MichiganTech Research Institute

GLEAMS
Great Lakes Environmental & Molecular Sciences Center

A dynamic decision support tool for understanding the potential health impacts of different fish consumption patterns for mercury and PCBs in Great Lakes rivers

Michigan Tech Research Institute:
Colin Brooks
Dr. Robert Shuchman
Eric Keefauver
Ben Koziol
Dr. Tyler Erickson

Western Michigan University:
Dr. Charles Ide

www.mtri.org www.wmich.edu/env/

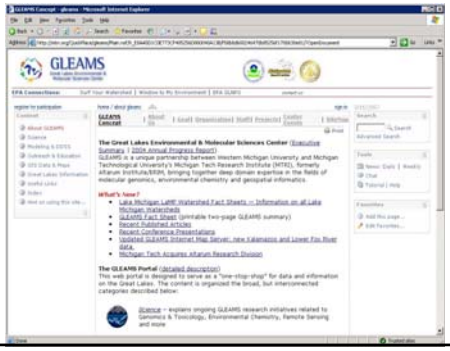
GLEAMS review

- Partnership between MTRI and the Western Michigan University (WMU) Environmental Institute; funded by EPA ORD
- Goal: Address the legacy of contamination on the Great Lakes and their watersheds
  - Help local & state stakeholders understand this legacy
- Project developed watershed-scale methods to assess and protect human and ecosystem health
  - Used the Kalamazoo River watershed as a example site
  - Modeled PCB risk and water quality
  - Expanded PCB Dynamic Decision Support System (DSS) to Lower Fox River, WI
  - Developed Fox River mercury DSS tool

2

GLEAMS web portal

- Resource for Great Lakes information, esp. for Kalamazoo River & Lower Fox River as demonstrations of risk analysis web decision support tools of intensive data collection
- www.greatlakesdecisionsupport.org
  - Science
  - GIS and Decision Support Systems
  - Modeling
  - Outreach
  - Great Lakes information



3

Mercury decision support tool – predict human health risk using GIS data & models

- Goal: Develop a tool to help users understand if local fish consumption is likely to lead to mercury exposure above EPA reference doses, esp. for women of 18-45, using spatial sediment data as starting point
- Used documented Wisconsin DNR Lower Fox River database – Lower Fox River Environmental Database (J.Kreider) –
  - for the WDNR Fox Environmental Information Management System (EIMS)
- Capture complexity of modeling health risk from mercury in a valid & user-friendly on-line mapping interface
  - http://maps.mtri.org/website/GLEAMS_foxriver/
- Enable user interaction, selection of scenarios: help community members to understand level & locations of risks

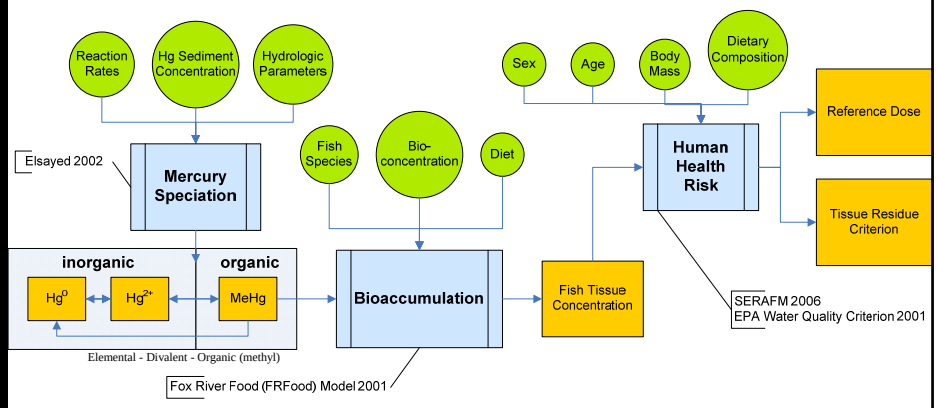
4

Mercury modeling issues

- Most common aquatic mercury chemical species:
  - Elemental, inert (Hg^0); Divalent, reactive (Hg^{2+}); Organic (MeHg)
- The first two, non-biologically available forms (elemental and divalent) are the most common often accounting for greater than 90% of total environmental mercury.
  - Opposite is true for biological uptake: > 90% of tissue-bound mercury is MeHg
- Mercury methylation typically occurs in the inactive, anoxic sediment layer of lakes and streams regulated by sulfide concentration, sulfate-reducing bacteria, pH, DOC/TOC, and temperature.
  - Speciation model is derived from a 'finite element model'
  - Bioaccumulation – modeled using a generalized hydrophobic bioaccumulation model.
  - Wide species applicability and simplified calibration procedure
  - Challenging to incorporate the effects of weight and age, highly sensitive to changes in bioconcentration factor
- Human Health
  - Two methods to assess health risks. Both originate from EPA recommendations:
    1. RfD (reference dose) → acceptable blood mercury level that can be physiologically maintained resulting in no noticeable health effects → 0.0001 mg MeHg/kg body weight-day (female and children), 0.0003 (male)
    2. TRC (tissue residue criterion) → fish tissue concentration that when consumed will not result in a RfD above the recommended value
       - A relatively simple calculation involving body weight, dietary intake, and fish tissue concentration

5

Generalized Mercury Model Diagram



Elsayed, N.B. 2002. A finite element model of mercury species fate in the Detroit River water column and sediment. Dissertation. Wayne State University, Detroit, MI.

EPA Water Quality Criterion. 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. Office of Science and Technology, Office of Water. U.S. Environmental Protection Agency. Washington, D.C. EPA-823-R-01-001.

Fox River Food (FRFood) Model. 2001. Fox River Food (FRFood) Model Documentation Memorandum, Lower Fox River, Wisconsin: Remedial Investigation and Feasibility Study. ThermoRetec Consulting Corporation. Prepared for: Wisconsin Department of Natural Resources.

