved	M200.7 ICP	0.2
Sulfate, dissolved	M300.0	10
pH	M150.1-Electrometric	0.1 su
Conductivity	M120.1-Meter	1 mmho/cm
Total Dissolved Solids	M160.2	10
Total Suspended Solids	M160.2	10
Hardness (as CaCO3)	M130.2	5

Data Gaps

Engineering studies would be required to evaluate the potential effectiveness of land application. It is recommended that additional information regarding flow rate, dissolved metals concentrations and seasonal variation be collected. Additionally, it is recommended that information on cultural and biological resources be collected in order to assess the effects of alternative treatments.

Option 2D: Treat the Discharged Water

Proposed Action and Discussion

The discharged water may need to be treated prior to discharge to Humbug Creek. Water treatment is expected to require significant initial cost and significant ongoing cost in the form of monitoring and maintenance. Engineering design and permitting would be required. Water conveyance and treatment structures would be required. Additional information is required regarding flow rate, dissolved metals concentrations and seasonal variation, as described above. A pilot treatment study would typically be required prior to final design.

3) Management of Physical Hazards at Tunnels and Shafts

The open outlet of the North Bloomfield Tunnel, inlet of the Hiller Tunnel, and several open access shafts associated with the North Bloomfield Tunnel (some narrow and more than 50 ft deep), present potential physical hazards. In a report to Senator Dianne Feinstein in 2007, the Office of Mine Reclamation indicated that the Malakoff Diggins site was listed in its Abandoned Mine Lands Database as a high priority for addressing physical hazards because the public is at risk from openings into underground mine workings (Craig, 2007).

Some of the vertical access shafts have some sort of wire fencing around their openings, and some shafts are filled with water. Locations, elevations and physical characteristics for each feature are listed in Table 16 on page 145. Locations are depicted on Figure 65 on page 146.

Five alternative strategies are considered for management of the potential physical hazards:

A. No Action

B. Fence Hazardous Features

C. Plug Hazardous Features

D. Install Bat Gates

E. Reroute Trail Segments

Option 3A: No Action

Proposed Action and Discussion

Shaft 1 is submerged and does not appear to present a physical hazard. Shafts 7 and 8 have not been located and are apparently collapsed, but could pose a physical hazard in the future. No action is presently proposed at these locations. Shafts 2, 3, 4, 5 and 6 are open and present physical hazards for public safety.

Option 3B: Fence Hazardous Features

Proposed Action

Shafts 2, 3, 4, 5 and 6 are open and present physical hazards. Access to the hazardous features may be restricted by installing fences and signage.

Discussion

Fencing and posting is estimated to cost $3,000 per location. Fencing and signage would require routine inspection and maintenance, and would be subject to vandalism.

Data Gaps

With respect to biological and historical resources, a determination of effect and adverse effect would need to be conducted following the cultural resource inventory and evaluation, and biological surveys such as bat surveys.

Option 3C: Plug Hazardous Features

Proposed Action

Shafts 2, 3, 4, 5 and 6 are open and present physical hazards. Access to the hazardous features may be restricted by installing fences and signage, foam plugs and/or wildlife-friendly gates.

Discussion

Foam plugs could be installed using a false bottom so that the foam does not come in contact with standing water in the access shafts. Installation of plugs would require less frequent inspection and maintenance than fencing, but would require engineering design and more invasive construction activities. Plugs may not be suitable in some instances because of wildlife habitation or potential hydrostatic pressure buildup. In these cases a vent incorporated in the foam plug could be used to allow for pressure equalization or fencing could be a more suitable option. The foam plugs could be covered with several feet of soil to improve the aesthetics and to prevent any direct access to the foam surface. Alteration to the historical fabric may be inconsistent with Park objectives.

Data Gaps

With respect to biological and historical resources, an assessment of the effects of proposed treatments would need to be conducted following the cultural resource inventory and evaluation, and biological surveys such as bat surveys.

Option 3D: Control Access to North Bloomfield Tunnel Outlet and Hiller Tunnel Inlet

Proposed Action

The North Bloomfield Tunnel outlet is open, and a bat-friendly gate may mitigate the safety hazard. Plug installation at the North Bloomfield Tunnel is not recommended based on water discharge and possible bat habitation. The Hiller Tunnel inlet is open and unstable, accumulation of sediment is occurring, and sloping back accumulated sediment may mitigate the safety hazard. Moving sediment near the inlet to Hiller Tunnel may be inconsistent with Park objectives, depending on design and access.

Discussion

Construction of a bat-friendly gate at North Bloomfield Tunnel is estimated to cost $10,000 to $15,000, considering biological survey requirements. Periodic monitoring of the bat-friendly gate is appropriate to address potential vandalism and maintenance. Installation of gate components on the historical resource may be inconsistent with Park objectives, depending on specific design. Sloping back accumulated sediment at the inlet to Hiller Tunnel is estimated to cost $10,000, considering biological and cultural requirements.

Data Gaps

Biological evaluation would be appropriate to determine habitation and disturbance to habitat. With respect to historical resources, an assessment of the effects of proposed treatments would need to be conducted following the cultural resource inventory and evaluation.

Option 3E: Reroute Trail Segments

Proposed Action

Reroute segments of the Humbug Trail around Shaft 3 and Shaft 5, and construct a boardwalk at Shaft 5.

Discussion

The Humbug Trail is located just above an eroding steep slope above Shaft 3. The trail could be re-routed upslope to allow a greater distance between the trail and the steep slope and the shaft opening. A boardwalk at Shaft 5 could be constructed to re-route the Humbug Creek Trail around Shaft 5, reducing the potential for Park visitors to come into contact with discharged water and precipitated solids. An interpretive feature at Shaft 5, such as an explanatory sign, would demonstrate to Park visitors the functions of monitoring and remediation in the context of legacy mining features.

Data Gaps

With respect to historical resources, a determination of effect and adverse effect would need to be conducted following the cultural resource inventory and evaluation.

Preliminary Management Recommendations

The purpose of this preliminary evaluation is to assist DPR with the selection of possible alternative management strategies for water quality compliance and protection of public health and safety at the Park while maintaining the Park's outstanding cultural values. Ranking criteria, as set forth in Table 15 on page 132, include:

- Aesthetic impacts,
- Maintenance needs,
- Effectiveness,
- Initial costs, and
- Long term cost.

The management strategies are intended to address the underlying environmental conditions rather than to serve as a temporary fix, and are intended to be consistent with DPR mission and management objectives to the maximum practicable extent. The management strategies are intended to limit impact to cultural and historical features, and to limit routine maintenance needs whenever practicable. Recommended management strategies are summarized in Figure 66 on page 152 and are described below.

1) Management of Sediment and Metals Discharge from Hydraulic Mining Pit

The following strategies are recommended for management of sediment and metals discharge from the Malakoff Diggins hydraulic mining pit.

- Construct a detention pond in the western end of the Malakoff Diggins hydraulic pit to equalize storm water discharge and to retain suspended solids, as depicted conceptually on Figure 61 on page 138.
- Incorporate safety features for the Hiller Tunnel inlet, and avoid the need for routine sediment removal (dredging). This may be accomplished by employing a filtering outlet structure that can be extended vertically as sediment is deposited. A profile and conceptual details of the outlet structure are depicted on Figure 62 on page 140.
- Construct a filtering outlet structure as depicted conceptually in Figure 62 on page 140 and Figure 64 on page 142. The outlet structure would address physical hazards at the Hiller Tunnel inlet because it would be secured to the inlet using a concrete bulkhead, and would

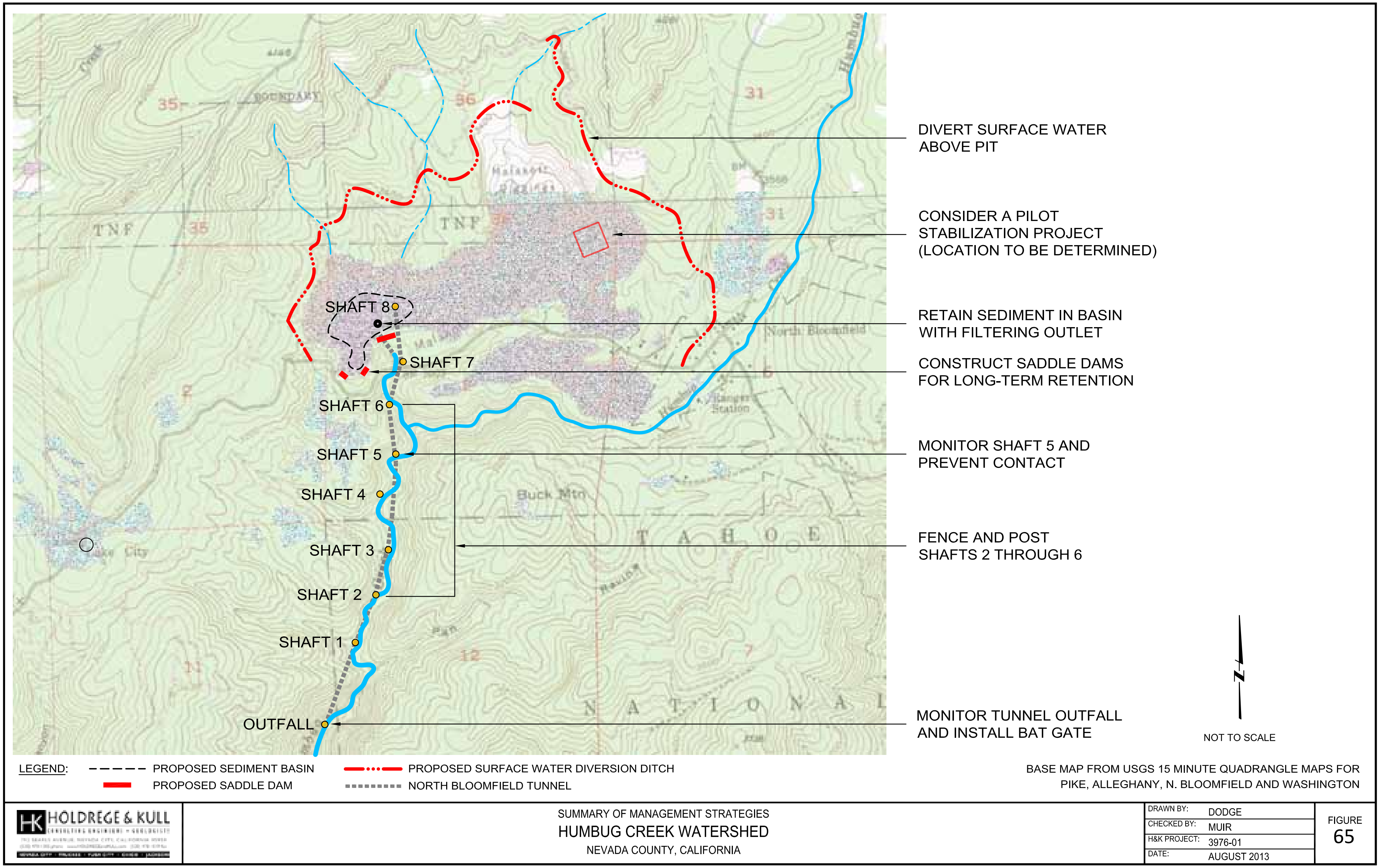


Figure 66. Summary of Management Strategies for Humbug Creek Watershed
The recommended management strategies include the combination of diversion ditches around the pit rim, detention basin and filtering standpipe. Additional recommendations include monitoring of Shaft 5 and the North Bloomfield Tunnel outlet, as well as physical hazard remediation of open shafts.

allow sediment to collect above the former tunnel inlet. The Hiller Tunnel inlet would no longer be accessible, but the Hiller Tunnel outlet would remain unchanged visually, as it would continue to have water flowing out of it from horizontal pipes on the tunnel floor that would receive water from the vertical filtering structure.

- Extend the filtering outlet structure vertically as sediment accumulates in the pit over the years, to maintain the basin's capacity for storm water equalization and sediment retention.
- Construct saddle dams on the southwestern pit rim, as shown conceptually on Figure 61 on page 138 and Figure 62 on page 140, to allow for long-term sediment retention as the pit accumulates sediment over time.
- Divert surface water above Malakoff Diggins in combination with sediment retention. Surface water diversion could be accomplished by construction of diversion ditches to direct water around the pit, or alternatively by construction of overside drains to collect surface water above the pit cliffs and direct it into the proposed basin outlet structure via closed pipe collectors. The size of the proposed detention basin could be reduced if surface water is diverted above the pit.
- Consider a pilot stabilization project to test specific reclamation strategies such as revegetation, surface water routing and erosion control. The pilot project would include performance monitoring and interpretive features to demonstrate to Park visitors why reclamation is important in the context of mining.

2) Management of Water and Metals Discharge from North Bloomfield Tunnel

The following strategies are recommended for management of water and metals discharge from the North Bloomfield Tunnel.

- Monitor Shaft 5 and the North Bloomfield Tunnel outfall to determine permitting requirements. Quarterly flow measurement, surface water sampling, laboratory analysis and reporting for a period of one year at Shaft 5 and the North Bloomfield Tunnel outfall is estimated to cost $8,000. Recommended monitoring parameters are listed in Table 13 on page 125.

3) Management of Physical Hazards at Tunnels and Shafts

The following strategies are recommended for management of physical hazards associated with the Hiller Tunnel, North Bloomfield Tunnel and access shafts.

- Repair fencing (install fence and fence posts) at Shafts 2, 3, 4, 5 and 6. Alternatively, foam plugs may be installed in Shafts 2, 3 and 4 provided that the features are first surveyed to determine whether bat habitation would preclude the use of a plug and whether there would be an impact to the historical qualities of the shafts. Plugging of Shafts 5 and 6 is not recommended based on the water levels in the shafts. Fencing and posting is estimated to cost $3,000 per location. Plugging may cost $12,000 to $15,000 per location, considering plug design and biological survey requirements.

- Install a bat-friendly gate at the North Bloomfield Tunnel outlet. Construction of a bat-friendly gate is estimated to cost $10,000 to $15,000, considering biological survey requirements. A bate gate consistent with Park objectives that does not lessen the historic qualities of the tunnel outlet may be feasible. Periodic monitoring of the bat-friendly gate is appropriate to address potential vandalism and maintenance.
- The detention basin design includes a bulkhead at the Hiller Tunnel inlet, which would tend to regulate storm water flow through the tunnel, and would tend to prevent debris from entering the tunnel. If this management approach is selected, then a bat gate could be considered at the outfall of Hiller Tunnel, and it could be placed back inside the tunnel so that it would not change the visual appearance of the outlet. A bat-friendly gate at Hiller Tunnel outlet is not possible unless the flow is controlled at the inlet by the proposed detention basin. Sloping back the aggraded sediment surrounding the inlet to Hiller Tunnel may reduce the physical hazard.
- Construct a boardwalk at Shaft 5, or re-route the Humbug Creek Trail around Shaft 5, to reduce the potential for Park visitor contact with discharged water and precipitated solids. An interpretive feature at Shaft 5, such as an explanatory sign, would demonstrate to Park visitors the functions of monitoring and remediation in the context of legacy mining features.

Data Gaps

The following data gaps were identified during the preliminary engineering evaluation. Additional investigation is recommended to address these data gaps and to facilitate the selection and design of management strategies.

1) Topography of hydraulic pit: aerial survey

A detailed topographic survey of the Malakoff Diggins hydraulic pit (e.g., an aerial survey with two-foot contour interval or airborne LiDAR) is recommended so that:

a. Pit erosion and deposition processes can be monitored and quantified to better understand processes and to help identify areas that can be targeted for erosion control techniques,

b. Design for surface water diversion and sediment retention can be based on accurate pit topography,

c. Elevation of the pit floor near the Hiller Tunnel inlet can be compared to the elevation of the saddle in order to predict how long it would take for sediment to reach the same elevation as the saddle, and

d. A detailed topographic map would show detail of drainages, facilitate future sampling efforts to refine sources areas, and enhance the cultural resources inventory and evaluation.

2) Water flow paths: design flows

A hydrologic model based on existing and additional hydrology data that includes the following parameters is recommended:

a. Discharge rates in the drainages above the pit need to be determined so that the design for surface water and sediment retention could developed. Additional monitoring of high flow events (i.e., two to four significant storm events for three consecutive years) could be conducted at the primary surface water pathways above and within the hydraulic pit. Monitoring would include storm water flow, suspended sediment load and bedload to further characterize the relationships among precipitation, runoff and sediment transport, and to assess the partitioning of sediment within the hydraulic pit.

b. Infiltration rates for sediment within the hydraulic pit need to be established so that the design for the detention basin outlet structure can be developed.

c. The filtration capacity of the proposed filter materials need to be determined so that the potential efficiency of the filtration systems with Malakoff Diggins' fine sediment and clay deposits can be understood. This could be accomplished on a pilot scale to support the design of the proposed detention basin and outlet structure.

