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Operational and Design Lessons

Over 8 years of implementation of Saturated Rock Fills

15 December 2025

Saturated Rock Fill - SRF

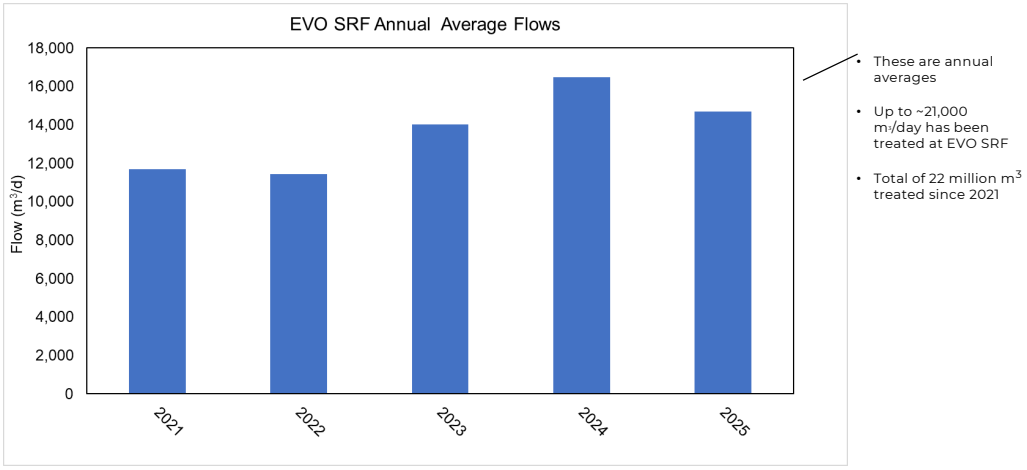
Agenda

1. Introductions and Background

2. Design
   - Challenges
   - Successes

3. Operations
   - Challenges
   - Successes

Background
Elkview Operations SRF



Hi everyone I'm Josh Miller. It's great to be here today to share some of our successes with you all

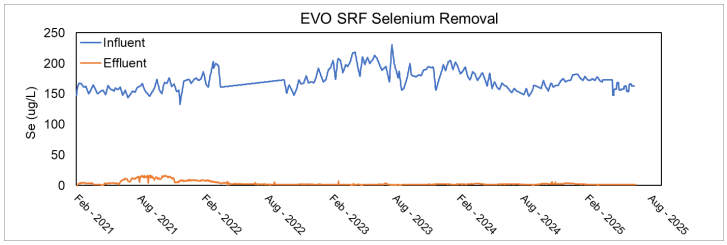
The graph you're seeing is showing the average daily flows at our Saturated Rock Fill within Elkview Mine

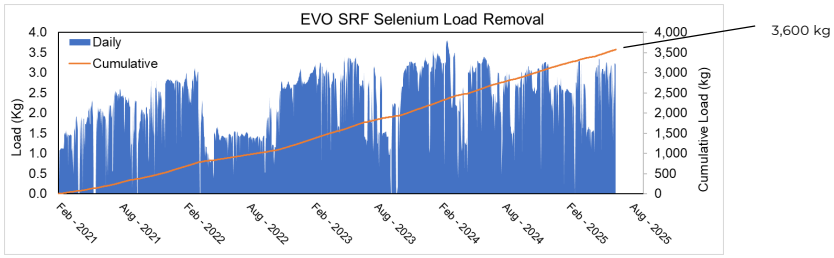
Although the SRF started flowing in 2018, it was in a trial phase. This data is showing its time after it became an approved treatment facility

The Elkview SRF has a designed throughput of about 21,000m3/d, and is capable of reaching this kind of flow day by day, however temperature-related shutdowns bring the annual average down. I'll explain further in another slide.