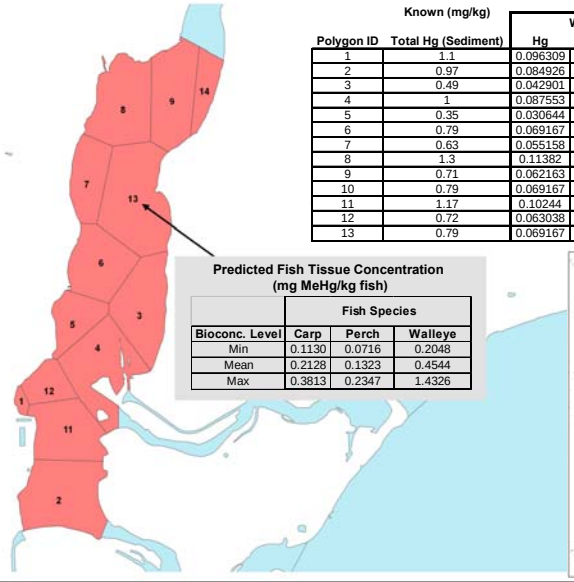
SERAFM. 2006. Development of an Ecological Risk Assessment Methodology for Assessing Wildlife Exposure Risk Associated with Mercury-Contaminated Sediments in Lake and River Systems. U.S. Environmental Protection Agency, Office of Research and Development. Washington, D.C. EPA-600-R-063-073. (Recommended by Dr. Elsie Sunderland, EPA ORD, Boston)

6

Example Data

1998 Mercury sediment concentrations from WDNR Low Fox River Environmental Information Management System (Jeff Kreider)

	Known (mg/kg)	Predicted (µg/L - Water, mg/kg - Sediment)					
		Water Column			Sediment		
Polygon ID	Total Hg (Sediment)	Hg	Hg2	MeHg	Hg	Hg2	MeHg
1	1.1	0.096309	0.0034791	0.00090023	0.71135	0.38575	0.0029014
2	0.97	0.084926	0.0030679	0.00079383	0.62727	0.34016	0.0025585
3	0.49	0.042901	0.0015498	0.00040101	0.31687	0.17183	0.0012925
4	1	0.087553	0.0031628	0.00081838	0.64667	0.35068	0.0026377
5	0.35	0.030644	0.001107	0.00028644	0.22634	0.12274	0.00092318
6	0.79	0.069167	0.0024986	0.00064653	0.51087	0.27704	0.0020838
7	0.63	0.055158	0.0019926	0.00051558	0.40741	0.22093	0.0016617
8	1.3	0.11382	0.0041117	0.0010639	0.84068	0.45589	0.003429
9	0.71	0.062163	0.0022456	0.00058105	0.45914	0.24898	0.0018727
10	0.79	0.069167	0.0024986	0.00064653	0.51087	0.27704	0.0020838
11	1.17	0.10244	0.0037005	0.00095751	0.75661	0.4103	0.0030861
12	0.72	0.063038	0.0022772	0.00058924	0.46561	0.25249	0.0018991
13	0.79	0.069167	0.0024986	0.00064653	0.51087	0.27704	0.0020838



Predicted Fish Tissue Concentration (mg MeHg/kg fish)

	Fish Species		
Bioconc. Level	Carp	Perch	Walleye
Min	0.1130	0.0716	0.2048
Mean	0.2128	0.1323	0.4544
Max	0.3813	0.2347	1.4326

7

Example Health Risk Scenarios

- Scenarios can be run under different bioconcentration levels to incorporate uncertainties associated with fish ecology (e.g. unconstrained movement ranges, size variability, age, etc.).
- Bioconcentration factors were calibrated to *in situ* fish tissue concentrations using a Monte Carlo-based optimization procedure.
- The range of bioconcentration factors allows the food web model to demonstrate a valid range of concentration predictions.
- Information below available through a mapping DSS interface

Example Typical Consumption		
	Meals	Kg/Month
Carp	0	0
Perch	0	0
Walleye	1.5	0.15 - 0.30

Example High Consumption		
	Meals	Kg/Month
Carp	0.25	0.03 - 0.05
Perch	1	0.10 - 0.20
Walleye	1.5	0.15 - 0.30

Green	Below Risk Criterion
Yellow	Near Risk Criterion
Red	Criterion Exceeded

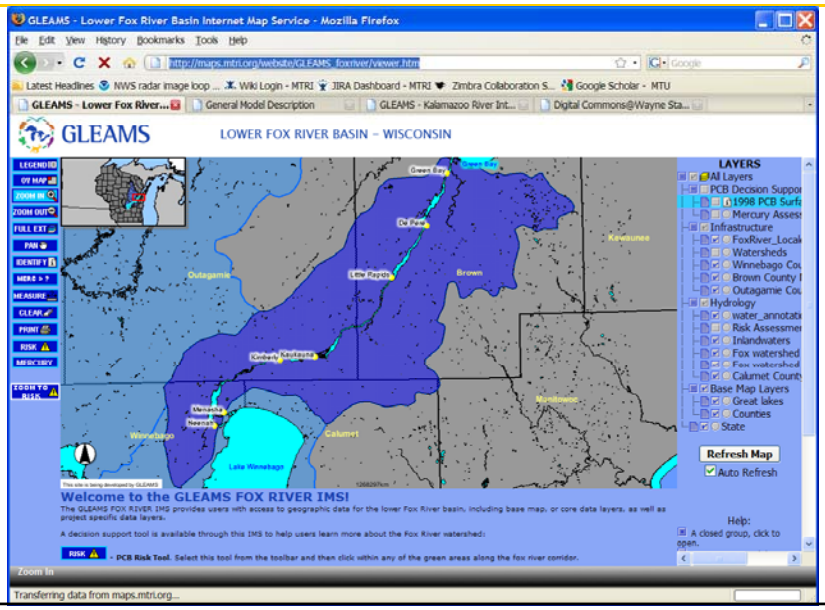
Weight (kg) / age / RefDose (mg MeHg/kg) BioConc. Level / Typical Consumption / High

Man	78	30	0.0003	Min	0.00005	0.00006
				Mean	0.00008	0.0001
				Max	0.0002	0.0002
Woman	65	30	0.0001	Min	0.00004	0.00006
				Mean	**0.00007**	**0.00009**
				Max	**0.0001**	**0.0002**
Teenager	45	15	0.0001	Min	0.00004	0.00006
				Mean	**0.00007**	**0.00009**
				Max	**0.0001**	**0.0002**

			Fish Tissue Residue Criterion (mg MeHg/kg)				
	Weight (kg)	Age	Bioconc. Level	EPA Criterion	Typical	EPA Criterion	High
Man	78	30	Min	2.1633	0.1874	0.9984	0.1202
			Mean		0.4371		0.2569
			Max		1.4152		0.6733
Woman	65	30	Min	0.6699	0.1874	0.3092	0.1202
			Mean		0.4371		**0.2569**
			Max		**1.4152**		**0.6733**
Teenager	45	15	Min	0.6680	0.1874	0.3083	0.1202
			Mean		0.4371		**0.2569**
			Max		**1.4152**		**0.6733**

