Formosa Mine

Riddle, Oregon
EPA Facility ID: ORN001002616
Basin: South Umpqua
HUC: 17100302

Executive Summary

The Formosa Mine site is an inactive mine encompassing approximately 20 ha (50 acres) on Silver Butte, south of Riddle, Oregon. Four tributaries of the South Umpqua River have their headwaters in the vicinity of the mine. Beginning in the early 1900s, the site was intermittently mined for copper, gold, silver, and zinc; the mine was closed in 1993. The primary contaminants of concern to NOAA are metals, including arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Groundwater transport, surface water runoff, stormwater discharge, and sediment transport are the primary pathways for the migration of contaminants from the site to NOAA trust resources. The habitats of primary concern to NOAA are Middle Creek, South Fork Middle Creek, and Cow Creek, which all provide habitat for coho salmon, Pacific lamprey, and steelhead trout. Oregon Coast coho salmon are listed as a federally threatened species under the Endangered Species Act, and this population of steelhead trout is also listed as a federal species of concern. Cow Creek also provides habitat for Chinook salmon.

Site Background

The Formosa Mine site is an inactive mine encompassing approximately 20 ha (50 acres) on Silver Butte, south of Riddle, Oregon. Four tributaries of the South Umpqua River—Middle Creek, South Fork Middle Creek, Russell Creek, and West Fork Canyon Creek—have their headwaters in the vicinity of the mine (Figure 1). When the mine was active, contaminated stormwater runoff was discharged directly to Middle Creek. Previous sampling investigations conducted in the vicinity of the site by the Bureau of Land Management found no detectable impacts to Russell Creek or West Fork Canyon Creek (Hart Crowser 2004a, 2004b).

Beginning in the early 1900s, the site was intermittently mined for copper, gold, silver, and zinc. From 1990 to 1993, the mine produced approximately 320 to 360 metric tons (350 to 400 tons) of copper and zinc per day. Mining ceased in 1993 after the Oregon Department of Geology and Mineral Industries issued a Closure Order and the Oregon Department of Environmental Quality (ODEQ) issued a Notice of Noncompliance (USEPA 2007).

In 1994, the Oregon Department of Geology and Mineral Industries ordered the operators of the Formosa Mine to reclaim the site. As part of the reclamation, mine workings were backfilled with high-grade ore, all mine entrances (adits) were sealed, and a drainage system was constructed. The tailings and water storage pond was also backfilled and capped; the area is now referred to as the encapsulation mound (Figure 2).

