



Revisit: Contribution of Bank Leaching to Hg Loading in Current CSM

*South River Science Team Meeting
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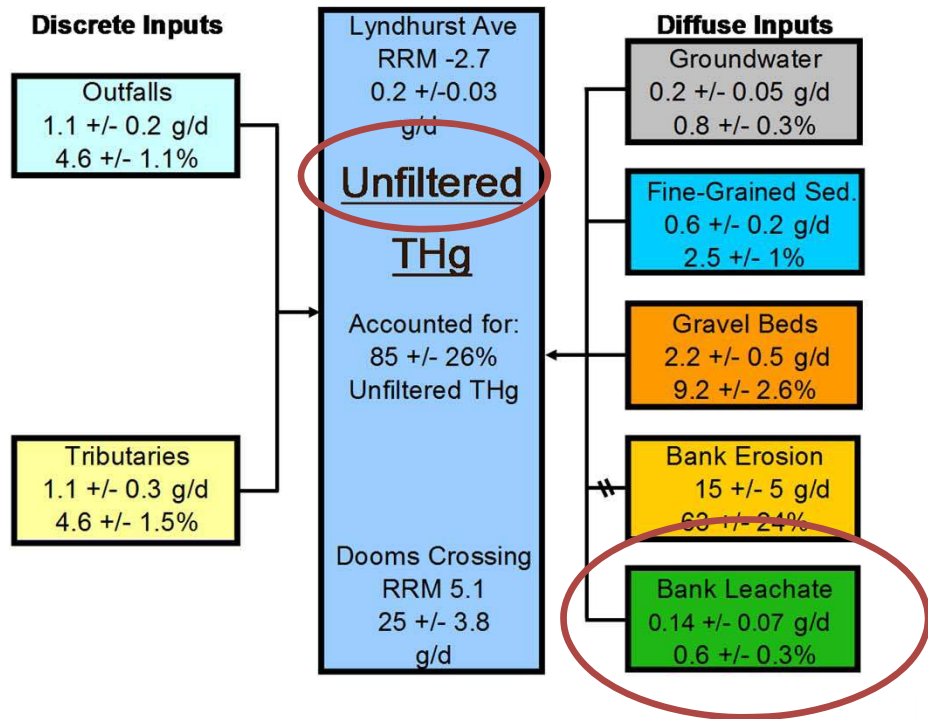
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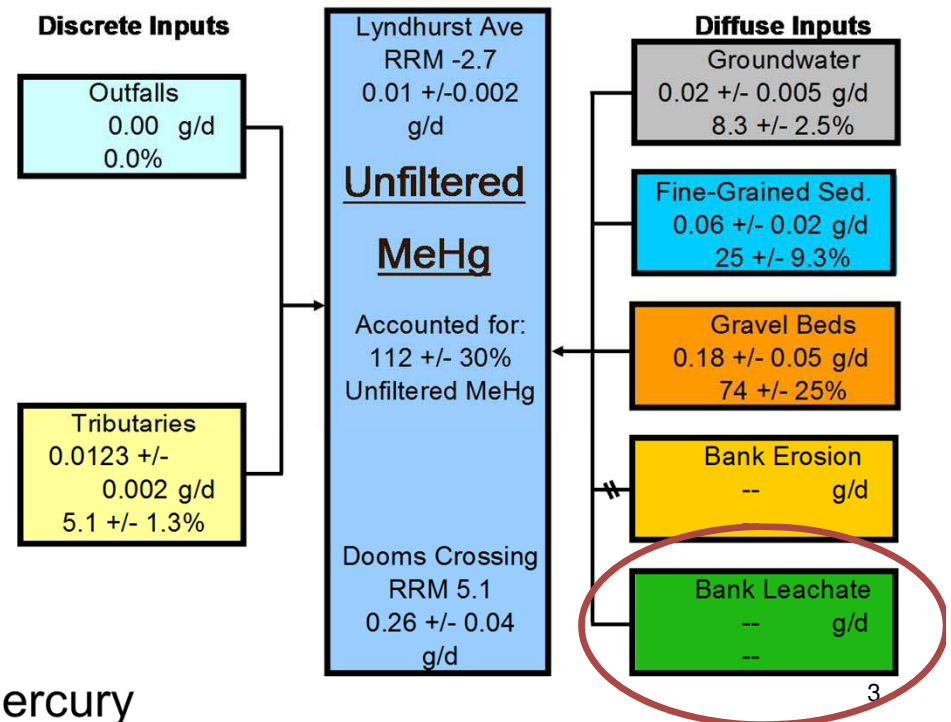
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Daily Water and Hg Mass Budgets - Lyndhurst to Crimora

