Trace Elements: 2011 Agency Meeting

SLR International Corp

February 1, 2012

Pebble Project EBD

Objectives

- Establish baseline concentrations of naturally occurring constituents (NOCs) in shallow soils, native plants (including aquatic plants), sediment, and fish tissue
- Evaluate variability in baseline levels of NOCs across different geochemistries, habitats, and species
  - Evaluate both spatial and temporal variability of NOCs in plants and soil
  - Evaluate spatial variability of NOCs in fish and sediment

Target Analytes

Parameter	Method	Soil	Sediment	Plants	Fish
Ammonia	E350.3	X	X	X	
Chloride	E300.0	X	X	X[c]	
Cyanide	E335.2	X	X	X	
Fluoride	SW4500FC	X	X	X[c]	
Sulfate	E300.0	X	X	X[c]	
Mercury	SW7471A	X	X	X	X
Metals	SW6010/6020	X[a]	X[a]	X[a]	X[b]
DRO/RRO	AK102/103	X[c]			
Pesticides/PCBs	EPA 8081/8082				X[c]
Organic Carbon	ASTM D4129-82M	X			

[a] 26 Metals; [b] 11 Metals; [c] Discontinued after 2005.

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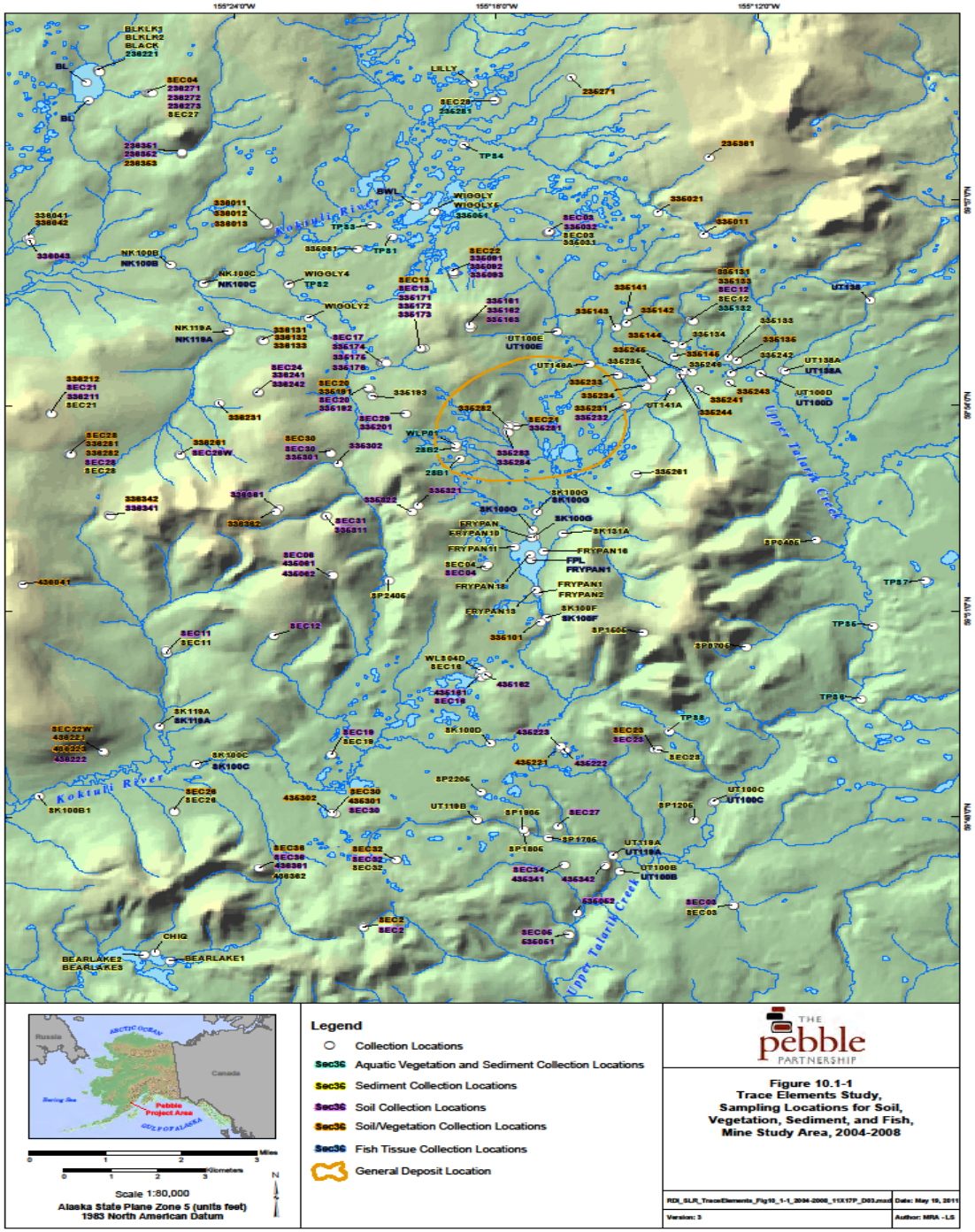
What Did the Program Include?

- Plant/soil/fish/sediment sampling began in 2004
- Plant/soil sampling program updated in 2005:
  - Sampling locations and density modified to be proportional to habitat abundance
  - All plant and soil sampling collocated
  - Two sampling events per season
    - Early season browse
    - Late season browse and berries
  - Aquatic plants and ponds added to program
  - Seep sediments sampled

