Independent investigation of reclamation at exploration drill holes at the remote Pebble copper prospect, Alaska

Kendra Zamzow[1], Dave Chambers,[2]

[1]*Center for Science in Public Participation, PO Box 1250 Chickaloon, AK 99674 US*
kzamzow@csp2.org
[2]*Center for Science in Public Participation, 224 North Church Avenue, Bozeman, MT, 59715 US*

Abstract The proposed Pebble mine in Alaska-- a copper, gold, molybdenum prospect – was intensively explored from 2004-2012. No core drilling has occurred since 2012. However, many drill holes have not been fully and properly abandoned and continue to require inspections. In 2016, one week apart, state regulators and a science team (Center for Science in Public Participation, CSP2) investigated over 100 drill sites each, and had different conclusions regarding the success of reclamation.

Key words acid soil, artesian, drill cuttings, mine water, reclamation

Introduction

Most mining projects do not make it past the exploration stage. Drilling began at the Pebble copper-gold-molybdenum prospect in 1988, with intensive exploration 2004 -2012, primarily by the Pebble Limited Partnership (PLP). All drilling was suspended after 2013. There are 1,355 drill holes ranging from piezometers as shallow as 1 foot deep to exploration holes 6,000 feet deep. As scientists unaffiliated with the mining company or State regulators, we investigated the impact of disposal practices, the success of reclamation, and the adequacy of the regulatory method of assessing closure.

Risks to salmon

The development of this world-class copper sulfide deposit poses the risk of releasing acid mine drainage and copper into the environment. Salmon are highly sensitive to copper which, at very low concentrations, affects navigation and predator avoidance (McIntyre et al. 2012). Waters in the area are very low in copper and low in the alkalinity and dissolved organic carbon that could ameliorate impacts of trace elements (PLP 2011; Zamzow 2011; Craven unpublished). Small concentrations of copper that enter salmon habitat could quickly become bioavailable. The deposit sits at the headwaters of three important salmon rivers. Lakes, shallow “kettle ponds”, wetlands, and over 4,000 documented springs are located around the deposit. Salmon have been documented in tributaries throughout the area, including on top of the deposit (Woody and O’Neal 2009).

Drill hole abandonment and waste disposal procedures

Exploration is conducted under a permit (DNR 2014-2016 Multiple Land Use Permit) that requires drill casings to be cut off at ground level, natural vegetation re-established and holes to be plugged

> *"with bentonite holeplug, a benseal mud…for a minimum of 10 feet within the top 20 feet of the drill hole in competent material. The remainder of the hole will be backfilled to the surface with drill cuttings….Complete filling of the drill holes…is the preferred method…"*

In the process of exploratory drilling, water pumped from local ponds and creeks is mixed with drilling muds and circulated downhole to bring "rock flour" drill cuttings to the surface. Drilling muds may contain petroleum distillate, bentonite clay, barite, polyacrylamide and other additives (Wober 2009). Drilling wastewater was discharged directly onto tundra, into kettle ponds, or circulated through drill sumps to settle cuttings before discharge. Drill wastewater sump pits were in partial use at the Pebble site at least as early as 2003, but waste was discharged without sumps through at least 2007 based on review of Alaska Department of Natural Resources (DNR) inspection reports. Drill waste was commonly pumped 500 to 1,000 feet away from the drill site. Records of disposal sites were not kept.

> *"The practice results in the deposition of finely ground rock, bentonitic clay, and other additive materials being deposited on the tundra. … Gray coatings of clay were seen in areas where drill fluids have been recently discharged….There is some concern in places where multiple wells are being discharged into topographic depressions…. considerable amounts of clay material being deposited in the depression."* (DNR inspection report July 26-27, 2007)

Regulatory inspections

PLP classifies sites as (1) active, (2) inactive (maintained for future use), or (3) plugged and (A-E) the extent of repair work remaining. A "3E" rating indicates plugged and fully reclaimed. DNR inspected sites at least twice a year 2004-2013 (active drilling) and annually 2014- 2015, apparently targeting sites without a 3E rating. Many sites were inspected only from the air, some inspected only during drilling but not after the hole was abandoned, and no environmental samples were collected.

PLP performed maintenance and revegetation work in fall 2015 and spring 2016. State inspections were July 26-27, 2016 targeting sites rated below 3E and added a selection of random sites. Based on available DNR field reports, over 1,000 sites never had a DNR inspection until 2016.

