Modern Mine Study:

Water Quality Performance and Predictions at U.S. Mines Permitted Since 1990

Prepared by Northeastern Minnesotans for Wilderness exclusively for Minnesota State regulatory agencies

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Executive Summary

Overview and questions addressed

This study reviews eight hardrock mines across the United States to determine whether U.S. nonferrous hardrock metallic mineral mines permitted under modern mining regulations have degraded the quality of downstream surface waters and/or downgradient groundwaters. The study reviews water quality predictions and monitoring data for post-1990 U.S. hardrock mines with a processing capacity of more than 1,000 tons of ore per day for which adequate data were available as of the report date. Mines in desert environments and mines located in areas with impacts from historic mining that cannot be separated from the impacts of the current operation were eliminated from consideration. Further detail regarding the issues considered or the selection of mines and the rationale for those selections can be found in the *Study Plan* (Appendix A) and the *Application of the Study Plan* (Appendix B).

This study seeks to address the following questions to the extent allowed by available data:

1. Has the mine increased the concentrations of any mine-related pollutant in surface water?
2. Has the mine increased the concentrations of any mine-related pollutant in groundwater?
3. Does the mine have any permit violations related to effluent discharges?
4. Has the mine resulted in any exceedances of surface water or groundwater quality criteria or standards?
5. Will mining-impacted water require long-term collection and treatment?
6. Was the quality of mine leachate, treated or untreated effluents or discharges, and/or receiving water accurately predicted?

An overview of the mines in terms of their basic components (including commodity, operational status, dates and type of operation and processing, and material extracted) is provided in Table ES-1. Information on aspects of the mines that affect their potential to adversely impact water resources is included in Table ES-2.

Overview of water quality and quantity impacts and prediction errors

Of the eight mines investigated, all have degraded downstream surface water quality. Seven of the eight mines are known to have degraded downgradient groundwater; at the eighth, no groundwater data are publicly available. At least six and possibly all eight mines have resulted in exceedances of water quality criteria or standards in either surface water or groundwater; seven have exceeded permit limits.

Six of the eight mines have numeric predictions and monitoring data available that enable a comparison of water quality predictions with water quality outcomes. At six mines, outcomes are significantly worse than predicted. In assessing the potential for waste rock at the mine site to generate acid, two underestimated the potential, two were accurate, and the remaining four have insufficient data for a determination. At least four mines underestimated the potential for non-acid generating rock to leach constituents under neutral pH conditions. Six of the mines underpredicted the volume of water that would need to be treated and/or discharged.

Of the eight mines included in this study, six include tailings facilities. The Beartrack Mine in Idaho processed ore using a heap leach process, which does not produce tailings. Spent ore remains at the Beartrack site on the heap leach pad. The Flambeau Mine in Wisconsin produced a high-grade ore that was shipped to Canada for processing. Conclusions regarding the potential to mine without impacting water quality cannot be drawn from the experience at Flambeau, as half of the mining process was conducted at another location for which we have no data or information.

For most of the mines in this study, compliance with water quality standards was the regulatory goal. However, a few of the mines had stricter goals for one or more facility. At the East Boulder Mine in Montana, discharge limits were set for several parameters based on a non-degradation goal. These limits have not been met. The permit for the Buckhorn Mine in Washington States includes limits that are often more protective than State water quality standards and that apply at monitoring locations outside the "capture zone." Again, these permit limits have been exceeded. Also, the Buckhorn Mine permit limits are set higher than actual background concentrations to avoid the possibility of charging the permittee with violations that are caused by natural background conditions. Even this more protective approach allows degradation of water quality. Finally, many mines include specific facilities that are deemed "zero discharge." These facilities should cause no degradation of groundwater or surface water downgradient of the facility. An example is the collection pond designed to capture leachate from the toe of the tailings facility at the Pogo Mine in Alaska (the "recycle tailings pond"). Built as a zero-discharge facility, groundwater downgradient of the pond has nonetheless been degraded to the point of exceeding water quality standards.

Three of the eight mines (Beartrack, Buckhorn, and Flambeau) have ceased operating and are in the closure phase. The Beartrack and Flambeau mines have had their greatest impact on water quality after closure. For all the mines, the record of water quality impacts is not yet complete. For most of the mines, the closure plan includes continuing water treatment until water quality standards can be met without treatment. At that point, degradation may increase. In particular, constituents such as total dissolved solids and sulfate (which are typically found at high levels in water treatment plant influent and typically have no enforceable surface water quality standard) will increase in the receiving water. This degradation will often be very long-term, if not permanent.

Table ES-1. Basic information on mines examined in this study and two proposed mines in Minnesota.

Mine or Project, State	Commodity	Active/ Closed/ Proposed	Production period (through 2024)	Disturbed acreage (total or plus tailings)	Underground/ Open pit	Deposit type	Processing method(s)	Ore processed (tons per day/total to date or LOM)	Waste rock (million tons to date or over life of mine)
Beartrack Mine, ID	Gold	Closed	1994-2000 (7 years)	700 (total)	Open pit	Mesothermal, orogenic, or shear zone-hosted deposit	Cyanide heap leaching	14,991/24 MT	35 MT
Buckhorn Mine, WA	Gold	Closed	2008-2017 (10 years)	46 (plus tailings and borrow site)	Underground	Skarn	Cyanide vat leaching	1,500/4 MT	500 tpd; 1.3 MT total?
Eagle Mine, MI	Nickel, copper	Active	2014-present (11 years)	92 (plus tailings)	Underground	Ultramafic intrusion; high-grade magmatic sulfide deposit with semi-massive and massive sulfides	Flotation	2,000/7.3 MT (to end of 2023)	2.4 MT (as of end of 2023)
East Boulder Mine, MT	Platinum, palladium	Active	2000-present (25 years)	263 (plus off-site land application wastewater disposal)	Underground	Precambrian Stillwater Complex: layered ultramafic gabbroic intrusion	Flotation	2,850/18 MT (as of 2023)	7.3 MT (as of 2023)
Flambeau Mine, WI	Copper	Closed	1993-1997 (5 years)	32 (no tailings or processing)	Open pit	Volcanogenic massive sulfide	None (ore shipped to Canada)	1,300/1.9 MT	7 MT
Haile Gold Mine, SC	Gold	Active	2017-present (8 years)	2,612 (total)	Open pit	Low-sulfidation, disseminated, sediment-hosted gold deposit; replacement type-epithermal deposit	Cyanide vat leaching	13,000/66.5 MT (projected LOM)	526 MT (projected LOM)

Mine or Project, State	Commodity	Active/ Closed/ Proposed	Production period (through 2024)	Disturbed acreage (total or plus tailings)	Underground/ Open pit	Deposit type	Processing method(s)	Ore processed (tons per day/total to date or LOM)	Waste rock (million tons to date or over life of mine)
Kensington Mine, AK	Gold	Active	2010-present (15 years)	239 (total)	Underground	Mesothermal gold-quartz deposit	Flotation	2,000/7.4 MT (to end of 2022)	3.5 MT (as of end of 2022)
Pogo Mine, AK	Gold	Active	2006-present (19 years)	360 (total)	Underground	Reduced Intrusive Related Gold Deposit, low sulfide content (typically <5%); typically pyrite, lacks primary magnetite or hematite	Flotation and cyanide vat leaching	3,000/18.6 MT (end of 2022)	13 MT (as of end of 2022) disposed of on surface (does not include backfill)
Mines proposed in Minnesota as basis for comparison									
NorthMet Project, MN	Copper	Proposed	20 years	1,718 (plus tailings)	Open pit	Disseminated sulfides with minor, local, massive sulfides hosted in ultramafic rocks	Flotation and autoclave leaching	32,000/225 MT	308 MT
Twin Metals Project, MN	Copper, nickel	Proposed	25 years	1,156 (total)	Underground	Contact-style mafic copper-nickel deposit	Flotation	20,000/180 MT	33 MT left underground; 1.7 MT brought to surface; 34.7 MT total
LOM life of mine; MT million tons; tpd tons/day									

Table ES-2. Information on the eight study mines and the two proposed mines in Minnesota that could affect the mine's potential to adversely impact water resources.

	Climate		*Facilities*				*Acid Generation Potential*			
Mine or Project, State	**Annual precipitation**	**Streams on site?**	**Tailings facility**	**Surface permanent waste rock stockpiles**	**Permanent pit lake?**	**Backfilled PAG waste?**	**Maximum sulfur content in ore or waste rock**	**PAG waste rock?**	**PAG tailings?**	**Maximum sulfur % in tailings**
Beartrack Mine, ID	23.8 in.	Yes	None	103 acres, unlined, NPAG; heap leach pad with spent ore remaining on pad	Yes	Yes	3.62% (ore)	Yes	Yes (spent ore on leach pad)	1.15% (spent ore)
Buckhorn Mine, WA	20 in.	Yes	Off-site, pre-existing; upstream construction	None	No	Yes	14.5% (waste rock)	Yes	Unknown	2.46%
Eagle Mine, MI	35 in.	No	Disposal in former mined-out pit; pre-existing, multiple projects	None	No	Yes	38% (ore)	Yes	Yes	32.8%
East Boulder Mine, MT	20-25 in.	No	Downstream construction	None	No	No	<1% (ore)	No	No	0.06% in composite sample
Flambeau Mine, WI	31 in.	Yes	None	None	No	Yes	4.8% (waste rock); >50% (ore)	Yes	No	n/a
Haile Gold Mine, SC	46 in.	Yes	Downstream construction	Several PAG and NPAG stockpiles, >1,000 acres	Yes	Yes	15%	Yes	Yes	30%

	Climate		*Facilities*				*Acid Generation Potential*			
Mine or Project, State	**Annual precipitation**	**Streams on site?**	**Tailings facility**	**Surface permanent waste rock stockpiles**	**Permanent pit lake?**	**Backfilled PAG waste?**	**Maximum sulfur content in ore or waste rock**	**PAG waste rock?**	**PAG tailings?**	**Maximum sulfur % in tailings**
Kensington Mine, AK	63-81 in.	Yes	Downstream construction	36 acres, unlined, NPAG	No	Yes	30.8% (ore)	Yes	No	0.04% in composite sample
Pogo Mine, AK	19 in.	Yes	Filtered ("drystack") facility with dammed catchment pond; paste backfill	PAG and NPAG, in tailings facility	No	Yes	2.98% (waste rock)	Yes	Yes (backfilled in mine)	unknown
Mines proposed in Minnesota as basis for comparison										
NorthMet Project, MN	28 in.	Yes	Upstream construction; pre-existing	526 acres, unlined, NPAG	Yes	Yes	5.0% (waste rock)	Yes	No	0.24%
Twin Metals Project, MN	30.2 in.	Yes	Filtered ("dry stack") facility with contact water storage ponds; backfill	None	No	Yes	5.0% (ore)	Yes	No	0.20%
PAG potentially acid generating; NPAG non-PAG										

Summary of Findings

Impacts on Water Quality

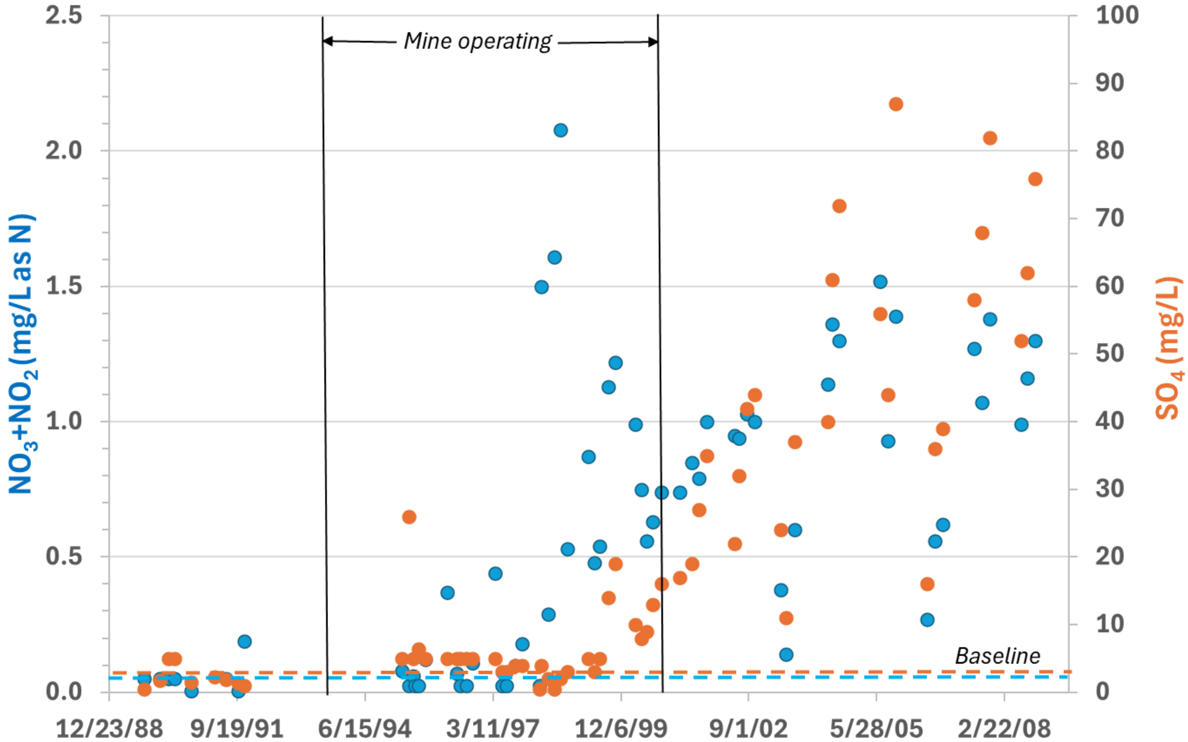
A primary purpose of this study is to determine the likelihood that modern mines will degrade the quality of downstream surface water and downgradient groundwater. This summary addresses two topics related to that question: impacts on water quality and accuracy of predictions. Two graphs representative of the changes in surface water and groundwater concentrations over time due to mining activity are included in this section.

Degradation of surface water quality

All eight mines in this study have degraded water quality in downstream surface waters.

Beartrack Mine, Idaho

- In a headwater stream, specific conductance rose from 37 to 217 µS/cm and sulfate concentrations rose from 2.3 to 63 mg/l.
- Mercury levels in brook trout fillets rose from 150 to 440 µg/kg.
- Farther downstream, specific conductance rose from 29 to 80 µS/cm, sulfate concentrations rose from 1 to 16 mg/l, and arsenic concentrations rose from less than 5 to 136 µg/l.
- Nitrate+nitrite concentrations (from the use of blasting agents) peaked during mine operations at 2.08 mg/l as N, while sulfate concentrations (from oxidation of sulfides in mined materials) began to rise in 1999 after the mine closed and peaked in 2005 at 87 mg/l. Concentrations of both constituents remained considerably elevated over baseline during the closure period, as shown in the following graph.



Beartrack Mine. Nitrate+nitrate and sulfate concentrations from 1989 to 2008 in Ward Gulch, WQ-4, downstream of the sedimentation pond dam and the South Pit, showing the dates of mine operation (1994-2000) and baseline values for the two constituents. (see the Beartrack Mine chapter for data sources)

Buckhorn Mine, Washington

- In a headwater stream, sulfate concentrations rose from 35 to 72 mg/l at the monitoring location closest to the mine, and from 25 to 42 mg/l one mile downstream.
- In a second headwater stream, chloride concentrations rose from 1.5 to 55 mg/l.
- Farther downstream, nitrate and sulfate concentrations are approximately 3 to 6 times higher than in more upstream locations. Sulfate concentrations increased from less than 10 mg/l to as high as 40 mg/l.

Eagle Mine, Michigan

- In a headwater stream, chloride and sulfate concentrations both rose from below the quantification limit of 1 mg/l to 1.7 mg/l.
- In the Escanaba River, TDS values increased from 114 mg/l to 192 mg/l, and sulfate concentrations increased from 3.2 to 27.5 mg/l from an unimpacted station to downstream of the treated effluent discharge location.

East Boulder Mine, Montana

- In the East Boulder River three thousand feet downstream of mine facilities, nitrogen concentrations are 50 to 60% higher than upstream of the mine. TDS values have increased from a baseline of 62 mg/l to 87 mg/l; sulfate concentrations increased from 2.4 to 4.2 mg/l.

Flambeau Mine, Wisconsin

- In a headwater stream, the copper concentration rose from a baseline of 2 to 4 µg/l to above 22 µg/l, with a maximum concentration of 88 µg/l.
- Insufficient monitoring is conducted in the Flambeau River to allow conclusions, but aluminum and manganese concentrations have increased above baseline values.

Haile Gold Mine, South Carolina

- In a headwater stream, specific conductance increased from 32 µS/cm upstream of the mine to 1930 µS/cm immediately downstream of the mine, and reached 1600 µS/cm a mile downstream. Sulfate concentrations increased from 19 to 27 mg/l in the early years of mining to above 1000 mg/l in 2019.
- In the Little Lynches River, specific conductance increased from 43 µS/cm upstream to 420 µS/cm downstream of the mine. Manganese concentrations increased from 50 µg/l upstream to as high as 5000 µg/l downstream of the mine.

Kensington Mine, Alaska

- In a headwater stream, TDS values increased tenfold, sulfate concentrations increased fiftyfold, and nitrate concentrations increased twentyfold between upstream of the mine and the most impacted monitoring location.
- In a second headwater stream, TDS values increase threefold, sulfate concentrations increased fortyfold, and nitrate concentrations increased fiftyfold downstream of the mine.

Pogo Mine, Alaska

- No monitoring is conducted in a headwater stream that is likely impacted by mine activity.
- In the Goodpaster River a half-mile downstream of all mine facilities, TDS values have increased from a baseline of 72 mg/l to 112 mg/l.

Of the eight mines, five are known to have increased sulfate concentrations in downstream waters by more than 10 mg/l, as shown in Summary Table 1. While there is no data showing this degree of impact at the East Boulder, Flambeau, and Pogo Mines, impacted headwater streams at the Flambeau and Pogo Mines are not monitored for sulfate. This is also true of the most impacted stretch of the East Boulder River at the East Boulder Mine.

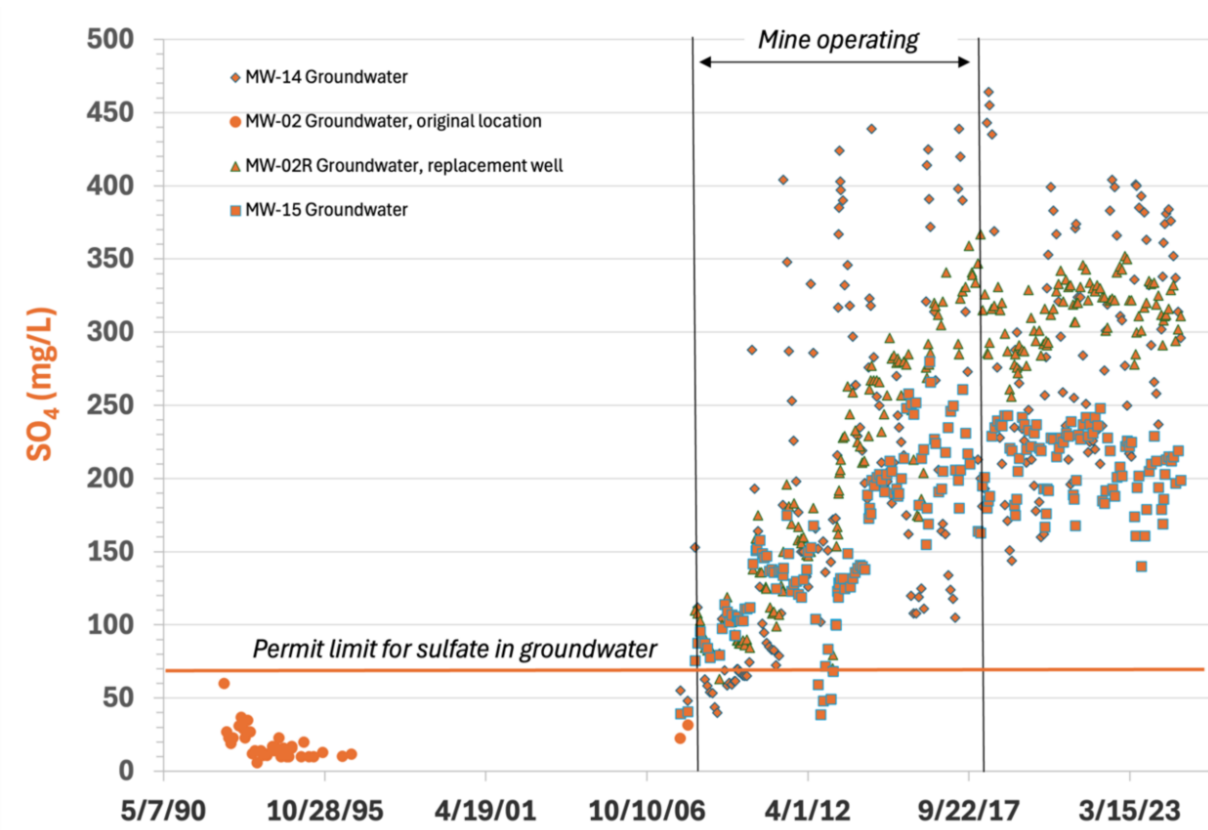
Summary Table 1: Increased sulfate concentrations in downstream surface waters.

Mine	Stream and station designation	Upstream or baseline concentration	Maximum impacted concentration	Distance from source	Type of source
Beartrack	Wards Gulch, WQ-4	2.3 mg/l (upstream)	63 mg/l	1,500 feet	Diffuse
	Napias Creek, WQ-9	2 mg/l (upstream)	17 mg/l	500 feet	Direct discharge
Buckhorn	Nicholson Creek headwaters, GW-02	35 mg/l (baseline)	88 mg/l	1,200 feet	Diffuse
	Nicholson Creek, SW-07	25 mg/l (baseline)	44 mg/l	One mile	Diffuse
	Sanpoil River, SW-4	< 10 mg/l (upstream)	44 mg/l	2,000 feet	Diffuse
Eagle	Salmon Trout River, STRM-002	< 1 mg/l (upstream)	1.6 mg/l	One mile	Diffuse
	Escanaba River, MER-003	3.2 mg/l (upstream)	27.5 mg/l	3,000 feet	Direct discharge
East Boulder	East Boulder River, EBR-4A	2.4 mg/l (upstream)	4.7 mg/l	3,000 feet	Diffuse
Haile	Haile Gold Mine Creek, SW-09	27 mg/l (baseline)	1100 mg/l	One mile	Diffuse and direct discharge
	Little Lynches River, SW-12A	< 5 mg/l (baseline)	605 mg/l	1.2 miles	Diffuse and direct discharge
Kensington	Ophir Creek, SH-103	2.5 mg/l (upstream)	201 mg/l	500 feet	Diffuse
	Sherman Creek, SH-113	8 mg/l (upstream)	62 mg/l	500 feet	Direct discharge
	Sherman Creek mouth, SH-105	8 mg/l (upstream)	30 mg/l	1.5 miles	Diffuse and direct discharge
	Slate Creek, SMP5	2.5 mg/l (upstream)	105 mg/l	500 feet	Direct discharge
	Slate Creek, SLB	2.5 mg/l (upstream)	117 mg/l	3,000 feet	Diffuse and direct discharge
Pogo	Goodpaster River, SW-41	34 mg/l (upstream)	36 mg/l	2,000 feet	Diffuse and direct discharge

Degradation of groundwater quality

Groundwater quality has been degraded at all seven mines that are monitored; the Kensington Mine includes no groundwater monitoring. Monitoring at the Beartrack and Flambeau mines is insufficient to determine the extent of impacts beyond those in the immediate location of backfilled pits, where downgradient groundwater is heavily impacted. We have insufficient data from the Haile Gold Mine to determine the extent of impacts, but constituents in groundwater are increasing in some locations.

The Buckhorn, Eagle, and Pogo mines have all degraded groundwater to the point of violations of water quality standards or permit limits at compliance points. At the East Boulder Mine, groundwater at a compliance well a mile downgradient of mine facilities has an average TDS concentration of 233 mg/l compared to 93 mg/l in unimpacted wells; the average sulfate concentration is 27.5 mg/l compared to 1.6 mg/l in unimpacted wells, and the average total inorganic nitrogen concentration is 2.85 mg/l compared to 0.1 mg/l in unimpacted wells. The following figures show the increase in sulfate concentrations in three groundwater compliance wells relative to pre-mining baseline values and the permit limit for groundwater outside the capture zone.



Buckhorn Mine. Groundwater in the NLF-3 Fault in MW14, MW2/2R, and MW15, outside the capture zone boundary, downgradient of the Gold Bowl Zone of the underground mine. The monthly average permit limit for sulfate is 69.5 mg/l. (see the Buckhorn Mine chapter for data sources)

Exceedances of water quality criteria and standards

At least six of the eight mines have caused exceedances of water quality criteria and standards in either surface water or groundwater. The Beartrack, Flambeau, Kensington, and probably Haile mines have caused exceedances of surface water standards.

At the Beartrack Mine, arsenic concentrations in Napias Creek were above the standard to protect human health from arsenic in fish for at least two years. The mine also appears to have caused an increase in fish tissue mercury to above the U.S. EPA standard to protect human health. The Flambeau Mine has caused ongoing exceedances of acute water quality criteria for copper and occasional exceedances of acute water quality criteria for zinc in a headwater stream. The Kensington Mine has a site-specific surface water standard of 1,000 mg/l for TDS, which has been exceeded in a headwater creek on at least three occasions. (The statewide standard is 500 mg/l.) The sulfate and nitrate standards are also occasionally exceeded. Also at the Kensington Mine, a tailings pipeline ruptured in January 2024, resulting in exceedances of the acute toxicity criteria for aluminum, copper, and zinc a half-mile downstream of the spill.

South Carolina's surface water criterion for nickel is based on the hardness of the water, but surface water monitoring at the Haile Gold Mine does not include hardness as a parameter. We therefore cannot say for certain what the nickel criterion is. However, using the baseline hardness of the receiving water, the nickel criterion was likely exceeded at the Haile Gold Mine Creek in late 2019/early 2020.

The Buckhorn, Eagle, Pogo, and East Boulder mines have all exceeded drinking water standards that apply to groundwater. At the Buckhorn Mine, groundwater wells outside the "capture zone" frequently exceed State groundwater quality standards for TDS (500 mg/l) and sulfate (250 mg/l). TDS values are also above the groundwater standard at the Kettle River Mill, where the Buckhorn Mine ore was processed.

Michigan does not have groundwater standards per se but applies the U.S. EPA standards for drinking water to groundwater. One well at the Eagle Mine had chloride concentrations above the 250-mg/l standard from winter 2013 through fall of 2017. Two wells at the Eagle Mine’s Humboldt tailings facility were above the chloride standard for 16-month periods in each well in 2020 and 2021.

At the Pogo Mine, the nitrate drinking water standard of 10 mg/l as N is often exceeded in groundwater downgradient of the tailings facility and the tailings recycle pond. In 2023, the exceedance extended to a well that is a mile downgradient of the mine. Arsenic concentrations were also above the drinking water standard in 2022.

Groundwater exceeds the drinking water standards for nitrate and TDS at the East Boulder Mine. In 2010, however, a compliance boundary was added to the permit; wells that exceeded groundwater standards were included within the boundary so that the exceedances would no longer be considered permit violations. One well that is just inside the boundary has an average nitrate level of 20 mg/l as N, twice the drinking water standard. Groundwater almost certainly exceeds the standard beyond the compliance boundary here, but there is no monitoring beyond the boundary in this location.

Extended exceedances of permit limits

Six of the eight mines (all but East Boulder and Flambeau) have had extended periods of exceedances of permit limits for one or more parameter. The East Boulder NPDES permit had no permit limits other than a nitrogen daily load limit (in total pounds rather than as a concentration) until September 2023. Its first exceedance of a permit limit (for lead) was in November 2023. The ongoing discharge from the Flambeau Mine causing exceedances of water quality standards is not subject to a NPDES permit and has no permit limits.

Extended exceedances for the other mines include:

> ***Beartrack Mine****:* Cadmium concentrations exceeded permit limits for 43 of 58 months from 2003 to 2008.
>
> ***Buckhorn Mine:*** Thousands of exceedances of permit limits for chloride, nitrate, sulfate, TDS, specific conductance, arsenic, ammonia, iron, manganese, zinc, mercury, copper, and lead occurred between 2008 and 2024.
>
> ***Eagle Mine:*** From 2017 to 2019, Eagle effluent at the Key Mill failed Whole Effluent Toxicity tests for chronic toxicity on seven occasions.
>
> ***Haile Gold Mine:*** Thallium concentrations exceeded permit limits for six months in 2019 and 2020. The effluent has repeatedly failed Whole Effluent Toxicity tests from 2021 to the present.
>
> ***Kensington Mine:*** Over two hundred discharge violations occurred prior to 2019; parameters included pH, copper, ammonia, sulfate, turbidity, manganese, and toxicity. In addition, stormwater discharge exceeded the zinc benchmark in all but one monitoring event since September 2021, and it consistently exceeded the benchmark for cadmium since June 2023.
>
> ***Pogo Mine****:* Cyanide concentrations in effluent exceeded the NPDES permit monthly average limits for a five-month period in 2022. In addition, groundwater limits for nitrate and chloride have been routinely exceeded for at least fourteen years.

Accuracy of predictions

A secondary purpose of this study is to assess the recent track record of the mining industry and regulators in accurately predicting a mining operation's impact on water. Factors affecting water quality range from the quality of leachate from disturbed rock (waste rock, tailings) at the site to the efficacy of mine water treatment.

Accuracy of water quality predictions

Most mine permitting and environmental review processes include preparing predictions for such things as the quality of water pumped out of the mine; leachate from waste rock; tailings interstitial or ponded (supernatant) water; and water quality in the mine workings after closure. Six of the eight mines have pre-mining numeric water quality predictions for at least one mine feature and operational monitoring results to compare to those predictions. We do not have a matched set of predictions and monitoring data for any mine feature at the Haile or Beartrack mines.

Of the six mines for which we have both numeric predictions and monitoring data, all predicted that water quality would be significantly better than it is.

Buckhorn Mine, Washington

- The mine water prediction for TDS ranged from 150 to 251 mg/l; the actual average was 894, with a maximum of 1760 mg/l. Other parameters that were underestimated include aluminum, chromium, copper, and iron, arsenic, ammonia, and nitrate.
- Leachate from waste rock was predicted to have a "worst case" TDS concentration of 1519 mg/l; in the only monitoring event for which we have data, the actual concentration was 2480 mg/l.

Eagle Mine, Michigan

- Actual mine water concentrations have been an order of magnitude higher than predictions for aluminum, barium, copper, and iron, and at least five times higher than predictions for sulfate and chromium.
- Leachate from waste rock has been 2 to 3 orders of magnitude higher than predicted for aluminum, cobalt, and manganese, more than an order of magnitude higher for chloride and molybdenum, and four times higher for sulfate.

East Boulder Mine, Montana

- In mine water, the TDS concentration was predicted to be 338 mg/l; operational monitoring results averaged 660 mg/l, with a maximum of 1230 mg/l. The nitrogen concentration in mine water was predicted to be 9.5 mg/l as N; the average of monitoring results was 57 mg/l, with a maximum of 142 mg/l as N.
- Groundwater at the discharge location was predicted to have a TDS concentration of 167 mg/l; monitoring results have averaged 503 mg/l. Manganese concentrations were predicted to be less than 20 µg/l; monitoring results have averaged 93 µg/l.

Flambeau Mine, Wisconsin

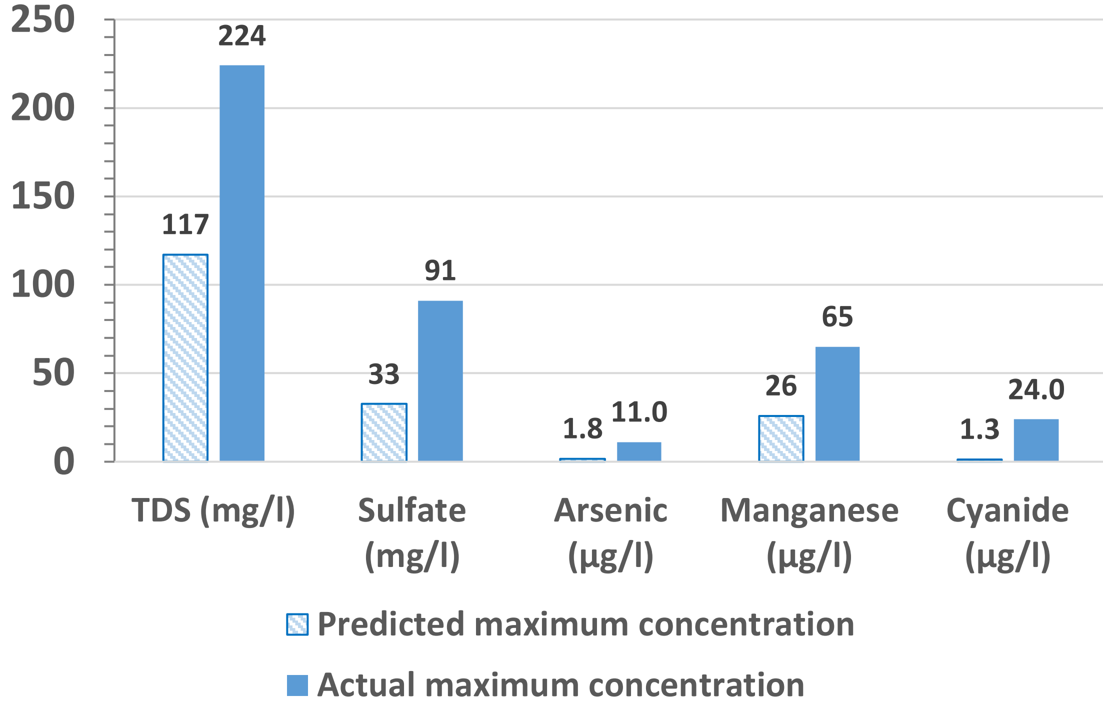
- The copper concentration in the backfilled pit groundwater was predicted to be 14 µg/l; results from monitoring data have been as high as 700 µg/l in the pit groundwater and as high as 170 µg/l in groundwater outside the pit.
- The manganese concentration in backfilled pit groundwater was predicted to be 725 µg/l; monitoring results showed that concentrations were as high as 40,000 µg/l in the pit backfill and 12,000 µg/l in groundwater outside the pit.
- It was predicted that pH would never fall below 6.5; it occasionally falls below 6.0.

Kensington Mine, Alaska

- Treatment plant influent was predicted to have an aluminum concentration of 550 µg/l; the monthly average from 2007 to 2011 was 6167 µg/l with a maximum concentration of 23,375 µg/l. Predicted copper, iron, lead, and zinc concentrations were also underestimated. Accurate influent concentrations are needed to plan for the most reliable mine water treatment approaches.
- Tailings water was predicted to have a mean TDS concentration of 259 mg/l and a maximum of 342 mg/l; actual values have averaged 592 mg/l, with a maximum of 961 mg/l. The predicted mean and maximum ammonia concentrations were 0.856 and 1.2 mg/l as N, respectively; monitoring results have averaged 2.74 mg/l, with a maximum of 5.35 mg/l as N. The predicted mean and maximum sulfate concentrations were 127 and 187 mg/l, respectively; monitoring results averaged 311 mg/l, with a maximum of 542 mg/l.

Pogo Mine, Alaska

- The predicted mean sulfate concentration in tailings water was 302 mg/l; monitoring results averaged 2220 mg/l in 2023. The predicted mean TDS value was 600 mg/l; mean monitoring results averaged 3950 mg/l. Maximum measured concentrations of arsenic, copper, and selenium all exceeded their predicted worst-case concentrations.
- Predicted maximum effluent concentrations in Outfall 001 were consistently lower than measured values, as shown in the following figure.



Pogo Mine. Predicted vs. Actual Maximum Concentrations in Treatment Plant Outfall 001.
See the Pogo Mine chapter for data sources.

Errors in predicting the potential for rock to generate acid

Planning a hardrock mine includes evaluating, through geochemical testing, the degree to which ore, waste rock, tailings, and pit walls or underground workings might generate acid. Of the eight mines in this study, two (Beartrack and Kensington) miscalculated the potential for the development of acidic conditions. One mine (Eagle) treats all rock at the site as potentially acid-generating, and another mine (East Boulder) appears to have no rock at the site with the potential to generate acid. There is insufficient data from the other four mines to determine whether acid drainage predictions were accurate.

Errors in predicting the potential for non-acid generating rock to leach mine contaminants

Waste rock predicted to have no potential to generate acid is often disposed of in unlined facilities or used in construction of roads or mine facilities. Several mines in this study have impacted water quality due to leachate from such rock, including the Beartrack, Buckhorn, East Boulder, and Kensington mines. The Eagle Mine treats all rock as potentially acid generating. The other three mines have insufficient data to determine the extent of leaching of mine contaminants from non-acid-generating mined materials.

Accuracy of water quantity predictions

Avoiding adverse impacts to water resources can also depend on accurate predictions of the volume of water that will need to be treated and/or discharged. At least three of the eight mines in this study underestimated the amount of water that would be pumped out of the mine for dewatering purposes and require treatment:

> ***Buckhorn Mine***: The predicted maximum groundwater inflow rate to the underground mine was 168 gallons per minute (gpm), with a maximum annual average of 93 gpm. In 2017, the maximum inflow was 252 gpm and the annual average was 105 gpm.

> ***Flambeau Mine***: The predicted average dewatering rate was 125 gpm with a maximum annual average of 175 gpm. The actual average was 167 gpm, and the maximum annual average was 186 gpm.

> ***Pogo Mine***: The predicted average mine water inflow rate was 139 gpm, with a maximum annual average of 205 gpm. By 2011 the inflow rate averaged 275 gpm, and by 2020 it averaged 400 gpm.

Errors were more widespread in predicting the volume of water that would need to be discharged. In addition to the above three mines, mines that were accurate or overestimated the volume of inflow water to the mine still underestimated the volume that would need to be discharged as treated effluent. Several of the mines have had to increase their treatment capacity.

> ***Beartrack Mine***: Maximum effluent discharge after 2003 was estimated at 0.3 mgd in low flow periods and 1.05 mgd in high flow periods. Monitoring results show that effluent discharge volumes during low flow periods have frequently been above 1 mgd; the maximum measured effluent discharge volume of 1.8 mgd occurred during the low flow period.

> ***Buckhorn Mine*****:** The predicted average treated effluent volume was 44 gpm. The original treatment plant was permitted for a capacity of 100 gpm. However, by 2014, the mine needed to increase treatment capacity to 500 gpm. In 2017 (the last year of operation), the mine discharged an average of 66 gpm of treated effluent.

> ***Flambeau Mine*****:** The predicted effluent discharge rate was 0.327 mgd; the actual rate was 0.466 mgd.

> ***Haile Gold Mine:*** The estimated effluent discharge volume was 800 gpm, with a 1600 gpm maximum in wet years. The actual average effluent discharge volume is 944 gpm, with a peak of 2361 gpm. The original treatment plant was unable to handle the volume of water needing treatment.

> ***Kensington Mine:*** The permit was written for a maximum effluent discharge volume of 3000 gpm, which has proven insufficient. The current expansion plan calls for an increase in the permit limit to 4500 gpm.

> ***Pogo Mine***: The maximum permitted effluent discharge volume at the time of original permitting was 600 gpm; that has now increased to 800 gpm.

Expected effectiveness of water treatment

Seven of the eight mines have had issues with water treatment not being as effective as anticipated:

Beartrack Mine: A new treatment plant was needed to treat the poorer quality influent that ensued after closure; the need for the plant was not anticipated or planned for.

Buckhorn Mine: The original ion exchange system was unable to meet permit limits and had to be upgraded to a reverse osmosis/ion exchange system.

Eagle Mine: The discharge location was moved from a wetland to the river because the plant could not meet the TDS limit that applied in the wetland.

East Boulder Mine: Predicted copper, iron, and nickel concentrations in treated effluent are an order of magnitude higher than predicted concentrations in untreated mine discharge water.

Flambeau Mine: A series of passive systems have been designed to lower copper and zinc concentrations in discharge, but have proved inadequate.

Haile Gold Mine: The company is in the process of building a new treatment plant due in part to the poor quality of its effluent.

Pogo Mine: The treatment plant effluent was predicted to have an average TDS concentration of 433 mg/l; the actual average is 1288 mg/l. Sulfate concentrations in treated effluent were predicted to average 206 mg/l but have averaged 556 mg/l. Maximum values were also underpredicted for these constituents as well as for arsenic, copper, iron, manganese, and cyanide.

Mine Summaries

Beartrack Mine, Idaho

1. Site and Mine Description and Background Information

Beartrack Mine was an open pit, heap leach gold mine in East Central Idaho's Salmon-Challis National Forest, in the upper Salmon River watershed.[1] The mine extracted ore (active operations) from 1994 to 2000, continued ore leaching until 2014, and is currently in the process of closure and reclamation with potential for reopening. We were unable to obtain records other than monitoring data and Discharge Monitoring Reports for the operational period, and some operational details are missing.

Beartrack produced a total of 24 million tons of ore[2] and approximately 35 million tons of waste rock.[3] The mining rate was 14,991 tons per day.[4] The project disturbed approximately 700 acres.[5] The majority of mine operations were located on National Forest land.

Meridian Gold Company (now renamed Meridian Beartrack Co.) submitted the initial Plan of Operations (POO) to the U.S. Forest Service in 1989. The Final Environmental Impact Statement (FEIS) was produced in 1991, and permits were issued the same year. The mine operates under an NPDES permit (initially issued by the U.S. EPA but now administered by the Idaho Department of Environmental Quality), a cyanidation permit (Idaho Department of Health and Welfare), and a reclamation plan permit (Idaho Department of Lands).[6] The Forest Service is the lead agency providing oversight.[7]

Beartrack is located in the headwaters of Napias Creek, a cold-water trout stream. Several small tributary creeks run through the site.[8] Napias Creek has a mean monthly flow ranging from 3.9 cubic feet per second (cfs) to 52 cfs.[9] Annual low flow is estimated at 2 cfs.[10]

The mine is in a mountainous setting, with elevations dropping from 8500 feet at the north end of the site to 6000 feet at the south end.[11] The climate is arid to semi-arid, with average annual

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[1] U.S. Dept. of Agriculture Forest Service, 1991. Beartrack Gold Project Environmental Impact Statement. *Beartrack.FEIS.USDA 1991.pdf [7]* Hereinafter, "FEIS."
[2] Kappes, Cassiday & Associates, 2023. Preliminary Feasibility Study NI 43-101 Technical Report on the Beartrack-Arnett Heap Leach Project. *Beartrack.NI 43-101.Kappes 2023.pdf [19]* Hereinafter, "NI 43-101 Report."
[3] FEIS. *Beartrack.FEIS.USDA 1991.pdf [39]*
[4] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [62]*
[5] U.S. EPA, 2002. Fact Sheet, NPDES Permit No. ID0027022. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [9]* Hereinafter, "2002 NPDES Fact Sheet."
[6] FEIS. *Beartrack.FEIS.USDA 1991.pdf [43-44]*
[7] Idaho Dept. of Lands, 2017. Letter re: Status update and amendment to Reclamation Plan S01073. *Beartrack.Reclamation letter.IDL 2017.pdf*; Whitman, Adam, 2017. Email re: 2nd Request for Reclamation Plan, S01073 Amendment. *Beartrack.Meridian email.Whitman 2017.pdf*
[8] Meridian Beartrack Co., 2024. 2023 Annual Water Quality Report. *Beartrack.2023 Annual Report.Meridian 2024.pdf [8]* (Map). Hereinafter, "2023 Annual Report."
[9] FEIS. *Beartrack.FEIS.USDA 1991.pdf [130]*
[10] FEIS. *Beartrack.FEIS.USDA 1991.pdf [127]*
[11] FEIS. *Beartrack.FEIS.USDA 1991.pdf [13]*

precipitation of 23.75 inches and annual average evaporation of approximately 32.6 inches.[12] Groundwater occurs in the Project area both in bedrock and in glacial moraine and alluvial soils. Depth to the water table follows topography and ranges from 140 feet at the higher elevations to 32 feet at the lower elevations.

The Beartrack Mine is located in a historic mining district, and placer mining had formerly been conducted at the site.[13] However, water quality in the creeks was excellent at the time the Beartrack Project was proposed, and the EIS concluded that baseline data showed "little, if any, impact due to these historic activities."[14] Downstream, Panther Creek is heavily impacted by historic mining in other tributaries.[15]

2. Mine Facilities, Operations, and Reclamation

The Beartrack Mine consisted of two large open pits (North and South), a small ancillary pit (Mason-Dixon), a lined heap leach pad with associated solution ponds, an unlined waste rock dump, and ancillary facilities.[16] The heap leach facility was a single-use pad; the spent ore remains on the pad with a cover. A pit lake has developed in the South Pit; the other two pits are at a higher elevation and are above the water table.

The North Pit has been backfilled with potentially acid-generating (PAG) waste rock. Drainage from the North Pit flows to the South Pit; excess treated South Pit water is discharged to Napias Creek under the NPDES permit. In 2017, there was some indication that treatment prior to discharge might be needed in perpetuity.[17]

The waste rock facility is located in the flow path of Ward's Gulch, a tributary of Napias Creek. Construction allows flow through the bottom of the facility. Drainage is collected in a 3-acre sedimentation pond behind a small dam.[18] Water is discharged from the pond after treatment under the NPDES permit as needed.[19]

Ore from the pits was crushed and moved by conveyor to the heap leach pad, where gold was extracted by cyanide solution. The leach pad had a polyethylene liner over a clay liner.[20] Three liner tears occurred during operations and were repaired.[21] Process water from the leach pad was recycled during operations. Drainage from the reclaimed leach pad is amended with caustic soda and reagents for pH

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[12] FEIS. *Beartrack.FEIS.USDA 1991.pdf [113]*
[13] FEIS. *Beartrack.FEIS.USDA 1991.pdf [126]*
[14] FEIS. *Beartrack.FEIS.USDA 1991.pdf [133]*
[15] FEIS. *Beartrack.FEIS.USDA 1991.pdf [154, 161]*
[16] 2002 NPDES Fact Sheet. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [9-10]*
[17] Idaho Dept. of Lands, 2017. Letter re: Status update and amendment to Reclamation Plan S01073. *Beartrack.Reclamation letter.IDL 2017.pdf*; Whitman, Adam, 2017. Email re: 2nd Request for Reclamation Plan, S01073 Amendment. *Beartrack.Meridian email.Whitman 2017.pdf*
[18] Meridian Gold Co., 1991. Plan of Operation, Beartrack Gold Project. *Beartrack.POO.Meridian 1991.pdf [38-41]* Hereinafter, "POO."
[19] 2023 Annual Report. *Beartrack.2023 Annual Report.Meridian 2024.pdf [8]* (map)
[20] FEIS. *Beartrack.FEIS.USDA 1991.pdf [242]*
[21] Meridian Beartrack Co., 2002b. Draft Reclamation Plan. *Beartrack.Reclamation Plan.Meridian 2002b.pdf [12]* Hereinafter, "Reclamation Plan."

adjustment and metal precipitation. As of 2020, average discharge was 10 gallons per minute (GPM),[22] which is considerably less than the predicted 35 GPM.[23]

Drainage and runoff water from the pits and waste rock dump, and from the leach pad since closure, is discharged to Napias Creek under NPDES permit ID0027022. The permit was first issued in 1991 and renewed in 2003. We were unable to locate a copy of the original permit; the following discussion is based on a draft attached to the FEIS[24] and the 2002 Fact Sheet.

During the operational period (1994-2000), wastewater treatment appears to have been limited to the addition of a flocculent and settling in a sedimentation pond.[25] No discharge occurred from June 2000 through October 2003,[26] when water from all sources went to the South Pit for accelerated filling.[27] Discharge resumed in November 2003 under the renewed NPDES permit, modified to address changes in the nature of the discharge.[28] The 2003 permit included a compliance schedule to provide time to build a new treatment plant. It is unclear what, if any, treatment occurred between 2003 and 2009.[29]

The permit compliance schedule (which applied to the cyanide, ammonia, and mercury limits) required the new treatment plant to be operational by November 1, 2006.[30] However, the deadline was extended for two years because the influent quality was worse than expected and the company had "difficulties with developing an effective and reliable treatment technology."[31] Discharge was suspended in November 2008 and resumed in August 2009,[32] presumably when the new plant began operating.

Current water management routes mine-impacted water to the South Pit for storage. Water from the South Pit and reclaimed leach pad is mixed and treated by microfiltration as needed to meet permit limits. It is then mixed with non-contact stormwater prior to discharge.[33]

The discharge outfall (Outfall 001) is at a downstream point on Napias Creek. The 7Q10 flow is 4 million gallons per day (MGD), and the approximate mean high flow is 54 MGD based on 1996-1999

[22] Meridian Beartrack Co., 2020b. Beartrack Mine Water Quality Monitoring Plan. *Beartrack.Monitoring Plan.Meridian 2020b.pdf [3]* Hereinafter, "2020 Monitoring Plan."
[23] FEIS. *Beartrack.FEIS.USDA 1991.pdf [227]*
[24] U.S. EPA, 1991. Draft NPDES Permit No. ID0027022. *Beartrack.NPDES Permit.EPA 1991.pdf* Hereinafter, "1991 NPDES Permit."
[25] 2002 NPDES Fact Sheet. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [42]*
[26] Meridian Beartrack Co., n.d. NPDES Permit ID0027022 Discharge Monitoring Reports. *Beartrack.DMRs.Meridian nd.pdf [811-1144]* Hereinafter, "NPDES DMRs;" *Beartrack.Pre-2007 DMR Spreadsheet.xlsx [001-A, Line 124]*
[27] Reclamation Plan. *Beartrack.Reclamation Plan.Meridian 2002b.pdf [10]*
[28] U.S. EPA, 2003. NPDES Permit No. ID0027022. *Beartrack.NPDES Permit.EPA 2003.pdf* Hereinafter, "2003 NPDES Permit."
[29] See Meridian Beartrack Co., 2006. 2005 Annual Water Quality Report. *Beartrack.2005 Annual Report.Meridian 2006.doc [14]* Hereinafter, "2005 Annual Report."
[30] 2003 NPDES Permit. *Beartrack.NPDES Permit.EPA 2003.pdf [8]*
[31] U.S. EPA, 2006. Fact Sheet, NPDES Permit No. ID0027022. *Beartrack.NPDES Fact Sheet.EPA 2006.pdf [5]*
[32] U.S. EPA, n.d. NPDES Monitoring Data Download, Facility ID: ID0027022. Downloaded from https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download on July 23, 2024. *Beartrack.NPDES Spreadsheet.xlsx [lines 34-44]* Hereinafter, "NPDES Spreadsheet."
[33] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [299]*

data.[34] Streamflow has trended downward since 1999.[35] For the first six months of operations, discharge was approximately ten times the otherwise highest flow of the river, averaging 654 MGD. Thereafter, discharge was substantially reduced and averaged 0.65 MGD during the remainder of the operational period.[36] The EIS predicted that pit dewatering would produce a maximum 500 to 800 GPM (1.15 MGD).[37]

Effluent limits in the 2003 permit were based on estimated maximum discharges of 0.3 MGD in July through April (low flow period) and 1.05 MGD in May and June (high flow period).[38] In actuality, discharge during the low flow period has frequently been higher than 1 MGD; the maximum discharge volume of 1.8 MGD occurred in October 2008. Although discharge volumes have since decreased, they are still frequently higher than 0.3 MGD during low flows.[39] For example, monthly maximum daily flows from December 2023 through April 2024 averaged 0.7 MGD. The permit does not include a limit on the volume of discharge, but rather limits the load (in pounds) of each constituent.[40] The permit includes a mixing zone,[41] and the outfall location has a multi-port diffuser to speed dilution.[42] Permit limits are further discussed in *Section 4.2, Effluent Water Quality*.

3. Geochemistry

3.1 Pre-mining Geochemical Characterization

Both static and kinetic testing of ore and waste rock were conducted prior to mining, but humidity cell tests ran for only ten weeks.[43] Pre-mining characterization concluded that both ore and waste rock had a low potential to generate acid.

Ore was classified as 48.5% oxide (< 0.1% sulfur), 21.7% sulfide (> 1% sulfur), and 29.8% mixed. Maximum sulfur content was 3.62%.[44] According to the EIS, "Despite indications that the sulfide component of the ore has excess acid generating potential, the spent ore is not predicted to generate acid mine drainage and associated metals," due to planned mitigation.[45] Spent ore (at the heap leach pad) was considered to have some potential to leach arsenic and zinc, however.[46]

The EIS stated, "Thirteen of 73 waste rock samples tested showed significant sulfur levels and a net acid-producing potential." Nevertheless, it was estimated that "over 99 percent of waste rock will

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[34] 2002 NPDES Fact Sheet. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [65]*
[35] Meridian Beartrack Co., 2023b. Investigating Mercury in Fish Tissue Trend at WQ-22. *Beartrack.Fish tissue mercury.Meridian 2023.pdf [5]* Hereinafter, "Mercury Report."
[36] *Beartrack.Pre-2007 DMR Spreadsheet.xlsx [001-A 1995-2003 and lead];* NPDES DMRs. *Beartrack.DMRs.Meridian nd.pdf* (page numbers provided on spreadsheet)
[37] FEIS. *Beartrack.FEIS.USDA 1991.pdf [248]*
[38] 2002 NPDES Fact sheet. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [67]*
[39] NPDES Spreadsheet. *Beartrack.NPDES Spreadsheet.xlsx [lines 13 to 223]*
[40] 1991 NPDES Permit. *Beartrack.NPDES Permit.EPA 1991.pdf [2]*
[41] 2002 NPDES Fact sheet. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [65]*
[42] 2002 NPDES Fact sheet. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [42]*
[43] FEIS. *Beartrack.FEIS.USDA 1991.pdf [122]*
[44] FEIS. *Beartrack.FEIS.USDA 1991.pdf [116]*
[45] FEIS. *Beartrack.FEIS.USDA 1991.pdf [116, 227]*
[46] FEIS. *Beartrack.FEIS.USDA 1991.pdf [12]*

have net acid consuming capability."[47] As with ore, waste rock was seen to have potential to leach zinc and arsenic.

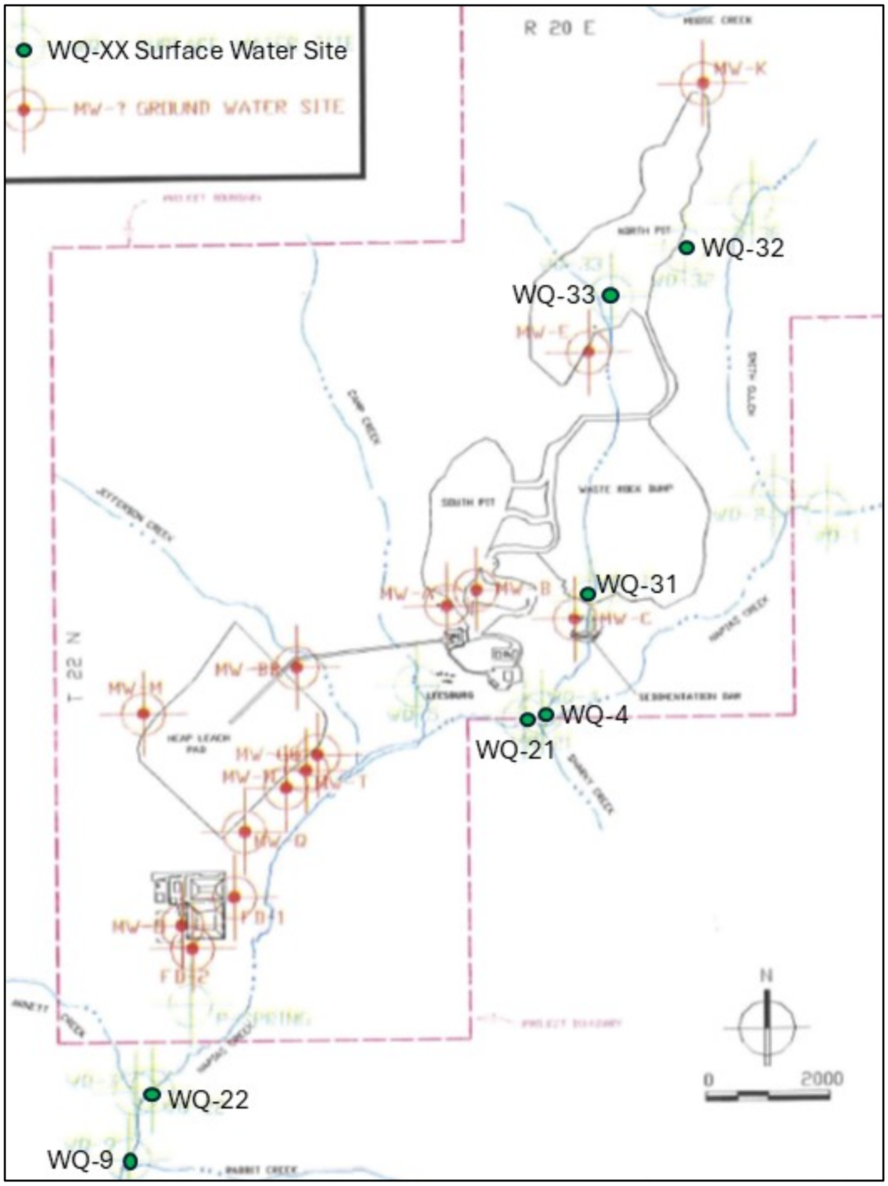
3.2 Field Results and Mitigation

The 1991 mine plan included "no requirement for specific handling or treatment of waste rock."[48] Ultimately, however, PAG waste rock was buried under a cap in the North Pit, a measure agreed to in 1999 (five years after mining began).[49] Additional added management measures included lime amendments and a contact water collection system.[50] As the bottom of the North Pit is above the water table, any PAG rock there is not submerged under water, which would lower its acid-generation potential. Acidic conditions have developed at the reclaimed North Pit. As of 2017, North Pit drainage was being treated with sodium hydroxide prior to discharge to the South Pit. The South Pit Lake is additionally amended with lime or caustic soda to raise the pH.[51]

4. Mine Water Quality

The water quality monitoring locations discussed for the Beartrack Mine site are shown in Figure 1. Pit underdrain water quality is discussed in *Section 4.1*. No direct measure of waste rock or heap leach pad leachate was available. Mining impacts on groundwater and surface water quality, including a location in a creek downgradient of the waste rock pile (WQ-31), are discussed in *Section 5*.

[47] FEIS. *Beartrack.FEIS.USDA 1991.pdf [20, 123, 225]*
[48] POO. *Beartrack.POO.Meridian 1991.pdf [20]*
[49] Meridian Beartrack Co., 2002b. Draft Reclamation Plan. *Beartrack.Reclamation Plan.Meridian 2002b.pdf [9]* Hereinafter, "Reclamation Plan."
[50] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [304]*
[51] E.g., 2023 Annual Report. *Beartrack.2023 Annual Report.Meridian 2024.pdf [14]*



Beartrack Figure 1. Beartrack Mine facilities and water monitoring locations.
Source: Modified from Meridian Beartrack Co., 2023. 2022 Annual Water Quality Report, Figure 1 (added hard-to-discern surface water location points). *Beartrack.2022 Annual Report.Meridian 2023a.pdf [7]*

4.1 Pit Underdrain Water Quality

Water quality is measured in two locations where underdrains surface at the northern and southern boundary of the North Pit, designated respectively as monitoring points WQ-32 and WQ-33.[52] We have numeric data only until 2008 for WQ-32 and until 2006 for WQ-33, and graphed data to 2022. Baseline data specific to this location are not available; median groundwater values for the site as a whole, as presented in the EIS, are provided in Tables 1 and 2 for comparison.

[52] Meridian Beartrack Co., 2002a. 2001 Annual Water Quality Report. *Beartrack.2001 Annual Report.Meridian 2002a.pdf [8]* Hereinafter, "2001 Annual Report."

Underdrain water quality at both locations sampled in the North Pit is acidic with sulfate and metal concentrations. In the north underdrain, acidity (low pH), sulfate, and concentrations of cadmium, copper, manganese, nickel, and zinc have increased over time and peaked in 2022 (Table 1). In the south underdrain, pH was lowest in 2022, while conductivity, sulfate, and concentrations of cadmium, copper, manganese, and zinc peaked in 2003, given the available data (Table 2). As noted in *Section 3.2*, PAG waste rock in the North Pit was buried under a cap after 1999, lime was added, and a contact water collection system was installed. These mitigation measures appear to have improved water quality in the North Pit south underdrain, as shown by decreasing metal concentrations over time (see Table 2). However, the pH in the south underdrain is still low (estimated pH was 3.2 in 2022), and pH, sulfate, and metal concentrations have continued to increase over time in the North Pit north underdrain (see Table 1). For comparison, at their peak, metal concentrations in the North Pit underdrains were one to two orders of magnitude higher than criteria for protection of aquatic life. As shown in Figure 1, Ward's Gulch (WQ-4 and WQ-31) flowed through the southern part of the North Pit and under the waste rock dump, and uncaptured mine-influenced water from these sources can adversely impact water quality in lower Ward's Gulch and Napias Creek.

Beartrack Table 1. Water Quality at WQ-32, North Pit, North Underdrain.

	pH (SU)	**Conductivity** (µmhos/cm)	**Total Dissolved Solids** (mg/l)	**Sulfate** (mg/l)
Sitewide groundwater median, 1988-1990	6.5	n/a	72	14
2001	3.7	388	n/a	183
2008	3.4	729	486	315
2022 (estimate)	3.4	1000	n/a	650

	Cadmium (µg/l)	**Copper** (µg/l)	**Manganese** (µg/l)	**Nickel** (µg/l)	**Zinc** (µg/l)
Sitewide groundwater median, 1998-1990	< 5	< 10	300	< 100	130
2001	52	133	1670	107	403
2008	68	173	2135	139	658
2022 (estimate)	195	300	3550	300	1590

1998-1990 values are the median of all groundwater samples taken at the entire site over a two-year period. Source: FEIS. *Beartrack.FEIS.USDA 1991.pdf [144-145]*
2001 and 2008 values are averages of all samples taken that year. Source: Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-32 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.MW-T 2008 Data.xls*
2022 values are estimated from graphs. Source: *Meridian Beartrack Company, 2023a. 2022 Annual Water Quality Report. Beartrack.2022 Annual Report.Meridian 2023a.pdf [39-42].*

Beartrack Table 2. Water Quality at WQ-33, North Pit, South Underdrain.

	pH (SU)	**Conductivity** (µmhos/cm)	**Total Dissolved Solids** (mg/l)	**Sulfate** (mg/l)
Sitewide groundwater median, 1998-1990	6.5	n/a	72	14
2001	7.2	789	n/a	402
2003	3.7	2850	n/a	2260
2006	4.2	1345	1117	850
2022 (estimate)	3.2	500	n/a	240

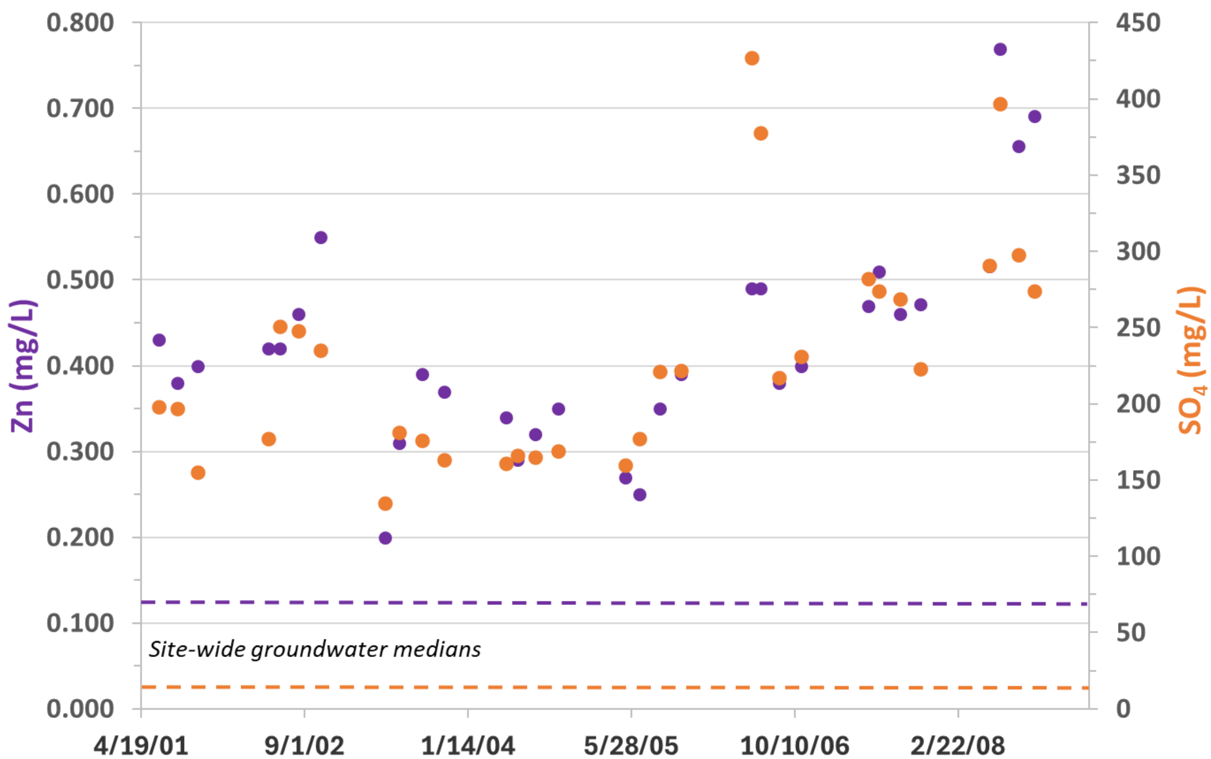
	Cadmium (µg/l)	**Copper** (µg/l)	**Manganese** (µg/l)	**Nickel** (µg/l)	**Zinc** (µg/l)
Sitewide groundwater median, 1998-1990	< 5	< 10	300	< 100	130
2001	400	820	5400	330	3120
2003	1420	2110	24,150	1065	12,470
2006	394	496	9167	357	3645
2022 (estimate)	< 100	100	2500	< 100	< 1000

1998-1990 values are the median of all groundwater samples taken at the entire site over a two-year period. Source: FEIS. *Beartrack.FEIS.USDA 1991.pdf [144-145]*
2001, 2003, and 2006 values are averages of all samples taken that year. Source: Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-33 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-33 2008 data.xls*
2022 values are estimated from graphs. Source: *Meridian Beartrack Company, 2023a. 2022 Annual Water Quality Report. Beartrack.2022 Annual Report.Meridian 2023a.pdf [43-46].*

Lead has become elevated at WQ-33 since 2008, with annual peaks between 200 and 450 µg/l.[53] Median baseline groundwater lead concentration was less than 50 µg/l.[54]

Sulfate and zinc concentrations over time in the north underdrain of the North Pit (WQ-32) are shown in Figure 2. All results are from 2001 to 2008, which is after the mine stopped extracting ore from the pits (extraction stopped in 2000). The pH of the underdrain leachate ranged from 3.3 to 4.5 during this time, with an average of 3.6. Concentrations of zinc, sulfate, cadmium, copper, manganese, and nickel continued to rise during the closure period (see Table 1). The zinc and sulfate trends follow each other closely suggesting that both result from the oxidation of metal sulfides in ore and waste rock in the pit and the pit walls.

[53] Meridian Beartrack Co., 2020. 2019 Annual Water Quality Report, Electronic Attachment: 4th Event WQ-33 annual graphs 2019. *Beartrack 2020 Graphs\Beartrack.WQ-33 2020 Graphs.pdf*
[54] FEIS. *Beartrack.FEIS.USDA 1991.pdf [144]*



Beartrack Figure 2. Zinc and sulfate concentrations in the North Pit north underdrain, WQ-32, 2001-2008. Zinc and sulfate concentrations reached an estimated 2.1 mg/l and 600 mg/l, respectively, in 2020. *Data source: Beartrack 2008 Data\Beartrack.WQ-32 2008 data.xls (see Table 1)*

Prior to the start of lime amendments in 2001, the pH in the South Pit was 4.9 at the surface and 3.5 at depth.[55] Currently, twice-annual amendments bring the pH up to about 10.[56] We have no data beyond 2008, but as of 2008, TDS and sulfate continued to rise despite the amendments. TDS rose from about 200 mg/l in 2001 to about 300 mg/l in 2008; sulfate rose from about 50 mg/l in 2000 to about 150 mg/l in 2008.[57]

4.2 Effluent Water Quality

The 1991 NPDES permit included discharge limits for several metals, total suspended solids, and pH. Monitoring only was required for manganese, with no numeric limit.[58] The 2003 permit tightened the limits for most metals, added limits for ammonia and cyanide, and dropped monitoring for manganese.[59] No monitoring was or is required under either permit for sulfate, total dissolved solids (TDS), or specific conductance.

[55] 2001 Annual Report. *Beartrack.2001 Annual Report.Meridian 2002a.pdf [165-178]; Beartrack.2001 Data Spreadsheet.Feb2025.xlsx*
[56] E.g., 2023 Annual Report. *Beartrack.2023 Annual Report.Meridian 2024.pdf [14]*
[57] Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment South Pit Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.South Pit 2008 data.xls [General Graphs]*
[58] 1991 NPDES permit. *Beartrack.NPDES Permit.EPA 1991.pdf [2]*
[59] 2003 NPDES Permit. *Beartrack.NPDES Permit.EPA 2003.pdf [6-7]*

During the operational period (1994-2000), arsenic and zinc were the constituents of highest concern.[60] The arsenic limits in the 1991 permit were set notably high: 5800 µg/l as a monthly average and 9500 µg/l as a daily maximum. As a point of reference, Idaho's current criterion to protect human health from arsenic by consumption of fish is 4.3 µg/l.[61] Arsenic and zinc concentrations in the effluent were as high as 160 and 200 µg/l, respectively. The 1991 permit set limits for zinc at 300 µg/l as a monthly average and 500 µg/l as a daily maximum; the highest monthly average was 235 µg/l, and the maximum value was 410 µg/l.

Manganese was also occasionally present in the effluent at elevated concentrations. Other metals were only occasionally detected, although cadmium concentrations exceeded limits on only one occasion. Mercury was usually below quantification limits, but on several occasions, it was measured between 0.1 and 0.5 µg/l (permit limit 0.6 µg/l).

After mining ended, drainage from the pits grew worse in quality due to prolonged contact with waste rock and pit walls. In addition, discharge began to include drainage from the reclaimed heap leach pad. The five years after operations ended and before the new treatment plant became operational was the period of the poorest quality effluent from the Beartrack project.

Table 3 presents Beartrack Mine effluent Concentrations during the early reclamation period (2003-2008), 2003 permit limits, and water quality criteria applicable in Napias Creek in 2002. Cadmium concentrations in mine effluent exceeded the 2003 permit limits for 43 of 58 months. Zinc concentrations in the effluent exceeded the monthly average twice and the daily maximum once. Mercury in the effluent exceeded the monthly average and daily maximum permit limits. We found no documentation of enforcement actions for any of these permit violations.