3) Additional source areas for mercury

It is recommended that additional sources of mercury within the Humbug Creek watershed be investigated, taking into consideration archaeological findings on how and where operations that used mercury took place including where it was applied, stored or retorted, including processing locations, sluices, and mine tailings. The locations would include other mines or erosion locations that contribute to Humbug Creek water quality. A map of the drainage patterns that shows all of the tributaries that come into the pit and their pattern through the pit would inform additional sampling. Water quality sampling for mercury and/or other metals based on the drainage pattern would help to confirm metal source areas. This includes additional investigation of sources of mercury to:

a. The Road 1 site which had a higher concentration of mercury in suspended sediments than downstream sites including the Malakoff Diggins pit discharge into Diggins Creek

b. The unnamed ravine that drains into Diggins Creek from the west (possibly New York Ravine).

c. Characterization of the substrate on the floor of Hiller Tunnel to determine whether Hiller Tunnel is a source of mercury to Diggins Creek.

d. Soil samples for mercury should be taken at additional locations in the Malakoff Diggins pit, along the cliff walls where drift mines may have been, and at other mine sites in the watershed such as the Derbec Mine, its sluice system and discharge locations.

4) Additional source areas for other metals

More research is recommended to determine the cause of and significance of total metal concentrations to Humbug Creek in certain locations, as well as to verify and refine source areas within the pit.

a. Monitoring of Shaft 5 and North Bloomfield Tunnel outlet flow and water quality is recommended in order to ensure that the correct regulatory requirements are applied to the site. Additional information is required regarding flow rate, dissolved metals concentrations and seasonal variation. At least four quarters of monitoring for flow and water quality are recommended at Shaft 5 and the North Bloomfield

Tunnel outlets. A weir could be constructed to facilitate monitoring discharge and/or a pressure transducer could be installed at Shaft 5 to determine if the stage of the discharge changes.

b. Monitoring for dissolved metals in shallow subsurface groundwater, including analysis of filtered samples, can be collected to confirm that water that may be dewatered does not have elevated dissolved concentrations of the metals of potential concern (mercury, copper, nickel, zinc, and iron).

c. Using LiDAR-generated drainage patterns, the previous sample locations can be overlaid to determine additional sampling that may be needed to refine and verify metal source areas.

5) Direct soil exposure in pit: test soil samples

It is recommended that soil samples be obtained from areas of routine visitation in the pit (i.e., trails) and analyzed for total concentrations of metals. The results could be compared to California Human Health Screening Level (CHHSL) values, as well as benchmarks for recreational exposure and regional background concentrations, to determine whether recreational visitation of the hydraulic pit presents a significant potential for chemical hazard.

6) Slope stability for pilot reclamation project: investigation and analysis

The cost of a pilot reclamation project would depend upon the slope stability of the project area and adjacent areas. Unstable areas with deep-seated failure planes, and locations adjacent to and downslope of the unstable areas, may not be suitable for a pilot project because they are subject to landslides. Therefore, it is necessary to investigate slope stability prior to planning a pilot project for slope stabilization and revegetation.

7) Cultural and biological resources: opinions on proposed actions

It is recommended that the area of impact associated with selected management strategies be defined and inventoried for cultural and biological resources. The Park-wide cultural resources inventory and evaluation would identify specific cultural values to consider during the design stage of all selected management strategies. Significant cultural resources would be avoided when feasible or appropriate treatments can be incorporated into the final design. The SHPO or Advisory Council on Historic Preservation must be afforded an opportunity to comment on the final design effects and proposed treatment measures. The evaluation of the effect on cultural resources is only possible after a complete inventory of the resource is completed. The evaluation of impacts to biological resources can only be determined after a variety of surveys are conducted including surveys for vegetation, birds, wildlife and herptiles.

Next Steps

Cultural Resources Next Steps

To assess the effects of treatment alternatives on Park cultural and natural resources, additional detail regarding possible environmental management alternatives is needed. Areas where a remedial action seems likely will need to be surveyed for cultural resources and anything identified will need to be evaluated against the NRHP's Criteria for Evaluation. DPR's Archaeology, History and Museums Division has obtained funding for the initial phase of the cultural resources inventory of the Park to fill this gap and has indicated that they will carry out a landscape-level evaluation. The inventory will be comprehensive and rely on archival research and field survey. The results of the cultural survey and evaluation studies would be used for consideration when remedial actions are better defined, and a report on the assessment of the effect of proposed treatments can be generated and supplied to the SHPO for review and comment.

Environmental Assessment Next Steps

While the majority of environmental assessment in the Humbug Creek watershed has been completed, a limited amount of additional investigation has been identified that is recommended to design and engineer remediation options. Specifically, a water and sediment budget for the Malakoff Diggins pit will inform remediation actions that alter these aspects of runoff and discharge. The steps identified below will fill the gaps to inform effective management techniques.

Water Quantity and Quality

A limited amount of additional research is recommended to complete full site characterization of water quality conditions present at Malakoff Diggins SHP, including the concentration of constituents of concern (COCs) and the calculation of the load of those constituents at specific locations. To calculate the load of COCs, discharge measurements are required. Continuous discharge measurements were obtained for Humbug Creek using gaging equipment; however, continuous discharge was neither measured for Shaft 5, Hiller Tunnel, nor for the streams flowing into Diggins Creek from the west (New York Ravine). The Shaft 5 discharge does not appear to change much throughout the year, but a weir or pressure transducer in Shaft 5 may be a way of gaining discharge measurements of the shaft to see if it is indeed constant. Measuring dissolved metals and dissolved organic carbon from Shaft 5 is an important next step to selecting water quality remediation options.

Quantifying the discharge from Hiller Tunnel is an important piece to consider for engineering the remediation recommendations that involve using the pit as a sediment detention basin.

Additional sampling of the Hiller Tunnel influent and effluent would be necessary to determine if Hiller Tunnel itself is a source of mercury. Hiller Tunnel discharge changes dramatically with storm events. Rather than installing continuous gage equipment that would be highly visible to the public, the tunnel dimensions could be surveyed, stage measurements collected and a stage-discharge relationship developed using the tunnel dimensions.

Sampling of additional source areas could be conducted based on archeological findings and interpretation of mining operations. Detailed topographic maps can be developed using LiDAR mapping methods. These maps would be used to develop a detailed drainage map of the pit and its inflow, which could be used to guide further sampling to refine and confirm mercury and metal source areas. In particular, it is recommended that soil samples be collected from areas where mercury was used, applied, stored or retorted, including the cliff walls near SS12 and SS15. Potential additional sources to Humbug Creek include an unnamed ravine that enters Diggins Creek from the west (New York Ravine) and drains mine-impacted land to the southwest of the pit.

Pit Erosion and Deposition

Three-dimensional images from a conventional aerial survey, land-based and airborne LiDAR would facilitate more accurate estimates of annual erosion, erosion rates and a better understanding of the drainage pattern, erosion and deposition processes taking place in the pit. Cultural resources inventory and evaluation would also benefit from detailed 3-dimensional mapping. A high resolution, three-dimensional map of the Malakoff Diggins pit would be generated from airborne LiDAR digital imaging technology using highly accurate radiometric and geometric images collected from low flying aircraft.

With a topographical map of the pit, the highly heterogeneous badlands topography could be categorized into different erosional units including colluvial slopes with gravity-driven rilling, placer tailings with seasonal drainages, and chronic mass wasting from gully erosion and slope failures. Using this topographical base map, a land form map could be generated that shows landslides, drainages, areas of active deposition (differentiating coarse sediment fans versus fine sediment downstream), tailings and unstable slopes. The erosional units could be characterized using grain-size distribution techniques, and lithology/geochemical methods including mineralogy (kaolinite/smectite ratio, quartz content, and quartz/feldspar ratio). A detailed survey would be used to identify geomorphological pit features and determine the extent (length, width and depth) of various pit features (gullies, slope faces and overhangs) to calculate and categorize these features to aid in remediation planning. Deposition estimates could be used to estimate the storage component of the sediment budget. These measurements would be used to construct a comprehensive water and sediment budget for the Malakoff Diggins pit. The sediment budget would inform the development of effective management techniques to abate sediment discharging from the pit.

NEXT STEPS SUMMARY

During the Cultural Resources Inventory work critical data gaps remaining as part of the Environmental Assessment will be filled to the extent possible. With the completion of the Cultural Resources Inventory work and biological surveys, it will be possible to evaluate the effect of the proposed remediation activities on the cultural and biological resources of the Park. The determination of effect of the recommended remediation actions will be used to revise the Project Description and Initial Study checklist (Appendix II) and will inform any additional environmental permitting.

References Cited

1867, Deeds: Nevada County Office of the Recorder, Nevada City, California, 27 p.

Alpers, C.N., Hunerlach., M.P., Hothem, R.L., and May, J.T., 2005, Mercury contamination from historical gold mining in California: U.S. Geological Survey Fact Sheet 2005-3014, 6 p., http://water.usgs.gov/pubs/fs/2005/3014/.

ATSDR, 1999, Public Health Statement, Mercury, CAS#: 7439-97-6: Agency for Toxic Substances and Disease Registry, March 1999: http://www.atsdr.cdc.gov/ (accessed July 2013).

Bean, E.F. (compiler), 1867, History and Directory of Nevada County, California, Daily Gazette Book and Job Office, Nevada City, California.

Benoit, J.M., Gilmour, C.C., Riedel, G.S., and Riedel, G.F., 1998, Behavior of Mercury in the Patuxent River Estuary, Biogeochem v. 40.

Blaney, G.B., and Warrington, G.E., 1983, Estimating Soil Erosion Using an Erosion Bridge, USDA Forest Service, Watershed Systems Development Group, Fort Collins, Colorado.

Blanford, J., 1989, Report of Phase One Archaeological Investigations, North Bloomfield Chinatown Project, Malakoff Diggins State Historic Park: Department of Anthropology, University of California, Berkeley.

Bouse, R.M., Fuller, C.C., Luoma, M.I., Jaffe, B.E., and Smith, R.E., 2010, Mercury-Contaminated Hydraulic Mining Debris in San Francisco Bay: San Francisco Estuary and Watershed Science, v.8 i.1.

Bowie, A.J., 1905, A practical treatise on hydraulic mining in California: New York, New York, D. Van Nostrand Company, 313 p.

Brown, L.F., Overview of Environmental Law: www.calepa.ca.gov/CUPA/Documents/Inspection/OvrviwEnvlaw.doc.

Bureau of Land Management (BLM), 2011, Master title plat and mineral survey plats MS302, MS316, MS469, MS589 and MS 3334: United States Department of Interior, Bureau of Land Management: http://www.blm.gov/ca/forms/mtp/search.php (accessed July 2013).

Cahill R.W., 1979a, Malakoff Diggins State Historic Park Resource Management Plan.

Cahill, R.W, 1979b, Survey of Cultural Resources at Malakoff Diggins State Historic Park, D 397-97 Standard Test Methods for Determining Sediment Concentration in Water Samples, ASTM International.

California Department of Conservation (CDOC), 2000, California's Abandoned Mines: A Report on the Magnitude and Scope of the Issue in the State, Office of Mine Reclamation, Abandoned Mine Lands Unit.

California Department of Conservation (CDOC), 2007, Mine Reclamation – FAQ.: http://www.conservation.ca.gov/omr/smara/Pages/faq.aspx#what_is_smara.

California Department of Fish and Game, 2011, California Natural Diversity Database: Special Animals (898 taxa):http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPAnimals.pdf.

California Department of Fish and Game, Lake and Streambed Alteration Program: http://www.dfg.ca.gov/habcon/1600/.

California Department of Parks and Recreation (DPR), 1975, State Park System Purpose Statements, Malakoff Diggins SHP #356, p. 206.

California Department of Parks and Recreation (DPR), 2010, Malakoff Diggins State Historic Park: http://www.parks.ca.gov/pages/494/files/MalakoffDigginsWebBrochure2010.pdf.

California Department of Water Resources (DWR), 1987, Erosion Control at Malakoff Diggins State Historic Park, Report to the Department of Parks and Recreation Interagency Agreement 05-07-075 (DWR 163543).

California Department of Water Resources (DWR), 2013, WSIHIST (12/19/13 0934): http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

California Department of Water Resources (DWR), 2007, Mercury Contamination in Fish From Northern California Lakes and Reservoirs: Northern District, http://www.dpla2.water.ca.gov/publications/water_quality/MercuryContaminationFinalOnline.pdf.

California Regional Water Quality Control Board (CRWQCB), 1976, Order No. 76-258, Waste Discharge Requirements for Malakoff State Historic Park, California Department of Parks and Recreation, Nevada County, WSID No. 5A290802001, Central Valley Region.

California Regional Water Quality Control Board (CRWQCB), 1998, Fourth Edition of the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins, Central Valley Region.

California Regional Water Quality Control Board (CRWQCB), 2005, Policy for Implementation of Toxic Standards for Inland Surface Waters, Enclosed Bays and Estuaries of California: California Environmental Protection Agency, State Water Board Resolution number 2005-0019.

Churchill, R.K., 2000, Contributions of Mercury to California's Environment from Mercury and Gold Mining Activities-Insights from the Historical Record, Extended abstracts for the U.S. EPA-Sponsored meeting, Assessing and Managing Mercury from Historic and Current Mining Activities.

Covelli, S., Faganeli, J., Horvat, M., and Brambati, A., 1999, Pore-water Distribution and Benthic Flux Measurements of Mercury and Methylmercury in the Gulf of Trieste (Northern Adriatic Sea): ELSEVIER Estuarine, Costal and Shelf Science, V. 48 I. 4, p. 113-125 doi: 10.1006/ecss.1999.0466.

Craig, D.W., 2007, Office of Mine Reclamation: http://www.conservation.ca.gov/omr/abandoned_mine_lands/Documents/2007_AMLPriorityListsFinal.pdf.

References Cited

Cruden, D.M. and Varnes, D.J., 1996, Landslide Types and Processes: in Turner, A.K., and Schuster, R.L., ed., 1996: Landslides - Investigation and mitigation, Special Report 247, Transportation Research Board, National Research Council, National Academy Press Washington D. C, p. 36–75.

Delongchamp, T.M., Ridal, J.J., Lean, D.R.S., Poissant, L., and Blais, J.M., 2009, Mercury Transport between Sediments and the Overlying Water of the St. Lawrence River: Area of Concern near Cornwall, Ontario: ELSEVIER Environmental Pollution, V. 158 I. 5, p. 1016 doi: 10.1016/j.envpol.2009.12.030.

Deukmejian, G., 1980, Opinion No. 79-906-1980 – Drainage from Abandoned Mine Now State Park.

Esri, et al., 2014, World Imagery, Scale 1:1,000,000 to 1:70,000: http://www.arcgis.com/home/webmap/viewer.html?webmap=716b600dbbac433faa4bec9220c76b3a (June 2014).

Felton, D.L., Porter, B.S., and Hines, P., 1979, Survey of Cultural Resources at Malakoff Diggins State Historic Park. California Department of Parks and Recreation, Cultural Heritage Section, Resource Preservation and Interpretation Division.

Fleck, J.A., et al., 2011, The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area, Nevada County, California: Concentrations, Speciation, and Environmental Fate--Part 1: Field Characterization: U.S. Geological Survey Open-File Report 2010-3125A.

Forest Technology Systems (FTS), 2010, DTS-12 Turbidity Sensor Operating Manual (Revision 14), Victoria, Canada.

Gill, G.A., Bloom, N.S., Cappellino, S., Driscoll, C.T., Dobbs, C., McShea, L., Mason, R., and Rudd, J.W.M., 1999, Sediment-Water Fluxes of Mercury in Lavaca Bay, Texas, Environmental Science and Technology, V. 33, I.5, p. 663–669, doi:10.1021/es980380c.

Gilbert, C., and Savitski, C., 1991, Historic Dredge Recordation, Malakoff Diggins State Historic Park, California Department of Parks and Recreation, Resource Management Program.

Gillett, L. 1997, Archaeological Addendum of the Mt. Blanc Timber Harvest Plan, David Levy Forestry, Nevada City, California.

Gracyk, J., 2011, North Bloomfield Cultural Landscapes Report, Terra Cognita Design and Consulting, Petaluma, California.

Gralia, R., and Gralia, M., 2012a, Monitor Report-Feature MD-90-“A-9,” a portion of CA-NEV-551H.