Methods

Site location and sample site selection

The site is located 200 air miles from Anchorage or ten miles from Nondalton village. There are no roads. The field sampling crew based out of Nondalton and was transported to the site daily by helicopter from August 1 – 5, 2016. Preliminary sites were selected based on a list of PLP's 1,355 drill holes, with age, depth, and reclamation rating. We chose reference sites (no history of issues) and sites with risk characteristics (e.g. a history of artesian conditions). We included a subset of ponds sampled by the US Geological Survey in 2007-2008 (Fey et al. 2009). Once at a target site, we visited drill holes within walking distance, for a total of 70 opportunistic sites. This optimized our time and introduced some randomness into site selection. In all 101 drill sites were inspected over five days, representing 8% of the total drill holes.

Field methods

Upon arrival at a site, the area was photo-documented. Water pH, temperature, and specific conductance (SC) were measured with a YSI 556 or a YSI 1030 meter at water bodies adjacent to drill sites, in standing water at the base of drill casings, and from the casing at artesian drill holes. Field meters were calibrated each morning and checked each evening in pH buffers (pH 4.01, 7.00, 10.01) and conductivity solution (447 μS/cm). Soil or sediment pH was measured in the field at select sites with a YSI meter after placing soil in a glass beaker and adding distilled water.

Sample collection

Water for general chemistry analysis was collected as grab samples in a 1 liter (1L) HDPE container rinsed three times in site water. Trip and equipment blanks were carried. Duplicate soil samples were collected at four sites and duplicate water samples were collected at three sites. Soil or sediment were collected along a depth of 3-6" and homogenized in a Ziploc© bag. At some sites, only the top layer of drill cuttings, evident as fine-grained gray or orange material, was collected. All samples were placed immediately in a cooler containing gel ice, placed in a refrigerator upon return to the field camp, and transported to the laboratory within two to seven days of collection. Samples were analyzed at the University of Alaska in Anchorage. Analyses were performed for pH, SC, fluoride, chloride, sulfate, nitrate, Be, Na, Mg, Al, K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sb, Ba, Tl, Pb, Th, and U. An ion chromatograph (Dionex ICS 5000+) was used to determine anion concentrations. Total metals were determined with an ICP-MS (EPA 200.8, extract method EPA 3050b). No dissolved metals analysis was conducted. For soil and sediment, anions, pH and SC were determined from 1:5 water extracts.

Results

We visited 101 drill holes (Table 1). Many drill sites did not have water on them. Acid drainage water was not observed. Sites with artesian flow, artesian containment (plugs, valves, and bolted plates), or impacted by drill cuttings have current or reasonably foreseeable future environmental impact. Patchy vegetation, while an impact, should resolve over time with the exception of four sites with non-native grasses. "Minor issues" sites had steel drill casings, frequently rusted with no cap, extending from 6 inches to two feet above the ground surface, posing a risk to indigenous hunters on snow machines; snowpoles marked some, but this is not a permanent solution as they require replacement.

Table 1 *Drill hole reclamation impact categories. We categorized drill sites based on visual impacts or analytical results. (First column) PLP ranked sites based on their own inspections as 1= active well 2= inactive 3=plugged A-D=sites with past issues or needing frequent inspection. E= fully reclaimed.*

PLP site ranking	Fully reclaimed sites	Drill hole cuttings	Drill waste discharge area	Artesian drill holes	Casings with bolts or valves	Vegetation issues	Minor issues
1 A-D	4	1	0	2	1	0	1
2 A-D	0	1	0	2	3	1	0
3 A-D	0	0	0	0	0	0	1
1E	13	4	2	0	2	5	11
2E	3	0	0	1	0	2	6
3E	9	6	1	1	1	13	1
Unknown	0	0	0	1	0	0	2
Total	29	12	3	7	7	21	22

Water samples were all low-neutral pH (pH 5.3 to 7.8). Surface water temperatures (ponds, wetlands) were 11˚C – 24˚C with specific conductance of 9-109 µS/cm. Artesian sites had lower water temperatures, reflecting groundwater sources, at 6˚C – 11˚C and higher SC of 97- 289 µS/cm, also generally associated with groundwater. Sediment (n=5) fell within natural wetland pH, between 4.9 and 7.2. Soil pH (n=7) was low-neutral (5.1 to 6.2) except where drill cutting were present.

Vegetation

Non-native species were observed at four sites and spreading downwind; at least one site was intentionally seeded. We consistently observed sites 4 to 13 years old at which natural vegetation had not re-established on reclaimed drill waste pits. Overburden soil covering pits had pH 5.1-6.2 suggesting material was uncontaminated with drill cuttings or sulfides. Failure of re-growth may be due to desiccation of tundra mats placed on overburden or poor reclamation practices.

Artesian drill holes

Artesian upwelling was observed at seven sites; including sites with and without drill casings (Fig. 1). Analytical samples were collected at five artesian sites. Although pH was generally consistent (pH 5.2-7.4), chemistry was not (Table 2). Only two were elevated in copper. Not shown are DDH 4202 and DDH 5330. These open drill stems were wet at the base; both had sediment elevated in copper and molybdenum but only DDH 4202 had elevated metals in water – it is likely both had been leaking at one time, but DDH 5330 is now under control.

