- Yukon Government and advisors
- first nation of the Nacho Nyuk Dun – whose traditional territory the Eagle mines lays within and their advisors.
- PWC and ECCC (environment and climate change Canada)

Eagle Mine Heap Leach Facility Failure

BQE Water

June 24th, 2024

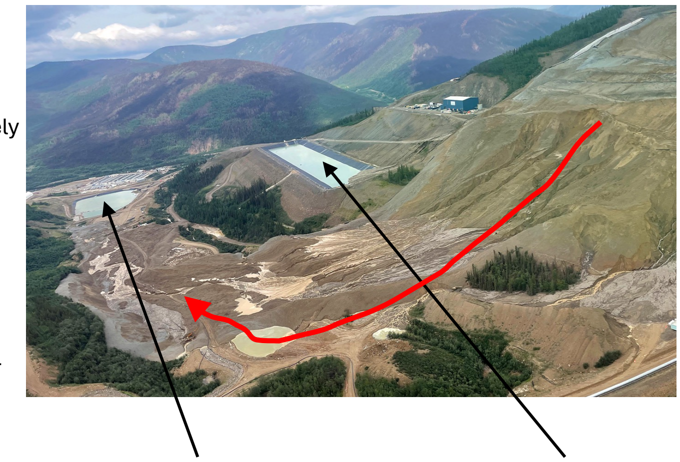
- **~ 4 million tonnes** of ore wetted with cyanide leach solution released to the valley
- Cyanide contaminated surface and ground water
- Efforts to contain contaminated water immediately initiated

August 14th, 2024

- Yukon Government appoints PwC as Eagle Mine Receiver

September 1st, 2024

- BQE contracted to retrofit the existing mine water treatment infrastructure for treatment of cyanide contaminated water
- 750,000 m^3 of CN leach solution requiring treatment and discharge to environment

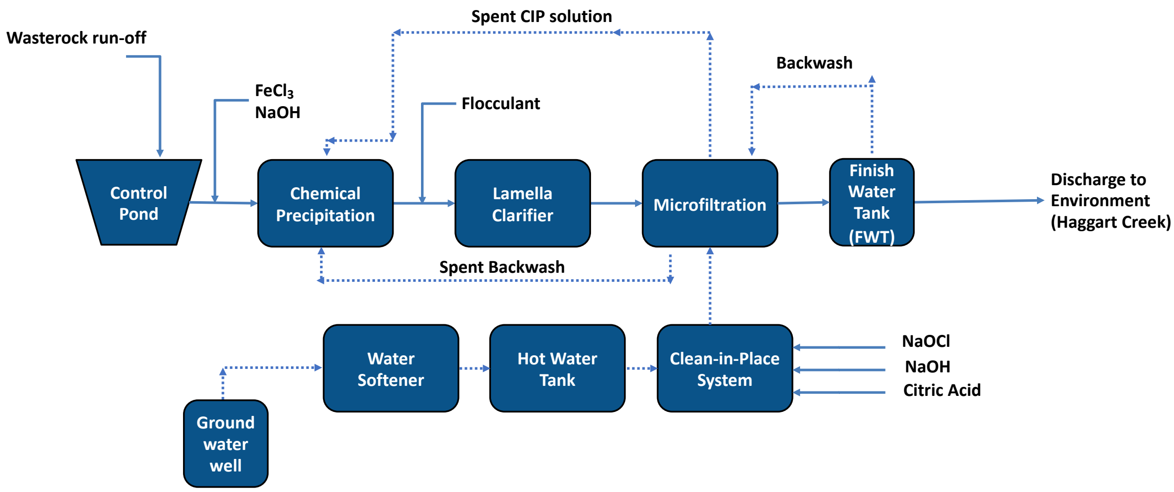


Events pond for unforeseen event, constructed to contain leach solution, double lined etc
Control pond for wasterock runoff, not designed for leach solution
Estimated 750k m3 contaminated water on site requiring treatment, not including freshet estimates

