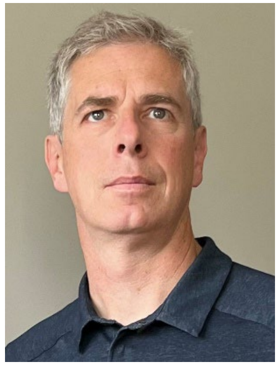
Trends in Mine Water Management

August 2024

Speakers



Eric Schraml, P.Eng.

Industrial National Market Sector Lead

- 30+ years of experience in industrial project delivery
- Specializes in the mining sector

Lucy Pugh, P.E., BCEE

Vice President, Global Industrial Water Practice Director

- 35+ years of experience in industrial wastewater treatment and reuse

AECOM

Agenda

Trends in the Mining Industry	Mining Water Management	Case Studies
Clean energy transition Novel mining approaches Global mining activity	Water Use and Water management Water quality considerations	Solar Glass Base Metals Mining Giant Mine

AECOM

Trends in the Mining Industry

Impacts of Clean Energy Transition

- Transition to clean energy sources increases the demand for various metals, including copper, nickel and zinc
- Electric vehicles and electronic devices also drive the demand for base metals and rare earth elements
- Copper demand expected to increase by 50% in next 20 years (World Bank)

Element	Wind	Solar photovoltaic	Concentrated solar power	Hydro	Geothermal	Energy Storage	Nuclear	Coal	Gas	Carbon capture and storage
Aluminum	●	●				●	●	●	●	
Chromium	●			●	●	●	●	●	●	●
Cobalt						●		●	●	●
Copper	●	●	●	●	●	●	●	●	●	●
Graphite						●				
Indium		●					●			
Iron	●					●				
Lead	●	●		●		●	●			
Lithium						●				
Manganese	●			●	●	●		●	●	●
Molybdenum	●	●		●	●		●	●	●	●
Neodymium	●									
Nickel	●	●		●	●	●	●	●	●	●
Silver		●	●				●			
Titanium				●	●		●	●	●	
Vanadium						●	●	●		
Zinc	●	●		●		●	●			
Total	10	8	2	8	6	11	11	9	8	6

World Bank: Minerals for Climate Action

AECOM

Increasing Mineral Demands - New Mining Approaches

- Shift from oxide ores to sulfide ores
- Metals extraction from non-conventional sources
  - Brine recovery
  - Legacy mine tails reprocessing
  - Minerals and metals recovery from e-waste and other wastes
- Optimizing water management and reuse

Water and Mining

Water is essential for mining operations

- Mining – dust suppression, cleaning equipment
- Processing – wet grinding, washing, flotation, leaching
- Transportation – pumping tailings and products
- Utilities – cooling water, pollution control

Water is impacted by mining operations

- Acid rock drainage from mine waste
- Residual chemicals in mine waste
- Tailings management
- Diversion of streams