Sampling Locations



Program Evolution

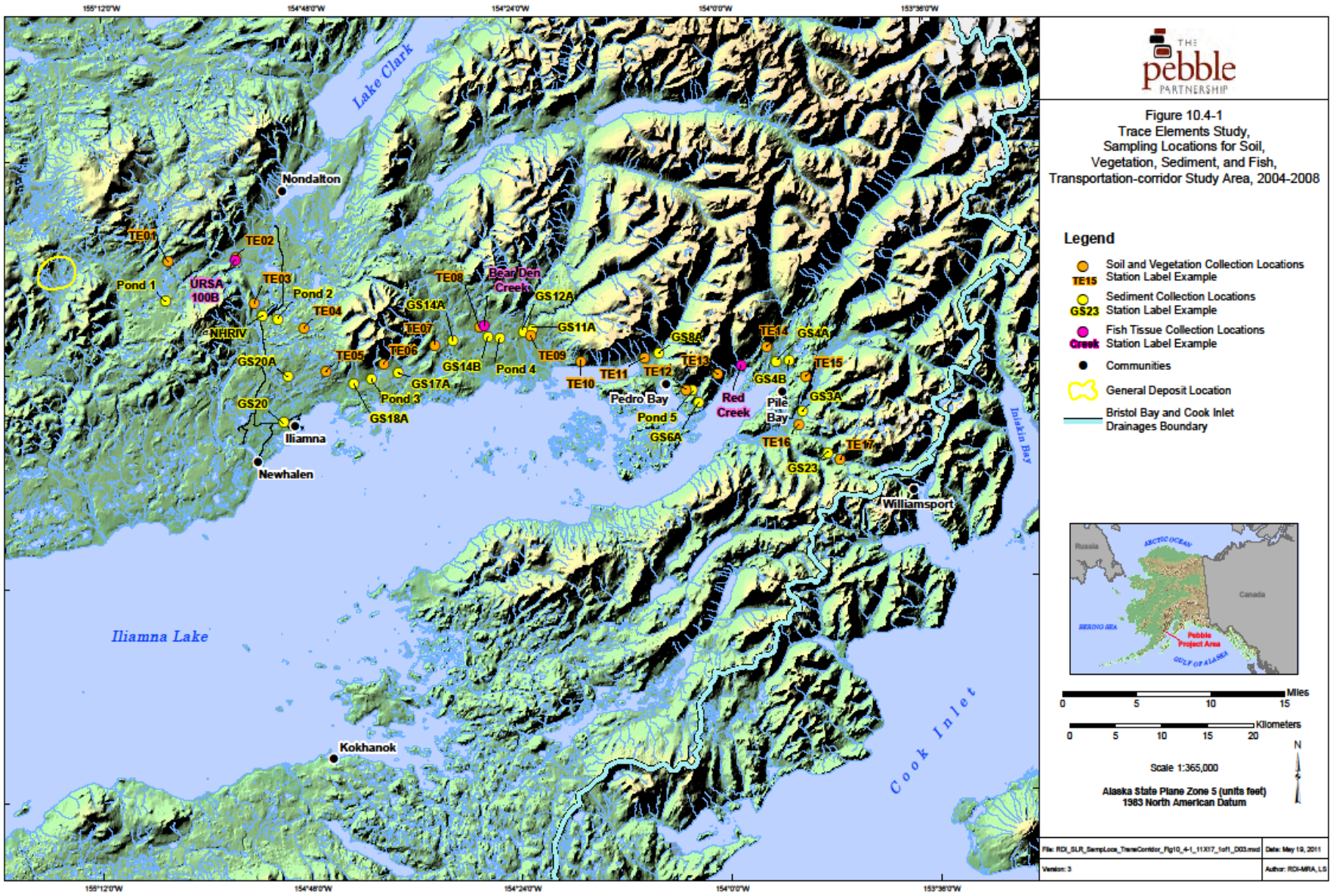
- Pebble East area added in 2006
- Subsurface soil sampling eliminated in 2006
- Aquatic plant/pond sampling expanded in 2006 to include:
  - Groundwater-fed ponds

  - Precipitation-fed ponds

  - Beaver dam impacted ponds


PRISM
GLNH

Sampling Locations: Transportation Corridor



Mine Study Area Soil Sampling

- Sampling initially based on random grid across study area
- Updated in 2005 to be proportional to relative abundance of seven upland habitats
- 117 Locations sampled

Mine Study Area Plant Sampling

- Sampling based on preliminary identification of seven upland habitats
- Over 50 different plant species, including:
  - Trees
  - Shrubs
  - Forbs
  - Moss
  - Lichen
  - Grasses
  - Sedges

- Each vegetation sampling location was visited twice per season to collect both early season browse and late season browse and berries
- 70 Locations sampled

Mine Study Area Sediment Sampling

- River (NFK, SFK) and Creek (UT, Kaskanak) sampling begun in 2004
  - 21 Locations, 50 samples in 2004
  - 18 Locations, 31 samples in 2005
  - 14 Locations, 14 samples in 2006
  - 14 Locations, 14 samples in 2007
- Pond and seep sampling begun in 2005
  - 6 Ponds, 14 samples in 2005
  - 14 Ponds,19 samples in 2006
  - 21 Ponds, 22 samples in 2007
  - 9 Seeps, 12 samples in 2005

- 21 Samples in 2004 from standing water in upland areas
- 197 Sediment samples collected and analyzed

Mine Study Area Sediment Sampling

Sediment Matrix	Number of Samples
North Fork Koktuli River	27
South Fork Koktuli River	40
Upper Talarik Creek	42
Ponds	55
Seeps	12

Mine Study Area Fish Sampling

- Sampling conducted as part of fisheries study
  - Five species: Arctic grayling, Northern pike, whitefish, salmon (coho and chinook), and Dolly varden
  - Four lakes sampled (grayling, pike, whitefish): Big Wiggly, Frying Pan, Black, Lake 2
  - Four rivers sampled (salmon and Dolly varden): NFK, SFK, UT, KC
- Whole-body analysis in river fish samples (366 total fish)
  - Dissected muscle-only analysis for some fish (55 samples)
- Muscle and liver analyzed in lake fish samples
  - Muscle analyzed in all 172 samples; liver in subset of 80 samples

Mine Study Area Fish Sampling

Water Body	Number of Samples
Lakes	162
North Fork Koktuli River	83
South Fork Koktuli River	136
Upper Talarik Creek	126
Kaskanak Creek	21

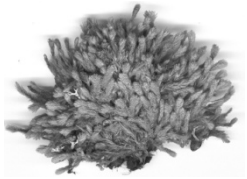
Plant Sampling Summary: Mine Study Area

Trees (4 species)
17 samples

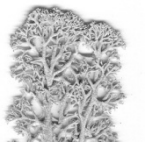
Shrubs (17 species)
300 vegetative samples
80 berry samples (5 species)

Forbs (16 species)
146 samples

Grasses and sedges (6 species)
85 samples



Mosses (5 species)
93 samples



Lichens (3 species)
66 samples

707 total plant samples, 51 species

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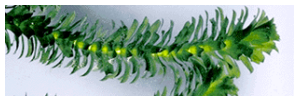
Why so Many Different Species Sampled?

- Adequate characterization of multiple habitats and species groups required
- Many different medicinal and traditional uses by natives
- Multiple food sources for wildlife
- Improves confidence in selecting indicator species

Traditional and Medicinal Plant Uses

Species	Food/Drink	Medicinal	Other	Sampled at Pebble
Trees				
Black Spruce			x	x
White Spruce			x	
Shrubs				
Shrub/dwarf Birch			x	x
Paper Birch			x	
Willows			x	x
Mountain Alder		x	x	x
Bog Blueberry	x			x
Crowberry	x			x
Salmonberry	x			x
Lingonberry	x			x
Forbs				
Putchkie Cow Parsnip	x	x		
Fireweed	x	x		x
Horsetail	x	x		x
Cloudberry	x			x
Angelica		x		
Stink Weed	x			
Sweet Gale		x	x	
Devil's Club		x		
Labrador Tea	x	x		
Skunk Currant	x		x	
Alaska Spirea			x	x
Elderberry		x	x	x
Mosses				
Terrestrial Green Moss			x	x
Lichens				
Caribou Lichen	x	x		x
Ferns				
Wood Fern	x	x		
Lady Fern	x	x		
Grasses and Sedges				
Blue Joint Grass	x	x	x	x
Beach Rye	x	x	x	
Sedges			x	x

Trace Elements: Mine Study Area Sampling Summary

Medium	2004	2005	2006	2007
Sediment 	71	57	33	36
Surface Soil 	80	86	41	30
Subsurface Soil 	9	7	0	0
Plant Tissues 	72	171	207	234
Berries 	12	27	16	25
Aquatic Plants 	0	7	8	8

Mine Study Area Soil Sampling: Results

- Total of 253 samples
  - 237 surface; 16 subsurface
- Elements generally consistent in concentrations in both surface and subsurface samples
  - Several metals and ions (Bi, Se, Ag, Sn, CN, and ammonia) present in surface samples at 2-3x concentration in subsurface samples
  - Subsurface sampling discontinued after 2005 based on these results