Water Treatment prior to Heap Failure

BQE Water

Eagle plant was designed to remove TSS and arsenic from wasterock run-off



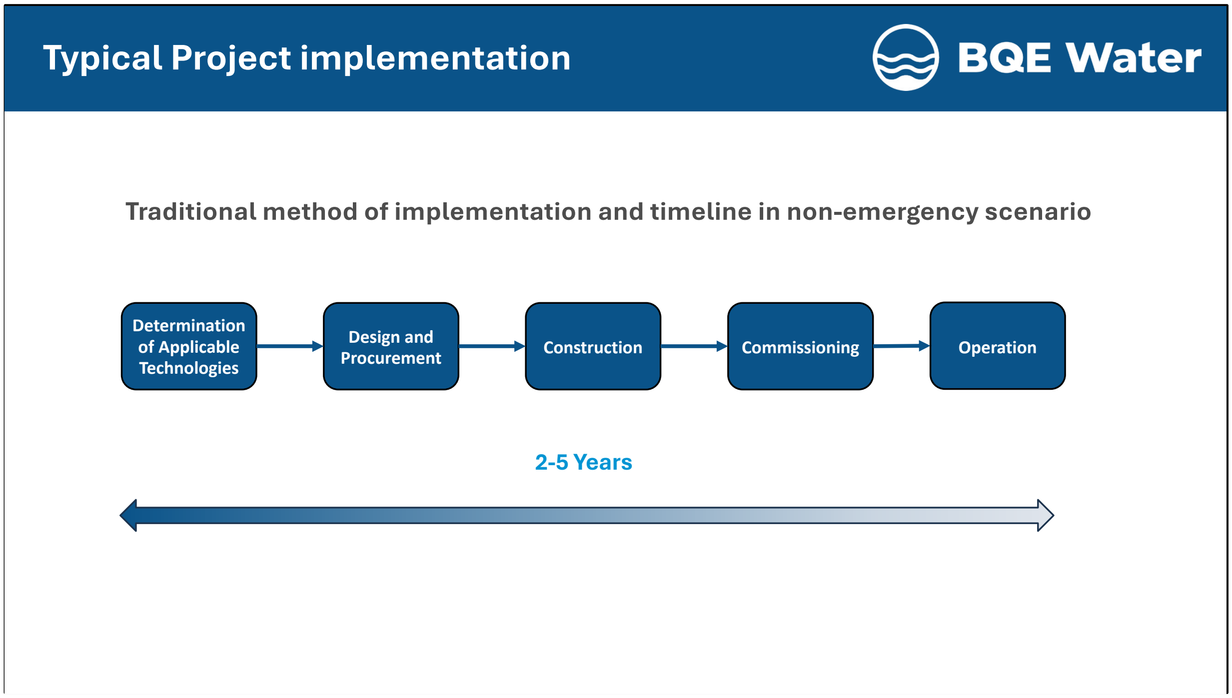
Key aspects of the plant was – reactor tanks design did not allow introduction of aeration. Ground water well was the source of clean water for hot water and CIP. MF Backwash recycled to reactors and spent CIP recycled to reactors. All of this presented a serious challenge to repurposing the existing plant for treating cyanide leach solution from the heap.

Challenge for Water Treatment post Heap Failure

BQE Water

COC	Water Use License [mg/L]	Event Pond [mg/L]	Control Pond [mg/L]
SO4	1850	235	161
Cl	250	64	192
Weak Acid Dissociable (WAD) CN	0.03	80	25
Strong Acid Dissociable (SAD) CN	1	82	24
NH_3-N	7.5	38	32
CNO^-	-	114	83
SCN^-	-	170	90
NO_3-N	19.5	49	32
NO_2-N	0.12	2.94	1.76
As	0.053	0.076	0.053
Se	0.025	0.116	0.061
Ag	0.01	0.142	0.1
Zn	0.23	7.05	1.43
Cu	0.026	25	11.5
Ni	0.5	6.32	3.77
Hg	0.00008	0.000945	0.000743
Cd	0.00125	0.007843	0.006348
Co	0.026	2.528	1.037

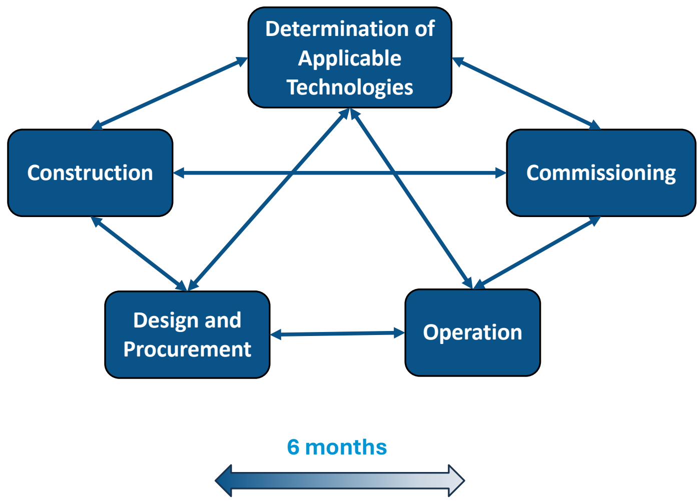
- **many new constituents requiring removal, most of which the existing system would be unable to treat.**
- **WTP designed to remove TSS some oxyanions and metals**
- Date sources for before HLF failure: Lorax 2020 report and Linkan Commissioning report