Figure 1 *Artesian site. Artesian water welled up at a site with two markers (Site DDH 7380/7386) where the casing has been removed. Some casings, like DDH 8410 pictured with a base of cracked cement, had plugs or plates bolted to them, presumably to prevent artesian flow. A similar bolted casing was artesian through a broken ball valve.*

Table 2 *Artesian water chemistry. Only site DDH 7386 had been inspected before; in 2016 the site we visited had two markers (DDH 7380, DDH 7386). Site DDH 7365 had artesian flow sampled by USGS in 2008; in 2016 flow was contained by a valve, opened to collect sample water. PLP classified site DDH 9475 as "converted to active well", but it had no casing above ground. Attempts to stop the artesian flow had failed. At site DDH 7382 – the drill casing was capped but grout and artesian water with elevated trace metals was seeping from around the base of the casing into a wetland. Bold = above Alaska chronic aquatic life criteria*

Site	pH	Sulfate mg/L	Cu µg/L	Na mg/L	Other analytes detected
DDH 7365, artesian contained	7.0	11	**15**	35	Fe, Mn, Pb
DDH 7365, artesian free-flowing (2008)	6.7	12	3	42	Fe
Artesian, leaking standpipe, no ID	6.9	6	0.7	8	Zn
DDH 7380/7386, artesian flow	na	8	**76**	13	Al, Ca, Zn, As, Cd and more
DDH 9475, artesian flow	6.9-7.4	700-720	< 2	196	Cl, Ca, Mg, Al, Fe, Mn
DDH 7382, wetland water downhill from leaking casing	5.2	7	**215**	5	Ba, Al, Fe, Mn, Zn, As, Pb

Drill cuttings

Fine-grained "rock flour" drill cuttings reached the surface in two ways. First, discharged into natural depressions during drilling, they remain on the surface in 2016. Second, post-drilling they appear to have discharged from casings, indicating groundwater pushed cuttings to the surface. Drill cuttings present as fine-grained gray or orange material in depressions, around the base of drill stems and as a trail from the casing downgradient. Cuttings covered and killed vegetation. Visually and chemically these are distinct from locations where vegetation did not re-establish on drill waste pits.

Drill cuttings were universally elevated in copper and molybdenum (Table 3). The pH of drill cuttings was acidic. Soil from depressions and areas in which drill waste had been discharged had pH of 2.7-6.6, depending on the amount of soil collected with the overlying cuttings (data not shown).

Table 3 *Drill cuttings chemistry. Baseline is from Fey et al. 2009 and PLP 2011.*

Sample description	pH	Sulfate mg/L	Ag mg/kg	As mg/kg	Cu mg/kg	Mo mg/kg
Baseline soil	5-6.0	13-67	<0.2	2-11	9-20	0.4 -16
DDH 3129, drill cuttings	3.2	72-546	<5	108-175	422 – 1,650	215-233
DDH 7392, drill cuttings	3.0	109-176	9	13	1,066	334
GH05-60, cuttings with soil	3.5	25-49	<5	14	122	21

Potential impact of drill pits on groundwater

In 2011 an active drilling site (DDH 11540) was sampled at the drill waste pit and in a wetland spring downgradient (Woody et al. 2012). In 2016 we re-sampled the wetland spring. The wetland spring in 2016 had the same pH and conductivity as the 2011 sample, but was elevated in minor and trace elements relative to 2011 (Table 4). We cored drill waste from deep in the pit: a blue-grey material that swelled. Pit waste was elevated in SC (1,150 µS/cm), Cu (475 mg/kg) and Mo (38 mg/kg) relative to background sediment (Cu < 200 mg/kg; Mo < 10 mg/kg). Pit material and water quality changes suggest potential mobilization of Cu and Mo from the pit into the wetland.

Table 4 *Wetland spring water, 2011 and 2016. The 2011 data is from Woody et al. 2012. na= not analyzed*

	pH	SC µS/cm	Al mg/L	As µg/L	Cu µg/L	Fe mg/L	Mn µg/L	Mo µg/L	Zn µg/L
2011 spring water	6.6	66	0.02	<0.15	0.25	0.09	6	na	2
2016 spring water	6.5	97	0.23	0.7	1.8	7	336	2	4

Discussion

From July 26-27, 2016, State inspectors visited 134 drill sites, requesting PLP perform further work at nine. Although artesian sites were noted by regulators, no samples were collected to understand how the environment was impacted. Discolored water was dismissed as "iron staining" or "anaerobic bacteria activity" with no evidence. They concluded: *"the operator …addresses maintenance and repair issues …to industry best management practices….. no violations of any other permits were identified"*. From August 1-5, 2016 we categorized only 29 of 101 drill sites as fully reclaimed to permit standards. Twenty-two sites were inspected by both DNR and CSP2; we both listed 14 with no problems. The remaining eight are artesian or holes with artesian water contained by valves or other means (Table 5).