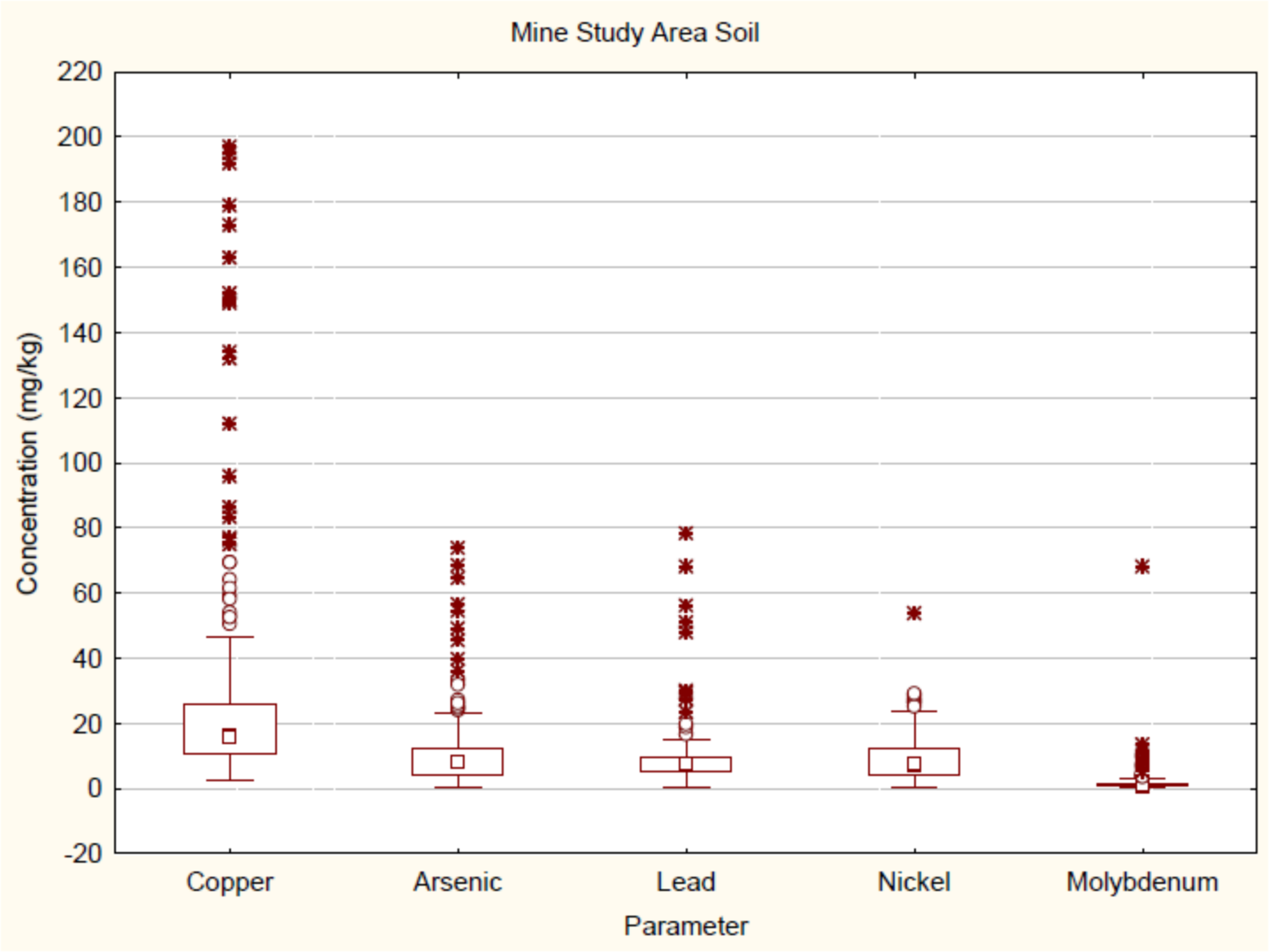
Mine Study Area: Soil Sampling Results

- Element soil concentrations highest in talus slope samples for more than half (16 of 26) of the metals
  - Particularly for As, Cu, Pb, and Ag
- Concentrations highest in moraine samples for 9 metals
  - Particularly for Ba
- CN highest in talus slope samples (0.25 mg/kg)

Mine Study Area: Key Soil Findings

- Elemental concentrations varied widely across locations, and also varied in their relative abundance within a location.
- Concentrations influenced by landform type (e.g., talus slope) and habitat (e.g., alpine rock), but no consistent significant correlations were apparent.
- Aluminum and iron were the most abundant elements.
- Biogenic sources of petroleum-range hydrocarbons present in shallow soil in all samples:
  - RRO = 1,286 mg/kg average concentration in surface (n=20)
  - DRO = 137 mg/kg
- DRO/RRO soil concentrations much greater in moraine samples than in other landforms (5-20x higher):
  - RRO average of 2,000 mg/kg in moraines, 100 mg/kg in outwash plains
  - Appropriate to identify a background concentration for DRO and RRO
  - Landform-specific background may be appropriate
- Cyanide is present in soil samples (FOD=84%) at concentrations ranging from 0.024 to 4.0 mg/kg (mean = 0.19 mg/kg).

Box Plot for Select Elements in Soil



Mine Study Area Plant Sampling: Results

- 707 Vegetation samples
- 80 Berry samples
- 23 Aquatic plant samples
- Most abundant plants sampled:
  - bog blueberry (51)
  - short-stalk sedge (49)
  - diamond-leaf willow (49)
  - reindeer lichen (45)
  - dwarf (shrub) birch (43)
  - sphagnum moss (34)
  - Crowberry (35)

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Mine Study Area: Key Plant Findings

- Different elemental concentrations across different plant species.
- Elemental concentrations generally lower in berries than vegetative samples.
  - Significant for Al, Ba, Ca, Co, Mg, Mn, Zn.
- Concentrations generally higher in mosses and lichens than other plants
  - Green terrestrial moss had substantially higher mean concentrations of several trace elements (Al, Sb, Fe, Pb, Ni) than other plant species.
- Higher concentrations of elements in talus slope soils not evident in plants
- Essential nutrients Ca, Mg, K had highest concentrations in plants.
- CN present in 36% of vegetative samples and 25% of fruit tissues.
  - This demonstrates that cyanide is naturally occurring at detectable levels in soil and many plant species
  - Cyanogenic bacteria may be primary source of cyanide in the area