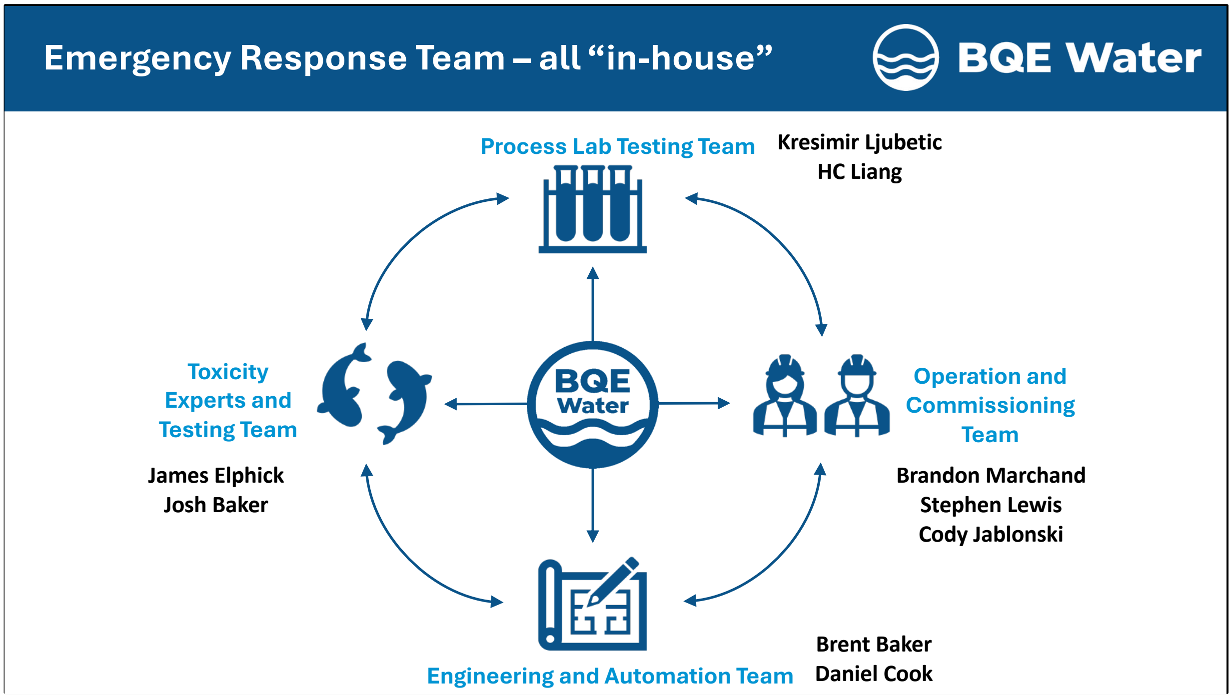
Obviously, for this project a timeline of 3-5 years would be unreasonable to achieve goals

Emergency Response Implementation Method

BQE Water



Needed the treatment plant ready for freshet



Kresi and Brent for taking lead in the project and representing BQE in all weekly stakeholder meetings
Brandon for working with the Nacho Nyuk Dun to bring in first nation operators and training them
James and josh for running toxicity investigations and analyzing toxicity data from the accredited labs

Emergency Treatment Concept & Questions

BQE Water

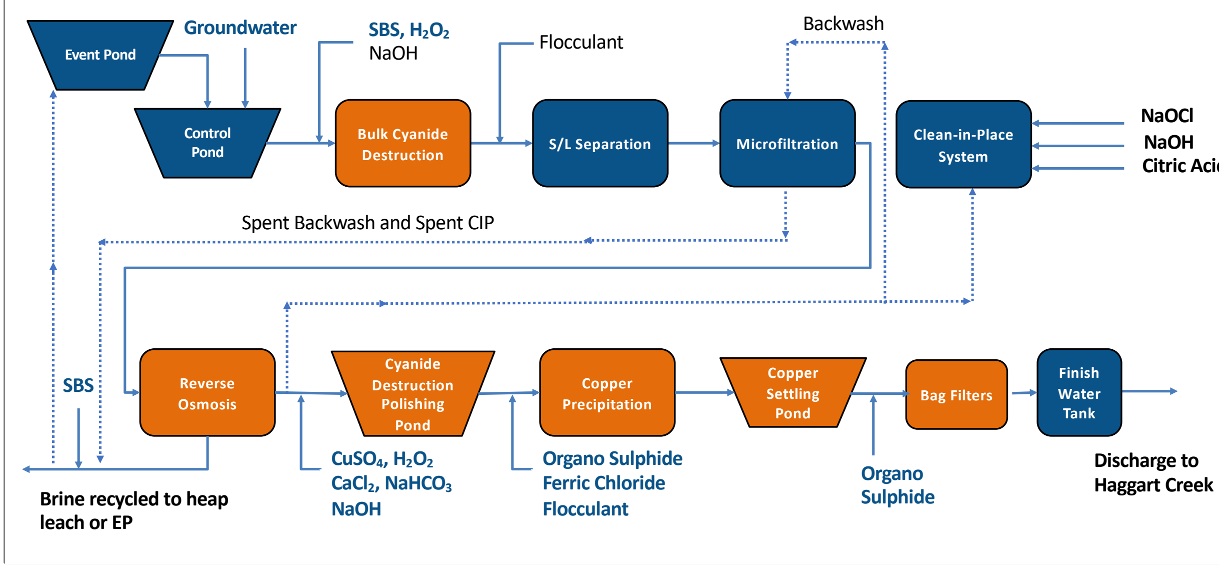
Heap Leach Solution → Pre-treatment ?? → Reverse Osmosis → Polishing ??? → Discharge to Haggart Creek

