Application of Ecological Risk Assessment to Water-Covered Mine Wastes

Gary Mann (ECOmetrix/EVS)

Randy Baker (Aqualibrium/EVS)

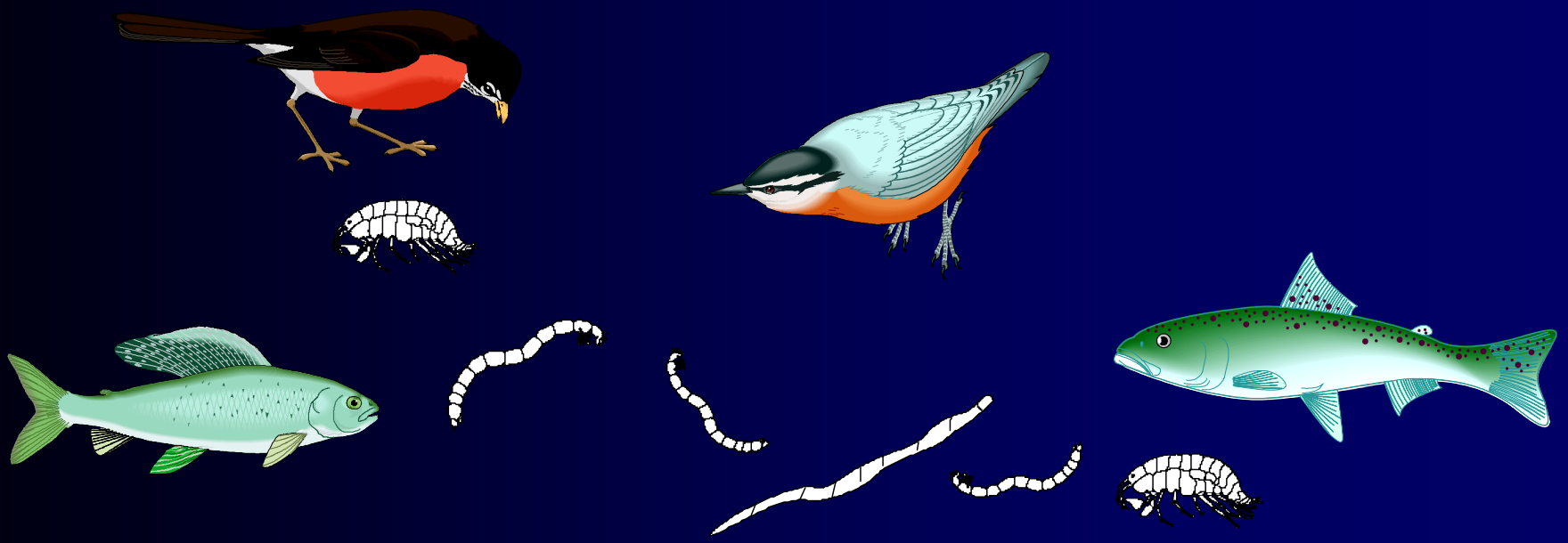
Overview

- Ecological Risk Assessment
  - Framework
  - Tools
- Field Application of ERA Tools
  - Bluebell Mine, BC

What is Ecological Risk Assessment?

Definition

"A tool that evaluates the likelihood that unacceptable adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors."



RISK = **Magnitude of Adverse Ecological Effects** X **Probability of Adverse Ecological Effects**

