Willamette Mercury TMDL

Modeling Results

Willamette Mercury TMDL Advisory Committee Meeting
September 19, 2018

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OVERVIEW OF PRESENTATION

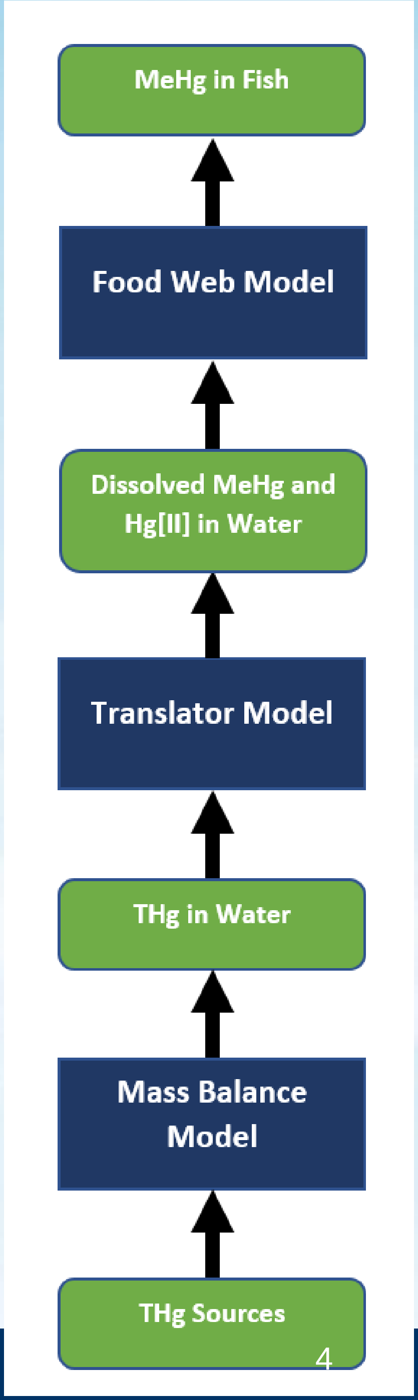
Overview of Presentation

- ► Recap of modeling tools
- ► Trailing questions from 8/21/18 meeting
- ► Modeling results
- ► Example of potential TMDL components and allocations

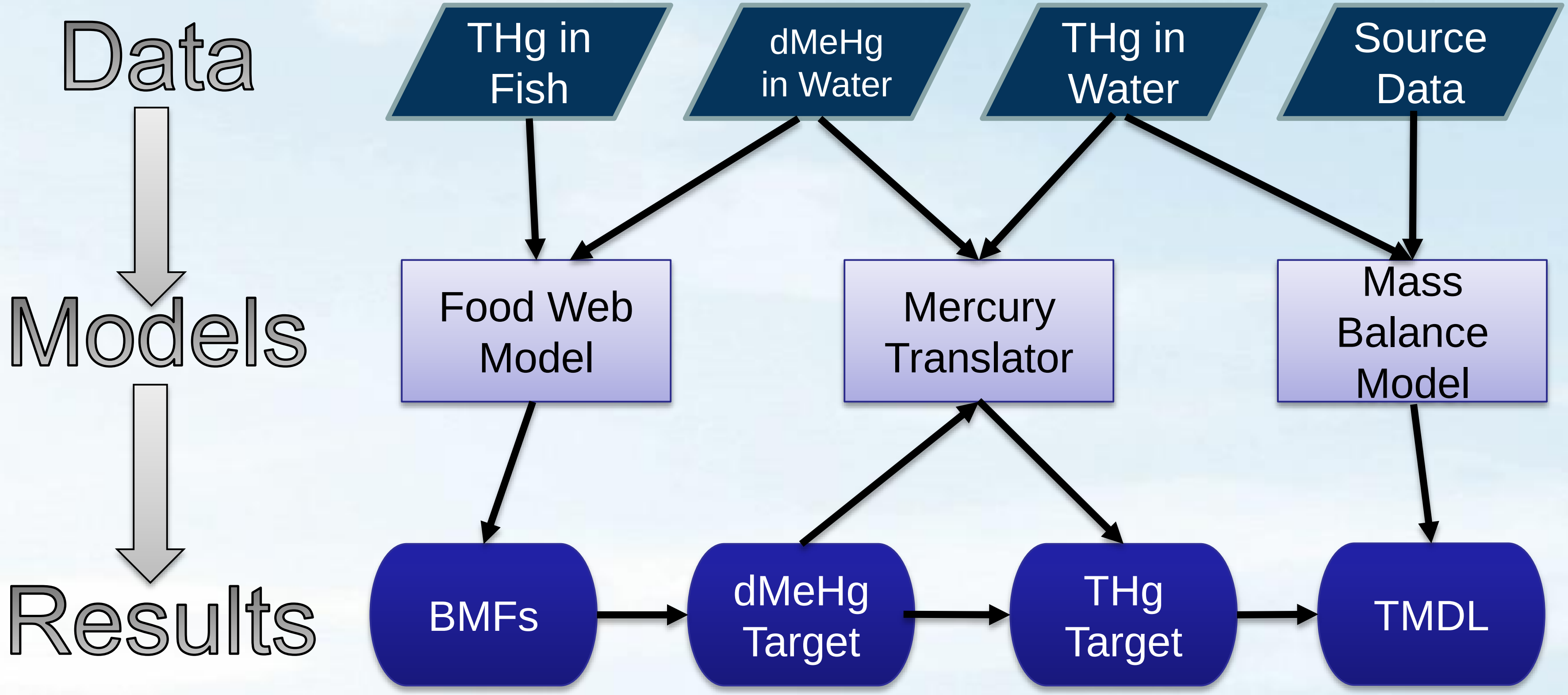
Note: Additional THg data for certain POTWs have been supplied. This will result in changes in Mass Balance Model loading calculations. Load results and potential allocations are presented here for example only and will change based on these data as well as other new data that may be received.

