IDENTIFICATION AND CHARACTERIZATION OF RARE EARTH ELEMENTS IN LARGE-SCALE MINE WASTES— TASK 4

DATA SUMMARY REPORT
YEAR 3 (2024–2025)



Matthew J. Vitale, Jackson T. Quarles, Terence E. Duaime, and Michael W. Calhoun

prepared for Army Research Laboratory,
Cooperative Agreement (CA): W911NF-22-2-0015

MBMG
Montana Bureau of Mines and Geology

Front photo: Stillwater Nye Mine, 2025.

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1.0 INTRODUCTION

The United States is reliant on foreign countries (e.g., China) for much of its rare earth element (REE) supply. This reliance is a major concern for the United States, affecting both domestic supply and military security. The purpose of this study is to identify REE occurrences in large-scale waste sources associated with past underground and open-pit mining and ore processing facilities throughout Montana. Mine types include metallic, non-metallic, and coal. Programs to identify REE deposits throughout the U.S. are underway; however, exploration and mine development can take decades before an increase in U.S. resources and production may occur. Recovery of REEs from abandoned/inactive sites would have fewer permitting requirements, thus potentially shortening the time necessary to produce REEs. Recovery of REEs from mine waste has the secondary benefit of aiding environmental cleanup by reducing waste source volume and toxicity and possibly providing an unforeseen revenue source.

This data summary report presents the results of aqueous and solid sample collection and analysis performed as part of a Cooperative Agreement titled "Materials Technology for Rare Earth Elements Processing (MT-REEP)." MT-REEP consists of several tasks focused on the Army Research Laboratory (ARL) sharing expertise with Montana Technological University, including the Montana Bureau of Mines and Geology (MBMG). Multiple research projects aim to demonstrate that REEs exist and can be produced economically—even from mining wastes—without environmental damage, thus reducing the Nation's dependence on foreign-based supply chains. Task 4 focuses on collecting samples from large-scale mining and ore processing sites throughout Montana. A preliminary list of sites was compiled and expanded over time as contact was made with various State and Federal agencies and private companies. The list currently consists of 26 sites; figure 1-1 shows the counties in which the sites are located, with hatched areas indicating counties where samples have been collected for analysis.

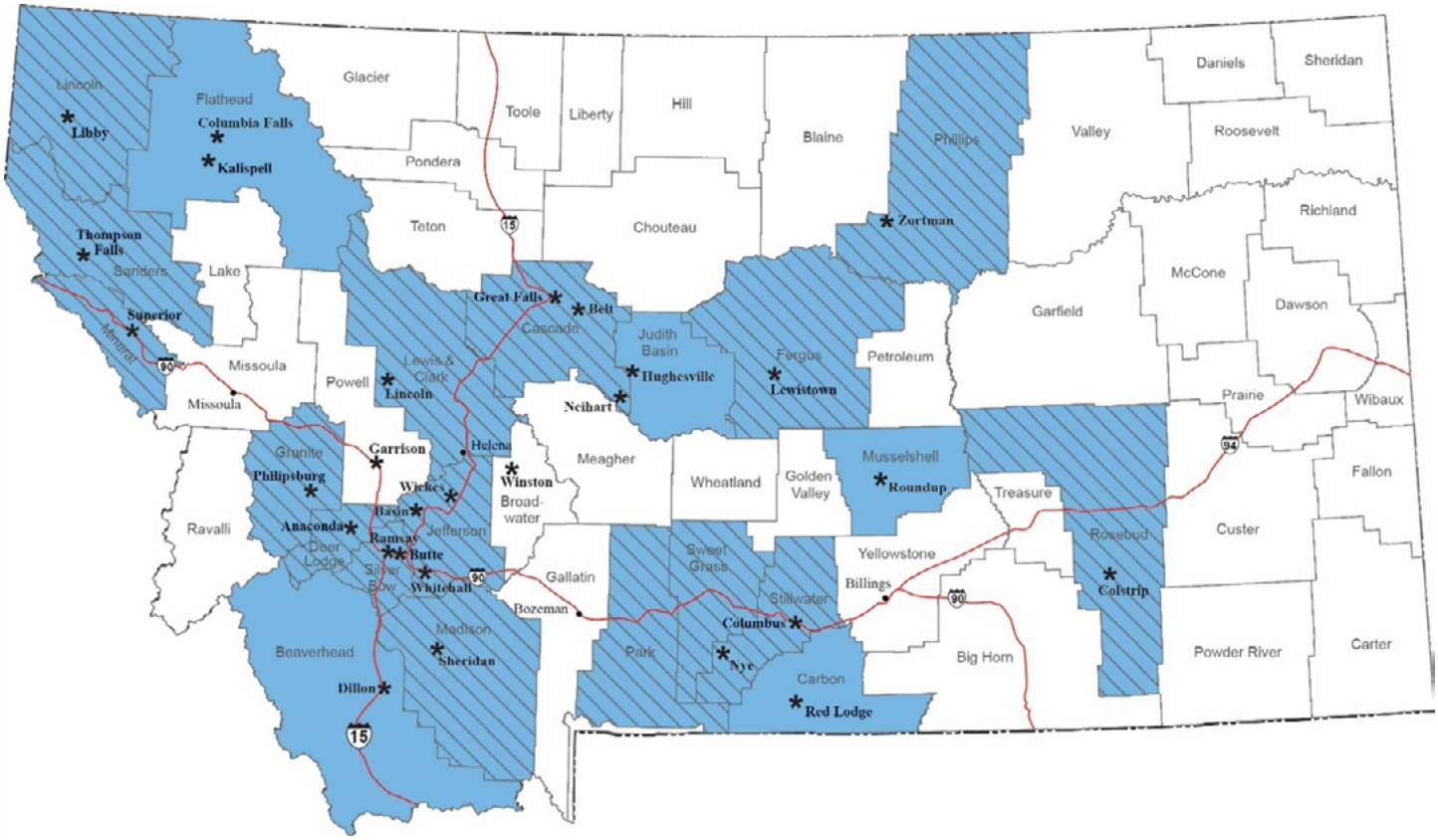


Figure 1-1. Sample site location map. Blue shading shows where study/sampling areas are located throughout Montana by county. Hatched areas show counties where samples were collected during years 1, 2, and 3. The stars represent cities as a geographic reference.

Year 3 work focused on the following activities:

1. Contact representatives of high-priority sites to coordinate sampling activities;
2. Continue field sampling and analysis program to collect opportunistic aqueous and solid samples for REE at sites located throughout Montana;
3. Review analytical data for evaluation of REE and germanium concentrations for additional sampling and recovery testing;
4. Update databases with analytical results;
5. Continue literature searches of existing information for each site and compile REE data;
6. Update field and laboratory quality assurance project plans (QAPPs) and sampling and analysis plans to ensure high-quality data are collected and analytical data meet the Army ARL program goals;
7. Contact property owners and regulatory agencies (i.e., USFS, EPA, and DEQ) for site access; and
8. Use analytical data and site information to begin development of REE resource areas.

This data summary report describes the sampling conducted for items 1 and 2 above. Sampling procedures followed those described in the project-specific QAPP developed under item 6 above. Many of the identified sites are part of ongoing U.S. Environmental Protection Agency Superfund activities or other regulatory action; therefore, sampling and analysis procedures, along with safety procedures, were designed to be compatible with those governing Superfund sites.

Solid samples were submitted to ALS Laboratories and West Virginia University (WVU) for REE analysis, while aqueous samples were submitted to the WVU lab for REE analysis and the MBMG Analytical Laboratory for analysis for the dissolved and total recoverable fractions. The MBMG water-quality data are available online from the Groundwater Information Center: https://mbmggwic.mtech.edu/data/dataProject.asp?project=ENV_REE&datatype=well&2.0

2.0 YEAR 3 SAMPLING OBJECTIVES

For Year 3, sampling was continued at sites where access was obtained and previous data suggested the presence of REEs in the waste material. Initial reconnaissance sampling entailed collecting an adequate number of solid and/or aqueous samples at specific sites to determine if REE concentrations merited more detailed sampling. More detailed, site-specific sampling was done to better characterize selected waste sources. Sample sites included acid mine drainage discharge, sludge from water treatment facilities, waste dumps, smelter wastes, coal residue, and process water, as well as mill tailings.

Sampling results are being used to develop more detailed sampling plans at sites with elevated REE concentrations. Sites with total REE concentrations above 412 (mg/kg) in solids/sludge (concentration approximately two times that found in Earth's crust; Balaram, 2019) and total REE concentrations above 499 (µg/L) in aqueous samples (value identified as having secondary recovery potential) are considered as sites with elevated concentrations. Sites were also evaluated on the ratio of the amount of critical REEs (i.e., neodymium, europium, terbium, dysprosium, erbium, and yttrium) in the REE sum to the amount of more abundant REEs, also known as the outlook coefficient (Coutl; Seredin and Dai, 2012). The higher the coefficient, the more promising the material is as a secondary source; sites with a coefficient of 0.7 or above are considered elevated for critical REEs.

3.0 BACKGROUND AND SAMPLE SITE DESCRIPTION

A total of 68 aqueous and 83 solid samples were collected from 14 sites during Year 3 activities. A description of each sample site and summary of aqueous, sludge, and solid sample results showing average, minimum, maximum concentrations, and number of samples collected are presented below.

3.1 Butte Mining District

Butte, Montana, has a long mining history that dates back to the 1860s with the discovery of placer gold deposits. Soon after, silver, copper, and zinc were found in quantity and began to be mined. Duaime and McGrath (2019) noted the existence of 517 underground mines on the Butte Hill, with depths reaching up to 1 mi; ore production from these mines

was prodigious, with more than 23 billion pounds of copper and 4.9 billion pounds of zinc produced from 1880 through 2017. Over 10,000 miles of underground workings (Duaime and others, 2002) were exhumed in search of these metals and several open pit mines (e.g., the Berkeley Pit and the Continental Pit) were operated as part of mining operations. In 1982 the mines closed and the dewatering pumps were turned off. Open pit mining ended in the Berkeley Pit in 1983, but resumed in the adjacent Continental Pit in 1986. The cessation of underground mine dewatering allowed heavy-metal-laden water to flood the abandoned workings and Berkeley Pit.

Third year sampling activities focused on sources from the Montana Resources Butte Operations, which includes the Berkeley Pit, the Continental Pit, and associated tailings and waste (fig. 3-1). Seeps from the Horseshoe Bend (HsB) area at the toe of the Yankee Doodle Tailings Impoundment (fig. 3-2) were sampled, including seeps from leach pads. Water was sampled from the precipitation plant where water from the Berkeley Pit and HsB are exposed to scrap metal for copper recovery. The Berkeley Pit was sampled again and samples were submitted for REE analysis, including sediment samples from the pit. Other opportunistic samples (both solid and aqueous) were collected in the Butte area, including samples from the Butte Reduction Works Manganese piles (fig. 3-3). These piles were sourced from numerous mines and created as World War II Department of Defense stockpiles. In total, 28 samples were collected and analyzed for REE; the results are presented in figures 3-4 through 3-10 and tables 3-1 through 3-14.

3.2 Anaconda Mining District

The town of Anaconda, Montana (fig. 3-11), was founded by Marcus Daly on June 25, 1883 for the purpose of constructing a smelter to process ore being mined in Butte, 26 mi to the east (Morris, 1997). The Anaconda Copper Mining Company (ACM), operated by Daly and his partners, began construction of the first concentrator and smelter on the north side of Warm Springs Creek in 1883; known as the Upper Works, the facility was put into operation in 1884. As ore production from ACM mines in Butte increased, Daly built an additional smelter in 1897, which became known as the Lower Works. Byproducts of the smelting process were slimes, slag, tailings, and airborne emissions of gases from the smelter stack. Tailings were sluiced to a series of ponds north of the town of Opportunity (which became known as the Opportunity Ponds) and, beginning in 1947, to two ponds just below the concentrator known as the Anaconda Ponds (Shovers and others, 1991). The Anaconda Smelter continued to operate until its closure in 1980.

The Anaconda Smelter Superfund site was a big target for this project due to its ease of access and large scale. An estimated 25 million cubic yards of slag now cover the area around the smelter (fig. 3-12). Most of the waste piles are capped with topsoil; a set of four samples was taken from random points across the uncapped piles. These samples were sent to ALS for assay, and the statistics can be found in figure 3-13 and tables 3-15 and 3-16.

3.3 Basin Mining District

The Basin mining district is located in Jefferson County, Montana (fig. 3-14), and encompasses a 77 mi^2 area around the town of Basin. Copper and gold mining started in the 1870s and continued through the 1960s (EPA, 2017a). Contamination of the watershed by mine wastes resulted in a Superfund listing in 1999. With mines such as the Crystal and the Bullion within the district already being monitored by the MBMG, the area was an easy addition to the ARL project. In addition to the sampling at the Crystal and Bullion mines, three wells located near the historic basin mill were sampled. Three solid samples were collected from sediment precipitation from the Crystal and Bullion AMD. Three water samples were collected from the Bullion (fig. 3-15) and Crystal AMD, as well as six water samples from the Basin wells (fig. 3-19). Assay results are presented in figures 3-16 through 3-18 and tables 3-17 through 3-22.

3.4 Philipsburg Mining District

The Philipsburg mining district began in the 1860s after mineable quartz was discovered in the area. In the 1880s, rich veins of silver were also discovered and began a renewed rush in the area (Walton, 2026a). In addition to silver, zinc and battery-grade manganese dioxide were also mined. The Philipsburg area is home to dozens of mining claims, including the prominent Granite Mountain and Speckled Trout mines. Two mines/claims were sampled in 2025, the Black Pine Mine and the Southern Cross Claim. The Black Pine Mine (fig. 3-20) was a gold mine that operated from 1882, when gold was first discovered, to 2000, with

several shut downs of operations in between. Over the course of operation, 174,863,770 g of gold was produced (Mindat, 2026a). The mine was reclaimed in 2018. Philipsburg remained a relatively active mining community until the 1980s, when declining prices caused a majority of mines to shut down. Six water samples were collected from the Black Pine Mine at various seeps and wells. The Southern Cross claim was established as a mining camp in 1868—gold was mined there until 1941 when the mine shut down (Walton, 2026b). Tailings and rock samples were collected from the historic Southern Cross claim. All solid samples were sent to ALS for assay, and all water samples were sent to WVU for assay. The assay results can be found in figure 3-21 and tables 3-23 and 3-24.

3.5 Golden Sunlight Mine

The Golden Sunlight mine (figs. 3-22, 3-23) sits just northeast of Whitehall, Montana, and is owned by the Barrick Gold Corporation. Mine operations began in 1975, with open pit operations shutting down in 2019 (Mindat, 2026b). In its 40 years of production, Golden Sunlight extracted over 3 million oz of gold and generated 23 million tons of tailings. In 2022, a new flotation plant was constructed and is currently reprocessing 2 million tons of tailings a year. Water that is accumulating in the abandoned pit was sampled via aerial drone, with two water samples collected. The results can be found in figure 3-24 and tables 3-25 and 3-26.

3.6 Sibanye–Stillwater Operations

Columbus, Montana, is home to the Columbus metallurgical complex, which is a smelting and refining facility for the Stillwater and East Boulder mines, both located on the JM-Reef. The facility has been processing platinum group elements (PGMs) since its opening in 1990, with over 1 million oz being produced in 2022. The Stillwater Mine is located in Nye, Montana (figs. 3-25, 3-26), and began operation in 1996 (Sibanye–Stillwater, 2026), while the East Boulder Mine was established in 2002 and is still in operation today. Both mines are underground operations, with nearby concentrating facilities. With the high REE content in the JM-Reef and the large amounts of ore being processed, these sites provided optimal sampling locations. Sibanye employees collected samples from various locations throughout the mine and during the concentrating process for the MBMG due to safety requirements. Samples consisted of waste rock, ore, concentrate, and mill tailings. Solid samples were sent to ALS for analysis, and decanted water samples were sent to WVU for REE analysis as well. Assay results of the samples can be found in figures 3-27 and 3-28, and tables 3-27 through 3-30.

3.7 Belt/Stockett/Sand Coulee

Development of the Great Falls coal fields (fig. 3-29) began in 1876 in the Sand Coulee Basin at Belt, Montana (Rossillon and others, 2009). In 1885, the combined production of coal from the Belt and Sand Coulee mines was 1,900 tons. From 1888 to 1892, the annual coal output grew, and in 1894 the Anaconda Mining Company acquired several mines in the Great Falls coal field and increased mining operations. In 1898, coal mining had begun in Stockett, Montana. The Lewistown coal fields began development in 1905 at the Spring Creek Mine, operated by the Spring Creek Company. Compared to the Great Falls coal field, the Lewistown coal field is smaller and less developed. After 1950, coal mining declined in the area, leaving abandoned coal mines ranging from small to large operations. This left deposits of mine waste and acid mine drainage from the abandoned mine workings and piles. The water that flows out of these abandoned coal mines is highly acidic and contains high amounts of heavy metals and REEs. The Montana DEQ has been working to implement treatment systems to contain and direct the flow of several AMD seeps across the Stockett/Sand Coulee/Belt area. A total of 15 water samples were collected from various mine seeps (fig. 3-30), while one sample was collected from a new well drilled into the Anaconda #4 mine workings. All samples were sent to WVU for REE analysis. Results can be found in figure 3-31 and tables 3-31 and 3-32.

3.8 East Helena Smelter

East Helena, MT (figs. 3-32, 3-33) is home to the 4,300-acre ASARCO Smelter Superfund site, a facility that left over 16 million tons of slag behind. The smelter produced zinc and lead bullion from 1888 to 2001 when it was shut down, citing environmental concerns (EPA, 2026). The State of Montana has been overseeing remediation since 2009 when ASARCO transferred it to their control. Slag is currently being shipped to Korea for zinc processing. Samples were collected from the different slag piles that varied in age, size, and whether they were fumed or unfumed. Fifteen slag samples were collected across the site,

including fumed and unfumed slag, and the samples varied in age depending on the pile. The samples were sent to ARL for assay. Sample results can be found in figure 3-34 and tables 3-33 and 3-34.

3.9 Mineral Hill Mine

The Jardine Mining district is located in the southern part of Park County, Montana, near the northern entrance of Yellowstone National Park. Placer mining began in the area after gold was discovered in 1866 (Montana History Portal, 2026). Development in the area quickly began and by 1884 there was a fully operating mill and mine site known as the Mineral Hill mine (figs. 3-35, 3-36). The site shut down in 1996 with no plans to re-open. Seven samples were collected from the 1300-level adit as well as from the tailings pond. Samples of the treatment media were also collected for analysis. Assay results can be found in figures 3-37 and 3-38, and tables 3-35 through 3-38.

3.10 Kendall Mine

The Kendall Mine (fig. 3-39) is located in the Northern Moccasin Mountains of Fergus County. Mining began in the early 1880s after gold was discovered in the region. In 1899, a small cyanide plant was built to process ore mined on the surface. Shortly after, a large mill was built and underground mining began. In 20 years, 500,000 oz of gold was produced (Walton, 2026c). In 1921, underground mining operations ended as the quality ore began to run out. In the mid-1930s, surface mining (fig. 3-40) and milling operations began in the northern extent of the district, and were shut down by government order during World War II. Canyon Resources purchased and reopened the Kendall Mine in the mid-1980s; it operated through 1996. Surface mining and cyanide heap leach extraction methods produced another 350,000 oz of gold during the time of operation. A water treatment plant was constructed to treat the heap-leach contaminated water. Seven samples were collected, consisting of two leach pad water samples and five solid samples. Zeolite used as a filtration medium was sampled along with rock samples from the previously mined open pit. Samples were sent to WVU and ALS for analysis. Assay results can be found in figures 3-41 and 3-42, and tables 3-39 through 3-42.

3.11 Zortman–Landusky Mines

The Zortman and Landusky mines (fig. 3-43) are two open pit mining operations encompassing 1,200 acres within the Little Rocky Mountains (Mitchell, 2004). The area has been mined since 1890, when rich gold and silver veins were discovered. Mining ceased in 1998 and the cleanup efforts began to try and stop the pollution of groundwater and surface water to the Fort Belknap reservation and surrounding areas. In 1999, the plant operator went bankrupt and the cleanup fell to the State and Federal government. Four water treatment plants were constructed to treat high-metal-laden waters and discharge waters that meet site discharge standards. Each plant produces sludge as a byproduct (fig. 3-44), which is stored in on-site repositories. Sludge samples were collected from the four water treatment plants, with solids and decant water submitted to ALS and WVU for analysis; the results are presented in figure 3-45 and tables 3-43 and 3-44.

3.12 Solvay Phosphate Plant

The Solvay plant was constructed in 1950 as a facility to produce elemental phosphorus (EPA, 2018). The plant was built on a 1.25 mi^2 site just outside of Ramsay, Montana (fig. 3-46). When Solvay closed its doors in 1997, a 500,000-gallon tank of phosphorus sludge was left behind. Cleanup of the site began in 2004, with a facility to process the leftover sludge constructed in 2020. The new facility operated using the Mud Still process, and as of 2022 was still actively recovering phosphorus. Eight slag samples were collected from two different piles, a granulated slag pile and a tailings pile (fig. 3-47). Samples were sent to ALS for analysis; the results are presented in figure 3-48 and tables 3-45 and 3-46.

3.13 White Fork ARD

Natural acid rock drainage (ARD) occurs in several locations throughout Montana, where mining has not occurred and natural processes are creating acidic waters. Mt. Evans (fig. 3-49), located in the Anaconda–Pintler Wilderness Area, has a source of ARD. A rock glacier near the summit of Mt. Evans discharges metal-rich waters (Gammons and others, 2021). White staining in the creek beds can be seen from the deposition of aluminum and other metals onto the creek bottom. Water samples were collected at the toe of the rock glacier (fig. 3-50), a major source of ARD. Another set of samples was collected downstream where several other creeks containing ARD converge (fig. 3-50). The samples were sent to WVU for analysis. The results are shown in figure 3-51 and tables 3-47 and 3-48.

