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NV – Assessment of Wildlife Hazards Associated With Mine Pit Lakes

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Executive Summary

Several open pit mines in Nevada lower groundwater to mine ore below the water table. After mining, the pits partially fill with groundwater to form pit lakes. Water quality in the pit lakes may be affected by a variety of factors including the quality of inflowing groundwater, atmospheric precipitation, sulfide oxidation in surrounding rock, dissolution of metals, precipitation of metals, and evaporative concentration. Oxidation reactions on exposed pit walls may release sulfate, acid, and metals into the pit lake. In some cases, water contained in the pit lakes may be of poor quality and may contain concentrations of metals or other inorganic constituents that greatly exceed water quality standards and published wildlife effect levels. Two types of pit lakes may form. The first type has a circumneutral pH and may develop a complex food web. The second type is highly acidic and will remain relatively sterile. While this second type may be less attractive to wildlife, it is highly toxic if water is consumed. Geochemical modeling to predict water quality in some future pit lakes has predicted long-term degradation of pit lake water quality. Wildlife use and the degree of threat presented by inorganic contaminants in pit lakes are uncertain, although at least limited riparian and aquatic communities will become established in most pit lakes where pH remains circumneutral. In these circumneutral pH pit lakes, wildlife use and fish introductions over the long-term are uncertain. Wildlife exposure to contaminants through drinking water and consumption of contaminated foods in the lakes may occur. Constituents that bioaccumulate or biomagnify in the food chain, such as selenium and mercury, are of greatest concern. Currently, little is known about biological characteristics of mine pit lakes. This investigation was designed to provide information on habitat and community development, habitat quality, wildlife use, inorganic contaminants behavior and partitioning, and the potential for wildlife exposure to inorganic contaminants in mine pit lakes.

Five pit lakes or pit lake complexes, including Yerington, Buena Vista complex, Tuscarora, Clipper, and Aurora, with a variety of mining histories were visited as a part of this study, with emphasis on the lakes at the abandoned copper mine near Yerington, Nevada, and the abandoned gold mine near Tuscarora, Nevada. Habitat, community development, and wildlife use varied among sites. All of these pit lakes maintained a circumneutral pH. Water quality, based on field measurements of specific conductance, was poorest at the Clipper pit lake and the best at the Tuscarora pit lake. Copper and selenium concentrations in water at the Yerington pit lake were elevated; however, copper concentrations were declining. Biological samples, including vegetation, aquatic invertebrates, fish, and bird eggs, were collected from the Yerington and Tuscarora pits for analysis of metals and trace elements.

Residues in vegetation and aquatic invertebrates were evaluated in relation to: avian dietary effect levels; residues in fish were evaluated in relation to effects on fish, avian consumption, and to human consumption; and residues in bird eggs were evaluated in relation to reproductive effects. Copper concentrations in algae and aquatic invertebrates from the Yerington pit lake were elevated; however, birds retain a very small portion of ingested copper. Mercury concentrations in amphipods and bass from

the Tuscarora pit lake were elevated in relation to adverse dietary effect levels for birds, whereas mercury levels in bass were in the range where adverse effects to fish and fish-eating birds may be expected. Mercury levels in the bass also exceeded a human health consumption advisory concentration. Selenium in algae and aquatic invertebrates from the Yerington pit lake was elevated and exceeded a dietary threshold associated with adverse reproductive effects in birds. Residues in swallow eggs from the Yerington pit were below adverse effect concentrations.

The information collected during this study and that of a previous study demonstrated elevated exposure of wildlife to selected inorganic contaminants at three pit lakes. This information points to the need for routine studies at pit lakes from their formation to beyond the completion of filling to determine risks to wildlife, including migratory birds. Without such studies, risks to wildlife will be unknown and uncontrolled.

Introduction

Several open pit mines in Nevada and other western states lower groundwater, typically by aggressive pumping, to mine ore below the water table (Miller et al. 1996). After mining, the remaining pits partially fill with groundwater to form pit lakes. In the foreseeable future, more than 35 such pit lakes will exist in Nevada. Sizes of the pit lakes will vary from less than one hectare to more than 360 hectares. The lakes that are expected to form will contain from less than 100 acre-feet (AF) to about 540,000 AF of water (Miller 2002). For comparative purposes, all existing reservoirs in Nevada, excluding Lake Mead, contain approximately 600,000 AF (Miller 2002). Pit lakes in the Humboldt River basin of Nevada will contain 2.5 times this amount.

Two types of pit lakes may form. The first type has a circumneutral pH and may develop a complex food web. The second type is highly acidic and will remain relatively sterile. While this second type may be less attractive to wildlife, it is highly toxic if water is consumed.

Water quality in the pit lakes is, or will be, affected by a variety of factors, including the quality of inflowing ground water, outflow of groundwater, atmospheric precipitation, sulfide oxidation in surrounding rock, dissolution of metals, precipitation of metals, and evaporative concentration. The interaction of groundwater with the walls and surrounding rock of the pit will be an important factor in the future quality of pit lake water (Miller 2002). Oxidation reactions on the exposed pit walls may release sulfate, acid, and metals into the lake. The host rock is dewatered when a pit is excavated below the water table. If the host rock is sulfide-rich, it will oxidize when exposed to air that is pulled onto the evacuated pore spaces (Miller 2002). Reaction products will be generated on the exposed surfaces, and the oxidation products will be flushed into the pit lake by groundwater as the pit refills. Sulfuric acid is one reaction product of concern which may result in the leaching of metals and trace elements into the pit lake and may lower water pH to hazardous levels.

In some cases, water contained in pits is, or is expected to be, of poor quality and may contain concentrations of metals or other inorganic constituents that greatly exceed water quality standards and published wildlife effect levels. For example, pit lake water in Nevada has been found to contain mercury at concentrations exceeding 80 µg/L (Macdonald 1992), selenium exceeding 100 µg/L (Macdonald 1992; Miller et al. 1996; Miller 2002; Brown and Caldwell 2003) and copper exceeding 30 mg/L (Macdonald 1992; Miller et al. 1996). The current mercury chronic (96 hour) standard for protection of aquatic life is 0.012 µg/L in Nevada (Nevada Administrative Code [NAC] 2000). Mercury strongly accumulates and magnifies in biological systems and low concentrations in water may be concentrated to hazardous levels in higher trophic levels (Zillioux et al. 1993). Waterborne selenium concentrations $\geq$ 2 µg/L are considered hazardous to the health and long-term survival of fish and wildlife (Lemly 1996). The acute and chronic aquatic life standards for copper are hardness dependent and are based on filtered samples. Although the copper concentrations reported above were for unfiltered samples, the concentrations were alarming in relation to effects on aquatic life as well as for irrigation and the watering of livestock where the Nevada standards are 200 and 500 µg/L, respectively (NAC 2000).

Geochemical modeling efforts to determine water quality at some future pit lakes have predicted long-term degradation of pit lake water quality. In some cases, water quality continued to deteriorate for the time period that the model was run (as long as 230 years) (U.S. Bureau of Land Management 1996). This may be due in part to evapoconcentration where the concentration factor may be 10 to 40 times the concentration in the ground water inflow (Atkinson 2002). Evapoconcentration is a major consideration for constituents such as arsenic, selenium, and other elements. However, modeling can be rather complex due to various uncertainties in the process (Moreno and Sinton 2002).