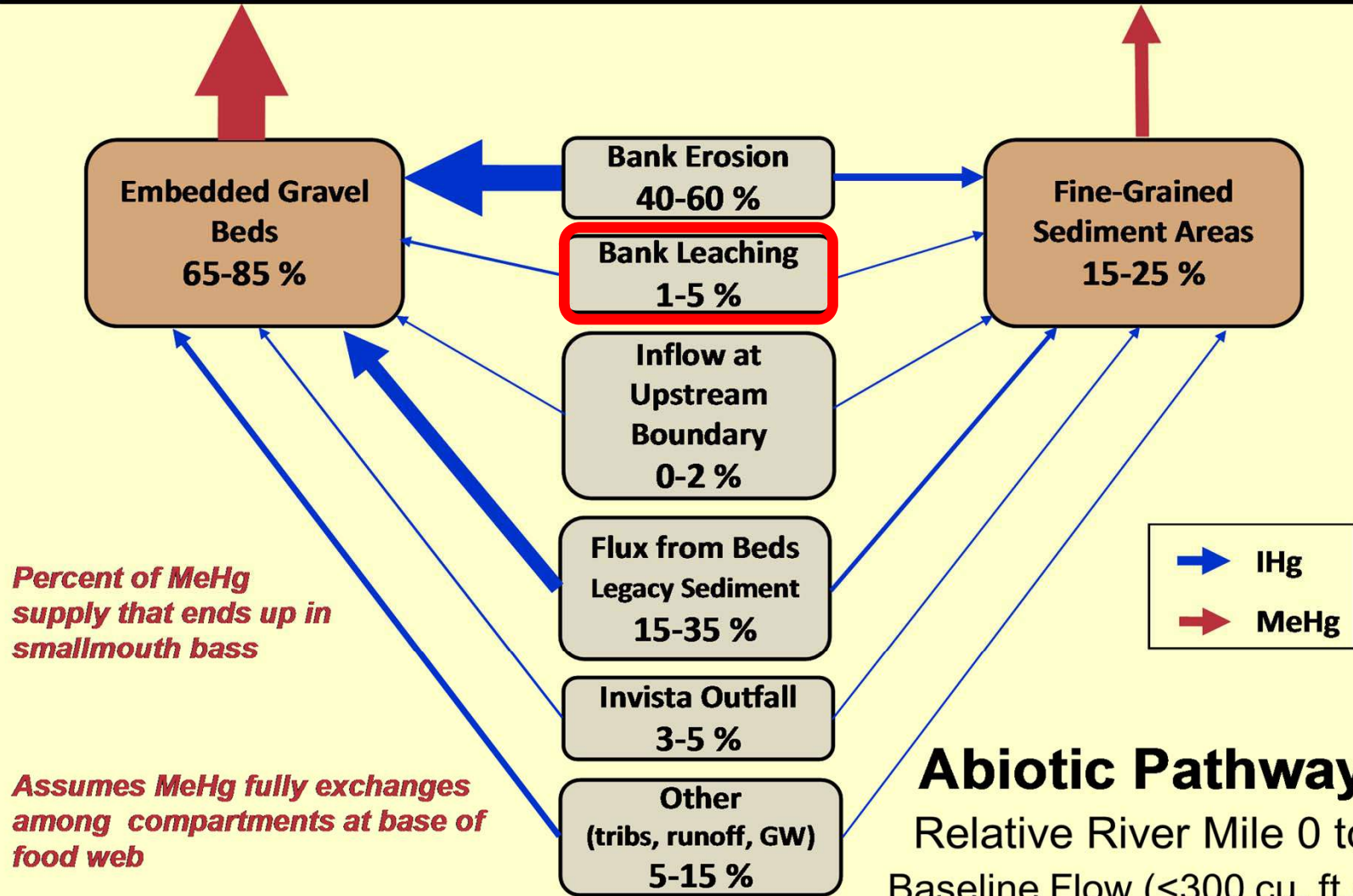
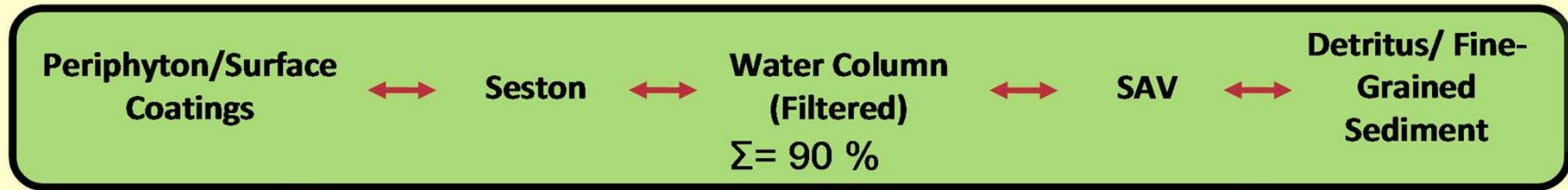


- Tributaries, millraces, wetlands & bedrock GW are minor sources
- Bank-to-bank sources important, particularly bank erosion and flux from embedded gravel beds



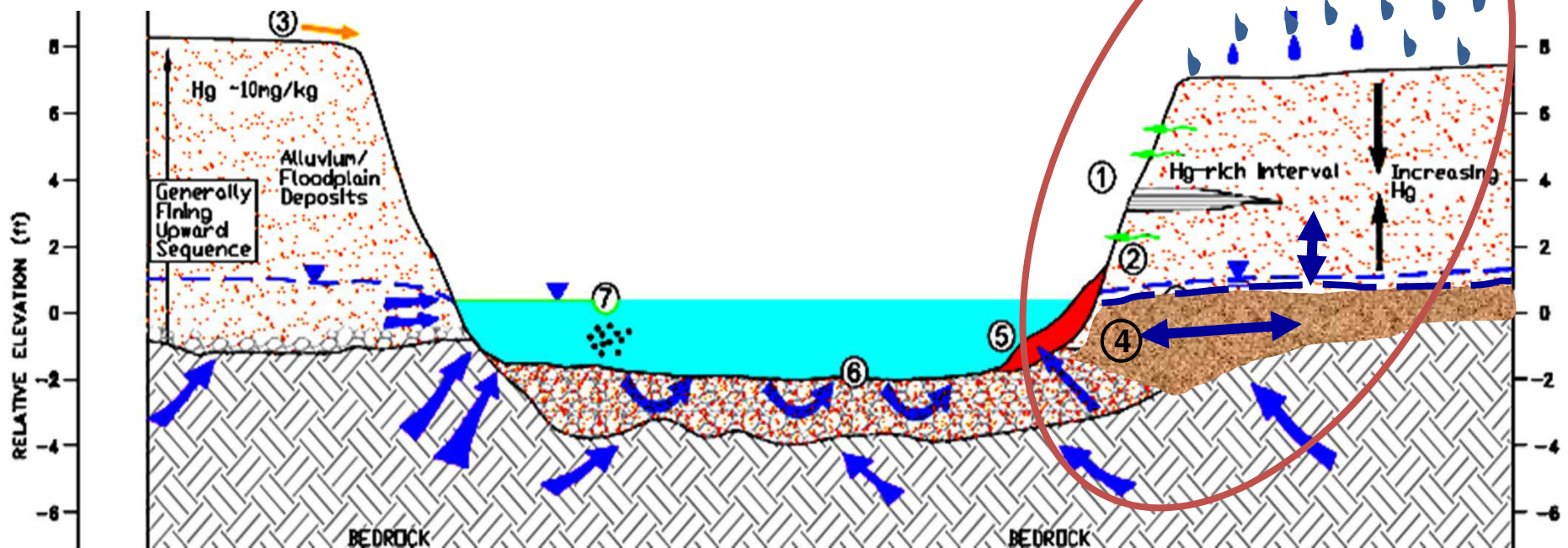
Note: All mass flux values were calculated independently, not by difference.

