

Assessment and Mitigation of Ecological Risks Posed by Mercury and PCBs in Peninsula Harbour Sediment, Lake Superior



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Sites National Workshop

M. Henning, K. Leigh, K. Merritt, V. Magar, R. Santiago
Vancouver, British Columbia

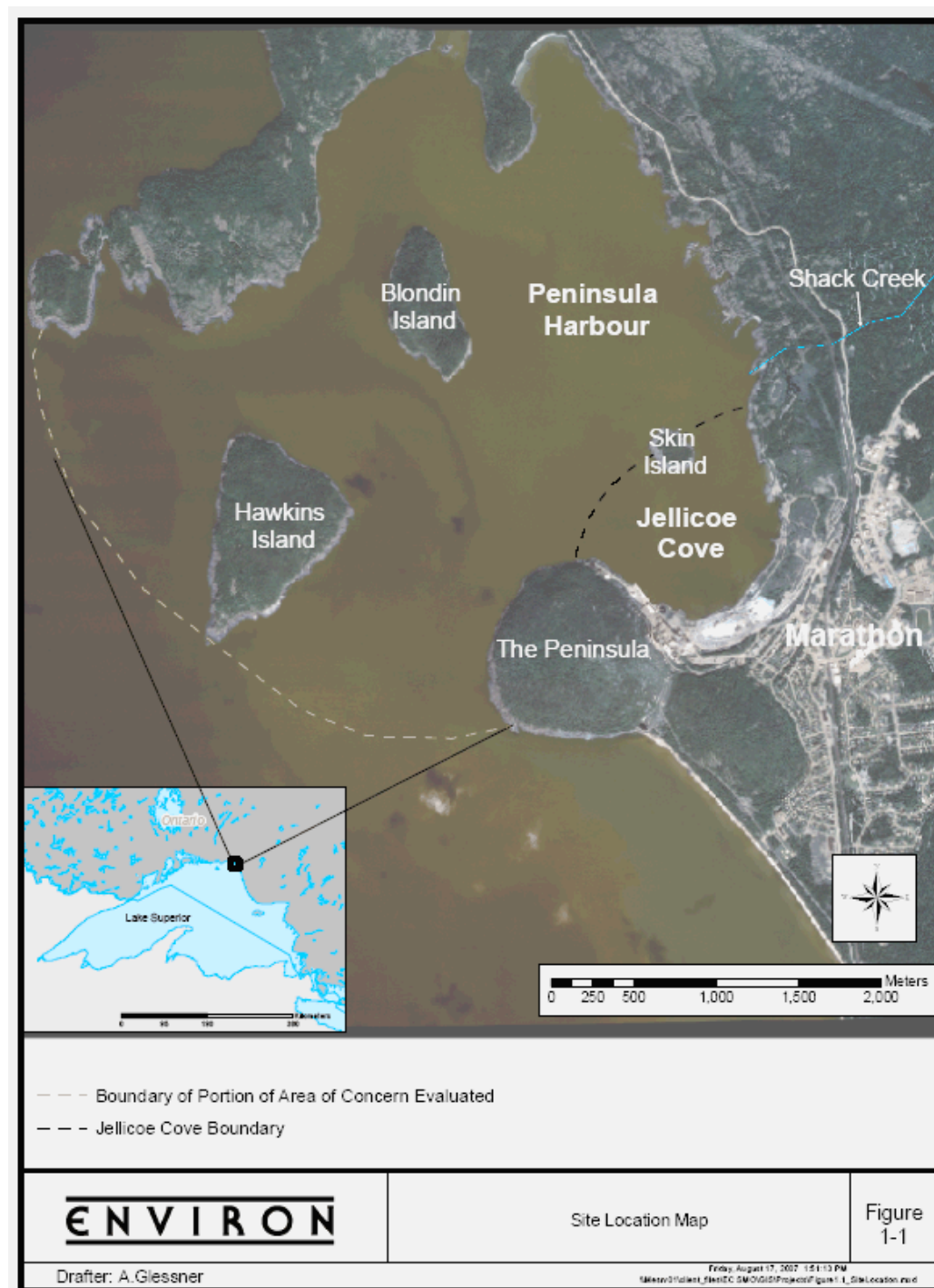
April 30, 2008

ENVIRON

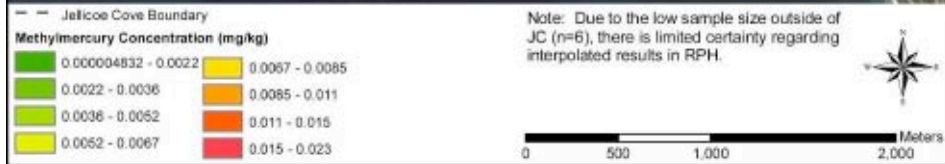
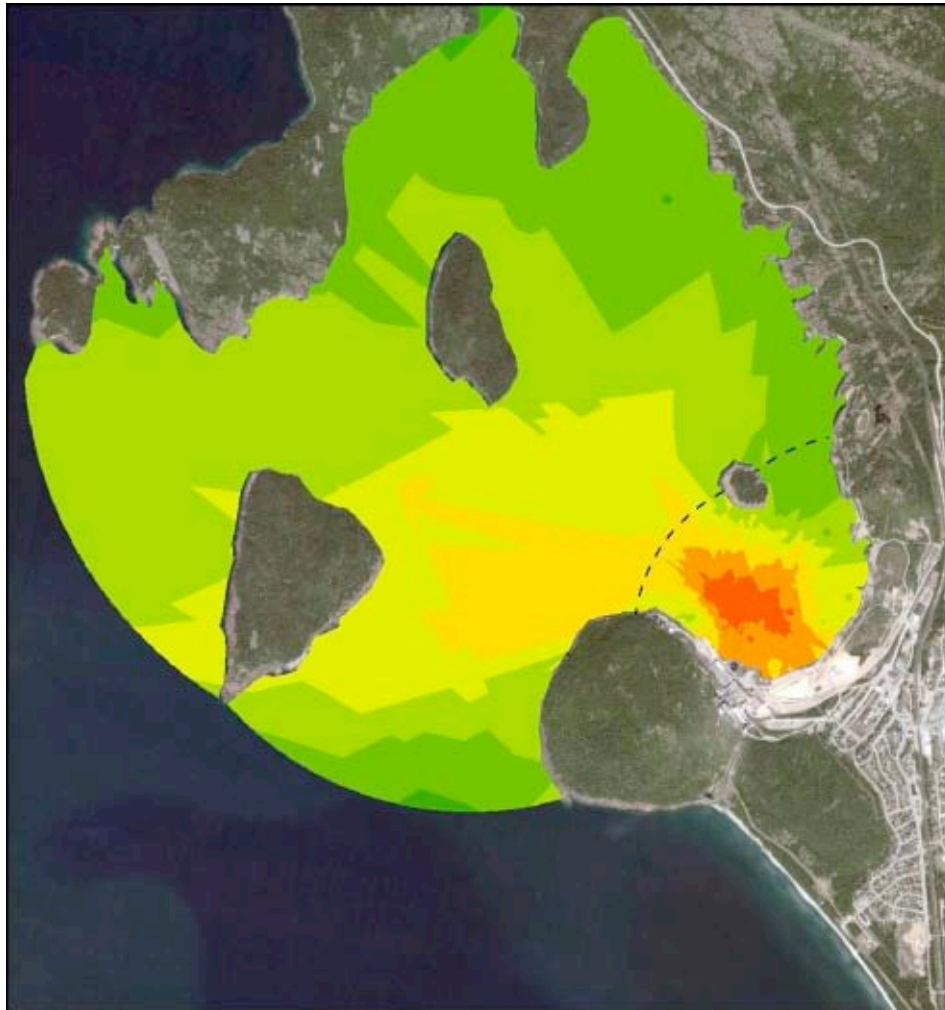


