Conceptual Site Model and Loading Analysis Update

South River Science Team
Advisory Panel Meeting
Harrisonburg, VA
October 21, 2015

Presented by Jim Dyer (on behalf of many)

Evolution of the Conceptual Site Model (CSM) for Hg Loading to the South River

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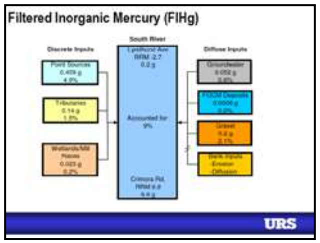
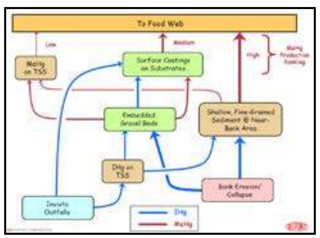
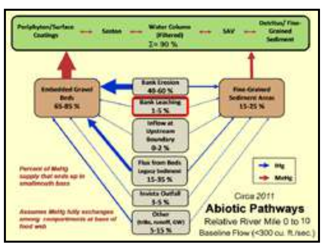


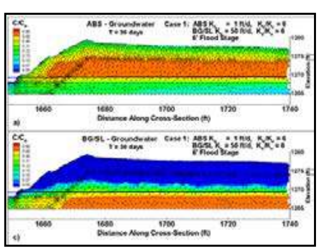
2008-2009 Water and Hg Daily Loading Budgets from Ecological Study *(Flanders and Morrison)*



2009-2010 Conceptual Pathway and Exposure Diagrams for IHg & MeHg *(Dyer, Flanders, Jensen, Morrison)*



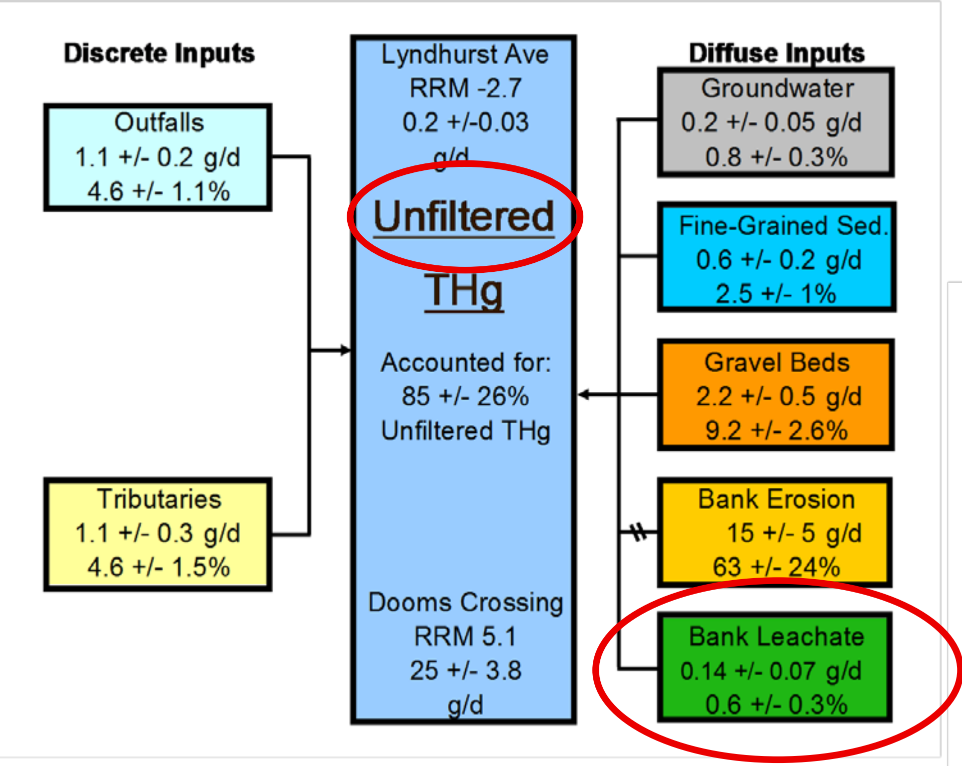
2011-2012 Conceptual Site Model Quantification and Report *(Harris, Dyer, Flanders, Grosso, Landis, Murphy, Pizzuto)*