Sodium in Vegetative Plant Tissues

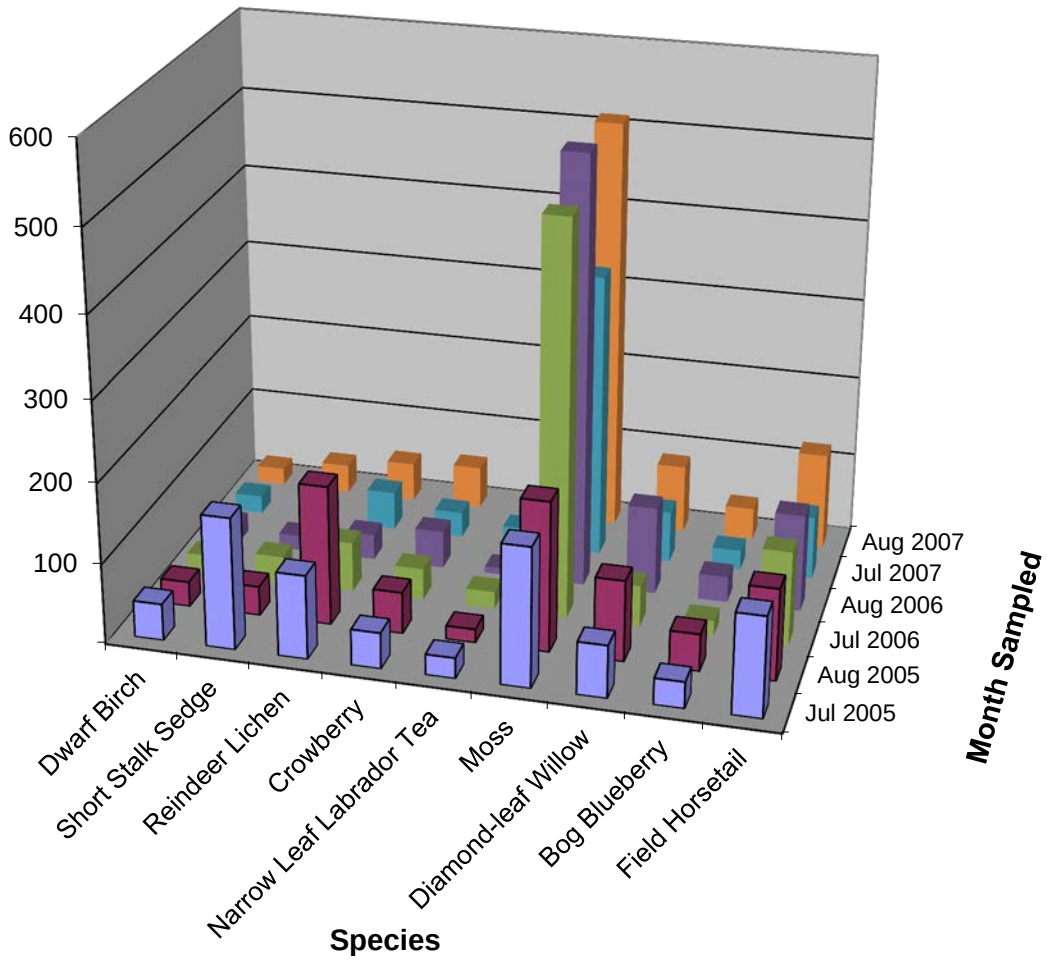


FIGURE 10.1-20
Mean Sodium Concentrations in Vegetative Tissue Samples, Mine Study Area, 2005-2007

Aluminum in Vegetative Plant Tissues

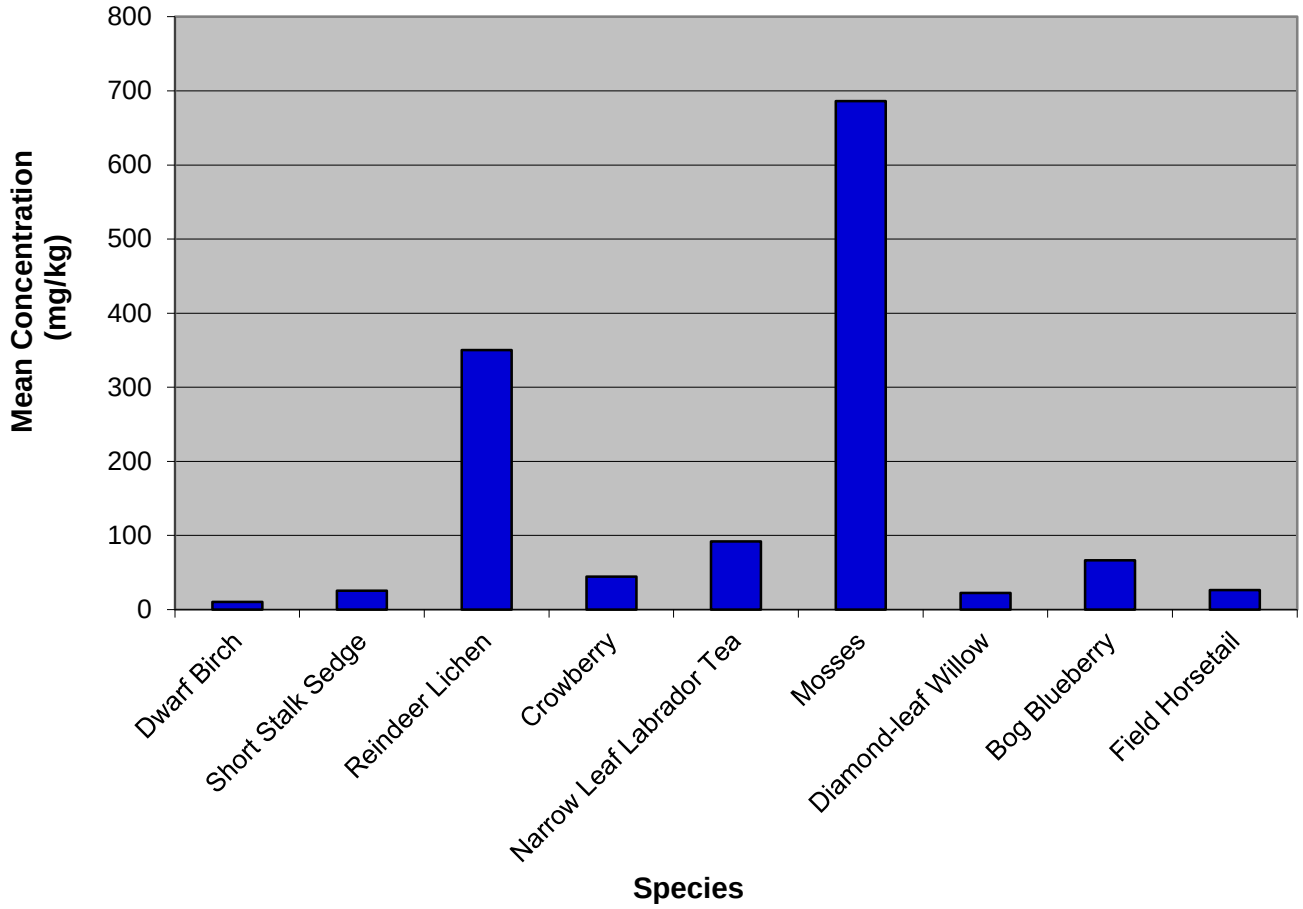


FIGURE 10.1-24
Mean Aluminum Concentrations in Vegetative Tissue Samples, All Sampling Events, Mine Study Area, 2005-2007

Mine Study Area Sediment Sampling: Results

- Total of 197 samples.
- Subset of 34 samples analyzed for acid-volatile sulfide, simultaneously extracted metals, to evaluate bioavailability.
- Elemental abundance similar to that for soil:
  - Al, Fe, Ca, Mg at highest average concentrations

Mine Study Area: Key Sediment Findings

- Each of the major drainages, ponds, seeps, and "minor drainages" have different signatures of natural levels of trace elements and ions.
  - Anions and cations generally have higher concentrations in ponds and "minor drainages" than rivers or seeps.
  - Seeps had lower concentrations of CN than other types of samples.