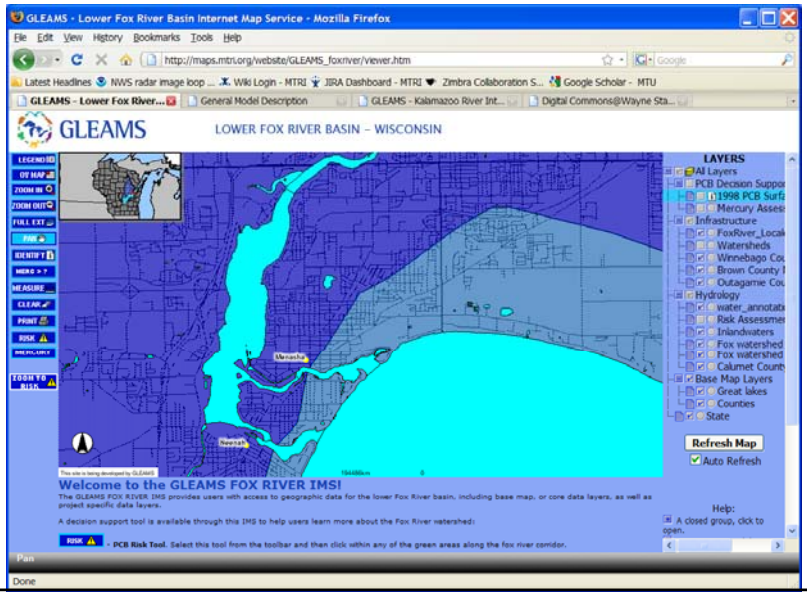
8

DSS entry page:
http://maps.mtri.org/website/GLEAMS_foxriver/



9

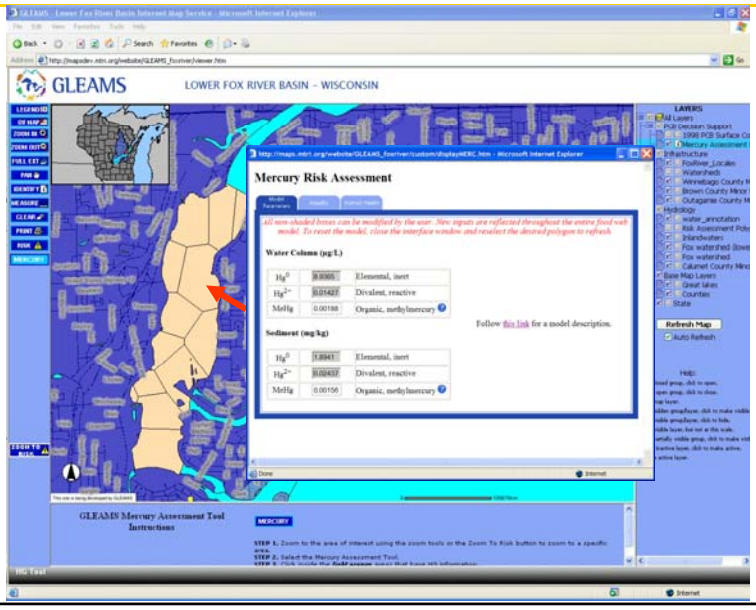
User selects area of interest



10

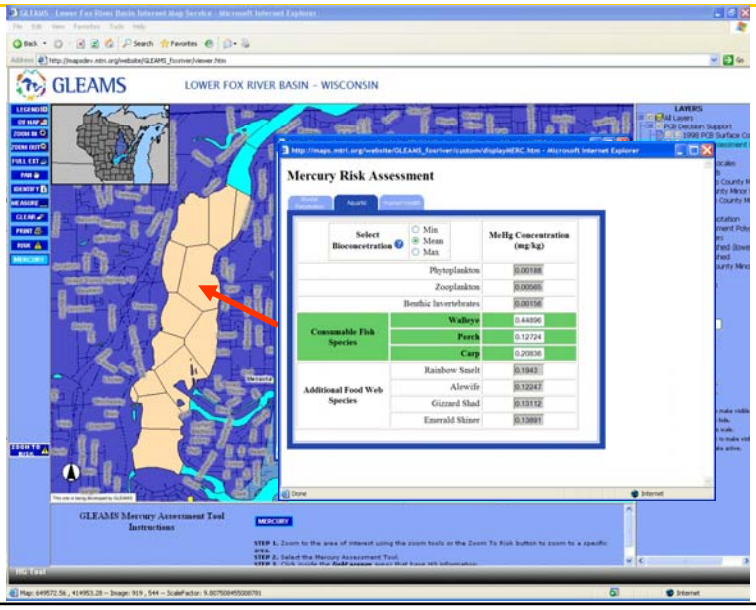
Mercury Tool Demo:
Querying data through tool for Lower Fox River

MERCURY



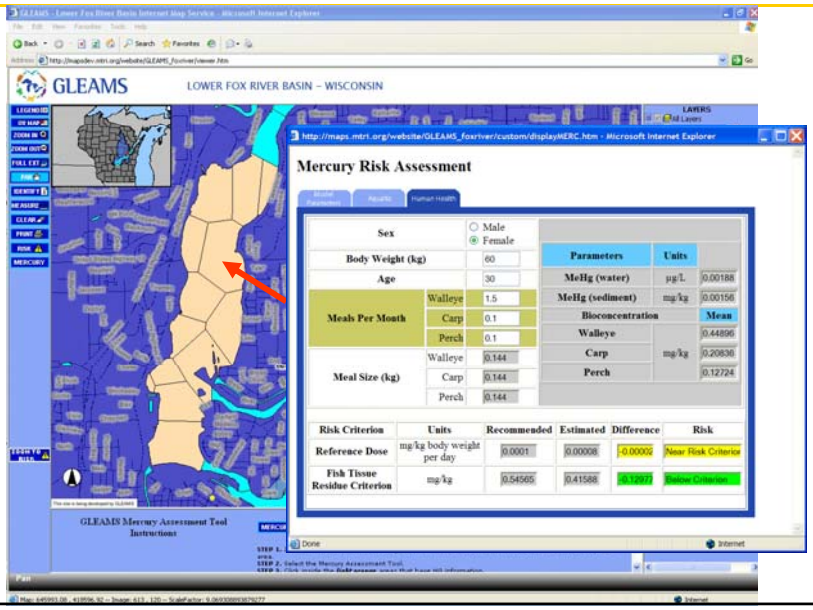
11

Mercury Tool Demo:
Bioaccumulation levels in fish



12

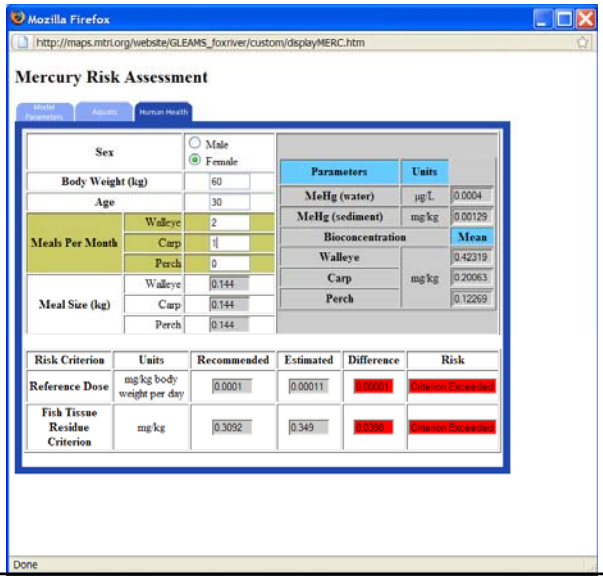
Mercury Tool Demo: Are the risk criteria exceeded?