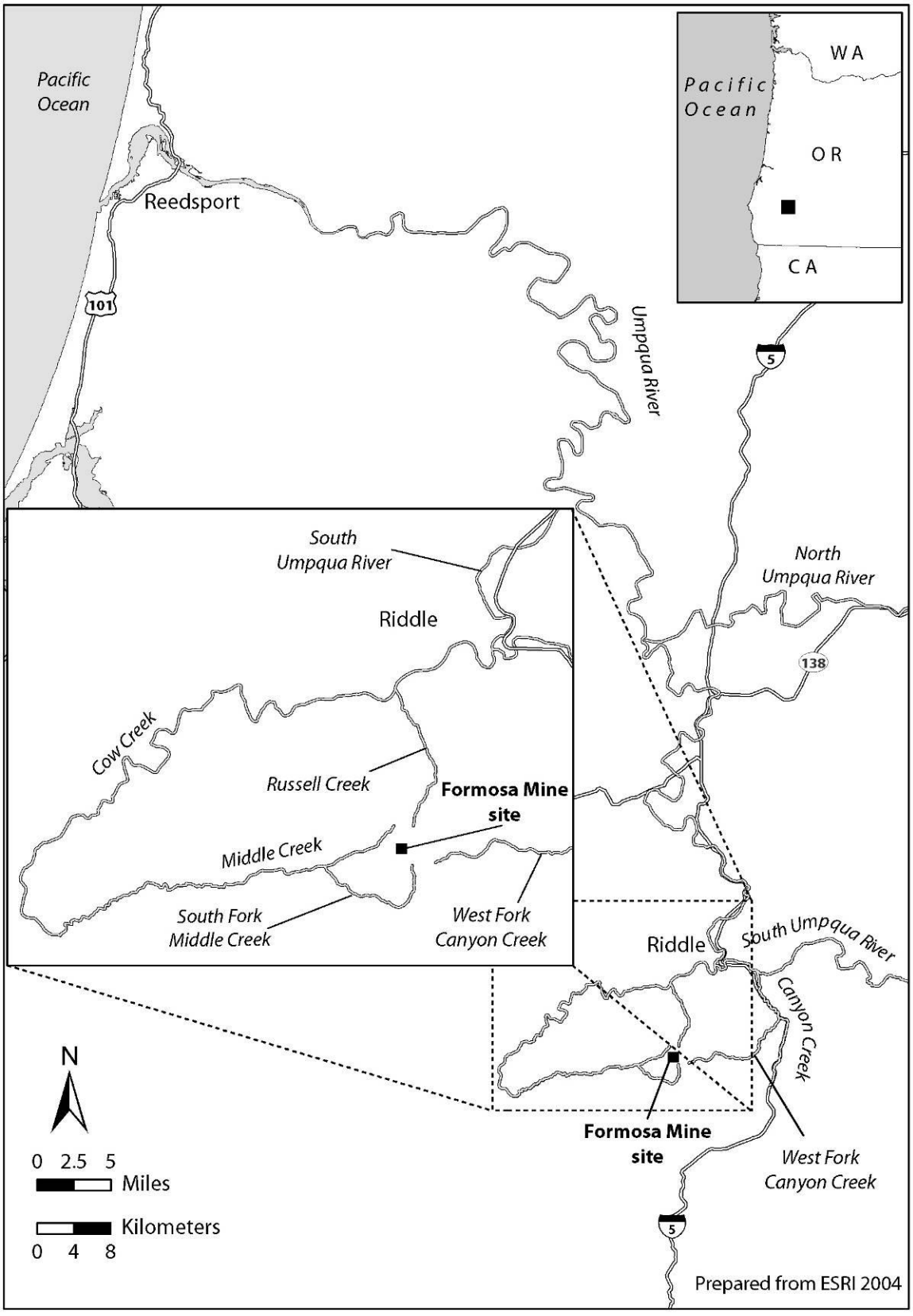

Figure 1. Location of the Formosa Mine site, Riddle, Oregon.