Beartrack Table 3. Beartrack Mine Effluent Concentrations, Early Reclamation Period (2003-2008), 2003 NPDES Permit Limits, and Water Quality Criteria applicable in Napias Creek in 2002 (**bolded** values exceed one or more permit limits)

	Arsenic (µg/l)	**Cadmium** (µg/l)	**Copper** (µg/l)	**Mercury** (µg/l)	**Zinc** (µg/l)
Permit limit, monthly average, low/high flow[62]	1900/980	1.4/1.3	11/12	0.075/0.15	69/69
Permit limit, daily maximum, low/high flow	3200/2000	2.7/2.7	21/24	0.074/0.15	137/133
Effluent overall average	431	2.16	4.4	**0.158-0.174**	17.6-20.3
Effluent maximum monthly average	1302	**4.5**	11	**2.44**	**76**
Effluent daily maximum	1620	**5.2**	17	**44**	**165**
Chronic WQC (aquatic life)	190	0.37	3.5	0.012	32
Acute WQC (aquatic life)	360	0.82	4.6	2.1	35
Human health criteria for fish consumption	50	--	--	0.15	--

Permit limits are from the 2003 NPDES Permit. *Beartrack.NPDES Permit.EPA 2003.pdf [6-7]*
Water Quality Criteria (WQC) are those in force in 2002. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [51-52]*

[60] Data for metals during the operations period is from *Beartrack.Pre-2007 DMR Spreadsheet.xlsx [001-A 1995-2003 and lead];* and NPDES DMRs. *Beartrack.DMRs.Meridian nd.pdf* (page numbers provided on spreadsheet).
[61] IDAPA 58.01.02. *Beartrack.Idaho WQS.pdf [152]*
[62] 2003 NPDES Permit. *Beartrack.NPDES Permit.EPA 2003.pdf [6]*

The effluent overall average is the average of all data points in the 2003 to 2008 time period.
The 2.44 maximum monthly average for mercury was removed as an outlier for the effluent overall average.
The average mercury value was calculated twice, with values below the quantification limit of 0.05 µg/l set at 0 and 0.05.
The average zinc value was calculated twice, with values below the quantification limit of 10 µg/l set at 0 and 10.
Effluent maximum monthly average is the highest monthly average in the 2003-2008 time period.
Effluent daily maximum was the highest value in the 2003-2008 time period.
Sources: NPDES DMRs. *Beartrack.DMRs.Meridian nd.pdf; Beartrack.Pre-2007 DMR Spreadsheet.xlsx [001-A, Line 124];* NPDES Spreadsheet. *Beartrack.NPDES Spreadsheet.xlsx [lines 230-251]*

Levels of all pollutants in the effluent dropped after the treatment plant opened,[63] but arsenic has had recurring monthly averages above 140 µg/l that have at times lasted several months; the most recent was in 2021. Mercury concentrations are below the quantification limit of 0.07 µg/l, which is high by today's laboratory standards and could be masking the discharge of mercury at harmful levels.[64]

Sulfate and TDS/specific conductance are undoubtedly present in the discharge, possibly at high levels, but they are subject to no water quality standards and are not monitored. Treatment of water prior to discharge is planned to end when water quality criteria can be met without it.[65] The concentrations of many constituents, including sulfate and TDS/specific conductance, in the effluent and downstream locations are likely to increase at that point. Water quality in the receiving water downstream of Outfall 001 at WQ-9 is discussed in *Section 6.2.*

5. Mining Impacts on Groundwater and Surface Water Quality

5.1 Groundwater Quality

Baseline groundwater quality data are available for most of the wells used for project groundwater monitoring and are included with monitoring data in annual reports. Groundwater generally had very low sulfate and TDS concentrations, with higher levels along a fault line that intersects the mine pits.[66] Baseline groundwater quality includes instances of high concentrations of many constituents (aluminum, arsenic, copper, iron, lead, manganese, nickel, and zinc), but median levels were below quantification limits for all metals except iron, manganese, and zinc.[67]

During the operations period (1994 to 2000), groundwater was impacted in at least two locations. A well downgradient of the South Pit (MW-B) had increasing concentrations of sulfate, TDS, manganese, and zinc that peaked in 2001 (Table 4). In the subsequent reclamation period, concentrations of these constituents were about twice their baseline levels. We have data for MW-B only through 2008; by 2013, monitoring had been discontinued.[68]

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[63] NPDES Spreadsheet. *Beartrack.NPDES Spreadsheet.xlsx [lines 261-350 and 574-643]*
[64] In the absence of state action and under court order, the U.S. EPA has proposed an Idaho mercury water quality standard of 0.0021 µg/l. 89 Fed. Reg. 24758 (April 9, 2024). *Beartrack.FedRegIdahoMercury.EPA 2004.pdf [4-5, 17]* The standard may be superseded by evidence that fish tissue in a waterbody meets the standard for mercury in fish tissue; as discussed below, fish in Napias Creek do not meet that standard.
[65] FEIS. *Beartrack.FEIS.USDA 1991.pdf [242]*
[66] FEIS*. Beartrack.FEIS.USDA 1991.pdf [142]*
[67] FEIS. *Beartrack.FEIS.USDA 1991.pdf [144]*
[68] Meridian Beartrack Co., 2014. *Beartrack.2013 Annual Report.Meridian 2014.pdf [6]*

Beartrack Table 4. Groundwater Monitoring Results for Well MW-B, Downgradient of the South Pit.

	Sulfate (mg/l)	**Total Dissolved Solids** (mg/l)	**Manganese** (µg/l)	**Zinc** (µg/l)
MW-B Baseline, 1990-1991	16	78	296	625
1994-2000	52	152	586	1,291
2001	103	216	1,722	2,120
2008	41	165	677	1,390

Values are averages of the period shown (2008 had only one measurement).
Baseline concentrations are an average of data collected at MW-B between March 1990 and September 1991.
1994-2000 and 2001 values are averages of all samples from the applicable time frame.
2008 values are from a single monitoring event (one data point for each parameter).
Source: Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment MW-B Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.MW-B 2008 Data.xls*

A second well in the same area, MW-A, was impacted to a lesser extent.[69] According to the FEIS, groundwater at the site flows in a southeasterly direction, and it appears that MW-A might not be along the groundwater flow path from the pit. Monitoring of well MW-A has been discontinued and replaced by monitoring of a nearby surface seep, also designated as MW-A. Monitoring of the MW-A seep is now the only monitoring of the impact of the South Pit on groundwater. Conductivity, iron, manganese, TDS, and sulfate have all been rising slowly in the MW-A seep since 2000, and values are now similar to those in MW-B in 2008.[70]

A second location where operations appear to have impacted groundwater is along the southeast (downgradient) side of the heap leach pad. Wells MW-T and MW-EE are located in this area. TDS and conductivity rose precipitously in MW-T in 1997 and 1999. Conductivity was about 60 µmhos/cm through May 1999; in June 1999, values rose by an order of magnitude to 734 µmhos/cm. TDS values were less than 200 mg/l until May 1997 and then rose by an order of magnitude to 2070 mg/l. TDS dropped slowly over the following year, with a smaller rise again in 1999. Both parameters declined nearly to pre-mining levels by 2008.[71] The only data we have for well MW-EE is from 2001, when TDS averaged 323 mg/l.[72]

A third location where groundwater is likely impacted is downgradient of the waste rock facility. Well MW-C is the only groundwater monitoring well in that vicinity, and monitoring did not indicate impacts at that well.[73] However, MW-C is a deep water well.[74] As discussed above, the water surfacing downgradient of the waste rock facility at WQ-31 is elevated in a number of constituents. WQ-31 data are likely more indicative of shallow groundwater impacts than MW-C data.

[69] Meridian Beartrack Co., 2002a. 2001 Annual Water Quality Report. *Beartrack.2001 Annual Report.Meridian 2002a.pdf; Beartrack.2001 Data Spreadsheet.Feb2021xlsx [Groundwater]*
[70] Meridian Beartrack Co., 2023a. 2022 Annual Water Quality Monitoring Report. *Beartrack.2022 Annual Report.Meridian 2023a.pdf [15-18]*; 2023 Annual Report. *Beartrack.2023 Annual Report.Meridian 2024.pdf [13]*
[71] Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment MW-T Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.MW-T 2008 Data.xls [Graph Data]*
[72] Meridian Beartrack Co., 2002a. 2001 Annual Water Quality Report. *Beartrack.2001 Annual Report.Meridian 2002a.pdf; Beartrack.2001 Data Spreadsheet.Feb2021xlsx [Groundwater]*
[73] Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment MW-C Annual Graphs 2008.From 2008 Annual Report. *Beartrack 2008 Data\Beartrack.MW-C 2008 Data.xls [Graph Data]*
[74] 2005 Annual Report. *Beartrack.2005 Annual Report.Meridian 2006.pdf [13]*

Monitoring at groundwater wells ended in 2020; the only continuing groundwater monitoring is at two points where groundwater surfaces in a seep or French drain.[75] Monitoring wells dropped gradually between 2000 and 2020; in 2019, only five wells were included in the monitoring program.[76] Concentrations in at least two of the five wells had not stabilized for some constituents when monitoring ended. At MW-E, which is downgradient of the backfilled North Pit, conductivity, copper, and nitrogen values were all rising slowly as of 2019.[77] At MW-BB, in an area that may have been impacted by transport of ore, sulfate was less than 2 mg/l in 2000 and began rising in 2010. As of 2016, it had reached 10 mg/l.[78]

As discussed above, water in the backfilled North Pit and the South Pit Lake has high levels of some constituents. It is unclear from the available information whether the South Pit Lake is being kept at an elevation that prevents or minimizes outflow to groundwater. We also have insufficient information on groundwater flow from the backfilled North Pit. With groundwater monitoring discontinued, there will be no indication of if and when the reclaimed pits could be impacting groundwater.

5.2 Surface Water Quality

The FEIS presents baseline water quality data for the site as a whole for the sampling period of October 1988 to September 1990. Median hardness was 6 mg/l; median TDS was 38 mg/l; and the median baseline sulfate concentration was 0.8 mg/l. Chloride, nitrate, and all metals except iron had median concentrations below the quantification limit. [79] Baseline data for specific locations are available in annual reports.

Surface water monitoring areas of interest from upstream to downstream locations (see Figure 1) include Ward's Gulch, a tributary of Napias Creek that is impacted by the waste rock pile at WQ-31 and by the South Pit and the sediment dam at WQ-4; Napias Creek, which is influenced by the waste rock pile and the South Pit at WQ-21, and downstream of the mine and upstream of Arnett Creek at WQ-22; and Napias Creek downstream of the NPDES Outfall 001 at WQ-9.[80] WQ-9 is the most downstream surface water monitoring location (see Figure 1).

5.2.1 Ward's Gulch

Monitoring site WQ-31 is located in Ward's Gulch, a tributary of Napias Creek upstream of the sediment dam/pond and in the waste rock area of influence. Again, we have numeric data from 2001 to 2008 (after mine extraction operations ceased) and graphed data to 2022. Baseline data specific to this location are not available; median groundwater values for the site as a whole are provided in Table 5.

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[75] 2020 Monitoring Plan. *Beartrack.Monitoring Plan.Meridian 2020b.pdf [6]*; Meridian Beartrack Co., 2021. 2020 Annual Water Quality Report. *Beartrack.2020 Annual Report.Meridian 2021.pdf [5]*
[76] Meridian Beartrack Co., 2020a. 2019 Annual Water Quality Report. *Beartrack.2019 Annual Report.Meridian.2020a [5]*
[77] Meridian Beartrack Co., 2020. 2019 Annual Water Quality Report, Electronic Attachment: 4th Event MW-E annual graphs 2019. *Beartrack 2019 Graphs\Beartrack.MW-E 2019 Graphs.xlsx*
[78] Meridian Beartrack Co., 2020. 2019 Annual Water Quality Report, Electronic Attachment: 4th Event MW-BB annual graphs 2019. *Beartrack 2019 Graphs\Beartrack.MW-BB 2019 Graphs.xlsx*
[79] FEIS. *Beartrack.FEIS.USDA 1991.pdf [132]*
[80] Meridian Beartrack Co., 2011. 2010 Annual Water Quality Report. *Beartrack.2010 Annual Report.Meridian 2011.pdf [6-7]*

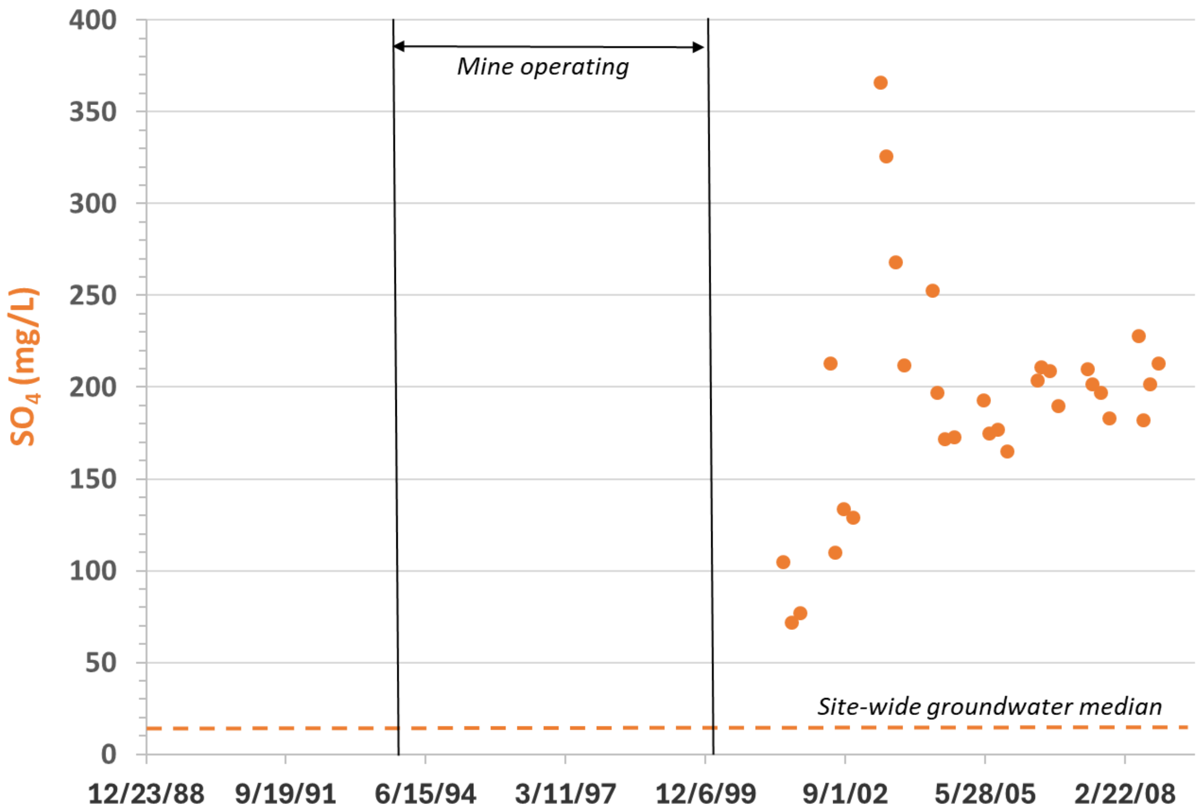
Sulfate concentrations from 2001 to 2008 are shown in Figure 3. Between 2001 and 2008, conductivity, sulfate, manganese, and zinc all followed a similar pattern of increasing concentrations over time. These parameters were elevated and increasing in the first two years, with a peak in 2003.[81] Using the available monitoring data, sulfate concentrations peaked in 2003 at 366 mg/l (see Figure 3). After 2003, the values decreased but remained above the site-wide median groundwater value. Conductivity and manganese levels have remained stable since 2008, sulfate and zinc levels have risen slowly, and pH values have slowly fallen.

Beartrack Table 5. Waste Rock Facility Drainage Water at WQ-31 in Ward's Gulch.

	Conductivity (µmhos/cm)	**Sulfate** (mg/l)	**Manganese** (µg/l)	**Zinc** (µg/l)	**Nitrate+ nitrate** (mg/l as N)	**pH (SU)**
Sitewide groundwater median, 1998-1990	n/a	14	300	130	n/a	6.5
2001	289	85	493	280	4.2	6.8
2002	418	146	2703	602	5.1	6.4
2003	671	293	5455	1115	6.5	5.2
2004-2008 range	507-567	177-206	269-1732	70-190	5.7-7.7	6.9-7.4
2022 (estimate)	500	225	500	300	5.0	5.8

1998-1990 values are the median of all groundwater samples taken at the entire site over a two-year period. Source: FEIS. *Beartrack.FEIS.USDA 1991.pdf [144-145]*
2001, 2002, and 2003 values are averages of all samples taken that year. Source: Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-31 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-31 2008 Data.xls*
2004-2008 values are the minimum and maximum annual averages during that time period. Source: *Beartrack 2008 Data\Beartrack.WQ-31 2008 Data.xls*
2022 values are estimated from graphs. Source: *Meridian Beartrack Company, 2023a. 2022 Annual Water Quality Report. Beartrack.2022 Annual Report.Meridian 2023a.pdf [35-38].*

[81] This peak was likely caused by North Pit water flowing under the waste rock dump. Meridian Beartrack Co., 2004. 2003 Annual Water Quality Report. *Beartrack.2003 Annual Report.Meridian 2004.doc [13]*



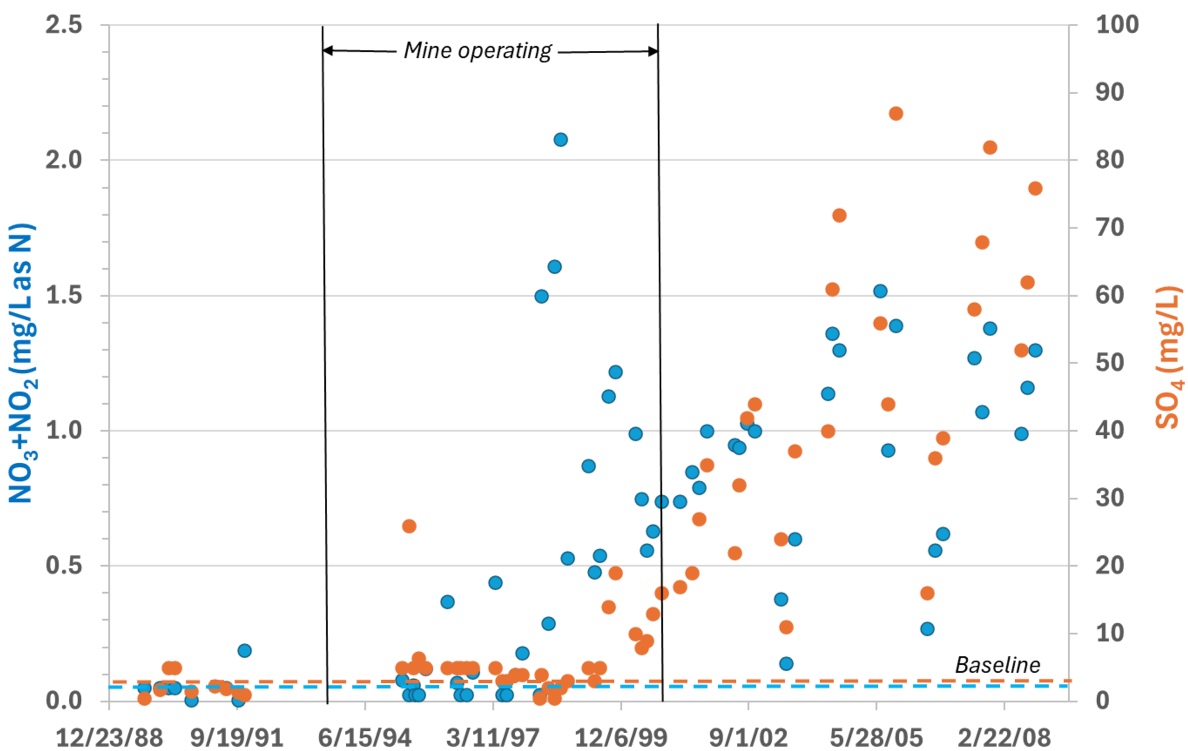
Beartrack Figure 3. Sulfate concentrations in Ward's Gulch at WQ-31, downgradient of the waste rock pile, from 2001 to 2008. *Data sources:* Site-wide groundwater median: FEIS. *Beartrack.FEIS.USDA 1991.pdf [144-145];* Monitoring data: Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-31 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-31 2008 Data.xls*

Two monitoring stations downstream of the dam and sedimentation pond are intended to reflect water flowing from the waste rock dump: WQ-4, in Ward's Gulch downstream of the sedimentation pond dam and the South Pit; and WQ-21, on Napias Creek just downstream of the confluence with Ward's Gulch. Results for WQ-21 are discussed in *Section 6.2.2*. As the waste rock facility and sedimentation pond are unlined, some portion of this water moves through groundwater to lower Ward's Gulch and Napias Creek. Both stations have baseline data and have been monitored throughout operations and closure.

At WQ-4, specific conductance, sulfate, and nitrogen rose steadily through the operations and early reclamation period (Table 6). Figure 4 shows nitrate+nitrite and sulfate concentrations from 1989 to 2008. Nitrate+nitrite concentrations peaked during mine operations at 2.08 mg/l as N, while sulfate concentrations began to rise in 1999 after the mine closed and peaked in 2005 at 87 mg/l. Concentrations of both constituents remained considerably elevated over baseline during the closure period.

Beartrack Table 6. Surface Water Quality at WQ-4, Ward's Gulch (Annual Averages)[82]

	Specific conductance (µmhos/cm)	Sulfate (mg/l)	Nitrogen (nitrate + nitrite) (mg/l as N)
Baseline	37	2.3	< 0.1
1996	46	3.7[83]	0.12
2000	84	11.2	0.73
2004	184	57.7	1.27
2008	217	63.3	1.15
2022[84]	140	45	0.3



Beartrack Figure 4. Nitrate+nitrate and sulfate concentrations from 1989 to 2008 in Ward Gulch, WQ-4, showing the dates of mine operation (1994-2000) and baseline values for the two constituents. Values below detection are plotted at one-half the quantitation limit. *Data sources: Baseline: Beartrack.FEIS.USDA 1991.pdf. Monitoring data: 2008 Annual Report and Beartrack 2008 Data\Beartrack.WQ-4 2008 data.xls*

5.2.2 Napias Creek

WQ-21, on Napias Creek just downstream of the Ward's Gulch confluence, is in the area of influence of the South Pit and the waste rock pile. This station has baseline data and has been monitored throughout operations and closure. At WQ-21, sulfate increased incrementally during the

[82] Other than 2022, data are from Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-4 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-4 2008 Data.xls [Graph Data]*
[83] Value is from 1997. Prior to June 1997, the quantification level was 10 mg/l, and sulfate was not quantifiable.
[84] Estimated from graphed data. Meridian Beartrack Co., 2023. 2022 Annual Water Quality Report. *Beartrack.2022 Annual Report.Meridian 2023a.pdf [21-23]*

early reclamation period, from a 2001 average of 1.2 mg/l to a 2008 average of 2.3 mg/l.[85] Graphed data through 2022 indicates a continuing slow increase. Sulfate at this location fluctuates seasonally; maximum concentrations (during low stream flows) from 2012 through 2022 were typically 4 to 5 mg/l.[86]

WQ-22 is on Napias Creek about two miles downstream of WQ-21, downstream of all mine facilities, and upstream of the confluence with Arnett Creek. At WQ-22, specific conductance rose from a baseline average of 30 µmhos/cm to an average of 41 µmhos/cm during the operational period. From 2001 to 2008, specific conductance dropped to 35 µmhos/cm.[87] It remained at that level until 2019, when it began to rise again. The average from 2020 to 2022 was about 40 µmhos/cm.[88]

The WQ-22 baseline average for sulfate was 1.4 mg/l. Sulfate concentrations did not begin to increase at this station until after the operational period.[89] The average appears to have remained less than 2 mg/l until 2011 but has been rising slowly since then. As of 2022, sulfate concentrations averaged about 6 mg/l. Annual maximum concentrations are in the range of 8 to 11 mg/l.[90]

Fish tissue monitoring for mercury has also been conducted at WQ-22 since at least 2004. Mercury levels in brook trout fillets rose from 150 µg/kg in 2006, to 250 in 2019, to 440 in 2022.[91] The nationwide EPA criterion for mercury in fish tissue that is safe for human consumption is 300 µg/kg;[92] the proposed rule for Idaho would set the Idaho criterion for total mercury in fish tissue at 225 µg/kg.[93] The Beartrack project included the creation of wetlands in the area upstream of WQ-22, and beaver activity has added to wetland acreage.[94] The increase of sulfate that has occurred at WQ-22 is within a range that may cause substantial increases in fish tissue mercury, particularly in wetland areas.[95,96]

About 2000 feet downstream of WQ-22, WQ-9 is located to monitor the impacts of effluent discharged under the mine's NPDES permit. Water quality has fluctuated at WQ-9, evidently in response

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[85] Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-21 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-21 2008 Data.xls [Graph Data]*
[86] Meridian Beartrack Co., 2022 Annual Water Quality Report. *Beartrack.2022 Annual Report.Meridian 2023a.pdf [28]* Hereinafter, "2022 Annual Report."
[87] Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-22 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-22 2008 Data.xls [Graph Data]*
[88] 2022 Annual Report. *Beartrack.2022 Annual Report.Meridian 2023a.pdf [29]*
[89] Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-22 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-22 2008 Data.xls [Graph Data]*
[90] 2022 Annual Report. *Beartrack.2022 Annual Report.Meridian 2023a.pdf [30]*
[91] Mercury Report. *Beartrack.Fish tissue mercury.Meridian 2023.pdf [3]*
[92] U.S. EPA, 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. *Beartrack.Methylmercury.EPA 2001.pdf [2]*
[93] U.S. EPA, 2024. Mercury Criterion to Protect Aquatic Life in Idaho, 89 Fed. Reg. 24758 (April 9, 2024). *Beartrack.FedRegIdahoMercury.EPA 2004.pdf [17]*
[94] Mercury Report. *Beartrack.Fish tissue mercury.Meridian 2023.pdf [2]*
[95] Engstrom, Daniel, 2021. Memo re: Minnesota Review of Siting Rule for Nonferrous Mines. *Beartrack.Mercury methylation.Engstrom 2021.pdf [2-4]*
[96] Myrbo, A., Swain, E. B., Johnson, N. W., Engstrom, D. R., Pastor, J., Dewey, B., Monson, P., Brenner, J., Dykhuizen Shore, M., Peters, E.B., (2017). Increase in nutrients, mercury, and methylmercury as a consequence of elevated sulfate reduction to sulfide in experimental wetland mesocosms. Journal of Geophysical Research: Biogeosciences, 122. https://doi.org/10.1002/2017JG003788. *Beartrack.Mercury methylation.Myrbo 2017.pdf [11]*

to the quality of the discharge.[97] Constituents that have increased at WQ-9 include arsenic, specific conductance, nitrate, sodium, and sulfate (Tables 7 and 8). These constituents all stayed close to baseline values through 2003, when post-mining discharge began. In 2004, concentrations rose suddenly, with levels that fluctuated with the volume of streamflow. Figure 5 shows the increases in arsenic and sulfate that resulted after Outfall 001 discharge resumed in 2003. This pattern of increasing concentrations continued at least through 2008. Monitoring for all these constituents except arsenic ended sometime between 2010 and 2013.[98] While effluent monitoring indicates that discharges of metals declined after 2009 (when the new treatment plant began operating), no information is available regarding sulfate or specific conductance.

Beartrack Table 7. Surface Water Quality at WQ-9, Napias Creek.

	Conductivity (µmhos/cm)	**Nitrate** (mg/l)	**Sodium** (mg/l)	**Sulfate** (mg/l)
Baseline, 1989-1991	29	< 0.1	1.8	1 (estimate)
1994-2003 average	30	< 0.1	2.0	1.6
2004-2008 average	80	0.97	5.4	16
2004-2008 maximum	204	3.87	14	47

Baseline values are an average of data collected at WQ-9 between September 1989 and September 1991.
Sulfate baseline value is an approximate average that includes several unquantified data points with varying quantification levels.
The sulfate average for 1994-2003 omits values prior to May 1997. Until then, the quantification level was 10 mg/l, and sulfate was generally below the quantification limit.
The nitrate average for 2004-2008 includes four (out of twenty) data points that were below the quantification level of 0.05 mg/l and were set at 0.025.
Source: Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-9 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-9 2008 Data.xls*

Beartrack Table 8. Arsenic Concentrations (µg/l) at WQ-9, Napias Creek, downstream of Effluent Discharge.

	Upstream average	**WQ-9 average**	**WQ-9 maximum**
1995-2003	n/a	< 5	11
2004	< 5	136	224
2005	< 5	115	232
2006	< 5	22.5	57
2007	< 5	33	105
2008	7	15	32
2009 - 2017	< 10	< 10	107
2018 - 2020	0.8	4	8

All values are averages of all available data points for the applicable time period.
Baseline arsenic values are not available; monitoring for arsenic began in May 1995.
Upstream monitoring is done in Napias Creek just upstream of the NPDES discharge outfall. This monitoring requirement was added to the NPDES permit in 2003 and does not have a WQ designation. Data source: NPDES DMRs. *Beartrack.DMRs.Meridian nd.pdf; Beartrack.Pre-2007 DMR Spreadsheet.xlsx [Sheets Rec-1 (WQ-9) 2004-2006 and Rec-1-Q arsenic]; Beartrack.NPDES Spreadsheet.xlsx [lines 922 to 1067]* (location Rec-5-1)
1995-2003 data are from Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-9 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-9 2008 Data.xls*

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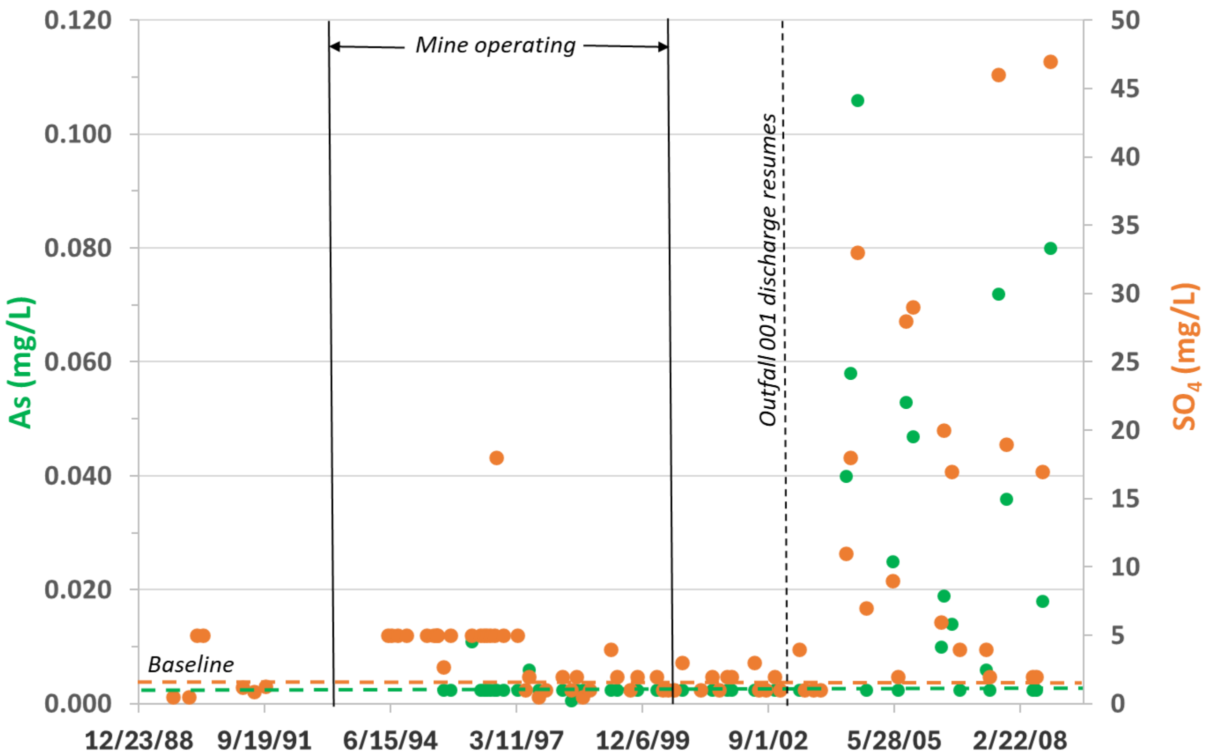
[97] Meridian Beartrack Co., 2006. 2005 Annual Water Quality Report. *Beartrack.2005 Annual Report.Meridian 2006.doc [14]*
[98] Meridian Beartrack Co., 2014. 2013 Annual Water Quality Report. *Beartrack.2013 Annual Report.Meridian 2014.pf [6]*

2004-2006 WQ-9 data are from NPDES DMRs. *Beartrack.DMRs.Meridian nd.pdf; Beartrack.Pre-2007 DMR Spreadsheet.xlsx [Sheets Rec-1 (WQ-9) 2004-2006 and Rec-1-Q arsenic]*
2007 to 2024 WQ-9 data are from *Beartrack.NPDES Spreadsheet.xlsx [lines 1503-1648]* (location Rec-Q-1)



Beartrack Figure 5. Arsenic and sulfate concentrations in Napias Creek at WQ-9, downstream of NPDES Outfall 001, 1989-2008 (sulfate) and 1995-2008 (arsenic). No discharge occurred from June 2000 through October 2003, when water from all sources went to the South Pit for accelerated filling; Outfall 001 discharge resumed in November 2003. Note that the sulfate practical quantitation limit (PQL) varied between 1 and 10 mg/l throughout the period of record; the arsenic PQL was 0.005 mg/l. Values below detection are plotted at one-half the PQL. *Data Sources:* FEIS. *Beartrack.FEIS.USDA 1991.pdf;* Meridian Beartrack Co., 2009. 2008 Annual Water Quality Report, Electronic Attachment WQ-9 Annual Graphs 2008. *Beartrack 2008 Data\Beartrack.WQ-9 2008 Data.xls*

The 2003 NPDES permit requires monitoring in Napias Creek at 100, 200, and 1600 feet downstream of the outfall.[99] WQ-9 is the 100-foot downstream location; the further downstream locations do not have sample designations. Arsenic values at these stations are similarly elevated; in some instances, concentrations are higher than at WQ-9. Arsenic data for all three locations has not been included in EPA's ECHO database since July 2020,[100] although Outfall 001 is still used for discharge.

[99] 2003 NPDES Permit. *Beartrack.NPDES Permit.EPA 2003.pdf [14]* Rec-Q-1 is the permit reporting designation for WQ-9. The 200 and 1600-foot stations are designated as Rec-R-1 and Rec-S-1, respectively.
[100] NPDES Spreadsheet. *Beartrack.NPDES Spreadsheet.xlsx [lines 1618-1648, 1833-1863, 1988-2010]*

In the years when the arsenic concentrations in Napias Creek were higher than 100 µg/l, the water quality standard to protect human health from arsenic in fish tissue was 50 µg/l.[101] The current standard is 4.3 µg/l.[102]

6. Accuracy of Water Quality Predictions

No quantitative water quality predictions were available for the Beartrack Mine. As noted in *Section 3.1*, both ore and waste rock were predicted to have a low potential to generate acid. And geochemical characterization results concluded that 99% of waste rock would have net acid consuming capability. Both ore and waste rock were determined to have some potential to leach arsenic and zinc. As shown in *Section 4.1*, pit underdrain water quality showed increasing acidity and specific conductance, TDS, sulfate, cadmium, copper, manganese, nickel, and zinc values over time. This leachate from the pit, from which ore and waste rock were extracted, clearly qualifies as acid mine drainage.

Predictions that waste rock would not produce acid and needed no specific handling or treatment were erroneous. Monitoring locations in the waste rock area of influence, WQ-21 and WQ-22, have seen increasing concentrations of sulfate over time, which is an indication of sulfide oxidation. The degree of water treatment that would be required prior to discharge in the reclamation period was also underestimated.

7. Summary of Water Quality Impacts

Source materials:

The North Pit has been backfilled with potentially acid-generating (PAG) waste rock. Underdrain water quality is acidic with high concentrations of sulfate and metals (cadmium, copper, manganese, nickel, and zinc) that have been increasing over time after the mine stopped operating. The drainage is sent to the South Pit Lake, which may require perpetual treatment before being discharged to Napias Creek. For comparison, at their peak, metal concentrations in the North Pit underdrains were one to two orders of magnitude higher than criteria for protection of aquatic life.

Effluent:

Arsenic and zinc concentrations in the effluent were as high as 160 and 200 µg/l, respectively, more than twice the standard for drinking water (arsenic) and nearly twice as high as criteria for protection of aquatic life (zinc). The effluent is discharged to Napias Creek downstream of the mine site. The five years after operations ended and before the new treatment plant became operational was the period of the poorest quality effluent from the Beartrack project. Cadmium concentrations in mine effluent exceeded the 2003 permit limits for 43 of 58 months. Zinc concentrations in the effluent exceeded the monthly average twice and the daily maximum once. Mercury in the effluent exceeded the monthly average and daily maximum permit limits.

[101] 2002 NPDES Fact sheet. *Beartrack.NPDES Fact Sheet.EPA 2002.pdf [51-52]*
[102] IDAPA 58.01.02. *Beartrack.Idaho WQS.pdf [152]*

Groundwater:

A well downgradient of the South Pit (MW-B) has had increasing concentrations of sulfate, TDS, manganese, and zinc that peaked in 2001 at approximately three to six times higher than baseline values. Other wells downgradient of the heap leach pad have TDS and conductivity values that have risen by an order of magnitude but declined to near baseline levels by 2008.

Surface Water:

Locations in Ward's Gulch are influenced by the waste rock area and the sedimentation pond (WQ-31), and the sedimentation pond and the South Pit (WQ-4). WQ-31 had increasing concentrations of sulfate, manganese, and zinc with peaks in 2003; values decreased after this time but remain elevated above baseline values. Nitrate concentrations (from blasting) peaked during operations, and sulfate concentrations continued to rise after the mine closed. Both parameters remained considerably elevated over baseline values during closure. In Napias Creek, below the Ward's Gulch confluence and more than two miles downstream, sulfate and specific conductance values are above baseline. Fish tissue mercury concentrations measured in brook trout at the downstream location (WQ-22) rose from 150 to 440 µg/kg from 2006 to 2022. Another location in Napias Creek downstream of the NPDES effluent discharge (WQ-9) had baseline concentrations of most constituents (arsenic, specific conductance, nitrate, sodium, and sulfate) until 2003, when effluent discharge resumed. In 2004, concentrations rose suddenly, including for arsenic and sulfate, indicating that treatment was not adequately removing mine contaminants.

8. Comparison to Potential Mines in the Rainy River Headwaters Watershed of Minnesota

The Beartrack Mine site is similar to sites in the Rainy River Headwaters Watershed in that small and larger creeks run through the property. However, both the land and the climate are, as a whole, much drier at Beartrack. Beartrack is in a location where evapotranspiration exceeds precipitation, reducing the need for discharge of mining-impacted water. Sulfide levels in ore and waste rock are similar. The Beartrack operation was smaller than those proposed for the Duluth Complex, although closer in range than many of the mines in this report.

9. Post-permitting and Potential Future Expansions

A Preliminary Feasibility Study Report for reopening the Beartrack Mine was released by Revival Gold, Inc. in 2023. The "Beartrack-Arnett Heap Leach Project" would be roughly comparable to the initial project in terms of daily production, with a total production of 40 million tons of ore. In addition to reopening the three existing pits, mining would be extended into the Arnett Creek watershed, which is currently unimpacted by mining activity. As water treatment is not anticipated for the Arnett watershed,[103] degradation of that creek may be similar to what has been allowed in Napias Creek.

The Beartrack-Arnett Heap Leach Project would mine ore of similar sulfur content and characterization as the initial project.[104] Deeper mineralization with a higher concentration of sulfide

[103] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [289]*

[104] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [35, 163]*

minerals is not proposed for mining at this time because it would not be amenable to heap leach processing. However, the company is also exploring a future project targeting the high sulfide ore.[105] It is also anticipated that additional low-sulfide ore will be identified in the Arnett watershed,[106] which could increase the scope of the currently proposed project. The anticipated timeline for the new project is to complete environmental review and permitting by the end of 2026 and to start construction in 2027.[107]

[105] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [39, 79]*
[106] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [351]*
[107] NI 43-101 Report. *Beartrack.NI 43-101.Kappes 2023.pdf [348]*

Buckhorn Mountain Mine, Washington

1. Site and Mine Description and Background Information

The Buckhorn Mountain Mine was a small underground gold mine located on an inholding in the Okanogan National Forest in eastern Washington near the Canadian border. The facility is owned and operated by Crown Resources Corporation, whose parent company is Kinross Gold USA, Incorporated.

The mine facilities are located primarily on 46 acres of private land that was conveyed from federal ownership, with roads and other impacts extending onto surrounding U.S. Forest Service, Bureau of Land Management, and Washington State property.[108] Ore was hauled forty-seven miles to the pre-existing Key Mill (also known as Kettle River Mill) for processing. Tailings were disposed of at the mill site.[109] Daily production averaged 1500 tons of ore, with a predicted lifetime total of 4 million tons.[110] Estimated waste rock production was 500 tons per day.

The mine was first proposed as an open-pit mine in the 1990s and was the subject of a 1997 EIS, under the name of Crown Jewel.[111] Mine proponents dropped that plan after mine opponents successfully appealed the water rights and 401 certifications to the Washington State Pollution Control Hearings Board. A new plan of operations was proposed in 2004.[112] The Washington Department of Ecology (WDOE) issued a Final Supplemental EIS in 2006, and the U.S. Forest Service issued a separate Final EIS for the haul road in 2007.[113] The mine site facilities operate under NPDES and State Waste Discharge Permit WA0052434,[114] which was originally issued by WDOE in 2007. Key Mill operates under a separate State Waste Discharge Permit. Mining began in 2008 and ended in 2017.[115]

The mine site is located on a rounded mountain top. Small creeks drain in several directions, and seeps and springs are prevalent lower on the hillside.[116] Gold Bowl, Nicholson, and Marias Creeks drain to the east toward Toroda Creek, and Bolster Creek drains to the west toward Myers Creek[117] (Figure 1). Average annual precipitation is approximately 20 inches.[118]

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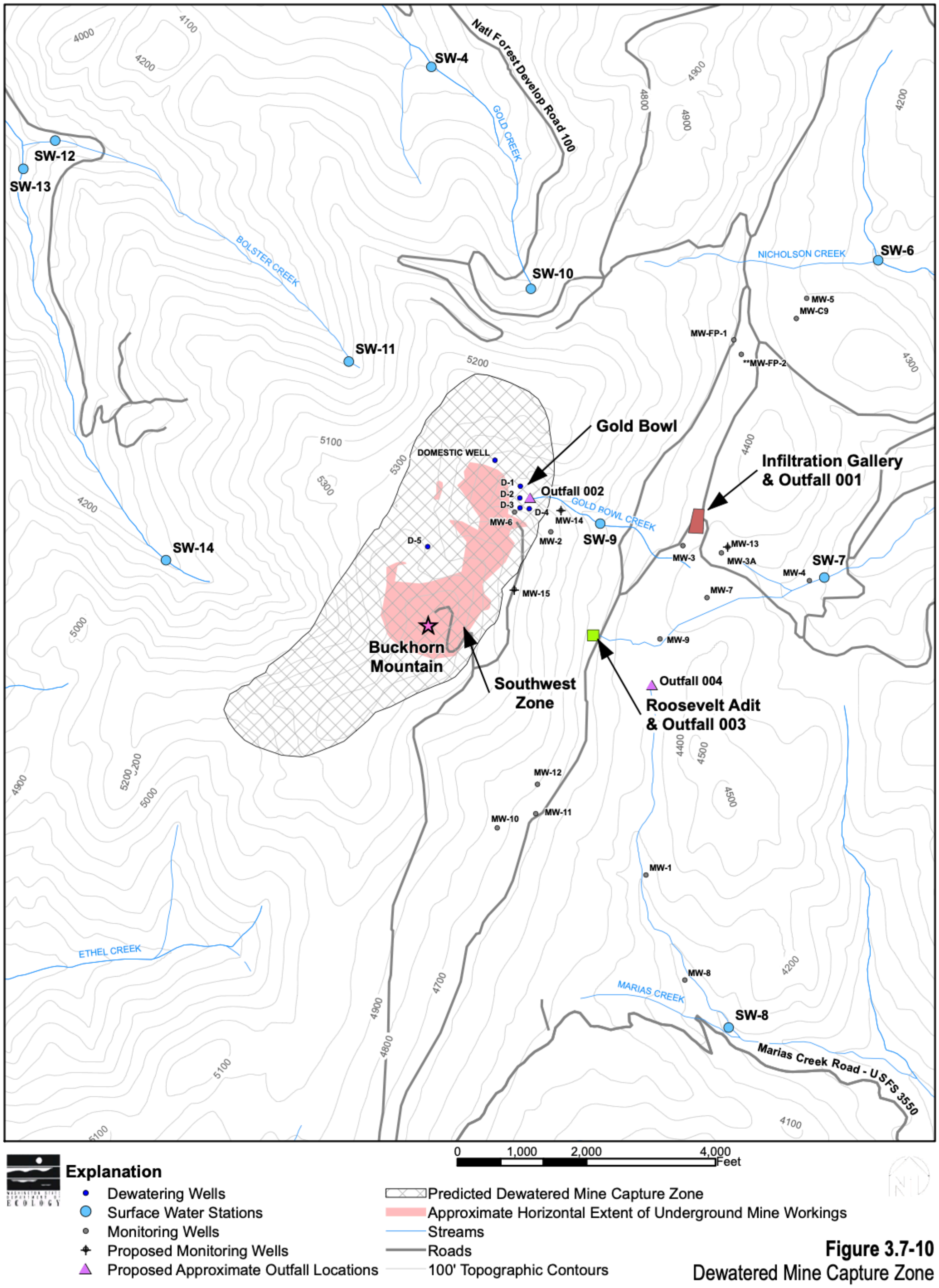
[108] Washington Dept. of Ecology, 2006. Buckhorn Mountain Project Final Supplemental Environmental Impact Statement Vol. I. Hereinafter, "FSEIS." FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [24]*
[109] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [89-92]*
[110] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [3]*
[111] USDA Forest Service and Washington Dept. of Ecology, 1995a. Draft Environmental Impact Statement, Crown Jewel Mine. *Buckhorn.Crown Jewel DEIS.USDA 1995a.pdf*
[112] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [23]*
[113] U.S. Dept. of Agriculture, 2007. Buckhorn Access Project Final Environmental Impact Statement. *Buckhorn.Access FEIS.USDA 2007 (folder)*
[114] Washington Dept. of Ecology, 2015. National Pollutant Discharge Elimination System Waste Discharge Permit No. WA0052434. Hereinafter, "2015 NPDES Permit." *Buckhorn.NPDES Permit.WDOE 2015a.pdf*
[115] Crown Resources Corp., 2024a. Buckhorn Mountain Mine Adaptive Management Plans Water Year 2023. Hereinafter, "2023 AMP." *Buckhorn.2023 AMP.Crown 2024a.pdf [9]*
[116] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [225, 249]*
[117] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [225]*
[118] Crown Resources Corp., 2018a. Buckhorn Mountain Mine Adaptive Management Plans Water Year 2017. Hereinafter, "2017 AMP." *Buckhorn.2017 AMP.Crown 2018a [102]*



Buckhorn Figure 1: Monitoring Stations and Outfalls. *Source:* Washington Dept. of Ecology, 2006. Buckhorn Mountain Project Final Supplemental Environmental Impact Statement Vol. I. *Buckhorn.FSEIS.WDOE 2006.pdf [272]*

At the mine site, bedrock is close to the surface, and groundwater exists primarily in the bedrock aquifer. At lower elevations and particularly along the creeks, groundwater exists in alluvium and glacial deposits as well.[119] Bedrock hydraulic conductivity varies widely (estimated at 10^{-5} ft/d to 1.5 ft/d) and decreases with depth.[120]

Groundwater at the Key Mill site consists of a shallow unconfined aquifer within surficial alluvium separated from a deep aquifer by "semi-impermeable glacial lake deposits" at the alluvium/bedrock interface.[121] The mill and tailings impoundment are located on the North Fork Sanpoil River.

Although the Buckhorn deposit itself had not been previously mined, a few historic small adits are located within 2,000 feet of the Buckhorn Mine. The pre-existing Roosevelt Adit discharges groundwater at a rate of 34 to 57 gallons per minute (gpm), forming the headwaters of Nicholson Creek.[122] Prior to the Buckhorn Mine, constituents in water at the Roosevelt Adit were marginally higher than at other monitoring locations, but adit water was still of good quality. (*See Section 5.2.1 below*.) To the extent this water is affected by previous mining, the impacts are included in baseline data, allowing an assessment of additional impacts from the Buckhorn Mine.

2. Mine Facilities, Operations, and Reclamation

Facilities at the mine site have included: underground workings; temporary stockpiles of waste rock, ore, backfill, and topsoil; a water treatment plant, infiltration system, piping, and outfalls; backfill operations; stormwater trenches; and water storage ponds.[123] The Key Mill site includes the mill, ore stockpile, and tailings impoundment. The two locations are 47 miles apart via the haul road and public roads.

During operations, mine dewatering water was pumped to a storage pond ("surge" pond) and then to a treatment plant. Groundwater inflow rates to the mine were underpredicted. The maximum predicted rate was 168 gpm, with a maximum annual average of 93 gpm.[124] In contrast, the 2017 maximum quarterly inflow was 252 gpm, and the annual average was 105 gpm.[125] It was assumed that grouting would minimize inflows above the predicted rates;[126] this mitigation measure was not implemented as extensively as described in the FSEIS and required by the regulator and has been less effective than anticipated.[127]

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[119] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [238]*
[120] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [243]*
[121] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [256]*
[122] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [245-249]*
[123] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [74]*
[124] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [264]*. Although the EIS notes that inflow rates could be higher in years with precipitation higher than 20 inches, precipitation has been lower than anticipated, and was 15.39 inches in 2017. 2017 AMP. *Buckhorn.2017 AMP.Crown 2018a.pdf [102]*
[125] 2017 AMP. *Buckhorn.2017 AMP.Crown 2018a.pdf [81]*
[126] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [266]*
[127] Washington Dept. of Ecology, 2013b. Letter to Gina Myers of Crown Resources Corp., Re: Shotcrete and Grouting Plan Review, January 23, 2013. *Buckhorn.Shotcrete letter.WDOE 2013b.pdf*

Waste rock and ore were transported to the surface and stored in temporary stockpiles. In accordance with the FSEIS, originally waste rock with a neutralization potential:acid production potential ratio of less than 3 was treated as potentially acid generating (PAG). However, the definition of PAG was reclassified later during operations as having a total sulfur content less than 0.3% as well as a neutralization potential:sulfide sulfur acid production potential ratio of less than 3.[128] All PAG waste rock was eventually backfilled into the mine; prior to backfill, it was stored on the surface with a marble pad and amendments to provide neutralization.[129]

Stormwater that included runoff from the stockpiles was collected in trenches and ponds, most of which were originally unlined. Liners were not required for the ponds or stockpiles because the mine dewatering system was expected to capture the groundwater under them.[130,131] Liners were added after impacts on groundwater outside the capture zone became apparent.[132]

Waste rock that was classified as non-potentially acid generating was used for construction and other purposes; stormwater that contacted this rock discharged to surface and groundwater without treatment, and is a likely source of elevated sulfate and nitrate concentrations in groundwater and surface water.[133,134] This material was partly removed after mine operations ceased as part of surface reclamation, but a significant amount remains in the area underlying the water treatment plant and other ongoing infrastructure.

The NPDES permit requires maintenance of a groundwater capture zone "to include all underground mine workings, the surge pond, and all surface stockpiles of ore and development rock."[135] The capture zone is illustrated in Figure 1. WDOE first issued an administrative order for violation of this requirement in April 2009,[136] and several mitigation measures were added, including stockpile and pond liners[137] and additional dewatering wells.[138] A geographic delineation of the capture zone and numeric limits for groundwater and surface water monitoring points outside the capture zone were added to the permit in 2014.[139] Specifically, in the updated permit, "the Capture Zone represents the farthest extent

[128] Washington Dept. of Ecology and Washington Dept. of Natural Resources, 2011. First Addendum to the Development Rock Management Plan, April 13, 2011. *Buckhorn.Rock Management Plan Addendum.WDOE 2011.pdf*
[129] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [85, 90, 292-293]*
[130] Washington Dept. of Ecology, 2007a. National Pollutant Discharge Elimination System Waste Discharge Permit No. WA0052434. Hereinafter, "2007 NPDES Permit." *Buckhorn.2007 NPDES Permit.WDOE 2007a.pdf [10]*
[131] Washington Dept. of Ecology, 2007. Fact Sheet for NPDES Permit No. WA0052434. Hereinafter, "2007 NPDES Fact Sheet." *Buckhorn.2007 NPDES Fact Sheet.WDOE 2007b.pdf [6]*
[132] Crown Resources Corp., 2018b. Hydrologic Data Report - Water Year 2017. *Buckhorn.2017 HDR.Crown 2018b.pdf [71]*
[133] Golder, 2018. Technical Memorandum: Response to Washington Department of Ecology Notice of Violation No. 15958. *Buckhorn.Response to NOV 15958.Golder 2018.pdf [3]*
[134] Washington Pollution Control Hearings Board, 2015. PCHB No. 14-018, Findings of Fact, Conclusions of Law, and Order. Hereinafter, "PCHB Findings of Fact." *Buckhorn.PCHB Findings of Fact.PCHB 2015.pdf [11]*
[135] 2015 NPDES Permit. *Buckhorn.NPDES Permit.WDOE 2015a.pdf [8];* 2007 NPDES Permit. *Buckhorn.2007 NPDES Permit.WDOE 2007a.pdf [10]*
[136] Washington Dept. of Ecology, 2009. Administrative Order No. 6674. *Buckhorn.AO 6674.WDOE 2009.pdf*
[137] Washington Dept. of Ecology, 2014a. Fact Sheet for NPDES Permit No. WA0052434. Hereinafter, "2014 NPDES Fact Sheet." *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [7]*
[138] Washington Dept. of Ecology, 2013. State Environmental Policy Act Addendum, NPDES Permit No. WA0052434. SEPA Addendum. *Buckhorn.SEPA Addendum.WDOE 2013.pdf [10]*
[139] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [4]*

from the mine that mine-related contaminants in groundwater and surface water are allowed. This extends from the land surface to depth at which groundwater is not affected by mining activities."

Mine water and runoff from stockpiles and other potentially impacted areas are collected and treated prior to discharge. The initial treatment plant was undersized. The EIS predicted an average treatment and discharge rate of 44 gpm;[140] the treatment plant was permitted for a capacity of 100 gpm. By 2014, capacity had increased to 500 gpm.[141] In 2017 (the last year of operation), the mine discharged an average of 66 gpm.[142]

Under the initial NPDES permit, the primary outfall was a land infiltration gallery (Outfall 001). Three additional outfalls (002, 003, and 004) were used for flow augmentation and to accommodate discharge above the Outfall 001 volume limit.[143] The permit required the maintenance of ground stability at Outfall 001 to prevent landslides;[144] landslides nevertheless occurred at both Outfalls 001 and 002.[145] Outfall 001 was eliminated and Outfall 002 reconfigured.[146] Additional secondary outfalls were added.[147] The original outfall locations are shown on Figure 1.

The original treatment plant, an ion exchange system,[148] was replaced with a reverse osmosis system in 2012.[149] The second iteration of the NPDES permit includes stricter limits based on the past performance of the treatment system (i.e. if the plant could produce water that was better than water quality standards, it was required to do so).[150]

Ore from the Buckhorn Mine was hauled 47 miles to the Key Mill. Magnesium chloride was used for dust suppression on the haul road in the early years, but was eliminated in 2013 due to elevated chloride concentrations in surface waters.

The Key Mill (also known as the Kettle River Mill) first began operating in 1989, and processed ore from six other mines in the area prior to the Buckhorn operation.[151] The tailings impoundment was expanded to allow the disposal of 3 million tons of Buckhorn tailings, including raising the existing dam by 28 feet.[152] The tailings impoundment does not discharge directly to surface water, and thus does not have a NPDES permit, but operates under State Waste Discharge Permit ST-8033.[153] Water levels are controlled in part by an enhanced evaporation system.[154] The tailings impoundment has a

[140] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [268]*
[141] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [1-2]*
[142] Crown Resources Corp., 2018b. Hydrologic Data Report - Water Year 2017. *Buckhorn.2017 HDR.Crown 2018b.pdf [47]*
[143] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [243, 248, 268-69]*
[144] 2007 NPDES Permit. *Buckhorn.2007 NPDES Permit.WDOE 2007a.pdf [7]*
[145] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [18]*
[146] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [5]*
[147] PCHB Findings of Fact. *Buckhorn.PCHB Findings of Fact.PCHB 2015.pdf [14]*
[148] 2007 NPDES Fact Sheet. *Buckhorn.2007 NPDES Fact Sheet.WDOE 2007b.pdf [7]*
[149] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [18]*
[150] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [42-43]*
[151] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [78]*
[152] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [79, 126]*
[153] Washington Dept. of Ecology, 2015b. State Waste Discharge Permit Number ST0008033. *Buckhorn.State Waste Discharge Permit.WDOE 2015b [6-8]*
[154] 2023 AMP. *Buckhorn.2023 AMP.Crown 2024a.pdf [57]*

geomembrane liner with an underdrain.[155] Water collected by the underdrain (about 7.5 gpm) is treated at a biological water treatment plant and discharged to land infiltration galleries.[156] The permit requires monitoring of the effluent, but the only limit is for electrical conductivity,[157] which is designed to serve as an immediate alert of a liner leak.

3. Geochemistry

Based on static and kinetic geochemical testing results, it was acknowledged at the time of permitting that ore and some waste rock had the potential to generate acid.[158] The EIS predicted that drainage from PAG rock would have a pH range of 2.4 to 3.8 S.U.[159] Ongoing field data are not available; a single waste rock leachate sample taken in the third year of mining (2010) had a pH of 4.96.[160]

4. Mine-Influenced Water Quality

4.1 Mine Inflow Water Quality

Water quality monitoring data from mine sumps are available in a database maintained by the Okanogan Highlands Alliance. Dates vary for different parameters; the earliest data are from 2011. Monitoring data for sumps ended in 2017 with the end of mine dewatering. From 2011 to 2017, total dissolved solids (TDS) concentrations averaged 893 mg/l, with a maximum measurement of 2280 mg/l. The pre-mining baseline groundwater TDS level in the Gold Bowl mining area was 220 mg/l (Table 1). Additional parameters are shown in Table 5.

Buckhorn Table 1. Average Groundwater Concentrations of Chloride, Nitrate+Nitrite, TDS, and Sulfate.

a) **Chloride (mg/l).** Permit limit outside capture zone: 2 mg/l.

	MW6/6R (inside GW capture zone)	**MW2/2R (outside GW capture zone)**	**MW7 (~1,500 ft downgradient)**	**MW9 (~1,500 ft downgradient)**	**MW3 (Outside GW flow path)**
Baseline 1992-1996, and 2003-2007	1.2	1.3	1.0	1.3	1.5
Operations 2008-2017	36	26	6.6	6.7	0.8
Closure 2017-2023	23	14	8	9.2	0.8

[155] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [92]*
[156] 2023 AMP. *Buckhorn.2023 AMP.Crown 2024a.pdf [57]*
[157] Washington Dept. of Ecology, 2015b. State Waste Discharge Permit ST0008033. *Buckhorn.State Waste Discharge Permit.WDOE 2015b [6-8]*
[158] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [292, 294]*
[159] FSEIS Table 3.7-11. *Buckhorn.FSEIS.WDOE 2006.pdf [296]*
[160] Stratus Consulting, 2010. Analysis of Water Quality Impacts at the Buckhorn Mountain Mine and Recommendations for Improvement. Hereinafter "Stratus Report." *Buckhorn.Stratus report.Stratus.pdf [16]*

b) Nitrate + nitrite (mg/l as N). Permit limit outside capture zone: 1.33 mg/l.

	MW6/6R	MW2/2R	MW7	MW9	MW3
Baseline	1.5	1.1	0.1	0.1	0.1
Operations	34	5.2	1.0	0.5	0.1
Closure	22	3.6	2.5	1.28	0.2

c) TDS (mg/l). Permit limit outside capture zone: 290 mg/l.

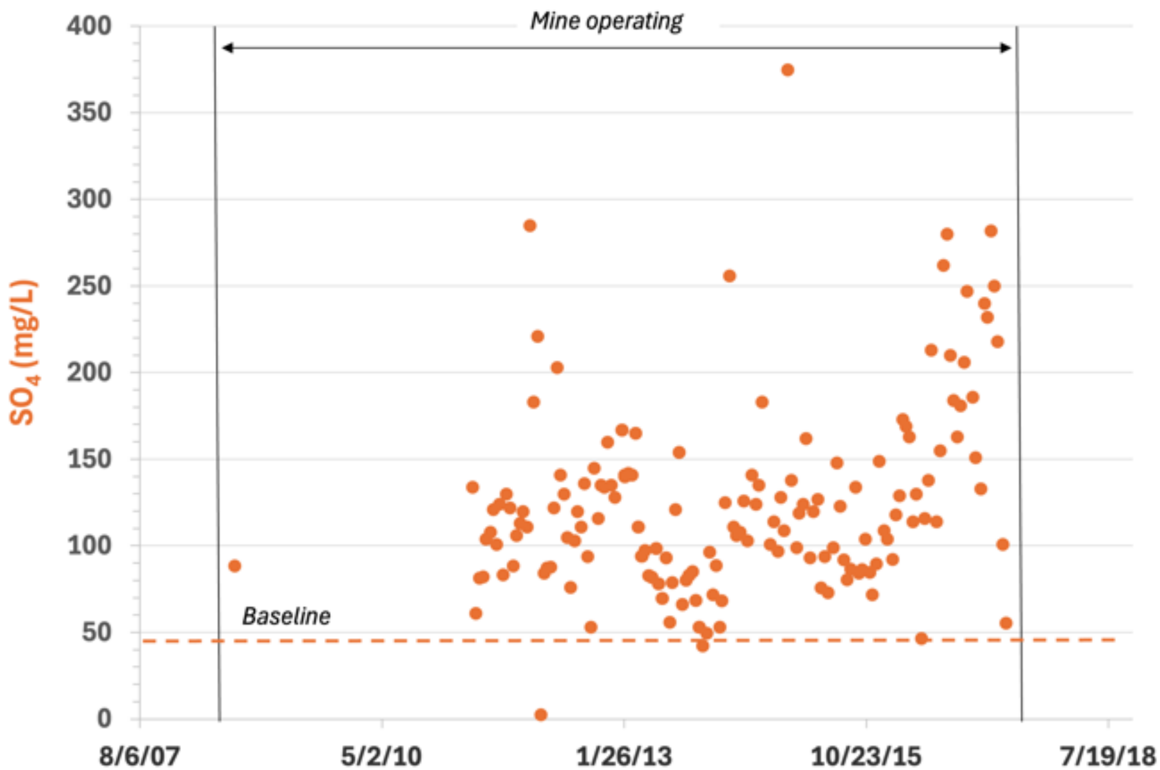
	MW6/6R	MW2/2R	MW7	MW9	MW3
Baseline	220	120	193	193	151
Operations	240	440	211	226	156
Closure	681	577	231	245	158

d) Sulfate (mg/l). Permit limit outside capture zone: 69.5 mg/l

	MW6/6R	MW2/2R	MW7	MW9	MW3
Baseline	48	17	34	34	12
Operations	192	195	44	46	10
Closure	263	313	58	62	11

MW6/6R is located inside the capture zone in the Gold Bowl mining area and is not a compliance location.
MW 2/2R is located near the Gold Bowl mining area, outside the groundwater capture zone boundary.
Permit limits are monthly averages from NPDES Permit. *Buckhorn.NPDES Permit.WDOE 2015a.pdf [16]*
Data are from Okanogan Highlands Alliance's database of monitoring data from the Buckhorn Mine. *Buckhorn.Buckhorn data spreadsheet.OHA 2024.xlsx*
Note: All values are averages for the applicable time period.

Sulfate concentrations in the Gold Bowl mining area in particular showed an increasing trend between 2013 and 2017. The pre-mining baseline sulfate concentration in the Gold Bowl area was 48 mg/l (Table 1 and Figure 2).



Buckhorn Figure 2. Sulfate Concentrations in Gold Bowl Mine Sump, 2008-2017.
Graphs created using data from database maintained by Okanogan Highlands Alliance.

4.2 Waste Rock Leachate Water Quality

Leachate water quality data are not available for either PAG or NPAG rock. However, a report prepared by for Okanogan Highlands Alliance includes data for a few parameters from a single monitoring event in 2010; a table from that report is reproduced as Figure 3.

Parameter	Unit	Measurement
PH	SU	4.96
Specific conductance	microSiemens/cm	3,070
Nitrate	mg/L as N	166
Sulfate	mg/L	1,110
TDS	mg/L	2,480

SU = standard pH units.
Source: Kinross e-mail, September 23, 2010.

Buckhorn Figure 3: Sampling results from PAG, development rock leachate collected on June 4, 2010. *Source:* Stratus Consulting, 2010. Analysis of Water Quality Impacts at the Buckhorn Mountain Mine and Recommendations for Improvement. *Buckhorn.Stratus report.Stratus.pdf [16]*

4.3 Tailings Water Quality

Monitoring data are not available for interstitial tailings water. However, an underdrain collects drainage water from the basin liner. Drainage water from 2008 to 2023 ranged from approximately 70 to 160 mg/l for sulfate and 350 to 600 mg/l for TDS.[161]

4.4 Effluent Water Quality

The original ion exchange treatment system was unable to meet permit limits. WDOE noted 74 exceedances for effluent in the 2008-2013 time period; parameters with violations included (among others) TDS (permit limit 500 mg/l), mercury (permit limit 20 ng/l), copper (permit limit 27 µg/l), lead (permit limit 9 µg/l), zinc (permit limit 83 µg/l), arsenic (permit limit 1 µg/l), and chloride (permit limit 250 mg/l).[162] Effluent has been in substantial compliance with permit limits since the reverse osmosis system became operational.[163] The 2015 NPDES permit limits for effluent include an average chloride limit of 3.2 mg/l; an average sulfate limit of 2.7 mg/l; and an average TDS limit of 214 mg/l.[164]

5. Impacts on Groundwater and Surface Water Quality

5.1 Groundwater Quality Impacts

5.1.1 Groundwater Quality Impacts at Mine Site

Baseline groundwater monitoring was conducted at a number of wells from 1992 to 1996 for the Crown Jewel EIS.[165] Wells were sampled monthly until June 1995, and semiannually thereafter. A second baseline monitoring program was undertaken from 2003-2007.[166] Data from baseline monitoring is included in the Okanogan Highlands Alliance database; the Buckhorn EIS provides averages of all pre-mining data for the entire site. [167]

The Buckhorn NPDES permit includes concentration limits for groundwater at the boundary of the groundwater capture zone.[168] While these limits ostensibly allow no degradation of groundwater, some are set significantly above the measured baseline level. This is done to account for natural variation, so that exceedances with natural causes are not attributed to the mining operation. However, the practical effect is that significant degradation is allowed even under a “no degradation” permit, as shown in Table 2.

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[161] 2023 AMP. *Buckhorn.2023 AMP.Crown 2024a.pdf [129-130]*
[162] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [24-33]*
[163] Crown Resources Corp., 2024b. Hydrologic Data Report - Water Year 2023. *Buckhorn.2023 HDR.Crown 2024b.pdf [498 et seq.]*
[164] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [45-47]*
[165] USDA Forest Service and Washington Dept. of Ecology, 1995b. Crown Jewel Mine Draft Environmental Impact Statement App. C, Hydrologic Summary Statistics. *Buckhorn.Crown Jewel Baseline.USDA 1995b.pdf*
[166] Washington Dept. of Ecology, 2005. Geochemistry, Surface Water, and Groundwater Quality Discipline Report. Hereinafter, "Baseline Report." *Buckhorn.Baseline WQ.WDOE 2005.pdf [37]*
[167] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [252]*
[168] 2015 NPDES Permit. *Buckhorn.NPDES Permit.WDOE 2015a.pdf [8];* 2007 NPDES Permit. *Buckhorn.2007 NPDES Permit.WDOE 2007a.pdf [10]*

Buckhorn Table 2. Potential Groundwater Degradation Allowed by Permit

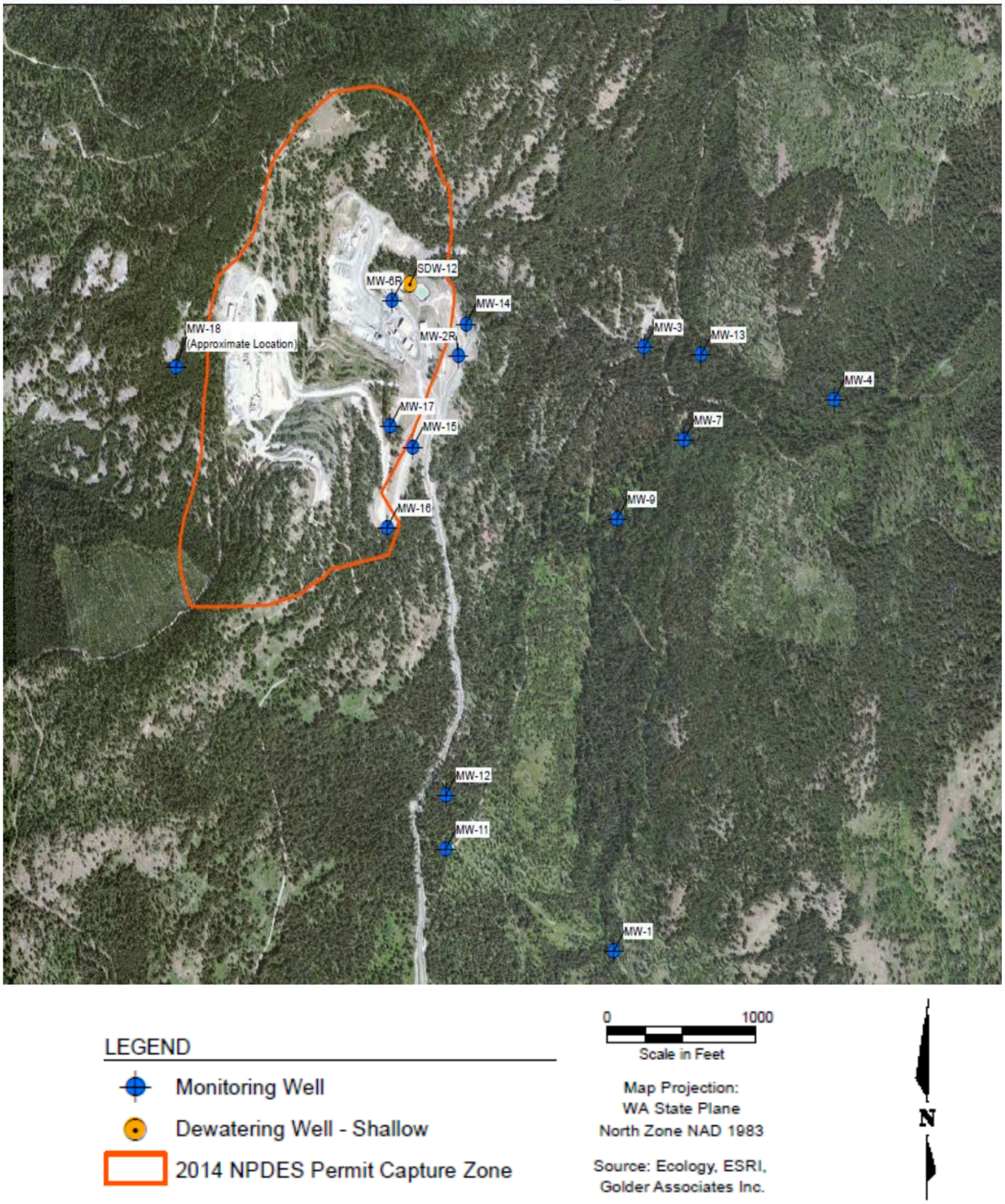
	Baseline average, all wells	Lowest baseline average, in a specific well	Permitted monthly average
TDS (mg/l)	186	120	290
Chloride (mg/l)	1.3	1	2
Sulfate (mg/l)	24	11	69.5
Nitrate (mg/l)	0.15	0.04	1.33
Arsenic (µg/l)	7	2	10
Zinc (µg/l)	20	10	30

Baseline average, all wells is from 1992-1996 and 2003-2005. Source: *Buckhorn.FSEIS.WDOE 2006.pdf [252]*
Lowest baseline average in a specific well is from 1992-1994. Source: Washington Dept. of Ecology, 2005. Geochemistry, Surface Water, and Groundwater Quality Discipline Report. *Buckhorn.Baseline WQ.WDOE 2005.pdf [79-81]*
Permit monthly average source: NPDES Permit. *Buckhorn.NPDES Permit.WDOE 2015a.pdf [16]*

WDOE first issued an administrative order for violation of the groundwater capture zone requirement in April 2009,[169] less than two years after mining began;[170] the operation has been continually out of compliance ever since.[171] In 2020 Clean Water Act lawsuits filed by Okanogan Highlands Alliance and the Washington Attorney General, the company stipulated to 3,538 monthly exceedances of numeric limits.[172] The WDOE Water Quality Permitting and Report System (PARIS) website lists 844 monthly numeric permit limit violations between October 18, 2022, and April 1, 2024.[173] Parameters with violations include chloride, nitrate, sulfate, TDS, electrical conductivity, arsenic, ammonia, iron, copper, manganese, and zinc.

Groundwater flowing both east and west from the mine site has been impacted. To the east, monitoring data suggest a migrating groundwater plume. Both baseline and ongoing data are available for seven monitoring wells in this general direction (Figure 4). Two wells located at the mine site (MW2/2R and MW6/6R) show the most impact; two wells that lie about 1500 feet downgradient from the mine (MW7 and MW9) show a lesser impact; and wells that appear to be outside of the groundwater flow path show little or no impact.

