Long-term performance of reclaimed tailings ponds at HVC in a warming climate – impacts on geochemistry and biological productivity

LARRATT AQUATIC

Highland Valley Copper

Teck

Presentation Outline

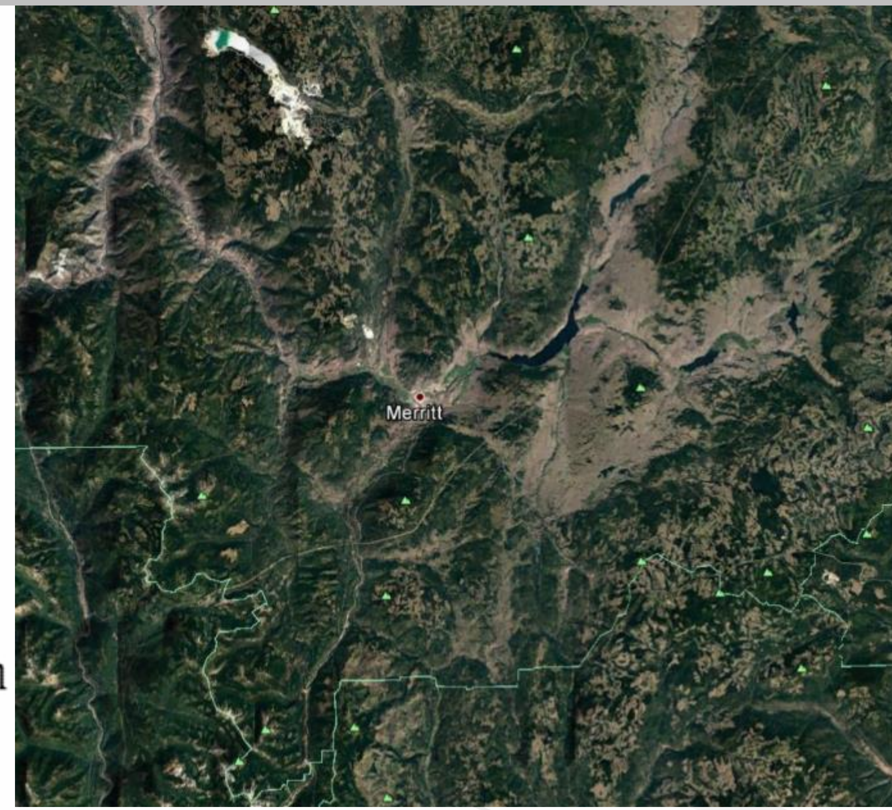
- Context:
- how did Southern Interior watersheds fare in 2016 & 2017?
- how did the tailings facilities at HVC fare in comparison?
- how can reclaimed HVC tailings facilities contribute to the region?

- Geochemical and biological functions - what does the work?
- what is needed to get these functions
- water management effects (diversions, spillways and dam safety)
- maturity, flexibility and diversity

- If we build it, can we keep it with a changing climate?
- fluctuating water levels with flood, drought
- required alterations to pond inflows for dam safety
- meeting foliar metal guidelines in tailings-grown riparian vegetation

- Design ideas and long-term successes at HVC (20+ yrs and counting)

Context



Climate change models predict more extreme events within mild, wetter winters and warmer, dry summers. This will mean greater irrigation/water supply demands, and a longer fire season in the summer months. Wildfire affects watershed resilience and increases water yield, nutrient concentrations and peak freshet flows.

Nicola Watershed Woes - 2017

Nicola watershed – town of Merritt

Spring 2017 Summer 2017

HVC tailings Spring and summer 2017

Trojan tailings Pond

HVC tailings   Spring and summer 2017

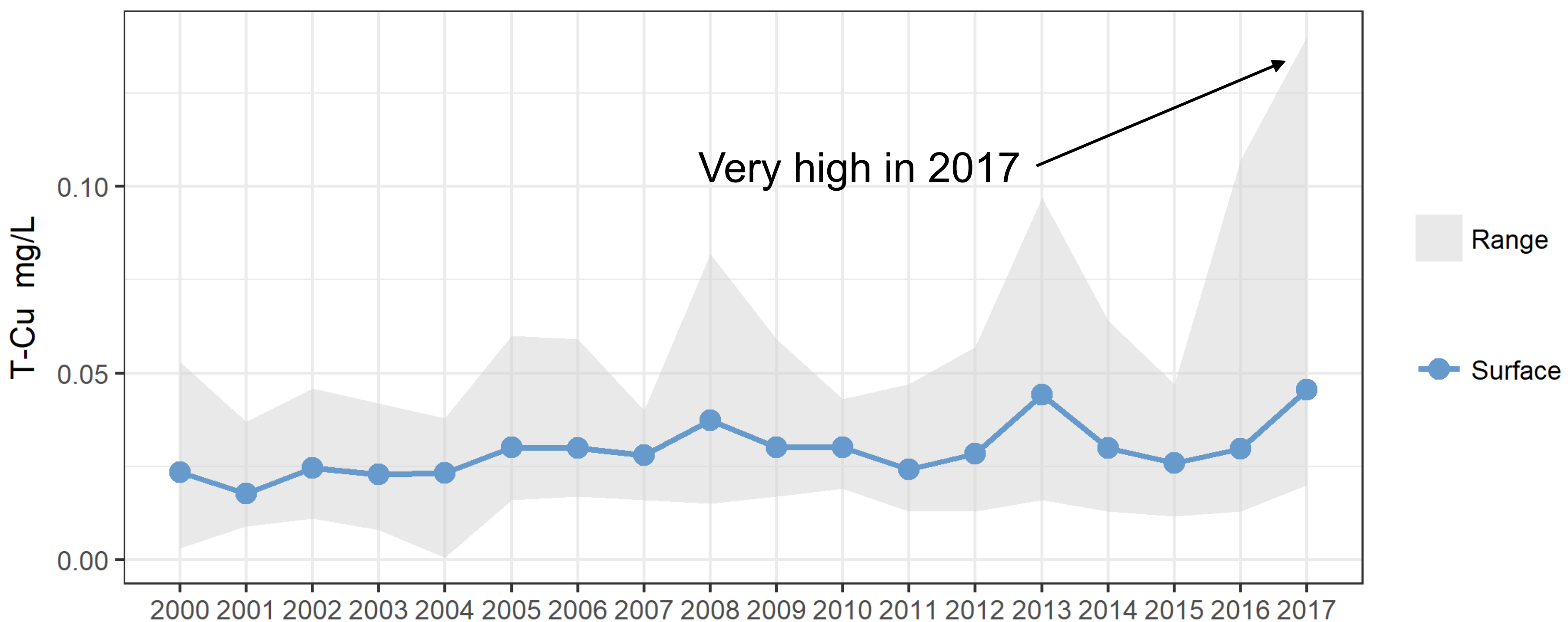
Bethlehem tailings pond

HVC tailings Spring and summer 2017

Highmont tailings pond

2017 freshet impacts on HVC water quality

- Total metal concentrations increased in inflowing creeks, above mine influence, to unusually high concentrations during the 2017 freshet
- Some dissolved metals followed suit



Can HVC help meet climate challenges in the Nicola region?

Considerations for end-use planning

- Water storage \ freshet management \ diversions
- Tailings reclaimed as wetland “sponges”
- Strategic releases to support fisheries, irrigation
- Habitat for waterfowl, shorebirds, wildlife, sport fishery
- Bioreactor functions of tailings facilities help meet water quality needs
- Design for increasing watershed resilience by “water banking” (with suitable WQ)

The Goal: Reclaim the tailings facility as sustainable habitat, and as a bio-reactor for parameters of concern (Mo Cu SO_4 N's)