Wildlife use and the degree of threat presented by inorganic contaminants in pit lakes are uncertain. It is assumed that riparian and aquatic communities will become established in most pit lakes at circumneutral pH. However, the nature of these communities is questionable. Water contained in mine pits may be nutrient-poor or may contain elevated concentrations of contaminants which may restrict productivity. Mine pit lakes will typically be deep and steep sided, thereby limiting riparian and shallow lentic habitat. However, benches and ramps in the mine pit, along with erosion of pit walls, may provide limited areas where shallow lentic or riparian communities may become established, especially following the completion of lake filling. Similarly, wildlife use and fish introductions over the long-term are uncertain. Wildlife using pit lakes may be exposed to hazardous levels of environmental contaminants in pit lakes. In an extreme case (Berkeley Pit near Butte, Montana) a large-scale avian die-off was attributed to poor quality pit lake water. In this incident, the death of 342 snow geese (*Chen caerulescens*) was attributed to acute metal toxicosis and sulfuric acid exposure resulting from exposure to and consumption of poor quality pit water (Hagler Bailly Consulting, Inc. 1996). Under less extreme conditions, exposure to inorganic contaminants may occur through exposure to water and consumption of contaminated foods from the pit lake. In other cases bioaccumulation and biomagnification become important factors affecting contaminant uptake.

Currently, little is known about biological and chemical characteristics of mine pit lakes. As a result, the ultimate hazards of these lakes are poorly understood. This investigation was designed to provide information on habitat and community development, habitat quality, wildlife use, inorganic contaminant behavior and partitioning, and the potential for wildlife exposure to inorganic contaminants in mine pit lakes.

Study Sites

Yerington

The Yerington Mine pit lake is located in Lyon County, Nevada, approximately 1.6 kilometers (km) west of the city of Yerington, in Mason Valley (Table 1; Figure 1). The pit was mined for copper ore from 1953 to 1978 (Brown and Caldwell 2003). The east-south-east end of the pit is within 0.4 km of the Walker River. Flows in the river were temporarily diverted into the pit during the flood of January 1997 to relieve flooding in the Yerington area, which increased the level of water in the pit lake (Brown and Caldwell 2003). This pit lake was visited on June 12 and 13, 2000. The pit lake was approximately 110 meters (m) deep at the time of this study and its surface was

approximately 70 to 110 m below the pit rim. The estimated volume of the lake at the time of this study was about 30,000 AF (Brown and Caldwell 2003). Pit walls are relatively steep sided, but three ramps are present running below the lake level where water levels are relatively shallow in limited areas. Pit lake water quality is dominated by elevated concentrations of copper and selenium.

Buena Vista Complex

This pit lake complex is located in Pershing County, Nevada, approximately 25 km southeast of Lovelock and north of the Carson Sink (Table 1; Figure 1). This iron mining district was active from 1943 until at least the early 1960s (Reeves 1964). Four abandoned mines in this complex were visited on May 31, 2000. Buena Vista 1 is located on the north side of the Buena Vista Hills. This pit is about 15 m deep and contained a small (0.1 hectare), shallow (< 20 cm deep) pit lake of likely meteoric water which may go dry. The Buena Vista 2 pit is < 30 to 45 m deep and contained a lake estimated to be more than 15 m deep and about 1.2 hectares in surface area. The lake was inaccessible. The Buena Vista 3 pit was approximately 30 to 45 m deep and contained a lake with a surface area of about 0.4 hectare that was estimated to be 30 m deep. The lake had a deep center and a shallow shelf. The Buena Vista 4 pit was long and narrow on a north to south axis, deep, with a lake < 10 m deep, and about 1.2 hectares in size, which was shallow at the south end.

Tuscarora

This pit lake is located in northwestern Elko County, Nevada (Table 1; Figure 1). This mining district had a long history of gold and silver production which primarily occurred in the 1870s to 1890s (http://www.nvghosttowns.topcities.com/pastpro/tuscaror.htm). The use of mercury amalgamation for the recovery of precious metals from ores was common during this era. Horizon Gold Shares Inc. began open pit gold mining operations in July 1987 and ceased in August 1989 (Nevada Division of Environmental Protection 1998). The site was visited on June 20-21, 2000 and July 16, 2001. The spring-fed lake is approximately 2 hectares in size, with an outflow. Pit walls are 0 to 10 m high in alluvium.

Clipper

This pit lake is located approximately 30 km southwest of Crescent Valley, Lander County, Nevada (Table 1; Figure 1). The site was visited on June 19, 2000 and July 17, 2001. The pit is steep-walled with the lake being about 90 m below the rim. One small bench is submerged on a haul road. The pit wall on the west side was sloughing. The site is an abandoned barite mine.

Aurora

This pit is located in southwestern Mineral County, Nevada (Table 1; Figure 1). The site was visited on June 13, 2000. The pit is about 40 m deep with a lake of about 4 hectares. Pit walls are relatively steep. The site is an abandoned gold mine.

Methods

Biological characteristics were assessed at least once at each pit lake that was visited. Data on aquatic and riparian vegetation occurrence and abundance and migratory bird and resident wildlife use were collected by direct observation. Aquatic macroinvertebrate occurrence and relative abundance data were collected with the use of kick nets, plankton nets, and light traps. Field measurements of water quality were obtained with use of a Hydrolab (Hydrolab Corporation, Austin, Texas) which was calibrated daily using reference standards. Measurements included water depth, temperature, dissolved oxygen, specific conductance, pH, and in some cases turbidity and salinity. Measurements were normally conducted at 10 m intervals in depth, and in larger lakes at up to four sites in the lake.

Composites of aquatic vegetation and macroinvertebrates were collected at the Yerington and Tuscarora pit lakes. Vegetation samples were collected with gloved hand, placed in chemically clean jars, placed on ice in the field, and frozen upon return to the laboratory. Aquatic macroinvertebrates were collected with a kicknet, sorted from debris, placed in chemically clean jars, placed on ice in the field, and frozen upon return to the laboratory. Three individual largemouth bass (*Micropterus salmoides*) were collected from the Tuscarora pit lake with nets, placed in individual clean containers, placed on ice in the field, and frozen upon return to the laboratory. Three pooled sets of bank swallow (*Riparia riparia*) eggs, each consisting of two to three eggs, all of which had failed to hatch, were collected from nests at the south wall of the Yerington pit. Egg contents were emptied into chemically clean glass jars, placed on ice in the field, and frozen upon return to the laboratory.

All collection gear used for sample collection for chemical analysis was thoroughly washed with Citranox (Alconox, Inc., White Plains, New York) prior to use in each pit lake. The gear was then washed with site water and a brush between collection sites in each pit lake and finally rinsed with deionized water before each use.

Samples were submitted to Laboratory and Environmental Testing, Inc., Columbia, Missouri, a contract laboratory under the Patuxent Analytical Control Facility (PACF), Laurel, Maryland, of the U.S. Fish and Wildlife Service, for metal and trace element analysis. Samples were homogenized, freeze dried to determine percent moisture, and digested in preparation for analysis. Mercury was analyzed by cold vapor atomic absorption (AA), arsenic and selenium by hydride generation AA, lead and cadmium by graphite furnace AA, and the remainder by inductively coupled plasma (ICP). Quality control/quality assurance (QA/QC) included the analysis of two procedural blanks (one each for animal and plant tissue), two duplicates (one each for an invertebrate and vegetation sample), two reference materials (apple leaves and lobster hepatopancreas), and two spike recoveries (one each for an invertebrate and vegetation sample). Recovery of arsenic from the spiked vegetation sample was low; therefore, the vegetation arsenic values may be biased low. QA/QC and analytical results were approved by PACF. All concentrations reported herein, including those from the literature, are expressed on a dry weight basis, unless noted otherwise.