[169] Washington Dept. of Ecology, 2009. Administrative Order No. 6674. *Buckhorn.AO 6674.WDOE 2009.pdf*
[170] 2014 NPDES Fact Sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [15]*
[171] U.S. EPA, 2004. DMR Exceedances Report. From https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedances?permit_id=WA0052434. Accessed June 15, 2024. *Buckhorn.Exceedances Report.EPA 2024.pdf*
[172] U.S. District Court, Eastern District of Washington 2022. Case No. 2:20-CV-00147-MKD, Order Granting Stipulated Motion Concerning Crown Resources Corporation's Partial Liability Under the Clean Water Act. *Buckhorn.2022 Court Order.USDistrictCt 2022.pdf*
[173] Washington Dept. of Ecology, 2024. Water Quality Permitting and Reporting Information System webpage, https://apps.ecology.wa.gov/paris/ComplianceAndViolations/ViolationsAndPermitTriggers.aspx. Accessed June 10, 2024. *Buckhorn.Recent violations spreadsheet.WDOE 2024.xlsx*

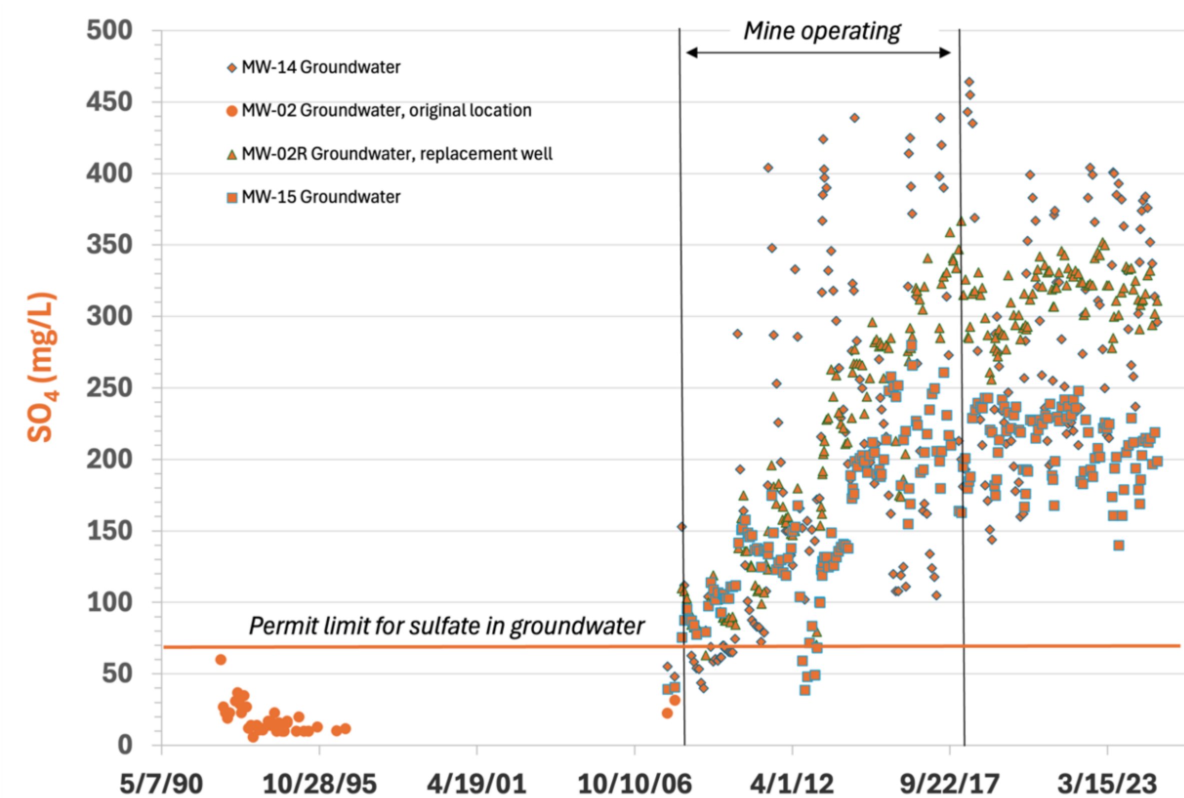


Buckhorn Figure 4. Buckhorn Mine Groundwater Monitoring Locations.
Source: Washington Dept. of Ecology, 2015. National Pollutant Discharge Elimination System Waste Discharge Permit No. WA0052434. *Buckhorn.NPDES Permit.WDOE 2015a.pdf [75]*

Monitoring wells and dewatering wells within the capture zone boundary had the most significant increases in mine-related contaminants. While not a compliance location, water quality concentrations in MW-6R are significantly elevated compared to baseline water quality from the original well, MW6 (Figure 5). Chloride and nitrate are expected to decline after mining ceases as the sources of those constituents are no longer being added to the system. The source material for sulfate remains at the site and sulfate is still being released.

Buckhorn Figure 5. Groundwater quality at MW6/6R, within the capture zone boundary, downgradient of the Gold Bowl Zone of the underground mine. a) nitrate+nitrite concentrations, b) TDS and sulfate concentrations. Graphs created using data from database maintained by Okanogan Highlands Alliance.

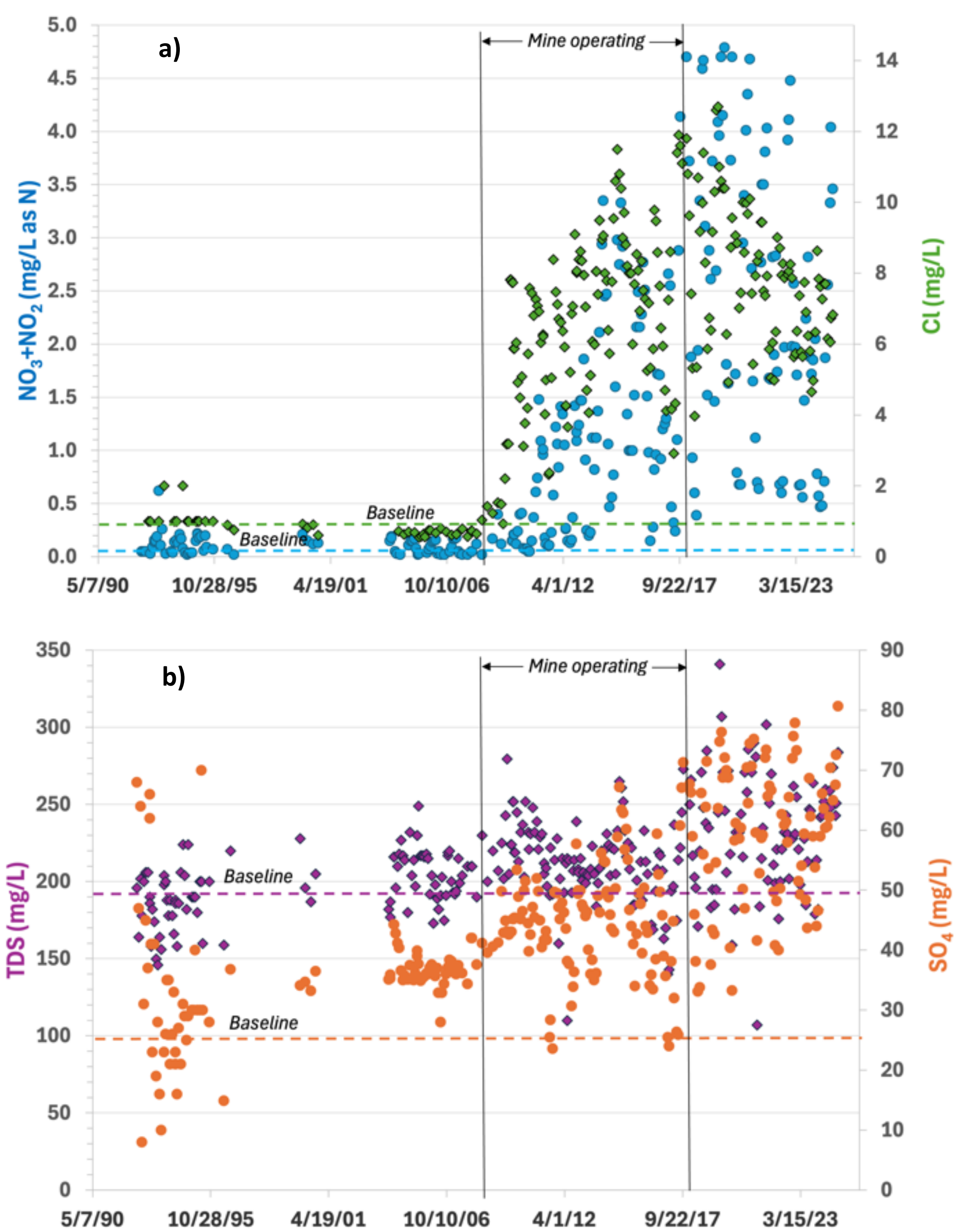
As indicated in Table 2, significant degradation is observed close to the mine but outside the capture zone in the NLF-3 Fault (Figure 6). Wells at this location always exceed the permit limits for chloride, nitrate, TDS, and sulfate, and frequently also exceed the much higher state water quality standards for TDS (500 mg/l) and sulfate (250 mg/l).[174]

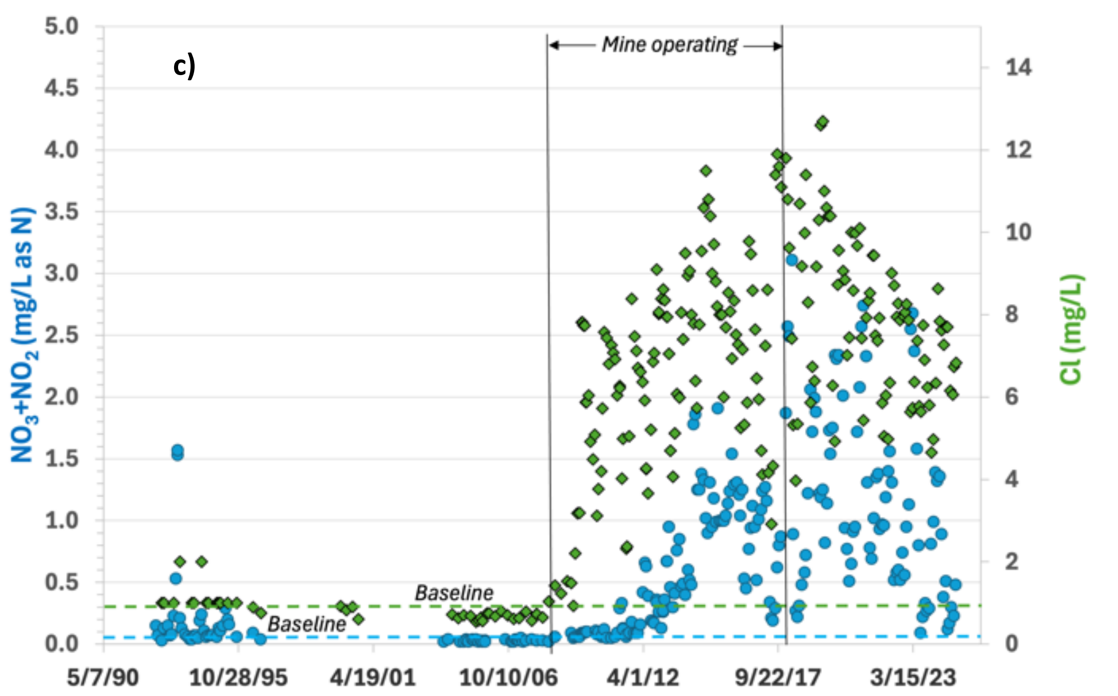


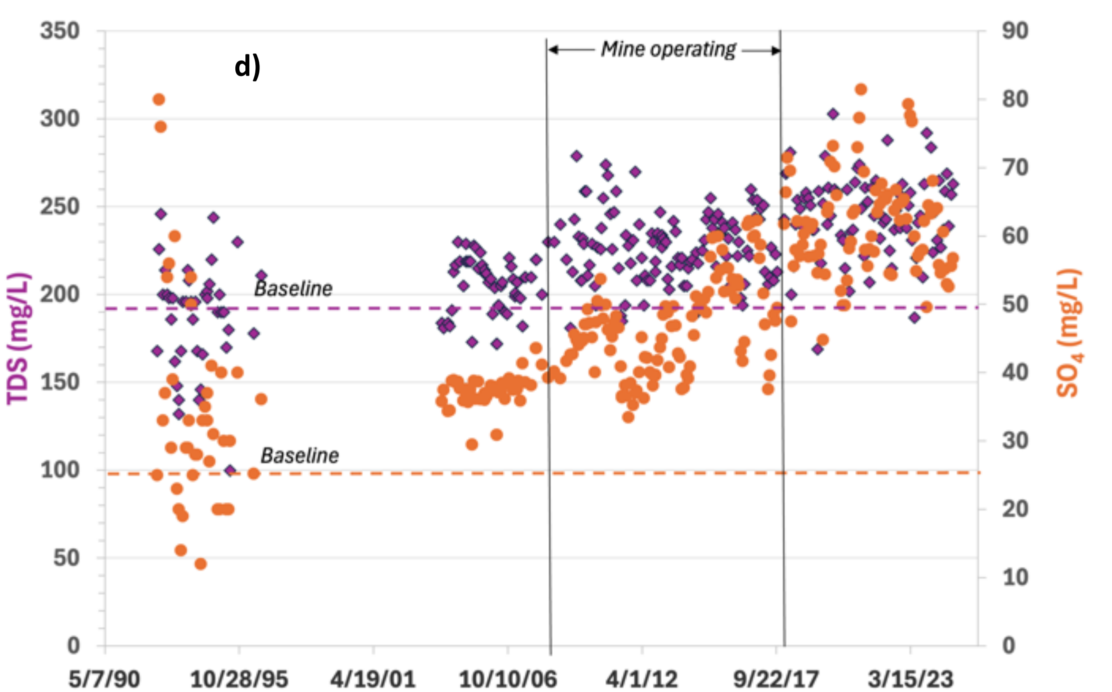
Buckhorn Figure 6. Sulfate concentrations in the NLF-3 Fault in monitoring wells MW14, MW2/2R, and MW15, outside the capture zone boundary, downgradient of the Gold Bowl Zone in the underground mine. Monthly average permit limit for sulfate is 69.5 mg/l. Graphs created using data from database maintained by Okanogan Highlands Alliance.

Fifteen hundred feet from the capture zone boundary at MW7 (Figure 7, a-b) and MW9 (Figure 7 c-d), groundwater consistently exceeds the permit limit for chloride, often exceeds the limit for nitrate, and has recently begun to show frequent exceedances of sulfate.

[174] WAC 173-200-040. *Buckhorn.WAC 173-200-040.pdf [2]*


a)
Mine operating
Baseline
Baseline
NO_3+NO_2 (mg/L as N)
Cl (mg/L)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
14
12
10
8
6
4
2
0
5/7/90
10/28/95
4/19/01
10/10/06
4/1/12
9/22/17
3/15/23
b)
Mine operating
Baseline
Baseline
TDS (mg/L)
SO_4 (mg/L)
350
300
250
200
150
100
50
0
90
80
70
60
50
40
30
20
10
0
5/7/90
10/28/95
4/19/01
10/10/06
4/1/12
9/22/17
3/15/23





Buckhorn Figure 7. Groundwater quality in monitoring wells MW7: a) nitrate+nitrite and chloride; b) TDS and sulfate and MW9: c) nitrate+nitrite and chloride; d) TDS and sulfate. Both wells are located ~1,500 ft downgradient of the groundwater capture zone boundary. Monthly average permit limits: chloride 2 mg/l, nitrate 1.33 mg/l, sulfate 69.5 mg/l, TDS 290 mg/l. Graphs created using data from database maintained by Okanogan Highlands Alliance.

The concentrations of certain metals have also increased sporadically in some locations in both groundwater and surface water.[175] An example is zinc in MW-07. The average baseline concentration was 11 µg/l, with a maximum value of 30 µg/l. Since mining began, the concentration has been higher than baseline, with a mean of 16 µg/l and a maximum of 41 µg/l. The average between September 2017 and December 2019 was almost 3 times the baseline value at 29 µg/l.[176]

The only groundwater monitoring well to the west of the mine (MW-18) was not constructed until 2014 and has no baseline data. Also, there are no wells downgradient to trace a plume. However, concentrations in MW-18 consistently exceed permit limits for arsenic, chloride, nitrate, specific conductance, and TDS.[177]

5.1.2 Groundwater Quality Impacts at the Mill and Tailings Area

Baseline shallow and deep groundwater monitoring at the mill and tailings site consisted of five monitoring events in 1988, prior to original start-up of the mill. TDS values averaged 296 mg/l in shallow groundwater and 248 mg/l in deep groundwater. Chloride concentrations averaged 8 mg/l in shallow groundwater and <1 mg/l in deep groundwater. Nitrate concentrations averaged 1.41 mg/l in shallow groundwater and 1.01 mg/l in deep groundwater. Sulfate data are not included in the reference document.[178]

The three groundwater monitoring wells for the tailings facility area increase in depth and distance from the impoundment, ranging from TP-1 (25 feet below ground surface and 800 feet downgradient of the impoundment) to TP-3 (90 to 120 feet below ground surface and 1000 feet downgradient of the impoundment). [179,180,181] These wells were installed in 1991, two years after start-up of the mill.[182] Early data provides a comparison of groundwater impacts from the Buckhorn project with impacts from earlier projects using the site. Sources were presumed to be seepage from the tailings basin dam, leakage from the liners, and/or leakage/seepage from the ore storage area.[183]

The Key Mill permit includes groundwater quality limits for nitrate, sulfate, and TDS. The TDS limit applies only to TP-3; the permit includes a compliance schedule with no end date and no interim or final limit at TP-1 and TP-2.[184] Although TDS concentrations have declined in well TP-1 since the start of the compliance period, values have risen steadily in TP-2 and TP-3. Concentrations of all three pollutants

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[175] In addition, in many cases true averages are unknown due to frequent samples below detection limits, particularly in earlier samples. For this reason, baseline averages are likely lower than the data indicates.
[176] *Buckhorn.Buckhorn data spreadsheet.OHA 2024.xlsx* Data is from Okanogan Highlands Alliance database of monitoring data from the Buckhorn Mine.
[177] Crown Resources Corp., 2024b. Hydrologic Data Report - Water Year 2023. *Buckhorn.2023 HDR.Crown 2024b.pdf [68-69, 435 et seq.]*
[178] Baseline Report. *Buckhorn.Baseline WQ.WDOE 2005.pdf [53]*
[179] 2023 AMP. *Buckhorn.2023 AMP.Crown 2024a.pdf [57]*
[180] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [256]*
[181] Aspect Consulting, 2023b. Key Mill 2022 Annual Status Report. *Buckhorn.Key Mill 2022 Annual AKART.Aspect 2023b.pdf [23]*
[182] Baseline Report. *Buckhorn.Baseline WQ.WDOE 2005.pdf [44]*
[183] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [257]*
[184] Washington Dept. of Ecology, 2015b. State Waste Discharge Permit ST0008033. *Buckhorn.State Waste Discharge Permit.WDOE 2015b [6, 23-24]*

have risen steadily at TP-3 since the start of the Buckhorn Mine, as shown in Table 3.[185] TP-3 has exceeded its TDS permit limit frequently since 2019. TDS values at TP-1 were above 600 mg/l for most of the Buckhorn operation period; the TDS value at TP-2 at the beginning of the operation period was about 320 mg/l, and rose to a peak of 690 mg/l in 2019. The TDS groundwater quality standard is 500 mg/l.

Buckhorn Table 3. Key Mill Groundwater Quality Downgradient of Tailings Impoundment.

Shallow Groundwater (TP-1) 80 ft downgradient of impoundment, 25-ft sample depth				
	Permit limit	**Baseline**	**2003**	**2008-2023**
TDS (mg/l)	---	296	607	400-900
Nitrate (mg/l)	10	1.41	5.55	1.4-11
Sulfate (mg/l)	235	n/a	50	60-220

Deep Groundwater (TP-3) 1000 ft downgradient of impoundment, 90- to 120-ft sample depth				
	Permit limit	**Baseline**	**2003**	**2008-2023**
TDS (mg/l)	391	248	249	300-440
Nitrate (mg/l)	6.6	1.01	2.55	4-6.3
Sulfate (mg/l)	123	n/a	60	50-100

Shallow groundwater baseline TDS and nitrate values are the arithmetic mean of single samples from five wells screened in the shallow alluvial deposits. Deep groundwater baseline TDS and nitrate values are the arithmetic mean of single samples from two wells screened in the lower glacial deposits and fractured bedrock. Baseline data are from June 1988.
2003 TDS and nitrate values are from a single monitoring event prior to start-up of the Buckhorn operation.
Baseline and 2003 TDS and nitrate data source: Washington Dept. of Ecology, 2005. Geochemistry, Surface Water, and Groundwater Quality Discipline Report. *Buckhorn.Baseline WQ.WDOE 2005.pdf [53-54]*
2003 sulfate values are approximated from graphed data. 2008-2023 values are the range of values in TP-1 and TP-3 since Buckhorn start-up, approximated from graphed data. Source: 2023 AMP. *Buckhorn.2023 AMP.Crown 2024a.pdf [125-27]*

5.2 Surface Water Quality Impacts

5.2.1 Surface Water Quality Impacts at the Mine Site

Surface water quality is monitored in creeks downgradient of the mine. Creeks impacted by the mine itself include Gold Bowl, Nicholson, and Marias to the east and Bolster to the west. Downstream of the confluence with Gold Bowl Creek, Nicholson Creek has an estimated flow of 64 to 110 gpm; Bolster Creek has an estimated flow of 12 to 19 gpm at the most upstream monitoring station.[186] Marias Creek is impacted primarily by the haul road, and is addressed separately below.

Baseline surface water monitoring was conducted between 1990 and 1996 for the Crown Jewel Project EIS. Additional monitoring for the Buckhorn project began in 2003. Until 2004, detection limits for many metals were above regulatory criteria; analytical methods were changed in 2004 to provide lower detection limits.[187] Baseline monitoring results from 1992 through 2007 averaged 0.8 mg/l

[185] Aspect Consulting, 2023a. Memorandum re: Key Mill Site ST8033 Annual Report for 2022. *Buckhorn.Key Mill 2022 Annual Report.Aspect 2023.pdf [14-16]*
[186] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [283]*
[187] Baseline Report. *Buckhorn.Baseline WQ.WDOE 2005.pdf [34]*

chloride, 0.5 mg/l nitrate, 189 mg/l TDS, and 35 mg/l sulfate.[188] Data from baseline monitoring are included in the Okanogan Highlands Alliance database; the Buckhorn EIS provides averages of all data for the entire site.[189]

The Buckhorn Mine NPDES permit includes enforceable limits for solutes in surface water downstream of the mine. These limits were added to the permit in 2014 as a component of the groundwater capture zone requirement,[190] with the assumption that exceedances of surface water permit limits indicate that impacted groundwater is escaping the capture zone and discharging to surface water.

The limits were extrapolated from baseline data.[191] However, as noted above for groundwater, this approach does not entirely prohibit water quality degradation because permit limits were set at levels well above the measured background concentrations. The EIS lists the average background value for sulfate in surface water as 45.6 mg/l; the permit limit is 72 mg/l. The average background concentration for copper is 2 µg/l; the permit limit is 10 µg/l. The average background concentration for manganese is 2 µg/l; the permit limit is 20 µg/l. The average background concentration for zinc is <7 µg/l; the permit limit is 30 µg/l.[192]

Two years after mining began, the 2010 Stratus Consulting report found that chloride, nitrate, and sulfate concentrations had risen and pH had fallen in South Fork Nicholson Creek (SW7) and Gold Bowl Creek (SW9). Chloride, nitrate and sulfate surface water quality standards were exceeded in Gold Bowl Creek.[193] Chloride, nitrate and TDS concentrations had also risen in Upper South Fork Bolster Creek (SW14).[194]

This situation has not improved. Table 4 shows results for average surface water concentrations in monitoring stations in the South Fork Nicholson Creek drainage, moving from farthest upstream (GW-02, at the Roosevelt Adit and SW9/SW9A in Gold Bowl Creek) to the farthest downstream (SW-07, downstream of the confluence with Gold Bowl Creek).[195] GW-02 is about 1200 feet, SW-9A is about 1500 feet, and SW-07 about one mile downstream of the capture zone boundary. JJ-26 and JJ-20 are seeps at intermediate locations close to the creek. SW-07 contains a mix of water from this flow path and the Gold Bowl Creek flow path.

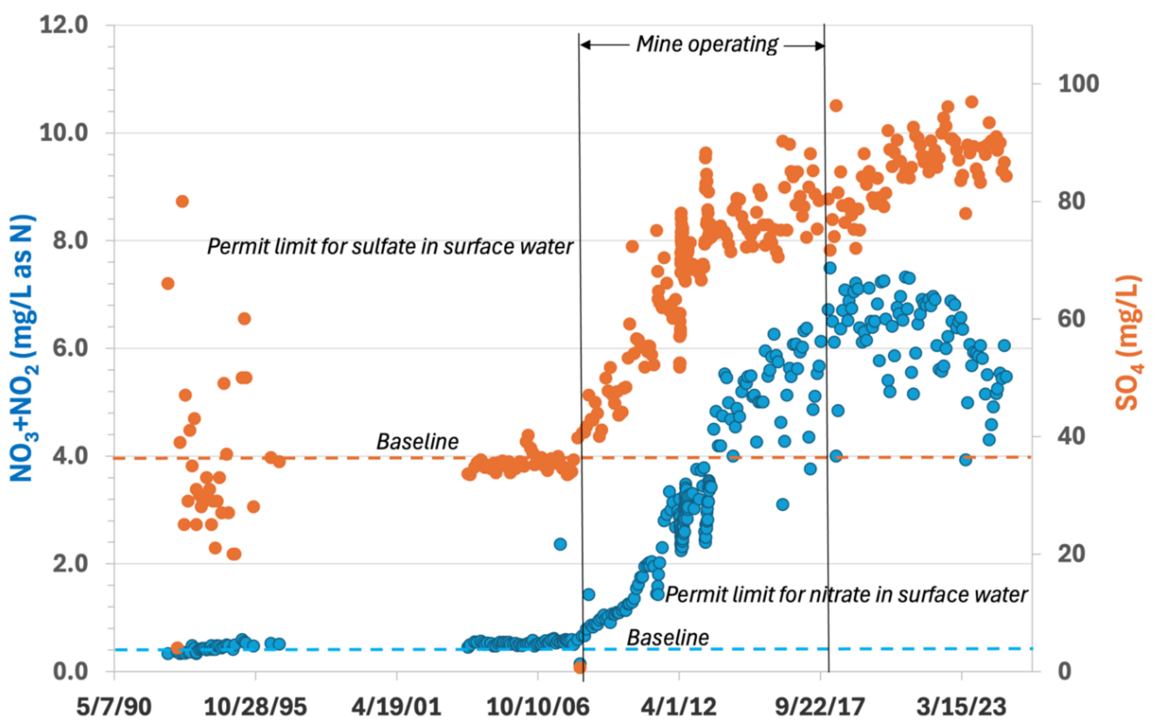
Buckhorn Table 4. Average Water Quality in Nicholson Creek and Associated Seeps.

	GW-02		JJ-26		JJ-20		SW-07	
	Baseline	'08-'23	Baseline	'08-'23	Baseline	'08-'23	Baseline	'08-'23
Chloride (mg/l)	0.86	13.3	1.05	10.7	0.86	7.62	0.91	9.89
Nitrate (mg/l as N)	0.52	3.85	0.03	0.67	0.19	2.09	0.02	1.18
TDS (mg/l)	189	279	238	259	189	205	211	219
Sulfate (mg/l)	35.3	72.4	47.3	61.4	23.3	49.2	24.6	41.6

188 Data from Okanogan Highlands Alliance database of monitoring data from the Buckhorn Mine. *Buckhorn.Buckhorn data spreadsheet.OHA 2024.xlsx*
189 FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [252]*
190 2015 NPDES permit. *Buckhorn.NPDES Permit.WDOE 2015a.pdf [8]*
191 2014 NPDES Fact sheet. *Buckhorn.2014 NPDES Fact Sheet.WDOE 2014a.pdf [74]*
192 FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [252]*
193 Stratus Report. *Buckhorn.Stratus report.Stratus.pdf [18-27]*
194 Stratus Report. *Buckhorn.Stratus report.Stratus.pdf [22]*
195 See 2015 NPDES permit. *Buckhorn.NPDES Permit.WDOE 2015a.pdf [79, 81]* for locations of surface water monitoring stations and seeps.

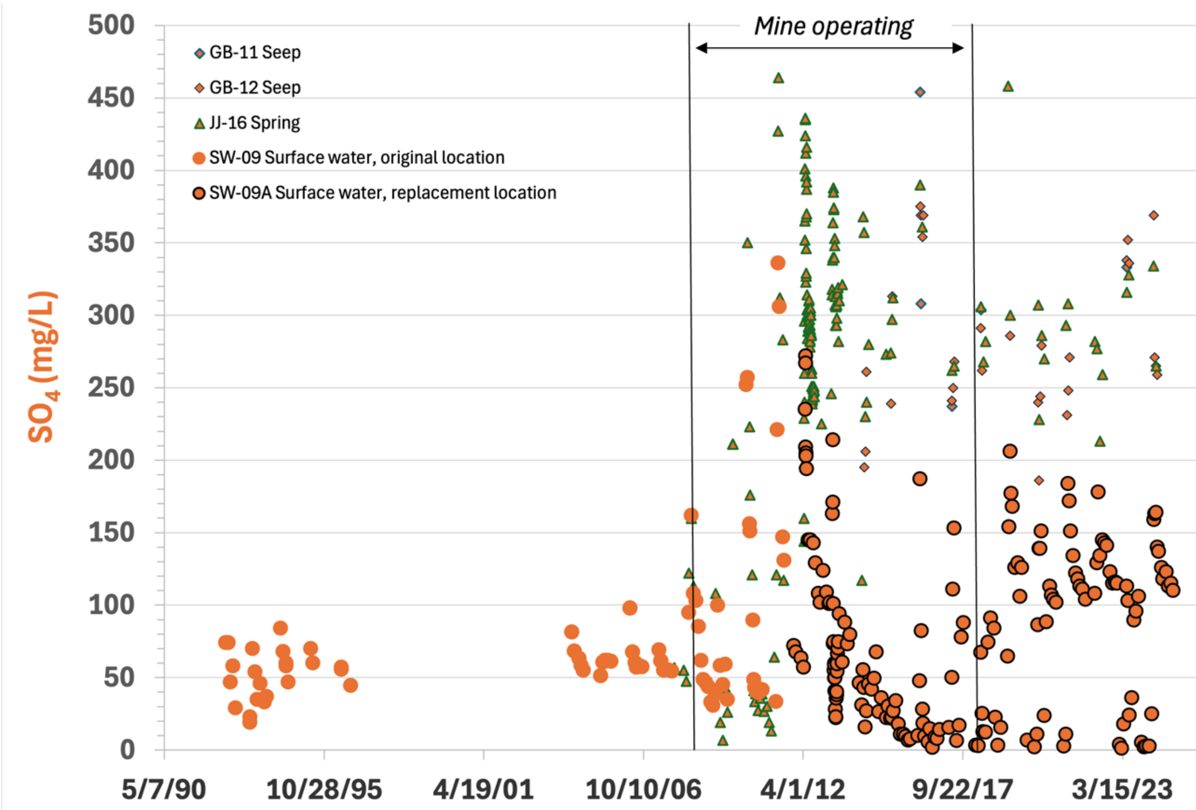
Source: Okanogan Highlands Alliance database of monitoring data from the Buckhorn Mine. *Buckhorn.Buckhorn data spreadsheet.OHA 2024.xlsx*
Baseline values are averages of data from 1992-1996 and 2004-2007.
Non-detects in chloride measurements from the 1992-1996 dataset are set at 1.0 mg/l.

Chloride and nitrate concentrations routinely exceed permit limits at all these stations; the TDS and sulfate limits are also often exceeded at GW-02 (Figure 8).



Buckhorn Figure 8. Nitrate+nitrite and sulfate concentration in the Roosevelt Adit at GW2, outside the capture zone boundary, downgradient of the Gold Bowl and Southwest Zones of the underground mine. Monthly average permit limits: sulfate 72 mg/l, nitrate+nitrite 0.32 mg/l as N. Graphs created using data from database maintained by Okanogan Highlands Alliance.

The original water quality monitoring station in Gold Bowl Creek, SW9, was destroyed by a landslide in 2011; SW9A is a replacement station. Sulfate concentrations at this location are high, consistent with concentrations in nearby seeps and spring JJ-16. However, sulfate concentrations at SW9A are also influenced by Outfall 002, which is upgradient and periodically discharges treated water, resulting in dilution that does not affect the seeps and spring (Figure 9).



Buckhorn Figure 9. Sulfate concentrations in Gold Bowl Creek at SW9/9A, outside the capture zone boundary, downgradient of the Gold Bowl Zone of the underground mine. Permit limit in surface water, monthly average: sulfate in 72 mg/l; permit limit in groundwater, seeps, and springs, monthly average: sulfate 69.5 mg/l. Graphs created using data from database maintained by Okanogan Highlands Alliance.

Nitrate and TDS values have also remained elevated at SW-14 on Upper South Fork Bolster Creek, to the west of the mine. The baseline nitrate+nitrite concentration was 0.22 mg/l as N; the average concentration since mining began is 2.53 mg/l as N. The baseline TDS concentration was 234 mg/l; the average concentration since mining began is 270 mg/l.

5.2.2 Surface Water Quality Impacts from Transportation

Marias Creek is impacted by the use of dust suppressants (magnesium chloride) on the haul road. Monitoring points begin at MC-01, located immediately upstream of where the river meets the haul road. MC-02 and MC-03 are located farther downstream along the following 2.8-mile stretch, where the road is located within 300 feet of the river.[196]

True baseline data for Marias Creek are not available; the earliest data are from 1992, when the road was in use as a general U.S. Forest Service road. At that time, chloride concentrations averaged 2 mg/l.[197] However, values from two 2007 monitoring events just prior to mine start-up were less than 1.5

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[196] USDA Forest Service, 2007a. Buckhorn Access Project, Final Environmental Impact Statement, Appendix D, Water Monitoring Plan. *Buckhorn.Access Project Monitoring Plan.USDA 2007a.pdf [9]*

[197] USDA Forest Service, 2007b. Buckhorn Access Project, Final Environmental Impact Statement, Chapter 3 (Table III-22). Buckhorn.Access FEIS.USDA 2007\Buckhorn Access Project--FEIS Chapter 3.pdf *[38]*

mg/l at all three stations. By 2012, the chloride concentration rose to 2.8 mg/l at MC-01, 18.5 mg/l at MC-02, and 19.8 mg/l at MC-03. The use of magnesium chloride for dust suppression was discontinued in 2013, but chloride levels continued to rise, peaking at 10.7 mg/l at MC-01 (2019), 48 mg/l at MC-02 (2016), and 55 mg/l at MC-03 (2016). In 2023, 10 years magnesium chloride use was discontinued, the average chloride concentration was 7 mg/l at MC-01, 13.5 mg/l at MC-02, and 15.4 mg/l at MC-03.[198]

5.2.3 Surface Water Quality Impacts at the Mill and Tailings Area

Groundwater impacted by the tailings facility at the Key Mill site discharges to the North Fork Sanpoil River. Monitoring is conducted at an upstream location (SW-3) and two downstream locations (SW-4, about 2000 feet downstream; and SW-7, about 3,000 feet downstream of the tailings facility). At its closest points, the river is located approximately 400 feet from the treated water infiltration gallery, 600 feet from the ore stockpile, and 700 feet from the tailings impoundment.[199]

We have not obtained baseline monitoring data for the Sanpoil River. However, the EIS notes that baseline TDS concentrations from 1988 were between 38 and 88 mg/l.[200] Regarding water quality in the years immediately preceding the start of the Buckhorn Mine, the EIS states, "There is no significant difference in the results of surface water quality data between the upstream (SW-4) and the downstream (SW-7) locations, indicating that there are no offsite impacts to the river from the Kettle River Mill and TDF."[201] Graphed data from this time period included in Buckhorn Mine annual reports indicate that this statement was untrue. From 1995 to 2008, TDS values ranged from about 30 to 110 mg/l at SW-3 and from about 50 to 200 mg/l at SW-4 and SW-7.[202]

Since the Buckhorn Mine began, TDS concentrations have ranged from about 70 to 200 mg/l at the downstream monitoring points. Comparisons of upstream and downstream monitoring results indicate that nitrate and sulfate concentrations are approximately 3 to 6 times higher downstream for both pollutants. Other than a period of particularly high concentrations in 2017-2018, TDS and nitrate levels have been similar to those in the pre-Buckhorn period. Sulfate concentrations appear to have increased.[203] Washington State does not have a surface water standard for sulfate, but the upstream location concentrations average less than 10 mg/l (the Minnesota standard for wild rice waters), while the downstream concentrations range from 10 to 40 mg/l.

6. Accuracy of Water Quality Predictions

The only mining-impacted water source for which we have both numeric water quality predictions and monitoring data is inflow to the mine. Predictions were inaccurate for several parameters. Table 5 compares EIS predictions with monitoring results from the mine sumps from 2009 through 2017.

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[198] *Buckhorn.Buckhorn data spreadsheet.OHA 2024.xlsx* Data from Okanogan Highlands Alliance database of monitoring data from the Buckhorn Mine.
[199] Aspect Consulting, 2023b. Key Mill 2022 Annual Status Report. *Buckhorn.Key Mill 2022 Annual AKART.Aspect 2023b.pdf [23]*
[200] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [258]*
[201] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [258]*
[202] 2023 AMP. *Buckhorn.2023 AMP.Crown 2024a.pdf [131-33]*
[203] 2023 AMP. *Buckhorn.2023 AMP.Crown 2024a.pdf [131-33]*

Buckhorn Table 5. Buckhorn Mine Predicted Versus Actual Mine Inflow Concentrations.

	Gold Bowl Zone mining area			South West Zone mining area		
	Predicted range	**Actual average**	**Actual maximum**	**Predicted range**	**Actual average**	**Actual maximum**
Ammonia (mg/l as N)	2	23	103	2	20	73
Nitrate (mg/l as N)	30-50	68	415	30-50	71	316
TDS (mg/l)	193-749	892	2280	150-251	894	1760
Arsenic (µg/l)	8-20	6	25	10-18	28	231

EIS predictions are from FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [296]*Average and maximum values are from Okanogan Highlands Alliance database of monitoring data from the Buckhorn Mine. *Buckhorn data spreadsheet.xlsx [Gold Bowl Sump and South West Sump]*
The Gold Bowl TDS maximum omits two outliers of 16700 and 4470 mg/l.

The EIS also included numeric predictions of leachate quality from the various stockpiles.[204] A report prepared for Okanogan Highlands Alliance includes data for a few parameters from a single monitoring event in 2010, two years after mining began (see Figure 3). The measured pH of 4.96 in 2010 had not dropped to the level predicted in the EIS (2.4-3.8), and the sulfate prediction was accurate at that point in time. However, the EIS predicted that the worst-case TDS concentration would be 1519 mg/l; the measured concentration in 2010 was 2480 mg/l. The EIS predicted that the nitrate concentration would be 50 mg/l as N, while the actual concentration in 2010 was 166 mg/l as N. Aluminum, chromium, copper, and iron concentrations were also underpredicted.[205]

The EIS predicted that all constituents from the PAG stockpile except ammonia and nitrate would attenuate to non-problematic levels before reaching groundwater,[206] and it was assumed that runoff from the PAG stockpile would be collected by sumps and that mine dewatering wells would capture mine-related releases to groundwater. [207] Although the specific sources of pollutants to groundwater have not been conclusively identified, polluted groundwater at the site indicates that these predictions were erroneous.

The EIS also assumed that if these predictions proved wrong, the collection system would be improved to prevent movement of impacted groundwater off the site.[208] This assumption was also erroneous.

Waste rock that was classified as non-potentially acid generating was used for construction and other purposes at the site and was leached by stormwater that discharged to surface water and groundwater without treatment. According to the EIS, this rock had the potential to leach ammonia and nitrate but no other constituents at problematic levels.[209] The EIS did not discuss the potential impacts of ammonia and nitrate on groundwater or surface water quality. Sources of pollution at the site have not been conclusively identified or quantified, but the construction rock is thought to be one of the

[204] FSEIS [296]
[205] Stratus Report. *Buckhorn.Stratus report.Stratus.pdf 2010 [32]*
[206] FSEIS [293]
[207] FSEIS [303]
[208] FSEIS [294]
[209] FSEIS [293]

sources of the observed elevated sulfate and nitrate concentrations in site groundwater and surface water.[210,211]

The EIS acknowledged that some waste rock had the potential to generate acid when exposed to the atmosphere,[212] but concluded that the acid drainage potential "is expected to be extremely low."[213] Data are not available to determine the accuracy of this statement; however, a 2010 report indicates that a leachate sample taken that year had a pH of 4.96 (see Figure 3),[214] suggesting that the PAG waste rock stockpile had become acidic.

7. Comparison to Potential Mines in the Rainy River Headwaters Watershed of Minnesota

The Buckhorn Mine is roughly comparable to potential Duluth Complex mines regarding the potential for acid generation from ore and waste rock and the leaching of metals under neutral conditions. The ore-to-waste ratio is also similar. Although the geology and hydrogeology are different, both regions have the potential for unidentified preferential groundwater flow paths, such as along fractures. On the other hand, the Buckhorn Mine was much smaller than proposed mining operations in the Duluth Complex. In addition, the Buckhorn Mine permit includes enforceable limits for downstream surface water and downgradient groundwater quality, which Minnesota permits do not.

[210] Golder, 2018. Technical Memorandum Re: Response to Washington Department of Ecology Notice of Violation #15958, Sept. 21, 2018. *Buckhorn.Response to NOV 15958.Golder 2018.pdf [3]*
[211] PCHB Findings of Fact. *Buckhorn.PCHB Findings of Fact.PCHB 2015.pdf [11]*
[212] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [292-93]*
[213] FSEIS. *Buckhorn.FSEIS.WDOE 2006.pdf [233]*
[214] Stratus Report. *Buckhorn.Stratus report.Stratus.pdf [16]*

Eagle Mine, Michigan

1. Site and Mine Description and Background Information

The Eagle Mine is an underground nickel and copper mine in Michigan's Upper Peninsula. At the time of permitting, the mine was owned by Kennecott Eagle Minerals Co., a subsidiary of Rio Tinto. It is now owned and operated by Eagle Mine LLC, a subsidiary of Lundin Mining.[215]

The mine is located primarily on state land about 10 miles from Lake Superior,[216] in a wilderness setting known as the Yellow Dog Plains. The site is in the headwaters of two highly valued trout streams, the Yellow Dog and Salmon Trout rivers, both of which flow to Lake Superior.[217] Surface disturbance at the mine site is approximately 92 acres.[218]

At the mine site, all waste rock is disposed of in the underground workings. Ore is hauled 47 miles to the pre-existing Humboldt Mill in the Escanaba and Black River watersheds, which flow to Lake Michigan.[219] The mill processes about 2,000 tons of ore per day.[220]

Michigan state law requires environmental review for nonferrous mines; review is done by the permit applicant and submitted as part of the application.[221] An Environmental Impact Assessment (EIA) was prepared in 2006, and a second for the Humboldt Mill in 2008. Permits were issued between 2007 and 2010. Construction began in May 2010, followed by underground mine development in September 2011;[222] the first ore was processed in September 2014.[223] An expansion into a second ore body (Eagle East) began in 2017.[224]

Annual precipitation on the Yellow Dog Plains is 35 inches; precipitation exceeds evapotranspiration.[225] There were no wetlands within the disturbed area at the mine site.[226] Geology consists of Precambrian bedrock covered by Quaternary deposits ranging from 0 to 255 feet thick.[227] Groundwater exists primarily in the Quaternary deposits.[228] Groundwater from the area of the surface

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[215] https://www.eaglemine.com/ Accessed 1 Feb 2025.
[216] Foth & Van Dyke, 2006a. Kennecott Eagle Minerals: Eagle Project Mining Permit Application Vol. II, Environmental Impact Assessment. *Eagle.EIA.Foth 2006a.pdf [80]* (Map) Hereinafter, "EIA."
[217] EIA. *Eagle.EIA.Foth 2006a.pdf [21-22, 59 et seq.]*
[218] EIA. *Eagle.EIA.Foth 2006a.pdf [22]*
[219] Foth, 2008a. Kennecott Eagle Minerals: Humboldt Mill Mining Permit Application Vol. II, Environmental Impact Assessment. *Eagle.Humboldt EIA.Foth 2008a.pdf [20]* Hereinafter, "Humboldt EIA."
[220] Eagle Mine, 2022a. 2021 Annual Mining and Reclamation Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [10]* Hereinafter, "2021 Annual Report."
[221] Michigan Compiled Laws 324.63205(2)(b). *Eagle.MCL 632.pdf [2]*
[222] 2021 Annual Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [6]*
[223] Eagle Mine, 2022b. 2021 Annual Mining and Reclamation Report, Humboldt Mill. *Eagle.2021 Humboldt Annual Report.Eagle 2022b.pdf [7]* Hereinafter, "2021 Humboldt Annual Report."
[224] Foth, 2017a. Mining Permit Application Amendment, Eagle East, Vol. I. *Eagle.Eagle East expansion app.Foth 2017a.pdf* Hereinafter, "Eagle East Expansion Application."
[225] EIA. *Eagle.EIA.Foth 2006a.pdf [45]*
[226] EIA. *Eagle.EIA.Foth 2006a.pdf [44]*
[227] EIA. *Eagle.EIA.Foth 2006a.pdf [28]*
[228] EIA. *Eagle.EIA.Foth 2006a.pdf [30]*

facilities discharges to headwater reaches of the Salmon Trout River about three-quarters of a mile downgradient.[229] Another reach of the Salmon Trout runs immediately above the underground workings. In this reach flow ranges from 0.9 to 5.3 cubic feet per second (cfs).[230]

At the Humboldt Mill site, wetlands are associated with both the Escanaba and the Black rivers. The groundwater regime is similar to that at the mine site, with groundwater existing primarily in the Quaternary deposits.[231] Flow of the Middle Branch Escanaba River ranges from 4.6 to 218 cfs, as measured in 2007.[232] Surface water and groundwater at the Humboldt Mill site were impacted by past mining prior to start-up of the Eagle project.[233]

2. Mine Facilities, Operations, and Reclamation

2.1 Mine Site

Facilities at the mine site include the underground workings and portal; a temporary development (waste) rock storage area ("TDRSA"); contact water basins and non-contact stormwater basins; a backfill plant; a wastewater treatment plant; a groundwater infiltration system for treated water discharge; and ancillary facilities.[234] There are no permanent waste rock stockpiles on the surface; all waste rock is backfilled. The Humboldt Mill site includes the mill; a wastewater treatment plant and discharge system; and a tailings basin, which is located in a mined-out taconite pit.[235] A 47-mile haul road connects the two sites.

The Eagle operation is unusual in that no rock from the excavation is used in construction or disposed of in unlined stockpiles, as all excavated rock is considered potentially acid generating (PAG). Although waste rock is ultimately backfilled in the mine workings, a portion of it is temporarily stored on the surface in the TDRSA. The volume of the TDRSA at the end of 2021 was 116,468 m^3.[236] Lime is added to the pile to increase neutralization capacity. Although waste rock is periodically removed from the pile for the backfill operation, apparently specific waste rock may stay on the surface indefinitely. The mine permit requires a temporary cover over portions of the pile,[237] but this proved impractical and has not been implemented.[238] The TDRSA has a double liner system, with a sump for water collection and a

[229] North Jackson Co., 2005. Kennecott Minerals Company Eagle Project, Environmental Baseline Study Hydrology Report, Vol. I. *Eagle.Hydrology study.North Jackson 2005.pdf [192]* Hereinafter, "Eagle Hydrology Study."
[230] Eagle Hydrology Study. *Eagle.Hydrology study.North Jackson 2005.pdf [93-94]*
[231] Humboldt EIA. *Eagle.Humboldt EIA.Foth 2008a.pdf [24]*
[232] Foth, 2008b. Humboldt Mill Mining Permit Application, Vol. IIA, Environmental Impact Assessment, App. B-1, Humboldt Mill Hydrology and Mill Investigation Studies. *Eagle.Humboldt hydrology study.Foth 2008b.pdf [45]* Hereinafter, "Humboldt Hydrology Study."
[233] Humboldt Hydrology Study. *Eagle.Humboldt hydrology study.Foth 2008b.pdf [46 et seq.]*
[234] Eagle Mine, 2024a. 2023 Annual Mining and Reclamation Report. *Eagle.2023 Annual Report 1.Eagle 2024a.pdf [40]* (site map) Hereinafter, "2023 Annual Report."
[235] Eagle Mine, 2024c. 2023 Annual Mining and Reclamation Report, Humboldt Mill. *Eagle.2023 Humboldt Annual Report.Eagle 2024c.pdf [32-33]* (site maps) Hereinafter, "2023 Humboldt Annual Report."
[236] 2023 Annual Report. *Eagle.2023 Annual Report 1.Eagle 2024a.pdf [13]*
[237] Michigan Dept. of Environmental Quality (MDEQ), 2007a. Nonferrous Metallic Mineral Mining Permit No. MP 01 2007. *Eagle.Mining permit.MDEQ 2007a.pdf [17]*
[238] Eagle East Expansion Application. *Eagle.Eagle East expansion app.Foth 2017a.pdf [29-30]*

second sump for leak detection. Both sumps are monitored; however, rainwater was apparently trapped between the liners during construction, adding some uncertainty to leak detection.[239]

Groundwater inflow to the mine has been considerably less than the 75 gallons per minute (gpm) estimated in the EIA.[240,241] Water pumped from the underground mine ("mine water"), TDRSA seepage, and mine contact (industrial) stormwater are collected in two lined contact water basins for treatment.[242] The basins do not have a leak detection system;[243] leak surveys using a towed probe are conducted periodically.[244] Stormwater from non-contact areas is collected in infiltration basins.[245] Groundwater monitoring wells are located downgradient of both contact and non-contact basins. Results from groundwater monitoring are discussed in *Section 5.1*.

Water collected in the contact water basins is treated by reverse osmosis (RO)[246] and discharged to land though a land infiltration system. The discharge is subject to Groundwater Discharge Permit No. GW1810162. The discharged effluent volume in 2023 was approximately 61 million gallons.[247] The discharge permit includes limits for pH, arsenic, boron, cadmium, copper, iron, mercury, selenium, silver, vanadium, and specific conductance.[248] The permit also includes a list of expected constituent concentrations, which are considerably lower than applicable water quality standards. The permit sets a trigger of five times the expected concentration for notification and consideration of additional mitigation measures.[249]

2.2 Humboldt Mill Site

The Humboldt Mill and tailings disposal facility are located at the site of a former taconite mine. The tailings basin is located in the Middle Branch of the Escanaba River watershed, while the mill site is in the Black River watershed.[250] Impacts from past operations make assessment of impacts exclusive to the Eagle project difficult in the mill area and Black River,[251] and this report is thus limited to impacts from the tailings basin and the discharge to the Escanaba River.

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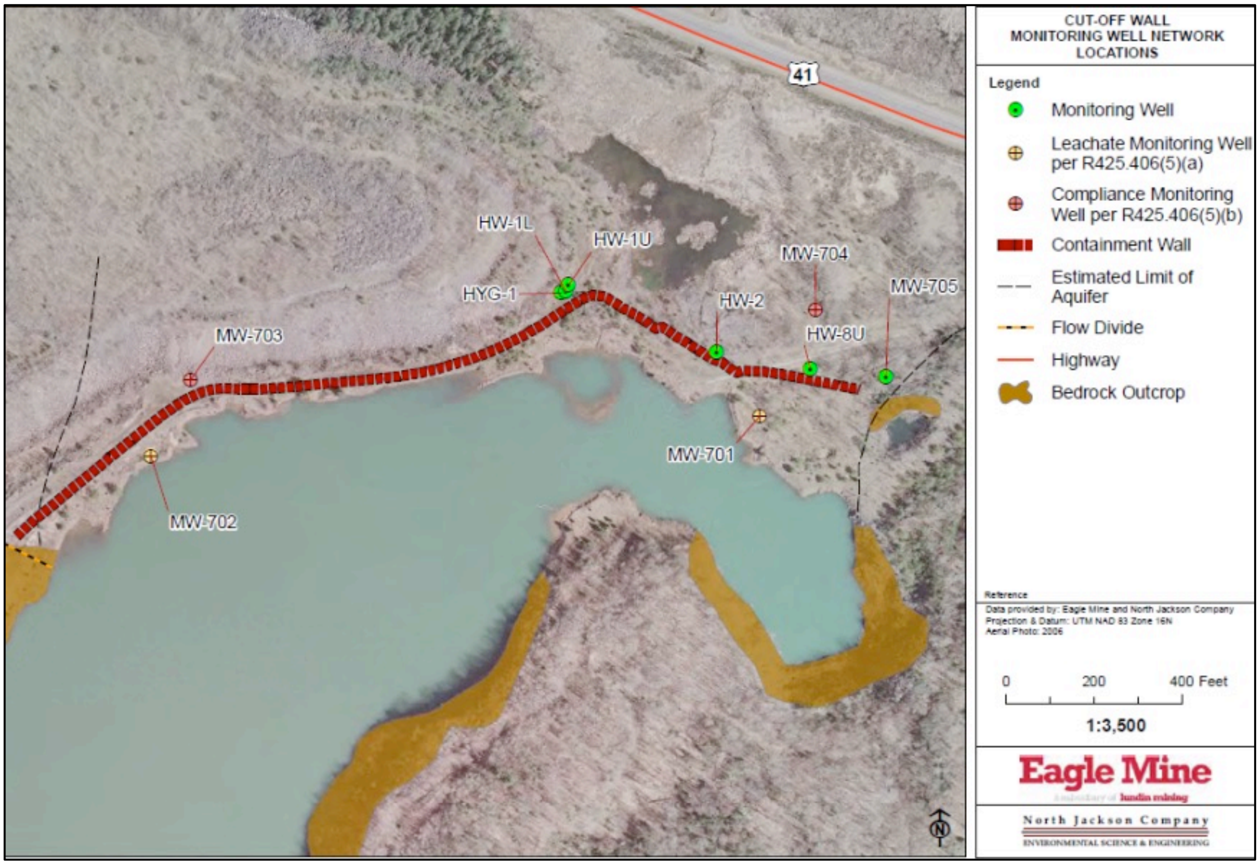
[239] 2021 Annual Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [13]*
[240] EIA. *Eagle.EIA.Foth 2006a.pdf [33]*
[241] 2021 Annual Report. *Eagle.2021 Annual Report.Eagle 2022.pdf [11]*
[242] 2021 Annual Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [17]*
[243] Foth & Van Dyke. Kennecott Eagle Minerals Eagle Project Mining Permit Application Vol. I. *Eagle.Mine permit app.Foth 2006b.pdf [150]* Hereinafter, "Mine Permit Application."
[244] 2021 Annual Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [38]*
[245] 2021 Annual Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [16]*
[246] Mine Permit Application. *Eagle.Mine permit app.Foth 2006b.pdf [50]*
[247] 2023 Annual Report. *Eagle.2023 Annual Report 1.Eagle 2024a.pdf [19]*
[248] MDEQ, 2007. Groundwater Discharge Permit No. GW1810162. *Eagle.GW Discharge Permit.MDEQ 2007b.pdf [4-5]* Hereinafter, "Groundwater Discharge Permit."
[249] Groundwater discharge permit. *Eagle.GW Discharge Permit.MDEQ 2007b.pdf [19]*
[250] Humboldt EIA. *Eagle.Humboldt EIA.Foth 2008a.pdf [83, 98]* (maps)
[251] Humboldt Hydrology Study. *Eagle.Humboldt hydrology study.Foth 2008b.pdf [26-32]*

High-sulfide tailings are disposed of underwater in the mined-out taconite pit, as is reject brine from the wastewater treatment plant.[252] In 2023, the operation began transporting RO concentrate from the mine site treatment plant to the tailings basin for disposal.[253]

The pit was first used for tailings disposal by the Ropes Gold Mine after taconite mining ended. The Ropes tailings were sulfidic and potentially acid-generating, and taconite mining may also have uncovered sulfide rock within the pit.[254] The pit thus contained water and tailings with high levels of many constituents prior to the Eagle project. The pit lake water was strongly stratified, with much poorer quality at depth than in the surface layer.[255]

Prior to start-up of the Eagle operation, leakage from the tailings basin moved through groundwater toward the Escanaba River. The Eagle operation added a cut-off wall at the downgradient end of the basin to prevent this outflow, as shown in Figure 1.[256] Monitoring wells are located inside and outside the cut-off wall to assess its effectiveness.[257] The monitoring results from the wells are inconclusive but seem to indicate that the wall reduces outflow but does not eliminate it. (See discussion in *Section 5.1*).

[252] Eagle Mine, 2020b. 2019 Annual Mining and Reclamation Report, Humboldt Mill. *Eagle.2019 Humboldt Annual Report.Eagle 2020b.pdf [38]*
[253] Eagle Mine, 2023d. Notification of Change in Facility Operations, Reverse Osmosis Concentrate, NPDES Permit MI0058649. *Eagle.NPDES RO Change.Eagle 2023d.pdf*
[254] Humboldt Hydrology Study. *Eagle.Humboldt hydrology study.Foth 2008b.pdf [65]*
[255] Humbodt Hydrology Study. *Eagle.Humboldt hydrology study.Foth 2008b.pdf [57, 257]*
[256] Golder Associates, 2011a. Humboldt Tailings Facility (HTDF) Cut-off Wall Site Characterization Study. *Eagle.Humboldt cutoff wall study.Golder 2011a.pdf [2]*
[257] 2021 Humboldt Annual Report. *Eagle.2021 Humboldt Annual Report.Eagle 2022b.pdf [24]*



Eagle Figure 1. Humboldt Mill cut-off wall (containment wall) and monitoring well locations.
Source: Eagle Mine, 2024. 2023 Annual Mining and Reclamation Report, Humboldt Mill, Appendix G. *Eagle.2023 Humboldt Annual Report.Eagle 2024c.pdf [53]*

Management of the tailings facility in the mined-out pit is focused on maintaining a stratified water column so that pollutants remain isolated at depth.[258] As mine expansion continues, however, the volume of tailings slated for disposal in the pit also increases, leaving less room for a stratified water column.[259] The maximum permitted tailings elevation was increased from 1420 to 1515 ft above mean sea level (AMSL) in 2018. Currently, the bottom elevation of the less-impacted top water layer is 1502 ft, and the highest tailings elevation is only 17 ft lower at 1485 ft elevation.[260] As of 2015, the target operating surface water elevation was 1529.5 ft.[261] In 2018, the operation began withdrawing water from the deepest layer of the water column for treatment and discharge, with the hope of reducing the thickness of the bottom layer.[262] As discussed in *Section 4.4*, TDS effluent limits were increased in the same year, and TDS and sulfate concentrations in the discharge also increased.

[258] E.g., 2021 Annual Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [33-36]*; 2023 Annual Report *Eagle.2023 Annual Report 1.Eagle 2024a.pdf [22-25]*
[259] Eagle Mine, 2020b. 2019 Annual Mining and Reclamation Report, Humboldt Mill. *Eagle.2019 Humboldt Annual Report.Eagle 2020b.pdf [38]*
[260] 2023 Humboldt Annual Report. *Eagle.2023 Humboldt Annual Report.Eagle 2024c.pdf [10, 23]*
[261] Eagle Mine, 2016b. 2015 Annual Mining and Reclamation Report, Humboldt Mill. *Eagle.2015 Humboldt Annual Report.Eagle 2016b.pdf [13]*
[262] Eagle Mine, 2018c. Re: Humboldt Mining Permit Application Amendment Request -- Request for Additional Information. *Eagle.Humboldt mine permit amendment.Eagle 2018c.pdf [2]*

The company has now proposed to dispose of dewatered tailings in the underground mine workings. The plan includes removing the pyrrhotite (the primary iron sulfide mineral in the ore that produces acid drainage) from the tailings; the pyrrhotite will be disposed of in the deep layer of the tailings basin, and the dewatered tailings will be trucked to the mine site.[263]

2.3 Incidents and Spills

While we do not have a comprehensive report on leaks and spills since start-up of the mine, recent reports provide an indication of the type of incidents that occur. Reports since 2021 include a spill of oil when a container was punctured by a forklift;[264] a leak of partially treated process water due to a corroded drain plug;[265] and a leak of wastewater treatment sludge during plant maintenance.[266] In 2019, a container of sulfuric acid was also punctured by a forklift, spilling its contents near the groundwater monitoring wells at the tailings basin cut-off wall. According to company reports, the acid "acutely affected" monitoring results in one well, hindering the assessment of the efficacy of the cut-off wall.[267] These spills were all under 300 gallons.

3. Geochemistry

The Eagle ore bodies include rock of massive (32-38% sulfur), semi-massive (12 to 15% sulfur), and disseminated (2.4 to 3.7% sulfur) sulfide content.[268] At Eagle East, less than 5% of the rock has a sulfur content under 0.2%; this was described as a lower sulfur level than the original Eagle orebody.[269] All rock (both ore and waste rock) is thus classified as potentially acid-generating.[270]

Tailings have a 4.5% to 32.8% sulfur content, essentially all as sulfide sulfur and thus also have a high potential to generate acid.[271] The pre-mining tailings characterization report stated that tailings could release high levels of sulfate and TDS, and concentrations of several metals could increase, even during the lag period before acidification.[272]

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263 Eagle Mine, 2024d. Re: Request for Amendment, Non-Ferrous Metallic Mineral Mining Permit MP 01 2020. *Eagle.Humboldt request for amendment.Eagle 2024d.pdf [1]*
264 Eagle Mine, 2023e. Spill or Release Report 05/02/2023. *Eagle.Incident 2023.05.02.Eagle 2023e.pdf [1]*
265 Eagle Mine, 2023f. Re: Notification of Humboldt Mill WTP Plug Flow Fenton's Reactor Water Discharge -- NPDES Permit No. MI0058649. *Eagle.Incident 2023.06.03.Eagle 2023f.pdf*
266 Eagle Mine, 2022d. Notification of Humboldt Mill unintentional Discharge--NPDES Permit No. MI0058649. *Eagle.Incident 2022.08.24.Eagle 2022d.pdf*
267 2021 Humboldt Annual Report. *Eagle.2021 Humboldt Annual Report.Eagle 2022b.pdf [19]*
268 Geochimica, 2004. Report on Phase I Eagle Project Acid Rock Drainage Study - Marquette County, Michigan. *Eagle.Geochemical Analysis.Geochimica 2004.pdf [22]* Hereinafter, "Eagle Geochemical Analysis."
269 Eagle East Expansion Application. *Eagle.Eagle East expansion app.Foth 2017a.pdf [76]*
270 Eagle Geochemical Analysis. *Eagle.Geochemical Analysis.Geochimica 2004.pdf [31]*
271 Geochemica, 2008. Technical Memorandum Re: Geochemical testing of bench-scale tailings samples for Kennecott Eagle Mining Company -- Results and implications for managing acid-rock drainage risk. *Eagle.Tailings geochemistry.Geochemica.2008.pdf [7]* Hereinafter, "Tailings geochemistry report."
272 Tailings Geochemistry Report. *Eagle.Tailings geochemistry.Geochemica.2008.pdf [9]*

4. Mine-Influenced Water Quality

4.1 Underground Mine Water Quality

As discussed in *Section 6*, the quality of the water pumped from the underground mine is much worse than expected at the time of permitting. Aluminum has averaged more than 9 mg/l, copper has averaged more than 3 mg/l, and iron has averaged more than 45 mg/l. In 2018, the expansion into the Eagle East orebody began, and concentrations of many constituents changed that year.[273] Average sulfate concentrations increased from 225 mg/l (2012-2017) to 626 mg/l (2019-2023). Average specific conductance values increased from 1790 µS/cm (2012-2017) to 9039 µS/cm (2019-2023).[274]

4.2 Waste Rock Leachate Quality

Sump water from the TDRSA is monitored; average results for many constituents are found in Table 4 (*See Section 6*). Sulfate concentrations in TDRSA leachate are considerably worse than in mine water and increased from an average of 1,374 mg/l in 2013-2017 to 2,039 mg/l in 2019-2023. Other constituents that increased dramatically with the initiation of mining in Eagle East include chloride (averaging 633 mg/l), cobalt (197 µg/l), and manganese (1.39 mg/l). Average specific conductance values increased from 4914 µS/cm in 2013-2017 to 6416 in 2019-2023. [275]

Water quality is also monitored in the contact water basins. Water in the basins is roughly similar to the mine water and TDRSA seepage.[276]

4.3 Tailings Water Quality

Although tailings basin water has apparently been subject to an extensive monitoring program since 2015,[277] the data was not available for this report.

4.4 Effluent Water Quality

4.4.1 Mine Site Treatment Plant

Effluent from the treatment plant at the mine site has consistently been within permit limits and lower than the expected concentrations for all constituents except nitrate.[278] Nitrate had an expected concentration of 0.168 mg/l as N, which translates to a trigger value of 0.84 mg/l as N. From 2019 through 2021, nitrate was above the expected concentration; in the summer months of 2020 and 2021 it was also frequently above the trigger level, with a maximum concentration in August 2020 of 1.6 mg/l as N.[279] Since then, nitrate levels have been reduced to below their expected concentration.

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[273] Eagle East Expansion Application. *Eagle.Eagle East expansion app.Foth 2017a.pdf [83-86]*
[274] Monitoring data and source citations are found in *Eagle.Mine site spreadsheet.Feb2025.xlsx*
[275] Monitoring data and source citations are found in *Eagle.Mine site spreadsheet.Feb2025.xlsx*
[276] Contact water basin data are located with mine water and TDRSA data in the annual reports. See 2021 Annual Report, *Eagle.2021 Annual Report.Eagle 2022.pdf*
[277] Eagle Mine, 2016b. 2015 Annual Mining and Reclamation Report, Humboldt Mill. *Eagle.2015 Humboldt Annual Report.Eagle 2016b.pdf [27-28]*
[278] *Eagle.Groundwater discharge DMRs [Folder]*
[279] *Groundwater discharge DMRs\DMR 2020.8.pdf [4]*

4.4.2 Humboldt Mill Treatment Plant

To maintain an optimum water level the Humboldt Tailings Disposal Facility (HTDF), water is pumped from the HTDF, treated, and discharged pursuant to National Pollution Discharge Elimination System (NPDES) Permit MI0058649. [280] The treated effluent from the HTDF was formerly discharged through a pipeline to the wetland contiguous to the Middle Branch Escanaba River at Outfall 001 and/or at Outfall 003, and is now discharged directly to the Middle Branch Escanaba River at Outfall 004, as shown in Figure 2.[281] As of 2018, treatment consisted of oxidation, neutralization/metals precipitation, settling, and ultrafiltration. This is followed by RO treatment for a portion of the water, which is then mixed with the non-RO-treated water to meet permit limits.[282] In 2021 a remineralization system was added to increase discharge hardness values when needed, and changes were made to the RO system to treat higher TDS levels in the influent.[283]

Eagle Figure 2. Humboldt Tailings Disposal Facility (HTDF) treated effluent discharge locations: Outfall 001 and Outfall 003 (wetland contiguous to the Middle Branch Escanaba River) and Outfall 004 (direct discharge to the Middle Branch Escanaba River). *Source:* Michigan Dept. of Environment, Great Lakes, and Energy, 2022. Fact Sheet, Permit No. MI0058649. *Eagle.NPDES Fact Sheet.EGLE 2022.pdf [4]*

The NPDES permit limits the effluent discharge volume to 1.22 million gallons per day (MGD) from October 1 through July 31, and 0.86 MGD from August 1 through September 30.[284] However, discharge volumes exceeded these limits for most of the period between December 2019 and December

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[280] MDEQ, 2018. Authorization to Discharge under the National Pollution Discharge Elimination System, Permit No. MI0058649. *Eagle.2018 NPDES permit.MDEQ 2018.pdf* Hereinafter, "2018 NPDES Permit."
[281] Michigan Dept. of Environment, Great Lakes, and Energy, 2022 (MI EGLE). Fact Sheet, Permit No. MI0058649. *Eagle.NPDES Fact Sheet.EGLE 2022.pdf [4]*
[282] Eagle Mine, 2018c. Re: Humboldt Mining Permit Application Amendment Request -- Request for Additional Information. *Eagle.Humboldt mine permit amendment.Eagle 2018c.pdf [3]*
[283] 2021 Humboldt Annual Report. *Eagle.2021 Humboldt Annual Report.Eagle 2022b.pdf [12]*
[284] 2018 NPDES Permit. *Eagle.2018 NPDES permit.MDEQ 2018.pdf [3]* Hereinafter, "2018 NPDES Permit."

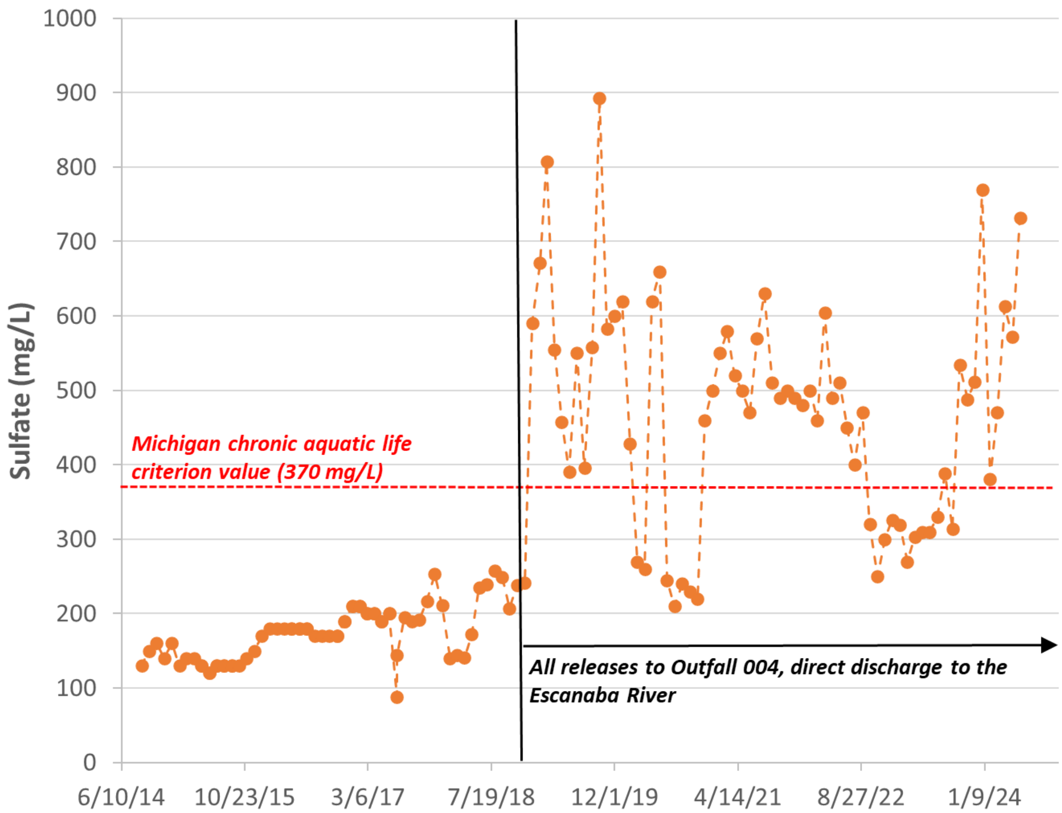
2020; the average discharge volume in September 2020 was 1.32 MGD.[285] This discharge volume is the equivalent of 2 cfs, which is close to half the river flow during low flow conditions.

Initially, discharge was to wetlands contiguous to the Middle Branch Escanaba River (see Figure 2);[286] in 2018, the permit was amended to also allow discharge directly to the Middle Branch Escanaba River.[287] Permit limits on metal concentrations were tightened, but the TDS limit increased from 500 mg/l in the 2015 permit[288] to 2,200 mg/l in the 2018 permit.[289] (Higher limits are due to the higher flow in the river, allowing for a dilution factor.)

The Humboldt Mill treatment plant effluent exceeded permit limits on a number of occasions from 2017 through 2020. Parameters included pH, chlorine, manganese, nickel, and cyanide. The effluent also failed Whole Effluent Toxicity tests for chronic toxicity on several occasions.[290] TDS values have remained below the permit limit due to the increase in the limit mentioned above. The TDS concentration of the effluent rose from an average of 383 mg/l in 2017 to an average of 927 mg/l in 2019.[291]

The permit does not include a limit for sulfate. Michigan's sulfate water quality standard to protect aquatic life from chronic toxicity, which was promulgated in 2019,[292] is 370 mg/l. Daily maximum sulfate concentrations in effluent from the mill site treatment plant rose from an average of 131 mg/l in 2015 to an average of 543 mg/l in 2019. The highest daily maximum concentration (in 2019) was 893; recent (2024) values have been as high as 732.[293] Figure 3 shows the dramatic increase in sulfate concentrations released to the outfalls over time. Even though the Humboldt Mill treatment plant uses ultrafiltration followed by RO, which will effectively remove sulfate, the mixing of the RO-treated water with the non-RO-treated water results in high sulfate concentrations. The vertical black line in Figure 3 indicates the date when the permit limit was raised and discharge directly to the Escanaba River via Outfall 004 began.

[285] U.S. EPA, n.d. NPDES Monitoring Data Download, Facility ID: MI0058649. Downloaded from https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download on July 5, 2024. *Eagle.Humboldt NPDES dataset.xlsx* Hereinafter, "Humboldt NPDES Dataset."
[286] MDEQ, 2010a. Authorization to Discharge under the National Pollution Discharge Elimination System, Permit No. MI0058649. *Eagle.2010 NPDES permit.MDEQ 2010a.pdf [3]*
[287] 2018 NPDES permit. *Eagle.2018 NPDES permit.MDEQ 2018.pdf [3]*; Michigan Dept. of Environment, Great Lakes, and Energy, 2022 (MI EGLE). Fact Sheet, Permit No. MI0058649. *Eagle.NPDES Fact Sheet.EGLE 2022 [4]* (map)
[288] MDEQ, 2015a. Authorization to Discharge under the National Pollution Discharge Elimination System, Permit No. MI0058649. *Eagle.2015 NPDES permit.MDEQ 2015a.pdf [3]*
[289] 2018 NPDES permit. *Eagle.2018 NPDES permit.MDEQ 2018.pdf [4-5, 9-10]*
[290] U.S. EPA, 2024. Effluent Limits Exceedances Report. *Eagle.Humboldt exceedances.EPA 2024.xlsx*
[291] Humboldt NPDES Dataset. *Eagle.Humboldt NPDES dataset.xlsx*
[292] MI EGLE, 2023. Rule 57 Surface Water Quality Values. *Eagle.MI water quality standards.EGLE 2023.xlsx*
[293] Humboldt NPDES Dataset. *Eagle.Humboldt NPDES dataset.xlsx*



Eagle Figure 3. Sulfate concentrations in Humboldt Mill treated effluent released to outfalls, 2014 to 2024. *Data source:* Humboldt NPDES Dataset. *Eagle.Humboldt NPDES dataset.xlsx*

The Michigan manganese water quality standards to protect aquatic life are based on hardness; we have not determined the standards that applies at the discharge site. (For comparison, the Canadian chronic toxicity standard ranges from 290 to 590 µg/l for water with a hardness of less than 100 µg/l and pH of less than 7,[294] conditions that prevail in the Middle Branch of the Escanaba River.[295]) The Humboldt Mill NPDES permit limit for manganese is 1300 µg/l as a monthly average and 1600 µg/l as a daily maximum. Measured manganese concentrations in the effluent have varied, ranging from an average of 176 µg/l in 2019 to an average of 708 µg/l in 2020. Concentrations in one five-month period from late 2019 to early 2020 averaged 1332 µg/l and included several permit violations.

