Simulation Results Reaching New Heights
Technical Advisory Committee - Oct., 2008

DEQ Virginia Department of Environmental Quality

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Recap

- TAC 1 – TMDL process overview; Project study design
- TAC 2 – Nationwide review of Hg TMDLs; HSPF modeling approach; Empirical BAF model
- TAC 3 – Source characterization
- TAC 4 – Point source loadings; Hydrologic and sediment calibration; HSPF demo
- TAC 5 – Mercury calibration; Preliminary model results
- TAC 6 (today) – Existing condition results; TMDL reduction scenarios; Extrapolation to SF Shenandoah and Shenandoah Rivers; Sensitivity analysis

TMDL (Total Maximum Daily Load) regulatory process is driven by fish tissue Me-Hg concentrations being above 0.3 ppm

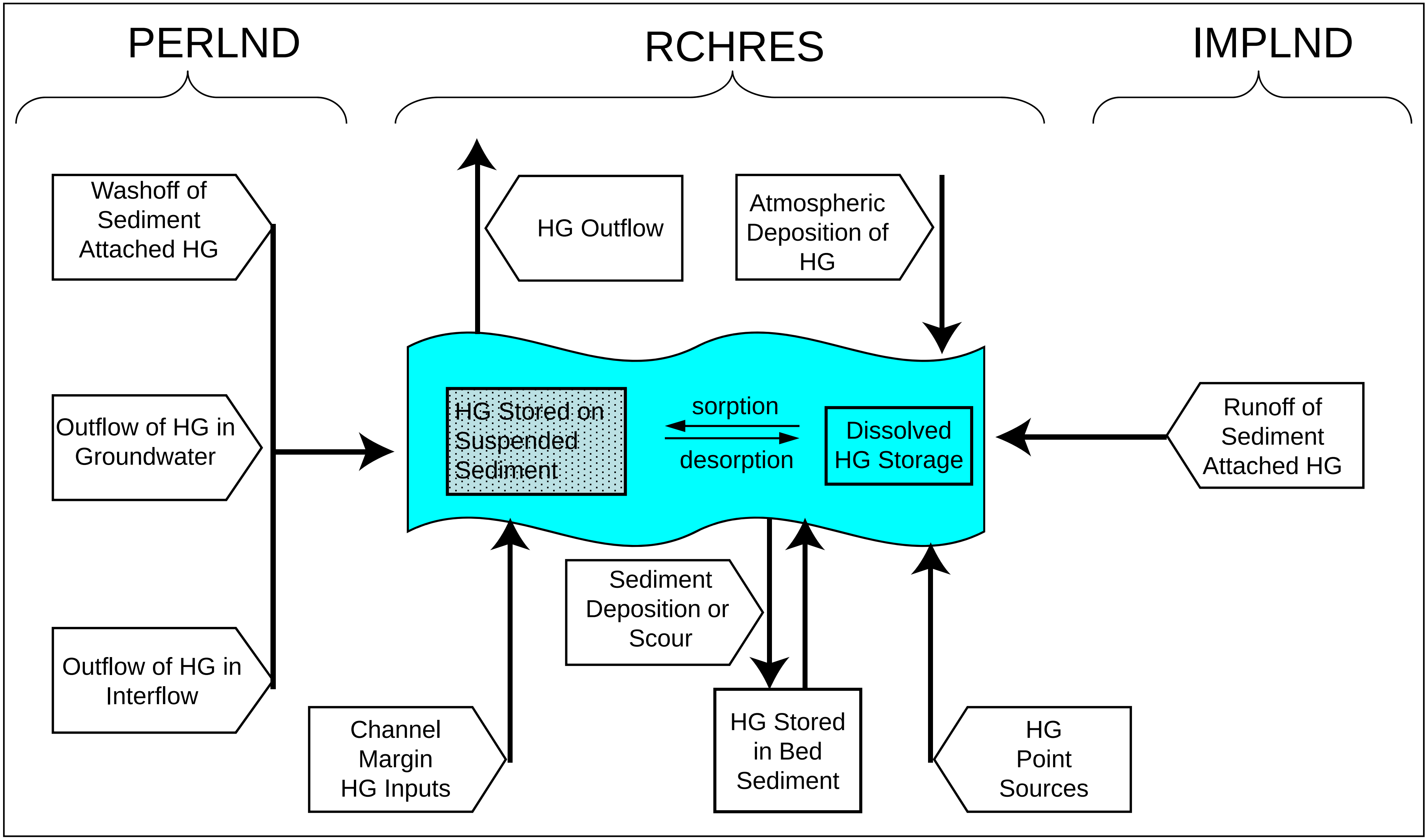
How much mercury can get into the South River without raising fish tissue Hg above 0.3 ppm?

Current load - No. Fish currently have Hg concentrations above 0.3 ppm
0 kilograms/year – Yes but not feasible.
10 kilograms/year - ??
1 kilograms/year - ??