Results

Biological Observations

Yerington

Vegetation around the pit lake was limited to small areas of cottonwoods (*Populus* sp.), willow (*Salix* sp.), tamarisk (*Tamarix* sp.), cattails (*Typha* sp.), and shrubs that were concentrated in areas of spring inflows. Four samples of algae (*Cladophora*) were collected from the lake for analysis; sample weights ranged from 20 to 50 g. Fish were absent from the lake, as confirmed by gill netting for 2 days.

Bird observations conducted during this study recorded the following species and maximum numbers or relative abundance during the period of June 12-14, 2000: bank swallow, abundant, nesting on pit walls and foraging over the lake (three pooled egg samples were collected for analysis; sample weights ranged from 1.1 to 2.5 g); western grebe (*Aechmophorus occidentalis*), one foraging in shallow water along the east side of the lake; eared grebe (*Podiceps nigricollis*), three; killdeer (*Charadrius vociferous*), one; unidentified passerines, eight along the south side uplands; unidentified duck, two; unidentified cormorant, one; Canada goose (*Branta canadensis*), one. Two mule deer (*Odocoileus hemionus*) were also seen, along with several lizards. Mule deer were seen coming to the lake to drink during later observations. Bird observations made at later dates, outside the time-frame of this study, found larger total numbers (up to about 300) during the winter, with Canada geese, several species of ducks, and grebes being predominant.

Daphnia (Cladocera) and copepods (Order Calanoida) were found in plankton hauls from the lake conducted on June 13, 2000. The contents of a light trap recovered on June 14, 2000 included abundant numbers of *Daphnia* of at least two species, one *Ceriodaphnia* (Cladocera), copepods (Copepoda) of two orders (Calanoida and Cyclopoida), as well as one unidentified insect. Three samples of dragonfly larvae (Odonata, *Libellula* sp.) and one sample of naucorids (Hemiptera, Naucoridae, *Ambrysus* sp.) were collected by kicknet for analysis. Sample weights of invertebrates ranged from 21 to 33 g.

Buena Vista Complex

The Buena Vista 1 lake had a fringe of tamarisk trees. Wildlife was not noted at this site. Algae were present in the Buena Vista 2 lake and a sparse fringe of shrubs was present around the lake. The only wildlife noted at this site was approximately 10 unidentified passerines. A fringe of tamarisk and small shrubs was present at Buena Vista 3. Unidentified blackbirds and wrens were present at this site as well as one common crow (*Corvus brachyrhynchos*) and one Say's phoebe (*Sayornis saya*). Aquatic invertebrates that were present included: corixids (Corixidae) and copepods, which were abundant; mayflies (Ephemeroptera) which were common; and stoneflies (Plecoptera). Algae and pondweed (presumably *Potamogeton* sp.), the latter on a shelf, were also present in the lake. Vegetation at Buena Vista 4 included a sparse fringe of shrubs and tamarisk, with algae being abundant in the water. Birds observed at this site included an unidentified wren, one red-tailed hawk (*Buteo jamaicensis*), and one great horned owl

(*Bubo virginianus*). Hemiptera were abundant in the lake, whereas dragonflies and mayflies were ranked as sparse.

Tuscarora

A few willows were present on the east-north-east shore; submergent vegetation was sparse. Three samples of submergent vegetation, later identified as golden dock (*Rumex maritimus*), were collected for analysis; sample weights ranged from 17 to 22 g. Wildlife observations in June 2000 included the following (maximums): Brewer's blackbird (*Euphagus cyanocephalus*), seven; unidentified swallows, 15 nesting on west pit wall; killdeer, four, nesting; American robin (*Turdus migratorius*), one; common nighthawk (*Chordeiles minor*), one; black-necked stilt (*Himantopus mexicanus*), one; unidentified shorebird, two; unidentified duck, one, and unidentified ground squirrel, three. Three largemouth bass (350 to 365 mm total length and 688 to 805 g total weight) and three samples of amphipods (Amphipoda; sample weights ranged from 9 to 20 g) were collected for analysis. *Daphnia* and amphipods were abundant, whereas corixids and beetles (Coloeptera) were common in captures from light traps. Copepods (Orders Cyclopoida and Calanoida) were also captured in a plankton net.

Wildlife observations in July 2001 included the following maximum numbers during two observation periods: unidentified swallow, > 30; common raven (*Corvus corax*), three, one with a nest; mourning dove (*Zenaida macroura*), two; common nighthawk, one; Swainson's hawk (*Buteo swainsoni*), three; killdeer, one; red-tailed hawk, two; red-shafted flicker (*Colaptes auratus*), one; coyote (*Canus latrans*), six; and black-tailed hare (*Lepus californicus*), one. The following aquatic invertebrates were also found: amphipods, abundant; two types of Coleoptera, one common and one sparse; corixids, abundant; naucorids, common; and *Daphnia*, common. More than three largemouth bass were seen in the lake.

Clipper

Observations in June 2000 reported that sparse amounts of algae were present in the lake, with sparse amounts of tamarisk present around the edges of the lake, and sparse vegetation on the benches of the pit walls. Wildlife observations in June 2000 reported the following: great horned owl, three; raven, two; unidentified swallow, > six; and American coot (*Fulica americana*), one. Speckled dace (*Rhinichthys osculus*) were common in the lake. Aquatic invertebrates that were found, all recorded as sparse, included: notonectid (Hemiptera, Notonectidae), damselflies (Odonata, adults and juveniles), corixids, Hymenoptera (adult), chironomid (Chironomidae) larvae, and Coleoptera (Georyssidae). Observations conducted in July 2001 reported an unidentified type of aquatic vegetation to be common and cattails to be sparse. Wildlife observations included: olive-sided flycatcher (*Contopus borealis*); dusky flycatcher (*Empidonax oberholseri*); common nighthawk; and an unidentified bat.

Aurora

Wildlife observations made during the June 2000 visit recorded the following: unidentified swallows, 20-30 nesting on the pit high walls; starling (*Sturnus vulgaris*); unidentified hawk; upland birds in the vicinity; and deer sign.

Field Measurements of Water Quality

Data on field measurements of water quality are provided in Table 2. At the Yerington pit lake, water temperature declined rapidly with depth from the surface to approximately 30 m and then was relatively constant. Dissolved oxygen increased from the surface to about 20 meters in depth and declined with increasing depth. Specific conductance increased slightly with depth, whereas pH tended to decline with depth. At the Tuscarora pit lake, water temperature was the highest at the surface, dissolved oxygen was somewhat variable in relation to depth depending on the location, specific conductance increased slightly with increasing depth, and pH generally declined with increasing depth. In addition to the data presented in Table 2, turbidity measurements ranged from 14.5 to 24.7 nephelometric turbidity units (NTU) at the Tuscarora pit lake in July 2001. At the Clipper pit lake, water temperature declined with depth, dissolved oxygen was somewhat variable, specific conductance was relatively stable, and pH declined slightly with increasing depth. Turbidity was also measured at the Clipper pit lake in July 2001 and ranged from 15.0 to 28.9 NTU. Salinity measurements at the same site ranged from 1.28 to 1.34 parts per thousand. Surface water quality data for Buena Vista 1, 3, and 4 and Aurora are also provided in Table 2.