13

Example consumption scenarios

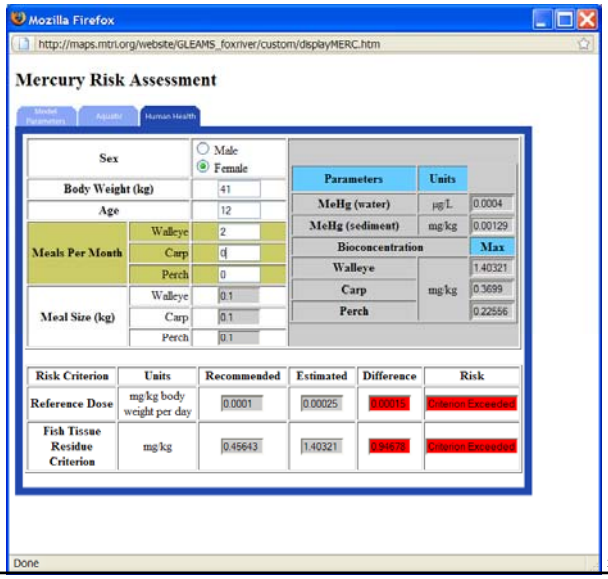
- User can test different consumption scenarios.
- Example 1: 2 walleye & 1 perch per / month, no carp
- Woman, age 30, 60 kg (132 lbs)
- Reference dose & fish tissue residue criterion exceeded
- 45 of 57 WDNR 1998 sediment surface samples had mercury concentrations higher than 0.49 mg/kg (which result in criteria being exceeded)
- Other scenarios can easily explored



14

Child scenario

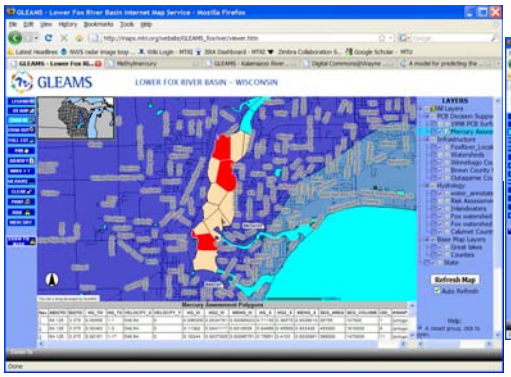
- 41 kg (90 lb), 12-year-old girl, 2 walleye / month
- Mean vs. max bioconcentration factor
- With maximum bioconcentration, risk criteria are exceeded

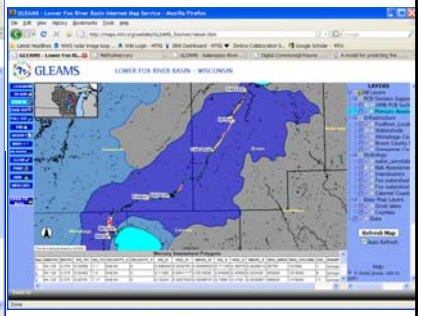


15

Interactive concentration queries

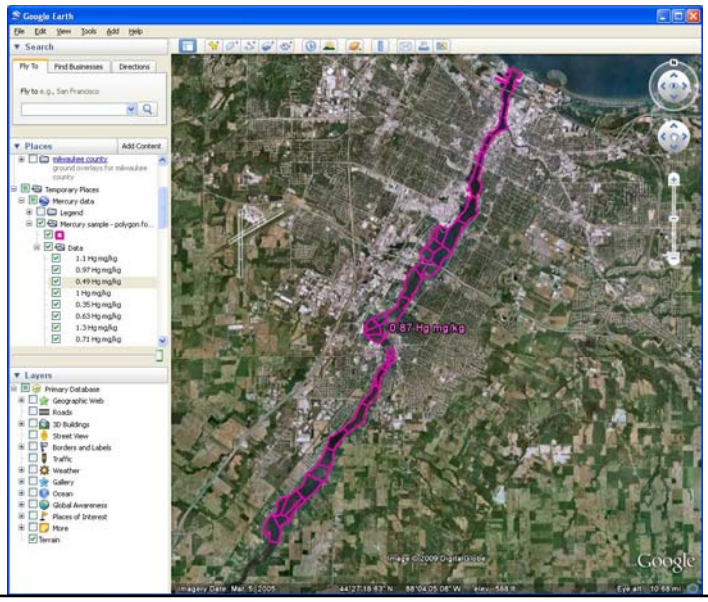
- User can select the mercury concentration query tool & find all areas with total mercury above certain concentrations.
- Example: All 1998 samples with total Hg > 1.0 mg/kg = 20 locatoins along Lower Fox River





16

Future: display tools & tools with new mapping tools (Google Earth)



17

Tool flexibility

- User changeable variables – can replace modeled information:
  - Methyl mercury for sediment and water column
  - MeHG fish tissue concentration
- Bioconcentration factors – range of possible fish mercury concentrations (based on F. Gobas 1993 & WDNR fish tissue data) – helps capture fish mobility, diet changes, size variability
- Consumption variables:
  - Gender
  - body weight
  - Age
  - meals per month
- Flexibility is intended to provide ability for users to explore & discover mercury, food web, and consumption relationships & help stakeholders understand the science in a more accessible way

18

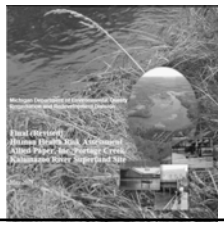
GLEAMS PCB tool

- Tool maps the concentrations of sediments contaminated with polychlorinated biphenyls (PCBs) in the Kalamazoo River
- Data comes from Potentially Responsible Parties (PRPs)
- Ties sediment concentrations into human health risks based on MDEQ ecological & human health risk model
- Uses ArcIMS web mapping technology
- Ties into a dynamic Decision Support System (DSS) tool that enables users to understand potential health risks of eating contaminated fish from the river
- New functionality:
  - Find the areas above 0.5 ppm PCB concentration
  - Evaluate exposure likely from more rain events causing increase in exposure from contaminated sediments