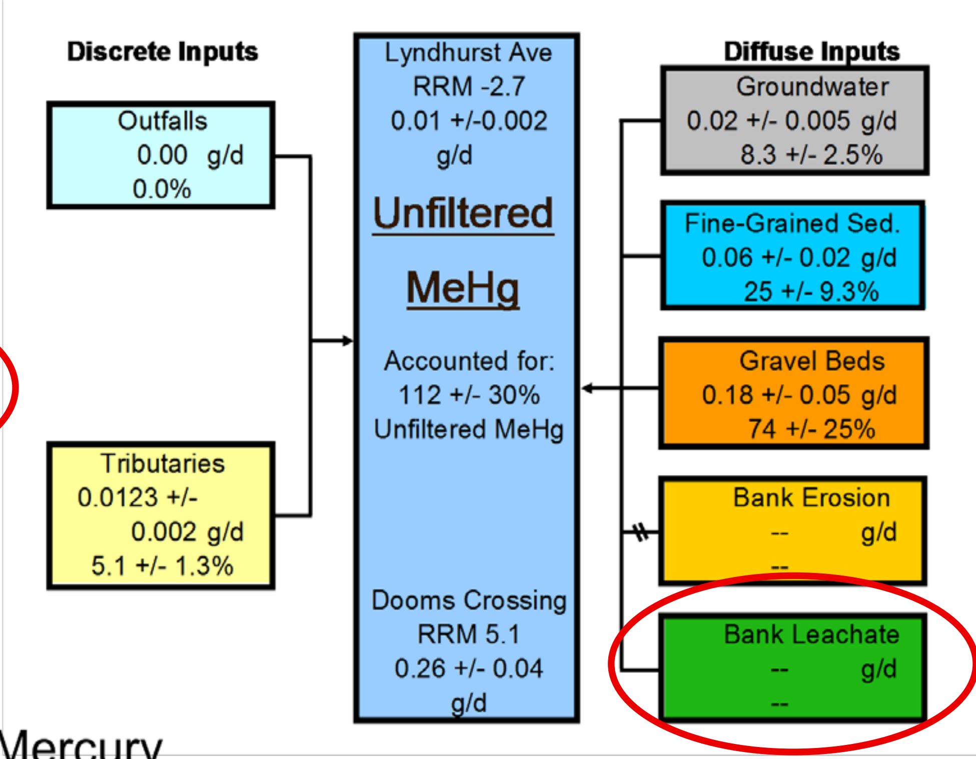
2013-2015 Refinement of Bank Leaching Model and Impact on Loading *(Dyer, Landis, Grosso, Sherrier, Ohr, Collins, Aquanty, Univ. Delaware, Univ. Waterloo, Texas Tech)*