Metals and Trace Elements in Water

Concentrations of metals and trace elements have been reported for the Yerington, Tuscarora, and Aurora pit lakes by other investigators. Selected data are provided here (Table 3) in an effort to relate water quality to residues of various constituents in biological samples that were collected.

The recent data (1991-2001) for the Yerington pit lake were compiled by Brown and Caldwell (2003). However, the data presented in Table 3 are limited to samples that were specifically designated as being total (i.e., not filtered) or dissolved (i.e., filtered), which eliminated the bulk of the data and narrowed the data set to the years 1995-1998. Ranges of concentrations of various constituents in both filtered (dissolved) and unfiltered (total) samples did not appear to be biased by collection location due to avoidance of samples collected near surface water inputs. Data from a variety of depths in the lake are included. The depth-averaged dissolved copper concentration in 1995 was 136 µg/L; however in 2000 and 2001 the concentration had declined to only about 20 µg/L (R. Hershey, pers. comm.). Selenium concentrations for the same period, on the other hand, have been relatively stable and have remained within the range of 100 to 130 µg/L.

Water quality in the Tuscarora pit lake was provided by L. Stillings (pers. comm.). All data were for dissolved constituents. Samples were collected in January, April, July, and November 2000 from five variable depths during each sampling event (Table 3). Specific conductance ranged from 246.6 to 364.7 µS/cm, and generally increased with depth. No other consistent trends in water quality parameters were noted in relation to season or depth.

Water quality data in the Aurora pit lake were measured by Kempton (1996) in 1995. The data provided in Table 3 are for dissolved constituents in one sample each from the epilimnion and hypolimnion. Total dissolved solids concentrations were 478

and 524 mg/L, whereas pH was 7.59 and 7.68 for the epilimnion and hypolimnion, respectively.

Metals and Trace Elements in Biological Samples

Geometric means and ranges of concentrations of metals and trace elements for samples from the Yerington and the Tuscarora pit lakes that were collected during this study are provided in Tables 4 and 5, respectively. At the Yerington pit lake, naucorids usually had similar or lower concentrations of all elements than dragonfly larvae, with the exception of zinc where the concentration was twice as high, and especially for cadmium where the concentration was an order of magnitude higher in naucorids. However, caution should be used in comparisons due to the small number of samples analyzed. Ranges of concentrations within a given sample type were highly variable for chromium and manganese in algae, and mercury in swallow eggs. For the samples from the Tuscarora pit lake, ranges of concentrations within a given sample type were highly variable for aluminum and iron in amphipods.

Discussion

Water Quality

Overall, water quality, as indicated by specific conductance, was poorest (i.e., high conductivity) at the Clipper pit lake and the best (i.e., low conductivity) at the Tuscarora pit lake. Water pH was similarly circumneutral among all sites sampled.

Concentrations of metals and trace elements in pit lake water (Table 3) were compared to Nevada water quality standards for aquatic life, irrigation, and watering of livestock (Nevada Administrative Code 2000). However, standards for aquatic life are often hardness-related. A hardness of 275 mg/L for the Yerington pit lake, based on data from R. Hershey (pers. comm.) was used in calculations. For the Yerington pit lake, standards for irrigation and watering livestock were not exceeded, with the exception of selenium which exceeded both standards (i.e., 20 and 50 µg/L, respectively). Copper concentrations in earlier samples exceeded the acute (i.e., 39 µg/L) and chronic (i.e., 24 µg/L) aquatic life standards; however, samples collected in 2000 and 2001 had concentrations lower than these standards. The single reported dissolved molybdenum concentration exceeded the aquatic life standard of 19 µg/L. Total selenium concentrations in water greatly exceeded the acute (i.e., 20 µg/L) and chronic (i.e., 5 µg/L) aquatic life standards. No other elements exceeded the Nevada standards. The elevated copper and selenium concentrations in water are in agreement with the elevated concentrations that were found in algae and macroinvertebrates. It should be noted that the State of Nevada does not apply water quality standards to pit lakes.

Water quality in the Tuscarora pit lake was generally good, with no dissolved concentrations exceeding aquatic life standards for Nevada. However, no data for mercury were available. Water quality in the Aurora pit lake was generally good except for selenium, where the concentration was approximately two times the chronic aquatic life standard for Nevada.

Relation of Element Concentrations to Avian Dietary Effects

Concentrations of metals and trace elements in biological samples were evaluated as potential food sources to migratory birds. However, it should be noted that algae and the portions of golden dock that were collected may not be commonly consumed by migratory birds. Effect concentrations for barium, beryllium, iron, magnesium, manganese, and strontium are not known and these constituents are not discussed further.

Aluminum

An aluminum concentration of 5,000 µg/g was considered an adverse dietary effect level in waterfowl (Sparling 1990), with diets less than 1,000 µg/g considered to be not harmful (Sparling and Lowe 1996). However, interactions with calcium and phosphorus are likely important. The higher concentration above was exceeded in all algae samples and in two of three samples of dragonfly larvae from the Yerington pit lake and in one of three samples of golden dock from the Tuscarora pit lake.

Arsenic

The dietary no-observed-adverse effect-level (NOAEL) for two aquatic avian species were 19-22 µg/g (wet weight) when based on sodium arsenite in the diet and 3.4-3.9 µg/g (wet weight) when based on copper acetoarsenite (U.S. Department of the Interior 1998). An arsenic concentration of 30 µg/g in the diet of mallard (*Anas platyrhynchos*) ducklings was associated with reduced weight gain (Camardese et al. 1990). Arsenic concentrations in algae, aquatic invertebrates, and fish from both pit lakes did not exceed the latter concentration.

Boron

Weight gain of mallard ducklings whose parents received a diet containing 30 µg/g boron was significantly reduced, whereas the reproductive success of adult mallards that received a diet containing 1,000 µg/g was significantly reduced (Smith and Anders 1989). Only one of four algae samples from the Yerington pit lake contained more than 30 µg/g, with the geometric mean being lower. No other samples exceeded this concentration.

Cadmium

All cadmium concentrations in algae, aquatic invertebrates, and fish from both pit lakes were more than an order of magnitude below a level of concern in mallard ducklings of 20 µg/g (Cain et al. 1983).

Chromium

Potential adverse effects on health and reproduction of wildlife would be expected when chromium in the diet exceeds 10 µg/g (Eisler 2000a). Three of four algae samples and one of three dragonfly samples from the Yerington pit lake equaled or exceeded this threshold, with concentrations in biological samples from the Tuscarora pit lake being much lower.

Copper

Eisler (2000a) considered poultry diets containing < 200 µg/g of copper to be safe. Copper concentrations in all samples of both algae and aquatic invertebrates from the Yerington pit lake exceeded this level, with three algae samples exceeding it by more than an order of magnitude. However, birds retain a very small portion of ingested copper (Eisler 2000a). Copper concentrations in biological samples from the Tuscarora pit lake were all less than 65 µg/g.