Gralia, R., and Gralia, M., 2012b, Summary – Historic Metal Objects.

Gudde, E.G., 1975, California Gold Camps: A Geographical and Historical Dictionary of Camps, Towns, and Localities where Gold was Found and Mined; Wayside Stations and Trading Centers: University of California Press, Berkeley.

Hammon Engineering Company, 1917, Malakoff report: Unpublished Engineering Report, 107 p.

Hanks, H.G., 1882, Second Report of the State Mineralogist of California, Form December 1, 1880, to October 1, 1882: Sacramento, http://babel.hathitrust.org/cgi/pt?id=nnc1.cu00234362;view=1up;seq=7.

Harding, J., 1977, Ecological Studies at Malakoff Diggins State Park, a compilation of student papers: Department of Environmental Horticulture University of California Davis.

Hines, P., 1994, Archaeological Survey for the Proposed Outdoor Educational Facility: Malakoff Diggins State Historic Park, California State Parks.

Hines, P. and Rivers, B., 1994, An Archeological and Review of Previous Archeological Projects at North Bloomfield, Chinatown: California State Parks.

Horton, R.E., 1945, Erosional Development of Streams and Their Drainage Basins; Hydrophysical Approach to Quantitative Morphology: Bulletin of the Geological Society of America, V. 56, p. 275-370.

Hunerlach, M.P., Rytuba, J.J., and Alpers, C.N., 1999, Mercury contamination from hydraulic placer-gold mining in the Dutch Flat mining district, California, in Morganwalp, D.W., and Buxton, H.T., eds., U.S. Geological Survey Toxic Substances Hydrology Program—Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999, U.S. Geological Survey Water-Resources Investigations Report 99-4018B, p. 179-189: http://ca.water.usgs.gov/mercury/dutch/wrir994018b.pdf (May 2013).

Ing, R.G., 1995, Archaeological and Historical Resources Survey and Impact Assessment; Supplemental Report for a Timber Harvest Plan: Logan THP.

Interagency Minerals Coordinating Group (IMCG), 1996, Dictionary of Mining, Mineral, and Related Terms, 2nd Edition: U.S. Department of the Interior: http://webharvest.gov/peth04/20041015011634/imcg.wr.usgs.gov/dmmrt/

Jackson, W.T., 1967, The North Bloomfield Mining District: Report on the Malakoff Mine, The North Bloomfield Mining District, and the Town of North Bloomfield.

Jaffke, D., 2005, Archaeological Testing Report at Malakoff Diggins State Park, North Bloomfield, Barber Shop Electrical Line Project, CEQA No. 6170; District Tracking No. 356-2004-03: California State Parks-Sierra District.

Jaffke, D., 2006a, Archaeological Survey Report for the North Bloomfield Fuel Reduction Project in Malakoff Diggins State Historic Park, North Bloomfield Fuel Reduction Project, CEQA No. 6745; District Tracking No. 356-2005-04: California State Parks-Sierra District.

Jaffke, D., 2006b, Archaeological Monitoring at Malakoff Diggins State Park, North Bloomfield, Barber Shop Electrical Line Project, CEQA No. 6170; District Tracking No. 356-2004-03: California State Parks-Sierra District.

Jaffke, D., 2007, Archaeological Survey Report-Addendum-for the Lake City-Humbug Road Fuelbreak Project, Malakoff Diggins State Historic Park, Post-project implementation Report, PDMC-PJ-09-CA-2003-018: California State Parks-Sierra District.

Jarman, A., 1927, Bloomfield Hydraulic Mine: San Francisco, California, California State Mining Bureau Report, p. 130.

Kallenberger, W.W., 1957, History of the Famous Malakoff, Oakland Tribune.

References Cited

Kirchner, E. M., 2002, Remote sensing measurements of streambank migration and Erodibility, Earth Surface Processes and Landforms, v. 27, p. 627-639.

Krabbenhoft, D.P., Gilmour, C.C., Benoit, J.M., Babiarz, C.L., Andren, A.W., and Hurley, J.P., 1998, Methyl Mercury Dynamics in Littoral Sediments of a Temperate Seepage Lake, Aquatic Sci, v. 55, p. 835-844.

Landrum, K., 2014, Quantifying Surfacial Processes in Malakoff Diggins, A Historic Hydraulic Mine [MS Thesis]: California State University, Chico.

Lindström, S., 1990, A Historic Sites Archaeological Survey of the Main Hydraulic Pit Basin, Malakoff Diggins State Historic Park, North Bloomfield, Nevada County: California Department of Parks and Recreation, Resource Protection Division, Interagency Agreement No. 4-827-0004.

Lukas, D., 2002, Willow Flycatcher Survey, Malakoff Diggins State Historic Park, 4 pp.

Mac Boyle, E., 1919, Mines and Minerals of Nevada County, Chapters of State Mineralogist's Report Biennial Period 1917–1918, California State Printing Office: Sacramento.

MacDonald, L., 1989, Prospects for Reducing Sediment Yield from Malakoff Diggins State Historic Park, Phillip Williams and Associates, Ltd..

Marvin-DiPasquale, M., Agee, J.L., Kakouros, E., Kieu, L.H., Fleck, J.A., Alpers, C.N., 2011, The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area, Nevada County, California: Concentrations, Speciation, and Environmental Fate—Part 2: Laboratory Experiments: U.S. Geological Survey Open-File Report 2010-1325B, 66 p.

May, J.T., Hothem, R.L., Alpers, C.N., and Law, M.A., 2000, Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California: U.S. Geological Survey Open-File Report 00-367, 30 p. http://ca.water.usgs.gov/archive/reports/ofr00367/index.html.

McElroy, E., 2012, Foothill Yellow-legged Frog Population data for Humbug Creek, Hiller Tunnel and Diggins Ponds: Visual Encounter and Habitat Assessment Survey of Foothill Yellow-legged Frogs (Rana Boylii). [B.S. Thesis]: California State University, Chico.

Monohan, C., 2011a, Gold Country Angler Survey: A Pilot Study to Assess Mercury Exposure from Sport Fish Consumption in the Sierra Nevada, The Sierra Fund: Nevada City, CA.

Monohan, C., 2011b, Gold Country Recreational Trails and Abandoned Mines Assessment: A Pilot Study to Assess Exposure Potential to Toxins from Mine Waste and Naturally Occurring Hazardous Substances.

National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center, Public Trust Doctrine, Module 1, Lesson 2: http://www.csc.noaa.gov/ptd/module01/lesson02/0102a.htm.

Nevada County Resource Conservation District (NCRCD), 1978, Malakoff Diggins Water quality Study: Phase I Report.

Nevada County Resource Conservation District (NCRCD), 1979a, Malakoff Diggings Water Quality Study Phase II Progress Report.

Nevada County Resource Conservation District (NCRCD), 1979b, Malakoff Diggings Water Quality Study Phase III Progress Report.

Office of Environmental Health Hazard Assessment (OEHHA), 1999, Prevalence of selected target chemical contaminants in sport fish from two California lakes: public health designed screening study: Sacramento, California.

Payen, L.A., 1989, Archaeological Excavations at Shoot Hill, Malakoff Diggins State Historic Park, Nevada County, California.

Peterson, D.H., 1979, A Study of Modern Sedimentation at Malakoff Diggins State Historic Park, Nevada County, California [M.S. thesis]: University of California, Davis.

Porter, B., 1979, Malakoff Diggins State Historic Park: Resource Management Plan: California State Parks.

R Core Team, 2014, R: Language and Environment for Statistical Computing: Vienna, Austria.

Rhoades, M., 1992, Cultural Resources Inventory of the North Bloomfield Station.

Roos-Collins, R., 2005, A Plan to Restore the Public Trust Uses of Rivers and Creeks: Texas Law Review, v. 83, no. 7, p. 1929-1939: http://ssrn.com/abstract=874775.

Rossman, 1990, Design Stream Flows Based on Harmonic Means: Journal of Hydraulics Engineering, v. 116, no. 7.

Saucedo, G.J., Wagner, D.L., Martin, R., 1992, Geologic Map of the Chico Quadrangle, California: U.S. Geological Survey, scale 1:250,000, 1 sheet.

Schumm, S.A., 1964, Seasonal Variations of erosion rates and processes on hillslopes in western Colorado: Zeitschrift fur Geomorphologie Supplementband, 5: p. 215-238.

Selby, M.J., 1993, Hillslope Materials and Processes (second edition): Oxford University Press, Oxford, p. 451.

Shilling, F., White, A., Lippert, L., and Lubell M., 2010, Contaminated fish consumption in California's Central Valley: Environmental Research, v. 110, p. 334-344, doi: 10.1016/j.envres.2010.02.002.

Singer, M.B., Aalto, R., James, L.A., Kilham, N.E., Higson, J.L., Ghoshal, S., 2013, Enduring legacy of a toxic fan via episodic redistribution of California gold mining debris: Proceedings of the National Academy of Science of the United States of America, v. 110, i. 46, p. 18436–18441, doi: 10.1073/pnas.1302295110.

Sirvent, J., Desir, G., Gutierrez, M., Sancho C., and Benito G., 1997, Erosion rates in badland areas recorded by collectors, erosion pins and profilometer techniques (Ebro Basin, NE-Spain): Geomorphology v. 18, i. 2, p. 61-75, doi: 10.1016/S0169-555X(96)00023-2.

Slotton, D.G., Ayers, S.M., Reuter, J.E., and Goldman, C.R., 1997, Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams (1997 revision), Appendix B in Larry Walker Associates, Sacramento River watershed mercury control planning project.

Stammerjohan, G., Wheeler, T., and Hines, P., 1985, The Hydraulic Pit of Malakoff Diggins State Historic Park; A Preliminary Report of the Phase One, 1984-1985: Department of Parks and Recreation, Cultural Heritage Section, Resource Protection Division.

State Water Resources Control Board (SWRCB), 2005, Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California: California Environmental Protection Agency.

State Water Resources Control Board (SWRCB), 2013a, 2006 CWA Section 303(d) List of Water Quality Limited Segments being addressed by USEPA Approved TMDLs: California Environmental Protection Agency, State Water Resources Control Board, http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/303dlists2006/epa/state_06_wtmdl.pdf (July 2013).

State Water Resources Control Board (SWRCB), 2013b, Final Draft NPDES Industrial General Permit Documents for Public Comment: State Water Resources Control Board, http://www.swrcb.ca.gov/ water_issues/progs/stormwater/industrial_permitdocs.shtml (July 2013).

State Water Resources Control Board (SWRCB), 2013c, Statewide Mercury Control Program for Reservoirs: http://www.waterboards.ca.gov/water_issues/programs/mercury/reservoirs/docs/factsheet.pdf.

Taylor, T.L., 1987, Final Report: Malakoff Diggins State Historic Park: Humbug Creek fishery evaluation: California Department of Parks and Recreation, Resource Protection Division, Natural Heritage Section, 16 p.

United States Department of Labor, 2013, CPI Inflation Calculator: Bureau of Labor Statistics, http://www.bls.gov/data/inflation_calculator.htm (August 2013).

United States Environmental Protection Agency (USEPA), 1987, Guidance on Implementing the Antidegradation Provisions of 40 CFR 131.12, Appended to APU 90-004, Region 9: http://water.epa.gov/scitech/swguidance/standards/adeg/ upload/Region9_antideg_guidance.pdf (August 2013).

United States Environmental Protection Agency (USEPA), 1993, Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliances, Federal Register, V. 57, I. 246, P. 60848: http://water.epa.gov/lawsregs/rulesregs/ntr/ (June 2013).

United States Environmental Protection Agency (USEPA), 1996, Method 1669 Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels: http://www.epa.gov/caddis/pdf/Metals_Sampling_EPA_method_1669.pdf.

United States Environmental Protection Agency (USEPA), 1997, Mercury Study Report to Congress, Volume III: Fate and Transport of Mercury in the Environment, Office of Air Quality Planning and Standards, and Office of Research and Development, Publication EPA-452-R-97-005: http://www.epa.gov/ttn/caaa/t3/reports/volume3.pdf (July 2013).

United States Environmental Protection Agency (USEPA), 2000, California Toxics Rule, http://www.epa.gov/region9/water/ctr/ (July 2013).

United States Environmental Protection Agency (USEPA), 2001, Water Quality Criterion for the Protection of Human Health: Methylmercury, Final. Publication EPA-823-R-01-001: http://www.epa.gov/waterscience/criteria/methylmercury/document.html (July 2013).

United States Environmental Protection Agency (USEPA), 2005, Tier 2 Antidegradation Reviews and Significance Thresholds, Office of Science and Technology: http://water.epa.gov/scitech/swguidance/standards/adeg/upload/tier2.pdf (August 2013).

United States Environmental Protection Agency (USEPA), 2006, Roadmap for Mercury, Publication EPA-HQ-OPPT-2005-0113: http://www.epa.gov/ mercury/archive/roadmap/index.html (August 2013).

United States Environmental Protection Agency (USEPA), 2012, National Environmental Policy Act (NEPA) Basic Information: http://www.epa.gov/compliance/basics/nepa.html.

United States Environmental Protection Agency (USEPA), 2013a, Summary of the Clean Water Act: http://www2.epa.gov/laws-regulations/summary-clean-water-act.

United States Environmental Protection Agency (USEPA), 2013b, Summary of the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund): http://www2.epa.gov/laws-regulations/summary-comprehensive-environmental-response-compensation-and-liability-act.

United States Environmental Protection Agency (USEPA), 2013c, Summary of the Endangered Species Act: http://www2.epa.gov/laws-regulations/summary-endangered-species-act.

United States Environmental Protection Agency (USEPA), 2013d, National Recommended Water Quality Criteria, http://www.epa.gov/waterscience/criteria/wqcriteria.html (August 2013).

URS Corporation, Inc., 2004, Administrative Draft Cultural Resources Technical Report: Lake City-Humbug Roadside Fuelbreak, California State Department of Parks & Recreation (PDMC-PJ-CA-2003-018), California Department of Parks and Recreation, Sierra District, Tahoma.

Wheeler, T., 1987, Archeological Testing at CA-NEV-356/H, Malakoff Diggins SHP: California Department of Parks and Recreation-Cultural Heritage Section.

White, G., 1991, A Report of a Supplementary Excavation at the Shoot Hill Site, CA-NEV-356/H, Malakoff Diggins State Historic Park, Nevada County: California Department of Parks and Recreation, Cultural Heritage Section, Resource Protection Division.

Whitney, J.D., 1880, The Auriferous Gravels of the Sierra Nevada of California, Contributions to American Geology v. I.: Cambridge, Massachusetts, Cambridge University Press.

Whittlesey, N., 2002, Archaeological Addendum of the Optimist Timber Harvest Plan, Whittlesey Enterprises: Grass Valley, California.

References Cited

Wieczorek, G.F., Jakob, M., Motyka, R.J., Zirnheld, S.L., and Craw P., 2002, Preliminary Assesment of Landslide-Induced Wave Hazard Assessment: Tidal Inlet, Glacier Bay National Park, Alaska: U. S. Geological Survey Open-File Report 03-100.

Willis, R., 2005, An Archaeological Survey Report for the Lake City Timber Harvesting Plan, County of Nevada, California.

Wood, M.L., Foe, C.G., Cooke, J., Louie, S.J., 2010, Amendments to the Water Quality Control Plan for The Sacramento River and San Joaquin River Basins for the Control of Methlymercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary, p. 3.

Wyckoff, R.M., 1964, Hydraulic Mining and the Malakoff Diggin's, Nevada County Historical Society Bulletin v. 18 i. 3: Nevada City, California.

Yarnell, S.M., 2005, Spatial Heterogeneity of Rana boylii Habitat: Physical Processes, Quantification and Ecological Meaningfulness [Ph.D. Dissertation]: University of California, Davis.

Yarnell, S.M., and Larsen, E., 2000, Foothill Yellow-legged Frog Population Data for Selected Tributaries of the South Yuba River: Nevada County, CA.

Ypsilantis, W.G., 2011, Upland soil erosion monitoring and assessment: An overview, Tech Note 438: Bureau of Land Management, National Operations Center: Denver, CO.

Yuan, G., 1979, The Geomorphic Development of a Hydraulic Mining Site in Nevada County, California [M.S. Thesis]: Stanford University.

Zalarvis-Chase, D., 2004, Malakoff Fuels Reduction: Archaeological Inventory, TNF 1839, R2003-0517-00100: Tahoe National Forest.