Daily Water and Hg Mass Budgets - Lyndhurst to Crimora

Baseline Flow Conditions, Daily Load

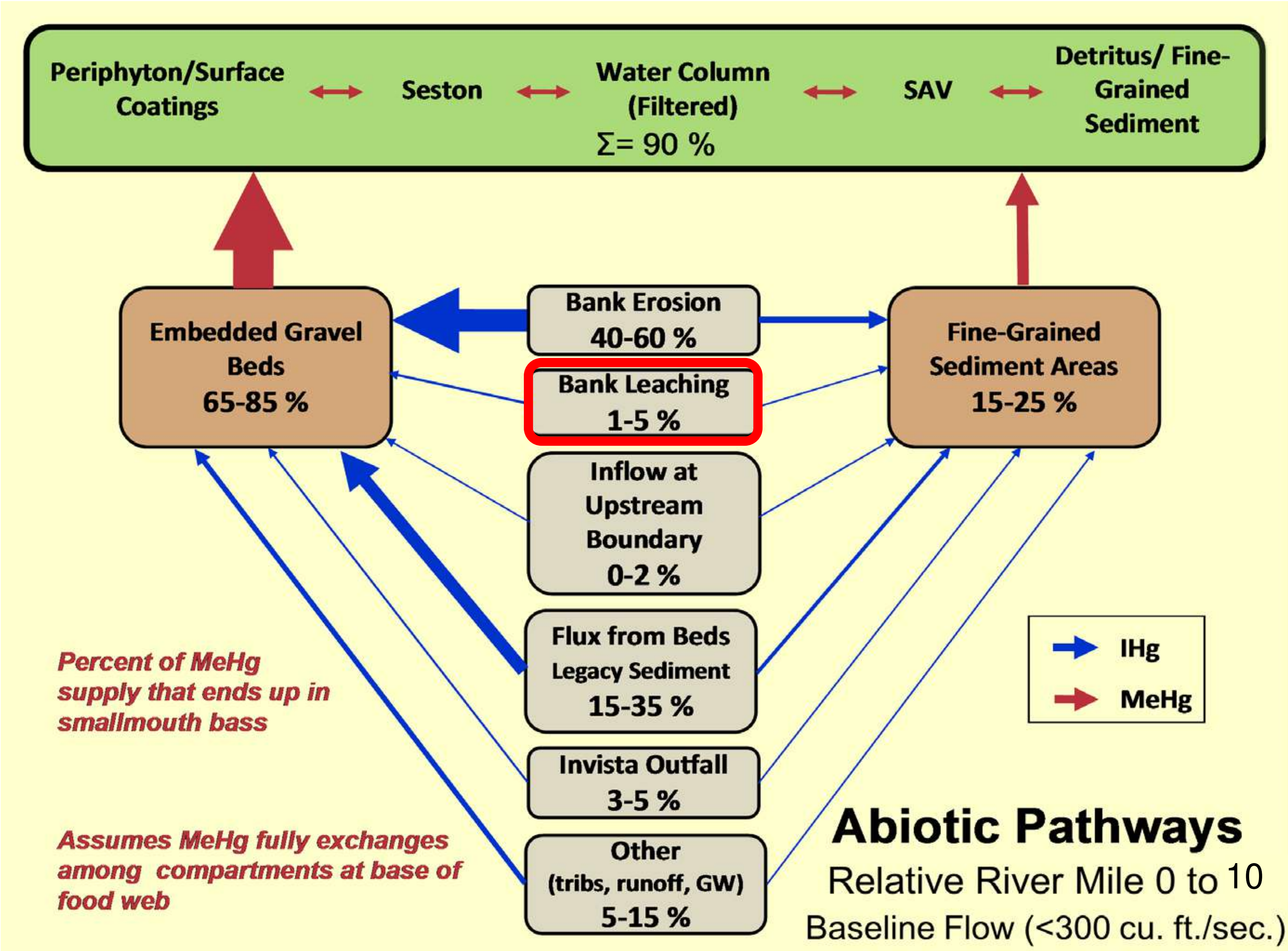


- Tributaries, millraces, wetlands & bedrock GW are minor sources
- Bank-to-bank sources important, particularly bank erosion and flux from embedded gravel beds



Note: All mass flux values were calculated independently, not by difference.