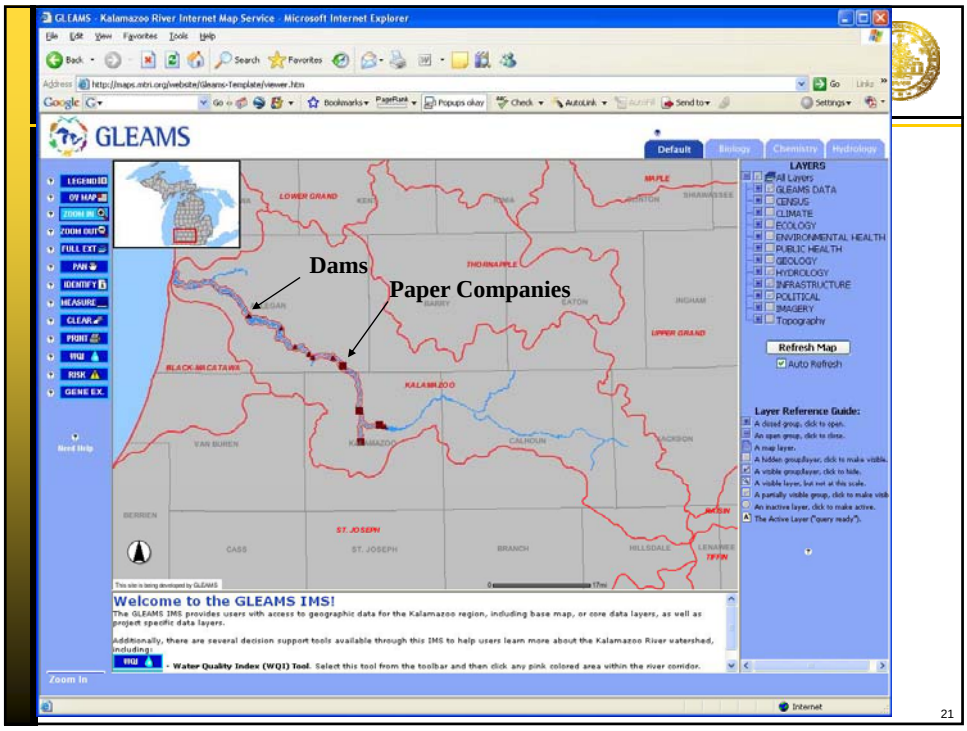
19

Example Decision Support System (DSS) Scenarios

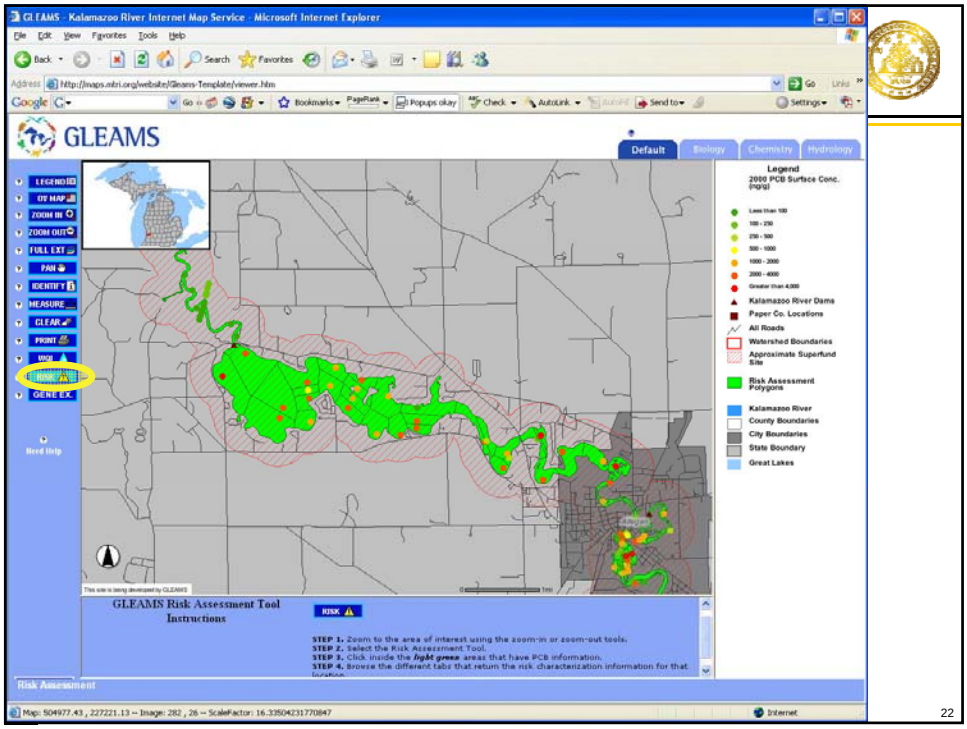
- For Lake Allegan, Michigan, along the Kalamazoo River
  - Member of a local watershed group trying to understand risks
  - A community leader helping local citizens understand impacts of the legacy of pollution
  - *Agency person working on fish consumption guidelines*
- Where are the risky areas? What are the risks?
  - Kalamazoo River (Superfund site)
  - PCBs – cancer / immune system / reproductive health risks
- Used MDEQ reports for assessing risk:
  - Baseline Ecological Risk Assessment (263 pages)
  - Human Health Risk Assessment (169 pages)