This facility treats water from a fish-bearing creek, and to reach this creek, the team installed a very large pipeline with a careful control system to allow the "Flow In" to equal the "Flow Out"

Background
Elkview Operations SRF - Selenium





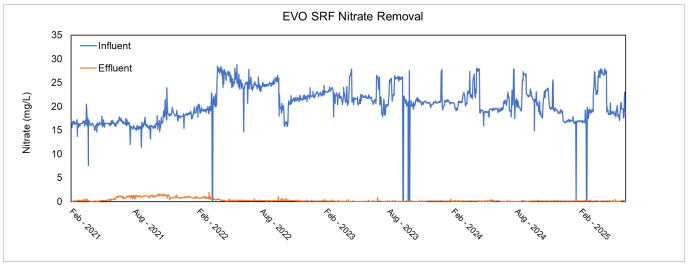
Let's Look at selenium first

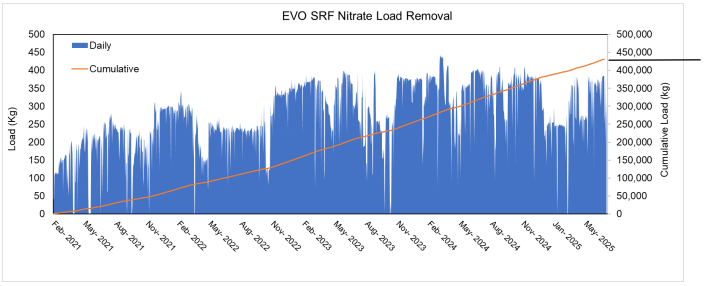
These graphs show a couple different ways of demonstrating how well the Elkview SRF removes Selenium

Graph on top shows the concentration reduction between influent water, at 150ug/L, and effluent water, 1-2ug/L. Essentially, it is near complete removal

Graph on the bottom shows the daily selenium removal rates in blue, averaging 2Kg/d, as well as the cumulative removal (orange line), surpassing 3000Kg by this year

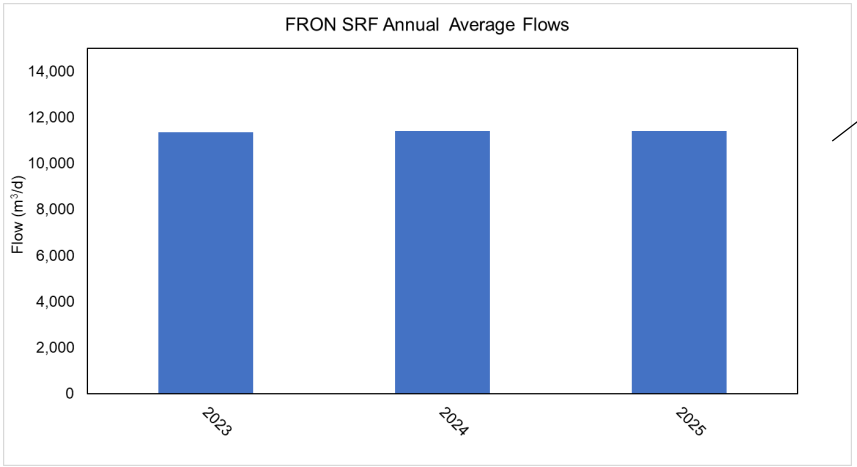
Background
Elkview Operations SRF - Nitrate





This slide is tracking nitrate in the same way as selenium from the previous slide, and shows how the SRF removes nitrate as effectively as selenium, with the graph on top showing near-complete removal, and graph on the bottom showing an average daily load removal of around 400Kg, totaling over 400,000Kg over its lifetime

Background
Fording River North SRF - Flow



- These are annual averages
- Up to ~20,000 m^3/day has been treated at FRON
- Total of 8.5 million m^3 treated since 2023

This is a throughput graph of our other SRF, the Fording North SRF, which is located within the Fording River Mine, north of Elkford BC. It has been running water since 2022, but officially started treating water in 2023, when it expanded from 5,000m3/d to 20,000m3/d. It is currently undergoing an expansion to about 40,000m3/d