3.14 Tenmile Creek Drainage

The Tenmile Creek Drainage area, also known as the Rimini Mining District, encompasses 53 mi^2 in Lewis and Clark County, Montana (figs. 3-52, 3-53). Mining began in the 1870s and continued through the 1930s (EPA, 2017b). During this time, about 150 mines were opened, mining gold, silver, lead, copper, and zinc. In total the mining district produced 80,000 oz of gold, 3,310,000 oz of silver, and 13,500,000 lbs of lead in addition to smaller quantities of other metal (E^2 Inc, 2004). The mines were left abandoned and heavy-metal-rich waste rock was left without cleanup. This waste rock was even used as filler material for roads, yards, and local waterways. The site was designated a Superfund site and cleanup efforts began in 1996. The Luttrell pit, an open pit from the Basin Creek gold mine, was used as a repository for the mine waste scattered over the mining district. Thirteen solid samples were collected from various mine dumps including the Pocahontas, Lucky Joe, RV Ranch Stockpile, Bullion, and Beatrice prior to them being added to the Luttrell repository. All samples were sent to ALS for analysis. The results are presented in fig. 3-54 and tables 3-49 and 3-50.

4.0 Summary

Task 4 Year 3 field activities focused on the continued collection and analysis of solid and aqueous samples from the initial site list and sites added throughout the year. Some additional, more detailed sampling occurred at sites considered a higher priority due to results of previous sampling efforts. A total of 151 samples were collected at 14 sites. Several of the sampled sites are Superfund sites or have mine closure monitoring activities; however, some sampling occurred at active mine operations (e.g., Montana Resources active Butte mining operations).

Sample results showed REE present in all of the samples collected; however, concentrations vary considerably between sites and waste sources. REE concentrations were higher in surface-water and groundwater sites where pH values were less than or equal to 4.0. Sludge and solid samples with the highest REE concentrations were from sites treating acid mine water with lime, which concentrated REEs contained in the waste sludge. Figures 3-55 through 3-58 show average total REE concentrations for all sites compared to each other.

More detailed and reconnaissance sampling will continue. These data, combined with previous results, will be used to identify sites with elevated REE concentrations for further, more detailed sampling and characterization.

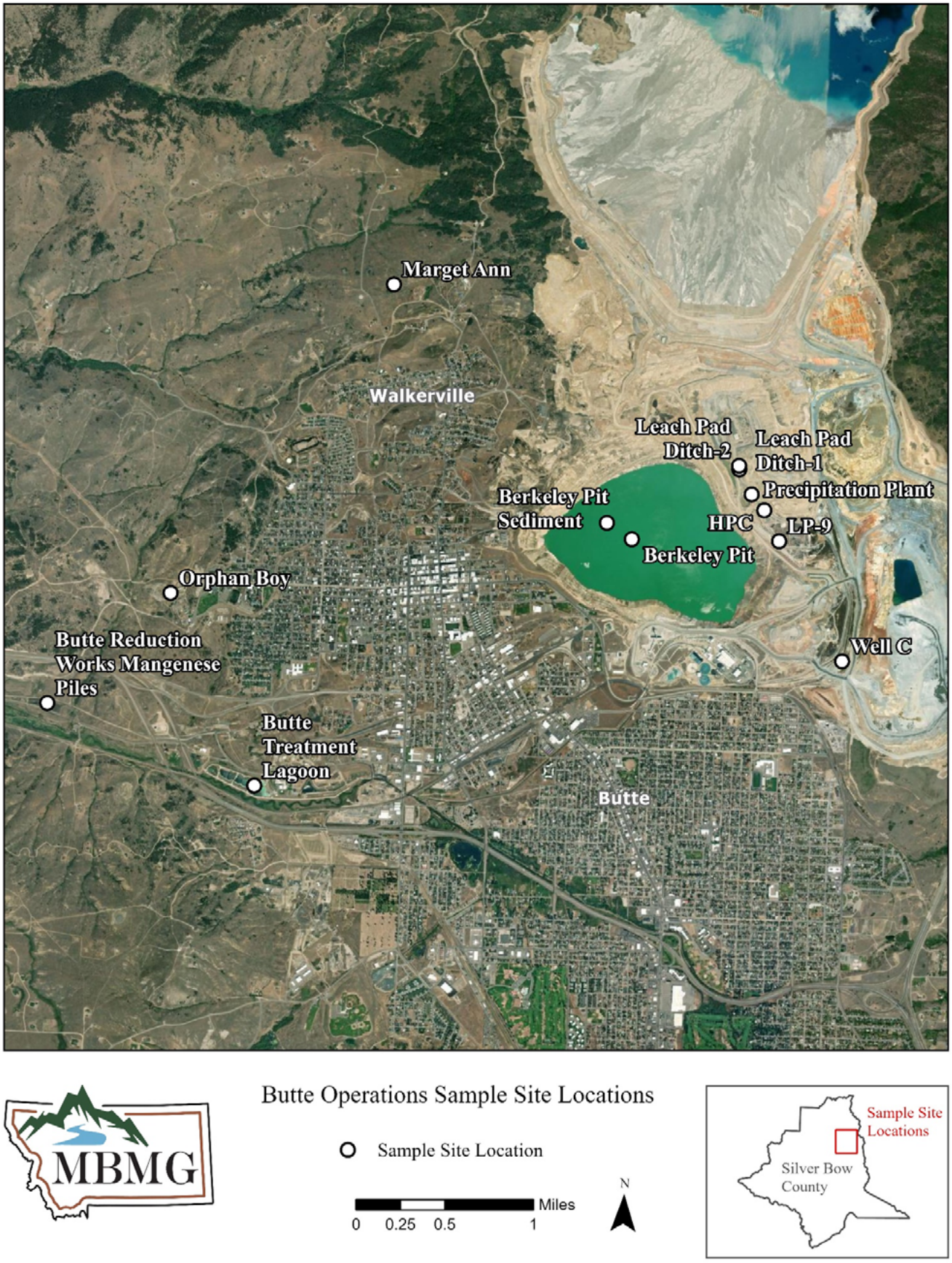


Figure 3-1. Butte operations sample site map.



Figure 3-2. Yankee Doodle Tailings Impoundment.



Figure 3-3. Butte Reduction Works manganese piles.

Table 3-1. Berkeley Pit aqueous data.

Sample ID	Ge µg/L	Dy µg/L	Er µg/L	Ho µg/L	Lu µg/L	Tb µg/L	Tm µg/L	Y µg/L	Yb µg/L
BP-3 Diss.	3.11	287.07	175.03	58.93	23.58	43.55	23.81	1,433.52	151.96
BP-426 Diss.	2.55	312.25	192.20	64.46	25.82	47.02	26.29	1,424.55	167.69
BP-3 Tot. Rec.	2.66	300.55	184.42	61.25	24.83	45.31	25.08	1,402.01	159.90
BP-426 Tot. Rec.	2.38	305.30	188.59	63.09	25.63	46.02	25.76	1,400.17	165.65
BP-4-Tot. Rec.	2.15	179.94	111.45	36.70	14.83	27.53	15.24	929.16	96.85
BP-37-Tot. Rec.	2.79	244.92	149.07	49.55	19.88	36.92	20.50	1,230.23	132.01
BP-147-Tot. Rec.	2.33	219.16	134.13	44.49	17.92	33.06	18.49	1,057.56	118.84
BP-441-Tot. Rec.	2.95	272.48	167.34	55.35	22.08	40.69	22.80	1,357.27	146.58
BP Water-1 Tot. Rec.	2.82	294.55	179.12	60.08	24.19	44.30	24.42	1,408.32	156.25
BP Water-2 Tot. Rec.	2.69	300.08	185.23	61.85	24.85	45.52	25.25	1,410.38	160.68
BP-23m	2.81	276.54	170.63	57.82	22.45	42.01	23.24	1,421.72	149.52
Mean	2.70	272.10	167.00	55.80	22.40	41.10	22.80	1315.90	146.00
Minimum	2.20	179.90	111.40	36.70	14.80	27.50	15.20	929.20	96.90
Maximum	3.10	312.20	192.20	64.50	25.80	47.00	26.30	1433.50	167.70

Sample ID	Ce µg/L	Eu µg/L	Gd µg/L	La µg/L	Nd µg/L	Pr µg/L	Sm µg/L	Sc µg/L
BP-3 Diss.	1358.50	175.03	263.04	366.13	621.50	143.57	171.70	27.41
BP-426 Diss.	1375.50	192.20	283.75	371.86	643.10	148.35	180.20	27.44
BP-3 Tot. Rec.	1360.70	184.42	273.58	365.72	632.70	145.28	176.80	27.93
BP-426 Tot. Rec.	1364.30	188.59	277.80	365.29	638.60	146.40	177.70	27.52
BP-4-Tot. Rec.	919.49	111.45	167.54	254.61	439.90	94.921	109.40	17.49
BP-37-Tot. Rec.	1219.10	149.07	227.38	340.78	593.10	125.40	145.60	23.15
BP-147-Tot. Rec.	1064.20	134.13	204.13	296.03	525.10	110.28	129.60	20.30
BP-441-Tot. Rec.	1351.40	167.34	250.06	372.43	624.40	137.03	161.50	26.15
BP Water-1 Tot. Rec.	1318.37	179.12	268.83	363.65	614.37	143.90	174.13	28.15
BP Water-2 Tot. Rec.	1372.53	185.23	274.39	365.10	649.86	146.13	176.64	28.26
BP-23m	1274.87	170.63	249.56	340.59	637.94	138.50	166.62	25.22
Mean	1270.80	167.02	249.09	345.65	601.87	134.55	160.90	25.37
Minimum	919.49	111.45	167.54	254.61	439.93	94.92	109.41	17.49
Maximum	1375.45	192.20	283.75	372.43	649.86	148.35	180.19	28.26

Table 3-2. Berkeley aqueous evaluation.

Sample ID	Total REE (µg/L)	Coutl
BP-3 Diss.	5327.45	1.78
BP-426 Diss.	5485.18	1.79
BP-3 Tot. Rec.	5373.06	1.77
BP-426 Tot. Rec.	5408.83	1.78
BP-4-Tot. Rec.	3528.68	1.74
BP-37-Tot. Rec.	4709.33	1.75
BP-147-Tot. Rec.	4129.68	1.75
BP-441-Tot. Rec.	5178.12	1.73
BP Water-1 Tot. Rec.	5284.56	1.81
BP Water-2 Tot. Rec.	5414.66	1.78
BP-23m	5170.67	1.88

Table 3-3. Berkeley Pit solids data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
Berkeley Pit Sediment 1	1.30	2.75	1.67	0.58	0.32	0.47	0.30	13.60	1.94
Berkeley Pit Sediment 2	1.20	3.05	1.90	0.62	0.29	0.51	0.32	14.30	2.24
Berkeley Pit Sediment 15 m	1.00	3.95	2.15	0.79	0.32	0.68	0.30	15.60	2.11
Mean	1.17	3.25	1.91	0.66	0.31	0.55	0.31	14.50	2.10
Minimum	1.00	2.75	1.67	0.58	0.29	0.47	0.30	13.60	1.94
Maximum	1.30	3.95	2.15	0.79	0.32	0.68	0.32	15.60	2.24

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Berkeley Pit Sediment 1	41.70	0.75	3.11	17.20	21.90	5.04	4.32	13.00
Berkeley Pit Sediment 2	35.80	0.76	3.17	12.10	18.00	4.07	3.60	8.00
Berkeley Pit Sediment 15 m	56.30	1.18	4.50	22.10	27.60	6.63	5.68	8.00
Mean	44.60	0.90	3.59	17.13	22.50	5.25	4.53	9.67
Minimum	35.80	0.75	3.11	12.10	18.00	4.07	3.60	8.00
Maximum	56.30	1.18	4.50	22.10	27.60	6.63	5.68	13.00

Table 3-4. Berkeley solids evaluation.

Sample ID	Total REE (mg/kg)	Coutl
Berkeley Pit Sediment 1	129.95	0.92
Berkeley Pit Sediment 2	109.93	0.98
Berkeley Pit Sediment 15 m	158.89	0.86

Table 3-5. MR-Misc. aqueous REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
P.P. Influent	2.70	247.99	152.82	51.51	20.26	38.10	20.98	1370.38	132.07
Leach Pad Ditch-1	1.24	241.25	143.44	49.37	20.08	37.78	20.83	911.21	138.73
Leach Pad Ditch-2	1.03	236.46	136.31	47.57	18.96	37.32	19.72	861.97	132.82
Mean	1.66	241.90	144.19	49.48	19.77	37.73	20.51	1047.86	134.54
Minimum	1.03	236.46	136.31	47.57	18.96	37.32	19.72	861.97	132.07
Maximum	2.70	247.99	152.82	51.51	20.26	38.10	20.98	1370.38	138.73

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
P.P. Influent	1239.15	39.61	231.38	338.32	592.65	132.71	154.68	25.24
Leach Pad Ditch-1	1033.36	43.09	233.94	209.21	775.59	157.18	177.30	1.24
Leach Pad Ditch-2	1070.68	43.34	231.75	245.19	777.70	155.02	174.66	1.03
Mean	1114.40	42.01	232.36	264.24	715.31	148.30	168.88	9.17
Minimum	1033.36	39.61	231.38	209.21	592.65	132.71	154.68	1.03
Maximum	1239.15	43.34	233.94	338.32	777.70	157.18	177.30	25.24

Table 3-6. MR-Misc. aqueous REE statistics.

Sample ID	Total REE (µg/L)	Coutl
P.P. Influent	4790.54	1.83
Leach Pad Ditch-1	4194.87	1.92
Leach Pad Ditch-2	4191.51	1.81

Table 3-7. MR-Misc. solids REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
HPC	1.42	52.72	30.76	10.58	3.82	8.17	4.04	347.29	24.91
GM S10-S20	2.08	9.22	4.85	1.72	0.48	1.51	0.56	45.03	3.575
Leach Pad Ditch #1	2.20	4.03	2.34	0.84	0.41	0.71	0.39	25.20	2.39
Leach Pad Ditch #2	1.70	7.07	4.78	1.62	0.67	1.13	0.68	74.90	4.21
Mean	1.85	18.26	10.68	3.69	1.35	2.88	1.42	123.10	8.77
Minimum	1.42	4.03	2.34	0.84	0.41	0.71	0.39	25.20	2.39
Maximum	2.20	52.72	30.76	10.58	3.82	8.17	4.04	347.29	24.91

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
HPC	35.29	8.99	54.21	95.63	153.76	35.29	36.87	1.66
GM S10-S20	76.88	2.91	12.05	31.04	56.65	12.07	14.17	8.97
Leach Pad Ditch #1	89.10	1.09	4.67	47.10	34.60	10.00	6.32	13.00
Leach Pad Ditch #2	59.10	1.53	7.62	58.20	40.60	10.70	7.50	8.00
Mean	65.09	3.63	19.64	57.99	71.40	17.02	16.21	7.91
Minimum	35.29	1.09	4.67	31.04	34.60	10.00	6.32	1.66
Maximum	89.10	8.99	54.21	95.63	153.76	35.29	36.87	13.00

Table 3-8. MR-Misc. solids REE statistics.

Sample ID	Total REE (mg/kg)	Coutl
HPC	1198.42	1.61
GM S10-S20	281.66	1.44
Leach Pad Ditch #1	229.19	0.73
Leach Pad Ditch #2	280.31	1.96

Table 3-9. Butte flooded mineshafts REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
LP-9 Tot. Rec	6.06	779.60	520.73	169.78	77.52	118.69	74.54	3001.00	499.89
LP-9 Diss.	2.60	925.43	601.72	192.17	83.62	139.60	83.38	3223.84	581.49
Orphan Boy Dissolved	<0.035	0.02	0.02	<0.007	<0.007	<0.006	<0.007	0.19	0.02
Marget Ann	<0.035	0.02	0.01	<0.007	<0.007	<0.006	<0.007	0.13	0.01
Well C	<0.035	0.24	0.22	0.07	0.02	0.03	0.03	3.33	0.13
Mean	4.33	341.06	224.54	120.67	53.72	86.10	52.65	1245.70	216.31
Minimum	2.60	0.02	0.01	0.07	0.02	0.03	0.03	0.13	0.01
Maximum	6.06	925.43	601.72	192.17	83.62	139.60	83.38	3223.84	581.49

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
LP-9 Tot. Rec	8815.74	112.58	705.41	1391.00	2314.57	517.13	489.21	15.53
LP-9 Diss.	8477.46	139.14	1037.65	1724.43	2630.92	605.27	594.81	16.46
Orphan Boy Dissolved	<0.026	<0.011	0.01	<0.025	0.03	<0.008	<0.035	0.09
Marget Ann	0.13	<0.011	0.01	0.05	0.06	0.01	<0.035	0.06
Well C	0.14	0.02	0.19	0.03	0.09	0.01	0.04	0.13
Mean	4323.37	83.91	348.65	778.88	989.13	280.61	361.35	6.45
Minimum	0.13	0.02	0.01	0.03	0.03	0.01	0.04	0.06
Maximum	8815.74	139.14	1037.65	1724.43	2630.92	605.27	594.81	16.46

Table 3-10. Butte flooded mineshafts REE statistics.

Sample ID	Total REE (µg/L)	Coutl
LP-9 Tot. Rec	19608.99	0.75
LP-9 Diss.	21059.99	0.87
Orphan Boy Dissolved	0.38	N/A
Marget Ann	0.49	N/A
Well C	4.71	15.39

Table 3-11. Butte Reduction Works REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
BRW-Mn-1	4.20	2.15	1.36	0.40	0.17	0.32	0.17	13.00	1.35
BRW-Mn-2	5.50	1.91	1.18	0.35	0.15	0.30	0.16	13.20	1.13
BRW-Mn-3	4.20	2.99	1.62	0.53	0.24	0.41	0.23	18.60	1.41
BRW-Mn-4	5.70	3.59	2.37	0.77	0.39	0.56	0.36	23.10	2.21
BRW-Mn-5	11.00	2.31	1.47	0.44	0.19	0.27	0.19	14.20	1.26
BRW-Mn-6	4.30	3.14	2.05	0.55	0.28	0.55	0.30	20.10	1.98
BRW-Mn-7	4.30	2.22	1.49	0.46	0.18	0.36	0.20	15.00	1.37
Mean	5.60	2.62	1.65	0.50	0.23	0.40	0.23	16.74	1.53
Minimum	4.20	1.91	1.18	0.35	0.15	0.27	0.16	13.00	1.13
Maximum	11.00	3.59	2.37	0.77	0.39	0.56	0.36	23.10	2.21

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
BRW-Mn-1	21.70	0.65	2.06	13.00	10.00	2.51	2.08	4.00
BRW-Mn-2	20.20	1.01	1.80	13.00	9.70	2.40	1.90	4.00
BRW-Mn-3	25.00	1.54	2.78	16.00	12.30	3.05	2.80	4.00
BRW-Mn-4	32.00	0.77	3.33	20.60	15.70	4.11	2.68	5.00
BRW-Mn-5	14.80	0.62	1.78	8.80	6.90	1.89	1.48	4.00
BRW-Mn-6	28.10	0.99	2.77	16.80	13.30	3.40	2.88	4.00
BRW-Mn-7	23.50	0.78	2.27	14.50	10.40	2.77	2.25	4.00
Mean	23.61	0.91	2.40	14.67	11.19	2.88	2.30	4.14
Minimum	14.80	0.62	1.78	8.80	6.90	1.89	1.48	4.00
Maximum	32.00	1.54	3.33	20.60	15.70	4.11	2.88	5.00

Table 3-12. Butte Reduction Works REE statistics.

Sample ID	Total REE (mg/kg)	Coutl
BRW-Mn-1	70.92	1.16
BRW-Mn-2	68.39	1.24
BRW-Mn-3	89.50	1.37
BRW-Mn-4	112.54	1.29
BRW-Mn-5	56.60	1.53
BRW-Mn-6	97.19	1.29
BRW-Mn-7	77.75	1.18

Table 3-13. Butte Treatment Lagoon REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
A-1 Sludge	<0.032	0.10	0.03	0.01	<DL	0.02	0.00	1.19	0.01
Drying Bed Sludge	4.17	1.34	0.84	0.29	0.10	0.22	0.12	12.95	0.71
Mean	4.17	0.72	0.44	0.15	0.10	0.12	0.06	7.07	0.36
Minimum	4.17	0.10	0.03	0.01	0.10	0.02	0.00	1.19	0.01
Maximum	4.17	1.34	0.84	0.29	0.10	0.22	0.12	12.95	0.72

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
A-1 Sludge	1.22	0.07	0.36	0.56	1.43	0.30	0.36	0.28
Drying Bed Sludge	13.18	0.18	1.44	7.22	5.03	1.36	1.04	1.26
Mean	7.20	0.12	0.90	3.89	3.23	0.83	0.70	0.77
Minimum	1.22	0.07	0.36	0.56	1.43	0.30	0.36	0.28
Maximum	13.18	0.18	1.44	7.22	5.03	1.36	1.04	1.26

Table 3-14. Butte Treatment Lagoon REE statistics.

