Preassessment Screen for the Chino, Tyrone, and Morenci Mine Sites, Grant County, New Mexico, and Morenci, Arizona

Prepared for:

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June 18, 2003
SC10292

PREASSESSMENT SCREEN DETERMINATION

Based on the information in this preassessment screen, the Trustees hereby determine that current information indicates that there is a reasonable probability of making a successful NRDA claim pursuant to section 107 of the CERCLA and that all criteria and requirements in 43 CFR — 11, generally, and 43 CFR — 11.23(a)-(g), — 11.24, and — 11.25, specifically, have been satisfied.

Jim Baca 6/17/03

Jim Baca
Trustee, State of New Mexico
Office of Natural Resources Trustee

Date

H Dale Hall 6/18/03

H. Dale Hall
Authorized Official
U.S. Department of Interior
U.S. Fish and Wildlife Service

Date

Preface

The U.S. Fish and Wildlife Service (USFWS), in coordination with the New Mexico Office of Natural Resources Trustee, the Bureau of Land Management, and the Bureau of Reclamation (collectively, the Trustees), has begun to assess natural resource damages resulting from releases of hazardous substances from three large open-pit copper mines in southwestern New Mexico and southeastern Arizona: the Chino Mine, the Tyrone Mine, and the Morenci Mine. The assessment is being conducted in accordance with the natural resource damage assessment (NRDA) regulations issued by the U.S. Department of Interior (DOI) at 43 CFR Part 11.[1] These regulations are not mandatory. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 U.S.C. § 9607(f)(2)(C)]. The first step in the process established by DOI is the preparation of a preassessment screen. The preassessment screen documents the Trustees' conclusion that there is a reasonable probability of making a successful claim for natural resource damages at each of the three mines.

This document contains three distinct parts, corresponding to each of the three mines, preceded by an executive summary. Part A focuses on the Chino Mine, Part B focuses on the Tyrone Mine, and Part C addresses the Morenci Mine. Each part is organized using a consistent structure: Chapter 1 introduces the intent of the preassessment screen and criteria to be addressed; Chapter 2 provides information on the site; Chapter 3 provides a preliminary identification of resources at risk; Chapter 4 presents an assessment of each of the determination criteria; and Chapter 5 provides references cited.

This screen was prepared by Stratus Consulting under contract to the USFWS.

1. 43 CFR Part 11 regulations were authored by the U.S. DOI, and are referred to as the DOI regulations in this document.

S.1 Introduction

This document contains the Preassessment Screen and Determination for a natural resource damage assessment (NRDA) for three large open-pit copper mines in southwestern New Mexico and southeastern Arizona: the Chino Mine, the Tyrone Mine, and the Morenci Mine. The NRDA is being performed by the U.S. Fish and Wildlife Service (USFWS), in coordination with the New Mexico Office of Natural Resources Trustee, the Bureau of Land Management, and the Bureau of Reclamation (collectively, the Trustees). The preassessment screen documents the Trustees' conclusion, based on a "rapid review of readily available information" that there is a reasonable probability of making a successful claim for natural resource damages for resources for which the federal and state agencies listed above may assert trusteeship [43 CFR § 11.23(b)]. This document was prepared by Stratus Consulting under contract to the USFWS.

S.2 Background

The Chino, Tyrone, and Morenci copper mines form a complex of mines in southwestern New Mexico and southeastern Arizona (Figure S.1). The Phelps Dodge Corporation (Phelps Dodge) is the parent company with sole ownership of the Tyrone Mine and majority ownership in the Chino and Morenci Mines. The Heisei Minerals Corporation, a subsidiary of Mitsubishi Materials Company, holds a one-third interest in the Chino Mine. Sumitomo Metal Mining Ltd. holds a 15% interest in the Morenci Mine. The Chino and Tyrone Mines are located to the southeast and southwest of Silver City, New Mexico, respectively, approximately 14 miles apart. The Morenci Mine is located approximately 60 miles west of the Tyrone Mine, to the west of the Burro and San Francisco mountain ranges. The Tyrone and Morenci Mines are both located in the Gila River drainage.

The Trustees have begun to assess natural resource damages resulting from releases of hazardous substances from the Chino, Tyrone, and Morenci Mines in accordance with the NRDA regulations issued by the U.S. Department of Interior (DOI) at 43 CFR Part 11. These regulations are not mandatory. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 U.S.C. § 9607(f)(2)(C)]. The first step in the process established by DOI is the preparation of a preassessment screen. This preassessment screen documents the Trustees' conclusion that there is a reasonable probability of making a successful claim for natural resource damages at the three mines.

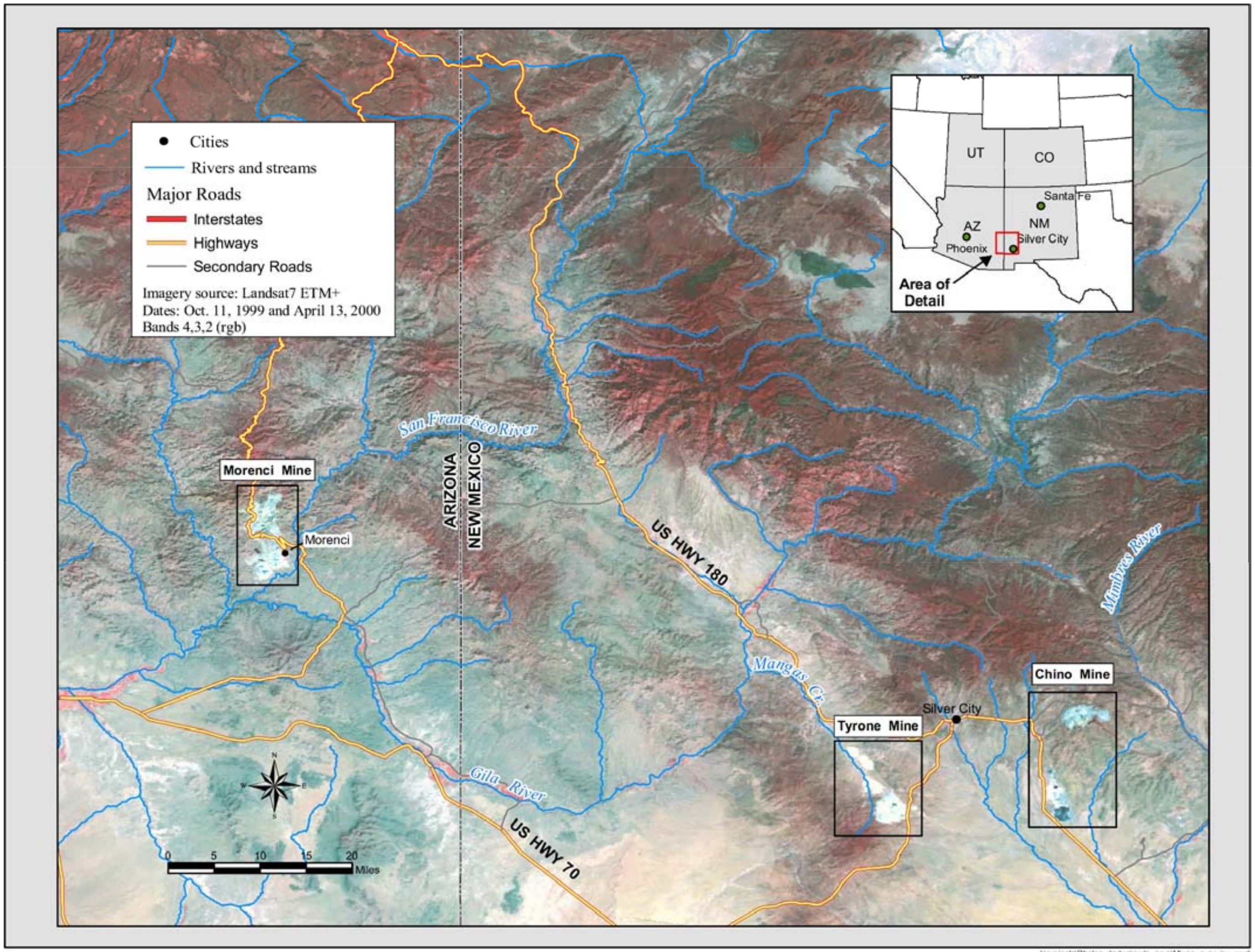

Figure S.1. Location of the Chino, Tyrone, and Morenci Mines in southwestern New Mexico and southeastern Arizona.

Because of the geographic proximity of these mines, common majority ownership by Phelps Dodge, and the possibility that the mines can injure the same natural resources (e.g., endangered fish in the Gila River could be affected by releases from both the Tyrone and Morenci Mines; migratory birds could be exposed to hazardous substances released from more than one mine), the Trustees are pursuing a single NRDA that includes all three facilities. To this end, a single Preassessment Screen that encompasses all three sites in three distinct parts has been prepared. At the same time, the Trustees acknowledge that each mine is a large and complex facility with different sources of hazardous substance releases, pathways of contaminant transport, exposed areas, and potentially affected resources. To address the individual nature of each mine and to demonstrate that there is a reasonable probability of making a successful claim for natural resource damages at each mine, this report contains separate parts in which the preassessment criteria are addressed for each mine separately. Part A documents the Trustees' conclusion that there is a reasonable probability of making a successful claim for natural resource damages at the Chino Mine, Part B documents the same conclusion for the Tyrone Mine, and Part C documents the same conclusion for the Morenci Mine. Citations for the information presented in the following summary are in the relevant parts of this document.

S.3 Preassessment Screen Determination Criteria

The DOI regulations establish five determination criteria, all of which must be met, for a preassessment screen [43 CFR § 11.23(e)]. These five criteria and a brief summary of information readily available to the Trustees that supports these criteria are presented below. Further detail for each mine is presented in each of the relevant parts.

S.3.1 Releases of Hazardous Substances Have Occurred

Multiple studies and data collection efforts, including those of the New Mexico Environment Department (NMED), the Arizona Department of Environmental Quality (ADEQ), the USFWS, the U.S. Geological Survey (USGS), Chino Mines Company, Phelps Dodge Tyrone Inc., and Phelps Dodge Morenci, Inc., have demonstrated that multiple and at times continuous releases of hazardous substances have occurred and continue to occur as a result of operations at the Chino, Tyrone, and Morenci Mines. Hazardous substances released from the mines include, but may not be limited to, antimony, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, nickel, zinc, and sulfuric acid. Investigators have also documented elevated concentrations of hazardous substances in surface water, groundwater, and/or biota at each site that have resulted from releases of hazardous substances at the sites.

S.3.2 Natural Resources for Which the Trustees Can Assert Trusteeship Have Been, or Are Likely To Be, Adversely Impacted by the Release

Natural resources [as defined in 43 CFR § 11.14(z)] for which the Trustees have trusteeship that have been or are likely to have been adversely affected by releases of hazardous substances include, but may not be limited to:

- surface water, groundwater, geological, and biological resources
- migratory birds protected by the Migratory Bird Treaty Act
- threatened, endangered, or proposed endangered species potentially inhabiting the San Francisco and Gila rivers or found in ephemeral waterways, such as the Gila chub (*Gila intermedia*); the Gila topminnow (*Poeciliopsis occidentalis occidentalis*); the Gila trout, (*Oncorhynchus gilae*); and the Chiricahua leopard frog (*Rana chiricahuensis)*
- habitat for trust resources that is provided by surface water, soils, and terrestrial vegetation.

In each part, Chapter 3 presents data confirming elevated concentrations of hazardous substances in Trustee natural resources at each of the three mines.

S.3.3 Quantity and Concentration of Released Hazardous Substances Are Sufficient to Potentially Cause Injury

Numerous investigations at the three mines have documented elevated levels of hazardous substances that are sufficient to potentially cause injuries to natural resources.

S.3.3.1 Surface water/sediments

The DOI regulations present a number of definitions of injury for surface water resources. These definitions of injury to surface water include the following:

- concentrations of hazardous substances exceeding Safe Drinking Water Act (SDWA) or other relevant federal or state criteria or standards for drinking water [43 CFR § 11.62(b)(1)(i)]

- concentrations and duration of substances in excess of applicable water quality criteria established by Section 304(a)(1) of the Clean Water Act (CWA), or by other federal or state laws or regulations that establish such criteria . . . in surface water that before the discharge or release met the criteria and is a committed use . . . as a habitat for aquatic life, water supply, or recreation [43 CFR § 11.62(b)(1)(iii)]

- concentrations and duration of hazardous substances sufficient to have caused injury to biological resources when exposed to surface water [43 CFR § 11.62(b)(1)(v)].

At the mine sites, for ponded water present on tailings impoundments and associated lakes, uncovered PLS ponds, and ponded water in stormwater retention basins, the concentrations and duration of hazardous substances have been sufficient to potentially cause injury to birds and invertebrates exposed to surface waters and to other biological resources as well. Bird carcasses discovered at the Tyrone, Chino, and Morenci Mines, at tailings ponds and associated lakes, PLS ponds, or stormwater retention basins from September to November 2000 indicate that the concentrations and duration of hazardous substances at these ponds have been sufficient to cause injury to birds (Table S.1). Considering the numerous "feather spots" and other highly decomposed bird remains that were observed but not collected during the 2000 USFWS investigation, the actual number of birds injured may be far greater than that reported in Table S.1.

For ephemeral surface water drainages at the Chino Mine, an ecological risk assessment performed for the site found that cadmium, copper, lead, and zinc in surface water samples exceeded acute or chronic water quality standards or amphibian toxicity reference values. Cadmium in sediments also exceeded a threshold effects concentration. The risk characterization predicted low to moderate risks to aquatic receptors in ephemeral drainages along the Hanover and Whitewater Creek corridor, and intermediate level risks to amphibians and aquatic receptors in stock tanks.

For ephemeral stream flows in the Mangas Creek at the Tyrone Mine, injury to surface water may occur when concentrations of hazardous substances exceed water quality criteria established under Section 304(a)(1) of the CWA for the protection of aquatic life [43 CFR § 11.62(b)]. Three of five samples collected in August 2001 exceeded the acute and chronic toxicity criteria for copper. In addition, the Tyrone Closure/Closeout plan stated that "elevated concentrations of sulfate, total dissolved solids, copper, and cadmium have been observed periodically at flow samplers 1, 2, and 4," which are located in the Mangas Creek.

At the Morenci Mine, elevated concentrations of copper and zinc in surface water and sediment in the San Francisco and Gila Rivers downstream from the mine suggest that hazardous substances may have been transported from the mine to these perennial rivers. Downstream of

Table S.1. Bird carcasses at the Tyrone, Morenci, and Chino Mines, discovered September to November 2000

	Number of carcasses		
Species	**Tyrone**	**Morenci**	**Chino**
American avocet	3		
American wigeon	1		
Blue-winged teal	1		
Great blue heron	6	3	
Green-winged teal	5		
Killdeer	4		
Mallard	1	10	1
Northern pintail	25	10	
Northern rough-winged swallow	2		
Northern shoveler	7		
Pied-billed grebe		2	
Ring-billed gull	1	1	1
Snow goose	1		
Snowy plover	1		
Song sparrow	1		
Teal	2	1	
Towhee	1		
Unknown ducks	82		
Unknown hummingbird	2		
Unknown passerine	5	1	
Unknown sparrow	2	1	
Variety	33		
Western sandpiper	2	1	
Western kingbird		1	
Total	**188**	**31**	**2**

Source: Unpublished data, USFWS records.

the mine, concentrations of total and dissolved zinc have exceeded 1,000 μg/L in the Gila River, and concentrations of dissolved copper have exceeded 100 μg/L in the San Francisco River.

S.3.3.2 Groundwater

Definitions of injury to groundwater resources presented in the DOI regulations include the following:

- concentrations of hazardous substances exceeding SDWA or other relevant federal or state criteria or standards [43 CFR § 11.62(c)(1)(i), (ii), (iii)]

- concentrations of hazardous substances sufficient to cause injury to other natural resources that come in contact with the groundwater (e.g., surface water) [43 CFR § 11.62(c)(1)(iv)].

Criteria relevant to all the mine sites include Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs) established by sections 1411-1416 of the Safe Drinking Water Act. In addition, for the Chino and Tyrone Mine Sites, relevant criteria are found in the New Mexico Water Quality Standards for groundwater (NMAC 20.6.2.3103). For the Morenci Mine, relevant criteria are found in the Arizona Aquifer Water Quality Standards (AAC R18-11-401 to R18-11-408). A comparison of hazardous substances measured in groundwater and seeps at the mine with groundwater standards demonstrates that hazardous substance concentrations in groundwater are sufficient to potentially cause injury at all of the sites.

At the Chino Mine, concentrations of cadmium, copper, lead, and manganese in groundwater have exceeded New Mexico criteria by more than a factor of 10. At the Tyrone Mine, copper concentrations in perched groundwater have exceeded the SMCL by more than a factor of 20, and manganese concentrations in regional groundwater have exceeded New Mexico criteria by more than a factor of 10. At the Morenci Mine, concentrations of antimony, beryllium, and cadmium in groundwater have exceeded Safe Drinking Water Act standards. These concentrations indicate that groundwater at all the sites is potentially injured. Injured groundwater that emerges through seeps and springs to surface water may be a pathway of injury to trust resources, including endangered species of aquatic biota.

S.3.3.3 Birds

According to U.S. DOI regulations [43 CFR § 11.62(f)], an injury to biological resources has resulted from the discharge of a hazardous substance if the concentration of the hazardous substance is sufficient to:

- cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

The bird carcasses (Table S.1) found at the Chino, Tyrone, and Morenci Mines during just a three-month period in 2000 confirm adverse impacts to birds at each of the sites. At the Chino Mine, elevated concentrations of hazardous substances in bird, small mammal, and reptile tissues provide further evidence that wildlife potentially have been exposed to hazardous substances at the site. The ecological risk assessment found risk to small ground-feeding birds at the Chino Mine based on exposure to elevated concentrations of copper in soil, seeds, foliage, and invertebrates. Risks to other wildlife, including raptors, small mammals, mammalian predators, and ruminants, were also found from cadmium, lead, and zinc. In addition, supporting terrestrial habitat at the site, including soils and vegetation, potentially has been injured by exposure to hazardous substances. Risks to aquatic biota, including amphibians, were found from cadmium, copper, lead, and zinc in surface water at the Chino Mine site.

S.3.4 Data Sufficient to Pursue an Assessment Are Available or Likely to Be Obtained at Reasonable Cost

Data relevant to conducting an assessment of natural resource damages at the Chino, Tyrone, and Morenci Mines have been collected as part of regular monitoring activities at all the mines; as part of the Closure/Closeout and Mine Reclamation planning processes in New Mexico and Arizona; as part of the application process, and under conditions of groundwater discharge permits for the Chino and Tyrone Mine issued by the State of New Mexico; as part of the application for the Morenci Mine’s aquifer protection permit issued by the State of Arizona; and pursuant to an Administrative Order on Consent (AOC) signed by the Chino Mines Company and the New Mexico Environment Department. Such data include information on hazardous substances sources, releases, pathways, and concentrations in the environment. Since the preassessment screen is intended to determine only whether there is sufficient cause to pursue an NRDA, omission of any information in the preassessment screen does not preclude consideration of such information in the course of an NRDA. Additional data for the purposes of performing a damage assessment are expected to be obtainable at reasonable cost.

S.3.5 Response Actions Will Not Sufficiently Remedy the Injury to Natural Resources without Further Action

Response actions at the three mines are not sufficient to remedy the injury to natural resources without further action. At all three mines, certain corrective actions have been undertaken. Under the requirements of groundwater discharge permits with the NMED Ground Water Quality Bureau, actions of the Chino Mines Company and Phelps Dodge Tyrone, Inc. have included installing interceptor wells and trenches, replacing a lined PLS pond with a stainless steel tank, and managing runoff stormwater. These actions, however, are not sufficient to either prevent ongoing and future injuries or to remedy past injuries. For example, sampling at the Chino and Tyrone Mines has indicated ongoing exposure of ephemeral surface water to hazardous substances and continued elevated concentrations of hazardous substances in groundwater. At the Morenci Mine, as part of a settlement reached in 1986 with the EPA, Phelps Dodge Morenci, Inc. agreed to construct the $9 million-plus Chase Creek diversion, which diverts Upper Chase Creek around mining operations through a control system that consists of a reservoir, pumps, and a 7.5 mile pipeline to Lower Chase Creek. The Aquifer Protection Permit for the Morenci Mine indicates some required corrective actions for aquifer protection, but no data on results of corrective actions were available for review.

In addition, ponded water on top of tailings impoundments, in uncovered process water ponds, and in stormwater ponds at all three mines continues to serve as ongoing sources of potential injuries to wildlife. Efforts at the Tyrone Mine to neutralize low pH ponds with liming at the tailings impoundments have not been successful at maintaining pH values between 6 and 8. There appears to have been some success at the Morenci Mine to maintain the pH between 6 and 8: USFWS personnel measured a pH of 8.9 in the Southwest Tailings Dam 1 pond in October 2000. Current hazing activities at the Tyrone and Morenci Mines may reduce some future injuries to wildlife, but are not sufficient to remedy injury and do not occur at all the locations of ponded water at the site. The Trustees are unaware of any hazing activities to reduce injuries to wildlife at the Chino Mine.

S.4 Conclusions

Based on an evaluation of the preassessment determination criteria, the following conclusions can be made:

- A release of hazardous substances has occurred.
- Natural resources for which the Trustees have trusteeship have been or are likely to have been adversely affected.

- The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury.

- Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.

- Response actions will not sufficiently remedy the injury to natural resources without further action.

Based on an evaluation of these five criteria, the Trustees have determined that there is a reasonable probability of making a successful natural resource damages claim and that an NRDA should be performed to assess damages to natural resources caused by releases of hazardous substances from the Chino, Tyrone, and Morenci Mines.

Part A:
Preassessment Screen for Chino Mine Site, Grant County, New Mexico

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Contents

Acronyms and Abbreviations

AGP	acid-generating potential
ANP	acid-neutralizing potential
AOC	Administrative Order on Consent
CMC	Chino Mines Company
CWA	Clean Water Act
DOI	U.S. Department of the Interior
LOAELs	lowest-observed-adverse-effect levels
MCLs	Maximum Contaminant Levels
NMED	New Mexico Environment Department
NOAELs	no-observed-adverse-effect levels
NRDA	natural resource damage assessment
PLS	pregnant leach solution
PRP	potentially responsible party
RI/FS	remedial investigation/feasibility study
SDWA	Safe Drinking Water Act
SMCLs	Secondary Maximum Contaminant Levels
SPLP	synthetic precipitation leaching procedure
SX/EW	solution extraction/electrowinning
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TRV	toxicity reference values
USFWS	U.S. Fish and Wildlife Service

Figures

Tables

1. Introduction

Hazardous substances have been released to the environment as a result of mining and mineral processing activities at the Chino Mine near Silver City, New Mexico. The U.S. Fish and Wildlife Service (USFWS), in coordination with the New Mexico Office of Natural Resources Trustee, has begun to assess natural resource damages resulting from releases of hazardous substances from the Chino Mine in accordance with the natural resource damage assessment (NRDA) regulations issued by the U.S. Department of Interior (DOI) at 43 CFR Part 11.[1] These regulations are not mandatory. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 U.S.C. § 9607(f)(2)(C)]. The first step in the process established by DOI is the preparation of a preassessment screen. This preassessment screen documents the Trustees' conclusion that there is a reasonable probability of making a successful claim for natural resource damages at the Chino Mine. This screen was prepared by Stratus Consulting under contract to the USFWS.

1.1 Intent of the Preassessment Screen

The purpose of a preassessment screen is to determine whether a discharge or release of a hazardous substance warrants conducting an NRDA. It is intended to be based on "a rapid review of readily available information . . . [to] ensure that there is a reasonable probability of making a successful claim" [43 CFR § 11.23(b)]. This preassessment screen is not intended to serve as an assessment of natural resources injuries or damages.

A variety of quantitative and qualitative data sources were relied on for this review of readily available information. Information sources included the following:

- The Chino Mine Closure/Closeout Plan and appendices prepared for the New Mexico Environment Department (NMED) by the Chino Mines Company (CMC) and its contractors (M3, 2001). Although the documents are dated 2001, the majority of the data in the documents was obtained in 1998 or before.

- The draft Ecological Risk Assessment prepared for the Chino Mine Investigation Area and its associated sample database (MFG, 2002).

1. 43 CFR Part 11 regulations were authored by the U.S. DOI, and are referred to as the DOI regulations in this document.

- Analytical data for water and sediment samples collected at the Chino Mine tailings ponds and analyzed by the USFWS (unpublished data).

- A preliminary inventory of bird mortalities at the Chino Mine in 2000 (unpublished data).

- Various published reports about Phelps-Dodge, including an assessment prepared by the Interhemispheric Research Council (IRC, 2001).

- Site visits, photographs, and videos of the site taken by USFWS personnel in 2000 and 2002.

All literature and data sources relied on in the preparation of this preassessment screen are presented in the references provided at the end of this report.

1.2 Criteria to be Addressed by the Preassessment Screen

The content and requirements of a preassessment screen are described in 43 CFR Part 11.23. As described in the regulations, the Trustees evaluated whether all of the following criteria have been met [43 CFR § 11.23(e)]:

1. **A release of a hazardous substance has occurred.** This criterion was evaluated by reviewing information on sources of hazardous substances, evidence of releases of hazardous substances (including spills and continuous releases), and data demonstrating elevated concentrations of hazardous substances in natural resources.

2. **Natural resources for which the Trustees may assert trusteeship have been or are likely to have been adversely affected by the release.** This criterion was evaluated by reviewing information documenting migratory bird mortalities at the site, data demonstrating exposure of natural resources to hazardous substances, and the results of the ecological risk assessment.

3. **The quantity and concentration of the released hazardous substance are sufficient to potentially cause injury to those natural resources.** This criterion was evaluated by reviewing information documenting migratory bird mortalities at the site, by comparing concentrations of hazardous substances in surface water and groundwater to regulatory criteria, and by reviewing the ecological risk analysis for terrestrial and aquatic resources.

4. **Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.** Monitoring data for surface water and groundwater already exist at the site, and an ecological risk assessment has been prepared. Additional data collected as part of the ecological risk assessment include soil analysis, vegetation sampling,

phytotoxicity tests, and tissue concentration data for invertebrates, vegetation, small mammals, birds, and reptiles. Additional data collection activities for resources that have not been evaluated could be conducted at reasonable cost.

5. **Response actions carried out or planned will not sufficiently remedy the injury to natural resources without further action.** An Administrative Order on Consent (AOC) has been signed between the CMC and the NMED. The ecological risk assessment for the site was completed pursuant to this process. However, no response actions have yet been undertaken under the AOC. Other response actions at the site, such as stormwater management, rerouting of Whitewater Creek, and installation of groundwater interceptor wells, have not been sufficient to eliminate ongoing injury to natural resources.

This preassessment screen presents data sufficient to support the above criteria based on information readily available to the Trustees. It is *not* a comprehensive summary and review of all existing data.

2. Information on the Site [43 CFR § 11.24]

2.1 Location and Description of the Chino Mine

The Chino Mine facility is located approximately 12 miles southeast of Silver City, in Grant County, New Mexico (Figure 2.1). The facility includes an open-pit copper mine (the Santa Rita pit), a copper concentrator, a solution extraction/electrowinning (SX/EW) facility, leach stockpiles, rock stockpiles, tailings impoundments, pipelines and other associated mine facilities and infrastructure (Figures 2.2 and 2.3). In addition, a smelter is located southwest of the mine in Hurley, New Mexico.

The climate of the site is semi-arid, with precipitation averaging 14.3 inches annually at the smelter in Hurley and 17.4 inches at Santa Rita. Most of the precipitation falls during thunderstorms in the monsoon season from July to October (M3, 2001, p. 2-10). Elevations at the site range from approximately 5,200 to 7,700 feet above mean sea level (M3, 2001, p. 2-9). In the north mine area, vegetation communities include sparsely vegetated cliffs, oak/juniper woodland, juniper/pinyon savanna, and riparian mixed deciduous shrub (M3, 2001, pp. 2-17 to 2-18). In the south mine area, vegetation communities are typical of desert grasslands, and include mixed grasses/yucca/cactus, honey mesquite, and riparian deciduous shrub. In Grant County, there are 10 species of birds, amphibians, and mammals listed as federal species of concern (threatened, endangered, proposed, or species of concern) (USFWS, 2003). The CMC manages approximately 116,000 acres around the mine and processing facilities (MFG, 2002, p. 13).

The site is east of the Continental Divide and drains into ephemeral drainages in the Mimbres River watershed. The Mimbres River is a closed-basin desert stream; a well-defined river channel terminates approximately 10 miles east of Deming, New Mexico (NMWRRI, 2000, p. 30). Major drainages at Chino include Whitewater Creek, Hanover Creek, and Lampbright Draw. Hanover Creek is an intermittent stream that originates northeast of the Chino Mine and joins Whitewater Creek near the Ivanhoe concentrator. Whitewater Creek is an intermittent stream that is the primary drainage for the north and south mine areas. Whitewater Creek flows into the San Vicente Arroyo south of the mine. Lampbright Draw is an intermittent stream draining the eastern portions of the north mine area that flows south and eventually joins San Vincente Arroyo (M3, 2001, pp. 2-12 to 2-13).

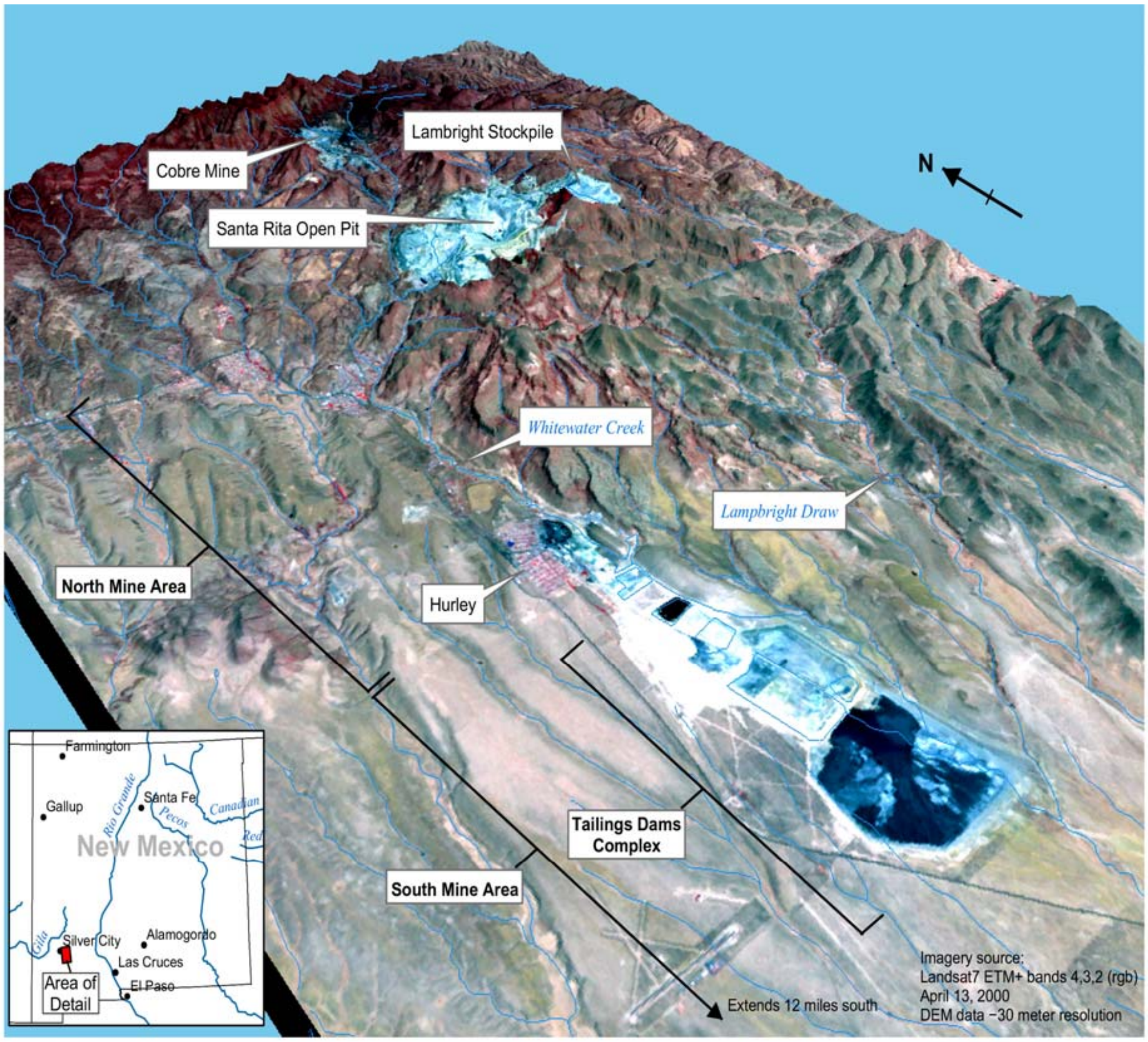

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Figure 2.1. Chino Mine facility in southwestern New Mexico.

Sources: Landsat7, 2000; ARIA, 2001.

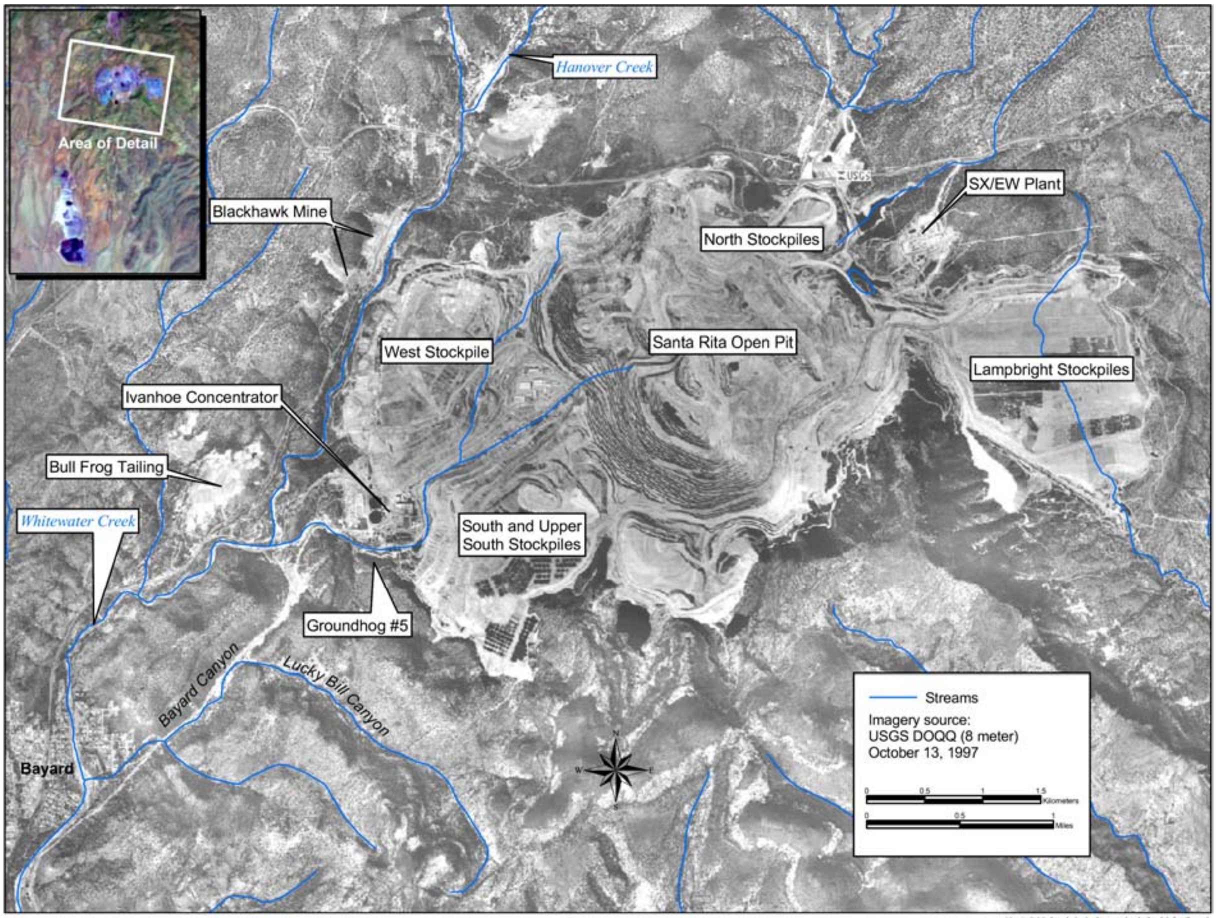

Figure 2.2. Mine facilities and streams for the northern portion of the Chino Mine, including the Santa Rita open pit and stockpiles.

Source: USGS, 1997.

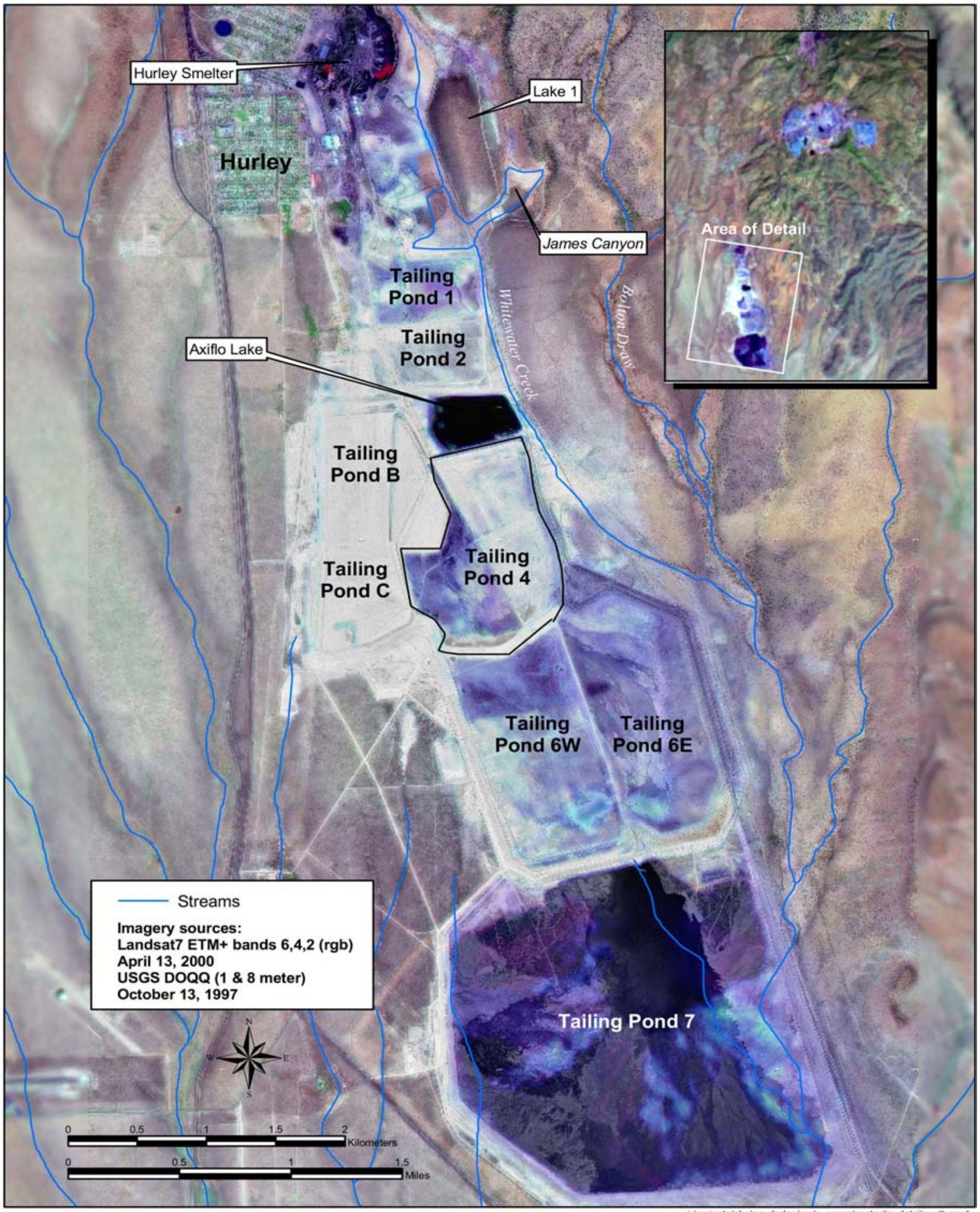

Figure 2.3. Mine facilities at the Chino Mine, for the southern portion of the mine, including Lake 1, Axiflo Lake, and the tailings ponds.

Sources: USGS, 1997; Landsat7, 2000.

2.2 History of Mining at the Chino Mine

Copper deposits at Chino were known to the Apache Indians. The Spanish began mining the Chino copper deposits in the early 1800s. In 1889, the Santa Rita Mining Company purchased the property. In 1909, the Chino Copper Company was formed and took control of the property. In the mid-1920s, mergers resulted in the formation of the company Nevada Consolidates. In 1933, Kennecott Copper Corporation purchased Nevada Consolidates and the Santa Rita Mine. In 1980, Mitsubishi Corporation bought a one-third interest in the mine from Kennecott. In 1986, the Phelps Dodge Corporation (Phelps Dodge) bought Kennecott's remaining interest in the mine. Since 1986, Phelps Dodge has held a two-thirds interest in the mine and Mitsubishi has retained a one-third interest in the mine (M3, 2001, pp. 2-3 to 2-4).

Open-pit mining at Chino began in 1910. In 1998, the Santa Rita open pit was approximately 1,500 feet deep, 1.8 miles in diameter, and over 1,500 acres (M3, 2001, p. 2-22) (Figure 2.4). The uppermost level of the pit rim at that time was on the south side at 6,600 feet above mean sea level, and the lowest level was near the south-center of the pit at 5,100 feet above mean sea level. The Santa Rita pit has been developed with 50 foot benches, with gradients of 2.1 to 2.9 feet horizontal to 1 foot vertical (M3, 2001, p. 2-22). The pit is actively dewatered, which induces groundwater flow toward the pit (M3, 2001, pp. 2-12 to 2-13).

Figure 2.4. Santa Rita open pit at the Chino Mine in October 2002.

In 1911, a mill and concentrator were built near the current Hurley smelter site. Grinding and flotation were used to increase the copper concentration before transporting the ore for smelting. In mid-1982, a new mill and concentrator (called the Ivanhoe concentrator) near the open pit replaced the original Hurley mill and concentrator. The Hurley smelter was completed in 1939 (Figure 2.5). Tailings from the concentrators are deposited east of Hurley along Whitewater Creek.

Figure 2.5. Hurley smelter at the Chino Mine (in background).

In 1936, leaching operations of low-grade ore stockpiles near the open pit began. Copper was extracted from leach solutions at precipitation plants. In 1988, the SX/EW plant was constructed east of the open pit, and additional leaching activities began (M3, 2001, p. 2-2). In the SX/EW process a weak acid solution drips through a network of pipes on top of the leach piles to leach copper out of the ore, forming a pregnant leach solution (PLS) with a high copper concentration. The PLS is collected in uncovered ponds near the leach stockpiles (Figure 2.6), and then pumped to the SX/EW plant, where it is first contacted with an organic solvent, known as extractant, in the SX stage. The copper-bearing organic solution is stripped of copper by mixing it with a strongly acidified aqueous solution, which is transferred to the EW process. During EW, an electric current plates the copper from the copper sulfate solution onto a metallic copper cathode, which is 99.99% pure copper. After copper is stripped from the PLS, the PLS is recycled for further leaching (Dresher, 2001).

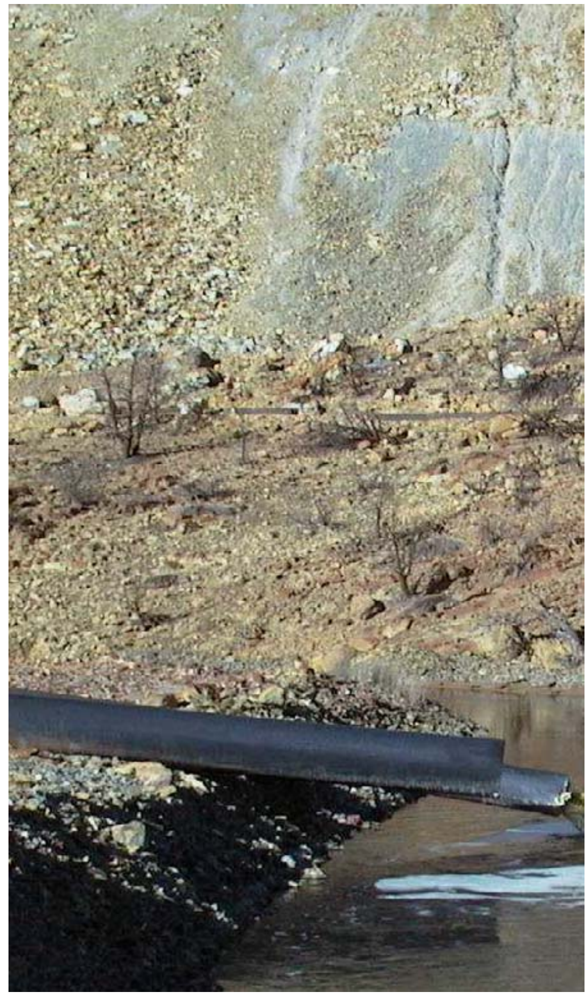

Figure 2.6. PLS collection pond at the Lampbright leach pad at the Chino Mine.

In 1997, 99,900 tons of copper were produced by the concentrate and precipitate process at the Chino Mine, and an additional 69,100 tons of copper were produced by the SX/EW process. In 2001, this production rate had dropped to 18,300 tons of copper produced by concentrate and precipitate and 59,900 tons of copper produced by SX/EW (U.S. Securities and Exchange Commission, 2002, p. 7). The copper concentrator was shut down temporarily in March 2001. In January 2002, the Chino Mine and the Hurley smelter were temporarily closed (U.S. Securities and Exchange Commission, 2002, p. 4). As of October 2002, the mine, concentrator, and smelter remained closed (observation from USFWS site visit).

Located within the permit boundary of the Chino Mine, the Groundhog Mine is a historical underground mine. Lead carbonate was first mined along the Groundhog fault in the late 1860s. Controlling interest in the three claims that make up the mine was sold to Asarco in 1928, and mining continued into the 1970s. In 1994, Asarco sold the property to the CMC. As a condition for the sale, Asarco moved the stockpiles from Bayard Canyon to the San Jose shaft area and covered them with a thin layer of soil. One uncovered stockpile (Groundhog No. 5) remains (M3, 2001, pp. 2-25-2-26).

2.3 Identification of Potentially Responsible Parties

The Trustees have identified the CMC, its two parent companies, Phelps Dodge Corporation and Heisei Minerals Corporation, and Mitsubishi Materials Corporation (the majority owner of Heisei Minerals) as the primary potentially responsible parties (PRPs) for the Chino Mine. The term PRP as used in this document refers to parties potentially liable for natural resource damages under CERCLA. Phelps Dodge Corporation has held a two-thirds interest in the mine since 1986, while Heisei Minerals Corporation, a subsidiary of Mitsubishi Materials Corporation, has held a one-thirds interest since 1980 (U.S. Securities and Exchange Commission, 2002, p. 3). In 2002, Phelps Dodge Corporation was #428 on the Fortune 500 list of the largest corporations in the United States, with annual revenues of more than $3.7 billion. In 2002, the net sales of Mitsubishi Materials Corporation was $7.9 billion (Mitsubishi Materials Corporation, 2002, p. 21).

Other PRPs at the site could include Kennecott Copper Corporation, which owned 100% of the mine from 1933 to 1980 and two-thirds of the mine from 1980 to 1986 (M3, 2001, pp. 2-4). In addition, there may be PRPs associated with inactive mines in the Chino area that could be releasing hazardous substances. The Mining Remedial Recovery Company (Bayard Copper Company) currently owns the Bullhill and Bullfrog mines. Asarco Mining Company owned the Groundhog/San Jose Mine from 1928 to 1994, at which point it was sold to the CMC. Paramount Communications is the current owner of Gulf & Western, Inc., which bought the Empire Zinc Mine in 1965.

2.4 Releases of Hazardous Substances

Studies completed for the Chino Mine Closure/Closeout Plan (M3, 2001) documented releases of hazardous substances from the mine and identified actual or potential sources of these releases. Further evidence of hazardous substance releases was documented at site visits to the mine by the USFWS and reports of spills at the mine.

2.4.1 Hazardous substances released

Hazardous substances (as given in the List of Hazardous Substances and Reportable Quantities, Table 302.4 at 40 CFR § 302.4, July 1, 1999 revision) are present in source materials at the Chino Mine and have been released to the environment. Whole-rock analyses indicate that hazardous substances present in source rock taken from the Santa Rita pit at the Chino Mine include, but are not limited to, arsenic, barium, chromium, copper, lead, nickel, thallium, and zinc (Appendix C of Golder Associates, 1998).[1] In addition, a subsample of mineral assemblages was subjected to humidity cell leach tests. Leachate from these tests included the hazardous substances cadmium, cobalt, copper, manganese, nickel, and selenium in concentrations above State of New Mexico regulatory criteria for human health standards, domestic water supply, or irrigation use (NMWQCC 20 NMAC 6.2, Subpart III, 3103) (Table 4-6 in Golder Associates, 1998). Detectable concentrations of the hazardous substances antimony, barium, beryllium, chromium, silver, and thallium were also detected in leachate from multiple samples (Appendix G of Golder Associates, 1998). Detectable concentrations of lead and mercury were found in single leach samples on one occasion (Appendix G of Golder Associates, 1998). Additional sources of hazardous substances come from mine operations. Sulfuric acid is a listed hazardous substance that is used to leach copper ore from leach stockpiles and is present in the raffinate solution, which is a byproduct of the SX/EW process.

Elevated concentrations of hazardous substances detected in soil, surface water, and groundwater at the mine indicate that hazardous substances present in source materials at the Chino Mine have been released to the environment (see Tables 3.1, 3.3, and 3.10 in this report). Based on the information described above, hazardous substances identified as having been released from the Chino Mine facilities include, but may not be limited to:

- arsenic and compounds
- cadmium and compounds
- chromium and compounds
- copper and compounds
- lead and compounds
- manganese and compounds
- mercury and compounds
- nickel and compounds
- selenium and compounds
- zinc and compounds
- sulfuric acid.