Chlorine and chloride concentrations in the effluent do not exceed permit limits but are discharged at concentrations approaching State of Michigan surface water quality standards for protection of aquatic life. The chlorine acute water quality criterion is 38 µg/l; effluent concentrations ranged up to 38 µg/l, which is also the permit limit (note that the chronic Tier 1 value is only 1 µg/L). The chloride chronic water quality criterion value is 150 mg/l; effluent concentrations have ranged up to 115 mg/l. Boron concentrations in the effluent, while still present at relatively low levels have risen from an average of 77 µg/l in 2015 to an average of 615 µg/l in 2023. (The chronic criterion value is 7200 µg/l.)

[294] Canadian Council of Ministers of the Environment, 2019. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Manganese (dissolved). *Eagle.Canadian manganese standard.CCME 2019.pdf [1, 8]*
[295] 2021 Humboldt Annual Report. *Eagle.2021 Humboldt Annual Report.Eagle 2022b.pdf [101]*

Some of these values represent substantial increased pollutant loads to the Escanaba River in addition to impacts from previous mining operations. Prior to the start-up of the Eagle project, there was no direct discharge from the basin or mill; discharges to the Escanaba River stemmed solely from leakage through groundwater. Concentrations of sulfate, TDS, and manganese in direct discharges to the river from the Eagle project are considerably higher than in water that leaked from the basin prior to start-up, as shown in Table 1. (*See Section 5.2 for impacts on river water* quality.)

Eagle Table 1. Humboldt Mill Site groundwater and discharge concentrations before and after startup of Eagle Mine operations.

Parameter	Maximum groundwater concentrations near cut-off wall immediately prior to Eagle project	Highest annual average discharge concentrations, Humboldt Mill Site
TDS mg/l	450	949 (2021)
Sulfate mg/l	130	543 (2019)
Manganese µg/l	350	708 (2020)

TDS and sulfate concentrations immediately prior to Eagle start-up are from Golder Associates, 2011b. Humboldt Tailings Facility (HTDF) Cut-off Wall Site Characterization Study -- Drawings. *Eagle.Humboldt cutoff wall drawings.Golder 2011b.pdf [5]*.
The manganese concentration immediately prior to Eagle start-up is an average of data from wells as reported in Humboldt Hydrology Study. Monitoring wells are HW-1, HW-1A, HW-2, HW-5, HW-5A, HW-6, HW-6A, and HYG-1. *Eagle.Humboldt hydrology study.Foth 2008b.pdf [110] and [167]* (map)
Annual averages for Eagle Project are from Humboldt NPDES Dataset. *Eagle.Humboldt NPDES dataset.xlsx*

5. Mining Impacts on Groundwater and Surface Water Quality

5.1 Groundwater Quality

5.1.1 Mine Site

The groundwater quality monitoring locations for the Eagle Mine Site are shown in Figure 4. Baseline groundwater quality data were collected at the mine site between May 2004 to May 2005. Sampling was conducted in quaternary (QAL) and bedrock wells. The fourteen baseline quaternary wells or well nests each have five to seven data points. Specific conductance in the shallow quaternary wells ranged from 15 to 158 µS/cm, and in the deep quaternary wells from 68 to 221 µS/cm. Sulfate was typically less than the detection level of 5 mg/l in the shallow wells, and was often undetected in the deep wells but ranged up to 33 mg/l.[296]

[296] Eagle Hydrology Study, Table 18. *Eagle.Hydrology study.North Jackson 2005.pdf [142-169]*

Eagle Figure 4. Mine site groundwater monitoring well locations. Discharge permit wells are shown in green, and mining permit wells are shown in orange; the treated water infiltration system is #4 on the map. Water quality results are plotted for the two compliance wells highlighted in light yellow.
Source: 2023 Annual Report. *Eagle.2023 Annual Report 1.Eagle 2024a.pdf [40]*

The groundwater discharge permit at the mine site requires groundwater monitoring upgradient and downgradient of the treated water infiltration system. Limits on concentrations in groundwater are included, with the requirement that discharge not cause exceedances of the limits.[297] A 2016 report by the Community Environmental Monitoring Program of the Superior Watershed Partnership provides a review of exceedances to that date. The report indicates occasional exceedances for copper, molybdenum, aluminum, and lead.[298] These occasional exceedances in groundwater have continued,[299] but the effluent concentrations remain lower for these constituents than the groundwater monitoring data. The 2016 report also indicates frequent exceedances of the upper pH limit prior to 2015; in 2015, the limit was raised from 9 to 9.7. To our knowledge, the 9.7 limit has not been exceeded. In recent years, all parameters have been in substantial compliance except vanadium.

Exceedances for vanadium in wells downgradient from the treated water infiltration system have been an ongoing issue. Prior to 2015 the groundwater limit was 2.1 µg/; this limit was frequently exceeded in four wells.[300] In 2015, the limit was raised to 3.1 µg/l, and two wells with ongoing, consistent concentrations above 3.1 µg/l were excluded from the limit.[301] However, exceedances

297 Groundwater Discharge Permit. *Eagle.GW Discharge Permit.MDEQ 2007b.pdf [7-9]*
298 Superior Watershed Partnership and Land Trust, 2016. Eagle Mine -- Groundwater Discharge Permit Exceedance Summary through Q1 2016. *Eagle.GW Discharge Exceedance Summary.SWP&LT 2016.pdf [7-8]*
299 E.g., *Eagle.GWDP wells\GWDP 2022 Q2.pdf* (aluminum); *GWDP 2016 Q2.pdf* (chromium); *GWDP 2016 Q3.pdf* (aluminum).
300 Superior Watershed Partnership and Land Trust, 2016. Eagle Mine -- Groundwater Discharge Permit Exceedance Summary through Q1 2016. *Eagle.GW Discharge Exceedance Summary.SWP&LT 2016.pdf [9-10]*
301 MDEQ, 2015. Groundwater Discharge Permit No. GW1810162. *Eagle.2015 GW Discharge Permit.MDEQ 2015b.pdf [9]*

continue in other wells, one of which has exceeded the limit continually since early 2020.[302] The effluent itself consistently has a vanadium concentration below the level of detection of 1.0 µg/l; the conclusion is that the low ionic strength of the RO discharge water mobilizes vanadium in the soil.[303]

A second groundwater monitoring program assesses impacts on groundwater from other facilities at the mine site, and a third program assesses groundwater impacts at the Humboldt Mill site (*Section 5.1.2*). Both are governed by the respective mining permits.[304,305] Although many of the monitoring wells are deemed "compliance" wells, this seems to mean only that the results at these wells are compared to "benchmark" values. Neither the mining permits nor the discharge permits include numeric limits for groundwater contamination, nor are the benchmarks treated as enforceable limits in practice.

Groundwater quality at the mine site has worsened considerably since mining began. At wells located to detect leaks from the TDRSA and contact water basins, specific conductance, chloride, and nitrate all increased by an order of magnitude and sulfate doubled.[306] At the most impacted location, specific conductance rose from less than 40 to more than 4,000 µS/cm; chloride rose from less than 2 to 1500 mg/l; and sulfate rose from 2 to 20 mg/l. The same constituents rose to a lesser degree in monitoring wells located to detect impacts from the non-contact water infiltration basins, including at the underground mine site.[307] The Humboldt Mill site has had a similar experience, with specific conductance rising from 246 to 5058 µS/cm and chloride rising from undetectable to 1270 mg/l from one quarter to the next at the most impacted well.[308]

Increased concentration of specific conductance and chloride have been attributed to the use of deicing salt (usually sodium chloride but could also include magnesium chloride as a deicing agent) on roads and parking lots.[309] However, concentrations of nitrate have also risen in some wells. Figures 5a and b show nitrate concentrations in two Quaternary alluvium (QAL) wells downgradient of the TDRSA. Well QAL-67A is immediately downgradient of the TDRSA, while well QAL-24A is farther downgradient. Nitrate concentrations are generally higher in QAL-24A, but nearly all values in both wells are higher than the 2012-2013 benchmark value for nitrate. Increasing nitrate concentrations are related to the use of ammonium nitrate-fuel oil blasting agents, which leaves residue on waste rock, tailings, and any materials blasted from the underground mine. Nitrate is not associated with the use of deicing salt.

While de-icing salt may be a primary source of some constituents, it also serves to mask any possible impacts from other sources (e.g., leakage through liners or the cut-off wall). Furthermore, the

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[302] Eagle Mine, 2024e. Re: Eagle Mine, LLC -- QAL051D and QAL075A Vanadium Results, Groundwater Discharge Permit (GW1810162). *Eagle.Vanadium letter.Eagle 2024e.pdf*

[303] Chatterson, Eric, 2021. Hydrogeologic Summary -- New Permit -- Update. *Eagle.Vanadium memo.Chatterson 2021.pdf [9]*

[304] MDEQ, 2007a. Nonferrous Metallic Mineral Mining Permit No. MP 01 2007. *Eagle.Mining permit.MDEQ 2007a.pdf*

[305] MDEQ, 2010b. Nonferrous Metallic Mineral Mining Permit No. MP 01 2010. *Eagle.Mining permit.MDEQ 2010b.pdf*

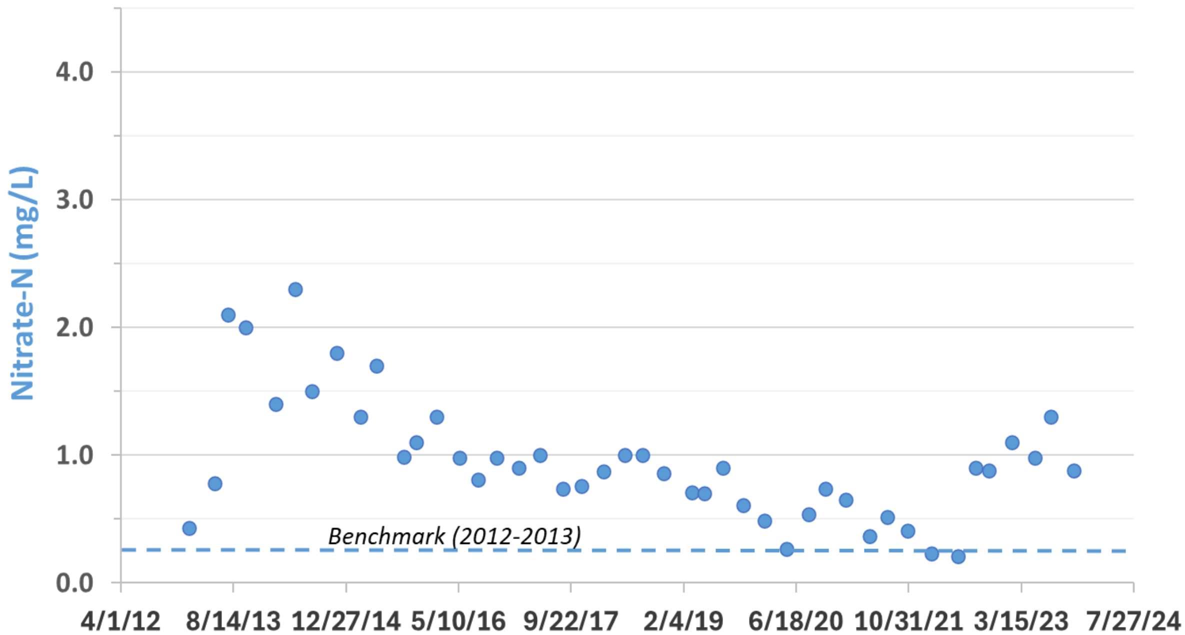
[306] *Eagle.Mine site spreadsheet.Feb2025.xlsx*

[307] Eagle Mine, 2020a. 2019 Annual Mining and Reclamation Report. *Eagle.2019 Annual Report.Eagle 2020a.pdf [21]*

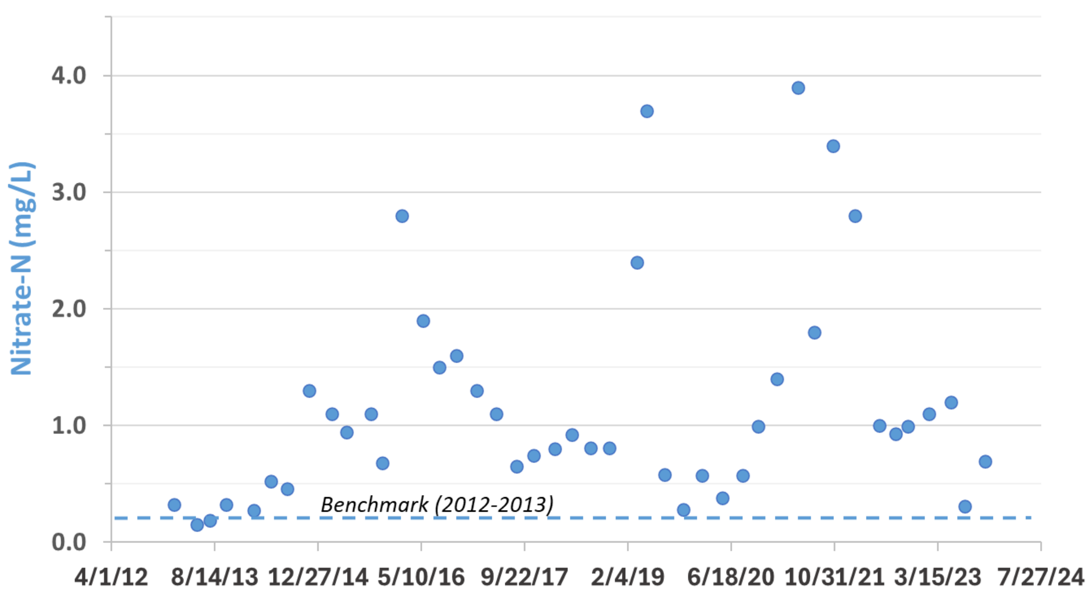
[308] *Eagle.Humboldt spreadsheet.Feb2025.xlsx [H wells]*

[309] Eagle Mine, 2021a. 2020 Annual Mining and Reclamation Report. *Eagle.2020 Annual Report.Eagle 2021a.pdf [22-24]*

situation illustrates the impacts that land development and transportation at the level required for mining operations has on groundwater. These results also illustrate the failure of environmental review, which in this case completely ignored potential impacts on groundwater from deicing and other sources mobilized by stormwater.[310]



Eagle Figure 5a. Nitrate concentrations over time in alluvial well QAL-67A compared to the benchmark. *Data source:* Eagle Mine, 2011 to 2023 Annual Mining and Reclamation reports. *Eagle.Mine site spreadsheet.Feb2025.xlsx* Not all quarters have available water quality data.



Eagle Figure 5b. Nitrate concentrations over time in alluvial well QAL-24A compared to the benchmark. *Data source:* Eagle Mine, 2011 to 2023 Annual Mining and Reclamation reports. *Eagle.Mine site spreadsheet.Feb2025.xlsx* Not all quarters have available water quality data.

[310] EIA. *Eagle.EIA.Foth 2006a.pdf [33]*

5.1.2 Humboldt Mill Site

Groundwater at the Humboldt site was impacted by previous mining operations, as noted in *Section 2.2*, and we are unaware of any true baseline data at that location. Our review is thus limited to assessing changes over the course of the Eagle project. A critical feature at the tailings basin is the cut-off wall (see Figure 1), and well pairs are located to measure water quality inside and outside the cut-off wall. One well downgradient of the wall (MW-704) mimics the pattern of its paired well inside the wall (MW-701) for many constituents, including pH (exceedances of high and low benchmark values), calcium, magnesium, chloride, and sodium. Concentrations rose dramatically in late 2018, with a peak in 2020 and subsequent decline.[311] This is the same pattern seen in wells that are presumed to be affected by road salt, so a definitive answer regarding the effectiveness of the cut-off wall is not possible. However, a company report suggests sulfate as an appropriate parameter for comparison.[312] At MW-701, sulfate rose from 37 to 104 mg/l from 2015 to 2019, and at MW-704 it rose from 13 to 67 in that time period. In addition, concentrations of manganese in MW-704 rose above benchmark values in the upper fractured bedrock (UFB).

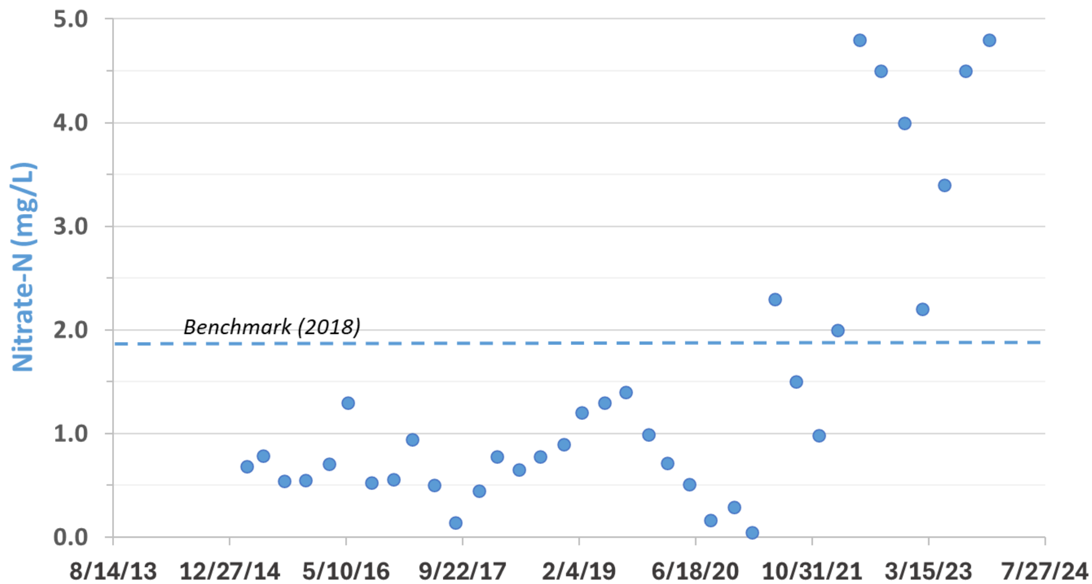
Nitrate and ammonia are related to the presence of blasting residue on the tailings in the impoundment. Mercury is leached from the tailings itself; the flotation operation is not designed to specifically remove mercury, so some of the metal reports to the tailings rather than the concentrate. Figures 6a through e show the presence of nitrate, ammonia, and mercury in shallow alluvial monitoring wells downgradient of the tailings impoundment. The graphs show that concentrations of nitrate, ammonia, and mercury have been increasing over time since processing started at the Eagle Mine in 2014. Even though other operations disposed their tailings in the impoundment before it was used by the Eagle Mine, the results show that Eagle Mine tailings have increased groundwater concentrations of mine-related contaminants inside and outside the cut-off wall. Well MW-701 has the highest nitrate concentrations and is inside the cut-off wall (Figure 6a). Wells MW-702 and MW-703 are paired wells inside and outside the cut-off wall, and MW-703 is one of only two compliance wells at the Humboldt Mill site. Concentrations of mercury in MW-702 are well above the groundwater-surface water interface (GSI) criterion value of 1.3 ng/l and the less-protective 2018 benchmark value, reaching a peak of nearly 10 ng/l in 2022 (Figure 6b). Nitrate concentrations in MW-703, which is paired with MW-702 and outside the cut-off wall, increased monotonically from the beginning of monitoring for the Eagle Mine project through 2022; all values are above the 2014 benchmark, and most values from August 2017 November 2023 are higher than the less protective 2018 benchmark value (Figure 6c). The concentrations in Figures 6 a, b, and c have not leveled off and may continue to increase over time. The fact that concentrations in the compliance well MW-703, located outside the cut-off wall, have been increasing after the Eagle Project began and are higher than benchmark values, indicates that the cut-off wall is not accomplishing the goal of preventing tailings leachate from migrating away from the impoundment.

Nitrate concentrations in MW-704, the other compliance well located outside the cut-off wall, are shown in Figure 6d. The four 2015 values were consistently below the more protective 2014 benchmark value. Concentrations fluctuate between below detection (<0.05 mg/l as N) and 1.5 mg/l as N from 2016 through 2023, but no seasonal pattern is evident. All values in this time period are above the 2014 benchmark but below the less protective 2018 benchmark (with one exception above the 2018

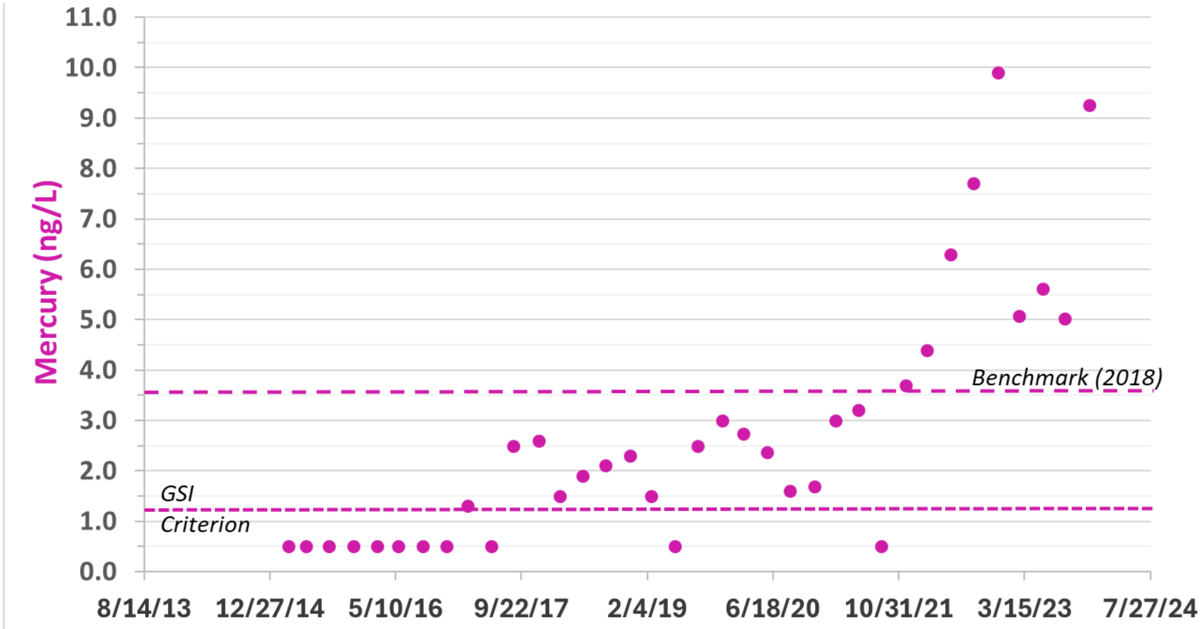
[311] *Eagle.Humboldt spreadsheet.Feb2025.xlsx [Cutoff wall]*
[312] 2021 Humboldt Annual Report. *Eagle.2021 Humboldt Annual Report.Eagle 2022b.pdf [24]*

benchmark). The higher concentrations compared to the 2015 values indicate that nitrate is migrating from the impoundment beyond the cut-off wall.

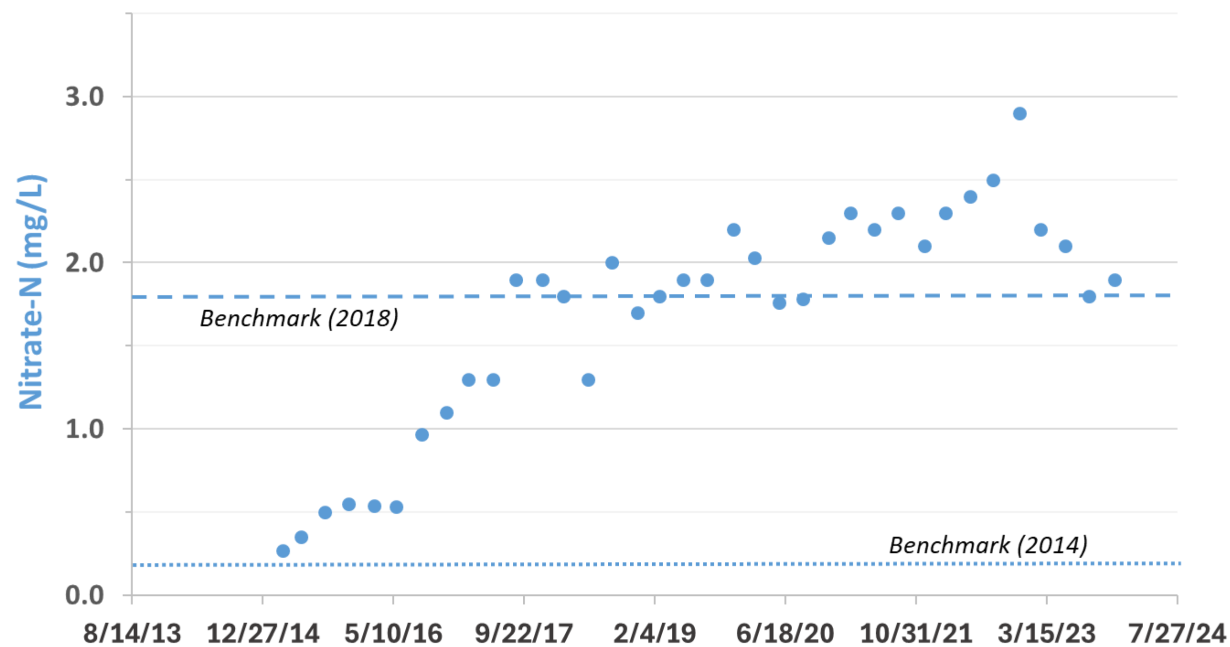
Well MW-705 is located near the edge of the alluvial aquifer with no cut-off wall between it and the impoundment. Benchmark ammonia values did not change markedly between 2014 and 2018, but 80% of the values after mid-2018 are higher than the less protective 2018 benchmark value (Figure 6e). Overall, the results suggest that the cut-off wall is ineffective in preventing downgradient contaminant migration from the tailings impoundment.



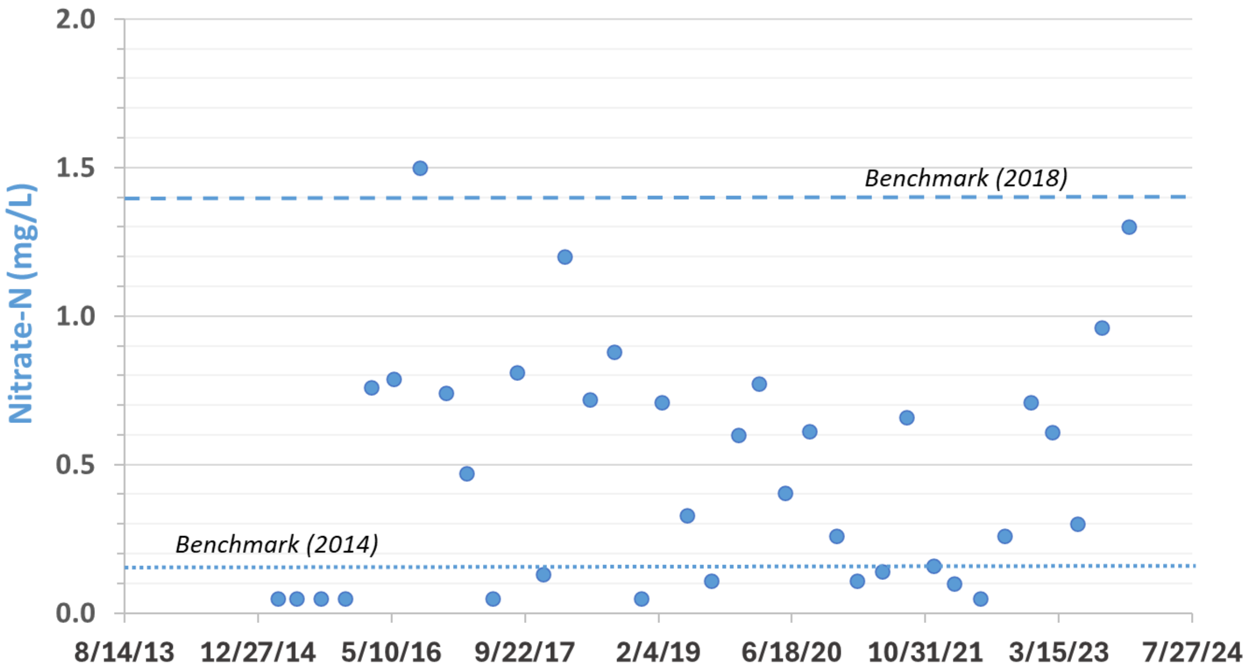
Eagle Figure 6a. Nitrate concentrations over time in MW-701, inside the cut-off wall, compared to the benchmark value. *Date source:* Eagle Mine, 2015-2023 Annual Mining and Reclamation Reports, Humboldt Mill. *Eagle.Humboldt spreadsheet.Feb2025.xlsx*



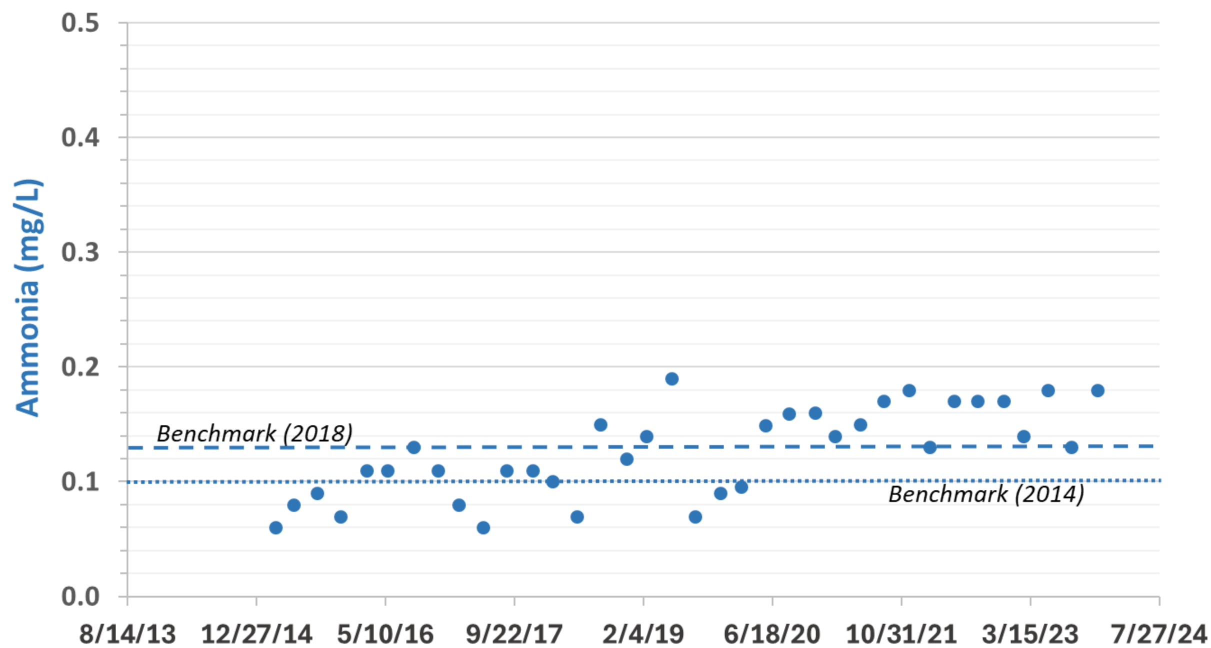
Eagle Figure 6b. Mercury concentrations over time in MW-702, inside the cut-off wall, compared to groundwater-surface water interface (GSI) criterion (1.3 ng/l) and the benchmark value.
Data sources: Eagle Mine, 2015-2023 Annual Mining and Reclamation Reports, Humboldt Mill. *Eagle.Humboldt spreadsheet.Feb2025.xlsx. GSI:* Foth, 2008c. Humboldt Mill Mining Permit Application, Vol. IIE, Environmental Impact Assessment, App. B-1, App. F, Surface Water and Sediment Sampling Results*. Eagle.Humboldt baseline report.Foth 2008c.pdf [428, 430]*



Eagle Figure 6c. Nitrate concentrations over time in MW-703, outside the cut-off wall and paired with MW-702, compared to the 2014 and 2018 benchmark values. *Data sources:* Eagle Mine, 2015-2023 Annual Mining and Reclamation Reports, Humboldt Mill. *Eagle.Humboldt spreadsheet.Feb2025.xlsx*



Eagle Figure 6d. Nitrate concentrations over time in MW-704, the compliance well outside the cut-off wall, compared to the 2014 and 2018 benchmark values. *Data sources:* Eagle Mine, 2015-2023 Annual Mining and Reclamation Reports, Humboldt Mill. *Eagle.Humboldt spreadsheet.Feb2025.xlsx*

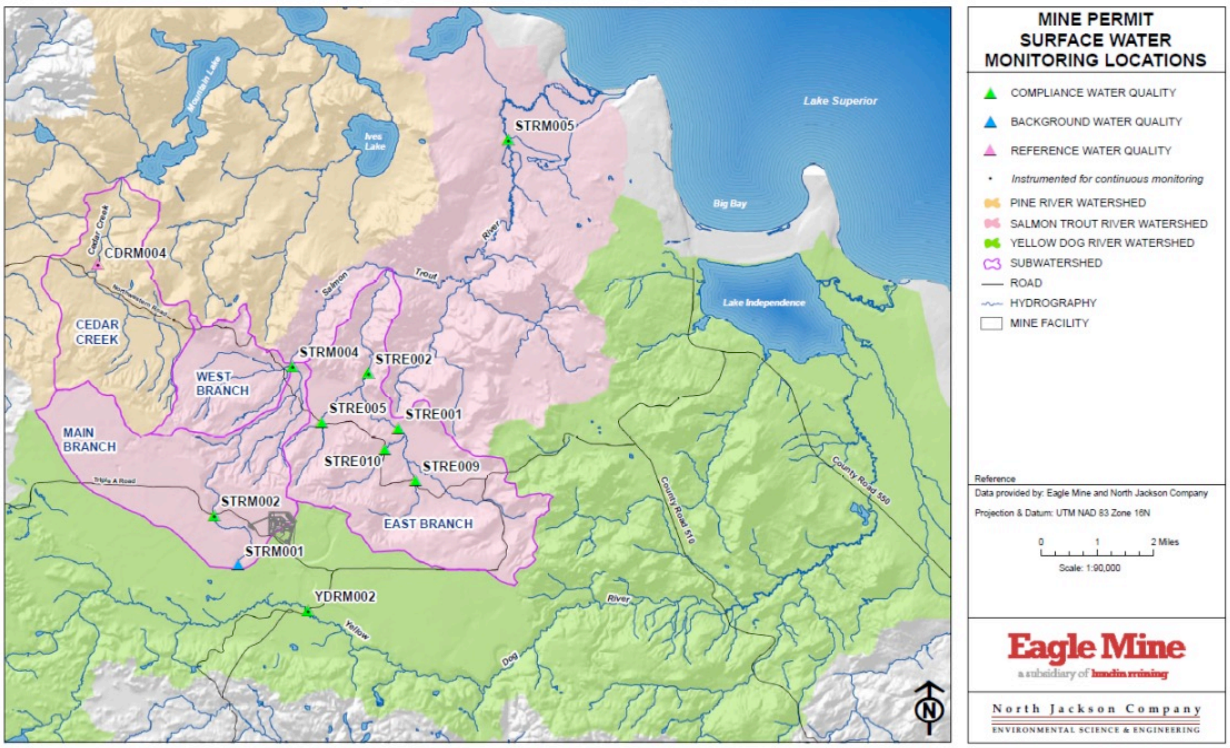


Eagle Figure 6e. Ammonia concentrations over time in MW-705, outside the cut-off wall, compared to the 2014 and 2018 benchmark values. *Data sources:* Eagle Mine, 2015-2023 Annual Mining and Reclamation Reports, Humboldt Mill. *Eagle.Humboldt spreadsheet.Feb2025.xlsx*

5.2 Surface Water Quality

5.2.1 Mine Site

Baseline surface water quality data were collected at the Eagle Mine site from 2002 to 2005. The baseline data set includes fourteen data points for two critical monitoring locations on the Salmon Trout River (STRM-001 and STRM-002), and a varying degree of data for a number of other sites on both the Salmon Trout and Yellow Dog Rivers.[313] The surface water quality monitoring locations are shown in Figure 7.



Eagle Figure 7. Surface water compliance, background, and reference water quality monitoring locations. *Source:* Eagle Mine, 2022. 2021 Annual Mining and Reclamation Report, Appendix I. *Eagle.2021 Annual Report.Eagle 2022a.pdf [170]*

The only facilities within a quarter mile of surface water are the facilities above the underground mine. This includes the main ventilation air raise, a non-contact water infiltration basin, and an area cleared for access.[314] These facilities are about 250 feet from a headwater reach of the Salmon Trout River. Both baseline and ongoing monitoring are done at a point upstream of the facilities (STRM-001) and at a point about a mile downstream of the facilities (STRM-002).[315]

In baseline monitoring, specific conductance averaged 46 µS/cm at STRM-001 and 58 µS/cm at STRM-002. Chloride and sulfate concentrations were only occasionally above detection limits; both almost always remained below 1 mg/l.[316] Other than a few low-level measurements of chloride and

[313] Eagle Hydrology Study, Table 13. *Eagle.Hydrology study.North Jackson 2005.pdf [105-128]*
[314] 2023 Annual Report. *Eagle.2023 Annual Report 1.Eagle 2024a.pdf [40]*
[315] 2023 Annual Report. *Eagle.2023 Annual Report 1.Eagle 2024a.pdf [166]*
[316] Eagle Hydrology Study. *Eagle.Hydrology study.North Jackson 2005.pdf [105-108]*

sulfate values, concentrations have not increased at STRM-001. However, both chloride and sulfate have seen small but measurable increases at STRM-002. Chloride ranged from 1.3 to 1.7 mg/l between 2013 and 2018. (This is the same time frame that elevated chloride was measured in the groundwater monitoring well at this location.) Sulfate concentrations rose to 1.7 mg/l in 2019, and have remained above 1 mg/l since then. Mercury and aluminum also appear to have increased more at STRM-002 than at STRM-001.[317] Although the cause is undetermined, these increases would be consistent with low-level increases in runoff and groundwater infiltration from cleared areas and small increases in deposition of air pollutants.

5.2.2 Humboldt Mill Site

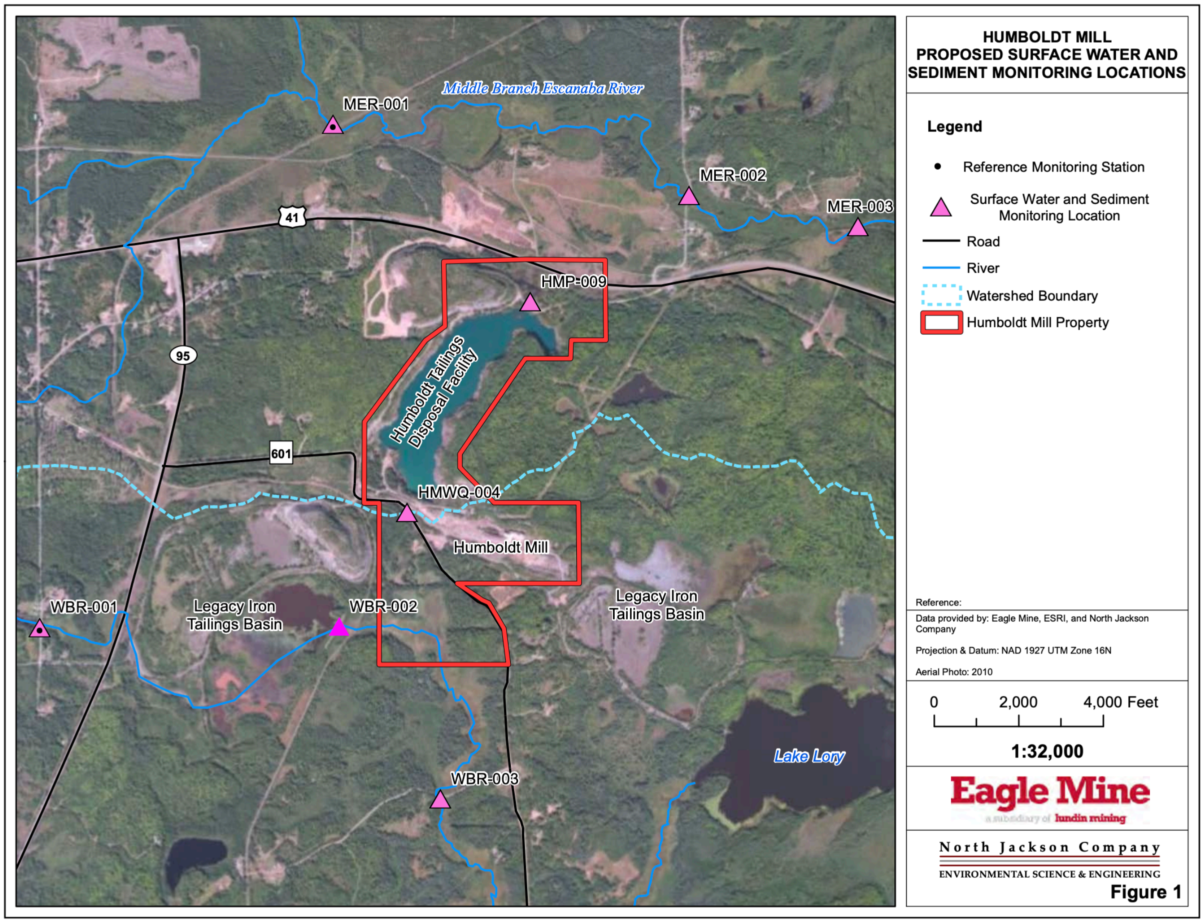
Assessing impacts on the Escanaba and Black rivers at the Humboldt Mill site is complicated because the rivers are impacted by wastes from past mining operations, some of which may still be leaching constituents to groundwater. The Black River, which is at the south end of the Humboldt Mill site, is within the sphere of impact from the mill. It appears to be more heavily impacted than the Escanaba River,[318] but impacts from the Eagle operation could not be assessed due to the continuing presence of legacy pollution and facilities from past operations.

Four quarters of data were collected on the Escanaba River in 2006-2007,[319] allowing a comparison of Eagle monitoring data for that window of time. Monitoring points include MER-001, upstream of Eagle project impacts; MER-002, which is upstream of the current NPDES outfall but may be affected by groundwater flow paths; and MER-003, which is the first monitoring point downstream of direct effluent discharge to the river (Figure 8).

[317] *Eagle.Mine site spreadsheet.Feb2025.xlsx [Salmon Trout]*

[318] E.g., 2021 Humboldt Annual Report. *Eagle.2021 Annual Report.Eagle 2022a.pdf [104-106]*

[319] Foth, 2008c. Humboldt Mill Mining Permit Application, Vol. IIE, Environmental Impact Assessment, App. B-1, App. F, Surface Water and Sediment Sampling Results. *Eagle.Humboldt baseline report.Foth 2008c.pdf [310-313, 331-334, 340, 353-357, 363, 373-377, 416]*



Eagle Figure 8. Surface water monitoring locations at the Humboldt Mill site, including those north of the site in the Middle Branch Escanaba River (MER) and south of the site in the Black River (WBR).
Source: 2023 Humboldt Annual Report. *Eagle.2023 Humboldt Annual Report.Eagle 2024c.pdf [107]*

Concentrations of several constituents, including specific conductance, sulfate, iron, and manganese, have risen at MER-003, as shown in Table 2. Figure 9 shows sulfate and manganese concentrations at MER-003 over time. Note that discharge in 2015 was to wetlands; the effect on the river was likely not as immediate as in later years, when discharge was directly to the river. Iron and manganese concentrations also rose in MER-002, which might be affected by groundwater pathways between the HTDF and the river. These levels do not exceed Michigan's water quality standards. However, Michigan does not have a sulfate standard to protect wild rice. In Minnesota, that standard is 10 mg/l.

Eagle Table 2. Concentrations of Pollutants in the Escanaba River.

	Specific conductance (µS/cm)				**Sulfate** (mg/l)		
	MER-001	**MER-002**	**MER-003**		**MER-001**	**MER-002**	**MER-003**
2006-2007	115	117	147		6.1	8.8	10.5
2015	110	105	73		6.4	11	15
2020	109	127	151		3.2	5.0	24
2023	114	114	192		3.2	4.8	27.5

	Iron (µg/l)				**Manganese** (mg/l)		
	MER-001	**MER-002**	**MER-003**		**MER-001**	**MER-002**	**MER-003**
2006-2007	1040	1646	1402		49	104	101
2015	1380	1936	1600		103	175	166
2020	1697	2400	2202		127	155	190
2023	1810	2707	2302		208	434	260

All values are annual averages based on quarterly monitoring.
2006-2007 data are from Foth, 2008c. Humboldt Mill Mining Permit Application, Vol. IIE, Environmental Impact Assessment, App. B-1, App. F, Surface Water and Sediment Sampling Results. *Eagle.Humboldt baseline report.Foth 2008c.pdf [310-313, 331-334, 340, 353-357, 363, 373-377, 416]*
2015-2023 data are from *Eagle.Humboldt spreadsheet.Feb2025.xlsx*; data sources are provided in the spreadsheet.
Discharge in 2015 was to wetlands draining to the river; direct discharge to the river began in 2018.

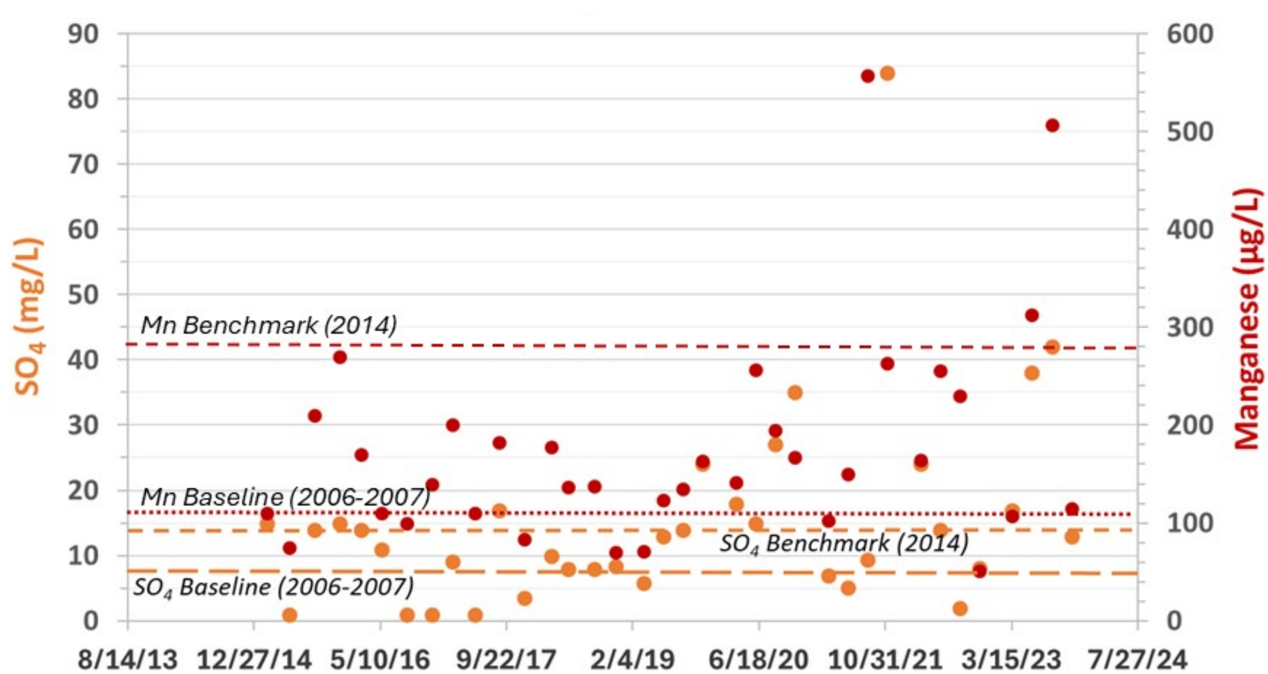


Figure 9. Sulfate and manganese concentrations over time in the Escanaba River, most downstream monitoring location, MER-003. *Data sources:* Eagle Mine, 2015-2023 Annual Mining and Reclamation Reports, Humboldt Mill. *Eagle.Humboldt spreadsheet.Feb2025.xlsx*

Water quality degradation may grow worse after mine closure. The reclamation plan includes stopping treatment of tailings basin water and allowing overflow to run out to the Escanaba River.[320] While concentrations of constituents will presumably be low enough to meet water quality standards after mixing with river water, some constituent levels will likely be higher than they are in treated discharge. This is a particular problem for TDS/specific conductance values, which are very high in tailings basin water and have no State surface water quality standard.

6. Accuracy of Water Quality Predictions

As indicated in Tables 3 and 4 and Figures 10a and 10b, both water pumped from the underground mine and TDRSA leachate are of much poorer quality than predicted. A few parameters worsened after the expansion into the Eagle East orebody began in 2018. This ore body was not considered in the original predictions, nor were predictions updated for the expansion. The application for the amended permit states, "Based on the strong geological and geochemical similarities, there is no basis for believing that the new development rock would behave any differently than did the originally tested country rock."[321] According to the EIA, the exception was for total dissolved solids, which are much higher at the Eagle East orebody.[322] However, after 2018, sulfate, barium, and iron levels have been considerably higher in mine inflow water and sulfate, chloride, cobalt, and manganese have been considerably higher in TDRSA water.

Eagle Table 3. Eagle Mine Predicted Versus Actual Concentrations in Underground Mine Water.

	Sulfate (mg/l)	**Aluminum** (µg/l)	**Barium** (µg/l)	**Chromium** (µg/l)	**Copper** (µg/l)	**Iron** (µg/l)	**Vanadium** (µg/l)
Predictions	118	156	28	10	155	7,247	7
2013-2017	225	9,620	88	65	3,886	45,839	37
2019-2023	626	8,738	346	67	3,727	65,783	20

2013-2017 and 2019-2023 values are averages of all data from the given timeframe.
Predictions are from Foth & Van Dyke, 2005. WWTP Influent and Effluent Calculations. *Eagle.Influent predictions.Foth 2005.pdf [3]* ("Composite Mine Drainage")
2013-2023 data are from *Eagle.Mine site spreadsheet.Feb2025.xlsx*; data sources are provided in the spreadsheet.

Other constituents that were under-predicted in mine water include lead, molybdenum, zinc, and total inorganic nitrogen (nitrate + nitrite + ammonia). TDS was predicted at 184 mg/l, however TDS is not monitored but has been replaced by specific conductance monitoring. Specific conductance averaged 1790 µS/cm in 2012-2017 and 9039 µS/cm in 2019-2023.

The concentrations of several constituents in TDRSA water were also underpredicted. In addition to those shown in Table 4, barium, boron, cadmium, chromium, iron, and selenium were all underpredicted.

[320] Humboldt EIA. *Eagle.Humboldt EIA.Foth 2008a.pdf [26]*
[321] Eagle East Expansion Application. *Eagle.Eagle East expansion app.Foth 2017a.pdf [83-86]*
[322] Foth, 2017b. Environmental Impact Assessment Eagle East. *Eagle.Eagle East expansion EIA.Foth 2017b.pdf [332]*

Eagle Table 4. Eagle Mine Predicted Versus Actual Concentrations in TDRSA Leachate.

	Sulfate (mg/l)	Chloride (mg/l)	Aluminum (µg/l)	Cobalt (µg/l)	Manganese (µg/l)	Molybdenum (µg/l)
Predictions	575	10	1	0.8	5	1.5
2013-2017	1,374	121	147.5	10.65	551	17.2
2019-2023	2,039	633	--	197	1,391	28.5

2013-2017 and 2019-2023 values are averages of all data from the given timeframe.
Predictions are from Foth & Van Dyke, 2005. WWTP Influent and Effluent Calculations. *Eagle.Influent predictions.Foth 2005.pdf [3]* ("TDRSA Contact Runoff"); and Logsdon, Mark J. Technical Memo re: Water Quality from the Development Rock Storage Pad During Operations. *Eagle.TDRSA predictions.Logsdon 2005.pdf [6, 9]*
2013-2023 data are from *Eagle.Mine site spreadsheet.Feb2025.xlsx*; data sources are provided in the spreadsheet.

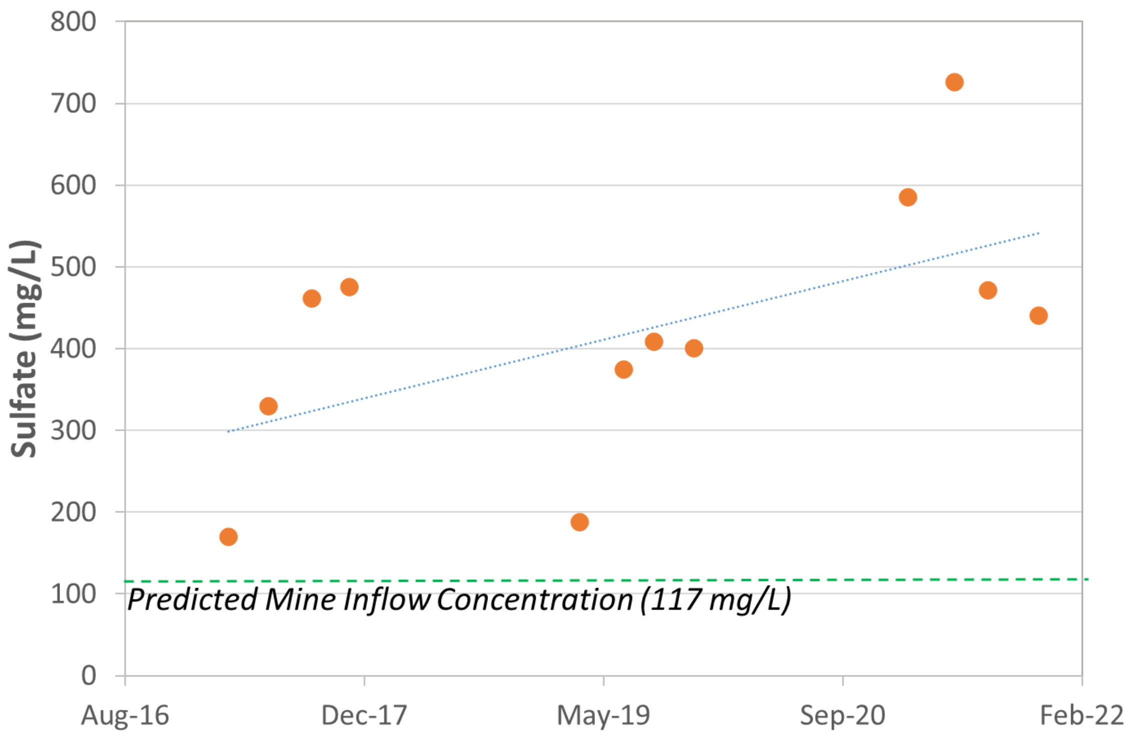
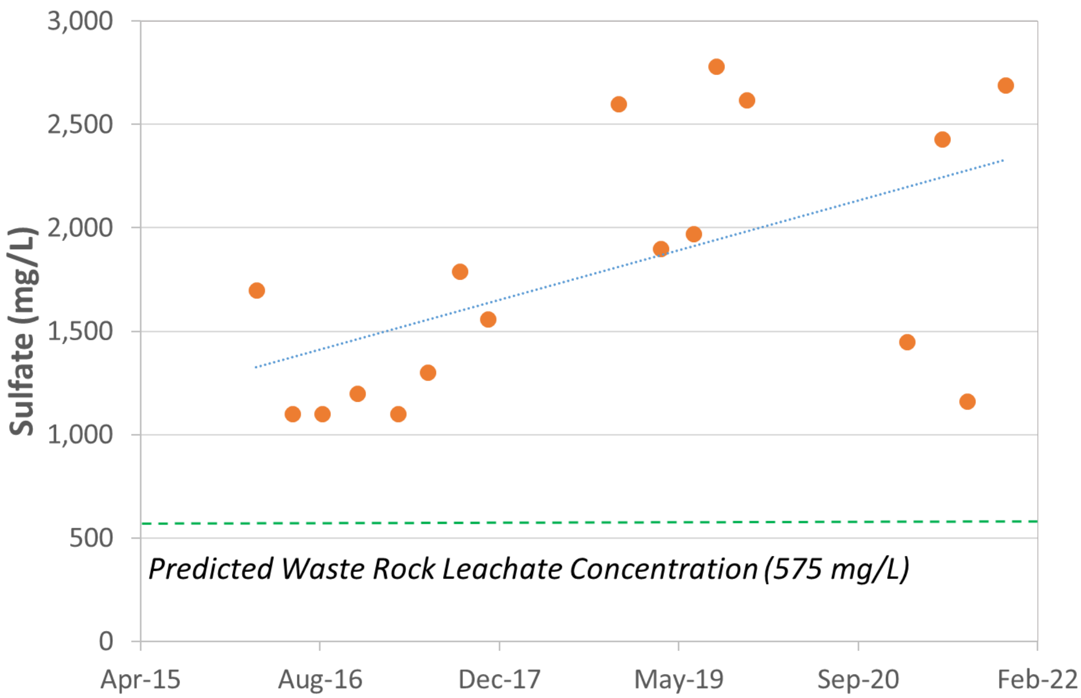


Figure 10a. Comparison of predicted vs. actual sulfate concentrations in composite mine inflow. Actual values from 2017 to 2021. *Data sources:* Predictions: Foth & Van Dyke, 2005. WWTP Influent and Effluent Calculations. *Eagle.Influent predictions.Foth 2005.pdf [3];* measured results*:* Eagle Mine, 2017 to 2021 Annual Mining and Reclamation reports. *Eagle.Mine site spreadsheet.Feb2025.xlsx*



Eagle Figure 10b. Comparison of predicted vs. actual sulfate concentrations in waste rock leachate. Actual values from 2017 to 2021. *Data sources:* Predictions: Logsdon, Mark J. Technical Memo re: Water Quality from the Development Rock Storage Pad During Operations. *Eagle.TDRSA predictions.Logsdon 2005.pdf [6, 9];* measured results: Eagle Mine, 2017 to 2021 Annual Mining and Reclamation reports. *Eagle.Mine site spreadsheet.Feb2025.xlsx*

7. Summary of Water Quality Impacts

Surface water:

- In a headwaters stream, chloride and sulfate both rose from below the quantification limit of 1 mg/l to 1.7 mg/l.
- In the Escanaba River, TDS increases from 114 mg/l to 192 mg/l and sulfate increases from 3.2 to 27.5 mg/l from an unimpacted station to downstream of the effluent discharge location.

Groundwater:

- Eagle Mine has degraded groundwater to the point of violations of water quality standards at compliance points. One well at the Eagle Mine was above the 250 mg/l criteria for chloride from winter 2013 through fall of 2017. Two wells at the Humboldt tailings basin were above the chloride criteria for 16-month periods each, in 2020 and 2021.

Effluent:

- From 2017 to 2019, Eagle discharge at the Key Mill failed Whole Effluent Toxicity tests for chronic toxicity on seven occasions.
- The discharge location was moved from a wetland to the river because the plant could not meet the TDS limit that applied in the wetland.

Accuracy of water quality predictions:

- Eagle treats all rock as potentially acid generating.
- Mine water has been an order of magnitude higher than predictions for aluminum, barium, copper, and iron, and at least five times higher than predictions for sulfate and chromium.
- Leachate from waste rock has been 2 to 3 orders of magnitude higher than predicted for aluminum, cobalt, and manganese, more than an order of magnitude higher for chloride and molybdenum, and four times as high for sulfate.

8. Comparison to Potential Mines in the Rainy River Headwaters Watershed of Minnesota

The Eagle Mine site is similar to sites in northeastern Minnesota in climate and in the high quality of water resources that are not impacted by mining. However, streams, lakes, and wetlands are more ubiquitous in the Rainy River Headwaters. The Eagle Mine is much smaller than mines proposed for the Rainy River headwaters; mines in Minnesota would therefore have larger volumes of waste rock; tailings; and mine-influenced water. Eagle Mine ore and waste rock are higher in sulfide content than Duluth Complex ore, making acid generation less certain at Minnesota mines. However, the geology of the Eagle Mine is such that all rock is considered potentially acid-generating and is backfilled into the mine. Eagle Mine has thus avoided the problems that other mines have had with the leaching of constituents from non-acid generating rock used in construction and/or stockpiled without liners. Mines being considered in the Duluth Complex include the use of waste rock in construction.

9. Post-permitting and Potential Future Expansions

As discussed in *Section 4.1*, mining expanded into a second orebody in 2018, about eight years after permits were first issued. Discharge quality at the Humboldt Mill deteriorated immediately after mining of the Eagle East orebody began, with total dissolved solids concentrations rising from an average of 384 mg/l in 2017 to an average of 928 mg/l in 2019. Increases were seen in boron and sulfate concentrations. An expansion into a third ore body was proposed in 2023.[323] The additional ore results in an increased volume of tailings; it is unclear at this point what the impact will be on the tailings basin and the Escanaba River.

[323] Eagle Mine, 2023g. Re: Upper Eagle East Expansion. *Eagle.Upper Eagle East.Eagle 2023g.pdf*

East Boulder Mine, Montana

1. Site and Mine Description and Background Information

The East Boulder Mine is an underground platinum and palladium mine located in the Gallatin National Forest about 30 miles south of Big Timber, Montana. The mine is owned and operated by Stillwater Mining Company, which was originally a partnership between Chevron U.S.A., Inc. and Manville Sales Corp. under the name of Stillwater PGM Resources.[324] Stillwater Mining Company is now a subsidiary of Sibanye-Stillwater.[325]

Mine facilities are within two miles of the Absaroka-Beartooth Wilderness area[326] and thirty miles of Yellowstone National Park.[327] The mine site is on the East Boulder River downstream of the wilderness area. Although the river meets water quality standards at and immediately downstream of the mine, reaches farther downstream are on Montana's impaired waters list for chlorophyll-a, flow alterations, sedimentation, nitrogen, and several metals.[328]

The mine processes about 2,850 tons of ore per day.[329] At the time of the original environmental review, total anticipated production was estimated at 18,030,000 tons of ore[330] and 7,290,000 tons of waste rock.[331] Surface disturbance estimated in the EIS was 233 acres.[332] Up to 822 acres are currently approved for disturbance, 609 of which are on national forest land.[333]

The first Final Environmental Impact Statement (EIS) for the project was released in 1992, and permits were issued in 1993. A lawsuit ensued, which was preempted by legislative changes to the Montana Water Quality Act.[334] Construction of the mine began in 1998, and production began in 2002.[335] An expansion of the mine has recently been proposed, with a Draft EIS completed in 2023.[336]

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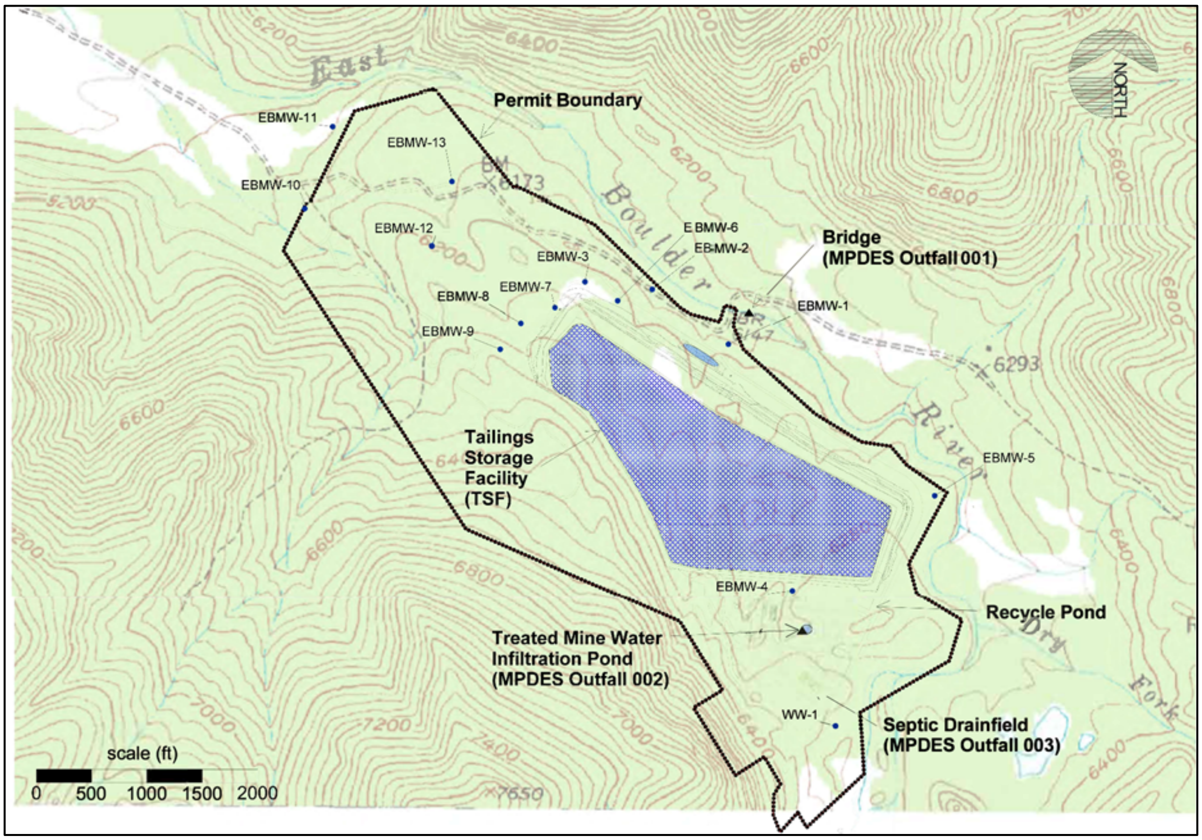
[324] U.S. Forest Service (USFS), Montana Dept. of State Lands, and Montana Dept. of Health and Environmental Sciences, 1992. East Boulder Mine Project Final Environmental Impact Statement. Hereinafter, "1992 FEIS." *EastBoulder.FEIS.USFS 1992.pdf [53]*
[325] 1992 FEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [13]*
[326] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [476]*
[327] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [54]*
[328] Montana Dept. of Environmental Quality (MDEQ), 2023. Montanta Pollution Discharge Elimination System (MPDES) 2023 Permit Fact Sheet, Permit No. MT0026808. Hereinafter, "NPDES Permit Fact Sheet." *East Boulder.NPDES Fact Sheet.MDEQ 2023.pdf [15]*
[329] U.S. Dept. of Agriculture (USDA) and MDEQ, 2023. East Boulder Mine Amendment 004 Draft Environmental Impact Statement. Hereinafter, "2023 DEIS." *EastBoulder.2023 DEIS.USDA 2023.pdf [63]*
[330] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [103]*
[331] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [94]*
[332] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [71]*
[333] 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [129]*
[334] Northern Plains Resource Council, nd. The Story of the Good Neighbor Agreement (webpage). Accessed May 7, 2024. *https://northernplains.org/gna-history/*
[335] USDA and MDEQ, 2012. Stillwater Mining Company's Revised Water Management Plans and Boe Ranch LAD. Hereinafter, "2012 FEIS." *EastBoulder.2012 FEIS.USDA 2012.pdf [68]*
[336] 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf*

Annual precipitation in the East Boulder area is 20 to 25 inches.[337] Although the evaporation rate exceeds precipitation,[338] the mountainous terrain and substantial inflows to the mine result in the need to discharge water. The river flow in the vicinity of the mine has been measured at 5 to 588 cfs; 5 cfs was calculated as the seven-day, ten-year low flow for purposes of environmental review.[339] Depth to groundwater ranges from about 30 to 200 feet. At most of the site, bedrock is more than 250 feet below the ground surface. Hydraulic conductivity is high, with preferential pathways through coarse-grained glacial lenses.[340]

2. Mine Facilities and Operations

The East Boulder mining operation consists of the underground mine workings, a mill with attendant facilities, a water treatment facility, and a tailings facility (Figure 1). There are no permanent surface waste rock stockpiles; waste rock is used for construction of the tailings impoundment or is backfilled to the underground mine workings.



East Boulder Figure 1. East Boulder Mine facilities. *Source: MDEQ, 2023. Montanta Pollution Discharge Elimination System (MPDES) 2023 Permit Fact Sheet, Permit No. MT0026808. East Boulder.NPDES Fact Sheet.MDEQ 2023.pdf [53]*

[337] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [42]*
[338] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [351]*
[339] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [200]*
[340] Sibanye-Stillwater Mining Co. (SMC), 2023. East Boulder Mine Consolidated Operations and Reclamation Plan. Hereinafter "2023 CORP." *EastBoulder.CORP.SMC 2023.pdf [42-44]*

Mine water is pumped from the mine to the treatment facility, which includes a thickener, clarifier, 100-micron bag filters, anoxic biological treatment, pH adjustment, and a 10-micron disc filter. The thickener and the 10-micron filter were added in 2021 and have improved the quality of the effluent.[341] The system discharges to a percolation pond, designated as Outfall 002 (see Figure 1) by NPDES Permit No. MT0026808.[342] Discharge at Outfall 002 mixes with groundwater, which then flows toward the East Boulder River.[343] Actual adit and discharge flow rates are lower than EIS-predicted flows.[344]

Montana recognizes that degrading water quality from its natural condition can be a significant adverse impact even if water quality is better than standards.[345] The East Boulder NPDES permit includes nondegradation limits on the concentration of several solutes in the effluent to ensure that surface water concentrations will not be degraded beyond an established level of nonsignificance. However, these limits apparently apply only to increases stemming from controlled discharges. Degradation of groundwater from the East Boulder Mine appears to stem primarily from waste rock used to construct the tailings facility, which is not governed by the NPDES permit. Thus, although the regulatory level of nonsignificance for nitrate in groundwater at the compliance boundary is 1.5 mg/l,[346] it is not treated as a numeric limit for compliance purposes. Although both the NPDES permit and the Operating Permit[347] require groundwater monitoring, neither includes concentration limits for groundwater, and general water quality standards are used for compliance (10 mg/l for nitrate).[348]

Mine operations resulted in exceedances of the nitrate groundwater standard, and a 2010 Administrative Order on Consent[349] led to the addition of in-situ treatment wells and groundwater interception wells in 2011. An underdrain for the embankment was added in 2014 for subsequent stages of tailings impoundment construction.[350] In 2022, the underdrain captured approximately 28,081 pounds of nitrogen, equating to a load of about 79 pounds per day,[351] or more than twice the NPDES-permitted daily load of 32 lb/day.[352] (Because this nitrogen is not from the intentional discharge at Outfall 002, it is not applied to the permit limit.) However, the underdrain exists only in the new portions of the embankment and does not remove nitrogen from the preexisting embankment.

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[341] U.S. EPA, n.d. NPDES Monitoring Data Download, Facility ID: MT0026808. Downloaded from https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download on February 17, 2025. *East Boulder.NPDES Spreadsheet.xlsx* Hereinafter, "NPDES Spreadsheet."
[342] NPDES Permit Fact Sheet. *East Boulder.NPDES Fact Sheet.MDEQ 2023.pdf [5-6]* The permit also allows direct discharge to the river, but this option has never been used. Land application was used briefly but discontinued. The operation is also permitted to use underground injection at Boe Ranch, about four miles away; impacts at that site are beyond the scope of this review.
[343] NPDES Permit Fact Sheet. *East Boulder.NPDES Fact Sheet.MDEQ 2023.pdf [16]*
[344] 2023 CORP. *EastBoulder.CORP.SMC 2023.pdf [51]*
[345] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [47]*
[346] NPDES Permit Fact Sheet. *East Boulder.NPDES Fact Sheet.MDEQ 2023.pdf [65]*
[347] Mont. Dept. of State Lands, 1993. Operating Permit No. 00149. *East Boulder.OperatingPermit.MDSL 1993.pdf [5]*
[348] MDEQ, 2010. Administrative Order on Consent, Docket No. WQA-10-04. *East Boulder.AOC.MDEQ 2010.pdf [1]*
[349] MDEQ, 2010. Administrative Order on Consent, Docket No. WQA-10-04. *East Boulder.AOC.MDEQ 2010.pdf*
[350] SMC, 2016. 2015 Water Resources Monitoring Report. *East Boulder.2015 Annual Report.SMC 2016.pdf [12-14]*
[351] SMC, 2023. 2022 Water Resources Monitoring Report. *East Boulder.2022 Annual Report.SMC 2023.pdf [10].*
[352] MDEQ, 2023. Authorization to discharge under the Montana Pollutant Elimination Discharge System, Permit No. MT0026808. Hereinafter, "2023 NPDES Permit." *East Boulder.2023 NPDES.MDEQ 2023.pdf [5]*

In 2017, the Michigan Department of Environmental Quality (MDEQ) approved a groundwater mixing zone that extends approximately 2,500 feet beyond the toe of the tailings facility and to within approximately 100 feet of the East Boulder River. The effect is that wells that exceed the nitrogen water quality standard are no longer considered out of compliance.[353,354]

3. Geochemistry

Comprehensive ore and waste rock characterization was not conducted prior to permitting; results from the nearby Stillwater Mine were deemed to be representative of mined materials at the East Boulder Mine. Subsequent analyses have proven this to be true. Agency and company analyses found sulfide minerals at less than 1% in ore and substantially lower than that in waste rock. An independent analysis found a sulfur content of 0.06% in tailings and less than 0.16% in waste rock.[355]

4. Mine-Influenced Water Quality

4.1 Adit Water Quality

As discussed in *Section 4.6*, the quality of adit water is substantially worse than expected. Total dissolved solids (TDS) concentrations averaged 660 mg/l from 2018 to 2022, and reached a maximum of 1,230 mg/l in 2021.[356] Sulfate averaged 180 mg/l from 2018 to 2022, with a ten-year maximum of 208 in 2016. Total inorganic nitrogen averaged 57 mg/l from 2018-2022, with a ten-year high of 142 mg/l in 2016.[357] As shown in Figure 2, sulfate and total inorganic nitrogen concentrations have been increasing over time, and (for a point of comparison) all available nitrogen data from 2009 to 2022 exceeded the drinking water standards.