There are important differences in the interpretation of "reclaimed". Our interpretation is that sites with drill casings above ground have not met permit conditions. Sites with artesian flow contained by valves or other means may be "stable" but are not fully reclaimed – they will require maintenance.

Interpretation differences influence policy. Our visual observations and analytical chemistry showed discharging drill waste to tundra allows cuttings oxidize and turn acid; this should be stopped. It suggests drill waste pits may leach into groundwater springs; pits may need to be lined. Holes drilled more than ten years ago required replacement of Margo plugs. It is in the best interest of the State of Alaska to understand how frequently these fail and whether sites will need maintenance in perpetuity, and how frequently, drill cuttings have flushed out of abandoned holes. Yet there is no incentive for PLP to provide this information if there are no repercussions for violating permit conditions.

Conclusions

Our investigation determined that often permit conditions were not completely met. Environmental impacts are occurring and will occur in the future. Changes in policies and practices could achieve more effective reclamation and minimize environmental impacts. However, if regulators continue to base their interpretations only on visual inspections, do not recognize disturbances such as non-native vegetation and surface drill cuttings, and rely on mining company assessments to determine sites to inspect, they limit the information they can use to change drilling practices.

Acknowledgements

The authors thank United Tribes of Bristol Bay, Dillingham, Alaska for funding this project. We are deeply appreciative for the accompaniment and knowledge of George Alexie, tribal member of Nondalton.

Table 5 *Sites inspected by both DNR and us. The 14 sites with no impact are not shown. Sites with asterisk appear to have had no State inspection until 2016. All sites are ranked as needing* *maintenance/inspection.*

Drill site	Our assessment	DNR assessment	PLP rank
DDH 5330	Former artesian under control	Artesian repaired with Margo plug 2015. Surface water may be ponded precipitation.	1D
DDH 5332*	No problems	Small artesian flow. Ask PLP for a work plan.	3C
DDH 7365*	Artesian controlled with valve. Standpipe water high in Cu and more	No problems	1C
DDH 7382*	Artesian. Wetland water very high in Cu; many other elements detected.	No problems	2D
DDH 8413	Artesian controlled with bolt or plug.	No problems.	2D
DDH 8423	Artesian controlled with bolt or plug.	No problems. New Margo plug installed 2015.	2D
DDH 9475*	Artesian. Some elements elevated.	Artesian. Fall 2015 re-grouting failed. Ask PLP to continue to investigate a resolution.	1D
GH 06-72*	Artesian. Not sampled.	Minor upwelling. Margo plug is rusty. Sheen is probably bacterial. Change rating to 1B.	1D

References

Craven A, Maest A, Ryan J, Aiken G, Lipton J, Morris J, Zamzow K (unpublished) Laboratory estimation of Cu-dissolved organic matter complexation and its relevance to fish toxicity in streams draining the Pebble deposit in Alaska

Fey DL, Granitto M, Giles SA, Smith SM, Eppinger RG, Kelly KD (2009) Geochemical data for samples collected in 2008 near the concealed Pebble porphyry Cu-Au-Mo deposit, southwest Alaska: U.S. Geological Survey Open-File Report 2009-1239, 107 p, http://pubs.usgs.gov/of/2009/1239

McIntyre JK, Baldwin DH, Beauchamp DA, Scholz NL (2012) Low-level copper exposures increase visibility and vulnerability of juvenile coho salmon to cutthroat trout predators. Ecol Applications 22 (5): 1460-1471

PLP (2011) Environmental Baseline Document, Chapter 10 – Trace elements

Wober G (2009) Case 3AN-09-9173 Exhibit no. 3053 Supreme Court of the State of Alaska

Woody CA, O’Neal S (2009) Fish surveys in headwater streams of the Nushagak and Kvichak river drainages, Bristol Bay, Alaska, 2008-2009. Nature Conservancy, Anchorage, AK

Woody CA, Zamzow K, Welker M, O’Neal S (2012) Water quality at Pebble prospect drill rig #6, South Fork Koktuli River, Bristol Bay, Alaska 22-23 Oct 2011. Nature Conservancy, Anchorage, AK

Zamzow K (2011) Surface water quality near the Pebble prospect, southwest Alaska, 2009-2010: Nushagak, Kvichak, and Chulitna drainage headwaters. Nature Conservancy, Anchorage, AK