

Shortly after the Anaconda Company, in April 1982, shut off the underground pumps that were used to keep underground mines in Butte, Montana and the nearby Berkeley Pit dewatered, the Berkeley Pit became the disposal point for contaminated surface water from the mine operations (fig. 1). Additional surface water was diverted to the Berkeley Pit in July 1983 following the complete shutdown of the Anaconda Company mining operations. Beginning in early to mid-1984, groundwater began to flow into the Berkeley Pit from interconnected underground mines. Surface water that came from mine sources, i.e., the deactivated leach pads and ponds, and the Horseshoe Bend drainage (fig. 2), contained elevated concentrations of dissolved metals, including aluminum, cadmium, copper, iron, manganese, and zinc (Duaine and others, 2019).

Between 1983 and 1990, access to the water in the pit was limited due to erosion of the abandoned haul roads (fig. 3). In mid-1991, the water level in the pit had reached a point that the haul roads could be safely reopened for monitoring and sampling associated with recently begun Superfund investigations. Shortly thereafter, the Montana Bureau of Mines and Geology (MBMG), U.S. Environmental Protection Agency, Montana Department of Environmental Quality, Atlantic Richfield, and Montana Resources began receiving requests for bulk water samples for treatability testing and research purposes. These requests were forwarded to staff at the MBMG, who were participating in ongoing monitoring/sampling activities and had been involved with previous Berkeley Pit water sample collection. State and Federal agencies, along with private parties involved with Butte Mine Flooding Superfund investigations, designated the MBMG as the entity responsible for the collection and shipment of pit water samples. This designation was formalized in the 2002 Butte Mine Flooding Operable Unit Consent Decree. Fourteen sample requests were filled in 1991, followed by six the next year.

In 2001, requests for bulk water samples from Horseshoe Bend were received, with the announcement that Montana Resources and Atlantic Resources were beginning the design of a water treatment plant for Horseshoe Bend water and possibly Berkeley Pit water in the future. Overall, more than 200 samples of water have been collected and shipped throughout the United States and worldwide since 1991 (table 1). The accompanying map shows the countries and cities where samples have been shipped.

Water samples from the Berkeley Pit were collected from the surface or at depth; depth samples were typically collected at depths of 200 ft or 650 ft depending on tubing intake depths. Figures 4–6 show bulk water collection from the Berkeley Pit. Note the water color difference in the spring and summer samples shown in figure 5. This demonstrates the chemical changes that occurred seasonally in the pit chemistry. Both samples were collected from the 200-foot depth. The left sample shows dissolved ferric iron mixed throughout the water column, while the right sample shows the blue-green color associated with dissolved copper-sulfate waters. The ferric iron hydrolyzes to form precipitates, giving rise to the turbidity in the ochre-colored sample. Because dissolved oxygen is higher at the water surface, these precipitates typically form in shallower water and may sink to depths. Their seasonal appearance in the shallow depths may also be due to turnover dynamics operating in the pit lake water.

Bulk Horseshoe Bend water samples, used for treatability and research purposes, were collected from the surface of the drainage ditch or pond area behind weir structures used for monitoring flow rate.

References
Duaine, T.E., McGrath, S.F., Icopini, G.A., and Thale, P.R., 2019, Butte Mine Flooding Operable Unit, water-level monitoring and water-quality sampling, 2017 Consent Decree Update, Butte, Montana, 1982–2017, MBMG Open-File Report 709.



Figure 1. General schematic of source areas and volumes of water diverted to Berkeley Pit in 1982 and 1983.



Figure 2. Aerial view of surface sources that were diverted to the Berkeley Pit for disposal following the 1982 suspension of underground mine dewatering and 1983 shutdown of the Butte mining operations.



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Where Has the Water Gone?

Destinations Where Water Samples from the Berkeley Pit and Horseshoe Bend Have Been Sent for Treatability Studies and Research Purposes

Duaine, T.E., Thale, P.R., and Thomson, C.J.
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Figure 3. View looking northeast showing erosion of pit haul roads from surface-water discharge, September 1984.

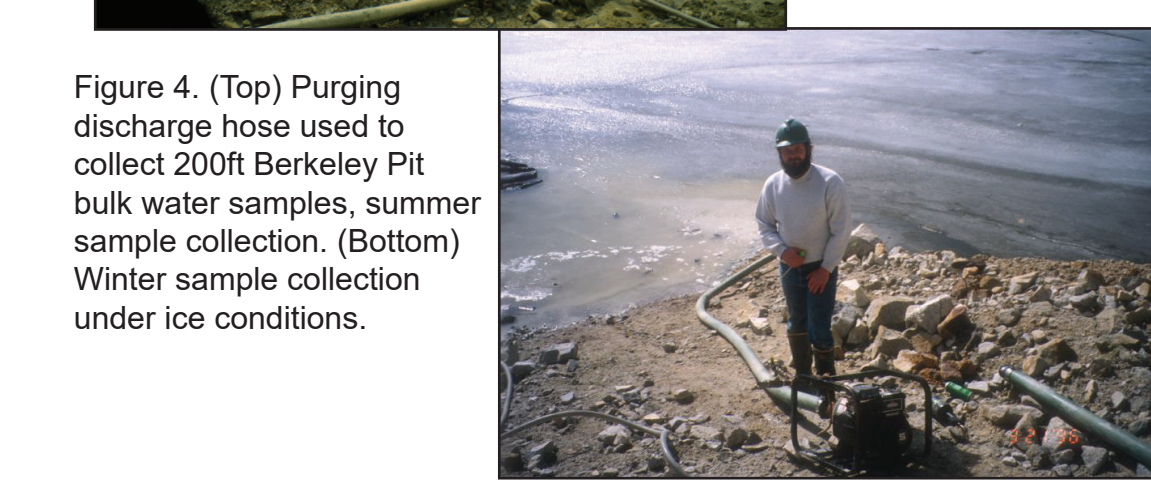


Figure 5. Berkeley Pit water color, bulk sampling, March 1995 (left) and August 1995 (right).



Figure 6. Floating barrels supporting sample tubing used for collection of bulk water samples.

Table 1. Locations where water samples from Berkeley Pit have been sent.

United States	
State	Number of samples
Alaska	4
Arizona	5
California	11
Colorado	12
Florida	1
Georgia	6
Idaho	8
Illinois	4
Indiana	4
Kansas	1
Louisiana	2
Massachusetts	5
Minnesota	1
Montana	70
Nevada	3
New Jersey	5
New York	5
North Carolina	2
North Dakota	2
Ohio	6
Oregon	3
Pennsylvania	6
Tennessee	2
Texas	10
Utah	7
Virginia	2
Washington	13
West Virginia	3
Wisconsin	1
Other Countries	
Country	Number of samples
Australia	3
Canada	12
Great Britain	3
Israel	2
Japan	2

Maps may be obtained from:
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 438-4167
<http://mbmg.mtech.edu>