1. The Trustees realize that hazardous substances occur naturally in source rock at the Chino Mine. The Trustees are pursuing an NRDA at the Chino Mine because of evidence that these substances have been released to the environment in concentrations potentially sufficient to injure natural resources for which the Trustee agencies have trusteeship.

2.4.2 Sources of hazardous substance releases

Potential sources of hazardous substance releases at the Chino Mine include, but are not limited to, tailings impoundments and associated lakes, waste rock and leach stockpiles, mine process facilities and associated infrastructure, and the Hurley smelter. Each of these sources is discussed briefly in the following sections.

Tailings impoundments and associated lakes

There are eight inactive tailings impoundments (also called tailings ponds or tailings dams) at the Chino Mine and one active tailings impoundment (Tailings Pond 7) (Figure 2.3; Table 2.1). In 1911, tailings were first deposited along the west edge of Whitewater Creek near the Hurley concentrator, which was located near the Hurley smelter (Daniel B. Stephens & Associates, 1996, pp. 2-9 to 2-15). Construction began on Tailings Pond No. 1 in 1911. In 1998, the total footprint area of the inactive tailings was approximately 2,140 acres; the footprint area of the active tailings pond (No. 7) was 1,563 acres (Table 2.1).

Lake One and Axiflo Lake are associated with the tailings ponds at Chino Mine. Lake One was created in 1910, when an earthen dam was built across Whitewater Creek to provide water to the Hurley concentrator. Before 1984, Lake One periodically received overflow from PLS that flowed over the dam at the Precipitation Plant located near the Ivanhoe Concentrator (Daniel B. Stephens & Associates, 1996, pp. 2-14 to 2-15). In 1984, Whitewater Creek was diverted eastward around Lake One, and the lake was drained. Ponded water from precipitation, local runoff, and upstream seepage currently forms on Lake One (M3, 2001, p. 2-37). Axiflo Lake was built in 1919 just south of Tailings Pond No. 2 for storage of tailings decant return water (Daniel B. Stephens & Associates, 1996, p. 2-15). It is currently used for storage of tailings decant return water from Tailings Pond No. 7, production well water, and interceptor system discharge from Tailings Pond No. 7 (M3, 2001, p. C-4).

Laboratory analysis of borehole samples from tailings ponds, Lake One, and Axiflo Lake, indicate that hazardous substances present in tailings and in sediments from Lake One and Axiflo Lake include, but are not limited to, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium and zinc (Table 2.2). All of the older tailings ponds are potentially acid-generating, as indicated by acid generating potentials that significantly exceed acid neutralization potentials. The net acid generation potential for borehole samples from Lake One, and from Tailings Ponds 1, 2, 4, B, C, 6W, and 6E, ranged from -12.2 to -207 g $CaC0_3$/kg dry tailings (Daniel B. Stephens & Associates, 1997, Table 9-1). As water drains from the tailings, the upper portions of the tailings ponds are exposed to the atmosphere, causing the oxidation of sulfide minerals in acid-generating tailings; this can result in porewater becoming more acidic (Golder Associates, 1999, p. 27). Decreasing pH can result from acid (H^+) produced as a product of the oxidation and dissolution of pyrite (FeS_2)and other metal sulfides in tailings (U.S. EPA,

Table 2.1. Tailings ponds and associated lakes at the Chino Mine

Tailings pond or lake	Size (acres)[a]	Description[b]
Lake One	220	Inactive reservoir (constructed in 1910, draining began in 1984), historically used for water storage and flood retention; received overflow of pregnant leach solution from the precipitation plant
Tailings Pond #1	159	Whitewater Creek on east side; receives run-on from Tailings Pond #2 and possibly from the west; inactive since 1953
Tailings Pond #2	150	Receives run-on from Tailings Pond B; runoff goes to Axiflo Lake; inactive since 1944
Tailings Pond B	238	Runoff goes to Tailings Pond #2 and Axiflo Lake; inactive sine 1993; has been capped with local soils to control fugitive dust
Tailings Pond C	158	Inactive sine 1993; has been capped with local soils to control fugitive dust
Tailings Pond 4	362	Runoff to Axiflo Lake and Tailings Ponds 6W and 6E; inactive since 1988; used for temporary disposal of excess water; has been capped with local soils to control fugitive dust
Tailings Pond 6W	425	Receives run-on from Tailings Pond #4; runoff goes to Tailings Pond No. 7; inactive since 1961
Tailings Pond 6E	428	Receives run-on from Tailings Pond #4; runoff goes to Tailings Pond No. 7; inactive since 1988; used for temporary disposal of excess water; has been capped with local soils to control fugitive dust
Total area: Inactive	**2,140**	
Axiflo Lake	91	Constructed in 1919; used for storage of tailings decant return water and other discharges; receives run-on from Tailings Ponds 2, B, and 4
Tailings Pond No. 7 (in 1998)	1,563	Run-on from Tailings Ponds 6E and 6W, inflow from groundwater interceptor wells; active since 1988; engineering measures include an interceptor well system, seepage collection sump, Whitewater Creek diversions, and dust cover capping on the outslope
Total area: Active	**1,654**	

a. Source: Footprint area of tailings ponds (top surface plus sideslopes) in 1998, as reported in Table 5-1 in M3, 2001.
b. Source: Appendix C in M3, 2001.

Table 2.2. Concentrations of hazardous substances in Chino Mine tailings ponds (mg/kg)

Tailings pond	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Se	Zn
Lake 1 — North sample[a]	25.4	4.2	26.2	8,972	0.08	833	24.4	225	31.2	640
Lake 1 — South sample[a]	24.3	3.4	25.5	4,034	0.13	1,194	18.9	88	11.5	1,243
Tailings Pond #1[a]	6.9	0.2	23.7	3,944	0.06	85	7.8	8	6.6	35
Tailings Pond #2[a]	8.8	0.5	8.9	4,854	0.04	105	7.8	16	6.2	45
Tailings Pond #4[a]	28.1	0.6	11.8	1,290	0.05	438	18.4	14	54.4	58
Tailings Pond B[a]	8.9	0.3	4.1	1,680	0.05	35	7.2	9	18.2	15
Tailings Pond C[a]	24.5	0.5	10.6	1,734	0.05	255	12.3	9	19.6	43
Axiflo Lake[b]	5	3.75	7.97	2,340	0.02	222	24.8	11.6	6.71	182
Lake 1[b]	4.66	1.94	16.3	2,558	0.11	103	6.98	24.7	6.98	41.8
Tailings Pond No. 7[b]	3.05	1.18	6	728	< 0.02	330	14.2	< 4.86	2.3	63.4

a. Samples collected September 1995 from boreholes. Results are means of five samples taken at different depths. Source: Table 3-4 in Daniel B. Stephens & Associates, 1997. Not specified as dry weight or wet weight.
b. Composite samples collected September 2000 from top oxidized layer of tailings. Source: Unpublished data, samples collected by USFWS, analyzed at the Research Triangle Institute. Results are mg/kg dry weight.

1994b). The oxidation and dissolution of pyrite results in the formation of reduced iron (Fe^{2+}), sulfate (SO_4^{2-}), and acid (H^+):

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+. \qquad (2.1)$$

The presence of the iron-oxidizing bacterium, *Thiobacillus ferrooxidans*, greatly accelerates the rate of oxidation of reduced iron:

$$4\ Fe^{2+} + O_2 + 4H^+ \leftrightarrow 4\ Fe^{3+} + 2\ H_2O. \qquad (2.2)$$

The oxidized iron (Fe^{3+}) promotes the further oxidation and dissolution of pyrite, with additional releases of acid:

$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+. \qquad (2.3)$$

As precipitation ponds on the surface of the tailings impoundments and interacts with these upper oxidized tailings, the concentration of metals, total dissolved solids, and sulfate in the water will increase, while pH will decrease.

Figure 2.7. Water ponded on the surface of tailings.

Consequently, after precipitation events, ponded water in contact either with oxidized tailings or with contaminated sediments in Axiflo Lake and Lake One can serve as a pathway of hazardous substances to birds and wildlife attracted to ponded water in the arid Southwest (Figure 2.7). The ponds are intermittent, depending on precipitation and evaporation rates, but remain a source of future releases after periods of surface water accumulation.

Hazardous substances, including arsenic, cadmium, chromium, copper, manganese, nickel, and zinc, have been measured in ponded water from Tailings Pond No. 7, Lake One, and Axiflo Lake (Table 2.3). At Tailings Pond No. 7, drainage and oxidation of the top layers of tailings have not yet begun because deposition is active. Therefore, water ponded on the top of Tailings Pond No. 7 is not highly acidic (pH = 6.9 in September 2000; USFWS, unpublished data), but still contains elevated concentrations of hazardous substances (Table 2.3).

Table 2.3. Concentrations of hazardous substances measured in ponded water on Chino tailings dams and associated lakes (mg/L)

Location	pH	As	Be	Cd	Cr	Cu	Mn	Ni	Zn
Axiflo Lake	7.1	< 0.0056	< 0.0004	0.0137	< 0.0056	1.38	1.1	0.0262	0.19
Lake One	2.7	0.0981	0.045	0.982	0.276	1,213	49.1	2.3	19.8
Tailings Pond #7	6.9	< 0.0056	< 0.0004	0.004	< 0.0056	0.533	1.04	0.0178	0.0719

Source: Unpublished data, samples collected by USFWS, analyzed at the Research Triangle Institute. Sampled on September 15, 2000.

Tailings piles can serve as continuous sources of hazardous substance releases through 1) precipitation-induced erosion, storm-water runoff, and windblown emissions from tailings; 2) ponding of precipitation on the surface of the tailings; and 3) spills of tailings. Releases of hazardous substances, including but not limited to arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, and zinc, from the tailings impoundments most likely have been multiple and at times continuous, beginning at least from the time when the tailings impoundments became inactive (1944 for Tailings Pond No. 2) and extending to either the present or to the time when the tailings impoundments were capped. In 1991, the CMC began capping older tailings ponds with native soils (Gila Conglomerate) to control dust (Daniel B. Stephens & Associates, 1996, p. 2-16). By 1995, parts of Ponds 2, B, and 4 had been covered. By 2001, Tailings Ponds B, C, 4, 6E, and 6W were reported as capped with local soils to reduce dust and wind-blown tailings (M3, 2001, pp. C-3 to C-9).

Inactive and uncapped tailings impoundments can serve as ongoing sources of hazardous substance releases through the formation of acidic metal-laden ponds on the surface of the impoundments and through wind-blown emissions. Evidence of wind-blown emissions as a source of hazardous substances comes from surface soil samples collected downwind of the Chino tailings ponds which had elevated copper concentrations compared to reference soil samples collected upwind of the tailings ponds (M3, 2001, p. 3-26). The Comprehensive Groundwater Characterization Study: Phase 3 Report further noted that “fugitive dust blown from the tailings impoundments, stormwater erosion and tailings discharge beyond the pond perimeters, have affected soil adjacent to the impoundments” (Table 2.2.1 in Golder Associates, 1999).

Multiple spills of tailings have served as releases of hazardous substances that are present in the tailings (Table 2.4). The largest event occurred in 1999, when 3.25 million gallons of tailings spilled into Whitewater Creek (IRC, 2001, p. 18). Additional tailings spills were reported in 1991, 1992, 1993, 1996, 1997, and 2000 (Table 2.4).

Table 2.4. Tailings spills at the Chino Mine from 1991 to 2000

Date	Description of spill or release	Citation
August 1991	3,200 gallons of tailings released into Whitewater Creek when a tailings pipeline ruptured; CMC was issued a Notice of Violation by NMED for this release	a
August 1992	120,000 gallons of tailings spilled into a basin	b
1993	208 tons and 91,500 gallons of tailings accidentally released to Whitewater Creek in six separate incidents resulting from the rupture of degraded pipes	a
April 1996	152,000 gallons of liquid tailings spilled into Whitewater Creek	b
May 1997	100,000 gallons of tailings spilled into Whitewater Creek	b
August 1999	3.25 million gallons of tailings spilled into Whitewater Creek	b
August 1999	10,000 gallons of tailings spilled on Phelps-Dodge property	b
December 2000	480,000 gallons of tailings slurry discharged; 93,000 gallons entered Whitewater Creek	b

a. U.S. EPA, 1997, p. 179.
b. IRC, 2001.

Waste rock and leach stockpiles

Figure 2.8. Erosion at the Lampbright leach stockpile at the Chino Mine.

Near the Santa Rita pit, stockpiles used for leaching encompass approximately 1,700 acres in five piles, and waste rock stockpiles encompass approximately 340 acres in seven stockpiles (Table 2.5). In addition, four small stockpiles with a total area of approximately 2.4 acres are located along upper Whitewater Creek. Releases of hazardous substances, including but not limited to cadmium, copper, lead, and manganese, from stockpiles at the site have been multiple and at times continuous, most likely beginning at least from the start of leaching operations of low-grade ore stockpiles near the open pit in 1936 (M3, 2001, p. 2-2) and extending to the present. Multiple surface piles of waste rock and leach stockpiles at the Chino Mine are able to serve as continuous sources of hazardous substances through 1) releases of PLS from leach stockpiles, 2) acidic seepage from acid-mine drainage at waste rock piles, and 3) precipitation-induced erosion, storm-water runoff, or windblown emissions from waste rock and leach stockpiles. An example of erosion on a leach stockpile is shown in Figure 2.8. Some releases of hazardous substances into groundwater may be captured by pumping of the Santa Rita pit, if the direction of groundwater flow is toward the pit.

Mined rock at the Chino Mine was delivered to different locations, depending on the ore type and copper concentrations. Mineralized materials with the highest copper content were sent to the concentrator and did not become part of the stockpiles (> 0.6% Cu for supergene sulfide ore; > 0.3% Cu for hypogene sulfide ore or mineralized skarn).[2] Mineralized materials with intermediate copper content were sent to the leach stockpiles (0.1% < Cu < 0.6% for supergene sulfide ore). Mineralized materials with low copper content were sent to the waste rock stockpiles (< 0.1% Cu for supergene sulfide ore; < 0.3% Cu for hypogene sulfide ore or mineralized skarn). Ore containing soluble copper oxides or native copper has been sent to both leach and waste rock stockpiles. In addition, waste stockpiles also receive nonmineralized rock, known as overburden (Golder Associates, 1998, p. 4).

2. Hypogene mineralization is also called primary mineralization and consists of pyrite as the main sulfide mineral. Supergene mineralization indicates weathering-related mineralization and includes chalcocite and chrysocolla (SARB, 1999, pp. 10-11). Skarn is defined as contact rock of igneous silicate masses with limestone.

Table 2.5. Leach and waste rock stockpiles at the Chino Mine

Stockpile	Size (acres)[a]	Description[b]
Lampbright leach stockpiles: main and south Lampbright	619	Ore stockpile used for leaching. Direction of groundwater flow is to Lampbright Draw and main pit. Downstream drainage into Lampbright Draw. East of main pit. Has PLS and stormwater collection system and toe control systems.
West stockpile	544	Low-grade leach stockpile with PLS and stormwater collection system, toe control, and interceptor wells. Direction of groundwater flow is to Hanover Creek and main pit. West of main pit.
South stockpile	583	Low-grade leach stockpile with PLS and stormwater collection systems. Direction of groundwater flow is to Whitewater Creek and main pit. Southwest of main pit.
North pit stockpile	Not given	Leach stockpile located inside the Santa Rita open pit.
Total for leach stockpiles	**1,746**	
Southwest Lampbright stockpile	80	Non-leach rock stockpile. Downstream drainage into Lampbright Draw. Direction of groundwater flow is to Lampbright Draw. Bermed, graded, and watered for dust control.
East pit perimeter access stockpile	39	Non-leach rock stockpile. East of upper south stockpile. Direction of groundwater flow is to main pit.
Groundhog No. 5 stockpile	2	Non-leach rock stockpile from the Groundhog Mine. West of south stockpile. In Mimbres Basin drainage. Groundwater flow unknown.
Upper south stockpile	104	Non-leach rock stockpile. Direction of groundwater flow is to main pit. Adjacent to south stockpile.
North stockpile	18	Waste stockpile not used for leaching. Direction of groundwater flow is to main pit. North of main pit. Has stormwater collection system.
Northwest stockpile	20	Non-leach rock stockpile. Direction of groundwater flow is to Hanover Creek and the main pit. Northwest of main pit.
Northeast stockpile	78	Non-leach ore stockpile. Has stormwater collection system. Located along the perimeter of the main pit. Direction of groundwater flow unknown.
Total for waste rock stockpiles near main pit	**341**	
CG Bell	0.1	Non-leach rock stockpile. Materials potentially acid generating. Groundwater flows to the southwest and may be partially intercepted by pumping of the Star Shaft.
Tenderfoot B	0.2	Non-leach rock stockpile. Materials potentially acid generating. Groundwater flows to the southwest and may be partially intercepted by pumping of the Star Shaft.
Star Rock	1.9	Non-leach rock stockpile. Materials not acid generating.

Table 2.5. Leach and waste rock stockpiles at the Chino Mine (cont.)

Stockpile	Size (acres)[a]	Description[b]
Osceola	0.2	Non-leach rock stockpile. Materials potentially acid generating. Groundwater flows to the southwest and may be partially intercepted by pumping of the Star Shaft.
Total for upper Whitewater Creek stockpiles[c]	**2.4**	

a. Source: Footprint area of stockpiles (top surface plus sideslopes) in 2001, as reported in Table 5-2 in M3, 2001.
b. Source: M3, 2001, Appendix C and pp. 2-24 to 2-26 for in-pit stockpiles. For upper Whitewater Creek Stockpiles: CMC, 1998, p. 9; Golder Associates, 1999, Appendix C.
c. Source: Area estimate for upper Whitewater Creek stockpiles estimated from sketch maps in CMC, 1998, Appendix C.

Extensive sampling and testing of different rock types present in the Chino Mine ore body was conducted to characterize the geochemical properties of the waste rock stockpiles (Golder Associates, 1998). Results of these tests determined that a majority of the waste rock samples at Chino Mine have the potential to be acid generating, based on a ratio of less than 3 for total sulfur acid-neutralizing potential to acid-generating potential (ANP/AGP) (Golder Associates, 1998, p. 31). Humidity cell test data for waste rock samples indicate that leachate from these samples contained the hazardous substances cadmium, cobalt, copper, manganese, nickel, and selenium in concentrations greater than New Mexico water quality standards for human health, domestic water supply, or irrigation use (Table 4-6 in Golder Associates, 1998).

Hazardous substances have been released into groundwater at the Chino Mine from multiple source areas (Golder Associates, 1999, pp. 43-48, Appendix C). Concentrations of hazardous substances in groundwater in exceedence of NMWQCC standards confirm releases to groundwater throughout the Chino Mine (Table 2.6). Twenty-nine potential groundwater source areas have been identified for the Chino Mine (Golder Associates, 1999, p. 68). Elevated metals in groundwater, in combination with elevated sulfate concentrations and total dissolved solids (TDS), have been observed in 19 of the 29 groundwater potential source areas (Table 4.1 in Golder Associates, 1999).

Groundwater flow modeling for the North Mine area indicates that contaminated groundwater in four of these areas (Lampbright leach facility, Tributary 1 source area, Tributary 2 source area, and the Ivanhoe concentrator source area) is not captured by dewatering in the main pit (Figure 4.1N in Golder Associates, 1999). For example, groundwater samples collected at the north end of the Lampbright leach facility (well Nos. 376-97-02, 376-97-04, 376-97-06) had

Table 2.6. Percentage of groundwater wells where analytes were detected in exceedence of NMWQCC standards

Area	Facility	N	Lead	Sulfate	Mn	Cu	Cd	TDS	pH[a]
NMWQCC standard for groundwater (mg/L; std pH units for pH)		—	*0.05*[b]	*600*[c]	*0.2*[c]	*1.0*[c]	*0.01*[b]	*1000*[c]	*Between 6 and 9*
East of Santa Rita pit	Lampbright stockpile — south	34	0%	12%	0%	0%	0%	12%	0%
	Lampbright stockpile — north	8	0%	100%	100%	0%	38%	100%	50%
	Lampbright stockpile — east	9	11%	11%	11%	0%	0%	11%	0%
	SX/EW plant area	10	10%	80%	90%	40%	60%	10%	30%
Santa Rita pit	Santa Rita pit	4	0%	50%	75%	25%	0%	50%	0%
South of Santa Rita pit	Reservoir 3A	3	0%	33%	67%	0%	33%	0%	33%
	South-southeast	3	0%	0%	33%	0%	0%	0%	0%
West of Santa Rita pit	Maintenance facility	3	0%	100%	100%	67%	67%	100%	67%
	West stockpile	19	11%	84%	79%	11%	21%	79%	21%
	Ivanhoe concentrator/ precipitation plant	16	19%	100%	88%	25%	31%	100%	19%
	Lucky Bill Canyon	1	0%	0%	0%	0%	0%	0%	0%
	South stockpile	5	0%	0%	60%	0%	0%	20%	20%
Middle Whitewater Creek	Middle Whitewater Creek	12	8%	50%	25%	0%	8%	50%	25%
Hurley	Hurley	3	0%	33%	67%	0%	33%	33%	0%
Old Ponds	Lake One	8	0%	50%	50%	13%	13%	50%	25%
	Old tailings ponds	21	5%	52%	0%	0%	0%	52%	0%
	Pond 7 — east	46	9%	50%	0%	0%	0%	54%	4%
Lower Whitewater Creek	Lower Whitewater Creek	8	0%	50%	0%	0%	0%	50%	0%

a. pH exceedences include samples both above and below pH standard range.
b Human health standards.
c. Other standards for domestic water supply, as given in NMAC 20.6.2.3103, standards for groundwater of 10,000 mg/L TDS concentration or less.

Source: Tables 3.6.1 to 3.6.8 in Golder Associates, 1999.

concentrations up to 149 mg/L of the hazardous substance manganese and up to 0.61 mg/L of the hazardous substance copper (Table A-8 and Figure 2.1N in Golder Associates, 1999). Elevated concentrations of manganese (4.67 mg/L) were also found in a groundwater sample in Rustler Canyon (well No. 526-96-16) approximately one mile south of the Lampbright Stockpile (Table A-8 and Figure 2.1N in Golder Associates, 1999).

In the South Mine area, groundwater has exceeded NMWQCC standards for manganese and cadmium at Middle Whitewater Creek, Hurley, and Lake One, and has exceeded standards for copper at Lake One. Sulfate exceedences were found across the South Mine area (Table 2.6).

Because the majority of the waste rock samples at Chino Mine have the potential to be acid generating, stockpiles have the capacity to produce seeps with elevated concentrations of metals. As a result, the stockpiles can serve as sources of hazardous substances to groundwater, especially because the stockpiles are not lined with high-density polyethylene or any other barrier to separate the rock materials and the soil. Acidic seeps are present at the West stockpile. At the dam 11 and dam 13 seeps at the West stockpile, pH was reported to average 2.0 and 3.3, respectively (Daniel B. Stephens & Associates, 1999, p. 57). Although concentrations of metals in these seeps were not reported, measurements of acidic seeps at waste rock piles at the nearby Tyrone Mine with similar acid-generating sulfide minerals revealed elevated concentrations of copper, manganese, and zinc (Table 7 in Harlan & Associates, 2001). Seep LB-2401, located at the northeast corner of the main Lampbright stockpile at Chino, had concentrations of 1.17 mg/L copper and 1.11 mg/L cadmium in May 1995 (M3, 2001, p. 3-4; Table A-9 in Golder Associates, 1999).

Mine process facilities and associated infrastructure

Releases of hazardous substances from mine process facilities and associated infrastructure have been multiple and at times continuous, most likely beginning with the start of leaching operations in 1936 (M3, 2001, p. 2-2). and extending to the present. Mine process facilities have included the Ivanhoe concentrator, the precipitation plant, and the SX/EW plant. Associated with the mine process facilities are uncovered collection ponds for the PLS, a system of pipes for pumping PLS, reservoirs, and stormwater impoundments. These uncovered ponds serve as ongoing sources of hazardous substances to wildlife that may come into contact with the ponds (Figure 2.9).

Figure 2.9. PLS entering uncovered pond at the Lampbright stockpile at the Chino Mine.

Highly acidic water (pH < 3 was measured in nine different PLS ponds, reservoirs, and stormwater impoundments at the Chino Mine (Table 2.7). Information on concentrations of hazardous substances in these ponds was not available for review for this preassessment screen. Based on similarities in mineral composition and processing methods between the Chino and Tyrone mines, however, the Trustees believe that PLS ponds and other reservoirs and impoundments at the Chino Mine with low pH water (Table 2.7) also contain elevated concentrations of metals. Elevated metal concentrations in low pH water are likely because low pH water can be produced when water contacts oxidized sulfide minerals. The Chino Mine ore bodies contain generally similar sulfidic ores to the ores found at the Phelps Dodge Tyrone Mine in southwestern New Mexico, including chalcopyrite and chalcocite (SARB, 1999; Verburg et al., 1999). Leaching procedures and processing of the leachate at an SX/EW plant are similar at both mines. Analyses of PLS and seepage collection ponds at the Tyrone Mine have found elevated concentrations of hazardous substances in combination with low pH (Table 2.8).

Table 2.7. Measured pH of process water ponds and stormwater impoundments at the Chino Mine on September 15, 2000

Location	pH
Pond 6E — small stormwater basin near Tailings Pond 6E	2.8
Reservoir 4A on Whitewater Creek	2.7
Lampbright PLS ponds (four separate ponds)	1.9, 1.9, 2.8, 2.1
Reservoir #8 at the Lampbright stockpile	1.9
Pond at top of Lampbright Draw	2.1
Small pond on Lampbright Draw	2.5

Source: Field pH measurements, USFWS unpublished data, September 15, 2000.

Table 2.8. Concentrations of hazardous substances measured in uncovered process solution ponds at the Tyrone Mine, southwest of Silver City, New Mexico (mg/L)

Location	pH	As	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
1A PLS pond[a]	2.46	0.11	1.62	4.5	0.14	502	309	2.98	0.07	280
Gettysburg PLS pond[a]	2.6	0.11	2.24	3.84	0.21	264	269	1.4	No data	220
#2 Leach dump pregnant solution[a]	1.93	0.55	16.98	23.45	0.72	1,615	1,315	11.4	2.46	2,093
5E pond, installed as part of corrective action[b]	3.7	< 0.005	0.203	0.93	< 0.01	414	32.7	0.31	0.07	20.7

a. Source: Table 4-1 in SARB, 2000. Averages calculated from approximately 9 samples at the 1A PLS pond, 7 samples at the Gettysburg PLS pond, and 10 samples at the #2 leach dump.
b. Source: Brunner, 2002.

Plant releases and upsets from the precipitation and SX/EW plants and associated infrastructure have resulted in intermittent releases of hazardous substances into the environment, including spills of raffinate, sulfuric acid, and stockpile runoff (Table 2.9). Table 2.9 gives a chronology of spills and releases at the Chino Mine from 1990 to 1999 associated with the SX/EW plant and infrastructure.

Table 2.9. Plant spills and releases at Chino Mine from 1990 to 1999 associated with mine process facilities and related infrastructure

Date	Description of spill or release
March 1990	270,000 gallons of sulfuric acid waste spilled into Hanover Creek
November 1990	1,440 gallons of raffinate released into Whitewater Creek
May 1992	1,110 gallons of concentrated sulfuric acid spilled from an SX/EW pond
August 1994	Detection of a sump pump leak, allowing raffinate (low pH, high copper concentration), to escape periodically into groundwater
August 1999	72,000 gallons of stockpile runoff (pH 3.5) entered Buckhorn Gulch 35,000 gallons of raffinate spilled on Phelps-Dodge property

Source: IRC, 2001.

The Existing Data Report for the Chino Mine Tailings Ponds states that “prior to 1985, ephemeral surface-water flows in Whitewater Creek often carried highly contaminated stormwater overflow from the Precipitation Plant many miles downstream . . .” (Daniel B. Stephens & Associates, 1996, p. 5-9). Additional overflows from the Precipitation Plant reservoir occurred on October 9 and 10, 1985; May 6, 1986; and October 6, 1986 (NMEID, 1986, as cited in Daniel B. Stephens & Associates, 1996, p. 2-14). Other spills and releases are likely to have occurred before and after this time period.

Hurley smelter

The Hurley smelter was constructed in 1939 by the Kennecott Copper Corporation (Huggard, 1994). The smelter has most likely been a source of hazardous substances at the site from the beginning of its operation. Concentrations of copper in soil are most elevated near the smelter and decrease with increasing distance from the smelter (see Figure 3.8 in this report), a pattern consistent with aerial deposition of hazardous substances. Higher concentrations of cadmium, copper, lead, and zinc in soils exposed to aerial deposition compared to soils protected from aerial deposition also confirm aerial deposition of hazardous substances at the Chino Mine (see Table 3.3 in this report). In 1982, the smelter met standards for 90% reduction in sulfur dioxide and particulate emissions (Huggard, 1994), which means that most likely the quantity of hazardous substances released from the smelter has been reduced.

Slag is generated during the smelting process. Briefly, the smelting process involves heating metal-sulfide concentrates with silica flux to the melting point to form two liquid phases: matte and slag. Matte contains the separated metals and other constituents partition into the slag. Slag was separated and placed on the slag stockpile, on the north side of Lake One (Daniel B. Stephens & Associates, 1999, pp. 17-20). Slag piles and the smelter cover 195 acres (NMED, 2001). Toxicity characteristic leaching procedure (TCLP) testing of slag found detectable concentrations in leachate of the hazardous substances silver, cadmium, and copper, with concentrations of copper in the leachate ranging from 1.35 to 3.36 mg/L, which exceed NMWQCC standards for domestic water supply. Synthetic precipitation leaching procedure (SPLP) testing found detectable concentrations in leachate of silver, cadmium, chromium, copper, manganese, nickel, and zinc, but no concentrations exceeded regulatory criteria (Table 5 in Daniel B. Stephens & Associates, 1999). TCLP testing extracts material using an acetic acid buffer solution, while SPLP testing uses a nitric and sulfuric acid solution (U.S. EPA, 1992, 1994a).

Ivanhoe concentrator

The Ivanhoe concentrator and associated pipelines are located within the Whitewater Creek drainage basin. Hazardous substances have been released to surface water, soils, and sediments from tailings pipeline spills, including the hazardous substances arsenic, cadmium, chromium, copper, mercury, manganese, nickel, lead, selenium, and zinc contained in Chino Mine tailings (Table 2.2) (M3, 2001, pp. 3-19 to 3-21).

2.4.3 Time, quantity, duration, and frequency of releases

At the Chino Mine tailings ponds, the Trustees believe it is likely that releases of hazardous substances have occurred at each tailings impoundment, beginning roughly at the time when it stopped receiving new tailings and began to oxidize. Tailings Pond No. 2, which became inactive in 1944, was the first tailings impoundment to become inactive. Ponded water in contact with oxidized tailings and spills of tailings have served as ongoing sources of releases from the tailings ponds. A spill of 3.25 million gallons of tailings into Whitewater Creek in 1999 is one measure of the quantity of releases. The frequency of releases from ponded water depends on the time period when the ponded water is present, which is a function of precipitation and evaporation. Inspections and remote sensing imagery from different times of the year, including April (before the monsoon season) and October (during the monsoon season), have documented persistence of ponded water (Landsat7, 2000; USFWS site visit notes). In addition, surface runoff and erosion of tailings, and wind erosion of dry tailings, occur repeatedly throughout the year. Releases of hazardous substances from surface erosion of tailings and ponding of water on oxidized surfaces have been reduced or eliminated by the capping of tailings ponds with native soils. Ponds 2, B, and 4 were capped by 1995, and Ponds C, 6E, and 6W were capped by 2001 (M3, 2001, pp. C-3 to C-9).

At the waste rock and leach stockpiles, releases of hazardous substances are likely to have occurred from 1910, when mining began (M3, 2001, p. 2-2), to the present. A spill of 72,000 gallons of stockpile runoff (pH 3.5) into Buckhorn Gulch in 1999 is an example of quantity of releases. Erosion of rock, storm-water runoff, and windblown emissions are likely sources of releases as well. Releases of hazardous substances have been ongoing in the areas of the waste rock and leach stockpiles.

At mine process facilities and associated infrastructure, releases of hazardous substances are likely to have occurred from 1936 to the present, which is the time period of active leaching. Uncovered ponds provide ongoing sources of hazardous substance releases to biota that come into contact with the ponds (Figure 2.7). In addition, periodic spills and releases have resulted in releases of hazardous substances from these facilities (Table 2.9).

In summary, existing reports and observations at the Chino Mine have identified sources of hazardous substances, pathways by which hazardous substances are released and transported to expose other natural resources, continual physical processes of release of hazardous substances, and elevated concentrations of hazardous substances in groundwater, surface water, and in standing water at tailings ponds and associated lakes. Together, these observations confirm that hazardous substance releases from the Chino Mine facilities have been multiple and at times continuous, and most likely extend from the beginning of mining in 1910 to the present.

2.5 Relevant Operations Occurring at or near the Mine

Relevant operations occurring at or near the mine include activities such as an ecological risk assessment undertaken pursuant to an AOC signed by the CMC and the NMED. The Trustees are not aware of any response actions that have been undertaken under the AOC. The Chino Mine and the Hurley smelter have been closed temporarily since January 2002. Leaching of stockpiles and operation of the SX/EW plant are ongoing activities. The CMC also continues to actively dewater the open pit.

The CMC maintains groundwater discharge permits with the NMED Ground Water Quality Bureau (Table 2.10). These permits require ongoing monitoring and corrective action when spills occur or impacts to groundwater are observed. The CMC has reportedly told the USFWS that it drains low-pH stormwater ponds (Russ MacRae, USFWS, personal communication, May 6, 2003). No hazing activities are known to take place at the Chino Mine.

Table 2.10. Summary of discharge permits held by the Chino Mines Company. Permitted effluent describes the volume and type of material covered by the discharge permit. The permits do not authorize the release of these materials in exceedence of surface water or groundwater standards.

Discharge permit	Location and facilities[a]	Permitted effluent: Type	Permitted effluent: Volume (gpd)
DP-376	Lampbright stockpiles (covering approximately 830 acres) and Reservoir 8	Pregnant leach solution	26.5 million
DP-591	SX/EW plant and Reservoirs 6 (approximately 93 million gallons) and 7 (approximately 82 million gallons)	Acidic leach solution	23.0 million
DP-459	North pit leach stockpiles, north, northwest, and northeast waste rock stockpiles, Reservoir 5, and Santa Rita pit	All discharges	6.48 million
DP-493	Reservoir 3A (unlined, with a capacity of 1.2 billion gallons)	Mine water and stormwater	10.0 million
DP-526	A large part of the Chino Mine that lies west and southwest of the Santa Rita pit including the Whitewater stockpiles, process water Reservoirs 2 and 4A, stormwater and seepage control Reservoirs 10 and 7, the former precipitation plant area, ore processing facilities, the Santa Rita Class D landfill, and Whitewater Creek between the Ivanhoe concentrator and Lake One	Acidic leach solution	24.5 million
DP-213	Ivanhoe concentrator and associated pipelines	Tailings slurry	24.5 million
		Copper concentrate	237,600
		Domestic wastewater	3,200
DP-214	The Hurley smelter, Lake One (approximately 220 acres), Axiflo Lake (approximately 90 acres), the older tailings ponds (covering a total of about 1,920 acres), and Whitewater Creek from Lake One to its confluence with San Vicente Arroyo approximately 12 miles south of Hurley	Emergency flow to Ponds 4, 6E and 6W	—
		Decanted flows from Pond 7	8.7 million
		Makeup water from interceptor wells to Axiflo Lake	5 million
		Axiflo Lake to 230 foot diameter tank clarifier	13.4 million

Table 2.10. Summary of discharge permits held by the Chino Mines Company. Permitted effluent describes the volume and type of material covered by the discharge permit. The permits do not authorize the release of these materials in exceedence of surface water or groundwater standards.

Discharge permit	Location and facilities[a]	Permitted effluent: Type	Permitted effluent: Volume (gpd)
DP-484	Tailings Pond 7 (approximately 1,563 acres) and the 1988 Whitewater Creek diversion channel (located along the eastern perimeter of Tailings Pond 7	Tailings slurry from concentrator	24.5 million
		Sewage effluent from Tri-City	1 million
		Sewage effluent from North Hurley	9,900
		Treated mine water during heavy rainfall	1.4 million
DP-1340[a]	Open pit, Hurley smelter, tailings impoundments, waste rock piles, leach ore stockpiles, and associated facilities at the Chino Mines facility	— [b]	— [b]

a. Supplemental discharge permit for closure, proposed as of December 21, 2001.
b. Permit requires management of discharge in accordance with the current Operational Discharge Permits (DP-376, -591, -459, -493, -526, -213, -214, and -484).

Source: M3, 2001, pp. 2-29 to 2-38 and Table 2-4.

2.6 Damages Excluded from Liability

The Trustees currently are not aware of any natural resource damages that would be excluded from liability under CERCLA. Based on the available information, none of the conditions for exclusion from CERCLA liability apply [43 CFR § 11.24(b)]. Specifically:

1. **The damages resulting from the releases have not been specifically identified as an irreversible and irretrievable commitment of natural resources in an environmental impact statement or other comparable environmental analysis, no decisions were undertaken by the State to grant permits or licenses authorizing such commitments of natural resources, and PRP facilities were not otherwise operating within the terms of such permits or licenses.** Although the Chino Mine operates under a number of permits, the Trustees are currently unaware of any terms of such permits or licenses that would authorize injuries to natural resources such as birds, wildlife, surface water, and groundwater and resulting damages. In addition, permits do not allow for the spills and uncontrolled releases that have occurred at the site.

2. **Damages and the releases of hazardous substances from which such damages resulted have not occurred wholly before enactment of CERCLA.** Information reviewed for this preassessment screen indicates that releases of hazardous substances, natural resource injuries, and associated damages have occurred since 1980 and continue through to the present.

3. **Damages have not resulted from the application of a pesticide product registered under the Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. §§ 135-135k.** This criterion does not apply to releases from the Chino Mine, which do not involve applications of a pesticide product.

4. **Damages have not resulted from any other federally permitted release, as defined in §§ 101(10) of CERCLA.** Although the Chino Mine operates under a number of permits, including groundwater discharge permits issued by the NMED, the Trustees are currently unaware of any terms of such permits or licenses that would authorize injuries to natural resources such as birds, wildlife, surface water, and groundwater and resulting damages. In addition, permits do not allow for the spills and uncontrolled releases that have occurred at the site.

3. Preliminary Identification of Resources at Risk [43 CFR § 11.25]

3.1 Preliminary Pathway Identification [43 CFR § 11.25(a)]

As described in Chapter 2, actual or potential sources of hazardous substance releases to the assessment area include inactive and uncovered tailings impoundments; waste rock and leach stockpiles; mine process facilities and associated infrastructure, including uncovered ponds and pipelines; the Ivanhoe concentrator; and plant releases and spills. Hazardous substances deposited on upland soils and on sediments in ephemeral waterways also can serve as sources of releases when the substances are mobilized and transported. Exposure pathways that may transport hazardous substances released from sources to other natural resources include direct contact of biota with hazardous substances, surface water and sediments, groundwater, aerial transport, soil, and food chain. Figure 3.1 depicts potential pathway relationships between sources, pathways (direct contact, aerial transport, soil, and food chain), and Trustee resources. Figure 3.2 depicts a conceptual wildlife food web for terrestrial resources at the Chino Mine developed on behalf of the NMED as part of the ecological risk assessment. Pathways of hazardous substance transport at the Chino Mine are described briefly in the sections below.

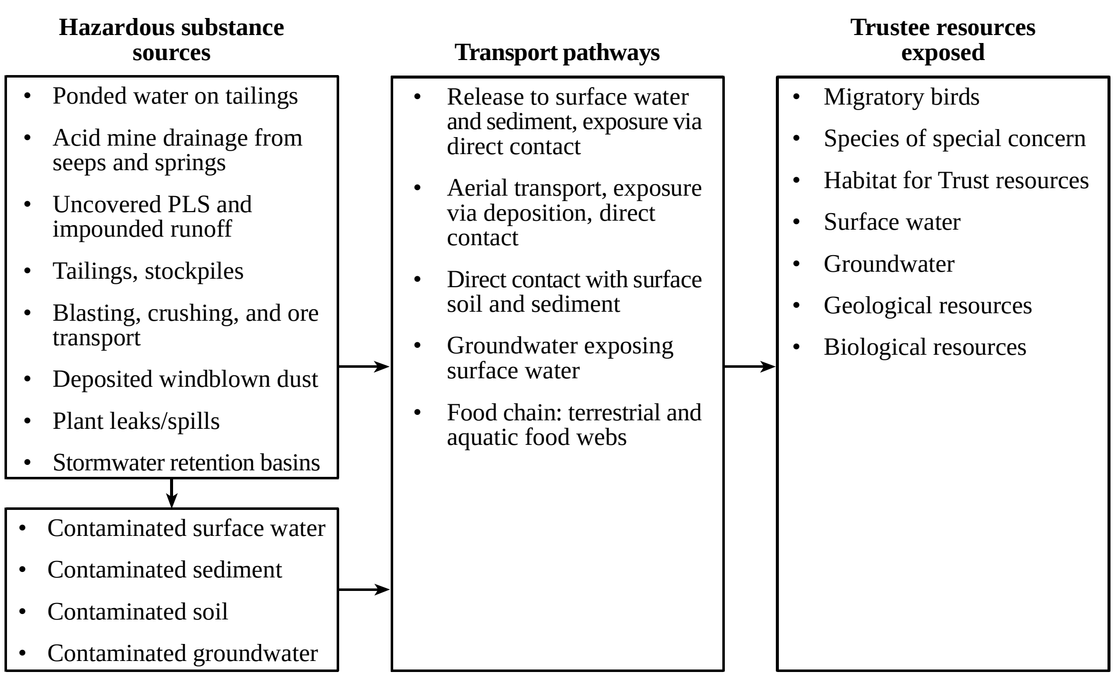

Figure 3.1. Potential hazardous substance transport pathways at the Chino Mine.

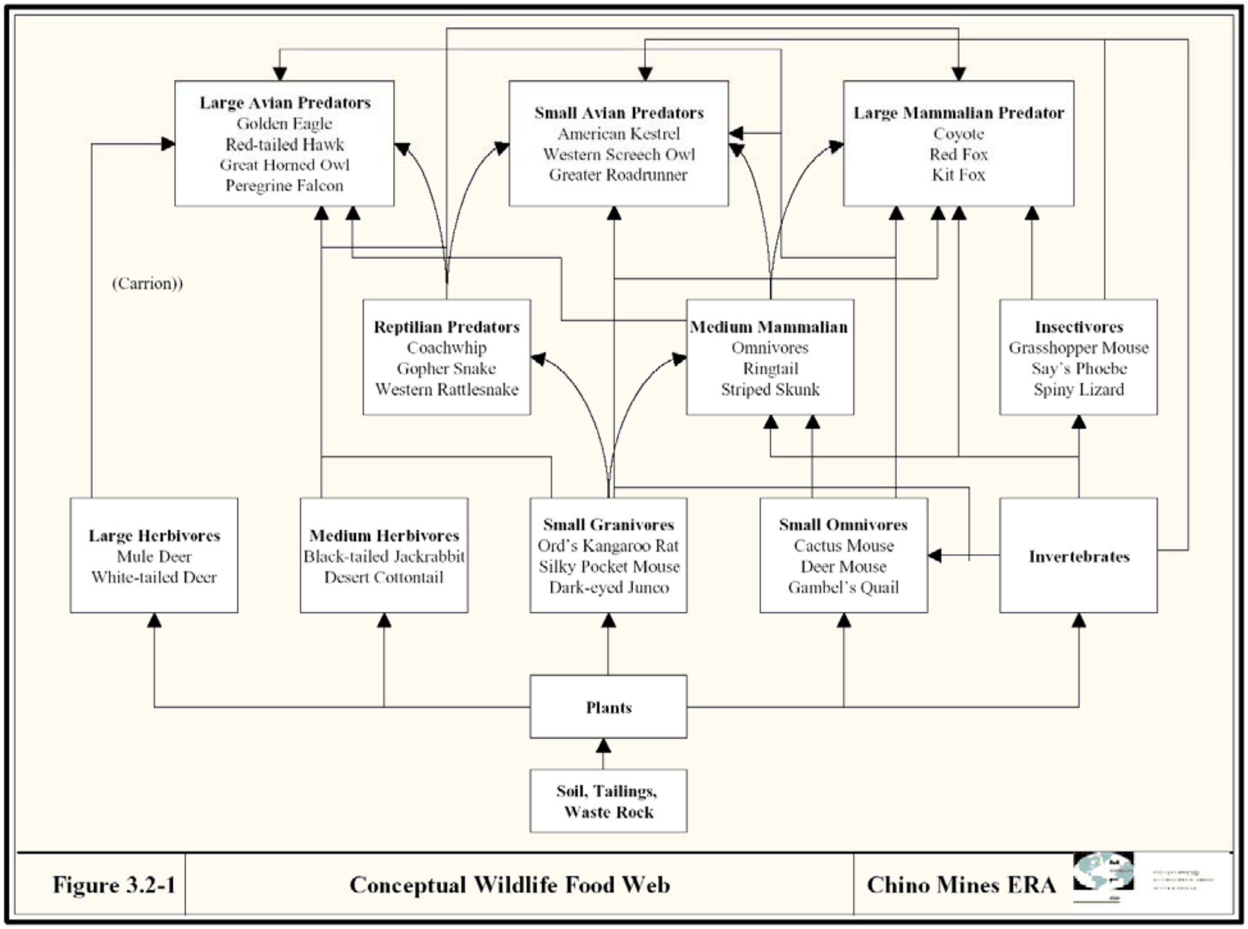

Figure 3.2. Potential foodchain pathways of hazardous substances at the Chino Mine.

Source: Chino Mines Ecological Risk Assessment (MFG, 2002).

3.1.1 Direct contact of biota with hazardous substances

Terrestrial biota may come in direct contact with hazardous substances through dermal, inhalation, and ingestion exposure from the 2,000 acres of leach stockpiles and waste rock stockpiles, the 1,700 acres of uncovered tailings, and the 1,500 acre open pit (as of 1998) at the Chino Mine (Tables 2.1 and 2.5 of this report) (M3, 2001, p. 2-22). Spills and releases of tailings, mine process waters, and hazardous substances provide additional points of direct contact of biota with hazardous substances (Tables 2.4 and 2.9 of this report).

Figure 3.3. Dead ring-billed gull found at Lake One in September 2000.

As precipitation ponds on the surface of the tailings impoundments and interacts with upper oxidized tailings, the water will have increasingly elevated metal concentrations and decreasing pH (Table 2.3 of this report). Uncovered process water ponds (especially PLS ponds), reservoirs, and stormwater impoundments can also serve as sources of hazardous substances that can be contacted directly by biota (Figure 2.9 of this report). Several sources of information suggest that wildlife are exposed to hazardous substances from ponded water on the Chino tailings impoundments, associated reservoirs, and uncovered process water and stormwater ponds. The Closeout/Closure plan for the Chino Mine noted that in 1996 and 1997 ecological surveys "some species were documented as using disturbed areas of the mine (i.e., Santa Rita Pit and tailings ponds)" (M3, 2001, p. 2-19). In September 2000, a dead mallard was found at Axiflo Lake and a dead ring-billed gull was found at Lake One (unpublished USFWS data) (Figure 3.3). Bird mortalities also have been documented at ponded water formed on the surface of uncovered tailings impoundments and at PLS ponds at nearby Phelps-Dodge mines (Tyrone in New Mexico and Morenci in Arizona). The Trustees are unaware of any hazing activities to reduce exposure of wildlife to hazardous substances at the Chino Mine.

3.1.2 Surface water/sediment pathway

Surface water and associated sediments are exposed to hazardous substances released from the Chino Mine through a variety of pathways, including leaks and spills of process water; tailings spills; dryfall from smelter emissions; windblown materials, runoff, and infiltration or percolation from tailings and waste stockpiles; and erosional transport of hazardous substances from upland soils into drainages (MFG, 2002, pp. 117-118). The three major drainages at Chino, Whitewater Creek, Hanover Creek, and Lampbright Draw, are ephemeral streams that flow in response to rainfall or snowmelt, and typically have peak discharges associated with summer monsoonal storms (M3, 2001, p. 2-11; MFG, 2002, p. 115). Temporary surface water pools within drainages can persist for several weeks. Persistent aquatic habitat at Chino includes natural seeps and springs, some of which occur near the West stockpile; persistent pools in Bayard Canyon, Bolton Draw, and in different locations along Lampbright Draw; and stock tanks that have been constructed along Lampbright Draw and in Martin Canyon (MFG, 2002, pp. 113-115).

Whitewater Creek has been repeatedly exposed to hazardous substances. The Existing Data Report for the Chino Mine Tailings Ponds states that “from the 1930s to 1985 upper Whitewater Creek stream bed alluvium and the underlying shallow alluvial aquifer repeatedly received inputs of acid leach stockpile water. During this time period, the stream bed sediments as well as the underlying shallow alluvial aquifer became contaminated” (Daniel B. Stephens & Associates, 1996, p. 5-11). The report also noted that “prior to 1985, ephemeral surface-water flows in Whitewater Creek often carried highly contaminated stormwater overflow from the Precipitation Plant many miles downstream before this water completely infiltrated into the Whitewater Creek floodplain alluvium” (Daniel B. Stephens & Associates, 1996, p. 5-9).

Enlargement of the Precipitation Plant reservoir was completed in August 1985 to prevent overflows of leachate solution into Whitewater Creek. Above-average precipitation, however, caused the new reservoir to overflow and discharge waters to Whitewater Creek on October 9 and 10, 1985; May 6, 1986; and October 6, 1986. Corrective measures, including enlarging reservoirs and improving storm runoff diversion, were undertaken at least until March 1989.

In 1988, heavy rains led to the release of 180 million gallons of acidic wastewater into Whitewater Creek over a 35 day period beginning August 20 (McClellan, 1989). Analyses of the wastewater indicated that it had 30 times the allowed levels of the hazardous substance cadmium, as well as more than 30 times the allowed levels of sulfates (McClellan, 1989).