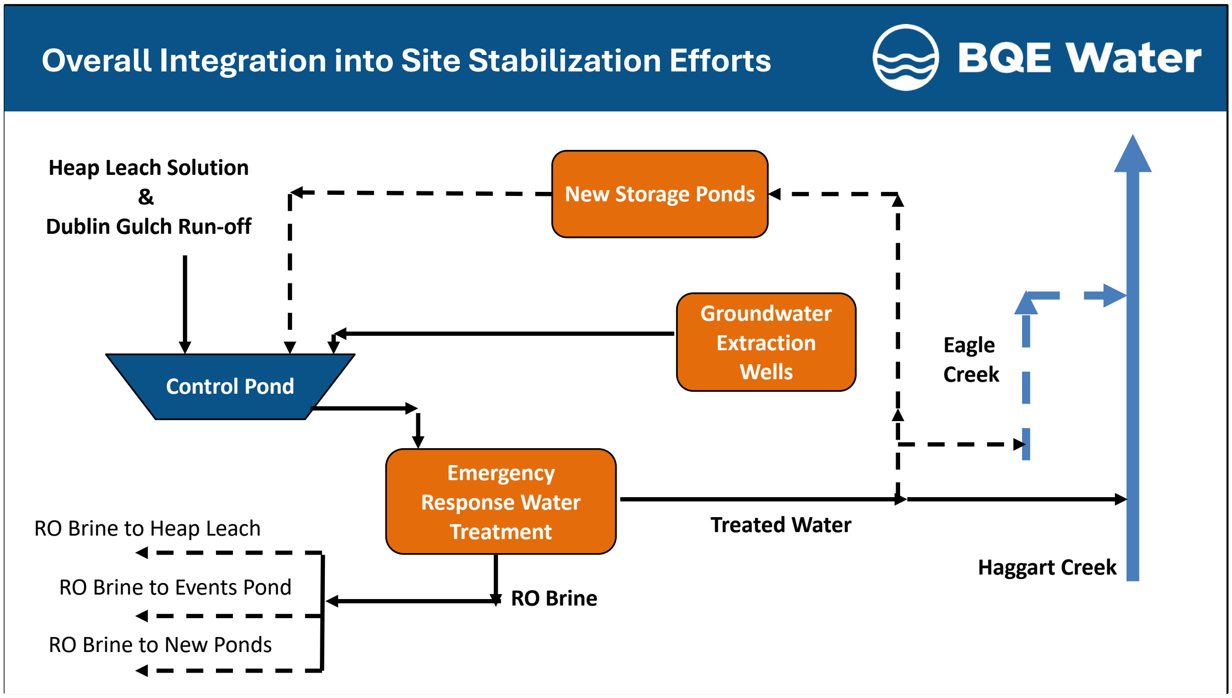
- ❑ **RO needed to achieve simultaneous removal of more than 20 constituents with > 90% efficiency. *(retains gold in solution for recovery)***
- ❑ **Cyanide is the main toxicant and compliance with 30 ppb WAD CN limit is paramount. Getting cyanide destruction right is key.**
- ❑ **What kind of pre-treatment and polishing treatment is needed???**

30 ppb CN target unprecedented in normal situations where treated leach solution is discharged to the environment

Emergency Treatment "as Implemented"

BQE Water





New storage ponds instrumental to commissioning the plant before discharge (non compliant water)
Groundwater was continually being contaminated from in-heap pond; therefore new interception wells were drilled to direct water to treatment
Eagle Creek within mine, initial discharge here as 2 km of wetlands before reaching Haggart (discharge to environment)

Surprises & Learnings that Triggered Pivots

BQE Water

- ❑ % rejection of ALL cyanide species by RO is lower than predicted by models regardless of pH and ionic charge.

- ❑ Application of RO downstream of cyanide destruction is not straightforward
  - CuSCN precipitates and fouls RO.
  - Special cleaning recipe had to be developed.
  - Chemical attack on membranes reduces rejection.

- ❑ Fine copper particles can be ingested by *Daphnia* and induce toxicity. Not predicted by Biotic Ligand Model assuming only dissolved copper is bioavailable.