Zhong, H., and Wang W., 2008, Effects of Sediment Composition on Inorganic Mercury Partitioning, Speciation and Bioavailability in Oxic-Surficial Sediments: Environmental Pollution, v. 151, i. 1 p. 222-230, DOI: 10.1016/j.envpol.2007.01.049, http://www.sciencedirect.com/science/article/pii/S0269749107001510.

Appendix I: Student Projects

CSU Chico Student Projects in Malakoff Diggins State Historic Park, 2012-2014

California State University, Chico graduate students in the Geological and Environmental Sciences Department have conducted assessment activities at Malakoff Diggins State Historic Park under the direction of The Sierra Fund's Science Director, Dr. Carrie Monohan, who is also adjunct professor at CSU Chico. These projects were part of The Sierra Fund's Humbug Creek Assessment project that was conducted in cooperation with California Department of Parks and Recreation. The graduate students helped with data collection and developed specific research projects for their master's projects.

Master's theses at Malakoff Diggins State Historic Park during 2012-14 include:

- *Mercury and Suspended Sediment Sources and Loads in Humbug Creek in Malakoff Diggins State Historic Park* (Harihar Nepal) (completed Summer 2013)
- *Subsurface Waters at Malakoff Diggins Pit, North Bloomfield Tunnel and Hiller Tunnel* (David Holl Demaree) (completed Summer 2013)
- *Particle-Size Distribution Analysis and Sediment Deposition on the Pit Floor at Malakoff Diggins State Historic Park* (Cameron Lee Liggett) (completed Spring 2014)
- *Quantifying Surficial Processes in Malakoff Diggins, A Historic Hydraulic Mine* (Keith Landrum) (completed Summer 2014)
- *Aquatic Invertebrates as Mercury Bioindicators in Humbug Creek and Malakoff Diggins* (Susan Miller) (anticipated completion Fall 2015)
- *Soil Quality and Health of Malakoff Diggins State Historic Park: A Comparative Study to Characterize Disturbed and Undisturbed Sites* (Kathleen Berry-Garrett) (anticipated completion Summer 2015)
- *Quantifying Surface Water and Suspended Sediment Load at Malakoff Diggins Pit; Inflow and Outflow Model* (Peter van Daalen Wetters) (anticipated completion Summer 2015)

Appendix II: Initial Study

Initial Study: Malakoff Diggins Physical Hazards Mitigation and Water Quality Improvements
Project Description Draft - May 16, 2014

As part of the Sierra Nevada Conservancy (SNC) grant requirement, The Sierra Fund is required to provide initial study and CEQA documentation on the potential alternative solutions to address water quality and physical hazards issues identified by the SNC-funded project "Humbug Creek Watershed Assessment and Management Plan Recommendations for Malakoff Diggins State Historic Park (SHP)." However, the California Department of Parks and Recreation (DPR) has not made a selection of the proposed alternative solutions presented in the Humbug Watershed Assessment and Management Plan Recommendations at this time.

DPR and TSF realize there are data gaps that still exist in many areas including but not limited to water quality and water budget, location of mercury and other heavy metal source(s), Malakoff Diggins pit sedimentation rate and budget, and sensitive biological and cultural resources that need to be addressed before alternatives can be evaluated. DPR has determined that a Cultural Resource Inventory is needed for Malakoff Diggins SHP in order to fully understand the significance of impacts of any projects proposed for this park unit, because the North Bloomfield Historic District within Makaloff Diggins SHP is listed on the National Register of Historic Places. The additional information may eliminate, constrain, or refine what project(s) may be the most appropriate solution(s) to address Malakoff Diggins' water quality and physical hazards issues. DPR may use some of the information provided in this preliminary conceptual project description and draft initial study for future water quality and physical hazards projects at Malakoff Diggins SHP.

PROJECT PURPOSE

The purpose of the Malakoff Diggins Physical Hazards Mitigation and Water Quality Improvement Project is to mitigate physical hazards associated with legacy mining features and to reduce mining-related heavy metal and sediment discharges to waters, specifically from the Malakoff Diggins pit into Humbug Creek. These actions are recommended in order to improve public health and safety and natural resource conditions while continuing to preserve the historic mining legacy that the Park was created to memorialize.

PROJECT LOCATION AND SITE

Malakoff Diggins hydraulic mine site is in the Humbug Creek watershed, which is a tributary of the South Yuba River. It is located in Nevada County, California, about 14 mi northeast of Nevada City, and 63 air mi northeast of Sacramento (Figure 3 on page 21). This mine site was once one of the largest hydraulic gold mines during California's 19th century mining heyday and the most prominent feature of Malakoff Diggins SHP. The Park is just over 3,000 ac in size and includes five distinct anthropogenic mining features: 1) the Malakoff Diggins hydraulic pit, 2) the Hiller Tunnel that drains the Malakoff Diggins pit surface water runoff into Diggins Creek, which in turn drains in to Humbug Creek, 3) the North Bloomfield Tunnel that drains into Humbug Creek, 4) a series of access shafts that are associated with the North Bloomfield Tunnel, and 5) the Bloomfield Tunnel (the Lake City Tunnel). Humbug Creek drains into the South Yuba River.

BACKGROUND AND PROBLEM

The Malakoff Diggins hydraulic mine pit measures approximately 340 ac (6,800 ft long, ranging from 1,000-3,800 ft wide from north to south, and is 600 ft deep in places (DPR, 2010)). Its contributory drainage area (including the pit) measures approximately 1,200 ac (1.9 mi^2). The surface water drainage from the pit is currently discharged though the Hiller Tunnel. Hydraulic mining left this large pit denuded of vegetation and it continues to be a source of sediment-laden runoff to the South Yuba River watershed. The pit has a pond in its western half and a large patch of willows growing on the pit floor. The pit receives water from ephemeral drainages that flow into the pit from the north rim and from the eastern end of the pit. The forested area surrounding the pit is second-growth ponderosa pine with incense cedar, black oak, white fir and sugar pine, and white-leaf manzanita as the dominant woody shrub (DPR, 2010).

There are two tunnels associated with the Malakoff Diggins pit, the Hiller Tunnel and the North Bloomfield Tunnel. The Hiller Tunnel was constructed in 1856 and is 557 ft long. The Hiller Tunnel is the current discharge point for surface water runoff from the Malakoff Diggins pit. Discharge from the pit through the Hiller Tunnel drains into Diggins Creek, which drains into Humbug Creek and into the South Yuba River. The North Bloomfield Tunnel is 7,847 ft long and was constructed by 1874 to drain the pit during peak operations from 1874-1884. The North Bloomfield Tunnel was dug 200 ft below the Hiller Tunnel through bedrock from the Malakoff Diggins pit to Humbug Creek. The North Bloomfield Tunnel is currently blocked but has a small amount of leakage/discharge at the outlet and at one of its access shafts. There are eight access shafts associated with the North Bloomfield Tunnel at approximately 1,000 ft intervals. The access shafts are labeled 1 through 8 with Shaft 8 being in the pit and Shaft 1 near the outlet of the tunnel along Humbug Creek. Many of the access shafts hold standing water, one of which visibly discharges to Humbug Creek, Shaft 5 (the Red Shaft) (Figure 7 on page 28).

A 1979 study estimated erosion of the Malakoff Diggins pit at approximately 45,000 yd^3/yr, with deposition of about 0.15 ft of sediment on the floor of the pit each year (Peterson, 1979). Long term sediment deposition has resulted in a change in the elevation of the pit floor that has resulted in direct movement of water and sediment into Hiller Tunnel.

Mercury is an element that was used widely to extract gold as part of gold mining during the mid- to late 1800s. Humbug Creek is listed as impaired for copper, mercury, sedimentation, and zinc and is listed on the CWA Section 303(d) list of impaired water bodies by the State Water Resources Control Board (SWRCB, 2013a). It is estimated that mercury-contaminated sediment discharged from Hiller Tunnel may contribute at least 100 g of mercury/yr to Humbug Creek.

Project Objectives

Objective 1: To assess and mitigate as necessary the potential physical hazards associated with legacy mining features

Providing a safe environment for the public to enjoy Malakoff Diggins State Historic Park is a key objective for this project. Presently, Hiller Tunnel, the Bloomfield Tunnel (also referred to as Lake City Tunnel) and North Bloomfield Tunnel are open tunnels. Additionally, the Humbug Trail generally parallels Humbug Creek and the openings of a number of the vertical access shafts associated with the North Bloomfield Tunnel are visible from the trail. Access shafts 2, 3, and 4 have steep walls and these shafts have openings exposed at the ground surface. At Shaft 5, (the Red Shaft) above the North Bloomfield Tunnel, the hiking trail crosses through an area where red-colored exudate and water discharge from Shaft 5. Additional potentially hazardous openings existing within the Park continue to be found.

Objective 2: To improve water quality by reducing mining-related sediment and metals discharge from the Malakoff Diggins pit and North Bloomfield Tunnel

Improving the water quality in the Park and in the downstream watersheds is a key objective for this project. Managing and reducing sediment and metals discharge from the mining pit via Hiller Tunnel, and North Bloomfield Tunnel and associated access shafts will reduce copper, mercury, nickel, zinc, and sediments from entering Humbug Creek and further affecting the Yuba River watershed.

Description of Project Alternatives

Assessment and Mitigation of Physical Hazards

The open outlets of the Bloomfield (Lake City) and North Bloomfield Tunnels, and several open access shafts associated with the North Bloomfield Tunnel, present potential physical hazards. Park visitors and wildlife could fall, in some cases more than 50 ft, into the narrow vertical shafts. In a report to Senator Dianne Feinstein in 2007, the California Office of Mine Reclamation indicated that the Malakoff Diggins site was listed in its Abandoned Mine Lands Database as a high priority for addressing physical hazards because the public is at risk from openings into underground mine workings (Craig, 2007). Some of the vertical access shafts have some sort of wire fencing around their openings, and some are filled with water.

A) Short Term Alternatives to Address Physical Hazards

- Reroute Humbug Trail and Construct Boardwalk at Shaft 5: A boardwalk at Shaft 5 could be constructed to re-route the Humbug Creek Trail around Shaft 5, reducing the potential for Park visitors to come into contact with discharged water and precipitated solids. An interpretive feature at Shaft 5, such as an explanatory sign, would demonstrate to Park visitors the functions of monitoring and remediation in the context of legacy mining features. The boardwalk would be built out of natural products such as wood.
- Reroute Trail at Shaft 3: The Humbug Trail is located just above an eroding steep slope above Shaft 3. The trail could be re-routed upslope to allow a greater distance between the trail and the steep slope and the shaft opening.
- Maintain or Upgrade Exclusion Fences around Shafts 2, 3, 4, 5, and 6: Although the access shafts are fenced, maintenance and possibly upgraded fencing may be needed.
- Install Interpretive Signs: Interpretive signs would serve to educate the public about the significance of the access shafts and the North Bloomfield Tunnel and how they relate to mining at Malakoff Diggins.

B) Long Term Alternatives to Address Physical Hazards

- Foam Plugs in Steep-Walled Shafts 2, 3, and 4: Foam plugs could be installed using a false bottom so that the foam does not come in contact with standing water in the access shafts. A vent incorporated in the foam plug will allow for pressure equalization and overflow water to be released should the hydrology in the North Bloomfield Tunnel change. The foam plugs will be covered with several feet of soil to improve the aesthetics and to prevent any direct access to the foam surface. This option will require further studies.
- Bat-Friendly Gates at Tunnel Openings: Bat-friendly gates could be installed vertically at the tunnel outlets for both the North Bloomfield and Bloomfield (Lake City) tunnels to prevent public access. Gates can be constructed of material that will not rust and will not impede water flow out of the tunnel outlets. Periodic monitoring of the gates would be required to address potential vandalism and maintenance. Horizontal bat-friendly gates could alternatively be used at Shafts 3 and 4 instead of foam plugs. This option will require further studies.

Possible Management and Reduction of Mining-Related Sediment and Metals Discharge from Hiller and North Bloomfield Tunnels

The following strategies could be employed to divert surface water runoff flow from entering the pit and for managing water flow into the Hiller Tunnel. Specific water quality threats include discharge out of Hiller Tunnel, discharge from the North Bloomfield Tunnel, and discharge from access shafts along the North Bloomfield Tunnel. These and other potential treatments will require additional data collection and evaluation to determine level of impacts and feasibility.

A) Alternatives for Managing Sediment and Metals Include:

- Divert Surface Water Inflow around Hydraulic Pit: Reduction of surface water input to the pit would help reduce erosion and sediment transport out of the pit. Surface water runoff that occurs in ephemeral drainages during storm events could be diverted around the pit by constructing two diversion ditches that direct water around the pit to nearby surface drainages that circumvent the pit and flow into Humbug Creek. Proposed locations for drainage ditches are displayed in Figure 59 on page 134 and a conceptual diversion ditch profile in Figure 60 on page 136. By reducing the amount of water that enters the pit, the surface runoff would not come in contact with contaminated sediments in the pit, the contaminated discharge from Hiller Tunnel would be reduced, and the capacity of the proposed storm water detention basin and passive water filtration structure (described below) could be reduced.

- Retain Surface Water in Hydraulic Pit and Filter Discharge: Filtering the water before it leaves the Malakoff Diggins pit via Hiller Tunnel could reduce the concentration of mining-related sediments and metals discharging into Diggins Creek and the downstream Humbug Creek watershed. This option includes the following actions:

    * Construct a storm water detention basin and passive water filtration structure in the western end of Malakoff Diggins hydraulic pit near the inlet to Hiller Tunnel to capture storm water discharge and retain suspended solids, allowing filtered water to discharge through Hiller Tunnel (depicted conceptually in Figure 61 on page 138). The coarser sediment would settle in the pond and the finer grained sediments with adhered heavy metals would be retained in the sand filter.

    * Construct a filtering outlet structure or standpipe at the entrance to the Hiller Tunnel inlet within the Malakoff Diggins pit. The standpipe would require periodic extensions as sediment accumulates to maintain the basin's capacity for storm water equalization and sediment retention. Additional studies will help determine the rate of expected accumulation. The entrance to the Hiller Tunnel inlet within the Malakoff Diggins pit would be blocked because the standpipe would be secured to the inlet using a concrete bulkhead, and would allow sediment to collect above the former tunnel inlet. The Hiller Tunnel inlet would no longer be accessible, but the Hiller Tunnel outlet would visually remain unchanged. A profile and conceptual details of the filtering standpipe structure are depicted in Figure 62 on page 140 and Figure 64 on page 142, respectively.

    * Dams in the low areas, or saddles, of the Malakoff Diggins pit perimeter may be needed to allow for long-term sediment retention capacity as the basin fills with

sediment over the years. Saddle dams would be constructed on the southwestern pit rim, as shown conceptually in Figure 61 on page 138. A dam plan and profile are depicted in Figure 62 on page 140.

Discussion

Additional physical hazard features and contamination sources are likely present at Malakoff Diggins State Historic Park that are not included in this project description. It is anticipated that this project description will be amended when additional features and/or contamination sources are identified and appropriate mitigation activities articulated. DPR has obtained funding for the initial phase of a Cultural Resources Inventory that will develop a comprehensive list of features which will need to be evaluated. In parallel, additional contamination sources in Humbug Creek will be the focus of a DWR-funded IRWMP project which will include aerial LiDAR mapping of the entire watershed, ground-based LiDAR in the pit, and water samples from Hiller Tunnel. Additional drainage areas will need to be investigated such as the ravine that enters Diggins Creek from the west upstream of the confluence of Humbug Creek, and point sources that may impact Humbug Creek between Road 1 and the confluence with Diggins Creek.

Unknowns

Even within the proposed mitigation strategies in this Project Description there are unknowns, including:

- The extent of flooding in the pit if a detention basin is created;
- The effectiveness of the standpipe to function as a filter, since this is difficult to predict without a reliable deposition rate, and with the fine silt and clay particles in the discharge;
- The extent to which the detention pond and ditches will need to be maintained;
- Whether the attraction of Hiller Tunnel for visitors will be diminished if visitors are no longer able to walk through the full length of Hiller Tunnel; and
- Amount of habitat loss for birds and wildlife in the pit if the vegetation on the pit floor is flooded.

Additional permits that will be obtained as this project moves forward include:

- CESA SECTION 2081 (B) (C): The California Endangered Species Act (CESA) allows the California Department of Fish and Wildlife (CDFW) to the taking (section 2081 B and C) of state-listed threatened, endangered, or candidate species if certain conditions are met. A CESA 2081 (B) (C) permit may be necessary to determine the impact on threatened species.
- CPRC 5024: The California Public Resources Code requires state agencies to ensure the preservation of state-owned historical resources under their jurisdictions. Actions required

may include evaluating resources for the National and California Historical Landmark eligibility; maintaining an inventory of eligible and listed resources; and managing these historical resources so that that they will retain their historic characteristics.