Sample ID	Total REE (mg/kg)	Coutl
A-1 Sludge	5.93	2.28
Drying Bed Sludge	51.45	1.43

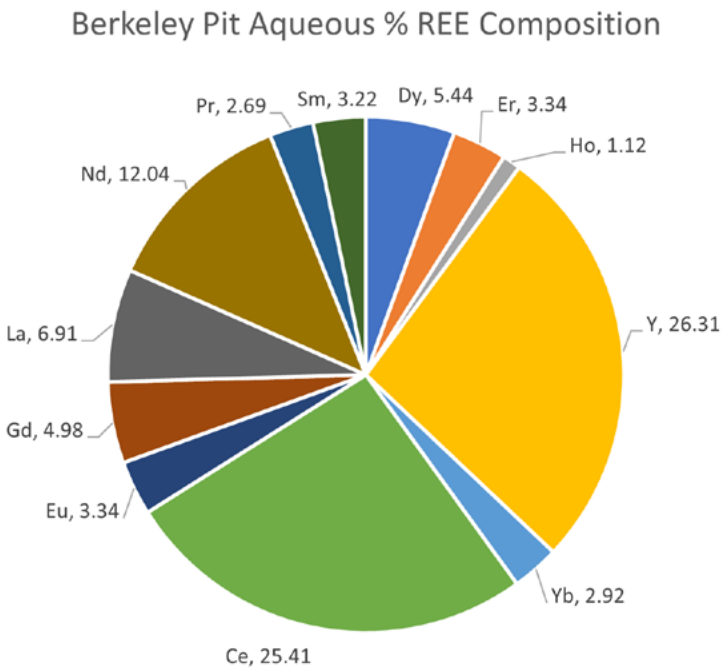


Figure 3-4. The breakdown of REE concentration percentages based on total REEs for all samples taken at the Berkeley Pit. Elements with less than 1% concentration were removed.

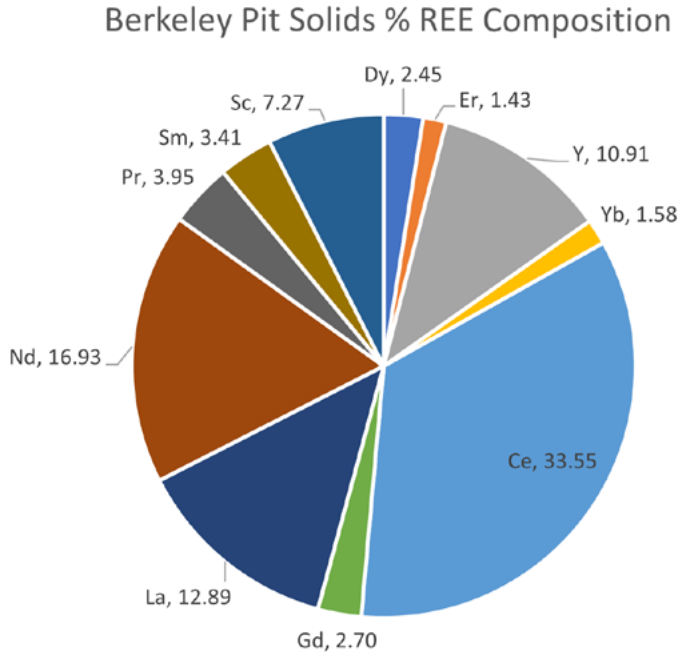


Figure 3-5. The breakdown of REE concentration percentages based on total REEs for all solid samples taken at the Berkeley Pit. Elements with less than 1% concentration were removed.

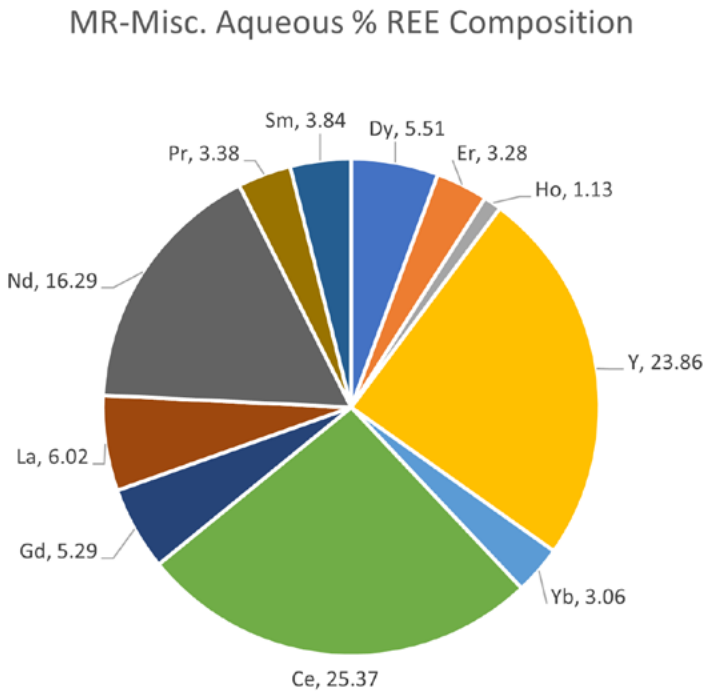


Figure 3-6. The breakdown of REE concentration percentages based on total REEs for all aqueous samples taken at Montana Resources. Elements with less than 1% concentration were removed.

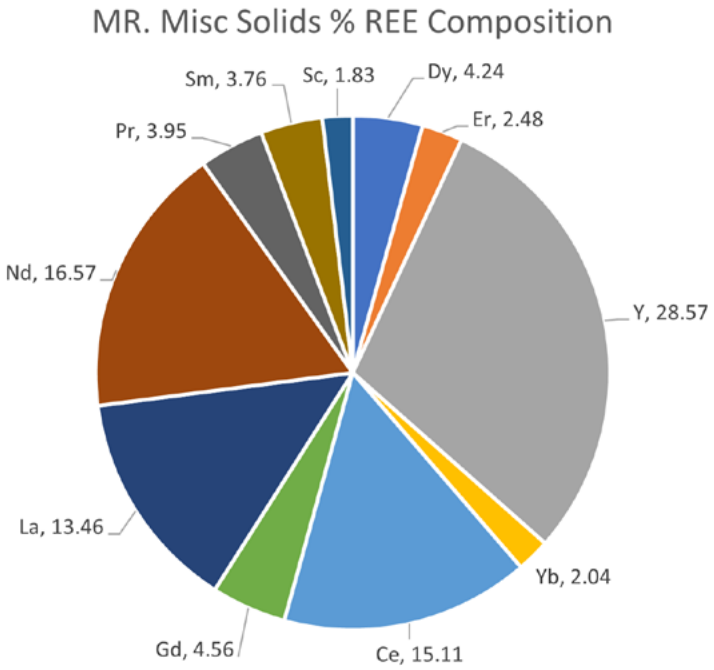


Figure 3-7. The breakdown of REE concentration percentages based on total REEs for all solid samples taken at Montana Resources. Elements with less than 1% concentration were removed.

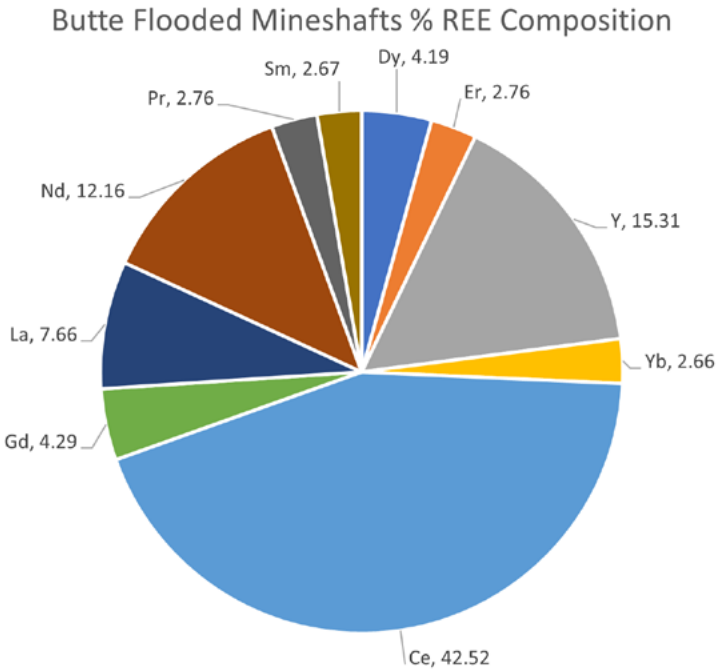


Figure 3-8. The breakdown of REE concentration percentages based on total REEs for all aqueous samples taken at the Butte flooded mineshaft. Elements with less than 1% concentration were removed.

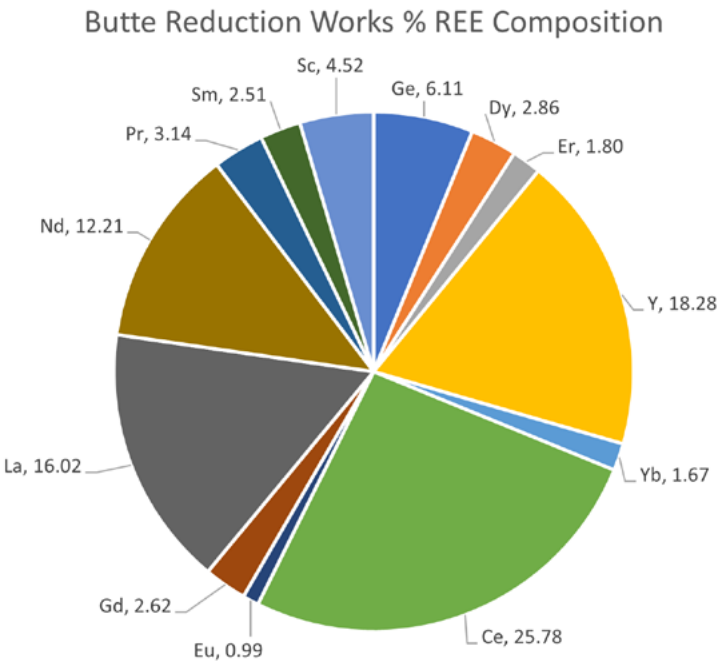


Figure 3-9. The breakdown of REE concentration percentages based on total REEs for all samples taken from the BRW-Mn piles. Elements with less than 1% concentration were removed.

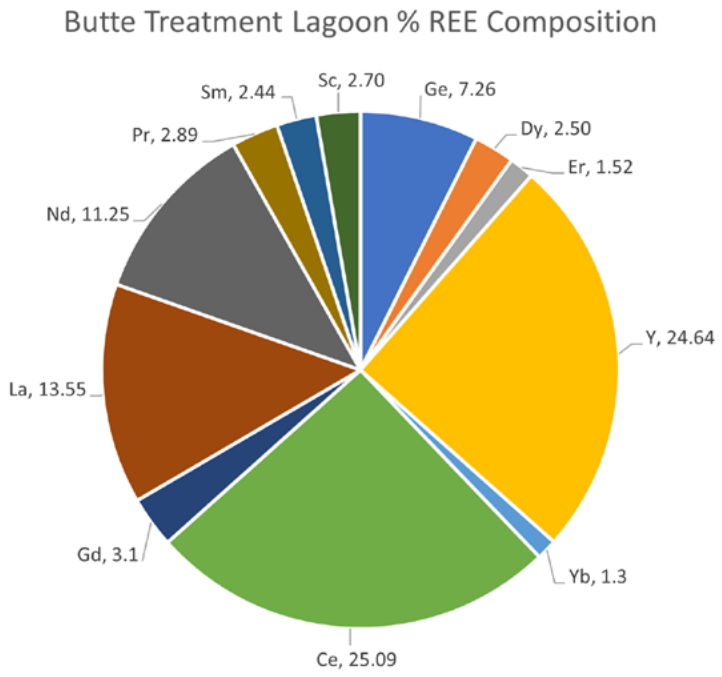


Figure 3-10. The breakdown of REE concentration percentages based on total REEs for all samples taken from the Butte Treatment Lagoon. Elements with less than 1% concentration were removed.



Figure 3-11. Anaconda slag pile sample site map.



Figure 3-12. Anaconda slag pile.

Table 3-15. Anaconda slag REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
AR-Slag-9	15.60	2.84	1.73	0.58	0.24	0.52	0.25	15.80	80.00
AR-Slag-10	21.00	2.35	1.36	0.54	0.18	0.39	0.22	13.70	81.00
AR-Slag-11	30.30	3.01	1.74	0.58	0.28	0.47	0.23	16.30	75.00
West Granular Pile 1	41.90	2.13	1.46	0.46	0.24	0.41	0.18	12.30	82.00
West Granular Pile 2	33.30	2.43	1.45	0.41	0.19	0.38	0.19	13.80	83.00
Flue Dust Repository	5.90	1.99	1.29	0.38	0.15	0.31	0.16	12.10	96.00
Mean	24.67	2.46	1.51	0.49	0.21	0.41	0.21	14.00	82.83
Minimum	5.90	1.99	1.29	0.38	0.15	0.31	0.16	12.10	75.00
Maximum	41.90	3.01	1.74	0.58	0.28	0.52	0.25	16.30	96.00

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
AR-Slag-9	41.50	0.67	3.27	23.10	19.40	5.24	3.36	4.60
AR-Slag-10	32.90	0.65	2.29	18.60	16.50	4.13	2.82	4.50
AR-Slag-11	43.40	0.71	3.05	22.00	19.40	4.97	3.77	3.40
West Granular Pile 1	31.80	0.47	2.48	17.60	13.50	3.98	2.65	6.00
West Granular Pile 2	34.30	0.65	2.74	20.10	16.90	4.31	3.25	13.50
Flue Dust Repository	32.90	0.54	2.16	17.90	14.70	3.73	2.76	23.20
Mean	36.13	0.62	2.67	19.88	16.73	4.39	3.10	9.20
Minimum	31.80	0.47	2.16	17.60	13.50	3.73	2.65	3.40
Maximum	43.40	0.71	3.27	23.10	19.40	5.24	3.77	23.20

Table 3-16. Anaconda slag REE statistics.

Sample ID	Total REE (mg/kg)	Coutl
AR-Slag-9	218.70	0.93
AR-Slag-10	203.13	0.99
AR-Slag-11	228.61	0.90
West Granular Pile 1	219.56	0.89
West Granular Pile 2	230.90	0.98
Flue Dust Repository	216.17	0.89

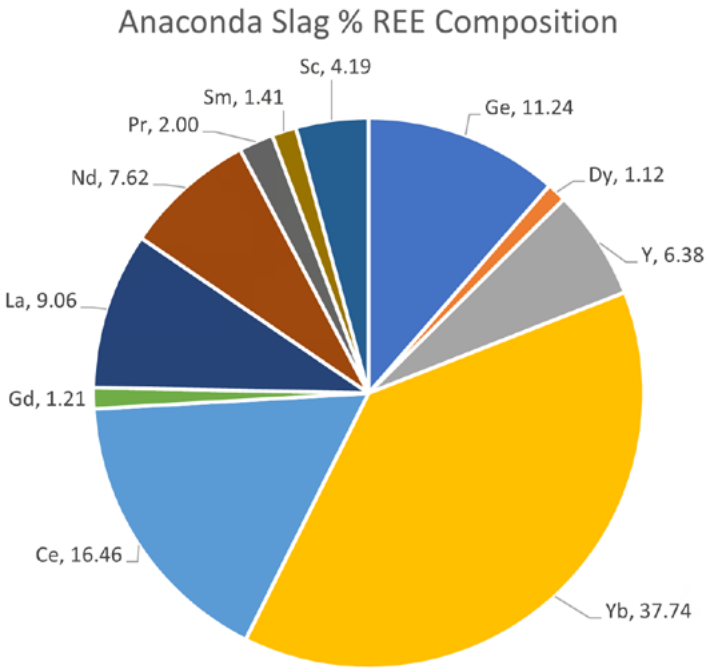


Figure 3-13. The breakdown of REE concentration percentages based on total REEs for all samples taken at the Anaconda slag pile site. Elements with less than 1% concentration were removed.



Figure 3-14. Basin/Ten Mile watershed, Crystal and Bullion sample site map.



Figure 3-15. Upper Bullion Discharge.

Table 3-17. Crystal-Bullion aqueous REE data.

Sample ID	Ge µg/L	Dy µg/L	Er µg/L	Ho µg/L	Lu µg/L	Tb µg/L	Tm µg/L	Y µg/L	Yb µg/L
Upper Bullion Tot. Rec.	0.45	4.71	3.10	0.99	0.46	0.73	0.44	29.12	3.01
Lower Bullion Tot. Rec.	0.18	5.10	3.35	1.07	0.48	0.78	0.47	31.20	3.21
Crystal Tot. Rec.	0.14	2.39	1.61	0.52	0.22	0.36	0.22	19.08	1.43
Mean	0.26	4.07	2.69	0.86	0.39	0.62	0.38	26.47	2.55
Minimum	0.14	2.39	1.61	0.52	0.22	0.36	0.22	19.08	1.43
Maximum	0.45	5.10	3.35	1.07	0.48	0.78	0.47	31.20	3.21

Sample ID	Ce µg/L	Eu µg/L	Gd µg/L	La µg/L	Nd µg/L	Pr µg/L	Sm µg/L	Sc µg/L
Upper Bullion Tot. Rec.	28.46	0.74	4.70	12.05	16.54	3.81	3.85	1.42
Lower Bullion Tot. Rec.	30.90	0.79	5.08	13.75	18.10	4.22	4.18	1.54
Crystal Tot. Rec.	18.57	0.24	2.31	9.44	7.85	2.06	1.72	0.31
Mean	18.57	0.24	2.31	9.44	7.85	2.06	1.72	0.31
Minimum	18.57	0.24	2.31	9.44	7.85	2.06	1.72	0.31
Maximum	30.90	0.79	5.08	13.75	18.10	4.22	4.18	1.54

Table 3-18. Crystal and Bullion aqueous REE statistics.

Sample ID	Total REE (µg/L)	Coutl
Upper Bullion–Tot. Rec.	114.58	1.81
Lower Bullion–Tot. Rec.	124.41	1.80
Crystal–Tot. Rec.	68.47	1.61

Table 3-19. Crystal and Bullion solids REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
Upper Bullion Sediment	0.80	1.64	1.12	0.32	0.19	0.25	0.16	10.20	1.10
Lower Bullion Sediment	1.10	2.07	1.25	0.40	0.21	0.33	0.19	12.10	1.35
Crystal Sediment	1.20	1.53	1.04	0.32	0.17	0.27	0.15	9.40	1.10
Mean	1.03	1.75	1.14	0.35	0.19	0.28	0.17	10.57	1.18
Minimum	0.80	1.53	1.04	0.32	0.17	0.25	0.15	9.40	1.10
Maximum	1.20	2.07	1.25	0.40	0.21	0.33	0.19	12.10	1.35

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Upper Bullion Sediment	31.00	0.44	1.70	15.90	11.90	3.21	2.17	4.00
Lower Bullion Sediment	44.90	0.51	2.21	23.40	16.90	4.56	2.94	5.00
Crystal Sediment	38.60	0.39	1.66	20.00	13.70	3.92	2.09	2.00
Mean	38.17	0.45	1.86	19.77	14.17	3.90	2.40	3.67
Minimum	31.00	0.39	1.66	15.90	11.90	3.21	2.09	2.00
Maximum	44.90	0.51	2.21	23.40	16.90	4.56	2.94	5.00

Table 3-20. Crystal and Bullion solids REE statistics.

Sample ID	Total REE (mg/kg)	CoutI
Upper Bullion Sediment	86.10	0.78
Lower Bullion Sediment	119.42	0.70
Crystal Sediment	97.54	0.65

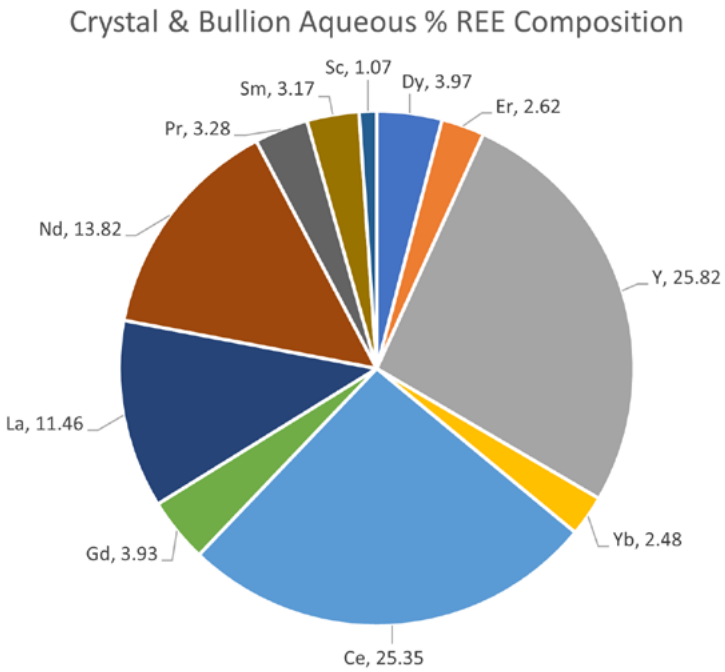


Figure 3-16. The breakdown of REE concentration percentages based on total REEs for all aqueous samples taken from the Crystal–Bullion Mines. Elements with less than 1% concentration were removed.

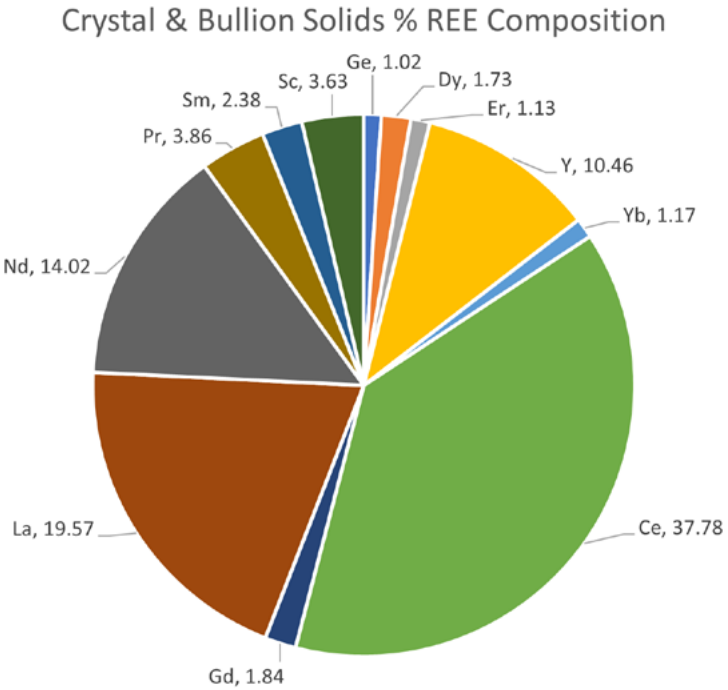


Figure 3-17. The breakdown of REE concentration percentages based on total REEs for all solid samples taken from the Crystal–Bullion Mines. Elements with less than 1% concentration were removed.