Whitewater Creek below Lake One also has been exposed to hazardous substances. Before 1984, when Whitewater Creek was diverted eastward around Lake One, overflow from the Precipitation Plant that resulted in leachate flowing into Whitewater Creek “was at times sufficient to flood Lake One and overtop the Lake One dam into the lower Whitewater Creek diversion channel” (CMC, 1981, as cited in Daniel B. Stephens & Associates, 1996, p. 2-14). Lake One also discharged into James Canyon, before a dam was constructed across the entrance of James Canyon sometime between 1983 and 1991 (Daniel B. Stephens & Associates, 1996, p. 2-4). Although the Trustees are not aware of surface water quality data for Lake One and Lower Whitewater Creek from before 1984, several lines of evidence suggest that hazardous substances were released. First, Lake One was described as “largely filled with tailing” by 1981 (Daniel B. Stephens & Associates, 1996, p. 2-5), suggesting that any overflow from Lake One would contain the hazardous substances found in Chino Mine tailings, including arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, and zinc (Table 2.2 of this report). In fact, a study was conducted in 1981 to determine the feasibility of processing tailings in Lake One, where selected tailings materials averaged copper concentrations of 2.8% (Daniel B. Stephens & Associates, 1996, p. 2-32).

Whitewater Creek has been further exposed to hazardous substances through repeated spills of tailings, which contain hazardous substances, including arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, and zinc (Tables 2.2 and 2.4 of this report). For example, in 1999, 3.25 million gallons of tailings spilled into Whitewater Creek (IRC, 2001). In December 2000, the NMED fined the Chino Mines Company $50,400 for a 93,000 gallon spill of process water and tailings slurry that entered Whitewater Creek in violation of the State Water Quality Act (Anonymous, 2001).

According to the Closure/Closeout plan, some locations in Lampbright Draw have been exposed to hazardous substances where seeps with impacted water emerge. For example, seep LB-2401, located at the northeast corner of the main Lampbright stockpile, had concentrations of 1.17 mg/L copper and 1.11 mg/L cadmium in May 1995, which both exceed NMWQCC standards for irrigation and livestock watering (NMAC 20.6.4) (Table A-9 in Golder Associates, 1999; M3, 2001, p. 3-4).

Concentrations of the hazardous substances cadmium, cobalt, copper, lead, and zinc exceeding NMWQCC metal standards for livestock/watering use in surface water samples at Whitewater Creek provide additional evidence that surface water has been exposed to hazardous substances (Table 3.1). Also, the ecological risk assessment reported elevated concentrations of the hazardous substances copper and zinc in surface water samples from five different drainages at the Chino Mine, including Hanover/Whitewater Creek, Bayard Canyon, Bolton Draw, the unnamed drainage between Bolton Draw and Lampbright Draw, and Lampbright Draw (Figures 3.4 and 3.5). In addition, cadmium, lead, and nickel were detected in a few sampling locations in Hanover/Whitewater Creek, Bolton Draw, and Lampbright Draw (Table 4.3-1 in MFG, 2002).

Table 3.1. Concentrations of dissolved hazardous substances in ephemeral surface water in Whitewater Creek

Location[a]	Hazardous substance	N	Concentration (mg/L) mean (maximum)	No. of samples exceeding NMWQCC standards[b]
Grunerud	Cadmium	25	0.032 (0.062)	1
B-Ranch		27	0.039 (0.086)	4
Hwy-180		4	0.019 (0.027)	0
B-Ranch	Chromium	27	0.004 (0.015)	0
Hwy-180		4	0.007 (0.019)	0
Grunerud	Cobalt	24	0.868 (1.44)	7
B-Ranch		26	1.24 (2.02)	21
Hwy-180		4	0.369 (0.458)	0
Grunerud	Copper	24	4.04 (8.24)	24
B-Ranch		27	6.17 (13.3)	25
Hwy-180		4	2.19 (2.76)	4

Table 3.1. Concentrations of dissolved hazardous substances in ephemeral surface water in Whitewater Creek (cont.)

Location[a]	Hazardous substance	N	Concentration (mg/L) mean (maximum)	No. of samples exceeding NMWQCC standards[b]
Grunerud	Lead	25	0.05 (0.228)	4
B-Ranch		27	0.051 (0.318)	3
Hwy-180		4	0.015 (0.021)	0
Grunerud	Zinc	25	13.2 (23.5)	0
B-Ranch		27	17.1 (43.4)	4
Hwy-180		4	7.04 (12.2)	0

a. Locations are presented upstream to downstream.
Grunerud = 1.5 miles north of Lake One.
B-Ranch = near inlet to Lake One.
Hwy-180 = near Highway 180 crossing, approximately 2 miles south of Pond No. 7.
b. Concentrations compared to NMWQCC standards for livestock/wildlife watering use.

Source: Appendix H and Table 3.9-4 of Daniel B. Stephens & Associates, 1996.

Terrestrial biota can be exposed to hazardous substances via the surface water/sediment pathway by ingestion and dermal absorption. Aquatic biota at Chino Mine, including aquatic invertebrates and amphibians, may be exposed to hazardous substances via the surface water/sediment pathway by ingestion and dermal absorption. Chiricahua leopard frogs, listed as a threatened species by the USFWS in June 2002, have historically been present in ephemeral drainages at the Chino Mine, including Lampbright Draw.

3.1.3 Groundwater pathway

Groundwater throughout the Chino Mine facility has been exposed to hazardous substances through a variety of pathways. The Comprehensive Groundwater Characterization Phase 3 Study confirmed 20 different mine source areas that have affected groundwater quality, including seepage from the Lampbright and Whitewater leach facilities, the SX/EW plant, reservoirs, the Ivanhoe concentrator, waste rock stockpiles, contaminated sediments and bank soil, Lake One, and inactive and active tailings impoundments (Table 3.2). Many of these source areas have exposed groundwater that flows toward the Santa Rita pit and is captured by pumping in the open pit. Potential source areas in the North Mine area at Chino are shown in Figure 3.6.

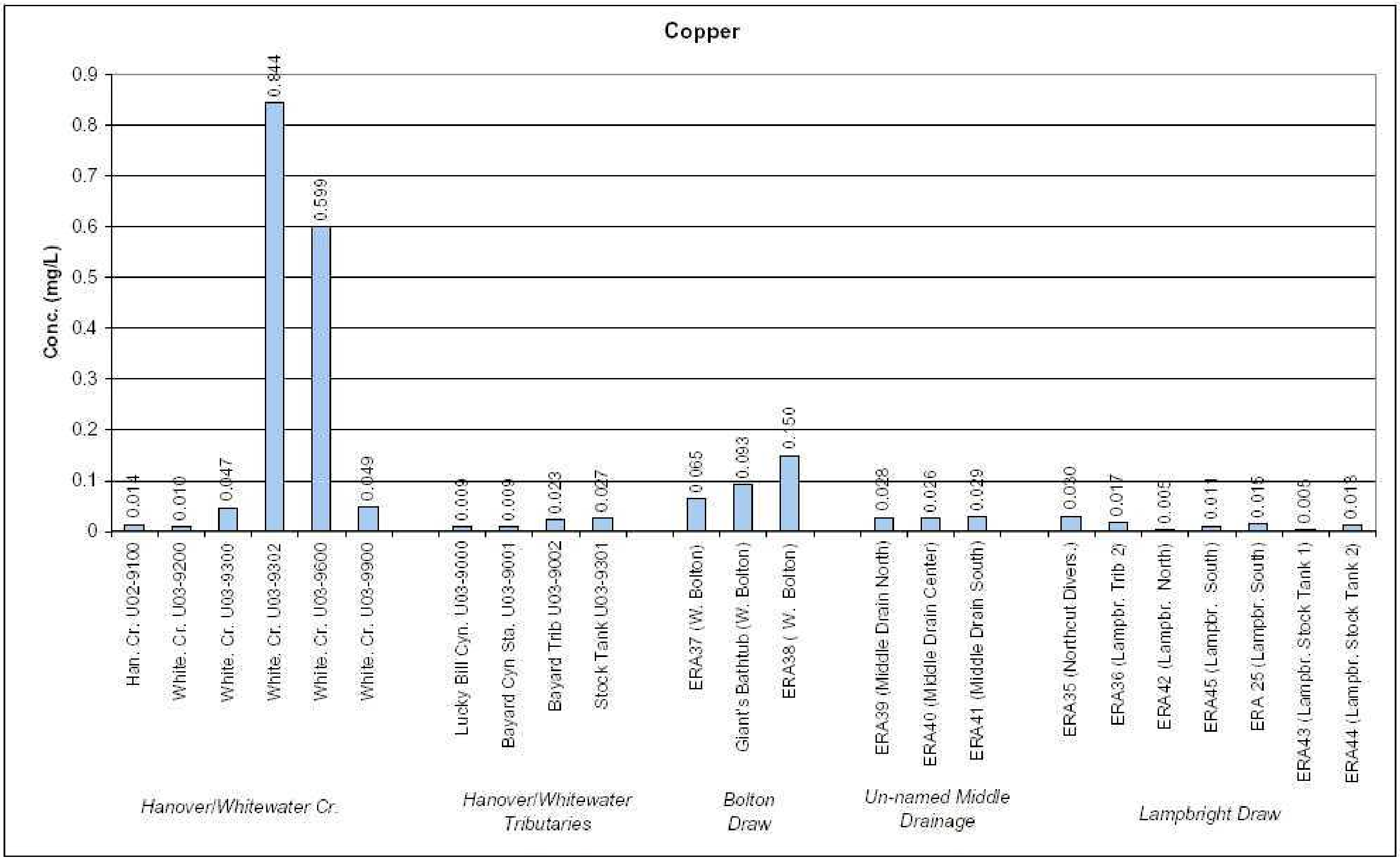

Figure 3.4. Copper concentrations in surface water at the Chino Mine.

Source: Figure 4.3-1 in MFG, 2002.

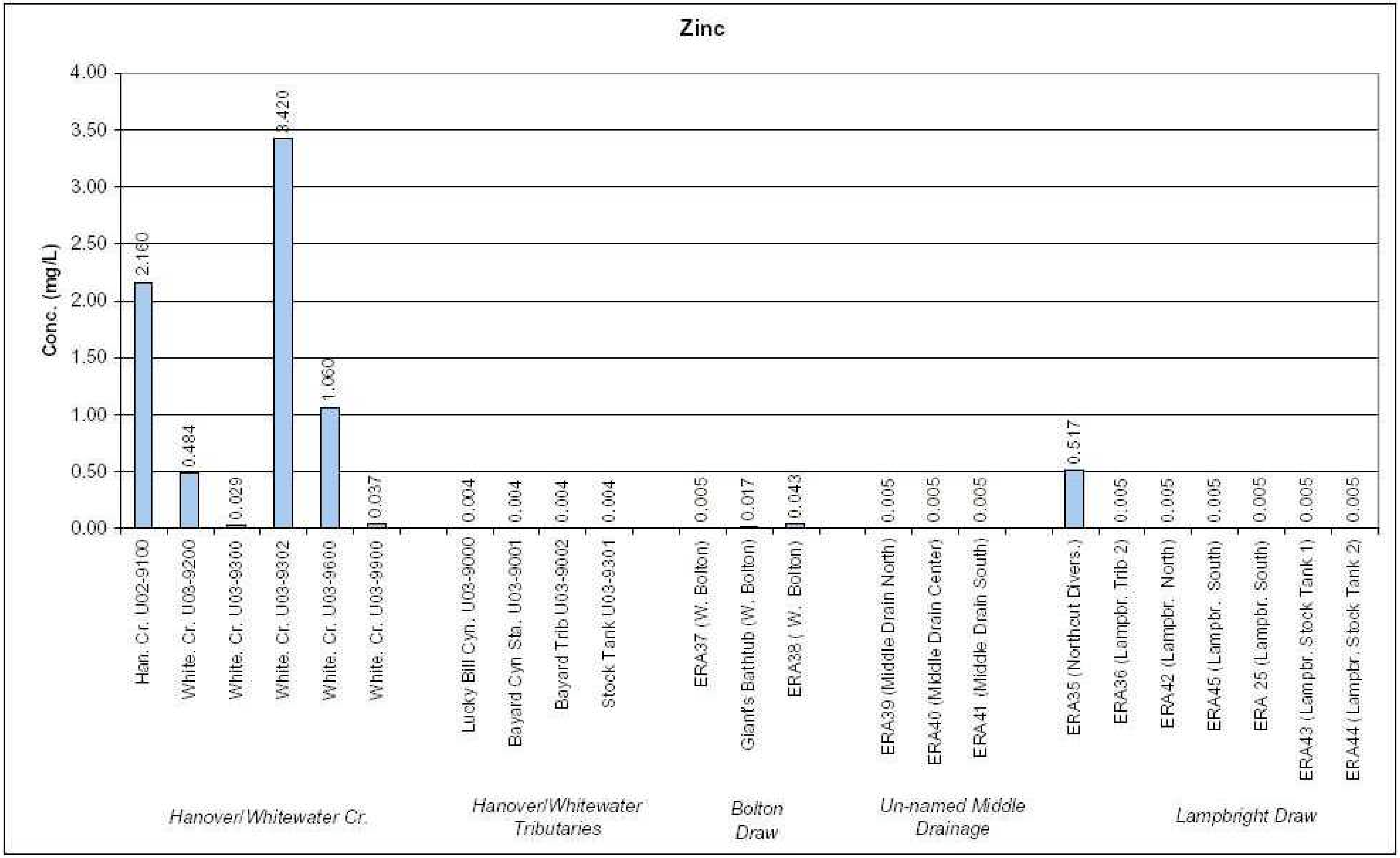

Figure 3.5. Zinc concentrations in surface water at the Chino Mine.

Source: Figure 4.3-1 in MFG, 2002.

Table 3.2. Summary of groundwater contamination source areas at the Chino Mine

Source area	Description[a]	Effects on groundwater[b]
Lampbright leach facility	At this source area, leach solution is applied to the surface of the stockpile and seeps through the material to the original ground surface of the drainage where it is collected for processing.	Elevated TDS, sulfate, and metals in an area south of the southeast Lampbright stockpile and north of the main Lampbright stockpile
Tributary 2	This source area consists of a drainage that extends southeast from the Lampbright leach facility. Sediments in this drainage may have been exposed to hazardous substances from stormwater runoff or processed water seepage.	Elevated TDS, sulfate, and metals in groundwater in the northern portion of the drainage and at seep LB-2401
SX/EW plant	This source area consists of the SX/EW plant and related infrastructure. In 1997, a lined raffinate pond that had leaked into groundwater was replaced with a stainless steel tank.	Elevated TDS, sulfate, and metals in groundwater to the east and southwest of the SX/EW plant
Reservoirs 6 and 7	These are located just west of the SX/EW plant, between the plant and the Santa Rita pit. They receive stormwater and process water during storm events.	Elevated TDS, sulfate, and metals in groundwater flowing to the southwest toward the Santa Rita pit
North pit leach facility	Source area includes a leach and non-leach stockpile located at the north end of the Santa Rita pit, a clay-lined PLS pond, and contaminated sediments in the southern portion of Reservoir 5.	Elevated TDS, sulfate, and metals in groundwater flowing to the west and southwest toward the Santa Rita pit
Santa Rita pit source area	Open pit and associated mining operations.	Elevated manganese in groundwater contained within the pit
Maintenance facilities	This source area is located west of the Santa Rita pit.	Elevated TDS, sulfate, metals, and benzene in groundwater flowing toward the Santa Rita pit
Ivanhoe concentrator	Source of groundwater contamination unclear. Groundwater quality has not changed substantially since the early 1980s.	Elevated TDS, sulfate, and metals

Table 3.2. Summary of groundwater contamination source areas at the Chino Mine (cont.)

Source area	Description[a]	Effects on groundwater[b]
Whitewater leach facility	Includes South stockpile, West stockpile, and former Precipitation Plant. Groundwater quality is improving to the northwest of the West stockpile, and deteriorating to the west and southwest of the stockpile, where it flows toward interceptor wells and Hanover Creek. Groundwater is also affected in the former Precipitation Plant area, where it flows toward interceptor wells and is captured by pumping of the Star Shaft.	Elevated TDS, sulfate, and metals
Reservoir 3A	This source area is located south of the Santa Rita pit and is a 1.2 billion gallon unlined mine water and stormwater reservoir. Groundwater to the northwest has been affected and flows toward the Santa Rita pit.	Elevated TDS, sulfate, and metals
Star Rock stockpile	Source area is located southwest of the Ivanhoe concentrator on Upper Whitewater Creek. Sampling indicates that the stockpile probably does not affect groundwater, but other sources have most likely affected groundwater in this area.	Elevated TDS, sulfate, and metals
CG Bell Rock stockpile	Source area is located southwest of the Ivanhoe concentrator on Upper Whitewater Creek. Sampling indicates that leached metals could potentially affect groundwater. Groundwater flows to the southwest and may be partially intercepted by pumping of the Star Shaft.	Elevated TDS, sulfate, and metals
Osceola Rock stockpile	Source area is located southwest of the Ivanhoe concentrator on Upper Whitewater Creek. Sampling indicates that leached metals could potentially affect groundwater. Groundwater flows to the southwest.	Elevated TDS, sulfate, and metals
Hanover Creek sediments/bank soil	Chino and non-Chino mining operations may have affected creek sediments and bank soils between Highway 152 and the confluence at Whitewater Creek. Historically, contaminated surface water entered Hanover Creek and may have served as a pathway to groundwater.	Elevated TDS, sulfate, and metals
Upper Whitewater Creek sediments/bank soil	Source area is located between the Ivanhoe concentrator and the confluence with Hanover Creek. Mining processes appear to have affected sediments and bank soils, serving as a pathway to surface water and groundwater. Groundwater is affected and flows to the southwest toward a series of interceptor wells, and may be partially intercepted by pumping of the Star Shaft.	Elevated TDS, sulfate, and metals

Table 3.2. Summary of groundwater contamination source areas at the Chino Mine (cont.)

Source area	Description[a]	Effects on groundwater[b]
Middle Whitewater Creek sediments/bank soil	Source area is located south of the confluence with Hanover Creek and north of Lake One. Mining processes appear to have affected sediments and bank soils, serving as a pathway to surface water and groundwater. Privately owned small-scale precipitation plants may have contributed to contamination. Groundwater flows within alluvium to the southwest through Bayard and then south toward Lake One.	Elevated TDS, sulfate, and metals
Old tailings impoundments	Includes Axiflo Lake; Tailings Ponds: 1, 2, 4, 6, B, C; and the Hurley smelter Class D solid waste landfill. Groundwater immediately adjacent to Pond 6W and east of the source area has been affected.	Elevated TDS, sulfate, and metals
Lake One and James Canyon	Lake One was used a reservoir for process water for the former Hurley Concentrator. It became filled with sediment and tailings and use was discontinued in 1981. In 1984, Whitewater Creek was diverted eastward around Lake One. Affected groundwater has improved to the north, but remained unchanged to the south. Groundwater flows to the south.	Elevated TDS, sulfate, and metals
Pond No. 7 tailings impoundment	Groundwater has been affected to the east, west, and south, with concentrations increasing until 1995 and then remaining constant. Interceptor wells have been installed to the west and south.	Elevated TDS, sulfate, and metals
Lower Whitewater Creek sediment/bank soil	Located south of Pond No. 7 to the confluence with the San Vicente Arroyo. Surface water releases from upstream may have affected groundwater, sediments, and bank soil. Groundwater quality appears to have been affected along the axis of the creek.	Elevated TDS, sulfate

a. Source: Appendix C of Golder Associates, 1999.
b. Source: Table 4.1 in Golder Associates, 1999.

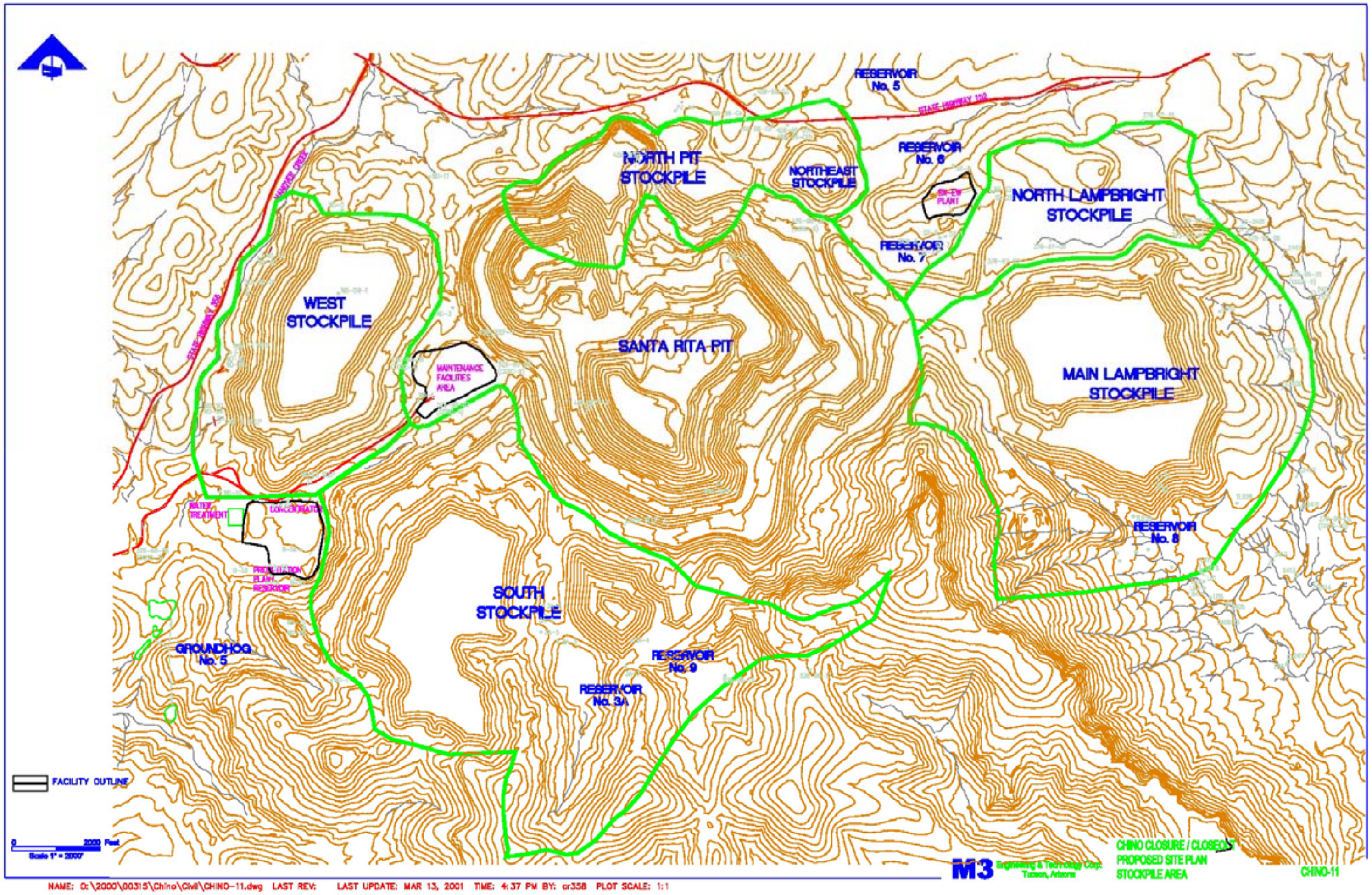

Figure 3.6. Potential groundwater source areas in the North Mine area of Chino Mine.

Source: M3, 2001, Drawing: Chino-11.

Elevated metal concentrations in groundwater, in combination with elevated sulfate concentrations and TDS have been measured in 18 of the 20 groundwater source areas (Table 3.2). Concentrations of hazardous substances in groundwater in exceedence of NMWQCC standards further confirm exposure of groundwater (Table 2.6 of this report). Contaminated groundwater from the northern portion of the mine is released to surface water via springs and seeps, and through discharge to canyon bottoms, Whitewater Creek alluvium, and Lampbright Draw alluvium (Golder Associates, 1999, p. 35). Contaminated groundwater in Whitewater Creek alluvium in the southern portion of the mine can discharge to surface water during streamflow events (Golder Associates, 1999, p. 49). Seep LB-2401, located at the northeast corner of the main Lampbright stockpile, has shown elevated concentrations of copper and cadmium (M3, 2001, p. 3-4; Golder Associates, 1999, Table A-9). Before 1984, copper concentrations exceeding 1 mg/L were detected in middle Whitewater Creek alluvium (Golder Associates, 1999, p. 51). Thus, surface water, aquatic resources, and terrestrial resources may be exposed to contaminants via this pathway of groundwater discharge.

3.1.4 Aerial transport pathway

Aerial transport of hazardous substances at the Chino Mine has exposed soils and sediments to hazardous materials. Aerial transport has occurred through deposition of emissions from the Hurley smelter, and from windblown materials from unvegetated waste rock, leach rock, and tailings piles. Redistribution of contaminated soils and sediments through wind erosion is another mechanism of aerial transport. Transport of contaminants via this pathway has most likely been reduced but not eliminated since the installation of emissions controls on the Hurley smelter in 1982 and the covering of several tailings ponds with soil between 1991 and 2001.

Soil samples collected for the ecological risk assessment confirm that soils and sediments have been exposed to hazardous substances through aerial transport. Specifically, surface soils (0-6 inches deep) were collected in the area of the Hurley smelter and the tailings piles from uncovered soils and from soils underneath boulders at least 1 foot in diameter. This sampling was designed to compare soils that had received aerial deposition (uncovered soils) from soils that had been protected from aerial deposition (covered soils). Results from these samples demonstrated that uncovered soils had substantially higher concentrations of the hazardous substances cadmium, copper, lead, and zinc, compared to covered soils that had been protected from deposition (Table 3.3). For example, cadmium was up to 4.8 times higher, copper was up to 17.9 times higher, lead was up to 2.1 times higher, and zinc was up to 1.5 times higher for an uncovered sample that received deposition versus a nearby protected sample.

Additional surface soil samples (0-6 inches below ground surface) collected for the ecological risk assessment confirm that study area upland soils had significantly elevated concentrations of hazardous substances compared to reference area upland soils. Sampling locations for the

Table 3.3. Comparison of hazardous substance concentrations in uncovered and covered soils in the vicinity of the Hurley smelter and Chino Mine tailings impoundments (mg/kg)

	Cadmium		Copper		Lead		Zinc	
Location	**Covered**	**Uncovered**	**Covered**	**Uncovered**	**Covered**	**Uncovered**	**Covered**	**Uncovered**
ERA01	0.7	2.6	1,190	5,280	28.2	55	77.7	113
ERA02	0.6	2.9	627	976	20.6	30.7	42.5	49.8
ERA04	0.2 nd	1.1	56	1,000	10.4	21.8	29.2	39.1
ERA09	0.2 nd	0.5	199	560	17.1	17.7	23.1	22.8
ERA10	0.2 nd	0.3	34	277	9.1	11.5	14.1	13.9
ERA15	0.4	1.1	310	1,090	16.1	23.7	43.3	55.9

Source: Table 2.2-1 in MFG, 2002.

ecological risk assessment are shown in Figure 3.7. Specifically, the hazardous substances chromium, cobalt, lead, mercury, thallium, and zinc were significantly elevated at one to three locations; cobalt and nickel were significantly elevated at five locations; cadmium and selenium were significantly elevated at most locations; and copper was significantly elevated at all locations (statistical comparisons presented in Arcadis, 2001 as cited in MFG, 2002, p. 25). In general, subsurface soil samples (6-12 inches below ground surface) had lower copper concentrations compared to surface soils, which provides additional evidence that hazardous substances in soils are the result of aerial deposition (MFG, 2002, p. 27).

The ecological risk assessment reported that concentrations of copper in surface soils decreased with increasing distance eastward from the Hurley smelter (Figure 3.8). This gradient analysis further suggests that aerial transport of emissions from the Hurley Smelter has exposed soils at the Chino Mine to hazardous substances.

In surface soils sampled from ephemeral drainages, the hazardous substances cobalt, copper, manganese, and mercury were elevated at one to three locations each, while cadmium, lead, selenium, and zinc were elevated at most locations, compared to reference area samples. Compared to upland locations, copper concentrations in subsurface soils were more similar to surface soils in ephemeral drainage samples (Figure 2.2-3 in MFG, 2002), suggesting that additional soil deposition may have taken place since tailings and smelter deposition, or that soils in ephemeral drainages are more highly mixed than in upland locations (MFG, 2002, p. 28).

Terrestrial biota, aquatic biota, and surface water resources at the Chino Mine may be exposed to hazardous substances that are transported through aerial deposition at the Chino Mine. These pathways are described more fully in the following section.

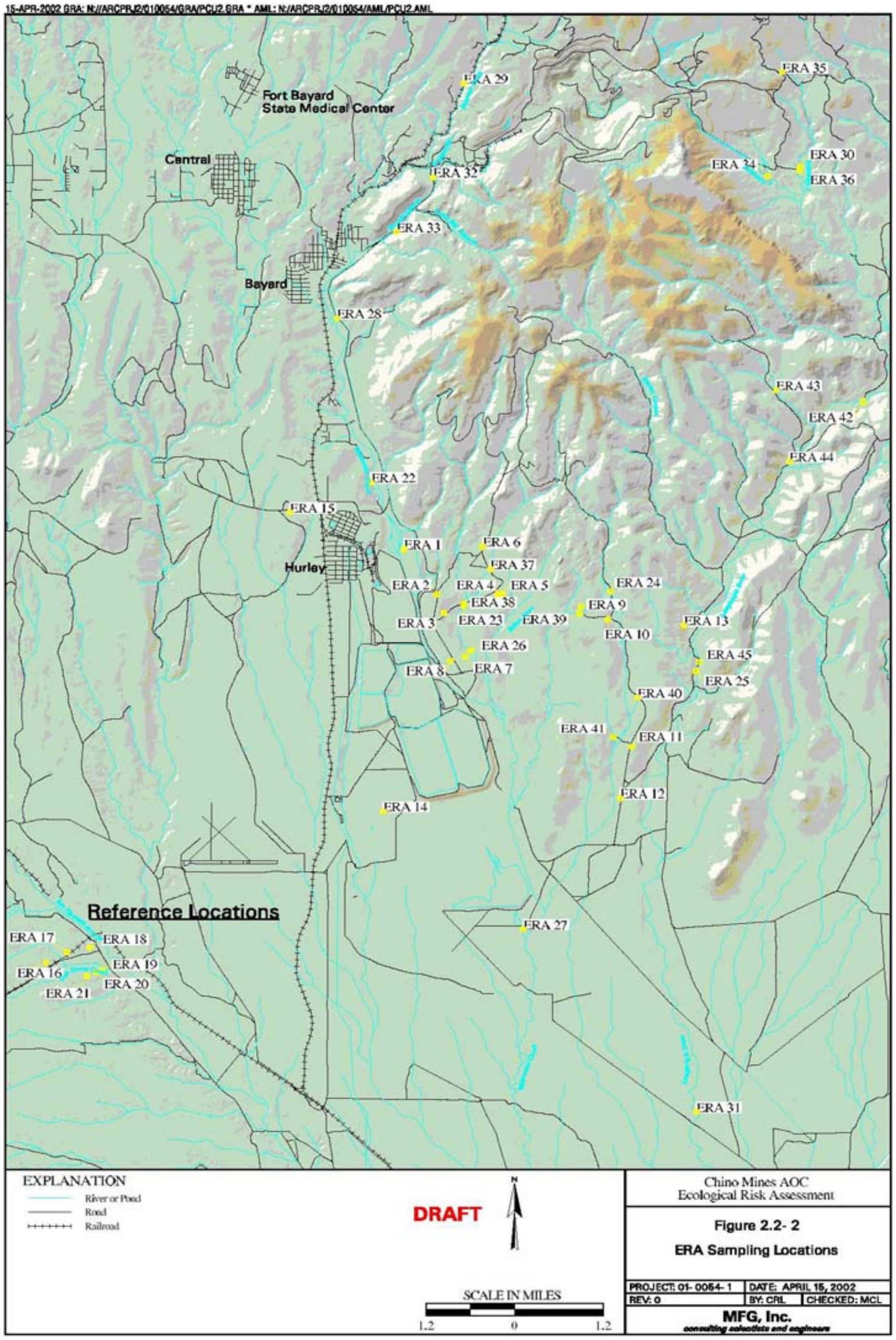

Figure 3.7. Sampling locations for ecological risk assessment.

Source: Figure 2.2-2 in MFG, 2002.

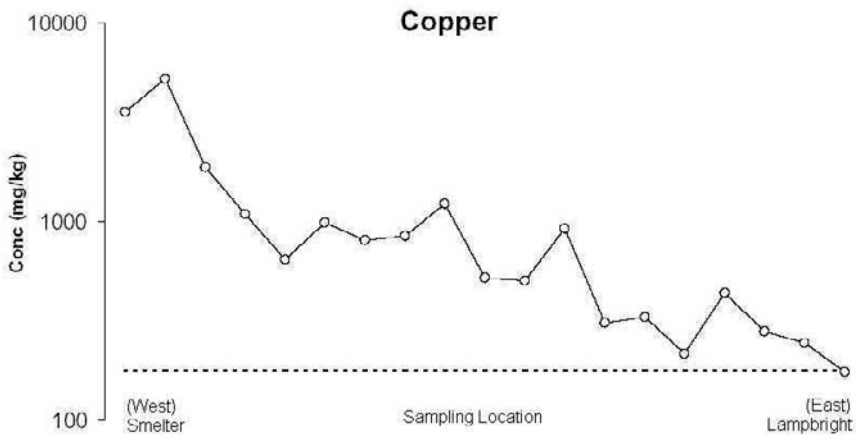

Figure 3.8. Copper concentrations in surface soils at locations from the Hurley smelter east to Lampbright Draw, a distance of approximately 5.5 miles. Note log scale for copper concentrations. Horizontal line indicates 95% upper confidence limit for mean of reference samples.

Source: Figure 2.2-5 in MFG, 2002.

3.1.5 Soil pathway

Soils that have been exposed to hazardous substances either through aerial transport or directly from plant spills and upsets can provide a pathway of exposure to terrestrial biota, aquatic biota, and surface water resources. Terrestrial vegetation may be exposed to hazardous substances in soil through root uptake. Terrestrial wildlife may be exposed to hazardous substances in soil through dermal contact, uptake, and ingestion.

Sampling conducted for the ecological risk assessment confirms that vegetation in uplands and ephemeral drainages have been exposed to hazardous substances. Seed and foliage tissue collected from upland sampling locations generally had higher mean and maximum concentrations of the hazardous substances cadmium, cobalt, copper, manganese, nickel, selenium, and zinc compared to upland reference sites (Tables 3.4 and 3.5). Seed and foliage tissue collected from ephemeral drainage sites had higher mean and maximum concentrations of the hazardous substances cadmium, cobalt, copper, lead, manganese, nickel, selenium, and zinc compared to upland reference sites (Tables 3.4 and 3.5).

Table 3.4. Hazardous substance concentrations in seed tissue for upland, ephemeral drainage, and reference areas at the Chino Mine. Values shown are mean concentrations, with maximum concentrations in parentheses.[a]

Location	Cadmium total (mg/kg)	Cobalt total (mg/kg)	Copper total (mg/kg)	Lead total (mg/kg)	Manganese total (mg/kg)	Nickel total (mg/kg)	Selenium total (mg/kg)	Zinc total (mg/kg)
Reference	0.0589 (0.12)	0.0822 (0.13)	8.77 (11.4)	1.6 (3.9)	65.8 (102)	0.982 (3.2)	0.0683 (0.17)	32.3 (49.5)
Upland	0.0652 (0.195)	0.239 (0.83)	25.7 (66.6)	5.5 (39.2)	36.9 (106)	3.99 (7.7)	0.477 (2)	32.1 (76)
Ephemeral drainage	0.401 (1.8)	0.264 (1.6)	24.2 (71.9)	5.36 (32)	73.8 (307)	2.5 (14.2)	0.132 (0.43)	81.3 (460)

a. Sample sizes were 18 for reference areas, 43 for uplands, and 39 for ephemeral drainage sites.

Source: Table 3.3-4 in MFG, 2002.

Table 3.5. Hazardous substance concentrations in foliage tissue for upland, ephemeral drainage, and reference areas at the Chino Mine. Values shown are mean concentrations, with maximum concentrations in parentheses.[a]

Location	Cadmium total (mg/kg)	Cobalt total (mg/kg)	Copper total (mg/kg)	Lead total (mg/kg)	Manganese total (mg/kg)	Nickel total (mg/kg)	Selenium total (mg/kg)	Zinc total (mg/kg)
Reference	0.096 (0.15)	0.172 (0.4)	7.77 (13.6)	1.86 (5.4)	48.9 (84.4)	0.769 (1.9)	0.06 (0.15)	21.4 (34.4)
Upland	0.137 (0.43)	0.282 (0.78)	65.2 (261)	1.51 (5)	66.4 (168)	2.71 (9.6)	0.482 (1.9)	56.1 (138)
Ephemeral drainage	0.512 (3.4)	0.583 (5.9)	39.8 (158)	6.23 (43.3)	89.6 (575)	2.31 (8.9)	0.161 (0.7)	127 (562)

a. Sample sizes were 18 for reference areas, 44 for uplands, and 39 for ephemeral drainage sites.

Source: Table 3.3-5 in MFG, 2002.

3.1.6 Food chain pathway

Food chain exposures occur when prey organisms accumulate hazardous substances in their tissues. Predators are subsequently exposed to these contaminants when they consume these prey. Studies have documented the uptake and subsequent terrestrial food chain movement of the hazardous substances copper and zinc (Beyer, 1990). The ecological risk assessment evaluated food chain exposures at the Chino Mine. Elevated concentrations of hazardous substances, including cobalt, copper, lead, manganese, and selenium, were measured in invertebrate, reptile, small mammal, and bird samples collected at the Chino Mine from upland and ephemeral drainage sites (Tables 3.6-3.9). For invertebrates and small mammals, mean and maximum concentrations of all five of the hazardous substances in Tables 3.6 and 3.8 were more elevated in the upland and ephemeral drainage sites than in the reference sites. For birds, the concentrations of all five of the hazardous substances in Table 3.9 were more elevated in the ephemeral drainage site than in the reference sites For reptiles, maximum concentrations of manganese were higher in the upland and ephemeral drainage sites compared to the reference sites (Table 3.7). A similar pattern was not observed for the other metals.

Table 3.6. Summary of invertebrate tissue sampling results for selected contaminants[a]

Location	n	Cobalt total (mg/kg)	Copper total (mg/kg)	Lead total (mg/kg)	Manganese total (mg/kg)	Selenium total (mg/kg)
Reference	6	0.252 (0.38)	39.6 (53.8)	0.18 (0.24)	6.62 (9.3)	0.09 (0.12)
Upland	15	0.319 (1.1)	62 (135)	0.281 (0.59)	10.1 (24.3)	0.279 (0.61)
Ephemeral drainage	12	0.298 (0.67)	35 (56.4)	0.772 (4.6)	20.2 (141)	0.146 (0.2)

a. Mean (maximum).

Source: Table 3.3-3 in MFG, 2002.

Table 3.7. Summary of reptile tissue sampling results for selected contaminants[a]

Location	n	Cobalt total (mg/kg)	Copper total (mg/kg)	Lead total (mg/kg)	Manganese total (mg/kg)	Selenium total (mg/kg)
Reference	2	0.2-0.34	1.9-39.4	0.19-1.2	1.4-2.6	0.18-0.69
Upland	3	0.11-0.25	2.7-7.1	0.07-0.24	0.39-3	0.2-0.57
Ephemeral drainage	2	0.27-0.37	1.5-5.1	0.17-0.66	2.4-25.2	0.17-0.34

a. Minimum-maximum.

Source: Table 3.3-8 in MFG, 2002.

Table 3.8. Summary of small mammal whole body tissue sampling results for selected contaminants[a]

Location	n	Cobalt total (mg/kg)	Copper total (mg/kg)	Lead total (mg/kg)	Manganese total (mg/kg)	Selenium total (mg/kg)
Reference	7	0.108 (0.195)	3.79 (5.78)	0.168 (1.45)	2.76 (4.29)	0.196 (0.268)
Upland	24	0.158 (0.311)	7.61 (72.6)	0.258 (1.66)	3.1 (17.4)	0.329 (0.896)
Ephemeral drainage	18	0.181 (0.361)	6.53 (13.6)	0.183 (3.04)	3.61 (7.22)	0.221 (0.567)

a. Median (maximum).

Source: Table 3.3-6 in MFG, 2002.

Table 3.9. Summary of bird tissue sampling results for selected contaminants[a]

Location	n	Cobalt total (mg/kg)	Copper total (mg/kg)	Lead total (mg/kg)	Manganese total (mg/kg)	Selenium total (mg/kg)
ERA18 — reference	5	0.05 (0.07)	3.38 (4)	0.122 (0.15)	2.02 (2.7)	0.276 (0.35)
ERA23 — ephemeral drainage	5	0.076 (0.11)	7.24 (11.6)	0.228 (0.32)	2.76 (3.7)	0.394 (0.51)

a. Mean (maximum).

Source: Table 3.3-7 in MFG, 2002.

3.2 Exposed Areas [43 CFR § 11.25(b)]

This section presents preliminary estimates of exposed areas based on a rapid review of readily available information. This section is not a comprehensive quantification of all exposed areas.

3.2.1 Primary exposure areas

Past and ongoing mining activities have resulted in a significant area that has been exposed directly to hazardous substances. These areas include, but are not limited to:

- seven inactive tailings impoundments and two associated lakes at the Chino Mine covering approximately 2,100 acres (Table 2.1 of this report)

- one active tailings impoundment and Axiflo Lake, covering approximately 1,654 acres (Table 2.1 of this report)

- seven mining waste rock stockpiles, covering approximately 341 acres (Table 2.5 of this report)
- four leach stockpiles, covering approximately 1,746 acres (Table 2.5 of this report)
- Santa Rita open pit, covering approximately 6.3 bottom acres and 1,755 sideslope acres (Table 5-4 in M3, 2001)
- slag stockpile, covering approximately 195 acres together with the Hurley smelter (NMED, 2001, p. 3).

3.2.2 Areas exposed through pathways

Areas exposed via contaminant pathways from primary areas may include the following:

- Surface water, bank, bed, and floodplain sediments of Hanover Creek, Whitewater Creek, Lampbright Draw, and other ephemeral drainages at Chino Mine. Figures 3.4 and 3.5 provide evidence of exposure of surface water to hazardous substances. Table 3.1 confirms exposure of surface water in Whitewater Creek to hazardous substances approximately 2 miles south of Tailings Pond No. 7.
- Groundwater aquifers throughout the Chino Mine. Table 2.6 (of this report) confirms that groundwater across the site has been exposed to concentrations of hazardous substances exceeding NMWQCC standards. Manganese and cadmium in groundwater have been detected above standards in the southeast portion of the town of Hurley. Manganese also was above standards south of the Hurley smelter (Golder Associates, 1999, p. 61).
- Areas indirectly exposed to hazardous substances from the mine via aerial transport of materials. Table 3.3 and Figure 3.8 confirm that soils at the Chino Mine have been exposed to hazardous substances, including cadmium, copper, lead, and zinc, from aerial transport.

3.2.3 Areas of indirect effect

Areas of indirect effect, where no hazardous substance has spread but where biological populations may have been affected as a result of animal movement, include:

- geographic extent of migratory birds that are exposed to hazardous substances at the site or injured via loss of habitat or forage base

- geographic extent of other terrestrial resources (e.g., reptiles, ungulates) that are exposed to hazardous substances through food chain pathways or injured via loss of habitat or forage base

- geographic extent of aquatic resources (e.g., amphibians) that may be exposed to hazardous substances through food chain pathways or injured via loss of habitat or forage base.

3.3 Estimates of Concentrations [43 CFR § 11.25(b)]

This section presents examples of concentrations of hazardous substances that have been measured in natural resources of the site, based on available information. This information is not a comprehensive review of all studies that have been conducted at the site, some of which were not available for review. Rather, this section presents examples drawn from a rapid review of the readily available literature.

3.3.1 Surface water

Different types of surface water resources have been exposed to hazardous substances released from the Chino Mine. Exposed surface water resources include ephemeral waterways such as Hanover Creek, Whitewater Creek, and Lampbright Draw. Monitoring of ephemeral surface water in Whitewater Creek has demonstrated exposure of surface water to hazardous substances. Examples of hazardous substance concentrations in Whitewater Creek are given in Table 3.1. Dissolved cobalt concentrations have exceeded 2 mg/L, copper concentrations have exceeded 13 mg/L, and dissolved zinc concentrations have exceeded 43 mg/L. In samples of ponded surface water taken across ephemeral drainages in the Chino Mine, copper concentrations have exceeded 0.8 mg/L and zinc concentrations have exceeded 3.4 mg/L (Figures 3.4 and 3.5).

3.3.2 Groundwater

Extensive sample collection has shown that groundwater across the Chino Mine has been exposed to hazardous substances (Table 2.6 of this report). Examples of hazardous substance concentrations in groundwater wells in the North Mine area at the Chino Mine are given in Table 3.10. Copper has been detected at concentrations up to 734 mg/L. Manganese has been detected at concentrations up to 701 mg/L.

Table 3.10. Hazardous substances in groundwater in the North Mine area at the Chino Mine. Concentrations in mg/L.

Area	Facility	Well #	Date	Cadmium	Copper	Lead	Manganese	pH
East of Santa Rita pit	Lampbright stockpile — north	376-97-04	3/4/98	< 0.02	0.61	< 0.4	149	6.11
	Lampbright stockpile — east	CGCS-9	7/15/98	< 0.002	0.02	0.002	0.785	7.32
	SX/EW plant — north	SX-6	4/8/98 (pH measured on 3/2/98)	< 0.002	0.03	< 0.04	2.18	6.33
	SX/EW plant — west	CGCS-8	7/8/98	0.55	734	< 0.1	701	3.66
	SX/EW plant — east	SX-2S	3/31/98 (pH measured on 3/2/98	< 0.002	0.006	< 0.04	2.23	6.3
	SX/EW plant — southwest	SX-7	4/1/98	0.089	22.1	0.13	312	na
Santa Rita Pit	Santa Rita pit — north	PZ-7R	3/12/98 (Pb measured on 1/7/98	na	5.67	< 0.04	28.7	na
	Santa Rita Pit — central	459-98-04	4/28/98	< 0.002	< 0.004	< 0.04	1.04	6.2
South of Santa Rita Pit	Reservoir 3A	3A-5	3/30/98 (Pb and Cd measured on 1/7/98	0.024	0.437	< 0.04	42.1	3.88
	South-southeast	526-96-16	1/21/98	< 0.002	< 0.004	< 0.04	4.67	na

na = not available.

Source: Tables 3.6.1-3.6.5 and Table A-8 in Golder Associates, 1999.

3.3.3 Biota

Elevated concentrations of hazardous substances have been detected in vegetation, invertebrates, small mammals, reptiles, and birds collected at the Chino Mine (Tables 3.4-3.9). Copper concentrations in seeds averaged 25.7 and 24.2 mg/kg in upland and ephemeral drainage vegetation (Table 3.4). Copper in foliage averaged 65.2 and 39.8 mg/kg in upland and ephemeral drainage vegetation (Table 3.5). Copper concentrations in invertebrates averaged 62 and

35 mg/kg in upland and ephemeral drainage samples (Table 3.6). For small mammals, maximum copper concentrations were 72.6 and 13.6 mg/kg in upland and ephemeral drainage samples (Table 3.8). For birds, the maximum copper concentration was 11.6 mg/kg in an ephemeral drainage sample (Table 3.9).

3.4 Potentially Affected Resources [43 CFR § 11.25 (3)(1)]

The data presented in this chapter and in the following chapter support the conclusion that natural resources for which the Trustees have trusteeship have been affected or potentially affected by releases of hazardous substances from the Chino Mine facilities. Potentially affected resources include, but are not limited to:

- ephemeral surface water resources, including Hanover Creek, Whitewater Creek, and Lampbright Draw, and associated ponds both ephemeral and permanent
- groundwater resources and aquifer materials at and downgradient of the mine facilities
- terrestrial and aquatic biota resources and supporting habitat
- geological resources.

3.5 Preliminary Estimate of Affected Services [43 CFR § 11.25(e)(2)]

Services provided or potentially provided by the resources identified in Section 3.4 include, but are not limited to, the following:

- supporting habitat for wildlife, including food, shelter, breeding and rearing areas, and other factors essential to long-term survival
- consumptive and nonconsumptive outdoor recreation, including hunting, hiking, wildlife viewing, and photography
- passive use and option values
- other ecological and biological services provided by natural resources.

Passive use values are values unrelated to one’s own use of the injured resource. These values can be bequest values (value for use by future generations) or existence values (value of the resource even if it is never used by anybody) [56 Fed. Reg. 19760]. Ecological services provided by natural resources include habitat, biodiversity, carbon sequestration, nutrient cycling, food sources, and other biological, chemical, and physical functions and processes.

Groundwater may provide many services to society, including potable drinking water, irrigation for crops, livestock watering, inputs into manufacturing and mining activities, electricity generation, and prevention of land subsidence. Groundwater recharge also provides a pathway to support surface water services (National Research Council, 1997).

Groundwater serves as the primary drinking water source for Silver City, New Mexico. The 40-Year Water Plan for the town of Silver City (Gordon et al., 1993) indicates that Silver City's water supply is completely from well water. As of 1993, they were using 60% of their total water right of 4739.22 acre-feet per year. The Town of Silver City (2003) indicates the town's current water rights remain at this level (4739.22 acre-feet per year), so they continue to use about 60% (3000/4739.22 acre-feet per year).

This plan implies there may ultimately be a concern about scarcity of groundwater resources in the region. In 1993, the town had applications for 12,000 acre feet in water rights, and wells were dropping 1.4 to 5.0 feet per year. The Gila River Basin is closed to new water rights, and Mimbres Basin was thought to be an unlikely source for procurement of new water rights (Gordon et al., 1993).

The useful lives of four nearby towns' wells were estimated to be:

- 37.8 years from 1993 (28.8 years from 2002) for Franks
- 56.9 years from 1993 (47.9 years from 2002) for Woodward
- 30.6 years from 1993 (21.6 years from 2002) for Gabby Hayes
- 28.0 years from 1993 (19.0 years from 2002) for Anderson.

Phelps-Dodge may be a possible source for future water rights if water is uncontaminated (Gordon et al., 1993). The company has water rights to 20,000 acre-feet of groundwater and 11,600 acre feet of surface water (Whitewater Creek) associated with the Chino Mine. In the Mimbres Basin, Phelps-Dodge has water rights to 690 acre-feet of groundwater and 11,750 acre-feet of surface water (Gila River). In 1993 Phelps-Dodge had applications for a further 10,000 acre-feet in water rights.