    Consistent with cyanogenic bacteria hypothesis

Zinc in Sediments

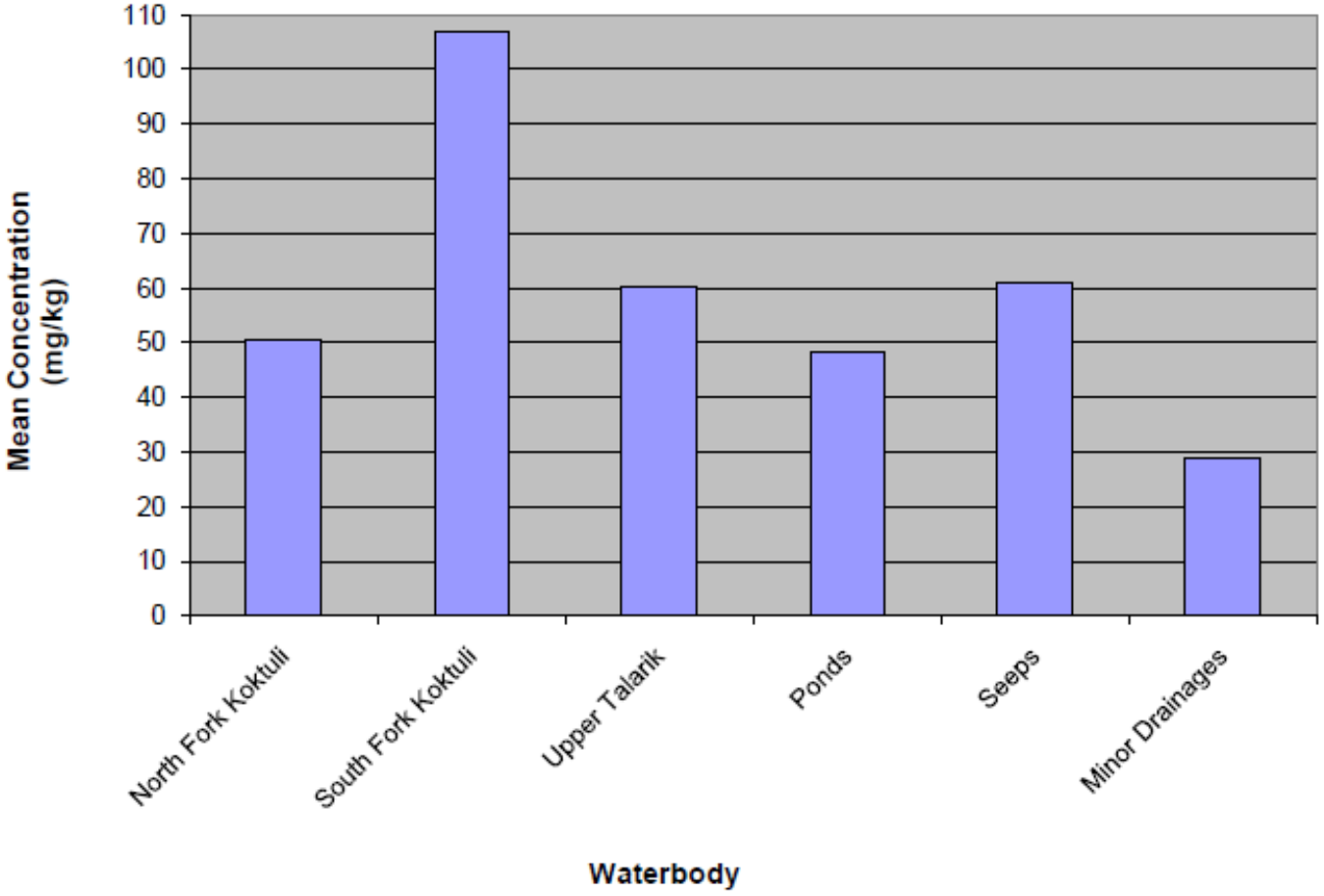


FIGURE 10.2-32
Mean Zinc Concentrations in Sediments, Mine Study Area, 2004-2007

Chloride in Sediments

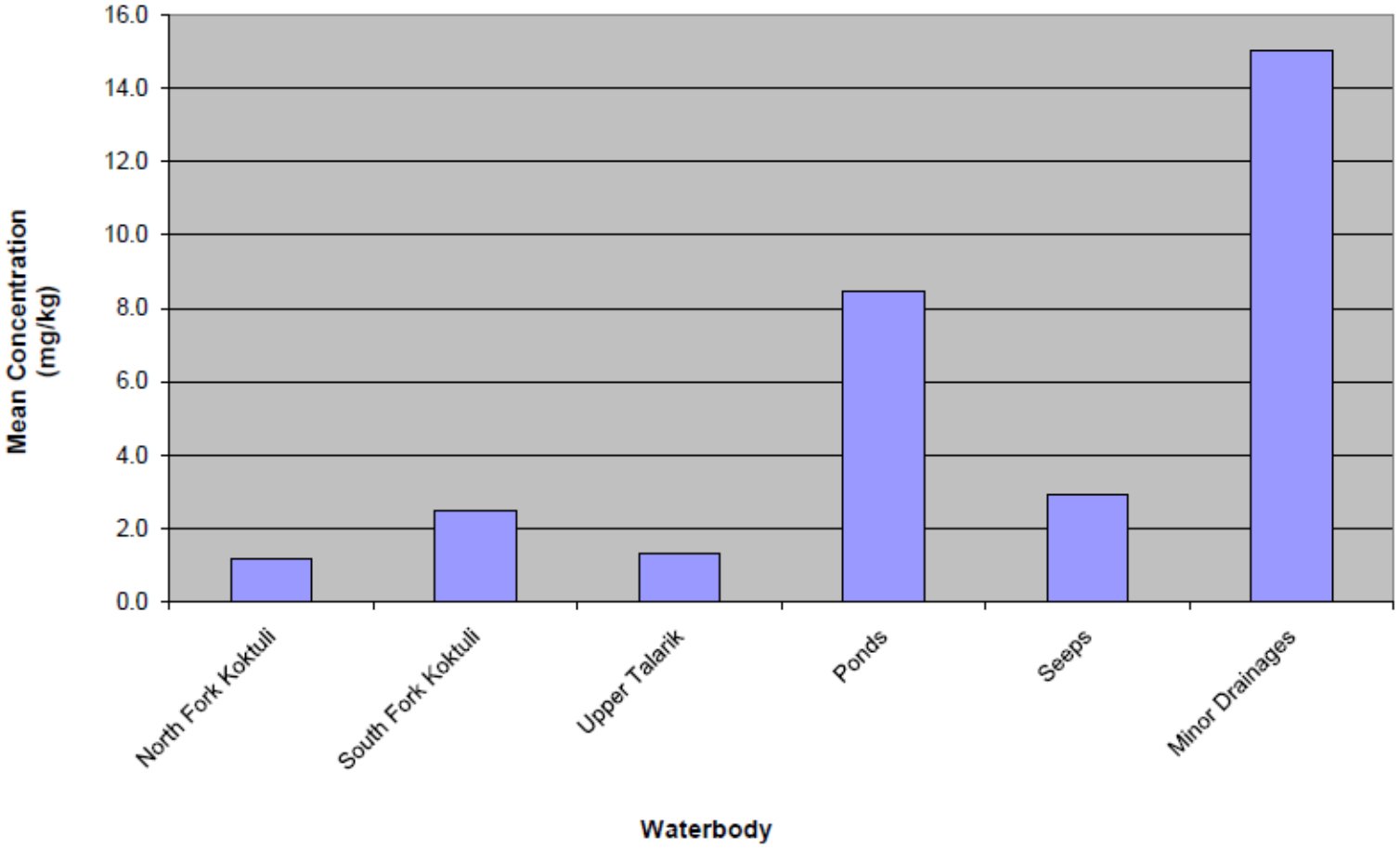


FIGURE 10.2-10
Mean Chloride Concentrations in Sediments, Mine Study Area, 2004-2007