Goals & Objectives

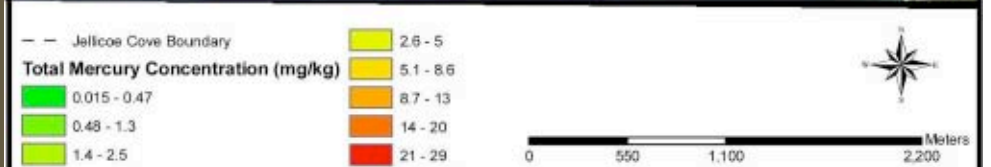
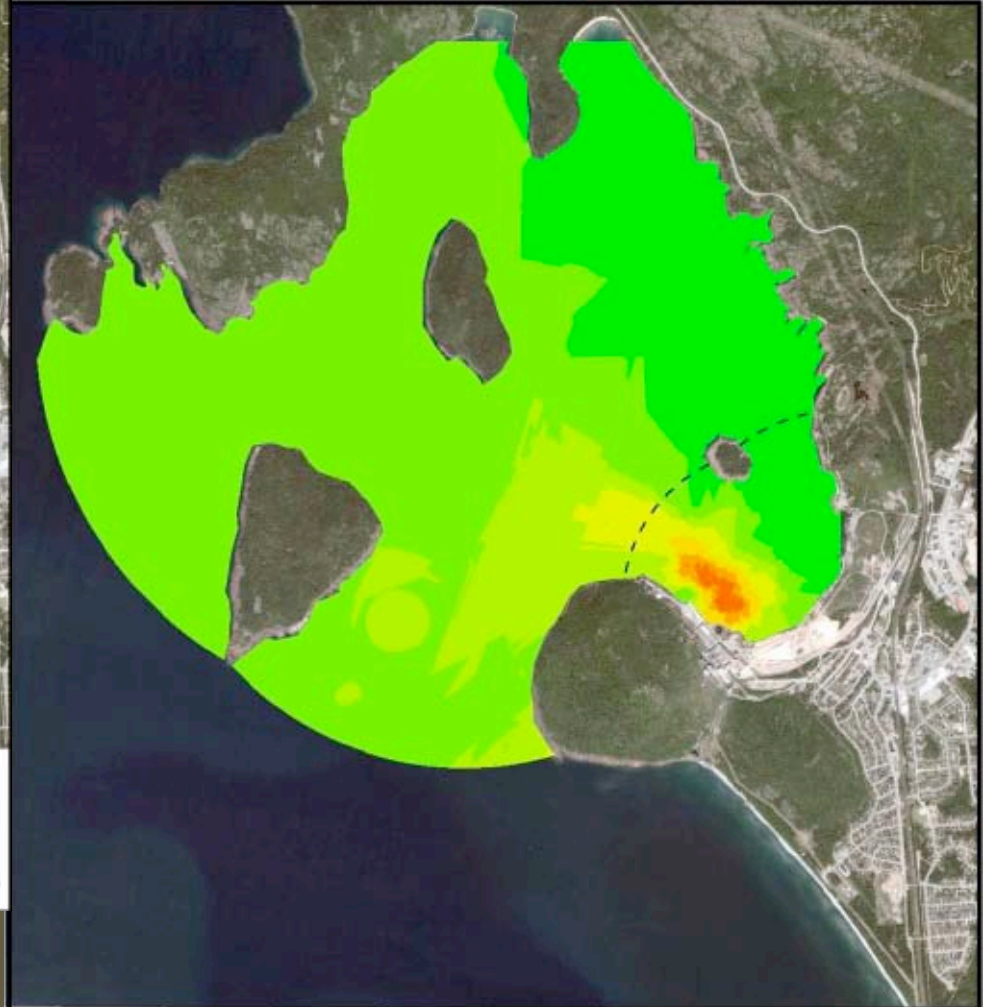
- Develop technical basis for sediment management strategy in Peninsula Harbour AOC
 - Estimate risks posed by Hg and PCBs