TMDL Linkage Analysis

- Link sources of total mercury (THg) to methylmercury (MeHg) in fish
- Three components:
  1. **Mass Balance Model**: Link THg sources in the watershed to instream concentrations
  2. **Mercury Translator**: Link THg concentrations to MeHg and Hg[II] exposure concentrations
  3. **Food Web Mode**l: Link exposure concentrations of MeHg to fish tissue concentrations



Information Flow



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TRAILING QUESTIONS FROM 8/21/18 MEETING

7. Mercury in sediment may be a better starting point.

- Most Hg in environment is in inorganic forms
- Converted to MeHg by bacteria under low oxygen conditions in saturated soils, sediment, or lake bottom water
- Non-linear process that depends on temperature, carbon, sulfur, and reduction/oxidation conditions
- Spatial coverage of sediment Hg data is very limited
- Insufficient data to mechanistically model these processes in the WRB

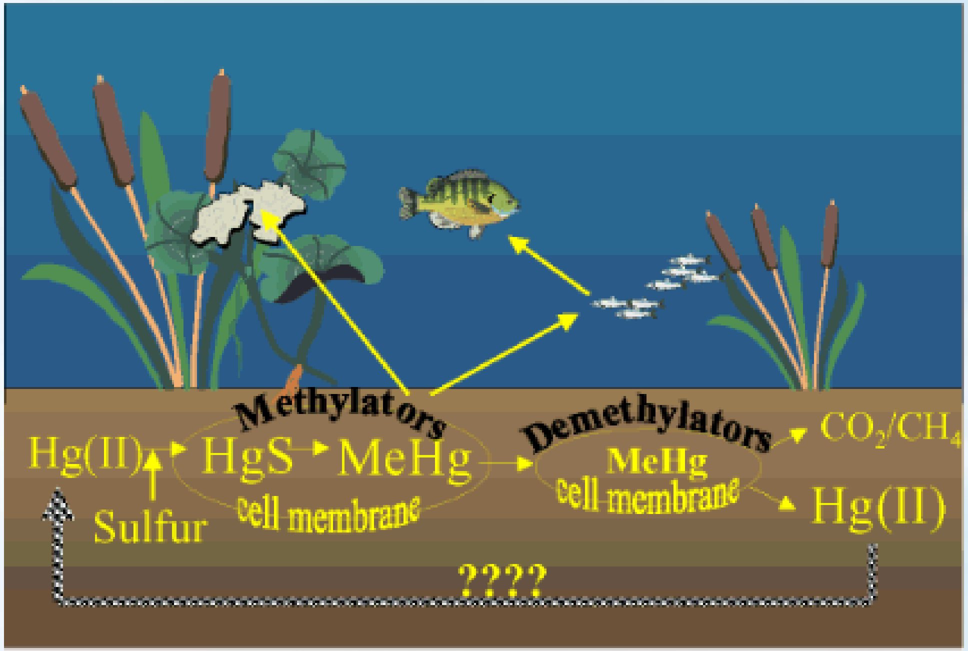


Image source: South Florida Restoration Science Forum (https://sofia.usgs.gov/sfrsf/rooms/acme_sics/acme/)