Shallow (1-5 m) tailings ponds

Waterfowl + shorebird + wildlife habitat

Deep (>7 m) tailings ponds

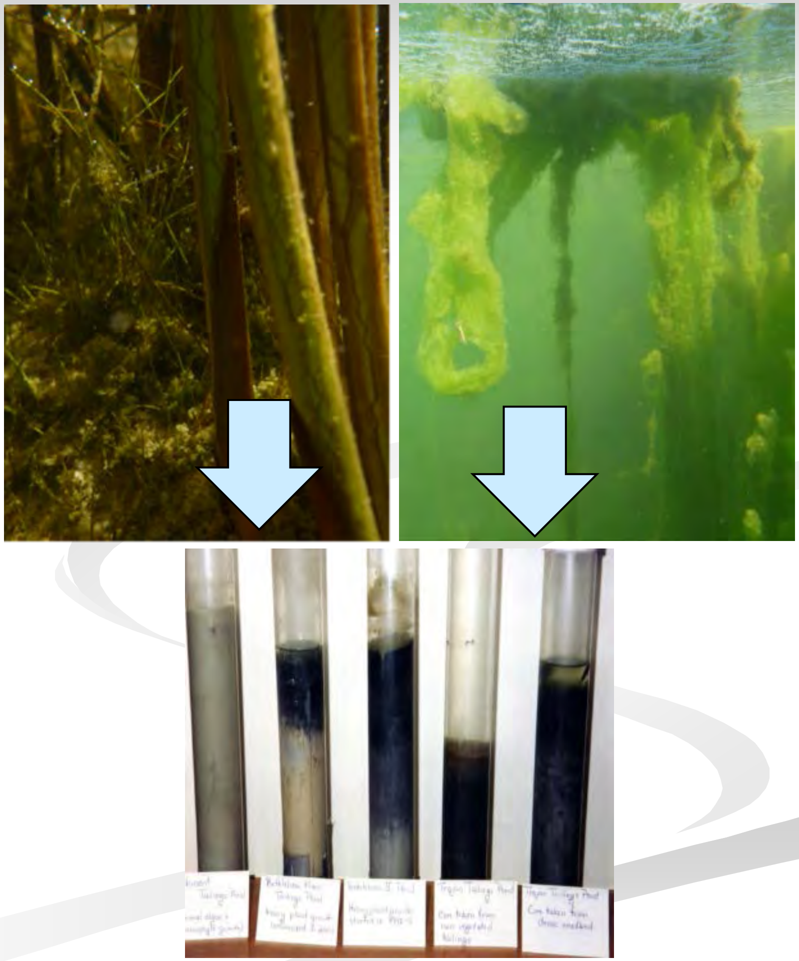
Fisheries + wildlife





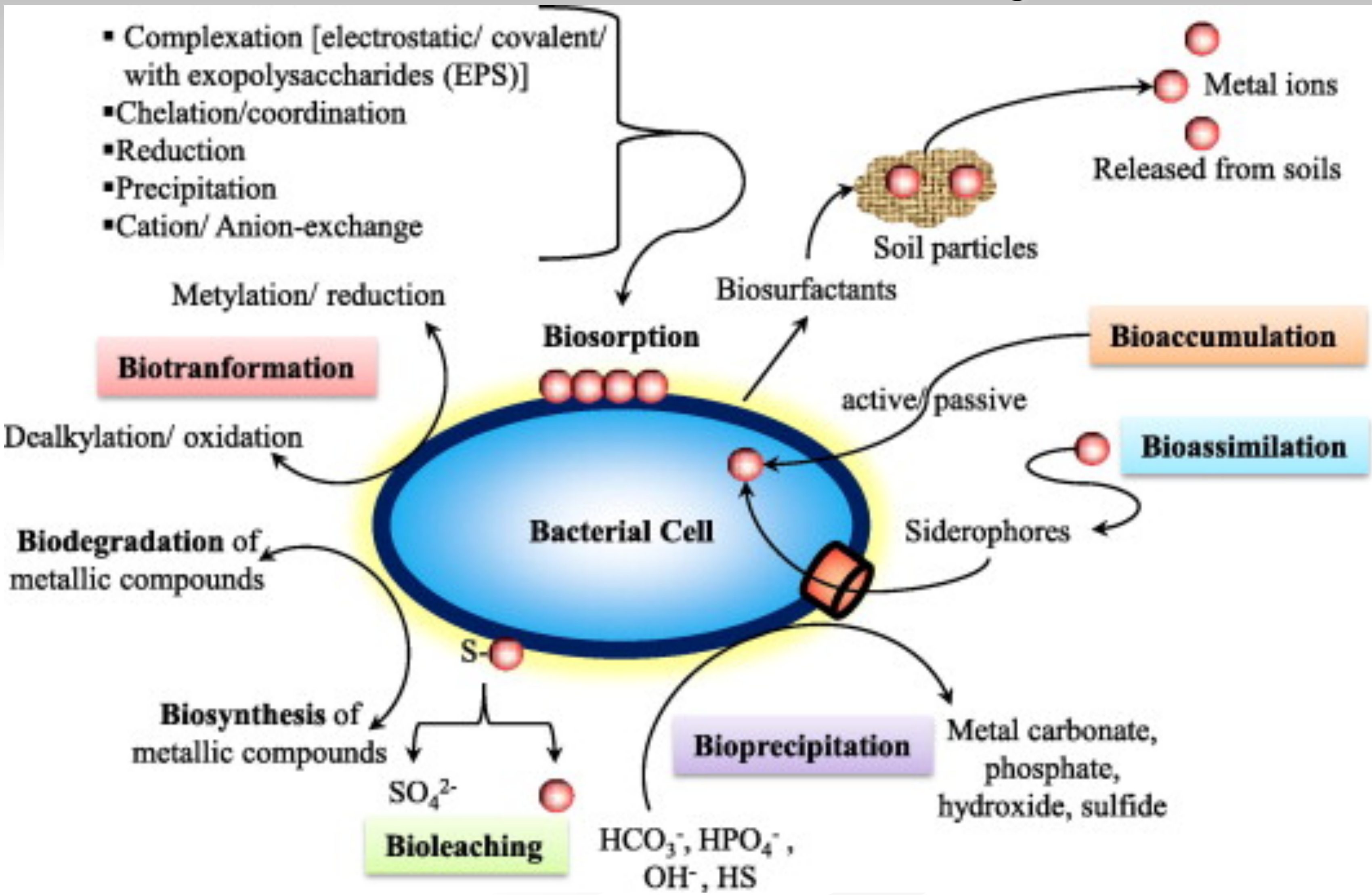

Accumulating organic sediments are essential to habitat value and bioreactor function

- With the inorganic nutrients in place, bacterial development starts and a nutrient/vitamin-rich organic sediment layer will begin to form <1 mm/year initially (or add carbon)
- The upper few mm of sediments hosts 99% of all the bacteria in every water body and is crucial habitat for invertebrates
- Key bacterial families include: decomposers, methanogens, SRB, IRB



Important reactions in water-covered tailings

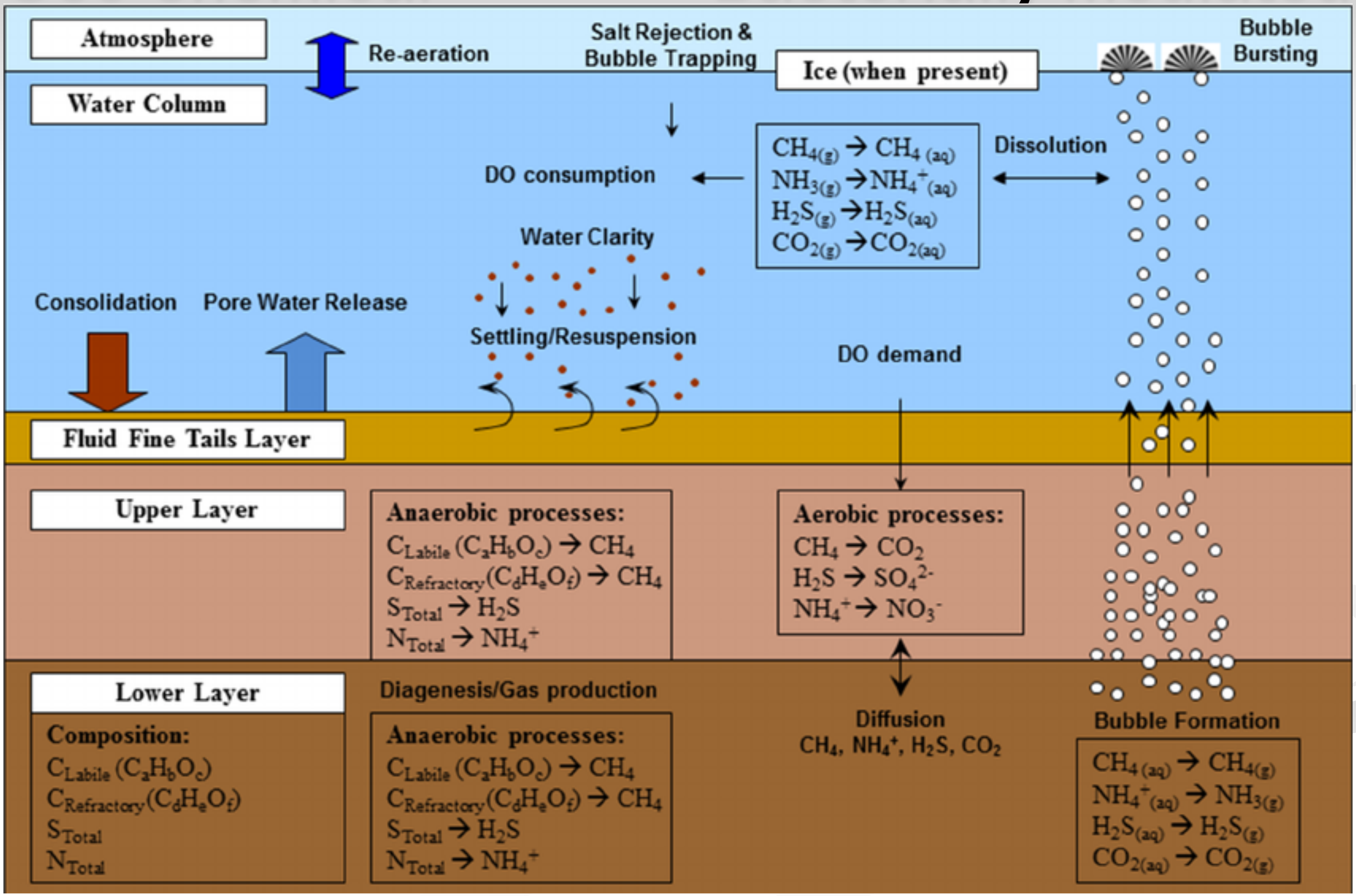
Geo-chemical Bacterially mediated



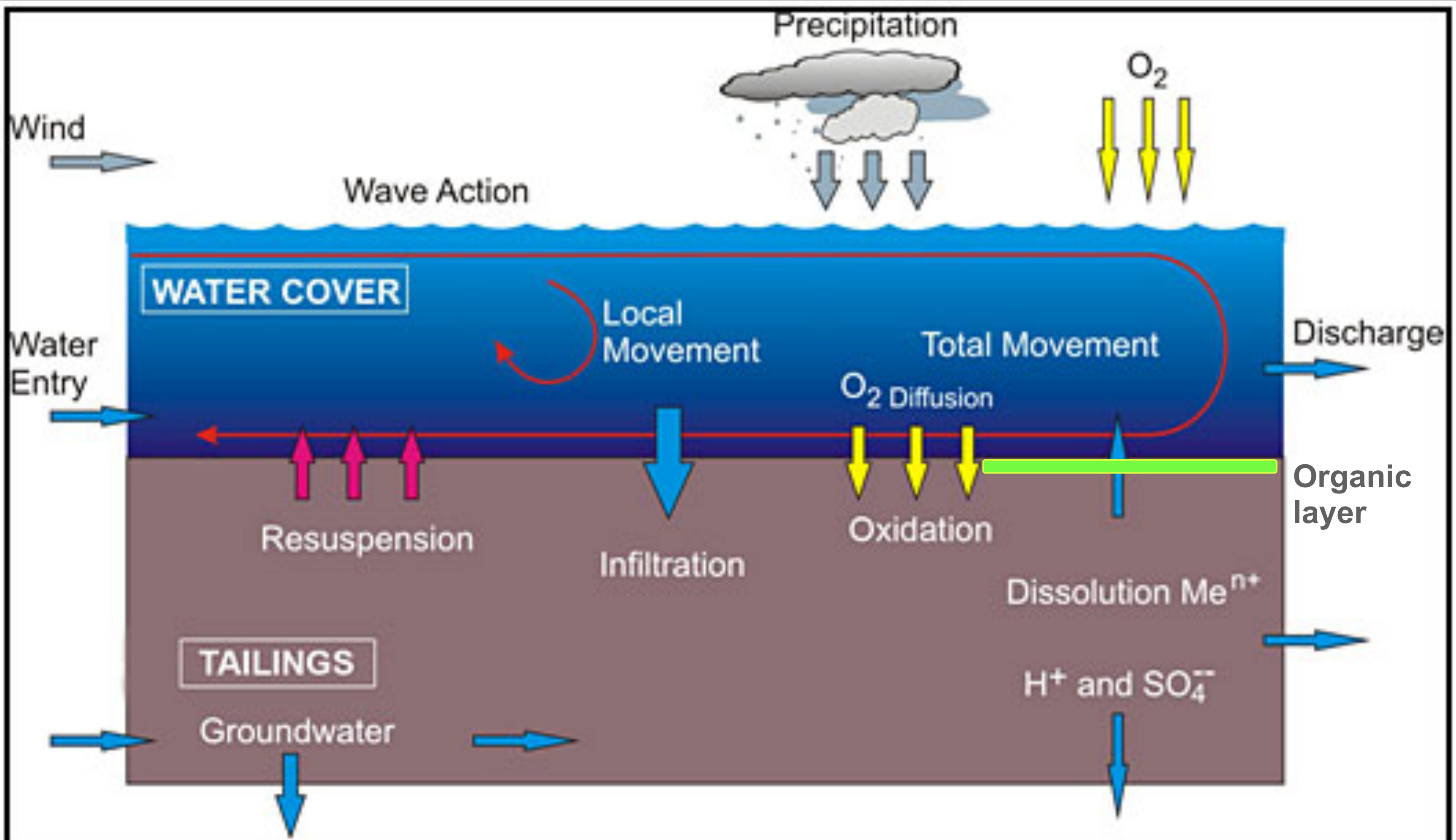
Summary of important reactions in water-covered HVC tailings