Cyanide in Sediments

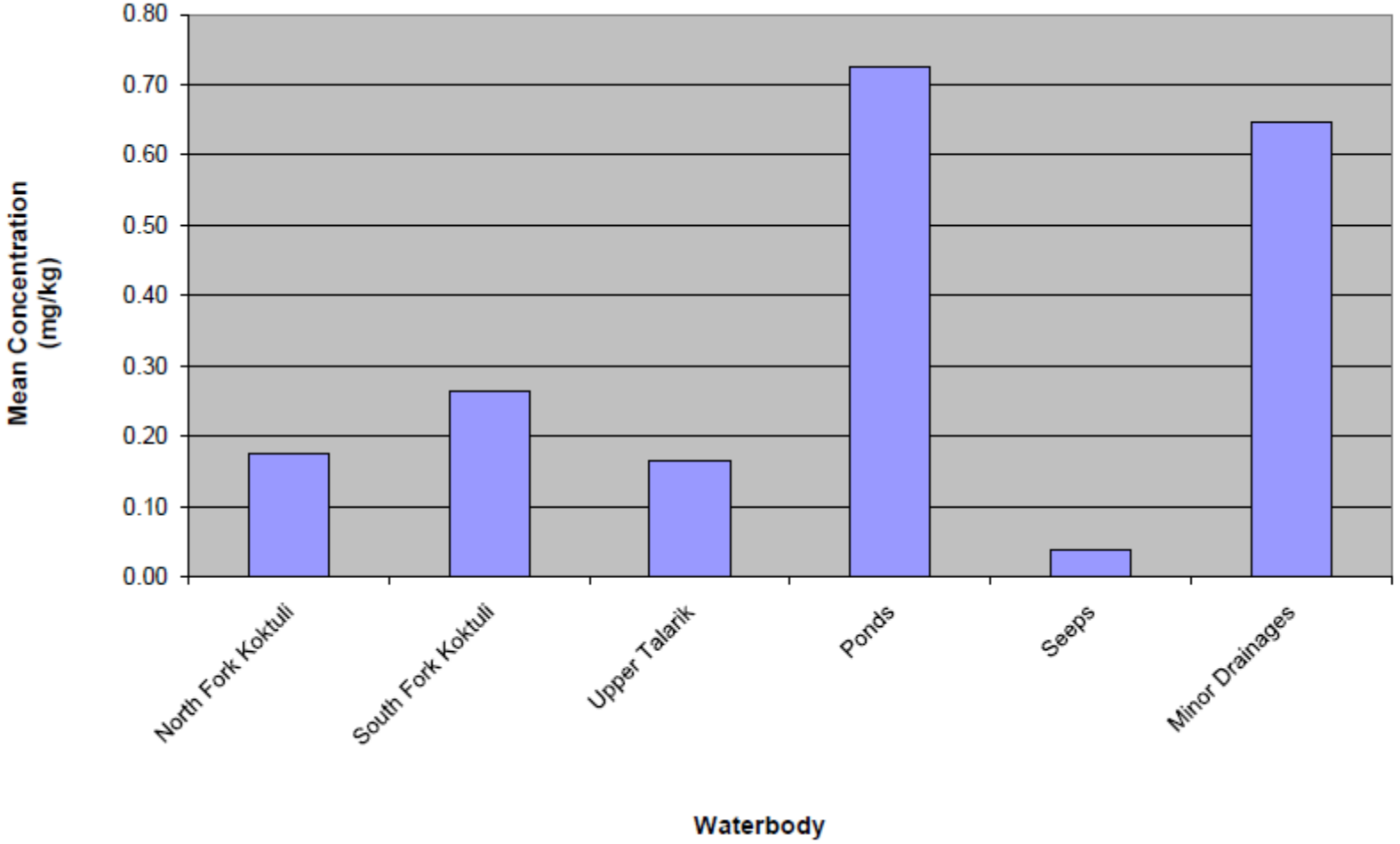
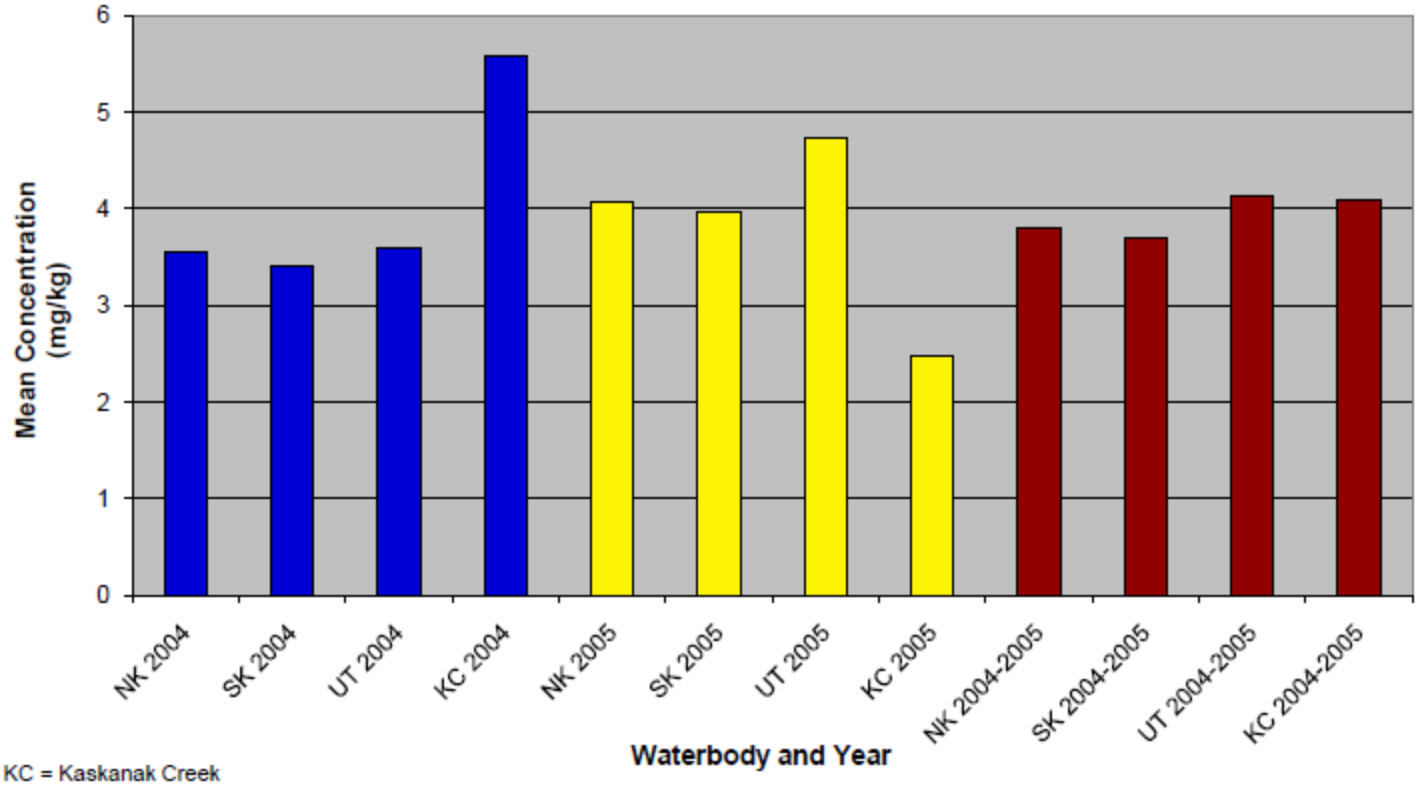