AECOM

Increased Focus on ESG

Competition for fresh water in water-scarce areas

Water management in coastal areas driven by climate change

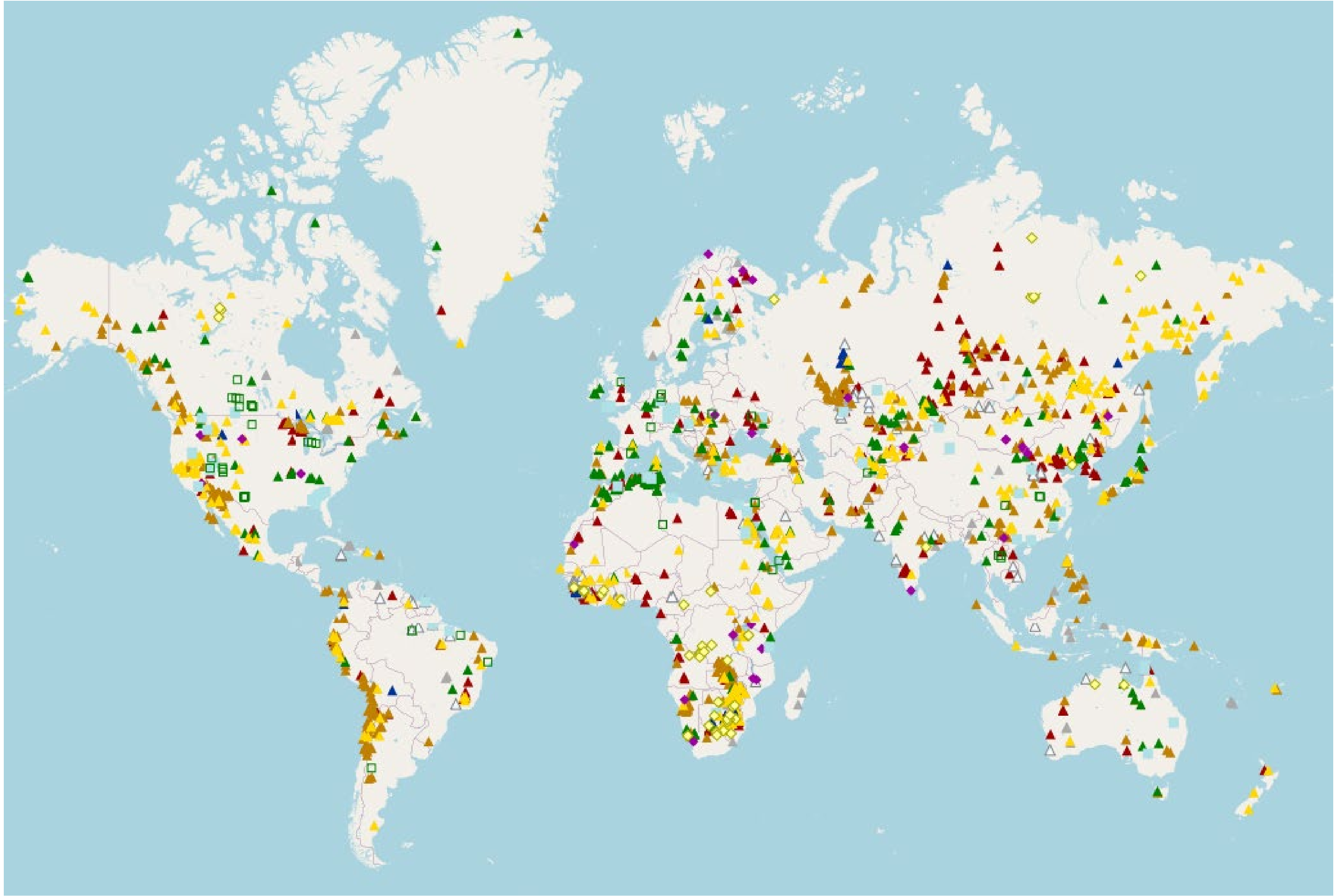
Increasingly stringent water discharge requirements

- Suspended solids
- Dissolved solids
- Sulfate
- Selenium
- Mercury
- Other substances of concern