Figure 3-18. Basin wells sample site map.

Table 3-21. Basin wells REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
North Well #1–Diss.	<0.035	0.02	0.02	0.01	0.003	0.004	0.002	0.15	0.01
South Well #3–Diss.	0.05	0.01	0.01	0.003	<0.002	<0.002	<0.002	0.10	0.009
Middle Well #2–Diss.	1.45	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	0.03	<0.004
North Well #1–Tot. Rec	<0.035	0.03	0.02	0.01	0.002	0.004	0.002	0.21	0.01
South Well #3–Tot. Rec	0.06	0.02	0.01	0.01	0.002	0.003	<0.002	0.16	0.01
Middle Well #2–Tot. Rec	1.74	0.39	0.19	0.07	0.02	0.07	0.02	1.63	0.15
Mean	0.82	0.09	0.05	0.02	0.01	0.02	0.01	0.38	0.041
Minimum	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.009
Maximum	1.74	0.39	0.19	0.07	0.02	0.07	0.02	1.63	0.153

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
North Well #1–Diss.	0.05	0.009	0.02	0.04	0.06	0.01	0.02	0.06
South Well #3–Diss.	0.06	0.004	0.01	0.02	0.03	0.007	0.007	0.06
Middle Well #2–Diss.	0.03	<0.003	0.008	0.00	0.01	0.004	<0.004	0.04
North Well #1–Tot. Rec	0.12	0.007	0.02	0.11	0.11	0.02	0.01	0.07
South Well #3–Tot. Rec	0.24	0.006	0.02	0.11	0.10	0.02	0.01	0.08
Middle Well #2–Tot. Rec	7.68	0.11	0.53	3.67	3.43	0.87	0.62	1.39
Mean	1.37	0.03	0.11	0.67	0.63	0.16	0.14	0.29
Minimum	0.03	0.004	0.01	0.01	0.02	0.004	0.01	0.04
Maximum	7.68	0.11	0.54	3.67	3.43	0.88	0.63	1.39

Table 3-22. Basin Wells REE data.

Sample ID	Total REE (µg/L)	Coutl
North Well #1–Diss.	0.50	4.33
South Well #3–Diss.	0.41	N/A
Middle Well #2–Diss.	1.59	N/A
North Well #1–Tot. Rec	0.79	2.8
South Well #3–Tot. Rec	0.89	N/A
Middle Well #2–Tot. Rec	22.63	0.74

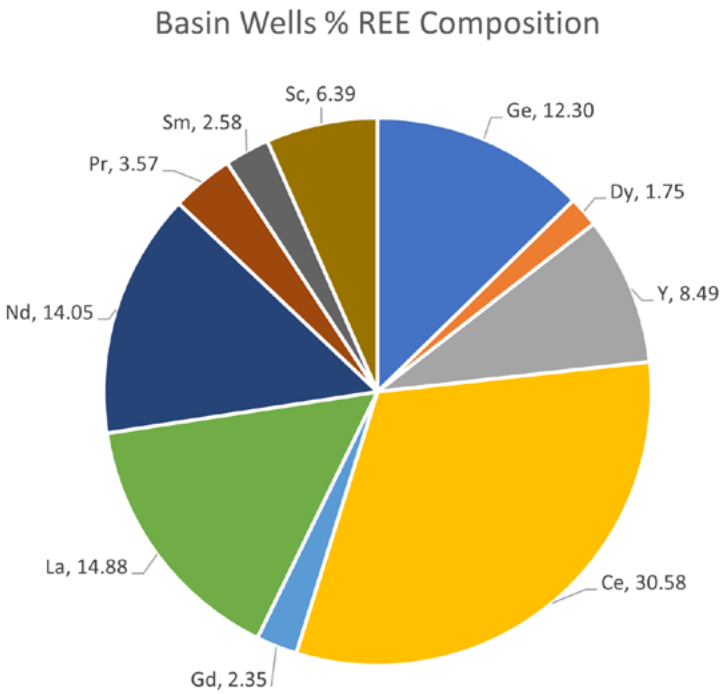


Figure 3-19. The breakdown of REE concentration percentages based on total REEs for all samples taken from the Basin wells. Elements with less than 1% concentration were removed.



Figure 3-20. Black Pine Mine sample site map.

Table 3-23. Black Pine Mine REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
BRM-RY-SP-04	0.06	0.73	0.36	0.13	0.03	0.13	0.04	2.71	0.29
CPS-2	0.22	8.75	4.99	1.74	0.63	1.47	0.67	33.10	4.28
CPS-1-Vault	<0.035	0.50	0.28	0.09	0.03	0.08	0.03	2.82	0.25
MW-4	<0.035	0.15	0.09	0.03	0.01	0.02	0.01	0.87	0.10
CPS-8	0.14	3.25	1.79	0.64	0.21	0.55	0.23	13.19	1.48
BRM-RY-SR-01	<0.035	0.22	0.12	0.04	0.01	0.03	0.01	1.01	0.11
Mean	0.15	2.27	1.28	0.45	0.16	0.39	0.17	8.96	1.09
Minimum	0.07	0.15	0.10	0.03	0.02	0.02	0.01	0.87	0.11
Maximum	0.23	8.75	5.00	1.74	0.63	1.48	0.67	33.14	4.28

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
BRM-RY-SP-04	7.82	0.19	0.96	3.79	4.62	1.07	0.95	0.11
CPS-2	9.23	2.10	10.26	21.22	36.91	7.95	9.38	0.19
CPS-1-Vault	0.74	0.10	0.54	1.16	1.51	0.34	0.39	0.17
MW-4	0.15	0.03	0.17	0.20	0.46	0.09	0.14	0.06
CPS-8	5.66	0.77	3.94	8.74	14.33	3.09	3.48	0.39
BRM-RY-SR-01	1.80	0.05	0.28	0.92	1.21	0.27	0.27	0.05
Mean	4.24	0.54	2.70	6.01	9.84	2.14	2.44	0.17
Minimum	0.16	0.03	0.17	0.20	0.47	0.09	0.14	0.06
Maximum	9.23	2.10	10.26	21.22	36.91	7.96	9.39	0.39

Table 3-24. Black Pine Mine REE statistics.

Sample ID	Total REE (µg/L)	Coutl
BRM-RY-SP-04	24.07	1.08
CPS-2	153.17	7.11
CPS-1-Vault	9.11	5.80
MW-4	2.64	7.40
CPS-8	61.96	5.01
BRM-RY-SR-01	6.48	1.41

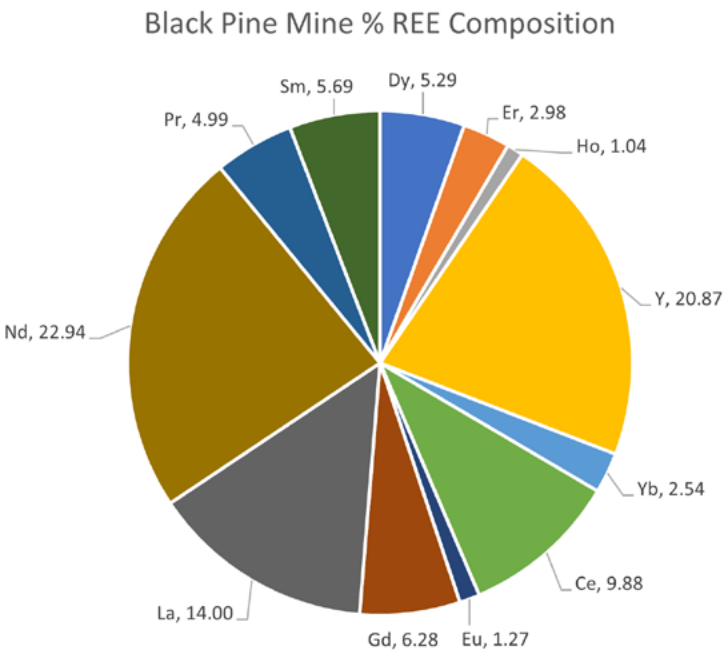


Figure 3-21. The breakdown of REE concentration percentages based on total REEs for all samples taken from the Black Pine Mine. Elements with less than 1% concentration were removed.



Figure 3-22. Golden Sunlight sample site map.



Figure 3-23. Golden Sunlight flooded open pit.

Table 3-25. Golden Sunlight REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
GS Pit Diss.	0.02	0.01	0.01	0.01	0.002	0.003	0.002	0.24	0.01
GS Pit Tot. Rec.	0.05	<0.040	<0.040	<0.020	<0.020	<0.020	<0.020	2.59	<0.040
Mean	0.03	0.01	0.01	0.01	0.002	0.003	0.002	1.41	0.01
Minimum	0.02	0.01	0.01	0.01	0.002	0.003	0.002	0.24	0.01
Maximum	0.05	0.01	0.01	0.01	0.002	0.003	0.002	2.59	0.01

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
GS Pit Diss.	0.09	0.003	0.01	0.05	0.03	0.01	0.01	0.22
GS Pit Tot. Rec.	1.14	<0.030	0.07	0.64	<0.080	0.16	0.06	0.53
Mean	0.09	0.003	0.01	0.05	0.03	0.01	0.01	0.22
Minimum	0.09	0.003	0.01	0.05	0.03	0.01	0.01	0.22
Maximum	1.14	0.003	0.07	0.64	0.03	0.16	0.06	0.53

Table 3-26. Golden Sunlight REE statistics.

Sample ID	Total REE (µg/L)	CoutI
GS Pit Diss.	0.72	2.94
GS Pit Tot. Rec.	5.24	N/A

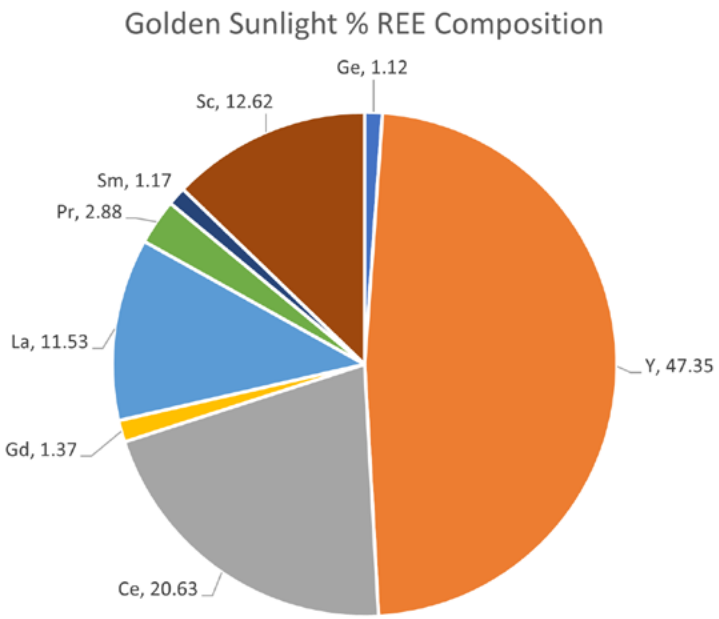
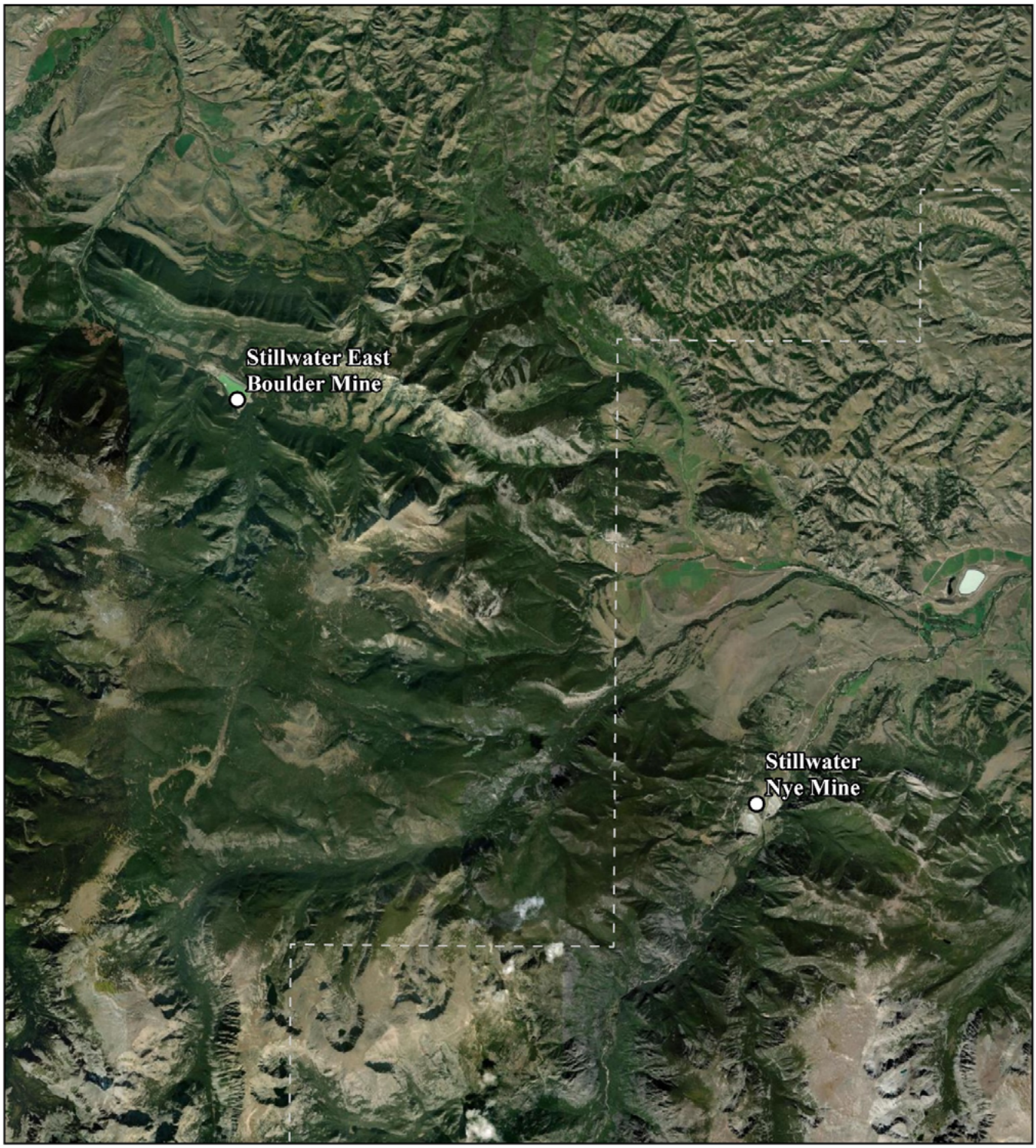


Figure 3-24. The breakdown of REE concentration percentages based on total REEs for all samples taken from the Golden Sunlight Mine. Elements with less than 1% concentration were removed.



MBMG

Sibanye-Stillwater Sample Site Locations

Sample Site Location

County Boundary

Miles

0 1 2 4

N

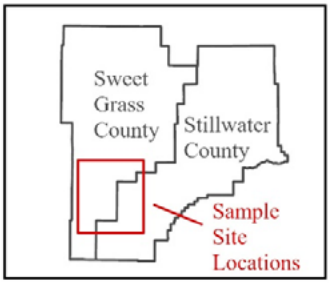


Figure 3-25. Sibanye–Stillwater sample site map.



Figure 3-26. Stillwater Nye Mine surface workings.

Table 3-27. Sibanye–Stillwater aqueous REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
East Boulder Concentrate Decant	0.07	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	0.02	<0.004
East Boulder Whole Tailings Decant	0.04	<0.004	<0.004	<0.002	<0.002	<0.002	<0.002	0.01	<0.004
Nye Mill tailing Decant	0.33	0.28	0.21	0.06	0.04	0.04	0.03	1.55	0.25
Nye Mill Concentrate Decant	0.13	0.11	0.07	0.02	0.01	0.01	0.01	0.80	0.07
Mean	0.14	0.19	0.14	0.04	0.02	0.03	0.02	0.60	0.16
Minimum	0.04	0.11	0.07	0.02	0.01	0.01	0.01	0.01	0.07
Maximum	0.33	0.28	0.21	0.06	0.04	0.04	0.03	1.55	0.25

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
East Boulder Concentrate Decant	0.03	<0.003	<0.003	0.02	<0.008	<0.003	<0.004	0.10
East Boulder Whole Tailings Decant	0.02	<0.003	<0.003	0.01	<0.008	<0.003	<0.004	0.11
Nye Mill tailing Decant	2.75	0.17	0.25	1.15	0.95	0.26	0.19	5.04
Nye Mill Concentrate Decant	0.85	0.02	0.10	0.25	0.28	0.06	0.03	0.28
Mean	0.02	0.02	0.10	0.01	0.28	0.06	0.03	0.10
Minimum	0.02	0.02	0.10	0.01	0.28	0.06	0.03	0.10
Maximum	2.75	0.17	0.25	1.15	0.95	0.26	0.19	5.04

Table 3-28 Sibanye–Stillwater aqueous REE statistics.

Sample ID	Total REE (µg/L)	Coutl
East Boulder Concentrate Decant	0.17	N/A
East Boulder Whole Tailings Decant	0.16	N/A
Nye Mill tailing Decant	13.53	1.10
Nye Mill Concentrate Decant	3.10	1.45

Table 3-29. Sibanye–Stillwater solids REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (µg/L)
East Boulder Whole	0.55	0.44	0.27	0.11	0.02	0.04	0.06	2.50	0.34
Nye Geo Ore	0.30	0.28	0.19	0.06	0.02	0.04	0.03	1.90	0.20
Nye Geo Waste	0.41	0.51	0.36	0.11	0.04	0.08	0.06	2.80	0.36
Nye Mill Concentrate	0.22	0.42	0.26	0.09	0.06	0.07	0.05	2.30	0.37
Nye Mill Tailings	0.29	0.32	0.28	0.06	0.02	0.06	0.03	1.90	0.28
East Boulder Conc.	0.23	0.27	0.25	0.06	0.04	0.04	0.03	1.80	0.22
East Boulder Waste	0.52	0.87	0.54	0.18	0.08	0.11	0.07	4.40	0.59
East Boulder Ore	0.36	0.29	0.27	0.06	0.05	0.06	0.04	2.20	0.29
Mean	0.36	0.43	0.30	0.09	0.04	0.06	0.05	2.48	0.33
Minimum	0.22	0.27	0.19	0.06	0.02	0.04	0.03	1.80	0.20
Maximum	0.55	0.87	0.54	0.18	0.08	0.11	0.07	4.40	0.59

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
East Boulder Whole	2.00	0.15	0.55	1.10	1.00	0.31	0.33	9.00
Nye Geo Ore	1.60	0.19	0.30	1.00	0.80	0.28	0.07	6.00
Nye Geo Waste	1.20	0.13	0.41	0.60	0.80	0.15	0.26	28.00
Nye Mill Concentrate	3.10	0.03	0.22	1.20	1.00	0.26	0.22	16.00
Nye Mill Tailings	2.20	0.13	0.29	1.00	0.90	0.26	0.19	9.00
East Boulder Conc.	1.30	0.10	0.23	0.60	0.70	0.10	0.18	11.00
East Boulder Waste	1.70	0.18	0.52	0.90	1.00	0.24	0.31	39.00
East Boulder Ore	1.10	0.09	0.36	0.70	0.90	0.13	0.28	7.00
Mean	1.78	0.13	0.36	0.89	0.89	0.22	0.23	15.63
Minimum	1.10	0.03	0.22	0.60	0.70	0.10	0.07	6.00
Maximum	3.10	0.19	0.55	1.20	1.00	0.31	0.33	39.00

Table 3-30. Sibanye–Stillwater Solids REE Statistics.

Sample ID	Total REE mg/kg	Coutl
East Boulder Whole	18.77	1.73
Nye Geo Ore	13.26	1.78
Nye Geo Waste	36.28	2.64
Nye Mill Concentrate	25.87	1.11
Nye Mill Tailings	17.21	1.38
East Boulder Conc.	17.15	1.91
East Boulder Waste	51.21	2.71
East Boulder Ore	14.18	2.47

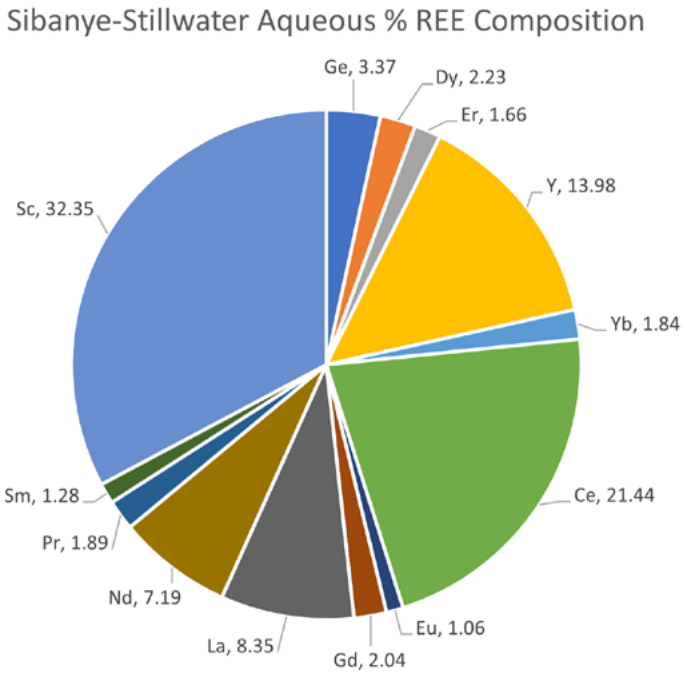


Figure 3-27. The breakdown of REE concentration percentages based on total REEs for all aqueous samples taken from Sibanye–Stillwater. Elements with less than 1% concentration were removed.