Mercury

Adverse reproductive effects in mallards were associated with a dietary concentration of 0.5 µg/g (Heinz 1979). All mercury concentrations in algae and aquatic invertebrates from the Yerington pit lake were well below this concentration. However, mercury concentrations in amphipods and especially largemouth bass from the Tuscarora pit lake were much higher, with concentrations in amphipods ranging from 0.74 to 2.5 µg/g and concentrations in bass ranging from 14 to 20 µg/g (dry weight). The mercury concentrations in bass on a wet weight basis ranged from 3.8 to 5.6 µg/g. These concentrations, especially those found in fish, may have significant adverse effects to some migratory birds. Nearly all mercury in fish is in the more toxic methyl form (Wiener and Spry 1996). Barr (1986) found adverse effects to common loon (*Gavia immer*) reproduction and behavior when their diet contained 0.3 µg/g (wet weight). However, at least some fish-eating birds are able to demethylate methyl mercury, thereby providing protection from toxic effects (Henny et al. 2002).

Molybdenum

Growth reduction in birds was associated with a lower dietary concentration of molybdenum of 200 µg/g (Eisler 2000b). All molybdenum concentrations in biological samples from both pit lakes were one to two orders of magnitude lower than this concentration.

Nickel

A dietary concentration of 800 µg/g (fresh weight) of nickel has been associated with adverse effects to adult mallards (Eisler 2000a). All nickel concentrations in biological samples from the both pit lakes were far below this level.

Lead

An avian dietary concentration of < 5 µg/g of lead was proposed to be protective (Eisler 2000a). All lead concentrations in biological samples from both pit lakes were below this level.

Selenium

The lower threshold of dietary exposure associated with adverse reproductive effects in birds is 3 µg/g (U.S. Department of the Interior 1998). Three of four algae samples from the Yerington pit lake had selenium concentrations that exceeded this threshold and all samples of aquatic invertebrates had far higher concentrations, with two of four exceeding it by more than an order of magnitude. Selenium concentrations in

biological samples from the Tuscarora pit lake were much lower, with only the concentrations in amphipods approaching this threshold concentration.

Vanadium

The avian dietary concern level for vanadium is 100 µg/g (White and Dieter 1978). Vanadium concentrations in aquatic invertebrates and algae from both pit lakes were well below the concern level.

Zinc

The dietary effect levels proposed for birds are < 178 µg/g to prevent marginal sublethal effects and < 2000 µg/g to prevent the death of chicks and ducklings (Eisler 2000a). Zinc concentrations in aquatic invertebrates and algae from both pit lakes were well below these levels.

Summary

In general, residues of mercury in amphipods and bass from the Tuscarora pit lake and selenium in algae and aquatic invertebrates from the Yerington pit lake were of greatest concern in relation to fish and/or wildlife effect levels. Although aluminum, chromium, and copper concentrations in algae and aquatic invertebrates from the Yerington pit lake were elevated, their potential effects are less clear.

Residues in Eggs in Relation to Effects

Concentrations of metals and trace elements in bank swallow eggs from the Yerington pit were evaluated in relation to published effect levels. The no observed effect level of inorganic arsenic in avian eggs is 1.8 µg/g, whereas the corresponding level for boron is 22 µg/g (Seiler et al. 2003). Arsenic and boron concentrations in bank swallow eggs were well below these levels. The background level of cadmium in eggs was listed as 0.15 µg/g (Seiler et al. 2003), with no information being provided on a no observed effect level. One of three bank swallow eggs had a cadmium concentration exceeding this level. Copper concentrations in bank swallow eggs were below the listed background level of 5.5 µg/g (Seiler et al. 2003). The no observed effect level and the dose-response threshold in avian eggs for mercury were both listed as 3.0 µg/g by Seiler et al. (2003), with the background level being 0.1 µg/g. Mercury concentrations exceeded the background level, but not the no observed effect level. The background level, no observed effect level, and lowest observed effect level for molybdenum in avian eggs were 0.25 µg/g, 23 µg/g, and 23 µg/g, respectively (Seiler et al. 2003). Molybdenum was not detected in bank swallow eggs at a detection limit of 2 µg/g. The background level for selenium in avian eggs was listed as 1.9 µg/g, with the dose response threshold for toxic effects being 6.0 µg/g (Seiler et al. 2003). Selenium concentrations in bank swallow eggs were only slightly above the listed background level. The background level for zinc in avian eggs was listed at 50 µg/g; no information was provided on concentrations related to toxic thresholds (Seiler et al. 2003). Zinc concentrations in all bank swallow egg samples exceeded the background concentration.

Bank swallows that nest on the southern cliff face of the Yerington pit may forage, in part, over riparian areas and adjacent fields along the Walker River as well as

over the pit lake. Therefore, their accumulation of metals and trace elements from sources in the pit lake may be limited. Their assumed foraging behavior may explain the low concentrations of many constituents in their eggs. The presence of moderate mercury concentrations in bank swallow eggs may be due to mercury contamination of the Walker River from historic mining (Wiemeyer 2002). Overall, the metal and trace element concentrations in bank swallow eggs from the Yerington pit were not high enough to be of concern. Information is needed on selenium concentrations in tissues of aquatic birds, such as grebes, that have been observed foraging on the Yerington pit lake.

Effects Levels in Fish

Elevated concentrations of metals and trace elements in fish tissues may cause adverse effects to fish. Concentrations of selected elements were evaluated in relation to concentrations found in bass from the Tuscarora pit lake. Decreased growth and survival of juvenile bluegill (*Lepomis macrochirus*) was related to a concentration of 2.1 µg/g arsenic (wet weight; Gilderhus 1966); arsenic concentrations in bass were far lower. Eisler (2000a) suggested that a chromium concentration > 4.0 µg/g indicated probable exposure; the chromium concentration in one bass (i.e., 3.2 µg/g) approached this level. Whole body concentrations of mercury that were associated with sublethal or lethal toxic effects were about 5 µg/g (wet weight) for brook trout (*Salvelinus fontinalis*) and about 10 µg/g (wet weight) for rainbow trout (*Oncorhynchus mykiss*) (Wiener and Spry 1996). Mercury concentrations in bass from the Tuscarora pit lake ranged from 3.8 to 5.6 µg/g (wet weight), which overlaps the lower range of effect concentrations for trout. However, the comparative sensitivity of largemouth bass is unknown. Predator avoidance behavior in fish may be adversely affected at lower concentrations. For example, avoidance behavior of golden shiners (*Notemigonus crysoleucas*) with a whole body concentration of 5.18 µg/g (wet weight) mercury was adversely affected (Webber and Haines 2003). Selenium concentrations of 4 µg/g in whole bodies of fish have been associated with mortality of juveniles and reproductive failure (Lemly 1996). This concentration has also been proposed as a national tissue-based criterion for the protection of aquatic life in the United States (Hamilton 2002). Selenium concentrations in bass from the Tuscarora pit lake were somewhat lower. The elevated mercury concentrations may be due in part to its use in recovery of precious metals at the Tuscarora mining district in the late 1800s.