Social awareness – minimize community impacts

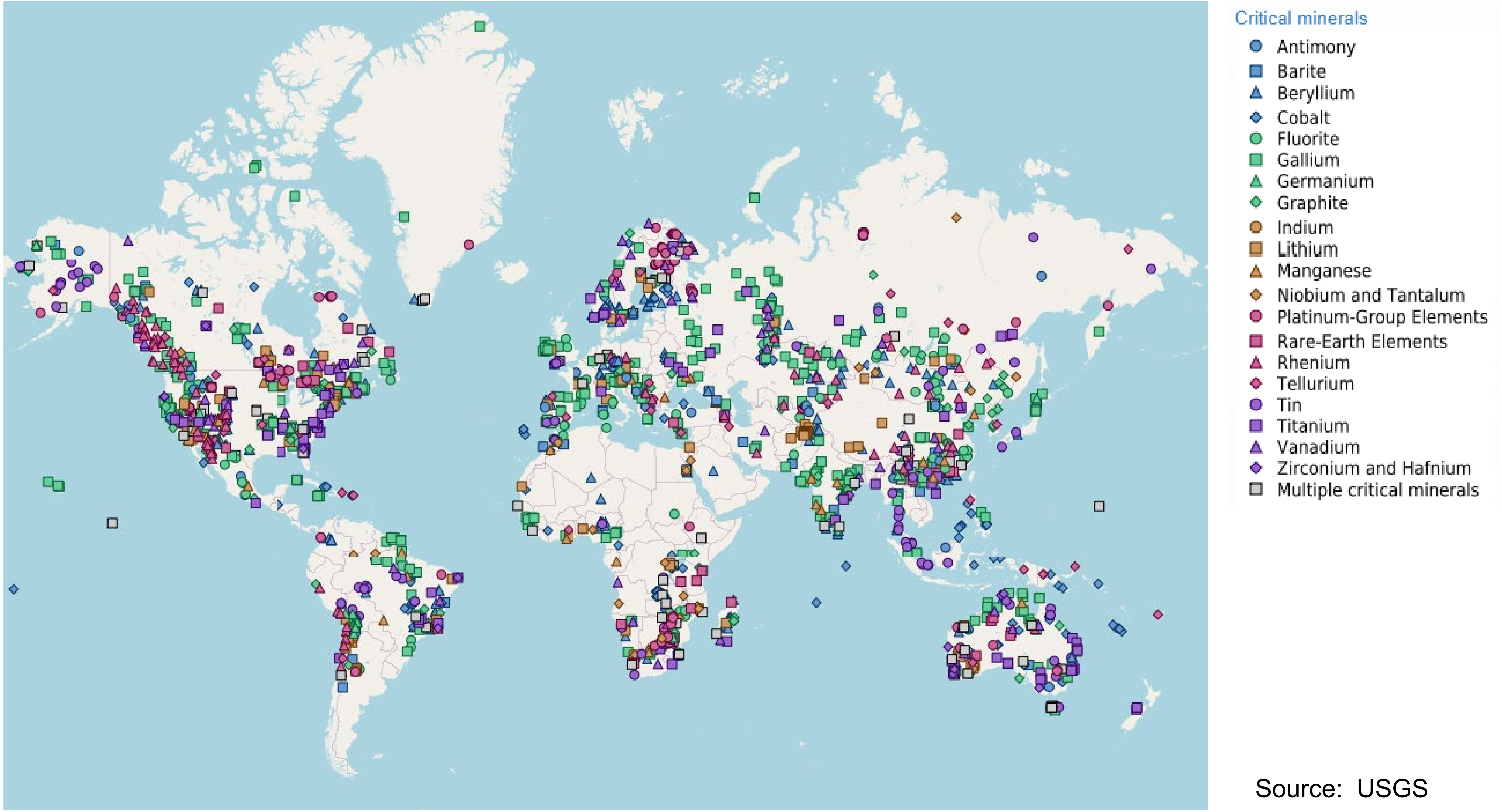
AECOM

Global Mining Activity – Major Mineral Deposits



Source: USGS

Global Mining Activity – Critical Minerals

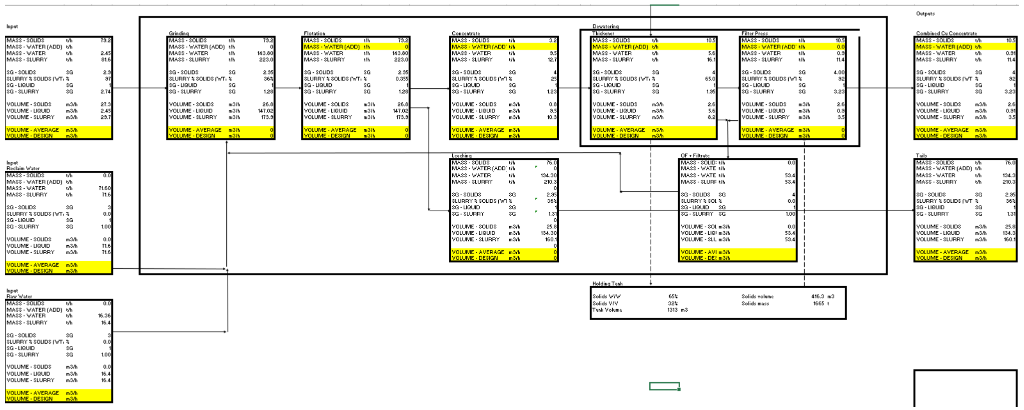


Source: USGS

AECOM

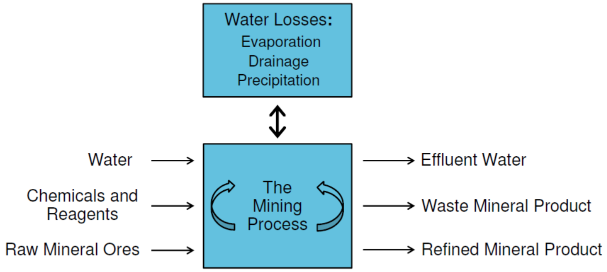
Mining Water Management

Water Use and Management



- Surface / stormwater
  - Prevent contamination / manage dilution
- Mine dewatering water / waste rock impact (AMD)
  - Water generated naturally
  - Underground production (tools, service garages, dust suppression)
- Raw water intake
  - Enabling infrastructure (housekeeping, maintenance activities, fire suppression, environmental controls, thermal processes)
  - Process water
- Process tails
  - Slurry
  - Dry stack
- Reclaim water
  - Process make-up water

Water Balance in a Typical Mine

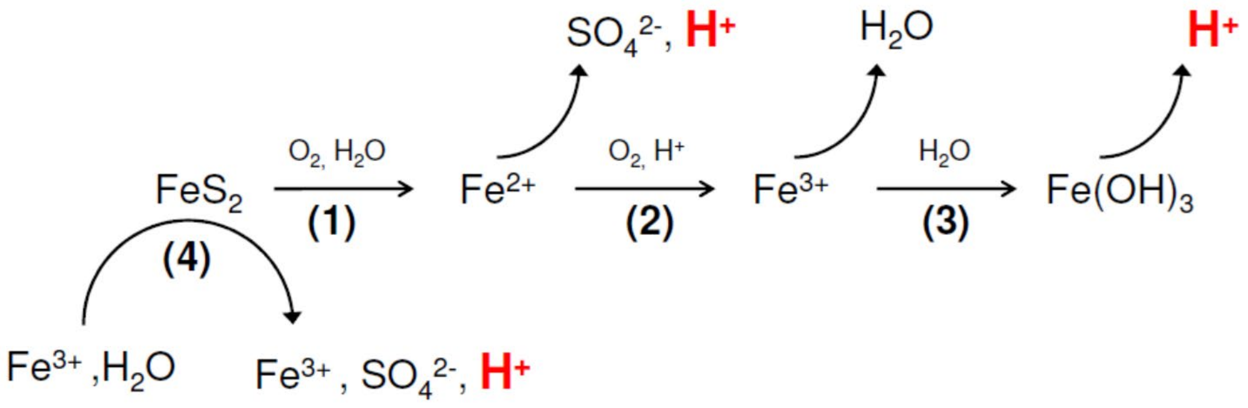


Source: Water for Mining: Opportunities in Scarcity and Environmental Regulation. Global Water Intelligence. 2011. Figure 3.2.

AECOM

Acid Mine Drainage (AMD) Considerations

- Exposed metal sulfides in the presence of water and oxygen react to produce very low pH
- Ferric iron can be self-catalytic, perpetuating acidic conditions
- Other factors that influence acid formation:
  - Type of metal sulfide; pyrite is most common
  - Surface area / size distribution of the exposed metal sulfide
  - Alkalinity of the surrounding rock (i.e. limestone)
  - Exposure to oxygen and water (surface rock, buried, etc.)
  - Presence of biological catalysts (*Thiobacillus* bacteria)
  - Flushing frequency of the surrounding water
  - pH



Water Quality Considerations

- Underground water for production – OH&S considerations
- Process chemistry (bleed requirements) – this limits reclaim water use and increases raw water draw
- Process losses (water lost to product, water lost to enabling infrastructure, utility water)
- Potable water (personnel, laboratory, process analyzers)