*  * 

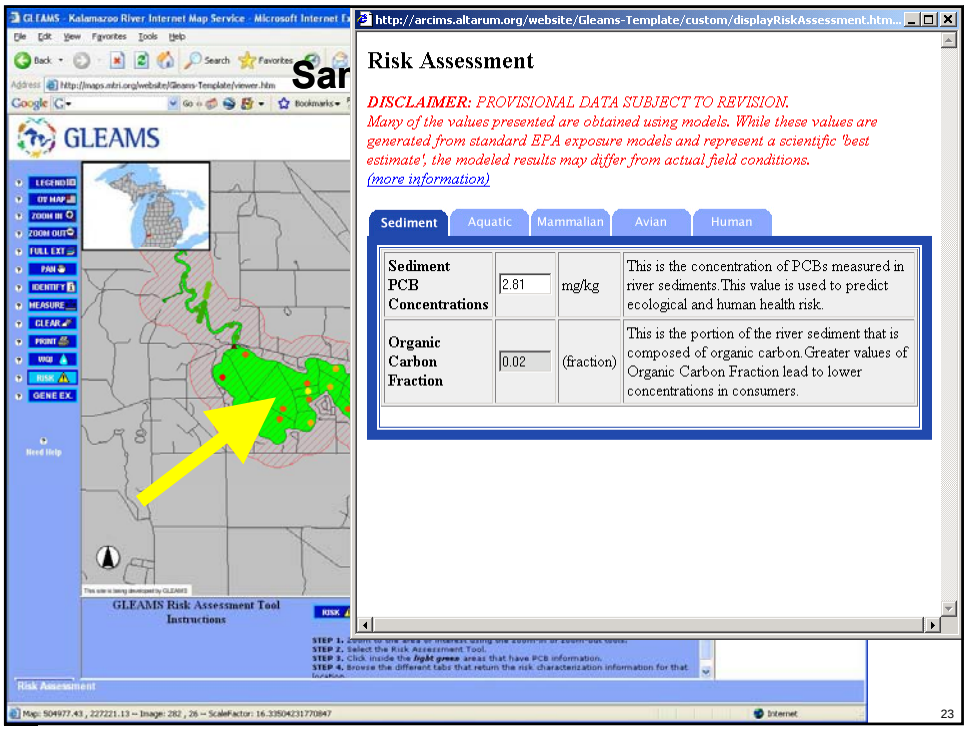
20

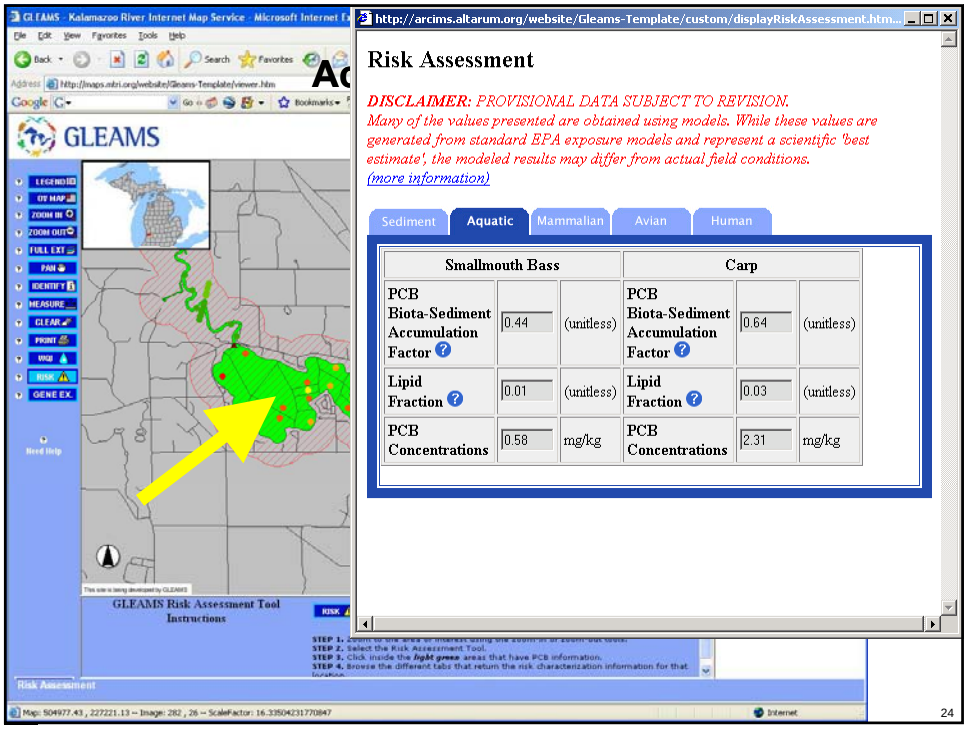

GLEAMS - Kalamazoo River Internet Map Service - Microsoft Internet Explorer
GLEAMS
Default
Biology
Chemistry
Hydrology
Dams
Paper Companies
LAYERS
All Layers
GLEAMS DATA
CENSUS
CLIMATE
ECOLOGY
ENVIRONMENTAL HEALTH
PUBLIC HEALTH
GEOLOGY
HYDROLOGY
INFRASTRUCTURE
POLITICAL
IMAGERY
Topography
Refresh Map
Auto Refresh
Layer Reference Guide:
Welcome to the GLEAMS IMS!
The GLEAMS IMS provides users with access to geographic data for the Kalamazoo region, including base map, or core data layers, as well as project specific data layers.
Additionally, there are several decision support tools available through this IMS to help users learn more about the Kalamazoo River watershed, including:
- Water Quality Index (WQI) Tool. Select this tool from the toolbar and then click any pink colored area within the river corridor.
Zoom In
Internet