Empirical Approach to TMDL

- We can't identify or describe all the complex pathways that determine net methylation
- Over the long term, dMeHg in the water column is proportional to THg (empirical Translator)
- Median THg concentrations in water reflect the long-term THg load to that location

and

- Court order directs us to redo the 2006 TMDL with new data and new fish tissue target

9. How do [the Food Web Model] results compare to the tissue criterion?

- ► Food Web Model is tuned to fit the observed distribution of THg in 8 fish species

Biomagnification Factors

+

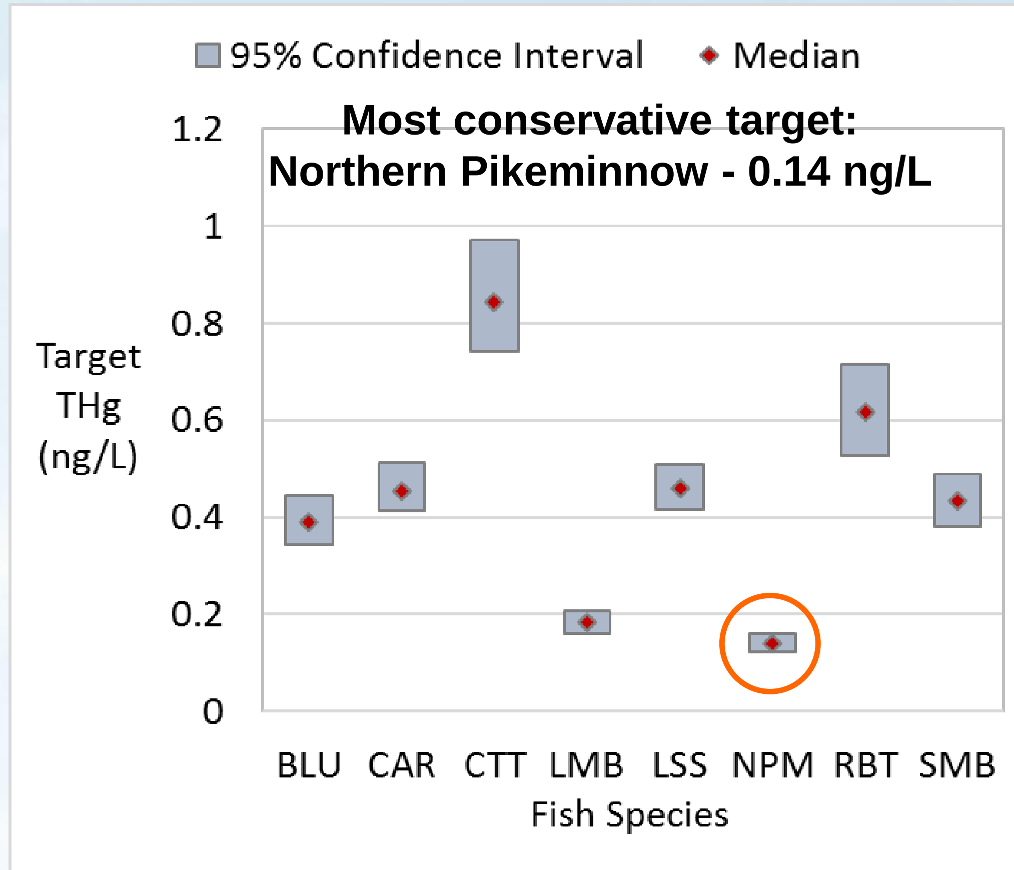
Revised Fish Tissue Criterion

+

Mercury Translator

→