Cu

Pb

Zn

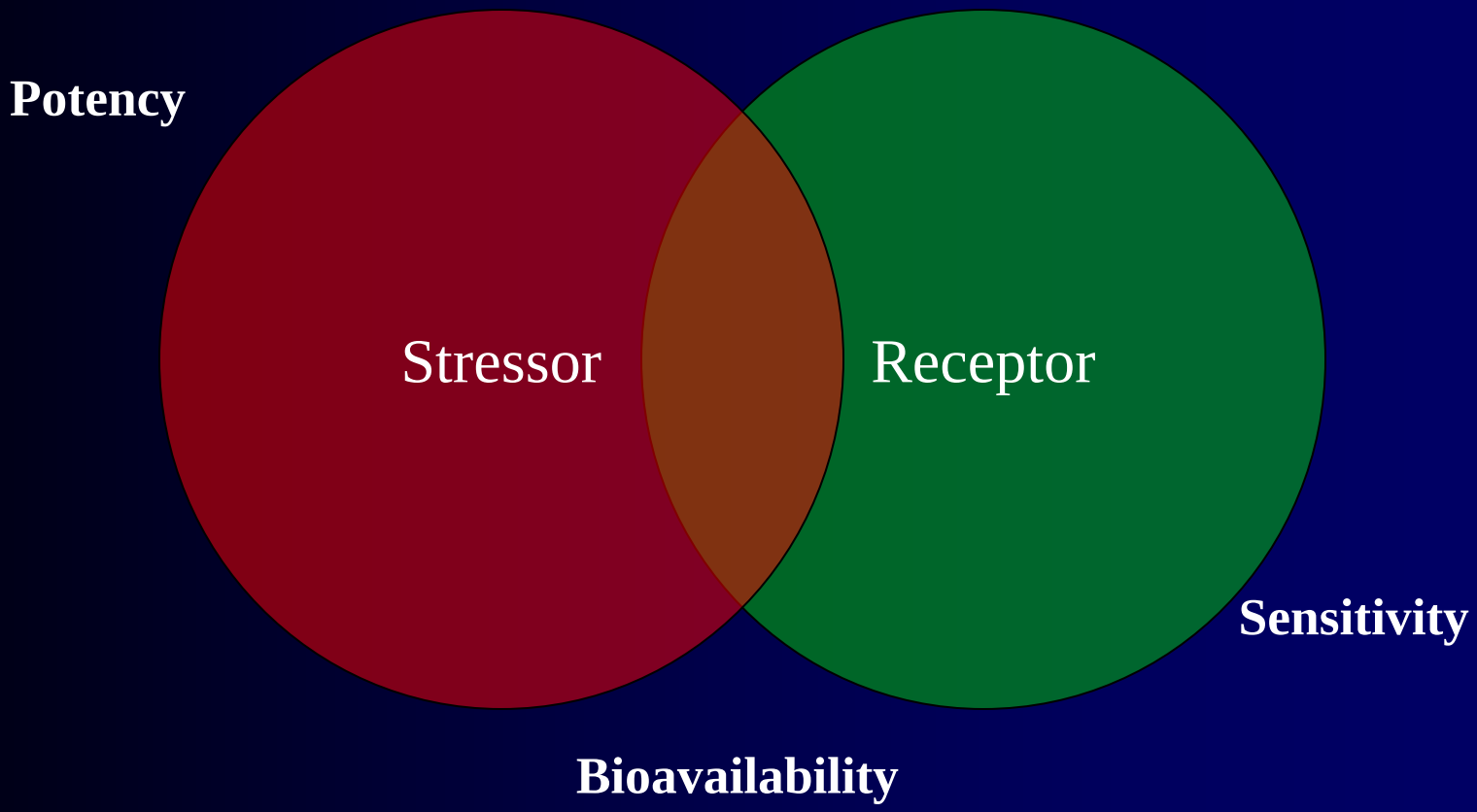
As

Hg

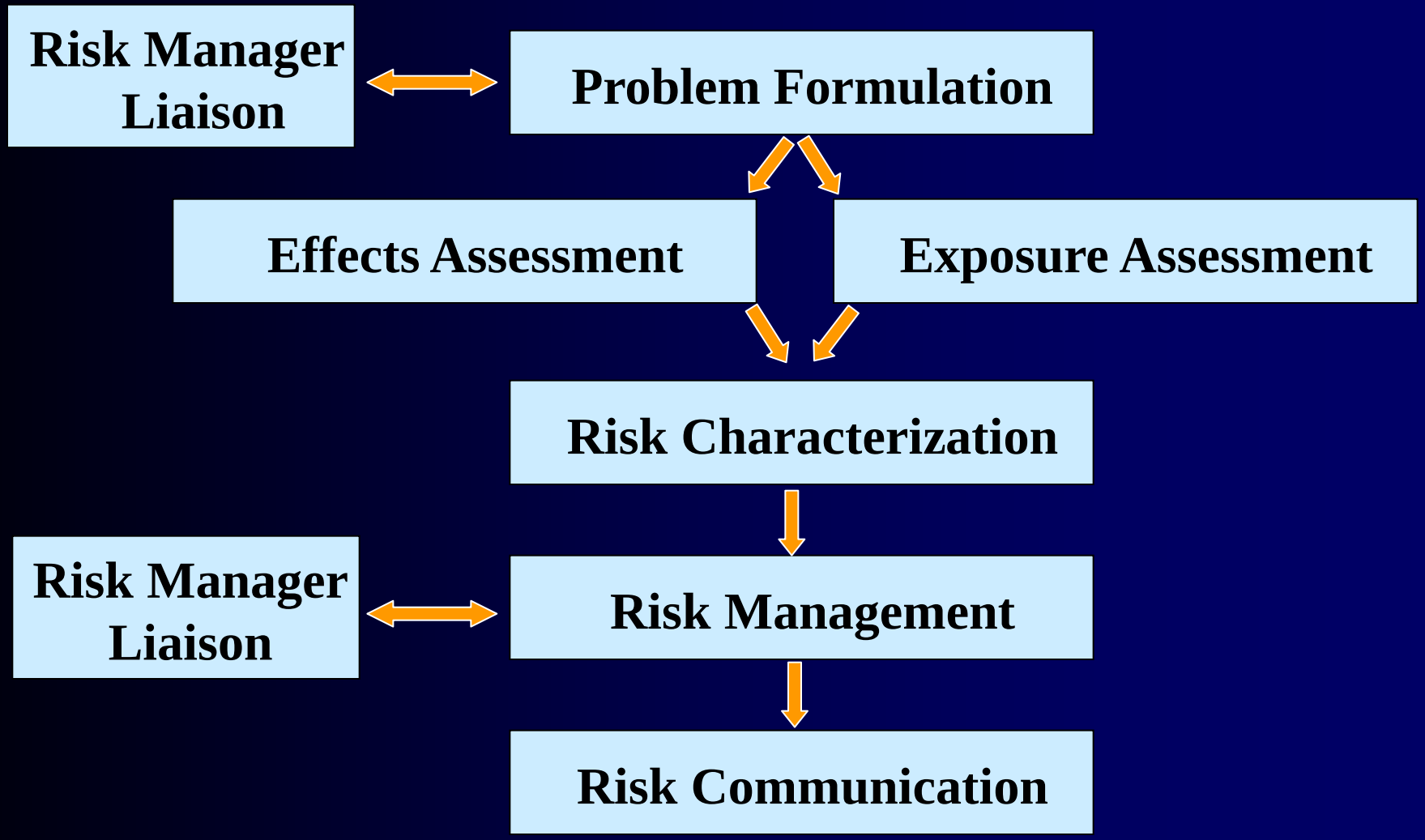
Key ERA Terminology

- Stressor - entity (chemical, biological, physical) with potential to cause adverse ecological effects.
- Receptor - ecological resource (individual, population, community, habitat) potentially affected by stressor.
- Exposure - contact between a stressor and a receptor.

Requirements for Risk



Ecological Risk Assessment Framework



ERA Framework

Risk Manager Liaison

Problem Formulation

Problem Formulation

Problem formulation sets the stage for the entire ERA process

- systematic planning helps identify the major factors that need to be considered
- both risk assessors and risk managers should be involved
- defines protection goals (human values) for the environment
- documents the ERA process

Protection Goals: Big Picture

- What are we trying to protect?
- Natural vs. engineered empoundments
- Is water-covered mine waste a habitat?
- Do we care about benthic invertebrates?
- Are we attracting waterfowl to contaminated habitat?