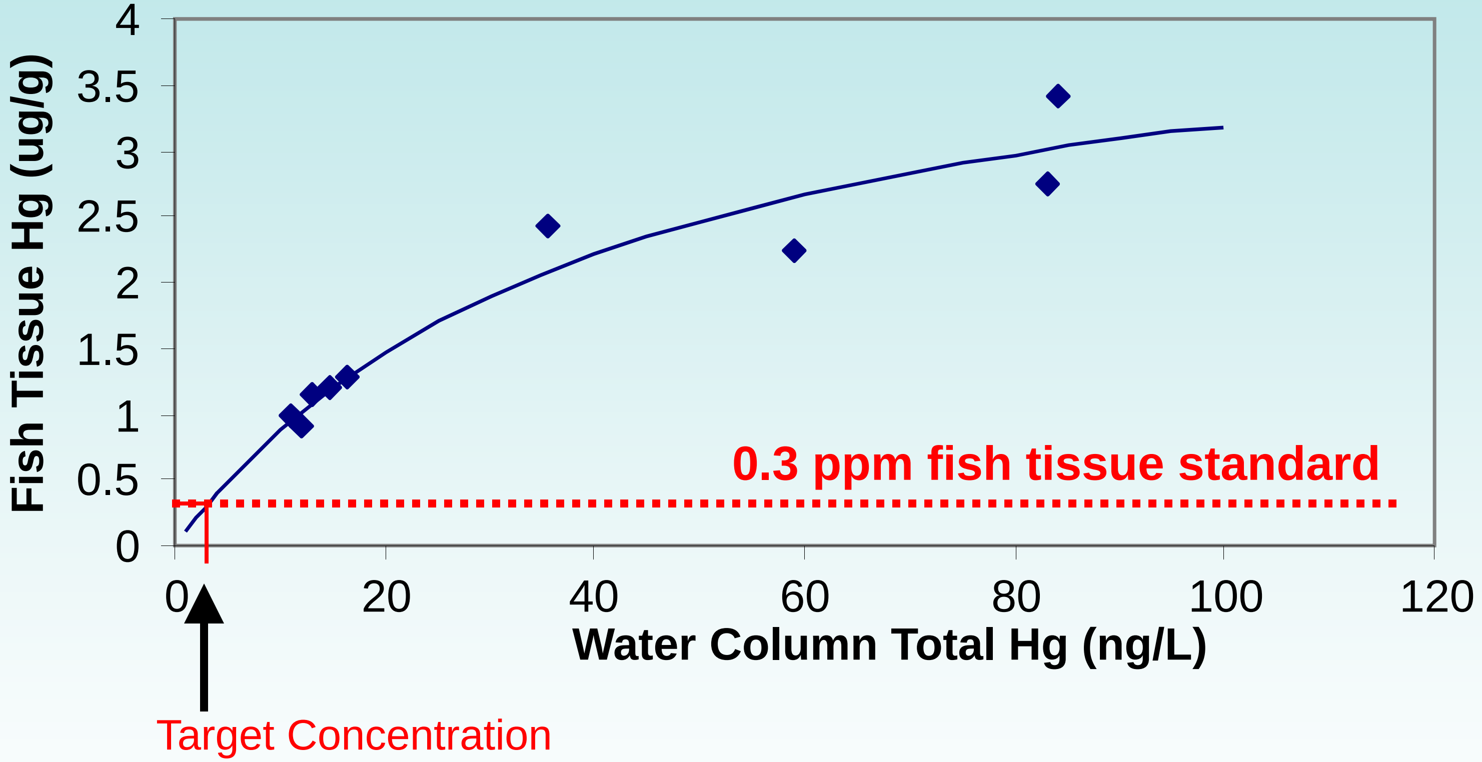
Goal of TMDL study is to answer the question using best available methods.

- Assumptions:
  - Mass balance of mercury, Hg bank account must be balanced
    - implemented via simulation using HSPF
  - Fish tissue Hg conc. derived from correlation with water column Hg
    - implemented via bioaccumulation factor model (BAF)

HSPF Simulation of Mercury in the South River Watershed



BAF model relates fish tissue Hg to water column Hg



- Relationship is not linear
- This non-linear relationship can be used to predict a protective water column concentration

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Target Concentrations Vary by River

Bigger fish have higher tissue Hg concentrations.
So rivers with bigger fish need lower aqueous Hg concentrations for fish to stay below 0.3 ppm Hg in fish tissue

Water body	Normalized Fish Size (g)	Target THG Concentration ng/L
South River	218	3.8
SF Shenandoah River	253	3.2
Shenandoah River	321	2.5

Simulated total Hg concentrations below the target are assumed to be protective of the 0.3 ppm fish tissue criterion

Simulated Existing Conditions, 2005-2007

Model River Reach	Reach End Node	Miles Downstream from Plant Site	THG Concentration (ng/L) Simulated median
1	Waynesboro (01626000)	-2.8	1.2
2	Hopeman Parkway (01626850)	2.3	21.7
3	Dooms (01626920)	5.3	69.6
4	Harriston (01627500)	16.5	91.4
5	Port Republic	24.0	93.4

Simulated Existing Conditions, 2005-2007

Model River Reach	Endpoint	USGS Station ID	Distance Downstream (mi)	Total HG Flux (kg/year)
1	Waynesboro	01626000	-2.8	1
2	Hopeman Pkwy	01626850	2.3	61
3	Dooms	01626920	5.3	148
4	Harriston	01627500	16.5	184
5	Port Republic	NA	24.0	189

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Modeled Mercury Sources to the South River

Hg Source to South R.	Data Used to Determine Initial Concentrations	How Simulated in Model
Atmos. deposition on river	EPA MADP (ref)	Precip HG = 21.8 ng/L
Groundwater/interflow from uncontaminated land areas	THG_F at Waynesboro gage (01626000)	Groundwater dissolved HG = 0.49 ng/L
Groundwater and interflow from HG cont. floodplain	Ground-water samples,	Groundwater HG = 2.9 ng/L
Sediment HG runoff from uncontaminated areas	Sediment samples from uncontaminated areas	THG_{Sed} = 0.07 (ug/g) for all uncontaminated HRUs
Sediment HG runoff from contaminated floodplain	Sediment samples within respective reaches	THG_{Sed} varies by reach and HRU from (7.6 to 16.7 ug/g)
Point source discharges	VAPDES data, grab samples, plant site monitoring data	Point sources to river, flow and HG flux specified
Channel margin inputs	THG at Waynesboro (01626000), Dooms (01626920), and Harriston (01627500)	Inputs tied to groundwater discharge and interflow, by reach

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Hg Loads under existing conditions

	Total Mercury (grams/year)					
Reach	1	2	3	4	5	Total all Reaches
Point Sources	1	604	0	0	41	646 (0.34%)
Direct Precip to River	28	7	2	11	8	55 (<0.1%)
Interflow Discharge	382	46	48	151	41	667 (0.35%)
Groundwater Discharge	54	8	7	24	6	99 (<0.1%)
Runoff	573	144	3,998	21,205	3,316	29,237 (15%)
Channel Margin Inputs	0	59,179	82,742	14,551	2,241	158,713 (84%)
Totals	1,038 (1%)	59,989 (32%)	86,797 (46%)	35,942 (19%)	5,653 (3%)	189,418 (100%)

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Channel Margin Inputs

Source of channel margin input mercury is contaminated bank materials along the river

Transport Mechanisms :

- Bank collapse (~100 kg/yr Rhoads, Oneal, Pizzuto 2008)
- Diffusion from contaminated channel bed (<1 g/yr)
- Ecological extraction of mercury, for example through periphyton growth (?)
- Disturbance of banks by animals, fishermen, boaters, researchers (~0.5 kg/yr)
- Diffusion into interflow and groundwater discharge (?)
- Displacement of contaminated material by interflow and groundwater discharge (?)
- Other mechanisms (?)