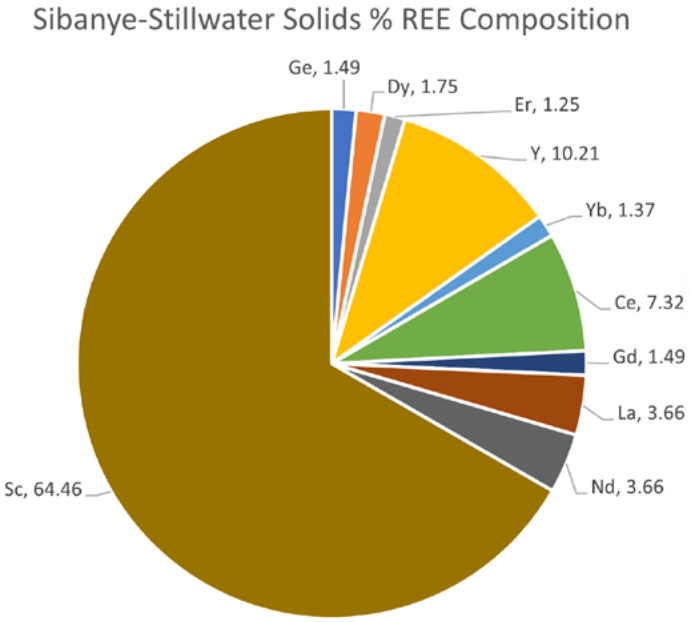


Figure 3-28. The breakdown of REE concentration percentages based on total REEs for all solid samples taken from Sibanye–Stillwater. Elements with less than 1% concentration were removed.

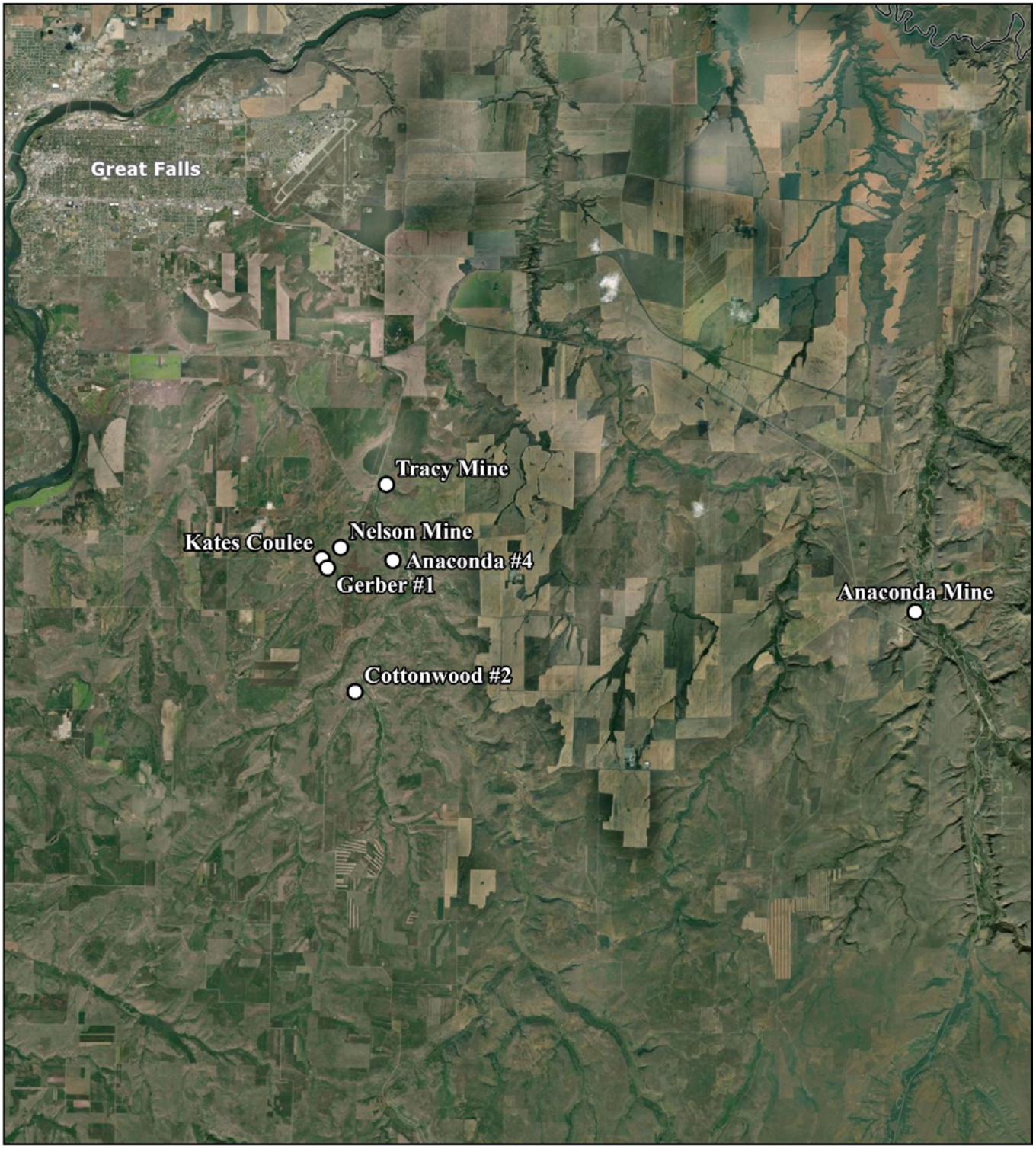


Figure 3-29. Belt/Stockett/Sand Coulee sample site map.



Figure 3-30. Cottonwood #2 AMD.

Table 3-31. Belt/Stockett/Sand Coulee REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
Anaconda Mine–Diss	1.00	55.40	20.54	8.99	1.91	10.83	2.40	174.65	13.75
Tracy Mine–Diss	0.83	12.48	4.84	2.05	0.44	2.51	0.58	49.20	3.26
Nelson Mine–Diss	2.07	139.79	53.63	22.60	5.07	27.68	6.29	373.52	36.36
Cottonwood #2–Diss	2.81	451.76	158.90	66.26	14.52	75.11	18.67	1082.24	108.59
Kates Coulee–Diss	1.22	82.35	34.61	14.08	3.24	15.11	4.11	318.90	23.33
Gerber #1–Diss	2.61	281.57	117.43	48.18	10.73	51.53	14.04	980.84	80.18
Old Sand Coulee–Diss	1.65	145.25	61.78	25.26	5.83	26.21	7.48	543.26	42.93
Anaconda Mine–Tot. Rec.	0.96	53.90	19.90	8.70	1.83	10.43	2.31	170.40	13.12
Tracy Mine–Tot. Rec.	0.89	12.44	4.83	2.02	0.44	2.53	0.57	48.36	3.17
Nelson Mine–Tot. Rec.	2.25	140.93	53.38	22.79	5.03	28.01	6.32	372.47	36.12
Cottonwood#2–Tot. Rec.	3.19	463.34	163.89	68.19	14.81	77.70	19.09	1070.28	109.58
Kates Coulee–Tot. Rec.	1.36	82.86	34.39	14.22	3.20	15.20	4.10	318.63	23.24
Gerber #1–Tot. Rec.	2.91	271.98	112.64	46.47	10.27	50.03	13.41	950.80	75.86
Old Sand Coulee–Tot. Rec.	1.92	148.98	62.53	25.72	5.87	27.16	7.55	545.12	42.72
Tracy Mine–Diss	0.71	10.59	4.21	1.72	0.41	2.09	0.49	32.92	2.85
Anaconda #4-Diss	6.26	498.94	168.69	71.98	15.35	88.31	18.95	702.50	110.62
Mean	2.04	178.28	67.26	28.08	6.18	31.90	7.90	483.38	45.36
Minimum	0.71	10.59	4.21	1.72	0.41	2.09	0.49	32.92	2.85
Maximum	6.26	498.94	168.69	71.98	15.35	88.31	19.09	1082.24	110.62

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
Anaconda Mine–Diss	262.71	14.34	74.39	107.05	192.87	38.94	55.93	45.92
Tracy Mine–Diss	105.83	3.68	18.03	43.04	63.12	14.42	15.35	6.01
Nelson Mine–Diss	998.46	39.11	188.25	367.82	633.39	140.81	159.37	105.96
Cottonwood #2–Diss	2258.64	111.93	598.41	682.16	1668.09	348.92	428.12	202.03
Kates Coulee–Diss	349.66	18.27	96.81	127.92	251.92	53.28	69.40	38.93
Gerber #1–Diss	1147.96	66.54	331.23	375.17	864.37	178.99	249.75	133.18
Old Sand Coulee–Diss	533.16	32.01	166.53	176.85	403.81	84.21	119.59	106.79
Anaconda Mine–Tot. Rec.	257.47	13.86	72.14	103.56	183.29	37.68	54.47	48.16
Tracy Mine–Tot. Rec.	107.44	3.66	18.31	43.81	63.27	14.34	15.44	5.88
Nelson Mine–Tot. Rec.	1099.16	39.35	190.78	370.82	678.59	141.73	159.70	119.55
Cottonwood#2–Tot. Rec.	2325.03	114.13	607.97	708.63	1708.25	355.31	438.34	243.22
Kates Coulee–Tot. Rec.	357.73	18.39	97.44	129.20	254.94	53.20	70.36	43.42
Gerber #1–Tot. Rec.	1199.53	64.33	325.74	368.34	893.92	174.07	242.64	148.23
Old Sand Coulee–Tot. Rec.	561.28	33.02	173.23	184.65	423.70	87.76	123.83	125.82
Tracy Mine–Diss	85.77	2.84	15.02	34.64	49.11	11.14	11.75	4.20
Anaconda #4–Diss	2876.11	117.33	649.30	1075.51	1895.67	403.21	446.34	293.81
Mean	907.87	43.30	226.47	306.20	639.27	133.62	166.27	104.44
Minimum	85.77	2.84	15.02	34.64	49.11	11.14	11.75	4.20
Maximum	2876.11	117.33	649.30	1075.51	1895.67	403.21	446.34	293.81

Table 3-32. Belt/Stockett/Sand Coulee REE statistics.

Sample ID	Total REE (µg/L)	Coutl
Anaconda Mine–Diss	1081.61	1.70
Tracy Mine–Diss	345.67	1.25
Nelson Mine–Diss	3300.15	1.23
Cottonwood #2–Diss	8277.16	1.50
Kates Coulee–Diss	1503.15	1.94
Gerber #1–Diss	4934.30	1.93
Old Sand Coulee–Diss	2482.58	2.12
Anaconda Mine–Tot. Rec.	1052.16	1.67
Tracy Mine–Tot. Rec.	347.39	1.22
Nelson Mine–Tot. Rec.	3466.98	1.16
Cottonwood#2–Tot. Rec.	8490.92	1.48
Kates Coulee–Tot. Rec.	1521.85	1.91
Gerber #1–Tot. Rec.	4951.13	1.85
Old Sand Coulee–Tot. Rec.	2580.86	2.07
Tracy Mine–Diss	270.45	1.15
Anaconda #4–Diss	9438.86	1.16

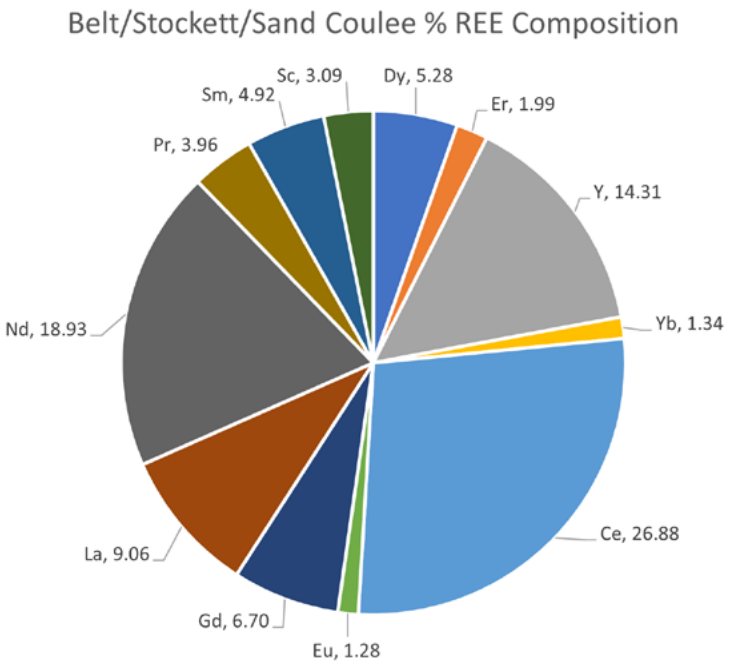


Figure 3-31. The breakdown of REE concentration percentages based on total REEs for all samples taken from the Belt/Stockett/Sand Coulee area. Elements with less than 1% concentration were removed.



Figure 3-32. East Helena sample site map.



Figure 3-33. East Helena slag pile.

Table 3-33. East Helena REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
1940-1980 Fume Slag Sample #1	67.00	3.58	2.05	0.71	0.29	0.64	0.29	22.80	1.81
1940-1980 Fume Slag Sample #2	37.80	3.82	2.20	0.82	0.28	0.62	0.34	23.00	1.89
1940-1980 Fume Slag Sample #3	45.60	3.86	2.18	0.78	0.30	0.67	0.32	23.10	2.05
1940-1980 Fume Slag Sample #4	71.30	3.93	2.25	0.84	0.31	0.69	0.32	23.70	1.97
1940-1980 Fume Slag Sample #5	56.00	3.92	2.20	0.81	0.27	0.72	0.32	24.00	2.00
Pre 1940 Unfumed Slag Sample #1	4.80	4.42	1.98	0.81	0.26	0.77	0.29	23.30	1.70
Pre 1940 Unfumed Slag Sample #2	4.30	4.83	2.66	0.91	0.29	0.81	0.36	27.40	2.09
Pre 1940 Unfumed Slag Sample #3	4.00	5.66	2.83	1.06	0.36	0.95	0.42	31.70	2.52
Pre 1940 Unfumed Slag Sample #4	4.10	4.00	2.05	0.78	0.25	0.69	0.29	22.20	1.81
Post 1983 Unfumed Slag Sample #1	47.80	4.17	2.77	0.86	0.34	0.70	0.36	24.70	2.15
Post 1983 Unfumed Slag Sample #2	45.70	4.19	2.36	0.87	0.33	0.63	0.33	24.90	2.05
Post 1983 Unfumed Slag Sample #3	53.70	3.65	2.22	0.79	0.30	0.57	0.34	23.60	2.00
Post 1983 Unfumed Slag Sample #4	55.20	4.24	2.43	0.85	0.32	0.62	0.35	24.50	2.01
Unknown Pile Sample #1	4.80	3.06	1.71	0.61	0.24	0.50	0.24	19.30	1.42
Unknown Pile Sample #2	4.80	2.69	1.54	0.57	0.21	0.46	0.20	17.40	1.33
Mean	33.79	4.00	2.23	0.80	0.29	0.67	0.32	23.71	1.92
Minimum	4.00	2.69	1.54	0.57	0.21	0.46	0.20	17.40	1.33
Maximum	71.30	5.66	2.83	1.06	0.36	0.95	0.42	31.70	2.52

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
1940-1980 Fume Slag Sample #1	46.80	1.18	3.92	26.20	21.10	5.57	4.59	5.00
1940-1980 Fume Slag Sample #2	42.70	1.24	3.98	23.00	19.10	5.07	4.21	5.00
1940-1980 Fume Slag Sample #3	47.60	1.58	4.19	26.20	19.70	5.44	4.80	5.00
1940-1980 Fume Slag Sample #4	45.50	1.54	4.34	24.30	19.80	5.38	4.61	5.00
1940-1980 Fume Slag Sample #5	49.20	1.72	4.3	27.20	20.50	5.44	4.85	5.00
Pre 1940 Unfumed Slag Sample #1	38.60	2.84	5.53	17.40	20.50	4.93	5.79	4.00
Pre 1940 Unfumed Slag Sample #2	35.90	2.64	4.87	17.00	17.60	4.35	5.18	4.00
Pre 1940 Unfumed Slag Sample #3	46.20	3.36	6.06	21.60	23.90	5.93	6.37	4.00
Pre 1940 Unfumed Slag Sample #4	30.00	2.36	4.02	13.60	15.40	3.69	4.33	3.00
Post 1983 Unfumed Slag Sample #1	49.40	1.10	3.96	33.40	23.60	6.24	3.85	4.00
Post 1983 Unfumed Slag Sample #2	38.90	0.90	3.61	23.80	21.40	5.02	3.36	4.00
Post 1983 Unfumed Slag Sample #3	104.50	0.97	3.30	31.50	19.00	5.59	3.36	4.00
Post 1983 Unfumed Slag Sample #4	64.60	1.09	3.64	26.40	18.10	5.26	3.60	4.00
Unknown Pile Sample #1	37.90	0.74	3.15	19.40	16.50	4.45	3.63	5.00
Unknown Pile Sample #2	34.40	0.67	2.75	17.60	14.80	4.12	3.11	5.00
Mean	47.48	1.60	4.11	23.24	19.40	5.10	4.38	4.40
Minimum	30.00	0.67	2.75	13.60	14.80	3.69	3.11	3.00
Maximum	104.50	3.36	6.06	33.40	23.90	6.24	6.37	5.00

Table 3-34. East Helena REE statistics.

Sample ID	Total REE (mg/kg)	CoutI
1940-1980 Fume Slag Sample #1	213.53	1.03
1940-1980 Fume Slag Sample #2	175.07	1.09
1940-1980 Fume Slag Sample #3	193.37	1.00
1940-1980 Fume Slag Sample #4	215.78	1.06
1940-1980 Fume Slag Sample #5	208.45	1.01
Pre 1940 Unfumed Slag Sample #1	137.92	1.29
Pre 1940 Unfumed Slag Sample #2	135.19	1.41
Pre 1940 Unfumed Slag Sample #3	166.92	1.35
Pre 1940 Unfumed Slag Sample #4	112.57	1.41
Post 1983 Unfumed Slag Sample #1	209.40	1.07
Post 1983 Unfumed Slag Sample #2	182.35	1.28
Post 1983 Unfumed Slag Sample #3	259.39	0.46
Post 1983 Unfumed Slag Sample #4	217.21	0.75
Unknown Pile Sample #1	122.65	1.03
Unknown Pile Sample #2	111.65	1.02

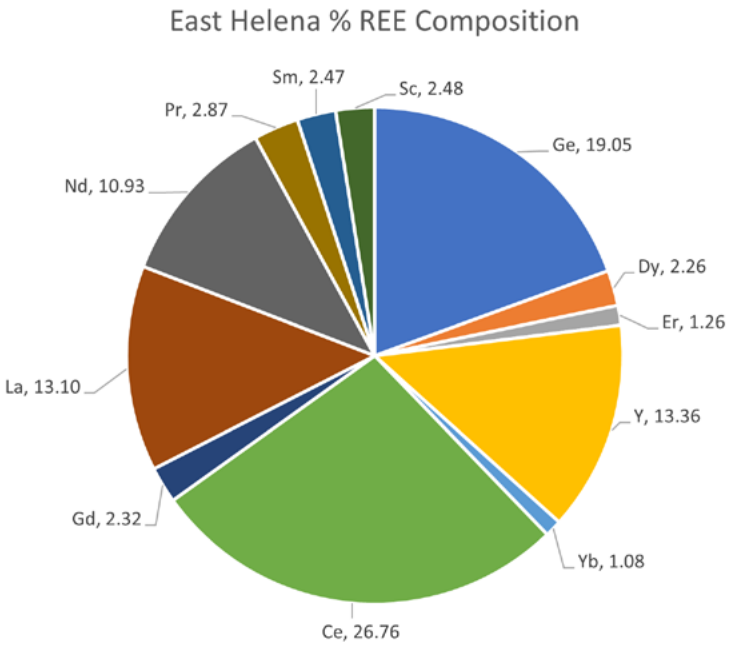


Figure 3-34. The breakdown of REE concentration percentages based on total REEs for all samples taken from the East Helena slag piles. Elements with less than 1% concentration were removed.