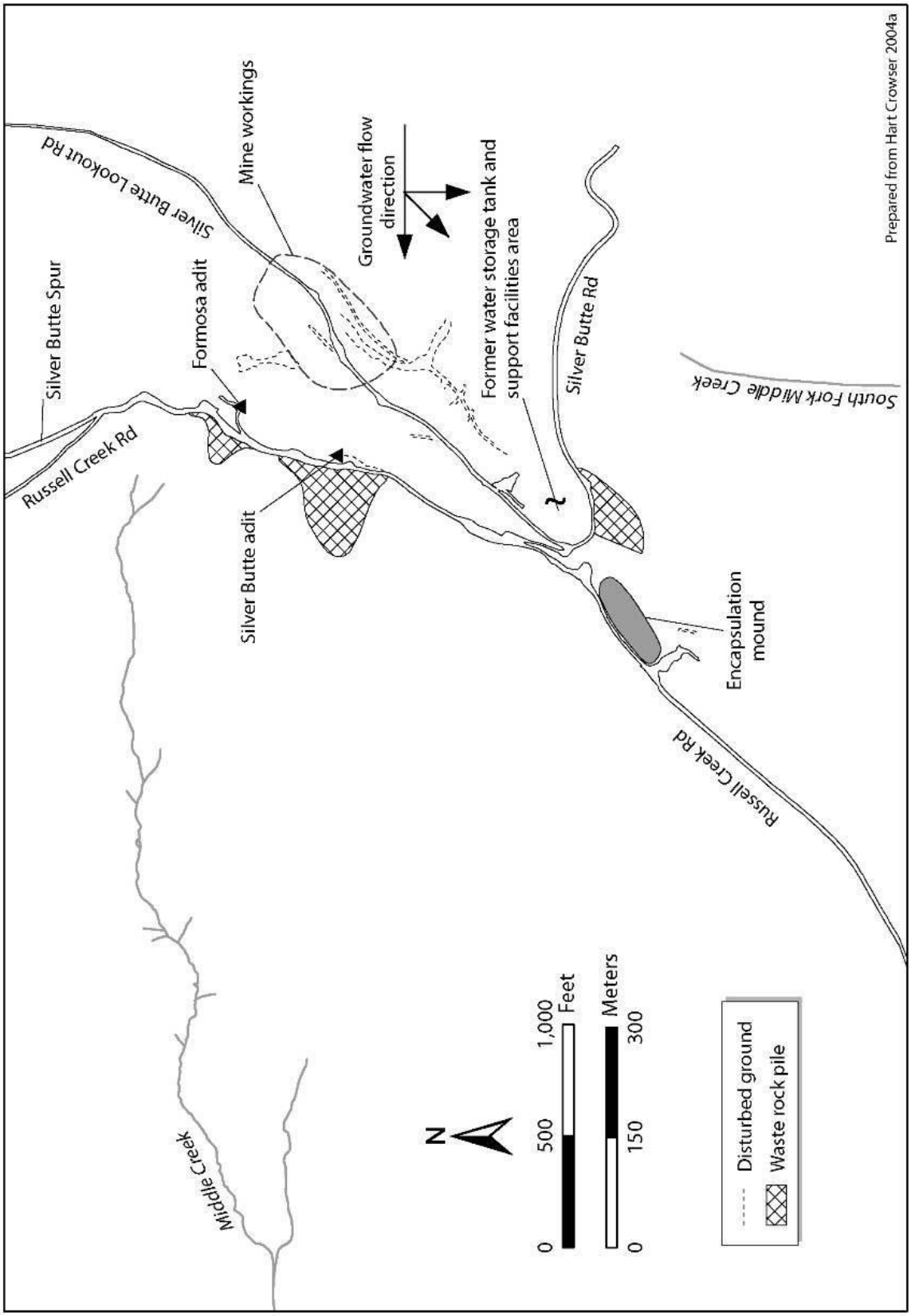

Figure 2. Detail of the Formosa Mine property.

Uncovered and uncontained waste rock piles with elevated concentrations of heavy metals still remain on the site (Figure 2).

According to the documents reviewed for this report, the drainage system never worked as intended and has resulted in contamination of the site and adjacent surface water bodies. During numerous investigations, elevated concentrations of metals were detected in samples of sediment, surface water, groundwater, and soil taken from the site, Middle Creek, South Fork Middle Creek, and Cow Creek (Hart Crowser 2004a, 2004b; USEPA 2007). Metals were detected in Middle Creek and South Fork Middle Creek at concentrations that exceed ODEQ screening-level values and U.S. Environmental Protection Agency (USEPA) ambient water quality criteria (AWQC) (Hart Crowser 2004a, 2004b).

Groundwater transport, surface water runoff, stormwater discharge, and sediment transport are the primary pathways for the migration of contaminants from the site to NOAA trust resources. Acidic water flows from the former mine adits to the underground mine shafts, encapsulation mound, and waste rock piles. The acidic water discharges to South Fork Middle Creek and Middle Creek. Groundwater underlying the site flows radially, following the topography of Silver Butte (Figure 2). Groundwater is encountered approximately 10 to 30 m (30 to 100 ft) below ground surface, with elevations changing quickly during heavy rainfall (Hart Crowser 2004a, 2004b).

A remedial investigation (RI) was conducted by the Bureau of Land Management, Roseburg District and the ODEQ in June 1999; that RI focused on the observed decline of biological conditions at the site since the mine was closed. In 2002, the ODEQ conducted a supplemental RI to better define the contaminant sources at the site (USEPA 2007). In 2004, a feasibility study and a baseline ecological risk assessment were conducted by the ODEQ. A hazard ranking system package was completed for the site by the USEPA in March 2007. The site was placed on the National Priorities List in September 2007 (USEPA 2007, 2008a). Current activities underway at the site are a combined remedial investigation/feasibility study (RIFS), which the USEPA initiated in July 2008 (USEPA 2008a).