- Stream alteration permit, for diverted water (Section 1602): According to Section 1602 of the California Fish and Game Code, it is illegal to substantially change the bed, channel, or bank of any river, stream, or lake, without first notifying the California Department of Fish and Game.
- Army Corps permits for stormwater basin (Section 404): Section 404 of the Federal CWA regulates the discharge of dredged material, placement of fill material, and the excavation within water. For the construction of new retention ponds, a preconstruction notification must be submitted Army Corps of Engineers prior to commencing construction.
- Point source controls (NPDES/WDR): The federal NPDES Program, implemented by the California SWRCB, also referred to as waste discharge requirements (WDRs), regulate point source discharges to waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches.

Initial Study/Checklist

Aesthetics

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Have a substantial adverse effect on a scenic vista?	☐	☑	☐	☐
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	☑
c) Substantially degrade the existing visual character or quality of the site and its surroundings	☑	☐	☐	☐
d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?	☐	☐	☐	☑

Setting

Malakoff Diggins State Historic Park contains trails that are used by the public to view the ecological and cultural resources in the Park. Currently, those trails pass by abandoned and exposed access shafts and open drainage tunnels that present physical hazards to the public.

Impacts

- Visual impact to recreational uses along trails include:
    - Seeing bat gates in open shafts, however the gates will be 9 m (30 ft) back
    - Seeing shallow depressions rather than open shafts,
    - Seeing the inlet to Hiller Tunnel where a pond with a standpipe will be visible rather than the piles of rocks and open shaft.

Relevant Regulations and Permits: N/A

Agricultural and Forest Resources

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Prog of the California Resources Agency, to non-agricultural use?	☐	☐	☐	☑
b) Conflict with existing zoning for agricultural use or a Williamson Act contract?	☐	☐	☐	☑
c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code §4526), or timberland zoned Timberland Production (as defined by government Code § 51104(g))?	☐	☐	☐	☑
d) Result in the loss of forest land or conversion of forest land to non-forest use?	☐	☐	☐	☑
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland to non-agricultural use or conversion of forest land to non-forest use?	☐	☐	☐	☑

* In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997), prepared by the California Department of Conservation as an optional model for use in assessing impacts on agricultural and farmland.

Air Quality

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Conflict with or obstruct implementation of the applicable air quality plan or regulation?	☐	☐	☐	☑
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☐	☑
c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is in non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?	☐	☐	☐	☑
d) Expose sensitive receptors to substantial pollutant concentrations (e.g., children, the elderly, individuals with compromised respiratory or immune systems)?	☐	☐	☐	☑
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☑

* Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied on to make these determinations.

Land Use Planning

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Physically divide an established community?	☐	☐	☐	☑
b) Conflict with the applicable land use plan, policy, or regulation of any agency with jurisdiction over the project (including, but not limited to, a general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☑
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☑

Biological Resources

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Have a substantial adverse effect, either directly or through habitat modification, on any species identified as a sensitive, candidate, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or the U.S. Fish and Wildlife Service?	☑	☐	☐	☐
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or the U.S. Fish and Wildlife Service?	☑	☐	☐	☐
c) Have a substantial adverse effect on federally protected wetlands, as defined by §404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?	☑	☐	☐	☐
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☑	☐	☐	☐
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☑
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☐	☑

Setting

Birds observed at Malakoff Diggins SHP during an ecological study in 1975 included red-tailed hawk, northern flicker, western wood peewee, Stellar's jay, mountain chickadee, Nashville warbler, orange-crowned warbler, oak titmouse, bushtit, Bewick's wren, Hutton's vireo, black-throated gray warbler, western tanager, purple finch, black-headed grosbeak, pileated woodpecker, spotted towhee, and many kinds of owls (Harding, 1977). Lukas (2002) described the Diggins areas as a healthy and diverse bird community that is becoming increasingly valuable as one of the most important sites for birds in the county. In addition to birds and small animals, the wild animal community includes black-tailed deer, coyote, bobcat, mountain lion, and black bear. Sensitive or special status bird and amphibian species occur or may occur at Malakoff Diggins SHP. Willow flycatcher (*Empidonax trailii*) surveys by David Lukas in 2002 documented two unconfirmed willow flycatcher (*Empidonax trailii*) calls at Malakoff Diggins pit. Willow flycatcher is a State endangered species. Other California Department of Fish and Wildlife designated bird species of special concern documented by David Lukas and/or DPR biologists in Malakoff Diggins SHP were the yellow warbler (*Dendroica petechial*), yellow-breasted chat (*Icteria virens*), olive-sided flycatcher (*Contopus cooperi*), and California spotted owl (*Strix occidentalis occidentalis*). The California red-legged frog (CRLF) (*Rana draytonii*) is a Federal Threatened Species and a California species of special concern. CRLF is known to occur within a couple of miles of the Park and critical habitat is adjacent to the southern Park boundary. No protocol-level surveys for CRLF have been conducted at the Park. The Foothill yellow-legged frog (FYLF) (*Rana boylii*) is a California species of special concern. FYLF surveys were conducted in 1999 and 2000 found a scattered population of FYLF in Humbug Creek (California Department of Fish and Game, 2011; Yarnell and Larsen, 2000; Yarnell, 2005). DPR surveys in 2013 also found a scattered population and different life stages of FYLF. A reconnaissance fisheries survey completed in 1978 noted that due to sedimentation, fish populations in Diggins Creek were absent and found to be "fairly low" in Humbug Creek below the confluence of Diggins Creek "when compared to similar streams in the area not having the severe sedimentation problem" (NCRDC, 1978; Taylor, 1987).

Impacts

a) Substantial adverse effect on candidate and sensitive species. Lukas (2002) detected two unconfirmed State Endangered willow flycatcher calls at Malakoff Diggins mining pit. Modification of this habitat could be a potentially significant impact. California red-legged frogs (CRLF) and foothill yellow-legged frogs are known to occur within a couple of miles of Malakoff Diggins SHP and it is unknown if CRLF occur in the ponds and wetlands at the Park unit. Until a presence or absence of CRLF is known, disturbance to the ground, riparian and wetland vegetation may be considered potentially significant. Yellow warblers and yellow-breasted chats, California species of special concern, are present at the Malakoff Diggins mining pit and potentially other sensitive wetland vegetation nesting species could be impacted by habitat modification. Alteration of the wetland and riparian vegetation will require consultation with the USFWS and CDFW prior to conducting work.

b) Impact to riparian habitat or sensitive natural community. The USFWS has designated CRLF Critical Habitat that adjoins Malakoff Diggins SHP. The USFWS would deem the proposed actions as potentially significant without confirmed presence/absence of CRLF at Malakoff Diggins SHP.

c) Adverse impact on wetlands, riparian. Depending on its extent, flooding of the wetland and riparian habitats as a permanent or temporary condition could be considered a significant impact. Diversion of waters around the Diggins area could potentially reduce the area of wetland and riparian vegetation and may be considered a potentially significant impact.

d) Interfere with movement of native wildlife, etc. Malakoff Diggins SHP is at least a migratory stop-over habitat for willow flycatcher, whether or not it is used for nesting.

e) Modifications to the runoff out of Malakoff Diggins into Humbug Creek are intended to improve stream water quality. During construction, structures may be required to keep any unintended sediment from entering Humbug Creek while small dams, berms, or filtering devices are constructed.

f) Bat populations may be impacted by the installation of foam plugs into access shafts. Surveys will be conducted for bats to detect the presence of these species before determining whether foam or bat friendly gates should be installed.

g) Construction activities will be conducted during times where ground- or shrub-nesting birds will not be disturbed.

Relevant Regulations and Permits
CESA Sections 2081 (b) and (c)
California Fish and Game Code

- 86 Take
- 2050 et seq. California Endangered Species Act
- 2080 Prohibition

California Environmental Quality Act

- 15380 Endangered, Rare, and Threatened Species
- Federal Migratory Bird Treaty Act of 1918

Cultural Resources

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Cause a substantial adverse change in the significance of a historical resource, as defined in §15064.5?	☑	☐	☐	☐
b) Cause a substantial adverse change in the significance of an archaeological resource, pursuant to §15064.5?	☑	☐	☐	☐
c) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☑

Setting

Malakoff Diggins is a State Historic Park and registered in the National Register of Historic Places. It is the site of California's largest hydraulic mine and contains rich cultural resources pertaining to early California history with an emphasis on mining in the Sierra Nevada. Malakoff Diggins is visited by the public and school groups who come to the Park to experience and learn about California's mining history. Because the Park is located within a historic hydraulic mine site, it is impacted by pollutants that were used as part of the mining process and abandoned tunnels and shafts that are physical hazards for visitors.

Impacts

The project may include building structures to improve water quality, physical hazard remediation using foam and gates, the construction of a boardwalk to keep visitors safe, and removing unsafe structures.

- The construction of dams, berms, or filtering devices may lead to some visual changes to Malakoff Diggins State Historic Park. Surveys will be conducted to determine extant cultural resources and will be outlined in the EIR.
- The use of interpretive signs will be employed to explain the dangers of pollutants and open shafts to further educate the public about the controversial legacy of hydraulic mining in California.
- To reduce physical hazards at the site, unsafe structures will be removed or repaired.

Relevant Regulations and Permits

California Public Resources Code Section 5024

Mandates that all State agencies preserve and maintain all state-owned historical resources and that potentially significant impacts to them be evaluated during the project planning stage. Significant impacts are defined in CEQA Section 15064.5. If there is a federal nexus (i.e., permitting and/or funding) to any aspect of the project, other regulations apply, namely the National Historic Preservation Act of 1966, as amended.

Geology and Soils

Would the Project:		Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a)	Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i)	Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map, issued by the State Geologist for the area, or based on other substantial evidence of a known fault? (Refer to Division of Mines and Geology Special Publication 42.)	☐	☐	☐	☑
ii)	Strong seismic ground shaking?	☐	☐	☐	☑
iii)	Seismic-related ground failure, including liquefaction?	☐	☐	☐	☑
iv)	Landslides?	☐	☐	☐	☑
b)	Result in substantial soil erosion or the loss of topsoil?	☐	☐	☐	☑
c)	Be located on a geologic unit or soil that is unstable, or that would become unstable, as a result of the project and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☐	☑
d)	Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1997), creating substantial risks to life or property?	☐	☐	☐	☑
e)	Have soils incapable of adequately supporting the use of septic tanks or alternative waste disposal systems, where sewers are not available for the disposal of waste water?	☐	☐	☐	☑
f)	Directly or indirectly destroy a unique paleontological resource or site, or unique geologic feature?	☐	☐	☐	☑

Greenhouse Gas Emissions

Would the Project:		Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a)	Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environmental?	☐	☐	☐	☑
b)	Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?	☐	☐	☐	☑

Hazards and Hazardous Materials

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☑
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and/or accident conditions involving the release of hazardous materials, substances, or waste into the environment?	☐	☐	☐	☑
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	☐	☐	☐	☑
d) Be located on a site which is included on a list of hazardous materials sites, compiled pursuant to Government Code §65962.5, and, as a result, create a significant hazard to the public or environment?	☐	☐	☐	☑
e) Be located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport? If so, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☑
f) Be located in the vicinity of a private airstrip? If so, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☑
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☑
h) Expose people or structures to a significant risk of loss, injury, or death from wildland fires, including areas where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☑

Hydrology and Water Quality

Would the Project:		Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a)	Violate any water quality standards or waste discharge requirements?	☐	☑	☐	☐
b)	Substantially deplete groundwater supplies or interfere substantially with groundwater recharge, such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level that would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	☑
c)	Substantially alter the existing drainage pattern of the site or area, including through alteration of the course of a stream or river, in a manner which would result in substantial on- or off-site erosion or siltation?	☐	☑	☐	☐
d)	Substantially alter the existing drainage pattern of the site or area, including through alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in on- or off-site flooding?	☐	☑	☐	☐
e)	Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☑	☐	☐
f)	Substantially degrade water quality?	☐	☐	☐	☑
g)	Place housing within a 100-year flood hazard area, as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map, or other flood hazard delineation map?	☐	☐	☐	☑
h)	Place structures that would impede or redirect flood flows within a 100-year flood hazard area?	☐	☐	☐	☑
i)	Expose people or structures to a significant risk of loss, injury, or death from flooding, including flooding resulting from the failure of a levee or dam?	☐	☐	☐	☑
j)	Result in inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☑

Setting

Malakoff Diggins State Historic Park has two major drain tunnel systems, Hiller Tunnel and the North Bloomfield Tunnel. The tunnel systems drain into Humbug Creek and the South Yuba River. Humbug Creek is listed as impaired for sedimentation, mercury, copper and zinc and is listed on the CWA Section 303(d) list of impaired water bodies by the SWRCB. It is estimated that at least 100 grams of mercury per year are washed down Humbug Creek. Remediating the water quality concerns will require managing sediment and metals discharge from the mining pit. Presently, the pit continues to erode at a rate of 27,000 cubic meters per year (35,000 cubic yards per year), depositing about 4.6 cm (0.15 ft) of sediment on the floor of the pit each year. Long term sediment deposition has resulted in a change in the elevation of the pit floor that has resulted in direct movement of water and sediment into the Hiller Tunnel. Remediation alternatives include diverting surface water around the pit, retaining sediment in the hydraulic pit and filtering water as it leaves the pit via a standpipe though the Hiller Tunnel and stabilizing portions of the pit walls to decrease the erosion rate.

Impacts

- Surface water that occurs in drainages during storm events may be diverted around the pit by diversion ditches and delivered to nearby surface drainages that circumvent the pit and flow into Humbug Creek. By reducing the amount of water that enters the pit, surface runoff would not come in contact with contaminated sediments in the pit, and the contaminated discharge from Hiller Tunnel would be reduced. The proposed diversions will change the way surface water moves around the site and impacts will need to be addressed in the EIR.
- The construction of a detention pond in the western end of the Malakoff Diggins hydraulic pit will be used to equalize storm water discharge and to retain suspended solids.

Relevant Regulations and Permits

Stream alteration permit, for diverted water (Section 1602)
Army Corps permit for stormwater basin (Section 404)
Stormwater permits for Hiller Discharge (NPDES/WDR) and North Bloomfield Discharge (NPDES/ WDR)

Mineral Resources

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Result in the loss of availability of a known mineral resource that is or would be of value to the region and the residents of the state?	☐	☐	☐	☑
b) Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan?	☐	☐	☐	☑

Noise

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Generate or expose people to noise levels in excess of standards established in a local general plan or noise ordinance, or in other applicable local, state, or federal standards?	☐	☐	☐	☑
b) Generate or expose people to excessive groundborne vibrations or groundborne noise levels?	☐	☐	☐	☑
c) Create a substantial permanent increase in ambient noise levels in the vicinity of the project (above levels without the project)?	☐	☐	☐	☑
d) Create a substantial temporary or periodic increase in ambient noise levels in the vicinity of the project, in excess of noise levels existing without the project?	☐	☐	☐	☑
e) Be located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport? If so, would the project expose people residing or workingin the project area to excessive noise levels?	☐	☐	☐	☑
f) Be in the vicinity of a private airstrip? If so, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☑

Population and Housing

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	☐	☐	☐	☑
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☑
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☑

Public Services

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Result in significant environmental impacts from construction associated with the provision of new or physically altered governmental facilities, or the need for new or physically altered governmental facilities, to maintain acceptable service ratios, response times, or other performance objectives for any of the public services:	☐	☐	☐	☑
Fire protection?	☐	☐	☐	☑
Police protection?	☐	☐	☐	☑
Schools?	☐	☐	☐	☑
Parks?	☐	☐	☐	☑
Other public facilities?	☐	☐	☐	☑

RECREATION

WOULD THE PROJECT:	POTENTIALLY SIGNIFICANT IMPACT	LESS THAN SIGNIFICANT WITH MITIGATION	LESS THAN SIGNIFICANT IMPACT	NO IMPACT
a) Increase the use of existing neighborhood and regional parks or other recreational facilities, such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☐	☑
b) Include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?	☐	☐	☐	☑

TRANSPORTATION/TRAFFIC

WOULD THE PROJECT:	POTENTIALLY SIGNIFICANT IMPACT	LESS THAN SIGNIFICANT WITH MITIGATION	LESS THAN SIGNIFICANT IMPACT	NO IMPACT
a) Conflict with an applicable plan, ordinance or policyestablishing measures of effectiveness for the performance of the circulation system, taking into account all modes of transportation including mass transit and non-motorized travel and relevant components of the circulation system?	☐	☐	☐	☑
b) Conflict with an applicable congestion management prog, including, but not limited to level of service standards and travel demand measures, or other standards established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☑
c) Cause a change in air traffic patterns, including either an increase in traffic levels or a change in location, that results in substantial safety risks?	☐	☐	☐	☑
d) Contain a design feature (e.g., sharp curves or a dangerous intersection) or incompatible uses (e.g., farm equipment) that would substantially increase hazards?	☐	☐	☐	☑
e) Result in inadequate emergency access?	☐	☐	☐	☑
f) Result in inadequate parking capacity?	☐	☐	☐	☑
g) Conflict with adopted policies, plans, or progs regarding public transit, bicycle, or pedestrian facilities, or otherwise decrease the performance or safety of such facilities?	☐	☐	☐	☑

Utilities and Service Systems

Would the Project:		Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a)	Exceed wastewater treatment restrictions or standards of the applicable Regional Water Quality Control Board?	☐	☐	☐	☑
b)	Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities?	☐	☐	☐	☑
	Would the construction of these facilities cause significant environmental effects?	☐	☐	☐	☑
c)	Require or result in the construction of new storm water drainage facilities or expansion of existing facilities?	☐	☐	☐	☑
d)	Would the construction of these facilities cause significant environmental effects?	☐	☐	☐	☑
e)	Have sufficient water supplies available to serve the project from existing entitlements and resources or are new or expanded entitlements needed?	☐	☐	☐	☑
f)	Result in a determination, by the wastewater treatment provider that serves or may serve the project, that it has adequate capacity to service the project's anticipated demand, in addition to the provider's existing commitments?	☐	☐	☐	☑
g)	Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☑
h)	Comply with federal, state, and local statutes and regulations as they relate to solid waste?	☐	☐	☐	☑

Mandatory Findings of Significance

Would the Project:	Potentially Significant Impact	Less than significant with Mitigation	Less than significant Impact	No Impact
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal?	☑	☐	☐	☐
b) Have the potential to eliminate important examples of the major periods of California history or prehistory?	☑	☐	☐	☐
c) Have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means the incremental effects of a project are considerable when viewed in connection with the effects of past projects, other current projects, and probably future projects?)	☐	☐	☐	☑
d) Have environmental effects that will cause substantial adverse effects on humans, either directly or indirectly?	☐	☐	☐	☑

Appendix III: Mining Toxins Working Group Members

The Sierra Fund's Mining Toxins Working Group provides oversight and technical advice to all aspects of our Reclaiming the Sierra Initiative including a human health outreach program, policy initiatives, and other activities.