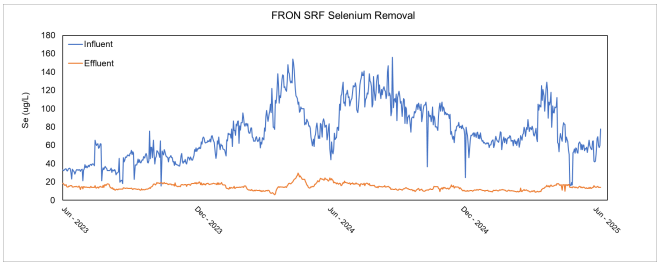
This SRF pulls water from several sources: from reservoirs within the mine boundary, to backfilled pits, to a fish-bearing creek

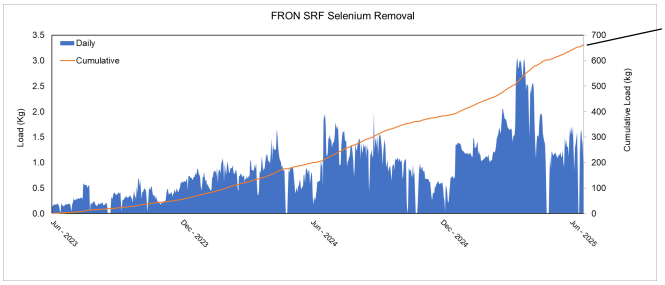
Both SRF's strive to maintain 95% availability throughout the year

Background
Fording River North SRF - Selenium

Operational differences at FRON SRF that contribute to lower removal:

- Facility is still ramping up to meet loading requirements for future phases
- Several intake sources: varying and inconsistent influent water quality is more complex to operate than EVO SRF
- Entrainment is higher at FRON SRF





This slide shows the same Selenium performance graphs as Elkview, but you'll notice in the top graph that the effluent selenium concentration in orange does not get quite as low as it does at Elkview SRF. There are some differences between the two facilities that affect the final effluent concentration

- First, this facility is continually ramping up to meet loading requirements for future phases
- Secondly, there are several intake sources, and some of them have quite inconsistent water quality, resulting in more challenges to keeping a steady treatment facility
- Lastly, entrainment is higher at Fording North SRF (which John, Shannon and Marcie spoke about in the earlier presentations, and we'll touch on it again later in this one)

Regardless, the graph below shows how the daily removal rates have been steadily increasing as Fording north continues to ramp up its treatment

Background
Fording River North SRF - Nitrate

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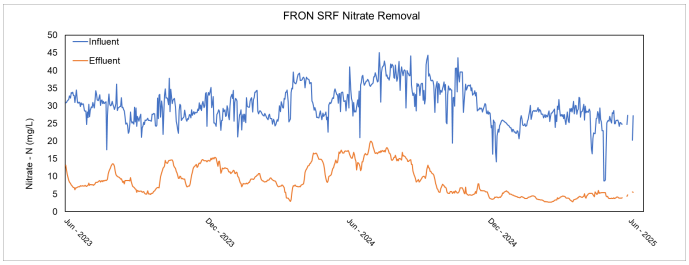

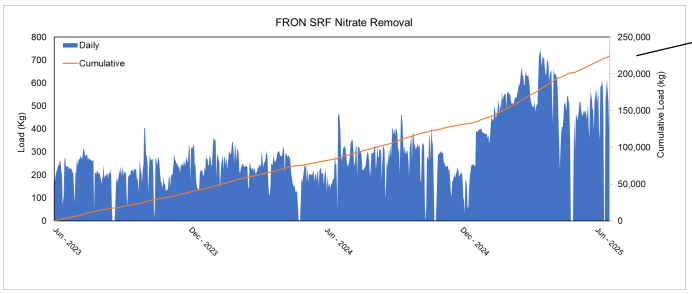

230,000 kg

As with Selenium, the same challenges impact Fording North's nitrate removal rates

But we can observe how nitrate removal has been ramping up in recent months as the facility matures

This year, Fording North has surpassed 200,000Kg of nitrate removed

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SRF Design Challenge
1. Recharge