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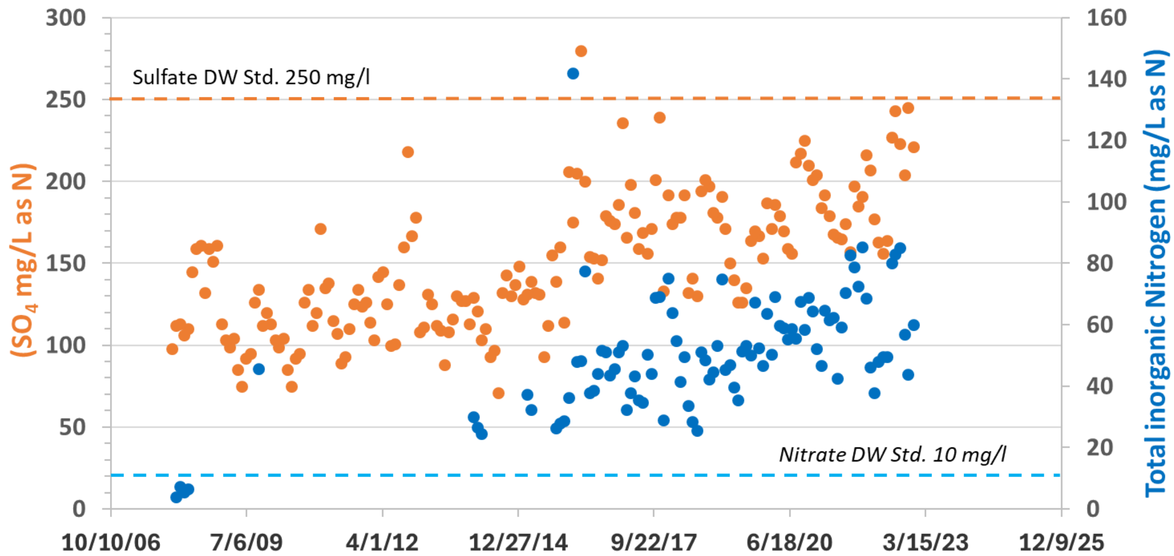
[353] MDEQ, 2017. East Boulder Mine Operating Permit 00149, Revision 17-001. *East Boulder.Mixing zone.MDEQ 2017.pdf*

[354] Hydrometrics, 2017. Application for source specific groundwater mixing zone, Stillwater East Boulder Mine. (Hereinafter, "Mixing zone applicaction.") *East Boulder.Mixing zone application.Hydrometrics 2017.pdf [33]*

[355] 2023 CORP. *EastBoulder.CORP.SMC 2023.pdf [69-70]*

[356] Data from 2017-2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx [Process N, Process SO4, and Process TDS]*

[357] SMC, 2018. 2017 Water Resources Monitoring Report, East Boulder Mine. *East Boulder.2017 Annual Report.SMC 2018.pdf [212]*



East Boulder Figure 2. Nitrate+nitrite and sulfate concentrations in adit water from 2008 to 2022, with drinking water standards for comparison. *Data sources:* Stillwater Mining Company 2008 to 2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*

4.2 Waste Rock Leachate Water Quality

Although there are no waste rock stockpiles at the East Boulder Mine, waste rock is used to construct the tailings facility. The waste rock contains residue from blasting agents and has become a source of nitrogen to downgradient groundwater;[358] it may also contribute to elevated levels of TDS and sulfate. It is unclear what percentage of the increased nitrogen, TDS, and sulfate in groundwater stems from construction rock, versus permitted discharge and/or leachate from the tailings.

4.3 Tailings Water Quality

Interstitial or ponded water in tailings facilities can discharge to groundwater through leaks and defects in the liner.[359] The embankment construction material has been identified as a significant source of pollutants, and it is unclear whether the tailings pond water itself is leaking to groundwater. The quality of tailings pond water is shown in Table 1.

East Boulder Table 1. East Boulder Mine Tailings Facility Water Quality.

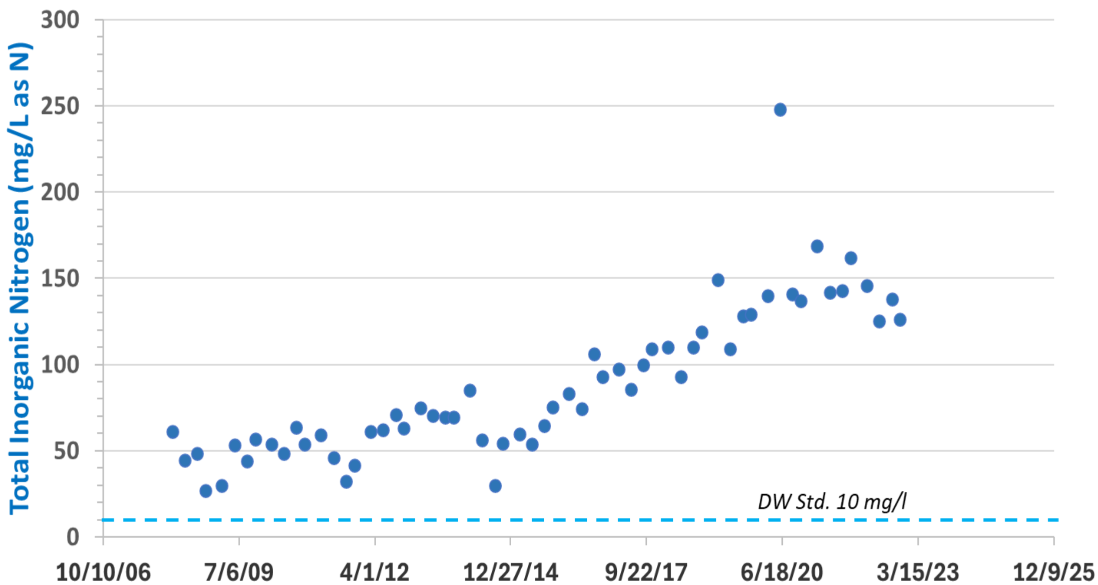
	Drinking water standard	2018-2022 Average	2018-2022 Maximum
TDS (mg/l)	250	1455	1740
Sulfate (mg/l)	250	344	450
Total inorganic nitrogen (mg/l as N)	10	138	248

TDS and nitrogen drinking water standards are from 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [359].* Montana no longer has a TDS standard. MDEQ, 2019. Circular DEQ-7, Montana Numeric Water Quality Standards. *East Boulder.DEQ-7.MDEQ 2019.pdf*
The sulfate standard is a U.S. EPA secondary standard. U.S. EPA, n.d. Drinking Water Regulations and Contaminants (webpage). Accessed May 8, 2024. *https://www.epa.gov/sdwa/drinking-water-regulations-and-contaminants#Secondary*

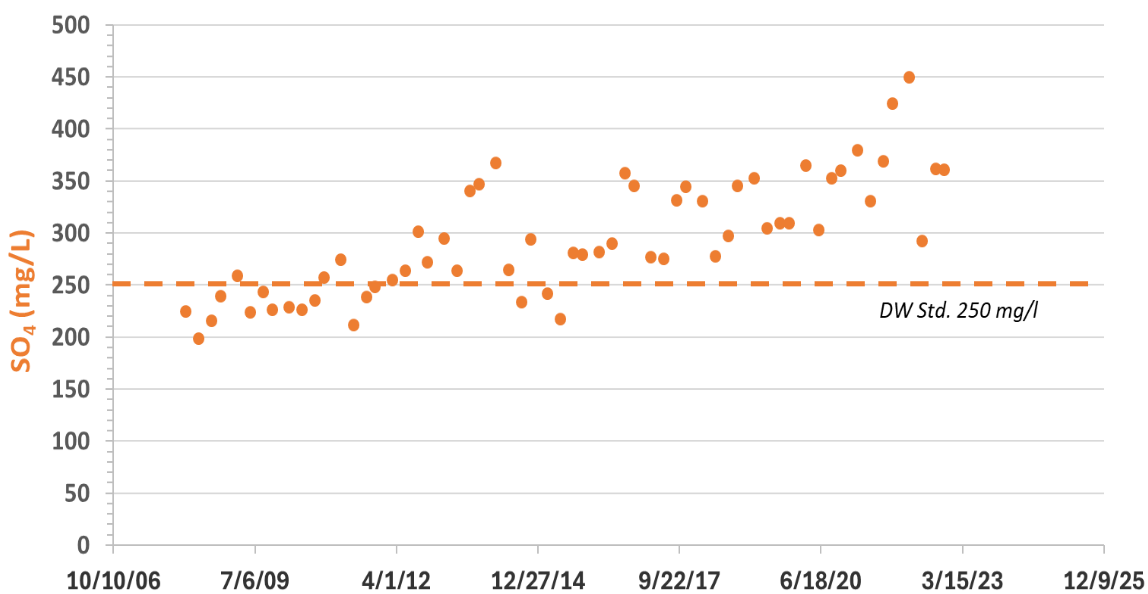
[358] 2023 CORP. *EastBoulder.CORP.SMC 2023.pdf [47]*
[359] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [352]*

Data sources: Stillwater Mining Company, 2018 to 2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*

As shown in Figure 3a and b, nitrate and sulfate concentrations in tailings pond water have been increasing since approximately 2008 for nitrate, and since about 2012 for sulfate. All nitrate values exceeded the drinking water standard (for comparison). Since early 2012 nearly all sulfate concentrations exceeded the drinking water standard (for comparison).



East Boulder Figure 3a. Total inorganic nitrogen concentrations in tailings pond water, 2008 to 2022, with the drinking water standard for comparison. *Data sources:* Stillwater Mining Company 2008 to 2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*



East Boulder Figure 3b. Sulfate concentrations in tailings pond water, 2008 to 2022, with the drinking water standard for comparison. *Data sources:* Stillwater Mining Company 2008 to 2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*

4.4 Effluent Water Quality

Prior to 2023, the NPDES permit placed no limits on the wastewater discharge at Outfall 002 other than for the daily load of nitrogen. A 2020 amendment set limits for cadmium, copper, iron, lead, mercury, nickel, zinc, and nitrogen that were to go into effect on September 1, 2023.[360] When the permit was renewed in August of 2023, some of these limits were loosened and others were dropped completely. Compliance with the copper limit is not required until July 31, 2028.[361] In November 2023, the mine had its first exceedance of the new limit for lead.[362] As shown in Table 2, current outfall quality also exceed the limits that were once set for iron and nickel.

East Boulder Table 2. East Boulder Mine Outfall 002 Metals Concentrations.

	Permit limit (monthly average)	2015-2020 Range	2021-2023 Range
Copper (μ/l)	0.63 [postponed]	2 to 12	< 2 to 4
Iron (μ/l)	[696 -- eliminated]	240 to 3920	40 to 730
Lead (μ/l)	1.1	0.3 to 3.5	<0.3 to 2.5
Nickel (μ/l)	[6.2 -- eliminated]	12 to 60	8 to 28
Zinc (μ/l)	24	< 8 to 36	<8 to 18

.Copper, lead, and zinc limits are from 2023 NPDES Permit. *East Boulder.2023 NPDES.MDEQ 2023.pdf [4].* The copper limit is scheduled to go into effect on July 31, 2028.
Eliminated limits are from MDEQ, 2020. Authorization to discharge under the Montana Pollutant Elimination Discharge System, Permit No. MT0026808. *EastBoulder.2020 NPDES.MDEQ 2020.pdf [6-7]*
2015-2023 values are from NPDES Spreadsheet. *East Boulder.NPDES Spreadsheet.xlsx* Outliers at the high end of the range are excluded.

TDS, sulfate, and manganese concentrations are not monitored in the effluent. Groundwater monitoring well EBMW-4, which is located just downgradient of the Outfall 002 percolation pond and upstream of the tailings impoundment, is the only indication of the concentrations of these pollutants in discharge water. All three, as well as total inorganic nitrogen, are elevated in EMBW-4 (Table 3).

East Boulder Table 3. East Boulder Mine Outfall 002 Discharge After Mixing with Groundwater, 2018-2022.

	Baseline (1991)	EBMW-4 Average	EBMW-4 Maximum
TDS (mg/l)	96	503	602
Sulfate (mg/l)	2	110	172
Total inorganic nitrogen (mg/l as N)	0.1	2.5	9.5
Manganese (mg/l)	0.001	0.093	0.287

Baseline values are from 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [352]*
EBMW-4 averages and maximum values are from 2018-2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*

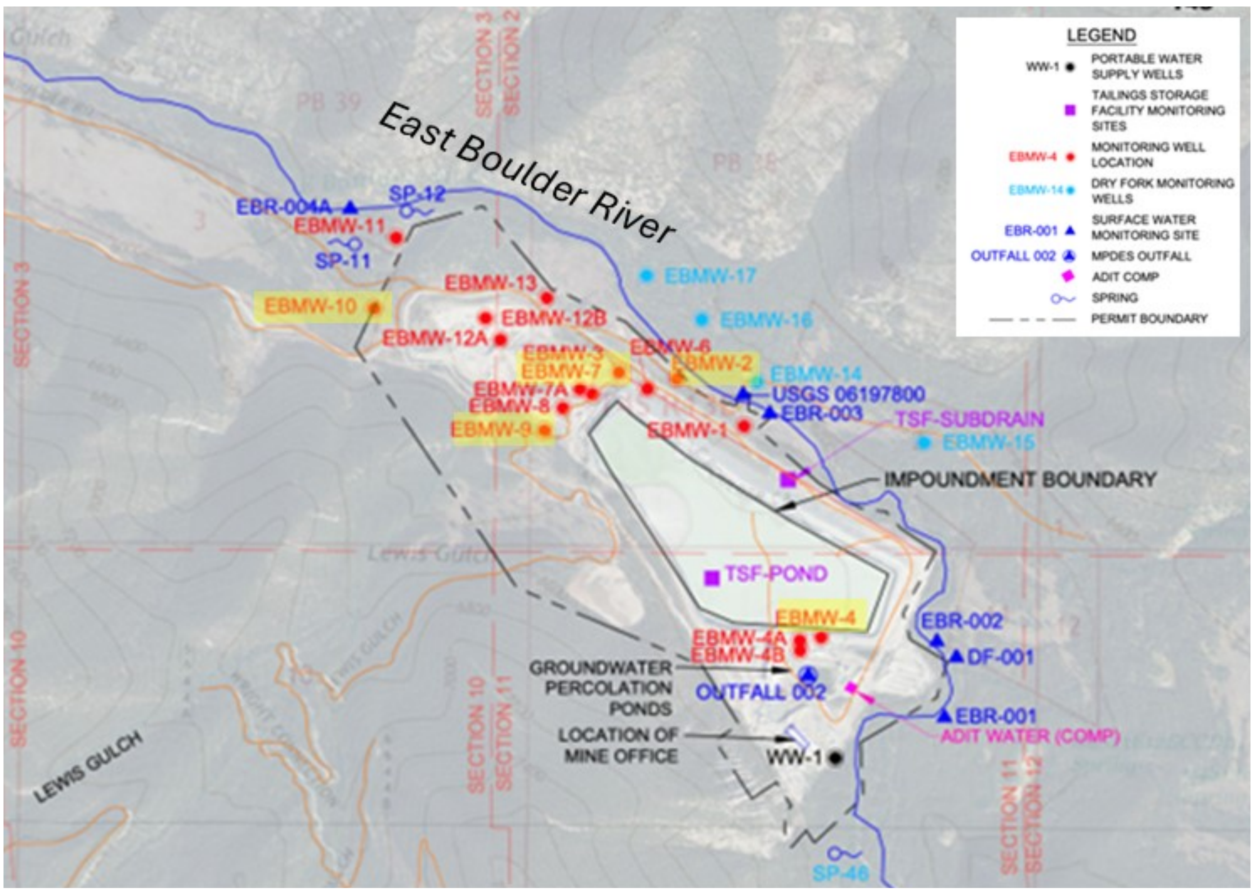
[360] MDEQ, 2020. Authorization to discharge under the Montana Pollutant Elimination Discharge System, Permit No. MT0026808. *EastBoulder.2020 NPDES.MDEQ 2020.pdf [6-7]*
[361] 2023 NPDES Permit. *East Boulder.2023 NPDES.MDEQ 2023.pdf [4]*
[362] U.S. EPA, nd. Enforcement and Compliance History Online, DMR Exceedances Report. Downloaded from *https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedances?permit_id=MT0026808* on May 8, 2024. *East Boulder.Exceedance Report.EPA 2024.xlsx*

5. Impacts on Groundwater and Surface Water Quality

The monitoring and Outfall locations are shown in Figure 4.

5.1 Groundwater Quality

Baseline groundwater quality monitoring of the general mine area was conducted in 1982 and 1989, and a baseline report was prepared in 1989.[363] However, most of the baseline wells are not within the area impacted by the project. Three wells were added in 1989 to assess the area proposed for the tailings facility, but only one data point was available for each well at the time the baseline report was prepared. The EIS provides "ambient groundwater quality" values based on four samples taken in 1991 from one of these wells (WW-1).[364] Table 4 provides data from an unimpacted well just upgradient of the tailings facility flow path as an alternative to baseline values. The data correlates well with the values for ambient groundwater provided in the EIS (shown as "Baseline" in Table 3).



East Boulder Figure 4. East Boulder Mine monitoring and outfall locations. Wells EBMW-2, -4, -7, -9 and -10 are highlighted in yellow. Surface water monitoring and Outfall locations are shown in dark blue. The tailings facility pond monitoring location is shown in purple. *Source:* Modified from SMC, 2023. 2022 Water Resources Monitoring Report. *East Boulder.2022 Annual Report.SMC 2023.pdf [8]*

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[363] Hydrometrics, 1990. Water Resources Baseline Report, Stillwater PGM Resources, East Boulder Project. *East Boulder.Baseline.Hydrometrics 1990.pdf [50 and Appendices D and E]*

[364] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [352]*

Groundwater in the percolation pond and tailings facility area is monitored by a fairly extensive network of wells. Wells in Table 4 were chosen as representative of important features at the site. The results in Table 4 demonstrate that groundwater has been adversely affected by mining activity.

East Boulder Table 4. East Boulder Mine Groundwater Quality Impacts, 2018-2022.

	EBMW-9 (Unimpacted) Ave./Max.	**EBMW-4 (Below Outfall 002) Ave./Max.**	**EBMW-7 (Below tailings) Ave./Max.**	**EBMW-2 (Below tailings) Ave./Max.**	**EBMW-10 (Compliance) Ave./Max.**
TDS (mg/l)	93.3/107	503/602	414.2/551	525.6/1410	233/322
Sulfate (mg/l)	1.6/2	109.8/172	58.9/67	46/78	27.5/42
Total inorganic nitrogen (mg/l as N)	0.1/0.14	3.1/9.5	13.5/24.2	20.8/108	2.85/4.03

Data sources: 2018-2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025xlsx*

Sulfate and total inorganic nitrogen concentrations in wells EBMW-9 (unimpacted), EBMW-4 (downgradient of Outfall 002), and EBMW-2 (just upgradient of the compliance location) over time are shown in Figures 5a and b. Unlike the unimpacted well, EBMW-9, concentrations of sulfate and total inorganic nitrogen have been increasing in EBMW-4 and EBMW-9 over time.

According to the NPDES permit fact sheet, a "nonsignificance" level of 1.5 mg/l applies to total inorganic nitrogen in groundwater.[365] This is approximately ten times the baseline level, as represented by EBMW-9, and is routinely exceeded, as shown in Figure 5a. MDEQ uses the water quality standard of 10 mg/l as N as the limit for compliance purposes.[366] There are no limits for TDS or sulfate. Many results for total inorganic nitrogen exceed the nonsignificance level in EBMW-4 and EBMW-2, and approximately half the results for EBMW-2 also exceed the drinking water standard (Figure 5a).

EBMW-2 is just upgradient of the compliance boundary, between the tailings facility and the river.[367] Given the high levels of nitrogen in water at EBMW-2, as shown in Figure 5a, groundwater almost certainly exceeds the water quality standard beyond the compliance boundary. However, there is no compliance well in this location.

Despite the nitrogen removal efforts discussed in *Section 4.2*, monitoring does not show a significant improvement in groundwater quality.[368] EBMW-2 recorded its highest and third-highest concentrations of nitrogen in the winters of 2020-21 and 2020-22. Recent data from EBMW-7 are higher than pre-2011 data; the highest levels are from the 2011-2015 period.

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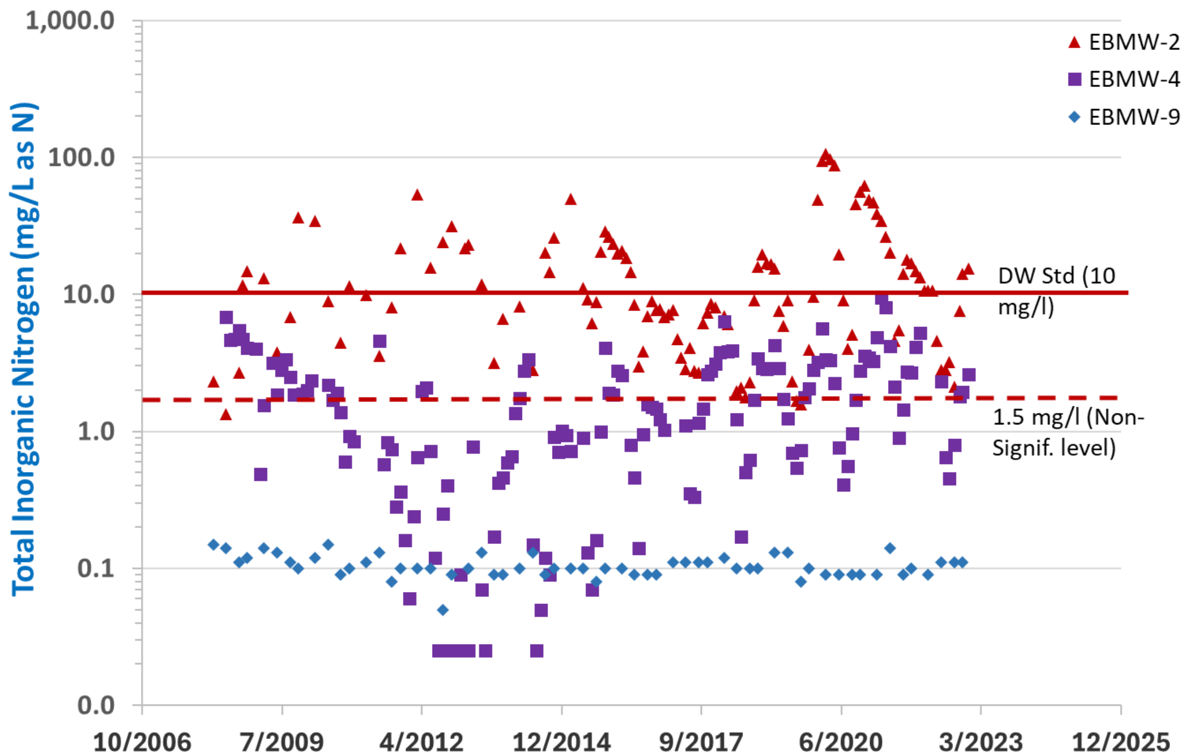
[365] NPDES Permit Fact Sheet. *East Boulder.NPDES Fact Sheet.MDEQ 2023.pdf [65]*

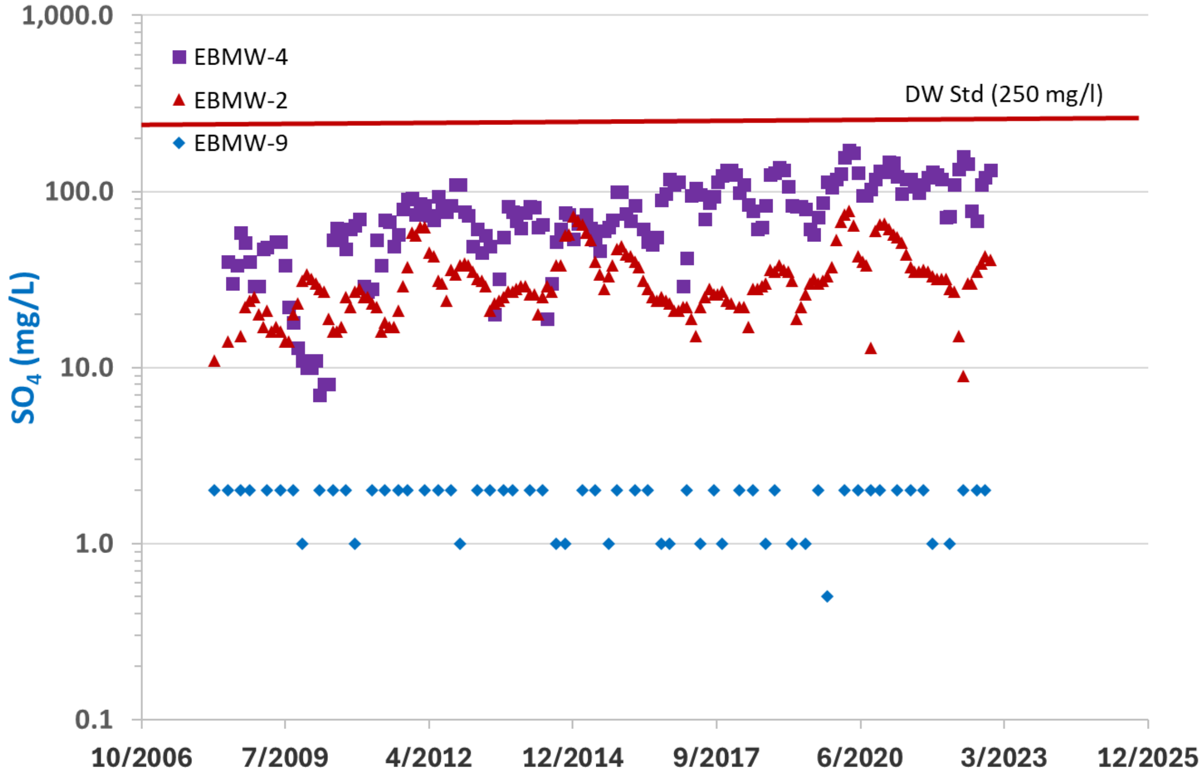
[366] SMC, 2023. 2022 Water Resources Monitoring Report. *East Boulder.2022 Annual Report.SMC 2023.pdf [26]*

[367] Mixing zone applicaction. *East Boulder.Mixing zone application.Hydrometrics 2017.pdf [33]*

[368] SMC, 2023. 2022 Water Resources Monitoring Report, East Boulder Mine. *East Boulder.2022 Annual Report.SMC 2023.pdf [95, 99, 102]*; SMC, 2018. 2017 Water Resources Monitoring Report, East Boulder Mine. *East Boulder.2017 Annual Report.SMC 2018.pdf [53, 57, 60]*; and SMC, 2014. 2013 Water Resources Monitoring Report, East Boulder Mine. *East Boulder.2013 Annual Report.SMC 2014.pdf [258, 264, 267]*



East Boulder Figure 5a. Total inorganic nitrogen concentrations in three groundwater monitoring locations from 2008 to 2022: EBMW-9 (unimpacted), EBMW-4 (downgradient of percolation ponds, above tailings impoundment, and EBMW-2 (just upgradient of compliance location and 250 ft upgradient of the East Boulder River). The data are plotted on a log scale to be able to see the low concentrations in EBMW-9. The non-significance level and the drinking water standard are included for comparison. *Data sources:* Stillwater Mining Company 2008 to 2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*



East Boulder Figure 5b. Sulfate concentrations in three groundwater monitoring locations from 2008 to 2022: EBMW-9 (unimpacted), EBMW-4 (downgradient of percolation ponds, above tailings impoundment, and EBMW-2 (just upgradient of compliance location and 250 ft upgradient of the East Boulder River). The data are plotted on a log scale to be able to see the low concentrations in EBMW-9. The drinking water standard is included for comparison. *Data sources:* Stillwater Mining Company 2008 to 2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*

5.2 Surface Water Quality

The 1992 EIS appears to have averaged all baseline data from all surface water monitoring locations to arrive at one "baseline" average to apply to the entire site,[369] and thus it is not useful to determine impacts at specific locations. However, baseline data for specific locations are available in a 1990 baseline report.[370] The locations of interest to this report are the former EBR 4 and 4.2 (now EBR-1), EBR 5.2 (now EBR-3) and EBR 6.2 (now EBR-4 and EBR-4A)[371] (see Figure 4). Baseline data used in this report are from 1988-1989.

The East Boulder Mine monitoring is conducted at six stations in the East Boulder River and at two springs between the groundwater compliance boundary and the river (see Figure 4). The river stations include EBR-1 and EBR-2, which are upstream of impacts; EBR-3, at a midway point along the

[369] 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [203-04]*

[370] Hydrometrics, 1990. Water Resources Baseline Report, Stillwater PGM Resources, East Boulder Project. *East Boulder.Baseline.Hydrometrics 1990.pdf [128-131]*

[371] EBR-4 is just upstream of EBR-4A, and monitoring data are very similar. Results from EBR-4A were used for this report because they are more comprehensive.

tailings facility; EBR-4 and EBR-4A, about 3,000 feet downgradient of the toe of the tailings facility, EBR-5, about three miles downstream, and EBR-8,[372] about 5 miles farther downstream. Springs 11 and 12 are in the vicinity of EBR-4 and EBR-4A.[373]

No surface water monitoring is done in the vicinity of the groundwater monitoring well EBMW-2, which is approximately 100 feet from the river and has high concentrations of TDS and total inorganic nitrogen, as discussed in *Section 4.5.1*; the next surface water monitoring point (EBR-4/4A) is nearly one mile downstream. The NPDES permit establishes a two-mile mixing zone beginning at EBR-4: "The maximum extent of the surface water mixing zone is as follows: ground water infiltration from immediately upstream of EBR-004A to immediately downstream of EBR-005 for a distance of 10,420 feet and the entire stream width of 10 feet, for the following parameters: total recoverable cadmium, copper, lead, mercury, nickel, and zinc; and total nitrogen."[374]

The East Boulder River at the mine site was pristine in 1989, when baseline data were collected. At the site currently designated as EBR-1, TDS concentrations averaged 25 mg/l, sulfate concentrations averaged 2.4 mg/l, and nitrate + nitrite concentrations averaged 0.05 mg/l as N. Nitrogen and sulfate concentrations increased downstream at EBR-3, but decreased again at EBR-4. (EBR-3 is located at a road crossing.) Nitrogen concentrations were slightly lower at EBR-4 than at EBR-1. TDS values rose progressively moving downstream, with an average of 62 mg/l at EBR-4.[375]

Concentrations of all three pollutants are higher now at all stations, including EBR-1.[376] Although EBR-1 is presumed to be upstream of the influence of mine facilities, this location may be affected by clearings and activities that support access to the underground workings, which are upstream in the watershed.[377] From a slight reduction from EBR-1 to EBR-4 at baseline, nitrogen concentrations at EBR-4 now are 50 to 60% higher than at EBR-1. Sulfate concentrations have remained the same at EBR-1 and have increased slightly at EBR-4, where they average about 4.2 mg/l with a maximum measurement of 9 mg/l. TDS values have increased 80% from an average of 25 mg/l to an average of 45 mg/l at EBR-1 and by 40% at EBR-4, where it has risen from an average of 62 mg/l to an average of 87 mg/l. Levels of all three pollutants remain below water quality standards.

The monitored springs are reflective of pollutant levels in groundwater. The Spring 11 maximum sulfate level is consistently above 10 mg/l, and recent averages have also been above that mark. Nitrogen levels average 0.27 mg/l, with a maximum value in 2022 of 1.31 mg/l. TDS concentrations averaged 167 mg/l, with a maximum value in 2022 of 205.[378]

Pollutant levels are higher at the downstream location EBR-5.[379] It is unclear to what extent elevated constituents are due to the mine versus other sources.

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[372] SMC, 2023. 2022 Water Resources Monitoring Report, East Boulder Mine. *East Boulder.2022 Annual Report.SMC 2023.pdf [8, 34]*
[373] 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [177]*
[374] 2023 NPDES Permit. *East Boulder.2023 NPDES.MDEQ 2023.pdf [3]*
[375] Hydrometrics, 1990. Water Resources Baseline Report, Stillwater PGM Resources, East Boulder Project. *East Boulder.Baseline.Hydrometrics 1990.pdf [128-131]*
[376] Data from Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*.
[377] See 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [171]* and 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [78-79].*
[378] Data from Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*.
[379] 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [47]*

6. Accuracy of Water Quality Predictions

EIS predictions of the quality of effluent from the East Boulder treatment facility have proven inaccurate. Table 5 compares measured metal concentrations in the percolation ponds that hold treated water to EIS predictions. The predictions were for effluent without treatment; metal concentrations in the treated effluent have been significantly higher than the predicted concentrations for untreated water. Table 6 presents predicted vs. actual TDS, sulfate, total inorganic nitrogen, and manganese concentrations in well EBMW-4, which represents effluent after mixing with groundwater. These predictions also underestimated groundwater impacts.

East Boulder Table 5. East Boulder Mine Predicted Untreated Metal Concentrations Versus Actual Metals Concentrations in Treated Effluent.

	EIS prediction	2015-2020 Range	2021-2023 Range
Copper (μ/l)	0.6	2 to 12	< 2 to 4
Iron (μ/l)	30	240 to 3920	40 to 730
Lead (μ/l)	0.4	0.3 to 3.5	<0.3 to 2.5
Nickel (μ/l)	5	12 to 60	8 to 28
Zinc (μ/l)	10	< 8 to 36	<8 to 18

EIS predictions are from 1992 FEIS Table 4.2-1, column "Estimated concentration in percolation ponds." *EastBoulder.FEIS.USFS 1992.pdf [355]*
2015-2023 values are from NPDES Spreadsheet. *East Boulder.NPDES Spreadsheet.xlsx* Outliers at the high end of the range are excluded.

East Boulder Table 6. East Boulder Mine Predicted vs. Actual Effluent Water Quality after Mixing with Groundwater (2018-2022).

	EIS Prediction	EBMW-4 Average	EBMW-4 Maximum
TDS (mg/l)	167	503	602
Sulfate (mg/l)	--	110	172
Total inorganic nitrogen (mg/l as N)	7.3	2.5	9.5
Manganese (mg/l)	<0.02	0.093	0.287

Predictions are from 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [98]*
EBMW-4 averages and maximum values are from 2018-2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*

Predictions of the quality of adit water prior to treatment systematically underestimated actual concentrations of TDS, sulfate, and nitrogen. The TDS concentration in adit water was predicted to be 338 mg/l;[380] from 2018 to 2022 it averaged 660 mg/l, and reached a maximum of 1,230 mg/l in 2021.[381] The sulfate concentration was predicted to be 108 mg/l; from 2018 to 2022 it averaged 180 mg/l, with a 10-year maximum of 208 in 2016.[382] The total inorganic nitrogen concentration was predicted to be 9.5 mg/l as N in the EIS; the mining company lowered that prediction to 6.17 mg/l as N in its 1999 Water

[380] Predictions are from 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [98]*
[381] Monitoring data from 2017-2022 Annual Reports. See *East Boulder.Monitoring Data Spreadsheet.Feb2025.xlsx*.
[382] SMC, 2018. 2017 Water Resources Monitoring Report, East Boulder Mine. *East Boulder.2017 Annual Report.SMC 2018.pdf [212]*

Management Plan.[383] The actual nitrogen concentration averaged 57 mg/l from 2018-2022, with a ten-year high of 142 mg/l in 2016.[384]

The EIS did not provide quantitative predictions of the quality of tailings facility water but stated that it was expected to be similar to the Stillwater Mine, which "is generally within drinking water standards with the exception of sulfate, nitrate, and TDS."[385] This prediction was accurate.

The EIS predicted that with no wastewater treatment, levels of TDS in the East Boulder River would increase from a baseline of 100 mg/l to 102 mg/l[386], an increase of 2%. The TDS baseline concentration at EBR-4 averaged 62 mg/l,[387] and has increased to an average of 87 mg/l, an increase of 40%. Regarding nitrogen, the EIS predicted an increase from a baseline of 0.1 to 0.3 mg/l for a project with no treatment,[388] and an increase of "less than 0.05 mg/l" for a project with optimum treatment.[389] The average increase (with wastewater treatment) has been about 0.05 mg/l as N. Maximum levels (which occur at low flow) have increased by about 0.11 mg/l as N. The EIS did not provide predictions for sulfate.

7. Summary of Water Quality Impacts

Surface water quality impacts:

- In the East Boulder River three thousand feet downstream of mine facilities, nitrogen is 50 to 60% higher than upstream of the mine. TDS has increased from a baseline of 62 mg/l to 87 mg/l; sulfate values have increased from 2.4 to 4.2 mg/l.

Groundwater quality impacts:

- Groundwater quality at a compliance well a mile downgradient of mine facilities has a TDS concentration of 233 mg/l compared to 93 mg/l at unimpacted wells; sulfate is 27.5 mg/l compared to 1.6 mg/l at unimpacted wells, and nitrate is 2.85 mg/l compared to 0.1 mg/l at unimpacted wells.
- Groundwater exceeds the drinking water standards for nitrate and TDS. In 2010, however, a compliance boundary was added to the permit; wells that exceeded groundwater standards were included within the boundary so that the exceedances would no longer be considered permit violations. One well that is just inside the boundary has an average nitrate level of 20 mg/l as N, twice the drinking water standard. Groundwater almost certainly exceeds the standard beyond the compliance boundary here, but there is no monitoring beyond the boundary at this location.

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383 SMC, 1999. Water Management Plan, East Boulder Project. *East Boulder.Water Management Plan.SMC 1999.pdf [9]*
384 SMC, 2018. 2017 Water Resources Monitoring Report, East Boulder Mine. *East Boulder.2017 Annual Report.SMC 2018.pdf [212]*
385 1992 FEIS *EastBoulder.FEIS.USFS 1992.pdf [375]*
386 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [355]*
387 Hydrometrics, 1990. Water Resources Baseline Report, Stillwater PGM Resources, East Boulder Project. *East Boulder.Baseline.Hydrometrics 1990.pdf [128-130]*
388 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [355]*
389 1992 FEIS. *EastBoulder.FEIS.USFS 1992.pdf [145]*

NPDES permit issues:

- The East Boulder NPDES permit had no permit limits other than a nitrogen daily load limit (in total pounds rather than as a concentration) until September 2023. Its first exceedance of a permit limit (for lead) was in November 2023.

Accuracy of water quality and water quantity predictions:

- In mine water, the TDS concentration was predicted to be 338 mg/l; instead it averaged 660 mg/l, with a maximum of 1230 mg/l. The nitrogen concentration was predicted to be 9.5 mg/l; the actual average was 57 mg/l with a maximum of 142 mg/l.
- Groundwater at the discharge location was predicted to have a TDS concentration of 167 mg/l; the actual average has been 503 mg/l. The manganese prediction was less than 20 µg/l; the average has been 93 µg/l.
- East Boulder appears to have no rock at the site with the potential to generate acid. However, the mine has impacted water quality due to non-acidic leachate from mine waste.

Effectiveness of water treatment:

- Copper, iron, and nickel concentrations in treatment plant effluent are an order of magnitude higher than predicted.

8. Comparison to Potential Mines in the Rainy River Headwaters Watershed of Minnesota

In comparison to potential mines in the Rainy River Headwaters, the East Boulder Mine is smaller and has less potential for acid drainage or neutral metals leaching from waste rock. Greater depth to groundwater over much of the site makes groundwater impacts and subsequent releases to surface waters less likely. On the other hand, high conductivity of the thick glacial and alluvial deposits may result in more rapid transit of groundwater pollution to surface waters.

9. Post-permitting and Potential Future Expansions

As noted in *Section 4.2*, a compliance boundary was established fifteen years after production began, after the facility was unable to meet nitrogen limits. That change was followed by approval of a tailings facility expansion in 2020, which is now under construction.[390] The tailings facility as reviewed in the 1992 EIS was sized for 7.2 million tons of tailings with a height of 140 feet.[391] It is now approved for 11.1 million tons, with a height of 154 feet.[392]

The current proposed expansion would add a second tailings facility and a waste rock stockpile to the operation, both of which would be located close to the East Boulder River.[393] It would add another 167 to 180 acres of disturbed area and would nearly double the total size of the permit site.[394] The

[390] 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [63]*
[391] 1992 FEIS [90]
[392] 2023 CORP. *EastBoulder.CORP.SMC 2023.pdf [25]*
[393] 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [85]*
[394] 2023 DEIS. *EastBoulder.2023 DEIS.USDA 2023.pdf [25]*

Forest Service has indicated it intends to approve the expansion,[395] which is on hold due to low metal prices.[396]

[395] U.S. Forest Service, 2023. Draft Record of Decision, East Boulder Mine Amendment 004. *East Boulder.2023 ROD.USFS 2023.pdf [15]*
[396] Hanson, Amy Beth, 2023. Montana miner backs off expansion plans, lays off 100 due to lower palladium prices. The Hill, November 30, 2023. *https://thehill.com/homenews/ap/ap-business/ap-montana-miner-backs-off-expansion-plans-lays-off-100-due-to-lower-palladium-prices/*

Flambeau Mine, Wisconsin

1. Site and Mine Description and Background Information

The Flambeau Mine was a small, open-pit copper mine located on private land in northern Wisconsin. It is owned and was operated by Flambeau Mining Company, a subsidiary of Kennecott.

The 32-acre, 225-foot-deep pit was located on the edge of the Flambeau River. Production as planned averaged about 1,300 tons of ore per day, with a 1.9-million-ton total over the life of the mine.[397] The ore was shipped to Canada for processing; there is no tailings facility associated with the mine.

A state Environmental Impact Statement (EIS) was prepared for the Flambeau operations in 1990. Mining began in 1993 and was completed in 1997. Reclamation of the mine pit was completed in 2007. Reclamation of the entire site was certified as complete in 2022.[398] A Wisconsin Department of Natural Resources (WDNR) mine permit regulates impacts to groundwater at the site.[399] Mine water was treated and discharged to the Flambeau River during operations pursuant to NPDES permit WI0047376,[400] which is no longer active.

The climate in northern Wisconsin is similar to that in Minnesota, with 31 inches of precipitation per year and precipitation exceeding evapotranspiration.[401] The 181-acre site includes about 20 acres of wetlands;[402] depth to groundwater prior to mining averaged less than 20 feet.[403]

The Flambeau River, which is only 140 feet from the mine pit, acts as a drain for surface water and groundwater. The average flow of the Flambeau River is 1,855 cfs, with a seven-day, ten-year low flow of 435 cfs.[404] Tributary Stream C is a small intermittent stream that flows through a portion of the site; its flow has been measured at 6 cfs.[405]

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[397] Wisconsin Dept. of Natural Resources, 1990. Final Environmental Impact Statement: Flambeau Mining Co. Copper Mine, Ladysmith, Wisconsin. Hereinafter, "FEIS." *Flambeau.FEIS.WDNR 1990.pdf*
[398] Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [4]*
[399] Wisconsin Div. of Hearings and Appeals 1991. Application of Flambeau Mining Company for Permits to Build and Operate a Surface Mine in Rusk County, Wisconsin, Decision, Findings of Fact, Conclusions of Law, and Permits. Hereinafter, "Mine Permit." *Flambeau.Mine Permit.WDHA 1991.pdf [89-126]*
[400] Wisconsin Dept. of Natural Resources, 1992. Permit to Discharge Under the Wisconsin Pollutant Discharge Elimination System WI-0047376-1. *Flambeau.NPDES permit.WDNR 1991.pdf*
[401] Foth & Van Dyke, 1989a. Environmental Impact Report Vol. II. Hereinafter, "EIR Vol. II." *Flambeau.EIR Vol II.Foth 1989.pdf [13]*
[402] FEIS. *Flambeau.FEIS.WDNR 1990.pdf [5]*
[403] FEIS. *Flambeau.FEIS.WDNR 1990.pdf [85]*
[404] FEIS *Flambeau.FEIS.WDNR 1990.pdf [97]*
[405] Foth & Van Dyke, 1989b. Environmental Impact Report Vol. 6, Appendix 3.7-A to 4.3-A. *Flambeau.Stream navigability.Foth 1989b.pdf [3]*

2. Mine Facilities, Operations, and Reclamation

Flambeau Mine facilities consisted of an open pit mine, temporary waste rock stockpiles, an ore crusher, rail transport facilities, ponds, a wastewater treatment plant, and ancillary facilities (Figure 1). Waste rock was backfilled into the open pit. There are no remaining above-ground waste rock stockpiles and no tailings facility at the reclaimed site.

During operations, waste rock was stored on the surface in two stockpiles (designated as Type I for low sulfur and Type II for high sulfur) (see Figure 1). The high sulfur stockpile was lined, although the degree of leakage to groundwater through the liner is unknown. Other liners at the mine that could be checked visually were prone to tears and punctures.[406] The low sulfur stockpile was unlined and intentionally drained to groundwater. The mine plan relied on soil materials stockpiled below the waste rock to absorb metals before leachate reached the water table.[407] No monitoring was done of groundwater downgradient of the stockpile, and it is unclear how successful the soil layer was in minimizing transport of stockpile leach to downgradient locations.

The mine pit was dewatered at an average rate of 167 gallons per minute (gpm); the maximum annual average was 186 gpm.[408] This compares to a predicted average of 125 gpm and maximum annual average of 175 gpm.[409] A treatment plant treated mine water and runoff from the stockpiles using lime neutralization, sulfide precipitation, and filtration technologies.[410] Treated water was discharged to the Flambeau River at the average rate of 0.466 million gallons per day.[411] The predicted discharge rate was 0.327 million gallons per day.[412]

When mining ended, the pit was backfilled with waste rock, with high sulfur rock at the bottom and low sulfur rock layered above it. Limestone was added to the waste rock to reduce the potential for acid generation.[413] Groundwater now flows through the backfilled pit and discharges at a low volume to the Flambeau River.

An area now referred to as the "Industrial Outlot" held the ore crusher, rail transport facilities, ponds, wastewater treatment plant, and part of the high-sulfur waste rock stockpile. Although these facilities no longer exist, the area remains contaminated and continues to be a source of pollution to surface water, as discussed in *Section 5.2*. A series of passive treatment systems and infiltration

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[406] E.g., Flambeau Mining Co., 1995. 1994 Annual Report. *Flambeau.Annual Reports.1994.pdf [242]*

[407] Foth & Van Dyke, 1989h. Prediction of Chromium, copper and iron concentration in Vadose Zone Water reaching the Water Table Beneath the Unlined Type I Stockpile for the Kennecott Flambeau Project. Flambeau.Mine permit application appendices.Foth 1989h [117]

[408] Flambeau Mining Company, 1998. 1997 Annual Report. *Flambeau.Annual Reports.1997.pdf [49]*

[409] FEIS. *Flambeau.FEIS.WDNR 1990.pdf [130]*

[410] FEIS. *Flambeau.FEIS.WDNR 1990.pdf [46]*

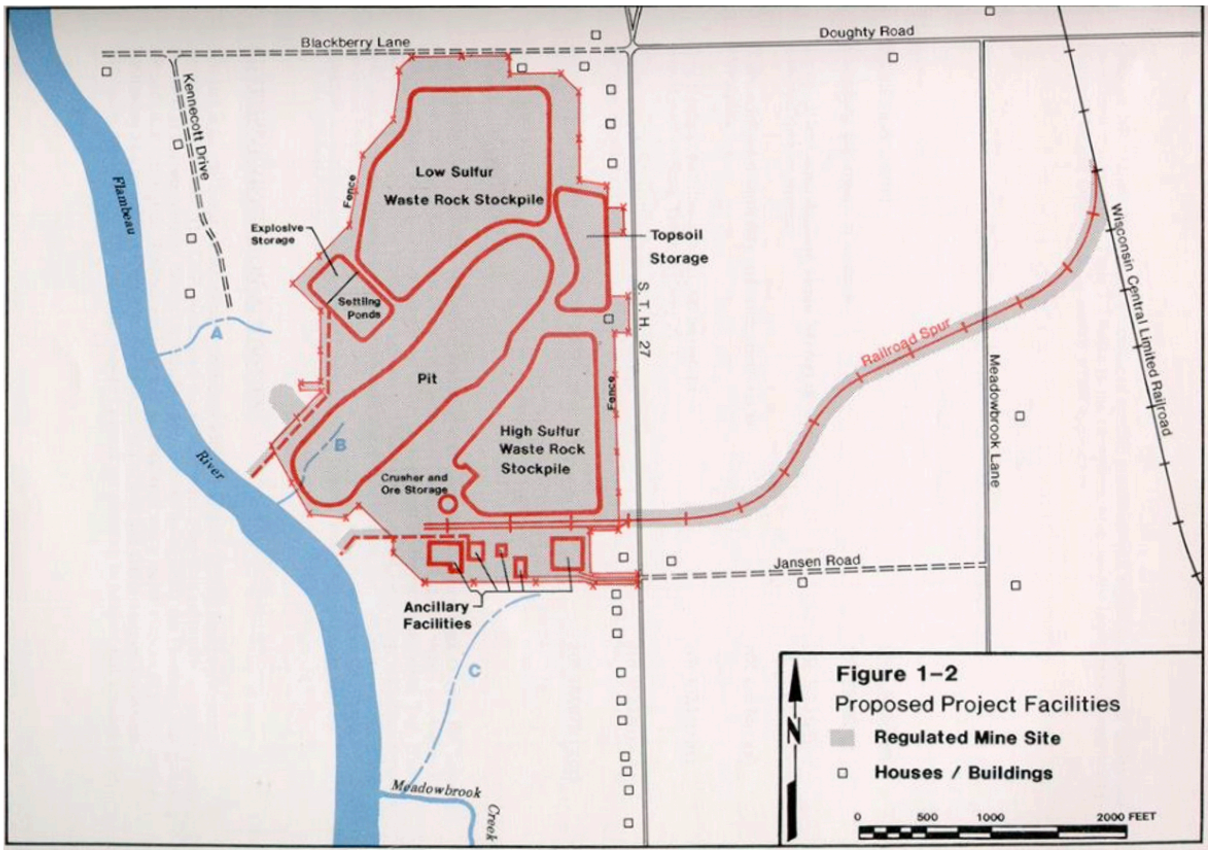
[411] Flambeau Mining Co., 1993-1998. Discharge Monitoring Reports. *Flambeau/DMRs (folder).* See *Flambeau.Flambeau Data spreadsheet.Feb2025.xls*

[412] FEIS. *Flambeau.FEIS.WDNR 1990.pdf [47]*

[413] Flambeau Mining Company, 1998. 1997 Annual Report. *Flambeau.Annual Reports.2023.pdf [14]*

impoundments have been used to reduce pollutant levels in runoff and seepage from this area,[414,415,416] with limited success.[417]

Runoff from other areas of the reclaimed site is directed to a biofilter before it discharges to the river.[418] Two large precipitation events occurred in 1998 that resulted in direct runoff to the Flambeau River, bypassing the biofilter despite activation of contingency plans.[419] The biofilter was sized for a 100-year storm event.



Flambeau Figure 1. Flambeau Mine facilities. *Source:* FEIS Figure 1-2*. Flambeau.FEIS.WDNR 1990.pdf [24]*

414 Applied Ecological Services, 1997. Supplement to the Surface Reclamation Plan for the Flambeau Mine. *Flambeau.1997 Reclamation Plan.AES 1997.pdf [17]*
415 Foth, 2011. Copper Park Business and Recreation Area Work Plan. *Flambeau.Copper Park Work Plan.Foth 2011.pdf [12]*
416 Foth, 2015. Copper Park Business and Recreation Area Work Plan Supplement. *Flambeau.Copper Park Work Plan Supp.Foth 2015.pdf [12]*
417 WDNR, 2012. Surface Water Quality Assessment of the Flambeau Mine Site. *Flambeau.Stream C Assessment.Roesler 2012.pdf [3]*
418 Applied Ecological Services, 1997. Supplement to the Surface Reclamation Plan for the Flambeau Mine. *Flambeau.1997 Reclamation Plan.AES 1997.pdf [15]*
419 Flambeau Mining Company, 1999. 1998 Annual Report. *Flambeau.Annual Reports.1998.pdf [11]* We found no additional information on the quality or volume of that water, or its effect on the river.

3. Geochemistry

The ore was known to be potentially acid producing at the time of environmental review and permitting. Waste rock was designated as "Type I" with sulfur content less than 1% and "Type II" with sulfur content greater than 1%. The EIS acknowledged that Type II rock could produce acid drainage but concluded that there was no potential for acid production from Type I rock. The EIS also acknowledged that leachate from Type I rock would likely increase the level of several constituents in groundwater under the stockpile but predicted no impacts to surface waters.[420]

4. Mine-Influenced Water Quality

4.1 Mine Pit Water Quality

No data are available regarding the quality of mine inflow water during operations.

Monitoring of the backfilled pit area began in 1998 with the installation of wells MW-1013 and MW-1014.[421] There are no baseline monitoring data for these wells; company reporting uses well MW-1005 as a background well for comparison. Although MW-1005 is upstream of all mine facilities, however, it is close to and downstream of a highway. Baseline data from MW-1005 are approximately three times higher in total dissolved solids (TDS) and specific conductance than other wells at the site (and is two magnitudes higher in chloride),[422] as shown in Table 1, and is not an appropriate background well for those parameters. Copper and manganese in the backfilled pit are highly elevated over background, as are sulfate and TDS. Arsenic levels have risen slowly and have approximately doubled since 2003.[423]

Flambeau Table 1. Flambeau Mine Backfilled Pit Water Quality.

	Maximum background MW-1005	1998-2023 Maximum MW-1013 & MW-1014	2023 Maximum MW-1013 & MW-1014
Arsenic (µg/l)	6	32	32
Copper (µg/l)	18	700	314
Manganese (mg/l)	0.8	40	29
Sulfate (mg/l)	22	2000	1780
TDS (mg/l)	800 (see note)	4000	3090

MW-1005 is located upgradient of all mine facilities.
MW-1013 and MW-1014 are located within the backfilled pit.
Background and 1998-2023 values are estimated from graphs in Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [28 et seq.]*
2023 Maximum values are from Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [56]*
TDS at MW-1005 was below approximately 800 mg/l until 2011; since then the maximum has been approximately 1800 mg/l. MW-1005 appears to be impacted by an adjacent highway; baseline TDS levels were approximately three times higher than all other wells at the site. Forth & Van Dyke, 1989f. Environmental Impact Report, Vol. 5, App. 3.6H, Groundwater Quality Data. *Flambeau.GW baseline.Foth 1989f [37].*

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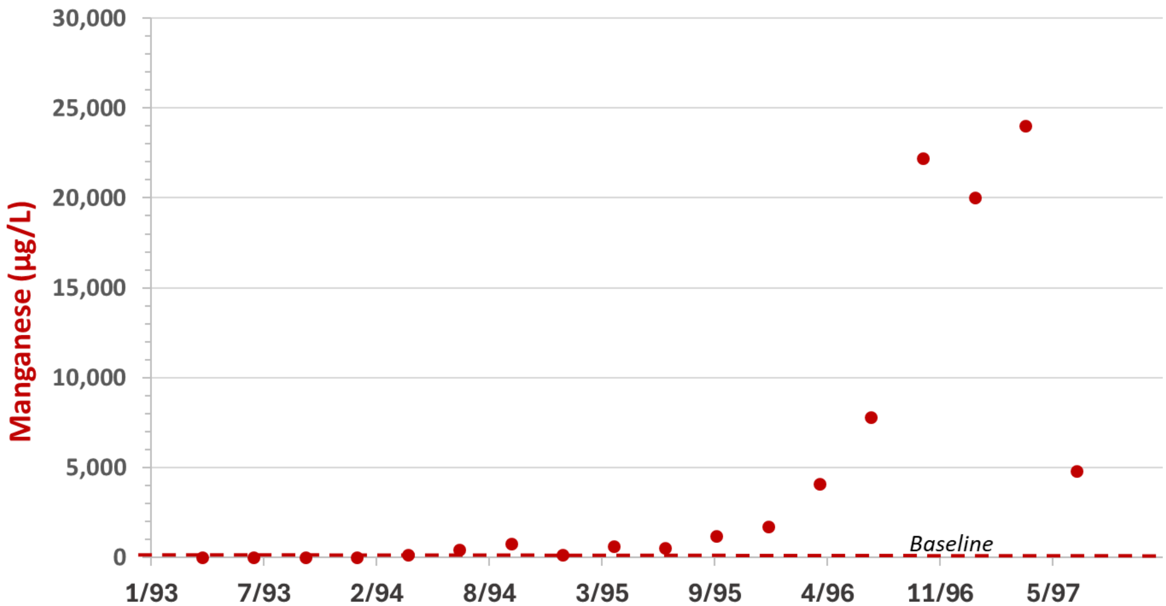
420 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [81, 131]*
421 Flambeau Mining Co., 1999. 1998 Annual Report. *Flambeau.Annual Reports.1998.pdf [15]*
422 Forth & Van Dyke, 1989f. Environmental Impact Report, Vol. 5, App. 3.6H, Groundwater Quality Data. *Flambeau.GW baseline.Foth 1989f [12, 32, 37]*
423 Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [52]*

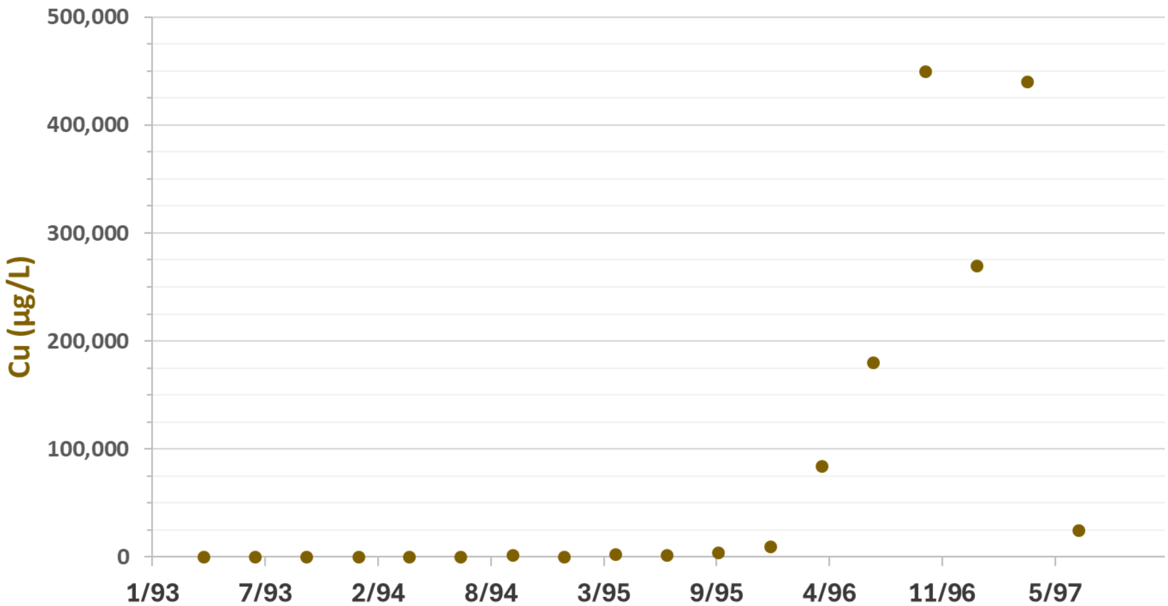
4.2 Waste Rock Leachate Water Quality

Leachate from the Type II Stockpile (high sulfur stockpile) was very high in manganese (up to 24,000 mg/l) and copper (up to 450 mg/l), with a pH dropping to 3.1; sulfate ranged up to 1400 mg/l (Figures 2a – 2d).[424] A seep at the Type I Stockpile (low sulfur stockpile) contained copper at up to 53.2 mg/l, had a minimum pH measurement of 5.2, and had a maximum conductivity measurement of 1402 µS/cm.[425] A lysimeter installed below the Type I Stockpile measured rising manganese levels that reached 1500 µg/l in 1997 (Figure 3).[426] These results demonstrate that even materials designated as "non-potentially acid generating" can leach high concentrations of metals and other solutes.

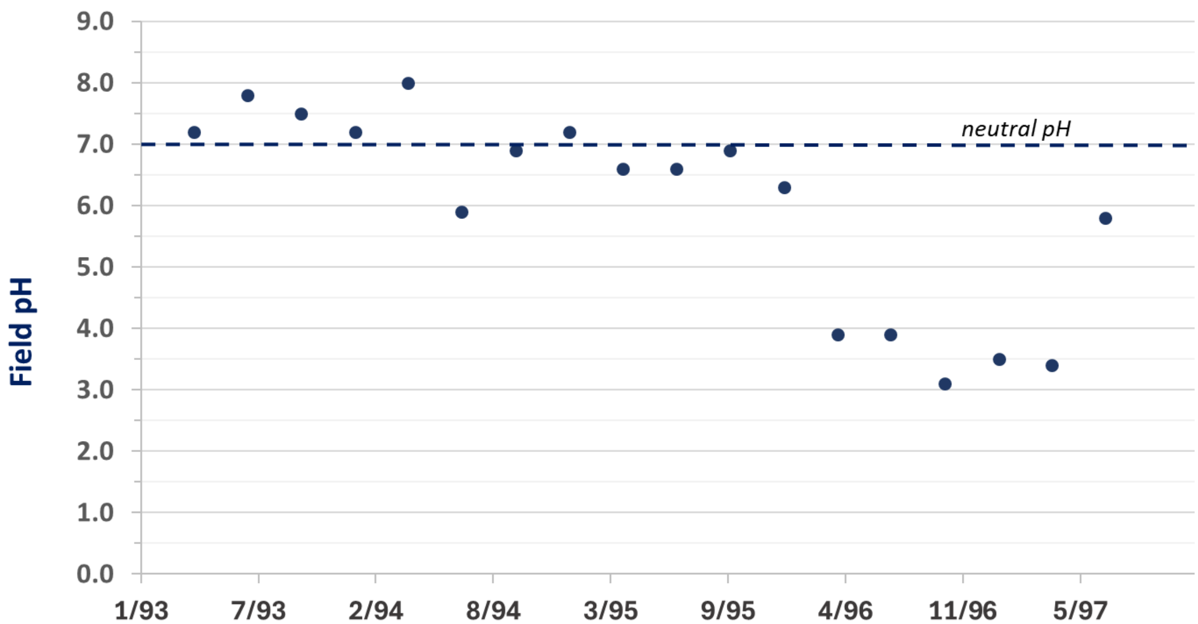


Flambeau Figure 2a. Manganese concentrations in Type II leachate (high sulfur stockpile) from 1994 to 1997. *Data sources:* Flambeau annual reports, 1993-1997. *Flambeau DMRs* (folder). See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx [Type II Leachate]*

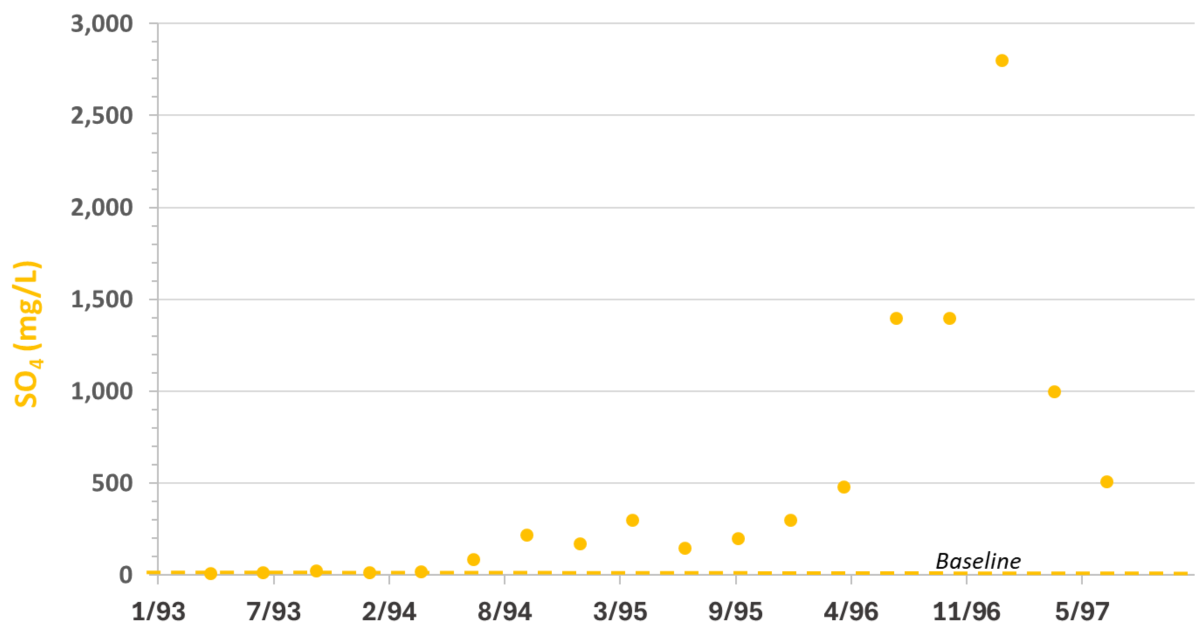
424 Flambeau Mining Co., 1997. 1996 Annual Report. *Flambeau.Annual Reports.1996.pdf [51]*
425 Murphy, Jana (1997). Letter from Flambeau Mining Co. to WDNR re: Flambeau Mining Company -- Type I Stockpile Evaluation, dated June 11, 1997. *Flambeau.Type I Stockpile.Murphy 1997 [7]*
426 See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx*. Data sources: *Flambeau.Annual Reports.1993.pdf [45]; Flambeau.Annual Reports.1994.pdf [46]; Flambeau.Annual Reports.1995.pdf [43]; Flambeau.Annual Reports.1996.pdf [47]; Flambeau.Annual Reports.1997.pdf [47]*



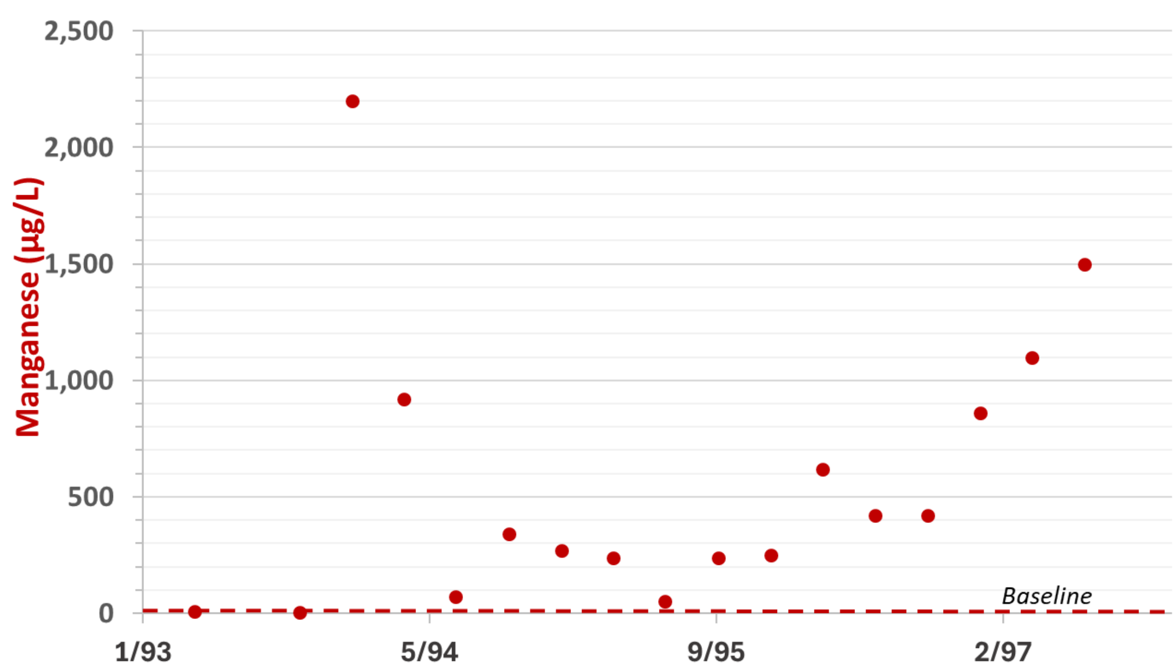
Flambeau Figure 2b. Copper concentrations in Type II leachate (high sulfur stockpile) from 1994 to 1997. *Data sources:* Flambeau annual reports, 1993-1997. *Flambeau DMRs* (folder). See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx [Type II Leachate]*



Flambeau Figure 2c. Field pH values in Type II leachate (high sulfur stockpile) from 1994 to 1997. *Data sources:* Flambeau annual reports, 1993-1997. *Flambeau DMRs* (folder). See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx [Type II Leachate]*



Flambeau Figure 2d. Sulfate concentrations in Type II leachate (high sulfur stockpile) from 1994 to 1997. *Data sources:* Flambeau annual reports, 1993-1997. *Flambeau DMRs* (folder). See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx [Type II Leachate]*



Flambeau Figure 3. Manganese concentrations in Type I leachate (low sulfur stockpile) from 1994 to 1997. *Data sources:* Flambeau annual reports, 1993-1997. *Flambeau DMRs* (folder). See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx [Type I Lysimeter]*

4.3 Tailings Water Quality

There are no tailings at the Flambeau Mine site.

4.4 Discharge Water Quality

The mining operation did not exceed its discharge permit limits during operations. However, permit limits were set much higher than the applicable water quality standards, and many times higher than background levels in the Flambeau River. The limits were calculated to meet water quality standards upon mixing with river water, with a discharge volume that was less than 1% of the river flow.[427] The monthly average copper concentration of the discharge was as high as 24.5 µg/l, compared to a chronic toxicity water quality standard for aquatic life of 5.99 µg/l. The monthly average zinc concentration was as high as 144 µg/l, compared to a chronic toxicity standard of 27.57 µg/l. The monthly average aluminum concentration was as high as 235 µg/l, compared to a chronic toxicity standard of 87 µg/l. [428,429] Total Dissolved Solids (TDS) averaged 317 mg/l over the life of the treatment plant. Sulfate, nitrogen, and chloride were not measured.

After mining ended, a series of passive treatment and infiltration systems were built to improve the quality of runoff water from the Industrial Outlot prior to discharge to Stream C, discussed in *Section 2*. As of 2011, discharge from the original biofilter ranged from 4.8 to 67 µg/l copper, with a mean of 30 µg/l. Two ditches that drained to Stream C had mean copper levels of 144 and 162 µg/l.[430]

5. Impacts on Groundwater and Surface Water Quality

5.1 Groundwater Quality Impacts

Baseline groundwater quality monitoring included six well nests with a total of 15 casings.[431] Samples were taken monthly for twelve months, from October 1987 to September 1988.[432] Four of the baseline well nests have continued to be used for monitoring during the operations and closure periods, and four additional wells or well nests have been added since mine closure. (See Figure 4.)

The Flambeau mine permit sets the compliance boundary for groundwater pollution at 1200 feet from the pit and stockpiles, which extends to the opposite side of the river.[433] This is the point at which the exceedance of numeric limits for specific pollutants becomes a violation of state law. In most cases the numeric limits are equal to drinking water standards. (Note that this allows significant degradation of groundwater even beyond the compliance boundary. For example, baseline groundwater averaged 5 to 11 mg/l sulfate;[434] the mining operation is permitted to degrade water quality at the compliance

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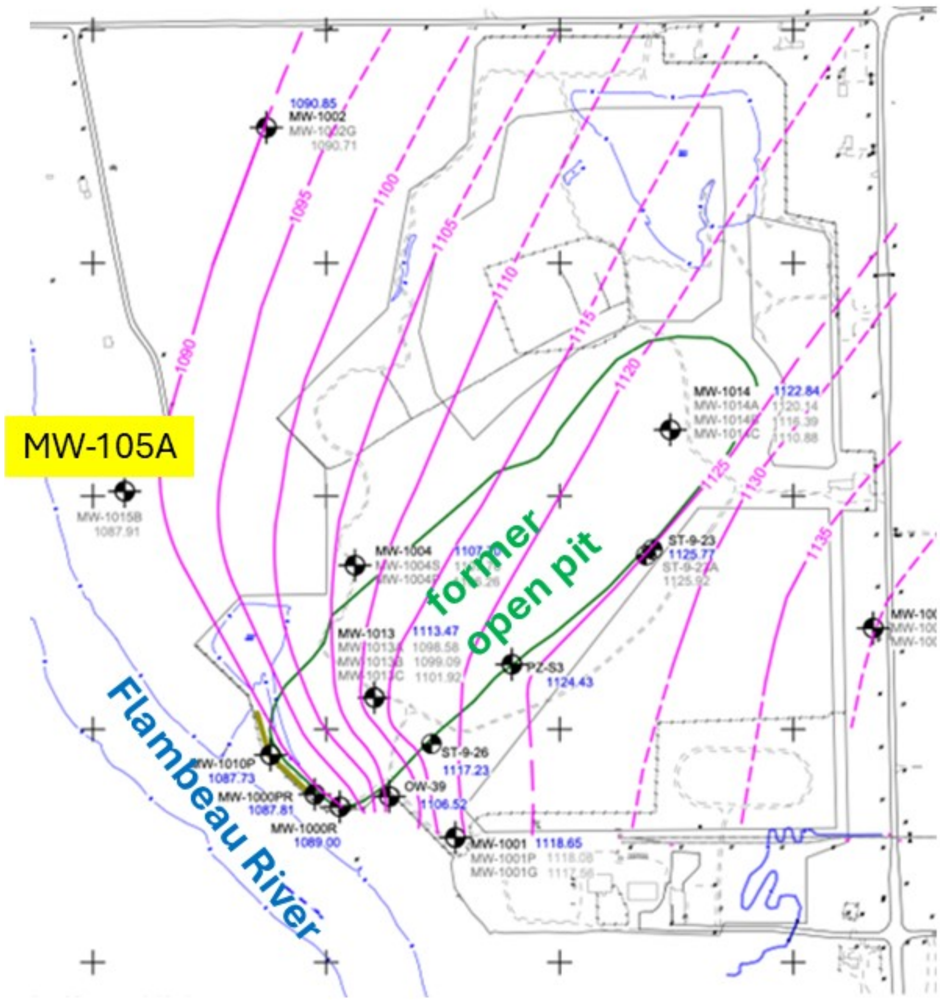
427 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [155]*
428 Flambeau Mining Co., 1993. Discharge Monitoring Reports. *DMRs/Flambeau.1993 DMRs.FMC 1993.pdf.* See *Flambeau.Flambeau Data spreadsheet.Feb2025.xlsx [Effluent and surface water]*
429 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [102].*
430 WDNR, 2012. Surface Water Quality Assessment of the Flambeau Mine Site. *Flambeau.Stream C Assessment.Roesler 2012.pdf [34]*
431 Foth & Van Dyke, 1989e. Environmental Impact Report Vol. I. *Flambeau.EIR Vol I.Foth 1989e.pdf [312,348]*
432 Forth & Van Dyke, 1989f. Environmental Impact Report, Vol. 5, App. 3.6H, Groundwater Quality Data. *Flambeau.GW baseline.Foth 1989f [7]*
433 Mine Permit. *Flambeau.Mine Permit.WDHA 1991.pdf [91]*
434 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [297]*

boundary to 250 mg/l.[435] Baseline copper averaged about 5 µg/l;[436] the mine is permitted to degrade water quality beyond the compliance boundary to 1000 µg/l.)