Geo-chemical

Bacterially mediated



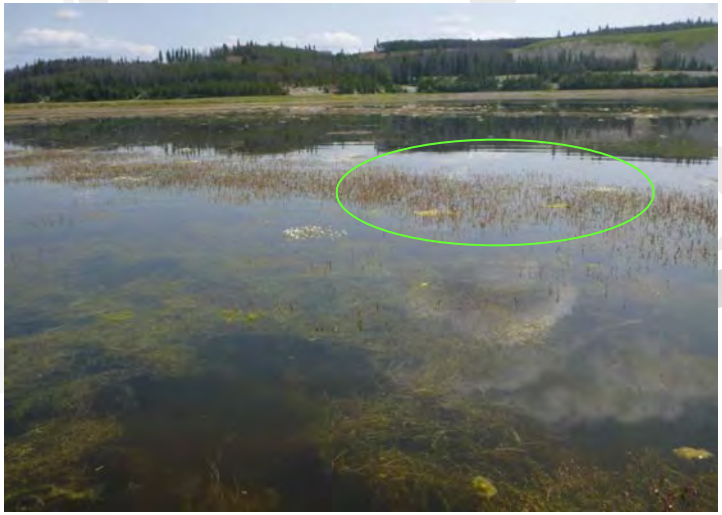
No stratification in shallow HVC tailings ponds (1 – 5m deep)



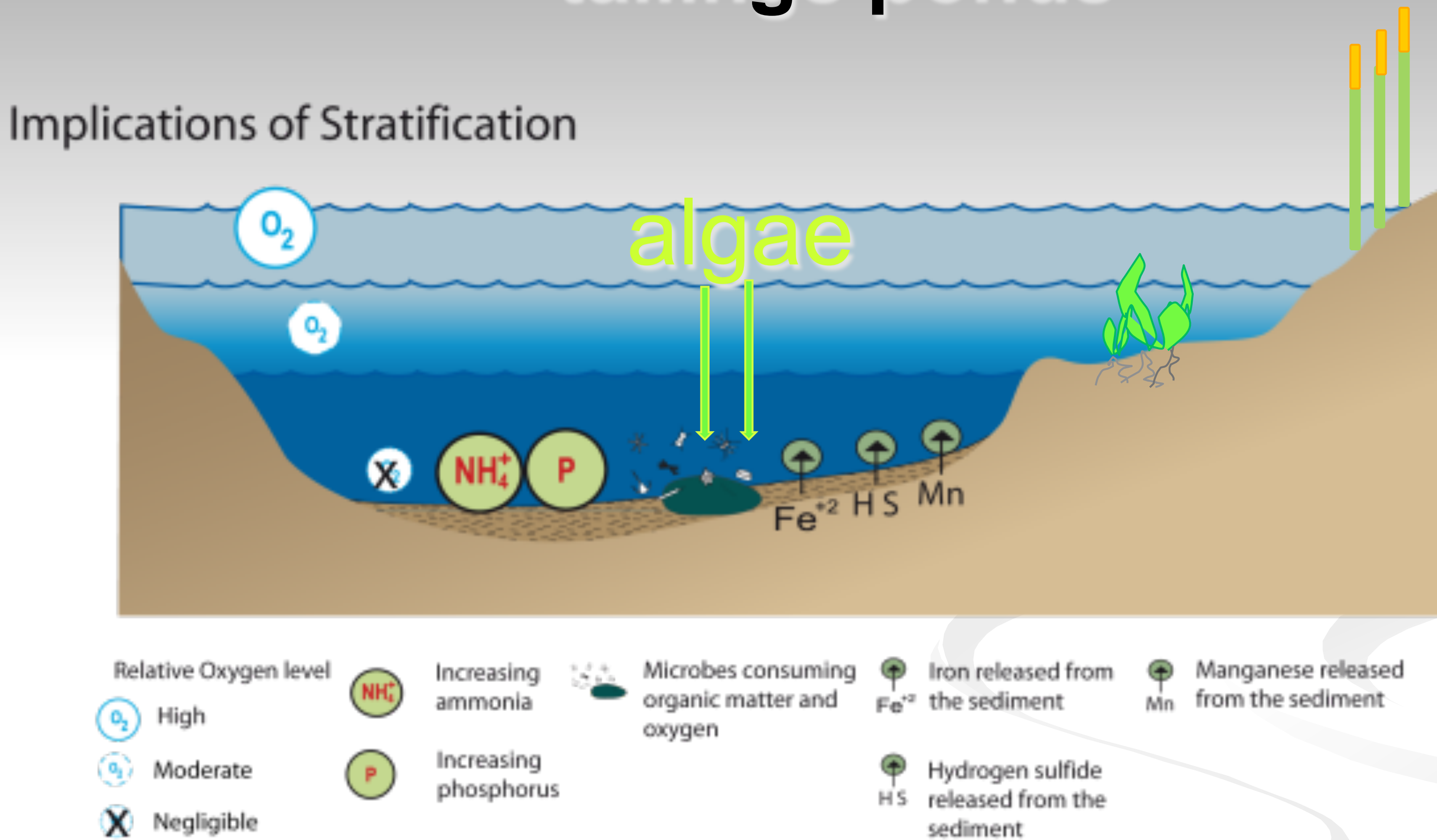
Water chemistry in shallow HVC tailings ponds

June/July 2016 HVC tailings maximum summer water cover					
			Beth Dam	Highmont	Trojan
	Units	RDL			
Turbidity	NTU		3.4	2.9	0.8
PO_4	mg/L	0.001	0.058	0.026	0.007
NO_2 & NO_3	mg/l	0.01	<0.01	<0.01	<0.01
NH_3	mg/l	0.01	0.0134	0.0293	0.0072
Total N	mg/l	0.01	1.11	1.48	0.39
SO_4	mg/l	10	340	139	3.2
pH	pH unit		8.69	9.72	8.01

NOTE: RDL = Reportable Detection Limit



Stratification in deep HVC tailings ponds



Water chemistry in deep tailings ponds - Trojan

2016 Average Values		Trojan Tailings Pond	
		Surface	Deep (~7m)
Turbidity	NTU	0.99	1.09
PO_4	mg/L	0.0063	0.0092
NO_3	mg/L	<0.005	<0.005
NH_3	mg/L	0.0068	0.0089
Total N	mg/L	0.422	0.424
SO_4	mg/L	3.05	3.13
pH	pH units	7.98	7.96

Oxygen changes everything;

When flooded:

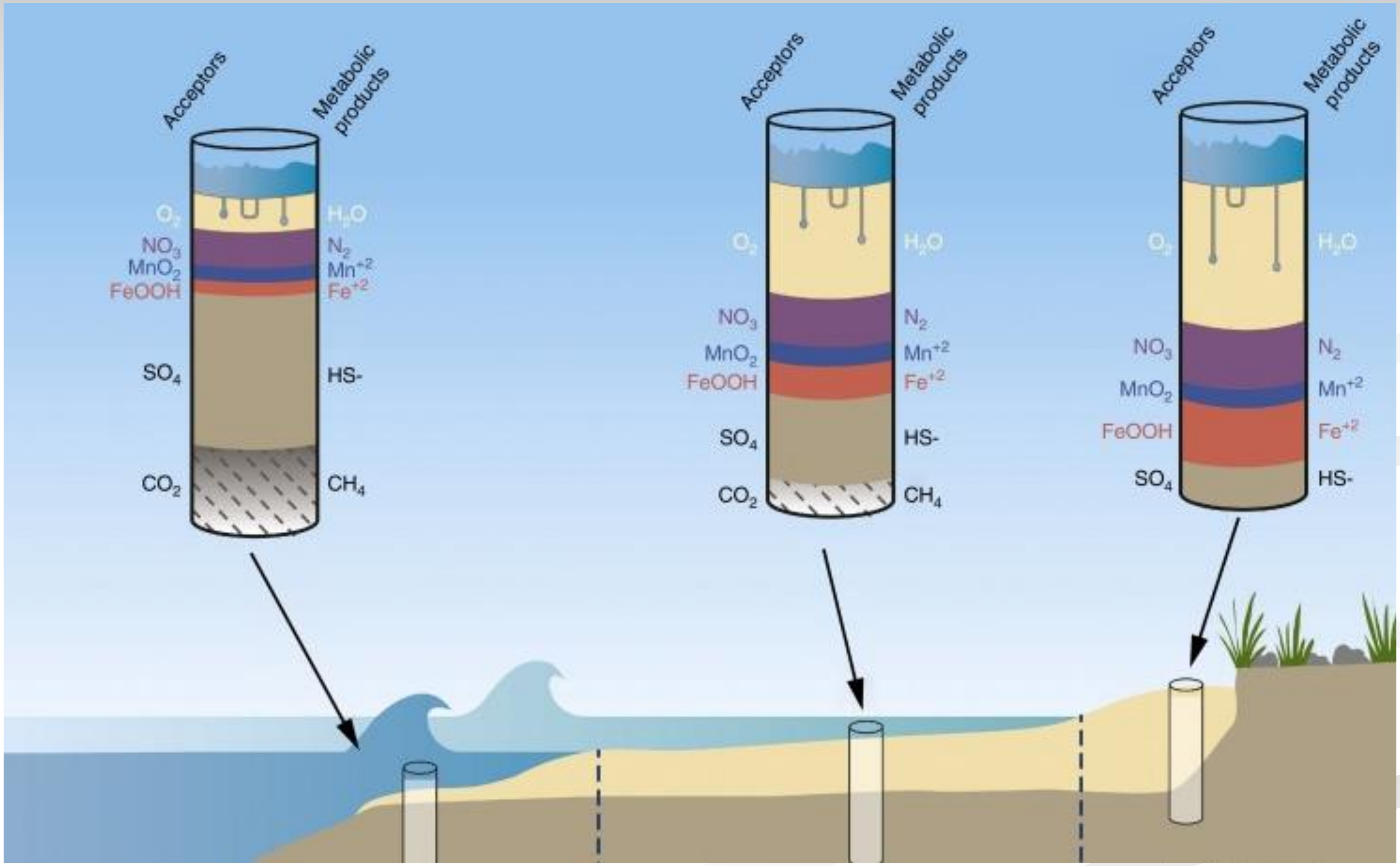
- Organic materials accumulate
- Aerobic bacteria dominate surface sediments, anaerobic bacteria beneath them
- Negative redox allows nutrient release to water cover, sulphate + metals are removed
- pH most stable and high during high water years; pH significantly lower in low water years