Water Column THg Targets

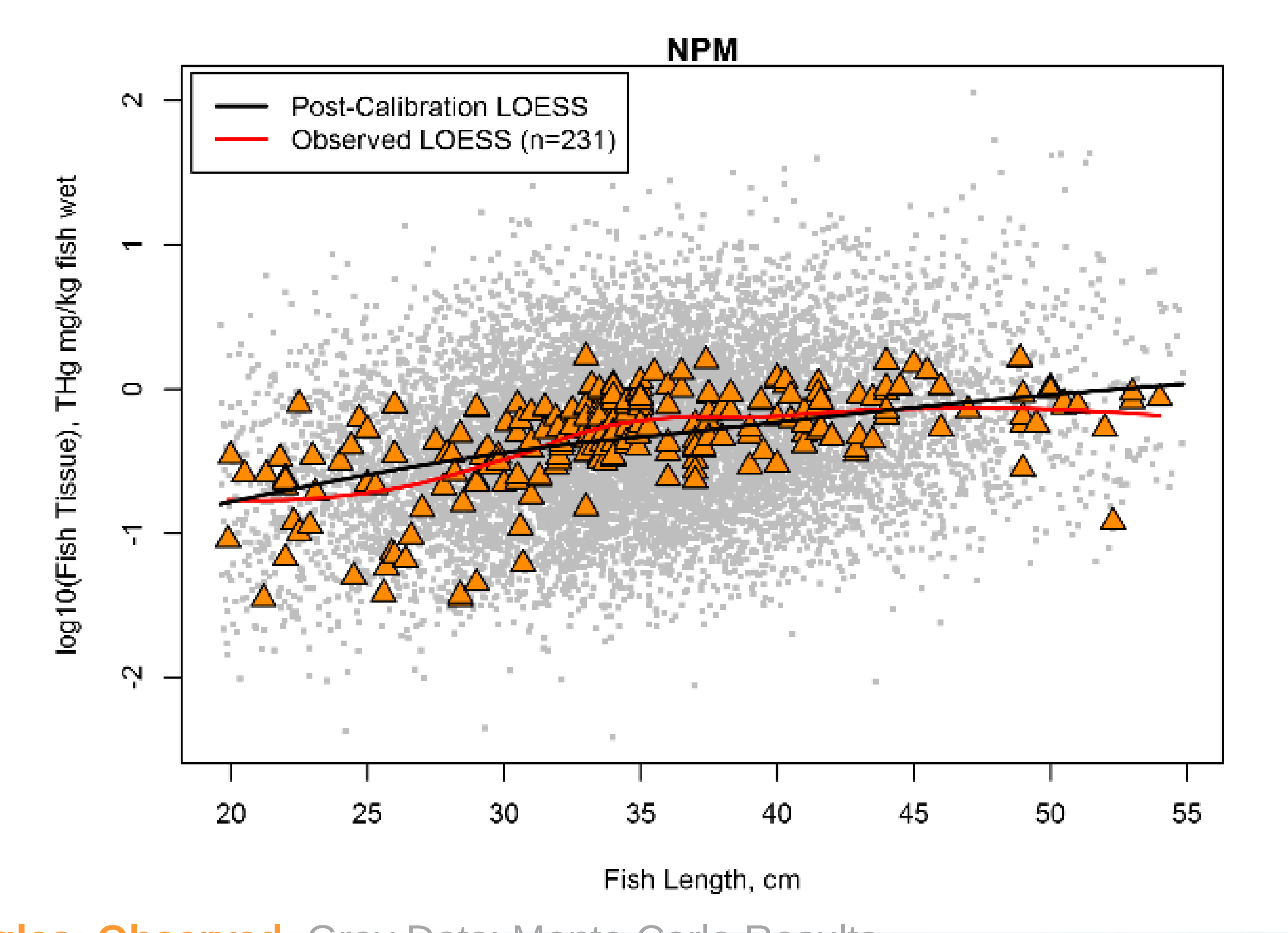


At a median concentration of 0.14 ng/L THg, the median northern pikeminnow will meet the 0.040 mg/kg wet weight tissue criterion

12. What is the variation/uncertainty in the [Food Web] model? Have any sensitivity analyses been completed?

- The Food Web Model is a probabilistic Monte Carlo model in which thousands of runs are undertaken, each one of which draws a random sample from each of the underlying input distributions.
- The process evaluates sensitivity to each input.
- The output provides thousands of predicted outcomes that allow estimation of confidence intervals on fish tissue concentrations and BMFs