The only designated compliance well (MW-1015A) is located not where it is likely to intercept the flow path, but at the location closest to the flow path that is on the same side of the river as the mine and 1200 feet from mine features (Figure 4). (The shortest flow path from the pit is intercepted by the river before reaching the compliance boundary; the assumption is that any flow from the pit enters the river and does not affect groundwater at the compliance boundary beyond the river.[437]) Baseline data specific to MW-1015A do not exist, but groundwater does not appear to be significantly degraded at this location.[438]



Flambeau Figure 4. Shallow groundwater potentiometric surface map, November 2023.
MW-105A is the only compliance monitoring location in groundwater.
Source: Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [11]*

435 Mine Permit. *Flambeau.Mine Permit.WDHA 1991.pdf [92]*
436 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [294]*
437 Foth & Van Dyke, 1999. Memorandum re: Groundwater Quality Evaluation. *Flambeau.GW quality evaluation.Foth 1999 [6]*
438 Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [44-47]*

The mine permit identifies additional wells as marking an "intervention boundary," located between the pit and the Flambeau River. An assessment of the potential for permit noncompliance is required if water in the intervention wells exceed predicted concentrations.[439] The original permit referenced the predictions in Appendix L of the mine permit application, which included 550 µg/l manganese and 14 µg/l copper.[440] The mine permit was amended in 2022, when the intervention limits were changed to the predictions as "updated in 1997." No document is referenced and no concentrations specified for the updated predictions, however the 1999 Annual Report suggests that the updated predictions include a manganese concentration of 2300 µg/l and a copper concentration of 560 µg/l.[441] The groundwater standard for manganese is 300 µg/l, and for copper is 1000 µg/l.[442]

Manganese in intervention wells exceeded both the pre-mining and 1997 predictions at least until 2018.[443] Copper exceeded the original prediction from 2004 until the present. Sulfate is elevated compared to baseline, but has not exceeded predicted levels. The company produced assessments in 1999 and 2000, concluding that no violation of limits at the compliance boundary would occur.[444]

There are no intervention limits for arsenic or TDS, which are also elevated over baseline in intervention wells. Arsenic has been slowly rising, with levels reaching approximately 30 µg/l[445] compared to a baseline of <5 µg/l, as shown in Table 2.[446] TDS concentrations began at approximately 1300 mg/l in 1999 and have been declining since then. TDS is currently in the 500 mg/l range,[447] compared to a baseline of average of 146 mg/l.[448]

Flambeau Table 2. Flambeau Mine Intervention Well Groundwater Quality.

	Maximum baseline	Water quality standard	Intervention well maximum, 2000-2023	Intervention well maximum, 2023
Arsenic (µg/l)	<5	10	30	17
Copper (µg/l)	85	1000	150	25
Manganese (mg/l)	0.750	0.300	10	1.9
Sulfate (mg/l)	46	250	600	175
TDS (mg/l)	350	500	1100	514

Maximum baseline values are from wells MW-1000 and MW-1000P. Source: Foth & Van Dyke, 1989f. Environmental Impact Report, Vol. 5, App. 3.6H, Groundwater Quality Data. *Flambeau.GW baseline.Foth 1989f [7-37]*
Water quality standards are from WDNR, 2024. Drinking Water & Groundwater Quality Standards/Advisory Levels. *Flambeau.GW WQS.WDNR 2024.pdf*
Intervention well values are from MW-1000PR, MW-1000R, and MW-1010P, located between the pit and the river.

439 Mine Permit. *Flambeau.Mine Permit.WDHA 1991.pdf [94].*
440 Foth & Van Dyke, 1989g. Prediction of Groundwater Quality Downgradient of the Reclaimed Pit for the Flambeau Project. *Flambeau.Pit predictions.Foth 1989g.pdf [30]*
441 *Flambeau.Annual Reports.1999.pdf [15] Flambeau.GW WQS.WDNR 2024.pdf [7]*
442 WDNR, 2024. Drinking Water & Groundwater Quality Standards/Advisory Levels. *Flambeau.GW WQS.WDNR 2024.pdf*
443 See Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [29].*
444 Flambeau Mining Co., 2001. 2000 Annual Report. *Flambeau.Annual Reports.2000.pdf [46]*
445 Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [28]*
446 Forth & Van Dyke, 1989f. Environmental Impact Report, Vol. 5, App. 3.6H, Groundwater Quality Data. *Flambeau.GW baseline.Foth 1989f [7]*
447 Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [30]*
448 Forth & Van Dyke, 1989f. Environmental Impact Report, Vol. 5, App. 3.6H, Groundwater Quality Data. *Flambeau.GW baseline.Foth 1989f [37]*

2000-2023 maximum values are estimated from graphs in Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [28 et seq.]*
2023 Maximum values are from Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [56]*

Concern regarding impacts on groundwater has focused on groundwater moving out of the backfilled pit, while little is known about the impacts of the former waste rock stockpiles. Monitoring wells existed that likely would have intercepted groundwater flow from the footprint of both stockpiles (MW-1001 for the Type II Stockpile and MW-1003 for the Type I Stockpile),[449] but no monitoring data are reported for these wells.[450,451] The FEIS predicted that soon after mining ceased, groundwater flow direction from the site of the Type I Stockpile would be north and west toward the Flambeau River (see Figures 1 and 4).[452] The stockpile was unlined and intentionally drained to groundwater. Manganese levels measured by a lysimeter below the pile reached 1500 µg/l.[453] However, with no downgradient groundwater monitoring, impacts cannot be determined.

5.2 Surface Water Quality Impacts

Baseline surface water monitoring was limited to two locations in the Flambeau River (Figure 5). The upstream location (SW-1) is ostensibly upstream of the point where impacts from the mine could occur; the downstream baseline location (SW-2) was about 2.5 miles downstream of the mine site.[454] SW-1 has remained at the same location during operations and closure; SW-2 was moved to a point about 400 feet downstream of where discharge from the backfilled pit is assumed to occur.[455] Thus, there are no baseline data specific to the monitoring location where impacts from the mine are assessed. In general, surface water monitoring results show little difference in water quality between SW-1 and SW-2, although as shown in Table 3, aluminum concentrations are higher at the more downstream location, SW-2.

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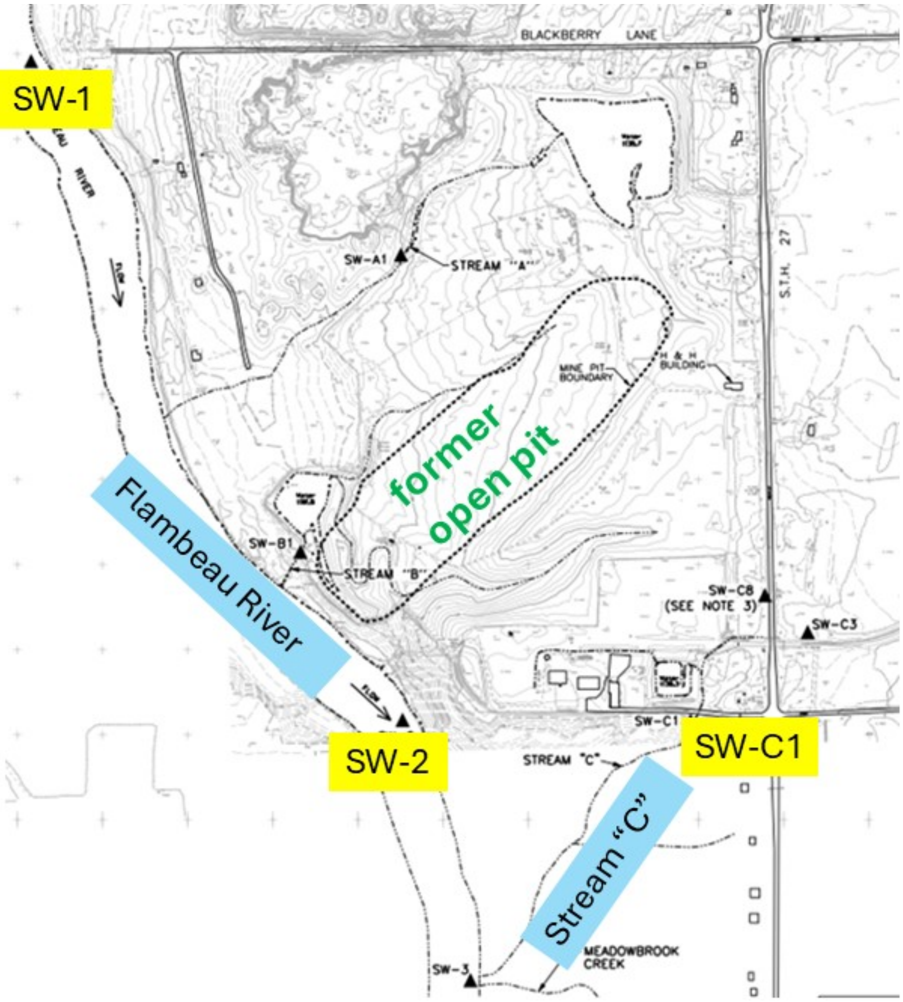
449 Flambeau Mining Co., 2018. 2017 Annual Report. *Flambeau.Annual Reports.2017.pdf [22]*
450 Flambeau Mining Co., 1998. 1997 Annual Report. *Flambeau.Annual Reports.1997.pdf [71-77]*
451 Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [28-55]*
452 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [140]*
453 See See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx*. Data sources: *Flambeau.Annual Reports.1993.pdf [45]; Flambeau.Annual Reports.1994.pdf [46]; Flambeau.Annual Reports.1995.pdf [43]; Flambeau.Annual Reports.1996.pdf [47]; Flambeau.Annual Reports.1997.pdf [47]*
454 EIR Vol. II. *Flambeau.EIR Vol II.Foth 1989.pdf [8, 31]*
455 Flambeau Mining Company, 1998. 1997 Annual Report. *Flambeau.Annual Reports.1997.pdf [23]*

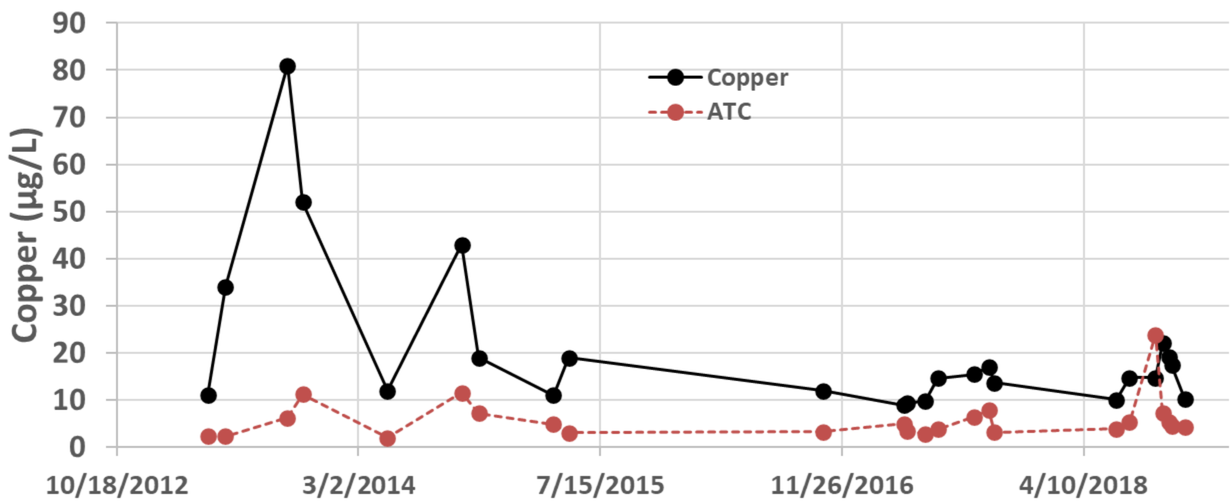


Flambeau Figure 5. Surface water monitoring locations. *Source:* Flambeau Mining Co., 2018. 2017 Annual Report. *Flambeau.Annual Reports.2017.pdf [292]*

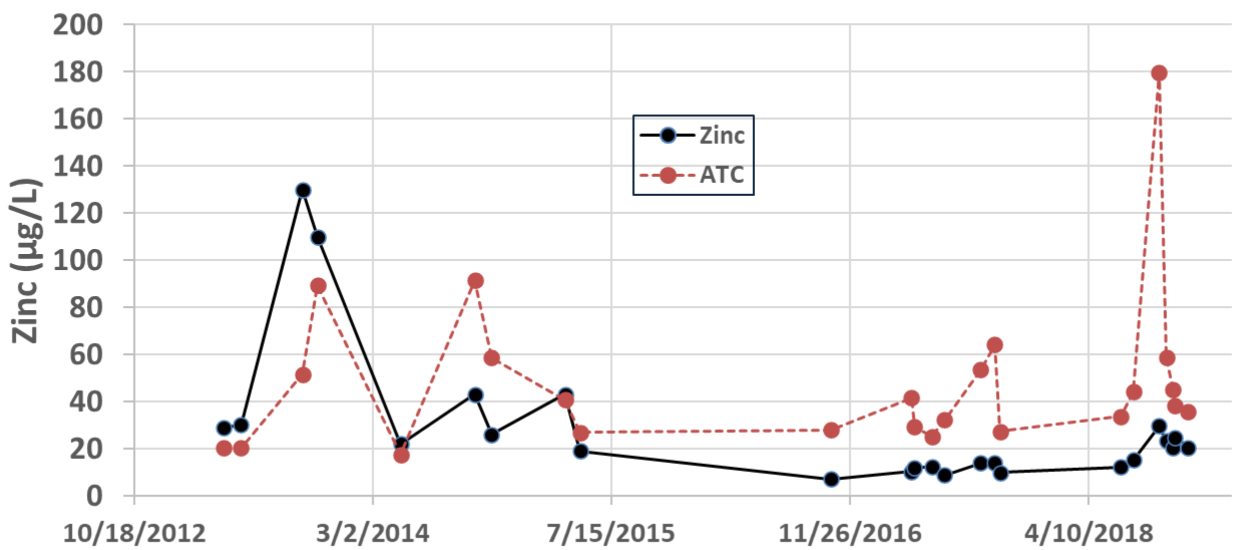
Surface water impacts have become apparent in a small tributary stream (Stream C), for which there are no baseline data.[456] Copper has consistently exceeded the acute toxicity criterion (ATC) value since 2002, and zinc has occasionally exceeded the ATC, as shown in Figures 6a and b.[457,458,459,460] The acute criterion is the value that would adversely affect aquatic life in a short period of time, whereas the chronic criterion is the value that would adversely affect aquatic life only after a longer period of time. Chronic and acute values are hardness-dependent, which explains the variability in ATC values in Figures 6a and b. At higher hardness values, copper and zinc are less toxic to aquatic biota. Pollution in Stream C

[456] WDNR, 2012. Surface Water Quality Assessment of the Flambeau Mine Site. *Flambeau.Stream C Assessment.Roesler 2012.pdf*
[457] Foth & Van Dyke, 2005. Memorandum re: Stream C -- 2005 Analysis of Collected Data. *Flambeau. Stream C 2005.Foth 2005.pdf [10]*
[458] Beranek, Ashley, 2017. 2018 Impairment Assessment for Stream C (WBIC 4000013). *Flambeau.2018 Stream C.Beranek 2017 [1]*
[459] Wisconsin Dept. of Natural Resources, nd. Flambeau Mine Surface Water Quality Data (Spreadsheet). *Flambeau.Stream C Data.WDNR nd.xlsx*
[460] Beranek, Ashley, 2021. 2022 Water Quality Assessment for Stream C (WBIC 4000013). *Flambeau.Stream C 2022.WDNR 2021.pdf [4]*

stems from the Industrial Outlot, discussed in *Sections 2* and *4.4*. Figure 7 was produced by Laura Gauger of Deer Tail Scientific:[461]

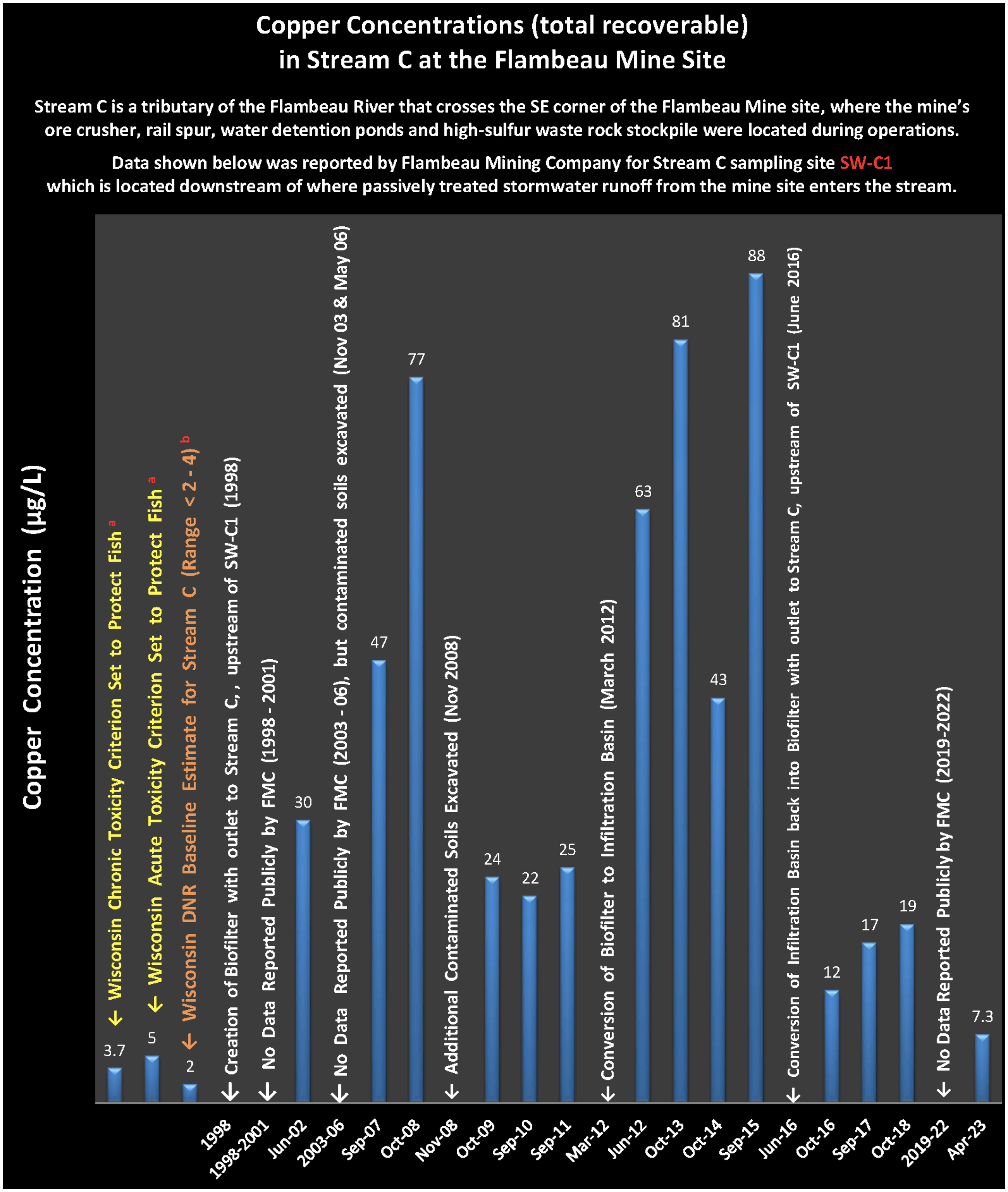


Flambeau Figure 6a. Copper concentrations in Stream C, SW-C1 compared to the acute toxicity criterion values over time. *Source:* Wisconsin Dept. of Natural Resources, nd. Flambeau Mine Surface Water Quality Data (Spreadsheet). *Flambeau.Stream C Data.WDNR nd.xlsx [Copper]*



Flambeau Figure 6b. Zinc concentrations in Stream C, SW-C1 compared to the acute toxicity criterion values over time. *Source:* Wisconsin Dept. of Natural Resources, nd. Flambeau Mine Surface Water Quality Data (Spreadsheet). *Flambeau.Stream C Data.WDNR nd.xlsx [Zinc]*

[461] Deer Tail Scientific, 2023. Graphs of Flambeau Mine Surface and Groundwater Quality Data. *Flambeau.Graphs.Deer Tail 2023.pdf [21]*



Flambeau Figure 7. Copper concentrations in Stream C, with information about mine operations and chronic and acute toxicity values. *Wisconsin Administrative Code, NR 105.06 (Nov 2008); Hardness-dependent toxicity; CTC value of 3.7 µg/L and ATC value of 5.0 µg/L (Total Recoverable) were calculated for a hardness of 30 mg/l (Hardness measured at SW-C1 in April 2023 was 27 mg/l). FMC failed to report baseline surface water quality data for Stream C. In 2010, however, Wisconsin DNR field staff identified a nearby stream deemed appropriate to use for estimating Stream C baseline conditions. A mean copper concentration of 2.2 µg/L was measured in the stream (range = <2-4; n = 5).*
Data Sources: Compilation of FMC Stream C and Biofilter Monitoring Data (1999-2010), Dr. David M. Chambers (Center for Science in Public Participation, Bozeman, MT), 2010; Compilation of FMC Stream C Surface Water Quality Data (2013-2018),

Wisconsin DNR, 2020; 2010 Stipulation Monitoring Report and corresponding reports issued in 2011 and 2012, FMC; Fall 2015 Surface Water Results, FMC; 2018 Stream C Impairment Assessment and corresponding reports issued in 2020 and 2022, Wisconsin DNR; and Spring 2023 Stream C Surface Water Results, FMC.
Graphic by Deer Tail Scientific, Duluth, MN (2023). https://deertailscientific.wordpress.com/flambeau-pollution-graphs/

Whether water quality in the Flambeau River itself has been impacted by elevated concentrations in Stream C is less clear. Stream C enters the Flambeau River downstream of the point where Flambeau water quality is typically monitored. Supplemental monitoring downstream of the mouth of Stream C has shown elevated copper levels,[462] but monitoring data reported for that location are sparse.

Impacts on the Flambeau River from other mine features (e.g., the backfilled pit and former waste rock stockpiles) are also indeterminate. Monitoring parameters and timing have varied considerably over the years, making assessment difficult. The lack of baseline data for the critical monitoring point (SW-2) adds to the difficulty.

A comparison of monitoring data to baseline data (Table 3) indicates that at least two parameters, aluminum and manganese, are or have been elevated above pre-mining levels.

Flambeau Table 3. Flambeau River Surface Water Monitoring Data.

	Baseline average	**SW-1 average**	**SW-2 average**	**Baseline maximum**	**SW-1 maximum**	**SW-2 maximum**
Aluminum (µg/l)	62	103	126	111	290	360
Manganese (µg/l)	< 50	68.7	70.1	80	190	189

Aluminum monitoring occurred from 1993 to 2000 and was then discontinued.
Manganese monitoring occurred in 1999 to 2012 and 2017 to 2023.
Baseline data are from FEIS. *Flambeau.FEIS.WDNR 1990.pdf [300]*
Aluminum data are from 1993-2000 Annual Reports. *Flambeau.Annual Reports.1993.pdf [25]; Flambeau.Annual Reports.1994.pdf [24]; Flambeau.Annual Reports.1995.pdf [25]; Flambeau.Annual Reports.1996.pdf [28]; Flambeau.Annual Reports.1997.pdf [28]; Flambeau.Annual Reports.1998.pdf [28]; Flambeau.Annual Reports.1999.pdf [25]; Flambeau.Annual Reports.2000.pdf [32]* See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx*
Manganese data are from 2017 to 2023 Annual Reports. *Flambeau.Annual Reports.2017.pdf [358-360]; Flambeau.Annual Reports.2018.pdf [105]; Flambeau.Annual Reports.2019.pdf [65]; Flambeau.Annual Reports.2020.pdf [88]; Flambeau.Annual Reports.2021.pdf [85]; Flambeau.Annual Reports.2022.pdf [90]; Flambeau.Annual Reports.2023.pdf [84]* See *Flambeau.Flambeau Data Spreadsheet.Feb2025.xlsx*

Assessment of data has focused on whether constituents consistently increase from the upstream (SW-1) to the downstream (SW-2) location,[463] which they do not. Prior to mining, however, constituents generally *decreased* from SW-1 to SW-2,[464] which does not appear to be the case since mining began. However, the change of location for SW-2 precludes an analysis that incorporates the changing relationship between constituent levels at the two stations. Further confounding the analysis, the flow of the river fluctuates greatly depending on both upstream dam operation and runoff from snowmelt and large rain events.[465] Significant runoff could influence the difference in pollutant concentrations at the two locations, but this assessment is not possible based on reported data.

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[462] Chambers, David, 2009. Report on Groundwater and Surface Water Contamination at the Flambeau Mine. *Flambeau.Report.Chambers 2009.pdf [5]*
[463] E.g., Flambeau Mining Company, 1998. 1997 Annual Report. *Flambeau.Annual Reports.1997.pdf [26]*
[464] EIR Vol. II. *Flambeau.EIR Vol II.Foth 1989.pdf [17 et seq.]*
[465] FEIS. *Flambeau.FEIS.WDNR 1990.pdf [96]*

Monitoring data reports do not include flow, and total suspended solids (which are usually higher in runoff than in groundwater) is not consistently monitored.

Furthermore, it is at least possible that SW-1 has been impacted by the Type I Waste Rock Stockpile, which was unlined and drained to groundwater. The stockpile covered 40 acres, and some of this area likely continued to drain northwest toward the river (rather than south toward the pit), as it did prior to excavation.[466] Although the cone of depression may have eventually captured most of the flow, it is unlikely that it did so during the early period of excavation, when most of the Type I waste rock was stockpiled.[467] Based on the company's model of groundwater flow direction, a plume from the northern part of the stockpile would enter the river upstream of monitoring point SW-1. Manganese was elevated (up to 1,500 µg/l) in leachate from the Type I Stockpile, and manganese is also elevated over baseline at SW-1. It appears that no groundwater monitoring or flow analysis has been done to assess the possibility that leachate from the Type I Stockpile has impacted the river at SW-1.

Sediment and fish in the Flambeau River have also been sampled. Mining company consultants conclude that monitoring has not revealed impacts from mining,[468] while an independent expert found that a definitive conclusion was not possible due to inadequate data and monitoring discrepancies.[469] That expert reported that evidence "of statistically significant increased copper concentrations in crayfish (whole-body specimens), walleye (liver tissue) and sediments (when 2008 downstream copper measurements are included) downstream from the mine site raises the possibility of a causal relationship."[470]

6. Accuracy of Water Quality Predictions

The Flambeau EIS included predictions of copper, iron, manganese, and sulfate in the backfilled pit.[471] All have been higher than predicted for the entire closure period, as shown in Table 4.[472]

Flambeau Table 4. Flambeau Mine Pit Water Quality Predictions and Actual Concentrations.

	EIS prediction	**In-pit maximum, 2000-2023**	**In-pit maximum, 2023**
Copper (µg/l)	14	700	300
Iron (mg/l)	0.320	29	29
Manganese (mg/l)	0.725	40	30
Sulfate (mg/l)	1360	2000	1780

In-pit wells include MW-1013 and MW-1014.
EIS predictions are from FEIS. *Flambeau.FEIS.WDNR 1990.pdf [92]*
Maximum values are approximate and are taken from graphs in the 2023 Annual Report. Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [48-55]*
2023 values are from Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [56]*

466 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [92]*;
467 Flambeau Mining Co., 1995. *1994 Annual Report Flambeau.Annual Reports.1994.pdf [9]*
468 E.g., Flambeau Mining Co., 1999. 1998 Annual Report. *Flambeau.Annual Reports.1998.pdf [178]*
469 E.g., Parejko, Ken, 2009. Flambeau River Monitoring at the Flambeau Mine, Rusk County, Wisconsin, 1. Flambeau River Sediments. *Flambeau.Sediments.Parejko 2009.pdf [19]*
470 Parejko, 2009. *Flambeau.Sediments.Parejko 2009.pdf [24]*
471 FEIS. *Flambeau.FEIS.WDNR 1990.pdf [146]*
472 Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [28-29]*

In addition, the pH of water in both in-pit wells and the intervention wells between the pit and the river periodically dips below 6.0.[473] The mining company predicted that pH would never fall below 6.5.[474]

7. Summary of Water Quality and Quantity Issues and Impacts

The Flambeau Mine had its greatest impact on water quality after closure. A summary of water quality and quantity issues and impacts is presented herein.

Surface water quality impacts:

- Flambeau has caused ongoing exceedances of water quality standards for copper and occasional exceedances of standards for zinc in a headwaters stream.
- In a headwaters stream, the copper concentration rose from a baseline of 2-4 µg/l to above 22 µg/l, with a maximum concentration of 88 µg/l.
- Insufficient monitoring is conducted in the Flambeau River to allow conclusions, but aluminum and manganese concentrations have increased over baseline.

Groundwater quality impacts:

- Monitoring at Flambeau is insufficient to determine the extent of impacts beyond those in the immediate location of the backfilled pit, where groundwater is heavily impacted.

NPDES permit issues:

- The ongoing discharge from the Flambeau Mine causing exceedances of water quality standards is not subject to a NPDES permit and has no permit limits.

Accuracy of water quality and water quantity predictions:

- Copper in the backfilled pit was predicted to be 14 µg/l; in actuality it has been up to 700 µg/l in the pit and up to 170 in groundwater outside the pit. Manganese was predicted to be 725 µg/l; in actuality it has been up to 40,000 in the pit and up to 12,000 in groundwater outside the pit. It was predicted that pH would never fall below 6.5; it occasionally falls below 6.0.
- At Flambeau, the predicted dewatering rate was an average of 125 gpm with a maximum annual average of 175 pgm. The actual average was 167 and the maximum annual average was 186.
- At Flambeau, the predicted effluent discharge rate was 0.327 mgd; the actual rate was 0.466 mgd.

Effectiveness of water treatment:

- At Flambeau, a series of passive systems have been designed to lower copper and zinc levels in discharge but have proved inadequate.

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473 E.g., Flambeau Mining Co., 2024. 2023 Annual Report. *Flambeau.Annual Reports.2023.pdf [30]* (MW-1000R) *and [50]* (MW-1013).

474 Foth and Van Dyke, 1989c. Prediction of Groundwater Quality Downgradient of the Reclaimed Pit for the Flambeau Project. *Flambeau.Groundwater Predictions.Foth 1989c.pdf [30]*

8. Comparison to Potential Mines in the Rainy River Headwaters Watershed of Minnesota

In comparison to potential mines in the Duluth Complex, the Flambeau Mine was a very small operation with a short mine life, with fewer and much smaller mine features that might result in water quality impacts. Most notably, the Flambeau ore was not processed in Wisconsin, and there is no tailings facility associated with this mine. On the other hand, the potential for acid rock drainage and leaching of metals on a per-ton basis was higher. Climate and hydrology are similar.

Haile Gold Mine, South Carolina

1. Site and Mine Description and Background Information

The Haile Gold Mine is an open pit mine on private land in north-central South Carolina. The mine is owned and operated by Haile Gold Mine, Inc., a wholly owned subsidiary of OceanaGold. Mining at the site goes back to 1827; the most recent previous mining operation closed in 1992. The former project was in the reclamation process when the current project was proposed.[475]

The project processes about 13,000 tons of ore per day as of 2020.[476] Current estimated project totals are 66.5 million tons of ore[477] and 526 million tons of waste rock.[478] Surface disturbance was estimated in the 2014 Environmental Impact Statement (EIS) at 2,612 acres.[479]

The Final EIS for the project was released by the U.S. Army Corps of Engineers (ACOE) in 2014. The mine operates under an NPDES wastewater discharge permit[480] and a state Mine Operating Permit,[481] both issued by South Carolina Dept. of Health and Environmental Control (SCDHEC) (which has since become South Carolina Dept. of Environmental Services). Construction began in 2015, and production began in 2017.[482] An expansion of the mine has recently been proposed, with a Supplemental EIS completed in 2022.[483]

The mine and tailings facility encompass the headwaters of two tributary creeks to the Little Lynches River. The mine pits have subsumed about a mile of Haile Gold Mine Creek. The tailings impoundment has subsumed a similar length of the uppermost reach of Camp Branch Creek.[484] Prior to the current project, these creeks each had a mean flow of about 4-5 cfs. Both creeks flow to the Little Lynches River, which had a mean flow of 43 cfs.[485] The river borders the mine property. The site has

[475] U.S. Army Corp of Engineers (ACOE), 2014. Final Environmental Impact Statement for the Haile Gold Mine Project. Hereinafter, "2014 FEIS." *Haile.2014 FEIS.ACOE 2014.pdf [61-65]*
[476] NewFields, 2020a. 2020 Annual Inspection, Duckwood Stage 2 Tailings Storage Facility, Haile Gold Mine. *Haile.2020 TSF Inspection.NewFields 2020a.pdf [6]*
[477] ACOE, 2022a. Haile Gold Mine Supplemental Environmental Impact Statement, Chapter 2: Proposed Action and Alternatives. Hereinafter, "2022 SEIS Chap. 2." *Haile.2022 SEIS Chap 2.ACOE 2022a.pdf [18]*
[478] ACOE, 2022b. Haile Gold Mine Supplemental Environmental Impact Statement, Chapter 3: Affected Environment. Hereinafter, "2022 SEIS Chap. 3." *Haile.2022 SEIS Chap 3.ACOE 2022b.pdf [7]*
[479] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [60]*
[480] SCDHEC 2022a. NPDES Permit No. SC0040479. Hereinafter, "2022 NPDES Permit." *Haile.2022 NPDES permit.SCDHEC 2022a.pdf*
[481] SCDHEC, 2022b. Mine Operating Permit No. I-000601, Modified Dec. 14, 2022. Hereinafter, "Mine Permit." *Haile.Mine Permit.SCDHEC 2022b.pdf*
[482] SCDHEC, 2022c. Fact Sheet and Permit Rationale, NPDES Permit No. SC0040479. Hereinafter, "2022 NPDES Fact sheet." *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [2]*
[483] *Haile.2022 SEIS* [Folder]
[484] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [69]*
[485] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [215]*

extensive wetlands lining the creeks,[486] annual precipitation of approximately 46 inches,[487] and an annual evapotranspiration rate of approximately 30 inches.[488]

Groundwater at the site includes three interconnected aquifers; the shallowest is typically less than 30 feet below ground surface and is highly connected to surface water. The fractured bedrock aquifer holds sufficient water to supply most of the public and private wells in the area.[489]

Historic mining at the site resulted in significant impacts to streams and water quality before this project began. However, the reclamation process ameliorated the impacts to some degree.[490] Haile Gold Mine is included in this study despite the prior impacts because it is a new project, rather than a continuation of activities that began under a different permitting scheme. For example, discharge from the ongoing reclamation averaged only 5.5 gallons per minute (gpm),[491] compared to 944 gpm for the current project. The project as planned in 2014 encompasses 4,552 acres,[492] only 176 of which were part of the previous project.[493] Baseline data reflect the impacts that preexisted the current project, allowing an assessment of impacts.

2. Mine Facilities, Operations, Spills and Accidents

The Haile Gold Mine consists of eight pits; a pit dewatering system; eight waste rock stockpiles, six of which are permanent; numerous contact water storage ponds; a processing mill with attendant facilities; and a tailings storage facility (TSF). Four of the pits will be or have been backfilled; the other four will remain as pit lakes.[494] Pits are dewatered using groundwater wells and mine sumps. The mine facilities as of 2022 are shown in Figure 1.

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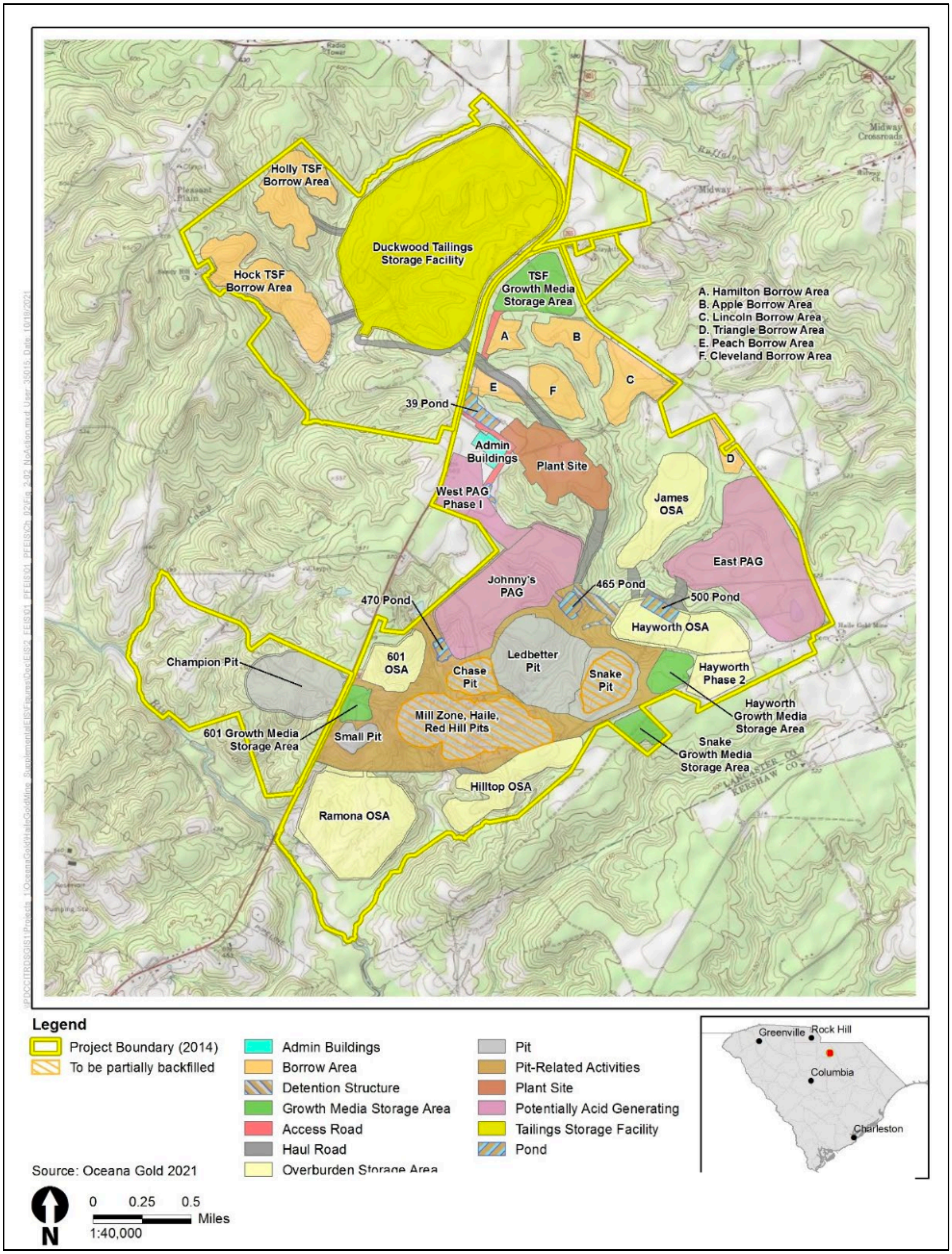
[486] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [280]*
[487] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [179]*
[488] South Carolina Dept. of Natural Resources, 2002. Ground-water Resources of Kershaw County, South Carolina. *Haile.Kershaw County Report.SCDNR 2002.pdf [12]*
[489] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [180]*
[490] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [145-46]*
[491] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [239]*
[492] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [60]*
[493] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [145]*
[494] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [67, 92]*



Haile Figure 1. Haile Gold Mine facilities, as of 2022. *Source:* ACOE, 2022a. Haile Gold Mine Supplemental Environmental Impact Statement, Chapter 2: Proposed Action and Alternatives*. Haile.2022 SEIS Chap 2.ACOE 2022a.pdf [7]*

The potentially acid-generating (PAG) stockpiles have liners and drainage systems to collect runoff and leachate.[495] It is assumed that any water that escapes from the PAG water collection system will drain to the mine pits. Non-PAG stockpiles are unlined; leachate is allowed to drain to groundwater and runoff is regulated under the state's general industrial stormwater permit. Non-PAG rock is also used to construct mine facilities.[496,497]

A new tailings facility was constructed for the current project. The facility is lined and has an underdrain system and collected water is used in the mill. The new tailings facility covers 524 acres.[498]

Mine inflow water and leachate and runoff from PAG ore and waste rock stockpiles are collected and treated before being discharged to Haile Gold Mine Creek. Until 2021, treated effluent was discharged upstream of the mine site. As of 2021, the discharge has been piped to an outfall located downstream of the mine site.[499]

The wastewater treatment plant consists of a two-stage hydroxide precipitation process designed to remove metals from the influent.[500] Hydroxide precipitation will not remove sulfate, TDS, or major cations to any significant extent. According to the mining company's antidegradation analysis, more advanced water treatment was economically infeasible, although the analysis provided no cost estimates or comparisons.[501] The company is in the process of building a new treatment plant using a similar process to accommodate an increase in contact water due to mine expansion and to address ongoing problems with the toxicity of the current effluent.

Haile has reported a number of spills and accidents over the years. Many of these spills and accidents occurred in 2018 to 2019. We do not have a full set of these reports, and the list here should not be taken as complete. Spills and accidents include:

- an electronic failure resulted in high-cyanide tailings disposed of in the TSF;[502]
- a hose spraying water from the TSF supernatant pond was left unattended and discharged water to an uncontained area;[503]
- a pipeline weld at a tailings spigot failed, resulting in a flow of tailings into wetlands;[504]

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495 East PAG Stockpile was added after initial permitting and environmental review. Oceana Gold, 2018a. Re: Haile Gold Mine Modification - Permit No. 1-000601 (Modification 19-1). *Haile.East PAG.Oceana 2018a.pdf [1]*

496 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [97]*

497 Oceana Gold, n.d. Detailed Project Description for Haile Gold Mine Expansion. *Haile.Project description.Oceana nd.pdf [88]*

498 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [96]*

499 Cedar Creek Associates, 2021. Re: 2021 NPDES Macroinvertebrates Sampling Results. *Haile.2021 Macroinvertebrates.Cedar Creek 2021.pdf [1, 6]*

500 2022 NPDES Fact sheet. *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [4]*

501 Civil and Environmental Consultants, 2021. Antidegradation Alternatives Analysis for NPDES Operation Permit Application. *Haile.Antideg.CEC 2021.pdf [11]*

502 Oceana Gold, 2019a. Subject: High $CN_{(WAD)}$ Tailings Effluent sent to Tailings Storage Facility. *Haile.Incident 2019.01.03.Oceana 2019a.pdf*

503 Oceana Gold, 2019b. Subject: Release of Reclaim Water Outside of Containment at the Haile Process Plant. *Haile.Incident 2018.12.07.Oceana 2019b.pdf*

504 Oceana Gold, 2019c. Major Incident Investigation Report. *Haile.Incident 2019.12.21.Oceana 2019c.pdf*

- a pump failed at a cyanide destruction tank, resulting in high cyanide levels in tailings disposed of in the tailings facility;[505]
- fresh water rinsate was inadvertently left on, flooding a containment area and running off to a stormwater ditch and wetlands;[506] and
- silt fences failed during a heavy rainfall resulting in high sediment in stormwater discharge.[507]

In addition, leaks of contact water ponds holding acidic water have been reported and are discussed in *Section 4.1*.

3. Geochemistry

Static and kinetic testing of ore, waste rock, and tailings was conducted prior to permitting. The kinetic tests were run for 140 weeks for overburden and 96 weeks for tailings.[508] A percentage of the overburden and the tailings was determined to be potentially acid-generating (PAG). Early testing indicated that pyrite abundance within mineralized zones commonly ranged from 1 to 15%.[509] Some of the pit lakes and stockpiles as well as the TSF are or are likely to become acidic and will need to be "maintained in an undisturbed condition for perpetuity."[510]

Waste rock is categorized according to its percentage of pyritic sulfur. "Green" waste rock has less than 0.2 percent sulfur and is considered non-PAG; "yellow" waste rock has between 0.2 and 1 percent sulfur and is considered to have a low potential for acid generation; and "red" waste rock has greater than 1 percent sulfur with high potential to generate acid.[511] The sulfur percentages used to categorize waste rock do not correspond with early geochemistry analysis, which found that rock with sulfur greater than 0.1 percent is moderately acid generating and will produce drainage with pH levels of 3.0 to 4.0. In addition, more than half the samples with less than 0.1% sulfur had no neutralizing capacity and could potentially produce pH values as low as 4.0.[512]

Three of the waste rock stockpiles hold potentially acid-generating (PAG) rock, designated as "red." To ensure adequate sorting, samples from the stockpiles are sent for laboratory testing. Segregation is considered unsuccessful if more than 10% of the samples from a non-PAG ("green") stockpile have a sulfur content higher than 0.2 percent. As of the end of 2019, two of three non-PAG stockpiles were unsuccessfully segregated. At one stockpile, 23% of samples had sulfur contents higher than the 0.2 percent limit.[513] The contingency measure was to spread lime over the surface of the

[505] SCDHEC, 2018. Re: Cyanide Destruct Tank Failure. *Haile.Incident 2018.11.19.SCDHEC 2018.pdf*
[506] Oceana Gold, 2019d. Subject: Release of Fresh Rinse Water Outside Containment at Haile Process Plan. *Haile.Incident.2019.02.03.Oceana 2019d.pdf*
[507] 2022 SEIS Chap. 3. *Haile.2022 SEIS Chap 3.ACOE 2022b.pdf [12]*
[508] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [519]*
[509] Schafer Limited, 2010. Haile Gold Mine Baseline Geochemistry Report. *Haile.Geochemistry.Schafer 2010.pdf [17]*
[510] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [98]*
[511] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [94]*
[512] Schafer Limited, 2010. *Haile.Geochemistry.Schafer 2010.pdf [9]*
[513] Oceana Gold, 2020. Fourth Quarter 2019 Overburden Management Monitoring Report. *Haile.2019 Overburden.Oceana 2020.pdf [7]*

stockpile;[514] the stockpile remains unlined. Rock sorting issues have continued; in the first quarter of 2021 two of six stockpiles were unsuccessfully segregated.[515]

Tailings are estimated to average three percent sulfur and have the potential to generate acid.[516]

4. Mine-Influenced Water Quality

4.1 Mine Water Quality

No information is available on the quality of water in the open pits. However, liner leaks in contact water ponds resulted in the water quality shown in Table 1. Results indicate that water in the ponds is acidic with high metal, sulfate, and total solute concentrations.

Haile Table 1. Monitoring results from contact water ponds, 2021 and 2022.

Parameter (units)	500 Pond A	500 Pond A	500 Pond B	19 Pond N	500 Pond A
Date	July 13, 2021	January 2022	July 13, 2021	January 2022	January 2022
pH (SU)	3.22	3.43	4.62	4.46	3.43
Temperature (°C)	27.2	--	28.2	--	--
Conductivity (µS/cm)	990	1894	546	1870	1894
Sulfate (mg/l)	--	3800	--	1300	3800
Aluminum (mg/l)	--	260	--	38	260
Copper (mg/l)	--	2.5	--	0.35	2.5
Iron (mg/l)	--	54	--	ND	54
TDS (lab; mg/l)	--	4400	--	1500	4400
ND below detection. Sources: No author, n.d. Leak Collection and Recovery Annual Report 2022. (Received from SCDHEC on Feb. 15, 2024.) *Haile.2022 Leak collection.No author nd.pdf;* Oceana Gold, 2021b. Re: Haile Gold Mine 500 B Pond. *Haile.500 B Pond.Oceana 2021b.pdf*					

Leak containment and recovery system (LCRS) water and water from the groundwater sumps were also monitored in 2021 for pH, conductivity and temperature. Measured pH values ranged from 6.07 to 6.82, conductivity ranged from 115 to 643 µS/cm (lowest in the LCRS and highest in groundwater pump 50-PP-62, and temperatures ranged from 23.1 to 26.3 °C.[517] The similarity in LCRS and groundwater water quality results (and the lack of similarity with the pond water) suggests that groundwater was entering the space between the two liners under the contact water ponds. The source of the groundwater was not described in the report.

In contrast to water in the contact water ponds, stormwater that infiltrates and runs off from non-PAG stockpiles is considered "noncontact" water and is discharged without treatment to groundwater and surface water.[518] Runoff is subject to a general stormwater permit; a 2021 SCDHEC

[514] Oceana Gold, 2020. *Haile.2019 Overburden.Oceana 2020.pdf [9]*
[515] Oceana Gold, 2021a. First Quarter 2021 Overburden Management Monitoring Report. *Haile.2021 Overburden.Oceana 2021a.pdf [7]*
[516] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [119]*
[517] No author, n.d. Leak Collection and Recovery Annual Report 2022. (Received from SCDHEC on Feb. 15, 2024.) *Haile.2022 Leak collection.No author nd.pdf*
[518] Oceana Gold, n.d. Detailed Project Description for Haile Gold Mine Expansion. *Haile.Project description.Oceana nd.pdf [88]*

inspection found the mine to be in violation of the permit in that it was unable to locate its stormwater management plan; failed to conduct routine inspections of stormwater control measures; failed to maintain structures designed to control erosion, sedimentation, and stormwater runoff; and failed to conduct required monitoring.[519] We do not have data on the quality of this water.

4.2 Waste Rock Leachate Water Quality

The mine permit requires monitoring of the leachate from the PAG stockpiles but does not explicitly require submitting the data to the State.[520] Although the permit requires that stockpile data "be summarized and reported semi-annually," the reports we received did not include stockpile leachate data.

However, a report from 2022 provides data from a PAG water collection pond following a liner failure. The water had a pH of 3.43, a sulfate level of 3800 mg/l, an aluminum level of 260 mg/l, a copper level of 2.5 mg/l, and a total dissolved solids (TDS) level of 4400 mg/l.[521] There have been two such failures so far.[522,523] It is unknown how much water escaped or what the impact was on groundwater and surface water.

4.3 Tailings Water Quality

As with waste rock leachate, the mining permit requires that drainage from the tailings be monitored, but the data are apparently retained on site.[524] Neither the data nor the required reports were provided in response to a public records request.

4.4 Effluent Water Quality

Haile Gold Mine discharges treated water pursuant to NPDES Permit No. SC0040479. At low-flow conditions the discharge makes up 100% of the water in the creek. The permit does not include a mixing zone for the effluent, and permit limits are set at water quality standards.[525]

Despite the absence of a mixing zone, permit limits for several constituents are quite high. Water quality standards for some metals (cadmium, chromium III and IV, copper, lead, nickel, and zinc) vary based on hardness of the water, with standards being higher when hardness is higher. In the first iteration of the permit (2014), water quality standards (and permit limits) for these metals were based on the hardness of the discharge water, which was estimated at 2,200 mg/l.[526] The resulting limits included a monthly average limit for copper of 94.9 µg/l, with a daily maximum of 160.8. The monthly average limit for lead was 49.9 µg/l, and for zinc, 750 mg/l.

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[519] SCDHEC, 2021. Compliance Evaluation, SWPPP. *Haile.2021 Stormwater.SCDHEC 2021.pdf [1]*
[520] Mine permit. *Haile.Mine Permit.SCDHEC 2022.pdf [15]*
[521] No author, n.d. Leak Collection and Recovery Annual Report 2022. (Received from SCDHEC on Feb. 15, 2024.) *Haile.2022 Leak collection.No author nd.pdf [2]*
[522] NewFields, 2022. Technical Memorandum Re: Monthly Construction Quality Assurance Report for 465 Pond Repairs – Report 003. *Haile.465 Pond.NewFields 2022.pdf [7]*
[523] Oceana Gold, 2021b. Re: Haile Gold Mine 500 B Pond. *Haile.500 B Pond.Oceana 2021b.pdf*
[524] Mine permit. *Haile.Mine Permit.SCDHEC 2022b.pdf [14]*
[525] 2022 NPDES Fact sheet. *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [5 et seq.]*
[526] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [220]*

These levels do not appear to comply with regulations. In calculating hardness-based standards, South Carolina regulations mandate using a maximum hardness of 400 mg/l and require using either the hardness of the receiving water or a calculated mix of the receiving water and the discharge.[527] In this case, the receiving water has a natural hardness ranging from 5 to 85 mg/l.[528] Both the calculated standards and the limits in the 2014 permit thus appear to be higher than allowed. As a point of comparison, for a similar class of water the highest monthly average for any discharge in Minnesota (with regulations based on the same U.S. EPA water quality criteria) is 23 µg/l for copper, 19 µg/l for lead, and 343 for zinc.[529]

When the Haile permit was renewed in 2022, the 10th percentile of the hardness of the effluent was used. That value was calculated as 144 mg/l.[530] While this is a significant improvement, the limits still ignore the much softer receiving water.

Mercury discharges and permit limits are also high. The monthly average mercury limit in the NPDES permit is set at the water column standard to protect human health from consumption of mercury in fish tissue, which is 51 ng/l.[531] (In comparison, the comparable Minnesota standard is 6.9 ng/l.[532]) The daily maximum permit limit rose from 74.5 ng/l in the 2014 permit to 168 ng/l in the current permit. The long-term average mercury in Haile Gold Mine effluent at the time the new permit was written was 170 ng/l.[533] These discharges are to a tributary to the Lynches River, which is subject to an SCDHEC advisory not to eat catfish and to eat only one meal per month of largemouth bass or chain pickerel due to mercury contamination.[534]

Another primary issue with permit compliance has been failure of whole effluent toxicity (WET) testing. The permit requires that no single test result in greater than 40% toxicity, and that the monthly average be no greater than 25% toxicity.[535,536] This could be understood as an allowance for the effluent to kill up to 40% of the test organisms in a single test, and up to 25% of the test organisms on average.

The effluent has regularly failed WET tests since November of 2020; the effluent has remained toxic to aquatic life for three and a half years and counting. In November 2020 and April 2023, toxicity

[527] SCDHEC, 2013. Fact Sheet and Permit Rationale, NPDES Permit No. SC0040479. *Haile.2013 NPDES Fact sheet.SCDHEC 2013.pdf [21]*
[528] ACOE, nd. Haile Gold Mine EIS App. J, Supporting Information and Analysis for Surface Water Resources. *Haile.App J Surface Water.ACOE nd.pdf [96]*
[529] Minn. R. 7050.2022. *Haile.Minn R 7050.MPCA 2018.pdf [128, 132, 137]*
[530] 2022 NPDES Fact sheet. *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [9]*
[531] South Carolina R.61-68. *Haile.SC R 61-68.pdf [40]*
[532] Minn. R. 7050.2022. *Haile.Minn R 7050.MPCA 2018.pdf [82]*
[533] 2022 NPDES Fact sheet. *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [16]*
[534] SCDHEC, n.d. Lynches River Fish Consumption Advisory. https://scdhec.gov/bow/aquatic-science-programs/fish-consumption-advisories/lynches-river-fish-consumption-advisory, accessed June 25, 2024. The Little Lynches River is not included in the testing program. https://scdhec.gov/bow/aquatic-science-programs/fish-consumption-advisories#index, accessed June 27, 2024.
[535] 2022 NPDES Fact sheet. *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [40]*
[536] 2022 NPDES permit. *Haile.2022 NPDES permit.SCDHEC 2022a.pdf [26]*

was 100%; in April 2024, toxicity was 89%.[537] This effluent is being discharged immediately upstream of the Little Lynches River, which is listed as impaired for aquatic life based on macroinvertebrate surveys.[538,539,540]

In addition to mercury and whole effluent toxicity, between 2017 and 2022 the discharge had exceedances of limits for cyanide, cadmium, thallium, and pH, as shown in Table 2.[541]

Haile Table 2. Permit exceedances in Haile Gold Mine effluent.

Parameter (units)	Permit Limits	Highest DMR values
Mercury (ng/l)	51 (avg monthly) 74.5 (max daily)	**200** (avg monthly, 10/2016) **200** (max daily, 3/2019)
Free cyanide (µg/l)	5.2 (avg monthly) 22 (max daily)	**10** (avg monthly; 5/2018) 20 (max daily; 2/2020)
Thallium (µg/l)	0.47 (avg monthly) 1.31 (max daily)	**1.0** (avg monthly; 5/2017) 1.2 (max daily; 12/2019)
pH (SU)	6.0 to 8.5	**5.05** (minimum; Dec 2019) **8.7** (maximum (Dec 2019)

*Values in **bold** exceed permit limits.*
Sources: U.S. EPA, 2024. ECHO DMR Exceedances Report Spreadsheet. Downloaded from https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedances?permit_id=SC0040479 on June 27, 2024. *Haile.Exceedances.EPA 2024.xlsx.* SCDHEC, 2022c. Fact Sheet and Permit Rationale, NPDES Permit No. SC0040479. *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf*

The discharge also likely has high levels of several pollutants that are not monitored. As discussed in *Section 5.2*, Haile Gold Mine Creek has had high levels of total dissolved solids, specific conductance, sulfate, and manganese beginning in 2019. None of these pollutants have surface water quality standards, nor will they be removed to any significant extent by the water treatment system (hydroxide precipitation). They are not monitored in the Haile discharge despite the prediction that influent to the treatment plant would have a sulfate level of 500 to 1,000 mg/l.[542] High levels of these pollutants in the discharge could be responsible for both the toxicity of the discharge and the high levels in Haile Gold Mine Creek and the Little Lynches River. Without appropriate monitoring data, however, that assessment is not possible.

537 U.S. EPA, 2024. ECHO DMR Exceedances Report Spreadsheet. Downloaded from https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedances?permit_id=SC0040479 on June 27, 2024. *Haile.Exceedances.EPA 2024.xlsx*
538 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [227]*
539 2022 NPDES Fact Sheet *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [41]*
540 For location of PD-632, see South Carolina Dept. of Natural Resources, 2009. South Carolina State Water Assessment Chapter 5, Pee Dee Watershed Assessment. *Haile.PeeDee.SCDNR 2009.pdf [5-21]*
541 2022 NPDES Fact sheet *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [4-17].*
542 Schlumberger Water Services, 2010. Technical Memorandum re: Mine Water Treatment System -- Permit Summary. *Haile.Influent predictions.Schlumberger 2010.pdf [3]*

5. Mining Impacts on Groundwater and Surface Water Quality

5.1 Groundwater Quality

Although groundwater quality is monitored at the tailings facility and mine sites, we do not have sufficient data to assess impacts. First, true baseline groundwater data are not available. Baseline groundwater quality monitoring was limited to a few wells clustered in the mine pit area, an area that was already impacted from past mining projects.[543] No baseline data are available from the tailings facility area, which is more than a mile away, upgradient, and less impacted by past activities.

Second, the permits are unclear as to what groundwater quality monitoring is required. The mine permit text requires implementation of the Groundwater and Surface Water Monitoring Plan as its only groundwater quality monitoring requirement.[544] A 2015 version of the monitoring plan was requested in a public records request, but only an earlier draft was received; it is unclear whether the draft was finalized and/or if any changes were made. A 2019 "Monitoring and Management Plan" was received, but the plan does not identify the specific wells to be monitored. Rather, it states: "The actual number of sampling locations and monitoring specifics are specified in Haile's Mining Permit."[545] The permit includes no such information.

Finally, monitoring data received in response to a public records request was incomplete at best. Monitoring is reported semiannually; in response to a December 2023 request for all semiannual reports to date, only reports through 2020 were received, which was four years from the start-up of mining. This is often insufficient time for groundwater impacts to be reflected in monitoring data. Furthermore, most of the monitoring reports received had blank pages in lieu of data tables.[546]

A map showing the groundwater monitoring locations in 2020 is presented as Figure 2. In practice, monitoring results are reported from thirteen wells.[547,] Three are located in the tailings facility area,[548] but do not appear to be positioned downgradient of the facility. The wells are located in the northwest and southeast corners of the facility, while the base of the facility is graded to flow to the southwest. In addition to the tailings area wells, five wells are located up- and down-gradient of waste rock stockpiles, and five are along the downgradient property line.[549] Several stockpiles do not have downgradient monitoring wells.[550]

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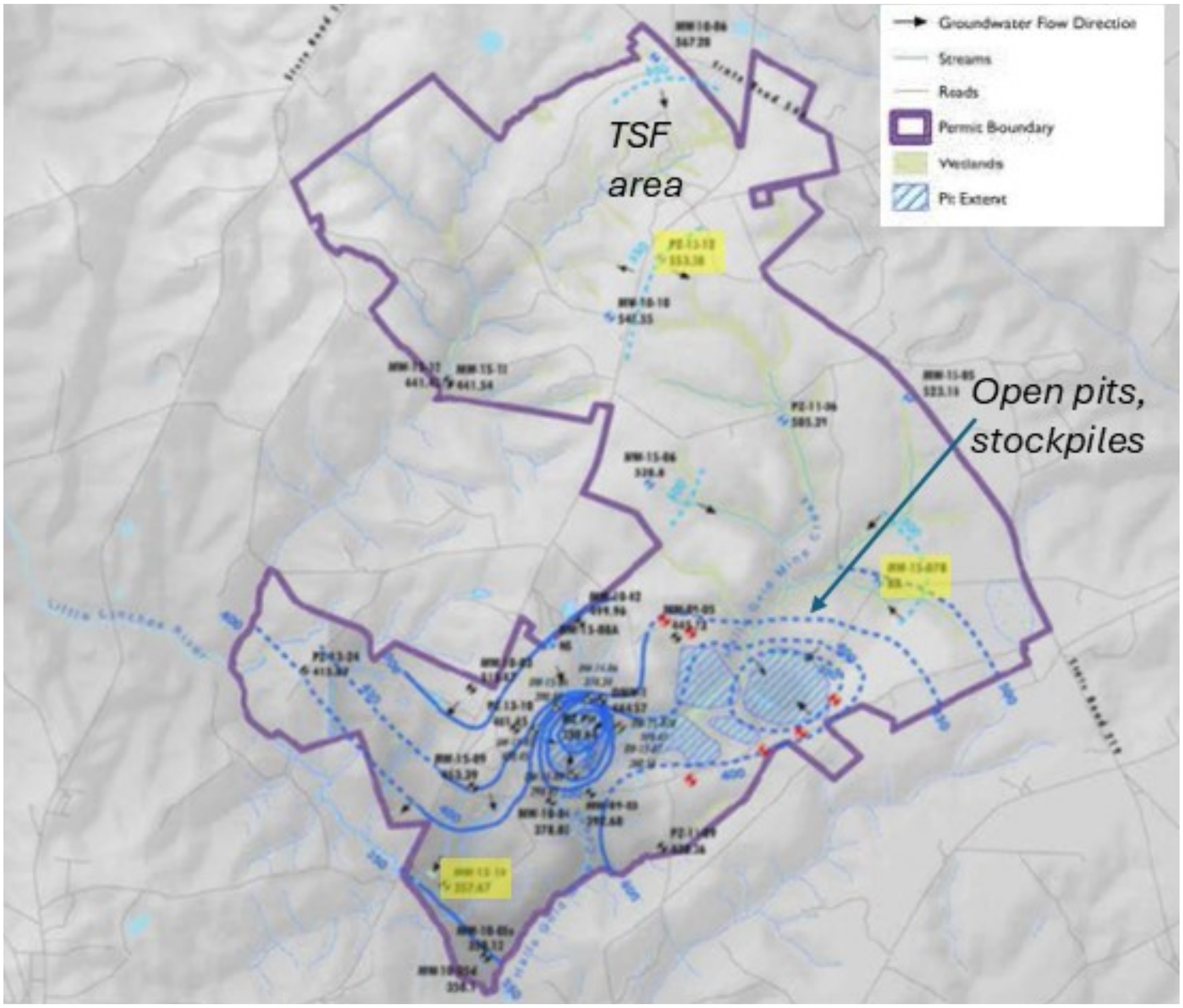
543 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [207]*
544 Mine Permit. *Haile.Mine Permit.SCDHEC 2022b.pdf [15-16]*
545 Oceana Gold, 2019e. Monitoring and Management Plan. *Haile.2019 Monitoring.Oceana 2019e.pdf [8]*
546 E.g., NewFields, 2021a. 2020 Second Semi-Annual Groundwater and Surface Water Monitoring Report. *Haile.2020 Second Semiannual.NewFields 2021a.pdf [23-38]*
547 NewFields, 2021b. Third Quarter 2021 Groundwater and Surface Water Monitoring Report. *Haile.2021 Third Quarter.NewFields 2021b.pdf [13-15]*
548 The tailings facility wells with monitoring data are MW10-06, MW10-10, and PZ13-12.
549 NewFields, 2020a. 2020 Annual Inspection, Duckwood Stage 2 Tailings Storage Facility, Haile Gold Mine. *Haile.2020 TSF Inspection.NewFields 2020a.pdf [8]*
550 The five wells with data in this area are MW15-05, -06, -07, -08, and -09. For a map of mine features prior to the 2022 expansion, see Figure 1.



Haile Figure 2. Haile Gold Mine, groundwater monitoring locations. The locations graphed in this section are highlighted in yellow. *Source: Modified from Figure 4, NewFields, 2021. 2020 Second Semi-Annual Groundwater and Surface Water Monitoring Report, Haile Gold Mine, Feb 18, 2021. Haile.2020 Second Semiannual.NewFields 2021a.pdf [42]*

While for the most part, the lack of data precludes analysis, slightly more data are available for specific conductance than for other parameters. Monitoring dates include the last half of 2015, the last half of 2017, all of 2018, the first half of 2019, and the first and third quarters of 2021. Again, this is a short time period for groundwater impacts to manifest (production began in 2017), and clear impacts are not apparent. However, levels appear to be rising in some down-gradient wells. For example, specific conductance at a well downstream of the Ramona non-PAG waste rock stockpile (MW15-10) averaged 208 µS/cm in 2015 and 264 in 2020; intervening years were 191 (2017), 210 (2018), and 238 (2019).[551]

[551]Data is from the following Semiannual and Quarterly Groundwater and Surface Water Monitoring Reports: *Haile.2015 Second Semiannual.NewFields 2016.pdf [22]; Haile.2017 Second Semiannual.NewFields 2018a [25]; Haile.2018 First Semiannual.NewFields 2018b.pdf [22]; Haile.2018 Second Semiannual.NewFields 2019a.pdf [25]; Haile.2019 First Semiannual.NewFields 2019b.pdf [23]; Haile.2021 First Quarter.NewFields 2021c.pdf; [14] Haile.2021 Third Quarter.NewFields 2021b.pdf [13]* See *Haile.Monitoring data spreadsheet.Feb2025.xlsx*

5.2 Surface Water Quality

The current Haile project involved the complete loss of miles of streams, estimated in the EIS at 26,460 linear feet.[552] Impacts on water quality in remaining streams have also been substantial. The dataset available is subject to the same limitations as for groundwater, discussed above. However, for surface water even this amount of data shows clear water quality impacts.

Surface water quality monitoring for the current project was done in 2008-2012.[553,554] Haile Gold Mine Creek and the Little Lynches River had been impacted by past mining projects at that time, and the 2008-2012 data should not be taken as reflecting natural, unimpacted water quality. Therefore, the pre-project monitoring results will be referred to as background rather than baseline data. The monitoring data do provide a background against which increases due to the current project can be assessed.

A majority of the background samples for the small creeks in the project area, including those not likely to have been impacted by mining, had pH values less than 6.0.[555] Background aluminum and iron levels were high at the mine site; they are also high in local creeks outside the mining area, but to a lesser degree.[556] Manganese levels vary, but background levels were typically below 1,000 µg/l in Little Lynches River; above 1,000 µg/l in Haile Gold Mine Creek; and below 100 µg/l in other headwater streams.

Many of the surface water monitoring station identifying numbers were changed between the background monitoring program and start-up. Some of the current monitoring points are designated by numbers that were used for other points in the background data.[557] In addition, some current monitoring points have no baseline or background data. To avoid confusion, the tables below use background data from the nearest monitoring point on the same stream segment, without designating the baseline location.[558] (Note that SW-13 and SW-15 designations are switched on maps of current monitoring sites. SW-13 is about one mile downstream of the confluence of Haile Gold Mine Creek with the Little Lynches River; SW-15 is upstream of the entire project. These designations have remained the same for data reporting, despite their switch on maps.) A map showing the surface water monitoring locations and mine facilities is presented in Figure 3.

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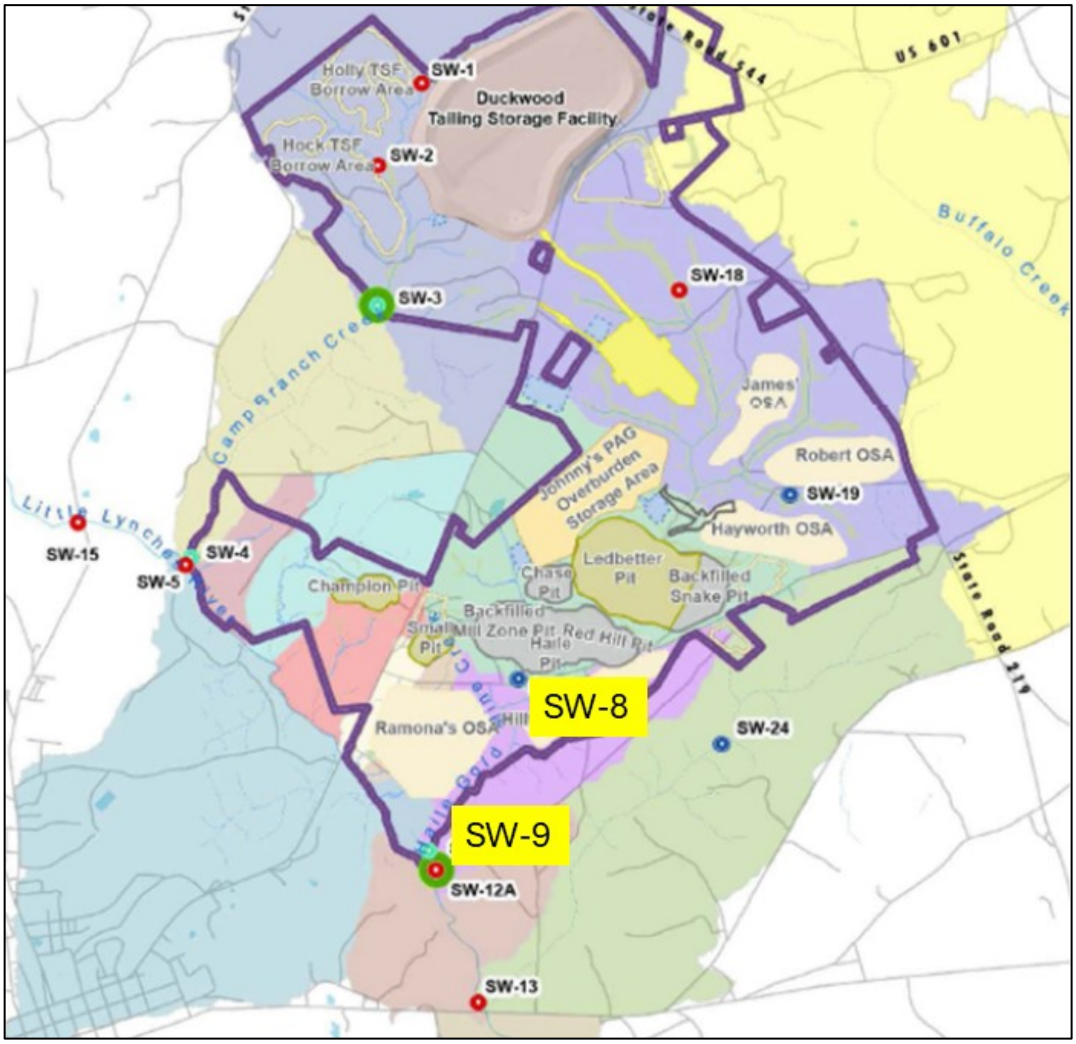
[552] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [157]*
[553] ACOE, nd. Haile Gold Mine EIS App. J, Supporting Information and Analysis for Surface Water Resources. *Haile.App J Surface Water.ACOE nd.pdf*
[554] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [242]*
[555] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [244]*
[556] See *Haile.Monitoring data spreadsheet.Feb2025.xlsx*
[557] Compare 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [243]* (baseline monitoring) and 2022 SEIS Chap. 3 *Haile.2022 SEIS Chap 3.ACOE 2022b.pdf [22]* (current monitoring)
[558] Designations of baseline monitoring points are identified in the Haile spreadsheet. *Haile.Monitoring data spreadsheet.Feb2025.xlsx*



Haile Figure 3. Haile Gold Mine surface water monitoring and mine facility locations. Locations SW-8 and SW-9, which have some of the highest sulfate concentrations, are highlighted in yellow.
Source: Modified from Figure 4, NewFields, 2016. 2015 Second Semi-Annual Groundwater and Surface Water Monitoring Report. *Haile.2015 Second.NewFields 2016.pdf [15]*

Rather than using the background values reported in the EIS to assess impacts of the current project, ongoing monitoring reports use "upper background concentration limits" or UBCLs.[559] In the absence of complete information on how the UBCLs were calculated, Table 3 uses average values from 2015 to 2018, and Table 4 uses the 50th percentile values from the EIS baseline report (Appendix J) as a median value.[560]

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559 NewFields, 2016. 2015 Second Semi-Annual Groundwater and Surface Water Monitoring Report. *Haile.2015 Second.NewFields 2016.pdf [15]* This report refers to the 2015 First Semi-Annual Report for a more detailed explanation; that report was not provided in response to a public records request.