MeHg: Methylmercury; THg: Total Mercury



- 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)

Focus of Test Site at RRM 3.5

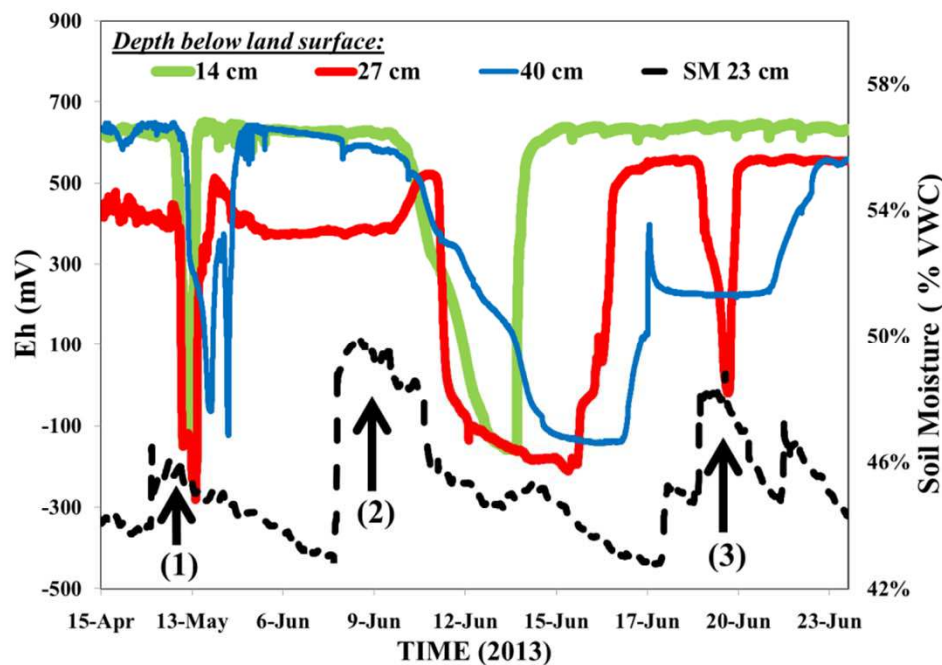


Primary Hypotheses Being Tested at RRM 3.5 Impacting Bank Leaching

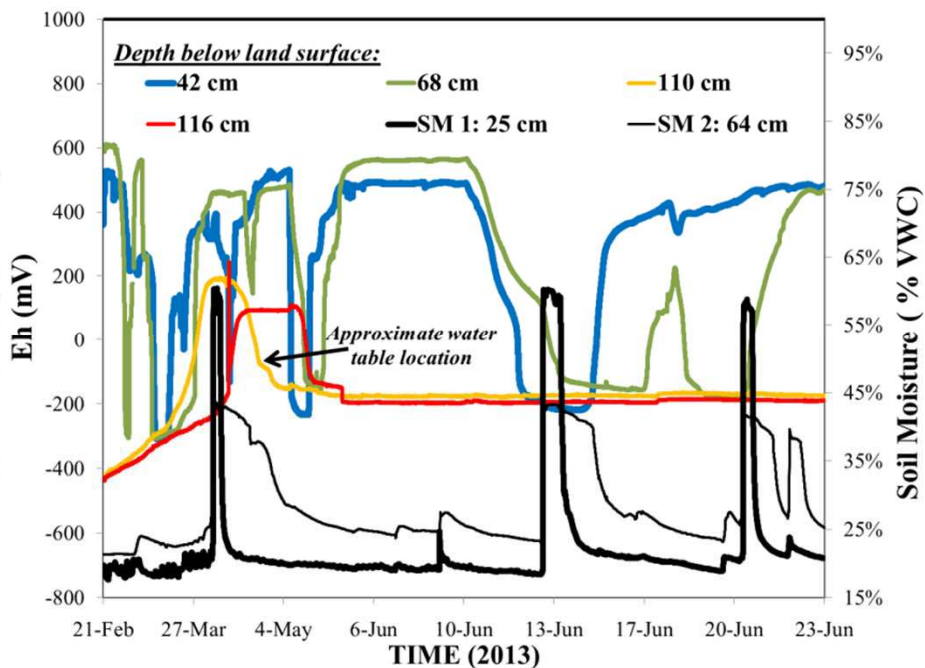
- Soil inundation, saturation and drainage occur
 - horizontally through a highly transmissive gravel zone at base of bank, wetting the organic-rich layer observed landward, and/or
 - vertically via drainage of precipitation and "interflow."
- Unsaturated/saturated soil conditions exist due to either sustained low/high surface water flow, facilitating downward/upward movement of capillary fringe. This affects soil redox potential, mineral dissolution, & Hg leaching from solid phase into dissolved & colloidal phases that are released to river.
- Inundation of near-bank floodplain soil can stimulate microbial methylation of IHg, potentially increasing MeHg production & transport to river via alluvial GW.