MeHg: Methylmercury; THg: Total Mercury


Periphyton/Surface Coatings
Seston
Water Column (Filtered)
Σ= 90 %
SAV
Detritus/ Fine-Grained Sediment
Embedded Gravel Beds
65-85 %
Bank Erosion
40-60 %
Bank Leaching
1-5 %
Fine-Grained Sediment Areas
15-25 %
Inflow at Upstream Boundary
0-2 %
Flux from Beds
Legacy Sediment
15-35 %
Invista Outfall
3-5 %
Other
(tribs, runoff, GW)
5-15 %
Percent of MeHg supply that ends up in smallmouth bass
Assumes MeHg fully exchanges among compartments at base of food web
IHg
MeHg
Abiotic Pathways
Relative River Mile 0 to 10
Baseline Flow (<300 cu. ft./sec.)

1 Hg release-age deposit (floodplain) and eroding banks
2 Interflow during precipitation events
3 Overland flow / TSS
4 Alluvial groundwater advective flux (near-bank deposits)
5 Fine-grained channel margin deposit
6 Hyporheic flow and stream bed pumping
7 Fine-grained particles in gravel bed (embedded reaches)

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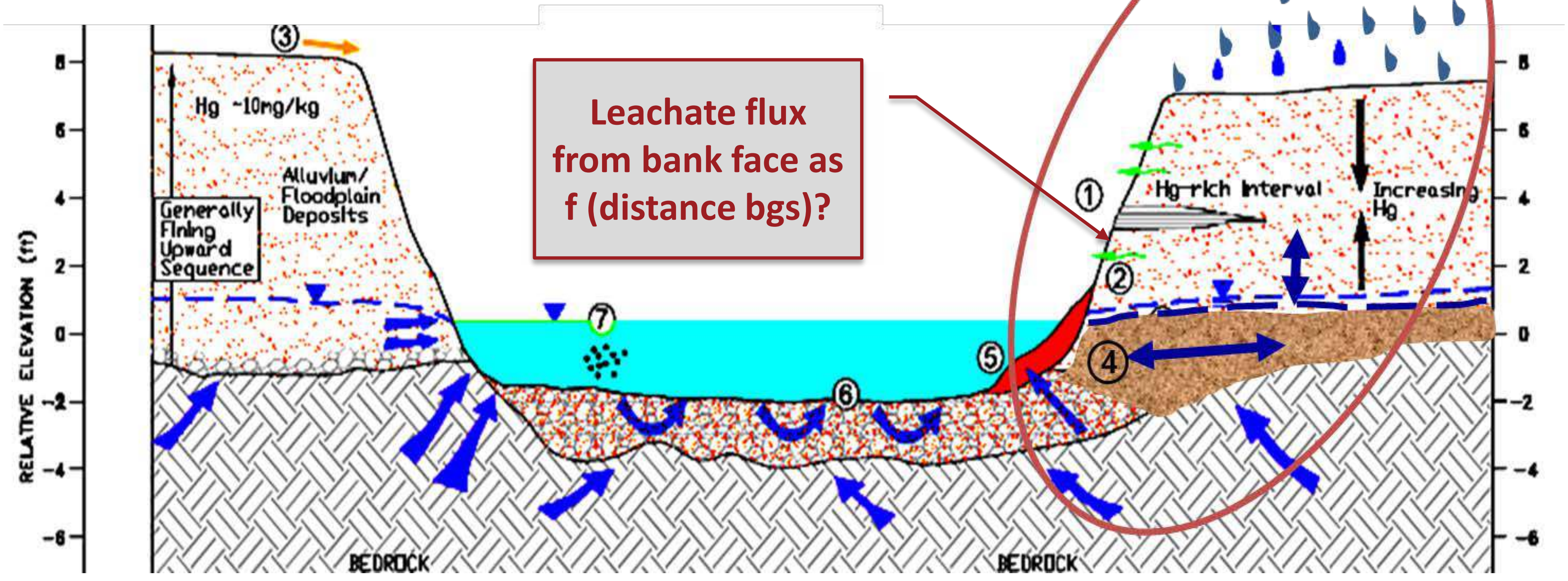
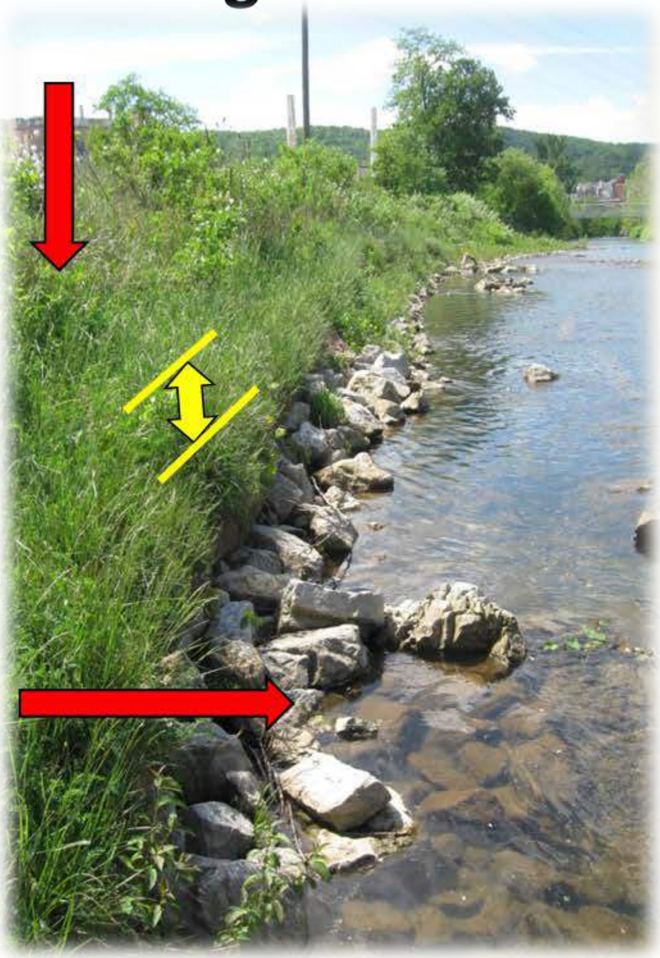
Focus of Test Site at RRM 3.5