560 ACOE, nd. Haile Gold Mine EIS App. J, Supporting Information and Analysis for Surface Water Resources. *Haile.App J Surface Water.ACOE nd.pdf* Page numbers are provided in the Haile Spreadsheet. *Haile.Monitoring data spreadsheet.Feb2025.xlsx*

Surface water impacts from the current project were apparent by 2021 (four years after mining began), as shown in Tables 3 and 4. Monitoring points in Tables 3 and 4 are arranged from farthest upstream (SW-18) to farthest downstream (SW-09). Monitoring points SW-18 and SW-19 are in Upper Haile Gold Mine Creek; SW-18 is considered to be upgradient of the mine pits, and SW-19 is downgradient; SW-08 is downstream of the mining area, and SW-09 is about a mile downstream of SW-08 (see Figure 3).

Haile Table 3. Specific Conductance (µS/cm) in Haile Gold Mine Creek.

	SW-18	SW-19	SW-08	SW-09
Average 2015-2018	35	79	79	100
March 2019	21	33	1536	96.7
April 2019	20	32	1930	1600
March 2021	13	23	dry	137
August 2021	24	dry	dry	367

No EIS baseline data are available for specific conductance.
For data sources, see Haile spreadsheet. *Haile.Monitoring data spreadsheet.Feb2025.xlsx*

As reflected in Table 4, the baseline concentrations of manganese at SW-08 and SW-09 are much higher than all other locations at the site. These values may be artifacts of the previous mining project, which was subject to additional reclamation after baseline monitoring was done. What is notable in this table is that levels increased suddenly and substantially from the levels recorded for the first four years of the current mining operation.

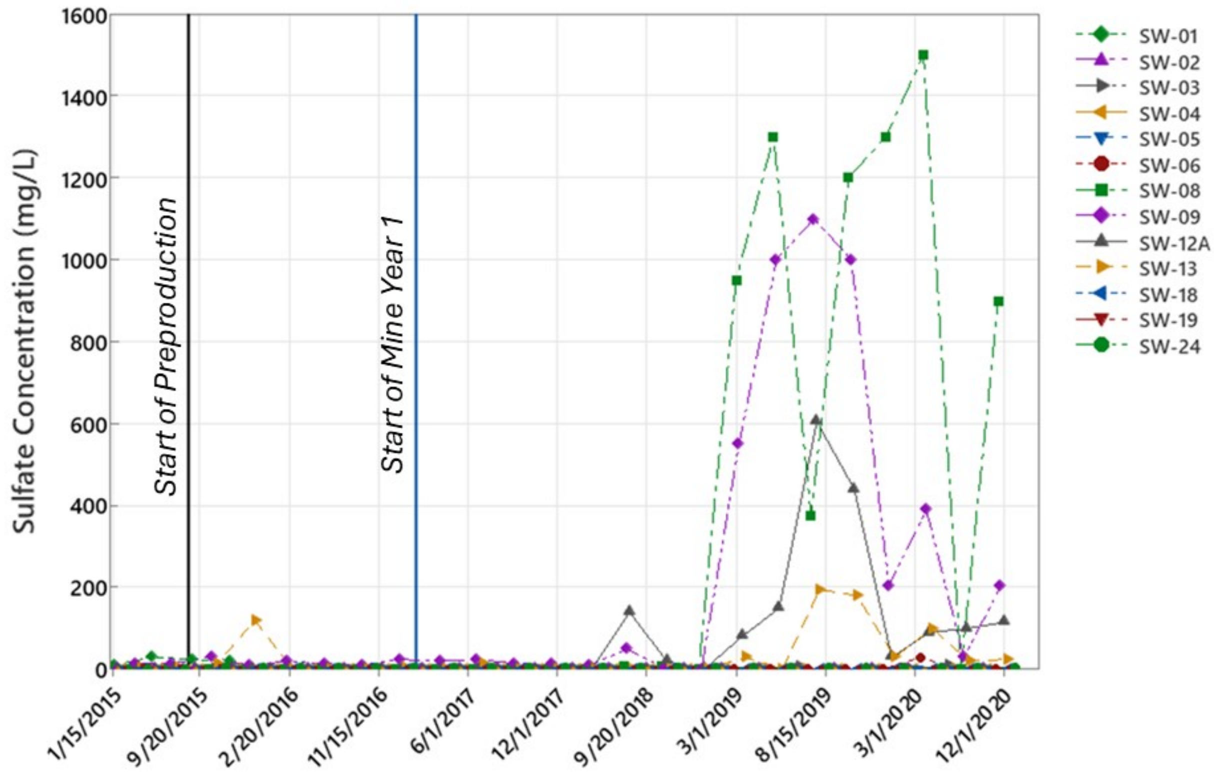
Haile Table 4. Manganese concentrations (µg/l) in Haile Gold Mine Creek.

	SW-18	SW-19	SW-08	SW-09
Baseline median, 2008-2012	10	13	1035	905
Average 2015-18	20	22	230	260
March 2019	27	45	6300	980
August 2021	123	dry	dry	802

Baseline median is the 50th percentile value from data reported in ACOE, nd. Haile Gold Mine EIS App. J, Supporting Information and Analysis for Surface Water Resources. *Haile.App J Surface Water.ACOE nd.pdf [80]*
For 2015-2021 data sources, see Haile spreadsheet. *Haile.Monitoring data spreadsheet.Feb2025.xlsx*

The available sulfate data are particularly sparse. However, the monitoring report for the second half of 2020 includes graphs that illustrate concentration changes over time.[561] In early 2019, sulfate concentrations at SW-08 and SW-09 rose from their 2015 to 2018 averages (of approximately 19 and 27 mg/l respectively) to above 1,000 mg/l, as shown in Figure 4. As of late 2020, sulfate concentrations at SW-08 were above 800 mg/l, and at SW-09 were above 200 mg/l. Sulfate concentrations are also elevated at SW-12A, located immediately downstream of the Haile Gold Mine Creek confluence in Little Lynches River (see Figure 3).

[561] NewFields, 2021a. 2020 Second Semi-Annual Groundwater and Surface Water Monitoring Report. *Haile.2020 Second Semiannual.NewFields 2021a.pdf [110]*]



Haile Figure 4. Sulfate concentrations in surface water monitoring locations, 2015 to 2020. Monitoring locations are shown in Figure 3. Numeric data were not provided in the NewFields 2021a report. Values were determined visually from Figure E-3 in NewFields (2021a) using horizontal and vertical gridlines; data were entered into Minitab and plotted, and data and graph were also saved as an Excel file. Minor errors in concentrations and dates may exist. *Sources:* NewFields, 2021a. 2020 Second Semi-Annual Groundwater and Surface Water Monitoring Report. *Haile.2020 Second Semiannual.NewFields 2021a.pdf [110]. HaileGoldMine_NewFields.Figure.E-3.GraphReproduce_5Mar2025.xlsx.*

The high levels of constituents in Haile Gold Mine Creek in turn impact the Little Lynches River. Again, monitoring points in Tables 5 and 6 are arranged from farthest upstream (SW-04) to farthest downstream (SW-13). Monitoring point SW-04 is upstream of all tributaries draining the mine area; SW-05 is immediately downstream of the confluence with Camp Branch Creek, which drains the tailings facility area; SW-12A is immediately downstream of the Haile Gold Mine Creek confluence; SW-13 is approximately one mile downstream of SW-12A (see Figure 3).

Haile Table 5. Specific Conductance (µS/cm) in Little Lynches River.

	SW-04	SW-05	SW-12A	SW-13
Average 2015-18	46	74	123	83
March 2019	44	64	234	267
April 2019	40	72	336	75
March 2021	36	7	65	95
August 2021	53	99	1046	115

No baseline data are available for specific conductance.
For data sources, see Haile spreadsheet. *Haile.Monitoring data spreadsheet.Feb2025.xlsx*

Haile Table 6. Manganese concentrations (µg/l) in Little Lynches River.

	SW-04	SW-05	SW-12A	SW-13
Baseline median, 2008-2012	76 (SW-15)	90	130	300
Average 2015-18	44	67	167	300
March 2019	60	60	210	240
August 2021	49	71	1090	777

No baseline monitoring was done at the current SW-04; the closest upstream baseline monitoring point is SW-15, approximately one-half mile upstream. The SW-04 that appears in the baseline monitoring data set is at a different location.
Baseline median is the 50th percentile value from data reported in ACOE, nd. Haile Gold Mine EIS App. J, Supporting Information and Analysis for Surface Water Resources. *Haile.App J Surface Water.ACOE nd.pdf [80]*
For 2015-2021 data sources, see Haile spreadsheet. *Haile.Monitoring data spreadsheet.Feb2025.xlsx*

Graphed data indicate that the manganese concentrations at SW-12A ranged from 2000 to 5000 µg/l for the last three quarters of 2019. The maximum manganese level at SW-13 in 2019 was 1800 µg/l.[562] Manganese concentrations increased considerably from upstream to downstream locations in baseline monitoring, indicating that Little Lynches River was already impacted prior to start-up of the current operation. What is most notable is the degree to which manganese levels have risen since the current project began.

Sulfate concentrations had a similar rise at SW-12A (see Figure 4), with values rising from an average of about 10 mg/l as of late 2018 to a maximum of 600 in 2019. As of late 2020, the concentration was about 100 mg/l.

Several metals of concern have water quality criteria that are hardness-dependent. However, hardness is not monitored. This makes it impossible to determine whether water quality criteria are exceeded for arsenic, cadmium, copper, lead, nickel, and zinc. It is likely that the nickel criterion has been exceeded in Haile Gold Mine Creek, however. The baseline hardness at SW-08 ranged from 25 to 83 mg/l.[563] At a hardness of 25 mg/l, the nickel value for chronic toxicity to aquatic life is 16 µg/l; the acute toxicity value is 150 µg/l.[564] In late 2019 and early 2020, nickel concentrations were measured at 150 to 200 µg/l at SW-08.[565] Although the nickel criteria were probably not exceeded in Little Lynches River, nickel concentrations also increased at SW-12A and SW-13 during the same time period; in both locations values were higher than the previously recorded maximum concentration for a year or more.[566]

Water quality changes at the tailings facility site are more difficult to assess. There are no monitoring stations for the headwater creeks draining the site that are truly upstream of all mine facilities; the two most upstream sites may be impacted by borrow pits. Furthermore, no baseline monitoring was done at these locations. Based on the data available, however, there is no indication that the tailings facility was impacting downstream waters as of August 2021.

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[562] NewFields, 2021a. 2020 Second Semi-Annual Groundwater and Surface Water Monitoring Report. *Haile.2020 Second Semiannual.NewFields 2021a.pdf [95, 98]*]
[563] ACOE, nd. Haile Gold Mine EIS App. J, Supporting Information and Analysis for Surface Water Resources. *Haile.App J Surface Water.ACOE nd.pdf [96]*
[564] South Carolina R.61-68. *Haile.SC R 61-68.pdf [40]*
[565] NewFields, 2021a. *Haile.2020 Second Semiannual.NewFields 2021a.pdf [90]*
[566] NewFields, 2021a. *Haile.2020 2nd Semiannual.NewFields 2021a.pdf [96, 99]*

Pollution in Haile Gold Mine Creek and Little Lynches River is likely to continue many years after mining ends. After the pits fill with water, groundwater will flow through them and continue downgradient to the creek and river. TDS concentrations are predicted to be in the range of 1,000 to 1,700 mg/l at the point of discharge to Little Lynches River, declining over a period of seventy-five years to 150 to 350 mg/l. At year ten, the manganese concentration is predicted to be 1 mg/l and the sulfate concentration is predicted to be above 750 mg/l.[567] Groundwater is also likely to be affected by downgradient flow through the backfilled pits.[568]

6. Accuracy of Water Quality Predictions

The Haile Gold Mine EIS did not include quantitative mine-influenced water quality predictions. However, the volume of water that would need to be collected and treated was underestimated. A water balance analysis estimated that by mine year 5, the effluent volume discharged would be 800 gpm, with a peak of 1,600 gpm in wet years.[569] The actual average volume from 2016 to 2021 was 944 gpm, with a maximum of 2,361 gpm.[570] The original treatment plant has thus been unable to handle the volume of water needing treatment.

7. Summary of Water Quality and Quantity Impacts

Groundwater:

- We have insufficient data from Haile to determine the extent of impacts, but constituents in groundwater are increasing in some locations.

Surface water:

- South Carolina's surface water quality criterion for nickel is based on the hardness of the water, but surface water monitoring at the Haile Mine does not include hardness as a parameter. We therefore cannot say for certain what the nickel standard is. However, using the baseline hardness of the receiving water, the nickel criterion was likely exceeded in Haile Gold Mine Creek in late 2019/early 2020.
- Sulfate concentrations in Haile Gold Mine Creek and Little Lynches River increased markedly in 2019, two years after current mining began.

Effluent:

- Thallium exceeded permit limits for six months in 2019-2020. The effluent has repeatedly failed Whole Effluent Toxicity tests from 2021 to the present. Between 2017 and 2022 the effluent also had exceedances of permit limits for mercury, cyanide, cadmium, thallium, and pH.

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[567] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [539-44]*
[568] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [546-47]*
[569] Ecological Resource Consultants, 2010. Haile Gold Mine Site Wide Water Balance Report. *Haile.2010 Water Balance.ERC 2010 [31]*
[570] 2022 NPDES Fact sheet. *Haile.2022 NPDES Fact Sheet.SCDHEC 2022c.pdf [4]*

Accuracy of predictions:

- We do not have a matched set of predictions and monitoring data for any mine feature at the Haile Gold Mine. In terms of predicted volumes requiring treatment, the discharge volume was estimated at 800 gpm, with a 1,600 gpm maximum in wet years. The actual average volume is 944 gpm, with a peak of 2,361 gpm. The original treatment plant was unable to handle the volume of water needing treatment.

8. Comparison to Potential Mines in the Rainy River Headwaters Watershed of Minnesota

Haile is roughly comparable in size to potential Minnesota mining operations. It is located on a similarly wet site; although the South Carolina coastal and Piedmont regions receive more precipitation, Minnesota sites tend to have more wetlands and other surface waters, and groundwater is closer to the surface. The Haile geology is higher in sulfur overall than Duluth Complex rock with a similarly low neutralization capacity; rock at the Haile Gold Mine is more likely to turn acidic. However, Duluth Complex rock may leach higher levels of trace metals under neutral conditions.

9. Post-permitting and Potential Future Expansions

The Haile operation began production in 2017; planning for expansion had begun by 2018.[571] The level of production rose from the 7,000 tons per day assessed in the EIS[572] to 9,000 tons in the third year of production, to 13,000 tons in the fourth.[573] Following the pending expansion, a production rate of 14,400 tons per day is planned.[574] The mine was originally projected to process a total of 41 million tons of ore; that has now risen to 66.5 million tons.[575] The water treatment plant proved inadequate within a few years; the effluent outflow is now increasing from a maximum of 1200 gpm to 2400 gpm.[576]

The original mine plan called for one stockpile of PAG rock.[577] In 2019, a second PAG stockpile was added; two more expansions of PAG stockpiles were approved in 2020 and 2022.[578] The 2014 EIS estimated the total amount of PAG rock in stockpiles and backfill at 109 million tons.[579] That estimate is now 263 million tons.[580]

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[571] Oceana Gold, 2018b. Detailed Project Description for Proposed Haile Gold Mine Expansion (Revision 1). *Haile.2018 Project Description.Oceana 2018b.pdf [11]*
[572] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [67]*
[573] NewFields, 2020a. 2020 Annual Inspection, Duckwood Stage 2 Tailings Storage Facility, Haile Gold Mine. *Haile.2020 TSF Inspection.NewFields 2020a.pdf [6]*
[574] 2022 SEIS Chap. 2. *Haile.2022 SEIS Chap 2.ACOE 2022a.pdf [13]*
[575] 2022 SEIS Chap. 2. *Haile.2022 SEIS Chap 2.ACOE 2022a.pdf [18]*
[576] Civil and Environmental Consultants, 2021. Antidegradation Alternatives Analysis for NPDES Operation Permit Application. *Haile.Antideg.CEC 2021.pdf [11]*
[577] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [123]*
[578] Mine Permit. *Haile.Mine Permit.SCDHEC 2022b.pdf [18]*
[579] 2014 FEIS. *Haile.2014 FEIS.ACOE 2014.pdf [123]*
[580] 2022 SEIS Chap. 3. *Haile.2022 SEIS Chap 3.ACOE 2022b.pdf [7]*

These expansions were approved while the mine was known to be discharging effluent that did not meet permit limits and significantly degrading public waters. The PAG stockpiles were allowed to expand while two PAG pond liners were failing and the rock segregation plan was proving unsuccessful.

Kensington Mine, Alaska

1. Site and Mine Description and Background Information

The Kensington Mine is an underground gold mine located 45 miles north of Juneau, Alaska (Figure 1).[581] It is owned and operated by Coeur Alaska, a subsidiary of Coeur Mining. The mine processes about 2,000 tons of ore per day. Annual production is 730,000 tons of ore and 300,000 tons of waste rock.[582] Surface disturbance as of 2021 was 239 acres, 170 of which are located on the Tongass National Forest.[583] An increase in both surface disturbance and annual production was approved by the U.S. Forest Service and the State of Alaska in 2022.[584,585]

The Kensington project was first proposed in 1990; an Environmental Impact Statement (EIS) was prepared in 1992, but the project was put on hold due to changes in ownership and an evolving mine plan. A supplemental EIS was prepared in 1997. The project as it was then planned received approvals, but again did not move forward. An amended mine plan was proposed, followed by a second supplemental EIS in 2004 (the EIS that pertains to the mine as built).[586] Construction for the current project began in 2005, but was halted by court order. The lawsuit was resolved in 2009, and the project began operations in 2010.[587]

The 2004 EIS does not describe initial excavation of the Kensington Mine, but excavation for exploration purposes began prior to planning for the current project, as discharge from the mine portal in the Sherman Creek watershed has been subject to a discharge permit and has been monitored at least since 1987.[588] The NPDES permit that applies to the project as built was first issued in 1998[589] and was amended for the current operation.[590] In addition, the mine operates pursuant to a state Waste Management Permit[591] and Reclamation Plan Approval.[592]

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[581] USDA Forest Service, 2004. Kensington Gold Project Final Supplemental Environmental Impact Statement, Vol. 1. Hereinafter, "2004 FSEIS." *Kensington.FSEIS Vol 1.USDA 2004.pdf [2, 63]*
[582] USDA Forest Service, 2021. Final Supplemental Environmental Impact Statement, Plan of Operations Amendment 1 for the Kensington Mine. Hereinafter, "2021 FSEIS." *Kensington.FSEIS.USDA 2021.pdf [38]*
[583] 2021 FSEIS. *Kensington.FSEIS.USDA 2021.pdf [8]*
[584] USDA Forest Service, 2022. Supplemental Environmental Impact Statement Plan of Operations Amendment 1 for the Kensington Mine, Final Record of Decision. *Kensington.ROD.USDA 2022.pdf*
[585] Alaska Dept. of Environmental Conservation, 2022. Waste Management Permit for the Kensington Mine, Permit No. 2022DB0001. Hereinafter "Waste Management Permit." *Kensington.WMP.ADEC 2022.pdf*
[586] 2004 FSEIS. The 2004 FSEIS "no action" alternative is the project as approved in 1997, which was never built. *Kensington.FSEIS Vol 1.USDA 2004.pdf*
[587] Coeur Alaska, 2010. Kensington Gold Project 2009 Annual Report. *Kensington.2009 Annual Report.Coeur 2010.pdf [4]*
[588] 2004 FSEIS, *Kensington.FSEIS Vol 1.USDA 2004.pdf [179]*
[589] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [62,71]*
[590] Alaska Dept. of Environmental Conservation (ADEC), 2019. Alaska Pollutant Discharge Elimination System Permit Number AK0050571 Mod. #3. *Kensington.NPDES.ADEC 2019.pdf*
[591] Waste Management Permit. *Kensington.WMP.ADEC 2022.pdf*.
[592] Alaska Dept of Natural Resources, 2022. Kensington Mine Reclamation Plan Approval, No. J20223158RPA. *Kensington.Reclamation Plan Approval. ADNR 2022.pdf*

The Kensington Mine is located in a northern rainforest. Annual precipitation is 63 to 81 inches,[593] and precipitation substantially exceeds evapotranspiration. Of the 197 acres approved for disturbance prior to mining, 96 acres were wetlands.[594]

Three streams drain the site. Slate Creek and Johnson Creek flow south to Berner's Bay of Lynn Canal. Johnson Creek flow as measured in 2000 and 2001 ranged from 7.61 to 96.95 cfs. Average annual flow at the mouth of Slate Creek was calculated for the 2004 EIS as 34 cfs. The flow immediately downstream of the former Lower Slate Lake (the discharge point for treated water from the Kensington Mine) prior to construction of the tailings facility was typically one-half to one-third of the flow at the mouth.

The northern portion of the site drains to Lynn Canal via Sherman Creek. Average annual flow of Sherman Creek about a mile downstream of the mine site was calculated as 43 cfs.[595]

The 2004 EIS indicates that the depth to groundwater in the Sherman Creek watershed is typically less than 20 feet. Hydraulic conductivity is highly variable. According to the EIS, "most groundwater in the project area likely flows through preferential pathways in the glacial till (gravel/sand lenses) and bedrock (fractures/faults)."[596] No investigation of groundwater depth or movement has been undertaken in the Johnson Creek and Slate Creek watersheds.[597]

2. Mine Facilities, Operations, and Reclamation

The Kensington Mine and its attendant facilities stretch over an approximately five-mile line encompassing three watersheds.[598] The original portal to the mine is located in the upper Sherman Creek watershed, along with a waste rock stockpile and two plants that treat mine drainage. The portal lies about 200 feet from a tributary to Sherman Creek.[599] The facilities in the three drainages (Sherman, Johnson, and Slate) are shown in Figure 1.

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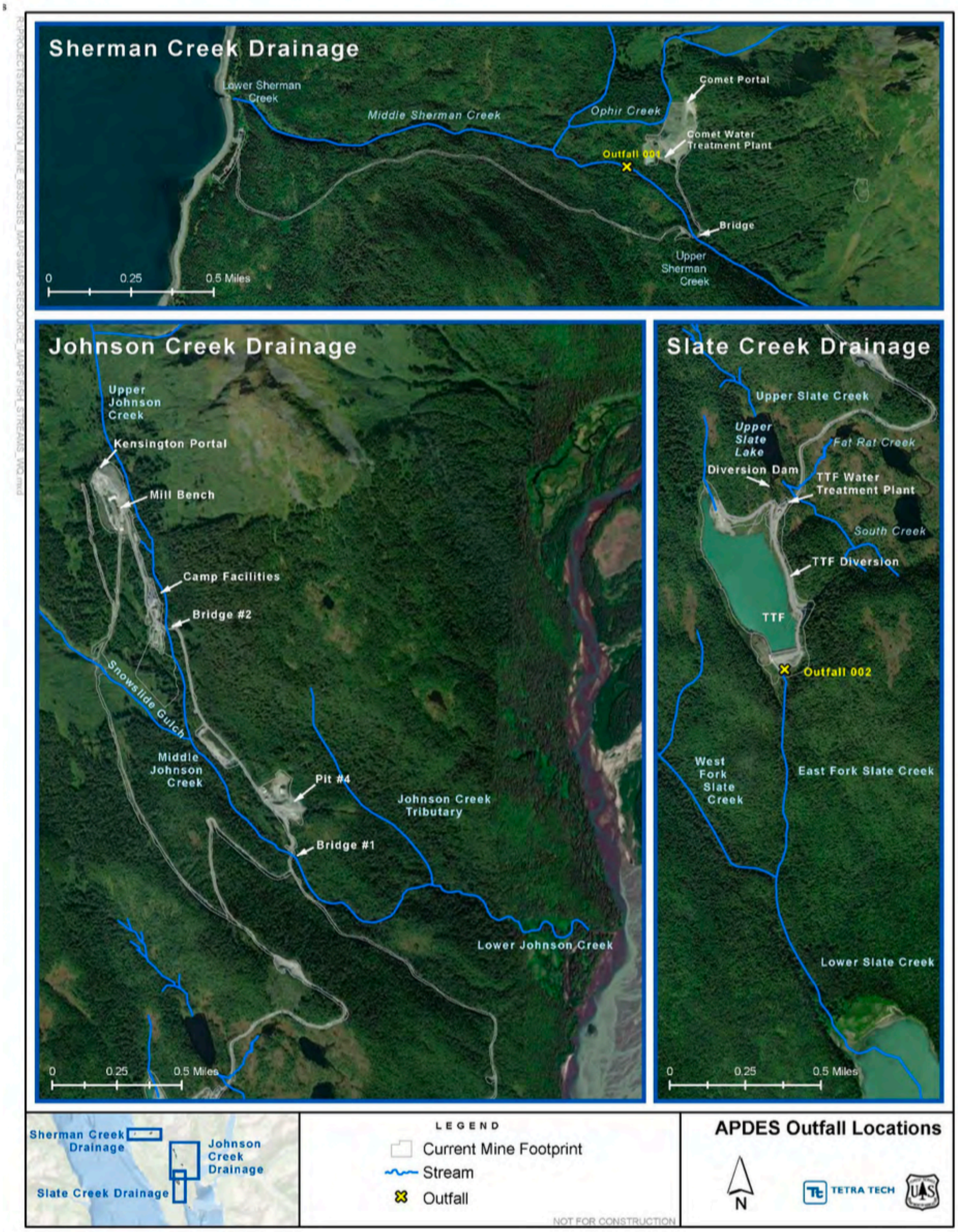
[593] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [168]*
[594] 2004 FSEIS *Kensington.FSEIS Vol 1.USDA 2004.pdf [7]*
[595] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [179-82]*
[596] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [187]*
[597] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [188]*
[598] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [81]* (map)
[599] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [84]*



Kensington Figure 1. Locations of Kensington Mine facilities in three drainages.
Source: USDA Forest Service, 2021. Final Supplemental Environmental Impact Statement, Plan of Operations Amendment 1 for the Kensington Mine. *Kensington.FSEIS.USDA 2021.pdf [128]*

About three miles to the southeast, the "Jualin Area" is located on Johnson Creek and holds a second portal to the mine, the ore crusher, coarse ore stockpile, mill and associated ponds, and a smaller waste rock stockpile. Mine facilities are 100 to 500 feet from Johnson Creek, with an infiltration gallery for wastewater disposal immediately adjacent to the creek.[600]

Farther south, the Slate Creek watershed holds the tailings facility, which has replaced a former instream lake (Lower Slate Lake). Excess water is treated using coagulation and flocculation, pH modification, clarification, and filtrations including through carbon filters.[601] The effluent is discharged at Outfall 002, where East Slate Creek now resumes below the toe of the tailings dam.[602] The area also contains storage for acid-producing rock that was excavated in construction of the tailings facility and other facilities.[603]

In addition, the project includes a marine terminal in Berner's Bay to the south of the mine.[604] The terminal and impacts it may have on marine life are outside the scope of this report.

Mine discharge water is pumped from the mine via the northern portal and is treated by chemical precipitation, clarification, and filtration. Treated mine water discharges to sedimentation ponds along with runoff collected from a waste rock stockpile.[605] Outfall 001, which is regulated by the mine's NPDES permit, discharges water from the sedimentation ponds to Sherman Creek. Mine discharge flow was predicted to average 450 to 1,800 gallons per minute (gpm),[606] which was accurate.[607] However, the maximum permitted flow of 3,000 gpm has proven insufficient. The current expansion plan calls for an increase in the permit limit to 4,500 gpm.[608]

Ore leaves the mine by the south portal in the Jualin area, where the mill is located. Sixty percent of the Kensington mill tailings are placed in permanent storage in a tailings facility, with the other forty percent returned to the mine workings as backfill.[609] Tailings are transported from the mill in a slurry by pipeline.[610] To maintain a safe water level in the impoundment, excess water is pumped to a reverse osmosis treatment plant and then discharged to East Slate Creek. The EIS was accurate in its estimated discharge of 960 to 1100 gpm.[611,612]

The waste management permit requires that all seepage from the tailings dam be captured and directed to the treatment plant.[613] However, the tailings impoundment is unlined and no groundwater

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600 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [85, 98]*
601 ADEC, 2017. Alaska Pollutant Discharge Elimination System Permit Fact Sheet -- Final. Figure 3. *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [8]* Hereinafter, "2017 NPDES Permit Fact Sheet."
602 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [92]*
603 2021 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [42]*
604 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [87]*
605 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [106-107, 296]*
606 2004 FSEIS *Kensington.FSEIS Vol 1.USDA 2004.pdf [54]*
607 U.S. EPA, n.d. NPDES Monitoring Data Download, Facility ID: AK0050571. Downloaded from https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download on April 18, 2024. *Kensington.NPDES Spreadsheet.xlsx* Hereinafter, "NPDES Spreadsheet."
608 ADEC 2023. APDES Inspection Report. *Kensington.Inspection Report.ADEC 2023.pdf [3]*
609 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [104]*
610 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [4]*
611 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [104]*
612 NPDES Spreadsheet. *Kensington.NPDES Spreadsheet.xlsx [data set beginning on line 2463]*
613 Waste Management Permit. *Kensington.WMP.ADEC 2022.pdf [7-8]*

monitoring is conducted, so the degree to which tailings seepage water is discharging to groundwater is unknown.

Two unlined waste rock stockpiles of 31 acres and 4.8 acres[614] were originally planned to hold non-potentially acid producing rock. Leachate and runoff from these waste piles infiltrate to shallow groundwater, either directly or by way of sedimentation ponds that collect runoff.[615] Discharges to surface waters are permitted under the Alaska general industrial stormwater permit.[616] The permit provides "benchmark" values for a number of pollutants, which are set at the applicable water quality standard for the receiving water. Monitoring is required only when there is a discernable surface discharge at an identified outfall, which apparently happens at only one of the five outfalls.[617]

In addition, construction of the tailings facility resulted in unanticipated excavation of acid-producing rock, and temporary storage areas were constructed for use until this material could be backfilled to the mine.[618] (See *Section 4.2*) An acid rock drainage (ARD) containment pond, treatment plant, and infiltration gallery were also added.[619]

3. Geochemistry

Static and kinetic testing in the 1990s determined that waste rock and tailings would not be acid producing; ore was considered to have very low potential for acid generation.[620] However, in 2013 the bright orange water typical of ARD was noticed flowing from disturbed rock in the tailings facility area.[621] The ARD, which had a pH of 2.5 to 3.5, stemmed from graphitic phyllite waste rock that was excavated during construction of the dam. In addition, graphitic phyllite rock with acid generation potential was excavated from an area known as "Pit 4" for use in road and stormwater conveyance construction.[622] This rock had not been characterized prior to permitting and was not expected to be acid generating.[623]

Acid-base accounting results for development rock (waste rock) and tailings for 2013 through 2022 samples are summarized in Coeur Alaska's 2022 4th Quarter monitoring report.[624] Total sulfur values were consistently low, with a maximum of 0.25 wt % in development rock and 0.54 wt % in tailings. Neutralization potential was many times higher than acid production potential, indicating a low potential to generate acid drainage. Graphitic phyllite waste rock, which is acid generating and occurs in the tailings facility area, was not included in any of these samples.

[614] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [95]*
[615] 2021 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [64]*
[616] ADEC, 2020. Authorization to Discharge Under the Multi-Sector General Permit for Storm Water Discharges Associated With Industrial Activity, No. AKR06AA50. *Kensington.Stormwater permit.ADEC 2020.pdf*
[617] U.S. EPA, n.d. NPDES Monitoring Data Download, Facility ID: AKR06AA50. Downloaded from https://echo.epa.gov/trends/loading-tool/get-data/monitoring-data-download on April 18, 2024. *Kensington.NPDES Stormwater Spreadsheet.xlsx* Hereinafter, "NPDES Stormwater Spreadsheet."
[618] Couer Alaska, 2014. Kensington Gold Project 2013 Annual Report. *Kensington.2013 Annual Report.Coer 2014.pdf [9]*
[619] ADEC, 2013. Notice of Violation. *Kensington.NOV.ADEC 2013.pdf [4]*
[620] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [170 et seq.]*
[621] ADEC, 2013. Notice of Violation. *Kensington.NOV.ADEC 2013.pdf [6]*
[622] Waste Management Permit. *Kensington.WMP.ADEC 2022.pdf [7]*
[623] ADEC, 2013. Notice of Violation. *Kensington.NOV.ADEC 2013.*pdf *[2]*
[624] Coeur Alaska, 2022. Kensington Mine Waste Management Permit No. 2013DB0002 4th Quarter 2022 Report. *Kensington.2022 4th Quarter.Coeur Alaska 2022.pdf [16,18]*

4. Mine-Influenced Water Quality

4.1 Mine Inflow Water Quality

Mine water inflowing to the water treatment plant has been monitored since 2013. Many concentrations peaked in spring 2013, likely from snowmelt runoff and infiltration, including nickel, manganese, hardness, iron (38.5 mg/l), aluminum (21,000 µg/l), turbidity, sulfate (617 mg/l), nitrate (6.76 mg/l as N), and ammonia (1.98 mg/l).[625] The timing coincides with the acidic seeps at the tailings impoundment area (see *Section 4.2*), but the inflow water did not have an acidic pH at that time. However, concentrations were higher in spring 2013 than in spring of other years.

4.2 Waste Rock Leachate Water Quality

Water quality of the ARD from waste rock above the tailings facility (shown in Figure 2) is compared to water quality standards in Table 1. This acid-generating rock is not part of the mine area excavation but was disturbed to create the tailings impoundment.

Kensington Table 1. Maximum metal concentrations in Kensington Mine waste rock seeps at the north end of the tailings facility, May 18, 2013. The reported pH ranged from 2.5 to 3.5 SU.

Parameter	Maximum concentration (µg/l)	Water quality standard (µg/l)
Aluminum (total)	180,000	87
Cadmium (dissolved)	3,070	0.09
Chromium (total)	624	100
Copper (dissolved)	16,000	2.74
Iron (total)	1,740,000	1,000
Manganese (total)	96,200	50
Nickel (dissolved)	17,500	16.10
Zinc (dissolved)	225,000	36.5

Source: ADEC, 2013. Notice of Violation. *Kensington.NOV.ADEC 2013.pdf [3]*

Although efforts are being made to isolate and treat the waste rock and runoff water, those efforts have not been entirely successful. It is unclear to what extent this water discharges to ground or surface water.[626] According to an enforcement consent decree, "During the winter of 2017-2018, the water elevation in the tailings treatment facility rose such that the ARD collection system became inundated and could not be operated, and [the company] could not collect the ARD as required by the remediation plan."[627]

[625] Coeur Alaska, 2022. Kensington Mine Waste Management Permit No. 2013DB0002 4th Quarter 2022 Report. *Kensington.2022 4th Quarter.Coeur Alaska 2022.pdf [2-4]*
[626] HDR, 2018. Kensington Mine 2017 Environmental Audit. *Kensington.2017 Audit.HDR 2018.pdf [19]*
[627] U.S. EPA, 2019. Docket No. CWA-10-2019-0101 Consent Decree. *Kensington.Consent Decree.EPA 2019 [12]*

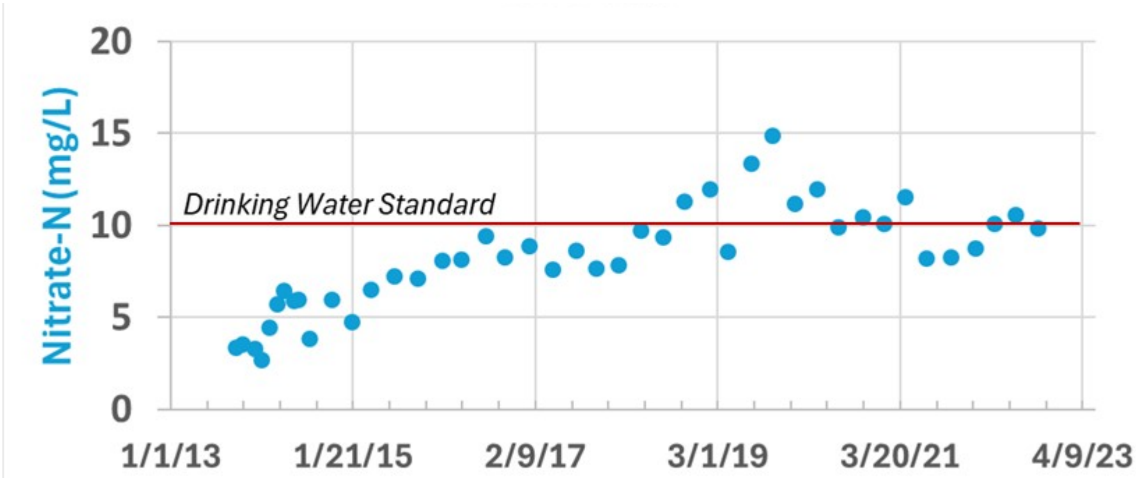
Kensington Figure 2. Acidic waste rock seeps flowing into the tailings facility, 2013. See Table 1 for water quality results. *Source:* ADEC, 2013. Notice of Violation. *Kensington.NOV.ADEC 2013.pdf [6]*

4.3 Tailings Water Quality

Tailings dam seepage is elevated in several constituents. These include total dissolved solids (TDS) (often above 1,000 mg/l), sulfate (often above 500 mg/l), aluminum (often above 1,000 µg/l), and manganese (generally above 200 µg/l). Other constituents are occasionally present at high levels, including copper, iron, nickel, and zinc.[628]

The tailings facility supernatant pond water has elevated concentrations of ammonia (up to 5.4 mg/l as N), sulfate (up to 542 mg/l), manganese (up to 255 µg/l), and nitrate (up to 14.9 mg/l as N). Nitrate concentrations have been rising over time in the tailings water, and for comparison, have reached values higher than the drinking water standard of 10 mg/l as N, as shown in Figure 3.

[628] Coeur Alaska, 2022. Kensington Mine Waste Management Permit No. 2013DB0002 4th Quarter 2022 Report. *Kensington.2022 4th Quarter.Coeur Alaska 2022.pdf [4-7]*



Kensington Figure 3. Concentrations of nitrate in the tailings pond from 2013 to 2022, compared to the drinking water standard (10 mg/l as N). *Data source:* Coeur Alaska, 2022. Kensington Mine Waste Management Permit No. 2013DB0002 4th Quarter 2022 Report, Table 1. *Kensington.2022 4th Quarter.Coeur Alaska 2022.pdf*

4.4 Effluent and Stormwater Quality

Discharges of pollutants at problematic levels began during construction, when sediment and debris entered the creeks during a heavy rainfall in 2005.[629,630] Between 2006 and start-up in 2010, construction also resulted in unanticipated excavation of acid-producing rock, which according to a U.S. EPA enforcement report resulted in "unpermitted discharge of acid rock drainage and sediment into Lower Slate Lake. The discharges were high in metals and entered East Fork Slate Creek."[631]

Effluent discharges have also exceeded permit limits many times since operations began.[632,633,634,635,636] Discharge from Outfall 002 has periodically exceeded permit limits for TDS, total suspended solids, sulfate, pH, aluminum, cadmium, manganese, iron, and whole effluent toxicity.[637,638] In its announcement of a 2019 enforcement action settlement wherein the company agreed to pay $240,000 in fines for NPDES violations, the U.S. EPA noted that the action had covered more than two hundred wastewater discharge violations.[639] Parameters with violations cited in that action included pH, copper, ammonia, sulfate, turbidity, manganese, and toxicity.[640]

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[629] U.S. EPA, 2006. Civil Enforcement Case Report No. 10-2006-0306. *Kensington.Case Report.USEPA 2006.pdf*
[630] North of 60 Mining News 2007. EPA resolves violations with mining firm on SE Alaska Kensington Mine. *Kensington.North of 60 Mining News 2007.pdf*
[631] U.S. EPA, 2010. Civil Enforcement Case Report No. 10-2011-0018. *Kensington.Case Report.USEPA 2010.pdf*
[632] NPDES Spreadsheet. *Kensington.NPDES Spreadsheet.xlsx [data set beginning on line 2463]*
[633] ADEC, 2017. Compliance letter. *Kensington.Compliance Letter.ADEC 2017.pdf*
[634] ADEC, 2019. Notice of Violation. *Kensington.NOV.ADEC 2019.pdf*
[635] ADEC, 2021. Notice of Violation. *Kensington.NOV.ADEC 2021.pdf*
[636] ADEC, 2023. Notice of Violation. *Kensington.NOV.ADEC 2023.pdf*
[637] NPDES Spreadsheet. *Kensington.NPDES Spreadsheet.xlsx [data set beginning on line 2463]*
[638] 2017 NPDES Permit Fact Sheet. *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [11-12]*
[639] U.S. EPA, 2019. Press Release: EPA and Coeur Alaska Settle Over Alleged Kensington Mine Pollution Discharges. *Kensington.EPA Press Release.USEPA 2019 [2]*
[640] 2017 NPDES Permit Fact Sheet. *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [9-10]*

The relaxation of permit limits for some constituents in 2017 has obviated exceedances.[641] For example, the daily maximum total ammonia permit limit for Outfall 001 was raised from 4 to 9 mg/l as N; discharge now often exceeds the former limit.[642] Also, a site-specific TDS standard of 1,000 mg/l was approved in 1997 for the Sherman Creek watershed;[643] the statewide standard is 500 mg/l, which the Outfall 001 discharge occasionally exceeds.[644]

Leachate and runoff from waste rock stockpiles are not covered by the facility-specific NPDES permit, but instead by the Alaska general industrial stormwater permit.[645] This water infiltrates to shallow groundwater, either directly or by way of sedimentation ponds that collect runoff.[646] The general permit provides "benchmark" values for a number of pollutants, which are set at the applicable water quality standard for the receiving water. Monitoring is required only when there is a discernable surface discharge at an identified outfall, which apparently happens at only at Outfall 018 on Ophir Creek, a tributary of Sherman Creek. Because no other monitoring of leachate or runoff from the waste rock stockpiles is required, the quality of waste rock drainage discharged through groundwater is unknown, though monitoring data from Outfall 018 offers a point of reference. At that outfall, zinc has exceeded the benchmark in all but one monitoring event since September 2021; in December 2023, the zinc concentration exceeded the acute water quality standard by an order of magnitude.[647,648] Since June 2023, cadmium has consistently exceeded the benchmark; copper and iron have individual exceedances. Comprehensive data from before September 2021 are not available, but the operation was cited for several turbidity exceedances in 2019-20.[649]

5. Impacts on Groundwater and Surface Water Quality

5.1 Groundwater Quality Impacts

Impacts on groundwater at the Kensington Mine are unknown; baseline monitoring was extremely limited, and no groundwater monitoring is required during operations. "Baseline"[650] monitoring in the Sherman Creek watershed conducted between 1989 and 2004 exhibited extreme variations in water quality.[651] No baseline groundwater monitoring was done in the other two watersheds, including the area under and downgradient of the tailings facility.[652]

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641 2017 NPDES Permit Fact Sheet. *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [14-17]*
642 Coeur Alaska, 2023. Kensington Mine Annual Meeting for 2022. *Kensington.Annual meeting.Coeur Alaska 2023.pdf [89]*
643 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [295]*
644 NPDES Spreadsheet. *Kensington.NPDES Spreadsheet.xlsx [data set beginning on line 7]*
645 ADEC, 2020. Authorization to Discharge Under the Multi-Sector General Permit for Storm Water Discharges Associated With Industrial Activity, No. AKR06AA50. *Kensington.Stormwater permit.ADEC 2020.pdf*
646 2021 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [64]*
647 NPDES Stormwater Spreadsheet. *Kensington.NPDES Stormwater Spreadsheet.xlsx [lines 270 to 304]*
648 Applicable water quality standards are found in 2017 NPDES Permit Fact Sheet. *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [43]*
649 ADEC, 2020. APDES Inspection Report. *Kensington.Inspeciton Report.ADEC 2020.pdf [4]*
650 Groundwater was likely already impacted by discharge from the mine portal and waste rock stockpile by 1989.
651 USDA Forest Service, 2004. Kensington Gold Project Final Supplemental Environmental Impact Statement, Vol. 2. *Kensington.FSEIS Vol 2.USDA 2004.pdf [416-431]*
652 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [189]*

It is likely that groundwater has been impacted, as the unlined waste rock stockpiles and tailings facility allow mine-influenced leachate to enter groundwater.[653] The quality of this runoff and leachate is unmonitored, however, as noted in *Section 4.3*, seepage through the tailings dam is elevated in many constituents, including sulfate, cadmium, copper, manganese, nickel, and zinc.

An environmental audit conducted in 2017 found that although graphitic phyllite material excavated for the tailings dam (*see Section 4.3*) had been removed to the underground mine, exposed graphitic phyllite remained on the surface and had not been properly remediated; seepage from this area may report to the tailings dam seepage sump or find a preferential pathway to shallow groundwater and the Slate Creek drainage.[654]

5.2 Surface Water Quality Impacts

Four streams at the Kensington Mine have the potential to be impacted by mine facilities: Sherman Creek and its tributary, Ophir Creek; Johnson Creek; and Slate Creek. All four streams have been degraded from natural conditions, with increased levels of dissolved solids, sulfate, and nitrate.

5.2.1 Sherman Creek Watershed

Baseline surface water quality was monitored in the Sherman Creek watershed between 1987 and 1995. The location of monitoring stations are shown in Figure 4. Data are available for five stations (SH-102, -103, -105, -109, and -110), plus one station in an adjacent watershed.[655] However, the exploratory mine adit was already discharging at that time, so results from stations impacted by adit water do not provide a true baseline. The largest impact in this watershed is to Ophir Creek, which receives runoff and leachate from the mine portal area and waste rock stockpile.

In light of the lack of true baseline data, we compared water quality monitoring results between an unimpacted upstream monitoring station (SH-111) and the most heavily impacted station (SH-103), which is downstream of the portal and the development rock stockpile. The increase is commonly tenfold for TDS, fiftyfold for sulfate, and twentyfold for nitrate. Mean sulfate concentrations are shown in Figure 5a. The natural background TDS concentration is about 23 mg/l;[656] the creek now periodically exceeds the site-specific 1,000 mg/l TDS water quality standard, with a maximum measurement of 1630 mg/l in 2017. Maximum sulfate concentrations exceed the 200 mg/l sulfate standard every year (Figure 5b).[657]

Mean and maximum nitrate concentrations are shown in Figures 6a and b. Maximum nitrate concentrations exceeded the 10 mg/l as N standard every year from 2016 through 2019, with a maximum measurement of 110 mg/l in 2017 (Figure 6b). The 2017 annual mean of 25 mg/l also exceeded the standard.[658]

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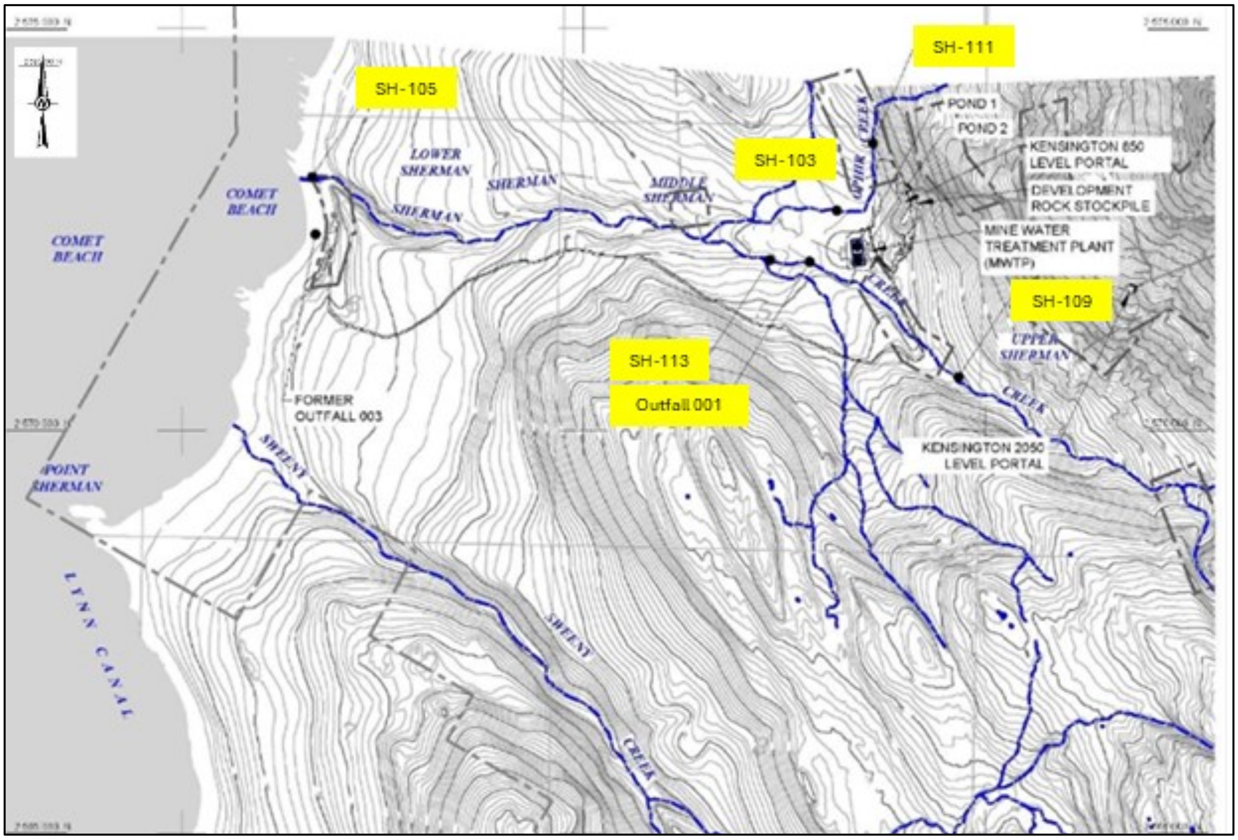
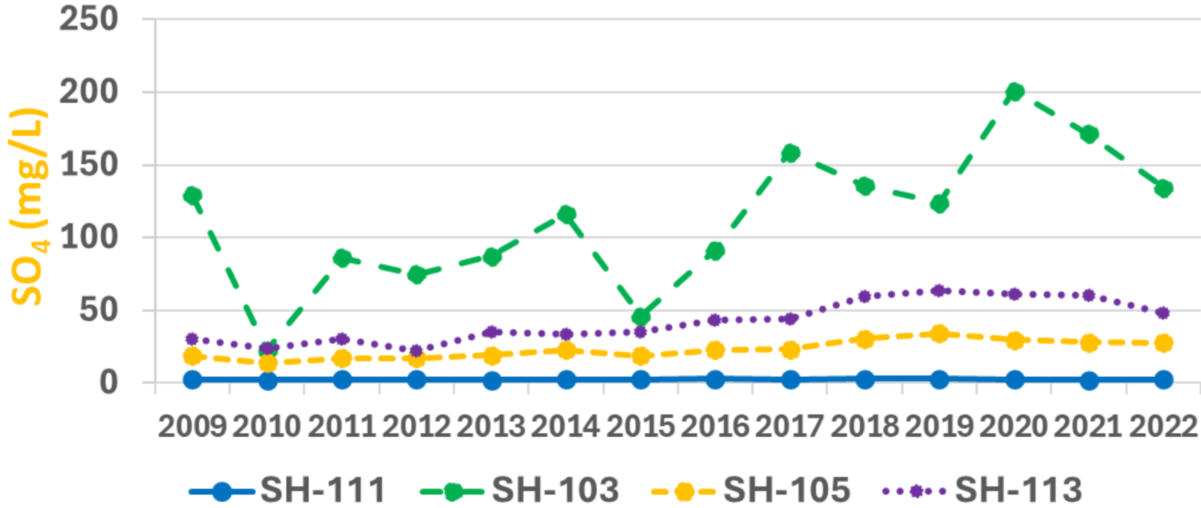
[653] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [307-308]*
[654] HDR, 2018. Kensington Mine 2017 Environmental Audit. Kensington.2017 Audit.HDR 2018.pdf [19]
[655] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [183]*
[656] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [185]*
[657] *Kensington.Surface water spreadsheet.Feb2025.xlsx* and data sources cited therein.
[658] *Kensington.Surface water spreadsheet.Feb2025.xlsx* and data sources cited therein.



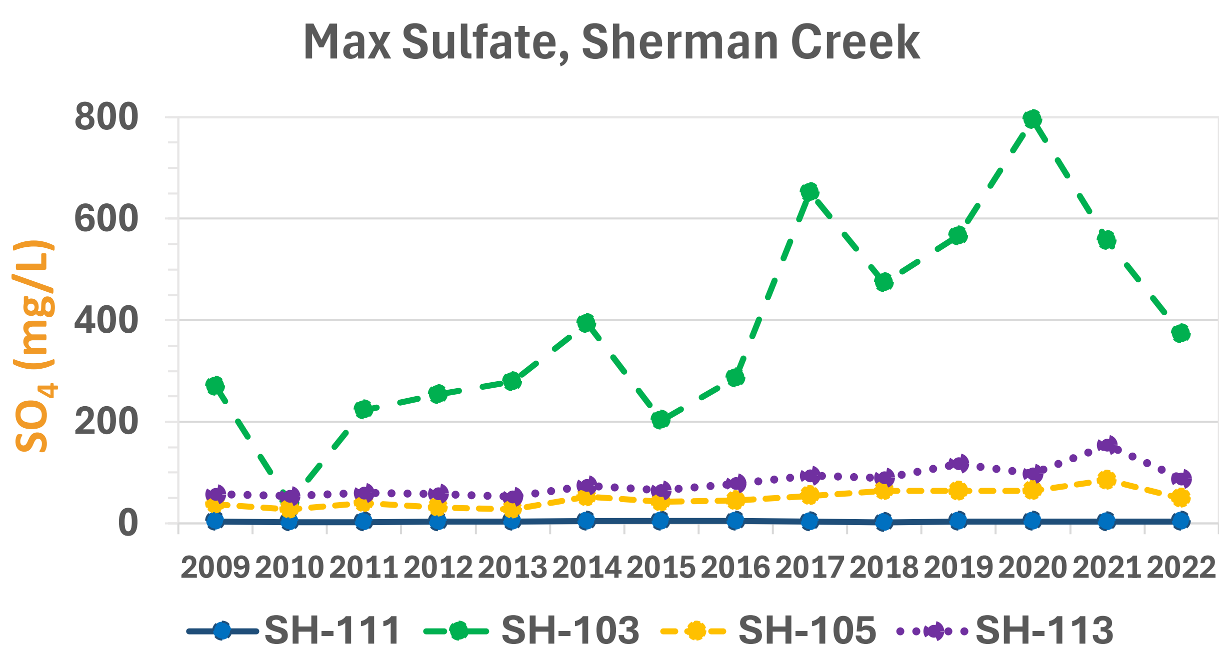
Kensington Figure 4. Sherman and Ophir Creek monitoring locations. Surface water and Outfall 001 locations are highlighted in yellow. *Source:* Modified from ADEC, 2017. Alaska Pollutant Discharge Elimination System Permit Fact Sheet -- Final (Figure 2). *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [37].*

Contributing to the same system, upper Sherman Creek receives discharge from NPDES Outfall 001, which consists of treated mine water mixed with runoff from the waste rock stockpile. Water quality just downstream of the outfall (and upstream of the inflow discussed above from Ophir Creek) shows an approximately threefold increase in TDS (over both baseline and the upstream location), a sixfold increase in sulfate, and a sixteen-fold increase in nitrate.[659]

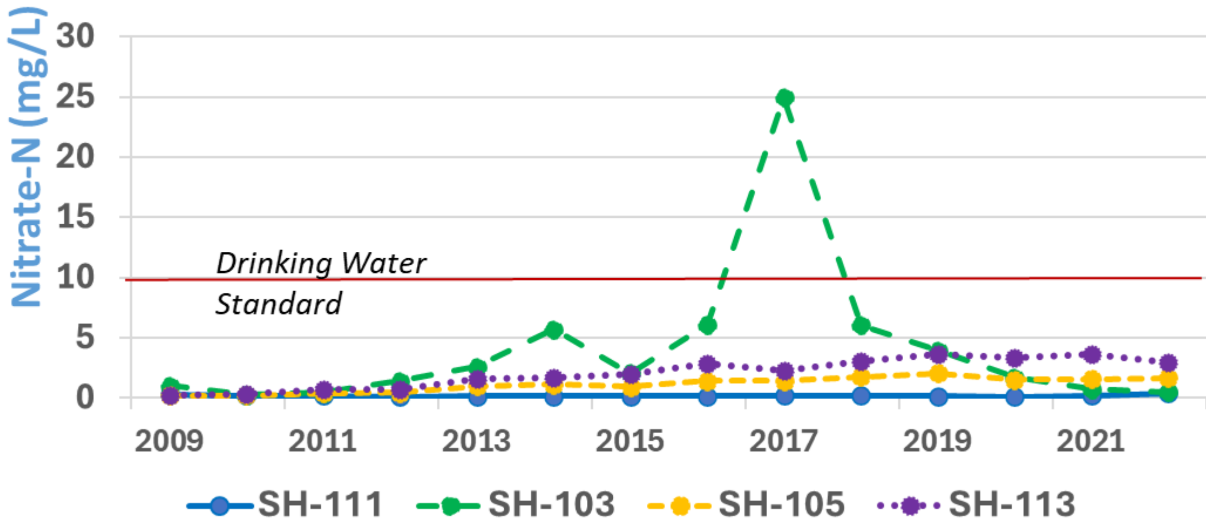
[659] Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx*



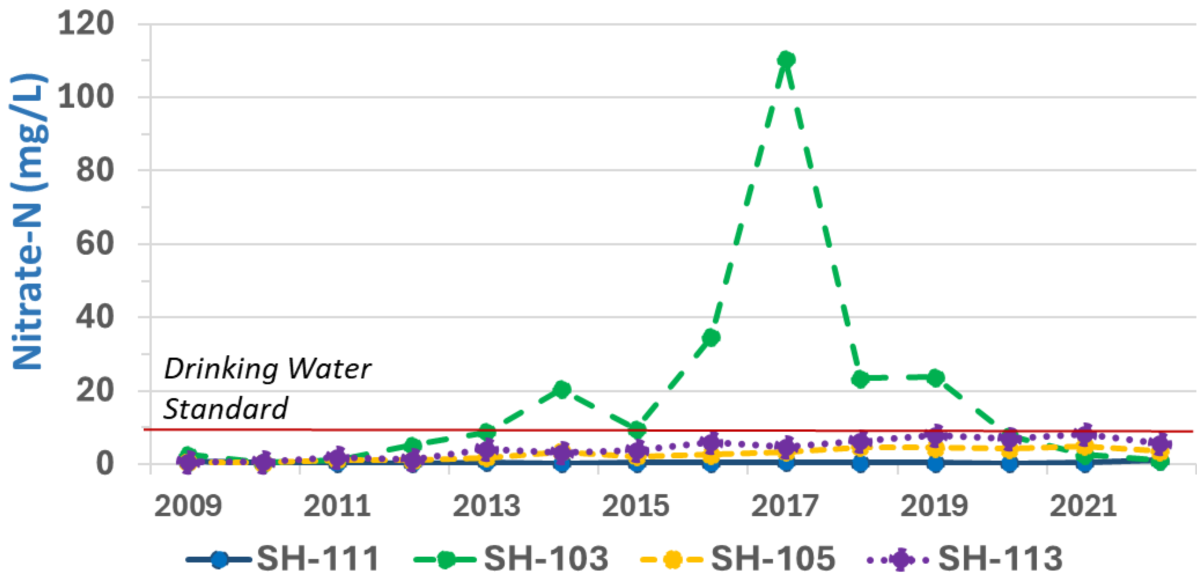
Kensington Figure 5a. Mean sulfate concentrations in the Sherman Creek watershed, 2009 to 2022. SH-111 is an unimpacted location in Ophir Creek, a tributary of Sherman Creek. *Data source:* Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx*



Kensington Figure 5b. Maximum sulfate concentrations in the Sherman Creek watershed, 2009 to 2022. SH-111 is an unimpacted location in Ophir Creek, a tributary of Sherman Creek.
Data source: Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx*



Kensington Figure 6a. Mean nitrate concentrations in the Sherman Creek watershed, 2009 to 2022, compared to the drinking water standard. SH-111 is an unimpacted location in Ophir Creek, a tributary of Sherman Creek. *Data source:* Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx*



Kensington Figure 6b. Maximum nitrate concentrations in the Sherman Creek watershed, 2009 to 2022, compared to the drinking water standard. SH-111 is an unimpacted location in Ophir Creek, a tributary of Sherman Creek. *Data source:* Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx*

The final monitoring point in this watershed is at the mouth of Sherman Creek (SH-105) which is impacted by both of the pollution sources described above. Again, there are no true baseline data, but TDS and nitrate levels have increased since the current operation began. (Sulfate was not included in baseline monitoring.) As lower Sherman Creek is a salmon stream, there is concern that TDS levels above 250 mg/l may affect spawning;[660] that level is occasionally exceeded.[661]

Mean annual sulfate concentrations in Ophir and Sherman creeks are compared to values in an unimpacted location in Ophir Creek in Table 2. The results show that concentrations in the locations downstream of mine sources have increased over time.

Kensington Table 2. Mean annual sulfate concentrations (mg/l) in Ophir Creek and Sherman Creek.

Year	SH-111, upper Ophir Creek (unimpacted)	SH-103, Ophir Creek downstream of mine adit and waste rock stockpile	SH-113, Sherman Creek upstream of Ophir confluence and downstream of Outfall 001	SH-105, mouth of Sherman Creek, ~5 miles downstream of mine discharges
2010	2.11	22.3	24.3	13.8
2012	2.69	74.7	22.5	17.3
2014	2.63	116	33.9	23.1
2016	2.84	91.5	43.4	22.9
2018	2.94	136	59.4	30.4
2020	2.54	201	61.6	29.9
2022	2.5	134	48.5	27.7

Sources: Kensington annual reports, 2010-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx.*

In addition, according to the 2017 NPDES Fact Sheet:

> A white residue in the Sherman Creek substrate sporadically occurs originating from Outfall 001 and ending near the mouth of the creek. An [Alaska Department of Fish and Game] biomonitoring study of Sherman Creek conducted in 2015 observed a lower abundance of sensitive taxa and lower proportions of sensitive aquatic insects in Lower Sherman Creek benthic macroinvertebrate samples in comparison to the previous year, which suggests that the residue may have a detrimental effect on the macroinvertebrate population.[662]

The NPDES permit includes a compliance schedule to determine the cause of the residue and modify the treatment system if necessary.

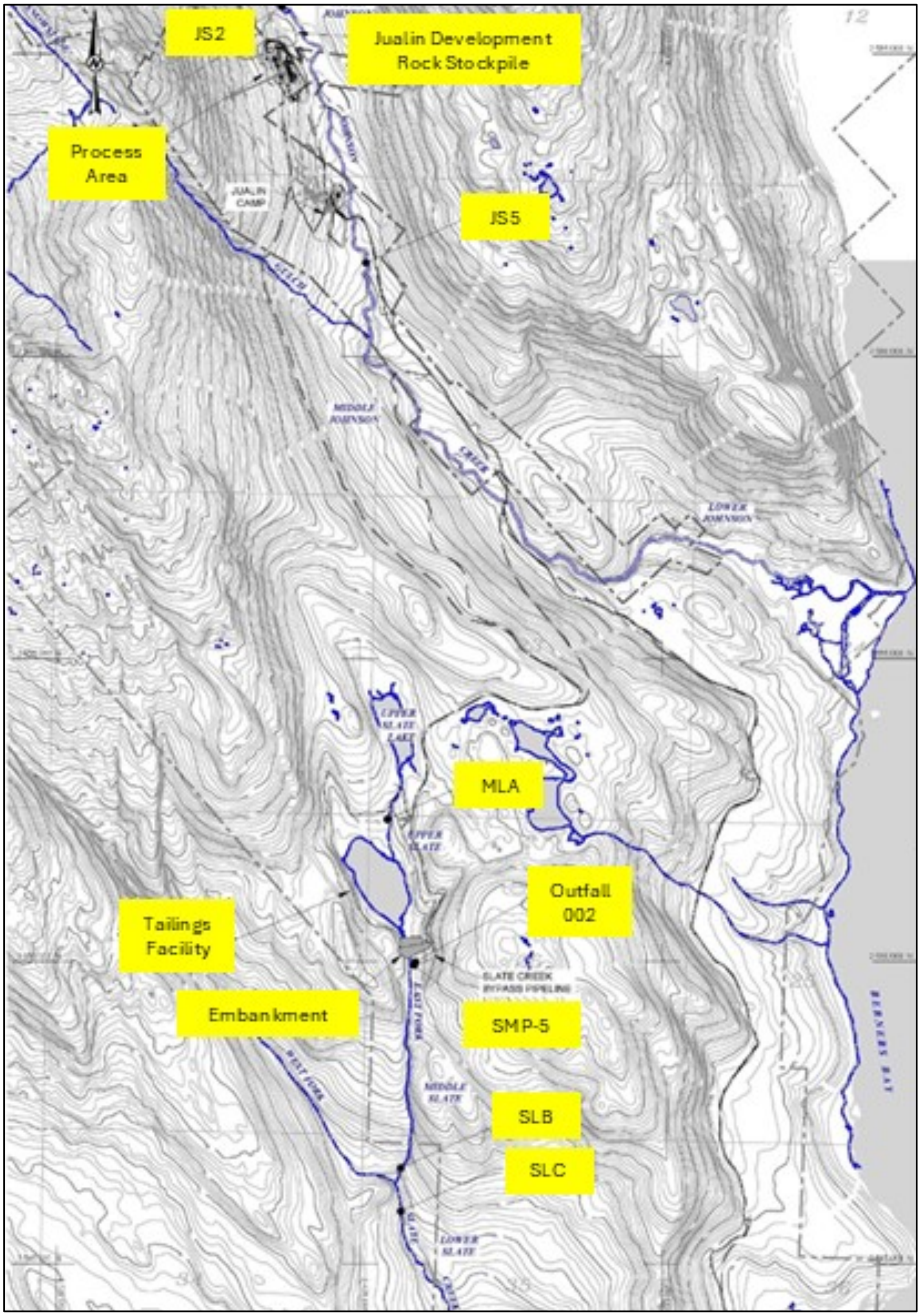
The Ophir and Sherman Creek discharges are predicted to continue after the mine has closed, likely in perpetuity. The plan to stop treating this water when it meets water quality standards means that these streams could be degraded for the long term, perhaps permanently, from their natural quality.

5.2.2 Johnson and Slate Creek Watersheds

The monitoring locations on Johnson Creek and Slate Creek are shown in Figure 7. As noted in *Section 2*, Johnson Creek includes mine facilities within 100 to 500 feet from the creek, including a second mine portal, the ore crusher, coarse ore stockpile, mill and associated ponds, and a smaller waste

[660] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [295]*
[661] Coeur Alaska, 2023. *Kensington.2022 Annual Report.Coeur Alaska 2023.pdf [233]*
[662] 2017 NPDES Permit Fact Sheet. *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [32]*

rock stockpile. A wastewater infiltration gallery is immediately adjacent to the creek. The Slate creek watershed includes the tailings facility and Outfall 002.



Kensington Figure 7. Johnson and Slate Creek and Outfall 002 locations. Surface water monitoring, Outfall 002, tailings, process area, and stockpile area locations are highlighted in yellow. MLA is a background location. *Source:* Modified from ADEC, 2017. Alaska Pollutant Discharge Elimination System Permit Fact Sheet -- Final (Figure 3). *Kensington.NPDES Fact Sheet.ADEC 2017.pdf [38]*

According to the 2004 EIS, baseline monitoring of Johnson Creek was conducted from 1995 to 1998.[663] The EIS provides the range of baseline data but does not reveal the number of monitoring events or average values. Baseline TDS ranged from <20 to 96 mg/l; sulfate ranged from <2 to 7.8 mg/l; and nitrate ranged from <0.1 to 0.8 mg/l. Sulfate and nitrate concentrations have both increased. Maximum baseline sulfate concentrations were similar in the upstream and downstream locations (5.8 and 7.8 mg/l, respectively). Maximum measurements at the upstream location, MLA, have remained below baseline and are generally in the 2-3 mg/l range. Maximum sulfate concentrations downstream of the mine are in the 10-25 mg/l range. The maximum upstream baseline nitrate concentration was 0.8 mg/l, and the downstream concentration was 0.5 mg/l. Maximum concentrations at the upstream location during mine operations have consistently been less than 0.8 mg/l, generally in the 0.2-0.6 mg/l range. Maximum concentrations downstream of the mine have been in the 0.8 to 1.8 range since 2012. Maximum TDS measurements have remained approximately the same.[664]

Johnson Creek was also recently impacted by a tailings spill. On January 31, 2024, a tailings pipeline rupture spilled 105,581 gallons of tailings slurry, an unknown quantity of which entered the creek.[665] Water quality at the monitoring point about a half mile downstream of the spill exceeded the aquatic life acute toxicity standard for aluminum (12,700 versus 750 µg/l), copper (18.2 µg/l versus 2.2 µg/l), and zinc (43.5 versus 23.1 µg/l).[666] The chronic standards for iron, lead, manganese, and turbidity were also exceeded. Although water quality recovered, most of the tailings water entered the ground before discharging to the creek; affected groundwater may have impacted the creek again after spring thaw.

The fourth impacted stream is Slate Creek, where the Kensington tailings impoundment occupies what was formerly Lower Slate Lake. As with Johnson Creek, the EIS provides the range of baseline data but does not reveal the number of monitoring events or average values. The TDS range was 21 to 99 mg/l, the sulfate range was <2 to 4.98 mg/l, and the nitrate range was 0.05 to 0.126 mg/l.[667] Monitoring is done at an unimpacted location upstream of the tailings facility (MLA), just downstream of the treatment plant discharge at Outfall 002 (SMP5), and at two locations further downstream (SLB and SLC) (Figure 7). Sulfate and nitrate concentrations over time at all four monitoring points are shown in Figures 8 and 9.