RRM 3.5 Near-Bank Area Redox Cycling

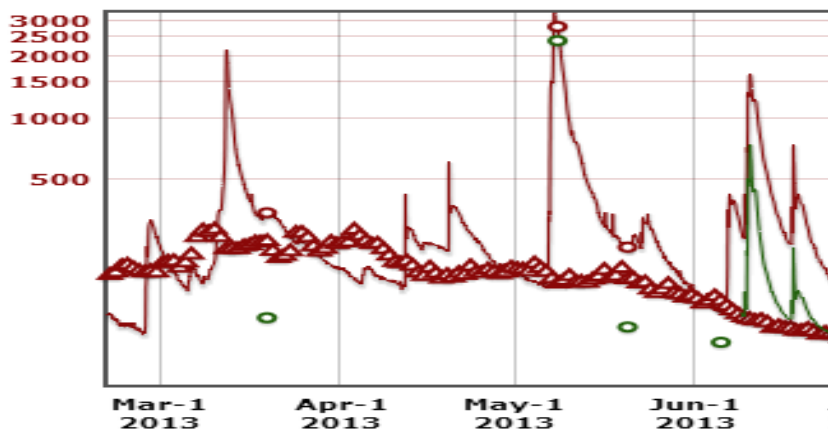
2 ft Inward from Bank



6 ft Inward from Bank



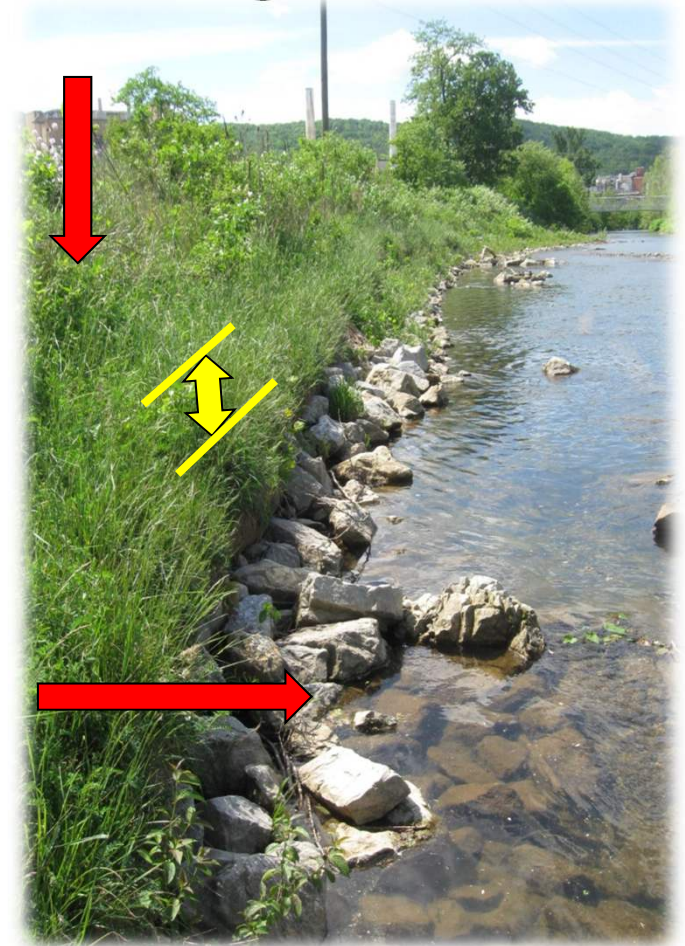
USGS 01626850 SOUTH RIVER NEAR DOOMS, VA



How Do We Estimate THg 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



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

Model Uncertainties

- Each conceptual model of bank leaching is an approximation
- Storm vs. base flow conditions
- Limited data from only one study area (anomalous?)
- Hg data from piezometer wells represent snapshot in time closer to base flow than storm flow conditions
- Extrapolation over entire river reach (temporal and spatial variability)
- Use probabilistic model to acknowledge some of these uncertainties

Basis for Model #1: U. Waterloo Saturated-Column Data

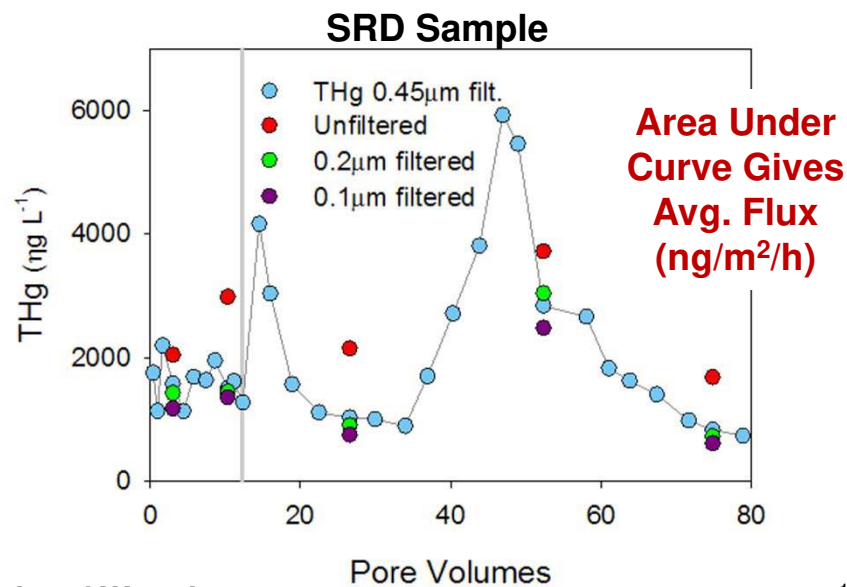
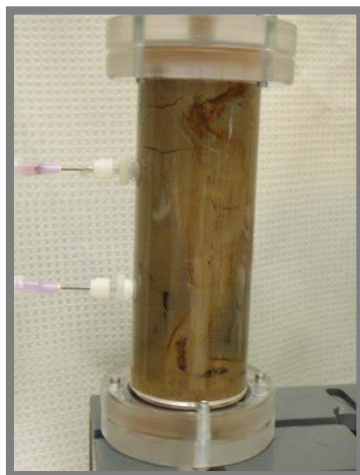


Bank Stabilization Pilot Area (RRM 0.1)



RRM 3.5 Study Area

Saturated
Column
Tests at
U. Waterloo



Model #1: Calculation Assumptions and Methodology

- Packed-column percolation tests at Waterloo using bank soils from RRM 0.1 & 3.5 yielded distribution of Hg flux rates