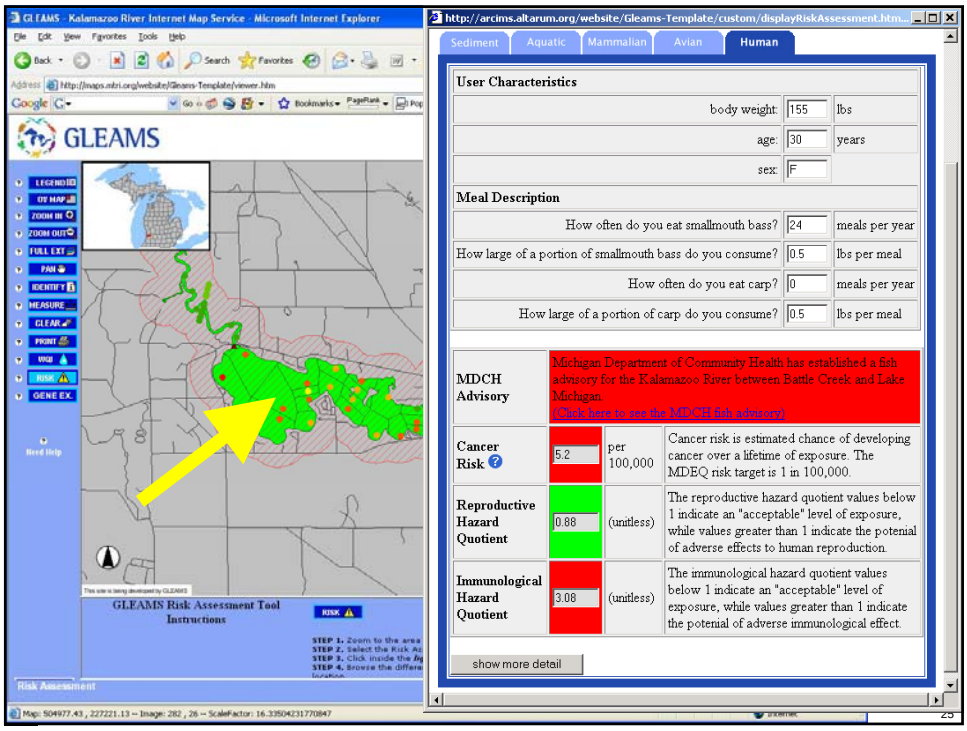
21

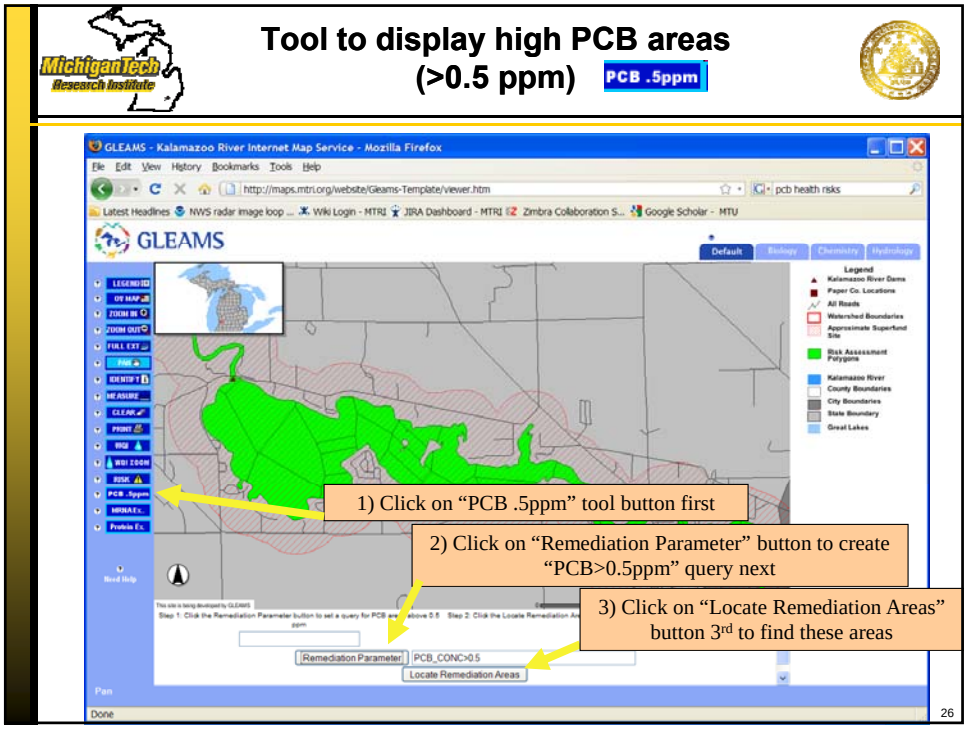

GLEAMS - Kalamazoo River Internet Map Service - Microsoft Internet Explorer
GLEAMS
Default
Biology
Chemistry
Hydrology
Legend
2000 PCB Surface Conc. (ng/g)
Kalamazoo River Dams
Paper Co. Locations
All Roads
Watershed Boundaries
Approximate Superfund Site
Risk Assessment Polygons
Kalamazoo River
County Boundaries
City Boundaries
State Boundary
Great Lakes
GLEAMS Risk Assessment Tool Instructions
RISK
STEP 1. Zoom to the area of interest using the zoom-in or zoom-out tools.
STEP 2. Select the Risk Assessment Tool.
STEP 3. Click inside the light green areas that have PCB information.
STEP 4. Browse the different tabs that return the risk characterization information for that
Risk Assessment
Internet

22

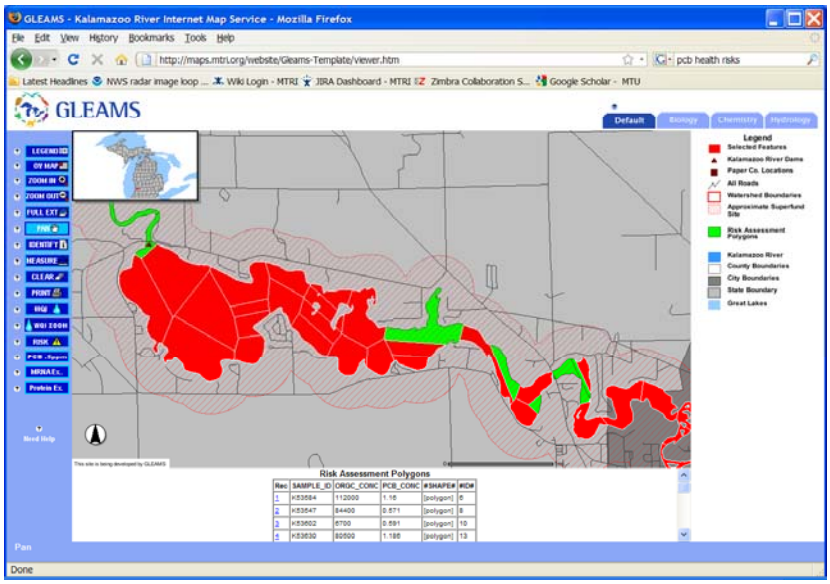

GLEAMS - Kalamazoo River Internet Map Service - Microsoft Internet Explorer
http://arcims.altarum.org/website/Gleams-Template/custom/displayRiskAssessment.htm...
GLEAMS
GLEAMS Risk Assessment Tool Instructions
Risk Assessment
DISCLAIMER: PROVISIONAL DATA SUBJECT TO REVISION.
Many of the values presented are obtained using models. While these values are generated from standard EPA exposure models and represent a scientific 'best estimate', the modeled results may differ from actual field conditions.
(more information)
Sediment
Aquatic
Mammalian
Avian
Human
Sediment PCB Concentrations
2.81
mg/kg
This is the concentration of PCBs measured in river sediments. This value is used to predict ecological and human health risk.
Organic Carbon Fraction
0.02
(fraction)
This is the portion of the river sediment that is composed of organic carbon. Greater values of Organic Carbon Fraction lead to lower concentrations in consumers.
23


GLEAMS - Kalamazoo River Internet Map Service - Microsoft Internet Explorer
http://arcims.altarum.org/website/Gleams-Template/custom/displayRiskAssessment.htm...
GLEAMS
GLEAMS Risk Assessment Tool Instructions
Risk Assessment
DISCLAIMER: PROVISIONAL DATA SUBJECT TO REVISION.
Many of the values presented are obtained using models. While these values are generated from standard EPA exposure models and represent a scientific 'best estimate', the modeled results may differ from actual field conditions.
(more information)
Sediment
Aquatic
Mammalian
Avian
Human
Smallmouth Bass
Carp
PCB Biota-Sediment Accumulation Factor
0.44
(unitless)
PCB Biota-Sediment Accumulation Factor
0.64
(unitless)
Lipid Fraction
0.01
(unitless)
Lipid Fraction
0.03
(unitless)
PCB Concentrations
0.58
mg/kg
PCB Concentrations
2.31
mg/kg
24