When exposed:

- Decomposition is 100's of times faster
- Anaerobic bacteria die off in upper substrates
- Mineral oxidation commences

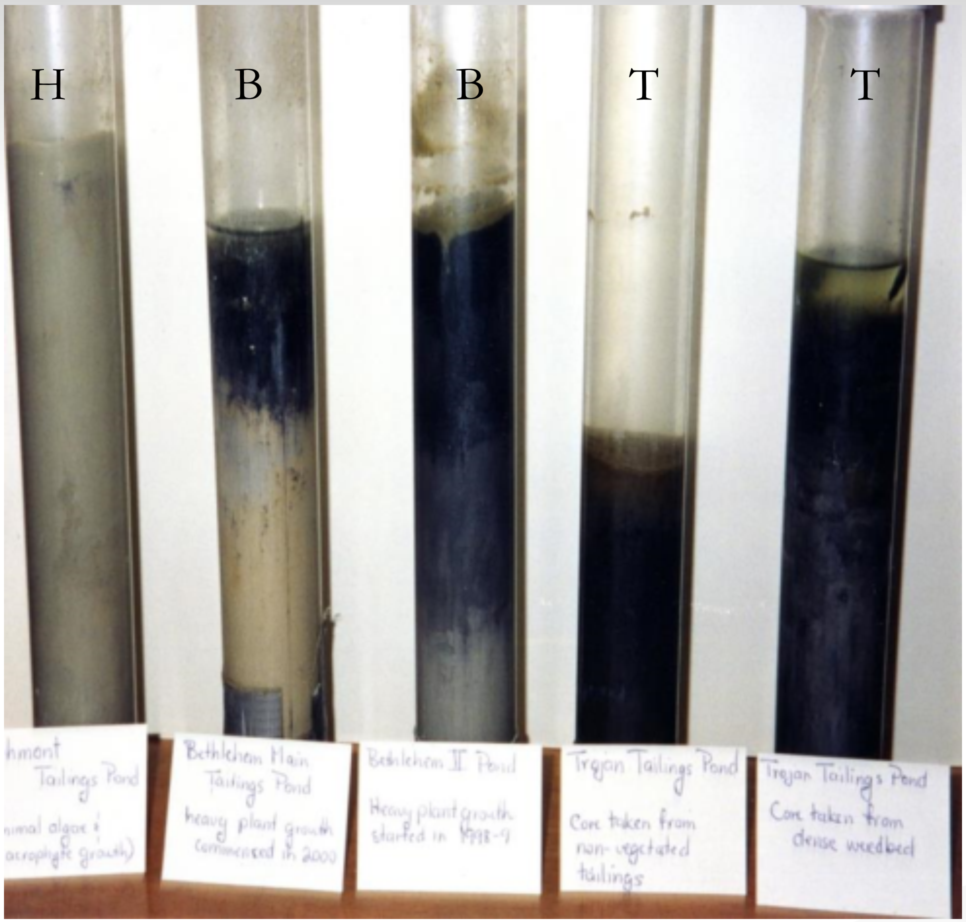
- When re-flooded:
- Nutrient surge following re-inundation
- An increase in some metal concentrations may occur in the water cover

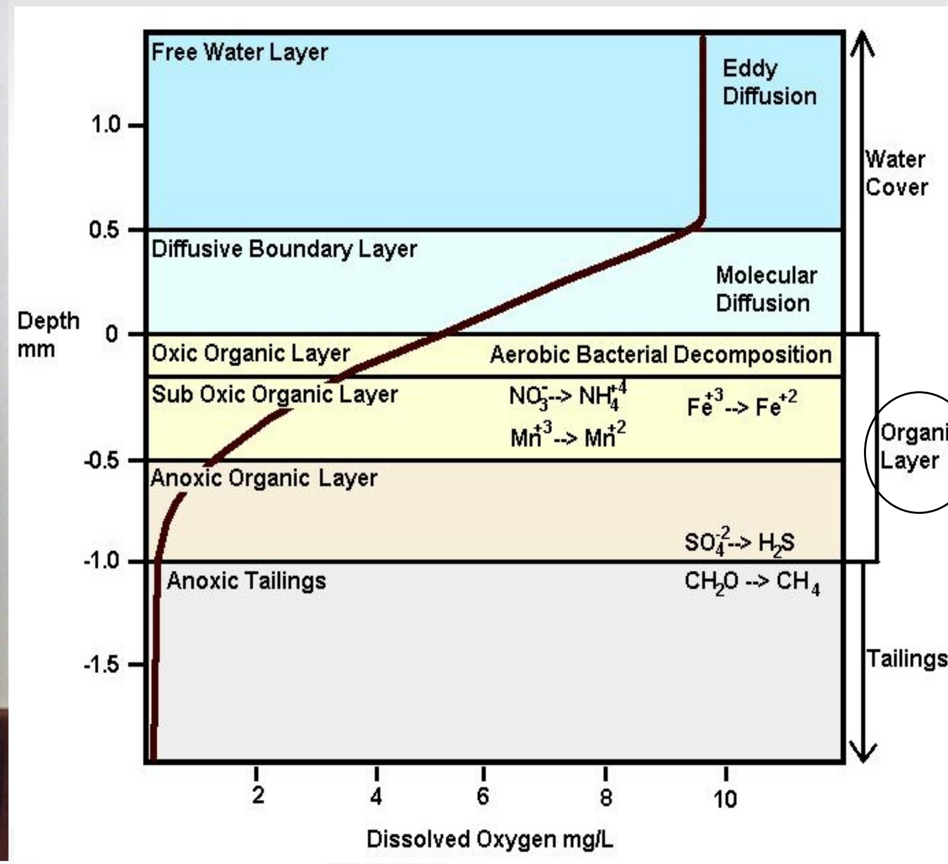
As oxygen invades a tailings beach substrate, the depths of bacterial activities shifts



Cream zone = few usable bacterial reactions at HVC

Examples of HVC sediment cores showing variable metal-sulphide (black), depending on water cover conditions, organic content





*Summer algae blooms in Highmont tailings pond increased pH dramatically from 8's to near 10, affecting metal cycling
*Metals readily adsorb to the algae filaments

Figure 4.4-2: Filamentous algae bloom at Highmont tailings pond

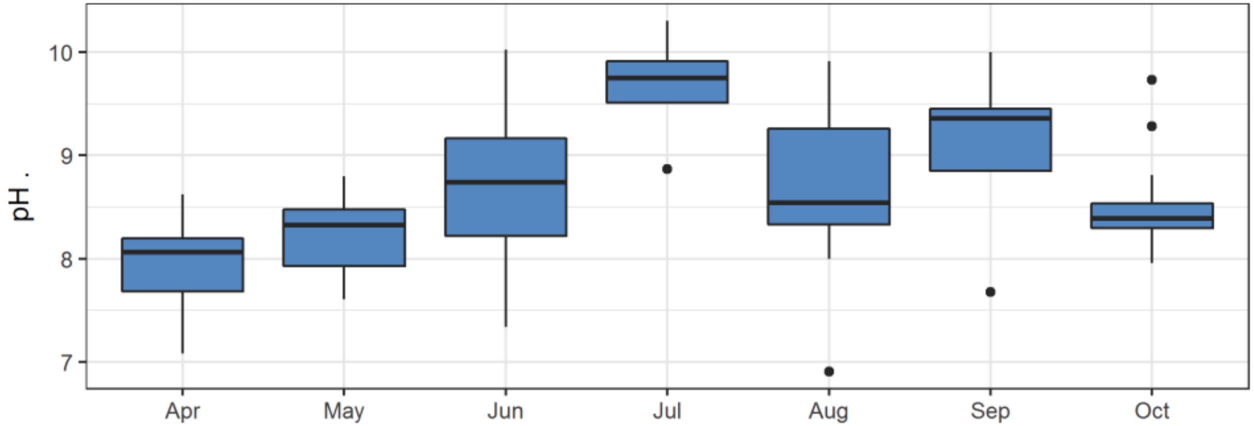
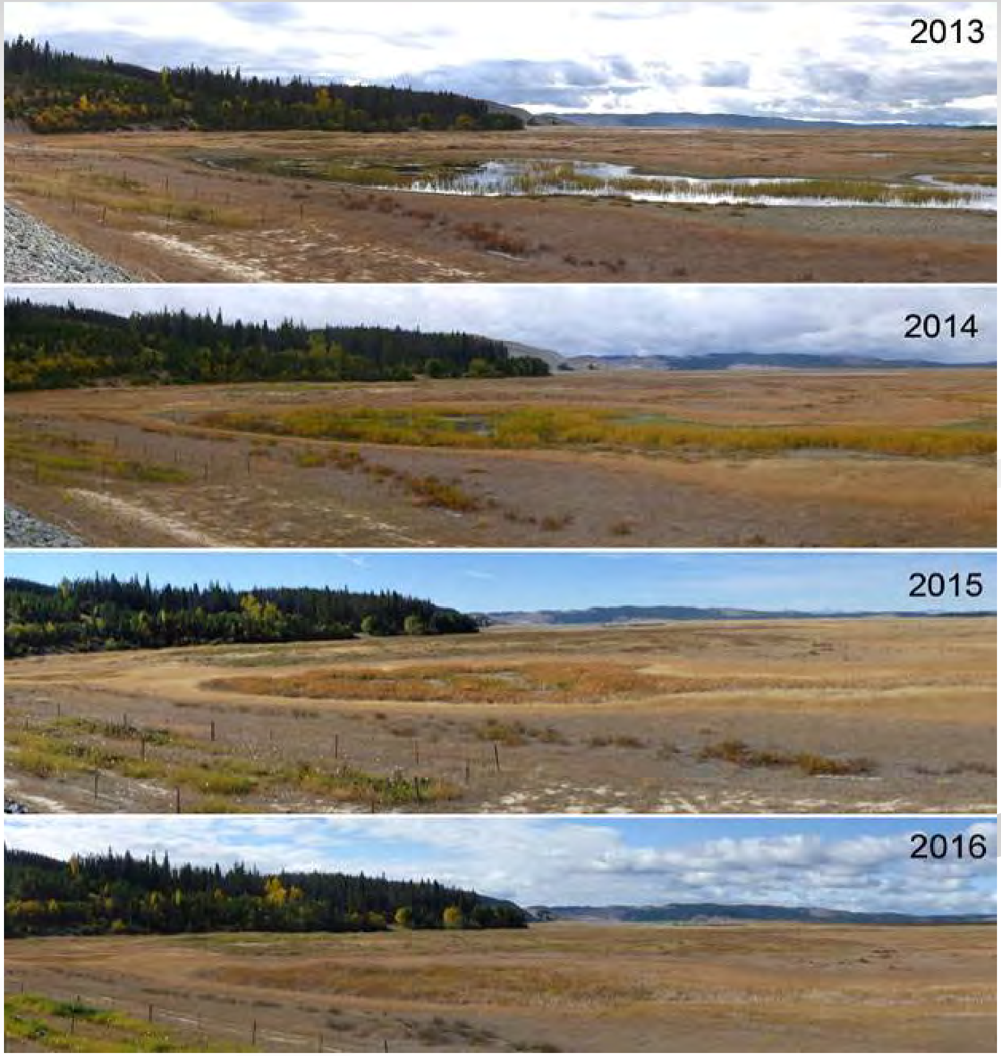