How Do We Estimate TlHg and MeHg Loading to the South River Via Bank Leaching?

Possible Approximations of Bank Leaching

- Model #1: THg leaching under seepage flow from saturated water columns at U. Waterloo (current CSM)
- Model #2: Rainfall infiltration across limited near-bank floodplain area x THg leachate concentrations from humidity test cells at U. Waterloo
- Model #3: URS hydrogeologic model to estimate GW flux x measured THg concentrations in piezometer wells at RRM 3.5 study area



Percent Contribution of Bank Leaching to Water-Column Loading

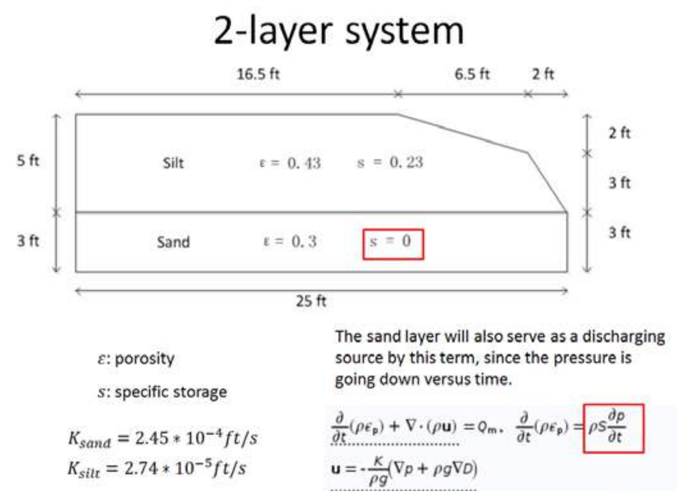
95% (50%) Probability Values from Monte Carlo Simulations