In 1993 charges for water from Silver City were:

- $1.60/1000 gallons for residential use
- $1.76/1000 gallons for the Tyrone Mine
- $1.90/1000 gallons (first million, then $2.90) for Arenas Valley
- $2.20/1000 gallons (first 697,500, then $3.20) for Pinos Altos.

Gordon et al. (1993) also explored the potential of new water supplies and found the following:

- The cost for the State of Alaska to deliver water to the Southwest was $1,000 to $2,000 per acre-foot (Duke and Montoya, 1993).

- In 1993, the town of Silver City could claim surface water from the Gila River through the Central Arizona Project (this right to this claim has since expired). Cost for water was $130 to $200 per acre-foot, not including pumping.

- Hernandez et al. (1984) gave a preliminary cost estimate of $650 to $1,000 to transmit water from the Connor Reservoir on the Gila River to recharge groundwater aquifers.

- The current cost for Phelps-Dodge to pump Gila River surface water by pipe is $0.28 per 1,000 gallons (although other costs are unknown). The pipe goes near two Silver City well sites.

- New water wells may be drilled by the town and current water rights transferred to the new locations, if they do not interfere with Phelps-Dodge Chino water rights (assuming these wells are not contaminated); negotiations to get water from Phelps-Dodge Chino may also be possible.

These sources of information suggest that the value of groundwater services in Silver City is high. The cost of water rights (in perpetuity) in the region may be in the thousands of dollars per acre-foot. The impending scarcity of drinking water supplies in the region will be of growing concern in the next few decades, and additional applications for water rights demonstrates that clean water supplies have value.

Passive use values for local and migratory bird morbidity and mortality at the Chino Mine may be highest for people living in the county directly affected by mining releases. In 2002, approximately 30,237 individuals lived in Grant County, New Mexico (U.S. Census, 2003), where the Chino and Tyrone Mines are located. In addition, a large body of economics literature has documented significant service reductions from bird kills, even when the species are not particularly unique or sensitive (e.g., Loomis et al., 1990; Rowe et al., 1991; Boyle et al., 1994). Thus, lost passive use services from migratory bird deaths at the Chino Mine may occur for people outside of the direct mine area.

4. Determination Criteria [43 CFR § 11.23(e)]

This chapter presents an evaluation of the preassessment determination criteria [43 CFR § 11.23(e)]. The information presented and summarized in this chapter confirms the following:

- A release of hazardous substances has occurred.
- Natural resources for which the Trustees have trusteeship have been or are likely to have been adversely affected.
- The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury.
- Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.
- Response actions will not sufficiently remedy the injury to natural resources without further action (note that no response actions are currently planned under the RI/FS process).

Based on the evaluation of the criteria presented below, the Trustees have determined that a Type B NRDA should be performed to assess damages to natural resources caused by releases of hazardous substances from the Chino Mine. The justification of the decision to perform a Type B NRDA will be presented in the Assessment Plan.

4.1 A release of hazardous substances has occurred

Multiple studies and data collection efforts, including those of the NMED, the CMC, and the USFWS have demonstrated that multiple and at times continuous releases of hazardous substances have occurred and continue to occur as a result of operations at the Chino Mine (Section 2.4). Hazardous substances released include, but may not be limited to, arsenic, beryllium, cadmium, chromium, copper, manganese, nickel, zinc, and sulfuric acid. Investigators have also documented elevated concentrations of hazardous substances in surface water, groundwater, and biota that have resulted from releases of hazardous substances at the site.

4.2 Trustee natural resources have been or are likely to have been adversely affected by the release

Natural resources [as defined in 43 CFR § 11.14(z)] for which the Trustees have trusteeship that have been or are likely to have been adversely affected by releases of hazardous substances include, but are not necessarily limited to, surface water, groundwater, geological, and biological resources, including supporting habitat for Trustee biological resources. These biological resources include waterfowl and migratory birds and the federally threatened Chiricahua leopard frog.

The ecological risk assessment produced in 2002 for the NMED (MFG, 2002) provides detailed evidence that elevated concentrations of hazardous substances at the Chino Mine are sufficient to potentially injure natural resources, as indicated by findings of risk to vegetation, wildlife, and aquatic communities. These findings are summarized below.

4.2.1 Potential adverse effects to habitat

Releases of hazardous substances from the Chino Mine most likely have adversely affected supporting habitat for Trustee biological resources. According to the ecological risk assessment, "elevated concentrations of copper and other metals, combined with depressed soil pH, have led to risk of phytotoxicity for some areas of the Chino Mine site. This conclusion is supported by both vegetation community characterization and laboratory phytotoxicity testing" (MFG, 2002, p. 5). Measurements of litter cover, canopy cover, and total species richness were significantly lower in upland study locations than in reference locations (Figure 4.1), indicating adverse effects to upland habitat that has been exposed to hazardous substances at the Chino Mine.

Phytotoxicity testing was conducted using soil samples from 16 of the 34 sampling locations where vegetation measurements were taken. Phytotoxicity tests confirm that elevated concentrations of copper and other metals in Chino area soils, together with depressed pH, have resulted in significant phytotoxic effects to vegetation. Specifically, surface soils (0-6 inches deep) at all study sites showed significant phytotoxicity compared to the reference soil in emergence, survival, or growth of perennial ryegrass or alfalfa (Table 2.2-3 in MFG, 2002). At one location (ERA 26), seeds failed to germinate or emerge (Figure 4.2). Site ERA 01, which is close to the Hurley smelter, showed the greatest phytotoxicity, with low emergence and minimal plant growth (Figure 4.2).

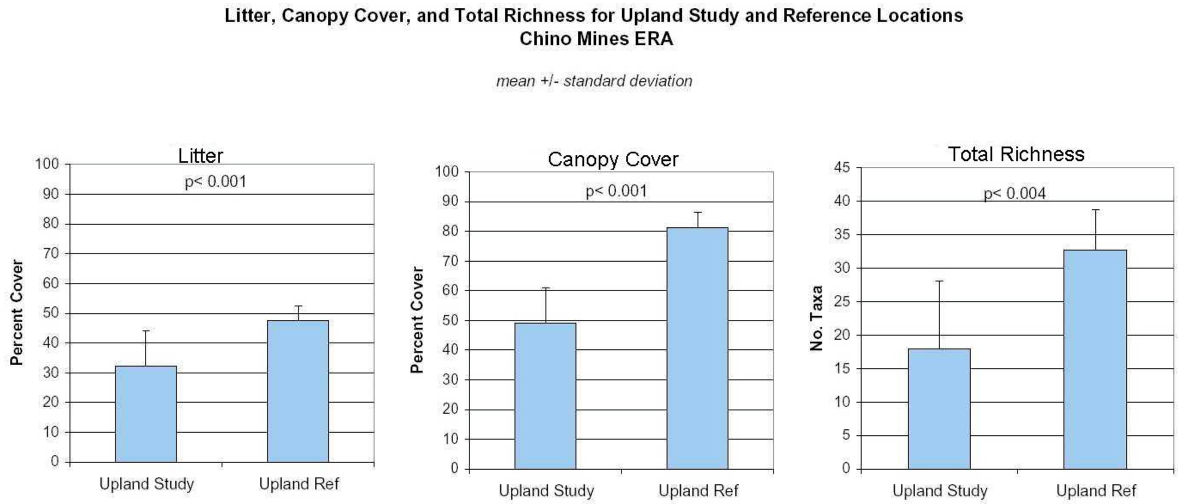

Figure 4.1. Comparison of vegetation community characteristics in upland study and reference locations.

Source: Figure 2.2-7 in MFG, 2002.

Statistical analysis conducted for the ecological risk assessment found that cupric ion activity and soluble copper concentration were the best predictors for vegetation community parameters and laboratory toxicity testing (Table 4.1). To measure cupric ion activity, soils were leached with deionized water, and ion-selective electrodes were used to detect cupric ion activity in the leachate. These statistical tests further confirm that releases of hazardous substances at the Chino Mine have most likely had adverse effects on supporting habitat for biological resources.

4.2.2 Potential adverse effects to terrestrial wildlife

Releases of hazardous substances from the Chino Mine have adversely affected terrestrial wildlife. A conceptual wildlife food web developed for the ecological risk assessment suggests potential food chain pathways that could result in exposure of wildlife to hazardous substances (Figure 3.2). Estimated exposure of different wildlife functional groups (omnivorous small mammals, large herbivores, mammalian predators, omnivorous/granivorous ground-feeding birds, avian predators) to hazardous substances was calculated using concentrations of hazardous substances measured in soil/sediment, food, and water at the Chino Mine (MFG, 2002, p. 7).

Figure 4.2. Phytotoxicity testing results at the Chino Mine. Note that sites ERA 01 – ERA 15 are upland study sites, ERA 16 is a reference area site, and sites ERA 22-31 are ephemeral drainage sites.

Source: Figure 2.2-9 in MFG, 2002.

Table 4.1. Summary of maximum R-squared values for linear regression analyses for vegetation community and laboratory phytotoxicity parameters[a]

Chemical variable	Species richness	Canopy cover	Root dry weight	Root length	Survival
Cupric ion activity (pCu^{2+})	0.614	0.462	0.694		
Soluble Cu				0.548	0.408

a. R-squared values for linear regression analyses shown only for the chemical variable with the maximum value.

Source: Table 2.3-1 in MFG, 2002.

Results of the screening-level analysis indicated exposure to hazardous substances in excess of “no-observed-adverse-effect levels” (NOAELs) for the following pairs of receptors and hazardous substances:

- cadmium: small ground-feeding birds
- chromium: small ground-feeding birds
- copper: small ground-feeding birds
- lead: all receptors
- selenium: small ground-feeding birds, omnivorous small mammals, mammalian predator
- zinc: small ground-feeding birds, large ground-feeding birds, raptors, omnivorous small mammals, and ruminants (MFG, 2002, p. 8).

A detailed analysis of risk was conducted for these pairs of receptors and hazardous substances using less conservative assumptions than the screening-level analysis, including basing the risk calculations on “lowest-observed-adverse-effect levels” (LOAELs) instead of NOAELs. The detailed risk analysis found that for cadmium, lead, and zinc, risks to wildlife were primarily restricted to the Groundhog Mine reclamation area (MFG, 2002, p. 8). For chromium, molybdenum, and selenium, “population-level risk appeared to be relatively low since concentrations did not generally exceed LOAELs at any location, or in sitewide estimates” (MFG, 2002, p. 9). For copper, a risk assessment using LOAELs and “realistic bioavailability levels” found that risk to ground-feeding birds was “isolated to relatively few locations near the smelter and along the Whitewater Creek corridor” (MFG, 2002, p. 9).

In addition, small mammal liver and kidney histopathology was assessed for samples collected at the site (Table 4.2). Liver (hepatic) lesions were more frequent in study area samples (i.e., samples from areas affected by hazardous substance releases) than in reference area samples. Kidney lesions (nephritis) were found in 9 of 42 study area samples and none of the 9 reference area samples (Table 4.2). Although statistical results were inconclusive because of

Table 4.2. Comparison of liver and kidney histopathology for reference and study area small mammals. Values shown are number of samples in each category.

	Liver data		Kidney data	
Location	**No effects**	**Lesions**	**No effects**	**Lesions**
Reference area	7	2	9	0
Study area	20	22	33	9

Source: Figures 3.6-39 and 3.6-40 in MFG, 2002.

small datasets, these data suggest that the percentage of animals affected with liver or kidney lesions is higher in the contaminated areas of the site than in the reference area (MFG, 2002, p. 108).

These analyses and calculations support the finding that releases of hazardous substances from the Chino Mine have resulted in potential adverse effects to wildlife. Risk calculations, however, are not equivalent to determinations of natural resource injuries to wildlife. The degree and extent of injury to wildlife at the Chino Mine will be determined during the assessment phase of the NRDA.

4.2.3 Potential adverse effects to aquatic biota

Releases of hazardous substances from the Chino Mine may have adversely affected aquatic biota, including amphibians. The ecological risk assessment compared concentrations of hazardous substances in surface water samples to acute water quality standards, chronic water quality standards, and toxicity reference values for amphibians. Acute and chronic water quality standards were those found in the New Mexico Water Quality Standards (NMAC 20.6.4.900). Details on the development of toxicity reference values for amphibians can be found in Schafer & Associates (1999), but were not available for review by the Trustees at the time of preparation of this preassessment screen.

The risk assessment found that concentrations of the hazardous substances cadmium, copper, lead, and zinc, exceeded either acute or chronic standards or toxicity reference values for amphibians for multiple sampling sites. Table 4.3 shows sites where standards were exceeded for multiple metals. At eight additional sites, copper concentrations exceeded only acute or chronic standards or toxicity reference values for amphibians (Table 4.4-1 in MFG, 2002). Surface water sites sampled for the ecological risk assessment included 23 sites in the Hanover Creek, Whitewater Creek, and Lampbright Draw drainages. These results demonstrate that amphibians and aquatic biota at the site are likely to have been adversely affected by releases of hazardous substances.

Table 4.3. Comparison of water quality data to water quality standards and amphibian toxicity reference values (TRV) for surface water sampling sites across the Chino Mine. Concentrations in exceedence of standards are highlighted in bold. All values are mg/L.

Location	Standard	Hardness	Cadmium	Copper	Lead	Zinc
Hanover Creek Station (U02-9100)	Acute WQS	—	0.022	0.050	0.477	0.379
	Chronic WQS	—	0.007	0.029	0.019	0.382
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	1,740	**0.0132**	0.0142	0.0013	**2.16**
Whitewater Creek Station (U03-9200)	Acute WQS	—	0.022	0.050	0.477	0.379
	Chronic WQS	—	0.007	0.029	0.019	0.382
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	1,314	**0.007**	0.0104	< 0.0011	**0.484**
Bayard Canyon Station	Acute WQS	—	0.008	0.022	0.159	0.182
	Chronic WQS	—	0.004	0.014	0.006	0.184
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	168.4	**0.0044**	**0.0536**	**0.0105**	**0.358**
Whitewater Creek Station (U03-9300)	Acute WQS	—	0.003	0.010	0.057	0.093
	Chronic WQS	—	0.002	0.007	0.002	0.093
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	75.7	0.00022	**0.047**	< 0.0027	0.029
Whitewater Creek Station (U03-99302)	Acute WQS	—	0.022	0.050	0.477	0.379
	Chronic WQS	—	0.007	0.029	0.019	0.382
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	400	**0.0134**	**0.844**	0	**3.42**
Whitewater Creek Station (U03-9600)	Acute WQS	—	0.022	0.050	0.477	0.379
	Chronic WQS	—	0.007	0.029	0.019	0.382
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	432	**0.0371**	**0.599**	< 0.0008	**1.06**
ERA35	Acute WQS	—	0.022	0.050	0.477	0.379
	Chronic WQS	—	0.007	0.029	0.019	0.382
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	2,342	**0.0052**	**0.0302**	**0.0495**	**0.517**
ERA38	Acute WQS	—	0.004	0.013	0.075	0.111
	Chronic WQS	—	0.002	0.008	0.003	0.112
	Amphibian TRV	—	0.004	0.02	0.005	0.2
	Concentration	94	**0.0056**	**0.15**	< 0.02	0.0434

Source: Table 4.4-1 in MFG, 2002.

4.3 The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury

4.3.1 Surface water/sediments

The DOI regulations present a number of definitions of injury for surface water resources. These definitions of injury to surface water include the following:

- concentrations of hazardous substances exceeding Safe Drinking Water Act (SDWA) or other relevant federal or state criteria or standards for drinking water [43 CFR § 11.62(b)(1)(i)]
- concentrations and duration of substances in excess of applicable water quality criteria established by Section 304(a)(1) of the Clean Water Act (CWA), or by other federal or state laws or regulations that establish such criteria . . . in surface water that before the discharge or release met the criteria and is a committed use . . . as a habitat for aquatic life, water supply, or recreation [43 CFR § 11.62(b)(1)(iii)]
- concentrations and duration of hazardous substances sufficient to have caused injury to biological resources when exposed to surface water [43 CFR § 11.62(b)(1)(v)].

For ponded water at Lake One and Axiflo Lake, the concentrations and duration of hazardous substances have been sufficient to potentially cause injury to birds exposed to surface waters, and to other biological resources as well. The dead ring-billed gull found at Lake One and the dead mallard found at Axiflo Lake in September 2000 show that the concentrations and duration of hazardous substances at these ponds have been sufficient to cause injury to birds (unpublished data, USFWS records).

For ephemeral drainages at the Chino Mine, the ecological risk assessment found that cadmium, copper, lead, and zinc in surface water samples exceeded acute or chronic water quality standards or amphibian toxicity reference values. Cadmium in sediments also exceeded a threshold effects concentration (MFG, 2002, pp. 124-126). The risk characterization predicted low to moderate risks to aquatic receptors in ephemeral drainages along the Hanover and Whitewater Creek corridor, and intermediate level risks to amphibians and aquatic receptors in stock tanks (MFG, 2002, p. 208).

4.3.2 Groundwater

Definitions of injury to groundwater resources presented in the DOI regulations include the following:

- concentrations of hazardous substances exceeding SDWA or other relevant federal or state criteria or standards [43 CFR § 11.62(c)(1)(i), (ii), (iii)]

- concentrations of hazardous substances sufficient to cause injury to other natural resources that come in contact with the groundwater (e.g., surface water) [43 CFR § 11.62(c)(1)(iv)].

Criteria relevant to the Chino Mine site include Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs) established by sections 1411-1416 of the Safe Drinking Water Act, and New Mexico Water Quality Standards for groundwater (NMAC 20.6.2.3103). A comparison of hazardous substances measured in groundwater at the mine with groundwater standards demonstrates that hazardous substance concentrations in groundwater are sufficient to potentially cause injury (Table 2.6). Concentrations of cadmium, copper, lead, and manganese in groundwater have exceeded New Mexico criteria by more than a factor of 10 (Tables 3.6.1 to 3.6.8 in Golder Associates, 1999). These concentrations indicate that groundwater at the site is potentially injured.

4.3.3 Biological resources

According to DOI regulations [43 CFR § 11.62(f)], an injury to biological resources has resulted from the discharge of a hazardous substance if the concentration of the hazardous substance is sufficient to:

- cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

The dead birds found at Lake One and Axiflo Lake at the Chino Mine in September 2000 confirm adverse impacts to birds caused by hazardous substances released from the site. Elevated concentrations of hazardous substances in bird, small mammal, and reptile tissues (Tables 3.7-3.9) provide further evidence that wildlife potentially have been injured by exposure to hazardous substances at the site.

The ecological risk assessment found risk to small ground-feeding birds at the Chino Mine based on exposure to elevated concentrations of copper in soil, seeds, foliage, and invertebrates (MFG, 2002). Risks to other wildlife, including raptors, small mammals, mammalian predators, and ruminants, were also found from cadmium, lead, and zinc in areas near the Groundhog Mine (MFG, 2002, pp. 7-8). In addition, supporting habitat at the site, including soils and vegetation, has been injured by exposure to hazardous substances (Figures 4.1 and 4.2). Risks to aquatic biota, including amphibians, were found from cadmium, copper, lead, and zinc in surface water at the site (Table 4.3). These sources of evidence all suggest that the quantity and concentration of released hazardous substances are sufficient to potentially cause injury to biological resources at the Chino Mine.

4.3.4 Summary

Based on a "rapid review of readily available information" [43 CFR § 11.23(b)], the Trustees conclude that the quantity and concentration of the released hazardous substance are sufficient to potentially cause injury to Trustee natural resources, including surface water, groundwater, geological, and biological resources.

4.4 Data sufficient to pursue an assessment are available or likely to be obtained at reasonable cost

Data relevant to conducting an assessment of natural resource damages at the Chino Mine have been collected as part of regular monitoring activities at the Chino Mine, as part of the Closure/Closeout planning process (e.g., M3, 2001, and appendices), and as part of the AOC process (e.g., MFG, 2002). Such data include information on hazardous substances sources, releases, pathways, and concentrations in the environment. Since the preassessment screen is intended to determine only whether there is sufficient cause to pursue an NRDA, omission of any information in the preassessment screen does not preclude consideration of such information in the course of an NRDA. Additional data for the purposes of performing a damage assessment are expected to be obtainable at reasonable cost.

4.5 Response actions will not sufficiently remedy the injury to natural resources without further action

Under the terms of the AOC signed by the CMC and the NMED, the development of a remedial investigation/feasibility study (RI/FS) is under way for areas of the site that may have been affected by historical release of contaminants. The ecological risk assessment was performed under the AOC. The Trustees are not aware, however, of any response actions that have been undertaken under the AOC. The Chino Mine and the Hurley smelter have been closed temporarily since January 2002. CMC has undertaken certain corrective actions, under the requirements of groundwater discharge permits with the NMED Ground Water Quality Bureau (Table 2.10). These actions have included installation of interceptor wells, replacement of a lined PLS pond with a stainless steel tank, and stormwater management activities. Stormwater management includes two major diversion channels: the north diversion channel routes runoff around the Lampbright stockpiles, the Whitewater Creek diversions route surface water around the tailings ponds and Lake One (M3, 2001, p. 2-28). These actions, however, are not sufficient to either prevent ongoing and future injuries or to remedy past injuries. For example, sampling has indicated ongoing exposure of ephemeral surface water to hazardous substances and continued elevated concentrations of hazardous substances in groundwater. Ponded water on top of tailings impoundments, in uncovered process water ponds, and in stormwater ponds also continues to serve as ongoing sources of potential injuries to wildlife. No hazing activities have been undertaken to reduce injuries to wildlife.

4.6 Conclusions

Based on an evaluation of the preassessment determination criteria, the following conclusions can be made:

- A release of hazardous substances has occurred.
- Natural resources for which the Trustees have trusteeship have been or are likely to have been adversely affected.
- The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury.
- Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.
- Response actions will not sufficiently remedy the injury to natural resources without further action.

Based on an evaluation of these five criteria, the Trustees have determined that an NRDA should be performed to assess damages to natural resources caused by releases of hazardous substances from the Chino Mine.

5. References

Arcadis, J.S.A. 2001. Administrative Order on Consent, Draft Phase II RI report for the Ecological IU. May (as cited in MFG, 2002).

Anonymous. 2001. State Fines Mining Company $50,400 for Spill. Silver City Daily Press Internet Edition. January 8.

ARIA. 2001. Digital Elevation Model Data — 30 Meter Resolution. Source date: March 19, 2001. Downloaded from Arizona Regional Image Archive (ARIA) (http://aria.arizona.edu) on April 3, 2003.

Beyer, W.N. 1990. Evaluating Soil Contamination. U.S. Fish and Wildlife Service Biological Report 90(2).

Boyle, K.J., W.H. Desvousges, F.R. Johnson, R.W. Dunford, and S.P. Hudson. 1994. An investigation of part-whole biases in contingent-valuation studies. *Journal of Environmental Economics and Management* 27:64-83.

Brunner, J. 2002. Letter to M. Reed, Ground Water Quality Bureau, New Mexico Environment Department. Re: Discharge Plan DP-166 — No. 2 Leach System. January 30.

CMC. 1981. Application of Chino Mines Company for Ground Water Discharge Plan Approval. before the New Mexico Environmental Improvement Division, Santa Fe, New Mexico. Chino Mines Company, Hurley, NM. April 7 (as cited in Daniel B. Stephens & Associates, 1996).

CMC. 1998. Comprehensive Groundwater Characterization Study Phase 2 Report. Prepared for the New Mexico Environment Department. August 28. Chino Mines Company, Hurley, NM.

Daniel B. Stephens & Associates. 1996. Existing Data Report: Chino Mine Tailing Ponds. Volume I: Sections 1 through 6. Prepared for Chino Mines Company, Hurley, NM. February 9.

Daniel B. Stephens & Associates. 1997. Phase I Investigation, Chino Mines Company: Older Tailing Source Areas. Volume I: Sections 1 through 11. Prepared for Chino Mines Company, Hurley, NM. June 12.

Daniel B. Stephens & Associates. 1999. Preliminary Stockpile Seepage Study, Chino Mine. Prepared for Chino Mines Company, Hurley, NM. July 31.

Dresher, W.H. 2001. How hydrometallurgy and the SX/EW process made copper the "green" metal. *Innovations.* Copper Development Association, Inc. August. http://innovations.copper.org/2001/08/hydrometallurgy.html.

Duke, E.M. and A.C. Montoya. 1993. Trends in water pricing: Results of Ernst and Young's national rate survey. *American Water Works Association Journal* 85(5):55-61.

Golder Associates. 1998. Waste Rock Characterization, Chino Mine. Prepared for Chino Mines Company, Hurley, NM. August 10.

Golder Associates. 1999. Comprehensive Groundwater Characterization Study Phase 3 Report, Volumes 1-2. Prepared for Chino Mines Company, Hurley, NM. January.

Gordon, N., G. Esqueda, and T. Kelly. 1993. A 40-Year Water Plan for the Town of Silver City, New Mexico. Prepared for the Town of Silver City by Engineers Inc, Silver City, and Geohydrology Associates, Albuquerque, NM. October.

Harlan & Associates. 2001. Tyrone Mine No. 2 Leach Stockpile Discharge Plan DP-166: Evaluation of Potential Seepage to Deadman Canyon. Supplemental Monitoring Results April 1 through September 30, 2001. Prepared by Harlan & Associates, Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. October 31.

Hernandez, J.W., W.G. Hines, and F.D. Trauger. 1984. Evaluation of a Municipal Water Supply for the Silver City Area Using Groundwater from Conner Reservoir on the Gila River. Prepared for Town of Silver City and New Mexico Interstate Stream Commission.

Huggard, C.J. 1994. Mining and the environment: the clean air issue in New Mexico, 1960-1980. *New Mexico Historical Review* 69(4):369-388.

IRC. 2001. Copper, Phelps Dodge, and the Future Grant County's Mining District. An IRC Community Report. Prepared by Interhemispheric Resource Center, Silver City, NM. October.

Landsat7. 2000. ETM+ digital data (bands 1-5, 7, 8). Imagery date: April 13, 2000. Downloaded from Arizona Regional Image Archive (ARIA) http://aria.arizona.edu on April 3, 2003.

Loomis, J.B., T. Wegge, M. Hanemann, and B. Kanninen. 1990. The economic value of water to wildlife and fisheries in the San Joaquin Valley: Results of a simulated voter referendum. In *Transactions of the 55th North American Wildlife & Natural Resources Conference*, pp. 259-268.

M3. 2001. End of Year 2001 through Year 2006 Closure / Closeout Plan: Chino Mines. Prepared for Chino Mines Company, Hurley, NM. March. M3 Engineering & Technology Corporation.

McClellan, D. 1989. Chino Mine Waste-Water Spill Prompts Suit. *Albuquerque Journal* p. 3, Section D. February 15.

MFG. 2002. Chino Mines Administrative Order on Consent: Sitewide Ecological Risk Assessment. Prepared for New Mexico Environment Department. MFG, Inc. August.

Mitsubishi Materials Corporation. 2002. Annual Report for the Year Ended March 31, 2002. http://www.mmc.co.jp/english/ir/financial/annual2002.pdf.

National Research Council. 1997. Valuing Ground Water: Economic Concepts and Approaches. National Academy Press, Washington, DC.

NMED. 2001. Proposed Supplemental Discharge Permit for Closure: DP-1340. Chino Mines Company. December 21. New Mexico Environment Department.

NMEID. 1986. Letter from Denise Fort, Director of Environmental Improvement Division, State of New Mexico, to Ken Vance, Manager of Chino Mines Company, regarding discharge of acidic fluids down Whitewater Creek (Discharge Plan 214). October 8. New Mexico Environmental Improvement Division.

NMWRRI. 2000. Trans-International Boundary Aquifers in Southwestern New Mexico. Prepared by the New Mexico Water Resources Research Institute, New Mexico State University, and California State University, Los Angeles for the U.S. EPA and the International Boundary and Water Commission – U.S. Section. March.

Rowe, R.D., W.D. Schulze, W.D. Shaw, D. Schenk, and L.G. Chestnut. 1991. Contingent Valuation of Natural Resource Damage due to the Nestucca Oil Spill: Final Report. Prepared by Hagler Bailly Consulting, Inc., Boulder, CO, for the Department of Wildlife, State of Washington, British Columbia Ministry of Environment, Victoria, British Columbia, and Environment Canada, Vancouver, British Columbia. June 15.

SARB. 1999. Geochemical Evaluation of Tailings and Stockpiles, Tyrone Mine. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, NM. SARB Consulting, Inc. December 22.

SARB. 2000. Pit Lake Water Quality Modeling, Tyrone Mine. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, NM. SARB Consulting, Inc. February 29.

Schafer & Associates. 1999. Chino Mines Administrative Order on Consent Sitewide Ecological Risk Assessment Technical Memorandum No. 1 (TM-1): ERA Workplan. May 14.

Town of Silver City. 2003. Water Department Description. http://www.townofsilvercity.org/utilities/water_page.htm. Accessed April 30, 2003.

U.S. Census. 2003. Table CO-EST2002-01-35-New Mexico County Population Estimates: April 1, 2000 to July 1, 2002. Source: Population Division, U.S. Census Bureau. Release Date: April 17, 2003. http://eire.census.gov/popest/data/counties/tables/CO-EST2002/CO-EST2002-01-35.php.

U.S. EPA. 1992. Method 1311: Toxicity Characteristic Leaching Procedure. Revision 0. July. http://www.epa.gov/epaoswer/hazwaste/test/pdfs/1311.pdf.

U.S. EPA. 1994a. Method 1312: Synthetic Precipitation Leaching Procedure. Revision 0. September. http://www.epa.gov/epaoswer/hazwaste/test/pdfs/1312.pdf.

U.S. EPA. 1994b. Technical Document: Acid Mine Drainage Prediction. Office of Solid Waste, Special Waste Branch. EPA 530-R-94-036. December.

U.S. EPA. 1997. Damage Cases and Environmental Releases from Mines and Mineral Processing Sites. U.S. Environmental Protection Agency, Office of Solid Waste.

U.S. Securities and Exchange Commission. 2002. Form 10-K for the Fiscal Year Ended December 31, 2001: Phelps Dodge Corporation (a New York Corporation).

USFWS. 2003. Endangered Species List. List of Species by County for New Mexico: Counties Selected: Grant. http:/ifw2es.fws.gov/EndangeredSpecies/lists/ListSpecies.cfm. Accessed May 7, 2003.

USGS. 1997. Digital Orthophoto Quarter Quadrangle (DOQQ) (8 and 1 meter resolution). Imagery date: Oct. 13, 1997. Downloaded from Microsoft Terraserver Site (http://terraserver.microsoft.com/) November 8, 2002.

Verburg, R., M. Grass, and M. Klisch. 1999. Technical Memorandum re: Stockpile Characterization — Chino Mines Company. To Ned Hall, Chino Mines Company. May 25.

Part B:
Preassessment Screen for Tyrone Mine Site, Silver City, New Mexico

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Contents

Acronyms and Abbreviations

ABA	acid-base accounting
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
DOI	U.S. Department of the Interior
DP	discharge permit
MCLs	maximum contaminant levels
n.d.	not detected
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NRDA	natural resource damage assessment
PDTI	Phelps-Dodge Tyrone, Inc.
PLS	pregnant leach solution
PRP	potentially responsible party
RI/FS	remedial investigation/feasibility study
SDWA	Safe Drinking Water Act
SMCLs	secondary maximum contaminant levels
SPLP	synthetic precipitation leach procedure
SX/EW	solution extraction/electrowinning
TRI	Toxics Release Inventory
U.S. EPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USNR	United States Natural Resources, Inc.

Figures

Tables

1. Introduction

Hazardous substances have been released to the environment by mining activities at the Tyrone Mine near Silver City, New Mexico. The U.S. Fish and Wildlife Service (USFWS), in coordination with the New Mexico Office of Natural Resources Trustee, has begun to assess natural resource damages resulting from releases of hazardous substances from the Tyrone Mine in accordance with the natural resource damage assessment (NRDA) regulations issued by the U.S. Department of Interior (DOI) at 43 CFR Part 11.[1] These regulations are not mandatory. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 U.S.C. § 9607(f)(2)(C)]. The first step in the process established by DOI is the preparation of a preassessment screen. This preassessment screen documents the Trustees' conclusion that there is a reasonable probability of making a successful claim for natural resource damages at the Tyrone Mine. This screen was prepared by Stratus Consulting under contract to the USFWS.

1.1 Intent of the Preassessment Screen

The purpose of a preassessment screen is to determine whether a discharge or release of a hazardous substance warrants conducting an NRDA. It is intended to be based on "a rapid review of readily available information . . . [to] ensure that there is a reasonable probability of making a successful claim" [43 CFR § 11.23(b)]. This preassessment screen is not intended to serve as an assessment of natural resources injuries or damages.

A variety of quantitative and qualitative data sources were relied on for this review of readily available information. Information sources included the following:

- The Tyrone Mine Closure/Closeout Plan and appendices prepared for the New Mexico Environment Department (NMED) by Phelps-Dodge Tyrone, Inc. (PDTI) and its contractors (M3, 2001). Although the documents are dated 2001, the majority of the data in the documents was obtained in 1998 or before.

- Documents from the administrative record of NMED for the discharge permits held by the mine, including quarterly monitoring reports for 2001 and 2002 submitted to NMED by PDTI.

1. 43 CFR Part 11 regulations were authored by the U.S. DOI, and are referred to as the DOI regulations in this document.

- Mine inspection reports from NMED (Dye, 1989; Phillip and Reed, 2001; Phillip, 2002).
- Reports of releases at the mine provided by PDTI to NMED (Shelley, 2000; Vaughn, 2001a,b,c,d,e).
- Analytical data for water, sediment, bird, and invertebrate samples collected at the Tyrone Mine tailings ponds and analyzed by the USFWS.
- A preliminary inventory of migratory bird mortalities at the Tyrone Mine in 2000.
- Various published reports about Phelps-Dodge, including an assessment prepared by the Interhemispheric Research Council (IRC, 2001).
- Site visits and photographs and videos of the site taken by USFWS personnel in 2000 and 2002.

All literature and data sources relied on in the preparation of this preassessment screen are presented in the Literature Cited section of the report (Section 5).

1.2 Criteria to be Addressed by the Preassessment Screen

The content and requirements of a preassessment screen are described in 43 CFR Part 11.23. As described in the regulations, the Trustees evaluated whether all of the following criteria have been met [43 CFR § 11.23(e)]:

1. **A release of a hazardous substance has occurred.** This criterion was evaluated by reviewing information on sources of hazardous substances, evidence of releases of hazardous substances (including spills and continuous releases), and data demonstrating elevated concentrations of hazardous substances in natural resources.

2. **Natural resources for which the Trustees may assert trusteeship have been or are likely to have been adversely affected by the release.** This criterion was evaluated by reviewing information documenting migratory bird mortalities at tailings ponds and data demonstrating exposure of natural resources to hazardous substances, including elevated concentrations of hazardous substances in surface water and groundwater.

3. **The quantity and concentration of the released hazardous substance are sufficient to potentially cause injury to those natural resources.** This criterion was evaluated by reviewing information documenting migratory bird mortalities at tailings ponds and by comparing concentrations of hazardous substances in surface water and groundwater to regulatory criteria.

4. **Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.** A record of bird mortality and monitoring data for surface water and groundwater already exist at the site. Additional data collection activities for resources that have not been evaluated could be conducted at reasonable cost.

5. **Response actions carried out or planned will not sufficiently remedy the injury to natural resources without further action.** No response actions have been undertaken at the Tyrone Mine pursuant to a remedial investigation/feasibility study. Response actions taken by PDTI in an attempt to comply with groundwater discharge permits have been inadequate to prevent ongoing injury. For example, a letter detailing the results of a September 24, 2002, inspection by NMED of the Tyrone Mine tailings ponds reveal highly acidic ponded water ($pH < 3$) and inadequate hazing equipment to prevent bird injuries (Phillip, 2002).

This preassessment screen presents data sufficient to support the above criteria based on information readily available to the Trustees. It is *not* a comprehensive summary and review of all existing data.

2. Information on the Site [43 CFR § 11.24]

2.1 Location and Description of the Tyrone Mine

The Tyrone Mine facility is located approximately 10 miles southwest of Silver City, New Mexico, in southwest Grant County (Figure 2.1). The facility includes an open-pit copper mine, a solution extraction/electrowinning (SX/EW) plant, an inactive mill and concentrator, tailing impoundments, waste rock and leach stockpiles, and associated mine facilities and infrastructure (M3, 2001, p. 2-18) (Figure 2.2).

The climate of the mine area is semi-arid, with precipitation averaging 16 inches annually and evaporative demand exceeding annual precipitation. Most of the precipitation falls during thunderstorm events in the monsoon season from July to October (M3, 2001, p. 2-6). Elevations at the site range from approximately 5,800 to 8,000 feet above mean sea level (M3, 2001, pp. 2-3 to 2-4). Vegetation surrounding the mine site includes alluvial grassland, piedmont scrub savanna, mountain slope scrub savanna, and mixed evergreen woodland (M3, 2001, pp. 2-9 to 2-12). Phelps Dodge manages grazing land to the north and east of the mine site, primarily through its subsidiary, Pacific Western Land Company (M3, 2001, p. 2-3).

The mine straddles the North American Continental Divide (M3, 2001, p. 2-3). Before open pit mining, the mine area drained toward the northwest into Mangas Creek, an ephemeral stream that flows north into the Gila River. Toward the southwest, the mine area drained into Brick Kiln Gulch and Oak Grove Wash, which flow into the Mimbres basin (M3, 2001, p. 2-3 to 2-4). Because open pit mining has altered surface water and groundwater hydrology, some surface water that would have flowed toward the Gila River basin or Mimbres basin now flows into the open pit (M3, 2001, p. 2-7), and some groundwater that would have flowed into the Gila-San Francisco underground basin or into the Mimbres Valley underground basin is now captured by the pit dewatering capture zones (M3, 2001, p. 2-8).

2.2 History of Mining at the Tyrone Mine

In the late 1870s through the early 1900s, a number of companies mined turquoise, copper, and fluorspar in the Tyrone Mine area. The Phelps Dodge Corporation (Phelps Dodge) consolidated the mining claims in the area by 1913 and developed a large-scale underground operation that shut down in 1921, with sporadic operations from 1921-1929 and 1941-1950. The Tyrone Mine and the SX/EW facility are currently operated by PDTI, which is wholly owned by Phelps Dodge (U.S. Securities and Exchange Commission, 2002). The current Tyrone Mine facility is an open pit copper mine (Figure 2.3).

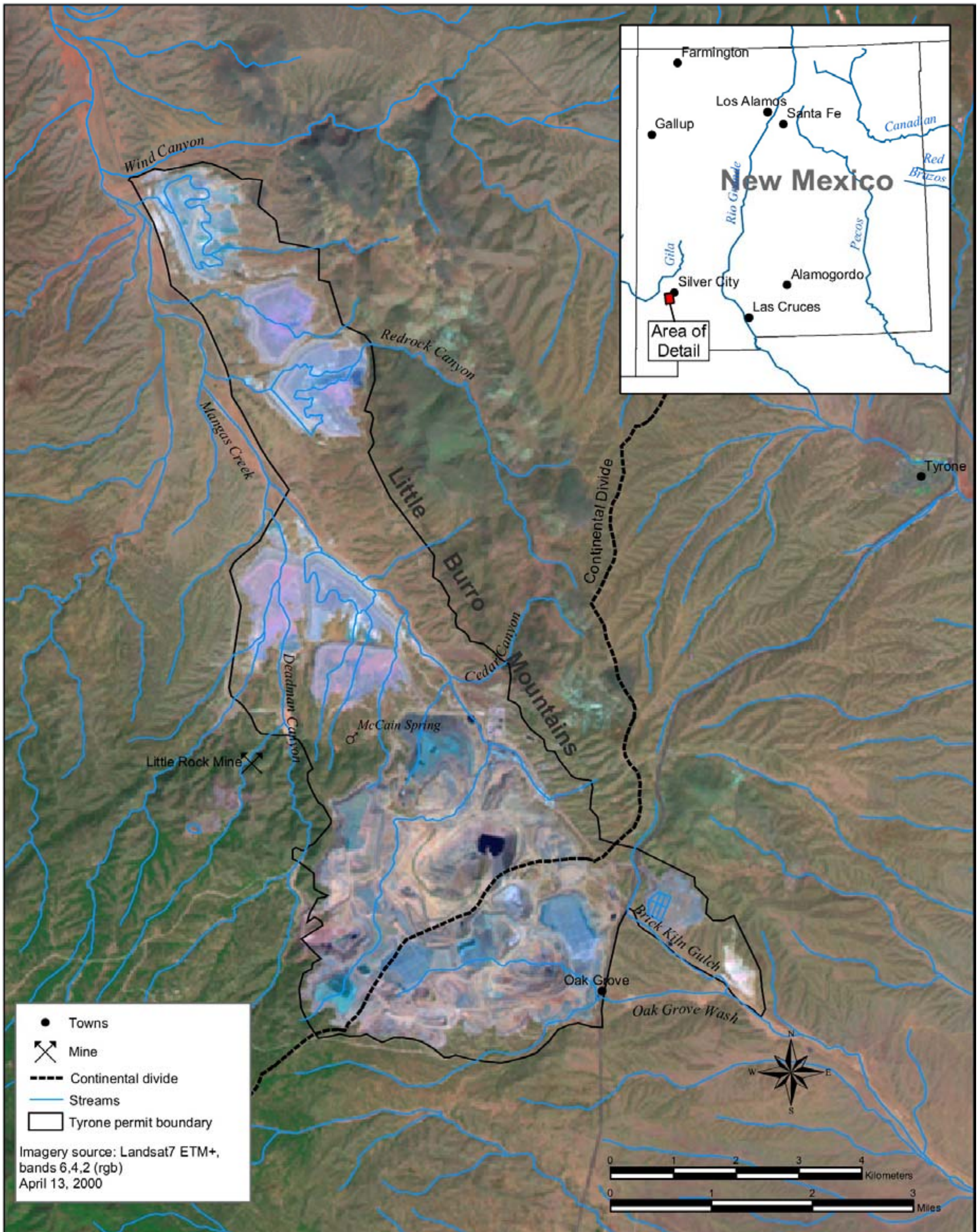

Figure 2.1. Location of the Tyrone Mine in southwestern New Mexico.

Source: Landsat7, 2002.

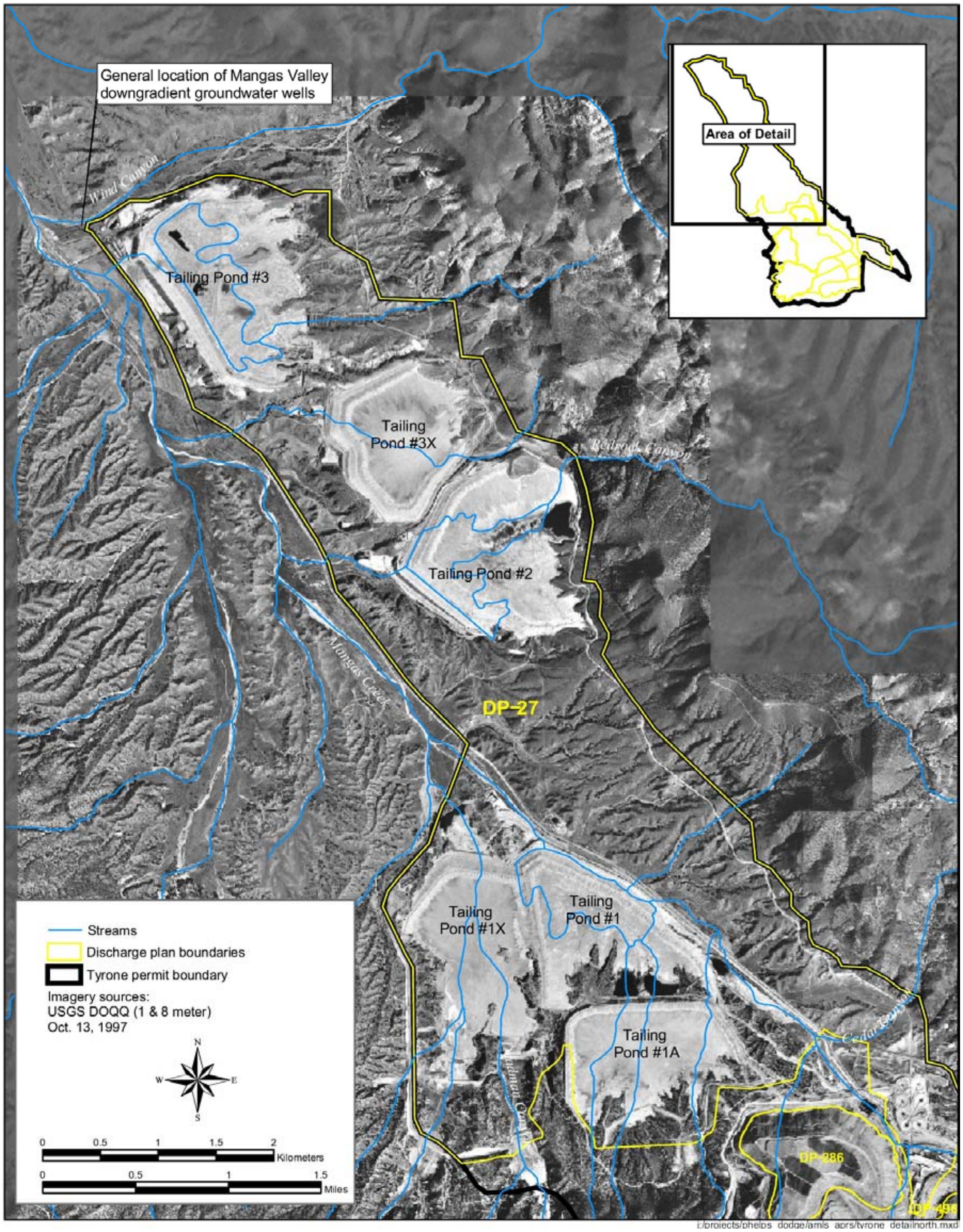

Figure 2.2a. Mine permit boundary, mine facilities, and discharge permit (DP) area boundaries at the Tyrone Mine, for the northern portion of the mine, including the Mangas Valley tailings facilities.

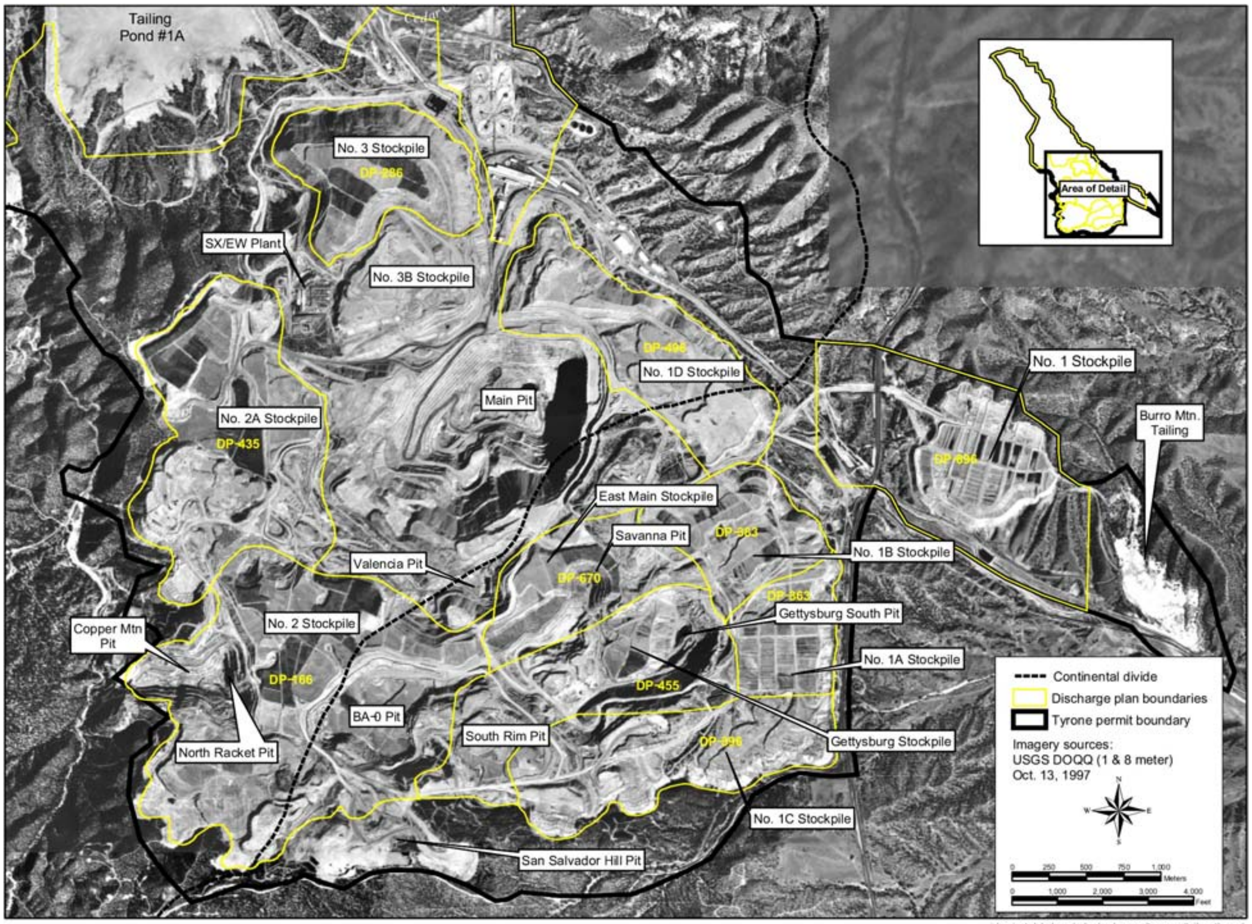

Figure 2.2b. Mine permit boundary, mine facilities, and DP area boundaries at the Tyrone Mine, for the southern portion of the mine, including the open pit and stockpiles.

Source: USGS, 1997.

Open pit mining began in 1967, when excavations were made to expose and mine the ore. By September 1969, 95 million tons of overburden had been removed from the Tyrone pit to allow the mining of copper ore to begin (SARB, 1999, p. 4). The Tyrone pit has been developed with 50 foot benches, with gradients of 1.3 feet horizontal to 1 foot vertical (M3, 2001, p. 2-19). In February 1999, the Tyrone open pit was approximately 1,400 feet deep and covered an area of about 1,400 acres (M3, 2001, p. 2-19). Parts of the pit have been partially or completely backfilled. The pit is actively dewatered, which induces groundwater flow toward the pit (M3, 2001, p. 2-7).