Monte Carlo Analysis of Uncertainty in the Food Web Model



Triangles: Observed, Gray Dots: Monte Carlo Results

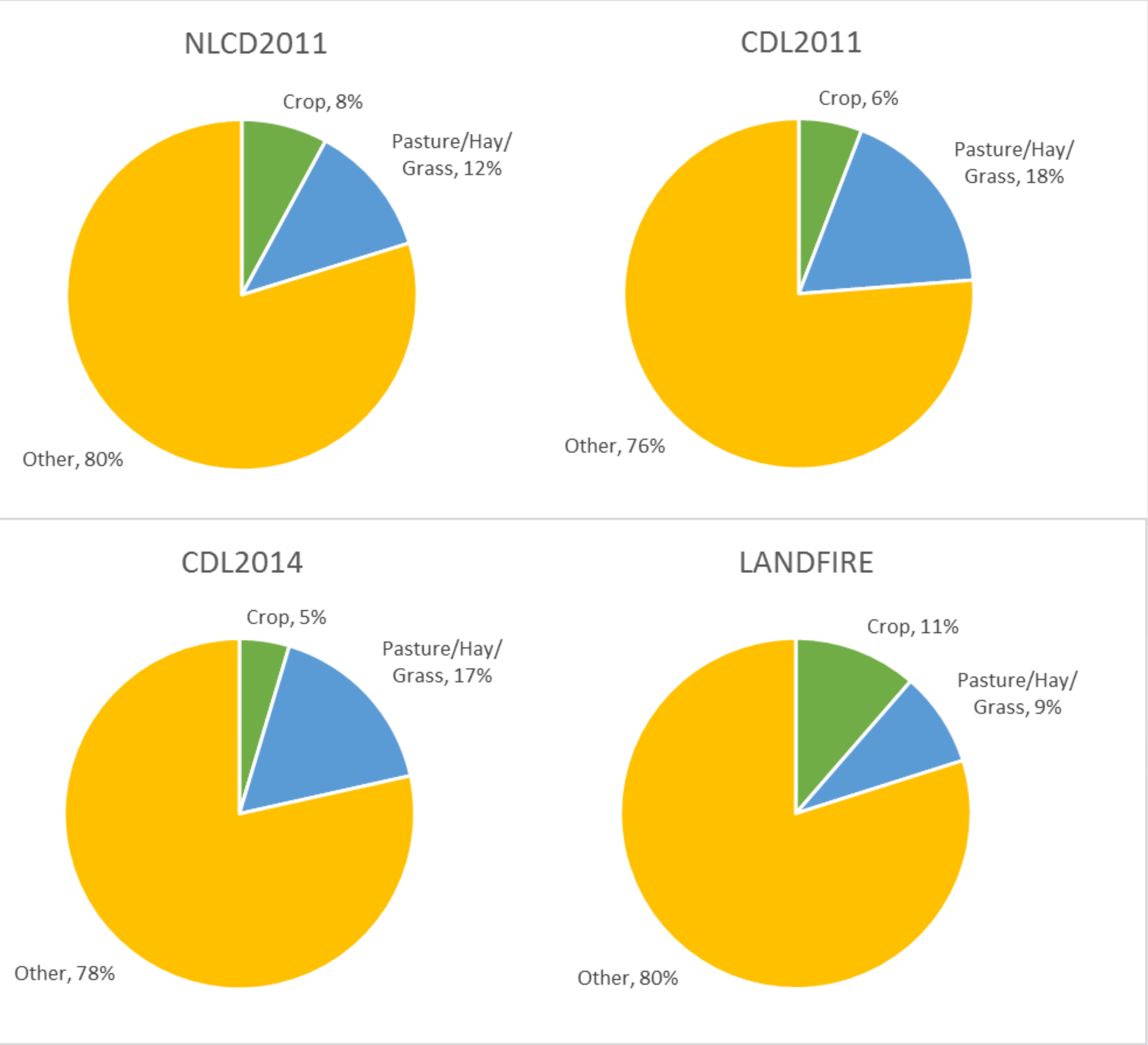
14. What about the processes of methylation that vary by waterbody? Why aren't we focusing on sites where methylation is actually occurring? It is also important to know why methylation rates vary.