Protection Goals: Details

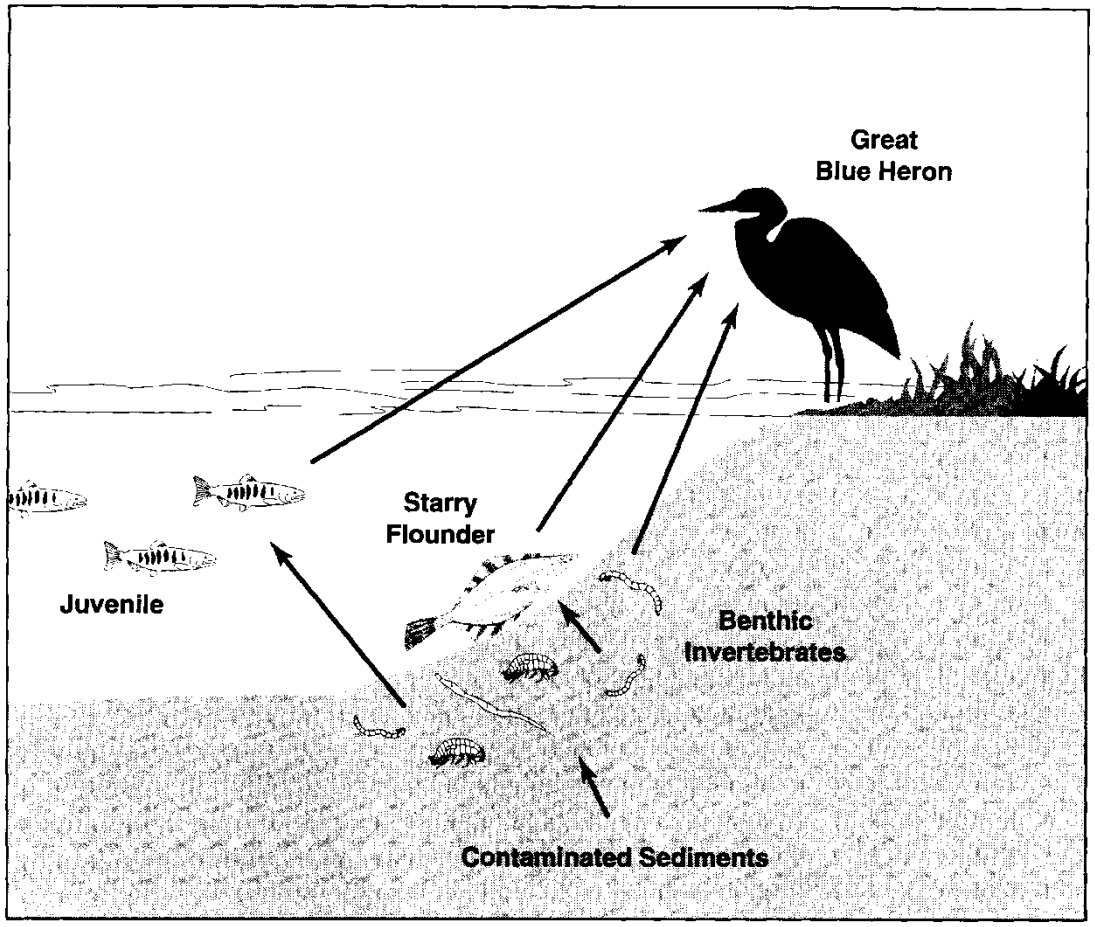
- Increased enzyme activity
- 20% reduction in fish population
- Accumulation of a contaminant in tissues
- Statistically significant decrease in fecundity
- 50% fish mortality in an acute toxicity test

What is “unacceptable”?

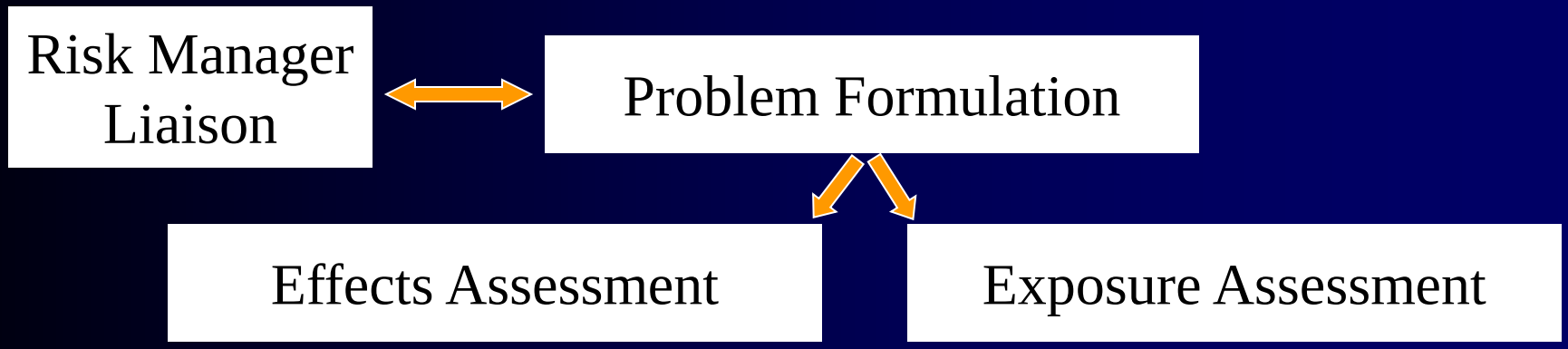
"One does not swat a gnat while being charged by elephants"

- Alvin Winberg (1987)