Model Scenarios involving changes to Hg loading

<table>
<tr><th>Type</th><th>Scenario #</th><th colspan="2">Changes to mercury loading</th></tr>
<tr><td>Existing conditions</td><td>1</td><td colspan="2">All current HG loads included</td></tr>
<tr><td>Future conditions</td><td>2</td><td>Point sources increased to maximum permitted discharge, outfall 011 added, precipitation and interflow concentrations reduced</td><td rowspan="6">All other future conditions main-tained</td></tr>
<tr><td rowspan="3">Single source reductions</td><td>3A</td><td>Pt. sources reduced to target stream concentrations</td></tr>
<tr><td>3B</td><td>Channel margin inputs eliminated</td></tr>
<tr><td>3C</td><td>Runoff cleaned up to background conditions</td></tr>
<tr><td rowspan="2">Multiple source reductions</td><td>4A</td><td>Channel margin loads eliminated and runoff cleaned to background conditions</td></tr>
<tr><td>4B</td><td>Additionally reduce pt sources to 3.8 ng/L</td></tr>
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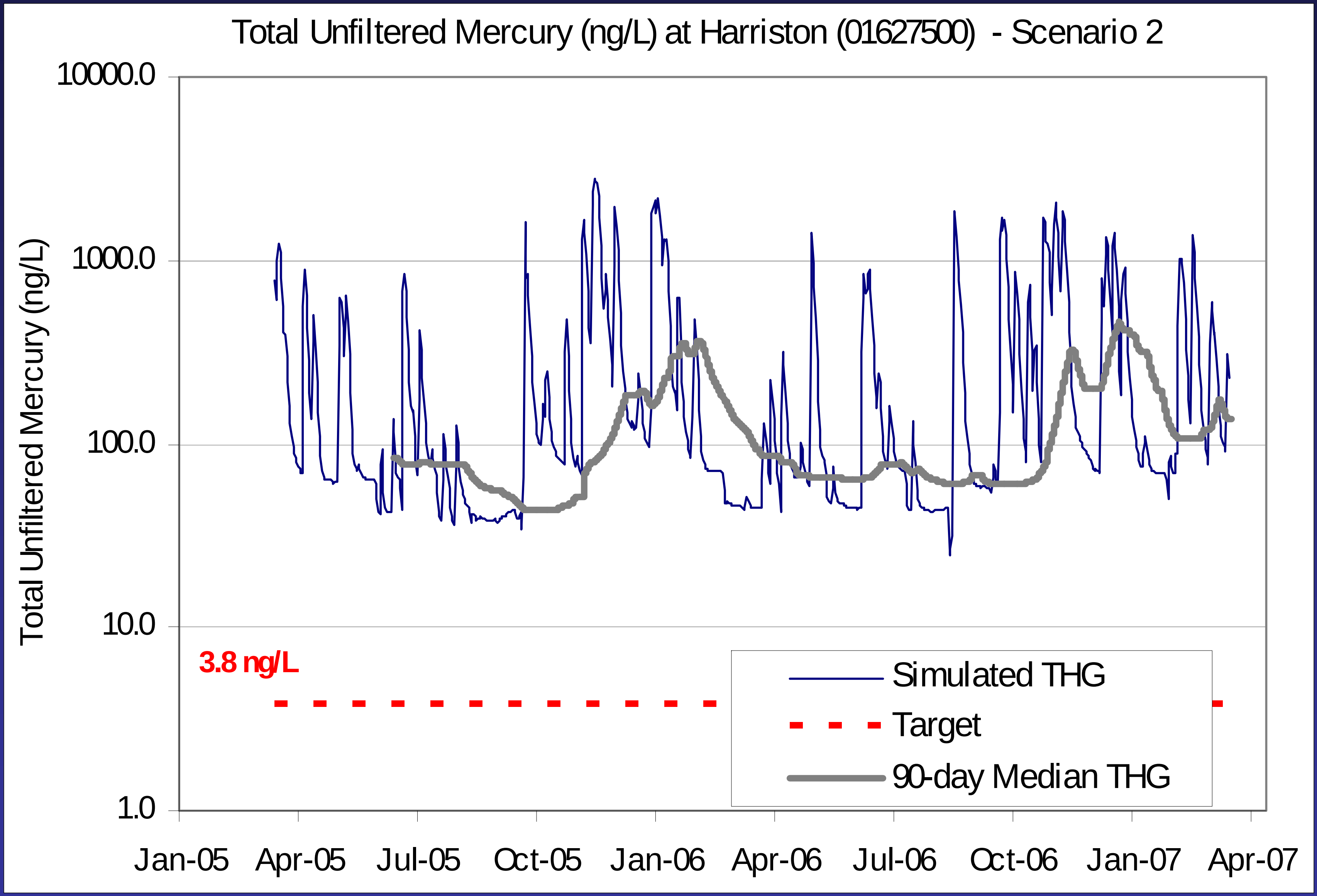
Model Scenario 2: Future Conditions