Reclaim Water

pH	Temp. deg C	Cond. S/m	Turbidity	Total SS mg/L	Total Cu mg/L	OB/Zn mg/L	Total Zn mg/L	Total Fe mg/L	Total Pb mg/L	Total Cd mg/L	Total As mg/L	Total Mn mg/L	Total Ni mg/L
7.26	20.8	0.1324			0.018	0.26	0.334	0.179	<0.1	<0.007		0.144	<0.05
6.83	21.8	0.1308			0.018	0.23	0.322	0.224	<0.1	<0.007		0.209	<0.05
7.63	23.7	0.1286			0.013	0.2	0.258	0.151	<0.1	<0.007		0.094	<0.05
7.05	22.3	0.1715			<0.013	0.17	0.248	0.161	<0.1	<0.007		0.082	<0.05
7.07	19.7	0.1335			<0.013	0.24	0.24	0.152	<0.1	<0.007		0.068	<0.05
6.89	19.7	0.133			<0.013	0.19	0.248	0.174	<0.1	<0.007		0.071	<0.05
6.67	20.9	0.1337			0.013	0.19	0.258	0.215	<0.1	<0.007		0.081	<0.05
6.66	21.6	0.127			<0.013	0.18	0.242	0.173	<0.1	<0.007		0.101	<0.05
7.00	20.2	0.1369			<0.013	0.21	0.252	0.224	<0.1	<0.007		0.099	<0.05
6.86	21.6	0.1494			<0.013	0.26	0.259	0.181	<0.1	<0.007		0.103	<0.05
6.21	21.9	0.1284			<0.013	0.18	0.27	0.156	<0.1	<0.007		0.122	<0.05
6.44	21.6	0.125			0.014	0.19	0.256	0.282	<0.1	<0.007		0.127	<0.05
7.17	17.0	0.1376			<0.013	0.23	0.273	0.102	<0.1	<0.007		0.086	<0.05
7.67	21.7	0.1366			<0.013	0.22	0.263	0.111	<0.1	<0.007		0.062	<0.05
6.26	22.2	0.1294			<0.013	0.24	0.276	0.07	<0.1	<0.007		0.06	<0.05
8.06	18.2	0.1261			<0.013	0.22	0.273	0.077	<0.1	<0.007		0.038	<0.05
6.45	18.7	0.1356			<0.013	0.22	0.254	0.079	<0.1	<0.007		0.039	<0.05

AECOM

Mine Process Water Treatment Technologies

Technology	Examples	Application
Neutralization	Lime or limestone addition	Acid rock drainage
Solids separation	Clarifiers, dissolved air flotation	Volume reduction of tailings
Passive treatment	Wetland systems	Polishing
Metals removal	Sulfide precipitation, biological filters, ion exchange or sorbent media	Metal recovery – saleable product
Membrane filtration	Microfiltration, ultrafiltration, reverse osmosis	Water reuse
Evaporators and concentrators	Brine concentrators, crystallizers, atomizers	Zero liquid discharge
Thickening and dewatering	Paste thickeners, pressure filters	Volume reduction of tailings
Cyanide neutralization	Alkaline chlorination, hydrogen peroxide	Gold processing effluent

Case Studies

Solar Glass

- Sensitive area (adjacent park lands)
- Indigenous community impacts
- Project targets:
  - Zero discharge permit
  - Make-up water for water lost to product only
  - Product quality achieved with mechanical process methods rather than chemical treatment to eliminate the need for discharge