Figure 4.4-3: pH in Highmont tailings pond by month, 2000-2016

The filamentous green taxa involved in the blooms were variable and included *Cladophora*, *Spirogyra, Mougeotia and Stigeoclonium*. Filaments of these algae bioaccumulated 190 - 210 ppm Mo and 170 - 280 ppm Cu in one growing season.

Hydrology impacts water chemistry and habitat values

Late summer water cover at Bethlehem tailings has retreated with altered watershed hydrology (MPB, logging, diversion) and Bethlehem is expected to remain flooded in spring/early summer *only* in future years – it will be a seasonal wetland/wet meadow most years



Seepage water chemistry reflects the redox condition of the tailings mass

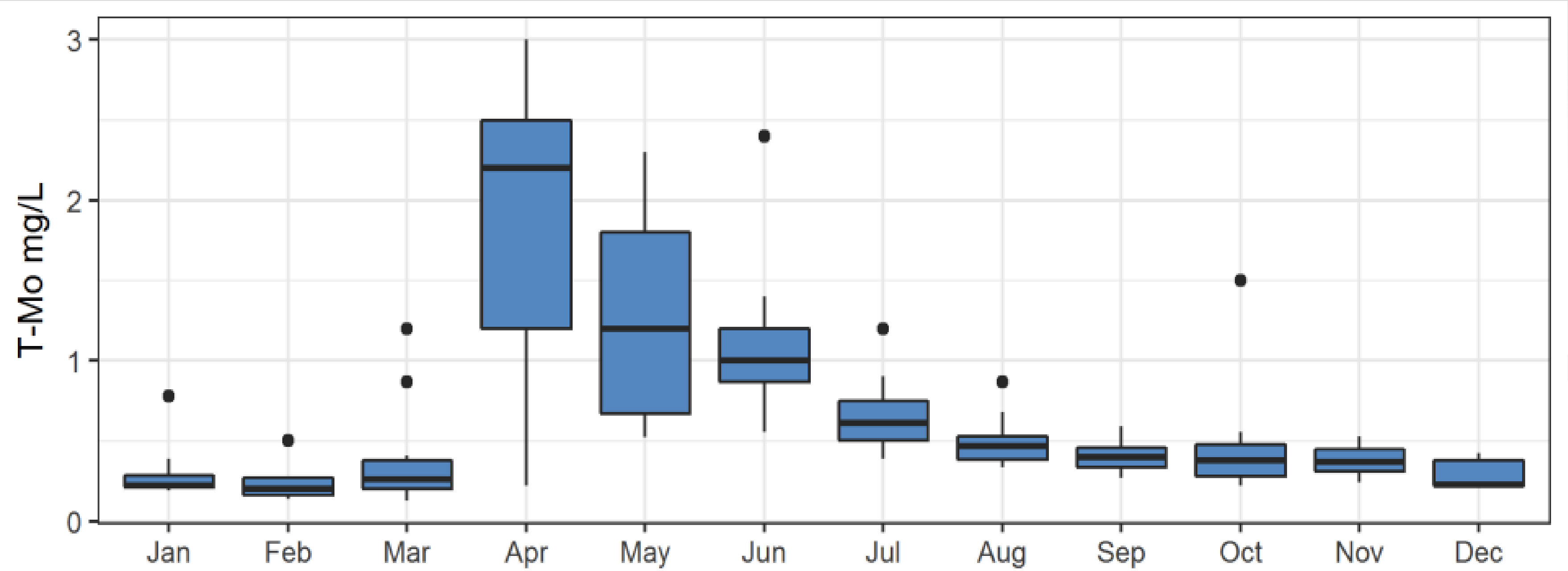
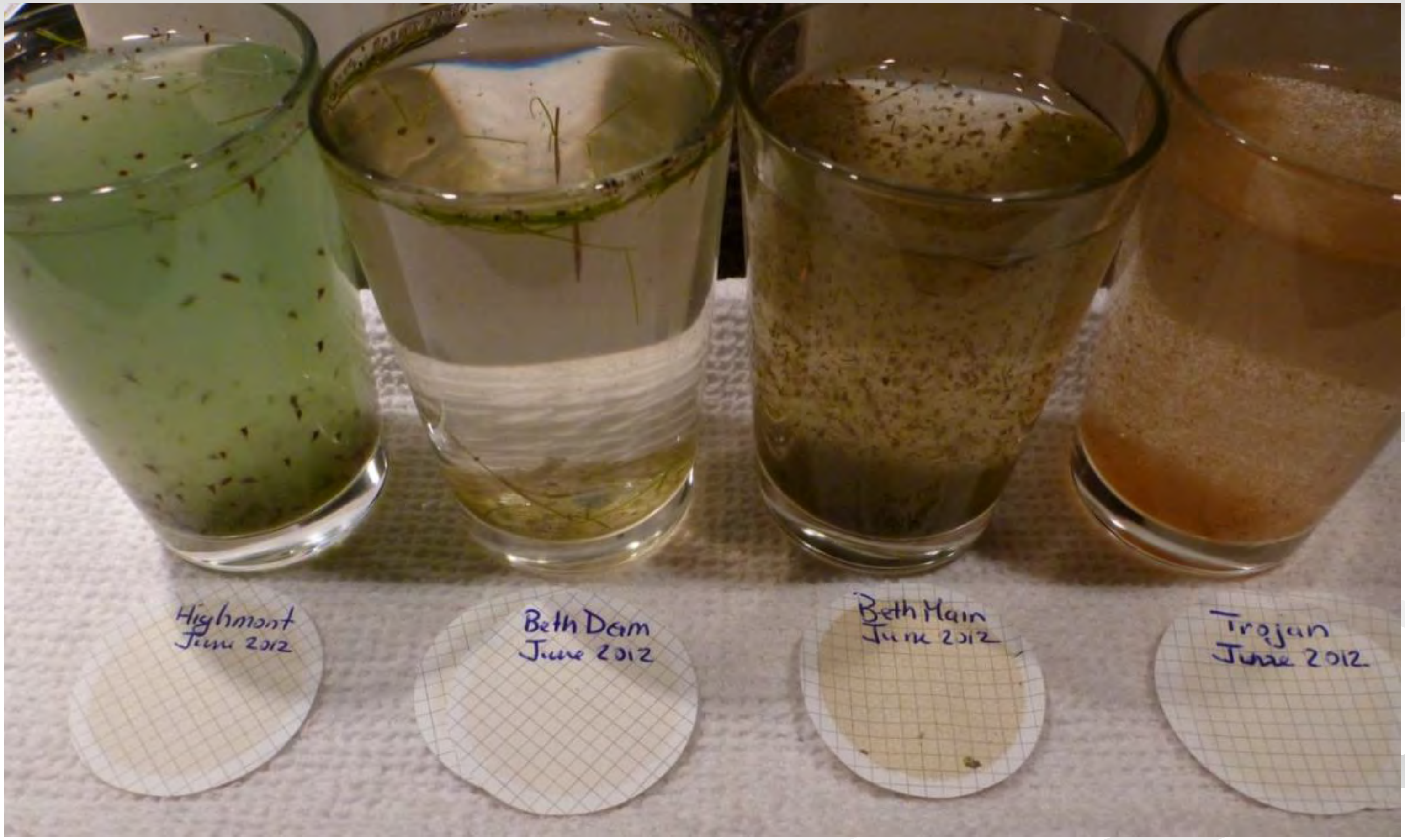
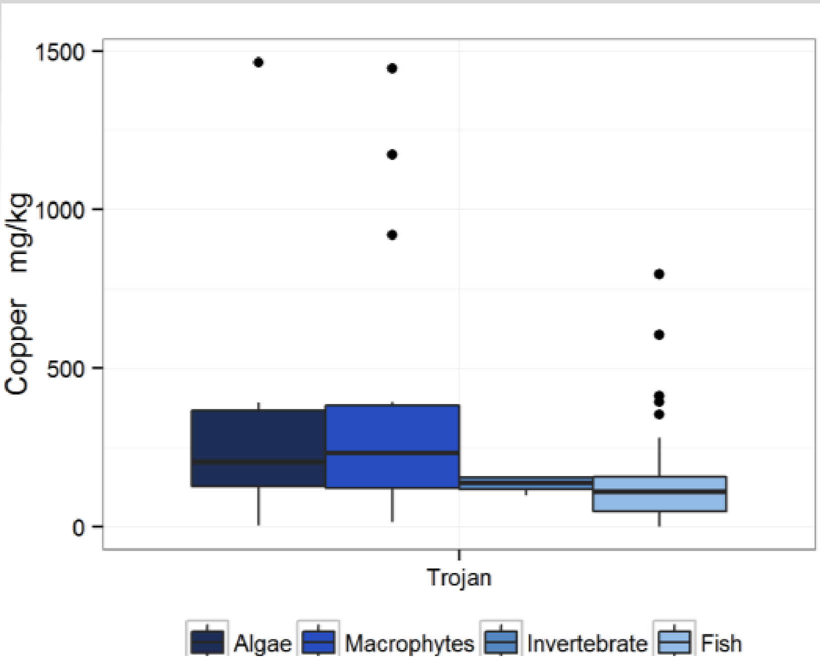