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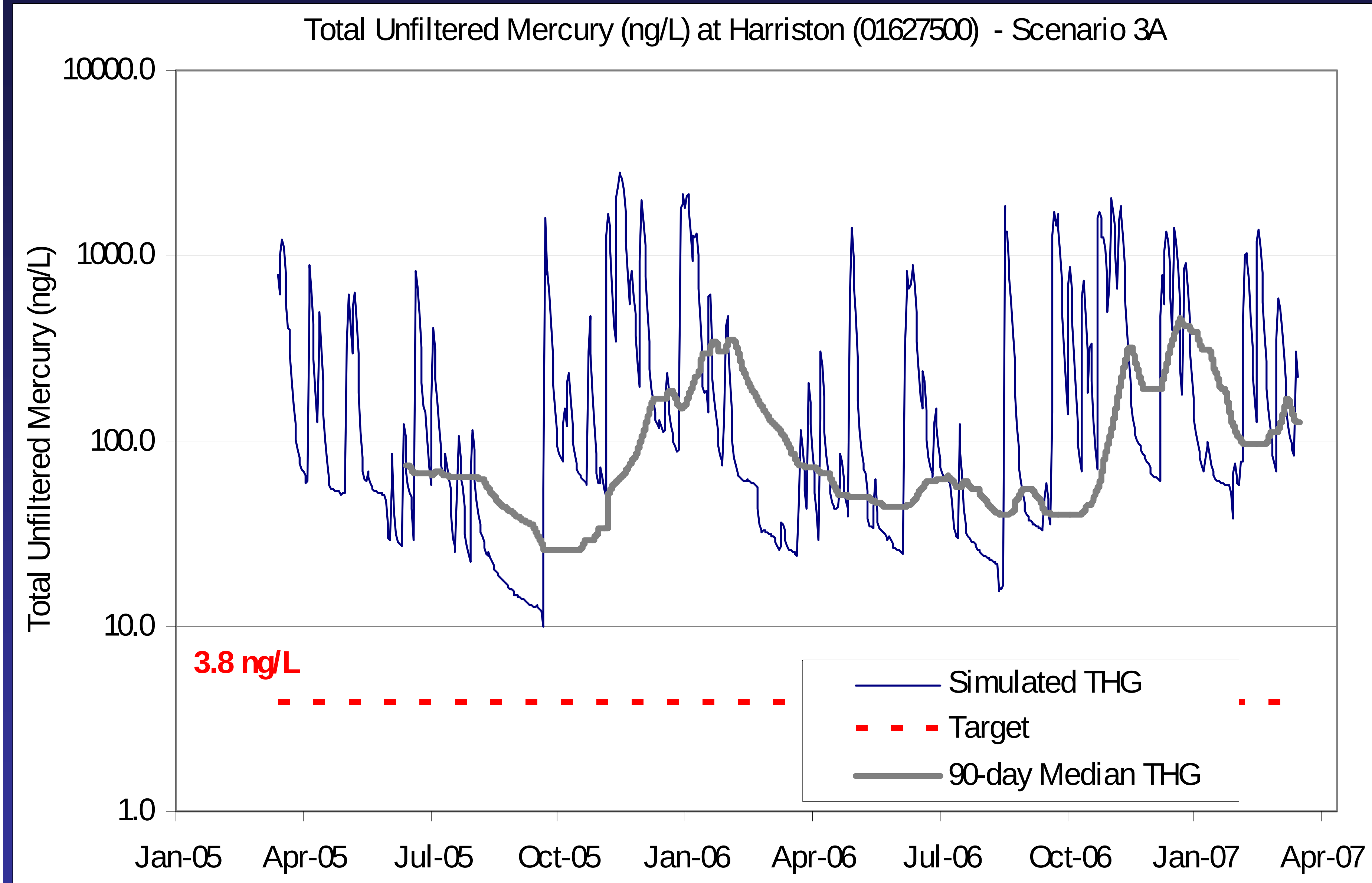
Model Scenario 3A: Point Sources Cleaned Up



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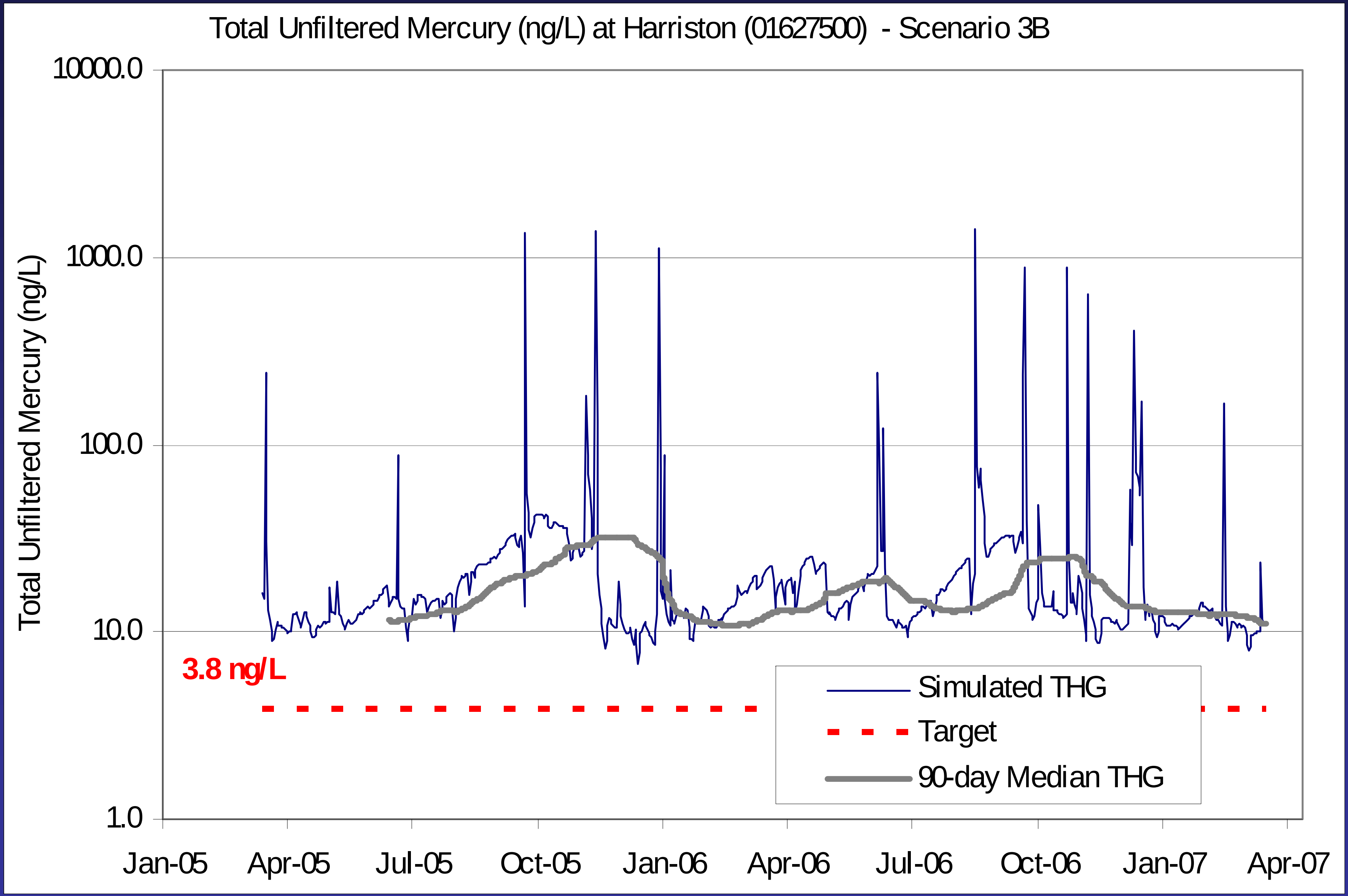
Model Scenario 3B: Channel Margin Inputs Eliminated