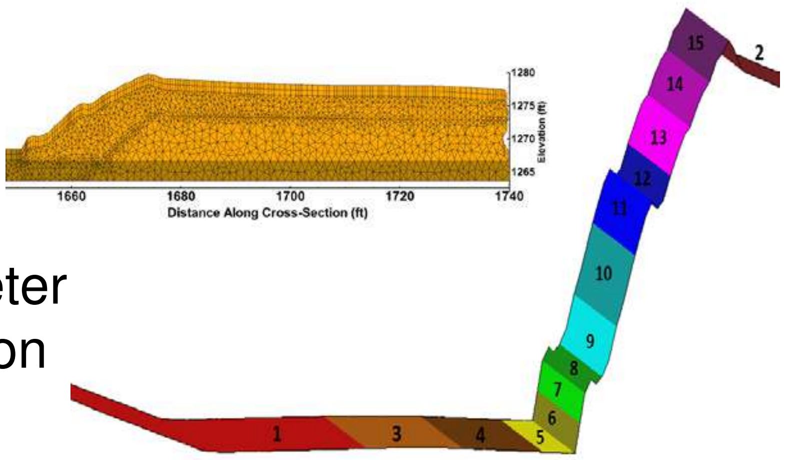
Model #	Description	UTHg	FTHg
1	Sat. Column Flux	< 9% (3%)	< 17% (6%)
2	Precipitation Infiltration	< 14% (6%)	< 7% (3%)
3	GW HydroGeo Model	< 6% (3%)	< 17% (8%)

March 2014 calculations suggested larger contribution to both unfiltered & filtered THg water-column loading **(5 to 15% @ 95 percentile) assuming HRAD conditions along both banks.**

Refinement of Bank Leaching Model

- Increased model complexity (rigor) to better simulate groundwater-surface water hydrodynamics
  - ✓1D, 1-layer analytical model → 2D and 3D multilayer numerical models
  - ✓Texas Tech (Reible research group) 2-layer (silt and sand) finite-element model
  - ✓Aquanty's HydroGeoSphere Simulator: 3D control volume finite-element simulator for modeling entire terrestrial portion of hydrologic cycle (15 domains /"layers")
- Appropriately matched DGT and piezometer well [Hg] data to drainage/seepage location
- Reconciled Hg loading predictions from different models





South River Bank Leaching Models
Texas Tech and Aquanty Comparison

Basis for Comparison

- Drainage Volumes: 3 ft river rise above baseline
- Storm Events: 12/yr @ 3 ft rise + 1/yr @ 5 ft rise
- [Hg] based on RRM 3.5 bank study (DGT + piezometer wells)
- Leaching occurs at 100% of banks on both sides of channel (worst case)
- Hg Loading: RRM 0 to 10, annualized, advective flux contribution

South River Bank Leaching Models
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Parameter	Texas Tech Model	Aquanty Model Case 1 (Base Case)	Aquanty Model Case 7 (High K)	Aquanty Model Case 4 (Equal K)
K_h for Silt Layer (ft/day)	2.3	1	10	10
K_h for Sand Layer (ft/day)	21	50	100	10
K_{silt}/K_{sand}	0.11	0.02	0.10	1.0
Total Drainage Volume for Silt Layer (L/ft)	25	1.5	47	151
Total Drainage Volume for Sand Layer (L/ft)	230	102	658	130
Total Drainage (L/ft)	255	103.5	705	281
% of Total Drainage Volume from Silt Layer	9.8%	1.4%	6.7%	54%

South River Bank Leaching Models
Texas Tech and Aquanty Comparison

Parameter	Texas Tech Model	Aquanty Model Case 1 (Base Case)	Aquanty Model Case 7 (High K)	Aquanty Model Case 4 (Equal K)
% Contribution to Total UTHg Load (Storms + Baseline)	10%	0.2%	5%	13%
% Contribution to Total UTHg Load (Storms Only)	7%	0.3%	6%	16%

Advective Hg flux due to bank leaching during a flood event contributes up to only 15% of total unfiltered Hg load when assuming HRAD conditions along both banks. Confirms March 2014 analysis.