Snow melt and rain enter the SRF bringing selenium and nitrate with it

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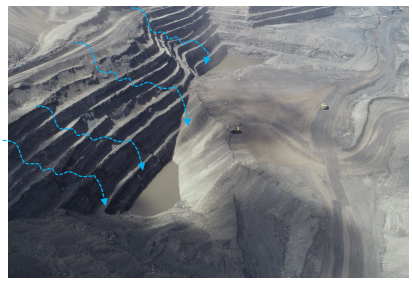
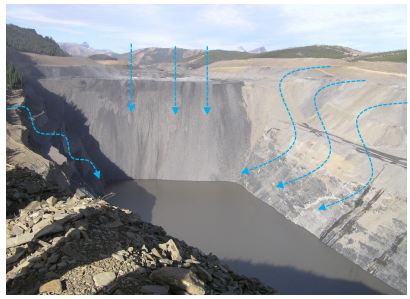
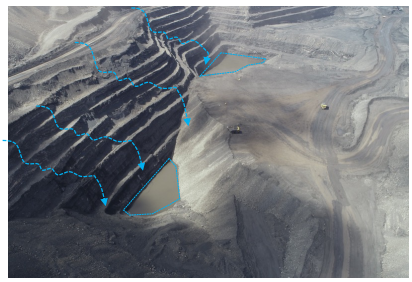


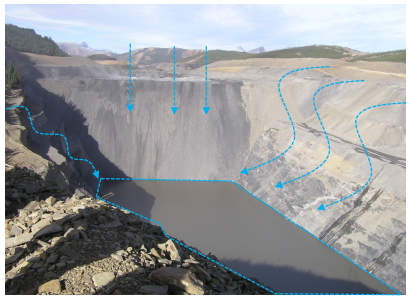


SRF Design Challenge
1. Recharge & *In-Situ Water*

Snow melt and rain enter the SRF bringing selenium and nitrate with it

Water in the pit, prior to SRF operations, can also have elevated selenium and nitrate





SRF Design Challenge
1. Recharge & *In-Situ Water* (i.e. entrainment)

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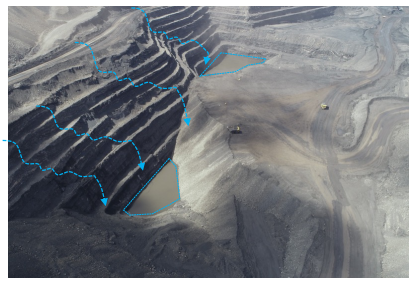
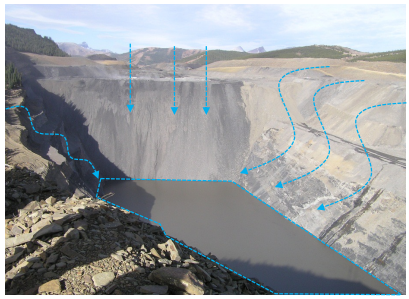
Water in the pit, prior to SRF operations, can also have elevated selenium and nitrate

These waters exit the pit through:

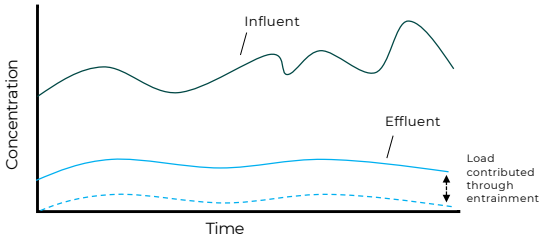
- Treatment extraction wells
- Dedicated collection wells





SRF Design Challenge
1. Recharge & In-Situ Water (i.e. entrainment)

- Challenge
  - Even if the water injected is fully treated, this load exiting the pit will present in effluent monitoring as incomplete removal of nitrate and selenium.