Members directly involved in the Humbug Creek Assessment Project, the subject of this report, are marked with an asterisk (*).

Community Mining Project Advisors:	
David Brown, Ph.D.*	California State University Chico
Syd Brown*	CA Department of Parks and Recreation (retired)
Marc Choyt	Fair Jewelry Action
Becky Damazo	California State University Chico, School of Nursing
Caleb Dardick*	South Yuba River Citizens League
Steve Evans	Friends of the River
Ellison Folk	Shute, Mihaly and Weinberger
Alison Harvey	Friends of the North Fork American River
Roger Hicks, M.D.	Yubadocs Urgent Care
Jane Hightower, M.D.	Internal Medicine
Rick Humphreys*	State Water Resources Control Board (retired)
Rachel Hutchinson*	South Yuba River Citizens League
Robert N. Joehnck	Attorney
Jonathan Kusel, Ph.D.	Sierra Institute for Community and the Environment
John Lane	Teichert Materials
John Lane*	Chico Environmental/State Mining and Geology Board
Kyle Leach , P.G.*	Consulting Geologist/Sierra Streams Institute
Stephen McCord, Ph.D.*	McCord Environmental, Inc.
Christina Miller	Ethical Metalsmiths
Jason Muir, P.E., G.E. *	Holdrege & Kull
Sherri Norris	California Indian Environmental Alliance
Micheal Ben Ortiz	Calling Back the Salmon
Lauren Pagel	EARTHWORKS
David Peterson*	The Geoservices Group
Chauncey Poston*	realtor
Mike Powell, D.O.	Internal Medicine and Rheumatology
Alberto Ramirez	Teichert
Gary Reedy*	South Yuba River Citizens League
Greg Reller*	Burleson Consulting

Appendix III: Working Group

Ren Reynolds	Enterprise Rancheria
Mark Selverston, M.A., RPA*	Sonoma State University Anthropological Studies Center
Jeff Shellito	fisheries advocate
Robert Shibatani	The Shibatani Group, Inc.
Fraser Shilling, Ph.D.	UC Davis
Darrel Slotton*	UC Davis
Greg Taylor, Ph.D.	CSU, Chico
Lisa Thompson, Ph.D.	UC Cooperative Extension
Craig Tucker, Ph.D.	Karuk Tribe
Steve Wilensky	Calaveras Co. Supervisor
Vida Wright	Veridico Group, Inc.
Kendra Zamzow, Ph.D. *	Center for Science and Public Participation

Agency Advisors: Local, state and federal agencies participate as resources to the Initiative, working with The Sierra Fund to ensure that this report accurately characterizes their agencies' roles, responsibilities and actions.

Randy Adams*	Department of Toxic Substances Control
Charles N. Alpers, Ph.D. *	U.S. Geological Survey
Steven Becker, P.G. *	Department of Toxic Substances Control
Diane Colburn	CA Assembly Water, Parks & Wildlife
Tim Crough	Nevada Irrigation District
Jennifer Curtis*	US Geological Survey
Grant Eisen	Nevada County Environmental Health
Jacob Fleck*	U.S. Geological Survey
Julie Griffith-Flatter*	Sierra Nevada Conservancy
Bill Haigh	Bureau of Land Management
Elizabeth Haven	CA State Water Resources Control Board
John Hillenbrand*	EPA Region 9
Victor Izzo*	Central Valley Water Quality Control Board
Sandy Karinen	Department of Toxic Substances Control
Dan Lubin*	CA Department of Parks and Recreation
Patrick Morris	Central Valley Water Quality Control Bd
Cy Oggins	CA State Lands Commission
Sarah Reeves	CA Department of Conservation
Tamara Sasaki*	CA Department of Parks and Recreation
Stephen Testa	State Mining & Geology Board
Alyce Ujihara	CA Department of Public Health
Cyndie Walck*	CA Department of Parks and Recreation
Ian Walker	CA Department of Public Health
Rick Weaver*	U.S. Forest Service
Phil Woodward*	Central Valley Water Quality Control Board

Appendix IV: Relevant Cultural and Environmental Laws

Federal Environmental Laws and Protections of Cultural Resources

Antiquities Act of 1906

The Antiquities Act (16 USC 431–433) authorized the President of the United States to designate National Monuments and provided criminal penalties for the unauthorized excavation, injury, or destruction of prehistoric or historic ruins and objects of antiquity located on federal lands. This act also authorized the Departments of the Interior, Agriculture, and War to issue permits to qualified institutions for the excavation of archaeological sites or removal of archaeological items if such actions were in the best interests of the country. This act only applies on federal lands.

National Historic Preservation Act of 1966

The NHPA (16 USC 470 et seq.) established the Advisory Council on Historic Preservation (ACHP), authorized the Secretary of the Interior to maintain a National Register of Historic Places (NRHP), directed the Secretary to approve state historic preservation programs that provided for a State Historic Preservation Officer (SHPO), established a National Historic Preservation Fund program, and codified the National Historic Landmarks program. The formal procedures for evaluating and listing resources in the NRHP were established by the Secretary of the Interior in 36 CFR Part 60.

Section 101 of the NHPA requires that programs be developed to ensure that tribal values are taken into account to the extent feasible, and recognizes that properties of traditional religious and cultural importance to Indian Tribes or Native Hawaiian organizations may be eligible for inclusion in the NRHP.

Section 106 of the NHPA requires federal agencies to take into account the effects of their actions on properties that are listed in or eligible for listing in the NRHP, and afford the ACHP a reasonable opportunity to comment. To determine whether an undertaking could affect historic properties, all cultural sites (including archaeological, historical, and architectural properties) that may be affected by the undertaking must be inventoried and evaluated for eligibility for listing in the NRHP. Regulations implementing Section 106 have been published by the Secretary of the Interior (36 CFR Part 800). The Section 106 process will need to be satisfied for the Humbug Creek remediation project if there is a federal nexus such as funding, permitting, or more directly such as the EPA executing some or all of the alternatives.

Appendix IV: Relevant Laws

Cultural Values – Section 106 of National Historic Preservation Act

Section 106 of the National Historic Preservation Act and the California Environmental Quality Act provide for the protection of significant or important cultural resources. It is important to understand exactly which values make a resource significant/important in order to understand if any given undertaking or project will adversely impact them. Impacts are adverse only if they diminish or eliminate the values for which a resource is considered significant. The process of determining whether a cultural resource possesses significant values is usually called an evaluation and the NRHP Criteria for Evaluation (36 CFR 60.4) is often the benchmark tool used. For the most part this process has not been carried out for cultural resources identified in the Park. Evaluations will not need to be carried out for the purposes of any remediation project unless identified cultural resources exist within the project area, or, more specifically, the Area of Potential Effects (APE), as determined by the lead agency.

Effect means "alteration to the characteristics of a historic property qualifying it for inclusion in or eligibility for the National Register" (36 CFR 800.16(i)). Effect means demolition, destruction, relocation, or alteration such that the physical characteristics of an historical resource that convey its historical significance are diminished and, that as a result, the significance of the historical resource itself is impaired. An effect is found when an undertaking may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the National Register in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association (36 CFR 800.5(a)(1)).

Cultural resources may be significant because they convey their association with events that have made a significant contribution to the broad patterns of history; or their association with the lives of persons significant in the past; or they embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction. All of these are criteria that are applicable and if a property has integrity and continues to convey one or more of these associations it may qualify for listing on the NRHP. At Malakoff Diggins for example, the hydraulic pit conveys both a sense of the scale of hydraulic mining that took place as well as the magnitude of environmental destruction that lead to the Sawyer Decision. Any action that would reduce or eliminate the pit's ability to convey this association would be considered adverse. Adverse actions are not necessarily forbidden, but typically require some form of mitigation or treatment.

Cultural Resources may also be eligible for the NRHP if they have yielded, or may be likely to yield, information important in prehistory or history. This value is entirely different than just described above, which is more commemorative, and has everything to do with archaeological study. Cultural resources that are significant for their data can be preserved through rigorous archaeological research guided by a research design. Impacts would not be adverse after a site's important data has been removed. Or, rather, adverse impacts could be treated or mitigated by a data recovery program. Assessment of proposed remedial alternatives should address this distinction. In all cases, focused cultural resource studies will need to be carried out as decisions are made and potential project locations selected.

National Environmental Policy Act of 1969

The NEPA (42 USC 4321 et seq.) declared, in part, that it is the policy of the federal government to preserve important historic, cultural, and natural aspects of the Nation's heritage. NEPA requires federal agencies to take environmental values into account in their decision making processes. Through environmental impact statements (EISs) on proposed projects that may significantly affect the quality of the environment, federal agencies have to evaluate their proposed actions and reasonable alternatives. After the public and other federal agencies have provided their input and then commented on the completed EIS, the federal agency prepares a public record to explain how its decision considered the EIS findings (USEPA, 2012). Title II of NEPA established the Council on Environmental Quality (CEQ). CEQ is responsible for conducting studies and research relating to ecological systems and environmental quality, ensuring that federal agencies meet their obligations under NEPA, and issuing guidelines for the implementation of this broad act. Title 40 CFR Part 1500 contains the regulations issued by CEQ for the implementation of NEPA.

Executive Order 11593 of 1971, Protection and Enhancement of the Cultural Environment

The President issued an Executive Order on 31 May 1971 emphasizing the leadership role of the federal government in preserving, restoring, and maintaining the historic and cultural environment of the nation. This Executive Order directed all federal agencies to locate and inventory all cultural resources under their jurisdiction to ensure that actions do not inadvertently affect significant cultural resources. Executive Order 11593 further directed agencies to consider the effects of actions authorized by federal permits or licenses on resources located on nonfederal lands.

American Indian Religious Freedom Act of 1978

AIRFA established federal policy to protect and preserve the inherent rights of freedom for American Indians, Eskimos, Aleuts, and Native Hawaiians to believe, express, and exercise their traditional religions on federal and tribal trust lands (Public Law [PL] 95-341; 42 USC 1996). These rights include, but are not limited to, access to sites, use and possession of sacred objects, and the freedom to worship through traditional ceremonies and rites. This act only applies to federal and tribal trust lands.

Archaeological Resources Protection Act of 1979

ARPA amended the Antiquities Act, set a broad policy that archaeological resources are important to the nation and should be protected, and required special permits before the excavation or removal of archaeological resources from public or Indian lands (16 USC 470aa-mm). The purpose of this act was to secure, for the present and future benefit of the American people, the protection of archaeological resources and sites that are on public lands and Indian lands. The act was also intended to foster increased cooperation and exchange of information between governmental authorities, the professional archaeological community, and private individuals having collections of archaeological resources and data obtained before 1979. ARPA also provides for maintaining the confidentiality of information on the nature and location of archaeological sites.

Native American Graves Protection and Repatriation Act of 1990

NAGPRA was intended to ensure the protection and rightful disposition of Native American cultural items and burials located on federal or tribal trust lands, and in the possession or control of the federal government (PL 101-601; 25 USC 3001 et seq.). NAGPRA requires federal agencies and certain recipients of federal funds (including state agencies) to document Native American human remains and cultural items within their collections, notify Native groups of their holdings, and provide an opportunity for the repatriation of these materials. This act also requires planning steps to deal with the potential inadvertent discovery and collection of Native American human remains and associated funerary objects, sacred objects, and objects of cultural patrimony on federal and tribal trust lands.

Executive Order 13007 of 1996, Indian Sacred Sites

The President issued an Executive Order on 24 March 1996 mandating that each executive branch agency with statutory or administrative responsibility for the management of federal lands shall, to the extent practicable permitted by law, (1) accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners and (2) avoid adversely affecting the physical integrity of such sacred sites. Where appropriate, agencies are required to maintain the confidentiality of sacred sites.

Executive Order 13175 of 2000, Consultation and Coordination with Indian Tribal Governments

The President issued an Executive Order on 6 November 2000 recognizing the unique legal relationship between the United States and American Indian tribal governments, and mandating that federal agencies consult and collaborate with federally recognized Indian Tribes as part of a process to strengthen government-to-government relationships. The Executive Order established policies for reviews of waiver applications by tribes, and established accountability practices for federal agencies in collaborating and consulting with Indian Tribes.

Clean Water Act - 33 U.S.C. §1251 et seq. (1972)

The CWA provided a framework for regulating discharges of pollutants to waters of the United States and for establishing surface water quality standards. Initially titled the Federal Water Pollution Control Act when passed in 1948, the legislation was renamed the "Clean Water Act" when it was substantially reorganized and expanded with amendments in 1972. Under authority provided by this legislation, EPA has set surface water quality standards for all contaminants. Under the National Pollutant Discharge Elimination System (NPDES), industrial, municipal, and other facilities must obtain permits for discharges into surface waters from discrete point sources. However, abandoned mines are considered non-point sources and NPDES permits are not required for their discharges into surface waters (EPA, 2013a).

Public Trust Doctrine

Under common law, certain resources such as the coastline between the high and low water marks and navigable waters are considered to be reserved for use by the public. A number of states have recognized that they have a trust responsibility to preserve public trust resources as a necessary condition for protecting their public uses (NOAA). In California, a series of judicial and administrative cases regarding Mono Lake were decided between 1983 and 1984 on the basis of the public trust doctrine. The decisions in these cases placed limits on the ability of holders of appropriative water rights to appropriate surface water in a way that "unnecessarily harms the public trust uses of navigation, fishing, commerce, and environmental quality" (Roos-Collins, 2005).

Endangered Species Act - 16 U.S.C. §1531 et seq. (1973)

The Endangered Species Act (ESA) established a framework to protect animals and plants designated as threatened and endangered as well as their habitats. The law gave the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Agency the lead responsibility for carry out the ESA. Furthermore, federal agencies are required by the ESA to consult with the U.S. Fish and Wildlife Service and/or the NOAA Fisheries Service to avoid the possibility that actions they carry out might adversely impact the continued existence of any listed species or the designated critical habitat for those species. In addition, the ESA forbids actions that result in "taking" of any listed species and import, export, interstate, and foreign commerce in listed species (EPA, 2013c).