- Agree this is important as MeHg is the form that bioaccumulates
- MeHg is a byproduct of bacterial reduction of sulfate under low oxygen conditions in soils, sediment, or lake bottom water
- Depends in non-linear ways on temperature, carbon, sulfur, and reduction/oxidation conditions – for much of which we have limited data in WRB
- Demethylation is also important, but likewise depends on site-specific factors (light, carbon)
- We can't get there with the modeling, but it would make sense to focus on areas of known or likely MeHg production as part of implementation

15. NLCD 2011 appears to underestimate agricultural lands in the basin. Maybe the shrub and grassland data files may actually be agricultural land?

- There is a misunderstanding about how agricultural land is defined in the model
- The Mass Balance Model is referring to tilled cropland – not all land zoned for agriculture and not including hay and pasture land
  - Tillage, harvest, and annual vegetation characteristics have known effect on soil Hg concentration and runoff potential
  - Satellite data are good at distinguishing tillage; not so good at separating hay, pasture, and native grassland
- Comparison to USDA Cropland Data Layer and USFS LANDFIRE coverages are consistent with NCLD
- Need to clarify presentation in the report!

Agricultural Land Area Estimates



- Model "Pasture/Hay" class is about 25% native grass, but classification is poor
- Model "Crop" class contains about 19% orchards & vineyards
- Would be difficult to separate these LUs in the model because the model was calibrated to the combined classes
- Could provide additional data that would help in developing implementation plans

TETRA TECH

16. Does EPA/Oregon plan to conduct additional groundwater sampling for mercury?

- No additional groundwater sampling for the purposes of calibrating the model is planned
- With 1 ng/L, LOADEST loads match model with central value of recommended THg decay rate
- Black Butte mine background well: <0.5, <0.5, 1.19 ng/L
- Hinkle Coast Fork study: Deep well at 0.25 ng/L, but two discharging springs at 5.19 and 1.25 ng/L.
- Remember: Mass Balance loads are not used in calculation of needed % reductions – but do contribute to the size of the pie

Questions on update of issues raised at 8/21/18 meeting?

Dorena Reservoir (NOAA copyright-free picture)