Key Take-Home Messages

- All models to date suggest that advective Hg flux due to bank leaching contributes < 15% of total unfiltered Hg load to the river.
- During a flood event, > 90% of infiltration and inundation water drains downward, exiting through the more highly transmissive basal gravel/sand layer at the base of a bank.
- GW velocities used in water-saturated soil columns at U. Waterloo agree well with drainage/seepage velocities predicted by Aquanty (positive implications for proposed biochar treatment layer).

Key Take-Home Messages

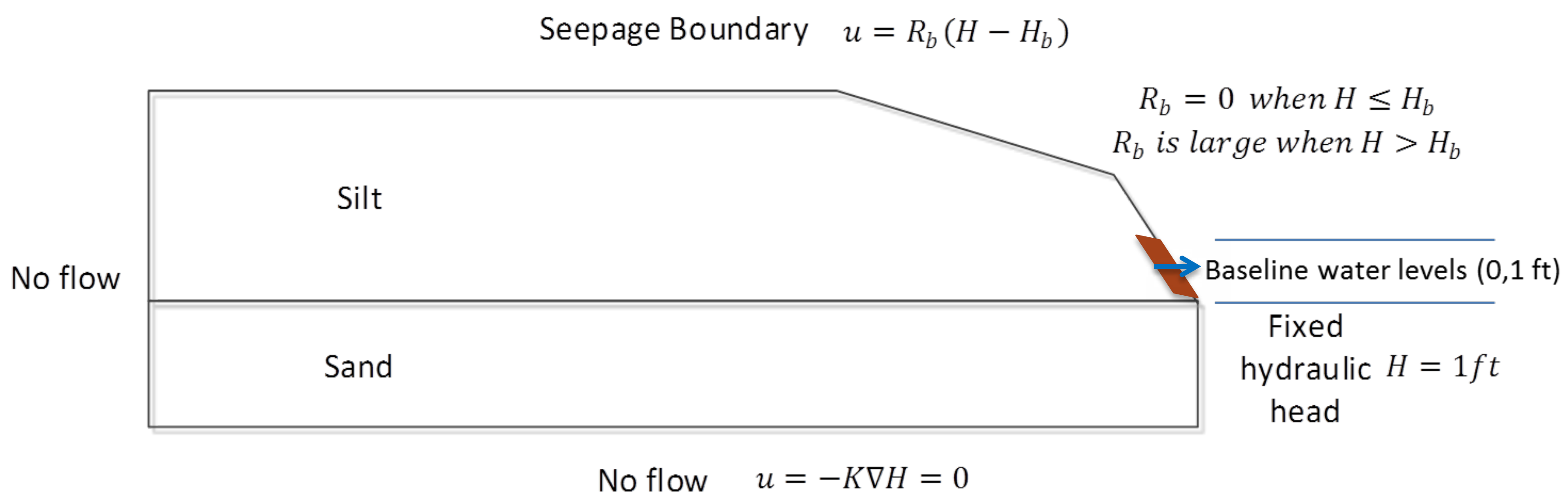
- Aquanty predicts that drainage of bank storage water through the basal gravel/sand layer occurs over 1 week to 1 month, meaning that bank leaching may partially contribute to Hg load during baseline flow.