 - Develop sediment cleanup goals
 - Evaluate cleanup options
 - Develop conceptual designs for preferred cleanup options

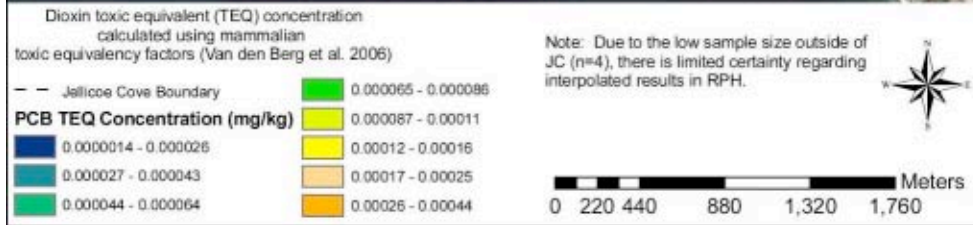
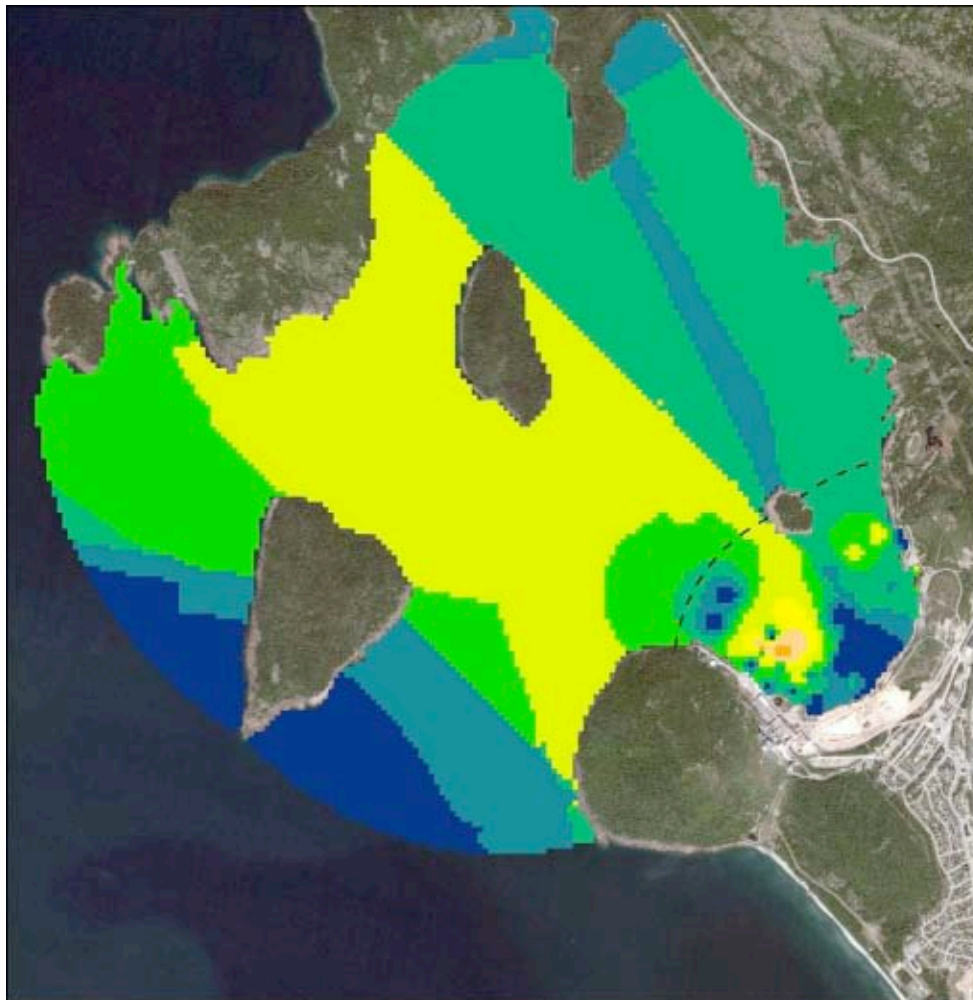