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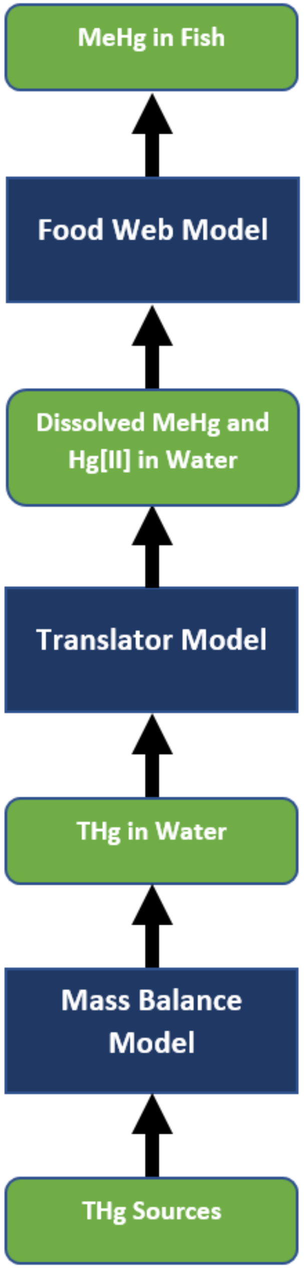
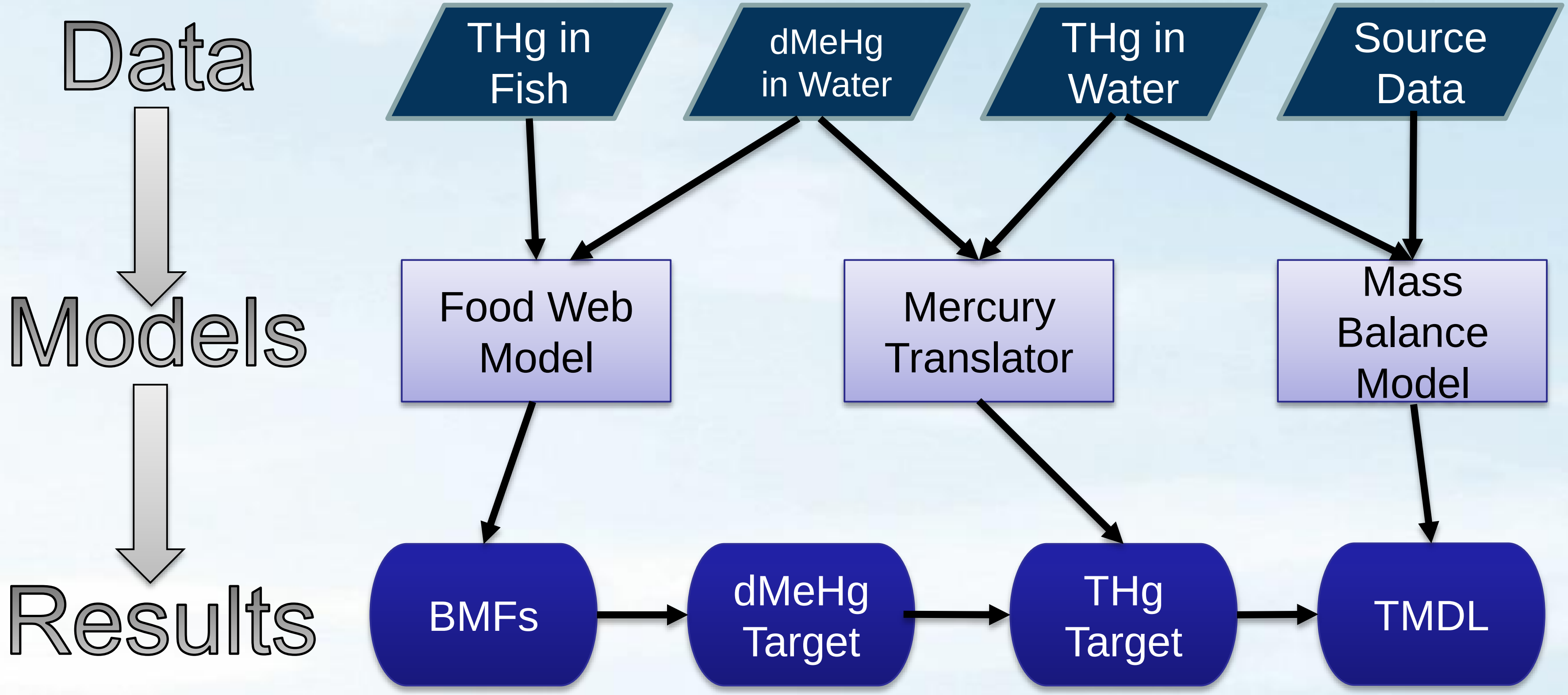
MODELING RESULTS



Information Flow



BMFs from FWM

- Relate fish tissue mercury concentration to the water column exposure concentrations (dissolved MeHg)
- Species specific (tropic level III and IV fish)

$$TL_n = \left[\frac{TC}{\underbrace{BMF_{ME,n}}\cdot\ \Omega}\right]\cdot CF$$

TL_n is the total mercury target level for the nth fish species (ng/L),
TC is the revised fish tissue criterion for MeHg in fish (0.040 mg/kg),
$BMF_{ME,\,n}$ is the biomagnification factor for the nth fish species (L/kg),
Ω represents the Mercury Translator, and
CF is a conversion factor ($1 \cdot 10^6$ ng/mg).

Biomagnification Factors from FWM (continued)

- Evaluated as a stochastic distribution
- Used to derive target levels for dMeHg

Fish Species	Mean	Standard Deviation	5th %ile	Median	95th %ile
Bluegill	1.22E+07	1.94E+07	1.43E+06	6.39E+06	2.76E+07
Common Carp	7.78E+06	8.35E+06	1.49E+06	5.48E+06	1.56E+07
Cutthroat Trout	4.81E+06	6.05E+06	4.59E+05	2.94E+06	1.08E+07
Largemouth Bass	2.74E+07	5.46E+07	2.16E+06	1.36E+07	5.71E+07
Largescale Sucker	7.69E+06	8.10E+06	1.53E+06	5.44E+06	1.55E+07
Northern Pikeminnow	3.26E+07	6.50E+07	2.63E+06	1.78E+07	7.01E+07
Rainbow Trout	7.59E+06	1.25E+07	5.78E+05	4.04E+06	1.68E+07
Smallmouth Bass	9.31E+06	1.25E+07	9.92E+05	5.73E+06	2.00E+07