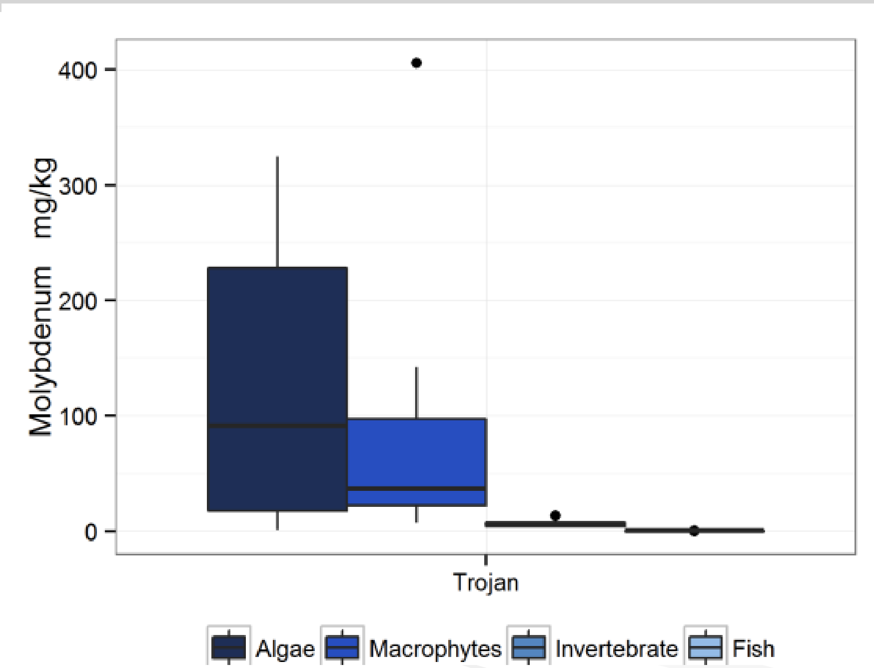
Figure 4.3-10: Monthly total molybdenum concentrations in the Bethlehem saddle dam seepage water, 2000-2016

Each HVC tailings pond developed different chemistry, microflora and zooplankton



Metals in algae, invertebrates, biomagnification?





Not in HVC tailings ponds

Metals in riparian vegetation grown on reclaimed tailings over 12-14 years are trending lower

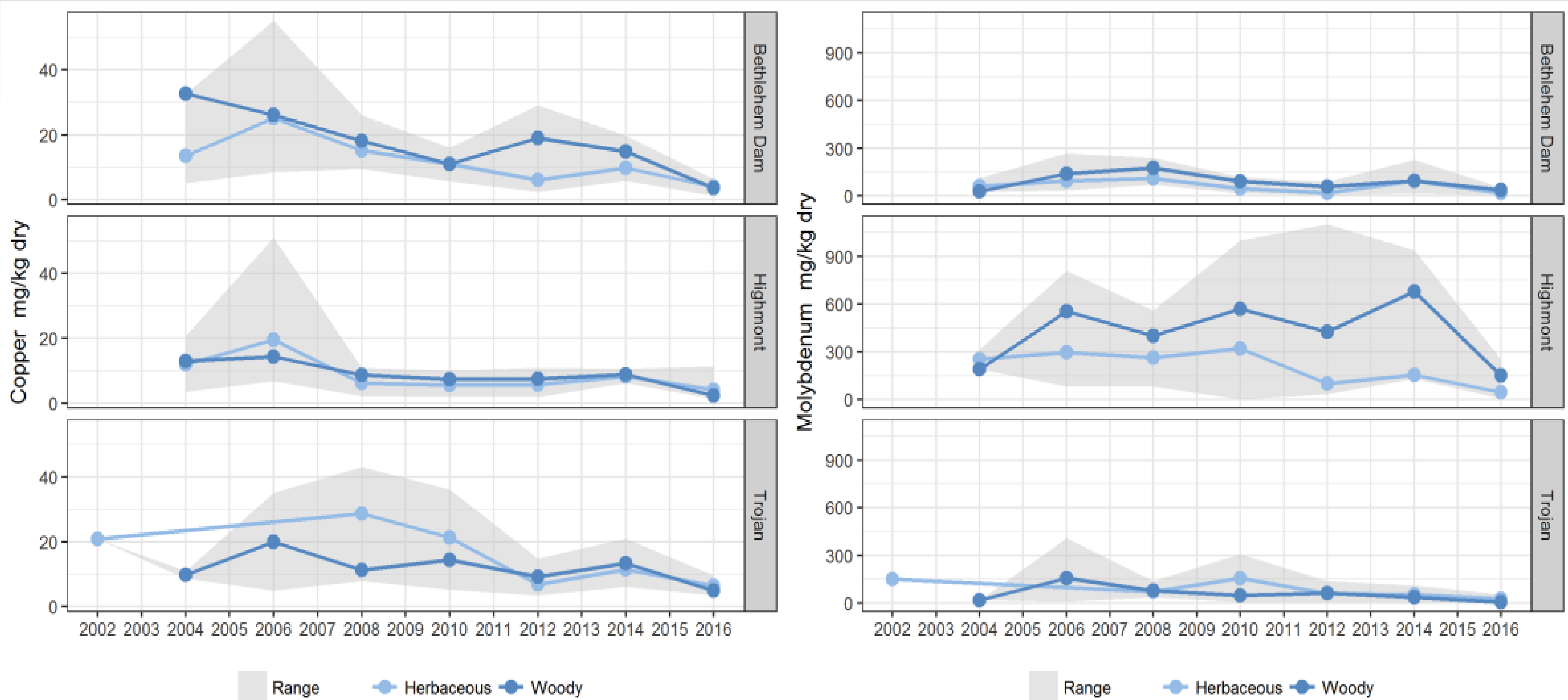
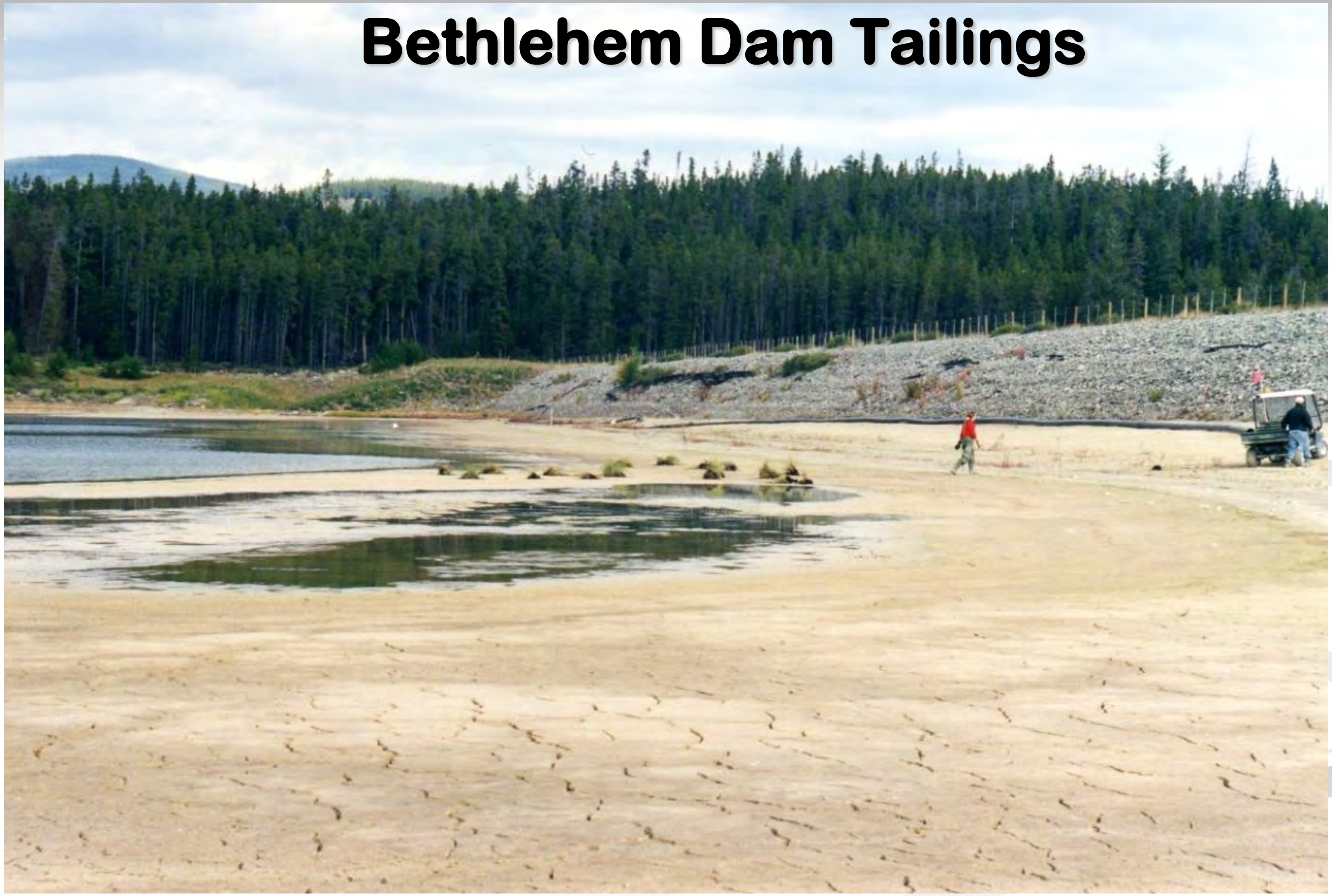
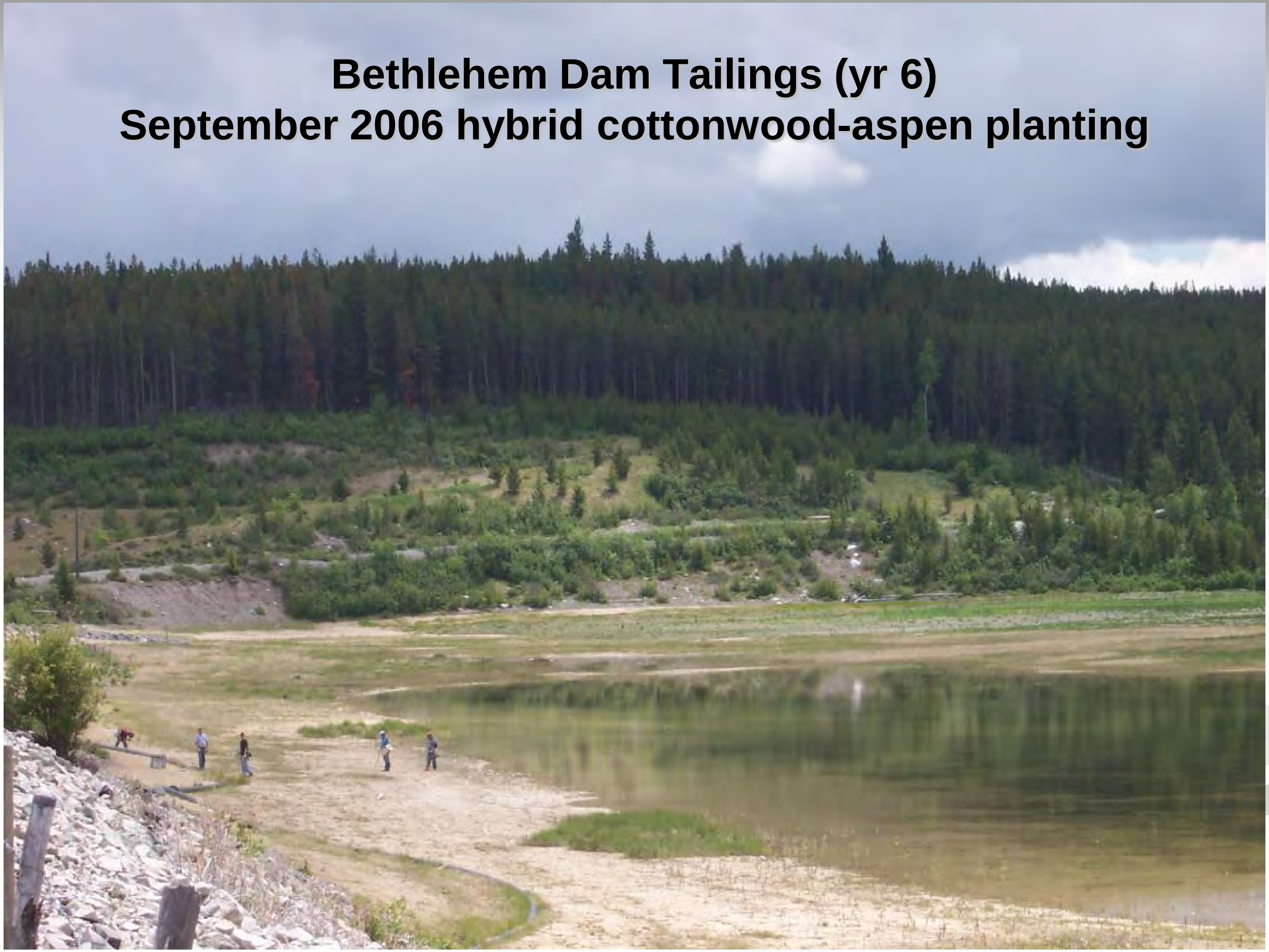