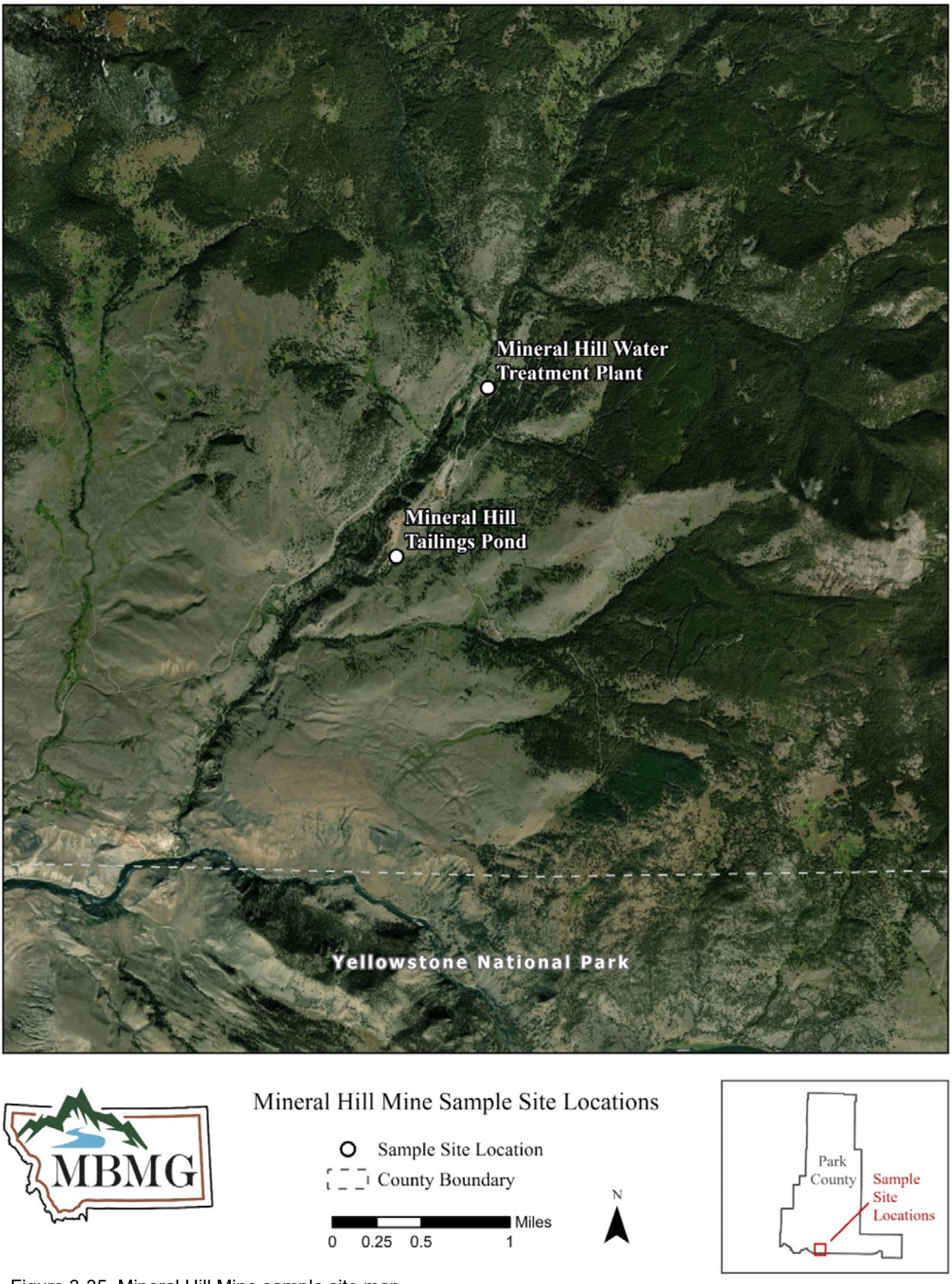


Figure 3-35. Mineral Hill Mine sample site map.



Figure 3-36. Mineral Hill Tailings Pond.

Table 3-35. Mineral Hill aqueous REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
Mineral Hill 1300 Adit	<0.035	0.02	0.01	<0.007	<0.007	<0.006	<0.007	0.26	<0.012
Mineral Hill Treatment Plant Effluent–Adit	<0.035	<0.013	<0.010	<0.007	<0.007	<0.006	<0.007	0.11	<0.012
Mineral Hill Tailings Pond–Tailings leachate	<0.350	0.14	<0.100	<0.070	<0.070	<0.060	<0.070	1.42	<0.120
Minerals Hill Tailings Discharge	0.45	0.31	0.18	<0.070	<0.070	<0.060	<0.070	4.10	0.12
Mean	0.45	0.16	0.10	0.00	0.00	0.00	0.00	1.48	0.12
Minimum	0.45	0.03	0.01	0.00	0.00	0.00	0.00	0.12	0.12
Maximum	0.45	0.32	0.18	0.00	0.00	0.00	0.00	4.10	0.12

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
Mineral Hill 1300 Adit	0.24	<0.011	0.03	0.32	0.20	0.04	<0.035	0.05
Mineral Hill Treatment Plant Effluent–Adit	0.05	<0.011	<0.013	0.10	0.06	0.01	<0.035	0.05
Mineral Hill Tailings Pond–Tailings leachate	2.29	<0.110	0.17	1.38	0.96	0.24	<0.350	<0.370
Minerals Hill Tailings Discharge	6.42	<0.110	0.43	3.82	1.96	0.52	<0.350	<0.370
Mean	2.25	0.00	0.22	1.41	0.80	0.21	0.00	0.05
Minimum	0.05	0.00	0.04	0.10	0.07	0.01	0.00	0.05
Maximum	6.42	0.00	0.44	3.83	1.96	0.52	0.00	0.05

Table 3-36. Mineral Hill aqueous REE statistics.

Sample ID	Total REE (µg/L)	Coutl
Mineral Hill 1300 Adit	1.21	N/A
Mineral Hill Treatment Plant Effluent-Adit	0.40	N/A
Mineral Hill Tailings Pond-Tailings leachate	6.63	N/A
Minerals Hill Tailings Discharge	18.33	N/A

Table 3-37. Mineral Hill solids REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
Mineral Hill Treatment Media	6.80	0.28	0.19	0.06	0.02	0.05	0.03	1.90	0.18
Mineral Hill Tailings Pond Sediment	1.20	3.23	1.84	0.66	0.28	0.60	0.29	17.00	1.68
Mineral Hill Tailings Pond Discharge	<0.5	3.33	1.92	0.71	0.18	0.58	0.22	38.10	1.14
Mean	4.00	2.28	1.32	0.48	0.16	0.41	0.18	19.00	1.00
Minimum	1.20	0.28	0.19	0.06	0.02	0.05	0.03	1.90	0.18
Maximum	6.80	3.33	1.92	0.71	0.28	0.60	0.29	38.10	1.68

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Mineral Hill Treatment Media	12.00	0.07	0.37	7.50	2.60	0.73	0.51	<1
Mineral Hill Tailings Pond Sediment	76.30	1.28	4.06	47.40	29.60	8.41	5.18	7.00
Mineral Hill Tailings Pond Discharge	65.10	0.69	4.43	33.10	21.60	5.88	3.12	<1
Mean	51.13	0.68	2.95	29.33	17.93	5.01	2.94	7.00
Minimum	12.00	0.07	0.37	7.50	2.60	0.73	0.51	7.00
Maximum	76.30	1.28	4.43	47.40	29.60	8.41	5.18	7.00

Table 3-38. Mineral Hill solids REE statistics.

Sample ID	Total REE (mg/kg)	Coutl
Mineral Hill Treatment Media	33.29	0.41
Mineral Hill Tailings Pond Sediment	206.01	0.68
Mineral Hill Tailings Pond Discharge	180.10	0.98

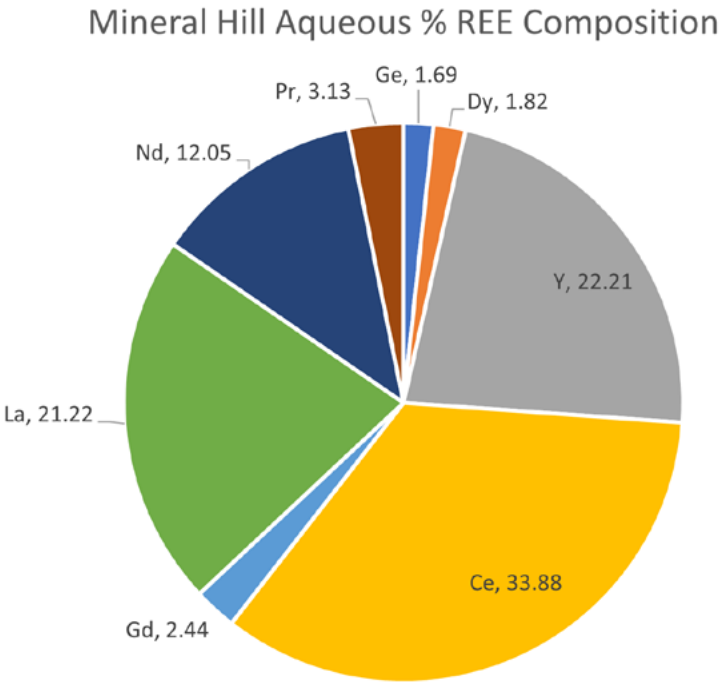


Figure 3-37. The breakdown of REE concentration percentages based on total REEs for all aqueous samples taken from the Mineral Hill Mine. Elements with less than 1% concentration were removed.

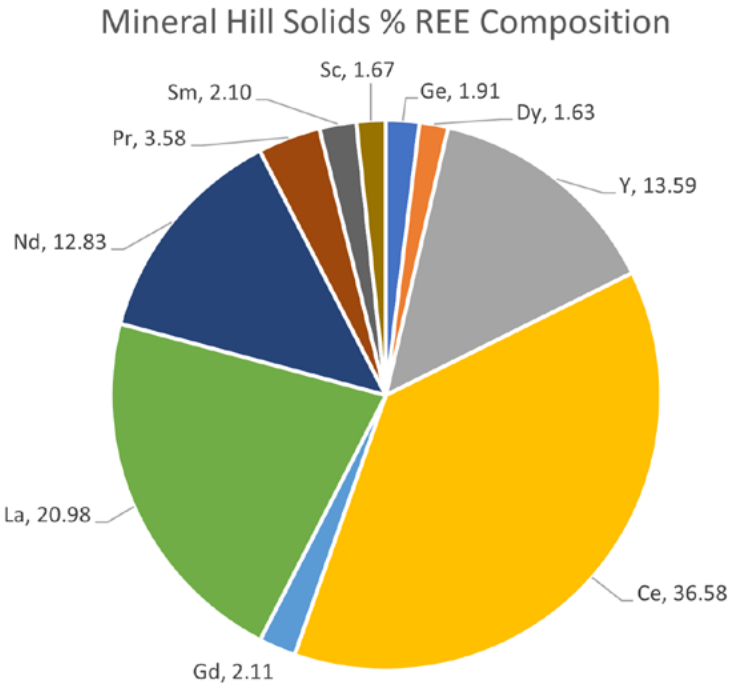
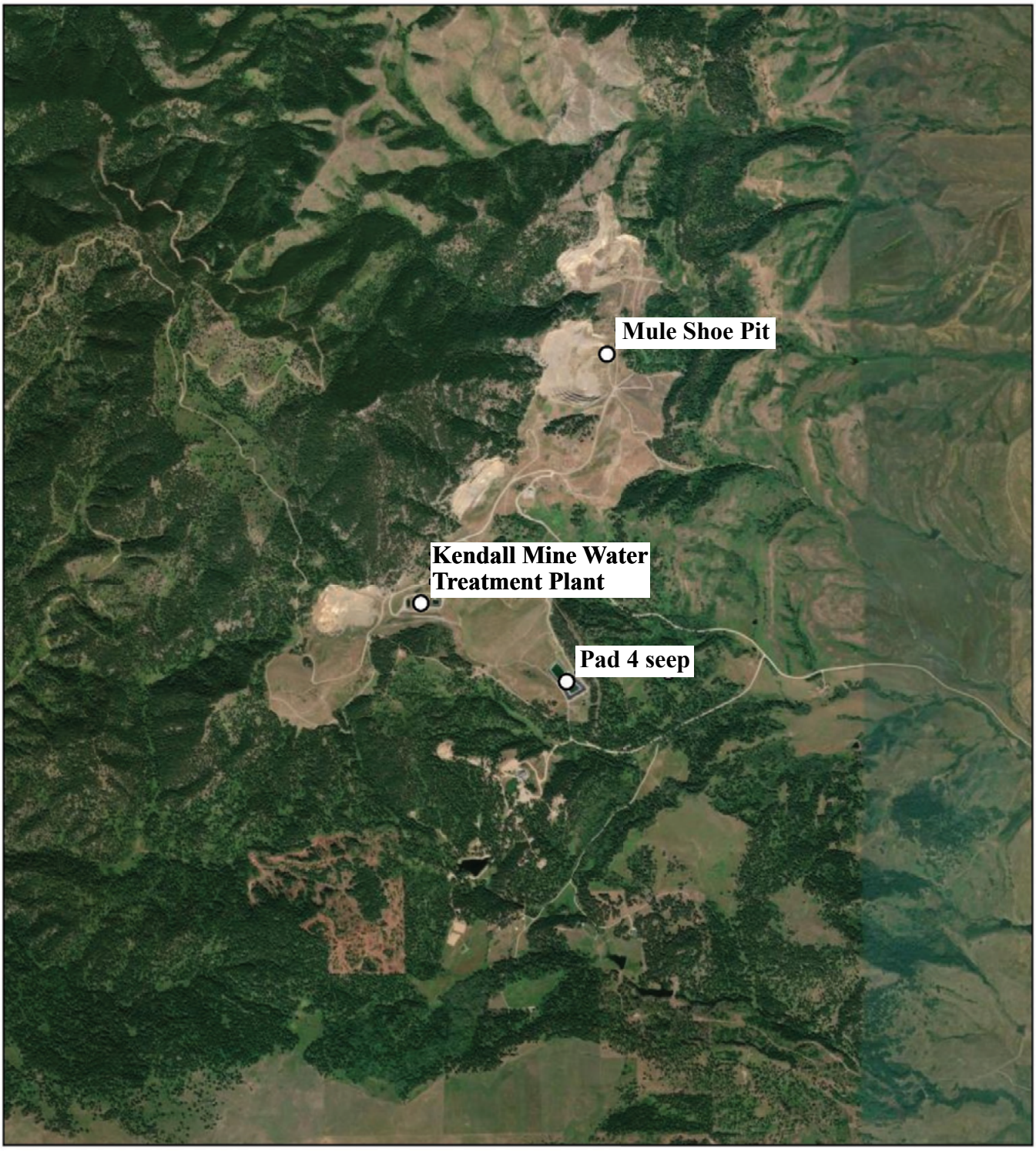


Figure 3-38. The breakdown of REE concentration percentages based on total REEs for all solid samples taken from the Mineral Hill Mine. Elements with less than 1% concentration were removed.



MBMG

Kendall Mine Sample Site Locations

Sample Site Location

0 0.25 0.5 1 Miles

N

Sample Site Locations

Fergus County

Figure 3-39. Kendall Mine sample site map.



Figure 3-40. Kendall Mine open pit.

Table 3-39. Kendall Mine aqueous REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
Pad 4 seep–Diss	0.45	4.71	3.10	0.99	0.46	0.73	0.44	29.12	3.01
Pad 4 seep–Tot. Rec.	0.18	5.10	3.35	1.07	0.48	0.78	0.47	31.20	3.21
Mean	0.31	4.91	3.22	1.03	0.47	0.75	0.46	30.16	3.11
Minimum	0.18	4.71	3.10	0.99	0.46	0.73	0.44	29.12	3.01
Maximum	0.45	5.10	3.35	1.07	0.48	0.78	0.47	31.20	3.21

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
Pad 4 seep–Diss	28.46	0.74	4.70	12.05	16.54	3.81	3.85	1.42
Pad 4 seep–Tot. Rec.	30.90	0.79	5.08	13.75	18.10	4.22	4.18	1.54
Mean	28.46	0.74	4.70	12.05	16.54	3.81	3.85	1.42
Minimum	28.46	0.74	4.70	12.05	16.54	3.81	3.85	1.42
Maximum	30.90	0.79	5.08	13.75	18.10	4.22	4.18	1.54

Table 3-40. Kendall Mine aqueous REE statistics.

Sample ID	Total REE (µg/L)	CoutI
Pad 4 seep–Diss	114.58	1.81
Pad 4 seep–Tot. Rec.	124.41	1.80

Table 3-41. Kendall Mine solids REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
Zeolite	0.60	2.43	1.50	0.49	0.26	0.39	0.23	14.10	1.47
Spent Zeolite	0.70	2.52	1.63	0.50	0.28	0.42	0.20	14.90	1.55
Mule Shoe 1	1.20	2.93	1.84	0.60	0.26	0.48	0.24	17.30	1.62
Mule Shoe 2	0.80	2.32	1.43	0.51	0.19	0.38	0.20	13.30	1.26
Mule Shoe 3	<0.5	0.42	0.26	0.09	0.03	0.06	0.03	2.40	0.17
Mean	0.83	2.12	1.33	0.44	0.20	0.35	0.18	13.00	1.21
Minimum	0.60	0.42	0.26	0.09	0.03	0.06	0.03	2.40	0.17
Maximum	1.20	2.93	1.84	0.60	0.28	0.48	0.24	17.30	1.62

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Zeolite	56.20	0.28	2.45	29.30	19.10	5.68	3.61	2.00
Spent Zeolite	53.80	0.35	2.40	29.10	19.10	5.59	3.29	2.00
Mule Shoe 1	36.20	0.68	3.18	18.30	16.90	4.48	3.62	6.00
Mule Shoe 2	34.80	0.58	2.48	17.50	16.10	4.13	3.19	7.00
Mule Shoe 3	2.60	0.08	0.37	1.40	1.40	0.37	0.35	1.00
Mean	36.72	0.39	2.18	19.12	14.52	4.05	2.81	3.60
Minimum	2.60	0.08	0.37	1.40	1.40	0.37	0.35	1.00
Maximum	56.20	0.68	3.18	29.30	19.10	5.68	3.62	7.00

Table 3-42. Kendall Mine solids REE statistics.

Sample ID	Total REE (mg/kg)	CoutI
Zeolite	140.09	0.64
Spent Zeolite	138.33	0.69
Mule Shoe 1	115.83	1.03
Mule Shoe 2	106.17	0.92
Mule Shoe 3	11.03	1.58

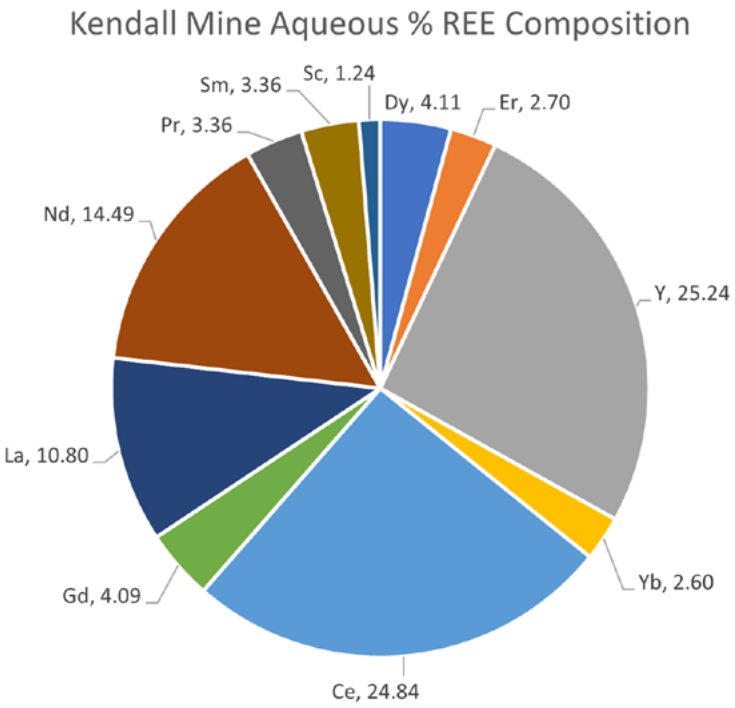


Figure 3-41. The breakdown of REE concentration percentages based on total REEs for all aqueous samples taken from the Kendall Mine. Elements with less than 1% concentration were removed.

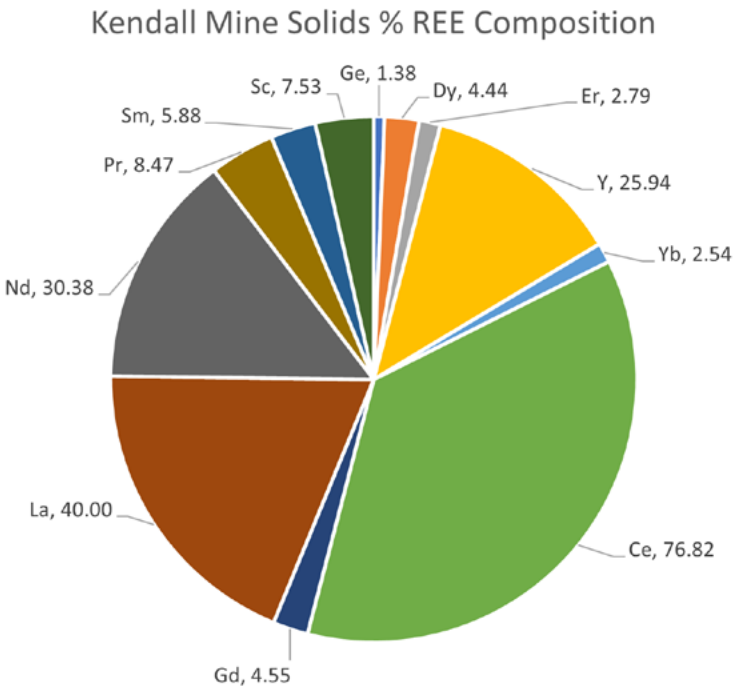


Figure 3-42. The breakdown of REE concentration percentages based on total REEs for all solid samples taken from the Kendall Mine. Elements with less than 1% concentration were removed.