Figure 2.3. Tyrone open-pit mine in October 2002.

Figure 2.4. Tyrone tailings impoundments in the Mangas Valley in October 2002 (behind tanks).

Initially, copper was recovered from the ore using a copper concentrator, with an initial capacity in 1969 of 29,000 tons of ore per day. In 1972, the concentrator capacity was expanded to 50,000 tons per day (SARB, 1999, p. 4). The copper concentrator operated from 1969 to 1992 (M3, 2001, p. 2-2), using grinding and flotation to increase the copper concentration before shipping the concentrate off-site for smelting. The concentrator process produced tailings as a byproduct, which were then piped to one of six tailings impoundments in the Mangas Valley (SARB, 1999, p. 4) (Figure 2.4).

Stockpile leaching began in 1972 on the No. 1 stockpile, with copper extracted from the leach solution in a precipitation plant. Additional leaching operations began in 1984, with the opening of the SX/EW plant (SARB, 1999, p. 4). In the SX/EW process a weak acid solution drips through a network of pipes on top of the leach piles to leach copper out of the ore, forming a pregnant leach solution (PLS) with a high copper concentration. The PLS is collected in uncovered ponds near the leach stockpiles (Figure 2.5), and then pumped to the SX/EW plant, where it is first

Figure 2.5. PLS collection pond at the Tyrone Mine.

contacted with an organic solvent, known as extractant, in the solvent extraction (SX) stage. The copper-bearing organic solution is stripped of copper by mixing it with a strongly acidified aqueous solution, which is transferred to the electrowinning (EW) process. During electrowinning, an electric current plates the copper from the copper sulfate solution onto a metallic copper cathode, which is 99.99% pure copper. After copper is stripped from the PLS, the PLS is recycled for further leaching (Dresher, 2001). In 2003, Discharge Permit 166 allowed the discharge of up to 35 million gallons per day of leach solution to the No. 2 leach stockpile and up to 49 million gallons per day of PLS to the SX/EW plant (NMED, 2003).

Since 1992, Tyrone has been solely a mine-for-leach operation (U.S. Securities and Exchange Commission, 2002, p. 3). From 1997 to 2001, annual production of copper through the SX/EW process at the Tyrone Mine ranged from 76,400 to 82,600 tons (U.S. Securities and Exchange Commission, 2002, p. 7). An additional 2,600 tons of copper were produced by the precipitate process in 1997, but no precipitate copper has been produced since (U.S. Securities and Exchange Commission, 2002, p. 7).

2.3 Identification of Potentially Responsible Parties

The Trustees have identified PDTI and its parent company, Phelps Dodge Corporation, as the primary potentially responsible party (PRP) for the Tyrone Mine. The term PRP as used in this document refers to parties potentially liable for natural resource damages under CERCLA. Phelps Dodge Corporation has been the owner of the Tyrone Mine since its development as an underground mine in 1913. At various times, different wholly owned subsidiaries of Phelps Dodge Corporation have operated the mine or the SX/EW plant. United States Natural Resources, Inc. (USNR) leached copper at the Copper Mountain stockpile and operated a precipitation plant in Deadman Canyon, west of the No. 2 leach stockpile, from 1970 to 1976 (Harlan & Associates, 2001, p. 2). In 2000, PDTI received permission from NMED and the New Mexico Mining and Minerals Division to include the former USNR stockpile and precipitation plant in its Discharge Permit #166, and to remove the former Copper Mountain stockpile, indicating that PDTI had assumed responsibility for the USNR infrastructure. Currently, PDTI is the operator of the Tyrone Mine. In 2002, Phelps Dodge Corporation was #428 on the Fortune 500 list of the largest corporations in the United States, with annual revenues of more than $3.7 billion.

2.4 Releases of Hazardous Substances

Studies completed for the Tyrone Mine Closure/Closeout Plan (M3, 2001) have documented releases of hazardous substances from the mine and have identified actual or potential sources of these releases. Further evidence of hazardous substance releases was documented at site visits to the Mine by the USFWS, spill reports made by Phelps Dodge to NMED, and information provided through the Toxics Release Inventory (TRI) program of the U.S. Environmental Protection Agency (U.S. EPA).

2.4.1 Hazardous substances released

Hazardous substances (as given in the List of Hazardous Substances and Reportable Quantities, Table 302.4 at 40 CFR § 302.4) are present in source materials at Tyrone Mine and have been released to the environment. Whole-rock analyses indicate that the following hazardous substances are present in source rock at Tyrone Mine: arsenic, cadmium, cobalt, chromium, copper, lead, manganese, nickel, and zinc (Daniel B. Stephens & Associates, 1997a).[1] In addition, a subsample of mineral assemblages was subjected to the synthetic precipitation leach procedure (SPLP) test. Leachate from these tests included the hazardous substances arsenic, cadmium, copper, manganese, and lead in concentrations greater than State of New Mexico regulatory criteria for domestic water supply or irrigation use (NMWQCC 20 NMAC 6.2, Subpart III, 3103) (Daniel B. Stephens & Associates, 1997a). In addition, the SPLP leachate included detectable concentrations of the hazardous substances cobalt and zinc (Daniel B. Stephens & Associates, 1997a).

Additional sources of hazardous substances come from mine operations. Sulfuric acid is a listed hazardous substance that is used to leach copper ore from leach stockpiles. Raffinate is a low pH solution used in the SX/EW process. Diesel oil also is stored on-site.

Elevated concentrations of hazardous substances detected in surface water, seeps, and groundwater at the mine indicate that hazardous substances present in source materials at the Tyrone Mine have been released to the environment. These hazardous substances include, but may not be limited to, arsenic, cadmium, cobalt, copper, lead, manganese, nickel, and zinc (see Tables 3.5 to 3.8 of this report). In addition, under the requirements of the TRI, PDTI reported releases to the environment between 1998 and 2000 of ammonia, cobalt, copper, lead, polycyclic aromatic compounds, and sulfuric acid (U.S. EPA, 2003).

1. The Trustees realize that hazardous substances occur naturally in source rock at the Tyrone Mine. The Trustees are pursuing an NRDA at the Tyrone Mine because of evidence that these substances have been released to the environment in concentrations potentially sufficient to injure natural resources for which the Trustee agencies have trusteeship.

2.4.2 Sources of hazardous substance releases

Potential sources of hazardous substance releases at the Tyrone Mine include, but are not limited to, open pits, tailings impoundments, waste rock and leach stockpiles, the SX/EW plant and associated infrastructure, and plant spills and releases. Each of these sources is discussed briefly in the following sections.

Tailings impoundments

There are six tailings impoundments (also called tailings ponds or tailings dams) in the Mangas Valley, as well as a historical tailings area near Burro Mountain, which drains toward the Mimbres basin (Figure 2.2; Table 2.1). The total footprint area of the tailings ponds is 2,254 acres. Releases of hazardous substances, including but not limited to cadmium, copper, and zinc, from the tailings impoundments have been multiple and at times continuous, beginning at least from the time when the tailings impoundments became inactive in 1992 and surface materials started to oxidize and extending to the present. Hazardous substance releases from the tailings impoundments may have occurred during the time period of active operations (1969-1992), but information on this time period was not available for review for this preassessment screen, with the exception of information about a tailings spill in 1980.

Table 2.1. Tailings ponds at the Tyrone Mine

Tailing pond	Size (acres)[a]	Description[b]
Tailing Pond #1	352	Uncovered; adjacent to Mangas Creek; in use from approx. 1969 through end of 1970s
Tailing Pond #1A	321	Uncovered; upstream of Tailing Pond #1
Tailing Pond #1X	377	Uncovered; adjacent to Mangas Valley; used for temporary water disposal; includes a groundwater pump-back system
Tailing Pond #2	423	Uncovered; adjacent to Redrock Canyon; used for temporary water disposal
Tailing Pond #3	443	Uncovered; decommissioned in 1980 after large tailings spill
Tailing Pond #3X	280	Uncovered; adjacent to Redrock Canyon
Burro Mountain tailings areas	58	Uncovered; received tailings from 1917 to 1921; in Mimbres Basin drainage
Total area	2,254	

a. Source: Footprint area of tailings ponds (top surface plus sideslopes) in 2001, as reported in Table 5-1 in M3, 2001.
b. Source: Appendix C in M3, 2001.

The six tailings impoundments at Tyrone are geochemically and mineralogically similar (SARB, 1999). The tailings ponds at Tyrone contain primarily sulfide-bearing mineral assemblages (Daniel B. Stephens & Associates, 1997c). SPLP test data for surficial samples from the tailings impoundments indicated that leachate from these samples contained the hazardous substances cadmium, cobalt, copper, manganese, and zinc (Daniel B. Stephens & Associates, 1997c). Samples of tailings collected by the USFWS in 2000 confirmed that tailings contained elevated concentrations of the hazardous substances arsenic, cadmium, chromium, copper, manganese, lead, and zinc (Table 2.2).

Table 2.2. Concentrations of hazardous substances in Tyrone Mine tailings ponds (mg/kg dry weight)[a]

Tailings pond	As	Be	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Zn
Burro Mountain	3.56	0.436	0.596	< 4.81	2,868	0.128	114	< 4.81	68.5	114
#1	1.55	< 0.198	0.23	< 4.94	149	< 0.0198	25.4	< 4.94	< 4.94	23.2
#1A	1.15	< 0.196	4.24	6.84	2,629	< 0.0196	157	< 4.91	34.2	623
#1X	1.64	< 0.198	3.58	5.82	1,523	< 0.0198	118	< 4.95	86.4	390
#2	2.46	0.267	2.68	< 4.81	988	< 0.0192	86.6	< 4.81	106	366
#3X	2.12	0.276	8.13	6.32	3,203	< 0.0199	336	< 4.97	84.1	930

a. Composite samples of tailings samples collected from top oxidized layer in September 2000.

The six unlined tailings impoundments in the Mangas Valley contain acid-generating materials. The Supplemental Materials Characterization (Daniel B. Stephens & Associates, 1997c) found that the average acid-base accounting (ABA) for the Nos. 1A and 2 tailings ponds were -38.9 and -26.7, respectively, indicating significant acid-generating potential. As water drains from the tailings, the upper portions of the tailings ponds are exposed to the atmosphere, causing the oxidation of sulfide minerals. As precipitation ponds on the surface of the tailings impoundments and interacts with these upper oxidized tailings, the concentration of metals, total dissolved solids, and sulfate in the water will increase, while pH will decrease.

Figure 2.6. Water ponded on the surface of Tailings Pond #1A in October 2002.

Consequently, following precipitation events, ponded water in contact with oxidized tailings can serve as a pathway of hazardous substances to birds and wildlife attracted to ponded water in the arid southwest (Figure 2.6). The ponds are intermittent, depending on precipitation and evaporation rates, but remain a source of future releases following periods of surface water accumulation. High concentrations of hazardous substances, including cadmium, copper, manganese, nickel, and zinc, and low pH have been measured in these intermittent ponds formed on the surface of tailings impoundments (see Table 3.1 of this report).

Figure 2.7. Tailings eroded into the channel above the Mangas Creek. A row of dead cottonwood trees is adjacent to the tailings.

Multiple surface piles of tailings are able to serve as continuous sources of hazardous substance releases through 1) precipitation-induced erosion, storm-water runoff, and windblown emissions from tailings; 2) formation of surface water on tailings ponds in response to precipitation events; and 3) multiple spills of tailings. An example of erosion of tailings into the area surrounding the Mangas Creek, observed in October 2002, is shown in Figure 2.7. In 1989, the report of a tailings pond inspection by the New Mexico Health and Environment Department noted serious erosion of tailings materials at Dam #3, resulting in gullies more than 10 feet deep and 5 feet wide, as well as erosion of the reclaimed area near Dam #3 that had been covered with top soil following the 1980 tailings spill (Dye, 1989). An inspection in 2001 noted rills, gullies, and exposed tailings in the same area (Phillip and Reed, 2001). We did not review any information measuring windblown deposition of tailings on soils or in ephemeral waterways, but this deposition is likely given the large surface area of uncovered tailings impoundments.

Multiple spills of tailings have served as releases of hazardous substances that are present in the tailings (Table 2.3). The largest event occurred at the No. 3 tailings dam in 1980, spilling 2.6 million cubic yards of tailings into the Mangas Valley (Table D-2 in Daniel B. Stephens & Associates, 1997b). Additional tailings spills were reported in 1990, 1992, and 2001 (Table 2.3).

Waste rock and leach stockpiles

Stockpiles used for leaching encompass approximately 1,757 acres in eight different piles (Table 2.4), while waste rock stockpiles encompass approximately 792 acres in four stockpiles. Releases of hazardous substances, including but not limited to cadmium, copper, and zinc, from stockpiles at the site have been multiple and at times continuous, most likely beginning with the

Table 2.3. Tailing spills at the Tyrone Mine from 1980 to 2001

Date	Description of spill or release	Citation
October 1980	2.6 million cubic yards of tailings spilled into Mangas Valley following a breach in the No. 3 tailings pond	a
1990	Minor tailing spills from the No. 1 tailing pond in January 1990, and similar minor spills from the No. 2 tailing pond during 1990	a
August 1992	Minor tailing spills from the No. 1 tailing pond	a
August 16, 2001	5 tons of tailings spilled into the Mangas Wash from the stormwater containment dike at the No. 1 tailings dam	b

a. Table D-2 in Daniel B. Stephens & Associates, 1997b.
b. Vaughn, 2001c.

Table 2.4. Leach and waste stockpiles at the Tyrone Mine

Stockpile	Size (acres)[a]	Description[b]
No. 1 stockpile	136	Leach stockpile with PLS collection system. In Mimbres basin drainage.
No. 1A stockpile	148	Leach stockpile with PLS collection system. In Mimbres basin drainage.
No. 1B stockpile	125	Leach stockpile with PLS collection system. In Mimbres basin drainage.
No. 2 stockpile	421	Leach stockpile with PLS and seepage collection systems. Located inside of main pit groundwater capture zone.
No. 2A stockpile	388	Leach stockpile with PLS and seepage collection systems. Inside of main pit groundwater capture zone.
No. 3 stockpile	272	Leach stockpile with PLS collection system, interceptor trenches and downgradient pumping. SE portion is inside main pit capture zone; NW portion is in Gila River basin drainage.
Gettysburg stockpile	100	Leach stockpile created by backfilling existing pit. Stockpile associated with PLS collection pond.
East main stockpile	167	Leach stockpile created by backfilling existing pit. Stockpile associated with PLS collection pond.
Total for leach stockpiles	**1,757**	
No. 1C stockpile	258	Waste stockpile not used for leaching. Partial capture of groundwater by Gettysburg pit dewatering. In Mimbres Basin drainage.
No. 1D stockpile	287	Overburden and waste stockpile not used for leaching. Inside main pit groundwater capture zone.
No. 3B stockpile	138	Waste stockpile not used for leaching. Inside main pit capture zone.

Table 2.4. Leach and waste stockpiles at the Tyrone Mine (cont.)

Stockpile	Size (acres)[a]	Description[b]
Upper main stockpile	109	Waste stockpile created by backfilling existing pit.
Total for waste rock stockpiles	**792**	

a. Source: Footprint area of stockpiles (top surface plus sideslopes) in 2001, as reported in Table 5-2 in M3, 2001, and Table 4-1 in Daniel B. Stephens & Associates, 1999b.
b. Source: Appendix C in M3, 2001 (also, p. 2-24 to 2-26 in M3, 2001 for in-pit stockpiles).

start of copper recovery in 1969 and extending to the present. Multiple surface piles of waste rock and leach stockpiles at the Tyrone Mine are able to serve as continuous sources of hazardous substances through 1) releases of PLS from leach stockpiles, 2) acidic seepage from acid-mine drainage at waste rock piles, and 3) precipitation-induced erosion, storm-water runoff, or windblown emissions from waste rock and leach stockpiles. An example of precipitation-induced erosion on a leach stockpile is shown in Figure 2.8.

Figure 2.8. Gully erosion on the No. 3 stockpile at the Tyrone Mine.

Waste rock and leach stockpiles at Tyrone contain primarily sulfide-bearing mineral assemblages, as well as neutral leached cap and oxide mineral assemblages (M3, 2001). SPLP test data for stockpile samples indicated that leachate from these samples contained the hazardous substances cadmium, cobalt, copper, manganese, and zinc (M3, 2001).

PLS has been released from leach stockpiles into groundwater because of incomplete capture of PLS by collection systems. PLS contains high concentrations of hazardous substances. Samples of PLS captured in a perched zone water sample at the No. 3 stockpile in 1990 had concentrations of 5,200 mg/L copper, 1,690 mg/L manganese, and 2,250 mg/L zinc (Daniel B. Stephens & Associates, 1997d, p. 5-16). Perched PLS seepage was detected in 1996 at the No. 1A leach system, and in 1996 and 1997 at the No. 1B leach stockpile. Elevated metals, sulfate, fluoride, and TDS and decreased pH were found in regional groundwater at the East Main Pit leach system, but exact sources have not been identified. Perched PLS seepage was found in 1997 at the No. 1 stockpile (Daniel B. Stephens & Associates, 1997b).

At waste rock stockpiles, the presence of sulfide-bearing mineral assemblages results in significant acid-generating potential. At Tyrone, 80% of the stockpile samples had negative acid-base accounting (ABA) (Table 7 in Daniel B. Stephens & Associates, 1997c). As a result, the stockpiles have the capacity to produce acidic seeps at the toes of the stockpiles, which serve as sources of hazardous substances to groundwater, especially because the stockpiles are not lined with high-density polyethylene or any other barrier to separate the rock materials and the soil. Acidic seeps are present at the toes of several stockpiles, including the No. 2 stockpile in Deadman Canyon, the USNR stockpile in Deadman Canyon, and the west side of the No. 2A stockpile (Daniel B. Stephens & Associates, 1999b). Concentrations of dissolved hazardous substances measured in the No. 5E seep at the No. 2 stockpile were as high as 1,020 mg/L of copper, 70.3 mg/L of manganese, and 62.5 mg/L of zinc (Harlan & Associates, 2001). All of these seeps, which are in the discharge permit (DP)-166 area, have served historically as sources of hazardous substances to perched zone water in Deadman Canyon (Daniel B. Stephens & Associates, 1997b). By 1997, HDPE-lined impoundments were constructed to capture seepage flow, as a corrective action for impacts to groundwater (Daniel B. Stephens & Associates, 1997b). Acidic seeps also are present in the No. 1C stockpile in Oak Grove Wash, within the DP-396 area.

SX/EW plant and associated infrastructure

Releases of hazardous substances, including but not limited to cadmium, copper, zinc, raffinate, and sulfuric acid, from the SX/EW plant and associated infrastructure have been multiple and at times continuous, most likely beginning with the opening of the SX/EW plant in 1984 (p. 4, SARB, 1999) and extending to the present. Raffinate contains the hazardous substance sulfuric acid (Daniel B. Stephens & Associates, 1997d). Hazardous substance releases are likely to have occurred during the time period of operation of the precipitation plant (1972-1997), but information on this time period was not available for review for this preassessment screen. The Supplemental Groundwater Study at the Tyrone Mine did note the precipitation plant as a source with the potential to affect water quality, and stated that "initial drilling results suggest that spills may have affected perched water quality" (Table D-2 in Daniel B. Stephens & Associates, 1997b).

Figure 2.9. PLS entering uncovered pond at the No. 3 stockpile at the Tyrone Mine.

The SX/EW plant is associated with uncovered collection ponds for the PLS and a system of pipes to pump the PLS to the SX/EW plant. These uncovered ponds serve as ongoing sources of hazardous substances to wildlife that may come into contact with the ponds (Figure 2.9). Plant releases and upsets from the SX/EW plant and associated infrastructure have resulted in intermittent releases of hazardous substances into the environment, including spills of raffinate and PLS (Table 2.5). Table 2.5 gives a chronology of spills and releases at the Tyrone Mine from 1997 to 2002 associated with the SX/EW plant and infrastructure, based on documents in the State of New Mexico's administrative record for groundwater discharge permits at the Tyrone Mine. Additional spills and releases are likely to have occurred before and after this time period.

Table 2.5. Plant spills and releases at Tyrone Mine from infrastructure associated with the SX/EW plant

Date	Description of spill or release	Citation
January 1997	65,000 gallons of raffinate leaked from a ruptured weld in a raffinate pipeline	a
September 26, 2001	720,000 gallon spill of raffinate from SX/EW raffinate tanks	b
September 27, 2001	10,000 gallon spill of PLS from No. 2A West PLS tank	c
December 9, 2001	300 gallon spill of a raffinate and organic solution from pipeline at 2A-raffinate booster tank	d
January 26, 2002	4,000 gallon spill of raffinate at raffinate tank area in vicinity of No. 3 stockpile	e

a. Tables D-1 and D-2 in Daniel B. Stephens & Associates, 1997b.
b. Vaughn, 2001b.
c. Vaughn, 2001d.
d. Vaughn, 2001e.
e. Reed, 2002.

Plant spills and releases

In addition to the spills and releases of tailings, raffinate, and PLS, described in Tables 2.2 and 2.4, additional spills and releases of mine process water, stockpile seepage, and stormwater at the Tyrone Mine may have served as sources of hazardous substances (Table 2.6). For example, concentrations of hazardous substances in the seep 5E pond, which overflowed in August 2001, were 616 mg/L copper and 31.4 mg/L zinc two months before the spill (Harlan & Associates, 2001). Additional spills preceding, during, and following the 1994-2001 period in Table 2.6 are likely to have occurred.

2.4.3 Time, quantity, duration, and frequency of releases

At the Tyrone Mine tailings ponds, releases of hazardous substances have occurred at least from 1980 to the present, which is the time period when there have been documented spills and formation of ponded water on oxidized tailings. Ponded water in contact with oxidized tailings and spills of tailings have served as sources of releases from the tailings ponds. Erosion of tailings, storm-water runoff, and windblown emissions are likely sources of releases as well. A spill of 2.6 million cubic yards of tailings into the Mangas Valley in 1980 is one measure of the quantity of releases. The frequency of releases from ponded water depends on the time period when the ponded water is present, which is a function of precipitation and evaporation. Inspections at different times of the year, including May (before the monsoon season) and October (during the monsoon season), have documented persistence of ponded water (Dye, 1989; USFWS site visit notes).

Table 2.6. Plant spills and releases at Tyrone Mine, excluding spills of tailings, PLS, and raffinate

Date	Description of spill or release	Citation
1994	No. 2 diesel fuel oil from two broken pipes was detected in perched groundwater.	a
No date	Spills from precipitation plant are inferred to be a cause of impacts to perched water quality in the Oak Grove Wash area.	a
July 31, 2000	3,600 gallons of seepage (likely stormwater) from the No. 1B leach stockpile which was contained in a collection ditch.	b
May 12, 2001	500-1000 gallons of solution leaked from the pipeline draining the 1A-S1 sump near the 1B stockpile into a collection ditch.	c
August 16, 2001	150 gallons from the Seep 5E pond overflowed with 75 gallons entering Deadman Canyon. Seepage had a pH of 4 and Deadman Canyon was flowing at approximately 50 gpm at the time.	d

a. Tables D-1 and D-2 in Daniel B. Stephens & Associates, 1997b.
b. Shelley, 2000.
c. Vaughn, 2001a.
d. Shelley, 2001.

At the waste rock and leach stockpiles, releases of hazardous substances are expected to have occurred from 1969 to the present, which is the time period of active copper mining. As an example of quantity of releases, the perched seepage collection systems in the No. 3 stockpile area alone, pumped 33.6 gallons per minute in 2002 (Daniel B. Stephens & Associates, 2002, p. 7). Before the collection systems were in place, this volume of seepage would have served as a source of hazardous substances to groundwater. Erosion of rock, storm-water runoff, and windblown emissions are likely sources of releases as well. Releases of hazardous substances have been ongoing in the areas of the waste rock and leach stockpiles.

At the SX/EW plant and associated infrastructure, releases of hazardous substances are likely to have occurred from 1984 to the present, which is the time period of active operation. Uncovered ponds provide ongoing sources of hazardous substance releases to biota that come into contact with the ponds (Figure 2.9). In addition, periodic spills and releases have resulted in releases of hazardous substances from these facilities (Table 2.5).

In summary, existing reports and observations at the Tyrone Mine have identified sources of hazardous substances, pathways by which hazardous substances are released and transported to expose other natural resources, continual physical processes of release of hazardous substances, and elevated concentrations of hazardous substances in groundwater and in standing water in contact with oxidized tailings. Together, these observations confirm that hazardous substance releases from the Tyrone Mine facilities have been multiple and at times continuous, and most likely extend from at least 1969 to the present.

2.5 Relevant Operations Occurring at or near the Mine

Relevant operations occurring at or near the mine include ongoing mining activities by PDTI, such as blasting in the open pit, transport of ore rock to leach stockpiles, transport of waste rock to waste rock piles, leaching of leach stockpiles, collection of PLS, and operation of the SX/EW plant. PDTI actively dewaters the open pit.

The Little Rock copper mine, owned by PDTI, is an inactive copper mine and ore leaching facility located adjacent to the northwest corner of the main Tyrone facility. Acidic, high metal concentration ponds and seeps are an ongoing hazard to wildlife in this otherwise undisturbed area adjacent to the Gila National Forest. PDTI has received approval for permits to reopen the Little Rock mine. Depressed copper markets, however, have postponed any active operations. Waste water from the Little Rock mine will be discharged to the Tyrone 1X tailings pond (PDTI, 1999).

PDTI maintains groundwater discharge permits with the NMED Ground Water Quality Bureau (Table 2.7). These permits require ongoing monitoring and corrective action when spills occur or impacts to groundwater are discovered. For example, under DP-166, the assessment of potential seepage from the No. 2 stockpile to Deadman Canyon resulted in corrective actions, including 1) installation of interception and barrier systems near seep #5E and near the USNR leach dumps in 1997, 2) movement of waste materials from west to east of the pre-mining drainage divide in 1998, 3) installation of a secondary collection trench downgradient of the seep #5E pond in 2000, 4) installation of seepage collection systems in 1998, and 5) removal of the USNR Copper Mountain stockpile (Harlan & Associates, 2001, pp. 1-3).

Under DP-286, an investigation in 1990 of PLS seepage from the No. 3 stockpile to perched seepage zones and the regional aquifer led to installation of an active containment and remediation program. The program includes a series of collection systems to remove impacted water and individual pumping wells at the toe of the stockpile (Daniel B. Stephens & Associates, 2002, pp. 1-6).

Under DP-363 and the pending DP-896, investigative and corrective activities began in 1996 to address contamination in a perched seepage zone in Lower Oak Grove Wash that extended approximately 3.4 miles east of the No. 1A stockpile. Corrective activities include pumpback wells that extract residual seepage from perched seepage zones between Upper and Lower Oak Grove Wash and the No. 1 stockpile area, and installation of a PLS collection system at the No. 1A stockpile in 1999 that includes surface catchments, barrier trenches, an aboveground PLS holding tank, an HDPE-lined overflow pond, and a clay-lined stormwater collection pond (Tetra Tech EM Inc., 2001, pp. 1-4).

Table 2.7. Summary of discharge permits held by Phelps Dodge Tyrone, Inc.

Discharge permit	Location and facilities[a]
DP-27	Mangas valley tailing unit: 1, 1A, 1X, 2, 3, and 3X tailings ponds
DP-166	Mine stockpile unit: No. 2 leach system
DP-286	Mine stockpile unit: No. 3 leach system and No. 3 and No. 1D stockpiles
DP-363	Mine stockpile unit: No. 1A leach system
DP-383	Mine stockpile unit: No. 1B leach system
DP-396	Mine stockpile unit: No. 1C leach system
DP-435	Mine stockpile unit: No. 2A leach system
DP-455	Mine stockpile unit: Gettysburg leach system
DP-670	Mine stockpile unit: East Main Pit leach system
DP-896 (pending)	East Mine Unit
DP-1341 (proposed)	Proposed supplemental discharge permit for closure

a. Sources: pp. 2-24 to 2-27 in M3, 2001; NMED, 2002.

Additional resource management activities at the mine include adding lime to increase the pH of standing water on the tailings ponds and hazing of birds at the tailings ponds to reduce exposure. Cattle grazing takes place north and east of the mine site, primarily through the Phelps Dodge subsidiary Pacific Western Land Company (M3, 2001, p. 2-3).

2.6 Damages Excluded from Liability

The Trustees currently are not aware of any natural resource damages that would be excluded from liability under CERCLA. Based on the available information, none of the conditions for exclusion from CERCLA apply [43 CFR § 11.24(b)]. Specifically:

1. **The damages resulting from the releases have not been specifically identified as an irreversible and irretrievable commitment of natural resources in an environmental impact statement or other comparable environmental analysis, no decisions were undertaken by the State to grant permits or licenses authorizing such commitments of natural resources, and PRP facilities were not otherwise operating within the terms of such permits or licenses.** Although the Tyrone Mine operates under a number of permits, the Trustees are currently unaware of any terms of such permits or licenses that would authorize injuries to natural resources such as birds, wildlife, surface water, and groundwater and resulting damages.

2. **Damages and the releases of hazardous substances from which such damages resulted have not occurred wholly before enactment of CERCLA.** Information reviewed for this preassessment screen indicates that releases of hazardous substances, natural resource injuries, and associated damages have occurred since 1980 and continue through to the present.

3. **Damages have not resulted from the application of a pesticide product registered under the Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. §§ 135-135k.** This criterion does not apply to releases from the Tyrone Mine, which do not involve applications of a pesticide product.

4. **Damages have not resulted from any other federally permitted release, as defined in §§ 101(10) of CERCLA.** Although the Tyrone Mine operates under a number of permits, including groundwater discharge permits issued by the NMED, the Trustees are currently unaware of any terms of such permits or licenses that would authorize injuries to natural resources such as birds, wildlife, surface water, and groundwater and resulting damages.

3. Preliminary Identification of Resources at Risk [43 CFR § 11.25]

3.1 Preliminary Pathway Identification [43 CFR § 11.25(a)]

As described in Chapter 2, actual or potential sources of hazardous substance releases to the assessment area include inactive and uncovered tailings impoundments (2,250 acres); waste rock and leach stockpiles (2,500 acres); the SX/EW plant and associated infrastructure, including uncovered ponds and pipelines; and plant releases and spills. Exposure pathways that may transport hazardous substances released from sources to other natural resources include direct contact of biota with hazardous substances, surface water and sediments, groundwater, aerial transport, soil, and food chain. Figure 3.1 depicts potential pathway relationships between sources, pathways (direct contact, aerial transport, soil, and food chain), and natural resources. Figure 3.2 depicts potential food chain pathways at the Tyrone Mine. Pathways of hazardous substance transport at the Tyrone Mine are described briefly in the sections below.

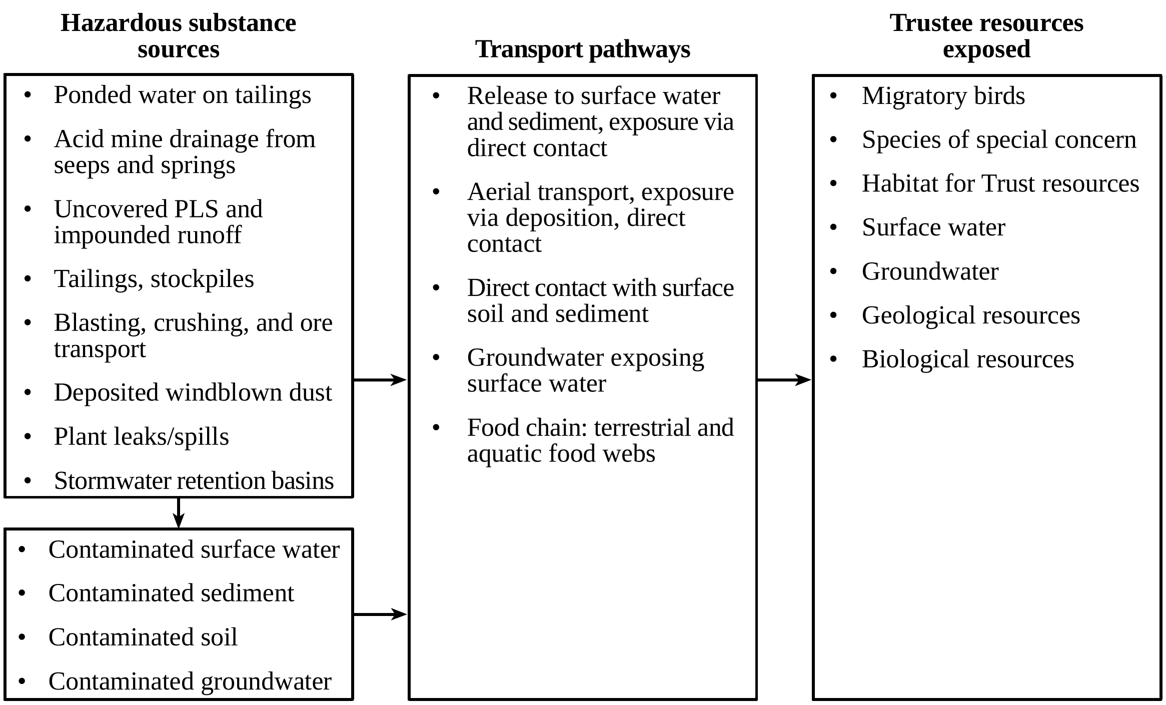

Figure 3.1. Potential hazardous substance transport pathways at the Tyrone Mine.

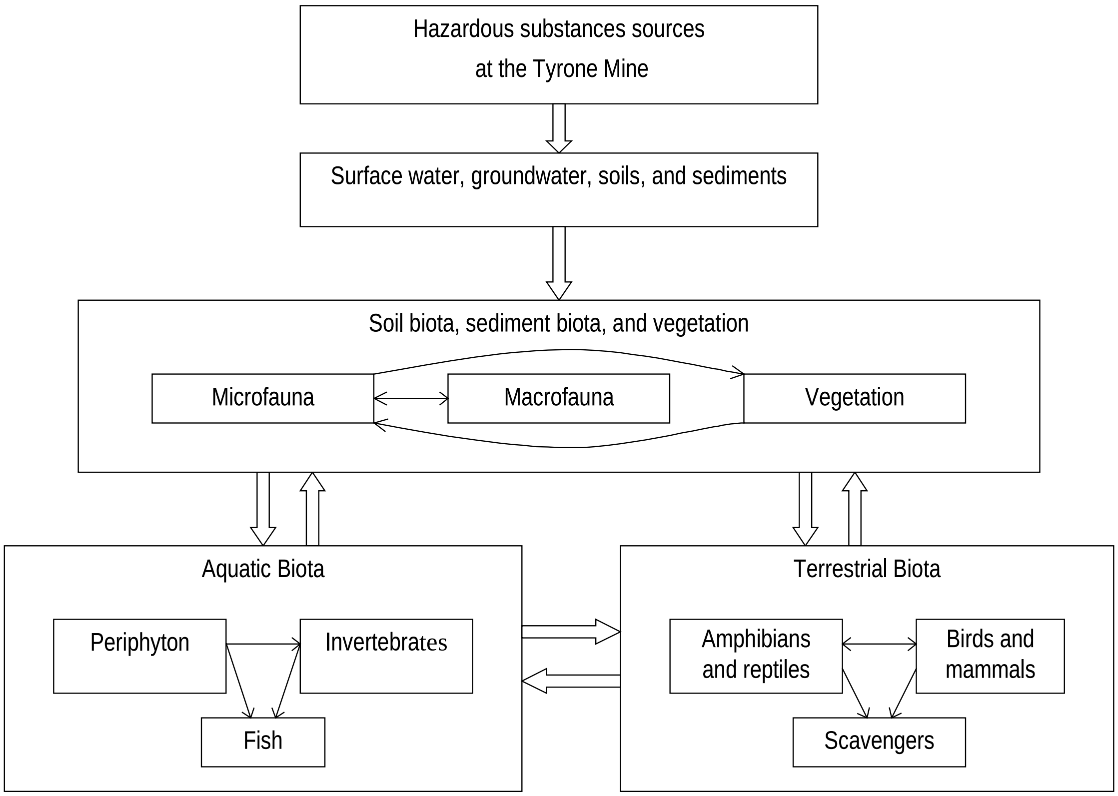

Figure 3.2. Potential foodchain pathways of hazardous substances at the Tyrone Mine.

3.1.1 Direct contact of biota with hazardous substances

Terrestrial biota may come in direct contact with hazardous substances through dermal, inhalation, and ingestion exposure from the 2,500 acres of leach stockpiles and waste rock, the 2,250 acres of uncovered tailings, and the 1,400 acre open pit (as of 1999) at the Tyrone Mine (Tables 2.1, 2.4 of this report) (M3, 2001, p. 2-19). Spills and releases of tailings, mine process waters, and hazardous substances provide additional points of direct contact of biota with hazardous substances (Tables 2.3, 2.5, 2.6 of this report).

As precipitation ponds on the surface of the tailings impoundments and interacts with upper oxidized tailings, the water will have increasingly elevated metals concentrations and decreasing pH.

Decreasing pH can result from acid (H^+) produced as a product of the oxidation and dissolution of pyrite (FeS_2)and other metal sulfides in tailings (U.S. EPA, 1994). The oxidation and dissolution of pyrite results in the formation of reduced iron (Fe^{2+}), sulfate (SO_4^{2-}), and acid (H^+):

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+. \tag{3.1}$$

The presence of the iron-oxidizing bacterium *Thiobacillus ferrooxidans* greatly accelerates the rate of oxidation of reduced iron:

$$4\ Fe^{2+} + O_2 + 4H^+ \leftrightarrow 4\ Fe^{3+} + 2\ H_2O. \tag{3.2}$$

The oxidized iron (Fe^{3+}) promotes the further oxidation and dissolution of pyrite, with additional releases of acid:

$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+. \tag{3.3}$$

Analyses of ponded water on top of tailings impoundments at the Tyrone Mine have shown elevated concentrations of hazardous substances arsenic, beryllium, cadmium, chromium, nickel, selenium, and zinc (Table 3.1). Elevated concentrations of hazardous substances in uncovered process water ponds (especially PLS ponds) and stormwater impoundments also can be contacted directly by biota (Figure 2.5, Table 3.2).

Table 3.1. Concentrations of hazardous substances measured in ponded water on Tyrone tailings dams (mg/L)

Location	**pH**	**As**	**Be**	**Cd**	**Cr**	**Cu**	**Mn**	**Ni**	**Se**	**Zn**
Sampled in December 1999 — Source: Table 5-12 in SARB, 1999										
Tailings Dam #2 — North Pond	2.7	No data	No data	0.9	No data	292	20.4	No data	No data	84.9
Tailings Dam #2 — South Pond	2.7	No data	No data	1.4	No data	780	25.7	No data	No data	222
Sampled on September 12, 2000 — Source: Unpublished data, samples collected by USFWS, analyzed at the Research Triangle Institute										
Burro Mountain tailings pond	2.9	0.0107	0.0391	0.263	0.0547	718	34.6	0.448	0.0145	32.5
Storm runoff to Pond 3	2.4	0.72	0.116	0.747	1.72	975	173	3.29	0.297	80.6
Tailings Pond (T.P.) #1	2.1	0.179	0.0803	1.22	1.81	536	38.4	1.71	0.073	88.9
T.P. #1A	2.1	0.22	0.347	11.5	4.64	4,916	342	6.43	0.359	1,610
T.P. #1X	2.6	0.0504	0.107	7.73	1.4	1,947	109	2.6	0.145	703
T.P. #2	2.3	0.299	0.137	4.43	2.17	1,522	151	2.99	0.272	534
T.P. #3X	2.5	0.25	0.347	21.9	4.19	5,844	738	10	0.534	2,014

Table 3.2. Concentrations of hazardous substances measured in uncovered process solution ponds (mg/L)

Location	pH	As	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
1A PLS Pond[a]	2.46	0.11	1.62	4.5	0.14	502	309	2.98	0.07	280
Gettysburg PLS Pond[a]	2.6	0.11	2.24	3.84	0.21	264	269	1.4	No data	220
#2 Leach Dump pregnant solution[a]	1.93	0.55	16.98	23.45	0.72	1,615	1,315	11.4	2.46	2,093
5E Pond, installed as part of corrective action[b]	3.7	< 0.005	0.203	0.93	< 0.01	414	32.7	0.31	0.07	20.7

a. Source: Table 4-1 in SARB, 2000. Averages calculated from approximately 9 samples at the 1A PLS Pond, 7 samples at the Gettysburg PLS Pond, and 10 samples at the #2 Leach Dump.
b. Source: Brunner (2002).

Several sources of information suggest that wildlife are exposed to hazardous substances from the ponded water on the Tyrone tailings ponds and from uncovered process water and stormwater ponds. The revised Closeout/Closure plan for the Tyrone Mine noted that wildlife were “using all of the water sources at or near the mine” (Daniel B. Stephens & Associates, 1999a). From September to November 2000, 177 mortalities of migratory birds, as defined in the Migratory Bird Treaty Act (16 U.S.C. §§ 703-712), were recorded at the Tyrone tailings ponds (unpublished USFWS data). In addition, during that time period, three ducks were found dead at PLS ponds, and five ducks and three other birds, including a great blue heron, were found dead at uncovered stormwater ponds (unpublished USFWS data). The Tyrone Mine began a hazing program for birds after discovery of bird remains in September 2000 (Figure 3.3), an indication that the ponded water serves as an exposure source for birds. The Trustees are unaware of any hazing efforts to prevent wildlife exposure to hazardous substances before 2000.

Comparisons of hazardous substance concentrations in invertebrate samples collected from reference sampling locations at the nearby Chino Mine with invertebrate samples collected from Tyrone Mine tailings ponds provide further evidence of exposure pathways at the Tyrone Mine (Tables 3.3, 3.4). For example, copper concentrations in unrinsed invertebrate samples from the Tyrone Mine tailings ponds were 75 to 442 times greater than mean copper concentrations in reference samples from the Chino Mine. Birds, reptiles, or mammals that ingest invertebrates with high concentrations of hazardous substances at the Tyrone Mine tailings ponds would be exposed to these substances.

Figure 3.3. Hazing cannon at a Tyrone Mine tailings pond, October 2002.

Table 3.3. Concentrations of hazardous substances in invertebrate samples collected from reference areas at the Chino Mine. Total concentrations in mg/kg; not specified as wet weight or dry weight; n = 6 samples.[a]

Value	As	Cd	Cu	Pb	Mn	Hg	Zn
Minimum	0.1	0.13	31.6	0.13	4.2	n.d.	39
Mean	0.142	0.2	39.6	0.18	6.62	n.d.	51.9
Maximum	0.15	0.32	53.8	0.24	9.3	n.d.	73.2

n.d. = Not detected.
a. Source: Table 3.3-3 in MFG, 2002.

Table 3.4. Concentrations of hazardous substances in unrinsed invertebrate samples collected at the Tyrone Mine tailings ponds in September 2000.[a] Concentrations in mg/kg dry weight.

Sample location	As	Cd	Cu	Pb	Mn	Hg	Zn
Tailings Pond #1A	1.48	32.9	14,790	28.2	703	0.06	4,134
Tailings Pond #2	2.33	5.71	3,002	< 1.98	170	0.107	778
Tailings Pond #3X	2.12	55.6	17,700	24.4	1,583	0.051	5,704

a. Source: Unpublished data, samples collected by USFWS, analyzed at the Research Triangle Institute.

3.1.2 Surface water/sediment pathway

Surface water is exposed to hazardous substances released from the Tyrone Mine through a variety of pathways. Mangas Creek, an ephemeral stream adjacent to the Tyrone Mine, which becomes perennial at Mangas Springs, has been exposed to hazardous substances through spills and potentially through runoff and erosion. In 1980, 2.6 million cubic yards of tailings spilled into the Mangas Valley following a breach in the #3 tailings pond (Table D-2 in Daniel B. Stephens & Associates, 1997b). After the breach, tailings were removed from Mangas Creek, deposited in small canyons adjacent to the creek, and covered with alluvial material. However, inspections in 1989 and again in 2001 noted that the reclaimed tailings area had eroded, removing the soil cover and exposing tailings (Dye, 1989; Phillip and Reed, 2001).

Elevated concentrations of copper at surface water flow samplers 1, 3, 4, 5, and 6 in Mangas Creek in August 2001 provide evidence that surface water has been exposed to hazardous substances (Table 3.5). These concentrations have exceeded water quality criteria established under Section 304(a)(1) of the CWA for the protection of aquatic life [43 CRF § 11.62(b)]. In addition, the Tyrone Closure/Closeout plan reported that copper and cadmium have been detected in surface water flow samplers 1, 2, and 4 in Mangas Creek downstream of the Tyrone Mine (M3, 2001). Arsenic, cadmium, chromium, copper, and lead have been detected in Mangas Creek below Mangas Springs, while manganese has been detected in Mangas Creek at the confluence with the Gila River (Table 3.5). Sampling points in the Gila River, downstream of the confluence with Mangas Creek, suggest that hazardous substances may have been transported from the mine to the Gila River (Figures 3.4, 3.5).

Intermittent flow in Deadman Canyon also has been exposed to hazardous substances. For example, on August 16, 2001, 150 gallons from the Seep 5E pond overflowed, and 75 gallons entered Deadman Canyon. Seepage had a pH of 4 and Deadman Canyon was flowing at approximately 50 gpm at the time (Shelley, 2001). Elevated concentrations of hazardous substances in Seep #5 in Deadman Canyon provide another surface water exposure pathway for biota (Table 3.6). The Trustees are currently unaware of any water chemistry data for ephemeral flow in Deadman Canyon.

Terrestrial biota are exposed to hazardous substances via the surface water/sediment pathway by ingestion and dermal absorption. Aquatic biota in Mangas Creek, and potentially in the Gila River, may also be exposed to hazardous substances via the surface water/sediment pathway by ingestion of contaminated prey and by gill uptake. Aquatic biota in Mangas Creek include the federally threatened fish species, spikedace (*Meda fulgida*), and loach minnow (*Tioroga cobitis*) (NMDGF, 2001).

Table 3.5. Concentrations of hazardous substances (mg/L) in ephemeral surface water in Mangas Creek. Values that exceeded the calculated aquatic life criteria (based on sample hardness) are indicated in shaded boxes.

Sampler	Arsenic	Cadmium	Copper	Lead	Source
Dissolved metals					
Flow sampler #1	n.d. = no data	< 0.005	0.05	< 0.05	a
Flow sampler #3	n.d.	< 0.005	0.05	< 0.05	a
Flow sampler #4	n.d.	< 0.005	0.04	< 0.05	a
Flow sampler #5	n.d.	< 0.005	0.09	< 0.05	a
Flow sampler #6	n.d.	< 0.005	0.01	< 0.05	a
Mangas Creek, below Mangas Springs	0.002	0.001	0.002	0.003	b
Total metals					
Mangas Creek, above Gila River on Route 809	< 0.005	< 0.001	0.180	0.030	c

a. Source: Brunner, 2002.
b. USGS STORET data for Station ID #09431100, October 15, 1980.
c. USGS STORET data for Station ID #GRB502.001515, July 22, 1987.

3.1.3 Groundwater pathway

Throughout the Tyrone Mine facility, groundwater in both the regional aquifer and the perched aquifers at the site has been exposed to hazardous substances through a variety of pathways. The Supplemental Groundwater Study at the Tyrone Mine identified 14 different mine area sources that have affected water quality, including seepage from tailings impoundments, leach stockpiles, and waste rock stockpiles (Table D-1 in Daniel B. Stephens & Associates, 1997b). Acidic seeps are present at the toes of several stockpiles such as the USNR and Nos. 2 and 2A stockpiles in Deadman Canyon, in the No. 2 leach system DP-166 area, and in the No. 1C stockpile in Oak Grove Wash. HDPE-lined ponds or interceptor wells and trenches generally capture this acidic seepage (Daniel B. Stephens & Associates, 1999b). Ongoing investigations and corrective actions are in place for seepage that has contaminated groundwater in the Tyrone Mine east side area (Tetra Tech EM Inc., 2001), the No. 3 stockpile area (Daniel B. Stephens & Associates, 2002), and the No. 2 leach stockpile area in Deadman Canyon (Harlan & Associates, 2001).

Contaminated groundwater is released to surface water via springs and seeps. In McCain Spring, located between the open pit area and the tailings ponds, copper concentrations have exceeded NMWQCC livestock watering standards (M3, 2001). At Seep #5 in Deadman Canyon, samples taken from 1996 to 2001 have shown elevated concentrations of cobalt, copper, nickel, zinc, and manganese (Table 3.6). Thus, surface water and terrestrial resources may be exposed to contaminants via this pathway of groundwater discharge.