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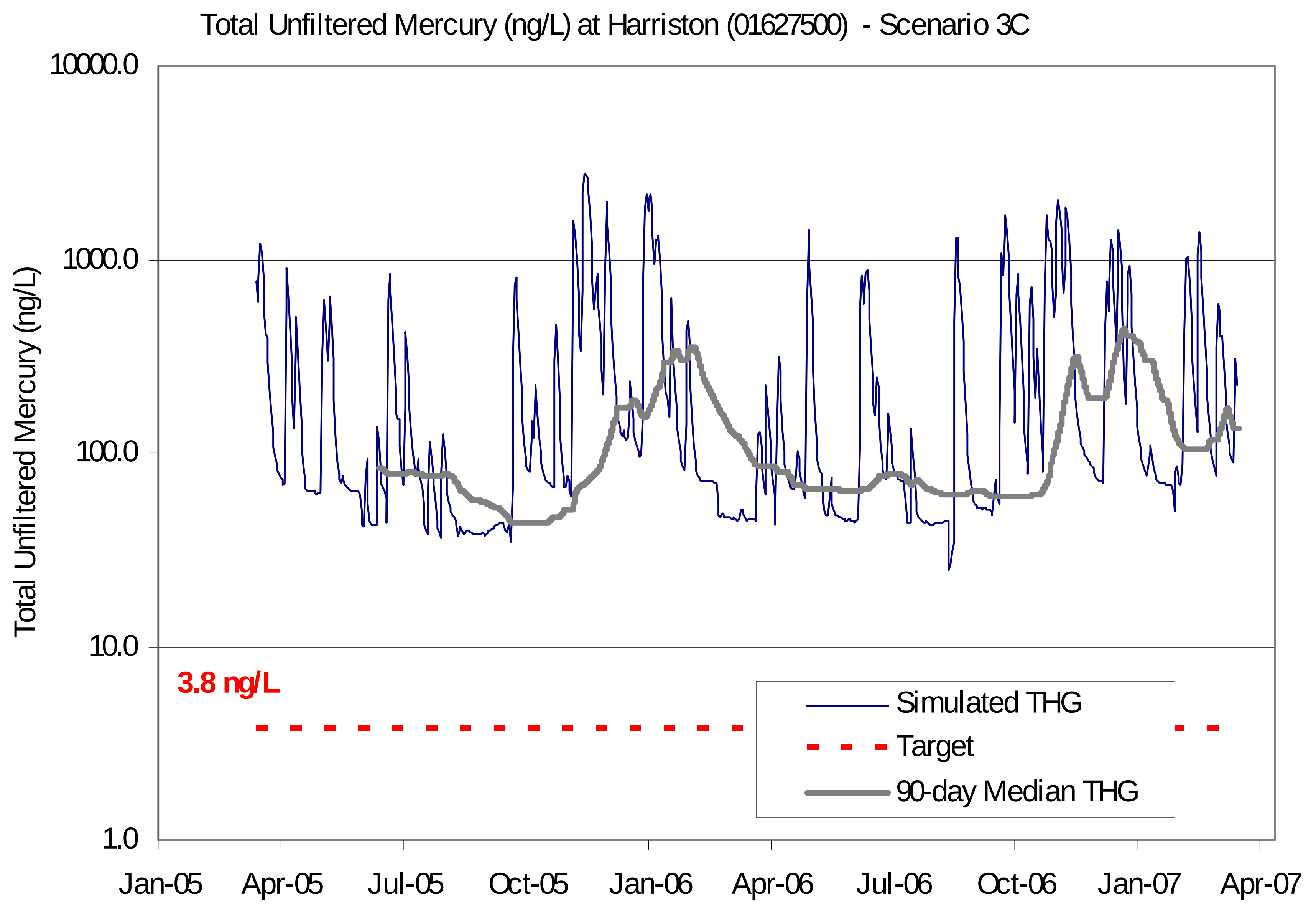
Model Scenario 3C: Runoff Cleaned Up



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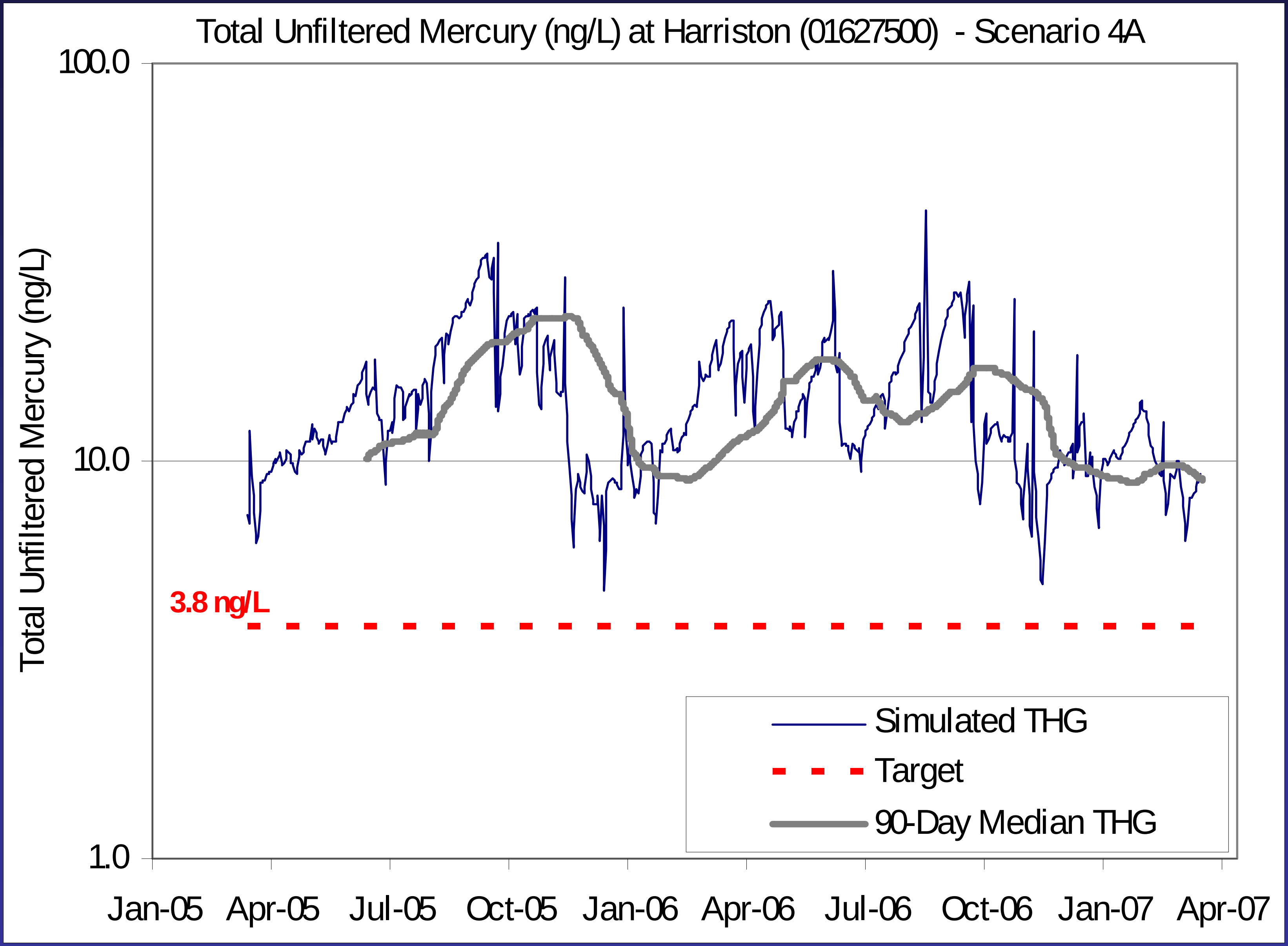
Model Scenario 4A: Channel margins and runoff cleaned up