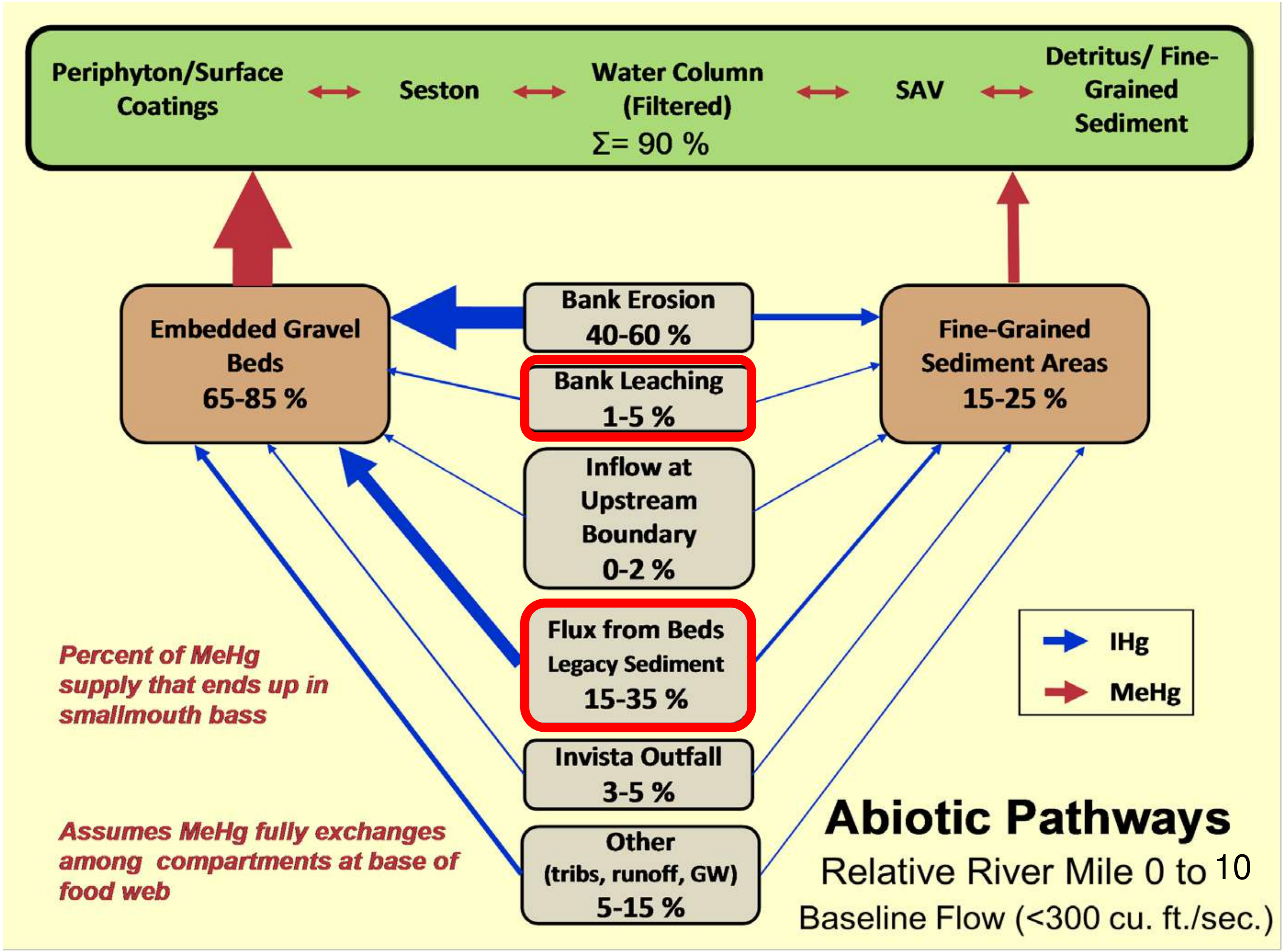
Parameter	Aquanty Model Case 1 (Base Case)	Aquanty Model Case 7 (High K)	Aquanty Model Case 4 (Equal K)
% Contribution to Baseline UTHg Load	1%	4%	1%
% Contribution to Baseline FTHg Load	2%	14%	3%

- Under this scenario, % contribution advective flux to baseline UTHg and FTHg load also < 15%.

Topic for Next ROPs Meeting

- Review of Texas Tech model results, including significance of potential diffusive flux contribution to bank leaching under baseline flow conditions.

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