- FTHg: 30 to 5,000 ng/m²/h
- UTHg: 60 to 10,000 ng/m²/h

- **Sat. Soil Height x Bank Length = Sat. Bank Area (m²)**

- sat. soil height = 0.3, 0.6, 1 m

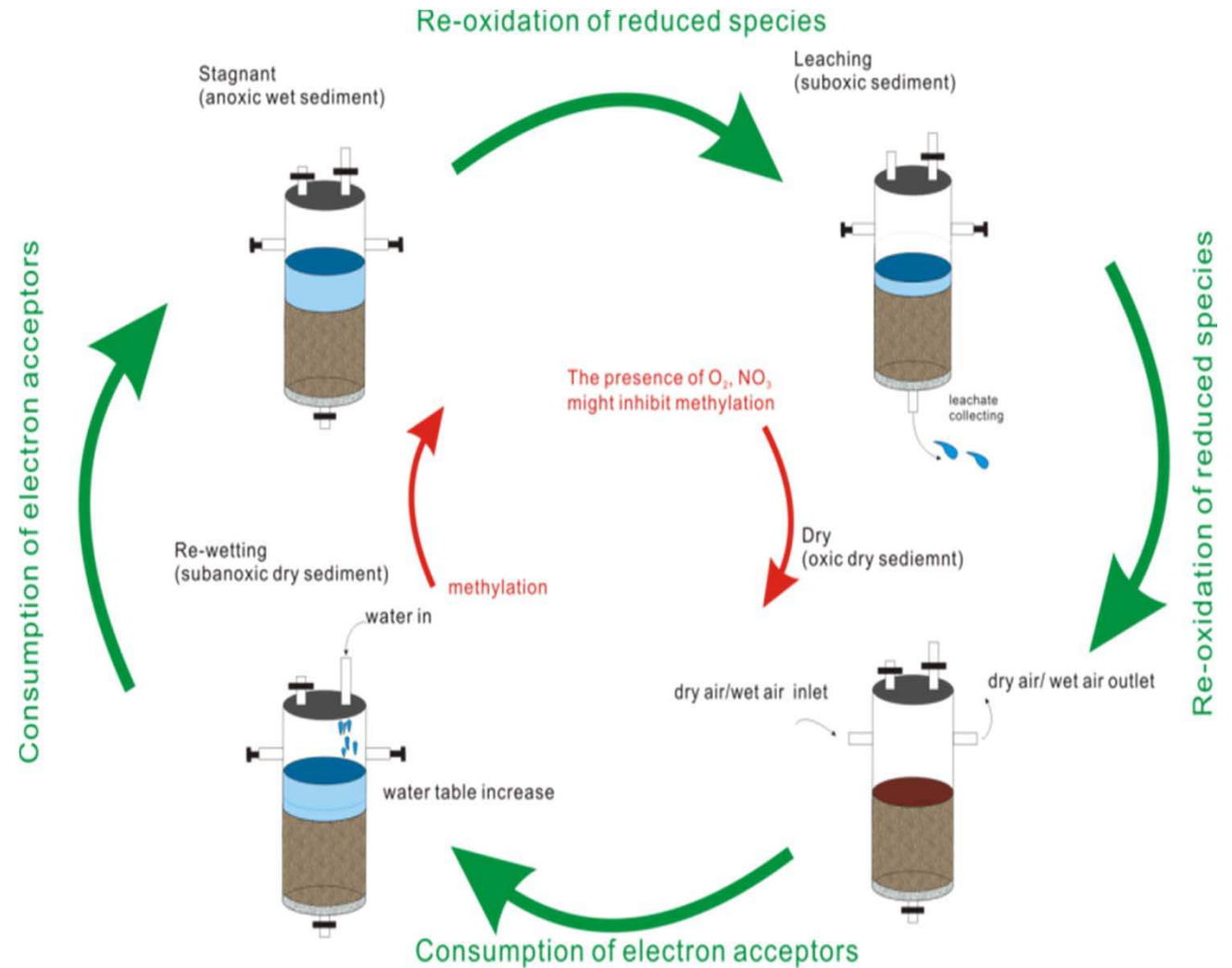
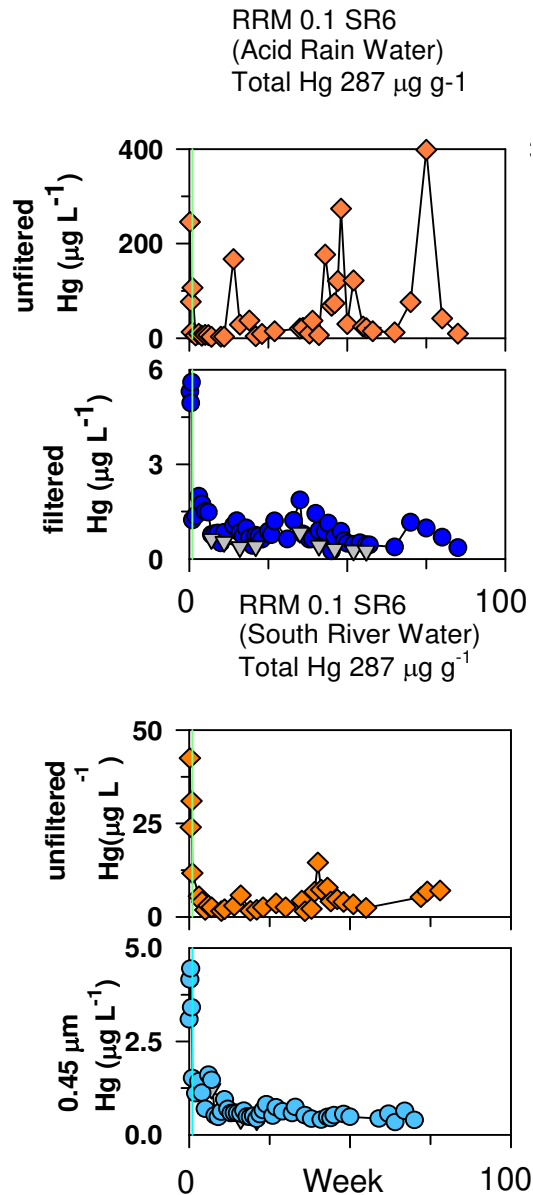
- **Mass Flux x Sat. Bank Area x % Leaching = Loading (g/d)**