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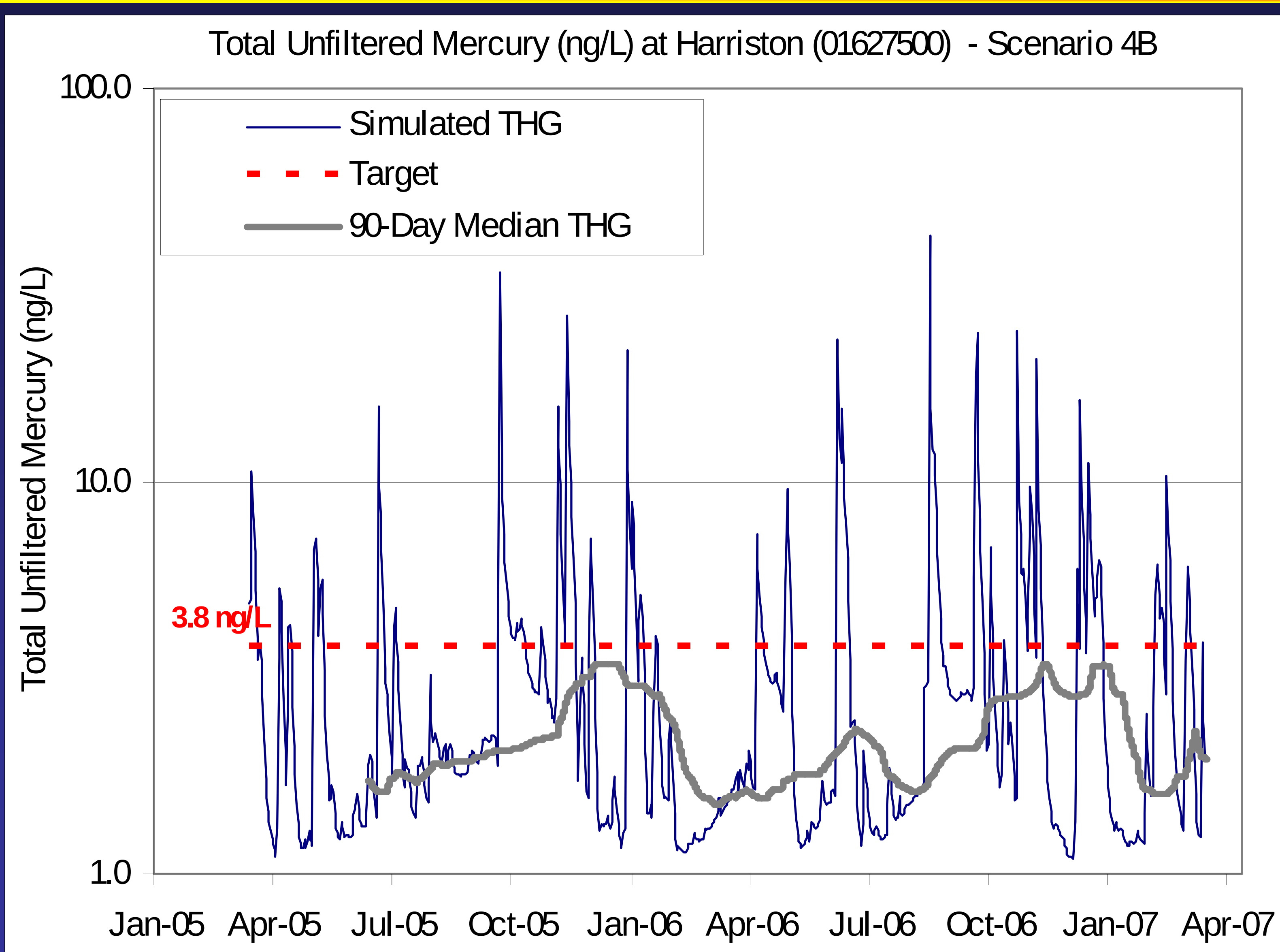
Scenario 4B: Channel margins, runoff, and pt sources cleaned up



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Hg Changes at Dooms under each scenario

Changes at Dooms (01626920) to THG loads and median concentrations (ng/L) relative to existing conditions

Scenario #	Scenario Description	% Change in Load	% Change in Concentration
1	Existing Conditions	-	-
2	Future Conditions	0%	13%
3A	Clean Pt Source	0%	-11%
3B	Clean Ch Margin	-96%	-77%
3C	Clean Runoff	-3%	9%
4A	Clean Ch Margin and Runoff	-99%	-78%
4B	Clean Ch Margin, Runoff, and Pt Sources	-99%	-97%

Scenario 4B: TMDL Scenario

	Existing Load grams	TMDL Load grams	Load Reduction %
Point Sources	646	107	-83%
Direct Precipitation to River	55	45	-18%
Interflow Discharge	667	544	-18%
Groundwater Discharge	99	99	0%
Runoff	29,237	1,216	-96%
Channel Margin Inputs	158,713	0	-100%
Total	189,418	2,010	-99%