Previous Biological Data

Kempton (1996) previously collected biological samples and conducted limited wildlife observations at the Yerington pit lake in August and September 1995. He found four species of Chlorphyta and three species of Cyanophyta (phytoplankton) as well as four species of Copepoda and several species of Rotifera (zooplankton) from tows in the epilimnion of the lake. He also reported the following from the littoral zone: macrophytes - cattails, *Ludwigia* sp., and tamarisk; periphyton, algae; and invertebrates - chironomids, aquatic beetles, and aquatic true bugs. The following wildlife species were observed: spotted sandpiper (*Actitis macularia*), California gull (*Larus californicus*), horned grebe (*Podiceps auritus*), eared grebe, rock wren (*Salpinctes obsoletus*), turkey

vulture (*Cathartes aura*), bank swallow, unidentified bat, and unidentified lizard. Cattail, *Ludwigia* sp., and an insect composite were collected for analysis of selected metals and trace elements (Table 6). Copper concentrations in *Ludwigia* and the insect composite were above the level reported to be safe (Eisler 2000a). Mercury in the insect composite exceeded the avian dietary effect concentration (Heinz 1979). Selenium concentrations in all biological samples exceeded the lower threshold dietary exposure associated with adverse effects to reproduction (U.S. Department of the Interior 1998).

Bass were said to have been introduced to the Yerington pit lake 10 or more years ago (J. Sawyer, pers. comm.) and fish could have been introduced when Walker River water was diverted into the pit lake in January 1997. The current absence of fish may be due to the toxicity of elevated concentrations of selected metals and trace elements in the water, with selenium and copper being the prime suspects.

Kempton (1996) also collected biological samples and conducted limited wildlife observations at the Aurora pit lake in August 1995. He found three species of Bacillariophyta (diatoms), three species of Chlorophyta (green algae), one species of Chryptophyta, two species of Cyanophyta (blue-green algae), and one species of Euglenophyta, all phytoplankton, in plankton tows. He also found three species of Cladophera (*Daphnia*), five species of Copepoda, and three species of Rotifera, all zooplankton, in plankton tows. He reported the following from the littoral zone: no macrophytes; the following invertebrates - backswimmers, aquatic mites, water boatmen, aquatic wasps, white flies, ephippia, chironomid larvae, and nematodes; and the following periphyton – blue-green algae (*Jaaginema*), and diatoms. Wildlife observations included spotted sandpiper, rock wren, bank swallow, Cooper's hawk (*Accipiter cooperii*), Townsend's ground squirrel (*Spermophilus townsendii*), and an unidentified bat. Black flies and *Daphnia* were collected for analysis of selected metals and trace elements (Table 7). Concentrations of four elements in the *Daphnia* sample approached or exceeded dietary concentrations associated with adverse effects in birds (see discussion above). The estimated cadmium concentration approached the concern level for mallard ducklings (Cain et al. 1983). The mercury concentration was four times the dietary concentration associated with adverse reproductive effects in mallards (Heinz 1979). The estimated selenium concentration was twice the lower threshold of dietary exposure associated with adverse reproductive effects in birds (U.S. Department of the Interior 1998). The zinc concentration was twice the proposed dietary effect level in birds to prevent sublethal effects (Eisler 2000a).

Recommendations

General

This report is only the first step in providing biological information on habitat and community development, habitat quality, wildlife use, including migratory birds, and the potential for wildlife exposure to inorganic contaminants in mine pit lakes in Nevada. The number of pit lakes that was visited was small and the number where contaminants data were collected was even more limited. However, the information that was obtained, demonstrating elevated exposure of wildlife to selected contaminants at two pit lakes and reinforced by the previous findings at a third pit lake, clearly points to the need for

routine studies at pit lakes from their formation, through the period of filling, and continued beyond the time of lake level stabilization. Such studies should be required by state and federal regulatory agencies as part of the mine permitting process. Without such studies, the risks to wildlife will be unknown and uncontrolled. Such studies may also eventually aid in understanding risks at future pit lakes prior to their filling, which might lead to management actions that could reduce risks to wildlife.

Human Health Concerns

The U.S. Environmental Protection Agency (2004) has provided monthly fish consumption limits for humans in relation to various concentrations of mercury in fish. The concentrations are for methylmercury in fish fillets; therefore, they cannot be directly related to mercury concentrations in whole fish. However, nearly all mercury in fish is in the methylmercury form, with concentrations in muscle tending to be higher than in whole body, at least for trout (Wiener and Spry 1996). No fish consumption was advised when methylmercury concentrations were > 1.9 µg/g (wet weight). Total mercury concentrations in largemouth bass from the Tuscarora pit lake ranged from 3.8 to 5.6 µg/g (wet weight), which are two to three times higher than the no consumption advisory. Therefore, it is recommended that no largemouth bass from this site be consumed by humans.

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Table 1. Locations and elevations of mine pit lakes in Nevada visited during the study, 2000-2001.

Pit lake	UTM's North	UTM's East	Elevation (meters)
Yerington	4316962	310036	1276
Tuscarora	4573575	564994	~1850
Buena Vista 1	4433199	401215	not recorded
Buena Vista 2	4433204	402125	1299
Buena Vista 3	4436234	397314	1247
Buena Vista 4	4438073	398620	1277
Clipper	4455332	514231	1654
Aurora	4240047	335245	2176

Table 2. Field measurements of water quality[a] at mine pit lakes in Nevada, 2000-2001.

Pit lake	Date	Depth (m)	Temp. (ºC)	DO (mg/L)	SpC (µS/cm)	pH (SU)
Yerington	6/13/00					
West end		0	20.43	7.52	830	8.41
		10	16.98	8.98	834	8.35
		20	8.69	9.95	867	8.35
		30	6.99	8.11	912	8.23
		40	6.61	7.66	863	8.12
		50	6.40	6.73	868	8.02
		60	6.33	6.34	869	7.95
		70	6.33	6.21	869	7.92
		80	6.33	5.92	870	7.88
East end		0	20.44	7.30	829	8.30
		10	18.25	9.13	834	8.36
		20	8.64	10.69	855	8.36
		30	7.32	9.22	857	8.28
		40	6.61	8.67	866	8.17
		50	6.66	7.20	869	8.13
		60	6.70	6.54	869	8.10
		70	6.71	6.10	867	8.08
		80	6.75	5.92	868	8.05
		90	6.73	5.41	870	8.04
		100	6.73	5.22	872	8.02
Middle		0	20.34	7.30	831	8.34
		10	16.02	8.50	835	8.35
		20	8.47	10.00	852	8.36
		30	7.14	9.60	860	8.30
		40	6.68	8.50	8.65	8.18
		50	6.48	7.26	8.69	8.08
		60	6.32	6.51	868	8.00
		70	6.35	6.30	869	7.97
		80	6.35	6.07	870	7.93
		90	6.33	5.94	867	7.90
		100	6.42	5.41	869	7.87
Tuscarora	7/16/01					
West end		0	18.99	8.58	306	8.87
		10	9.82	8.95	317	8.36
East end		0	19.07	8.07	307	8.90
		10	10.34	9.67	312	8.48
Middle		0	19.08	8.30	307	8.90
		10	9.43	11.08	314	8.40
		20	6.81	3.56	329	7.80
#1[b]	6/20/00	0	17.67	7.28	260	8.07
		10	10.20	8.05	283	8.03