Conceptual exposure diagram for foreshore sediments



ERA Framework

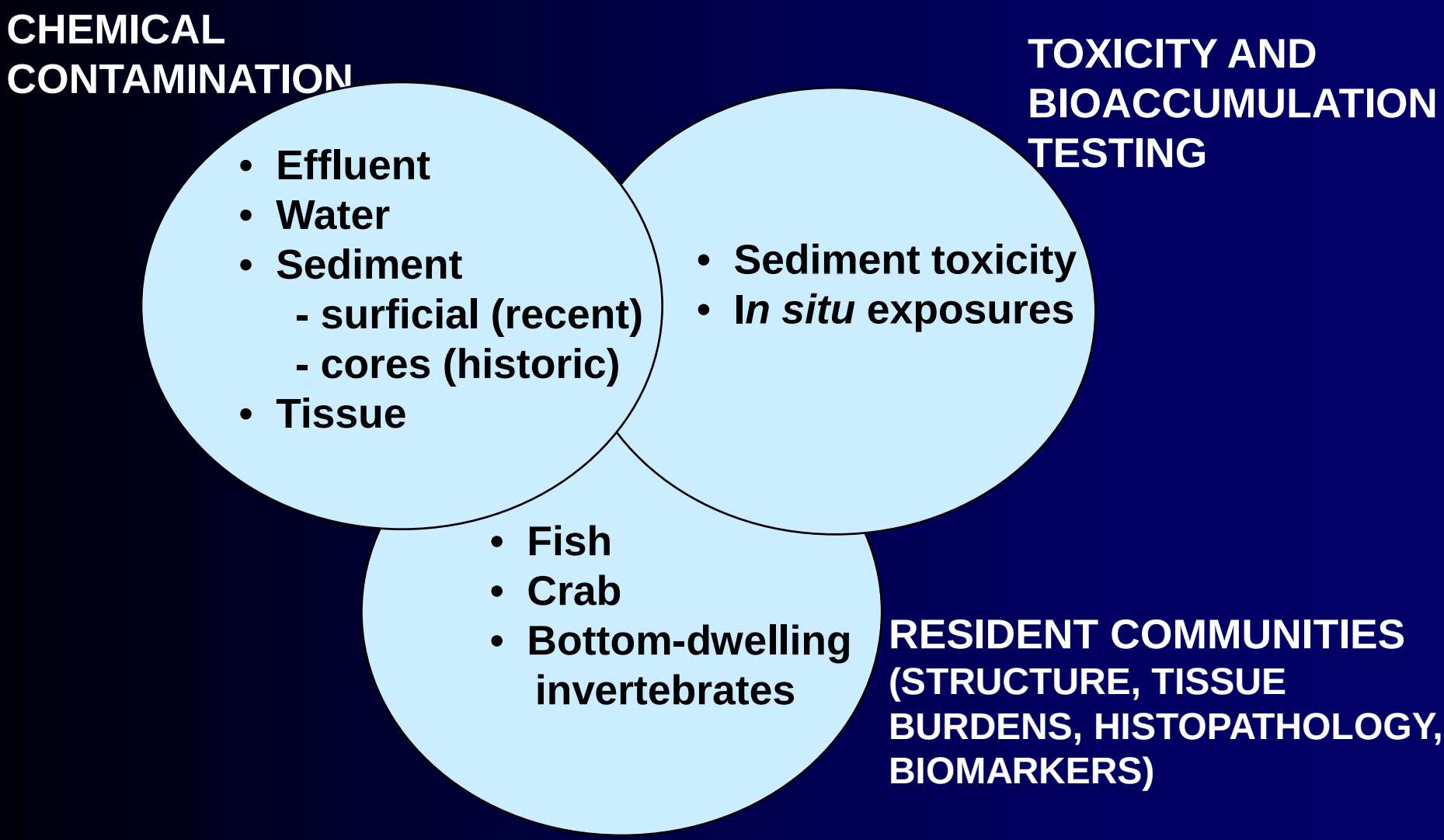


Simple Scenario

- Need to know (for each receptor/COPC):
  - EEC = expected environmental concentration **(exposure)**
  - BC = benchmark concentration **(effect)**

- Information from field, literature or lab
- Typically used at screening stage

Integrated Assessment



Top 3 Effects Assessment Issues for Mines…

- Bioavailability
- Bioavailability
- Bioavailability

Food Chain

- Sediments
- Water
- Benthos
- Plants
- Fish
- Birds

Aquatic Toxicity Test Organisms

- Algae/aquatic plants
- Invertebrates
- Fish
- Others (amphibians, bacteria, protozoa, etc.)

Focus has been on single-species tests, although some microcosm studies have also been conducted

Toxicity Testing - Water

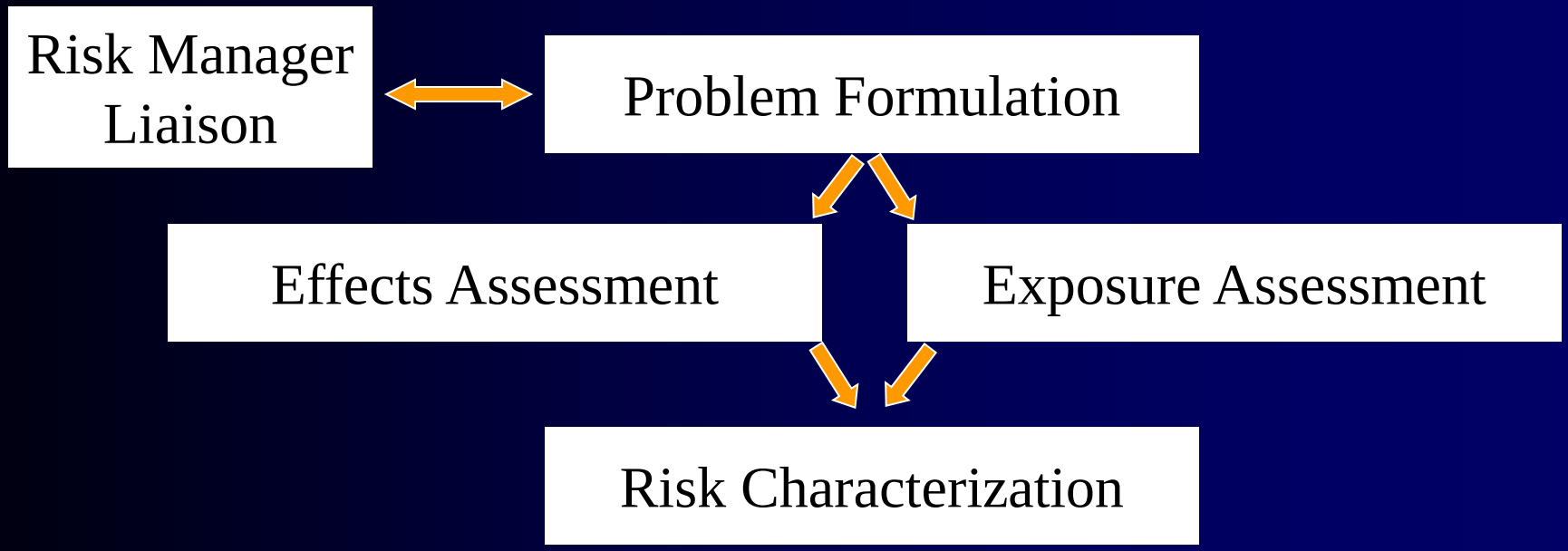
Toxicity Testing - Sediments

Benthic Community in Sediments

Healthy Sediment Community

Impacted Sediment Community

ERA Framework



Simple Scenario

HQ = EEC / BC

HQ = Hazard or Risk Quotient

EEC = expected environmental concentration **(exposure)**

BC = benchmark concentration **(effect)**

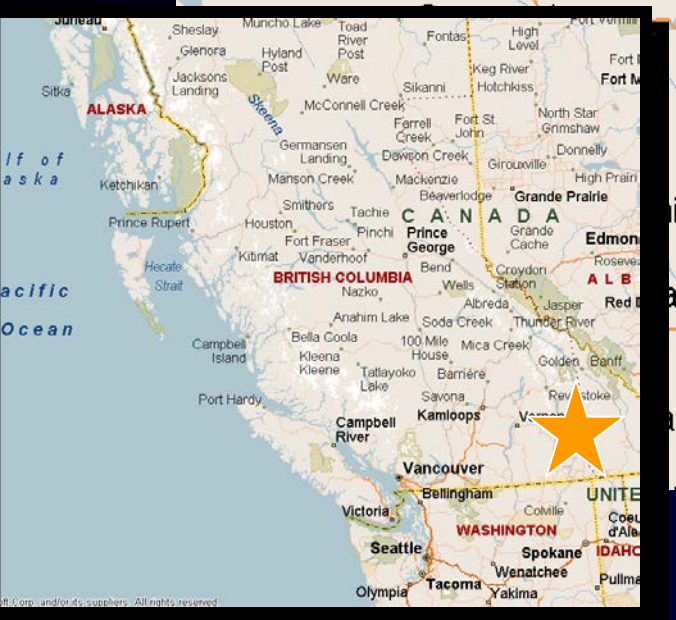
- HQs may be calculated for whole sites, or may be spatially distinct
- Limited application at most mine sites