Total Mercury



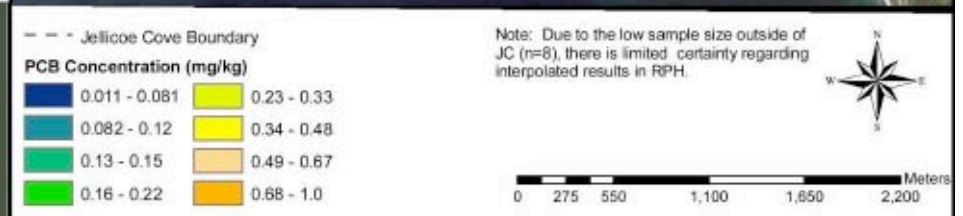
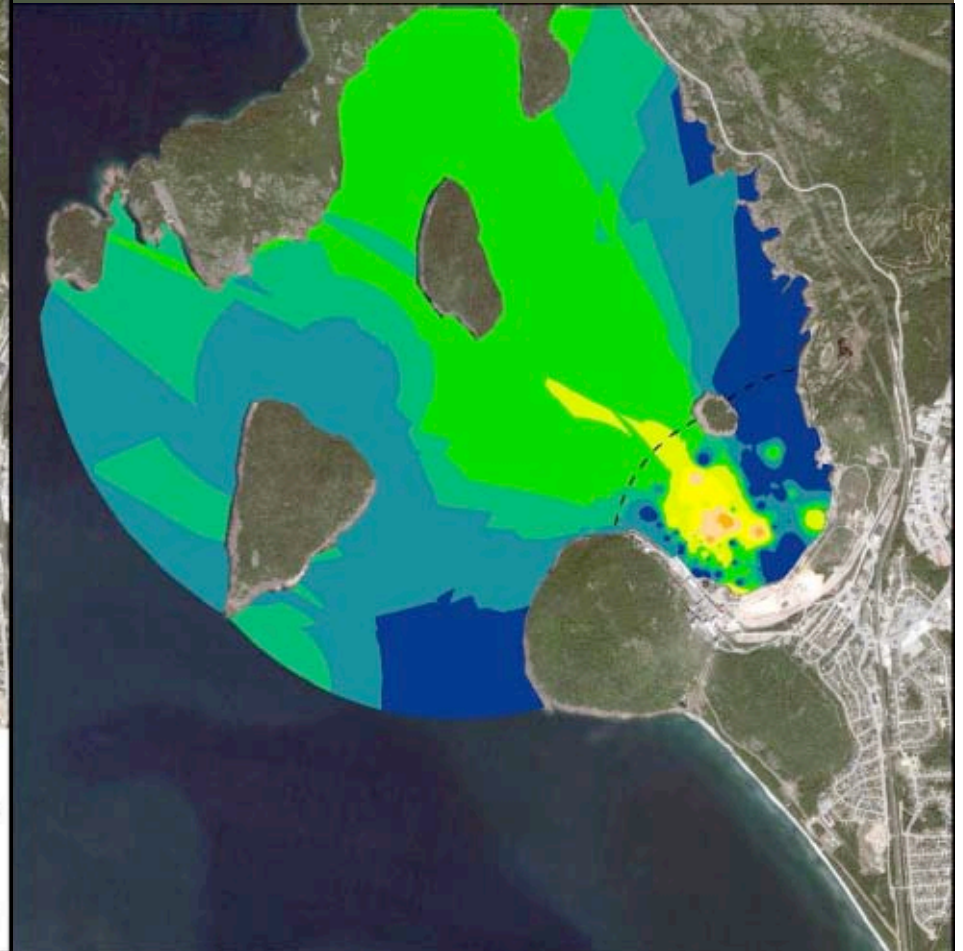
Methylmercury