Table 2. *continued*

Pit lake	Date	Depth (m)	Temp. (ºC)	DO (mg/L)	SpC (µS/cm)	pH (SU)
		~15	7.4	6.24	309	7.85
#2[c]	6/20/00	0	17.28	7.26	258	8.02
		10	10.46	7.90	275	7.99
#3[d]	6/20/00	0	17.23	7.50	260	8.03
		10	10.20	7.98	276	8.00
		~18	6.00	4.16	318	7.73
#4[e]	6/20/00	0	17.50	7.40	255	7.98
		10	10.23	8.40	277	8.03
		~15	6.37	7.33	316	7.85
Buena Vista 1	5/31/00	0	19.0	9.7	1080	7.3
Buena Vista 2	5/31/00	N.S.[f]				
Buena Vista 3	5/31/00	0	22.0	8.9	1940	7.8
Buena Vista 4	5/31/00	0	19.8	8.3	1070	7.8
Clipper	7/17/01					
West end		0	21.08	8.97	2493	8.37
		10	5.42	14.06	2383	7.39
		25	4.28	9.39	2392	7.12
East end		0	20.43	7.80	2484	8.47
		10	5.08	10.53	2383	7.78
		14	4.33	11.72	2386	7.54
Middle		0	20.42	8.65	2482	8.48
		10	5.07	10.80	2386	7.84
		20	4.17	9.01	2417	7.45
		23	4.28	7.65	2425	7.27
Aurora	6/13/00	0	17.00	8.1	1180	8.4

[a] DO = dissolved oxygen; SpC = specific conductance.
[b] 20 meters from west shore.
[c] About 50 meters east of site #1.
[d] About 50 meters east of site #2.
[e] About 50 meters east of site #3.
[f] N.S. = not sampled; inaccessible.

Table 3. Ranges of concentrations of selected metals and trace elements in water (total = unfiltered; dissolved = filtered) from the Yerington[a], Tuscarora[b], and Aurora[c] pit lakes.

Constituent	Yerington Total µg/L	Yerington Dissolved µg/L	Tuscarora Dissolved µg/L	Aurora Dissolved µg/L
Aluminum	21-43 (4)[d]	<0.99-21 (5)	3.4-38 (20)	<8.0-<26 (2)
Arsenic	2.82-4.73 (4)	<5.3-3 (5)	3.9-6.0 (20)	4.0-7.0 (2)
Barium	29-34 (4)	32-34 (5)	26-35 (20)	68-76 (2)
Beryllium	1 (4)	<4.8-1 (5)	<0.05-<0.06 (20)	<1.0 (2)
Boron	387-402 (2)	396-412 (2)	32.5-42.3 (20)	No data
Cadmium	2.0-2.4 (4)	2.0-2.4 (4)	<0.02 (20)	<2.0 (2)
Chromium	2.4-6.0 (4)	<0.51-5 (5)	<1-2 (20)	<3.0-<4.0 (2)
Copper	25-148 (4)	20-153 (5)	<0.5-0.8 (20)	<3.0 (2)
Iron	2-32 (4)	17-24 (4)	22-49 (20)	17 (2)
Lead	1-2 (4)	<3.1-1 (5)	<0.05-0.08 (20)	<1.0 (2)
Magnesium	No data	No data	6150-9000 (20)	19500-21600 (2)
Manganese	14-59 (4)	13-64 (5)	1.1-74 (20)	<1.0-57 (2)
Mercury	0.0019-0.00252 (4)	0.2[e] (4)	No data	<0.2 (2)
Molybdenum	No data	49 (1)	2.0-2.4 (20)	No data
Nickel	17-21 (4)	12-21 (5)	<0.1-0.1 (20)	<21 (2)
Selenium	95-123 (4)	92-122 (5)	<0.2-1.0 (20)	10-11 (2)
Strontium	No data	>0.40 (1)	220-330 (20)	No data
Vanadium	No data	7.2 (1)	0.49-1.4 (20)	No data
Zinc	4-9 (4)	<3.3-6 (5)	<0.5-21[f] (20)	<2.0-<7.0 (2)

[a] Data from Brown and Caldwell (2003). Data were collected in 1995-98.
[b] Data from L. Stillings (pers. comm.). Samples were collected in January, April, July and November 2000.
[c] Data from Kempton (1996). Data were collected in 1995. Some concentrations were estimated.
[d] Number of samples given in parentheses.
[e] Dissolved mercury data are highly questionable as they are much higher than data for total.
[f] Outlier; next highest concentration was 2.0 µg/L.

Table 4. Geometric mean (extremes) metal and trace element concentrations (µg/g dry weight) in biological samples collected in June 2000 from the Yerington Pit and pit lake.

Constituent	Algae (*Cladophora*) (n = 4)	Odonata dragonfly larvae (n = 3)	Naucorids creeping water bugs (n = 1)	Bank Swallow eggs (n = 3)
Aluminum	10947. (8830-12800)	4732. (3200-5780)	2440.	6.9 (3-11)
Arsenic	12.6 (9.5-16)	5.9 (5-7)	2.4	nd[1] (<0.4-<0.5)
Boron	25.7 (20-41)	7.6 (7.0-9.1)	5.0	nd (<2.0)
Barium	84.1 (55.9-103)	24.7 (16.0-39.7)	13.	7.7 (7.2-8.1)
Beryllium	0.35 (0.20-0.51)	0.16 (0.1-0.2)	<0.10	nd (<0.10)
Cadmium	0.29 (0.20-0.35)	0.79 (0.51-0.98)	7.8	nd (<0.1-1.2)
Chromium	20.8 (9.3-51.6)	8.0 (5.6-10)	4.8	nd (<0.50)
Copper	1995. (1250-3000)	1199. (911-1480)	634.	3.2 (2.8-4.1)
Iron	10678. (6900-14300)	4515. (2950-6000)	2100.	167. (160-170)
Mercury	0.25 (0.20-0.31)	0.20 (0.20)	0.30	0.55 (0.20-0.96)
Magnesium	7386. (6200-9030)	2958. (2210-3790)	2450.	478. (465-489)
Manganese	201. (84.6-521)	166. (93-258)	70.	2.5 (1.8-3.9)
Molybdenum	3.5 (3-4)	nd (<2.0-3.0)	<2.0	nd (<2.0)
Nickel	16.6 (9.3-26)	8.9 (7.3-10)	4.5	nd (<0.5-1.0)
Lead	2.5 (1.3-3.9)	1.5 (1.0-2.0)	0.74	nd (<0.20)
Selenium	6.1 (2.4-13)	34.7 (27-42)	14.	2.5 (2.1-2.9)
Strontium	177. (112-278)	63.0 (48.2-74.0)	54.7	27.4 (20.9-33.0)
Vanadium	27.7 (19-39)	10.1 (6.6-14)	4.3	nd (<0.50)
Zinc	38.2 (28.0-55.8)	93.8 (83.8-114)	229.	75.0 (64.9-86.9)

[1] nd = not detected or > 50% of samples with non-detectable concentrations.

Table 5. Geometric mean (extremes) metal and trace element concentrations (µg/g dry weight) in biological samples collected in June 2000 from the Tuscarora pit lake.