- ❑ Type of organo-sulphide and method of introduction both matter for compliance including effluent toxicity and total and dissolved concentrations of copper, nickel, and free cyanide

Reverse Osmosis

BQE Water

- ❑ **5 RO Trailers**
  - Closed circuit reverse osmosis (CCRO) capable
  - Brackish water membranes
- ❑ **Had to switch from CCRO mode to plug flow desalination (PFD) mode to improve permeate quality**
- ❑ **Membrane fouling with CuSCN**

Procured RO capable of running in CCRO mode to minimize brine generation and footprint.
Each trailer 2 RO systems, each system 16 membrane housings, with 6 membranes in each housing, totaling 192 membranes/trailer

ERLSTF – How we arrived at the Process

BQE Water

- Cyanide Destruction Polishing Pond
  - $CuSO_4$ had to be added
  - H_2O_2 dosed in large excess > 600% stoichiometric

- Frac tank with floc logs for HRT and flocculation of copper organo-sulphide & ferric particles
- Settling Pond for copper particles with curtains to minimize short-circuiting in the pond

- The RO reject most constituents to below limits,
- Pond - Due to limited space availability, and the HRT requirements to
- Cu catalysed peroxide required a dose of CuSO4 into the CN polishing pond – INCO needed O2, tighter pH control, SBS consume O2 – toxic effluent, still need added Cu
- Filtration methods were attempted to remove this copper from the treated solution, however the precipitates formed were too mal to filter with immediately available rental equipment (1 micron absolte bag filters)
- Decision was made to develop another settling pond to allow Cu-TMT solids to settle.
- Since settling pond has been incorporated, Cu-T has been maintained below MDMER limits

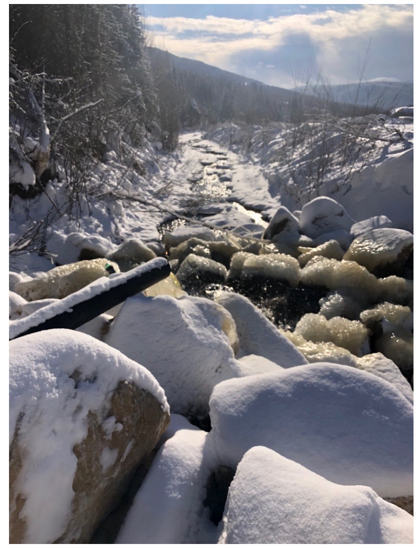
Definition of Success

BQE Water

- ❑ **Reduce inventory of contaminated water on site**
  - Achieve drain-down of Heap Leach Facility
  - Residual inventory allowing treatment to stop before freeze-up and resume before freshet in 2026.

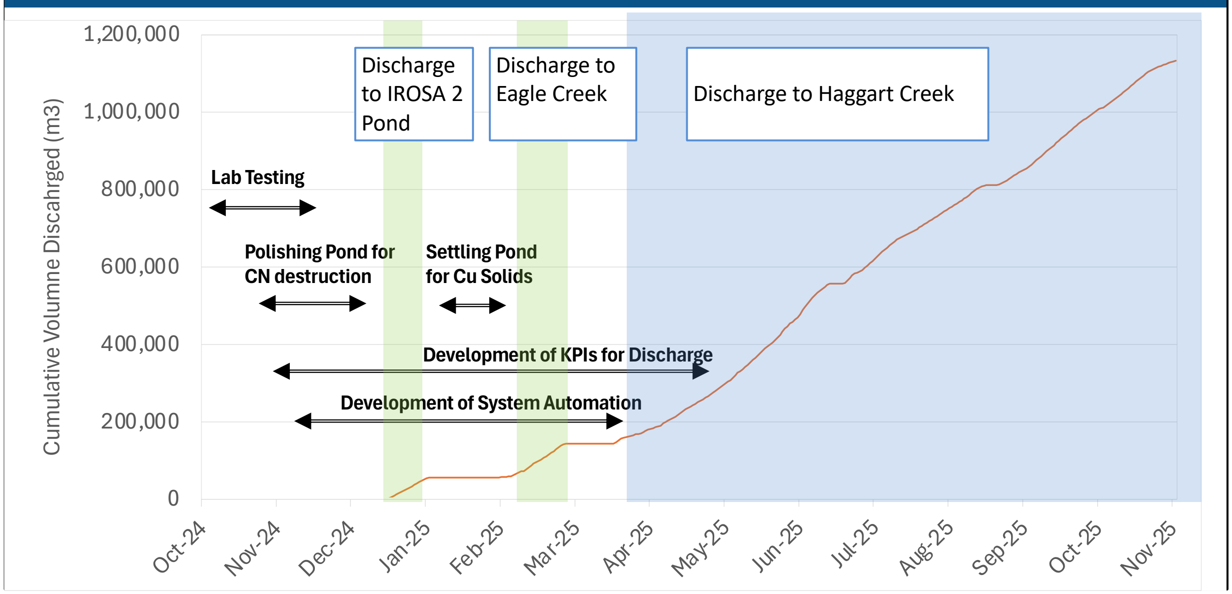
- ❑ **Ensure treated water is non-toxic.**

- ❑ **Remove as many constituents as possible to Water Use License limits** (many required >>99% removal)



Results – Implementation Timeline and Ramp-up

BQE Water



Before discharging – lab testing to proved the process and triggered the installation of the polishing pond for CN destruction. After initial field commissioning the need for settling pond for fine copper particles was established. The final discharge to Haggart Creek required automation to be complete and KPI's to be developed. KPIs continued to be enhanced even during actual discharge based on results of chemistry and toxicity tests.