- % bank length subject to this mechanism of leaching = 50-100%

Input	Name	Output	Unit	Comment
600	FHG_FLUX		ng/m ² /h	Mass flux rate FIHg
1200	THG_FLUX		ng/m ² /h	Mass flux rate TIHg
	CSAREA	19119.006720	m ²	cross-sectional area bank experiencing seepage
	BANK_LENGTH	31865.011200	m	Total length bank undergoing leaching
.6	BANK_HEIGHT		m	Height of bank undergoing leaching
100	PER_LEACHING		%	% bank length leaching
9.9	DISTANCE		mi	Length of river reach
	THG_LOAD	0.550627	g/d	TIHg loading from bank leaching
	FHG_LOAD	0.275314	g/d	FIHg loading from bank leaching
9.4	FIHG_WC		g/d	Water column loading filter-passing inorganic mercury
33.8	TIHG_WC		g/d	Water column loading unfiltered inorganic mercury
	%FIHG	2.928869	%	% bank leaching as filter-passing inorganic mercury
	%TIHG	1.629075	%	% bank leaching as unfiltered inorganic mercury

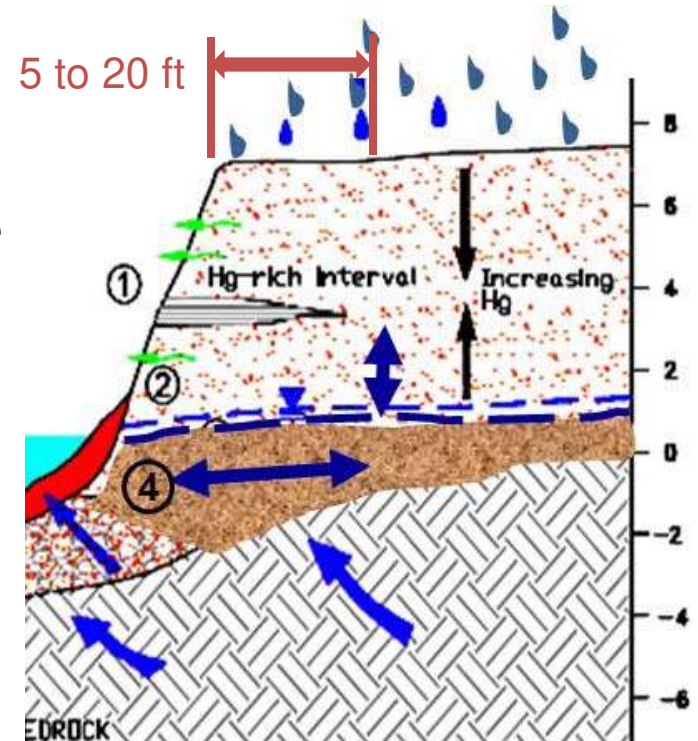
Name	Unit	Description	Distribution
FHG_FLUX	ng/m ² /h	Mass flux rate FIHg	Trapezoidal (30,200,1000,5000)
THG_FLUX	ng/m ² /h	Mass flux rate TIHg	Trapezoidal (60,400,2000,10000)
BANK_HEIGHT	m	Height of bank undergoing leaching	Triangular (0.3,1,0.6)
PER_LEACHING	%	% bank length leaching	Triangular (50,100,75)
FIHG_WC	g/d	Water column loading filter-passing inorganic mercury	Triangular (7.8,11.3,9.4)
TIHG_WC	g/d	Water column loading unfiltered inorganic mercury	Triangular (28,40,33.8)