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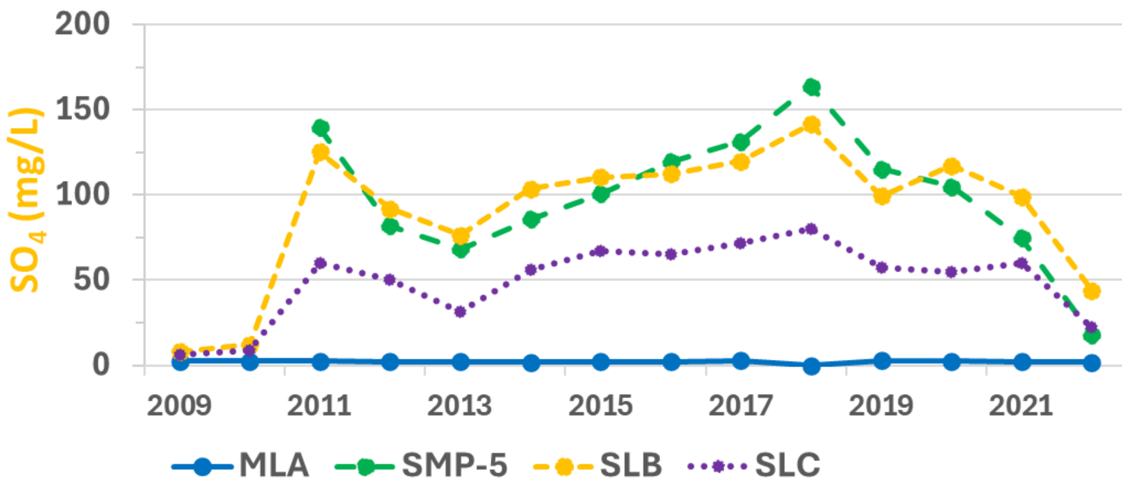
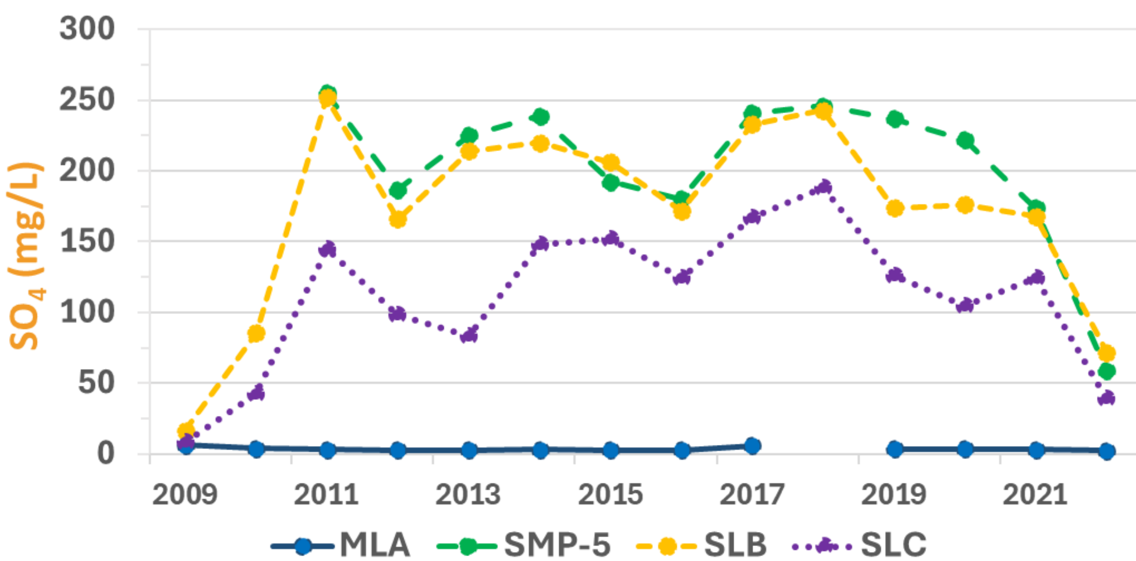
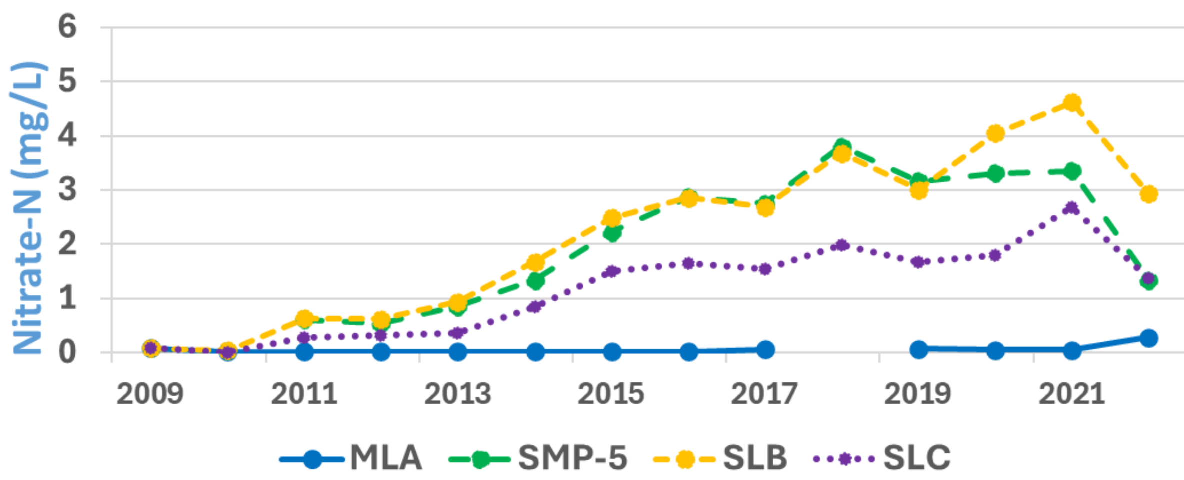
[663] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [184].*
[664] *Kensington.Surface water spreadsheet.Feb2025.xlsx* and data sources cited therein.
[665] Coeur Alaska, 2024. January, 2024 Kensington Mine Tailings Line Spill. *Kensington.Tailings Spill.Coeur Alaska 2024.pdf [1]*
[666] *Id. Kensington.Tailings Spill.Coeur Alaska 2024.pdf [12]*
[667] 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [184].*



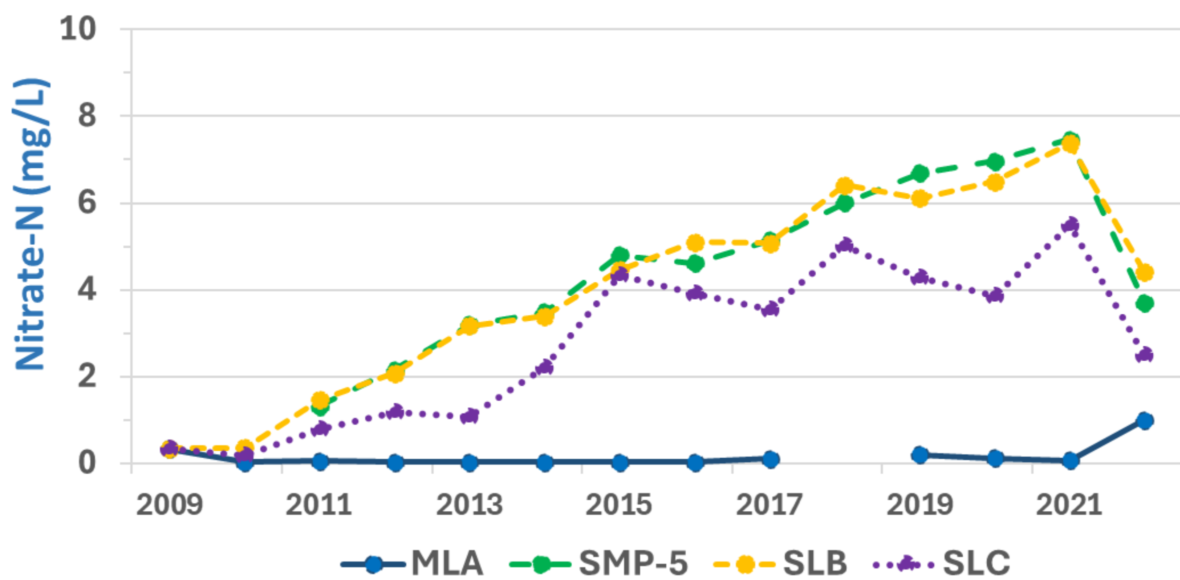
Kensington Figure 8a. Mean sulfate concentrations in the Slate Creek watershed. MLA is an unimpacted location in Upper Slate Creek. *Data source:* Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx.*



Kensington Figure 8b. Maximum sulfate concentrations in the Slate Creek watershed. MLA is an unimpacted location in Upper Slate Creek. *Data source:* Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx.*



Kensington Figure 9a. Mean nitrate concentrations in the Slate Creek watershed, 2009 to 2022. MLA is an unimpacted location in Upper Slate Creek. *Data source:* Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx.*



Kensington Figure 9b. Maximum nitrate concentrations in the Sherman Creek watershed, 2009 to 2022. MLA is an unimpacted location in Upper Slate Creek. *Data source:* Kensington annual reports, 2009-2022. See *Kensington.Surface water spreadsheet.Feb2025.xlsx.*

TDS, sulfate, and nitrate all occasionally increase between Outfall 002 and monitoring point SLB, which is about three-quarters of a mile downstream. A possible explanation is that tailings leachate is discharging to groundwater and entering the stream downstream of the outfall.[668]

[668] See 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [308]*

6. Accuracy of Water Quality Predictions

Quantitative water quality predictions for the Kensington project included the quality of mine drainage (influent to the treatment plant on Sherman Creek);[669] these predictions were inaccurate for several constituents. The prediction for the 90th percentile concentration for aluminum was 550 µg/l, while the monthly average between 2007 and 2011 was 6,167 µg/l; the maximum concentration was 23,375 µg/l. The prediction for copper was 20 µg/l; the monthly average between 2007 and 2011 was 50 µg/l, with a maximum of 238 µg/l. Iron, lead, and zinc were also underestimated.[670]

Predictions of treatment plant effluent quality at Outfall 001 were primarily based on legal requirements, i.e., the predicted concentrations were equal to the water quality standard.[671] Several of these predictions were inaccurate, as indicated in *Section 4.4* in the discussion of permit violations. For constituents that were expected to be better than permit limits and water quality standards, predictions were accurate.

The 2004 EIS also provides predictions of water quality for tailings facility water;[672] concentrations of TDS, ammonia, and sulfate were significantly underpredicted. The prediction for TDS was a mean of 259 and a maximum of 342 mg/l; actual values averaged 592, with a maximum of 961. The prediction for ammonia was a mean of 0.856 and a maximum of 1.202 mg/l; actual values averaged 2.74, with a maximum of 5.35. The prediction for sulfate was a mean of 127 and a maximum of 187 mg/l; actual values averaged 311, with a maximum of 542.[673]

Predictions for sulfate and TDS in tailings facility effluent (Outfall 002) were also inaccurate. For sulfate, the EIS predicted a mean of 94 mg/l and a maximum of 154 mg/l, while actual values averaged 199 mg/l, with a maximum of 309 mg/l. The prediction for TDS was a mean of 212 and a maximum of 296 mg/l, while actual values have averaged 413, with a maximum of 621.[674,675] Predictions for other parameters were mostly accurate, although several have had at least a few values that were above the predicted maximum.

The EIS did not provide quantitative predictions of impacts on surface waters, other than to say that applicable water quality standards would be met.[676] As discussed in *Section 5.2*, this is not always the case. The EIS also predicted that there would be no impacts on groundwater quality,[677] but without monitoring, there is no way to assess the accuracy of this prediction.

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669 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [294]*
670 NPDES Spreadsheet. *Kensington.NPDES Spreadsheet.xlsx [data set beginning on line 859]*
671 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [293]*
672 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [174, 305]*
673 Coeur Alaska, 2022. Kensington Mine Waste Management Permit No. 2013DB0002 4th Quarter 2022 Report. *Kensington.2022 4th Quarter.Coeur Alaska 2022.pdf [8-9]*
674 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [303]*
675 NPDES Spreadsheet. *Kensington.NPDES Spreadsheet.xlsx [data set beginning on line 2463]*
676 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [147]*
677 2004 FSEIS. *Kensington.FSEIS Vol 1.USDA 2004.pdf [148, 308]*

7. Summary of Water Quality Impacts

Surface water:

- In Sherman Creek downstream of mine facilities, TDS has increased tenfold, sulfate increased fiftyfold, and nitrate increased twentyfold between upstream of the mine and the most impacted monitoring location.
- The sulfate and nitrate standards are occasionally exceeded in Sherman Creek downstream of mine facilities.
- Selenium concentrations have been increasing at locations in Slate Creek downstream of the tailings impoundment and Outfall 002.
- A tailings pipeline rupture in January 2024 on Johnson Creek resulted in exceedances of the acute toxicity standards for aluminum, copper, and zinc a half-mile downstream of the spill.

Effluent and Stormwater:

- Kensington -- Over two hundred discharge violations occurred prior to 2019; parameters included pH, copper, ammonia, sulfate, turbidity, manganese, and toxicity.
- Stormwater discharge has exceeded the zinc benchmark in all but one monitoring event since September 2021 and has consistently exceeded the benchmark for cadmium since June 2023.
- The permit was written for a maximum effluent discharge of 3,000 gpm, which has proven insufficient. The current expansion plan calls for an increase in the permit limit to 4,500 gpm.

Groundwater:

- The Kensington operation includes no groundwater monitoring.

Predicted vs reality:

- The treatment plant influent was predicted to have an aluminum concentration of 550 µg/l; the monthly average from 2007 to 2011 was 6,167 µg/l with a maximum concentration of 23,375 µg/l. Copper, iron, lead, and zinc were also underestimated.
- Tailings facility water was predicted to have a mean TDS concentration of 259 mg/l and a maximum of 342 mg/l; actual values have averaged 592 mg/l, with a maximum of 961 mg/l. The prediction for ammonia was a mean of 0.856 mg/l and a maximum of 1.202 mg/l; actual values averaged 2.74 mg/l with a maximum of 5.35 mg/l. The prediction for sulfate was a mean concentration of 127 mg/l and a maximum of 187 mg/l; actual values have averaged 311 mg/l, with a maximum of 542 mg/l.

8. Comparison to Potential Mines in the Rainy River Headwaters Watershed of Minnesota

The Kensington Mine is much smaller than potential mines in the Rainy River Headwaters and has less potential for acid drainage from waste rock. It is similar in regard to the shallowness of groundwater and presence of surface water; however, the Kensington site receives much more precipitation.

9. Post-permitting and Potential Future Expansions

The mine expansion approved in 2022 includes increasing ore production from 2,000 to 3,000 tons per day. Tailings tonnage will increase from 4.5 to 8.5 million, the impoundment area will increase from 197 acres to 249 acres, and the tailings dam will be elevated. The waste rock stockpile impacting Ophir Creek will double in size, and 60 acres of stockpile will be added to the Johnson Creek watershed.[678] All of these facilities currently appear to be impacting downstream water quality, but there is no acknowledgment in the 2021 EIS that increasing their size may result in greater impacts.

[678] 2021 FSEIS. *Kensington.FSEIS.USDA 2021.pdf [5]*

Pogo Mine, Alaska

1. Site and Mine Description and Background Information

The Pogo Mine is an underground gold mine located on state land southeast of Fairbanks, Alaska. The mine was developed by Teck Pogo, Inc., a subsidiary of Teck Cominco. Sumitomo, a Japanese corporation, acquired Teck's share in the mine and took over operations in 2009 through its subsidiary, Sumitomo Metal Mining Pogo. The mine was transferred to Northern Star Resources, an Australian corporation, in 2018. It is currently operated by subsidiary Northern Star (Pogo).[679] The mine processes about 3,000 tons of ore per day. Estimated disturbed land is 360 acres.[680]

The 2003 Final Environmental Impact Statement (EIS) for the project was prepared by the U.S. Environmental Protection Agency (U.S. EPA)[681] with the U.S. Army Corps of Engineers (USACE) and Alaska Department of Natural Resources (DNR) as cooperating agencies. Development of a 30-acre area preceded preparation of the EIS.[682] Pre-EIS permits and approvals included a Clean Water Act Section 404 permit for a 14-acre wetland fill, coverage under the NPDES Stormwater General Permit, an Approved Plan of Operations, a Reclamation Plan for Advanced Exploration, and a Wastewater Disposal Permit for discharge of treated mine drainage by underground injection.[683] Permits for the full-scale project were issued in 2004, and production began in 2006.

The primary mine facilities drain to Liese Creek and then to the Goodpaster River, which is a tributary of the Tanana River in the Yukon basin[684] (Figure 1). Liese Creek is an intermittent stream with a low flow of zero. The EIS reported that when flow exists, it typically ranges from 0.5 to 2.0 cubic feet per second (cfs), with a peak flow of 6.1 cfs.[685] The Goodpaster River is a perennial river with flow ranging from 50 to 60 cfs in winter to an annual maximum of 950 cfs. Typical summer flows in the Goodpaster River are 400 to 600 cfs. The EIS estimated the 7Q10 low flow at 18 cfs at the mine site.[686]

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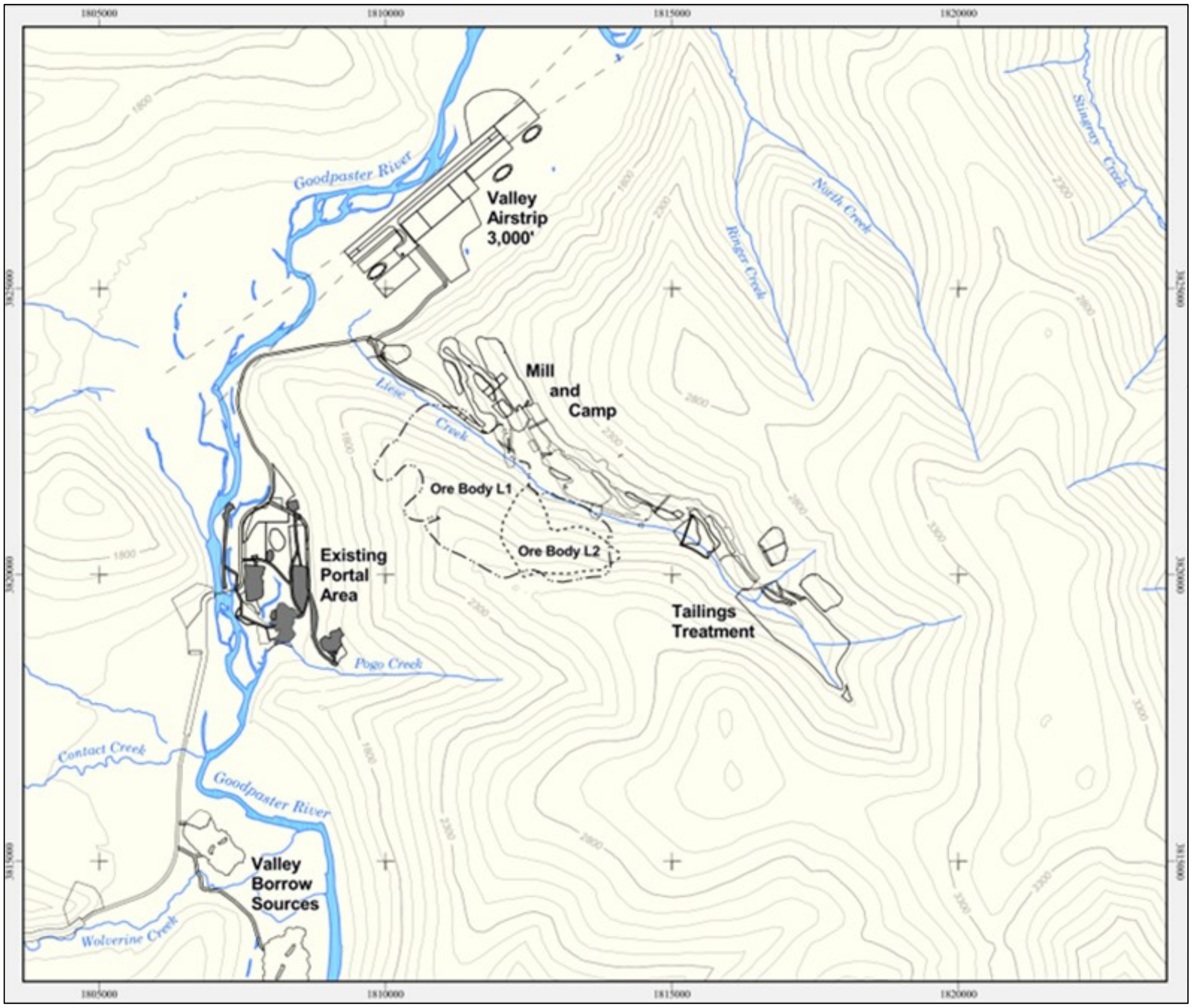
[679] Alaska Dept. of Environmental Conservation, 2017. Alaska Pollutant Discharge Elimination System Permit Fact Sheet -- Final. Hereinafter, "NPDES Fact Sheet." *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [5]*
[680] Northern Star Resources, Ltd., 2020b. Storm Water Pollution Prevention Plan and Best Management Practices Plan. Hereinafter, "SWPPP." *Pogo.SWPPP.Northern Star 2020b.pdf [10]*
[681] At the time, the U.S. EPA had authority over NPDES permits in Alaska; this authority has now been delegated to the Alaska Department of Environmental Conservation (ADEC).
[682] See "Advanced Exploration Project Facilities" map. U.S. Environmental Protection Agency, 2003. Final Environmental Impact Statement, Pogo Gold Mine Project. Hereinafter, "FEIS." *Pogo.FEIS.USEPA 2003.pdf [181, 237]*
[683] FEIS. *Pogo.FEIS.USEPA 2003.pdf [95-96]*
[684] FEIS. *Pogo.FEIS.USEPA 2003.pdf [27]*
[685] FEIS. *Pogo.FEIS.USEPA 2003.pdf [180]*
[686] FEIS. *Pogo.FEIS.USEPA 2003.pdf [183]*



Pogo Figure 1. Pogo Mine Facility Locations, Topography, and Surface Water Features.
Source: U.S. Environmental Protection Agency, 2003. Final Environmental Impact Statement, Pogo Gold Mine Project, Figure S-4. *Pogo.FEIS.USEPA 2003.pdf [27]*

Groundwater at the site is found both in an alluvial aquifer associated with the creek and river and in fractured bedrock. Groundwater flow is toward the Goodpaster River. Along the river, the alluvium is at least 100 feet thick and is about 50 feet thick along Liese Creek. Depth to groundwater ranges from 0 near the Goodpaster River, to 20 feet along Liese Creek, to 300 feet on ridges between creeks.[687] Wetlands are widespread along the river and streams, covering about 30% of the site prior to mining.[688] Estimated precipitation is 19 inches per year.[689]

According to the EIS, groundwater in the bedrock aquifer exists exclusively in fractures, faults, and joints, and hydraulic conductivity is extremely variable, ranging from 0.01 ft/year to 500 ft/year. The tailings facility was constructed in a creek bed, where the estimated median hydraulic conductivity is 33

[687] FEIS. *Pogo.FEIS.USEPA 2003.pdf [189]*
[688] FEIS. *Pogo.FEIS.USEPA 2003.pdf [233]*
[689] FEIS. *Pogo.FEIS.USEPA 2003.pdf [186]*

feet/year. A fault zone close to the creek was considered to be a potential major water-bearing structure about which little was known at the time of the EIS.[690]

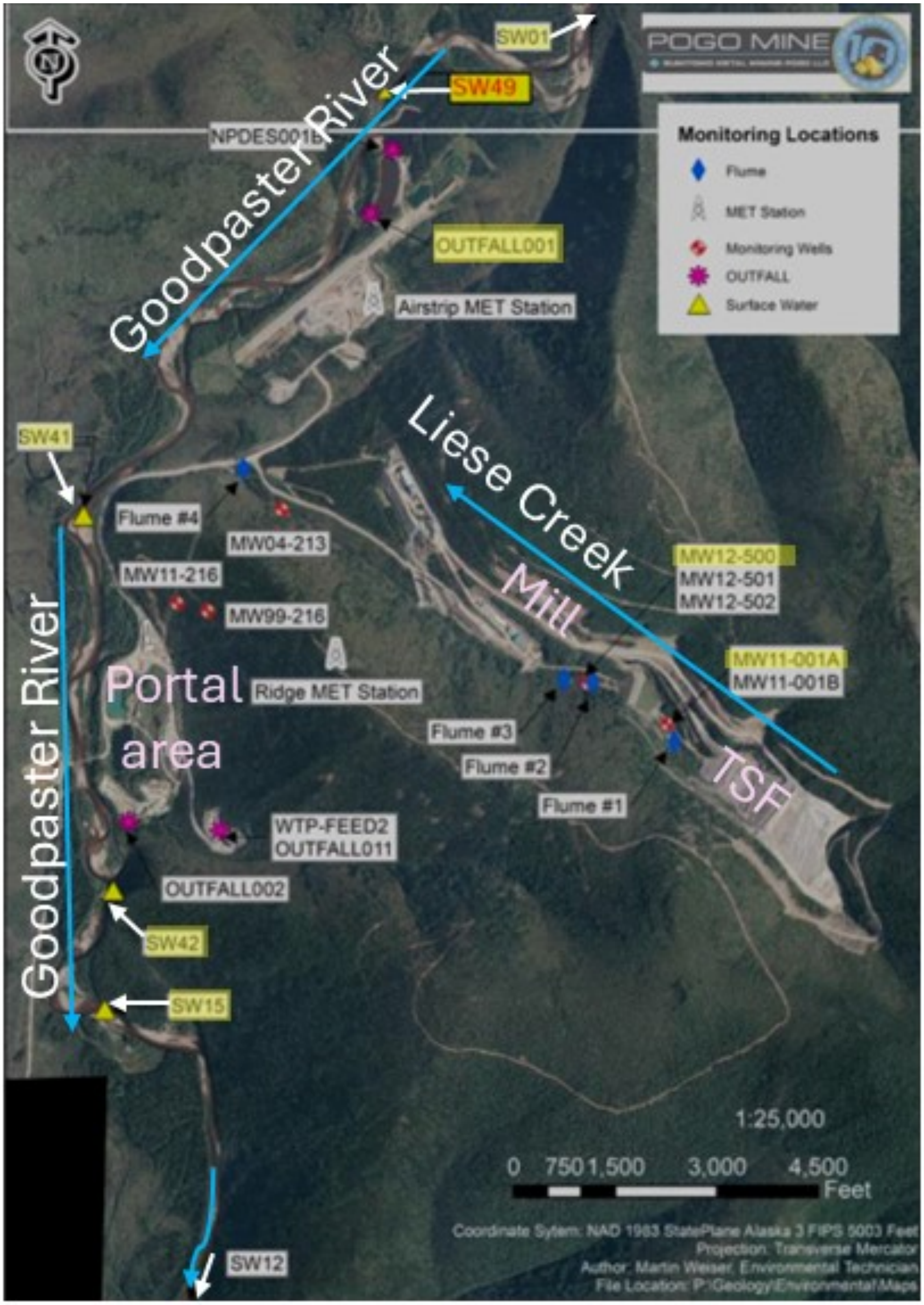
2. Mine Facilities, Operations, and Reclamation

The Pogo Mine consists of underground workings and three site locations, each within about a half mile of each other (see Figures 1 and 2).[691] The first is the "Advanced Exploration Area," with the original mine portal and associated facilities and Outfalls 002 and 011.[692] This area was first developed prior to the 2003 EIS.[693] The second site includes an airstrip, gravel pits,[694] and Outfall 001[695] (Figure 2). These two sites are immediately adjacent to the Goodpaster River. The third site is in the Liese Creek drainage. It includes a dry stack (filtered) tailings facility containing tailings and at least 5.5 million metric tonnes of waste rock, the associated Recycle Tailings Pond, two additional mine portals, and the mill and associated facilities.[696] The ore is processed using closed-circuit cyanide-vat leaching.[697] A fifty-mile road was constructed for access to the site.[698]

An approximate timeline of key mine facility constructions includes:

- 1998: Original mine portal and facilities installed ("Advanced Exploration Area")
- 1999: Mine adit construction began (5,000 ft length), and mine dewatering began discharging to the Goodpastor River
- 2003: Final EIS was prepared by US EPA, USACE, and Alaska DNR
- 2009: Sumitomo (Japanese) took over operations
- 2016: Water treatment system upgraded.

[690] FEIS. *Pogo.FEIS.USEPA 2003.pdf [193-94]*
[691] See maps in Northern Star Resources, Ltd., 2023. 2022 Annual Monitoring Report. *Pogo.2022 Annual Report.Northern Resources 2023 [34-42]*
[692] FEIS. *Pogo.FEIS.USEPA 2003.pdf [100]*
[693] FEIS. *Pogo.FEIS.USEPA 2003.pdf [77]*
[694] FEIS. *Pogo.FEIS.USEPA 2003.pdf [101]*
[695] NPDES Fact Sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [30]*
[696] FEIS. *Pogo.FEIS.USEPA 2003.pdf [102-104]*
[697] SWPPP. *Pogo.SWPPP.Northern Star 2020b.pdf [10]*
[698] FEIS. *Pogo.FEIS.USEPA 2003.pdf [105]*



Pogo Figure 2. Surface Water and Groundwater Monitoring Locations and Effluent Outfalls.
Source: Modified from Alaska Dept. of Environmental Conservation, 2017. Alaska Pollutant Discharge Elimination System Permit Fact Sheet – Final, Fig 2. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [30]*

Mine adit water and excess water from the Recycle Tailings Pond are treated and discharged to the Goodpaster River.[699] Treatment consists of "a high-density sludge process to achieve enhanced co-precipitation of metals, including arsenic; as necessary, lime softening and recarbonation . . . to reduce TDS; sulfide precipitation if . . . necessary . . .; and a microfiltration membrane system to polish the treated water."[700] The system was upgraded in 2016.

Effluent from the treatment plant discharges to the Off-River Treatment Works (ORTW). The ORTW intercepts a portion of the Goodpaster River flow and directs it to constructed ponds, where it mixes with treated water to dilute the concentration of contaminants in the effluent. The mixed water then flows back to the river at the point designated as "Outfall 001" (see Figure 2) under the facility's NPDES permit.[701] The maximum discharge from the treatment plant at the time of original permitting was 600 gallons per minute (gpm); that has now increased to 800 gpm, which is approximately one-tenth of the flow in the Goodpaster River at low flow (i.e. 7Q10) conditions.[702]

Waste rock is sorted into "mineralized" and "nonmineralized," with rock of 0.5 percent sulfur or 600 ppm arsenic classified as mineralized.[703] About two-thirds of the mineralized rock is backfilled in the underground mine workings, and the other one-third is disposed of in the unlined dry stack (filtered) tailings facility.[704] At times, however, mineralized rock is temporarily stored in unlined stockpiled on the surface, and runoff and leachate are allowed to seep to groundwater.[705]

According to the EIS, "nonmineralized" rock is more technically termed "weakly-mineralized" rock,[706] as it contains up to 0.5% sulfur and several trace minerals. It is used to construct mine facilities such as the tailings toe berm, roads, and the Recycle Tailings Pond.

Approximately half of the mill tailings are disposed of underground as cemented paste backfill.[707] The other half is filtered to remove water and trucked to the dry-stack tailings facility.[708] As of 2019, 9.4 million tons of tailings and 5.5 million tons of waste rock had been disposed of in the dry stack facility.[709] This is about twice the amount estimated in the EIS (11 million tons of ore/tailings and 1.9 million tons of waste rock).[710]

Precipitation through the dry-stack facility enters groundwater and travels downgradient to the Recycle Tailings Pond. The tailing facility and Recycle Tailings Pond have subsumed the upper creek bed of Liese Creek (see Figure 1). Stormwater is routed around these facilities by ditches that discharge below the pond, forming what is now the start of Liese Creek.

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[699] FEIS. *Pogo.FEIS.USEPA 2003.pdf [380]*
[700] NPDES Fact Sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [24]*
[701] NPDES Fact Sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [6]* This discharge option was described and assessed in the FEIS. *Pogo.FEIS.USEPA 2003.pdf [387]*
[702] NPDES Fact sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [12]*
[703] Golder, 2022. Environmental Audit of the Pogo Mine. *Pogo.Audit.Golder 2022.pdf [17]*
[704] FEIS. *Pogo.FEIS.USEPA 2003.pdf [371]*
[705] FEIS. *Pogo.FEIS.USEPA 2003.pdf [372]*
[706] FEIS. *Pogo.FEIS.USEPA 2003.pdf [368]*
[707] FEIS. *Pogo.FEIS.USEPA 2003.pdf [134]*
[708] FEIS. *Pogo.FEIS.USEPA 2003.pdf [111]*
[709] Northern Star Resources, Ltd., 2020a. 2020 Pogo Plan of Operations. Hereinafter, "2020 POO." *Pogo.POO.Northern Star 2020a.pdf [19]*
[710] FEIS. *Pogo.FEIS.USEPA 2003.pdf [98]*

Both the tailings facility and the Recycle Tailings Pond (RTP) are unlined.[711] The rock dam that holds the water has a geomembrane liner. [712] Although excess water in the RTP is sent to the treatment plant, the RTP also discharges to groundwater. A seepage collection well and pump-back system operate below the toe of the RTP dam.[713] The EIS estimated that the collection system would intercept and return about 80 percent of the water that escapes the pond. "Any discharges that escape the return wells are expected to enter the groundwater flow system discharging into the mine, or possibly to resurface farther downstream the Liese Creek valley."[714] Based on groundwater monitoring data (discussed in *Section 5.1* below), the latter has in fact been the case.

The Pogo Mine has experienced many spills and other unpermitted releases of various liquids over the years. The U.S. EPA issued a Notice of Violation in 2007 for releases that occurred during construction and initial operations. These included several releases of raw sewage of up to 10,000 gallons, untreated mine water up to 4,500 gallons, and 20,000 gallons of stormwater due to a flange failure.[715] The 2020 version of the mine's Storm Water Pollution Prevention Plan (SWPPP) lists releases between 2012 and 2019 of up to 8,000 gallons of raw sewage, up to 90,000 gallons of backfill paste, and 1,500 gallons of cyanide-bearing tailings slurry.[716] A 2022 inspection report has a more recent list that includes 22,000 gallons and 39,884 gallons of Recycle Tailings Pond water.[717] The mine has also been subject to an enforcement action and a $600,000 fine by the U.S. EPA for hazardous waste violations, which included mixing hazardous waste with backfill paste for disposal in the underground workings.[718]

3. Geochemistry

Acid-base accounting and kinetic laboratory testing of ore and waste rock was conducted prior to permitting.[719] Waste rock is classified based on its sulfur and arsenic content, with rock of 0.5 percent or greater sulfur and 600 ppm arsenic classified as "mineralized."[720] The sulfur content of waste rock ranges up to 2.98 percent. According to the EIS, "very few samples with a sulfur content less than 0.5 percent had the potential to generate acid, "[721] with the conclusion that "no net acid generation potential" was expected.[722]

4. Mine-Influenced Water Quality

4.1 Mine Inflow Water Quality

No data are available.

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711 See FEIS. *Pogo.FEIS.USEPA 2003.pdf [519-520]* (rejecting liner option)
712 Golder, 2022. Environmental Audit of the Pogo Mine. *Pogo.Audit.Golder 2022.pdf [18]*
713 FEIS. *Pogo.FEIS.USEPA 2003.pdf [120]*
714 FEIS. *Pogo.FEIS.USEPA 2003.pdf [354]*
715 U.S. EPA, 2007. Notice of Violation. *Pogo.NOV.USEPA 2007.pdf*
716 SWPPP. *Pogo.SWPPP.Northern Star 2020b.pdf [49-54]*
717 Alaska Dept. of Environmental Conservation, 2022. APDES Inspection Report. *Pogo.Inspection.ADEC 2022.pdf [6]*
718 U.S. EPA, 2022. Docket No. RCRA-10-2022-0244 Consent Agreement. *Pogo.RCRA Consent Agreement.USEPA.pdf 2022 [15-19]*
719 FEIS. *Pogo.FEIS.USEPA 2003.pdf [368]*
720 Golder, 2022. Environmental Audit of the Pogo Mine. *Pogo.Audit.Golder 2022.pdf [17]*
721 FEIS. *Pogo.FEIS.USEPA 2003.pdf [368]*
722 FEIS. *Pogo.FEIS.USEPA 2003.pdf [138]*

4.2 Waste Rock Leachate Water Quality

No data specific to mineralized waste rock leachate are available. A portion of the waste rock is disposed of in the dry stack tailings facility; water quality monitoring of interstitial tailings water discussed below likely reflects leachate from waste rock as well as tailings.

The only monitoring that may reflect the quality of leachate or runoff from "nonmineralized" waste rock is stormwater monitoring in a location near the temporary waste rock storage facilities. Stormwater runoff subject to benchmark monitoring includes runoff from waste rock and overburden storage piles in the Advanced Exploration Area. Monitoring is infrequent; the period of 2008 to 2017 included only 12 monitoring events. During that time, the benchmarks for zinc and iron were each exceeded once, and pH was below the minimum of 6.5 twice. Many of the benchmarks are set significantly higher than water quality standards, allowing for some dilution by the receiving water. There are no benchmark values for manganese or nitrate, but manganese concentrations have been measured as high as 229 µg/l and nitrate values as high as 9 mg/l as N.[723]

4.3 Tailings Water Quality

In 2023, sulfate concentrations in interstitial tailings water averaged 2220 mg/l, with a maximum of 2400 mg/l.[724] TDS values averaged 3950 mg/l. Concentrations of various parameters have peaked in different years. For example, TDS concentrations were particularly high in 2013, averaging 4492 mg/l.[725] Arsenic levels were above 5,100 µg/l on three out of four monitoring dates in 2016, with a maximum of 7360 µg/l. The same year, copper levels ranged from 57 to 1110 µg/l. Selenium was particularly high in 2012, ranging from 750 to 938 µg/l.[726] Nitrite + nitrate ranged from 130 to 230 mg/l in 2012.[727]

4.4 Effluent Water Quality

Limits on the concentration of pollutants in treated effluent are set to ensure that water quality standards are met; permit limits do not prevent degradation of existing water quality.[728,729] The daily maximum effluent limit for copper is 6.5 µg/l, which is equal to the acute toxicity criterion for aquatic life. The 30-day average limit for manganese is 50 µg/l, and the daily maximum is 109 µg/l; the secondary water quality standard for manganese is 50 µg/l.[730]

Both the discharge from the treatment plant before mixing with river water (NPDES Outfall 011) and the discharge from the Off-River Treatment Works after mixing with river water (NPDES Outfall 001)

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723 SWPPP. *Pogo.SWPPP.Northern Star 2020b.pdf [21-22 and 55-58]*

724 Northern Star Resources, Ltd., 2024. 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx [Sheet "PC003 Interstitial"]*

725 Northern Star Resources, Ltd., 2020c. 2019 Annual Report, Appendix E. Hereinafter, "2019 Spreadsheet." *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx [Sheet "Data 2013," rows 4005-11]*

726 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx [Sheet "Data 2016," rows 2269-76; Sheet "Data 2014," rows 4057-62; Sheet "Data 2012," rows 4100-06]*

727 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx [Sheet "Data 2012," rows 4100-06]*

728 FEIS. *Pogo.FEIS.USEPA 2003.pdf [357]*

729 NPDES Fact Sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [22-24]*

730 NPDES Fact sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [10, 35]*

are monitored (Figure 2). Permit limits apply primarily to Outfall 001. Several pollutants of concern have no permit limits and/or are no longer required to be monitored at 001, including sulfate, nitrogen, and TDS.[731]

Treatment plant effluent concentrations are generally above 500 mg/l sulfate and 1000 mg/l TDS. Both have risen slightly since the 2017 NPDES permit changes that dropped monitoring requirements for these parameters at Outfall 001 (the discharge after treated effluent is diluted with river water).[732] Concentrations of these and other parameters from 2010 to 2019 are shown in Table 1.[733]

Pogo Table 1. Discharge From Pogo Mine's Off-River Treatment Works (Outfall 001), 2010-2019.

	Baseline concentration at SW01 (2001)	Average Outfall 001 concentration	Maximum Outfall 001 concentration
TDS (mg/l)	No data	140	224
Sulfate (mg/l)	14.9	24	91
Arsenic (µg/l)	0.23	2	11
Manganese (µg/l)	6.7	11.9	65
Nitrate (mg/l)	0.236	3.33	5.88

Baseline concentrations are from FEIS. *Pogo.FEIS.USEPA 2003.pdf [199].* Baseline monitoring point SW01 is located upstream of Outfall 001. (*See Section 5.2 and Table 4 below*.)
2010-2019 data are from the 2019 Spreadsheet. Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx

Exceedances of NPDES permit limits have primarily been for cyanide. In recent years, the effluent has exceeded the monthly average limits for cyanide in April 2017;[734] August and October 2021;[735] June through October 2022;[736] and August 2023.[737] The effluent has also occasionally exceeded permit limits for metals, including cadmium, copper, iron, lead, and manganese, and has violated pH permit limits.[738,739,740]

5. Impacts on Groundwater and Surface Water Quality

5.1 Groundwater Quality Impacts

[731] NPDES Fact sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [10]*
[732] Northern Star Resources, Ltd., 2023. 2022 Annual Report. *Pogo.2022 Annual Report.Northern Resources 2023.pdf [50-51]*
[733] This time period was chosen for convenience, as the 2019 Annual Report is the last annual report with multi-year data.
[734] 2019 Spreadsheet. The Site Number (column 1) is "Outfall 001." *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx*
[735] Northern Star Resources, Ltd., 2022. 2021 Annual Report, Appendix F. *Pogo.2021 Annual Report App F.Northern Star 2022.xlsx [Sheet "Outfall 001"]*
[736] Northern Star Resources, Ltd., 2023. 2022 Annual Report, Appendix F. *Pogo.2022 Annual Report App F.Northern Star 2023.xlsx [Sheet "Outfall 001"]*
[737] Northern Star Resources, Ltd., 2024. 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx [Sheet "Outfall 011"]*
[738] Alaska Dept. of Environmental Conservation, 2011. Notice of Violation. *Pogo.NOV.ADEC 2011.pdf [2]*
[739] NPDES Fact sheet. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [6]*
[740] U.S. EPA, n.d. ECHO DMR Exceedances Report. *Pogo.NPDES exceedances.EPA 2024.xlsx* Downloaded from *https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedances?permit_id=AK0053341* on May 24, 2024.

Groundwater baseline data were collected from 1998 to 2000. Although samples were taken from a wide array of wells (30 for the Liese Creek area alone), the number of sampling events was limited (2 to 4 per well for the Liese Creek area wells).[741] Some site development for exploration occurred prior to baseline monitoring. (*See Section 1*)

Assessing impacts to groundwater at the Pogo Mine is also hindered by the fact that most wells used for baseline monitoring before operations began are not the same wells used for operational monitoring. However, wells in the same general locations can be identified and used for comparisons.[742] Primary points of concern are below and downgradient of the dry stack tailings and Recycle Tailings Pond.

Groundwater in the areas adjacent to the Goodpaster River and Liese Creek had low chloride and nitrogen concentrations prior to mining.[743] Increases in pollutant concentrations, along with TDS and sulfate, indicate that seepage from the dry stack tailings facility is entering groundwater. This can be seen in Table 2 and Figure 3, which show that impacts have tended to increase over time. (In general, metals of concern are typically less mobile in aquifers than nitrate, sulfate, and chloride. Possibly because of this, metal concentrations in groundwater are too variable in both baseline and subsequent data to be able to draw conclusions regarding whether they have affected the shallow aquifer.)

Pogo Table 2. Pogo Mine Average Groundwater Quality at Toe of Dry Stack Tailings Facility.

	TDS (mg/l)	**Sulfate** (mg/l)	**Chloride** (mg/l)	**Nitrate** (mg/l as N)
Baseline well LT-007B	184	51	0.3	1.1
Baseline well LT-009	132	26	0.3	0.8
Current well MW11-001A:				
2012	403	100	1.53	17.3
2013	576	127	2.31	16.7
2018	619	181	3.0	28.0
2023	600	184	3.25	28.5

Baseline data are from Golder and AMEC, 2001. Pogo Environmental Baseline Document, 2.3 Groundwater Quality. *Pogo.Groundwater baseline.Golder 2001.pdf [141-144]*
2012-2018 data are from the 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx*
2023 data are from the 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx*
All wells are in alluvium.
Location of baseline wells is provided in FEIS. *Pogo.FEIS.USEPA 2003.pdf [181]*

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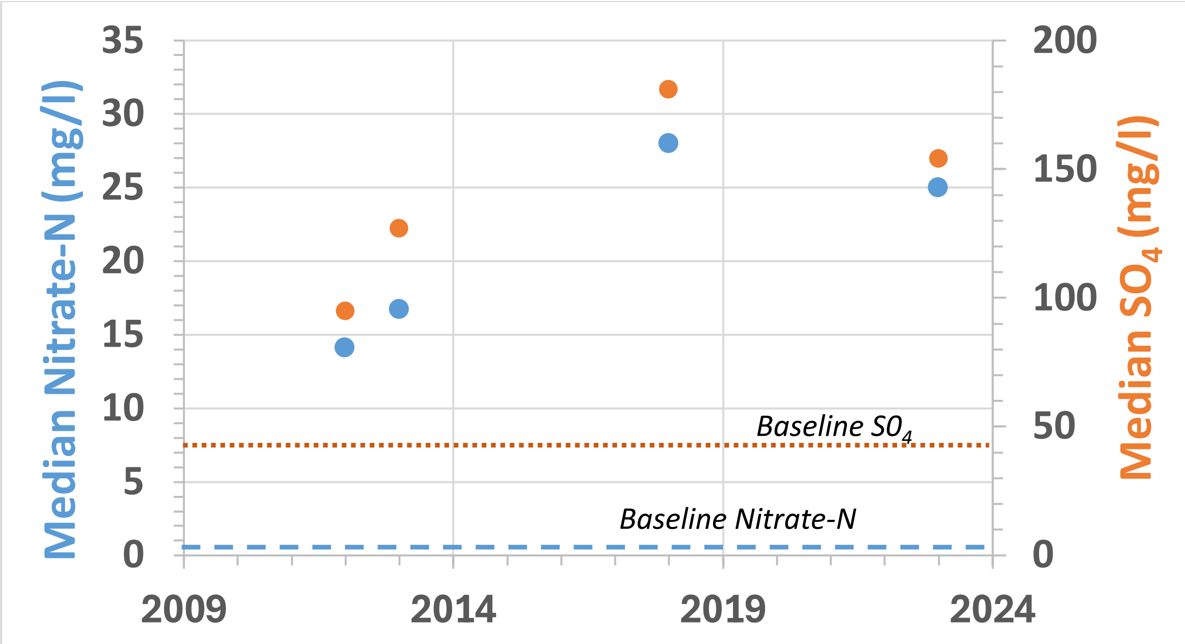
741 Golder and AMEC, 2001. Pogo Environmental Baseline Document, 2.3 Groundwater Quality. *Pogo.Groundwater baseline.Golder 2001.pdf [2-8]*
742 Compare *Pogo.FEIS.USEPA 2003.pdf [181]* and Northern Star Resources, Ltd., 2023. 2022 Annual Monitoring Report. Hereinafter "2022 Annual Monitoring Report." *Pogo.2022 Annual Report.Northern Resources 2023.pdf [34]*
743 Golder and AMEC, 2001. Pogo Environmental Baseline Document, 2.3 Groundwater Quality. *Pogo.Groundwater baseline.Golder 2001.pdf [93-98, 103-108, 139-144]* See *Pogo.Working spreadsheet.Feb2025.xlsx*



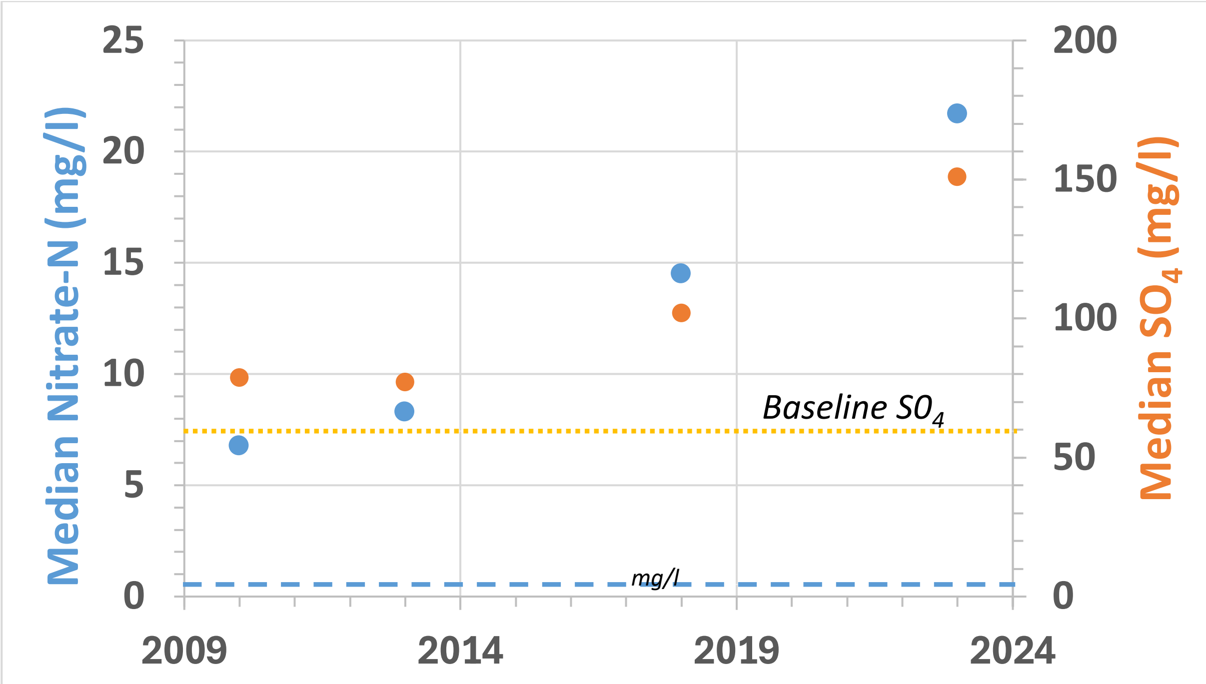
Pogo Figure 3. Groundwater Sulfate & Nitrate Concentrations, Toe of Dry Stack Tailings Facility (Pogo well MW11-001A). Baseline values are average concentrations from wells LT-007A, LT-007B, and LT-009.
See Table 2 for data sources.

The trend of increasing solute concentration in groundwater over time also appears in wells located farther downgradient from the tailings and waste-rock facility. Specifically, downstream of the Recycle Tailings Pond (RTP) dam, the concentrations of TDS, sulfate, chloride, and nitrate in groundwater consistently increased between 2010 and 2023. The groundwater quality shown in Table 3 and Figure 4 (wells MW3-500 and its replacement, MW12-500) are representative; other wells in the vicinity have similar trends, with concentrations of sulfate and nitrate increasing over time.

Pogo Table 3. Average Groundwater Quality Downgradient of the Recycle Tailings Pond (RTP).

	TDS (mg/l)	**Sulfate** (mg/l)	**Chloride** (mg/l)	**Nitrate** (mg/l as N)
Baseline (well LD-005)	215	62	0.3	0.6
Well MW3-500 or MW12-500:				
2010	283	80	2.3	11.38
2013	323	78	1.7	7.7
2018	376	104	2.0	14.9
2023	477	141	4.0	24.0

Baseline data are from Golder and AMEC, 2001. Pogo Environmental Baseline Document, 2.3 Groundwater Quality. *Pogo.Groundwater baseline.Golder 2001.pdf [91-92]*
2010-2018 data are from the 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx*
2023 data are from the 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx*
Well MW12-500 replaced well MW03-500 in 2012. Data in the table from 2010 is from MW 03-500.
All wells are in alluvium.
Location of baseline wells is provided in FEIS. *Pogo.FEIS.USEPA 2003.pdf [181]*
Location of MW11-001A is provided in Northern Star Resources, Ltd., 2023. 2022 Annual Monitoring Report. *Pogo.2022 Annual Report.Northern Resources 2023.pdf [34]*



Pogo Figure 4. Groundwater Sulfate & Nitrate Concentrations, Recycle Tailings Pond Area (Pogo Well MW12-500). Baseline groundwater concentrations from well LD-005. *See Table 3 for data sources.*

The RTP is permitted as a zero-discharge facility, with exceedances of designated values in downgradient wells triggering corrective action requirements. The designated values are about twice the baseline measurements: 0.79 mg/l for chloride and 1.28 mg/l as N for nitrate.[744] The corrective action triggers are and have been routinely exceeded for at least fourteen years. The nitrate water quality standard of 10 mg/l as N is also often exceeded. According to the 2022 Annual Report, containment of dam seepage is being evaluated in a "corrective action investigation."[745] It is unclear what corrective action is being considered.

Finally, samples of groundwater farther downstream along Liese Creek indicate that solutes released from the dry stack tailings are approaching the Goodpaster River. Baseline measurements taken in well MW-04-213 from 2004 to 2006 averaged 0.1 mg/l nitrate as N and 0.54 mg/l chloride[746] (location shown in Figure 2). Between 2010 and 2018, nitrate concentrations in well MW04-213 rose by approximately an order of magnitude.[747]

In 2018, MW04-213 was replaced by well pair MW18-003A and -003B, which are another 1,000 feet downstream (more than a mile downstream of the RTP and about 1,000 feet from the Goodpaster River).[748] Nevertheless, annual median nitrate concentrations have risen from about 3 mg/l as N in 2019

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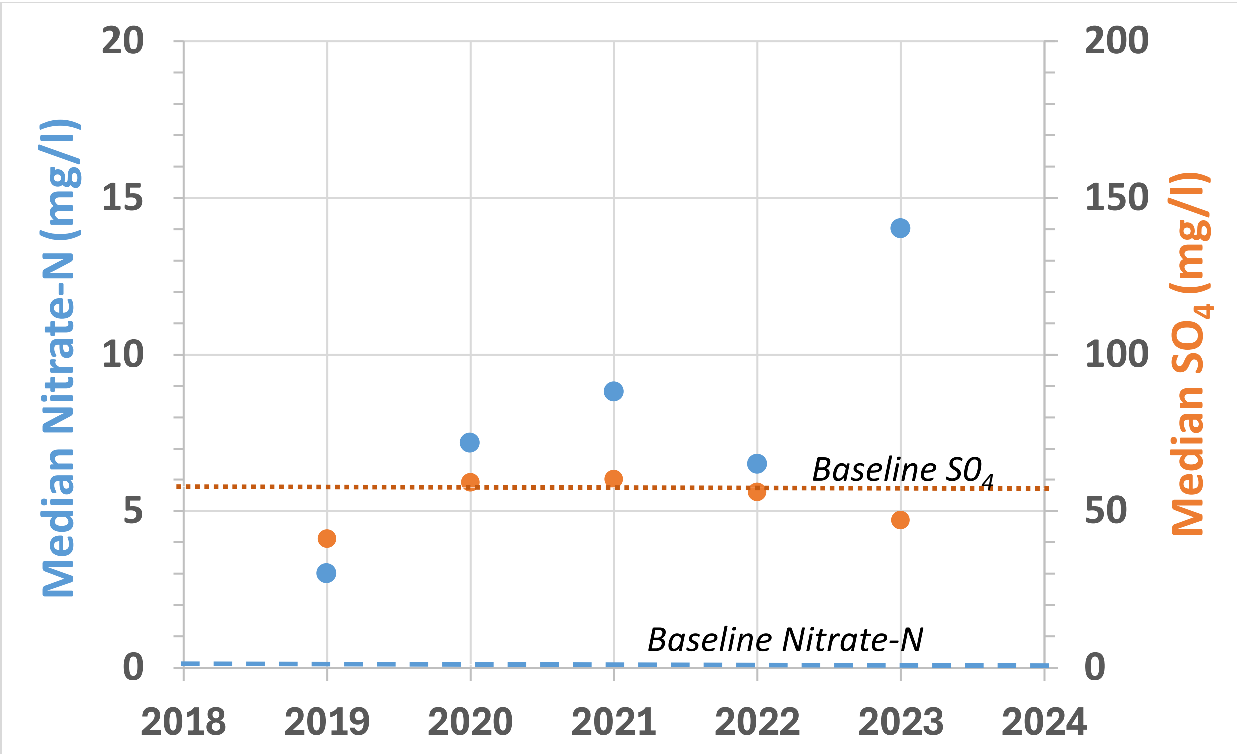
[744] Northern Star Resources, Ltd, 2020e. 2020 Pogo Mine Monitoring Plan. *Pogo.Monitoring Plan.Northern Star 2020e.pdf [17]*
[745] 2022 Annual Monitoring Report. *Pogo.2022 Annual Report.Northern Resources 2023.pdf [14]*
[746] Northern Star, Ltd., 2020e. 2020 Pogo Mine Monitoring Plan. *Pogo.Monitoring Plan.Northern Star 2020e.pdf [35-36]*
[747] 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx*
[748] Northern Star Resources, Ltd., 2023. 2022 Annual Report. *Pogo.2022 Annual Report.Northern Resources 2023.pdf [34]*

to 14 mg/l as N in 2023 (Figure 5). At this distance from the tailings, there appears to be some differential migration of solutes, with the very mobile nitrate arriving more quickly than sulfate. Maximum nitrate concentrations in groundwater have been above the 10 mg/l as N standard every year since 2020.



Pogo Figure 5. Groundwater Sulfate & Nitrate, near Liese Creek and Goodpastor R. (Pogo well MW13-003A). Baseline concentrations are from well MW04-213. *Data sources:* Northern Star Resources, Ltd., 2021. 2020 Annual Monitoring Report, Appendix F. *Pogo.2020 Annual Report App F.Northern Star 2021.xlsx;* Northern Star Resources, Ltd., 2022. 2021 Annual Monitoring Report, Appendix F. *Pogo.2021 Annual Report App F.Northern Star 2022.xlsx;* Northern Star Resources, Ltd., 2023. 2022 Annual Monitoring Report, Appendix F. *Pogo.2022 Annual Report App F.Northern Star 2023.xlsx;* Northern Star Resources, Ltd., 2024. 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx*

5.2 Surface Water Quality Impacts

As the EIS stated, surface water in the project area prior to mining was "essentially undeveloped and pristine."[749] Although two sets of data are provided in the baseline report,[750] the earlier set is unusable, and comparisons in this *Section* use the 1998 to 2001 data set. However, development of the Advanced Exploration Area began in 1998; in early 1999, a 5,000-foot adit was driven, and mine dewatering and underground injection began,[751] which ultimately discharged to the Goodpaster River.[752] Surface waters thus may already have been impacted when the 1998 to 2001 baseline monitoring occurred.

[749] FEIS. *Pogo.FEIS.USEPA 2003.pdf [177].*
[750] HDR Alaska, 2001. Pogo Environmental Baseline Document, Vol. 2 -- Water Quality. *Pogo.Baseline surface water.HDR 2001.pdf [20-28 and 30-44]*
[751] FEIS. *Pogo.FEIS.USEPA 2003.pdf [77]*
[752] FEIS. *Pogo.FEIS.USEPA 2003.pdf [343]*

Although baseline monitoring was done on Liese Creek (stations SW30 and SW05),[753] no ongoing surface water monitoring is conducted there. The EIS predicted that "impacts on Liese Creek water quality below the dam during operation would be low."[754] Based on groundwater monitoring data as described in *Section 5.1*, this prediction may be inaccurate, but no data are available to determine impacts.

Baseline surface water quality monitoring on the Goodpaster River (Figure 2) was done upstream of the mine site (SW01), about a half mile downstream of the lowermost mining development (the Advanced Exploration Area) (SW15), and about five miles farther downstream (SW12).[755] These stations have remained the same into operations. Monitoring sites have also been added. SW49 was added just upstream of the intake to the Off-River Treatment Works (unimpacted); SW41 was added downstream of the Liese Creek confluence (impacted by tailings facility and ORTW discharge); and SW42 was added downstream of the Advanced Exploration Area and upstream of SW15 (impacted by stormwater and treated domestic wastewater discharge).[756]

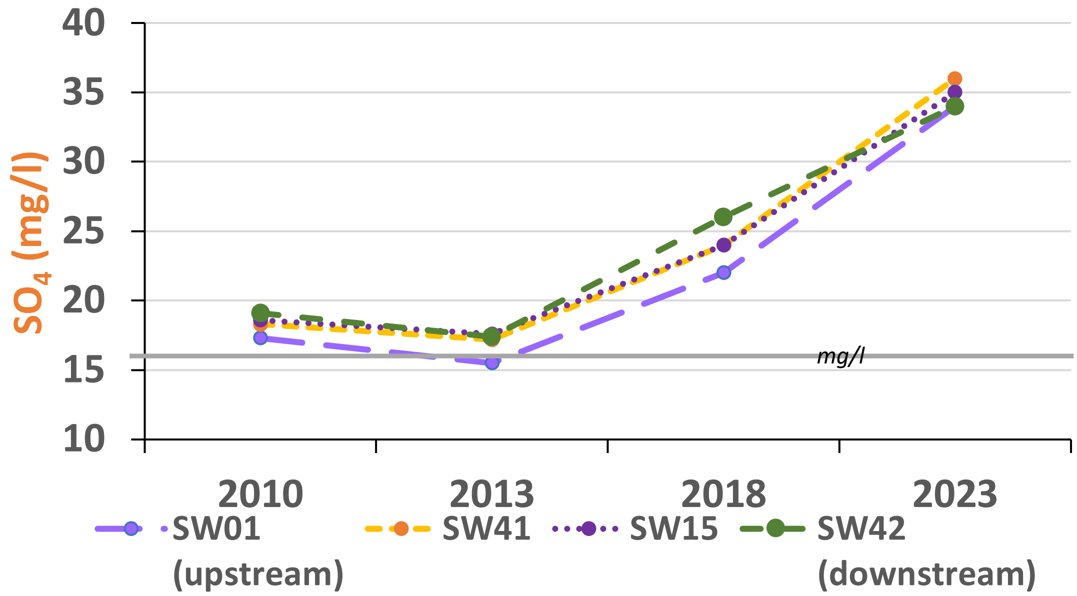
Since mining began, TDS, sulfate, and nitrate concentrations have been documented to increase as the Goodpaster River flows downstream. The increases are not large, but the pattern is consistent. This trend was not the case prior to mining, when TDS and nitrate concentrations decreased moving downstream. Representative TDS averages are shown in Table 4 and Figure 6. A confounding issue is that these constituents, including sulfate, have increased at upstream point SW01 as well as in downstream locations over time. The cause of the increase at SW01 is unclear.

Pogo Table 4. Average TDS Concentrations in the Goodpaster River over Time.

	SW01	**SW49**	**SW41**	**SW42**	**SW15**	**SW12**
Baseline, 1998-2000	79.6				71.8	72.8
2010	88.4		89	101	89.3	71.3
2013	74		87	87.5	88	86.3
2018	91	89	96	101	97	99
2023	107	101	110	106	112	117

All values are mg/l.
Monitoring stations are in order from farthest upstream (SW01) to farthest downstream (SW12). For map, see ACEC, 2017. Alaska Pollutant Discharge Elimination System Permit Fact Sheet -- Final. *Pogo.NPDES Fact Sheet.ADEC 2017.pdf [30]* (reproduced below).
Baseline data are from HDR Alaska, 2001. Pogo Environmental Baseline Document, Vol. 2 -- Water Quality. *Pogo.Baseline surface water.HDR 2001.pdf [20]*
Baseline averages are from a total of 23-26 sampling events.
2010-2018 data are from the 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx*
2023 data are from the 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx*

[753] For map, see FEIS. *Pogo.FEIS.USEPA 2003.pdf [181]*
[754] FEIS. *Pogo.FEIS.USEPA 2003.pdf [366]*
[755] FEIS. *Pogo.FEIS.USEPA 2003.pdf [181, 197]*
[756] Northern Star Resources, Ltd., 2023. 2022 Annual Report. *Pogo.2022 Annual Report.Northern Resources 2023.pdf [34]*



Pogo Figure 6. Surface-Water Sulfate Concentrations in the Goodpastor River. *See Table 4 for data sources.*

Water quality impacts may increase after mine closure, when treatment is likely to end. Most of the water that requires treatment is adit water from the underground workings; at closure, the mine's four adits will all be below the water table. To contain the outflow, the reclamation plan calls for plugging the adits. Even if water from the mine workings does not discharge directly to the Goodpaster River, it will ultimately discharge to the river through groundwater.[757] While this is not planned to occur until water quality standards can be met, water quality degradation may increase for parameters that do not have water quality standards or that are currently treated to a level significantly below water quality standards.

6. Accuracy of Water Quality Predictions

The EIS provides quantitative predictions regarding the water quality of several waste streams at the Pogo Mine. Of these, the treatment plant effluent and water in the tailings facility also have monitoring data that can be compared to the predictions.

In regard to effluent from the treatment plant prior to mixing with river water, both average and maximum TDS and sulfate levels were significantly underpredicted (Table 5). A review of data from 2010 through 2019 indicates that maximum values for arsenic, copper, iron, manganese, and cyanide were significantly underpredicted as well.[758]

[757] FEIS. *Pogo.FEIS.USEPA 2003.pdf [113, 353]*

[758] 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx* The Site Number (column 1) is "Outfall 011." Maximum values are from: arsenic 2011 and 2015; copper 2017 and 2019; iron 2011, 2012, and 2015; manganese 2011 and 2019; and cyanide 2010, 2011, 2017, and 2019.

Pogo Table 5. Treatment Plant Effluent, Predictions, and 2023 Measurements.

	Predicted average	Predicted maximum	Actual average	Actual maximum
TDS (mg/l)	433	551	1288	1470
Sulfate (mg/l)	206	272	556	654

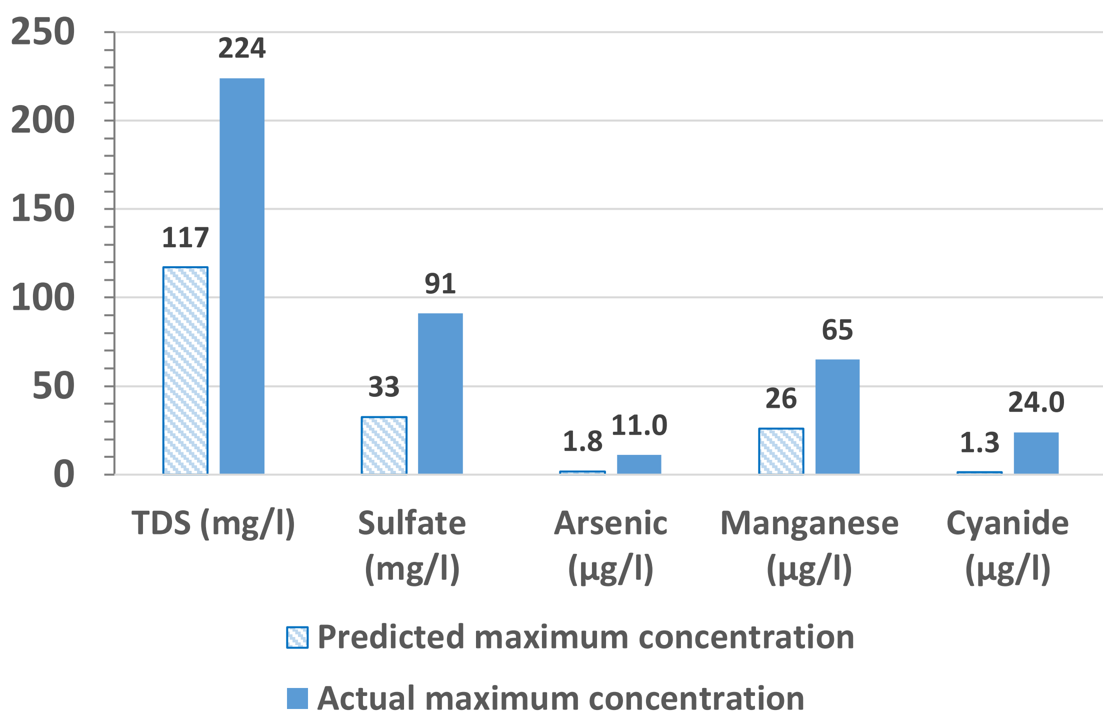
Predictions are from FEIS. *Pogo.FEIS.USEPA 2003.pdf [389]*
Monitoring data are from Northern Star Resources, Ltd., 2024. 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx [Sheet "Outfall 011"]*

The EIS also provided predictions of the quality of effluent after mixing with river water (Outfall 001), which were generally accurate in terms of average concentrations. An exception is TDS, which was predicted to average 113 mg/l but averaged 140 mg/l in the 2010 to 2019 time period. However, predictions of maximum concentrations were lower than measured maxima for several pollutants (Table 6 and Figure 7).

Pogo Table 6. Treatment Plant Discharge at Outfall 001, Predictions and 2010-2019 Data.

	Predicted maximum concentration	Actual maximum concentration
TDS (mg/l)	117	224
Sulfate (mg/l)	32.6	91
Arsenic (µg/l)	1.8	11
Manganese (µg/l)	26	65
Cyanide (µg/l)	1.3	24

Predictions are from FEIS. *Pogo.FEIS.USEPA 2003.pdf [389]*
Actual concentrations are from the 2019 Spreadsheet. The Site Number (column 1) is "Outfall 001." Maximum values are from 2011 (TDS and manganese) and 2016 (sulfate, arsenic, and cyanide). Extreme outliers were removed. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx*



Pogo Figure 7. Predicted vs. Actual Maximum Concentrations in Treatment Plant Outfall 001.
See Pogo Table 6 for data sources.

The EIS also provided water quality predictions for the tailings seepage and runoff. Interstitial tailings water is monitored and can be compared with the predictions. TDS and sulfate are consistently higher than the predicted “worst-case” seepage. In 2023, sulfate averaged 2,220 mg/l, with a maximum of 2,400.[759] All data points were above the predicted worst-case concentration of 2,000 mg/l. TDS averaged 3,950 mg/l, compared to a predicted worst-case concentration of 3,000 mg/l. The year 2023 was not an anomaly. For example, in 2013, TDS averaged 4,492 mg/l.[760]

Arsenic, copper, and selenium typically fall between the predictions for the average and "worst case" seepage. However, each occasionally exceeds the “worst-case” prediction (Table 7). In 2016, arsenic levels were above 5,100 µg/l on three out of four monitoring dates, with a maximum of 7360 µg/l. The same year, copper levels ranged from 57 to 1110 µg/l; in 2014, copper levels ranged from 78 to 521 µg/l. Selenium was particularly high in 2012, ranging from 750 to 938 µg/l.[761] These metals have fluctuated significantly over the years; thus, the EIS was also mistaken in its prediction that "the seepage water quality would remain relatively consistent over the life of the project."[762]

Pogo Table 7. Pogo Mine Tailings Water Worst-Case Predictions and 2010-2019 Data.

	Predicted worst-case runoff	Predicted worst case seepage	Actual worst case interstitial water
TDS (mg/l)	523	3,000	5,860
Sulfate (mg/l)	302	2,000	2,850
Arsenic (µg/l)	400	5,100	7,360
Copper (µg/l)	3	34	1,110
Selenium (µg/l)	6	130	938

Predictions are from FEIS. *Pogo.FEIS.USEPA 2003.pdf [364]*
Actual concentrations are from the 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx* The Site Number (column 1 or 2) is "PC003." Maximum values for sulfate, arsenic, and copper are from 2016; for TDS from 2015; and for selenium, 2012.

7. Summary of Water Quality Impacts

Source Materials:

The mixture of tailings and “mineralized” waste rock in the unlined dry-stack tailings facility is a potential long-term source of pollution. This waste rock can produce acidic and/or metal-laden leachate (“mineralized” rock contains >0.5% sulfide S and/or >600 ppm arsenic). Burial of the rock within the tailings should reduce or eliminate oxidation, and thus production of acid leachate; but as the tailings wash away over time, the mineralized rock will eventually load pollution to groundwater.

The tailings themselves are at least a short-term source of pollution. Although the tailings were dewatered prior to disposal (thus the term “dry stack”), dewatering leaves some residual water, and

[759] Northern Star Resources, Ltd., 2024. 2023 Annual Monitoring Report, Appendix E. *Pogo.2023 Annual Report App E.Northern Star 2024.xlsx [Sheet "PC003 Interstitial"]*
[760] 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx [Sheet "Data 2013," rows 4005-11]*
[761] 2019 Spreadsheet. *Pogo.2019 Annual Report App E.Northern Star 2020d.xlsx [Sheet "Data 2016," rows 2269-76; Sheet "Data 2014," rows 4057-62; Sheet "Data 2012," rows 4100-06]*
[762] FEIS. *Pogo.FEIS.USEPA 2003.pdf [363]*

infiltrating meteoric water flushes this interstitial water into groundwater. Numerous constituents in the interstitial tailings water far exceed surface and groundwater quality criteria. Specifically, maxima between 2012 and 2023 include sulfate (average 2,850 mg/l), arsenic (7.36 mg/l), copper (1.11 mg/l), and selenium (0.94 mg/l) (*Section 86* and Table 7). Although most of the tailings seepage to groundwater is captured, the tailings and the "Recycle Tailings Pond" are unlined, so seepage enters groundwater. Groundwater monitoring indicates that seepage from the tailings facility is indeed degrading groundwater beyond the interception wells.

Degradation of groundwater would increase if the pump-back capture and treatment system is discontinued. As of 2019, the dry-stack tailings facility contains 9.4 million tons of tailings and 5.5 million tons of mineralized waste rock.

The "non mineralized" waste rock is used for surface construction (roads, recycle tailings pond, and dry-stack toe berm). Though it has essentially "no net-acid generation potential," it may still contain up to 0.5% sulfur and thus remains a source of soluble sulfate and other constituents (such as arsenic and selenium) that are mobile at neutral pH. Given the location of monitoring points and the more noticeable impacts from tailings and mineralized rock, impacts from non-mineralized waste rock used in construction cannot be determined.

Effluent:

Excess water from underground workings and the tailings pump-back system are treated and diluted before discharge to the Goodpaster River. The discharge has occasionally exceeded permit limits for metals (cadmium, copper, iron, lead, and manganese), but monitoring has not shown impacts to the Goodpaster River itself.

Groundwater:

The dry stack tailings and Recycle Tailings Pond are unlined, and there is a strong indication that nitrate—a very mobile solute in aquifers—is moving in groundwater beyond the pump back capture system. From 1.1 mg/l in baseline samples, nitrate has increased to 28 mg/l at the toe of the tailings (MW11-001A), 24 mg/l downgradient of the Recycle Tailings Pond (MW12-005), and 14 mg/l farther down Liese Creek (MW18-003A). Sulfate and dissolved solids show similar but less dramatic temporal trends of increase in groundwater (Table 2 and Table 3). Pollutants that are more attenuated in groundwater (e.g., arsenic, selenium, copper) do not show pronounced increases in groundwater down-gradient of the tailings, but it is reasonable to assume that these solutes will eventually arrive, entering Liese Creek and the Goodpaster River.

Surface Water:

Based on groundwater monitoring, Liese Creek has likely been impacted but is not monitored.

TDS, sulfate, and nitrate have increased in the Goodpaster River downstream of Pogo Mine (Table 4). However, these solutes have also increased upstream of the mine, and it is unknown to what degree increases stem from mine facilities.

8. Comparison to Potential Mines in the Rainy River Headwaters of Minnesota

The Pogo Mine site is similar to sites in the Rainy River Headwaters Watershed in that it is wet, is in immediate proximity to a river, and is transected by a small creek. However, the Pogo site receives about 30% less precipitation. Sulfide levels in ore and waste rock are fairly similar. However, the Pogo Mine is smaller than Duluth Complex mines would be and appears to have less potential for acidic or neutral leaching of metals from waste rock.