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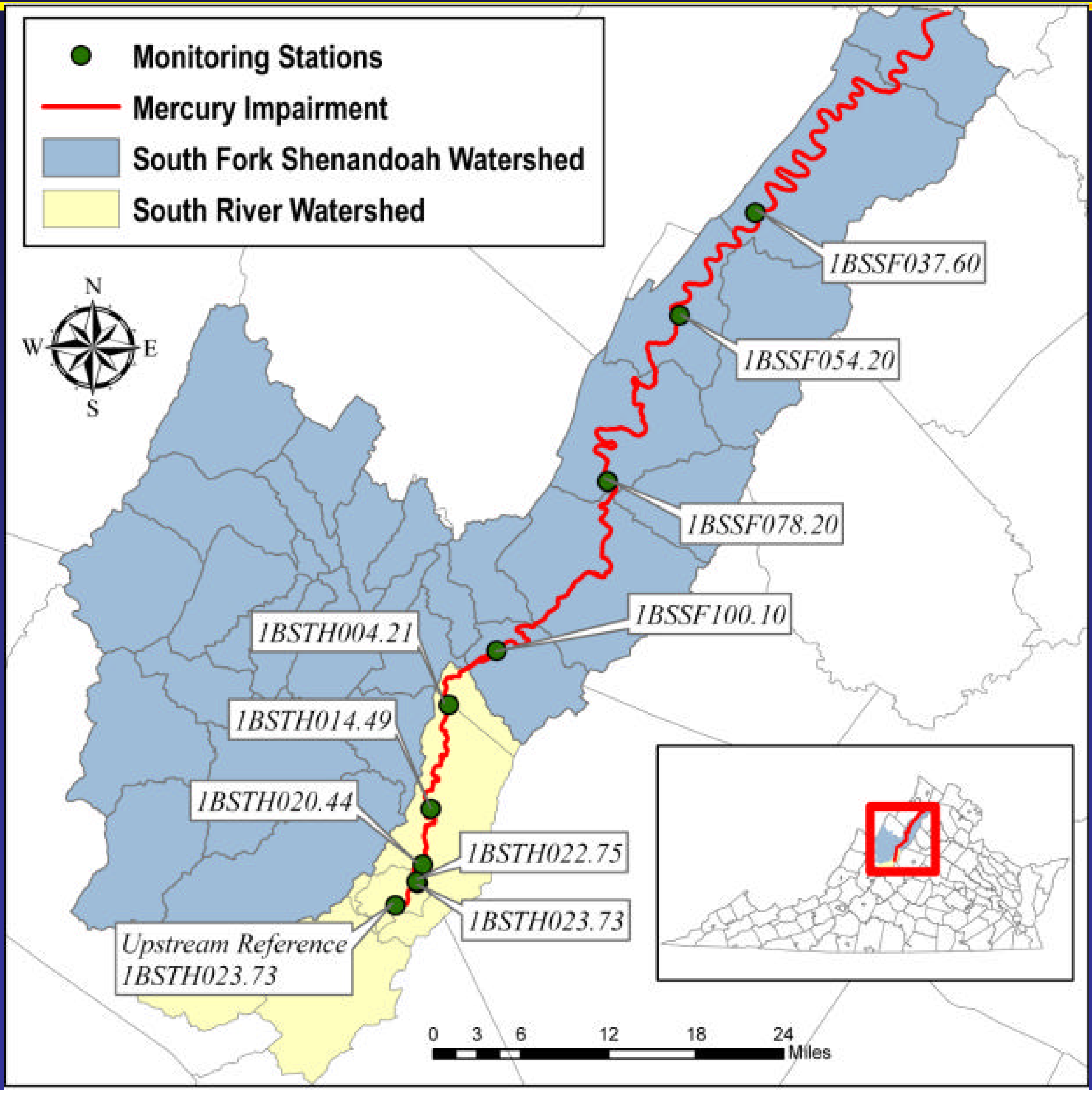
Downstream of the South River

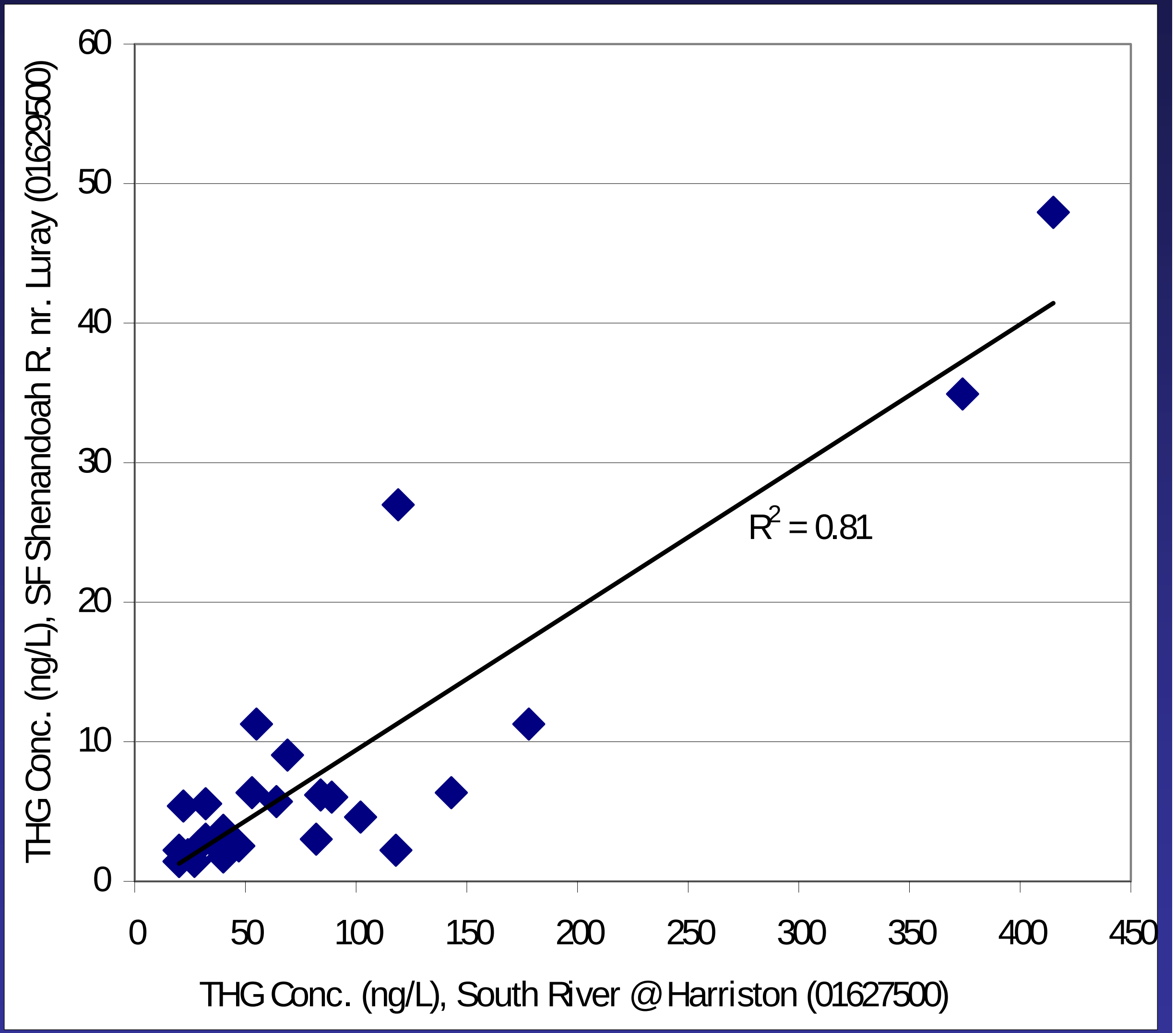


Comparing South River and SF Shenandoah Hg Loads

27 sampling events, <6 hr difference in sample time

22 showed higher loads at Harriston than at Luray

Average load decrease of 25%



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Approach for calculating TMDL in the Shenandoah River