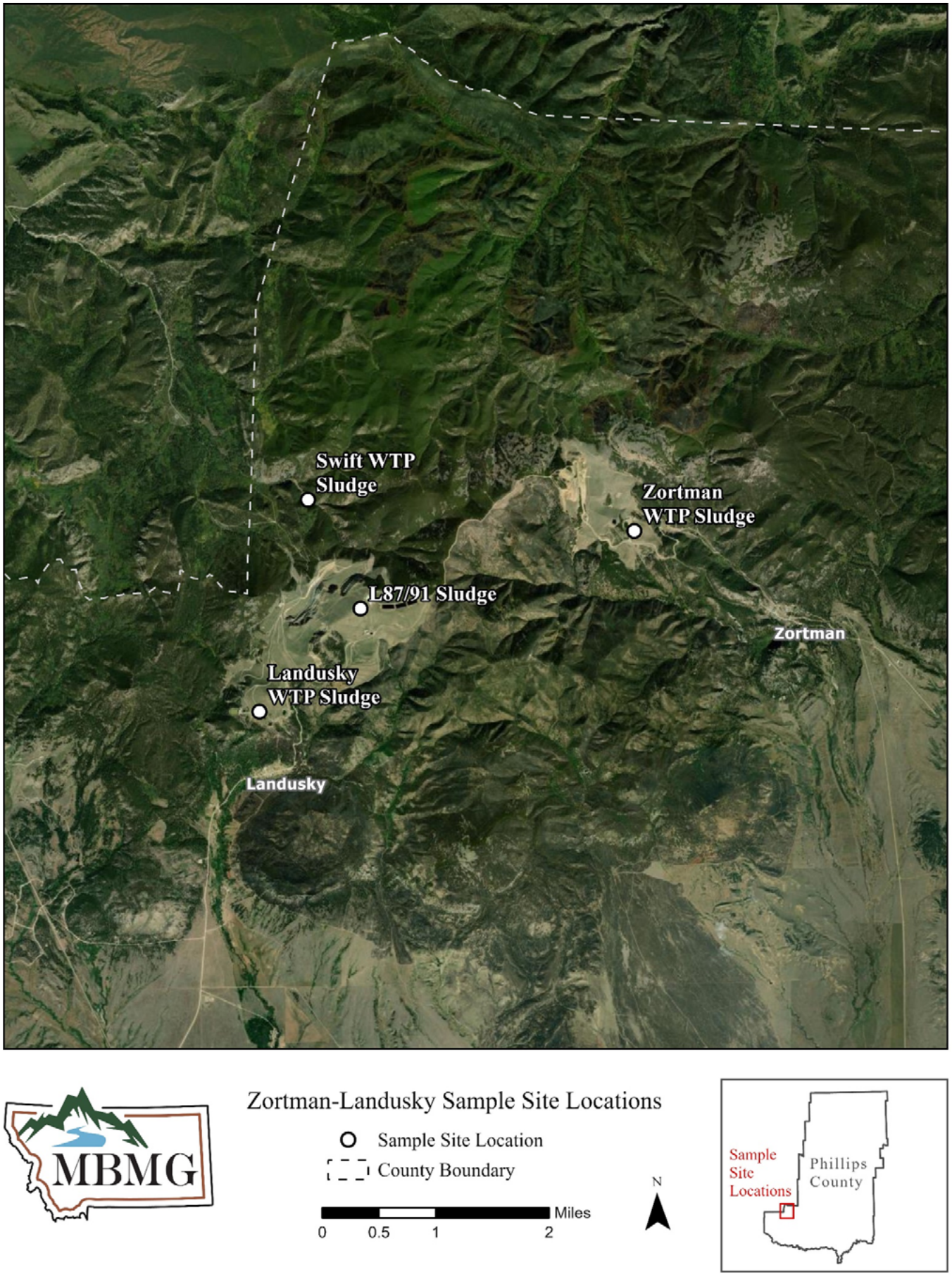


Figure 3-43. Zortman–Landusky sample site map.



Figure 3-44. Landusky sludge at the Zortman–Landusky Mine.

Table 3-43. Zortman–Landusky solids REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
Landusky WTP Sludge	1.30	103.00	54.10	20.50	6.12	18.15	7.29	691.00	42.30
Zortman WTP Sludge	<0.5	21.80	11.00	4.29	1.40	3.89	1.58	137.50	8.93
Swift WTP Sludge	<0.5	38.30	21.10	8.33	2.34	6.68	2.68	315.00	14.60
L87/91 Sludge	1.90	183.00	91.10	35.80	9.20	32.50	11.45	1275.00	63.40
Mean	1.60	86.53	44.33	17.23	4.77	15.31	5.75	604.63	604.63
Minimum	1.30	21.80	11.00	4.29	1.40	3.89	1.58	137.50	137.50
Maximum	1.90	183.00	91.10	35.80	9.20	32.50	11.45	1275.00	1275.00

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Landusky WTP Sludge	563.00	33.40	124.50	236.00	459.00	90.10	115.50	2.36
Zortman WTP Sludge	278.00	8.07	28.20	102.50	144.00	33.70	31.00	0.45
Swift WTP Sludge	273.00	11.00	48.60	129.50	168.00	35.50	36.30	3.89
L87/91 Sludge	1115.00	60.00	231.00	230.00	804.00	157.50	199.50	0.45
Mean	557.25	28.12	108.08	174.50	393.75	79.20	95.58	1.79
Minimum	273.00	8.07	28.20	102.50	144.00	33.70	31.00	0.45
Maximum	1115.00	60.00	231.00	236.00	804.00	157.50	199.50	3.89

Table 3-44. Zortman–Landusky solids REE statistics.

Sample ID	Total REE (mg/kg)	Coutl
Landusky WTP Sludge	3216.32	2.13
Zortman WTP Sludge	944.88	1.11
Swift WTP Sludge	1415.22	1.86
L87/91 Sludge	5712.40	1.98

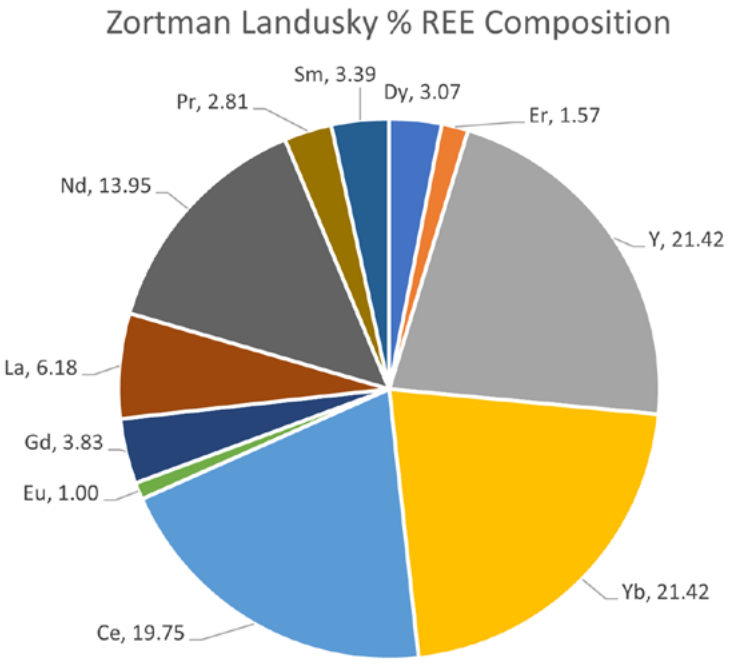


Figure 3-45. The breakdown of REE concentration percentages based on total REEs for all solid samples taken from the Zortman–Landusky Mine. Elements with less than 1% concentration were removed.



Figure 3-46. Solvay sample site map.



Figure 3-47. Solvay slag/tailings piles.

Table 3-45. Solvay REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
Solvay Granulated Slag 1	<0.5	16.70	13.10	3.99	1.72	2.46	1.82	246.00	10.90
Solvay Granulated Slag 2	<0.5	16.90	12.90	3.72	1.65	2.53	1.69	234.00	9.78
Solvay Granulated Slag 3	0.50	17.95	13.75	4.11	1.83	2.62	1.75	252.00	11.55
Solvay Granulated Slag 4	<0.5	16.15	12.05	3.93	1.62	2.46	1.65	234.00	10.35
Solvay Tailings 1	3.80	9.48	6.88	2.22	0.96	1.41	0.88	119.50	5.53
Solvay Tailings 2	4.40	10.15	7.13	2.23	0.94	1.58	0.99	126.00	6.35
Solvay Tailings 3	14.80	3.68	2.36	0.78	0.34	0.52	0.30	26.20	2.32
Solvay Tailings 4	3.20	9.16	6.53	2.21	0.97	1.48	0.83	114.50	5.88
Mean	5.34	12.52	9.34	2.90	1.25	1.88	1.24	169.03	7.83
Minimum	0.50	3.68	2.36	0.78	0.34	0.52	0.30	26.20	2.32
Maximum	14.80	17.95	13.75	4.11	1.83	2.62	1.82	252.00	11.55

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Solvay Granulated Slag 1	44.50	3.19	18.75	160.50	84.60	21.20	14.40	7.00
Solvay Granulated Slag 2	45.20	3.09	17.70	154.00	81.50	20.70	13.40	7.00
Solvay Granulated Slag 3	45.10	3.09	18.50	162.50	87.10	21.80	14.15	6.00
Solvay Granulated Slag 4	43.30	2.93	17.50	158.50	83.90	20.70	14.85	6.00
Solvay Tailings 1	31.00	1.75	10.35	82.90	47.40	12.00	7.68	7.00
Solvay Tailings 2	31.60	1.92	10.75	89.40	52.10	13.20	8.73	8.00
Solvay Tailings 3	46.60	0.99	4.12	32.90	23.50	6.38	4.54	7.00
Solvay Tailings 4	28.90	1.83	9.54	79.20	46.00	11.80	8.14	7.00
Mean	39.53	2.35	13.40	114.99	63.26	15.97	10.74	6.88
Minimum	28.90	0.99	4.12	32.90	23.50	6.38	4.54	6.00
Maximum	46.60	3.19	18.75	162.50	87.10	21.80	14.85	8.00

Table 3-46. Solvay REE statistics.

Sample ID	Total REE (mg/kg)	Coutl
Solvay Granulated Slag 1	650.83	5.82
Solvay Granulated Slag 2	625.76	5.66
Solvay Granulated Slag 3	664.30	5.85
Solvay Granulated Slag 4	629.89	5.78
Solvay Tailings 1	350.74	4.59
Solvay Tailings 2	375.47	4.72
Solvay Tailings 3	177.33	1.14
Solvay Tailings 4	337.17	4.63

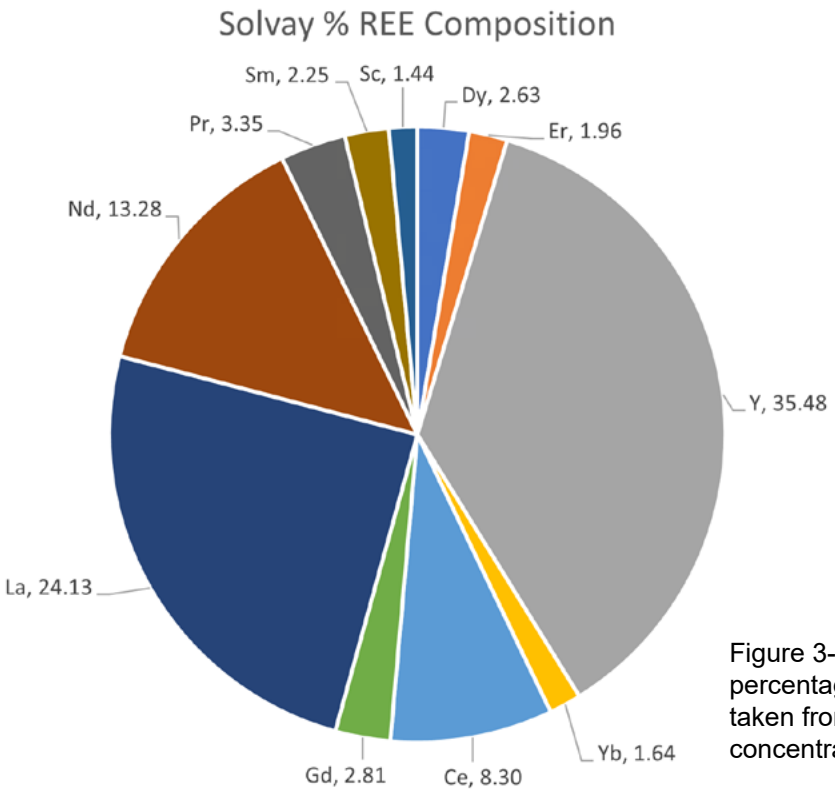


Figure 3-48. The breakdown of REE concentration percentages based on total REEs for all solid samples taken from the Solvay Plant. Elements with less than 1% concentration were removed.

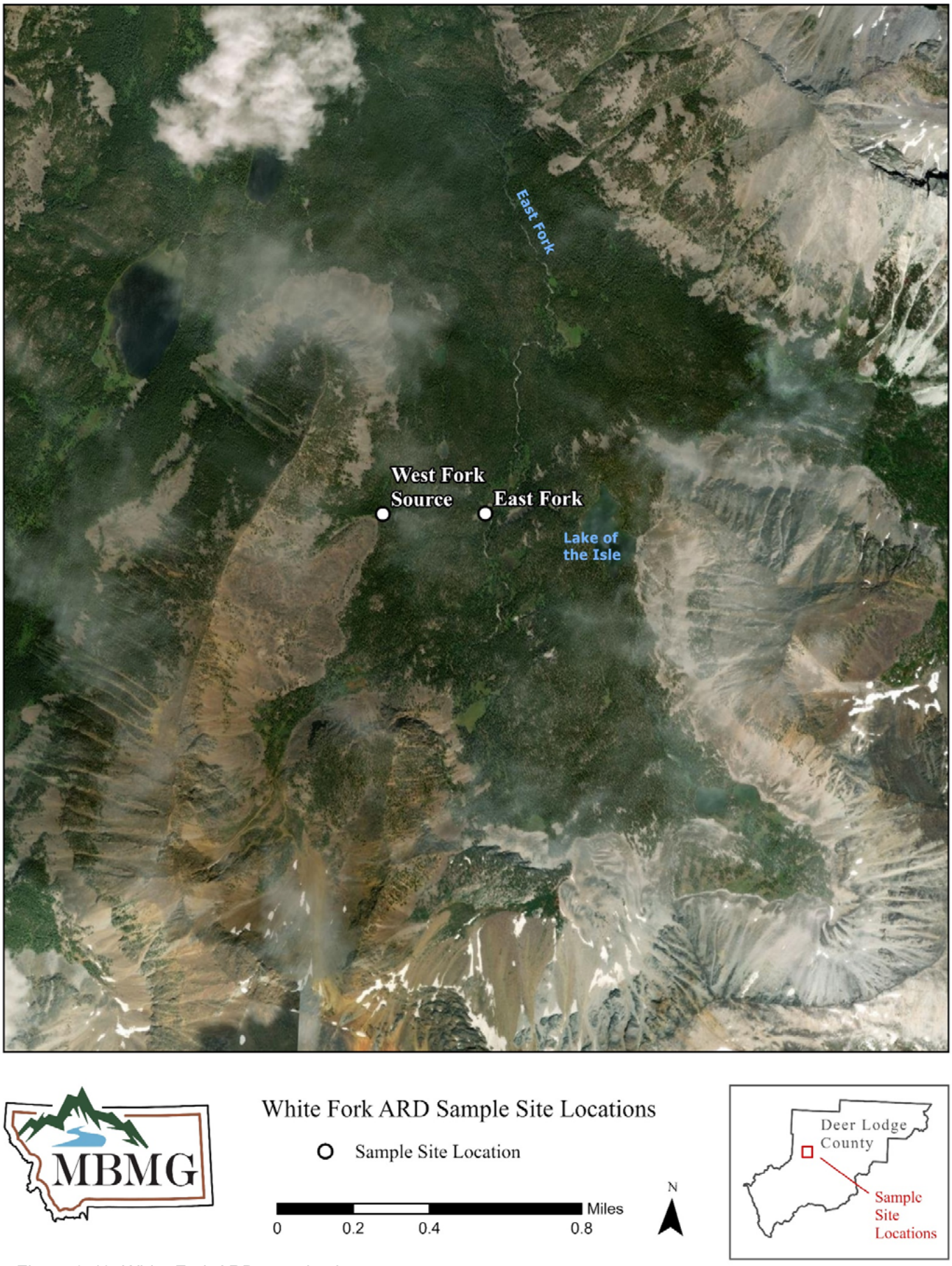


Figure 3-49. White Fork ARD sample site map.



Figure 3-50. White Fork Rock Glacier.

Table 3-47. White Fork ARD REE data.

Sample ID	Ge (µg/L)	Dy (µg/L)	Er (µg/L)	Ho (µg/L)	Lu (µg/L)	Tb (µg/L)	Tm (µg/L)	Y (µg/L)	Yb (µg/L)
West Fork Source Dis.	0.76	15.51	6.68	2.65	0.63	2.97	0.80	63.26	4.67
East Fork Dis.	<0.035	1.27	0.66	0.25	0.07	0.20	0.08	6.85	0.48
West Fork Source Tot. Rec.	0.81	15.56	6.62	2.64	0.65	2.92	0.80	63.06	4.78
East Fork Tot. Rec.	<0.035	1.31	0.69	0.25	0.07	0.21	0.08	6.89	0.50
Mean	0.79	8.41	3.66	1.45	0.35	1.57	0.44	35.01	2.61
Minimum	0.76	1.27	0.66	0.25	0.07	0.20	0.08	6.85	0.48
Maximum	0.81	15.56	6.68	2.65	0.65	2.97	0.80	63.26	4.78

Sample ID	Ce (µg/L)	Eu (µg/L)	Gd (µg/L)	La (µg/L)	Nd (µg/L)	Pr (µg/L)	Sm (µg/L)	Sc (µg/L)
West Fork Source Dis.	217.32	5.80	22.18	102.46	123.94	30.15	23.28	0.48
East Fork Dis.	5.41	0.36	1.21	2.71	3.85	0.84	0.85	0.13
West Fork Source Tot. Rec.	219.28	5.80	21.86	103.29	120.75	29.99	23.19	0.50
East Fork Tot. Rec.	5.50	0.38	1.24	2.81	3.82	0.84	0.89	0.10
Mean	111.88	3.08	11.62	52.82	63.09	15.46	12.05	0.30
Minimum	5.41	0.36	1.21	2.71	3.82	0.84	0.85	0.10
Maximum	219.28	5.80	22.18	103.29	123.94	30.15	23.28	0.50

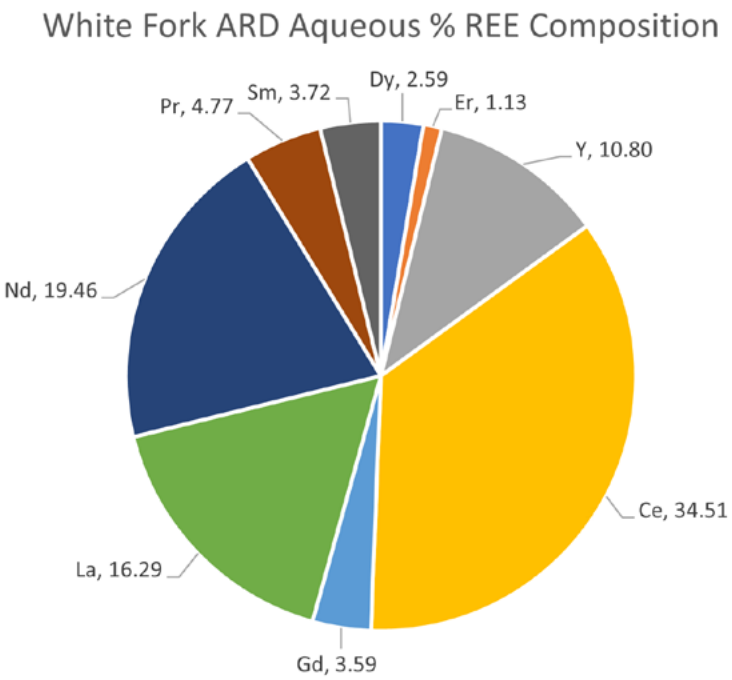
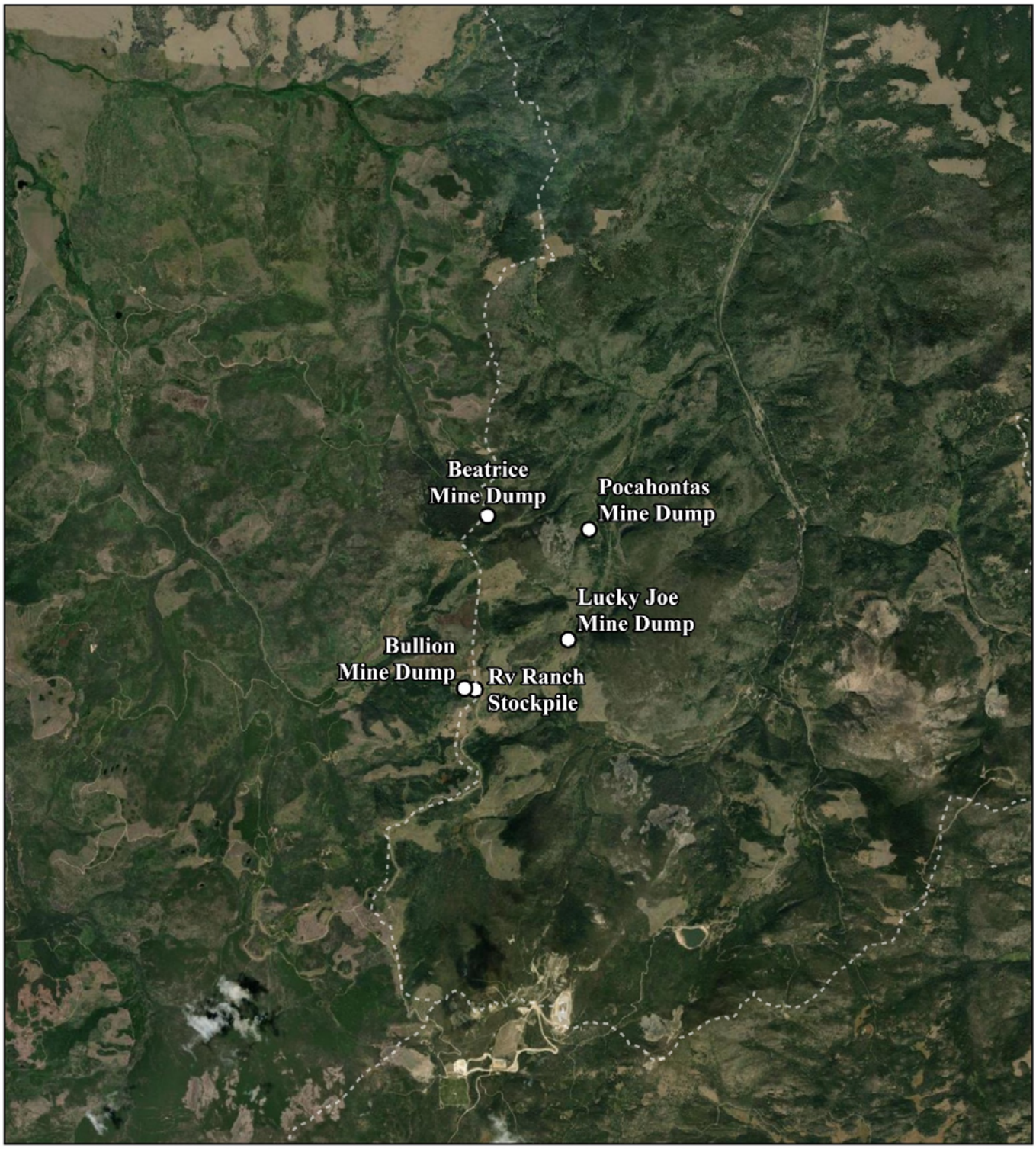


Figure 3-51. The breakdown of REE concentration percentages based on total REEs for all samples taken from the White Fork ARD. Elements with less than 1% concentration were removed.