Comprehensive Environmental Response, Compensation, and Liability Act - 42 U.S.C. §9601 et seq. (1980)

The Comprehensive Environmental Response, Compensation, and Liability Act -- otherwise known as CERCLA or Superfund -- created a Federal "Superfund" to pay for cleaning up uncontrolled or abandoned hazardous-waste sites as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment. Through CERCLA, EPA was given power to pursue and enforce against potentially responsible parties for releases. EPA was given the responsibility of cleaning up orphan sites when potentially responsible parties were not identified, or when the responsible parties were uncooperative. EPA has the authority to effect private party cleanups through orders, consent decrees, and small party settlements. Alternatively, EPA may undertake a response action and then recover the costs from financially viable individuals and companies when the response action has been completed (EPA, 2013b).

After purchasing the mine in the mid-1960s, DPR created the Malakoff Diggins State Historic Park in 1965. DPR subsequently nominated the Park to the National Register of Historic Places (Chronology document, 1989). The Malakoff Diggins – North Bloomfield Historic District was listed in 1973. As a consequence of listing, the California Environmental Quality Act (CEQA) may require an environmental review if a property is threatened by a project (California Department of Fish and Game).

California Environmental Laws and Protections of Cultural Resources

California Environmental Quality Act of 1970

CEQA states the intent of the California Legislature that all agencies of the State government that regulate activities that may affect the quality of the environment shall give consideration to preventing environmental damage (California Public Resources Code [PRC] 21000 et seq.). CEQA further states that public agencies should not approve projects if there are feasible alternatives or mitigation measures that would substantially lessen the significant environmental effects of proposed projects. CEQA acknowledges, however, that agencies may approve projects that cause significant environmental effects if economic, social, or other conditions make alternatives or mitigation measures infeasible. CEQA also establishes policies and directions for conducting environmental analysis, documenting those studies, and allowing for public review of environmental impact reports. State owned properties are subject to the provisions of Public Resources Code Section 5024 and 5024.5. Public Resources Code 15064.5 defines what historical resources are for the purposes of CEQA, and how to determine the significance of impacts on historical and unique archaeological resources. DPR as owner and manager of the Park will need to satisfy CEQA requirements as part of any remedial project. In many respects the process to determine whether a cultural resource is important or significant is the same as Section 106 of the NHPA.

Section 21083.2 of CEQA requires that the lead State agency determine whether a project may have a significant effect on unique archaeological resources. A unique archaeological resource is defined in CEQA as an archaeological artifact, object, or site about which it can be clearly demonstrated that there is a high probability that it:

(1) Contains information needed to answer important scientific research questions, and there is demonstrable public interest in that information;

(2) Has a special or particular quality, such as being the oldest of its type or the best available example of its type; or

(3) Is directly associated with a scientifically recognized important prehistoric or historic event or person.

Measures to avoid, conserve, preserve, or mitigate significant effects on these resources are provided.

Public Resources Code 5024

PRC 5024 requires all State agencies to preserve and maintain all state-owned historical resources. OHP has the authority to review State agency efforts to comply with the law. DPR and the SHPO operate under an MOU that provides for a Department Preservation Officer authority unless it is determined there will be an adverse effect on a historical resource. Ultimately, State agencies must work with OHP to demonstrate they are protecting and maintaining their historic resources and that no project will adversely impact those resources. A historical resource may be prehistoric, historic, ethnographic, or a traditional cultural property.

State CEQA Guidelines

The State CEQA Guidelines (California Code of Regulations [CCR] 15000 et seq.) are published by the Governor's Office of Planning and Research for adoption by the Secretary of Resources. These guidelines provide detailed instructions on how to conduct analyses under CEQA, as well as procedures for documenting these analyses, evaluating project alternatives and mitigation measures, and soliciting review of draft environmental documents by the public and responsible agencies before making final agency decisions. The State CEQA Guidelines are binding on all public agencies in California.

Section 15064.5 of the State CEQA Guidelines notes that "a project with an effect that may cause a substantial adverse change in the significance of a historical resource is a project that may have a significant effect on the environment." Agencies are expected to identify potentially feasible measures to mitigate significant adverse changes in the significance of a historical resource before they approve such projects. Historical resources are those that:

(1) Are listed in, or determined to be eligible for listing in, the California Register of Historical Resources (PRC 5024.1(k));

(2) Are included in a local register of historical resources (PRC 5020.1) or identified as significant in an historical resource survey meeting the requirements of Section 5024.1(g); or

(3) Are determined by a lead State agency to be historically significant.

Section 15064.5 also applies to unique archaeological resources, as defined in PRC 21084.1.

Appendix IV: Relevant Laws

Comprehensive Statewide Historic Preservation Plan for California

The California Office of Historic Preservation published a comprehensive planning guide in 1997 for historic preservation in the State, pursuant to Section 101 of the NHPA. This document has been updated twice. This document was intended to "serve as a guide for decision-making; to help communicate historic preservation policy, goals, and values to all levels of government and local organizations; and to ensure that our historic resources are preserved for many generations to come." The plan is intended to incorporate applicable preservation goals, concerns, and priorities described in the statewide plan.

Cal NAGPRA

Similar to the federal NAGPRA, Cal NAGPRA (AB 978) provides for repatriation of Native American burials or objects of cultural patrimony found on State land or held within State-owned repositories.

Surface Mining and Reclamation Act of 1975

The California Legislature passed the Surface Mining and Reclamation Act (SMARA) to provide an ongoing source of mineral resources, and to protect the public health, property, and the environment from negative impacts of surface mining. The Office of Mine Reclamation provides ongoing technical assistance to lead agencies and operators, maintains a database of mine locations and operational information statewide, and is responsible for compliance with regulations promulgated by the State Mining and Geology Board. The requirements of SMARA pertain to "anyone, including government agencies, engaged in surface mining operations in California (including those on federally managed lands) which disturb more than one acre or remove more than 800 m^3 (1,000 yd^3) of material. This includes, but is not limited to: prospecting and exploratory activities, dredging and quarrying, streambed skimming, borrow pitting, and the stockpiling of mined materials" (CDOC, 2007).

Porter-Cologne Water Quality Control Act

Like the federal CWA, the Porter-Cologne Water Quality Control Act, California Water Code sections 13300-13999 and Title 23 of the California Administrative Code, provides a framework for regulating discharges that may affect water quality in the state. However, unlike the CWA, the Porter-Cologne Act regulates groundwater as well as surface water. The Porter-Cologne Act authorizes the SWRCB and nine Regional Water Quality Control Boards (RWQCBs) to use planning, permitting, and enforcement processes to regulate water quality. The State Board has the responsibility for making state water quality policies and administering the NPDES permit system created under the CWA (Brown).

California Safe Drinking Water Act

The California Safe Drinking Water Act requires the establishment of Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs) for water designated as supporting municipal and domestic supply, including groundwater and surface waters. This act requires the California Office of Environmental Health Hazard Assessment to develop, promulgate, and update Drinking Water Public Health Goals (PHGs). PHGs are concentrations of chemicals in drinking water that are not anticipated to produce adverse health effects. PHGs are non-regulatory in nature but are used as the health basis to update the state's primary drinking water standards. Where primary drinking water standards are not promulgated, the Water Quality Control Boards take PHGs into consideration when establishing cleanup levels.

Proposition 65

This initiative is codified at Health and Safety Code sections 25249.5 et seq. Its two components deal with requirements for warning labels to the public and with discharges to drinking water. In effect, it forbids businesses to knowingly discharge into water specific carcinogens or mutagens (substances that cause genetic alteration) listed in the California Code of Regulations Title 22, section 12000 without first providing a warning. In the case of violations of its provisions, it allows civil penalties of up to $2,500 per day for each violation to be imposed. In addition, private parties are allowed to sue upon notice to the local district attorney and the Attorney General (Brown).

Fish and Game Code Section 1602

Notification to California Department of Fish and Wildlife is required by any person, business, state or local government agency, or public utility that proposes an activity that will: "substantially divert or obstruct the natural flow of any river, stream or lake; substantially change or use any material from the bed, channel, or bank of, any river, stream, or lake; or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake." Intermittent streams, desert washes, streams with a subsurface flow, and areas within the floodplain are affected. Upon receipt of a notification form and fee, DFW will determine whether the activity may have substantial adverse effects on fish and wildlife resources. In that case, DFW will prepare a Lake or Streambed Alteration Agreement that addresses conditions necessary to protect those resources and compliance with the California Environmental Quality Act (CEQA) (California Department of Fish and Game).

Appendix V: Malakoff Diggins Digital Document Library

Alpers, C.N., Hunerlach, M.P., Marvin-DiPasquale, M.C., Antweiler, R.C., Lasorsa, B.K., DeWild, J.F., and Snyder, N.P., 2006, Geochemical data for mercury, methylmercury, and other constituents in sediments from Englebright Lake, California, 2002: U.S. Geological Survey Data Series 151, 95 p.

Alpers, C.N., Hunerlach, M.P., May, J.T., and Hothem, R.L., 2005, Mercury contamination from historical gold mining in California: U.S. Geological Survey Fact Sheet 2005–3014, version 1.1, 6 p.

Brown, S.L., 1987, Draft Report to the California Regional Water Quality control Board, Central Valley Region, California Department of Parks and Recreation, management of Turbidity and Sedimentation in Lower Humbug Creek, Malakoff Diggins State Historic Park.

Cahill, R.W., 1979, Malakoff Diggins State Historic Park Resource Management Plan.

Cahill, R.W., 1979, Survey of Cultural Resources at Malakoff Diggins State Historic Park, D 397-97 Standard Test Methods for Determining Sediment Concentration in Water Samples, ASTM International.

Demaree D.H., 2013, Subsurface Waters at Malakoff Diggins Pit, North Bloomfield Tunnel and Hiller Tunnel [M.S. Thesis]: Chico, California State University.

Department of Parks and Recreation, 1978, Preliminary Draft; Survey of Cultural Resources at Malakoff Diggins State Historic Park, State of California, The Resources Agency.

Department of Water Resources (DWR), 1987, Erosion Control at Malakoff Diggins State Historic Park, Report to the Department of Parks and Recreation Interagency Agreement 05-07-075 (DWR 163543).

Deukmejian, 1980, Opinion No. 79-906-1980 – Drainage from Abandoned Mine Now State Park.

Fleck, J.A., et al., 2011, The Effects of Sediment and Mercury mobilization in the South Yuba River and Humbug Creek Confluence Area, Nevada County, California: Concentrations, Speciation, and Environmental Fate--Part 1: Field Characterization: U.S. Geological Survey Open-File Report 2010-3125A.

Gard, M. F., 1994, Biotic and Abiotic Factors Affecting Native Stream Fishes in the South Yuba River, Nevada County, California, [Ph.D. Dissertation]: Davis, University of California.

Gilbert, C., and Savitski, C., 1991, Historic Dredge Recordation, Malakoff Diggins State Historic Park, Department of Parks and Recreation, Resource Management Program.

Harding, J., 1977, Ecological Studies at Malakoff Diggins State Park, a compilation of student papers: Department of Environmental Horticulture University of California Davis.

Jackson, W.T., 1967, The North Bloomfield Mining District: Report on the Malakoff Mine, The North Bloomfield Mining District, and the Town of North Bloomfield.

Johnson, J., 1996, State of the Mine: Evidence for Recovery of Lower Montane Forest Vegetation at Malakoff Diggins State Historic Park.

Liggett, C.L., 2014, Particle-Size Distribution Analysis and Sediment Deposition on the Pit Floor at Malakoff Diggins State Historic Park [M.S. Thesis]: Chico, California State University.

MacDonald, L., 1989, Prospects for Reducing Sediment Yield from Malakoff Diggins State Historic Park, Phillip Williams and Associates, Ltd..

Malakoff Diggins CALFED Proposal 2001, Final Version.

Marchetti, M. P., 1994, Suspended Sediment Effects on the Stream Fauna of Humbug Creek [M.S. Thesis]: Davis, University of California.

Marvin-DiPasquale, M., Agee, J.L., Kakouros, E., Kieu, L.H., Fleck, J.A., Alpers, C.N., 2011, The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area, Nevada County, California: Concentrations, Speciation, and Environmental Fate—Part 2: Laboratory Experiments: U.S. Geological Survey Open-File Report 2010-1325B, 66 p.

May, J.T., Hothem, R.L., Alpers, C.N., and Law, M.A., 2000, Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California: U.S. Geological Survey Open-File Report 00-367, 30 p. http://ca.water.usgs.gov/archive/reports/ofr00367/index.html.

Montgomery, P., 2004, Vegetation Management Plan for Malakoff Diggins State Historic Park, Sierra District California State Parks.

Moyle, P.B., Gard, M., 1993, South Yuba River Fisheries Survey and Habitat Assessment, Report to the California State Department of Parks and Recreation.

Natural Heritage Section, Resource Protection Division, CDPR 1989 (June) Management of Turbidity and Sedimentation in Lower Humbug Creek. Malakoff Diggings State Historic Park,21 p.

Nepal H., 2013, Mercury and Suspended Sediment Sources and Loads in Humbug Creek in Malakoff Diggins State Historic Park [M.S. Thesis]: Chico, California State University.

Nevada County Resource Conservation District (NCRCD), 1978, Malakoff Diggins Water quality Study: Phase I Report.

Nevada County Resource Conservation District (NCRCD), 1979a, Malakoff Diggings Water Quality Study Phase II Progress Report.

Nevada County Resource Conservation District (NCRCD), 1979b, Malakoff Diggings Water Quality Study Phase III Progress Report.

Nevada County Resource Conservation District (NCRCD), 1980, Malakoff Diggings Water Quality Study Phase IV Progress Report.

Appendix V: Document Library

Peterson, D.H., 1979, A Study of Modern Sedimentation at Malakoff Diggins State Historic Park, Nevada County, California [M.S. thesis]: University of California, Davis.

Randall, P.J., 1990, Distribution and Ecology of Fish and Frogs in Tributaries to the South Fork Yuba River [M.S. Thesis]: University of California, Davis.

Rogers/Pacific, 1988, Technical Input for Request for Proposals Engineering Services Malakoff Diggins State Park Nevada County, California.

Taylor, T.L., 1987, Final Report: Malakoff Diggins State Historic Park: Humbug Creek Fishery Evaluation: California Department of Parks and Recreation, Resource Protection Division, Natural Heritage Section, 16 p.

Whitney, J.D., 1880, The Auriferous Gravels of the Sierra Nevada of California, Contributions to American Geology V. I.: Cambridge, Massachusetts, Cambridge University Press.

Yarnell, S.M., 2000, The Influence of Sediment Supply and Transport Capacity on Foothill Yellow-Legged Frog Habitat, South Yuba River, California [MS thesis]: University of California, Davis.

Yarnell, S.M., and Larsen, E., 1999, Foothill Yellow-legged Frog Population Data and Fluvial Geomorphic Data for Spring, Shady and Humbug Creeks, Nevada County, CA: submitted to California Department of Parks and Recreation, Gold Rush District.

Yarnell, S.M., and Larsen, E., 2000, Foothill Yellow-legged Frog Population Data for Selected Tributaries of the South Yuba River: Nevada County, CA.

Yarnell, S.M., Larsen, E., and Mount, J., 1998, Foothill Yellow-legged Frog Population Data and Fluvial Geomorphic Data for spring, Shady and Humbug Creeks Nevada County, CA: submitted to California Department of Parks and Recreation.