NOAA Trust Resources

The habitats of primary concern to NOAA are Middle Creek, South Fork Middle Creek, and Cow Creek, all tributaries to the South Umpqua River (Figure 1). The headwaters of Middle Creek and South Fork Middle Creek begin west and south of the mine, respectively. South Fork Middle Creek discharges to Middle Creek, which is a tributary of Cow Creek. Cow Creek ultimately discharges to the South Umpqua River.

In the vicinity of the site, tributaries of the South Umpqua River are generally moderate- to high-gradient streams flowing through deep valleys. The predominant vegetation in these valleys is the Douglas fir tree (Geyer 2003). Middle Creek is a Tier 1 Key Watershed under the Northwest Forest Plan (USFS 2006). Key Watersheds are a system of large refugia that provide high-quality water and are crucial for at-risk fish species and stocks. Key Watersheds include high-quality habitat as well as degraded habitat. Key Watersheds that include degraded habitat are given the highest priority for watershed restoration (USFS 2006).

The South Umpqua River watershed provides habitat for anadromous Chinook and coho salmon, Pacific lamprey, and steelhead trout (ODFW 2008; USEPA 2007), all of which are

NOAA trust resources that use Middle Creek, South Fork Middle Creek, and Cow Creek for spawning and rearing habitat and migratory routes (Table 1). NOAA Fisheries lists the Oregon Coast coho salmon as a threatened species under the Endangered Species Act and classifies this population of steelhead trout as a federal species of concern (NOAA Fisheries 2008).

Adult and juvenile coho salmon and steelhead trout have been observed in Middle Creek, South Fork Middle Creek, and Cow Creek during stream surveys. All three creeks provide spawning and rearing habitat for coho salmon and steelhead trout (ODFW 2008; USEPA 2007). Additionally, Cow Creek serves as a migration corridor for coho salmon and steelhead trout (ODFW 2008).

Cow Creek also provides spawning and rearing habitat and migratory routes for Chinook salmon (ODFW 2008).

Middle Creek, South Fork Middle Creek, and Cow Creek provide spawning and rearing habitat for Pacific lamprey, which has been documented in all three creeks (USEPA 2007). Pacific lamprey larvae, or ammocoetes, are an important food source for salmonids (BPA 2005). In recent years, groups have petitioned the U.S. Fish and Wildlife Service to protect Pacific lamprey under the Endangered Species Act (Geyer 2003). Historically, Pacific lamprey provided an important food source for Pacific Northwest tribes. The Pacific lamprey was also used by the tribes for medicinal and ceremonial purposes (BPA 2005).

Table 1. NOAA trust resources present in Middle Creek, South Fork Middle Creek, and Cow Creek near the Formosa Mine site (USEPA 2007; ODFW 2008).

Species		**Habitat Use**			**Fisheries**	
Common Name	Scientific Name	Spawning Area	Nursery Area	Migratory Route	Comm.	Rec.
ANADROMOUS FISH						
Chinook salmon	*Oncorhynchus tshawytscha*	♦	♦	♦		
Coho salmon	*Oncorhynchus kisutch*	♦	♦	♦		
Pacific lamprey	*Lampetra tridentata*	♦	♦	♦		
Steelhead trout	*Oncorhynchus mykiss*	♦	♦	♦		♦

There are no commercial fisheries on Middle Creek, South Fork Middle Creek, or Cow Creek. A sport fishery targeting steelhead trout and resident trout species occurs on Cow Creek and targets resident trout species on the tributaries of Cow Creek (USEPA 2007).

No fish consumption advisories are currently in effect for Middle Creek, South Fork Middle Creek, or Cow Creek (ODHS 2008).

Site-Related Contamination

Over the course of numerous environmental investigations, many surface water, sediment, and soil samples were collected at the Formosa Mine site and analyzed for metals (Hart Crowser 2004a, 2004b). The primary contaminants of concern to NOAA are metals, including arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, and selenium.