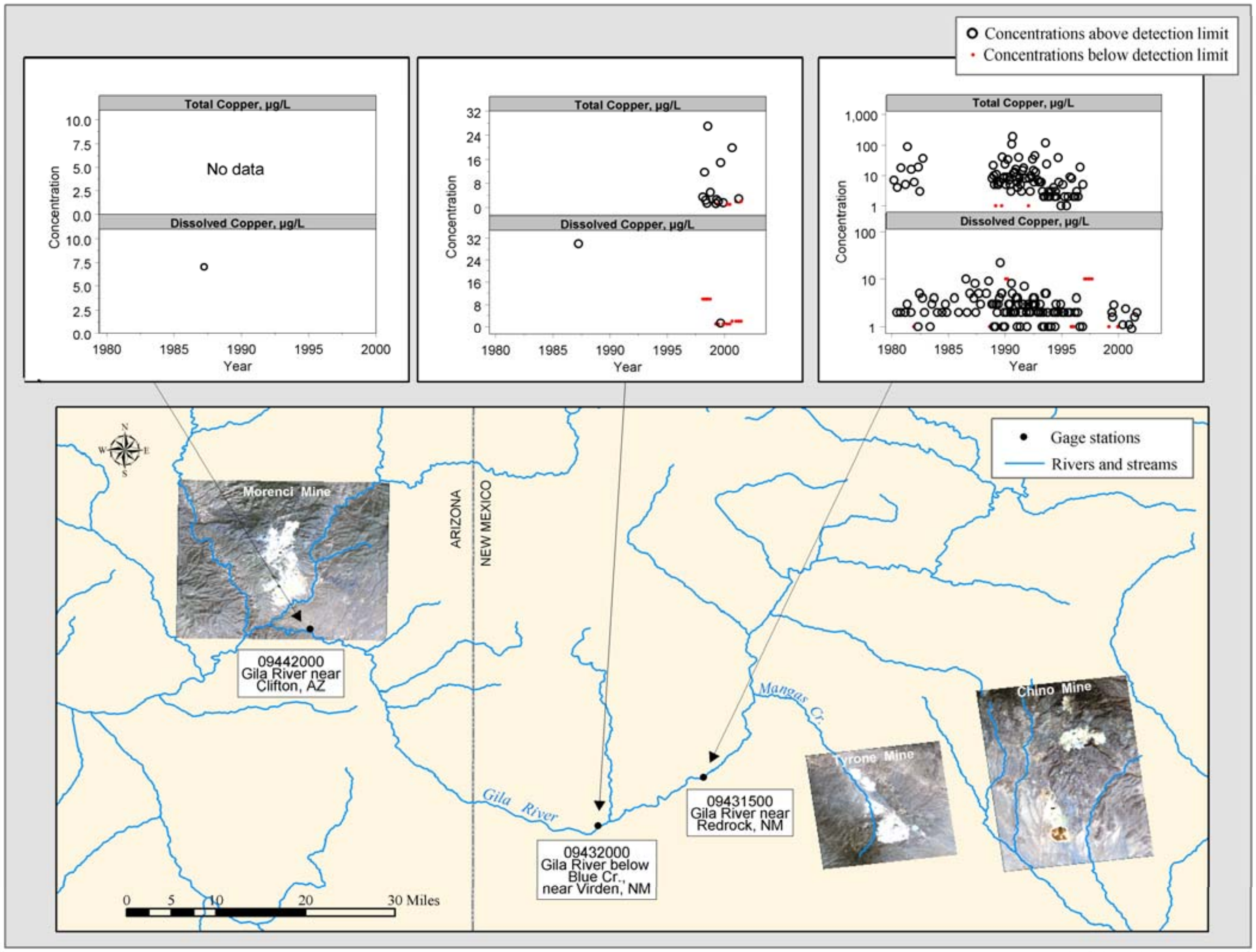

Figure 3.4. Dissolved and total copper concentrations in the Gila River, downstream of Mangas Creek, from 1980 to the present.

Source: USGS, 2003.

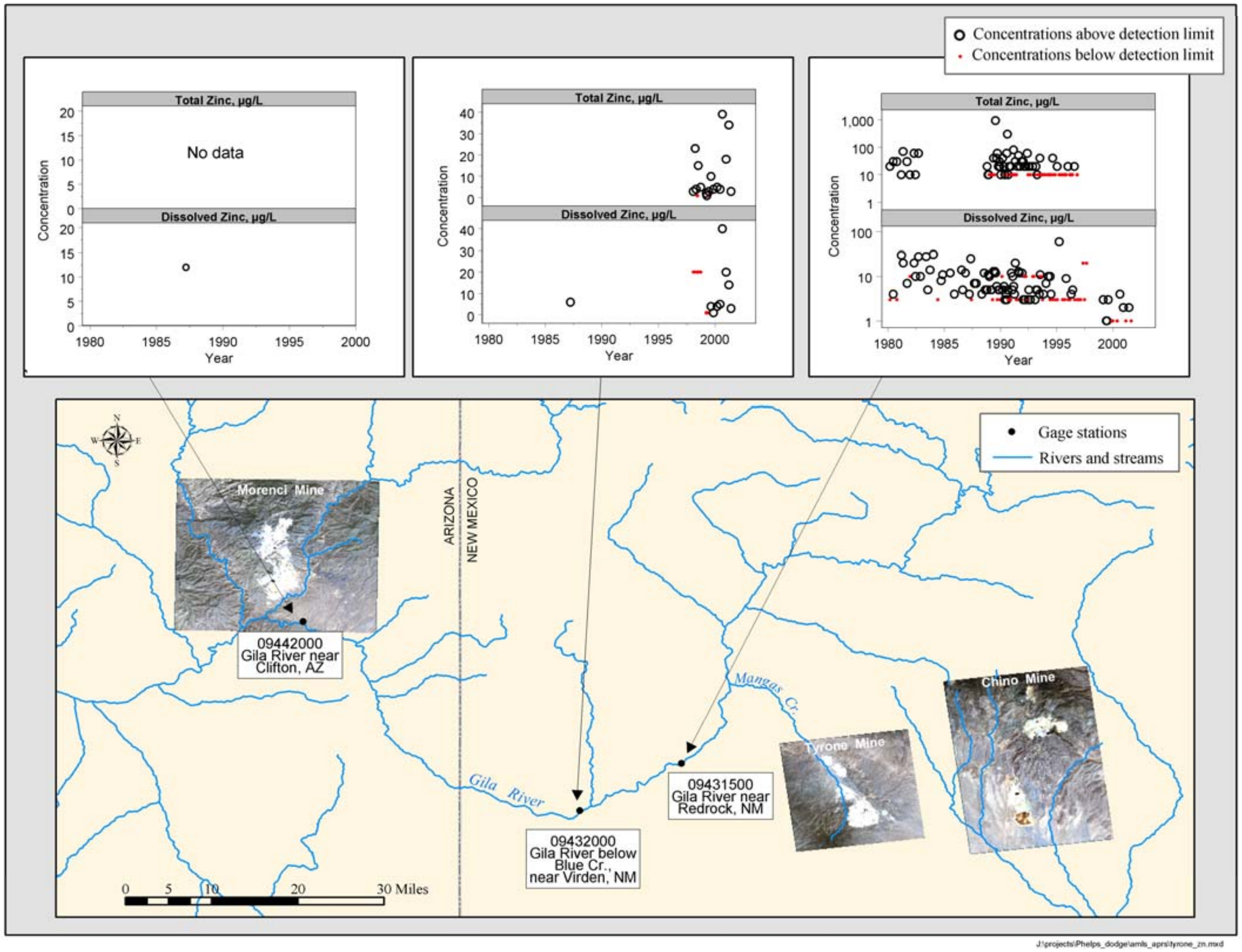

Figure 3.5. Dissolved and total zinc concentrations in the Gila River, downstream of Mangas Creek, from 1980 to the present.

Source: USGS, 2003.

Table 3.6. Dissolved concentrations of hazardous substances in Seep #5 in Deadman Canyon[a] (mg/L)

Sample date	Cd	Co	Cu	Ni	Pb	Zn	Mn
12/22/96	< 0.01	0.29	77.3	< 0.1	< 0.05	4.2	16.9
6/16/97	< 0.01	0.3	83	< 0.1	< 0.05	3.5	19
9/17/97	0.006	0.28	54	< 0.01	< 0.05	3.14	14.2
12/17/97	< 0.004	0.09	28.6	0.04	< 0.05	1.49	4.61
3/13/98	0.007	0.15	27.1	0.05	< 0.05	1.87	7.65
6/3/98	< 0.004	0.06	11.8	< 0.01	< 0.05	0.702	3.19
9/8/98	< 0.004	0.06	14.2	0.02	< 0.05	0.912	3.64
12/2/98	0.009	0.09	17.1	0.02	< 0.05	1.12	5.95
3/10/99	< 0.003	0.03	3.69	0.01	< 0.04	0.61	1.81
9/2/99	< 0.005	0.09	18.0	0.03	< 0.05	1.25	4.94
12/1/99	0.01	0.19	45.3	0.05	< 0.05	2.35	< 0.46
12/1/00	< 0.005	0.08	19.9	0.03	< 0.05	1.22	4.49
3/14/01	< 0.005	0.04	12.3	< 0.02	< 0.05	0.726	2.94
6/1/01	< 0.005	0.05	11.4	0.02	< 0.05	0.683	2.96
9/5/01	< 0.005	0.07	13.9	0.02	< 0.05	0.838	3.83

a. Source: Table 7 in Harlan & Associates, 2001.

3.1.4 Aerial transport pathway

Open, unvegetated waste rock, leach rock, and tailings piles cover more than 4,800 acres at the Site (Tables 2.1 and 2.4 of this report). Windblown materials from these piles can transport contaminants to adjacent upland areas. This pathway has been documented at the nearby Chino Mine (MFG Inc., 2002) and most likely exists at the Tyrone Mine as well. The Trustees are currently unaware, however, of data documenting the deposition of windblown materials at the Tyrone Mine. Terrestrial biota and surface water resources may be exposed to contaminants through this pathway.

3.1.5 Soil pathway

Soils are exposed to hazardous materials through aerial transport of contaminants and through plant spills and upsets that release hazardous materials to the soil (Tables 2.5 and 2.6 of this report). Terrestrial biota may be exposed to hazardous materials in soil through dermal contact, uptake, and ingestion.

3.1.6 Food chain pathway

Food chain exposures occur when prey organisms accumulate hazardous substances in their tissues. Predators are subsequently exposed to these contaminants when they consume these prey. Numerous studies have documented the uptake and subsequent terrestrial food chain movement of the hazardous substances copper and zinc (Beyer, 1990). For example, elevated concentrations of hazardous substances measured in unrinsed invertebrate samples (Table 3.4) could expose wildlife consuming these invertebrates.

Example food chain pathways for the Tyrone Mine were developed from species known to occur at the nearby Chino Mine site (MFG Inc., 2002) or near Silver City, New Mexico (NMDGF, 2002) because of a lack of site-specific wildlife data available for review for the Tyrone site. These pathways may include the following:

- Metals uptake by terrestrial invertebrates (e.g., beetles, grasshoppers) that serve as prey for omnivorous small mammals [e.g., deer mouse (*Peromyscus maniculatus*), brush mouse (*P. boylii*), pinyon mouse (*P. truei*)], omnivorous birds [e.g., scaled quail (*Callipepla squamata*), western kingbird (*Tyrannus verticalis*), Cassin's sparrow (*Aimophila cassinii*)], and reptiles [e.g., western rattlesnake (*Crotalus viridis*)], which in turn are consumed by raptors [e.g., golden eagle (*Aquila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*)] and carnivorous mammals [e.g., gray fox (*Urocyon cinereoargenteus*), kit fox (*Vulpes velox*)]

- Metals uptake by terrestrial vegetation that serves as forage for upland birds and small mammals that are primarily granivorous [e.g., pocket mice (*Perognathus* spp.), kangaroo rats (*Dipodomys* spp.), black-throated sparrow (*Amphispiza bilineata*)] and for large mammalian herbivores [e.g., mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*)].

3.2 Exposed Areas [43 CFR § 11.25(b)]

This section presents preliminary estimates of exposed areas based on a rapid review of readily available information. This section is not a comprehensive quantification of all exposed areas.

3.2.1 Primary exposure areas

Past and ongoing mining activities have resulted in a significant area that has been exposed directly to hazardous substances. These areas include, but are not limited to,

- six inactive tailings ponds at the Tyrone Mine plus historical tailings in the Burro Mountain Tailings Area, covering approximately 2,250 acres (Table 2.1)
- four mining waste stockpiles (Nos. 1C, 1D, 3B, Upper Main), covering approximately 800 acres (Table 2.4)
- eight leach stockpiles (Nos. 1, 1A, 1B, 2, 2A, 3, Gettysburg, East Main), covering approximately 1750 acres (Table 2.4)
- Tyrone mine open pit, covering approximately 120 bottom acres and 1,615 sideslope acres (Table 5.4; M3, 2001).

3.2.2 Areas exposed through pathways

Areas exposed via contaminant pathways from primary areas may include the following:

- Surface water, bank, bed, and floodplain sediments of Mangas Creek. Table 3.5 provides evidence of exposure of Mangas Creek surface water to hazardous substances, extending down to the confluence with the Gila River.
- Seeps and ephemeral surface water in Deadman Canyon. Table 3.6 provides evidence of exposure of Seep #5 in Deadman Canyon to hazardous substances.
- Gila River downstream from the confluence with Mangas Creek. Figures 3.4 and 3.5 provide evidence that the Gila River downstream of Mangas Creek potentially has been exposed to hazardous substances, including copper and zinc.
- Perched and regional groundwater aquifers at the Tyrone Mine and extending downgradient from the mine. Extensive studies have documented that perched and regional groundwater near the stockpiles has been exposed to hazardous substances

(Daniel B. Stephens & Associates, 1997b). There is evidence of elevated sulfate and TDS concentrations (i.e., impacted water) in the regional groundwater wells farthest down the Mangas Valley, at the northwest corner of the mine permit boundary (Figure 2.2a). In October 1996, sulfate was measured at 170 mg/L; background sulfate concentrations are below 43 mg/L (Daniel B. Stephens & Associates, 1997b, p. 4-11 and Plate 8). Also, elevated copper (0.2 mg/L) was detected in a groundwater well in this area (Appendix C-9 in Daniel B. Stephens & Associates, 1997b).

- Areas indirectly exposed to hazardous substances from the mine via aerial transport of materials. This pathway has been documented at the nearby Chino Mine (MFG Inc., 2002) and most likely exists at the Tyrone Mine as well.

3.2.3 Areas of indirect effect

Areas of indirect effect, where no hazardous substance has spread but where biological populations may have been affected as a result of animal movement, include:

- geographic extent of migratory birds that are exposed to hazardous substances at the site or injured via loss of habitat or forage base
- geographic extent of other terrestrial resources (e.g., reptiles, ungulates) that are exposed to hazardous substances through food chain pathways or injured via loss of habitat or forage base
- geographic extent of aquatic resources (e.g., fish, amphibians) that may be exposed to hazardous substances through food chain pathways or injured via loss of habitat or forage base.

3.3 Estimates of Concentrations [43 CFR § 11.25(b)]

This section presents examples of concentrations of hazardous substances that have been measured in natural resources of the site, based on available information. This information is not a comprehensive review of all studies that have been conducted at the site, some of which were not available for review. Rather, this section presents examples drawn from a rapid review of the readily available literature.

3.3.1 Surface water

Different types of surface water resources have been exposed to hazardous substances released from the Tyrone Mine. Exposed surface water resources include ephemeral waterways such as Mangas Creek and Deadman Canyon. There is also some evidence that the Gila River downstream from the mine also has been exposed to hazardous substances.

Routine quarterly monitoring has shown that ephemeral surface water in Mangas Creek has been exposed to hazardous substances. Examples of hazardous substance concentrations in Mangas Creek are given in Table 3.5. Copper concentrations at the five flow samplers ranged from 0.01 to 0.09 mg/L. Lead and cadmium were not detected in these samples.

In the Gila River downstream of Mangas Creek, concentrations of dissolved copper have exceeded 30 μg/L, while concentrations of total copper have exceeded 150 μg/L. Dissolved zinc concentrations have exceeded 50 μg/L, while concentrations of total zinc have exceeded 900 μg/L (Figures 3.4 and 3.5).

3.3.2 Groundwater

Extensive sample collection has shown that perched and regional groundwater near the Tyrone Mine have been exposed to hazardous substances. Examples of hazardous substance concentrations in December 2001 in groundwater wells screened in the regional aquifer in the vicinity of the #2 leach system are given in Table 3.7. Copper has been detected in the regional aquifer in all of the wells shown in Table 3.7, at concentrations ranging from 0.02 to 0.98 mg/L. Manganese and zinc have been detected in the large majority of these wells, at concentrations ranging from 0.02 to 2.53 mg/L for manganese and 0.025 to 0.915 mg/L for zinc.

Examples of hazardous substance concentrations in December 2001 in groundwater wells screened in the perched zone are given in Table 3.8. Copper and manganese were detected in all of the wells shown in Table 3.8, at concentrations ranging from 0.02 to 24.0 mg/L for copper and 0.03 to 9.22 for manganese. In addition, cobalt, nickel, and zinc have been detected in groundwater wells screened in the perched zone.

Extensive sample collection has shown elevated concentrations of hazardous substances in seeps in the Deadman Canyon area, west of the No. 2 leach stockpile and the No. 2A waste rock stockpile. Seep #5 in Deadman Canyon results from subsurface groundwater flow within alluvium being forced to the surface by a constriction in the depth and width of alluvial valley fill (Harlan & Associates, 2001). Sample collections from 1996 to 2001 have shown consistently elevated concentrations of hazardous substances in Seep #5 (Table 3.6). Dissolved copper

Table 3.7. Dissolved concentrations of hazardous substances in December 2001 in groundwater wells screened in the regional aquifer, in the vicinity of the #2 leach system (mg/L)

Sample ID	pH	Cu	Mn	Zn
Well 2-4	7.2	0.12	0.71	0.123
Well 2-5A	6.1	0.39	2.53	0.915
Well 2-11	7.0	0.21	0.33	0.265
Well 2-12	7.4	0.87	0.85	0.092
Well 2-13	7.5	0.02	0.12	< 0.025
Well 2-15	6.6	0.37	0.55	0.809
Well 2-16	6.6	0.98	0.23	0.378
Well TWS8	6.1	0.06	0.11	0.025
Well TWS9	6.3	0.03	0.02	< 0.025
Well TWS41	6.5	0.02	< 0.01	< 0.025
Well TWS42	6.9	0.03	< 0.01	0.039

Source: Brunner (2002).

Table 3.8. Dissolved concentrations of hazardous substances in groundwater wells — perched zone (mg/L)

Sample ID	pH	Cu	Mn	Zn
Well TWS-28	5.0	16.6	5.00	1.01
Well TWS-29	4.6	23.3	6.29	1.41
Well TWS-32	6.4	0.04	0.25	< 0.025
Well TWS-33	6.6	0.11	0.12	0.050
Well TWS-35	6.4	0.06	0.05	< 0.025
Well TWS-36	6.4	0.02	0.03	< 0.025
Well TWS-37	6.1	0.28	0.18	0.332
Well TWS-39	4.9	24.0	9.22	1.52
Well TWS-40	6.5	0.11	0.05	< 0.025

Source: Brunner (2002).

concentrations have ranged from 3.69 mg/L to 83 mg/L, and dissolved zinc concentrations have ranged from 0.61 mg/L to 4.2 mg/L. Cobalt and manganese also have consistently been detected in seep samples, and there have been occasional detections of cadmium and nickel.

3.3.3 Biota

Elevated concentrations of hazardous substances have been detected in invertebrates collected at the Tyrone Mine tailings ponds. For unrinsed invertebrates, concentrations (dry weight) ranged from 3,002 to 17,700 mg/kg copper and from 778 to 5,704 mg/kg zinc (Table 3.4).

3.4 Potentially Affected Resources [43 CFR § 11.25 (3)(1)]

The data presented in this chapter support the conclusion that natural resources for which the Trustees have trusteeship and that have been affected or potentially affected by releases of hazardous substances from the Tyrone Mine facilities include, but are not limited to, the following:

- surface water resources, including Mangas Creek and the Gila River (Table 3.5, Figures 3.4, 3.5)
- groundwater and aquifer materials at and downgradient of the mine facilities (Tables 3.7, 3.8)
- terrestrial biota resources, including multiple species of migratory birds (see Chapter 4, Table 4.1).

In addition, resources potentially affected by hazardous substance releases include fish and invertebrates in the perennial portion of Mangas Creek and the Gila River, plants, terrestrial invertebrates, small and large mammals at the mine site, and reptiles. Hazardous substances are present in resources that may be contacted by these biota, but no data were available for review for this preassessment screen to determine the likelihood that these resources have been affected by releases of hazardous substances.

3.5 Preliminary Estimate of Affected Services [43 CFR § 11.25(e)(2)]

Services provided or potentially provided by the resources identified in Section 3.4 include, but are not limited to, the following:

- supporting habitat for wildlife, including food, shelter, breeding and rearing areas, and other factors essential to long-term survival

- consumptive and nonconsumptive outdoor recreation, including fishing, hunting, hiking, trapping, wildlife viewing, and photography
- passive use and option values
- other ecological and biological services provided by natural resources.

Passive use values are values unrelated to one's own use of the injured resource. These values can be bequest values (value for use by future generations) or existence values (value of the resource even if it is never used by anybody) [56 Fed. Reg. 19760]. Ecological services provided by natural resources include habitat, biodiversity, carbon sequestration, nutrient cycling, food sources, and other biological, chemical, and physical functions and processes.

Groundwater may provide many services to society, including potable drinking water, irrigation for crops, livestock watering, inputs into manufacturing and mining activities, electricity generation, and prevention of land subsidence. Groundwater recharge also provides a pathway to support surface water services (National Research Council, 1997).

Groundwater serves as the primary drinking water source for Silver City, New Mexico. The 40-Year Water Plan for the town of Silver City (Gordon et al., 1993) indicates that Silver City's water supply is completely from well water. As of 1993, they were using 60% of their total water right of 4,739.22 acre-feet per year. The Town of Silver City (2003) indicates the town's current water rights remain at this level (4,739.22 acre-feet per year), so they continue to use about 60% (3,000/4,739.22 acre-feet per year).

This plan implies there may ultimately be a concern about scarcity of groundwater resources in the region. In 1993, the town had applications for 12,000 acre feet in water rights, and wells were dropping 1.4 to 5.0 feet per year. The Gila River Basin is closed to new water rights, and Mimbres Basin was thought to be an unlikely source for procurement of new water rights (Gordon et al., 1993).

The useful lives of four nearby towns' wells were estimated to be:

- 37.8 years from 1993 (28.8 years from 2002) for Franks
- 56.9 years from 1993 (47.9 years from 2002) for Woodward
- 30.6 years from 1993 (21.6 years from 2002) for Gabby Hayes
- 28.0 years from 1993 (19.0 years from 2002) for Anderson.

Phelps-Dodge may be a possible source for future water rights if water is uncontaminated (Gordon et al., 1993). The company has water rights to 20,000 acre-feet of groundwater and 11,600 acre feet of surface water (Whitewater Creek) associated with the Chino Mine. In the Mimbres Basin, Phelps-Dodge has water rights to 690 acre-feet of groundwater and 11,750 acre-feet of surface water (Gila River). In 1993 Phelps-Dodge had applications for a further 10,000 acre-feet in water rights.

In 1993 charges for water from Silver City were:

- $1.60/1000 gallons for residential use
- $1.76/1000 gallons for the Tyrone Mine
- $1.90/1000 gallons (first million, then $2.90) for Arenas Valley
- $2.20/1000 gallons (first 697,500, then $3.20) for Pinos Altos.

Gordon et al. (1993) also explored the potential of new water supplies and found the following:

- The cost for the State of Alaska to deliver water to the Southwest was $1,000 to $2,000 per acre-foot (Duke and Montoya, 1993).

- In 1993, the town of Silver City could claim surface water from the Gila River through the Central Arizona Project (this right to this claim has since expired). Cost for water was $130 to $200 per acre-foot, not including pumping.

- Hernandez et al. (1984) gave a preliminary cost estimate of $650 to $1,000 to transmit water from the Connor Reservoir on the Gila River to recharge groundwater aquifers.

- The current cost for Phelps-Dodge to pump Gila River surface water by pipe is $0.28 per 1,000 gallons (although other costs are unknown). The pipe goes near two Silver City well sites.

- New water wells may be drilled by the town and current water rights transferred to the new locations, if they do not interfere with Phelps-Dodge Chino water rights (assuming these wells are not contaminated); negotiations to get water from Phelps-Dodge Chino may also be possible.

These sources of information suggest that the value of groundwater services in Silver City is high. The cost of water rights (in perpetuity) in the region may be in the thousands of dollars per acre-foot. The impending scarcity of drinking water supplies in the region will be of growing concern in the next few decades, and additional applications for water rights demonstrates that clean water supplies have value.

Passive use values for local and migratory bird morbidity and mortality at the Tyrone Mine may be highest for people living in the county directly affected by mining releases. In 2002, approximately 30,237 individuals lived in Grant County, New Mexico (U.S. Census, 2003), where the Chino and Tyrone Mines are located. In addition, a large body of economics literature has documented significant service reductions from bird kills, even when the species are not particularly unique or sensitive (e.g., Loomis et al., 1990; Rowe et al., 1991; Boyle et al., 1994). Thus, lost passive use services from migratory bird deaths at the Tyrone Mine may occur for people outside of the direct mine area. In addition, a national contingent valuation method study found that passive use services may be significant for protection of critical habitat for nine endangered species in Southwest river basins, including the spike dace and loach minnow in the Gila River (Ekstrand and Loomis, 1998).

4. Determination Criteria [43 CFR § 11.23(e)]

This chapter presents an evaluation of the preassessment determination criteria [43 CFR § 11.23(e)]. The information presented and summarized in this chapter confirms the following:

- A release of hazardous substances has occurred.
- Natural resources for which the Trustees have trusteeship have been or are likely to have been adversely affected.
- The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury.
- Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.
- Response actions will not sufficiently remedy the injury to natural resources without further action (note that no response actions are currently planned under the RI/FS process).

Based on the evaluation of the criteria presented below, the Trustees have determined that a Type B NRDA should be performed to assess damages to natural resources caused by releases of hazardous substances from the Tyrone Mine. The justification of the decision to perform a Type B NRDA will be presented in the Assessment Plan.

4.1 A release of hazardous substances has occurred

Multiple studies and data collection efforts, including those of the New Mexico Environment Department, Phelps Dodge, Inc., and the U.S. Fish and Wildlife Services have demonstrated that multiple and at times continuous releases of hazardous substances have occurred and continue to occur as a result of operations at the Tyrone Mine (Section 2.4). Hazardous substances released include, but may not be limited to, arsenic, cadmium, cobalt, copper, lead, manganese, nickel, zinc, and acid. Investigators have also documented elevated concentrations of hazardous substances in surface water, groundwater, and biota that have resulted from releases of hazardous substances at the site.

4.2 Trustee natural resources have been or are likely to have been adversely affected by the release

Natural resources [as defined in 43 CFR § 11.14(z)] for which the Trustees have trusteeship that have been or are likely to have been adversely affected by releases of hazardous substances include, but are not necessarily limited to, surface water, groundwater, geological, and biological resources. These biological resources include waterfowl and migratory birds.

Chapter 3 presents data confirming elevated concentrations of hazardous substances in Trustee natural resources. Section 4.3 confirms that this exposure is at concentrations and of durations sufficient to potentially injure natural resources.

4.3 The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury

4.3.1 Surface water/sediments

The DOI regulations present a number of definitions of injury for surface water resources. These definitions of injury to surface water include the following:

- concentrations of hazardous substances exceeding Safe Drinking Water Act (SDWA) or other relevant federal or state criteria or standards for drinking water [43 CFR § 11.62(b)(1)(i)]
- concentrations and duration of substances in excess of applicable water quality criteria established by Section 304(a)(1) of the Clean Water Act (CWA), or by other federal or state laws or regulations that establish such criteria . . . in surface water that before the discharge or release met the criteria and is a committed use . . . as a habitat for aquatic life, water supply, or recreation [43 CFR § 11.62(b)(1)(iii)]
- concentrations and duration of hazardous substances sufficient to have caused injury to biological resources when exposed to surface water [43 CFR § 11.62(b)(1)(v)].

For ponded water on tailings impoundments and seeps at the site, the concentrations and duration of hazardous substances have been sufficient to potentially cause injury to birds and invertebrates exposed to surface waters, and potentially to other biological resources as well. The list of bird carcasses discovered at the Tyrone Mine tailings ponds from September to November 2000 shows that the concentrations and duration of hazardous substances at these ponds have been sufficient to cause injury to birds (Table 4.1). A 1989 memorandum written by the New Mexico Health and Environment Department (Dye, 1989) notes the presence of a large, dead bird (thought to be a great blue heron) at tailings dam #3 in April 1989.

Table 4.1. Bird carcasses at the Tyrone Mine, discovered September to November 2000

Species	Number of carcasses
American avocet	3
American wigeon	1
Blue-winged teal	1
Great blue heron	6
Green-winged teal	5
Killdeer	4
Mallard	1
Northern pintail	25
Northern rough-winged swallow	2
Northern shoveler	7
Ring-billed gull	1
Snow goose	1
Snowy plover	1
Song sparrow	1
Unknown ducks	82
Unknown hummingbird	2
Unknown passerine	5
Unknown sparrow	2
Variety	33
Western sandpiper	2
Teal	2
Towhee	1
Total	188

Source: Unpublished data, USFWS records.

For ephemeral stream flows in the Mangas Creek, injury to surface water may occur when concentrations of hazardous substances exceed water quality criteria established under Section 304(a)(1) of the CWA for the protection of aquatic life [43 CFR§ 11.62(b)]. For copper, the U.S. EPA acute and chronic toxicity criteria for aquatic life are hardness-dependent. Five of seven samples reported in Table 3.5 exceeded either the acute or chronic aquatic life criteria for cadmium or copper (adjusted for sample hardness), in one case more than tenfold for chronic criteria (Table 3.5). In addition, the Tyrone Closure/Closeout plan stated that “elevated concentrations of sulfate, total dissolved solids, copper, and cadmium have been observed periodically at flow samplers 1, 2, and 4” (M3, 2001), which are located in the Mangas Creek.

4.3.2 Groundwater

Definitions of injury to groundwater resources presented in the DOI regulations include the following:

- concentrations of hazardous substances exceeding SDWA or other relevant federal or state criteria or standards [43 CFR § 11.62(c)(1)(i), (ii), (iii)]

- concentrations of hazardous substances sufficient to cause injury to other natural resources that come in contact with the groundwater (e.g., surface water) [43 CFR § 11.62(c)(1)(iv)].

Criteria relevant to the Tyrone Mine Site include Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs) established by sections 1411-1416 of the Safe Drinking Water Act, and New Mexico Water Quality Standards for groundwater (NMAC 20.6.2.3103). A comparison of hazardous substances measured in groundwater and seeps at the mine with groundwater standards demonstrates that hazardous substance concentrations in groundwater are sufficient to potentially cause injury (Table 4.2). Copper concentrations in perched groundwater have exceeded the SMCL by more than a factor of 20, while manganese concentrations in regional groundwater have exceeded New Mexico criteria by more than a factor of ten. These concentrations indicate that groundwater at the site is potentially injured.

4.3.3 Birds

According to U.S. DOI regulations [43 CFR § 11.62(f)], an injury to biological resources (e.g., birds) has resulted from the discharge of a hazardous substance if the concentration of the hazardous substance is sufficient to:

- cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

Table 4.2. Relevant groundwater standards and ranges of detected concentrations in seep water, the regional groundwater aquifer, and the perched aquifer (standards for dissolved concentrations, mg/L)

	Standard	Seep #5, Deadman Canyon[a]	Regional aquifer, near #2 leach system[b]	Perched aquifer[c]
pH	6-9[d]		6.1-7.5	4.6-6.6
Cd	0.01[e]	0.006-0.01		0.006
Co	0.05[f]	0.03-0.3		0.11-0.15
Cu	1.0[d, g]	3.69-83	0.02-0.98	0.02-24.0
Mn	0.2[d]	1.81-19	0.02-2.53	0.03-9.22
Ni	0.1,[h] 0.2[f]	0.01-0.05		0.02-0.05
Zn	5.0,[g] 10[d]	0.61-4.2	0.025-0.915	0.05-1.52

a. Source: Table 7 in Harlan & Associates, 2001. Data from 12/1996 through 9/2001. See Table 3.6.
b. Source: Brunner, 2002. See Table 3.7.
c. Source: Brunner, 2002. See Table 3.8.
d. Other standards for domestic water supply. New Mexico Water Quality Standards for groundwater of 10,000 mg/L TDS concentration or less [New Mexico Administrative Code (NMAC) 20.6.2.3103].
e. Human health standards. New Mexico Water Quality Standards for groundwater of 10,000 mg/L TDS concentration or less (NMAC 20.6.2.3103).
f. Standards for irrigation. New Mexico Water Quality Standards for groundwater of 10,000 mg/L TDS concentration or less (NMAC 20.6.2.3103).
g. Secondary maximum contaminant level. Safe Drinking Water Act Standards (40 CFR § 141.8; 40 CFR § 141, 142; 40 CFR § 143.3).
h. Maximum contaminant level. Safe Drinking Water Act Standards (40 CFR § 141.8; 40 CFR § 141, 142; 40 CFR § 143.5), remanded on February 9, 1995.

The list of bird carcasses found at the Tyrone Mine tailings ponds in just a three-month period during 2000 confirms adverse impacts to birds caused by hazardous substances released from the site.

4.3.4 Summary

Based on a “rapid review of readily available information” [43 CFR § 11.23(b)], the Trustees conclude that the quantity and concentration of the released hazardous substance are sufficient to potentially cause injury to Trustee natural resources, including surface water, groundwater, geological, and biological resources.

4.4 Data sufficient to pursue an assessment are available or likely to be obtained at reasonable cost

Data relevant to conducting an assessment of natural resource damages at the Tyrone Mine have been collected as part of regular monitoring activities at the Tyrone Mine and as part of the Closure/Closeout planning process (e.g., M3, 2001, and appendices). Such data include information on hazardous substances sources, releases, pathways, and concentrations in the environment. Since the preassessment screen is intended to determine only whether there is sufficient cause to pursue an NRDA, omission of any information in the preassessment screen does not preclude consideration of such information in the course of an NRDA. Additional data for the purposes of performing a damage assessment are expected to be obtainable at reasonable cost.

4.5 Response actions will not sufficiently remedy the injury to natural resources without further action

No response actions are currently under way under an RI/FS process at the Tyrone Mine. PDTI has undertaken some corrective actions, under the requirements of groundwater discharge permits with the NMED Ground Water Quality Bureau (Table 2.7). These actions, however, are not sufficient to either prevent ongoing and future injuries or to remedy past injuries. For example, in the east side mine area, investigative and corrective activities began in 1996 to address contamination in a perched seepage zone in Lower Oak Grove Wash. Despite these activities, the groundwater plume in 2001 extended two miles east of the No. 1A stockpile, through Lower Oak Grove Wash (Tetra Tech EM Inc., 2001). Sampling in 2001 indicated ongoing exposure of Mangas Creek to hazardous substances and continued elevated concentrations of hazardous substances in perched and regional groundwater. Ponded water on top of tailings impoundments, in uncovered process water ponds, and in stormwater ponds also continues to serve as ongoing sources of potential injuries to wildlife. Efforts by PDTI to neutralize low pH ponds with liming at the tailings impoundments have not been successful at maintaining pH values between 6 and 8 (Phillip, 2002). Current hazing activities may reduce some future injuries to wildlife, but are not sufficient to remedy injury and do not occur at all the locations of ponded water at the site.

4.6 Conclusions

Based on an evaluation of the preassessment determination criteria, the following conclusions can be made:

- A release of hazardous substances has occurred.
- Natural resources for which the Trustees have trusteeship have been or are likely to have been adversely affected.
- The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury.
- Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.
- Response actions will not sufficiently remedy the injury to natural resources without further action.

Based on an evaluation of these five criteria, the Trustees have determined that an NRDA should be performed to assess damages to natural resources caused by releases of hazardous substances from the Tyrone Mine.

5. References

Beyer, W.N. 1990. Evaluating Soil Contamination. U.S. Fish and Wildlife Service Biological Report 90(2).

Boyle, K.J., W.H. Desvousges, F.R. Johnson, R.W. Dunford, and S.P. Hudson. 1994. An investigation of part-whole biases in contingent-valuation studies. *Journal of Environmental Economics and Management* 27:64-83.

Brunner, J. 2002. Letter to M. Reed, Ground Water Quality Bureau, New Mexico Environment Department. Re: Discharge Plan DP-166 – No. 2 Leach System. January 30.

Daniel B. Stephens & Associates. 1997a. Preliminary Materials Characterization Tyrone Mine Closure / Closeout. Prepared by Daniel B. Stephens & Associates Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. April 30.

Daniel B. Stephens & Associates. 1997b. Supplemental Groundwater Study: Tyrone Mine Closure / Closeout. Volume II: Appendices. Prepared by Daniel B. Stephens & Associates Inc. for Phelps Dodge Tyrone, Inc. Tyrone, NM. November 14.

Daniel B. Stephens & Associates. 1997c. Supplemental Materials Characterization, Tyrone Mine Closure / Closeout. Prepared by Daniel B. Stephens & Associates Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. October 31.

Daniel B. Stephens & Associates. 1997d. Preliminary Site-Wide Groundwater Study: Tyrone Mine Closure / Closeout. Prepared by Daniel B. Stephens & Associates Inc. for Phelps Dodge Tyrone, Inc., Tyrone, New Mexico. May 31.

Daniel B. Stephens & Associates. 1999a. Revised Closure/Closeout Plan Tyrone Mine. Prepared by Daniel B. Stephens & Associates Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. June 12.

Daniel B. Stephens & Associates. 1999b. Stockpile and Tailing Pond Seepage Investigation, Tyrone Mine. Prepared by Daniel B. Stephens & Associates Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. July 31.

Daniel B. Stephens & Associates. 2002. Seepage Investigation of the Tyrone Mine No. 3 Stockpile: Annual Progress Report January 16, 2001 through January 15, 2002. Prepared by Daniel B. Stephens & Associates Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. February 15.

Dresher, W.H. 2001. How hydrometallurgy and the SX/EW process made copper the "green" metal. *Innovations.* Copper Development Association, Inc. August. http://innovations.copper.org/2001/08/hydrometallurgy.html.

Duke, E.M. and A.C. Montoya. 1993. Trends in water pricing: Results of Ernst and Young's national rate survey. *American Water Works Association Journal* 85(5):55-61.

Dye, A. 1989. Memorandum to DP 27 file. Re: April 3 & 4, 1989 Inspection of the Phelps Dodge Mangas Valley Discharge Plan (DP-27) Facilities. New Mexico Health and Environment Department. May 3.

Ekstrand, E.R. and J. Loomis. 1998. Incorporating respondent uncertainty when estimating willingness to pay for protecting critical habitat for threatened and endangered fish. *Water Resources Research* 34:3149-3155.

Gordon, N., G. Esqueda, and T. Kelly. 1993. A 40-Year Water Plan for the Town of Silver City, New Mexico. Prepared for the Town of Silver City by Engineers Inc, Silver City, and Geohydrology Associates, Albuquerque, NM. October.

Harlan & Associates. 2001. Tyrone Mine No. 2 Leach Stockpile Discharge Plan DP-166: Evaluation of Potential Seepage to Deadman Canyon. Supplemental Monitoring Results April 1 through September 30, 2001. Prepared by Harlan & Associates, Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. October 31.

Hernandez, J.W., W.G. Hines, and F.D. Trauger. 1984. Evaluation of a Municipal Water Supply for the Silver City Area Using Groundwater from Conner Reservoir on the Gila River. Prepared for Town of Silver City and New Mexico Interstate Stream Commission.

IRC. 2001. Copper, Phelps Dodge, and the Future Grant County's Mining District. An IRC Community Report. Prepared by Interhemispheric Resource Center, Silver City, NM. October.

Landsat7. 2000. ETM+ digital data (bands 1-5, 7, 8). Imagery date: April 13, 2000. Downloaded from Arizona Regional Image Archive (ARIA) http://aria.arizona.edu on April 3, 2003.

Loomis, J.B., T. Wegge, M. Hanemann, and B. Kanninen. 1990. The economic value of water to wildlife and fisheries in the San Joaquin Valley: Results of a simulated voter referendum. In *Transactions of the 55th North American Wildlife & Natural Resources Conference,* pp. 259-268.

M3. 2001. Tyrone Closure / Closeout. M3 Engineering & Technology Corporation.

MFG Inc. 2002. Chino Mines Administrative Order on Consent: Sitewide Ecological Risk Assessment. Prepared for New Mexico Environment Department. August.

National Research Council. 1997. Valuing Ground Water: Economic Concepts and Approaches. National Academy Press, Washington, DC.

NMDGF. 2001. 2000 Annual Report, Scientific/Educational-Purpose Authorization/Permit. January 29. New Mexico Department of Game and Fish, Santa Fe, NM.

NMDGF. 2002. Biota Information System of New Mexico. http://nmnhp.unm.edu/bisonm/bisonquery.php. Accessed April 23, 2003.

NMED. 2002. Proposed Supplemental Discharge Permit for Closure: DP-1341, Tyrone Mine Inc. New Mexico Environment Department. April 19.

NMED. 2003. Public Notices for Applications Received Prior to September 15, 2002, to be Published on or before March 22, 2003. New Mexico Environment Department Groundwater Quality Bureau.

PDTI. 1999. Closure/Closeout Plan for the Little Rock Mine, Grant County, New Mexico. Phelps Dodge Tyrone Inc.

Phillip, M. 2002. Letter to J. Fenn, President, Phelps Dodge Tyrone, Inc. Re: September 24, 2002 Phelps Dodge Tyrone Mine Tailing Inspection. October 25.

Phillip, M. and M. Reed. 2001. Letter to R. Pennington, President, Phelps Dodge Tyrone, Inc. Re: January 23-24, 2001 Tyrone Mine Inspection Report. March 27.

Reed, M. 2002. Handwritten note reporting a telephone message from Tom Shelly. Re: 4000 gallon raffinate spill DP-166. January 26. DP-166 administrative record #A-328.

Rowe, R.D., W.D. Schulze, W.D. Shaw, D. Schenk, and L.G. Chestnut. 1991. Contingent Valuation of Natural Resource Damage due to the Nestucca Oil Spill: Final Report. Prepared by Hagler Bailly Consulting, Inc., Boulder, CO, for the Department of Wildlife, State of Washington, British Columbia Ministry of Environment, Victoria, British Columbia, and Environment Canada, Vancouver, British Columbia. June 15.

SARB. 1999. Geochemical Evaluation of Tailings and Stockpiles, Tyrone Mine. Prepared by SARB Consulting Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. December 22.

SARB. 2000. Pit Lake Water Quality Modeling, Tyrone Mine. Prepared by SARB Consulting Inc. for Phelps Dodge Tyrone, Inc., Tyrone, New Mexico. February 29.

Shelley, T.L. 2000. Letter to C. Marshall, Ground Water Quality Bureau, New Mexico Environment Department. Re: WQCC 1203 Release at the No. 1B Leach Stockpile (DP-383). August 4.

Shelley, T.L. 2001. Memorandum to M. Reed, Ground Water Quality Bureau, New Mexico Environment Department. Re: WQCC 1203 Spill Report – DP 166. August 21.

Tetra Tech EM Inc. 2001. Seepage Investigation of the Tyrone Mine East Side: Progress Report May 2001 through October 2001. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, NM. December 14.

Town of Silver City. 2003. Water Department Description. http://www.townofsilvercity.org/utilities/water_page.htm. Accessed April 30, 2003.

U.S. Census. 2003. Table CO-EST2002-01-35-New Mexico County Population Estimates: April 1, 2000 to July 1, 2002. Source: Population Division, U.S. Census Bureau. Release Date: April 17, 2003. http://eire.census.gov/popest/data/counties/tables/CO-EST2002/CO-EST2002-01-35.php.

U.S. EPA. 1994. Technical Document: Acid Mine Drainage Prediction. Office of Solid Waste, Special Waste Branch. EPA 530-R-94-036. December.

U.S. EPA. 2003. Toxics Release Inventory: Envirofacts Report. Facility Name: Phelps Dodge Tyrone, Inc. Data extracted March 7, 2003. http://oaspub.epa.gov/enviro/tris_control.tris_print?tris_id = 88065PHLPSHWY90.

USGS. 1997. Digital Orthophoto Quarter Quadrangle (DOQQ) (8 and 1 meter resolution). Imagery date October 13, 1997. Downloaded from Microsoft Terraserver Site http://terraserver.microsoft.com/ November 8, 2002.

USGS. 2003. Water Quality Data for the Nation. http://waterdata.usgs.gov/NWIS/qw. Accessed April 28, 2003.

U.S. Securities and Exchange Commission. 2002. Form 10-K for the Fiscal Year Ended December 31, 2001: Phelps Dodge Corporation (a New York Corporation).

Vaughn, D.R. 2001a. Letter to C. Marshall, Ground Water Quality Bureau, New Mexico Environment Department. Re: 1B Leach Stockpile (DP-383) Event Follow-Up and Corrective Action Report. May 17.

Vaughn, D.R. 2001b. Letter to M. Reed, Ground Water Quality Bureau, New Mexico Environment Department. Re: Follow-up and corrective action report SX/EW raffinate tanks (DP-166). October 4.

Vaughn, D.R. 2001c. Letter to M. Reed, Ground Water Quality Bureau, New Mexico Environment Department. Re: WQCC 1203 Follow-up and Corrective Action Report No. 1 Tailings Dam (DP-27), Mine Dewatering Line (DP-27). August 23.

Vaughn, D.R. 2001d. Letter to M. Reed, Ground Water Quality Bureau, New Mexico Environment Department. Re: WQCC 1203 Follow-up and Corrective Action Report No. 2A West PLS Tank (DP-435). October 4.

Vaughn, D.R. 2001e. Letter to M. Reed, Ground Water Quality Bureau, New Mexico Environment Department. Re: WQCC 1203 Release near the SX/EW Plant (DP-166) Follow-up and Corrective Action Report. December 14.

Part C:
Preassessment Screen for Morenci Mine Site, Morenci, Arizona

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Contents

Acronyms and Abbreviations

ADEQ	Arizona Department of Environmental Quality
APP	Aquifer Protection Permit
CWA	Clean Water Act
DOI	U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
gpd	gallons per day
MCLs	Maximum Contaminant Levels
MFL	mine-for-leach system
n.d.	not detected
NRDA	natural resource damage assessment
PDMI	Phelps-Dodge Morenci, Inc.
PLS	pregnant leach solution
POC	point of compliance
PRP	potentially responsible party
RI/FS	Remedial Investigation/Feasibility Study
SU	standard units
SX/EW	solution extraction/electrowinning
TRI	Toxics Release Inventory
USFWS	U.S. Fish and Wildlife Service

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1. Introduction

Hazardous substances have been released to the environment by mining activities at the Morenci Mine in the vicinity of Morenci and Clifton, Arizona. The U.S. Fish and Wildlife Service (USFWS), in coordination with the Bureau of Reclamation and the Bureau of Land Management (collectively, the Trustees), has begun to assess natural resource damages resulting from releases of hazardous substances from the Morenci Mine in accordance with natural resource damage assessment (NRDA) regulations issued by the U.S. Department of Interior (DOI) at 43 CFR Part 11.[1] These regulations are not mandatory. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 U.S.C. § 9607(f)(2)(C)]. The first step in the process established by DOI is the preparation of a preassessment screen. This preassessment screen documents the Trustees' conclusion that there is a reasonable probability of making a successful claim for natural resource damages at the Morenci Mine [43 CFR § 11.23(b)]. This screen was prepared by Stratus Consulting under contract to the USFWS.

1.1 Intent of the Preassessment Screen

The purpose of a preassessment screen is to determine whether a discharge or release of a hazardous substance warrants conducting an NRDA. It is intended to be based on "a rapid review of readily available information . . . [to] ensure that there is a reasonable probability of making a successful claim" [43 CFR § 11.23(b)]. This preassessment screen is not intended to serve as an assessment of natural resources injuries or damages.

Quantitative and qualitative data sources were relied on for this rapid review of readily available information. Information reviewed includes:

- the Phelps Dodge Morenci, Inc. (PDMI) Reclamation Plan (PDMI, 2002) and annual status reports for 2000, 2001 and 2002 that updated the original 1997 Reclamation Plan
- the State of Arizona Aquifer Protection Permit (and amendments) for the Morenci Mine (ADEQ, 2000, 2002)
- the State of Arizona Air Quality Class I Permit (ADEQ, 2001)

1. 43 CFR Part 11 regulations were authored by the DOI, and are referred to as the DOI regulations in this document.

- the results of an investigation of water quality, sediment, and biota of the Upper Gila River Basin (USFWS, 1994)
- USGS gauge station data from 1980 through 2002 for sites upstream and downstream of the Morenci Mine (Station Numbers 09466500, 09448500, 09444600, 09444500, 09444000) (USGS, 2003)
- the results of a preliminary inventory of migratory bird mortalities as defined by the Migratory Bird Treaty Act (16 USC §§ 703-712) (unpublished data, USFWS records)
- the results of a preliminary survey of water quality field parameters from the Morenci Mine tailings impoundments and process solution ponds from October 2000 conducted by the USFWS (unpublished data, USFWS records)
- various published reports about Phelps Dodge and PDMI
- photographs and videos of the site taken by USFWS personnel in 2000 and 2002.

The Trustees also evaluated the likelihood of hazardous substance releases and adverse effects on natural resources at Morenci, given the similarity between the Morenci Mine and nearby Phelps Dodge copper mines in New Mexico (Tyrone, Chino) for which more data were readily available.

1.2 Criteria to be Addressed by the Preassessment Screen

The content and requirements of a preassessment screen are described in 43 CFR Part 11, Subpart B. Before proceeding past the screening phase, the Trustees evaluated whether all of the following criteria have been met [43 CFR § 11.23(e)]:

1. **A release of a hazardous substance has occurred.** This criterion was evaluated by reviewing information on sources of hazardous substances, evidence of hazardous substance releases, and data demonstrating elevated concentrations of hazardous substances in natural resources.

2. **Natural resources for which the Trustees may assert trusteeship have been or are likely to have been adversely affected by the release.** This criterion was evaluated by documenting migratory bird mortalities at tailings ponds and other mine facilities.

3. **The quantity and concentration of the released hazardous substance are sufficient to potentially cause injury to those natural resources.** This criterion was evaluated by documenting migratory bird mortalities at tailings ponds and concentrations of hazardous substances in surface water and groundwater that exceed regulatory criteria.

4. **Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.** A record of bird mortality and monitoring data for surface water and groundwater already exist at the site. Additional data may be available from the State of Arizona. Data collection activities for resources that have not been evaluated could be conducted at reasonable cost.

5. **Response actions carried out or planned will not sufficiently remedy the injury to natural resources without further action.** No response actions have been undertaken at the Morenci Mine pursuant to a remedial investigation/feasibility study. As part of a settlement reached in 1986 with the EPA, PDMI agreed to construct the $9 million-plus Chase Creek diversion, which diverts Upper Chase Creek around mining operations through a control system that consists of a reservoir, pumps, and a 7.5 mile pipeline to Lower Chase Creek. This response action, however, did not affect other release pathways to surface water and groundwater at the mine. PDMI also has undertaken a bird hazing system based on radar reports of bird activity (http://www.avianradar.com/Phelps/radar.htm). The Trustees do not have information on the effectiveness of this system for reducing injuries to birds. In addition, the Trustees are unaware of any response actions to remedy injuries to other resources.

This preassessment screen presents data sufficient to support the above criteria based on information readily available to the Trustees. It is *not* a comprehensive summary and review of all existing data.