Constituent	Golden dock *Rumex maritimus* (n = 3)	Amphipoda *Gammarus* (n = 3)	Largemouth bass *Micropterus salmoides* (n = 3)
Aluminum	2061. (1340-3170)	2449. (893-5110)	58. (33-80)
Arsenic	2.2 (1.4-3.0)	7.3 (4.8-10)	nd[1] (<0.2-0.2)
Boron	23. (22-24)	2.9 (2-4)	nd (<2.0)
Barium	56. (49.6-61.4)	183. (163-231)	7.8 (6.9-8.8)
Beryllium	nd (<0.10-0.10)	0.08 (<0.10-0.10)	nd (<0.10)
Cadmium	0.16 (0.1-0.2)	0.50 (0.46-0.57)	nd (<0.10)
Chromium	1.5 (1.0-2.0)	1.2 (0.9-2.0)	1.4 (0.8-3.2)
Copper	11. (10-13)	58. (56.1-62.5)	2.7 (1.7-4.1)
Iron	1465. (918-2210)	1526. (419-3060)	73. (71-75)
Mercury	nd (<0.10)	1.3 (0.74-2.5)	17. (14-20)
Magnesium	5240. (4890-5920)	2786. (2640-2990)	1719. (1670-1790)
Manganese	354. (267-485)	58. (32.0-91.3)	4.1 (3.2-6.5)
Molybdenum	nd (<2.0)	nd (<2.0)	nd (<2.0)
Nickel	1.9 (1.5-2.3)	1.5 (1.0-3.2)	nd (<0.50)
Lead	1.4 (1.0-2.0)	1.9 (0.5-3.6)	nd (<0.20)
Selenium	0.36 (0.3-0.4)	2.4 (2.1-2.7)	1.7 (1.6-1.9)
Strontium	112. (100-133)	607. (565-676)	128. (114-138)
Vanadium	4.2 (3.0-5.8)	3.2 (1.0-8.4)	nd (<0.50)
Zinc	36. (35-37)	74. (70.5-77.5)	69. (59.4-82.6)

[1] nd = not detected or > 50% of samples with non-detectable concentrations.

Table 6. Residues of metals and trace elements (µg/g dry weight) in biota collected in 1995 from the Yerington pit lake reported by Kempton (1996). Concentrations were converted to a dry weight basis based on percent moisture values.

Constituent	Plant tissue *Typha* sp.	Plant tissue *Ludwigia* sp.	Macroinvertebrates Insect Composite
Antimony	<0.063	0.64	0.42
Arsenic	0.438	5.09	0.23*
Cadmium	<0.032	0.22	0.30*
Copper	51.4	1140.	582.
Lead	0.32	1.52	1.75*
Mercury	0.0037	0.14	1.97
Methylmercury	0.0017	0.013	1.85
Selenium	9.7	31.1	10.2*
Silver	<0.062	<0.062	<0.062
Zinc	14.8	25.4	108.

* Estimated values.

Table 7. Residues of metals and trace elements (µg/g dry weight) in biota collected in 1995 from the Aurora pit lake reported by Kempton (1996). Concentrations were converted to a dry weight basis based on percent moisture values.

Constituent	Simuliidae Black flies	Zooplankton *Daphnia*
Antimony	0.25	<0.063
Arsenic	4.3*	15.2*
Cadmium	0.10*	19.3*
Copper	27.7	23.4
Lead	0.94*	0.18*
Mercury	0.14	2.17
Methylmercury	0.001	0.03
Selenium	0.89*	6.38
Silver	0.29	0.58
Zinc	90.3	364.

* Estimated values.
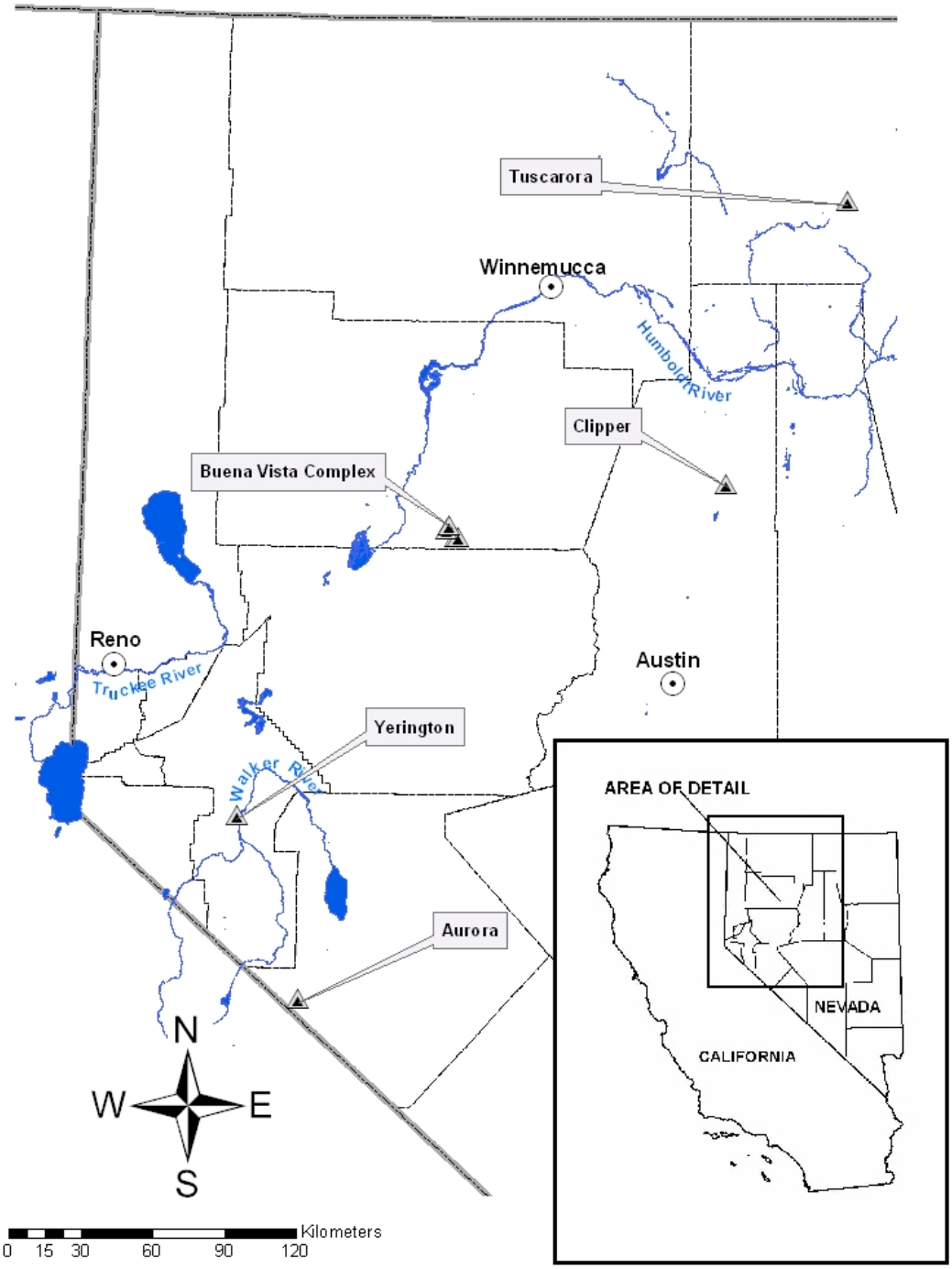
Figure 1. Location of mine pit lakes in Nevada included as part of this study, 2000-2001.