FIGURE 10.2-14
Mean Cyanide Concentrations in Sediments, Mine Study Area, 2004-2007

Mine Study Area Fish Sampling: Whole Body Results

- Dolly varden, Arctic grayling, coho and chinook salmon:
  - Copper and zinc present at highest mean concentrations in the three main rivers.
  - Nickel, chromium, and lead substantially higher in NFK fish than in SFK fish.
  - Cadmium substantially higher in SFK fish than NFK or UT fish.
  - Mercury lower in SFK fish than NFK or UT fish.
- Species-specific statistical differences within a water body identified for majority of elements.

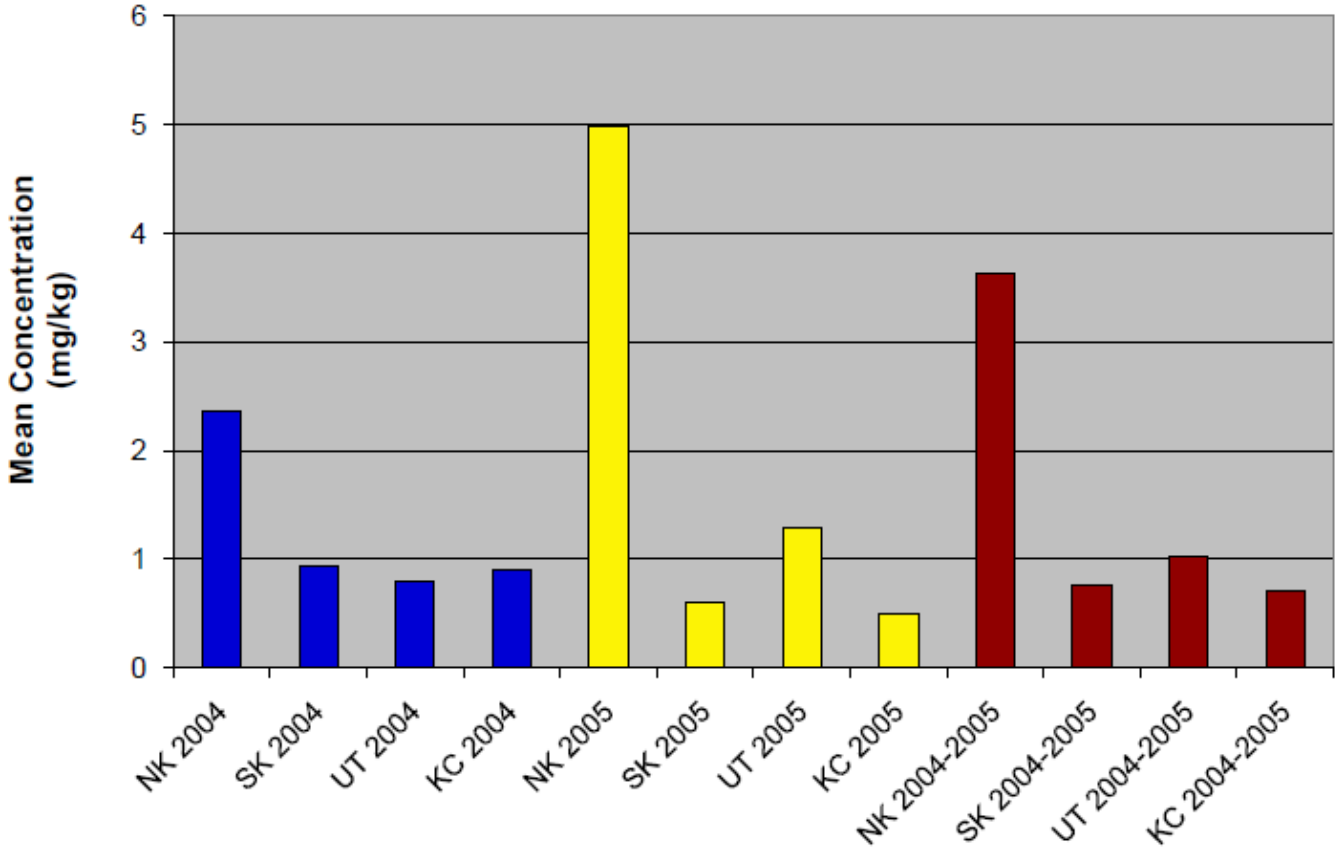
Copper in Whole Fish Samples



KC = Kaskanak Creek
NK = North Fork Koktuli River
SK = South Fork Koktuli River
UT = Upper Talarik Creek

FIGURE 10.3-3
Mean Copper Concentrations in Whole Fish, Mine Study Area, 2004-2005