These waters exit the pit through:
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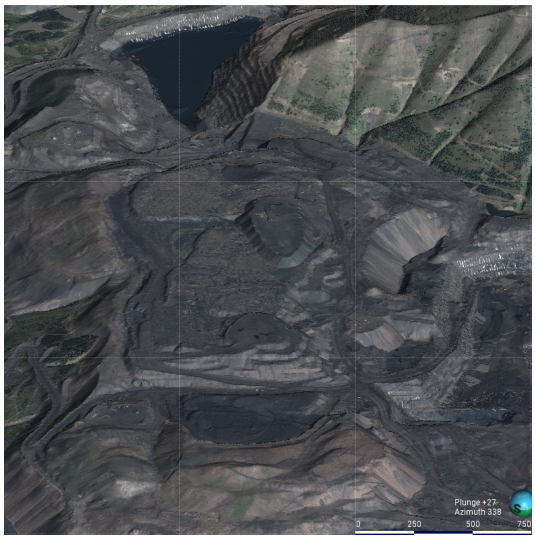
Make sure to make a note of how entrainment can change over time (i.e falling)

SRF Design Challenge
1. Recharge & *In-Situ* Water (i.e. entrainment)

- Challenge
  - Entrainment is an area-source
  - Knowing where to place and operate these wells to limit impacts on effluent



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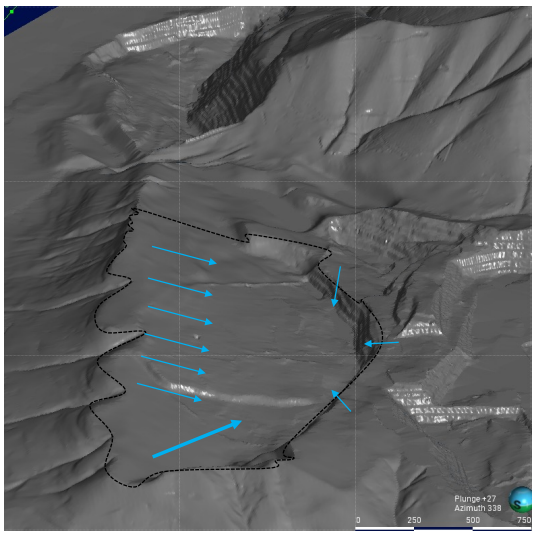

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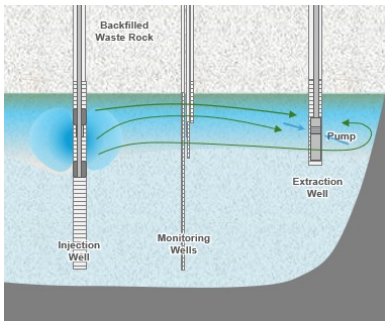
SRF Design Challenge
2. Wellfield Sizing

- Empirically measured treatment rates can help quantify removal rates but aren't appropriate to quantify maximum rates.



We may not know the specific rates and need to plan for that uncertainty going in with contingencies though through ahead of time.

SRF Design Challenge
2. Wellfield Sizing

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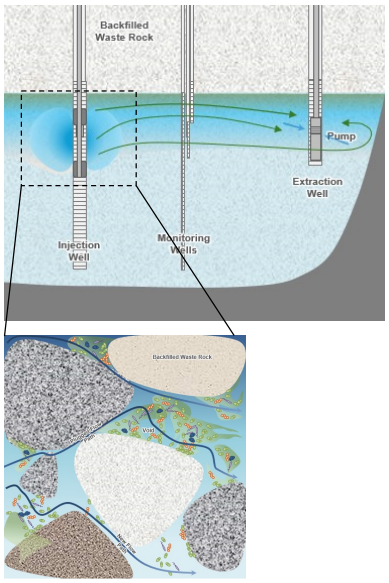

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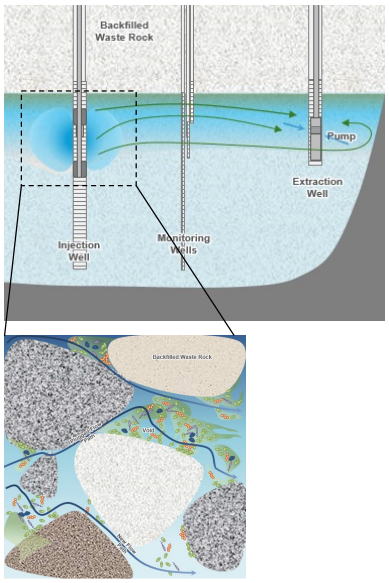
SRF Design Challenge
2. Wellfield Sizing

- Empirically measured treatment rates can help quantify removal rates but aren't appropriate to quantify maximum rates.
- Fouling of injection wells may be the limiting factor in treatment rates
- Challenge: how many injection and extraction wells are required; how far apart should they be placed?