Table 3-48. White Fork ARD aqueous REE statistics.

Sample ID	Total REE (µg/L)	Coutl
West Fork Source Dis.	623.54	0.99
East Fork Dis.	25.22	2.28
West Fork Source Tot. Rec.	622.50	0.96
East Fork Tot. Rec.	25.56	2.25



MBMG

Ten Mile Drainage Sample Site Locations

Sample Site Location

County Boundary

0 0.5 1 2 Miles

N

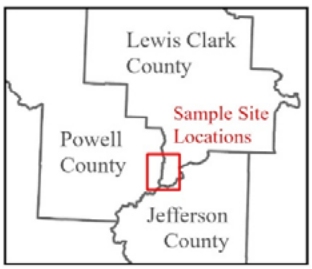


Figure 3-52. Ten Mile Drainage sample site map.



Figure 3-53. Reclaimed mines at the Basin Creek Mine.

Table 3-49. Ten Mile drainage REE data.

Sample ID	Ge (mg/kg)	Dy (mg/kg)	Er (mg/kg)	Ho (mg/kg)	Lu (mg/kg)	Tb (mg/kg)	Tm (mg/kg)	Y (mg/kg)	Yb (mg/kg)
Pocahontas 1	1.90	1.38	1.03	0.36	0.16	0.21	3.54	1.05	157.00
Pocahontas 2	1.60	1.09	0.72	0.25	0.19	0.19	4.56	0.90	153.00
Pocahontas 3	1.40	2.89	1.63	0.58	0.26	0.49	5.37	1.66	166.00
Lucky Joe 1	1.50	2.66	1.33	0.50	0.25	0.44	4.32	1.61	248.00
Lucky Joe 2	1.90	3.70	2.12	0.75	0.32	0.62	8.48	2.13	248.00
Lucky Joe 3	2.00	3.33	2.14	0.72	0.31	0.57	4.64	1.88	272.00
Rv Ranch Stockpile 1	3.30	3.75	2.22	0.76	0.34	0.64	2.84	2.17	220.00
Rv Ranch Stockpile 2	1.60	3.94	2.06	0.74	0.35	0.62	2.80	2.36	186.00
Bullion 1	1.90	1.48	0.87	0.26	0.12	0.22	2.48	0.85	211.00
Bullion 2	2.00	1.73	1.06	0.36	0.16	0.32	4.18	1.09	177.00
Beatrice 1	3.30	1.52	0.83	0.34	0.20	0.23	2.96	1.08	126.00
Beatrice 1 N	1.90	2.89	1.80	0.60	0.27	0.50	3.68	1.88	259.00
Beatrice 2 N	1.50	2.89	1.65	0.59	0.26	0.48	4.25	1.92	178.00
Mean	1.98	2.56	1.50	0.52	0.25	0.43	4.16	1.58	200.08
Minimum	1.40	1.09	0.72	0.25	0.12	0.19	2.48	0.85	126.00
Maximum	3.30	3.94	2.22	0.76	0.35	0.64	8.48	2.36	272.00

Sample ID	Ce (mg/kg)	Eu (mg/kg)	Gd (mg/kg)	La (mg/kg)	Nd (mg/kg)	Pr (mg/kg)	Sm (mg/kg)	Sc (mg/kg)
Pocahontas 1	23.10	0.23	1.25	13.20	7.90	2.37	1.66	7.00
Pocahontas 2	28.60	0.30	1.33	15.80	10.90	2.98	1.70	7.00
Pocahontas 3	67.30	0.75	2.86	37.10	23.80	7.00	3.63	8.00
Lucky Joe 1	106.00	0.70	3.12	62.40	32.60	10.20	4.87	8.00
Lucky Joe 2	152.50	0.98	4.13	91.30	44.50	13.85	6.17	8.00
Lucky Joe 3	85.20	0.89	3.94	45.40	32.40	9.09	5.13	8.00
Rv Ranch Stockpile 1	66.80	1.11	4.15	34.80	29.40	7.53	5.13	8.00
Rv Ranch Stockpile 2	70.20	1.15	4.19	36.60	29.90	7.82	5.18	8.00
Bullion 1	49.90	0.58	1.65	27.40	18.20	5.24	2.74	8.00
Bullion 2	53.60	0.62	2.34	27.90	21.50	5.94	3.44	9.00
Beatrice 1	34.40	0.31	1.38	18.90	12.90	3.72	2.00	6.00
Beatrice 1 N	85.90	0.47	3.64	47.80	31.70	9.04	5.66	12.00
Beatrice 2 N	72.70	0.71	3.47	33.50	27.70	7.21	4.82	12.00
Mean	68.94	0.68	2.88	37.85	24.88	7.08	4.01	8.38
Minimum	23.10	0.23	1.25	13.20	7.90	2.37	1.66	6.00
Maximum	152.50	1.15	4.19	91.30	44.50	13.85	6.17	12.00

Table 3-50. Ten Mile drainage REE statistics.

Sample ID	Total REE (mg/kg)	CoutI
Pocahontas 1	223.34	0.06
Pocahontas 2	231.11	0.08
Pocahontas 3	330.72	0.13
Lucky Joe 1	488.50	0.11
Lucky Joe 2	589.45	0.13
Lucky Joe 3	477.64	0.11
Rv Ranch Stockpile 1	392.94	0.14
Rv Ranch Stockpile 2	363.51	0.15
Bullion 1	332.89	0.08
Bullion 2	312.24	0.11
Beatrice 1	216.07	0.10
Beatrice 1 N	468.73	0.11
Beatrice 2 N	353.65	0.14

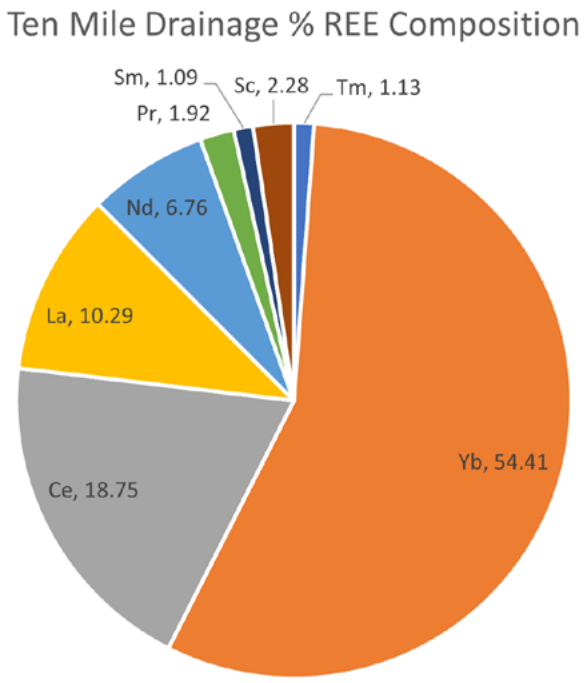


Figure 3-54. The breakdown of REE concentration percentages based on total REEs for all samples taken from the Ten Mile Drainage. Elements with less than 1% concentration were removed.

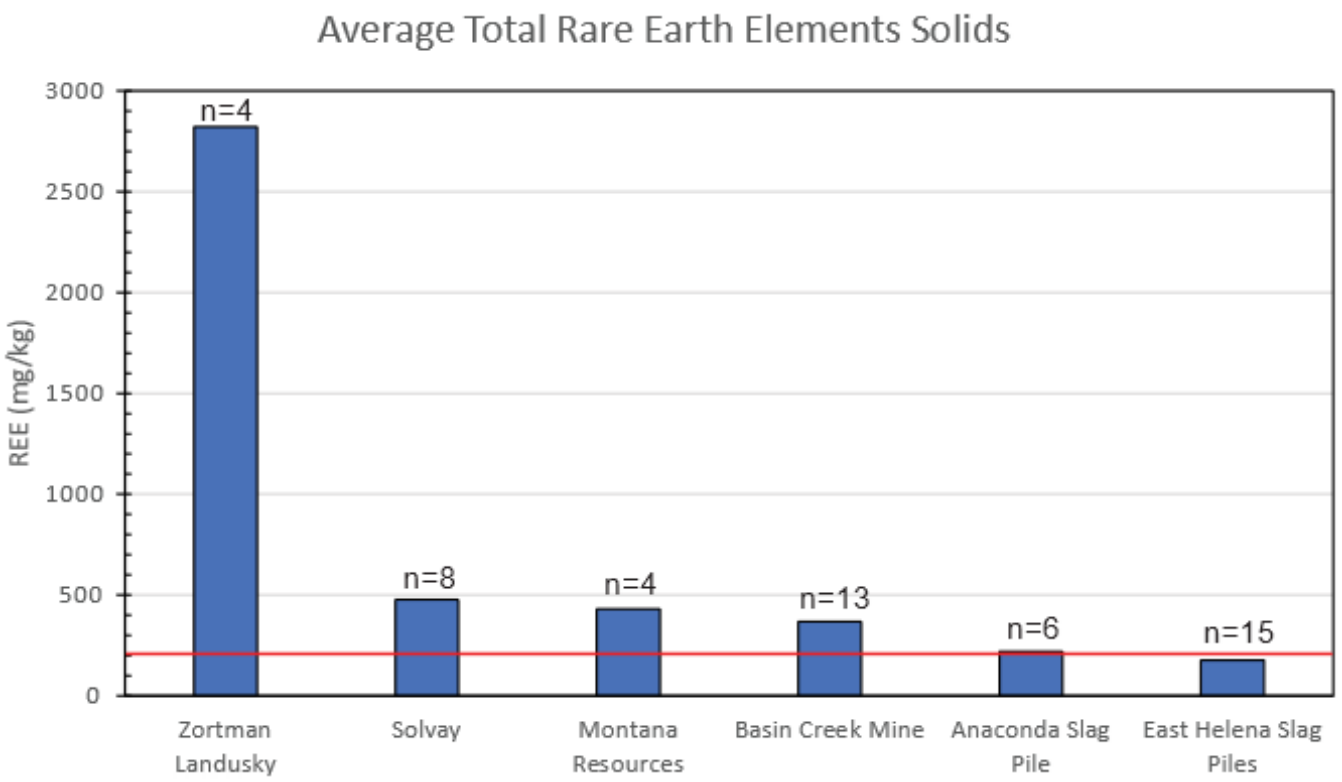


Figure 3-55. Average total REE concentrations per solid sample of all sites over 150 mg/kg. The red line represents the average REE concentration in the Earth's crust, which is ~206 mg/kg.

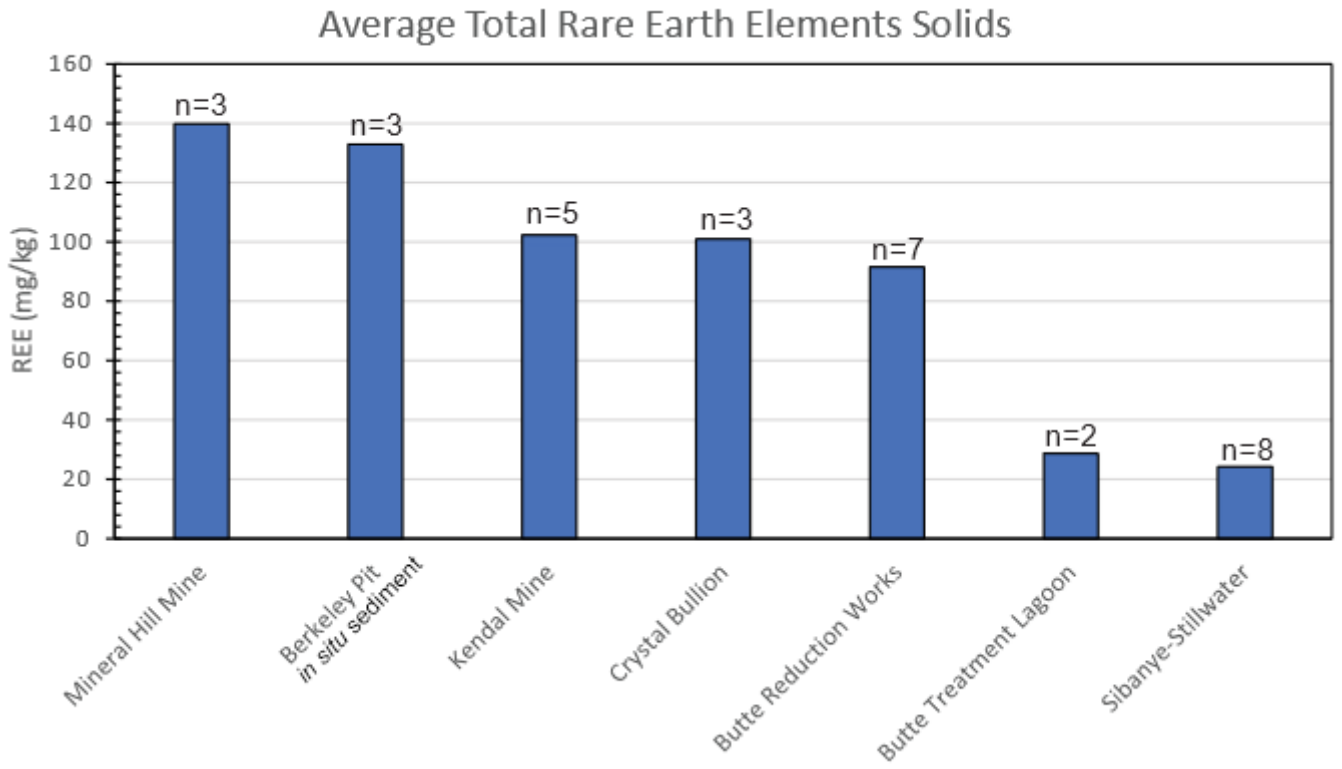


Figure 3-56. Average total REE concentrations per solid sample of all sites under 150 mg/kg.

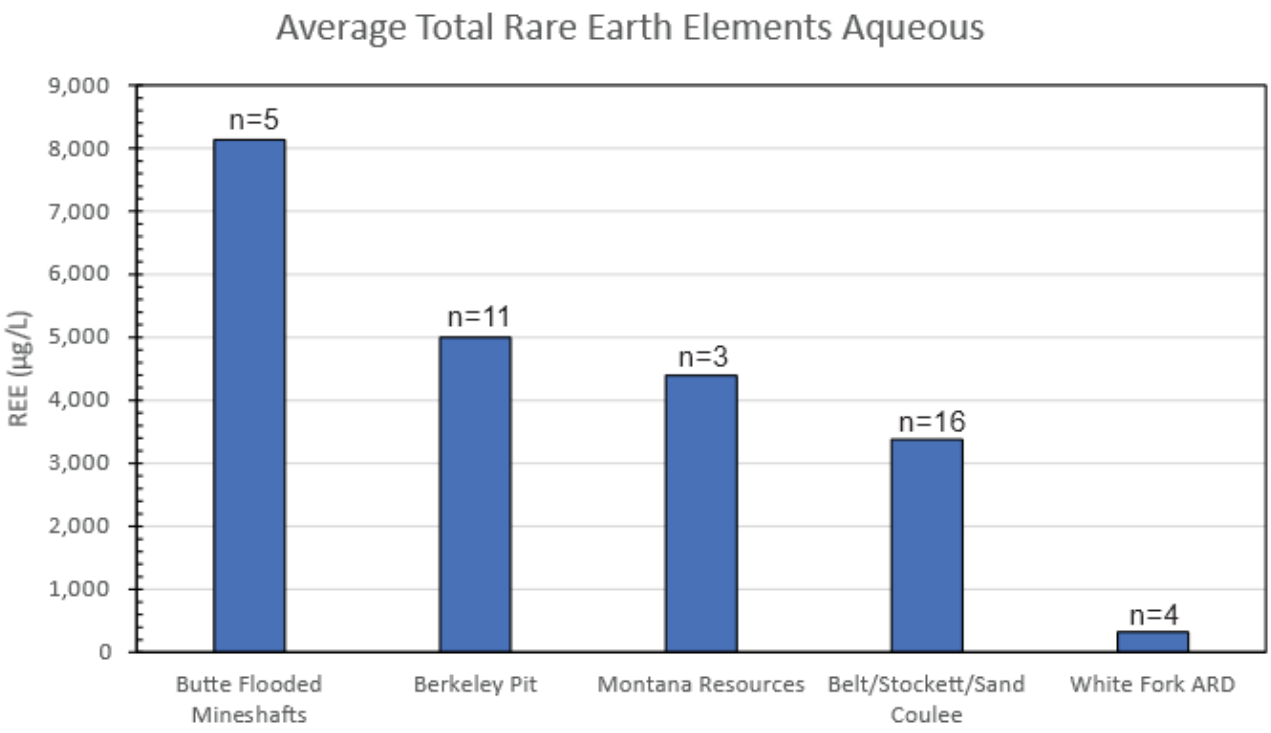


Figure 3-57. Average total REE concentrations per aqueous sample of all sites over 150 µg/L.

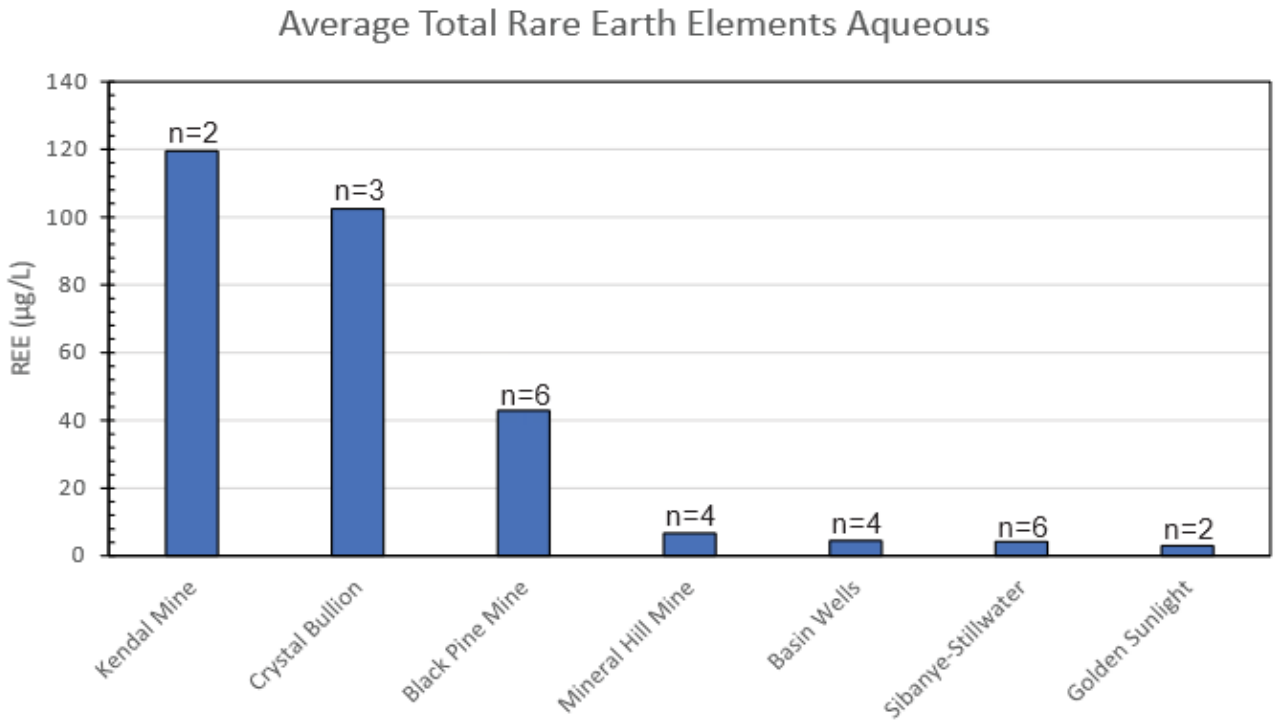


Figure 3-58. Average total REE concentrations per aqueous sample of all sites under 150 µg/L.

5.0 ACKNOWLEDGMENTS

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