2. Information on the Site [43 CFR § 11.24]

2.1 Location and Description of the Morenci Mine

The Morenci Mining District (the District) is located in southeastern Arizona, Greenlee County, near the towns of Clifton and Morenci (PDMI, 2002, p. 6) (Figure 2.1). The District is located near the Gila River, the San Francisco River, and Eagle Creek, all of which are perennial streams (PDMI, 2002, p. 14). Ephemeral drainages include tributaries of Chase Creek, Gold Gulch, and Rocky Gulch.

The Morenci Mine is the largest producing copper mine in North America (Securities and Exchange Commission, 2002, p. 2). The Morenci Mine comprises a large complex of open pits, numerous leach rock stockpiles and development rock stockpiles, process plants, tailings impoundment facilities, support facilities, and infrastructure (PDMI, 2002, p. 16). The open pit mining area is located in the Middle Chase Creek watershed, in the northern part of the District (PDMI, 2002, p. 6) (Figure 2.2). The tailings impoundments and most of the ore and solution processing facilities are located in the southern part of the District, near the San Francisco River (Figure 2.3).

The climate in the mine area is arid, with precipitation averaging 12.6 inches annually. Precipitation is evenly divided between winter showers and summer thunderstorms. Elevations at the site range from approximately 3,400 to 6,900 feet above mean sea level (PDMI, 2002, p. 12). Vegetation community types at the Morenci Mining District include interior chaparral, semidesert grassland, great basin conifer woodland, postclimax conifer woodland, xeroriparian mixed scrub, maple/oak mesoriparian habitat, *Baccharis*/cottonwood mesoriparian habitat, and herbaceous wetland (PDMI, 2002, p. 15).

2.2 History of Mining at the Morenci Mine

Copper was discovered in the District in 1865. Phelps Dodge invested in mining in the Morenci area in 1881, in a partnership called the Detroit Mining Company (Dresher, 2001). Ore concentrating and smelting by the Detroit Mining Company in Morenci, and the Arizona Copper Company in Clifton, began in the 1880s. In 1897, Phelps Dodge purchased the Detroit Copper Company, but retained the name (PDMI, 1999). In 1921, Phelps Dodge consolidated the assets of the Detroit Mining Company and the Arizona Copper Company under the Phelps Dodge name (Dresher, 2001). From that time until the mid-1980s, sulfide ore from the Morenci District was mined, concentrated, and smelted. Open pit mining began in 1937 (PDMI, 1999). Smelting at the Morenci Mine was discontinued in 1984, and the smelter was dismantled in 1995. After the

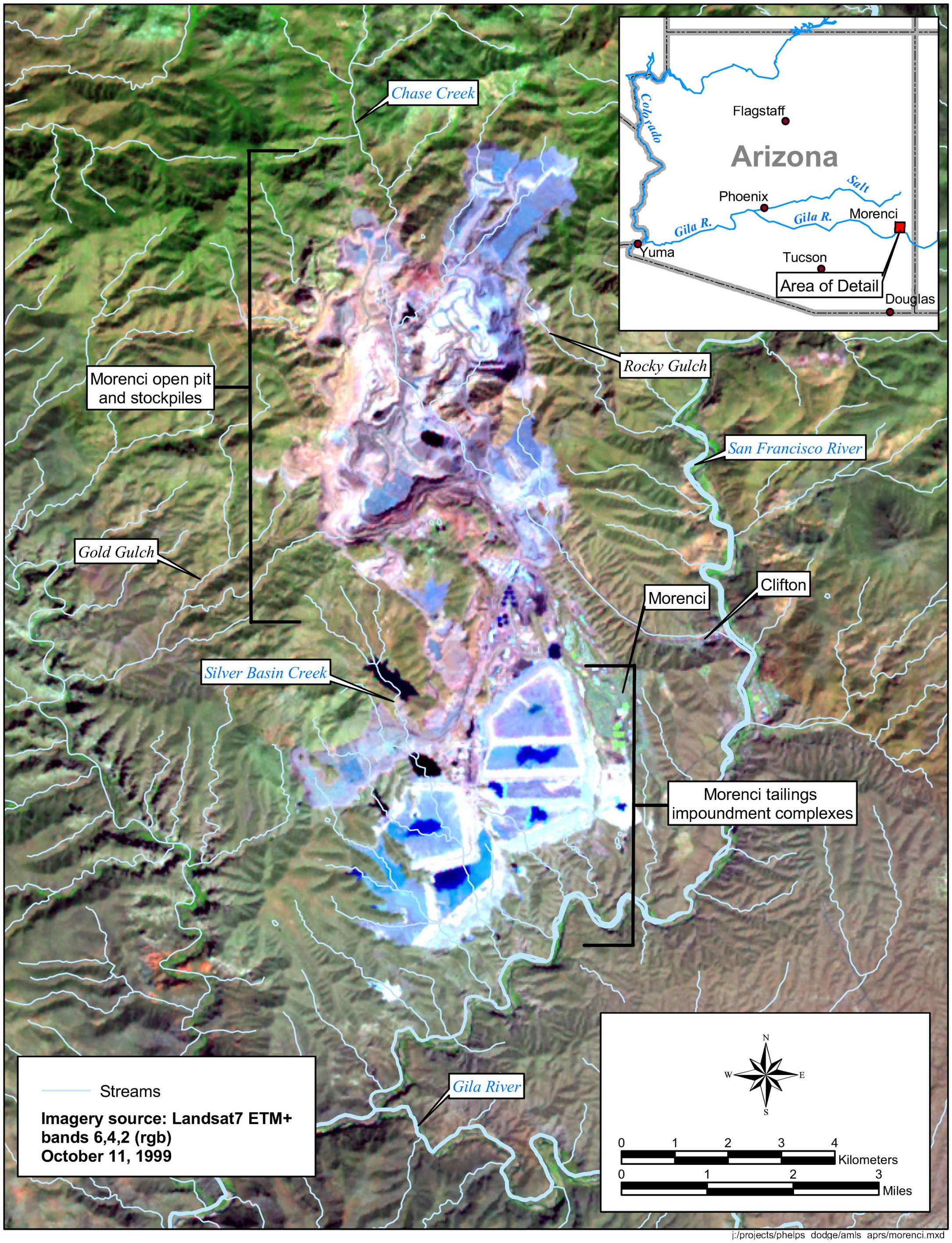
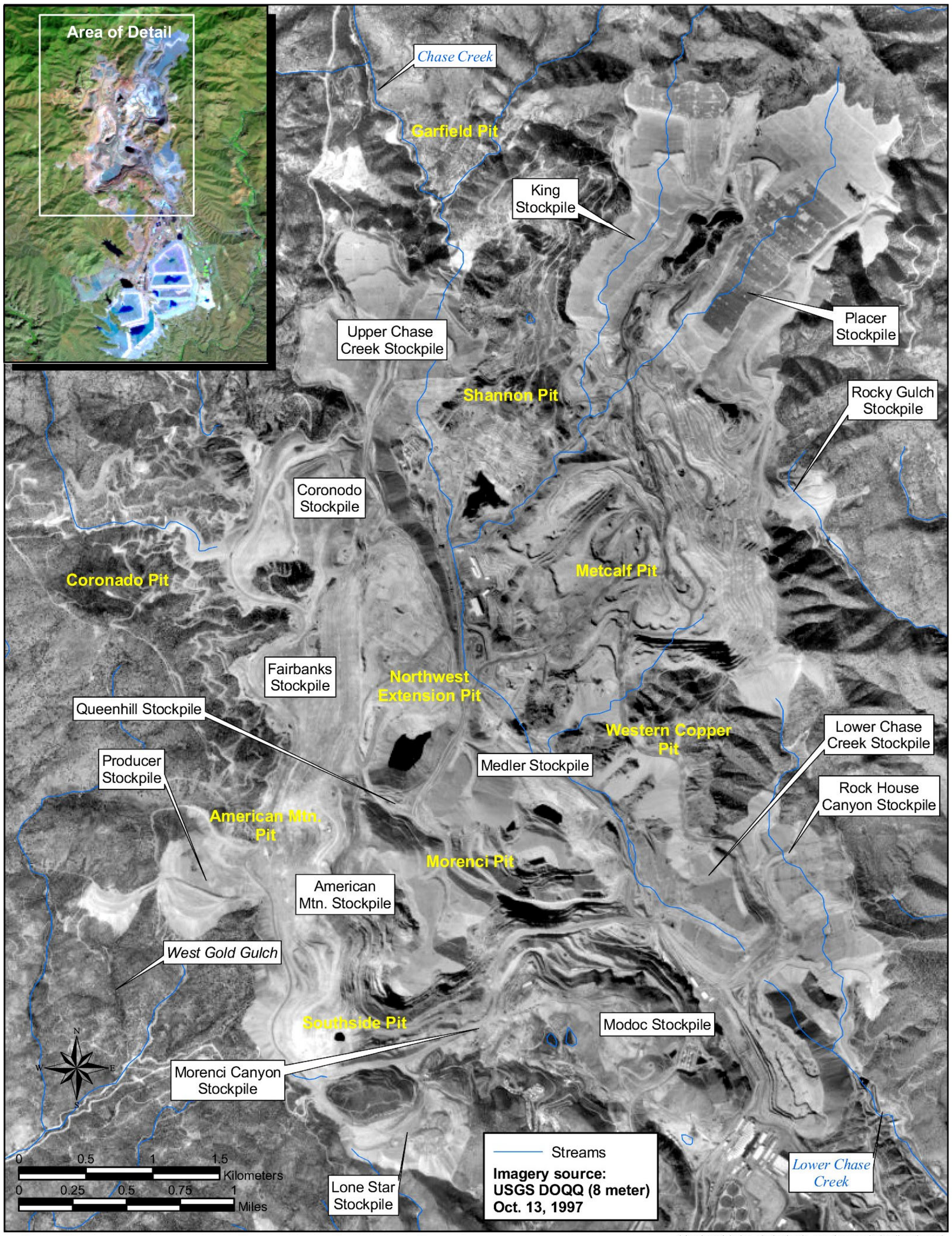


Figure 2.1. Morenci Mine in southeastern Arizona.

Source: Landsat7, 1999.



i:/projects/phelps_dodge/amls_aprs/morenci_detailnorth.mxd

Figure 2.2. Northern mine area at the Morenci Mine, including the open pits and stockpiles.

Source: USGS, 1997.

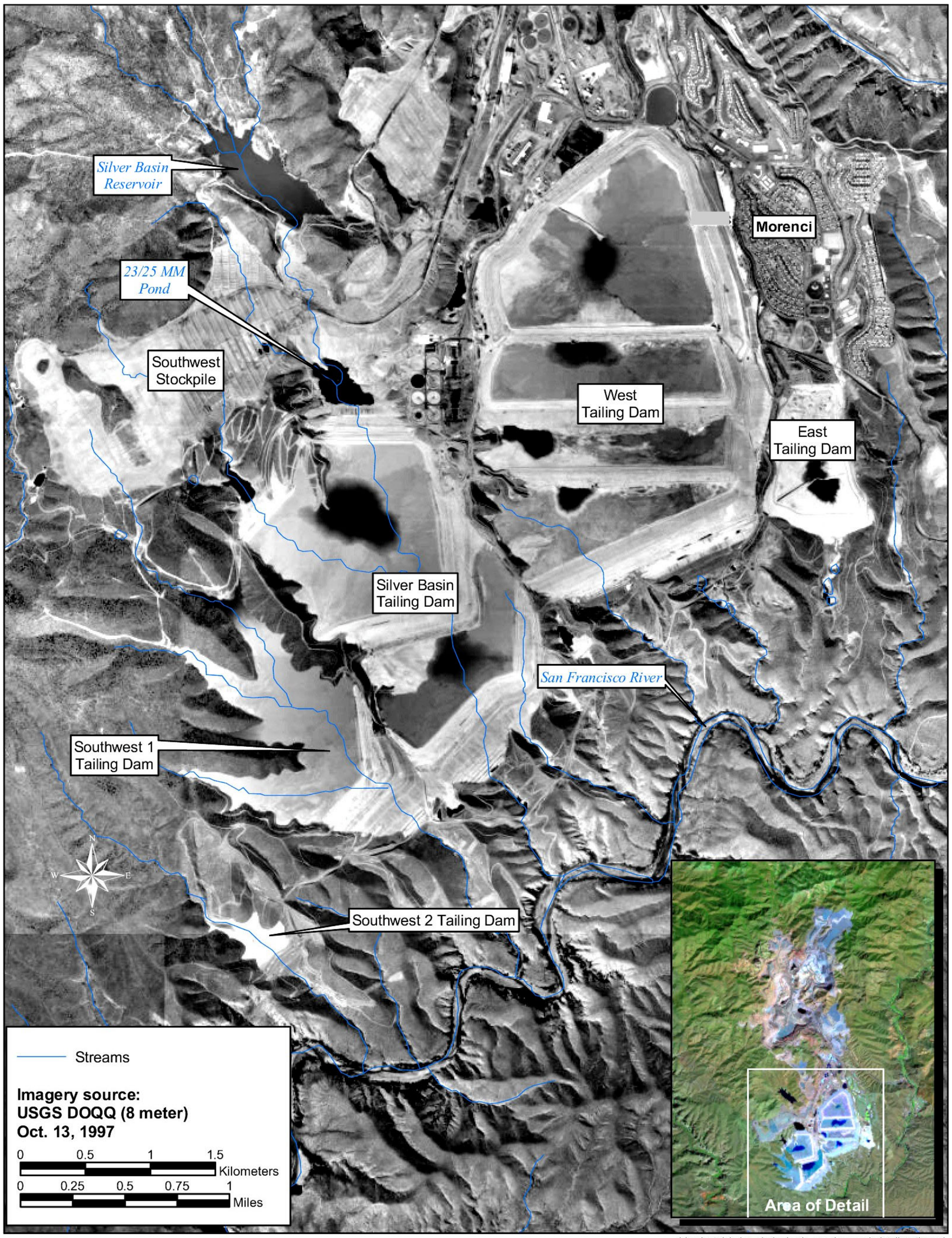


Figure 2.3. Southern mine area at the Morenci Mine, including Silver Basin Reservoir and the tailings dams.

Source: USGS, 1997.

closure of the smelter, concentrates were shipped by rail to the Phelps Dodge smelter in Hurley, New Mexico.

In 1986, Phelps Dodge Corporation sold 15% of the Morenci operation to Sumitomo Metal Mining Company, and Phelps Dodge Morenci, Inc. (PDMI) was formed (Dresher, 2001). In 2001, PDMI completed its $220 million conversion of operations at the Morenci Mine from conventional mining, milling, smelting, and refining to a “mine-for-leach” system (MFL) in which ore is mined exclusively for leaching (Dresher, 2001; Securities and Exchange Commission, 2002, p. 2). The MFL process uses bacteria and weak acid to extract copper from the ore and solution extraction/electrowinning (SX/EW) to recover copper from the resulting leach liquor (Dresher, 2001; PDMI, 2002, p. 10). In 1997, 269,900 tons of copper were produced by the concentrate and precipitate process at Morenci, and an additional 272,300 tons of copper were produced by SX/EW. In 2001, 23,500 tons of copper were produced by concentrate and precipitate, and 368,100 tons were produced by SX/EW (Securities and Exchange Commission, 2002, p. 7).

Morenci Mine facilities include a large open pit mining complex; stockpiles of rock, including leach stockpiles that contain ore which is currently mined or has been mined for copper, and development stockpiles which contain waste rock and ore of a grade that may be leached in the future; a large tailings impoundment complex; mineral processing plants, ponds, reservoirs, drainage ditches, pipelines, and ore and solution conveyances; and offices, warehouses, and other infrastructure (Figures 2.2 and 2.3).

In 1997, the Morenci Mine open pit mine complex comprised 3,055 acres (Table 3 in PDMI, 2002) (Figure 2.4). Ore is mined from the pit using conventional drill, blast, load, and haul techniques (PDMI, 2002, p. 7). In 2002, ore was mined from the Metcalf, Northwest Extension, and Coronado areas of the open pit. In 2001, ore was mined from the Southside and Garfield areas. Future mining is planned in the Western Copper, Southside, and Garfield areas of the pit.

Figure 2.4. Morenci Mine open pit, February 2003.

Before 2001, high grade sulfide ore was mined and concentrated at the Morenci Mine's Morenci and Metcalf concentrators (Dresher, 2001; PDMI, 2002, pp. 7-8). Neither is currently operating. According to the Securities and Exchange Commission (2002, p. 2), the Metcalf concentrator was permanently closed in 1999. However, according to PDMI, the concentrator was placed on standby in September 2000 (PDMI, 2002, p. 9). Operations at the Morenci concentrator ceased in February 2001 (PDMI, 2002, p. 9). Both concentrators reportedly could restart in the future, depending on economic conditions (PDMI, 2002, p. 9). When the concentrators operated, crushed ore was delivered to the concentrators for further crushing, grinding, and separation by flotation. The concentrate was delivered to a thickener system and a ceramic disk filter, where the final copper concentrate was produced. Concentrate and byproducts were shipped off-site by rail. Tailings were delivered to a separate thickener system, and then routed to the tailings impoundment complex (PDMI, 2002, pp. 9-10).

Since 2001, high grade sulfide ores have been leached using the MFL system. The high-grade sulfide ore is mined and hauled to an in-pit crushing and conveying system (PDMI, 2002, p. 8). Crushed ore is fed to two agglomeration units, where a mixture of acid and bacteria, or water, or both is mixed with the ore (Dresher, 2001; PDMI, 2002, p. 8). Agglomerated ore is fed to an overland conveying and stacking system at the Southwest (or Stargo Canyon) crushed ore stockpile for leaching.

The low-grade sulfide and oxide ores are transported as run-of-mine material (no crushing) by haul trucks to leach stockpiles (PDMI, 2002, p. 8). The low-grade sulfide and oxide ore stockpiles are treated with acidic raffinate solution (PDMI, 2002, p. 10). Raffinate is applied by sprinkler irrigation spray heads or drip emitters.

The raffinate percolates the stockpile, dissolving the minerals, and exits the toe of the stockpile as pregnant leach solution (PLS). The PLS is collected in ponds and pumped to one of four SX plants (PDMI, 2002, p. 10). The copper is recovered in the SX/EW process (Dresher, 2001; PDMI, 2002, p. 8). Copper is exchanged for hydrogen in the solvent using an organic extractant. The acid solution remaining after removal of the copper is returned to the leach pile for reuse. Copper is stripped from the organic extractant using depleted electrolyte. High purity copper is recovered by electrowinning, during which copper is exchanged for hydrogen at a cathode. The electrolyte becomes acidified as it is depleted of copper and is returned to the extraction plant for reuse (Dresher, 2001).

Process plant areas include crushing plants and conveyors, concentrators, ponds and thickeners, retention dams, pump stations, reservoirs, drainage ditches, SX/EW plants, labs, warehouses and other buildings, haul access roads, and electrical facilities (PDMI, 2002, p. 16). Mine facilities including roads, ponds, and process plant areas covered 1,117 acres (Table 3 in PDMI, 2002).

The storm water management program at the Morenci Mine is currently intended to function as a zero discharge control system to the perennial streams adjacent to the mine. Ephemeral flows in Upper Chase Creek are diverted around the mining operations through a control system that consists of a reservoir, pumps, and a 7.5 mile pipeline to Lower Chase Creek. The diversion system was constructed in 1986 as part of a settlement PDMI reached with the U.S. Environmental Protection Agency (EPA) for Clean Water Act violations resulting from the discovery that water flowing in Chase Creek was contaminating downstream surface waters in Chase Creek and the San Francisco River (Hilliard, 1993, p. 36). Lower Chase Creek flows through the town of Clifton and then into the San Francisco River. Rocky Gulch flows into the San Francisco River upstream of Chase Creek (Figures 5A and 5B in PDMI, 2002). A number of springs are located along ephemeral and intermittent drainages in the northern part of the mining district (PDMI, 2002, p. 14).

PDMI successfully petitioned in its 1996 Aquifer Protection Permit application to credit operations in the open pit mine as a passive containment capture zone for groundwater. The hydrologic sink created by operations in the open pit is considered by the Arizona Department of Environmental Quality (ADEQ) to be a Best Available Demonstrated Control Technology (ADEQ, 2000, 2002, pp. 2, 6).

2.3 Identification of Potentially Responsible Parties

The Trustees have identified PDMI, Sumitomo Metal Mining Arizona, Inc., and their parent companies, Phelps Dodge Corporation and Sumitomo Metal Mining Ltd., as potentially responsible parties (PRPs). The term PRP as used in this document refers to parties potentially liable for natural resource damages under CERCLA. According to information currently available to the Trustees, Phelps Dodge Corporation was the sole owner of the Morenci Mine from 1921 until 1986. In 1986, Phelps Dodge Corporation sold 15% interest in the mine to Sumitomo Metal Mining, and PDMI was formed. PDMI is the current operator of the mining complex (Dresher, 2001). Phelps Dodge Corporation currently owns an 85% undivided ownership in PDMI. Sumitomo Metal Mining Arizona, Inc. holds a 15% interest (PDMI, 2002, p. 1; Securities and Exchange Commission, 2002, p. 2). In 2002, Phelps-Dodge Corporation was number 428 on the Fortune 500 list of the largest corporations in the United States, with annual revenues of more than $3.7 billion. Sumitomo Metal Mining Arizona, Inc. is a jointly owned subsidiary of Sumitomo Metal Mining Co., Ltd. and Sumitomo Corporation (Securities and Exchange Commission, 2002, p. 2). Sumitomo Metal Mining Company had net sales of approximately $2.6 billion in 2002, with a gross profit of $306 million (Sumitomo Metal Mining, 2002, yen to dollar conversion made for fiscal year April 1, 2001 to March 31, 2002).

2.4 Releases of Hazardous Substances

Evidence of hazardous substance releases from the Morenci Mine has been documented by sampling conducted by ADEQ. Further evidence of hazardous substance releases was documented during site visits to the mine by the USFWS, and from information provided through the Toxics Release Inventory (TRI) program of the EPA.

2.4.1 Hazardous substances released

Hazardous substances are present in source materials at the Morenci Mine and have been released to the environment. The main sulfide minerals at Morenci are chalcocite (Cu_2S) and pyrite (FeS_2). Other sulfide ore minerals present in significant quantities include chalcopyrite ($CuFeS_2$) and covellite (CuS) (PDMI, 2002, p. 13). Brochantite ($Cu_4(OH)_6SO_4$), molybdenite (MOS_2), sphalerite ((Zn,Fe)S), and galena (PbS) are also present (Dresher, 2001). The main oxide minerals are goethite (FeO(OH)), hematite (Fe_2O_3), jarosite ($KFe_3(SO_4)_2(OH)_6$), chrysocolla ($Cu_2H_2(SiO_5)(OH)_4$), and malachite $CuCO_3(OH)_2$. Other oxide minerals include azurite ($Cu(CO_3)_2(OH)_2$), tenorite (CuO), and cuprite (Cu_2O) (Dresher, 2001; PDMI, 2002, p. 13). Mineral composition of Morenci Mine ore indicates that hazardous substances present in source rock include copper, lead, and zinc.[1]

Additional sources of hazardous substances come from mine operations. Sulfuric acid, a listed hazardous substance, is used in the SX/EW process and is released in power generation processes at the mine (ADEQ, 2001). Raffinate is a low pH solution containing elevated concentrations of metals, total dissolved solids, and sulfates resulting from the SX/EW process after copper extraction. Diesel oil also is stored on-site.

The main ore minerals at the Morenci Mine are sulfide minerals. Upon exposure to the atmosphere, these sulfide minerals react with oxygen and water to form sulfuric acid. Precipitation infiltrating development stockpiles produces acidic water that leaches metals from the rock, producing acid-mine drainage. Metal-laden water can seep from the stockpiles to surface water and to groundwater, resulting in releases of hazardous substances. For example, an EPA inspection in September 1984 discovered that water leaching through waste rock dumped into the Chase Creek drainage basin was highly acidified. Water pouring out of the waste rock piles was reported to be bright green from high copper concentrations (Hilliard, 1993, p. 36). In addition, precipitation and surface water runoff that ponds on the surface of oxidized tailings

1. The Trustees realize that hazardous substances occur naturally in source rock at the Morenci Mine. The Trustees are pursuing an NRDA at the Morenci Mine because of evidence that these substances have been released to the environment in concentrations potentially sufficient to injure natural resources for which the Trustee agencies have trusteeship.

impoundments react with sulfide minerals in the tailings to produce acid, resulting in ponded water with low pH and elevated metal concentrations.

Concentrations of hazardous substances measured in groundwater at the Morenci Mine and measured in the San Francisco and Gila rivers downstream of the mine provide further indications that hazardous substances present in the source materials at the Morenci Mine have been released to the environment. Hazardous substances measured in groundwater include, but may not be limited to, antimony, beryllium, and cadmium (Table 2.1). Elevated concentrations of copper and zinc have been measured at downstream San Francisco and Gila river sampling points (see Figures 3.5 and 3.6). In addition, under the requirements of the TRI program, PDMI reported releases to the environment between 1998 and 2000 of ammonia, arsenic, chromium, cobalt, copper, lead, mercury, nickel, zinc, toluene, polycyclic aromatic compounds, and sulfuric acid, including releases of lead, manganese, nickel, and zinc to surface water in West Gold Gulch in 1999 and 2000 (U.S. EPA, 2003).

Table 2.1. Hazardous substances measured in groundwater at the Morenci Mine (concentrations of metals are given in µg/L)

	Antimony	Beryllium	Cadmium	pH
Rocky Gulch Dam		16.6	20.2	4.37
Gold Gulch	9.2			

Source: U.S. EPA, 1997. Groundwater samples collected from the point-of-compliance monitoring well for Rocky Gulch Dam, and from a monitoring well in Gold Gulch by Arizona Department of Environmental Quality, April 25, 1996.

Based on the sources of information described above, the Trustees have reasonably concluded that hazardous substances present in the ore body have been released as a result of mining and mineral processing. Hazardous substances (as given in the List of Hazardous Substances and Reportable Quantities, Table 302.4 at 40 CFR § 302.4) identified as having been released from the Morenci Mine facilities include, but may not be limited to:

- antimony and compounds
- beryllium and compounds
- cadmium and compounds
- copper and compounds
- lead and compounds
- manganese and compounds
- nickel and compounds
- zinc and compounds
- sulfuric acid in pregnant leach solution and raffinate.

2.4.2 Sources of hazardous substance releases

Potential sources of hazardous substances releases at the Morenci Mine include, but are not limited to, tailings impoundments; development and leach stockpiles; the SX/EW plants and associated infrastructure, including uncovered and unlined ponds and pipelines; and the open-pit mine.

Tailings impoundments

Tailings facilities are large volume storage areas impounded by embankments (Figure 2.5). There are five tailings complexes in the Morenci District, including the Southwest 1, Southwest 2, Silver Basin, West, and East tailings dam complexes (Table 1 in ADEQ, 2002) (Table 2.2). All are located in the southern part of the Morenci District. Tailings deposition in the Southwest, Silver Basin, and West tailings impoundments reportedly will continue until the concentrators are closed (PDMI, 2002, p. 17); however, the concentrators are on standby since PDMI switched all mining to mine for leach in 2001. The East Tailing Dam complex is currently inactive (PDMI, 2002, p. 17).

Figure 2.5. Tailings pond outer embankment at the Morenci Mine.

Table 2.2. Tailings impoundments at the Morenci Mine

Tailing pond	Approximate size (acres)[a]	Description[b]
Southwest tailing dam 1	395	Uncovered; unlined. Southwest of Silver Basin; northeast of Southwest 2. North of San Francisco River.
Southwest tailing dam 2	31	Uncovered; unlined. Southwest of Southwest 1. North of San Francisco River.
Silver Basin tailing dam complex	975	Uncovered; unlined. Between Southwest 1 and West complexes. North of San Francisco River.
West Dam tailing complex	1,582	Uncovered; unlined. West and south of Morenci townsite. North of San Francisco River.
East Dam tailing complex	177	Uncovered; unlined; inactive. South of Morenci townsite.
Total area	3,160	

a. Areas estimated from USGS, 1997.

b. Sources: USGS, 1997; Figure 3A in PDMI, 2002.

In 1997, tailing facilities covered 3,160 acres (USGS, 1997). The edge of the tailings impoundments is located less than 500 feet from home sites in the town of Morenci. The Silver Basin tailing dam ends less than 2,800 feet from the San Francisco River (Figure 3A in PDMI, 2002).

Site-specific data on hazardous substance releases from the tailings impoundments were not available for review for this preassessment screen. However, the Morenci mine ore bodies contain generally similar sulfidic ores to the ore bodies found at the Phelps Dodge Tyrone Mine in southwestern New Mexico. Sulfide minerals present at both facilities include pyrite, chalcopyrite, galena, chalcocite, sphalerite, and covellite (SARB, 1999; Dresher, 2001; PDMI, 2002, p. 13). Chrysocolla is an oxide mineral found at both facilities. Both the sulfide and oxide minerals contain hazardous substances, including copper, lead, and zinc. Because the production of tailings results from crushing and concentrating the ore, hazardous substances present in the ore body are also likely to be present in tailings, as demonstrated by elevated concentrations of hazardous substances measured in samples taken from the Tyrone Mine tailings ponds (Table 2.3). Furthermore, PDMI has reserved the tailings for future mineral development using the SX/EW process to economically remine tailings (PDMI, 2002, p. 22), indicating that the Morenci tailings contain significant quantities of copper.

Table 2.3. Concentrations of hazardous substances in sediments from Tyrone Mine tailings ponds (mg/kg dry weight)[a]

Tailings pond	As	Cd	Cr	Cu	Mn	Pb	Zn
Burro Mountain	3.56	0.596	< 4.81	2,868	114	68.5	114
#1	1.55	0.23	< 4.94	149	25.4	< 4.94	23.2
#1A	1.15	4.24	6.84	2,629	157	34.2	623
#1X	1.64	3.58	5.82	1,523	118	86.4	390
#2	2.46	2.68	< 4.81	988	86.6	106	366
#3X	2.12	8.13	6.32	3,203	336	84.1	930

a. Composite samples of tailings samples collected from top oxidized layer in September 2000.
Source: USFWS, unpublished data.

Retention dams have been constructed downgradient of the tailings complexes and upgradient of the San Francisco River to contain stormwater runoff from the side slopes of the tailings impoundments. The retention dams are located between the southern edge of the tailings complexes and the San Francisco River, and as close as approximately 1,600 feet from the San Francisco River (Figure 3A in PDMI, 2002). The Aquifer Protection Permit (APP) identifies 30 tailing stormwater retention dams; all are dry under normal operating conditions (Table 1 in ADEQ, 2002).

Information on rates, volume, and content of hazardous substances eroded from the tailings impoundments was not available for review for this preassessment. However, during a site visit in October 2002, USFWS personnel were informed by PDMI personnel that stormwater retention pond 7A, which is approximately 800 feet downgradient of Southwest 1 Tailing Dam, is periodically dredged to remove accumulated tailings to maintain its stormwater holding capacity (USFWS, unpublished data) (Figure 2.6). PDMI's APP specifies annual removal of tailings accumulated behind stormwater retention dams as an operational requirement (ADEQ, 2000, 2002), further indicating that hazardous substances present in tailings are released to the environment through stormwater runoff.

Figure 2.6. Morenci Mine stormwater retention pond at Dam 7A, October 2002.

Windblown erosion and redistribution of the uncovered tailings are also likely sources of hazardous substance releases, given the arid climate, the large surface area, and the fine particle size of tailings. PDMI's air quality permit specifies measures recommended to reduce windblown tailings emissions (ADEQ, 2001, pp. 50-53). The Trustees are aware that tailings closest to the town of Morenci have been capped to reduce windblown tailings emissions, but large areas of tailings remain uncapped (USFWS site visit, October 2002).

The five unlined tailings impoundments in the Morenci District contain acid-generating materials. As water drains from the tailings, the upper portions of the tailings ponds are exposed to the atmosphere, causing the oxidation of sulfide minerals. As precipitation ponds on the surface of the tailings impoundments and interacts with these upper oxidized tailings, the concentrations of metals, total dissolved solids, and sulfate in the water increase, and the pH decreases.

Consequently, following precipitation events, ponded water in contact with oxidized tailings can serve as a pathway of hazardous substances to birds and wildlife attracted to ponded water in the arid southwest (Figures 2.7 and 2.8). The ponds are intermittent, depending on precipitation and evaporation rates, but they remain a source of future releases following periods of surface water accumulation. The remote sensing imagery (Landsat7, 1999) used to create the map in Figure 2.1

Figure 2.7. Ponded water on tailings at the Morenci Mine.

Figure 2.8. Evidence of bird and wildlife use at the Morenci Mine tailings impoundments. Clockwise from upper left: animal spine, dead waterfowl, animal tracks, and bird wing.

clearly shows ponded water on each of the tailings ponds. No data on metals concentrations in ponded water on Morenci Mine tailings impoundments were available for review. Measurements of metal concentrations in ponded surface water at similar tailings facilities at the Phelps Dodge Tyrone mine in New Mexico, however, found high concentrations of hazardous substances (Table 2.4). The Trustees believe that it is likely that ponded surface water on tailings at the Morenci Mine has served as a source of hazardous substance releases.

Runoff from the tailings complexes is impounded by the downgradient stormwater retention dams (Figure 2.6). Sixteen of the 30 have permit requirements to maintain the pH of any impounded water above 5 standard units (SU) (Table 2 in ADEQ, 2000, 2002). In October 2002, the USFWS measured the pH of water impounded in three stormwater retention ponds

Table 2.4. Concentrations of hazardous substances measured in ponded water on Tyrone tailings dams (mg/L)

Location	pH	As	Be	Cd	Cr	Cu	Mn	Ni	Se	Zn
Burro Mountain tailings pond	2.9	0.0107	0.0391	0.263	0.0547	718	34.6	0.448	0.0145	32.5
Storm runoff to Pond 3	2.4	0.72	0.116	0.747	1.72	975	173	3.29	0.297	80.6
Tailings Pond (T.P.) #1	2.1	0.179	0.0803	1.22	1.81	536	38.4	1.71	0.073	88.9
T.P. #1A	2.1	0.22	0.347	11.5	4.64	4,916	342	6.43	0.359	1,610
T.P. #1X	2.6	0.0504	0.107	7.73	1.4	1,947	109	2.6	0.145	703
T.P. #2	2.3	0.299	0.137	4.43	2.17	1,522	151	2.99	0.272	534
T.P. #3X	2.5	0.25	0.347	21.9	4.19	5,844	738	10	0.534	2,014

Source: Unpublished data, samples collected by USFWS on September 12, 2000, analyzed at the Research Triangle Institute.

downgradient of the East, West, and Southwest 1 tailings complexes. The measured pH in three ponds ranged from 1.6 to 2.6 (USFWS, unpublished data, October, 2000) indicating that runoff from the tailings is a source of extremely low pH water, and therefore most likely also contains elevated concentrations of metals. Thus, impounded acidic water in the retention dams may serve as a source of hazardous substance releases to biota and to underlying groundwater.

Leach stockpiles

Leach stockpiles comprise rock currently or historically leached for copper (PDMI, 2002, p. 16). In 1997, leach stockpiles covered 4,538 acres (Table 3 in PDMI, 2002). The leach stockpiles are associated with uncovered and unlined PLS collection and overflow impoundments, as well as sumps, ditches, and pipelines (Table 1 in ADEQ, 2000, 2002).

There are 13 existing leach stockpiles, and approximately 9 planned leach stockpiles or leach stockpile extensions (according to the 1997 Reclamation Plan, as amended through February 2002) (Table 2.5). Rock House Canyon (and the planned Rock House Canyon Expansion), Lower Chase Creek, Southwest (and the planned Southwest [Stargo] Expansion), Lone Star, and the planned Silver Basin stockpiles are outside of the capture zone of the hydrologic sink (Maps 3B and 3C in PDMI, 2002). Leach stockpiles located within the capture zone of the hydrologic sink include the Medler, Copper Mountain, American Mountain, Placer, King, Coronado, Queen Hill, Santa Rosa, and Upper Chase Creek stockpiles. Leach stockpiles identified as planned stockpiles include the King/Placer Expansion, Coronado Expansion, Upper Chase Creek Expansion, Metcalf in-pit, Morenci in-pit Expansion, and possibly Northwest Coronado stockpiles (Maps 3B and 3C in PDMI, 2002). The area of in-pit stockpiles is 1,433 acres (of the total 3,055 acres of the total open pit area) (Table 3 in PDMI, 2002).

Table 2.5. Leach stockpiles at the Morenci Mine[a]

Outside of hydrologic capture zone	Within the hydrologic capture zone
Lone Star	American Mountain
Lower Chase Creek	Copper Mountain
Rock House Canyon	Coronado
Southwest	King
*Southwest [Stargo] expansion	Medler
*Rock House Canyon expansion	Placer
*Silver Basin	Queen Hill
	Santa Rosa
	Upper Chase Creek
	*King/Placer expansion
	*Coronado expansion
	*Upper Chase Creek expansion
	*Metcalf in-pit
	*Morenci in-pit expansion
	*Northwest Coronado

a. Stockpiles marked with an asterisk were noted as "planned stockpiles" as of February 2002.
Source: Maps 3B and 3C in PDMI, 2002.

Potential releases of hazardous substances from leach stockpiles at the site probably began with the start of open pit mining in 1937 and extend to the present. The leach stockpiles at the Morenci Mine can serve as continuous sources of hazardous substances through releases of PLS from leach stockpiles and collection facilities.

PLS is the acidic, metal-rich solution that is the primary product of leaching operations. PLS may be released from leach stockpiles into groundwater because of incomplete capture of PLS by collection systems. No monitoring well data were available for review, but unlined PLS collection facilities outside the hydrologic capture zone of the pit, including the Horseshoe Sump, the 5X Sump, Dam BC-6, Dam BC-7, the 27MM Sump, Dam BC-8, Dam BC-9, the 29MM Sump, and the 23/25 MM Pond, were all scheduled for upgrade to reduce the saturated hydraulic conductivity of the impoundments (Table 1 in both ADEQ, 2000, 2002). Monitoring data from other mine sites, such as the Phelps Dodge Tyrone Mine, near Silver City, NM, have confirmed releases of hazardous substances, including copper, manganese, and zinc, resulting from the seepage of PLS to perched and regional aquifers (Daniel B. Stephens & Associates Inc., 1997).

Hazardous substances in uncovered PLS ponds also may be released directly to wildlife that ingest the process solution. PLS ponds at the Morenci Mine, such as the 23/25 MM Pond downgradient of the Southwest leach stockpile, attract wildlife, including migratory birds, in this arid desert environment (Figure 2.9).

Figure 2.9. 23/25 MM PLS collection pond at the Morenci Mine.

Development stockpiles

Development stockpiles are accumulations of waste rock and lower grade ore that do not support economic metal recovery with existing technology or at current metal prices (PDMI, 2002, p. 16). In 1997, development stockpiles covered 1,072 acres (Table 3 in PDMI, 2002).

Development rock stockpiles include Fairbanks, Morenci Canyon, Modoc, Rock House, Rocky Gulch, and Producer (Maps 3B and 3C in PDMI, 2002). West Coronado and Highway Relocation appear to be future development stockpiles (Maps 3B and 3C in PDMI, 2002). The 9/10 stockpile, historically designated as a development stockpile, was recently mined as a leach stockpile (PDMI, 2002; p. 22); it may now be the Coronado leach stockpile (PDMI, 2002, Attachment A to the Annual Status Report). In 1997, development stockpiles covered 1,072 acres (Table 3 in PDMI, 2002).

Potential and actual releases of hazardous substances from development stockpiles at the site probably began with the start of open pit mining in 1937 and extend to the present. Hazardous substances released may include, but not be limited to, antimony, beryllium, and cadmium, which were detected in groundwater, and copper, lead, and, zinc, which are present in source materials. The wasterock stockpiles at the Morenci Mine can serve as continuous sources of hazardous substances through 1) acidic seepage from acid-mine drainage at waste rock piles, and 2) precipitation-induced erosion, storm-water runoff, or windblown emissions from waste rock stockpiles.

Development stockpiles themselves are not included in PDMI's APP (Maps 3A and 3B in PDMI, 2002). The collection facilities downgradient from development stockpiles are subject to the APP, and data and information on stormwater collection systems associated with development stockpiles indicate that the development stockpiles are sources of hazardous substances.

For example, PDMI built an impoundment in the Rocky Gulch drainage after the discovery of contaminated water flowing into the San Francisco River (U.S. EPA, 1997, p. 43). The Rocky Gulch Dam is a storm water collection system located approximately 200 feet downgradient of the toe of the Rocky Gulch development stockpile. The dam captures water that seeps from the toe of the stockpile and stormwater runoff from areas upgradient and downgradient of the stockpile. In 1996, ADEQ collected samples from the point of compliance monitoring well for Rocky Gulch Dam. The samples exceeded Maximum Contaminant Levels for seven parameters, including the hazardous substances beryllium (16.6 μg/L) and cadmium (20.2 μg/L) (Table 2.1) (U.S. EPA, 1997, p. 44). The APP required that PDMI submit an assessment of the need for and effectiveness of a groundwater interceptor system, and to implement the system if necessary (Table 11 in ADEQ, 2002). The Trustees are currently unaware of any implementation of a groundwater interceptor system at this location.

The Gold Gulch Dam was built downgradient of the Producer Pile, a development stockpile in Gold Gulch. The Gold Gulch Dam contains runoff from the Producer Pile in an unlined impoundment (Table 1 in ADEQ, 2002). A "several-hundred-foot-long surface seep with a blue-green color indicative of a copper bearing precipitate" was noted by ADEQ in the mid-1990s (U.S. EPA, 1997, pp. 41-42). The contaminant source was considered by ADEQ to be "reasonably attributable to the Gold Gulch impoundment" (U.S. EPA, 1997, p. 42). No data on the quality of the seep water were available for review. However, the APP requires PDMI to submit a plan to address potential sources of exceedences of groundwater criteria at the Gold Gulch Dam point of compliance (Table 11 in ADEQ, 2002). The APP specifies that the pilot test be designed to increase the pH of the impoundment solution to minimize the potential for mobilization of lead from the bedrock. In addition, the TRI identifies releases of lead, manganese, nickel, and zinc to surface water in West Gold Gulch in 1999 and 2000 (U.S. EPA, 2003). West Gold Gulch (also downgradient of the Producer Pile) and the drainage below the Gold Gulch Dam converge approximately 3,000 feet downgradient of the dam (Map 3B in PDMI, 2002).

In 1984, EPA discovered that PDMI had dumped waste rock in the Chase Creek drainage, and that water flowing in Chase Creek was leaching through the waste rock, generating sulfuric acid and contaminating downstream surface waters in Chase Creek and the San Francisco River (Hilliard, 1993, p. 36). At the time, PDMI had no discharge permit, and EPA filed a civil suit against PDMI for Clean Water Act violations. As part of a settlement reached in 1986, PDMI paid $1 million in civil penalties to EPA, and $50,000 in civil penalties to the State of Arizona (Hilliard, 1993, p. 37). In addition, PDMI agreed to build the $9 million-plus Chase Creek diversion, which diverts Upper Chase Creek around mining operations through a control system that consists of a reservoir, pumps, and a 7.5 mile pipeline to Lower Chase Creek.

These examples indicate that the development stockpiles have been and continue to be sources of hazardous substance releases to groundwater and surface water, as well as likely pathways of hazardous substances to birds and wildlife attracted to surface water.

Information on rates, volume, and content of material eroded and leached from the development stockpiles was not available for review for this preassessment. However, PDMI's air quality permit identifies PDMI as a "major source," based on a potential to emit more than 100 tons per year of particulate matter (ADEQ, 2001, p. 1). Blasting, shoveling, crushing, and dumping ore and waste rock contribute to windblown emissions of hazardous substances contained in ore and waste rock.

Open pit mining and process plant facilities

The Morenci Mine open pit mine complex comprised 3,055 acres in 1997 (Table 3 in PDMI, 2002). Process plant areas include crushing plants and conveyors, concentrators, ponds and thickeners, retention dams, pump stations, reservoirs, drainage ditches, four SX plants, three EW plants, laboratories, warehouses and other buildings, haul access roads, and electrical facilities (PDMI, 2002, p. 16; Securities and Exchange Commission, 2002, p. 2). Mine facilities, including roads, ponds, and process plant areas, covered 1,117 acres in 1997 (Table 3 in PDMI, 2002).

In 1969, a flood washed 448,000 gallons of acidic wastewater into Chase Creek, which transported the contaminants to the San Francisco River, resulting in "massive fish kills over the length of the San Francisco River downstream of Chase Creek and 1 mile of the Gila River" (U.S. EPA, 1992; Hilliard, 1993, p. 36). The Trustees are also aware that the U.S. EPA imposed a penalty of $60,000 in September 1994 for discharges of pollutants in violation of an NPDES permit (U.S. EPA, 1994a).

Data on releases from process plant facilities and the open pit were unavailable for review. However, data from other mine sites suggest that spills, releases of hazardous substances from mining and copper recovery process operations, precipitation-induced erosion, stormwater runoff, and windblown emissions from solution processing and mining operations in the pit are likely. Response actions required in PDMI's APP suggest that the potential for leakages of PLS at the Morenci Mine are a concern for the State of Arizona. For example, PDMI's APP requires specific response actions to be undertaken following leakages of PLS in exceedence of action leakage rates of 294 gallons per day (gpd) for the Central SX Plant PLS Pond, and 415 gpd for the Modoc SX Plant PLS Pond. Additional response actions must be undertaken in the event of "rapid and large leakage" rates that exceed 1,070 gpd for the Central SX PLS Pond and 1,513 gpd for the Modoc SX Plant PLS Pond (ADEQ, 2002, pp. 11-12, pp. 11-12).

2.4.3 Time, quantity, duration, and frequency of releases

Based on information collected at the Phelps Dodge Tyrone mine in New Mexico, the Trustees believe that it is likely that releases of hazardous substances have occurred at each tailings impoundment, at least from the time period when it stopped receiving new tailings and began to oxidize. The frequency of releases from ponded water depends on the time period when ponded water is present, which is a function of precipitation and evaporation. In addition, surface runoff and erosion of tailings to downgradient impoundments, and wind erosion of dry tailings, occur repeatedly throughout the year, in all seasons.

Releases of hazardous substances through the formation of acid mine drainage from waste rock piles (development stockpiles) probably occur continuously or nearly so. Releases of hazardous substances were documented in 1984, when EPA discovered that PDMI had dumped waste rock in the Chase Creek drainage (Hilliard, 1993, p. 36). The Trustees believe it is likely that releases have occurred since open pit mining began in 1937 and wasterock piles began to be formed.

Releases of hazardous substances through the leakage of PLS from unlined impoundments and conveyances probably occur continuously or nearly so. In addition, hazardous substances in uncovered PLS ponds are continuously available to wildlife that come into contact with the process solution. In addition, spills of mine process water have been documented since at least 1969, when a flood washed 448,000 gallons of acidic wastewater into Chase Creek (U.S. EPA, 1992; Hilliard, 1993, p. 36). Based on reports of numerous spills of hazardous substances at the Phelps Dodge Tyrone and Chino mines (Daniel B. Stephens & Associates, 1997; IRC, 2001), the Trustees suspect that there have been ongoing spills at the Morenci mine as well.

2.5 Relevant Operations Occurring at or near the Site

Relevant operations occurring at or near the site include ongoing mining activities by PDMI, such as blasting in the open pit, transport of ore rock to leach stockpiles, transport of wasterock to development stockpiles, leaching of leach stockpiles, collection of PLS, and operation of the SX/EW plant. PDMI generates (or generated) power at the Morenci Steam Power Plant and the Metcalf Combined Cycle Power Plant (diesel combustion) (ADEQ, 2001). Other facilities include a lime plant, a concrete batch plant, gasoline storage tanks, and a diesel generator (ADEQ, 2001).

PDMI operates under the State of Arizona’s APP program. PDMI’s permit became effective in October 2000 (ADEQ, 2000). The APP specifies operational requirements for all individually permitted facilities, including monitoring frequency, parameters, and Action/Alter Levels and Aquifer Quality Limits. The permit requires monitoring of 20 point of compliance (POC) wells for ambient (existing) groundwater quality to allow calculation of Alert Levels and Aquifer

Quality Limits for each POC well, and quarterly compliance monitoring for POC wells thereafter. The permit requires a reassessment of the passive containment capture zone model every five years, and quarterly monitoring of static groundwater levels at 33 piezometers and annual monitoring of pH, total dissolved solids, and sulfate at two of the piezometers (after Action Levels are established) to determine if the hydrologic sink is being maintained. The permit requires that PDMI report exceedences of Alert Levels and Aquifer Quality Limits to ADEQ, and prepare corrective action plans for return to compliance with AQLs (ADEQ, 2000, pp. 3-5).

Phelps-Dodge is required by its NPDES permits to manage stormwater on site. In December 2002, EPA authorized ADEQ to implement discharge permitting under AZPDES. Permits held by PDMI were not available for review.

2.6 Damages Excluded from Liability

The Trustees currently are not aware of any natural resource damages that would be excluded from liability under CERCLA. Based on the available information, none of the conditions for exclusion from CERCLA apply [43 CFR § 11.24(b)]. Specifically:

1. **The damages resulting from the releases have not been specifically identified as an irreversible and irretrievable commitment of natural resources in an environmental impact statement or other comparable environmental analysis, no decisions were undertaken by the State to grant permits or licenses authorizing such commitments of natural resources, and PRP facilities were not otherwise operating within the terms of such permits or licenses.** Although the Morenci Mine operates under a number of permits, the Trustees are currently unaware of any terms of such permits or licenses that would authorize injuries to trust resources such as birds and wildlife and resulting damages.

2. **Damages and the releases of hazardous substances from which such damages resulted have not occurred wholly before enactment of CERCLA.** Information reviewed for this preassessment screen indicates that releases of hazardous substances, natural resource injuries, and associated damages have occurred since 1980 and continue to the present.

3. **Damages have not resulted from the application of a pesticide product registered under the Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. §§ 135-135k.** This criterion does not apply to releases from the Morenci Mine, which do not involve applications of a pesticide product.

4. **Damages have not resulted from any other federally permitted release, as defined in §§ 101(10) of CERCLA.** Although the Morenci Mine operates under a number of permits, including groundwater permits issued by ADEQ, the Trustees are currently unaware of any terms of such permits or licenses that would authorize injuries to trust resources such as birds and wildlife and resulting damages.