Integrative Assessment Response Patterns

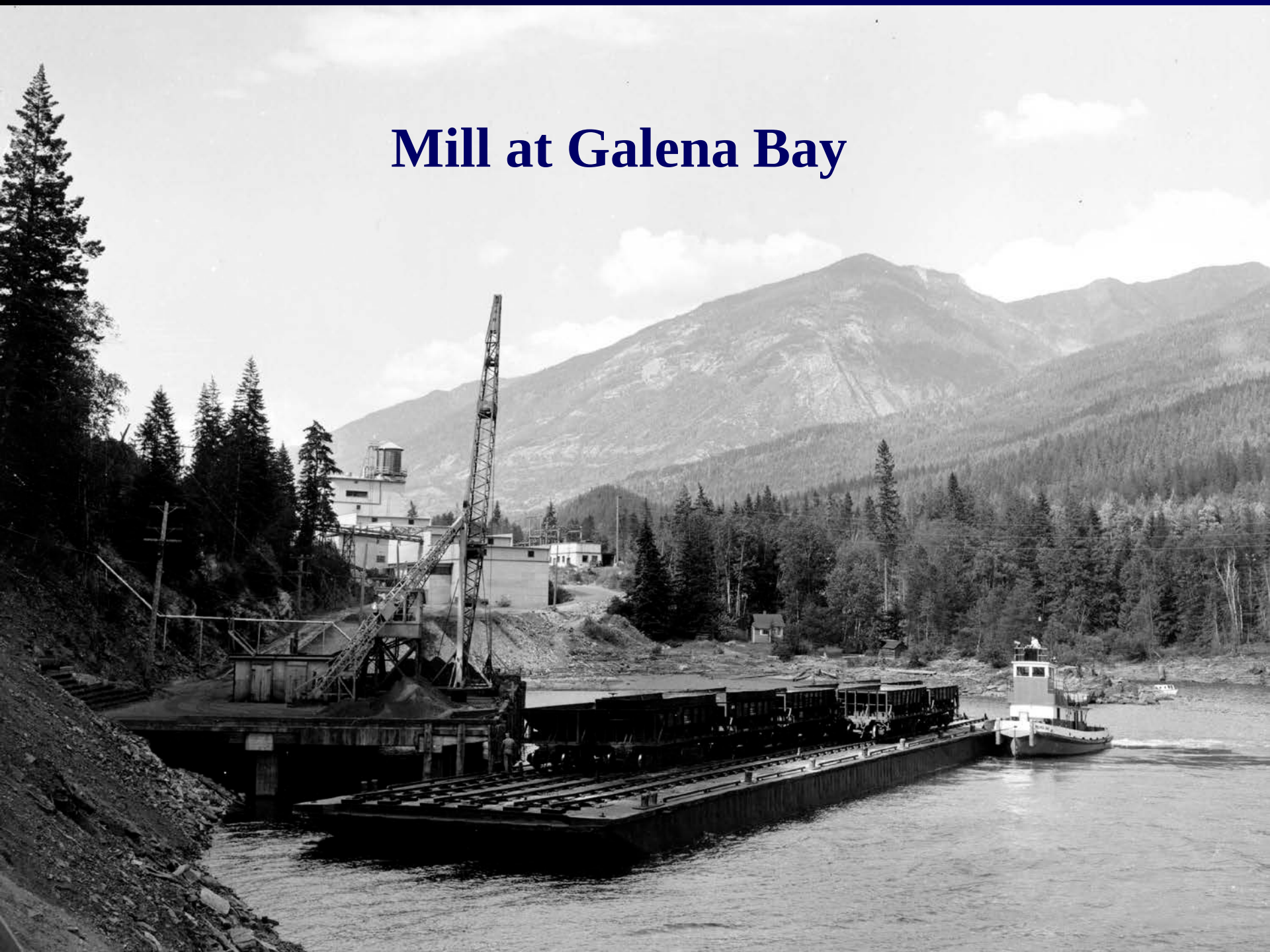
Chemical Contamination	Toxicity	Community Alteration
+	+	+
-	-	-
+	-	-
-	+	-
-	-	+
+	+	-
-	+	+
+	-	+


Application of
ERA Tools
Bluebell Mine

Kootenay Lake
British Columbia



Mill at Galena Bay



Sediment contamination in north basin Kootenay Lake

Metal (mg/kg dw)	CCME PEL	Range	Mean
Arsenic	17	5 - 2300	314
Cadmium	3.5	0.4 - 14.0	4.4
Chromium	90	14 - 52	25
Copper	197	32 - 142	70
Lead	91.3	16 - 3050	862
Zinc	315	115 - 3440	969