PCB TEQs

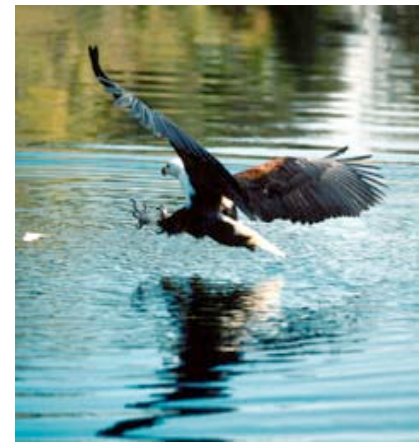
Total PCBs





Ecological Risk Assessment

- Purpose
 - To characterize and quantify current and potential risks to biota exposed to chemicals in the study area
- Assessment Endpoints
 - Bottom-dwelling invertebrate community structure, survival, and reproduction
 - Fish survival and reproduction
 - Bird survival and reproduction (bald eagle & loon)
 - Mammal survival and reproduction (mink)





Methods for Evaluating Exposure

- Benthic invertebrates
 - Concentrations of mercury and PCBs in sediment
- Fish
 - Concentrations of mercury and PCBs in fish tissue



- Wildlife
 - Estimated Dose = $\sum(\text{Concentration} \times \text{Proportion of Diet} \times \text{Ingestion Rate}) \times 1/\text{Body Weight}$
 - Concentration in prey
 - Modeled body burden for mink
 - AUFs



Methods for Evaluating Toxicity: Invertebrates

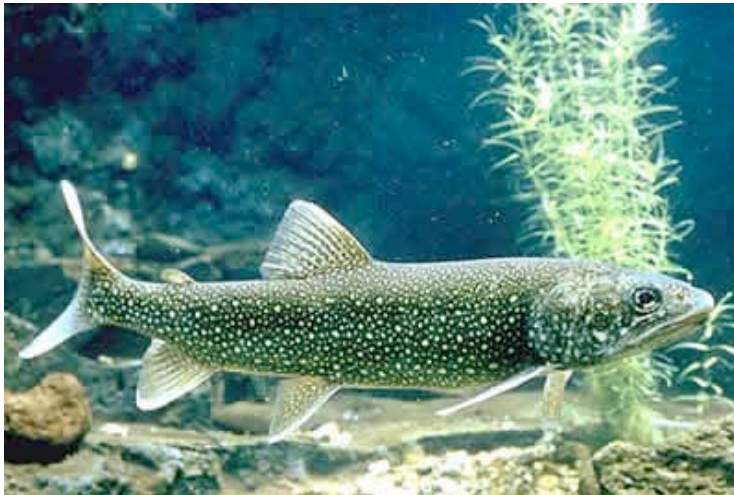
- Community survey
- Toxicity testing
 - 28-day survival and growth of amphipod *Hyallela azteca*
 - 10-day survival and growth of midge *Chironomus riparius*
 - 21-day survival and growth of mayfly *Hexagenia* spp.
 - 28-day survival and reproduction of worm *Tubifex tubifex*
- Sediment guidelines and literature





Methods for Evaluating Toxicity: Fish

- Community survey
 - BEAK (2000, 2001) surveyed fisheries resources
- TRVs based on fish tissue concentrations
 - Mercury: 0.2 mg/kg (Beckvar et al. 2005)
 - PCBs: 4.2 mg/kg (Hansen et al. 1974)





Methods for Evaluating Toxicity: Wildlife

Receptor	Chemical	Basis	Value	Reference
Birds	Mercury	Dose	0.029 mg/kg-day	Barr 1986
Mammals	Mercury	Dose	0.081 mg/kg-day	Wobeser et al. 1976
Both	Mercury	Diet/TRG	0.092 mg/kg	EC 2002
Common loon	PCBs	Dose	0.82 mg/kg-day	Tori and Peterle 1983
Osprey	PCBs	Dose	2.2 mg/kg-day	Fernie et al. 2001, 2003
Mammals	PCBs	Dose	0.053 mg/kg-day	Brunstrom et al. 2001
Both	PCBs (extrapolated from TEQs)	Diet/TRG	0.020 mg/kg	EC 1998