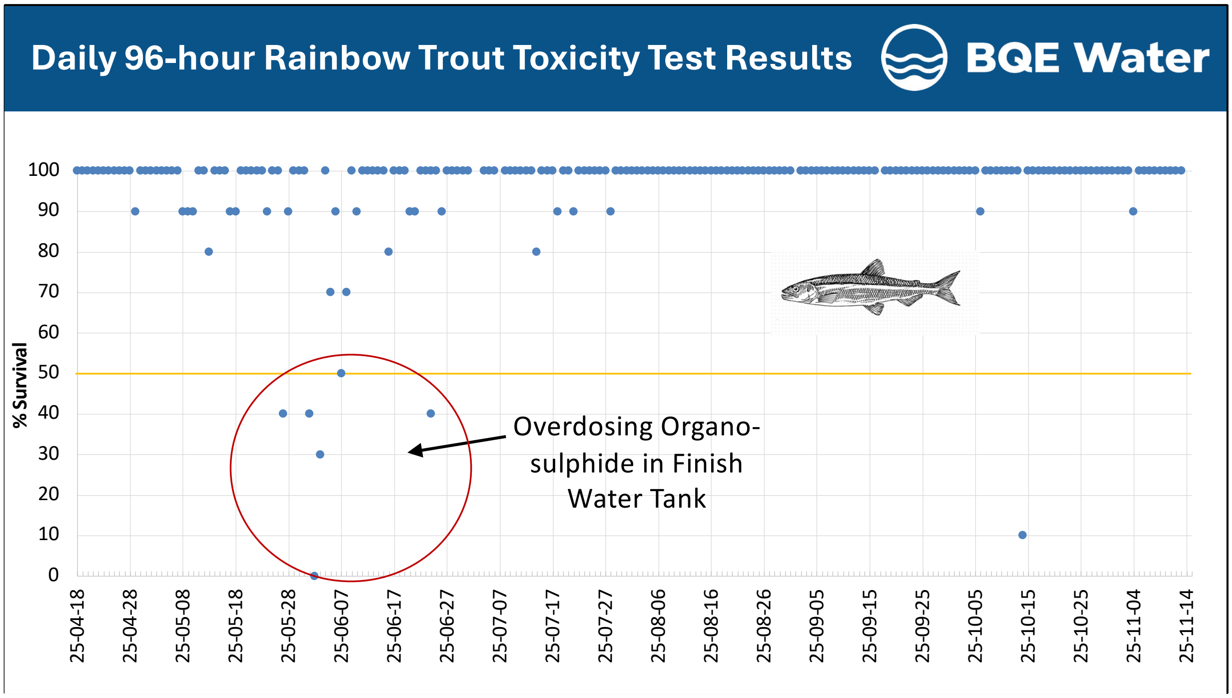
Process & Effluent Quality Monitoring

BQE Water

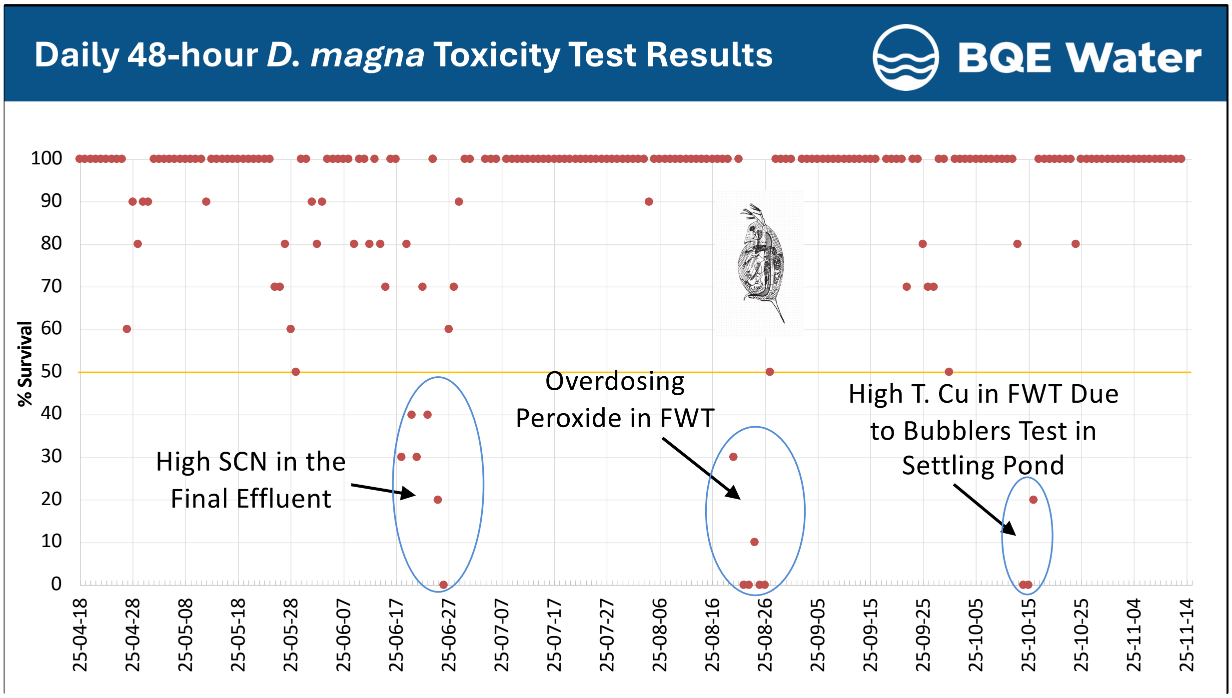
Since the continuous discharge into Haggart Creek was initiated