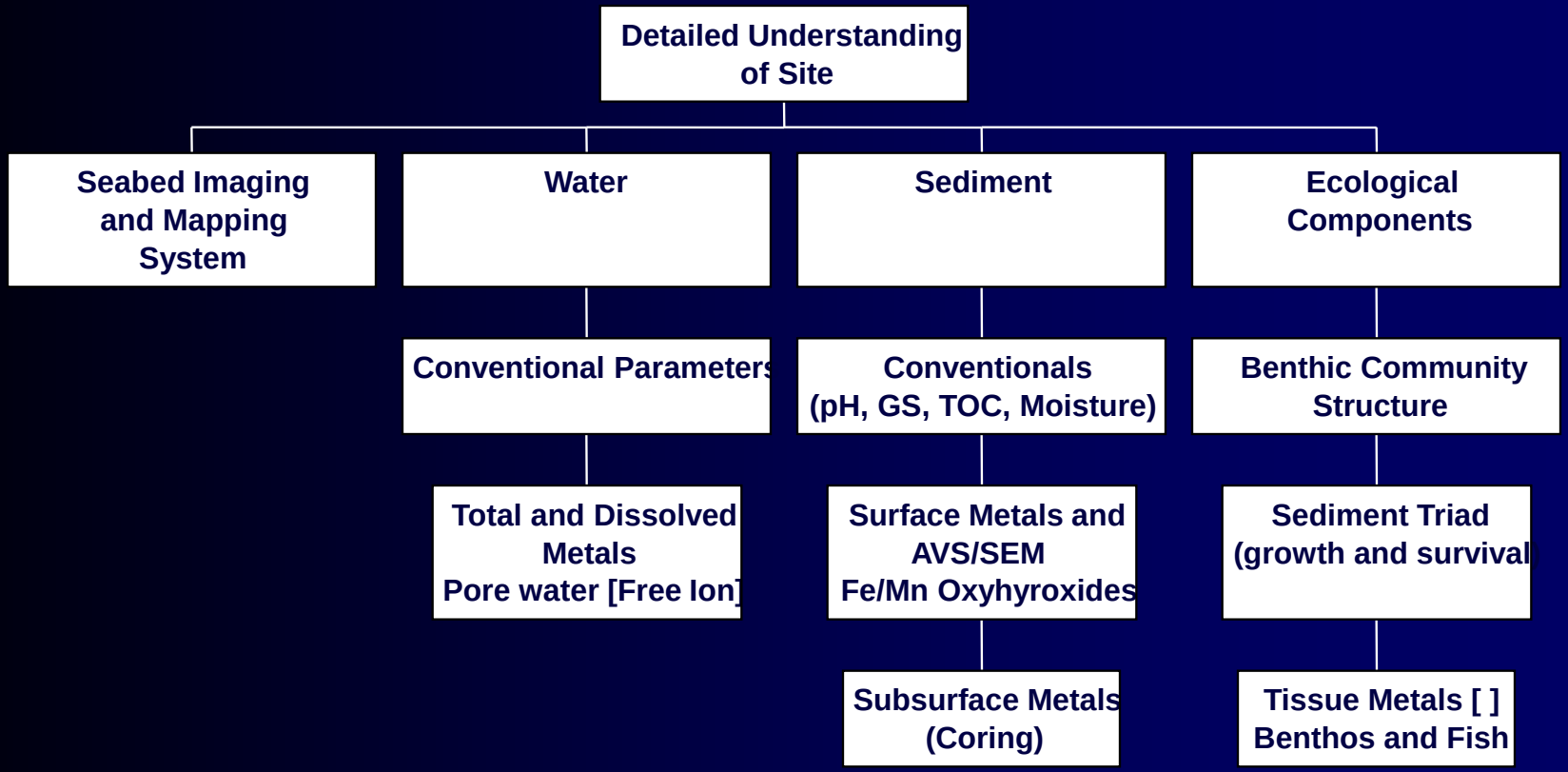
Source: Macdonald et al. 1994


Bluebell Bay
Galena Bay

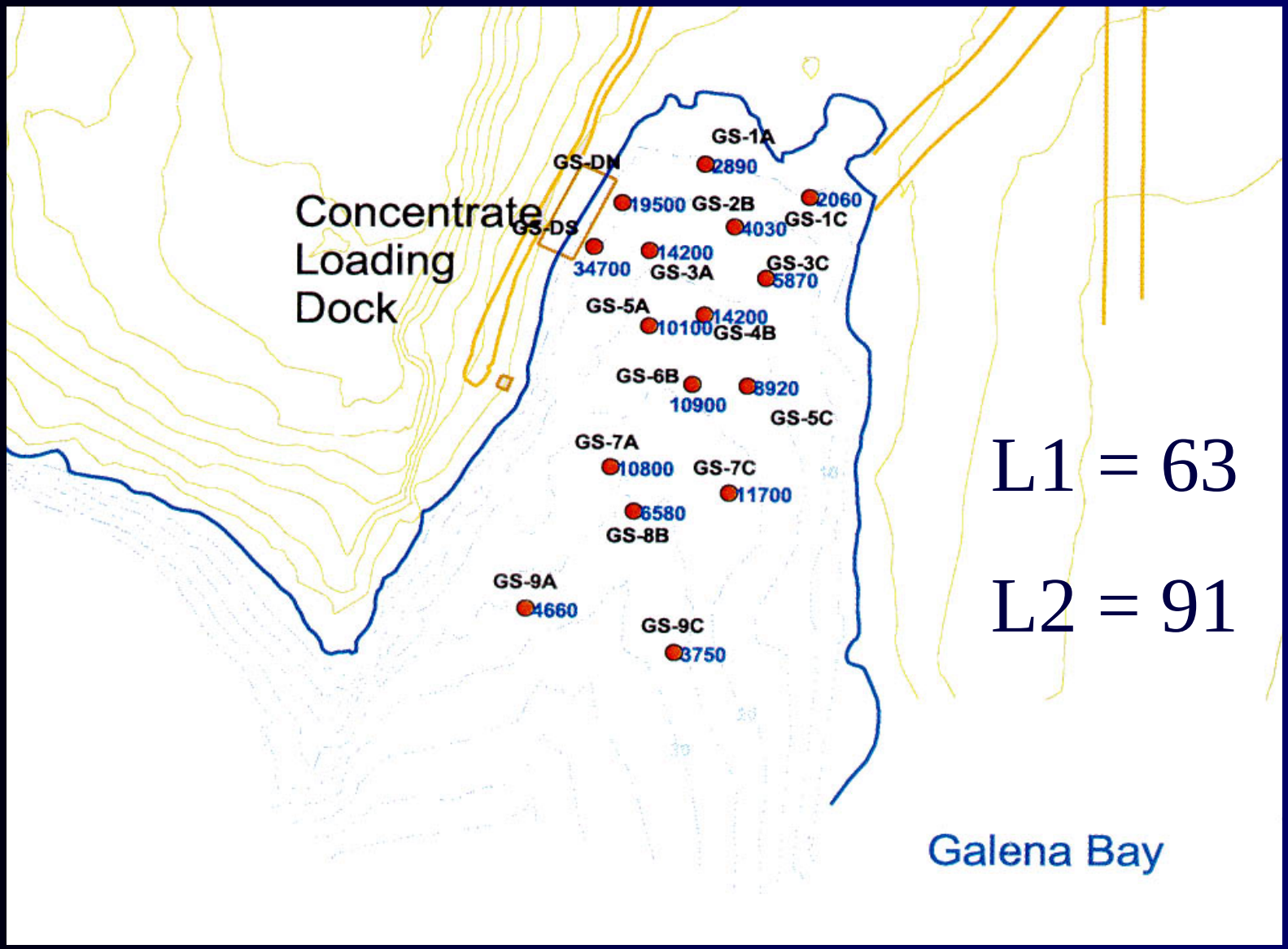
Objectives – 2000 Study

- Acquire an understanding of the physical, chemical and biological conditions at former Bluebell Mine to support site management.
- Determine the spatial extent and magnitude of metals contamination in Kootenay Lake.
- Determine the ecological and toxicological characteristics of surface sediments in Galena, Bluebell & Kootenay (reference) Bay.