GLEAMS - Kalamazoo River Internet Map Service - Microsoft Internet Explorer
GLEAMS
GLEAMS Risk Assessment Tool Instructions
http://arcims.altarum.org/website/Gleams-Template/custom/displayRiskAssessment.htm...
Sediment
Aquatic
Mammalian
Avian
Human
User Characteristics
body weight: 155 lbs
age: 30 years
sex: F
Meal Description
How often do you eat smallmouth bass? 24 meals per year
How large of a portion of smallmouth bass do you consume? 0.5 lbs per meal
How often do you eat carp? 0 meals per year
How large of a portion of carp do you consume? 0.5 lbs per meal
MDCH Advisory
Michigan Department of Community Health has established a fish advisory for the Kalamazoo River between Battle Creek and Lake Michigan.
(Click here to see the MDCH fish advisory)
Cancer Risk
5.2
per 100,000
Cancer risk is estimated chance of developing cancer over a lifetime of exposure. The MDEQ risk target is 1 in 100,000.
Reproductive Hazard Quotient
0.88
(unitless)
The reproductive hazard quotient values below 1 indicate an "acceptable" level of exposure, while values greater than 1 indicate the potenial of adverse effects to human reproduction.
Immunological Hazard Quotient
3.08
(unitless)
The immunological hazard quotient values below 1 indicate an "acceptable" level of exposure, while values greater than 1 indicate the potenial of adverse immunological effect.
show more detail

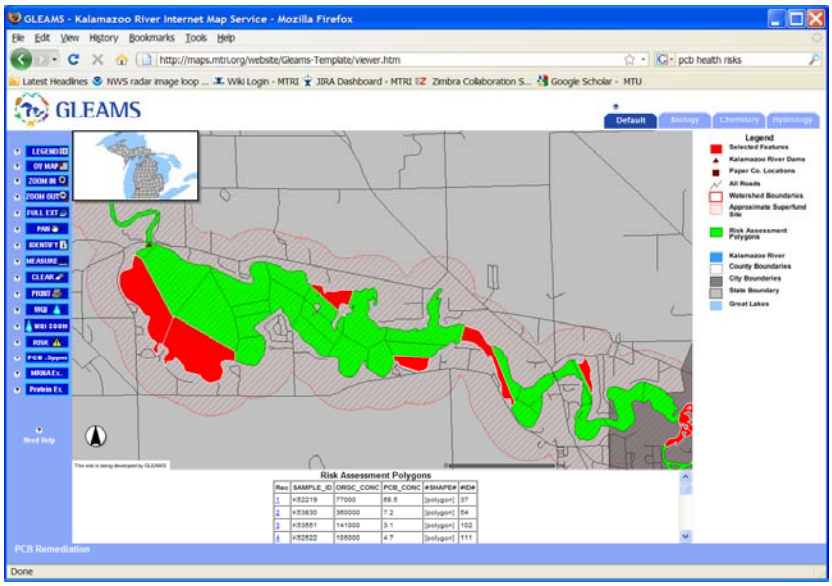

MichiganTech
Research Institute
Tool to display high PCB areas
(>0.5 ppm)
PCB .5ppm
GLEAMS - Kalamazoo River Internet Map Service - Mozilla Firefox
GLEAMS
1) Click on "PCB .5ppm" tool button first
2) Click on "Remediation Parameter" button to create "PCB>0.5ppm" query next
3) Click on "Locate Remediation Areas" button 3rd to find these areas
Remediation Parameter
PCB_CONC>0.5
Locate Remediation Areas
26

Example of PCB 0.5ppm tool – areas in Lake Allegan with PCBs >0.5 ppm



27

Areas in Lake Allegan > 3.0 ppm



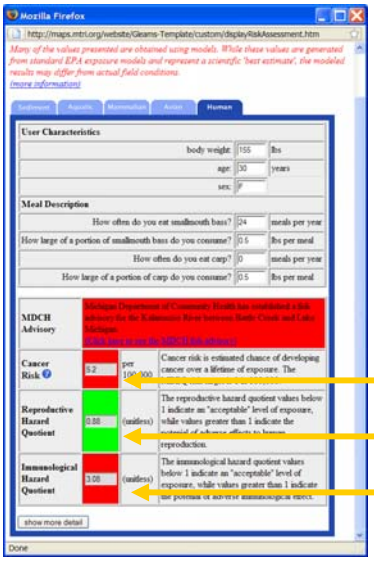
28

Climate Change scenario:
30% increase in BSAF due to storm events

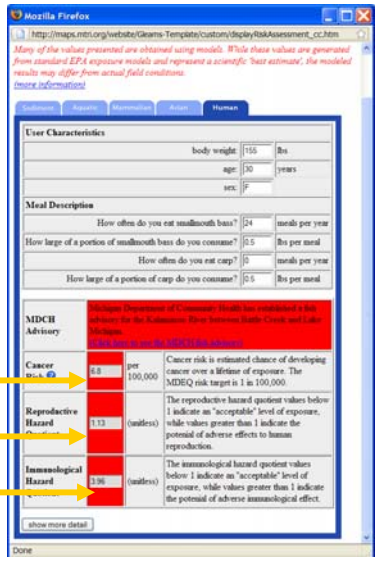
- We are estimating sediment loads in the Kalamazoo River representing an increase in extreme rain event (climate change) scenario
  - Using “Biota-Sediment Accumulation Factor” (BSAF)
  - BSAF is representative of the average surface sediment in the vicinity of an organism
  - We are assuming that more extreme rain events have increased this sediment/water interface exposure value by 30%
- Yield is increased exposure to PCBs in the food chain
- We are assuming that the food chain is being exposed to more contaminated sediment because of an increase in storm events (disturbance of the sediment/water interface)
- How does this cascade through the food chain & impact human health?

29

Difference in health risk:
Original vs. increased BSAF values



Risk with original BASF values



Risk with increased BASF values

30

GLEAMS Portal - DSS link

Contact info:

Colin Brooks

Environmental Science Lab Manager / Research Scientist

Michigan Tech Research Institute

3600 Green Court, Suite 100

Ann Arbor, MI 48105

colin.brooks@mtu.edu

Ph: 734-913-6858 Fax: 734-913-6880

Dr. Robert Shuchman: 734-913-6860 shuchman@mtu.edu

Dr. Chuck Ide: 269-387-5951 charles.ide@wmu.edu

- GLEAMS Portal: www.greatlakesdecisionsupport.org
  - Mercury & PCBs – Fox River web mapping site: http://maps.mtri.org/website/GLEAMS_foxriver/
  - PCB Kalamazoo River web mapping site:
  - http://maps.mtri.org/website/Gleams-Template/
- WMU Environmental Institute**:** www.wmich.edu/env/
- MTRI: www.mtri.org

31