Figure 4.0-2: Autumn Copper and Molybdenum Foliar Concentrations for Riparian Vegetation Grown on HVC tailings (standard error bars shown)


Bethlehem Dam Tailings

Time-Lapse Glory Shots



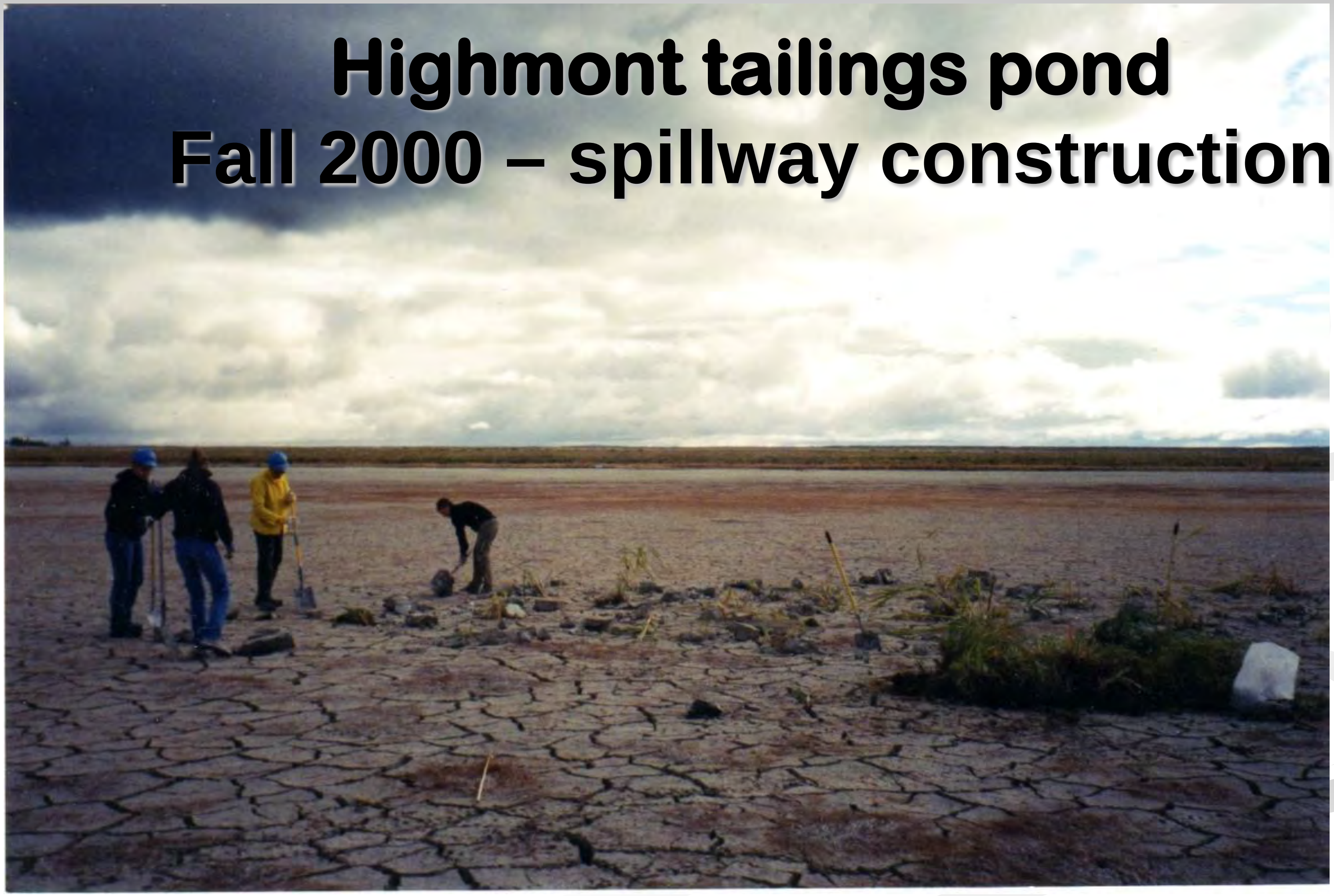
Transplanted and seeded riparian vegetation on Bethlehem Dam Tailings June 2010 (yr 10) and July 2012 (yr 12)

Bethlehem Dam Tailings
Fall 2013 (yr 13) and 2015 (yr 15)

Bethlehem Main Tailings

macrophyte resurgence with high water after 6-8 years with no water cover – if it dries out again, the macrophytes provide grown-in-place organics for the invading grasses etc.