Basis for Model #2: U. Waterloo Humidity Test Cell Data



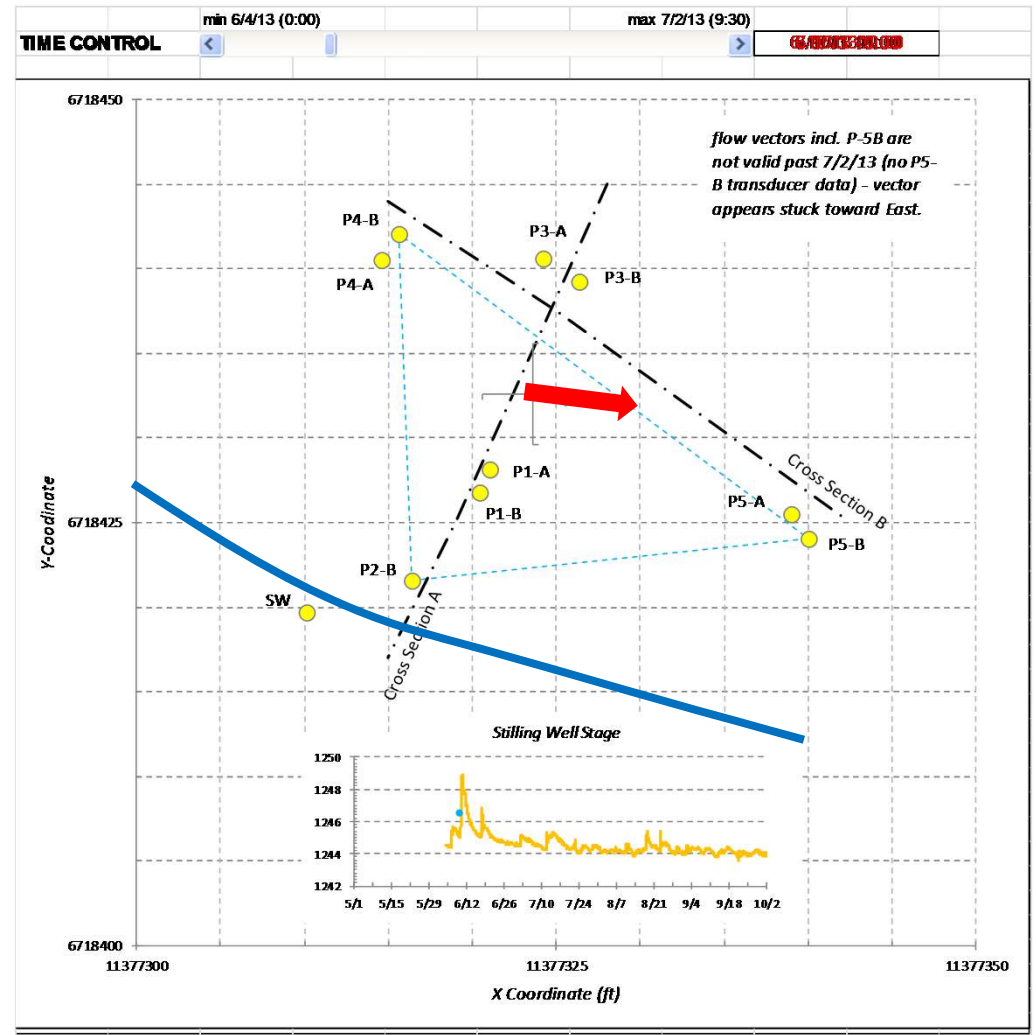
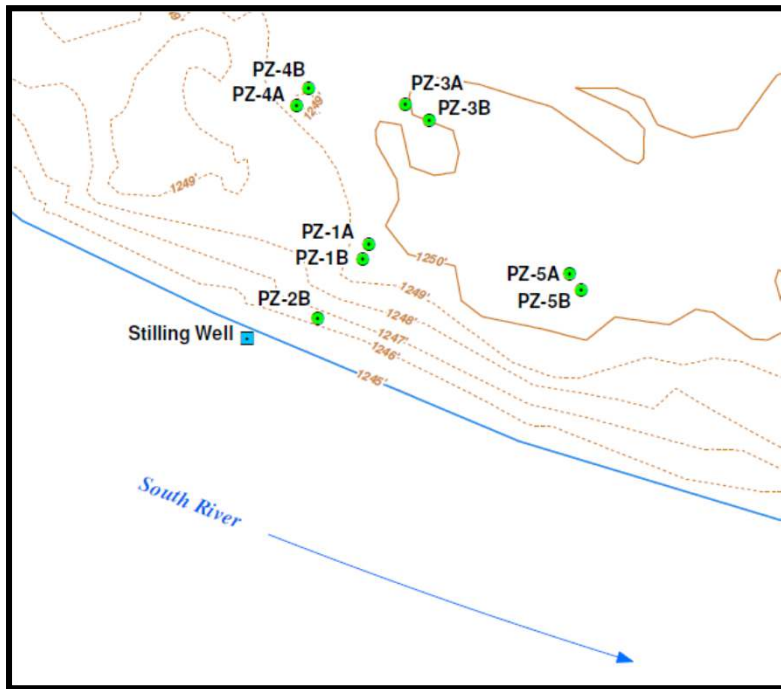
Model #2: Calculation Assumptions and Methodology

- Humidity test cells using bank soils from RRM 0.1 & 3.5 and acid rain yielded wide distribution of Hg concs. in leachate
 - FTHg: 200 to 2,000 ng/L
 - UTHg: 1,500 to 12,000 ng/L
- **Near-Bank Width x Bank Length = Infiltration Area (m²)**
 - Width = 5 to 20 ft.
- **Precipitation x Infilt. Area x % Infilt. x Hg Conc. Humidity Test Cells = Loading (g/d)**
 - 25 to 50 in. rain annually (Invista plant)
 - 5 to 20% infiltration



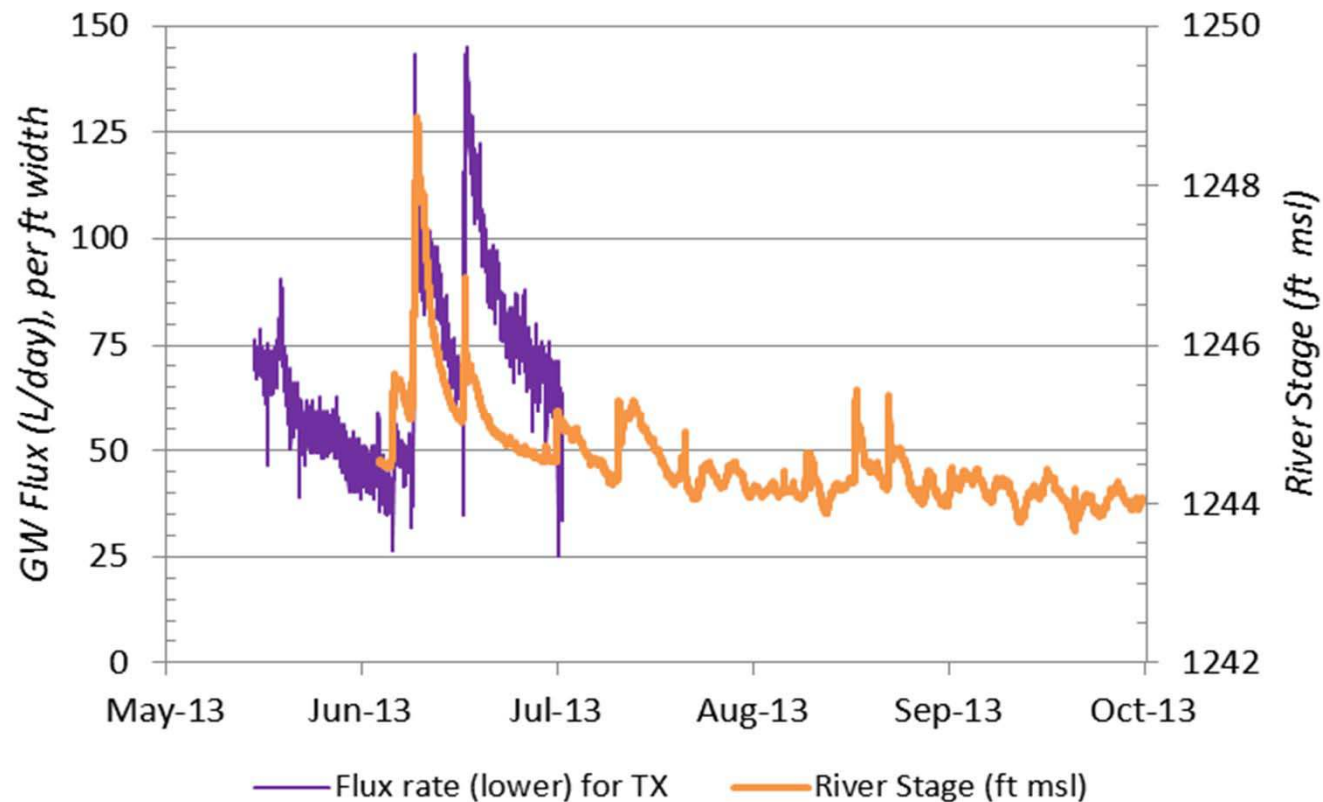
Basis for Model #3: URS Groundwater Model @ RRM 3.5