AECOM

Base Metals Mining

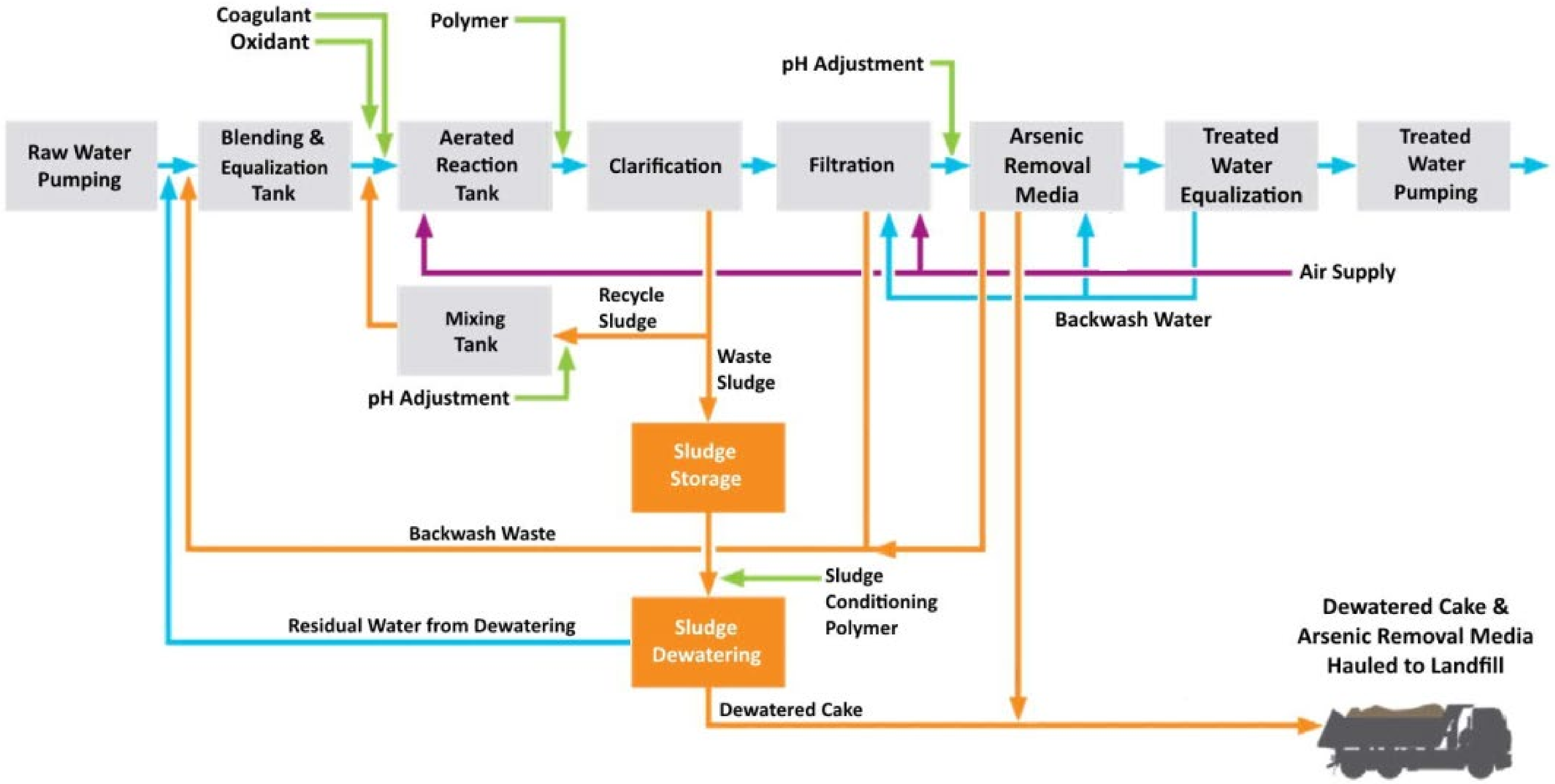
- Complexities:
  - Stormwater management from adjacent areas (surges)
  - Spring melt surges
  - Bulk conditioning prior to discharge (diluted with surge waters)
- Tactics
  - Diversion to old mine workings
  - Diversion of unimpacted surface dilution
  - Evaporation strategies
  - Flow buffering in conditioning areas
  - Re-processing to neutralize tails and recover trapped metals

AECOM

Giant Mine Water Treatment

- 50 years of operation; > 7 million ounces of gold
- 2,300 acres in Yellowknife, NT
- 8 open pits, 4 tailings ponds, 100 buildings
- Arsenic trioxide dust stored underground and pervasive throughout the site.
- Flooding of the underground through inflow and groundwater infiltration created a large, contaminated mine pool.
- Receding permafrost contributed to additional groundwater movement and seepage.

Giant Mine Water Treatment



AECOM

Giant Mine Water Treatment

Summary

Summary Remarks

Increased demand for base metals and rare earth elements

- Energy transition
- Electric vehicles and electronic devices

Water stewardship

- Regulatory safeguards
- Improved awareness of long-term impacts
- Focus on reducing water discharges

Innovations

- Metals/minerals recovery from unconventional sources
- Technological advancements for neutralization and recovery of trapped resources in tails

Q&A

Eric Schraml, P.Eng.
eric.schraml@aecom.com
+1 587 334 3285

Lucy Pugh, P.E., BCEE
lucy.pugh@aecom.com
+1 616 450 0127