Table 2 summarizes the maximum concentrations of contaminants of concern to NOAA detected during the site investigations and compares them to relevant screening guidelines. Site-specific or regionally specific screening guidelines are always included when available. In the absence of such guidance, the screening guidelines for surface water are the AWQC (USEPA 2006); the screening guidelines for sediment in a freshwater environment are the threshold effects concentrations (TECs; MacDonald et al. 2000). The screening guidelines for soil are the Oak Ridge National Laboratory final preliminary remediation goals (ORNL-PRGs; Efroymson et al. 1997) and the USEPA's ecological soil screening guidelines (USEPA 2008b). Exceptions to these screening guidelines, if any, are noted on Table 2. Only maximum concentrations that exceeded relevant screening guidelines or for which no screening guidelines are currently available, are discussed below. When known, the general sampling locations are also provided (refer to Figures 1 and 2).

Table 2. Maximum concentrations of contaminants of concern to NOAA at the Formosa Mine site (Hart Crowser 2004a, 2004b). Contaminant values in bold exceed or are equal to screening guidelines.

	Soil (mg/kg)		**Water (µg/L)**		**Sediment (mg/kg)**	
Contaminant	Soil	ORNL-PRG[a]	Surface Water	AWQC[b]	Sediment	TEC[c]
METALS/INORGANICS						
Arsenic	**260**	9.9	7.7	150	**28**	9.79
Cadmium	**8.0**	0.36[d]	**420**	0.25[e]	**30**	0.99
Chromium	**5.1**	0.26[d]	8.3	11[f]	**230**	43.4
Copper	**1,400**	28[d]	**40,000**	9[e]	**16,000**	31.6
Lead	**660**	40.5	**140**	2.5[e]	**47**	35.8
Mercury	**3.4**	0.00051	N/A	0.77[g]	**1.0**	0.18
Nickel	11	30	**120**	52[e]	**170**	22.7
Selenium	<2.5	0.21	**9.1**	5.0[h]	0.9	NA
Silver	**4.9**	2	0.33	3.2[e,i]	2.0	4.5[j]
Zinc	**2,500**	8.5	**54,000**	120[e]	**11,000**	121

a: Oak Ridge National Laboratory (ORNL) final preliminary remediation goals (PRG) for ecological endpoints (Efroymson et al. 1997).

b: Ambient water quality criteria for the protection of aquatic organisms (USEPA 2006). Freshwater chronic criteria presented.

c: Threshold Effects Concentration (TEC). Concentration below which harmful effects are unlikely to be observed (MacDonald et al. 2000).

d: Ecological soil screening guidelines (USEPA 2008b).

e: Criterion expressed as a function of total hardness; concentrations shown correspond to hardness of 100 mg/L $CaCO_3$.

f: Screening guidelines represent concentrations for $Cr.^{+6}$

g: Derived from inorganic, but applied to total mercury.

h: Criterion expressed as total recoverable metal.

i: Chronic criterion not available; acute criterion presented.

j: Freshwater upper effects threshold (UET) for bioassays. The UET represents the concentration above which adverse biological impacts would be expected.

k. N/A: Not analyzed for.

NA: Screening guidelines not available.

ND: Not detected.

Surface Water

Five metals and selenium were detected in surface water samples collected from the Formosa Mine site at maximum concentrations that exceeded the AWQC (Table 2). The maximum concentrations of cadmium, copper, lead, nickel, selenium, and zinc were detected in samples collected from Middle Creek. The maximum concentrations of cadmium and copper exceeded the AWQC by three orders of magnitude, and zinc and lead exceeded the AWQC by two orders and one order of magnitude, respectively. The maximum concentrations of nickel and selenium exceeded the AWQCs by factors of approximately two.

Sediment

Eight metals were detected in sediment samples collected from the Formosa Mine site at maximum concentrations that exceeded screening guidelines; selenium was also detected for which no screening guideline is currently available (Table 2). The maximum concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc were detected in samples collected from Middle Creek. The maximum concentration of copper exceeded the TEC by two orders of magnitude. The maximum concentrations of cadmium and zinc exceeded the TECs by one order of magnitude. The maximum concentrations of nickel, mercury, chromium, and arsenic exceeded the TECs by factors of approximately seven, 5.5, five, and approximately 2.5, respectively; lead slightly exceeded the TEC. No screening guidelines are currently available for comparison to the maximum concentration of selenium detected in the sediment samples.