Assumptions:

- **90-day median value again compared to target concentrations**
- **BAF + measured fish tissue concentrations used to calculated target concentrations as for South River**
- **All HG in the SF Shenandoah and Shenanadoah rivers is from South River inputs plus tributaries at background concentrations**
- **Assume that uncontaminated sub-watersheds have THG = 1.81 ng/L**
- **Mass balance approach used**
  - **19.8% of SF Shenandoah at Luray watershed is South River**
  - **9.8% of Shen River at Craigs Run confluence watershed is South River**

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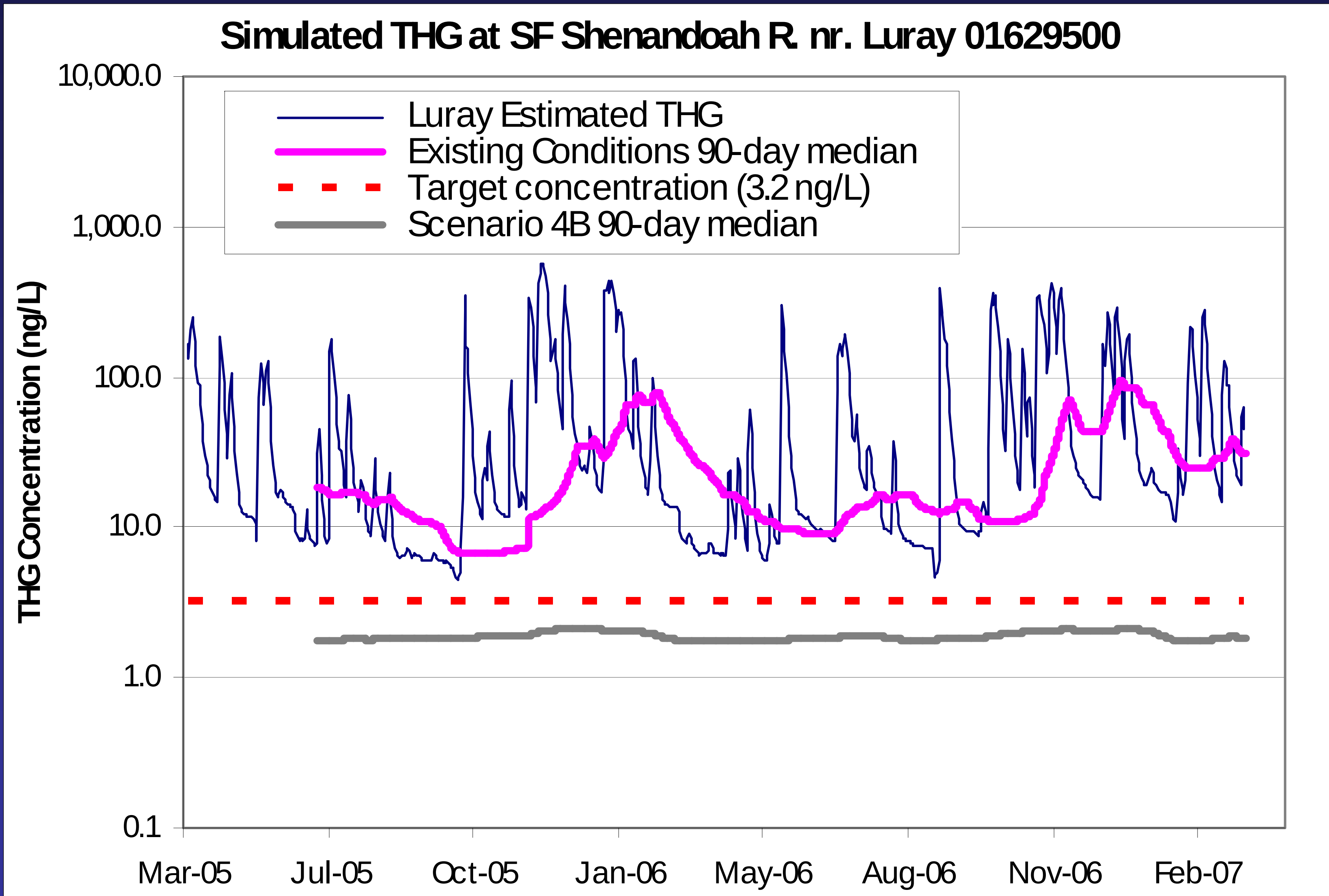
Resulting estimated THG values for the South Fork Shenandoah River near Luray



TMDL Conditions by River

River	Target THG Concentration (ng/L)	Total Mercury TMDL (kg)
South River at Port Republic	3.8	2.01
S. Fork Shenandoah River nr Luray	3.2	3.82
Shenandoah River at Craig's Run	2.5	5.82

TMDL reductions in South River should be sufficient to meet downstream targets

Sensitivity Analysis

		Median THG - Harriston			% Time in Violation		
Name	Description	-50%	Scenario 4B	+50%	-50%	Scenario 4B	+50%
Precipitation	Precipitation rates (in/yr)	2.03	2.11	2.18	0%	0%	0%
KRER	Sed. detachment rate coef.	1.99	2.11	2.21	0%	0%	3.9%
KSER	Sed runoff transport coef.	2.07	2.11	2.23	0%	0%	0%
W	Settling velocity	1.83	2.11	2.60	0%	0%	0%
TAUCD	Critical shear stress – Deposition	1.87	2.11	2.27	0%	0%	2.5%
TAUCS	Critical shear stress – Suspension	1.99	2.11	1.70	0%	0%	0%
M	Erodibility of bed sediment	1.95	2.11	2.02	0%	0%	0%
KD	Adsorption coef.	2.06	2.11	2.14	0%	0%	0%
ADRATE	HG phase transfer rate coef.	2.12	2.11	2.11	0%	0%	0%