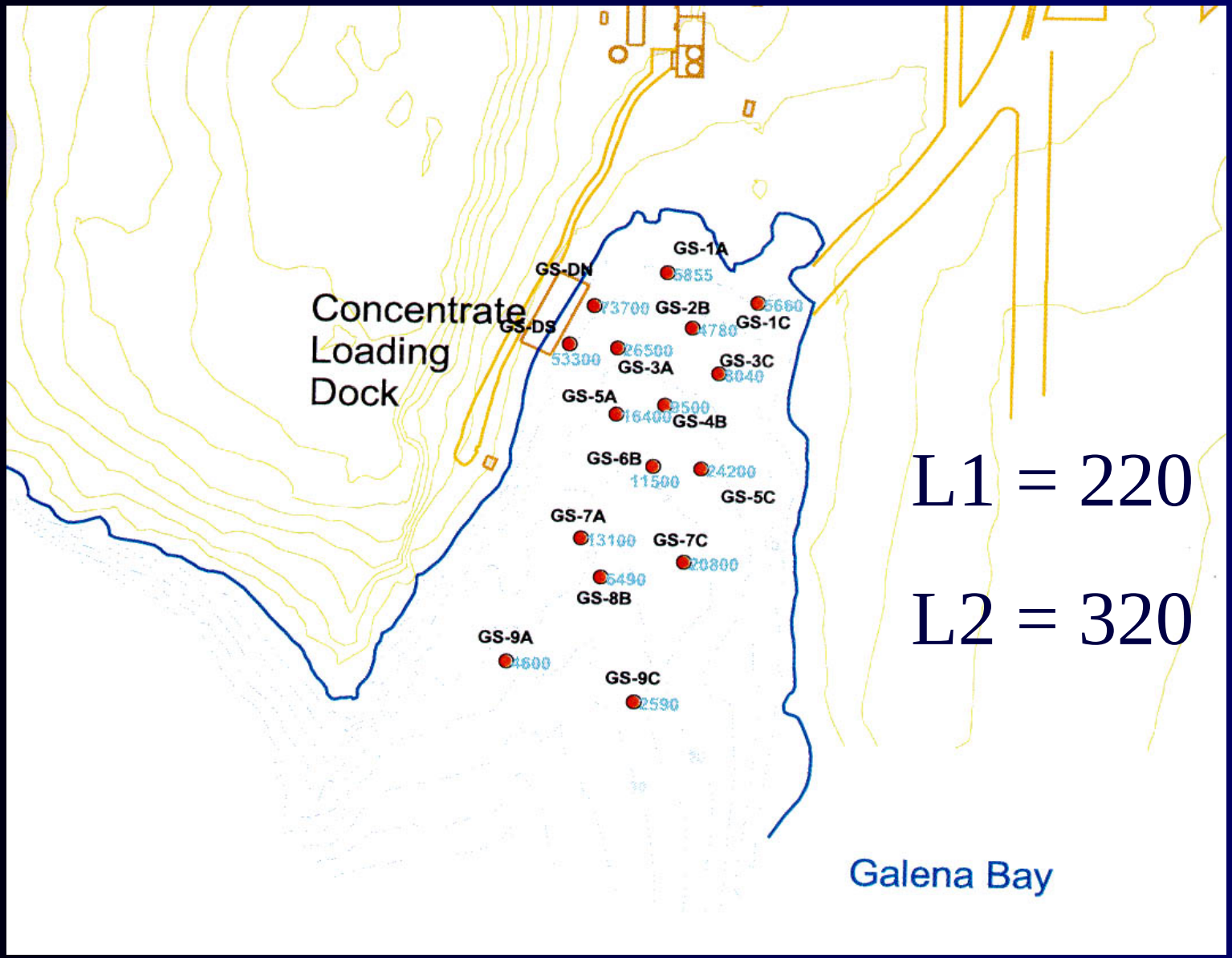
Overview of Studies Undertaken



Lead in Surface Sediments



Zinc in Surface Sediments



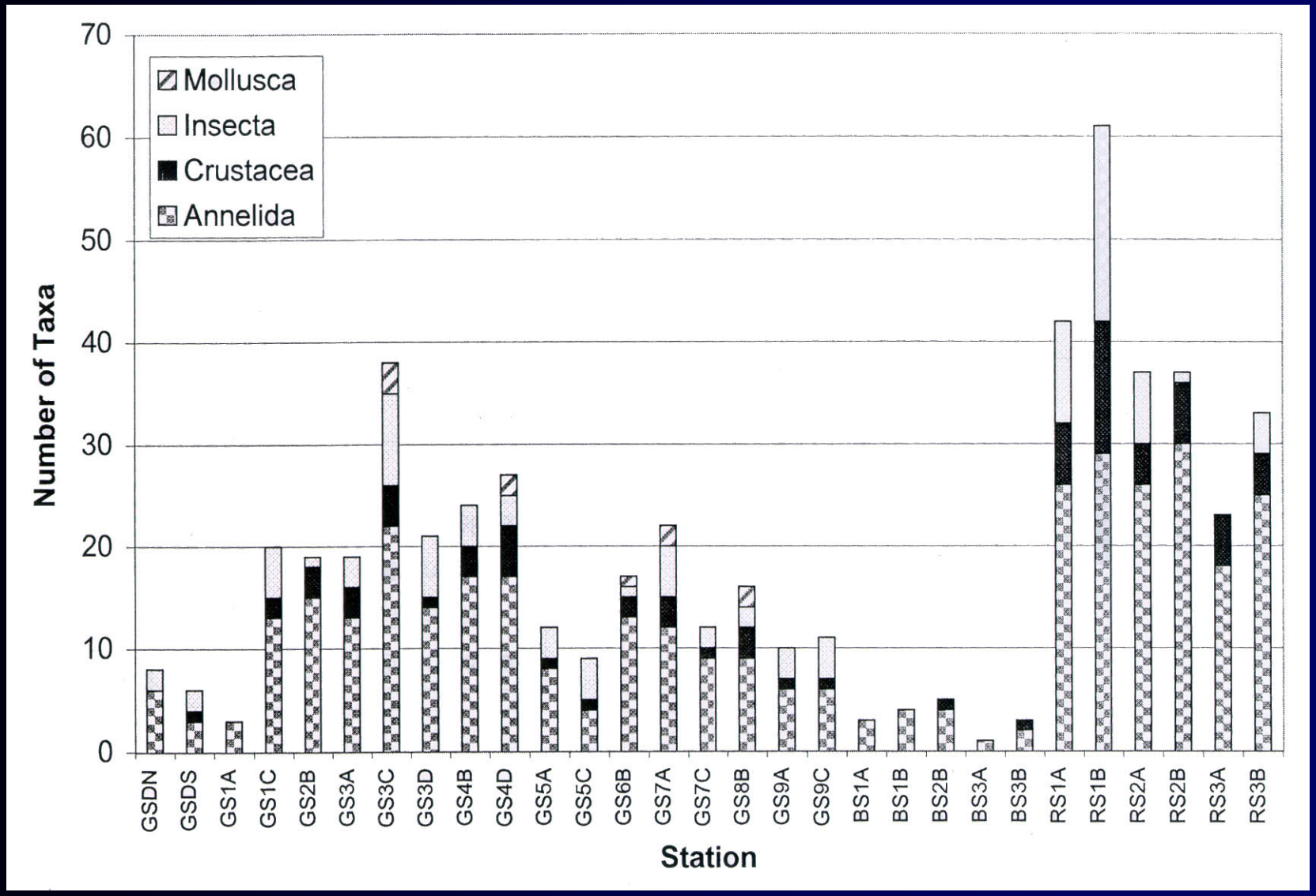
Amphipod Results

Location	Sample ID	Mean ± SD	
		Survival (%)	Dry weight (mg/indiv.)
	Negative Control	88.0 ± 8.4	0.1 ± 0.02
Galena Bay	GSDS	**0**	-
	GSDN	**10.0**	0.10
	GS1A	100.0	0.10
	GS1C	100.0	0.28
	GS2B	100.0	0.23
	GS3A	**30.0**	0.10
	GS3C	100.0	0.20
	GS4B	**70.0**	0.16
	GS5A	**50.0**	**0.06**
	GS5C	**70.0**	0.09
	GS6B	80.0	0.10
	GS7A	90.0	0.09
	GS7C	100.0	**0.07**
	GS8B	100.0	0.15
	GS9A	100.0	0.13
	GS9C	**10.0**	0.10
Bluebell Bay	BS1A	**0**	-
	BS1B	**0**	-
	BS2B	**0**	-
	BS3A	**10.0**	0.10
	BS3B	**0.0**	-
Kootenay Bay	RS1A	80.0	0.35
	RS1B	100.0	0.19
	RS2A	100.0	0.22
	RS2B	100.0	0.25
	RS3A	100.0	0.10
	RS3B	100.0	0.15

EC20 values: survival = 70.4% and dry weight criteria = 0.08 mg/individual

Exceeds either EC20 or criterion for effects (20% of control) n=1 per field replicate; n=5 for control

Benthos: Major Taxa Richness



Aquatic Effects Assessment

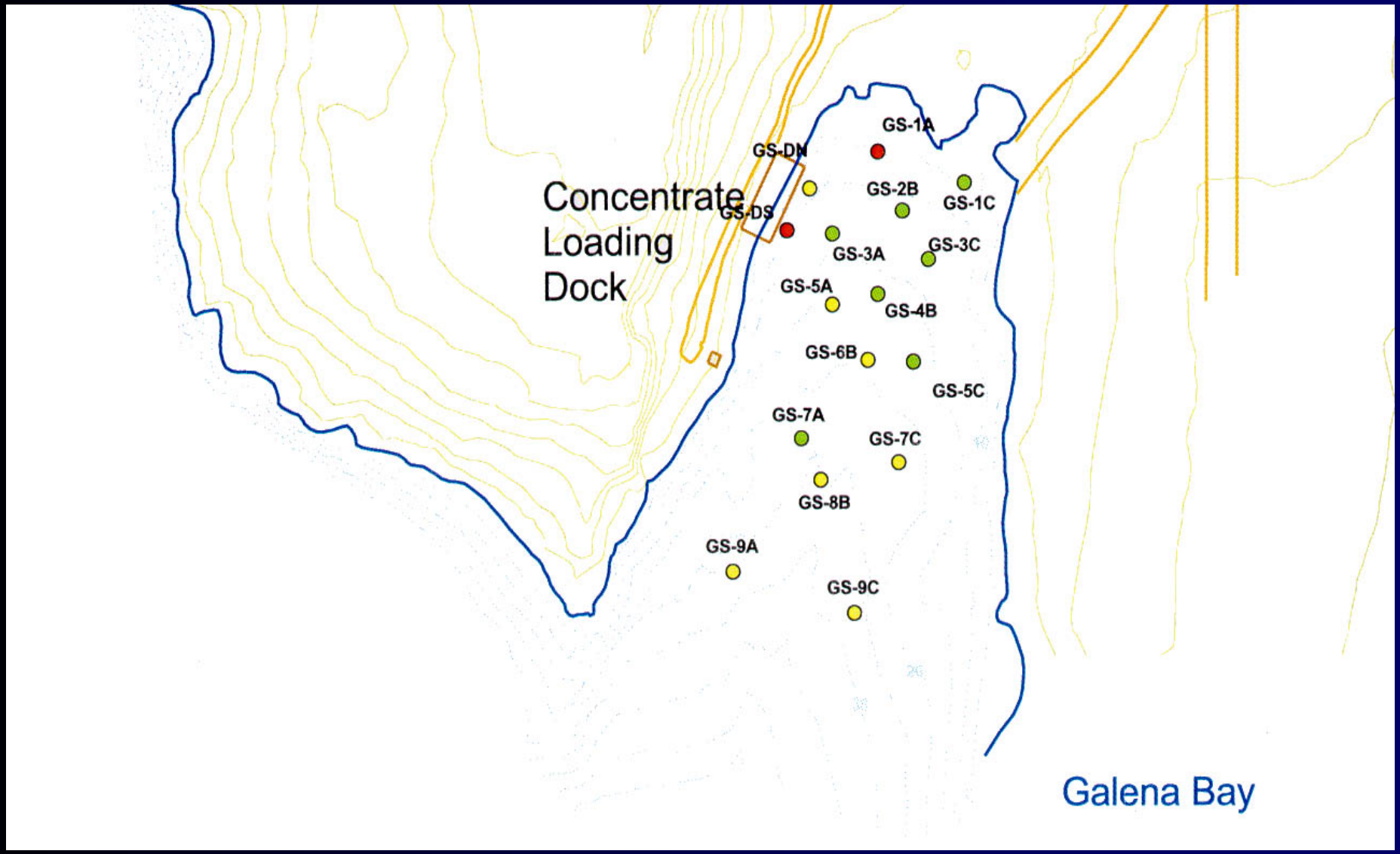
- Toxicity and benthic community structure data from Galena Bay and control stations were used to group stations according to:

No/Low Impact

Moderate Impact

High Impact

Results of Integrated Assessment of Sediment Quality



Take Home Messages

- Despite high bulk sediment chemistry, overlying water quality is good.
- Toxicity to chironomids and *Hyalella* is limited to area around concentrate loading dock.
- Benthic community structure shows low to moderate adverse effects at most stations.
- Overall, adverse effects are far less than expected given bulk sediment chemistry.

Follow-up Studies

Refining Linkages Among Triad Components

2001 Studies

- Detailed assessment of nearshore area (sediment metals, AVS/SEM, Fe/Mn oxyhydroxides, pore water metals).
- Toxicity testing (14-day and 28-day Hyalella).
- Sampling of profundal areas offshore of Galena Bay and linkage to Kootenay Lake.
- Repeat DFO 1978 sediment coring study to determine deposition history of lake.

2001 Studies (con't)

- Free metal ion [ ]'s in pore water will be modeled and used to link/predict effects (toxicity, benthic community structure).
- Combined with 2000 study results, decisions will be made regarding extent and form of management required.

Conclusions

- Traditional criteria-based approaches have limited usefulness at mines
- ERA is a flexible approach that can be tailored to specific situations
- ERA is a process that can incorporate the best tools available
- ERA success is dependent on the establishment of clear protection goals