Soil

Eight metals were detected in soil samples collected from the Formosa Mine at maximum concentrations that exceeded screening guidelines (Table 2). The maximum concentrations of arsenic, lead, mercury, and silver were detected in samples taken in the vicinity of the Silver Butte adit. The maximum concentration of mercury exceeded the ORNL-PRG by three orders of magnitude; arsenic and lead exceeded the ORNL-PRGs by one order of magnitude. The maximum concentration of silver exceeded the ORNL-PRG by approximately a factor of two. The maximum concentrations of cadmium, copper, and zinc were detected in samples taken in the vicinity of the encapsulation mound. The maximum concentration of zinc exceeded the ORNL-PRG by two orders of magnitude. The maximum concentrations of cadmium and copper exceeded the USEPA ecological soil screening guidelines by one order of magnitude. The maximum concentration of chromium, which was detected in a sample taken in the vicinity of the Formosa adit, also exceeded the USEPA ecological soil screening guideline by one order of magnitude.

References

Bonneville Power Administration (BPA). 2005. Fish and wildlife: Pacific lamprey. July. Available at: BPA, Environment Fish and Wildlife, Integrated Fish and Wildlife Program, http://www.efw.bpa.gov/IntegratedFWP/index.aspx (accessed August 23, 2008).

Efroymson, R. A., G. W. Suter II, B. E. Sample, and D. S. Jones. 1997. Preliminary remediation goals for ecological endpoints. August 1997. Prepared for U.S. Department of Energy, Oak Ridge, TN. Available at: Environmental Sciences Division, Oak Ridge National Laboratory, http://www.esd.ornl.gov/programs/ecorisk/documents/tm162r2.pdf (accessed June 24, 2008)

Environmental Systems Research Institute, Inc. (ESRI). 2004. ESRI data & maps 2004. Redlands, California.

Geyer, N. 2003. South Umpqua River watershed assessment and action plan. Prepared for the Umpqua Basin Watershed Council. November.

Hart Crowser, Inc. (Hart Crowser). 2004a. Feasibility study, Formosa abandoned mine land site, Douglas County, Oregon. December. Prepared for Oregon Department of Environmental Quality.

Hart Crowser, Inc. (Hart Crowser). 2004b. Human health and ecological baseline risk assessment, Formosa abandoned mine land site, Douglas County, Oregon. January. Prepared for Oregon Department of Environmental Quality.

MacDonald, D., C. Ingersoll, and T. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. *Archives of Environmental Contamination and Toxicology* 39:20-31.

National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries). 2008. Marine and anadromous fish. Available at: NOAA Fisheries, Office of Protected Resources, http://www.nmfs.noaa.gov/pr/species/fish/ (accessed February 14, 2008).

Oregon Department of Fish and Wildlife (ODFW). 2008. Fish distribution/habitat, StreamNet database. Available at: ODFW Natural Resources Information Management Program, Data Resources, http://nrimp.dfw.state.or.us/nrimp/default.aspx?p=259 (accessed January 25, 2008).

Oregon Department of Human Services (ODHS). 2008. Statewide fish consumption guidelines. Available at: http://oregon.gov/DHS/ph/envtox/fishconsumption.shtml#table (accessed January 22, 2008).

U.S. Environmental Protection Agency (USEPA). 2006. National recommended water quality criteria: 2006. Washington D.C.: U.S. Environmental Protection Agency, Office of Water.

U.S. Environmental Protection Agency (USEPA). 2007. Hazard ranking system package for Formosa Mine EPA ID: ORN001002616. USEPA Region 10. March.

U.S. Environmental Protection Agency (USEPA). 2008a. Superfund site progress profile for Formosa Mine, EPA ID: ORN001002616. Available at: USEPA Superfund Information Systems, http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=1002616 (accessed September 2, 2008).

U.S. Environmental Protection Agency (USEPA). 2008b. Ecological soil screening levels. March 2005. Available at: USEPA, ECOTOX Database, http://www.epa.gov/ecotox/ecossl/ (accessed June 24, 2008).

U.S. Forest Service (USFS). 2006. Northwest forest plan (NWFP) overview. November. Available at: USFS Pacific Northwest Region, http://www.reo.gov/general/aboutNWFP.htm (accessed March 19, 2008).