Appendix VI: GPS Locations of Sample Locations and Features

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 27, Figure 13, Figure 28, Figure 38	Road 1	4,359,574.00	680,987.00	North American 1983	HN	WS
Figure 27, Figure 13, Figure 28, Figure 38	Hiller 2	4,359,598.00	679,075.00	North American 1984	HN	WS
Figure 27, Figure 13, Figure 28, Figure 38	Gage 3	4,358,970.00	679,085.00	North American 1985	HN	WS
Figure 27, Figure 13, Figure 7	"Bloomfield Tunnel (BT) (Lake City) Outlet"	4,357,687.00	678,847.00	North American 1986	JM	
Figure 27	Downstream of BT	4,357,606.00	678,819.00	North American 1987	JM	
Figure 27, Figure 13, Figure 7, Figure 38	"North Bloomfield Tunnel (NBT) Outlet"	4,357,530.00	678,667.00	North American 1988	JM	
Figure 27	Downstream of NBT	4,357,411.00	678,690.00	North American 1989	JM	
Figure 27, Figure 13, Figure 7, Figure 38	Shaft 1	4,357,967.00	678,814.00	WGS 1984	DD	NBT
Figure 27, Figure 13, Figure 7, Figure 45	Shaft 2	4,358,214.00	678,885.00	WGS 1984	DD	NBT
Figure 27, Figure 13, Figure 7, Figure 43	Shaft 3	4,358,494.00	678,987.00	WGS 1984	DD	NBT
Figure 27, Figure 13, Figure 7, Figure 47	Shaft 4	4,358,771.00	678,999.00	WGS 1984	DD	NBT
Figure 27, Figure 13, Figure 7, Figure 52	Shaft 5	4,359,032.00	679,009.00	WGS 1984	DD	NBT
Figure 27, Figure 13, Figure 7, Figure 22	Shaft 6	4,359,317.00	678,995.00	WGS 1984	DD	NBT
Figure 27, Figure 13, Figure 7, Figure 23	Shaft 7	4,359,569.00	679,042.00	WGS 1984	DD	NBT-map

Appendix IV: GPS Locations

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 27, Figure 13, Figure 7, Figure 26	Shaft 8	4,359,840.00	678,999.00	WGS 1984	DD	NBT-map
Figure 27, Figure 13, Figure 7, Figure 28, Figure 29, Figure 38	Hiller Tunnel Inlet	4,359,793.00	679,023.00	WGS 1984	JM	HTun
Figure 27, Figure 13, Figure 7, Figure 28, Figure 29, Figure 38	Hiller Tunnel Outlet	4,359,612.00	679,047.00	WGS 1984	JM	HTun
Figure 28	Green Bubble Spring	4,359,942.10	680,138.20	NAD 1983 UTM 10S	MS	
Figure 28	Red Spring	4,359,973.00	680,137.50	NAD 1983 UTM 10S	MS	
Figure 28	R 1	4,359,596.00	678,291.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	R 2	4,360,294.00	678,653.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	R 3	4,360,503.00	678,865.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	R 4	4,360,772.00	679,224.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	R 5	4,361,210.00	679,459.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	R 6	4,361,317.00	679,579.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	R 7	4,361,410.00	679,761.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	R 8	4,361,415.00	680,003.00	NAD 1983 UTM 10S	PDW	RimR
Figure 28	SS1	4,359,776.00	679,333.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS2	4,359,822.00	679,438.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS3	4,359,855.00	679,497.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS4	4,359,868.00	679,562.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS5	4,359,999.00	680,106.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS6	4,359,946.00	680,125.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS7	4,360,117.00	680,053.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS8	4,359,975.00	680,130.00	NAD 1983 UTM 10S	HN	StoS

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 28	SS9	4,360,084.00	680,158.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS10	4,360,162.00	679,994.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS11	4,360,123.00	679,955.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS12	4,360,385.00	679,719.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS13	4,360,405.00	679,837.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS14	4,360,097.00	679,470.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS15	4,360,031.00	678,744.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS18	4,359,783.00	679,023.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS19	4,359,808.00	679,043.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS20	4,359,810.00	679,006.00	NAD 1983 UTM 10S	HN	StoS
Figure 28	SS21	4,359,631.00	679,044.00	NAD 1983 UTM 10S	HN	StoS
Figure 29	P-1	4,359,542.10	679,465.10	Datum Undefined	DD, KBG	PBor
Figure 29	P-2	4,359,541.90	679,464.30	Datum Undefined	DD, KBG	PBor
Figure 29	P-3	4,359,543.20	679,464.80	Datum Undefined	DD, KBG	PBor
Figure 29	P-4	4,359,542.10	679,465.10	Datum Undefined	DD, KBG	PBor
Figure 29	MC1	4,359,845.00	680,476.00	North American 1983	MS	MCSS
Figure 29	MC2	4,360,001.00	680,100.00	North American 1983	MS	MCSS
Figure 29	MC3	4,360,029.00	680,110.00	North American 1983	MS	MCSS
Figure 29	MC4	4,360,388.00	679,837.00	North American 1983	MS	MCSS
Figure 29	MC5	4,360,367.00	679,858.00	North American 1983	MS	MCSS
Figure 29	MC6	4,360,388.00	679,727.00	North American 1983	MS	MCSS
Figure 29	MC7	4,360,156.00	680,000.00	North American 1983	MS	MCSS
Figure 29	MC8	4,360,139.00	679,962.00	North American 1983	MS	MCSS

Appendix IV: GPS Locations

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 29	MC9	4,360,087.00	680,155.00	North American 1983	MS	MCSS
Figure 29	MC10	4,359,987.00	680,124.00	North American 1983	MS	MCSS
Figure 29	MC11	4,359,873.00	679,803.00	North American 1983	MS	MCSS
Figure 29	MC12	4,359,814.00	679,861.00	North American 1983	MS	MCSS
Figure 29	MC13	4,359,807.00	679,025.00	North American 1983	MS	MCSS
Figure 29	MC14	4,359,890.00	678,601.00	North American 1983	MS	MCSS
Figure 29	MC15	4,360,025.00	678,749.00	North American 1983	MS	MCSS
Figure 38	Reach 1 (north)	4,359,599.00	680,934.00	North American 1927	SM	BioS
Figure 38	Reach 1 (south)	4,359,355.00	680,714.00	North American 1927	SM	BioS
Figure 38	Reach 2 (north)	4,359,156.00	679,113.00	North American 1927	SM	BioS
Figure 38	Reach 2 (south)	4,359,003.00	679,054.00	North American 1927	SM	BioS
Figure 38	Reach 3 (north)	4,358,996.00	679,028.00	North American 1927	SM	BioS
Figure 38	Reach 3 (south)	4,358,872.00	679,044.00	North American 1927	SM	BioS
Figure 38	Reach 4 (north)	4,356,652.00	678,394.00	North American 1927	SM	BioS
Figure 38	Reach 4 (south)	4,356,387.00	678,212.00	North American 1927	SM	BioS
Figure 45	FP1	4,359,835.14	678,700.34	NAD 1983 UTM 10S	KL	FP
Figure 45	FP2	4,360,003.60	678,881.04	NAD 1983 UTM 10S	KL	FP
Figure 45	FP3	4,359,975.09	679,118.12	NAD 1983 UTM 10S	KL	FP
Figure 45	FP4	4,360,009.66	679,340.94	NAD 1983 UTM 10S	KL	FP
Figure 45	FP5	4,360,069.04	679,602.60	NAD 1983 UTM 10S	KL	FP
Figure 45	FP20	4,360,065.06	679,799.83	NAD 1983 UTM 10S	KL	FP
Figure 45	FP16	4,360,215.40	679,735.50	NAD 1983 UTM 10S	KL	FP
Figure 45	FP11	4,360,112.69	679,671.83	NAD 1983 UTM 10S	KL	FP

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 45	FP6	4,360,085.62	679,637.62	NAD 1983 UTM 10S	KL	FP
Figure 45	FP15	4,360,010.06	679,726.84	NAD 1983 UTM 10S	KL	FP
Figure 45	FP10	4,359,983.69	679,702.85	NAD 1983 UTM 10S	KL	FP
Figure 45	FP25	4,359,952.41	679,690.54	NAD 1983 UTM 10S	KL	FP
Figure 45	FP24	4,359,874.81	679,571.25	NAD 1983 UTM 10S	KL	FP
Figure 45	FP23	4,359,849.90	679,489.34	NAD 1983 UTM 10S	KL	FP
Figure 45	FP22	4,359,794.98	679,346.53	NAD 1983 UTM 10S	KL	FP
Figure 45	FP21	4,359,797.35	679,205.17	NAD 1983 UTM 10S	KL	FP
Figure 45	FP7	4,360,059.00	679,656.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP8	4,360,039.00	679,668.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP9	4,360,011.00	679,685.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP12	4,360,095.00	679,684.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP13	4,360,074.00	679,701.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP14	4,360,043.00	679,712.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP17	4,360,168.00	679,754.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP18	4,360,144.00	679,770.00	NAD 1983 UTM 10S	KL	FP
Figure 45	FP19	4,360,103.00	679,786.00	NAD 1983 UTM 10S	KL	FP
Figure 45	1N	4,359,866.54	678,689.22	NAD 1983 UTM 10S	KL	NM
Figure 45	2N	4,360,021.74	678,768.62	NAD 1983 UTM 10S	KL	NM
Figure 45	3N	4,360,021.56	678,907.68	NAD 1983 UTM 10S	KL	NM
Figure 45	4N	4,359,990.65	679,121.98	NAD 1983 UTM 10S	KL	NM
Figure 45	5N	4,360,015.58	679,320.38	NAD 1983 UTM 10S	KL	NM
Figure 45	6N	4,360,021.67	679,372.58	NAD 1983 UTM 10S	KL	NM

Appendix IV: GPS Locations

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 45	7N	4,360,076.30	679,524.06	NAD 1983 UTM 10S	KL	NM
Figure 45	8N	4,360,063.47	679,570.83	NAD 1983 UTM 10S	KL	NM
Figure 45	9N	4,360,075.86	679,592.10	NAD 1983 UTM 10S	KL	NM
Figure 45	10N	4,360,078.20	679,608.72	NAD 1983 UTM 10S	KL	NM
Figure 45	11N	4,360,103.07	679,629.77	NAD 1983 UTM 10S	KL	NM
Figure 45	12N	4,360,122.72	679,641.80	NAD 1983 UTM 10S	KL	NM
Figure 45	13N	4,360,135.82	679,651.80	NAD 1983 UTM 10S	KL	NM
Figure 45	14N	4,360,241.23	679,688.14	NAD 1983 UTM 10S	KL	NM
Figure 45	15N	4,360,276.04	679,713.93	NAD 1983 UTM 10S	KL	NM
Figure 45	16N	4,360,285.10	679,738.98	NAD 1983 UTM 10S	KL	NM
Figure 45	17N	4,360,307.48	679,758.45	NAD 1983 UTM 10S	KL	NM
Figure 45	18N	4,360,298.80	679,802.24	NAD 1983 UTM 10S	KL	NM
Figure 45	19N	4,360,195.13	679,852.35	NAD 1983 UTM 10S	KL	NM
Figure 45	20N	4,360,148.36	679,883.94	NAD 1983 UTM 10S	KL	NM
Figure 45	1	4,359,651.04	678,759.53	NAD 1983 UTM 10S	KL	OM
Figure 45	2	4,359,684.50	678,709.31	NAD 1983 UTM 10S	KL	OM
Figure 45	3	4,359,707.83	678,655.37	NAD 1983 UTM 10S	KL	OM
Figure 45	4	4,359,733.76	678,644.48	NAD 1983 UTM 10S	KL	OM
Figure 45	5	4,359,783.04	678,642.05	NAD 1983 UTM 10S	KL	OM
Figure 45	6	4,359,837.14	678,659.72	NAD 1983 UTM 10S	KL	OM
Figure 45	7	4,359,910.14	678,703.20	NAD 1983 UTM 10S	KL	OM
Figure 45	8	4,359,936.69	678,721.76	NAD 1983 UTM 10S	KL	OM
Figure 45	9	4,359,977.25	678,733.57	NAD 1983 UTM 10S	KL	OM

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 45	10	4,360,061.35	679,418.16	NAD 1983 UTM 10S	KL	OM
Figure 45	11	4,360,068.22	679,455.78	NAD 1983 UTM 10S	KL	OM
Figure 45	12	4,360,068.20	679,546.74	NAD 1983 UTM 10S	KL	OM
Figure 45	13	4,360,157.21	679,641.89	NAD 1983 UTM 10S	KL	OM
Figure 45	14	4,360,181.97	679,667.79	NAD 1983 UTM 10S	KL	OM
Figure 45	15	4,360,212.75	679,683.01	NAD 1983 UTM 10S	KL	OM
Figure 45	16	4,360,242.38	679,690.07	NAD 1983 UTM 10S	KL	OM
Figure 45	17	4,360,283.64	679,716.40	NAD 1983 UTM 10S	KL	OM
Figure 45	18	4,360,299.39	679,798.60	NAD 1983 UTM 10S	KL	OM
Figure 45	19	4,360,271.21	679,824.07	NAD 1983 UTM 10S	KL	OM
Figure 45	20	4,360,223.06	679,833.32	NAD 1983 UTM 10S	KL	OM
Figure 45	21	4,360,168.95	679,868.45	NAD 1983 UTM 10S	KL	OM
Figure 45	22	4,360,137.29	679,893.69	NAD 1983 UTM 10S	KL	OM
Figure 43	1	4,360,247.00	679,693.90	North American 1983	CL	SeisS
Figure 43	3	4,360,099.50	679,597.50	North American 1983	CL	SeisS
Figure 43	4	4,359,966.40	679,281.60	North American 1983	CL	SeisS
Figure 43	2a	4,360,251.90	679,690.70	North American 1983	CL	SeisS
Figure 43	2b	4,360,236.20	679,680.20	North American 1983	CL	SeisS
Figure 43	1'	4,360,123.60	679,839.00	North American 1983	CL	SeisS
Figure 43	3'	4,360,013.90	679,628.60	North American 1983	CL	SeisS
Figure 43	4'	4,359,717.70	678,839.30	North American 1983	CL	SeisS
Figure 43	2a'	4,360,213.40	679,758.60	North American 1983	CL	SeisS
Figure 43	2b'	4,360,230.30	679,691.20	North American 1983	CL	SeisS
Figure 47	C1	4,360,280.10	679,830.90	WGS 1984	CL	PSD

Appendix IV: GPS Locations

Figure(s)	Label on Map	Northing	Easting	Datum	Collected By*	Note(s)**
Figure 47	C2	4,360,184.70	679,740.00	WGS 1984	CL	PSD
Figure 47	C3	4,360,078.60	679,758.80	WGS 1984	CL	PSD
Figure 47	C4	4,360,026.80	679,540.20	WGS 1984	CL	PSD
Figure 47	C5	4,360,040.00	679,420.00	WGS 1984	CL	PSD
Figure 47	C6	4,359,834.00	679,023.00	WGS 1984	CL	PSD
Figure 47	P1	4,360,270.60	679,821.70	WGS 1984	CL	PSD
Figure 47	P2	4,360,188.90	679,756.30	WGS 1984	CL	PSD
Figure 47	P3	4,360,078.60	679,758.80	WGS 1984	CL	PSD
Figure 47	P4	4,360,004.60	679,536.20	WGS 1984	CL	PSD
Figure 47	P5	4,359,886.80	679,311.90	WGS 1984	CL	PSD
Figure 47	P6	4,359,861.20	679,119.80	WGS 1984	CL	PSD
Figure 52	Erosion Plot 1	4,360,298.90	680,428.00	WGS 1984	KL	ErP
Figure 52	Erosion Plot 2	4,360,336.00	680,433.60	WGS 1984	KL	ErP
Figure 52	Erosion Plot 3	4,360,293.90	680,439.30	WGS 1984	KL	ErP
Figure 52	Erosion Plot 4	4,359,946.50	680,208.90	WGS 1984	KL	ErP
Figure 52	Erosion Plot 5	4,359,822.60	678,972.00	WGS 1984	KL	ErP
Figure 52	Erosion Plot 6	4,359,918.80	679,774.00	WGS 1984	KL	ErP
Figure 52	Erosion Plot 7	4,360,151.90	680,313.80	WGS 1984	KL	ErP

*Collected By	Code
Cameron Liggett	CL
Keith Landrum	KL
Mark Selverston	MS
Susan Miller	SM
Kathleen Berry-Garrett	KBG
Peter van Daalen Wetters	PDW
David Demaree	DD
Jason Muir	JM
Harihar Nepal	HN

**Notes	Code
Water Sample	WS
North Bloomfield Tunnel	NBT
"North Bloomfield Tunnel, Hypothetical location from North Bloomfield Gravel Mining Co. Map"	NBT-Map
Hiller Tunnel	HTun
Rim Runoff	RimR
Storm Samples	StoS
Piezometer Borings	PBor
Malakoff Confirmation Soil Samples	MCSS
Biotic Samples	BioS
Fence Post	FP
New Marker	NM
Old Marker	OM
Seismic Surveys	SeiS
Particle Size Distribution	PSDistr
Erosion Plot	ErP

THE SIERRA FUND

About The Sierra Fund

The Sierra Fund is the only nonprofit community foundation dedicated to the Sierra Nevada. Our mission is to increase and organize investment in the region's natural resources and communities. We pursue this mission three ways: through Advocacy to bring public funding to the region, Philanthropy to provide a vehicle for private funding, and Strategic Campaigns that pursue critically needed programs in the Sierra.

Since 2006, the Reclaiming the Sierra Initiative has been our primary strategic campaign. The goal of this Initiative is to assess and address mining's toxic legacy: the ongoing cultural, environmental and human health impacts of toxins left over from the Gold Rush.

206 Sacramento Street, Suite 101, Nevada City, CA 95959

(530) 265-8454 - info@sierrafund.org

www.sierrafund.org