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SRF Design Successes

These challenges (and others) were managed by acknowledging there will be known unknowns as well as unknown unknowns.

Design Success came from the incorporation of:

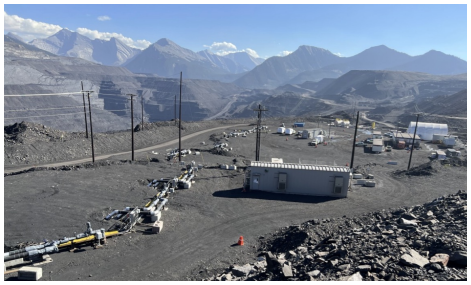
- Collaboration
- Operational Flexibility
- Contingency Planning

SRF Design Successes
Collaboration

- Four consulting groups, two universities and EVR
  - Coal miners mixed with academics, consultants
- We built a team with a broad experience base that trusted each other
  - Geochemistry, microbiology, water treatment, saturated and unsaturated flow, containment transport, instrumentation

SRF Design Success
Operational Flexibility

- What was included in design:
  - Broad monitoring network
  - Multiple injection/extraction locations/depths
  - Multiple recycle modes
  - Tracer addition
- What it allowed us to manage
  - Understand the process, manage stratification and entrainment
  - Heterogeneity in water quality at extraction wells.
  - Fouling of wells



There are 76 monitoring wells at EVO and 56 at FRON

There are 5 injection wells at EVO and 8 at FRON with ability to raise/lower each

There are also 10 extraction wells at EVO and 8 at FRON

SRF Design Success Contingencies

- What was included in designs
  - Contingency discharge locations
  - In pit storage below decant elevations
- What it allowed us to manage
  - Start up of the facility for the first time
  - Water levels
  - Discharge effluent to a safe location if required

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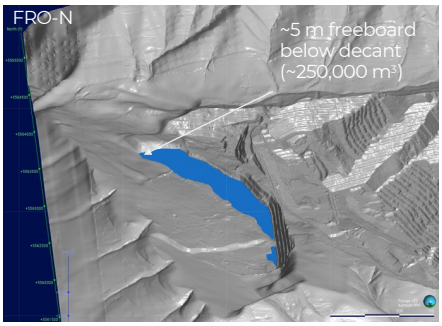

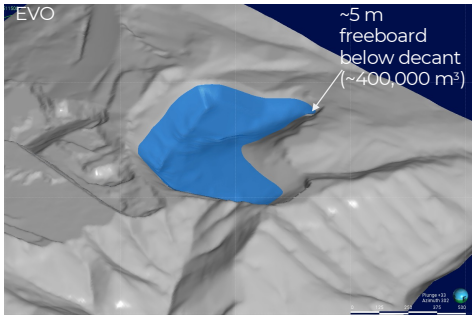

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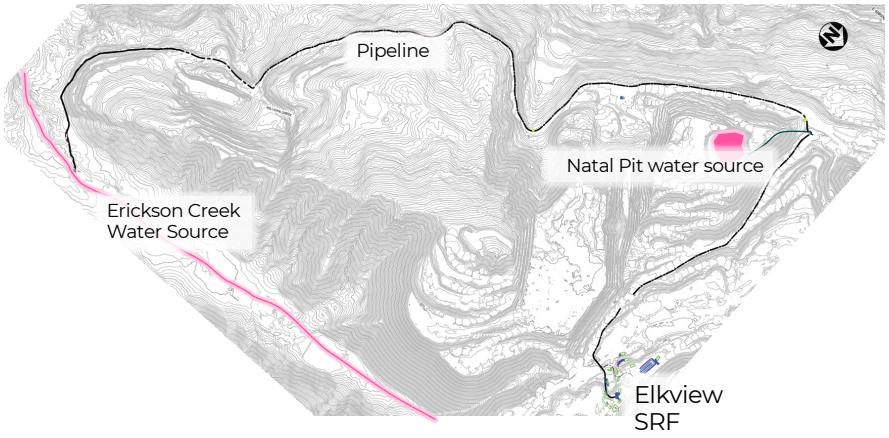
I'm going to touch on some of the challenges and successes that we've encountered over the years of operating these systems