Ecological Risk Results



■ Invertebrates

- Concentrations of Hg and PCBs greater than low end screening values
- Few sediment samples exhibited toxicity
- Community structure in Jellicoe Cove differed from reference sites, but differences reflected organic enrichment and water depth

■ Fish

- Hg: Mean and 95th percentile HQs > 1 for longnose suckers; 95th percentile HQs >1 for lake trout, lake whitefish, walleye, and longnose sucker
- PCBs: Mean and 95th percentile HQs < 1 for most fish species; 95th percentile HQ =2 for longnose sucker
- Jellicoe Cove fish less abundant but more diverse than Carden Cove fish; Hg and PCBs in AOC fish > Zone 7 fish

■ Wildlife

- Mink at risk from PCBs, but habitat constraints limit population size regardless of contamination
- Most highly exposed bald eagles may be adversely affected by Hg in Jellicoe Cove
- Widespread exceedances of tissue residue guideline protective of wildlife



Human Health Risk Assessment

- Objective: to evaluate potential risks to human health from consumption of fish caught in the AOC
- Exposure assessment based on local fish consumption survey
 - Some sport anglers fish in Peninsula Harbour and eat their catch.
 - Virtually all fish eaten are sportfish
 - No evidence of subsistence fishing
- Toxicity assessment
- Risk characterization





Human Toxicity Assessment

Chemical	Toxicity Reference Values	
	Tolerable Daily Intake (mg/kg-day)	Source
Methylmercury (adults)	4.7E-04	HC 2004b
Methylmercury (all other age categories)	2.0E-04	HC 2004c
Total PCBs	2.0E-05	WHO 2003; USEPA 2006 ^a



Human Risk Characterization

Exposure Area	Chemical	Hazard Quotient (EDI/TDI)			
		Sport Angler			
		Toddler 7 mo-4 yr	Child 5-11 yr	Adolescent 12-19 yr	Adult ≥ 20 yr
Entire AOC	MeHg	0.1	0.1	0.08	0.03
	PCB	3	2	1	1
JC	MeHg	0.2	0.2	0.1	0.05
	PCB	2	2	1	1
RPH	MeHg	0.1	0.1	0.07	0.03
	PCB	5	4	2	2



Sediment Management Goals

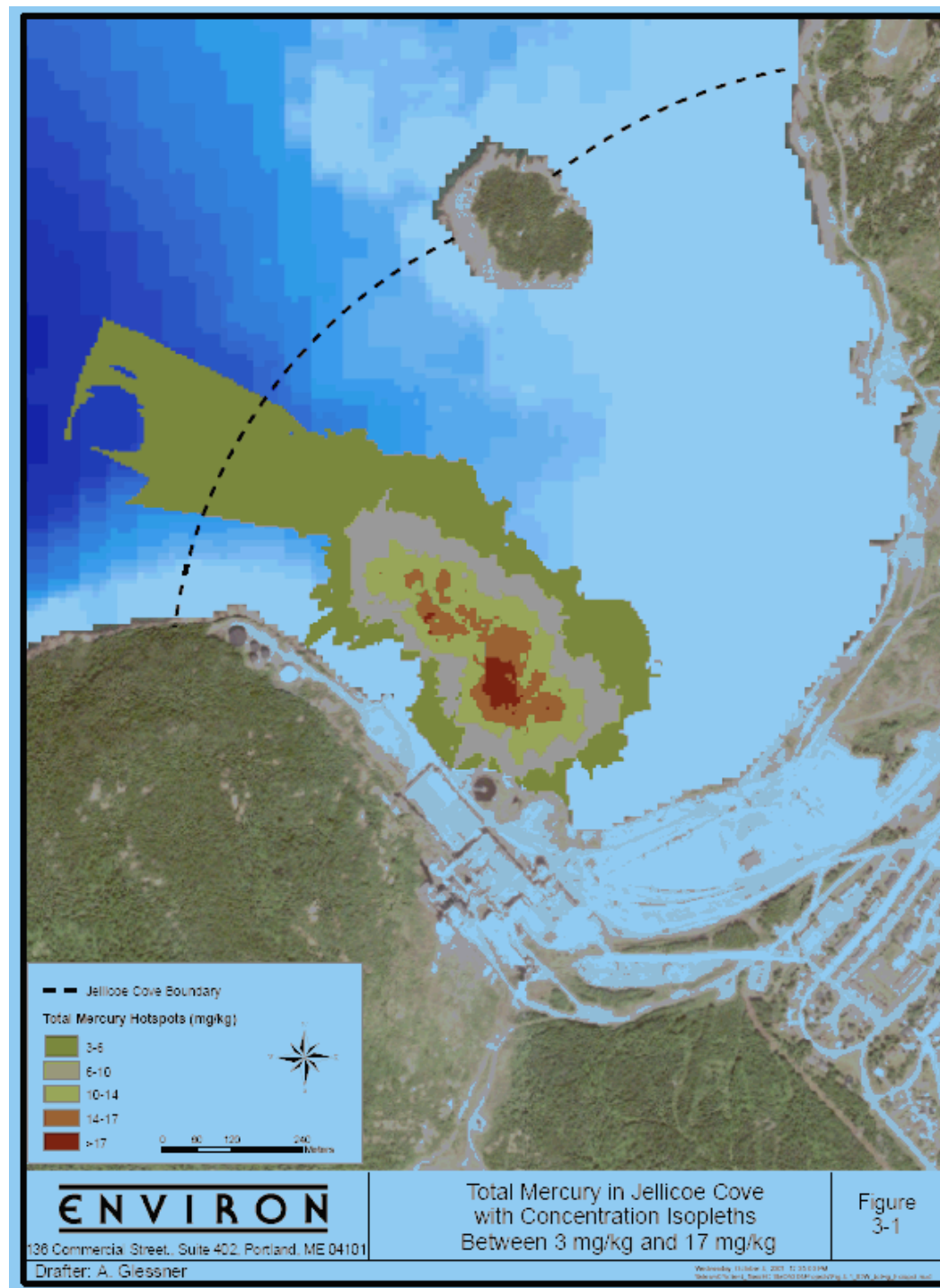
- Multiple approaches to setting sediment goals
 - Risk-based
 - Guideline-based
 - Background-based
 - Source control of hot spots