Daphnia Magna 48 hr Acute Toxicity Tests	225 tests (90.22% non-toxic)
Rainbow Trout 96 hr Acute Toxicity Tests	225 tests (98.2% non-toxic)
Total 3rd Party Chemical Assay	Over 2,000 samples

- Daily 24-hour composite samples for effluent toxicity and complete chemistry off site by accredited labs
- On-site grab samples every 4 hours from key process 2 locations – part of KPIs
- VGCX environmental staff collected grab samples randomly
- Government agencies collected samples periodically when visiting site



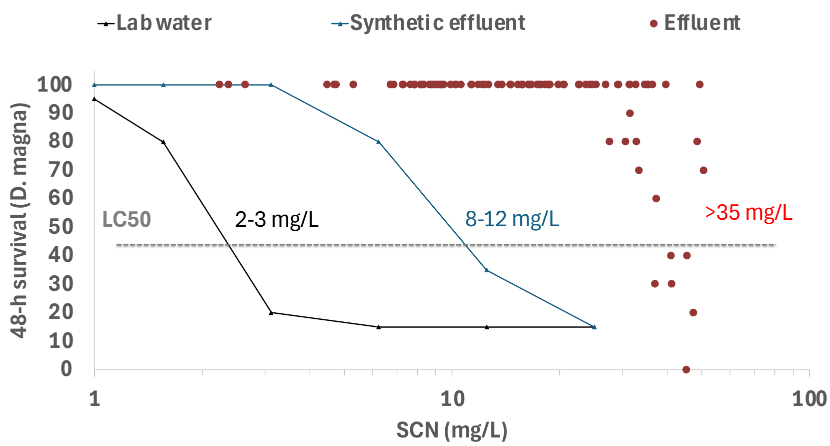
TMT dosed in FWT to offset TMT loss to peroxide oxidation in SP and/or scavenge metals released from cyanide in SP.



SCN toxicity controlled by switching from CCRO to PFD mode and maintaining permeate conductivity < 350 uS/cm - segway to the next slide

Thiocyanate toxicity to *Daphnia magna*

BQE Water



- **Historically MDMER only required rainbow trout toxicity testing – higher SCN threshold**
- **Daphnia Magna toxicity testing now required**

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Lab water – mild hardness water (MHW) used in toxicity testing
No federal limits on SCN – historically only rainbow trout toxicity (more resilient to SCN 100s of ppm), now with D. Magna added much lower toxicity threshold
Toxicity effect of SCN on *Daphnia magna* was confirmed by removing SCN by with **Ion Exchange**

Best Efforts to Meet Water Use License

BQE Water

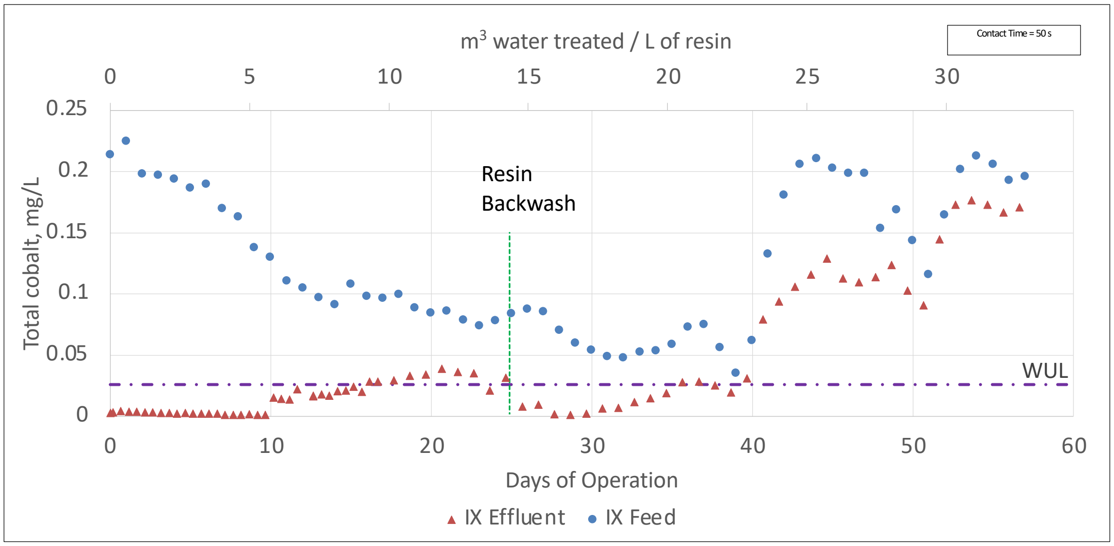
>99% Samples met MDMER Chemistry Limits
>99% Samples met MDMER Rainbow Trout Toxicity Limits
94% Samples met MDMER D. *magna* Toxicity Limits