SRF Operational Success
Flow Matching



This rendering shows the layout of the pipeline needed to bring Erickson Creek into Elkview SRF. It is 13km of twinned pipes installed through Elkview mine to creek at the outer edge of the mine. Water is conveyed through 16-20” pipelines and 3 booster stations to bring it up to the SRF

Because Erickson Creek is fish-bearing, the conveyance needs to Flow Match. This means the amount of water returned to Erickson Creek must be the same that has been drawn from it.

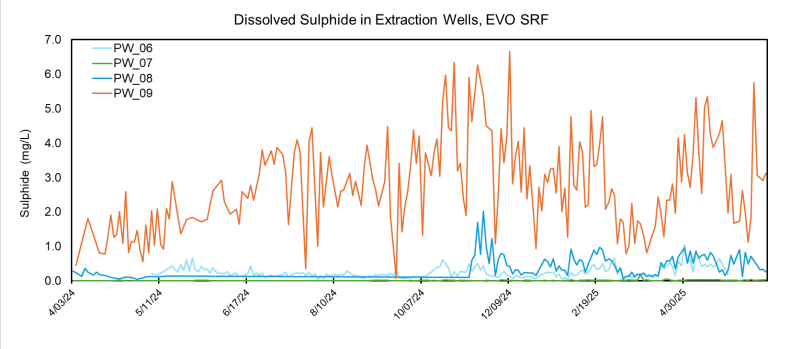
For the 5 years that Elkview SRF has been treating Erickson Creek, the difference between IN and OUT is just 144m3

To accomplish this, a great deal of automation is designed into the pumping system to allow the booster stations to automatically ramp up and down as needed, with precise monitoring of flows and pressures.

Looking ahead, Fording North SRF will be undergoing a future expansion that will see the installation of a similar conveyance

SRF Operations Challenges
Extraction Well Variability

- Variable flows available from extraction wells
- Variable water quality between extraction wells
  - Limited spatial relationship



Another challenge is the variability of water quality throughout the SRF

The graph here shows sulphide in four wells at Elkview SRF, with pumping well 9 in orange having much higher sulphide concentration than its peers, which are only a couple dozen meters away. Because sulphide can be acutely toxic at high enough levels, careful monitoring is required if this well were to be sent forward

Consistent effluent quality is maintained by manipulating extraction rates. Some extraction wells can be sent forward to the Effluent Retention Pond, while others flow in recycle. This daily flow guidance is provided by the site Process Engineer

This example is showing variability in SRF effluent, but the same level of process control is needed on the influent side, as variation can disrupt the treatment process. For example, because the process is fundamentally controlled by influent nitrate concentration, injecting too much nitrate can overwhelm the biomass and result in nitrite in the effluent.

SRF Operational Challenges
Effluent Retention Ponds

- Effluent retention ponds are used to confirm effluent quality prior to discharge
- Temperature can increase across the ponds and limit the amount that can be discharged to the receiving environment while meeting instream permit requirements.

Effluent retention ponds are used at both SRFs.