3. Preliminary Identification of Resources at Risk [43 CFR § 11.25]

3.1 Preliminary Pathway Identification [43 CFR § 11.25(a)]

As described in Chapter 2, actual or potential sources of hazardous substance releases to the assessment area include inactive and uncovered tailings impoundments (3,160 acres); stormwater retention basins associated with the tailings impoundments; wasterock and leach stockpiles (5,610 acres); and the SX/EW plants and associated infrastructure, including uncovered ponds and pipelines. Exposure pathways that may transport hazardous substances released from sources to other natural resources include direct contact of biota with hazardous substances, surface water and sediments, groundwater, aerial transport, soil, and food chain. Figure 3.1 depicts potential relationships between sources, pathways (direct contact, aerial transport, soil, and food chain), and natural resources. Figure 3.2 depicts potential exposure pathways at the Morenci Mine. Pathways of hazardous substance transport at the Morenci Mine are described briefly in the sections below.

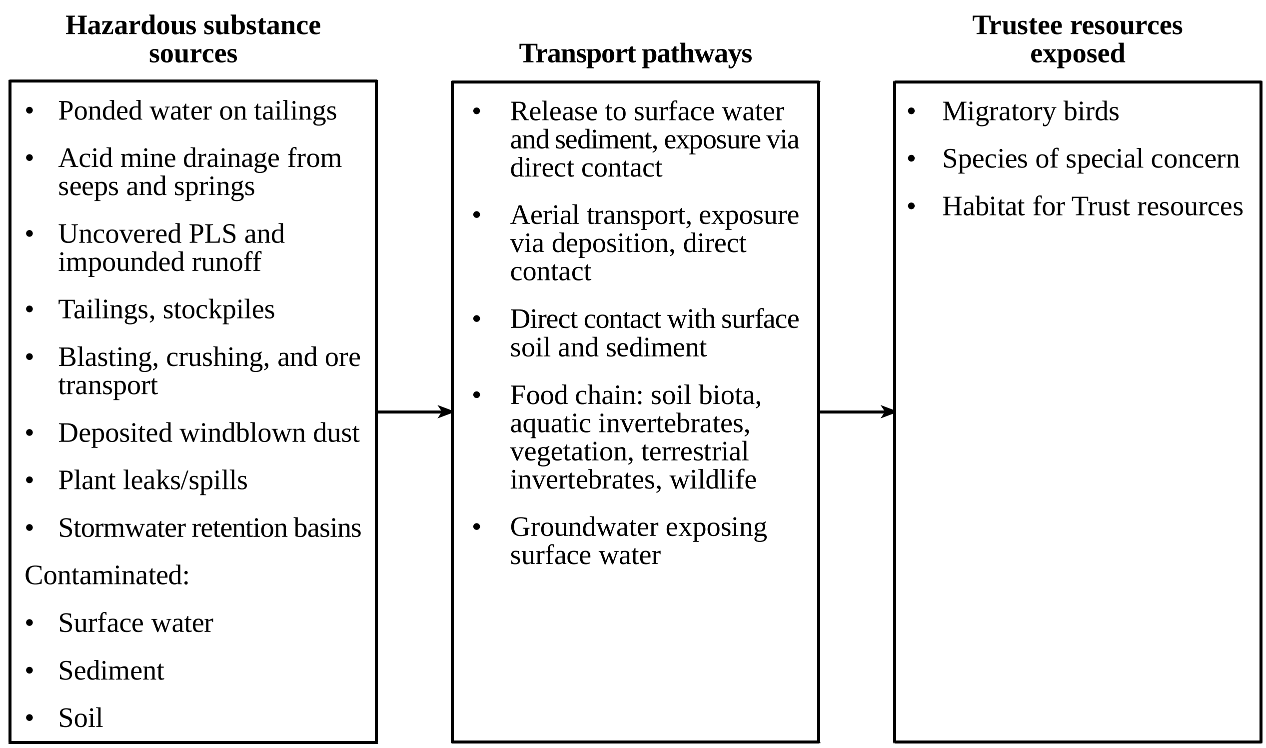


Figure 3.1. Potential hazardous substance transport pathways at the Morenci Mine.

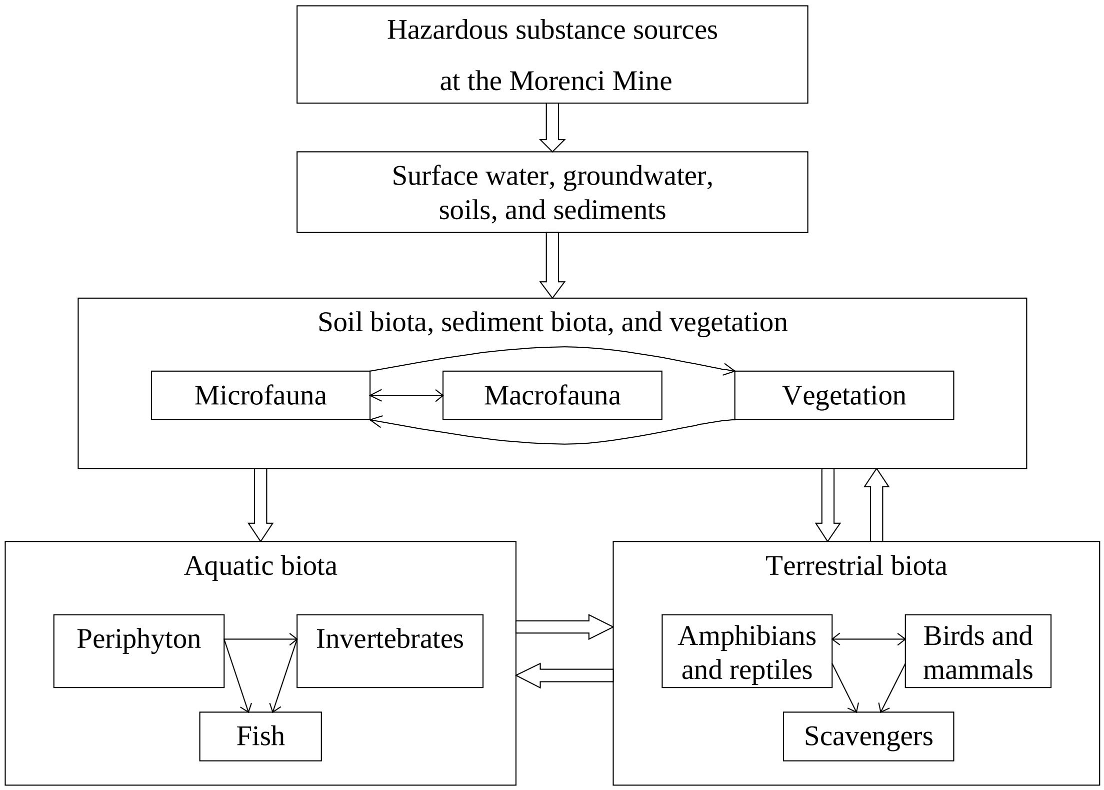


Figure 3.2. Potential exposure pathways of hazardous substances at the Morenci Mine.

3.1.1 Direct contact of biota with hazardous substances

Terrestrial biota may come in direct contact with hazardous substances through dermal, inhalation, and ingestion exposure from the 5,610 acres of leach stockpiles and waste rock, the 3,160 acres of uncovered tailings plus associated stormwater retention basins, and the 3,055 acre open pit (as of 1997) at the Morenci Mine (Table 2.2 of this report; Table 3 in PDMI, 2002).

Water collects on the tailings impoundments after precipitation events, and PDMI's air quality permit recommends maintaining water on the surface of the tailings to suppress dust (ADEQ, 2001). As water ponds on the surface of the tailings impoundments and collects in stormwater retention basins containing eroded tailings, the water interacts with upper oxidized tailings. As a result, the water will have increasingly elevated metal concentrations and decreasing pH.

Decreasing pH can result from acid (H^+) produced as a product of the oxidation and dissolution of pyrite (FeS_2)and other metal sulfides in tailings (U.S. EPA, 1994b). The oxidation and dissolution of pyrite results in the formation of reduced iron (Fe^{2+}), sulfate (SO_4^{2-}), and acid (H^+):

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+. \qquad (3.1)$$

The presence of the iron-oxidizing bacterium *Thiobacillus ferrooxidans* greatly accelerates the rate of oxidation of reduced iron:

$$4\ Fe^{2+} + O_2 + 4H^+ \leftrightarrow 4\ Fe^{3+} + 2\ H_2O. \qquad (3.2)$$

The oxidized iron (Fe^{3+}) promotes the further oxidation and dissolution of pyrite, with additional releases of acid:

$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+. \qquad (3.3)$$

Analyses of ponded water on top of tailings impoundments at the Morenci Mine have indicated low pH waters (Table 3.1), but data on concentrations of metals in ponded water at the Morenci Mine were not available for review for this preassessment screen. As discussed in Section 2.4.2, the Morenci mine ore bodies contain generally similar sulfidic ores to the ores found at the Phelps Dodge Tyrone Mine in southwestern New Mexico. Tailings were produced through a similar concentrator process at both mines. Analyses of ponded water on similar tailings impoundments at the Tyrone Mine have found high concentrations of hazardous substances in combination with low pH (Table 2.4). Based on similarities in mineral composition and processing methods between the Morenci and Tyrone mines, the Trustees suspect that ponded water at the Morenci tailings impoundments also contains hazardous substances in addition to low pH. High metal concentrations in ponded water are especially likely because low pH water promotes the dissolution of metals present in the tailings. Uncovered process water ponds (especially PLS ponds) with low pH and elevated concentrations of hazardous substances also can serve as pathways of hazardous substance transport to biota if animals come into direct contact with the ponds (Figure 2.9, Table 3.1).

Table 3.1. pH of uncovered stormwater and process solutions at the Morenci Mine

Location	pH
Stormwater collection pond 2B	2.6
Stormwater collection pond 4B	2.0
Stormwater collection pond 7A	1.6
23/25 MM pond (PLS)	2.2

Source: USFWS unpublished data, 2000.

Information collected by USFWS in October 2000 suggests that wildlife are exposed to hazardous substances from the ponded water on the Morenci tailings ponds, directly from uncovered tailings, and from uncovered process water and stormwater ponds. In October 2000, 31 carcasses of migratory birds were discovered at the Morenci tailings, stormwater, and PLS ponds (unpublished USFWS data; Figure 3.3). Photographs of animal tracks on the Morenci tailings ponds in October 2000 provide further evidence that wildlife are directly exposed to hazardous substances in tailings (Figure 2.8).

Figure 3.3. Close-up of dead bird found at the Morenci tailings in October 2000.

Morenci Mine has a hazing program for birds (Figure 3.4), indicating bird contact with ponded water on tailings is not uncommon.

Figure 3.4. Hazing cannon at a Morenci Mine tailings pond.

3.1.2 Surface water/sediment pathway

Surface water has been, and most likely continues to be, exposed to hazardous substances released from the Morenci Mine through a variety of pathways, including runoff and erosion from waste rock and tailings. Before the Chase Creek diversion was installed, water in Chase Creek flowed through waste rock deposited in the Chase Creek drainage basin, generating acidic drainage with elevated concentrations of the hazardous substance copper (Hilliard, 1993, p. 36). EPA sued PDMI in 1985 for violation of the Clean Water Act, and as part of the settlement, PDMI built a water diversion system to protect lower Chase Creek from wastewater discharges.

Currently, there are PLS collection dams and stormwater retention dams on many of the gullies and ephemeral drainages that exit from the leach stockpiles, development stockpiles, and tailings impoundments. The dams and impoundments are regulated under the APP, but no data were available for review of concentrations in impounded waters or downstream receiving waters on the mine site. In 1994, EPA imposed an administrative penalty of $60,000 on PDMI for violation of its NPDES permit. No other information was available for review regarding the details of the incident (U.S. EPA, 1994a).

Elevated concentrations of copper and zinc measured in surface water and sediment in the San Francisco River downstream from the Chase Creek confluence and in the Gila River suggest that hazardous substances may have been transported from the mine to the San Francisco and Gila rivers (Figures 3.5 and 3.6).

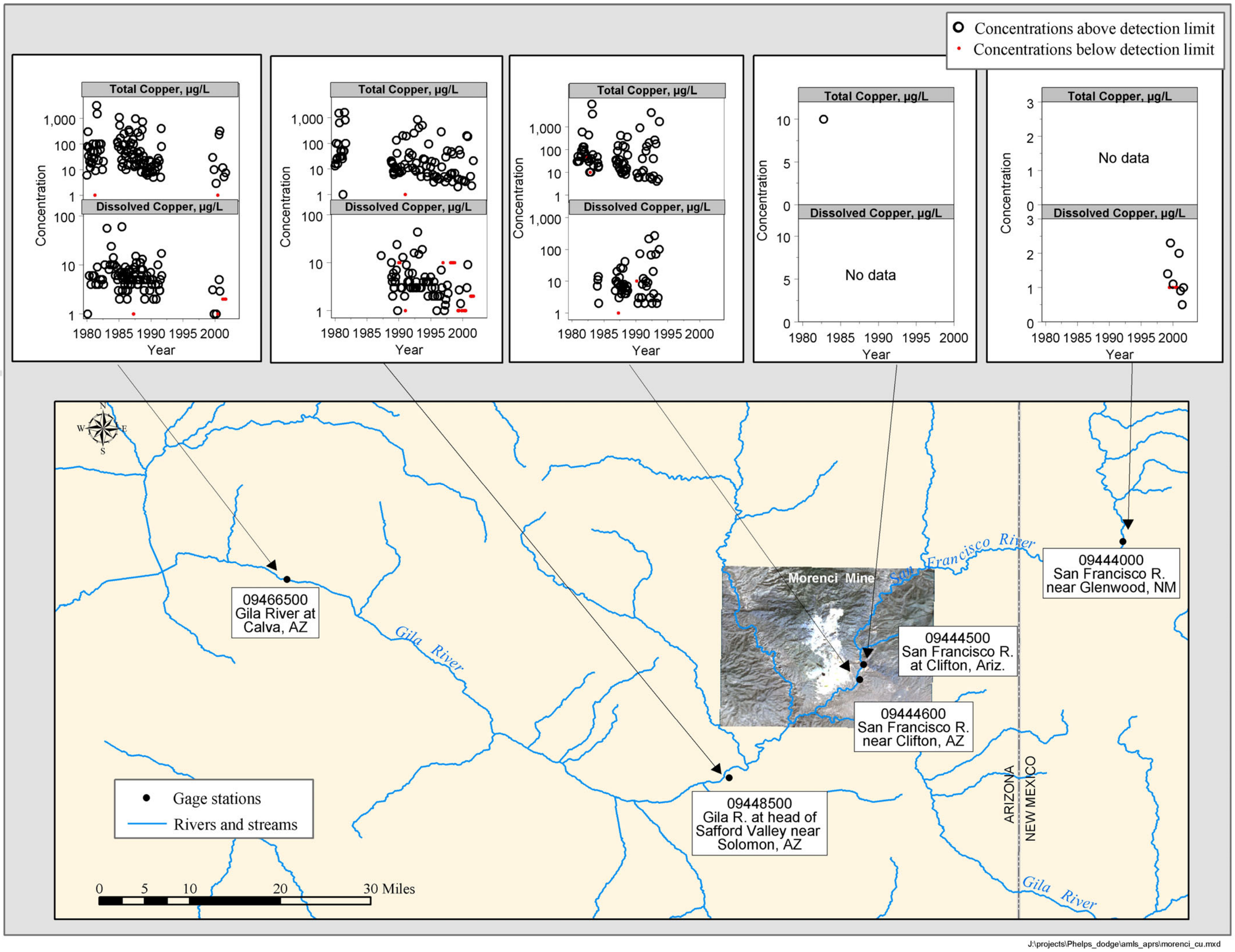


Figure 3.5. Dissolved and total copper concentrations in the San Francisco and Gila rivers, upstream and downstream of the Morenci Mine, from 1980 to the present.

Source: USGS, 2003.

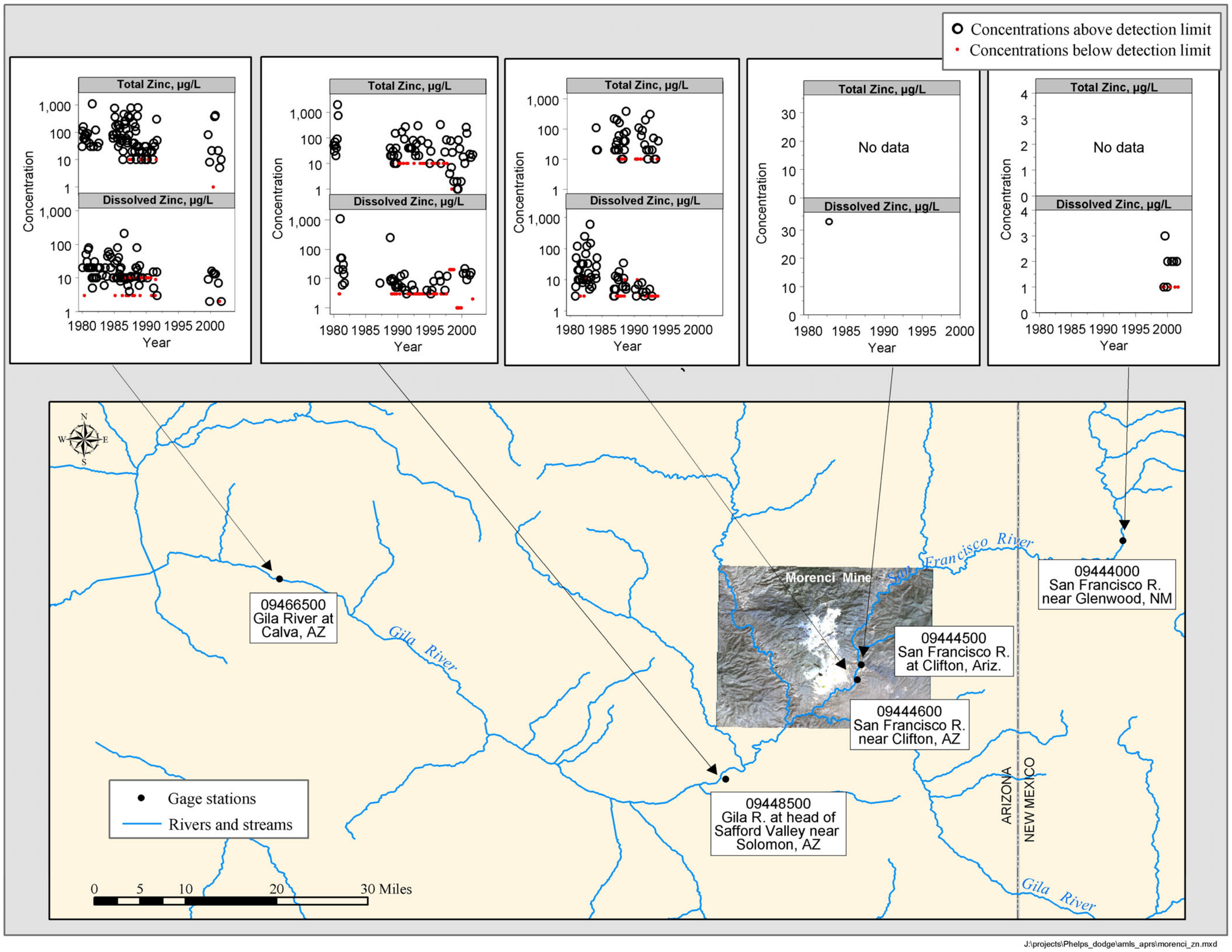


Figure 3.6. Dissolved and total zinc concentrations in the San Francisco and Gila rivers, upstream and downstream of the Morenci Mine, from 1980 to the present.

Source: USGS, 2003.

Terrestrial biota can be exposed to hazardous substances via the surface water/sediment pathway by ingestion and dermal absorption. Aquatic biota in the San Francisco River, and potentially in the Gila River, may also be exposed to hazardous substances via the surface water/sediment pathway by gill uptake and ingestion of contaminated prey.

3.1.3 Groundwater pathway

Groundwater at the Morenci Mine has been exposed to hazardous substances through a variety of pathways. PLS and acid mine drainage from waste rock piles are collected in unlined impoundments at the site, and groundwater downgradient from the impoundments can become contaminated when PLS and acid mine drainage infiltrate through the ground. Groundwater data are collected regularly at POC wells associated with stormwater retention basins, tailings impoundments, and within the open pit, to demonstrate compliance with levels specified in the APP. Compliance monitoring data were not available for review for this preassessment screen. However, groundwater data and information reported by EPA indicate that groundwater has been exposed to hazardous substances and is a pathway to surface water.

For example, the Rocky Gulch Dam is a storm water collection system located approximately 200 feet downgradient of the toe of the Rocky Gulch development stockpile. The dam captures water that seeps from the toe of the stockpile and stormwater runoff from areas upgradient and downgradient of the stockpile. Samples from the point of compliance monitoring well for Rocky Gulch Dam contained elevated concentrations of beryllium (16.6 µg/L), and cadmium (20.2 µg/L) (Table 2.1) (U.S. EPA, 1997, p. 44). That the APP requires PDMI to submit an assessment of the need for and effectiveness of a groundwater interception system is evidence that the dam has served as a pathway of groundwater contamination at the mine site.

Contaminated groundwater is released to surface water via springs and seeps. For example, the Gold Gulch Dam contains runoff from the Producer Pile in an unlined impoundment (Table 1 in ADEQ, 2002). A “several-hundred-foot-long surface seep with a blue-green color indicative of a copper bearing precipitate” was noted by ADEQ in the mid-1990s (U.S. EPA, 1997, pp. 41-42). The contaminant source was considered by ADEQ to be “reasonably attributable to the Gold Gulch impoundment” (U.S. EPA, 1997, p. 42). The APP requires PDMI to submit a plan to address potential sources of exceedences of groundwater criteria at the Gold Gulch Dam point of compliance (Table 11 in ADEQ, 2002), and the TRI identifies releases of lead, manganese, nickel, and zinc to surface water in West Gold Gulch in 1999 and 2000 (U.S. EPA, 2003). West Gold Gulch (also downgradient of the Producer Pile) and the drainage below the Gold Gulch Dam converge approximately 3,000 feet downgradient of the dam (PDMI, 2002, Map 3B).

Thus, surface water and terrestrial resources may be exposed to contaminants via this pathway of groundwater discharge, and can then serve as exposure sources to birds, fish, amphibians, reptiles, and mammals, including endangered fish species in the Gila River.

3.1.4 Aerial transport pathway

Open, unvegetated waste rock, leach stockpiles, and tailings piles cover more than 8,300 acres at the Morenci Mine (Table 3 in PDMI, 2002). Windblown materials from these piles can transport hazardous substances to adjacent upland areas. No data documenting the deposition of windblown materials at the Morenci Mine were available for review, but this pathway has been documented at the Chino Mine in New Mexico (MFG Inc., 2002) and most likely exists at the Morenci Mine as well. PDMI’s air quality permit identifies storage piles and mineral tailings as nonpoint sources, and specifies “reasonable precautions,” including wetting, chemical stabilization, and revegetation, among others, to prevent excessive amount of airborne dust from exposed tailings (ADEQ, 2001, p. 50). Terrestrial biota and surface water resources may be exposed to hazardous substances through this pathway.

3.1.5 Soil pathway

Soils potentially are exposed to hazardous substances through aerial transport of contaminants, and through plant spills and upsets that release hazardous materials to the soil. Terrestrial biota may be exposed to hazardous materials in soil through dermal contact, uptake, and ingestion. No data were available to confirm this pathway of exposure.

3.1.6 Food chain pathway

Food chain exposures occur when prey organisms accumulate hazardous substances in their tissues. Predators are subsequently exposed to these contaminants when they consume these prey. Studies have documented the uptake and subsequent terrestrial food chain movement of the hazardous substances copper and zinc (Beyer, 1990).

This pathway has not been evaluated yet at the Morenci Mine because of a lack of site-specific wildlife data, but example food chain pathways were developed from species known to occur in similar desert habitats (MFG Inc., 2002; NMDGF, 2002). These pathways may include the following:

- Metals uptake by terrestrial invertebrates (e.g., beetles, grasshoppers) that serve as prey for omnivorous small mammals (e.g., deer mouse, *Peromyscus maniculatus;* brush mouse, *P. boylii;* pinyon mouse, *P. truei)*; omnivorous birds (e.g., scaled quail, *Callipepla squamata;* western kingbird, *Tyrannus verticalis;* Cassin's sparrow, *Aimophila cassinii*); and reptiles (e.g., western rattlesnake, *Crotalus viridis*), which in turn are consumed by raptors (e.g., golden eagle, *Aquila chrysaetos;* red-tailed hawk, *Buteo jamaicensis*) and carnivorous mammals (e.g., gray fox, *Urocyon cinereoargenteus;* kit fox, *Vulpes velox*).

- Metals uptake by terrestrial vegetation that serves as forage for upland birds and small mammals that are primarily granivorous (e.g., pocket mice, *Perognathus* spp.; kangaroo rats, *Dipodomys* spp.; black-throated sparrow, *Amphispiza bilineata*) and for large mammalian herbivores (e.g., mule deer, *Odocoileus hemionus;* white-tailed deer, *O. virginianus*).

- Metals uptake by periphyton and aquatic invertebrates that serve as a food source for amphibians and fish in the San Francisco and Gila rivers, including the proposed endangered species Gila chub, *Gila intermedia;* and the endangered species Gila topminnow, *Poeciliopsis occidentalis occidentalis;* and Gila trout, *Oncoryhncus gilae*.

3.2 Exposed Areas [43 CFR § 11.25(b)]

This section presents preliminary estimates of exposed areas based on a rapid review of readily available information. This section is not a comprehensive quantification of all exposed areas.

3.2.1 Primary exposure areas

Past and ongoing mining activities have resulted in a significant area that has been exposed directly to hazardous substances. These areas include, but are not limited to,

- five tailings ponds covering approximately 3,160 acres (Table 2.2 of this report)

- 13 leach stockpiles, covering approximately 4,538 acres (Table 3 in PDMI, 2002)

- nine mining waste stockpiles, covering approximately 1,072 acres (Table 3 in PDMI, 2002)

- the Morenci Mine open pit, covering approximately 3,055 acres (Table 3 in PDMI, 2002)

- ponds, dams, impoundments, and collection trenches associated with PLS and stormwater capture.

3.2.2 Areas exposed through pathways

Areas potentially exposed via contaminant pathways from primary areas may include the following:

- Surface water, bank, bed, and floodplain sediments of Chase Creek, Rocky Gulch, the San Francisco River, the Gila River, and potentially other permanent and ephemeral waterways. Figures 3.5 and 3.6 provide evidence of exposure of San Francisco River and Gila River surface water to hazardous substances.

- Seeps and ephemeral surface water in Gold Gulch and Rocky Gulch, and other areas downgradient of stormwater impoundments below waste rock and tailings impoundments. Observation of a copper bearing precipitate in a surface seep in Gold Gulch (U.S. EPA, 1997, pp. 41-42) provides likely evidence of exposure to hazardous substances.

- Groundwater aquifers at the Morenci Mine outside of the hydrologic sink maintained by pumping in the open pit (ADEQ, 2000, 2002). For example, groundwater downgradient from the Rocky Gulch Dam has been exposed to hazardous substances (Table 2.1 of this document).

- Areas indirectly exposed to hazardous substances from the mine via aerial transport of materials. This pathway has been documented at the Chino Mine in New Mexico (MFG Inc., 2002) and most likely exists at the Morenci Mine as well.

3.2.3 Areas of indirect effect

Areas of indirect effect, where no hazardous substance has spread but where biological populations may have been affected as a result of animal movement, include:

- geographic extent of migratory birds that are exposed to hazardous substances at the site or injured via loss of habitat or forage base

- geographic extent of other terrestrial resources (e.g., reptiles, ungulates) that are exposed to hazardous substances through food chain pathways or injured via loss of habitat or forage base

- geographic extent of aquatic resources (e.g., fish, amphibians) that may be exposed to hazardous substances through food chain pathways or injured via loss of habitat or forage base.

3.3 Estimates of Concentrations [43 CFR § 11.25(b)]

This section presents examples of concentrations of hazardous substances that have been measured in natural resources at the Morenci Mine, based on available information. This information is not a comprehensive review of all studies that have been conducted at the site, some of which were not available for review. Rather, this section presents examples drawn from a rapid review of the readily available literature.

3.3.1 Surface water

Evidence that the San Francisco and Gila rivers downstream from the mine have been exposed to hazardous substances released from the Morenci Mine includes surface water and sediment data. Figures 3.5 and 3.6 present concentrations of copper and zinc measured in the San Francisco River and the Gila River downstream from the Morenci Mine, from 1980 to the present. Concentrations of total and dissolved copper are substantially more elevated in the San Francisco River downstream of Clifton (Chase Creek) than upstream. Upstream, detected concentrations of dissolved copper did not exceed 2.3 µg/L, and concentrations of dissolved zinc did not exceed 3.0 µg/L since 1980. Downstream of Chase Creek (station 09444600), concentrations of dissolved copper reach 270 µg/L, and concentrations of dissolved zinc reach 600 µg/L (USGS, 2003).

Sediment data collected in 1990 suggest that concentrations of hazardous substances in the San Francisco River downstream of Clifton, where Chase Creek enters the San Francisco River, are more elevated than concentrations upstream (USFWS, 1994) (Table 3.2). Copper and zinc concentrations downstream of Clifton were 521 and 177 µg/g dry weight, respectively, compared to 112 and 73 µg/g upstream. In addition, concentrations of hazardous substances in Gila River sediments downstream of the San Francisco River are more elevated than concentrations upstream of the confluence. Copper and zinc concentrations in the Gila River downstream of the San Francisco River were 77 and 91 µg/g, respectively, compared to 12 and 31 µg/g upstream. The data also suggest that contaminated sediments may be accumulating in the San Carlos Reservoir on the Gila River.

3.3.2 Groundwater

Concentrations of antimony, beryllium, and cadmium in groundwater outside of the hydrologic sink have exceeded Safe Drinking Water Act Maximum Contaminant Levels (MCLs). Table 3.3 presents concentrations measured in groundwater near Rocky Gulch Dam and Gold Gulch and applicable MCLs.

Table 3.2. Concentrations of hazardous substances measured in sediments in the Upper Gila River Basin, Arizona, 1990 (μg/g dry weight)

Location	As	Be	Cd	Cr	Cu	Pb	Mn	Ni	Hg	Zn
Upstream of the Morenci Mine										
San Francisco River, upstream of Clifton	3.8	1.3	5.7	21	112	9	678	49	0.11	73
Gila River upstream of Virden, NM	3.8	0.8	4.4	16	20	9	492	18	n.d.	46
Gila River at Guthrie, AZ (upstream of San Francisco River confluence)	1.9	1.1	2.4	9	12	7	197	11	n.d.	31
Downstream of the Morenci Mine										
San Francisco River, downstream of Clifton	9.4	3.7	9.9	31	521	18	578	65	0.16	177
Gila River at San Jose, AZ (downstream of San Francisco River confluence)	6.7	1.1	6.6	21	77	19	898	34	n.d.	91
Gila River at Pima	4.6	1.0	5.1	17	86	16	580	31	n.d.	68
Gila River at Ft. Thomas	5.0	0.6	n.d.	12	37	11	708	18	n.d.	51
Gila River at Bylas	10.4	1.8	8.6	31	82	22	1072	33	n.d.	102
San Carlos Reservoir	8.7	1.0	6.9	20	135	21	885	33	0.09	87

n.d.: not detected.

Source: Table 5 in USFWS, 1994.

Table 3.3. Exceedences of Safe Drinking Water Act Standards in groundwater in 1996 (concentrations in μg/L)

	Antimony	Beryllium	Cadmium	pH (SU)	TDS (mg/L)
Standard	6.0[a]	4.0[a]	5.0[a]	6.5-9[b]	500[b]
Rocky Gulch Dam		16.6	20.2	4.37	1270
Gold Gulch	9.2				

a. Maximum Contaminant Level.
b. National secondary drinking water regulations.

Source: U.S. EPA, 1997. Groundwater samples collected from the point-of-compliance monitoring well for Rocky Gulch Dam and in Gold Gulch by Arizona Department of Environmental Quality.

3.4 Potentially Affected Resources [43 CFR § 11.25 (3)(1)]

The data presented in this chapter support the conclusion that natural resources for which the USFWS has trusteeship and that have been affected or potentially affected by releases of hazardous substances from the Morenci Mine facilities include, but are not limited to, the following:

- migratory bird habitat, including surface water resources such as natural seeps in Chase Creek and other tributaries to the San Francisco River, the riparian zone, including surface water and sediments of the San Francisco River and the Gila River, terrestrial soils, and terrestrial vegetation.

- multiple species of migratory birds, as defined by the Migratory Bird Treaty Act

- endangered fish species in the Gila River (Gila topminnow, *Poeciliopsis occidentalis occidentalis;* and Gila trout, *Oncoryhncus gilae*) and proposed endangered fish species (Gila chub, *Gila intermedia*).

The State of Arizona has trusteeship for surface water and groundwater resources that have been affected by releases of hazardous substances from the Morenci Mine facilities.

3.5 Preliminary Estimate of Affected Services [43 CFR § 11.25(e)(2)]

Services provided or potentially provided by the resources identified in Section 3.4 include, but are not limited to, the following:

- ecological services for wildlife, including food, shelter, breeding and rearing areas, and other factors essential to long-term survival

- consumptive and nonconsumptive outdoor recreation, including fishing, hunting, hiking, wildlife viewing, photography, and river rafting

- passive use values for local and migratory bird morbidity and mortality.

Recreational services in the San Francisco and Gila rivers may be affected by releases of hazardous substances from the mine. For example, in 1969 a flood washed 448,000 gallons of acidic wastewater into Chase Creek, which transported the contaminants to the San Francisco River, resulting in “massive fish kills over the length of the San Francisco River downstream of Chase Creek and 1 mile of the Gila River” (U.S. EPA, 1992; Hilliard, 1993, p. 36). Ongoing elevated concentrations of copper and zinc in the San Francisco and Gila rivers (Figures 3.5 and 3.6) also may be causing chronic or acute injuries to fish populations. Any reductions in fish stocks or their catch rates will result in lost services to anglers if there are changes in the quantity or quality of the recreation undertaken.

The San Francisco and Gila rivers are the only two rivers near the mine that provide recreational services. Both are popular for their remoteness and solitude (River Management Society, 2003). Recreationists raft in this region during spring runoff, if flows are sufficient; fishing occurs in this region as well (J. Prislan, information officer of the Silver City Ranger District of the Gila National Forest, personal communication, April 16, 2003). The Trustees are currently unaware of sources documenting the magnitude of rafting or fishing on these water bodies.

Passive use values are values unrelated to an individual's use of the injured resource. Passive use values can be bequest values (value for use by future generations) or existence values (value of the resource even if it is never used by anyone) [56 Fed. Reg. 19760]. Passive use values for local and migratory bird morbidity and mortality may be highest for people living in the two counties directly affected by mining releases. In 2002, approximately 40,969 individuals lived in Greenlee and Graham Counties (U.S. Census, 2003), which are the two counties most likely to be directly affected by mine releases. In addition, a large body of economics literature has documented significant service reductions from bird kills, even when the species are not particularly unique or sensitive (e.g., Loomis et al., 1990; Rowe et al., 1991; Boyle et al., 1994). Thus, lost passive use services from migratory bird deaths at the Morenci Mine may occur for people outside of the direct mine area. In addition, a national contingent valuation method study found that passive use services may be significant for protection of critical habitat for nine endangered species in Southwest river basins, including the spike dace and loach minnow in the Gila River (Ekstrand and Loomis, 1998).

4. Determination Criteria [43 CFR § 11.23(e)]

This chapter presents an evaluation of the preassessment determination criteria [43 CFR § 11.23(e)]. The information presented and summarized in this chapter confirms the following:

- A release of hazardous substances has occurred.
- Natural resources for which the Trustees have trusteeship have been or are likely to have been adversely affected.
- The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury.
- Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.
- Response actions will not sufficiently remedy the injury to natural resources without further action [note that no response actions are currently planned under the Remedial Investigation/Feasibility Study (RI/FS) process]

Based on the evaluation of the criteria presented below, the Trustees have determined that a Type B NRDA should be performed to assess damages to natural resources caused by releases of hazardous substances from the Morenci Mine. The justification of the decision to perform a Type B NRDA will be presented in the Assessment Plan.

4.1 A release of hazardous substances has occurred

Data collected by the ADEQ, USFWS, and USGS have demonstrated that releases of hazardous substances have occurred and continue to occur as a result of operations at the Morenci Mine (Section 2.4). Hazardous substances released include, but may not be limited to, antimony, beryllium, cadmium, copper, lead, manganese, nickel, zinc, and sulfuric acid. Investigators have also documented elevated concentrations of hazardous substances in surface water and groundwater that have resulted from releases of hazardous substances at the site.

4.2 Trustee natural resources have been or are likely to have been adversely affected by the release

Natural resources [as defined in 43 CFR § 11.14(z)] for which the Trustees have trusteeship that have been or are likely to have been adversely affected by releases of hazardous substances include, but may not be limited to:

- Migratory birds as defined in the Migratory Bird Treaty Act.
- Endangered species potentially inhabiting the San Francisco and Gila rivers, such as the Gila topminnow, *Poeciliopsis occidentalis occidentalis*, and the Gila trout, *Oncoryhncus gilae;* and the proposed endangered species, the Gila chub, *Gila intermedia*.
- Habitat for trust resources that is provided by surface water, soils, and terrestrial vegetation. Habitat on land managed by the Bureau of Reclamation and by the Bureau of Land Management may have been adversely affected by hazardous substance releases.

Chapter 3 presents data confirming elevated concentrations of hazardous substances in Trustee natural resources. Section 4.3 confirms that this exposure is at concentrations and of durations sufficient to potentially injure natural resources.

4.3 The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury

4.3.1 Surface water/sediments

The DOI regulations present a number of definitions of injury for surface water resources. The definitions of injury to surface water include the following:

- concentrations and duration of substances in excess of applicable water quality criteria established by Section 304(a)(1) of the Clean Water Act (CWA), or by other federal or state laws or regulations that establish such criteria . . . in surface water that before the discharge or release met the criteria and is a committed use . . . as a habitat for aquatic life, water supply, or recreation [43 CFR § 11.62(b)(1)(iii)]
- concentrations and duration of hazardous substances sufficient to have caused injury to biological resources when exposed to surface water [43 CFR § 11.62(b)(1)(v)].

For uncovered PLS ponds and ponded water on tailings impoundments and in stormwater retention basins at the site, the concentrations and duration of hazardous substances have been sufficient to cause injury to birds exposed to surface waters, and potentially to other biological resources as well. The list of bird carcasses discovered at the Morenci Mine PLS ponds, tailings ponds, and stormwater retention basins from October 2000 suggests that the concentrations and duration of hazardous substances at these ponds have been sufficient to cause injury to birds (Table 4.1). Considering the numerous "feather spots" and other highly decomposed bird remains that were not collected during the October 2000 USFWS investigation, the actual number of birds injured may be far greater than reported. In addition, since the initial discovery of bird carcasses in October 2000, the USFWS has discovered over 40 additional dead birds in acidic, ponded water on now inactive tailings impoundments (unpublished data, USFWS Records, 2002).

Table 4.1. Bird carcasses at the Morenci Mine, discovered October 2000

Species	Number of carcasses
Great blue heron	3
Mallard	10
Northern pintail	10
Pied-billed grebe	2
Ring-billed gull	1
Unknown passerine	1
Unknown swallow	1
Unknown teal (blue-winged or cinnamon)	1
Western sandpiper	1
Western kingbird	1
Total	31

Source: Unpublished data, USFWS records.

4.3.2 Groundwater

Definitions of injury to groundwater resources presented in the DOI regulations include the following:

- concentrations of hazardous substances exceeding SDWA or other relevant federal or state criteria or standards [43 CFR § 11.62(c)(1)(i), (ii), (iii)]

- concentrations of hazardous substances sufficient to cause injury to other natural resources that come in contact with the groundwater (e.g., surface water) [43 CFR § 11.62(c)(1)(iv)].

Criteria relevant to the Morenci Mine Site include MCLs established by sections 1411-1416 of the Safe Drinking Water Act. A comparison of hazardous substances measured in groundwater at the mine with groundwater standards demonstrates that hazardous substance concentrations in groundwater are sufficient to potentially cause injury (Table 4.2). These concentrations indicate that groundwater at the site is potentially injured. Injured groundwater that emerges through seeps and spring to surface water may be a pathway of injury to USFWS trust resources, including endangered species of aquatic biota.

Table 4.2. Exceedences of Safe Drinking Water Act standards in groundwater in 1996 (concentrations in µg/L)

	Antimony	Beryllium	Cadmium	pH (SU)
Rocky Gulch Dam		16.6	20.2	4.37
Gold Gulch	9.2			
Standard	6.0[a]	4.0[a]	5.0[a]	6.5-9[b]

a. Maximum Contaminant Level, SDWA.
b. National secondary drinking water regulation, SDWA.

Source: U.S. EPA, 1997. Groundwater samples collected from the point-of-compliance monitoring well for Rocky Gulch Dam and in Gold Gulch by Arizona Department of Environmental Quality.

4.3.3 Birds

According to DOI regulations [43 CFR § 11.62(f)], an injury to biological resources (e.g., birds) has resulted from the discharge of a hazardous substance if the concentration of the hazardous substance is sufficient to:

- cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

The dead birds (Table 4.1) found at the Morenci Mine stormwater retention basins and PLS ponds in a single visit to the mine in October 2000 confirms adverse impacts to birds caused by hazardous substances released from the site.

4.3.4 Summary

Based on a “rapid review of readily available information” [43 CFR § 11.23(b)], the Trustees conclude that the quantity and concentration of the released hazardous substance are sufficient to potentially cause injury to Trustee natural resources, including surface water (as habitat), groundwater and geological resources (as pathways of injury), and biological resources.

4.4 Data sufficient to pursue an assessment are available or likely to be obtained at reasonable cost

Data relevant to conducting an assessment of natural resource damages at the Morenci Mine have been collected as part of regular monitoring activities at the Morenci Mine, and should be available from ADEQ. Data include information on hazardous substances sources, releases, pathways, and concentrations in surface water and groundwater, and possibly other media at the site. Since the preassessment screen is intended to determine only whether there is sufficient cause to pursue an NRDA, omission of any information in the preassessment screen does not preclude consideration of such information in the course of an NRDA. Additional data for the purposes of performing a damage assessment are expected to be obtainable at reasonable cost.

4.5 Response actions will not sufficiently remedy the injury to natural resources without further action

No response actions are currently under way under an RI/FS process at the Morenci Mine. As part of a settlement reached in 1986 with the EPA, PDMI agreed to construct the $9 million-plus Chase Creek diversion (Hilliard, 1993, p. 37), which diverts Upper Chase Creek around mining operations through a control system that consists of a reservoir, pumps, and a 7.5 mile pipeline to Lower Chase Creek. PDMI’s APP indicates some required corrective actions for aquifer protection, but no data on results of corrective actions were available for review. There appears to have some success at PDMI efforts to maintain the pH between 6 and 8: USFWS personnel measured a pH of 8.9 in the Southwest Tailings Dam 1 pond in October 2000 (USFWS, unpublished data). Ongoing hazing activities may reduce some future injuries to wildlife, but are not sufficient to remedy injury and do not occur at all the locations of ponded water at the site.

4.6 Conclusions

Based on an evaluation of the preassessment determination criteria, the following conclusions can be made:

- A release of hazardous substances has occurred.
- Natural resources for which the Trustees have trusteeship have been or are likely to have been adversely affected.
- The quantity and concentration of the released hazardous substances are sufficient to potentially cause injury.
- Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost.
- Response actions will not sufficiently remedy the injury to natural resources without further action.

Based on an evaluation of these five criteria, the Trustees have determined that an NRDA should be performed to assess damages to natural resources caused by releases of hazardous substances from the Morenci Mine.

5. References

ADEQ. 2000. State of Arizona Aquifer Protection Permit No. P-100193. Authorization for Phelps Dodge Morenci, Inc. to operate discharging facilities at the Phelps Dodge Morenci copper mine in Morenci, Arizona, Greenlee County. Arizona Department of Environmental Quality.

ADEQ. 2001. Air Quality Class I Permit. Permit Number M110734P1-99/PDMI-Morenci issued to Phelps Dodge Morenci, Inc. May 30, 2001 through May 30, 2006. Arizona Department of Environmental Quality.

ADEQ. 2002. State of Arizona Aquifer Protection Permit No. P-100193 and Other Amendment, January 2002. Authorization for Phelps Dodge Morenci, Inc. to operate discharging facilities at the Phelps Dodge Morenci copper mine in Morenci, Arizona, Greenlee County. Arizona Department of Environmental Quality.

Beyer, W.N. 1990. Evaluating Soil Contamination. U.S. Fish and Wildlife Service Biological Report 90(2).

Boyle, K.J., W.H. Desvousges, F.R. Johnson, R.W. Dunford, and S.P. Hudson. 1994. An investigation of part-whole biases in contingent-valuation studies. *Journal of Environmental Economics and Management* 27:64-83.

Daniel B. Stephens & Associates Inc. 1997. Supplemental Groundwater Study: Tyrone Mine Closure / Closeout. Volume II: Appendices. Prepared for Phelps Dodge Tyrone, Inc. Tyrone, NM. November 14.

Dresher, W.H. 2001. Phelps Dodge Morenci has converted all copper production to mine-for-leach. *Innovations.* Copper Development Association, Inc. August. http://innovations.copper.org/2001/08/phelpsdodge.html. Accessed May 10, 2003.

Ekstrand, E.R. and J. Loomis. 1998. Incorporating respondent uncertainty when estimating willingness to pay for protecting critical habitat for threatened and endangered fish. *Water Resources Research* 34:3149-3155.

Hilliard, T.J. 1993. Mining report card for Phelps Dodge Corporation. Prepared as part of the Mineral Policy Center Mining Accountability Project. Mineral Policy Center, Washington, DC.

IRC. 2001. Copper, Phelps Dodge, and the future Grant County's mining district. An IRC Community Report. Prepared by Interhemispheric Resource Center, Silver City, NM. October.

Landsat7. 1999. ETM+ digital data (bands 1-5, 7, 8). Imagery date: October 11, 1999. Downloaded from Arizona Regional Image Archive (ARIA) http://aria.arizona.edu April 3, 2003.

Loomis, J.B., T. Wegge, M. Hanemann, and B. Kanninen. 1990. The economic value of water to wildlife and fisheries in the San Joaquin Valley: Results of a simulated voter referendum. In *Transactions of the 55th North American Wildlife & Natural Resources Conference,* pp. 259-268.

MFG Inc. 2002. Chino Mines Administrative Order on Consent: Sitewide Ecological Risk Assessment. Prepared for New Mexico Environment Department. August.

NMDGF. 2002. Biota Information System of New Mexico. http://nmnhp.unm.edu/bisonm/bisonquery.php. Accessed April 23, 2003.

PDMI. 1999. 1872 to 1937 — 65 Historic Years. http://morenci.phelpsdodge.com/history/1872_to_1937.asp. Accessed May 2, 2003.

PDMI. 2002. Phelps Dodge Morenci, Inc. Reclamation Plan. Prepared by Phelps Dodge Morenci, Inc. and Environet Inc. for State of Arizona Mine Inspector's Office. February 5, 2002 revision of the April 1, 1997 Reclamation Plan.

River Management Society. 2003. http://www.river-management.org/rd-sanfrancisco.html. Accessed April 10, 2003.

Rowe, R.D., W.D. Schulze, W.D. Shaw, D. Schenk, and L.G. Chestnut. 1991. Contingent Valuation of Natural Resource Damage due to the Nestucca Oil Spill: Final Report. Prepared by Hagler Bailly Consulting, Inc., Boulder, CO, for the Department of Wildlife, State of Washington, British Columbia Ministry of Environment, Victoria, British Columbia, and Environment Canada, Vancouver, British Columbia. June 15.

SARB. 1999. Geochemical Evaluation of Tailings and Stockpiles, Tyrone Mine. Prepared by SARB Consulting Inc. for Phelps Dodge Tyrone, Inc., Tyrone, NM. December 22.

Securities and Exchange Commission. 2002. Form 10-K for the Fiscal Year Ended December 31, 2001: Phelps Dodge Corporation (a New York Corporation).

Sumitomo Metal Mining. 2002. Annual Report 2002 for the year ended March 31, 2002.

U.S. Census. 2003. Table CO-EST2002-01-04-Arizona County Population Estimates: April 1, 2000 to July 1, 2002. Source: Population Division, U.S. Census Bureau. Release Date: April 17, 2003. http://eire.census.gov/popest/data/counties/tables/CO-EST2002/CO-EST2002-01-04.php.

U.S. EPA. 1992. Copper Industry Profile: Final Draft. U.S. Environmental Protection Agency, Office of Solid Waste. January.

U.S. EPA. 1994a. Notice of Proposed Assessment of Clean Water Act Class II Administrative Penalty to Phelps Dodge Morenci, Inc. and Opportunity to Comment. Federal Register Document 94-25867. October 19.

U.S. EPA. 1994b. Technical Document: Acid Mine Drainage Prediction. Office of Solid Waste, Special Waste Branch. EPA 530-R-94-036. December.

U.S. EPA. 1997. Damage Cases and Environmental Releases from Mines and Mineral Processing Sites. U.S. Environmental Protection Agency, Office of Solid Waste.

U.S. EPA. 2003. Toxics Release Inventory: Envirofacts Report. Facility Name: Phelps Dodge Tyrone, Inc. Data extracted March 7, 2003. http://oaspub.epa.gov/enviro/tris_control.tris_print?tris_id = 88065PHLPSHWY90.

USFWS. 1994. Environmental Contaminant Investigation of Water Quality, Sediment and Biota of the Upper Gila River Basin, Arizona. Prepared by D.L. Baker and K.A. King, U.S. Fish and Wildlife Service Region 2 Contaminants Program. Project No. 22410-1130-90-2-053. Phoenix, AZ.

USGS. 1997. Digital Orthophoto Quarter Quadrangle (DOQQ) (8 and 1 meter resolution). Imagery date October 13, 1997. Downloaded from Microsoft Terraserver Site http://terraserver.microsoft.com/ November 8, 2002.

USGS. 2003. Water Quality Data for the Nation. http://waterdata.usgs.gov/NWIS/qw. Accessed April 28, 2003.