Constituent	Water Use License [mg/L]	Average Effluent [mg/L]
TSS	15	**6.5**
SO4	1850	**34.2**
Cl	250	**145**
WAD CN	0.03	**0.018**
SAD CN	1	**0.202**
NH_3-N	7.5	**6.9**
CNO^-	-	**12.8**
SCN^-	-	**23.4**
NO_3-N	19.5	**6.5**
NO_2-N	0.12	**0.285**
As	0.053	**0.0005**
Se	0.025	**0.0025**
Ag	0.01	**0.0005**
Zn	0.23	**0.0145**
Cu (t)	0.026	**0.111**
Cu (d)		**0.014**
Ni	0.5	**0.103**
Hg	0.000 080	**<0.000 005**
Cd	0.00125	**0.00005**
Co	0.026	**0.122**

Highlight WAD CN, SCN below 35 mg/L, Hg, Cd
NO2-N exceeded limit but did not cause toxicity, dissolved Cu was 14 ppb total was higher because of fine copper organosulphide particles, Co is SAD CN complex – pilot testing performed to address this next year –segway to the next slide

Removal of SAD CN Cobalt by Ion Exchange - Pilot

BQE Water



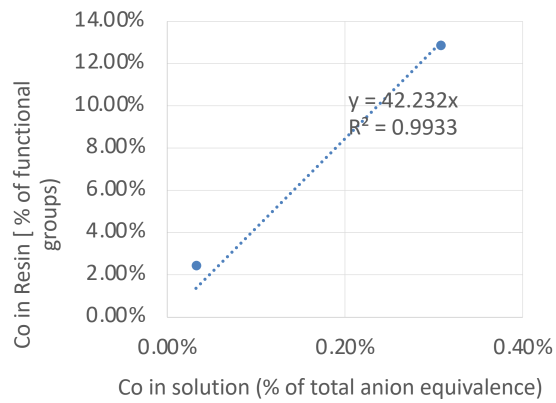
WUL limit is 26 ppb Co, we were meeting this for 40 days before break-through occurred. There were some residual solids that were caught on the resin and needed to be backwashed out half way though. Bottom line - approximately 30 m3 of effluent per liter of resin to reach full exhaustion – the full scale implementation would be lead-lag allowing the resin to reach full exhaustion while meeting the effluent limit.

Design of SAD CN Cobalt Removal for 2026

BQE Water

- ❑ **Pilot**
  - **Loading rate 24 BV/hr (less than 1 minute residence time);**
  - **Operating capacity dependent on feed composition**

- ❑ **Full Scale**
  - **Resin consumption < 12 m^3/year**
  - **< ~ $40,000/year**



Kinetics is very fast – less than 1 minute is more than sufficient. Replacement frequency will depend on Co concentration. The plot shows the capacity at different cobalt concentrations and speaks to the selectivity of Co capture over other anions concentrating Co from solution to the resin phase by a factor of 40 times within the full range of concentrations tested on site. After initial inventory of Cobalt in heap leach is scavenged, the frequency of replacement of IX resin will drop as the Co levels in leach solution were the result of years of accumulation.

Key Takeaways

BQE Water

1. **Experienced team with integrated expertise from different areas is key to success of emergency response.**

2. **Conventional CN destruction can get to WAD-CN levels below 30 ppb but requires long retention time and excess reagents.**

3. **Complexities of toxicity (copper particles, SCN, peroxide, organo sulphide)**

First bullet

- -lab testing, engineering, procurement, project management, automation, field commissioning, operations, and aquatic toxicology.
- Single entity with all required skills reduces interfaces, simplifies and accelerates. implementation, and allows the project to pivot quickly if results call for a change in direction.

3rd bullet

- Many co-dependencies and interplays between project specific water chemistry, treatment processes, and chemical reagents.
- White papers. models, and literature cannot substitute tests and science on actual effluent.

WHO DO YOU CALL ???

BQE Water