- Process
 - Determine target fish tissue concentrations associated with no risk, guidelines, and background
 - Apply food web bioaccumulation model to estimate sediment concentrations required to attain those fish concentrations
 - Compare current spatially weighted average concentrations (SWACs) to sediment management goals



Total Mercury Hotspot Delineated by Inverse Distance Weighting

- 3 mg/kg
- 6 mg/kg
- 10 mg/kg
- 14 mg/kg
- 17 mg/kg





Residual Risks & Risk Reduction: Fish

Scenario ^b	Hot Spot Defined by 2 mg/kg		Hot Spot Defined by 3 mg/kg		Hot Spot Defined by 6 mg/kg		Hot Spot Defined by 10 mg/kg	
	Residual HQ	Percent Reduction ^d	Residual HQ	Percent Reduction ^d	Residual HQ	Percent Reduction ^d	Residual HQ	Percent Reduction ^d
Scenario 1 (100% JC)	1.00	62%	1.4	47%	2.0	26%	2.3	15%
Scenario 2 (75% JC + 25% RPH)	0.99	55%	1.3	42%	1.7	23%	1.9	13%
Scenario 3 (50% JC + 50% RPH)	0.99	46%	1.2	34%	1.5	19%	1.6	11%
Scenario 4 (25% JC + 75% RPH)	0.98	30%	1.1	22%	1.2	12%	1.3	7%

- a. Although hazard quotients are typically rounded to a single significant digit, additional significant figures are presented here for purposes of calculating the percent reduction in hazard associated with the four hot spot remediation scenarios
- b. Scenario 5 (100% RPH) excluded from analysis because hot spot scenarios do not involve remediation outside of JC
- c. Baseline HQ is the predicted hazard under current conditions
- d. Percent reduction = (Baseline HQ - Residual HQ)/Baseline HQ x 100). Percent reduction illustrates the reduction in hazard relative to baseline predicted to from the four hot spot remediation options. For example, 62% risk reduction = (2.65 - 1.00)/2.65 x 100, while 30% risk reduction = (1.39 - 0.98)/1.39 x 100.

HQ: hazard quotient

JC: Jellicoe Cove

RPH: rest of Peninsula Harbour



Residual Risks & Risk Reduction: Mink

Scenario ^b	Hot Spot Defined by 2 mg/kg		Hot Spot Defined by 3 mg/kg		Hot Spot Defined by 6 mg/kg		Hot Spot Defined by 10 mg/kg	
	Residual HQ	Percent Reduction ^d	Residual HQ	Percent Reduction ^d	Residual HQ	Percent Reduction ^d	Residual HQ	Percent Reduction ^d
Scenario 2 (75% JC + 25% RPH)	1.0	44%	1.3	33%	1.6	17%	1.7	11%
Scenario 3 (50% JC + 50% RPH)	1.2	31%	1.4	23%	1.6	12%	1.7	8%
Scenario 4 (25% JC + 75% RPH)	1.5	16%	1.5	12%	1.6	6%	1.7	4%