Along with equilibrating the SRF discharge to surface conditions, these ponds provide 24 hours of response time before sending the water to the receiving environment

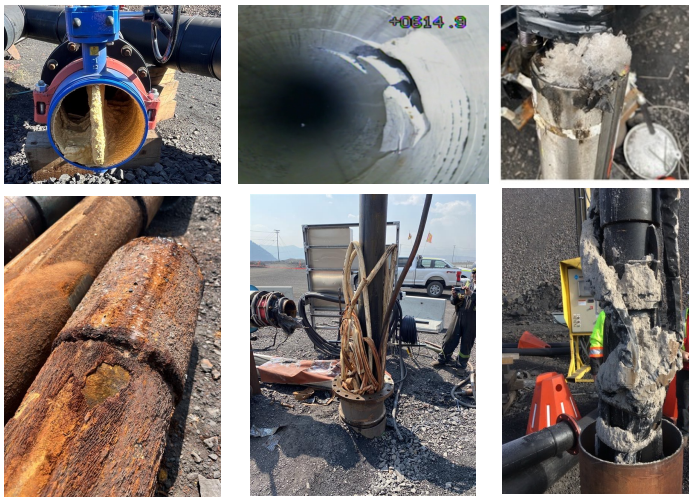
This provides a major time buffer to allow the operating crew to redirect discharge in the event of off-spec water, however, being large open bodies of water, these ponds typically warm in the sun, and when the water is discharged into Erickson creek with permit limits on temperature, there is sometimes no choice but to slow down treatment to avoid a non-compliance

And, there are times in the year when the natural temperature in the creek is nearly at the limit already, leaving no option but to cease treatment until the weather improves and the pond can cool

SRF Operational Challenges Infrastructure

In some locations wells are approaching 300m deep

- Monitoring wells fail from shifting spoils
- Frost movement
- Loggers fail from buried burning coal
- Corrosion – TDS can act like saltwater corrosion on steel pipes. Several PWs have corroded and failed
- Pipe/pump hydraulic limitations
- Calcite deposition



SRF infrastructure is primarily outdoors, so a lot of exposure to the elements

Aside from shifting ground due to nearby blasting or freeze/thaw, the water within the SRF has proven to be quite corrosive to the pumping components, leading the team to develop methods to extend pump and wellbore lifespans

The high hardness and alkalinity of the SRF water also leads to a lot of calcification, as seen in some of the photos shown here

And there's even a few examples where burning, buried coal has affected some of our components

SRF Operational Challenges Monitoring

Monitoring depths can change over time as water levels or flow paths change

Options tested

- Monitoring sheds with nested wells and fixed pumps are expensive
- Mobile sample trailers are cheaper but can be a challenge to build and operate

Each SRF has an extensive monitoring system developed to track the movement of water

Each SRF took a different approach to sampling the water. Elkview installed pumping stations with wells drilled to specified depths and permanent sampling pumps installed

For Fording North, a special mobile sampling trailer was designed, with a pump that could be raised and lowered to any depth in the well. If flow paths change, it's much easier to adjust sampling depth with a mobile pump.

These sampling trailers save on cost of drilling and well installation, but adds cost and complexity to sampling

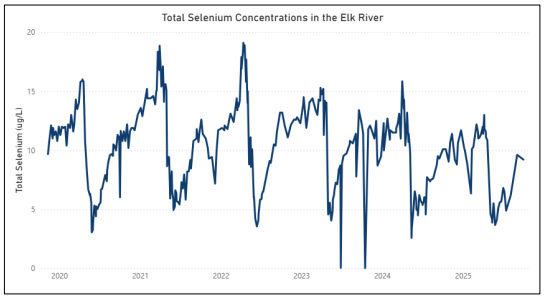
These facilities boast consistent performance with lower operator input

Being able to operate with no night shifts is an obvious advantage over an active water treatment facility

In 8 years for this technology to move from a pilot-scale system to a full-scale facility is a huge accomplishment, owing greatly to the combined effort of so many individuals

SRF Operational Success

- SRFs have successfully operated in the Elk Valley for ~8 years and are now operating at two mine sites
- ~30 million m^3 have been treated, removing:
  - 4,200 kg selenium
  - 660,000 kg of nitrate
- SRFs are contributing to stabilizing and lowering selenium concentrations to pre-2015 levels in the Elk River



We are developing a strong understanding of this treatment method, and have been running them for long enough to have confidence in their stability

This kind of selenium and nitrate removal is no small feat, and we're proud to contribute to their overall reduction in the Elk River

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