RRM 3.5 Study Area



Basis for Model #3: URS Groundwater Model @ RRM 3.5

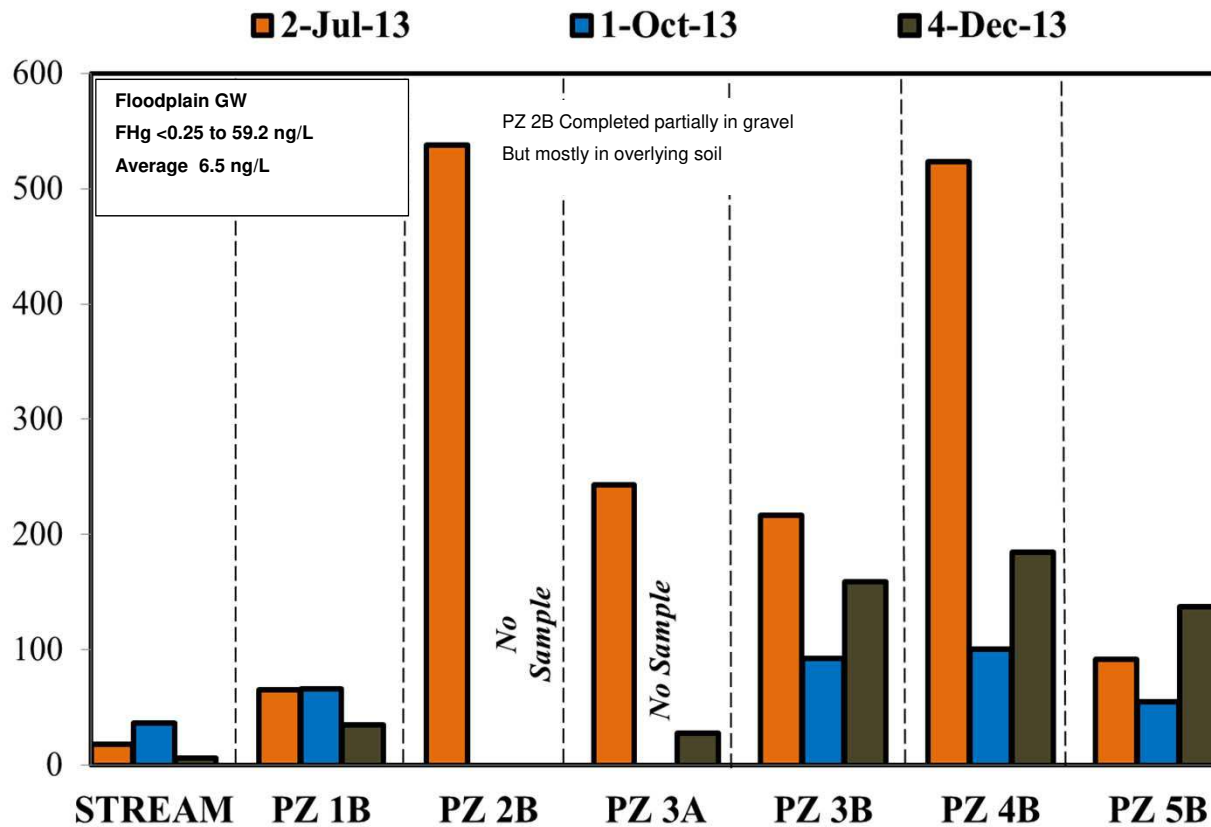
**Triangulation P2-B / P5-B / P4-B Study Period
May – July 2013**



Basis for Model #3: Piezometer Well Data @ RRM 3.5

Filter-Passing THg

Total Hg Concentration (ng/L) in Groundwater at RRM 3.5, South River, VA



Model #3: Calculation Assumptions and Methodology

GW Flux

- Min. GW flux = 25 - 50 L/d/ft bank (baseline flow)
- Max. GW flux = 125 - 150 L/d/ft bank

GW Flux x Bank Length x % Leaching x Hg Conc. = Loading (g/d)

- Assume UTHg = 1.2 (FTHg)
- FTHg: 35 - 217 ng/L
- UTHg: 52 - 260 ng/L
- July extreme values (500+ ng/L) excluded
 - PZ-2B & -4B likely completed in overlying soils rather than gravel zone where alluvial GW flow occurs. PZ-2B & -4B results more aligned with leaching in humidity test cells (Model #2: FTHg = 200-2,000 ng/L)
- % bank length leaching like RRM 3.5 study area = 65 to 100%

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%)

Current CSM attributes 1 to 5% UTHg loading to bank leaching based on a deterministic (rather than probabilistic) model

Conclusions

- GW-SW interaction, along with its impact on Hg mobility and methylation, is being studied at RRM 3.5 (HRAD)
- Current CSM: Contribution of bank leaching to UTHg water-column loading is 1 to 5%
- New data suggest larger contribution to both unfiltered & filtered THg water-column loading (5 to 15% @ 95 percentile) assuming HRAD conditions along both banks
- RRM 3.5 study area may help us gain more insight into bioavailable pool of Hg

Path Forward

- Basis of comparison in this analysis is Hg loading at base flow
- Next steps
 - Consider contribution to loading under storm flow conditions, which is when these dynamics occur
 - Estimate contribution of bank leaching to MeHg loading in water column. Current CSM assumes banks do not contribute to MeHg loading