- a. Although hazard quotients are typically rounded to a single significant digit, additional significant figures are presented here for purposes of calculating the percent reduction in hazard associated with the four hot spot remediation scenarios
- b. Scenario 1 (100% JC) excluded from analysis, because mink are not predicted to be at risk if deriving all of their food from JC
Scenario 5 (100% RPH) excluded from analysis, because hot spot scenarios do not involve remediation outside of JC
- c. Baseline HQ is the predicted hazard under current conditions
- d. Percent reduction = (Baseline HQ - Residual HQ)/Baseline HQ x 100). Percent reduction illustrates the reduction in hazard relative to baseline predicted to result from the four hot spot remediation options. For example, 57% risk reduction = (4.48 - 1.94)/4.48 x 100, while 16% risk reduction = (4.00 - 3.36)/4.00 x 100.

JC: Jellicoe Cove
RPH: rest of Peninsula Harbour



Sediment Management Options Analysis

■ Goal

Develop and evaluate options for addressing mercury and PCBs in Peninsula Harbour AOC

■ Evaluation Process

- Screen all options based on effectiveness, implementability, and cost
- Create short-list of preferred options
- Evaluate preferred options in detail
- Develop conceptual designs for preferred options





Cleanup Options


- Option 1: Thin layer cap sediment with total mercury > 3 mg/kg
- Option 2: Hydraulic dredging, thin layer capping, off-site disposal
 - Option 2a: Dredge > 17 mg/kg mercury & cap > 3 mg/kg
 - Option 2b: Dredge > 14 mg/kg mercury & cap > 3 mg/kg
- Option 3: Hydraulic dredging, thin layer capping, local disposal
 - Option 3a: Dredge > 17 mg/kg mercury & cap > 3 mg/kg
 - Option 3b: Dredge > 14 mg/kg mercury & cap > 3 mg/kg





Criteria for Remedy Selection

 Ability to achieve sediment management goals with defined targets

 Technical feasibility
(reliability, scheduling, and construction / operation requirements)

 Community acceptance

 Environmental impacts, human health implications, and ability to control residual contamination

 Requirements for chemical, physical and biological monitoring

 Compliance with regulatory requirements

 Overall project costs



Weighting Matrix

Criteria	Relative Importance	Thin Layer Capping	Hydraulic Dredging	Combined Thin Layer Capping and Hydraulic Dredging
Effectiveness	High	Better	Good	Best
Technical Feasibility	Medium	Best	Good	Good
Community Acceptance	Medium	Good	Better	Best
Risk	High	Better	Good	Best
Long-Term Monitoring Needs	Low	Good	Better	Good
Compliance with Regulations	Medium	Better	Good	Good
Cost Effectiveness	High	Best	Good	Better
SCORE		2.1	1.2	2.2



Estimated Cleanup Costs

Areas, Volumes, and Approximate Costs Associated with Remedial Alternatives

Total Mercury Threshold for Capping		<u>Total Mercury Threshold for Dredging</u>					
		0 mg/kg	3 mg/kg	6 mg/kg	10 mg/kg	14 mg/kg	17 mg/kg
	Volume Dredged (m ³)		34,000	20,000	13,000	5,000	1,000
	Dredge Option Cost		\$12,000,000	\$7,690,000	\$5,390,000	\$3,140,000	\$1,900,000
	Mass mercury removed (kg) ^b		227	194	160	96	24
3 mg/kg	Capped Area (m ²)	204,000	204,000	204,000	204,000	204,000	204,000
	Volume Dredged (m ³)	0	34,000	20,000	13,000	5,000	1,000
	Total Cost	\$2,670,000	\$14,670,000	\$10,360,000	\$8,060,000	\$5,810,000	\$4,570,000
6 mg/kg	Capped Area (m ²)	114,000	114,000	114,000	114,000	114,000	114,000
	Volume Dredged (m ³)	0	34,000	20,000	13,000	5,000	1,000
	Total Cost	\$1,930,000	\$13,930,000	\$9,620,000	\$7,320,000	\$5,070,000	\$3,830,000
10 mg/kg	Capped Area (m ²)	64,000	64,000	64,000	64,000	64,000	64,000
	Volume Dredged (m ³)	0	34,000	20,000	13,000	5,000	1,000
	Total Cost	\$1,520,000	\$13,520,000	\$9,220,000	\$6,910,000	\$4,660,000	\$3,430,000



Cost Uncertainties

- Weather
- Community negotiations
- Effect of location and timing on mobilization costs
- Timing uncertainties relative to in-water window
- Log debris removal before dredging
- Feasibility of dredging given depth, presence of debris and shallow bedrock
- Dewatering rate and whether decant water needs to be treated
- Availability of sand for cap construction