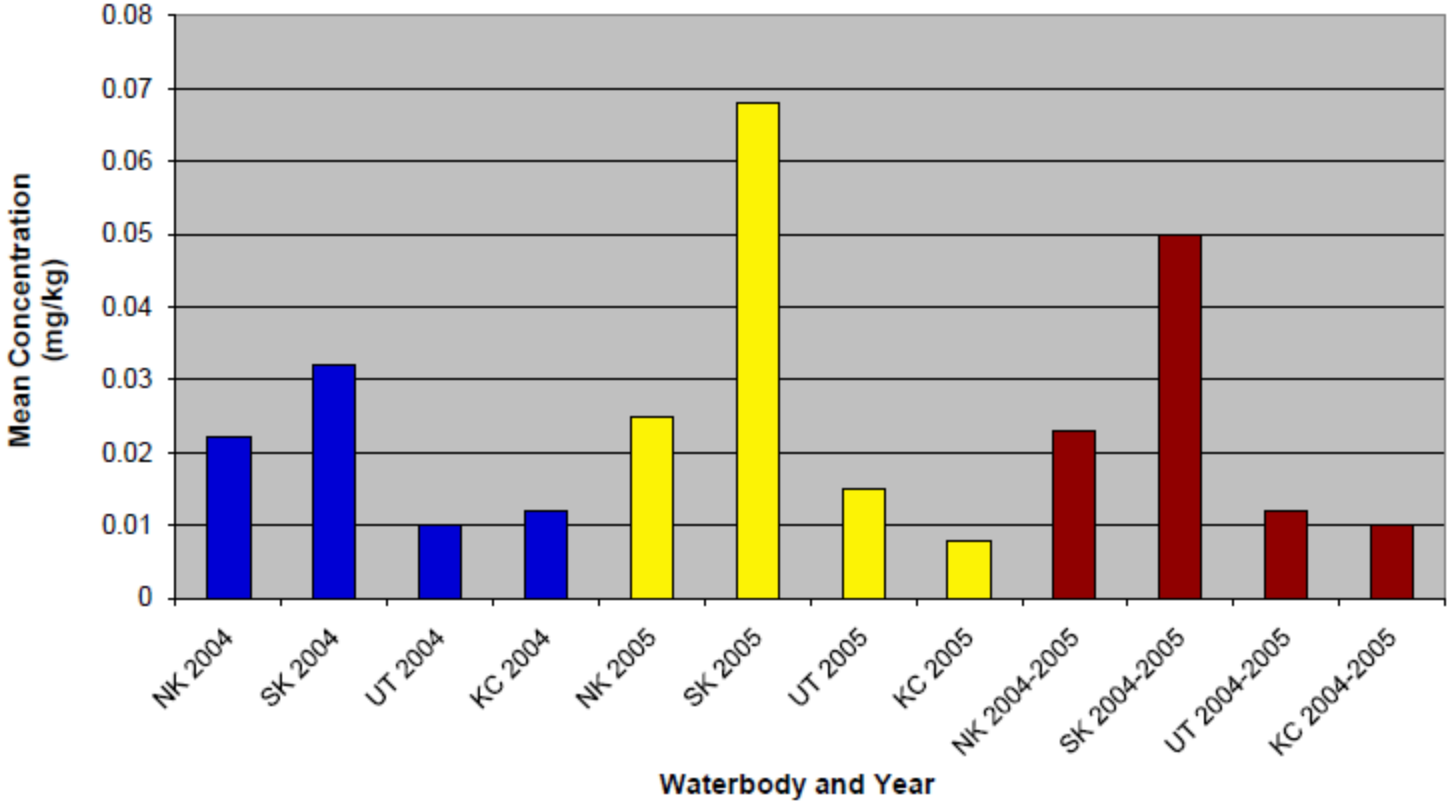
Nickel in Whole Fish Samples



KC = Kaskanak Creek
NK = North Fork Koktuli River
SK = South Fork Koktuli River
UT = Upper Talarik Creek

FIGURE 10.3-5
Mean Nickel Concentrations in Whole Fish, Mine Study Area, 2004-2005

Cadmium in Whole-Fish Samples



KC = Kaskanak Creek
NK = North Fork Koktuli River
SK = South Fork Koktuli River
UT = Upper Talarik Creek

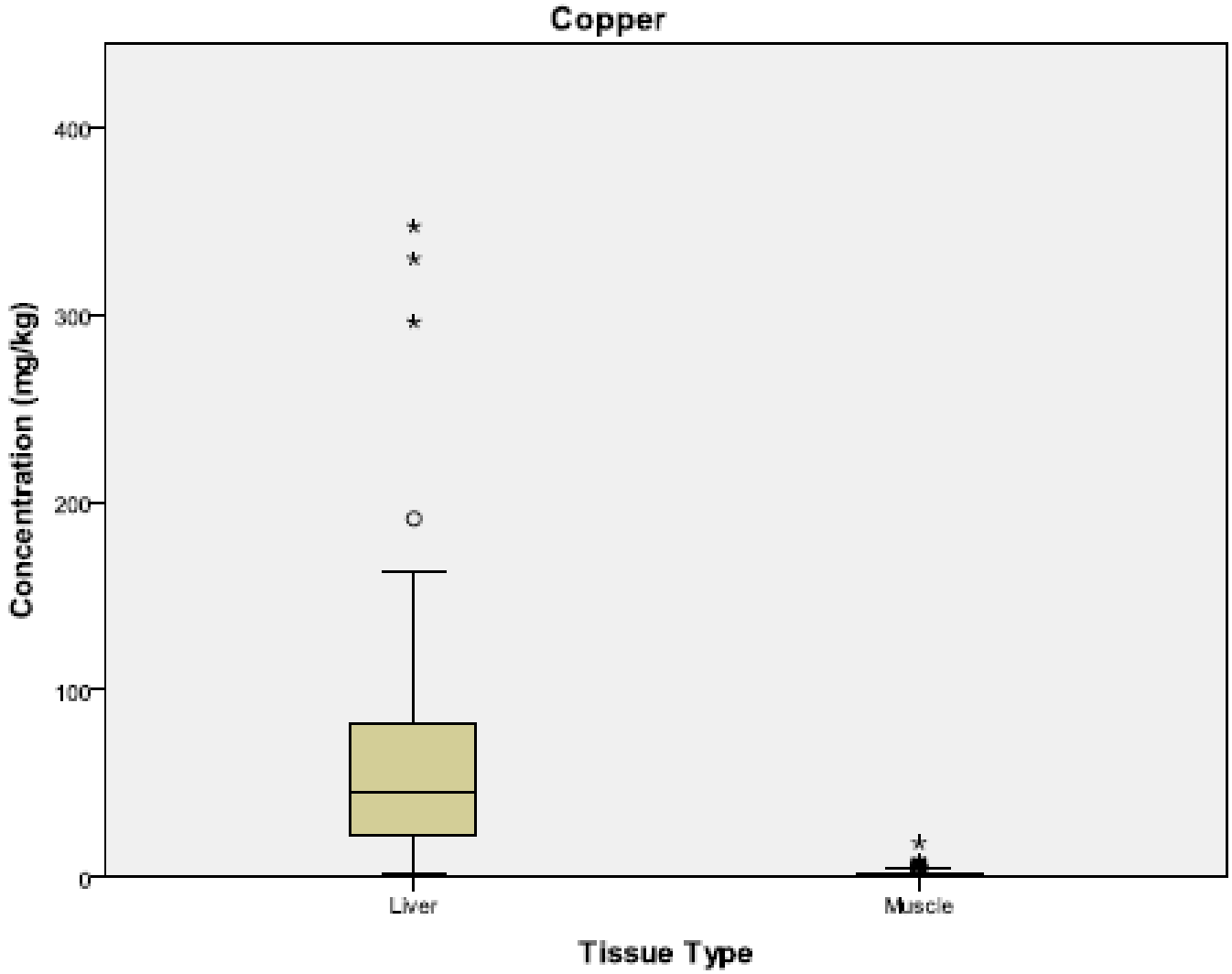
FIGURE 10.3-2
Mean Cadmium Concentrations in Whole Fish, Mine Study Area, 2004-2005

Mine Study Area Fish Sampling: Liver and Muscle Results

- Concentrations often similar between liver and muscle
  - Where different, liver tissues typically had higher concentrations (Cd, Cu, Mo, Ag)

    17 to 188 times higher in liver tissues than muscle tissues
  - Typically not consumed by humans
  - Muscle data more relevant for potential human exposure

Copper in Liver and Muscle Tissues



Conclusions

- Approximately 1,765 samples from soil, sediment, plants, berries, and fish across the mine site study area between 2004 and 2008
  - Mine site area adequately characterized for baseline conditions.
- Different drainages have different patterns of trace elements
  - Landform, habitat, species all differ in elemental patterns.


Thank You!!