Highmont tailings pond
Fall 2000 – spillway construction



Highmont tailings pond

Highmont tailings pond

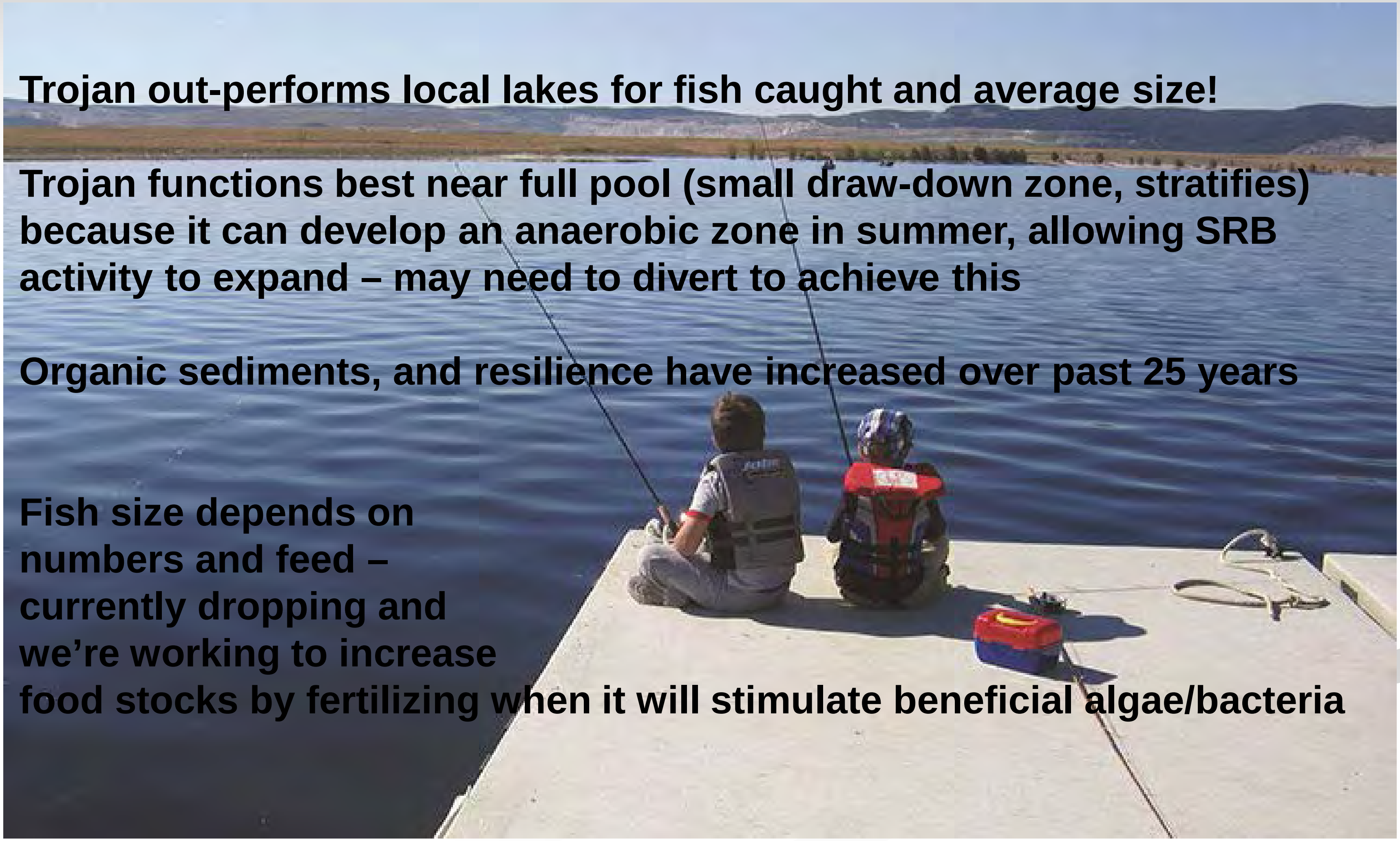
SUMMARY

* Established shallow aquatic ecosystems with habitat and bioreactor functions at HVC may transition into seasonal ponds, or provide grown-in-place organic substrates for seasonal pond/wetland/ meadow systems with consequences for seepage chemistry and water storage.

* Tailings reclaimed as wetland/meadows will cycle between wet and dry years and provide water storage, but the loss of a water cover affects seepage chemistry at HVC.

SUMMARY

Deep HVC Tailings Pond



Trojan out-performs local lakes for fish caught and average size!

Trojan functions best near full pool (small draw-down zone, stratifies) because it can develop an anaerobic zone in summer, allowing SRB activity to expand – may need to divert to achieve this

Organic sediments, and resilience have increased over past 25 years

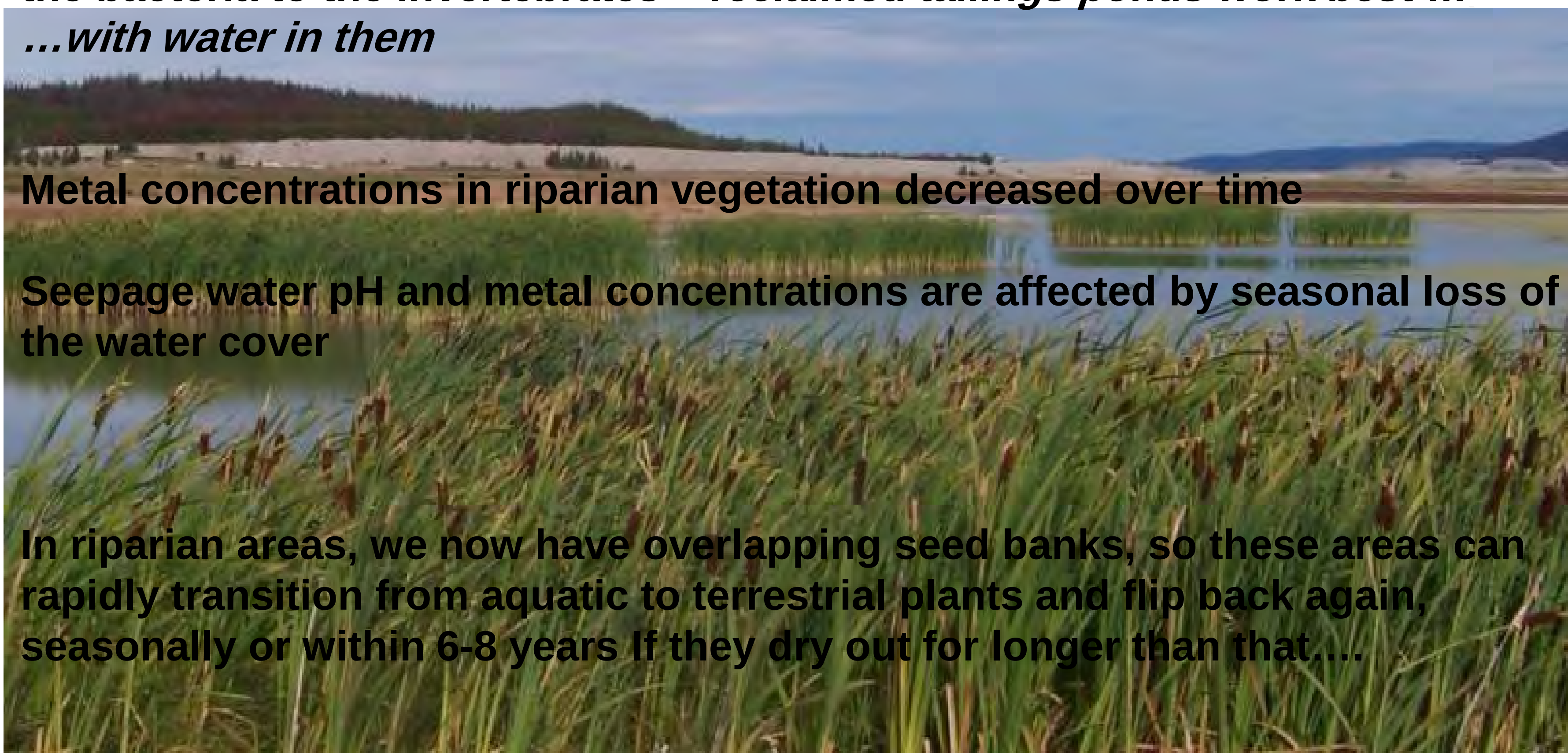
Fish size depends on numbers and feed – currently dropping and we’re working to increase food stocks by fertilizing when it will stimulate beneficial algae/bacteria

SUMMARY

Shallow HVC Tailings Ponds

Highmont tailings pond now hosts ½ of all the bird species found in BC!

Like all ponds and wetlands, diversity and resilience increased over time, from the bacteria to the invertebrates – ***reclaimed tailings ponds work best …***
…with water in them



Metal concentrations in riparian vegetation decreased over time

Seepage water pH and metal concentrations are affected by seasonal loss of the water cover

In riparian areas, we now have overlapping seed banks, so these areas can rapidly transition from aquatic to terrestrial plants and flip back again, seasonally or within 6-8 years If they dry out for longer than that….

Perspective: HVC tailings water compared to bottled mineral water?

Water quality mg/L	TDS	Aluminum	Arsenic	Barium	Cadmium	Chloride	Copper	Flouride	Lead	Mercury	Molybdenum	Nickel	Nitrate	Sodium	Sulphate	COST/L
Cnd Maximum acceptible concentration	--	0.5	0.01	1.0	0.005	250	1.0	1.5	0.05	0.001	--	0.15	10.0	--	500	Cnd 1990
European guidelines	--	0.2	0.01	0.1	0.005	25	0.1	1.5	0.05	0.001	--	0.05	25.0	20	25	Cnd 1990
Abenaskis	**23000**	nd			**0.064**				**0.14**			**0.2**	nd	**12000**	**685**	1.58
Apollinaris	1870	0.038	**0.037**	0.12	0.0002	188	0.024	0.5	0.014	**0.0035**	nd	0.026	1.8	820	**180**	1.69
Canada Dry Club Soda	830	0.026	nd		nd			1.1	nd			nd	nd	390	28	0.79
Evian		nd	0.00025	0.313	nd	4	0.001	0.1	nd	nd	nd		0.6		8	1.81
Gerolsteiner Sprudel	1750	0.29	nd	0.126	**0.01**	45	nd	0.5	0.035	0.0003	nd	0.04	0.6	300	34	1.69
Karlspring	2900	0.072			**0.01**			0.2	0.029			0.041	nd	**2000**	20	1.58
Montclair	1400	0.016	0.0002		0.005			1.0	nd			nd	nd	850	50	1.98
Montellier	800				0.004			**1.6**	nd			nd	nd	555	nd	1.58
Perrier	490	0.15	0.00025	0.075	0.005	33	nd	0.2	nd	**0.0012**	nd	nd	6.0	300	58	1.85
Pellegrino	1250	0.4			**0.006**			0.6	0.024			nd	nd	42	**500**	2.25
President's Choice E Canada	1000	0.078			**0.04**			**3.0**	nd			nd	nd	640	nd	1.45
President's Choice W Canada	1020	**2.4**			**0.007**			0.2	0.023			0.02	**17.0**	45	270	1.18
Radenska	2550	nd		0.112	**0.01**	73	nd	0.7	0.036	**0.0012**	nd	0.035	nd	**1400**	110	1.69
Radnor	1950	0.02			**0.008**			**2.2**	nd			0.022	nd	830	88	0.65
San Pellegrino	1100	nd	0.002	0.058	nd	80	0.002	**8.0**	nd	nd	0.34		nd	46.5	475	1.65
Sparcal	1170	0.25			**0.006**			0.2	0.016			nd	nd	31	**759**	1.56
Steinberg	1950	nd			**0.006**			1.0	nd			0.023	nd	**1500**	nd	0.52
Vichy Celestins	3200	nd	**0.22**	0.072	0.001	8	0.001	**6.5**	0.036	nd	nd	0.041	nd	**2400**	120	1.41
Vittel	640	0.022	**0.013**	0.109	**0.008**	8	0.002	0.3	0.031	0.0003	nd	0.022	1.5	3	**500**	0.56
Trojan tailings pond	119	0.033	0.0029	0.0479	0.0013	1.1	0.0398	nd	<0.005	nd	0.0137	nd	0.0	4	7	0.00
Highmont tailings pond	600	0.153	0.0060	0.0509	0.0018	16.0	0.0352	nd	<0.005	nd	2.7377	nd	0.3	58	165	0.00
Heustis pit lake	947	0.008	0.0022	0.0187	0.0012	22.4	0.0431	nd	<0.005	nd	2.5465	nd	0.4	82	**519**	0.00
	nd = not detected		many sources		analyses highly variable											

Questions?