Translator: THg Water Column Targets

Biomagnification Factors

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Revised Fish Tissue Criterion

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Mercury Translator

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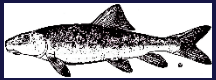
Water Column THg Targets



$$TL_n = \left[\frac{TC}{BMF_{ME,n} \cdot \Omega}\right] \cdot CF$$

TL_n is the total mercury target level for the n^{th} fish species (ng/L),
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Ω represents the Mercury Translator, and
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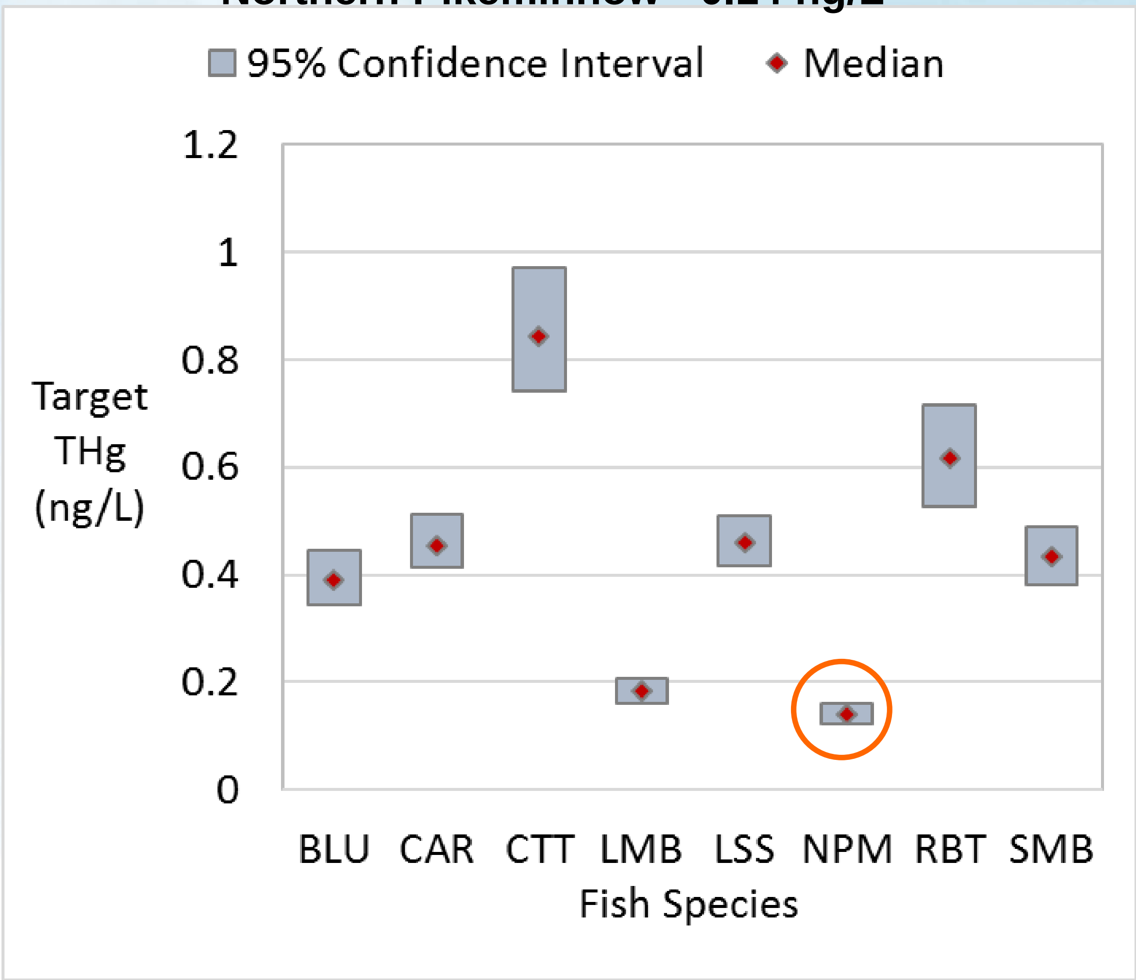
THg Water Column Targets (continued)

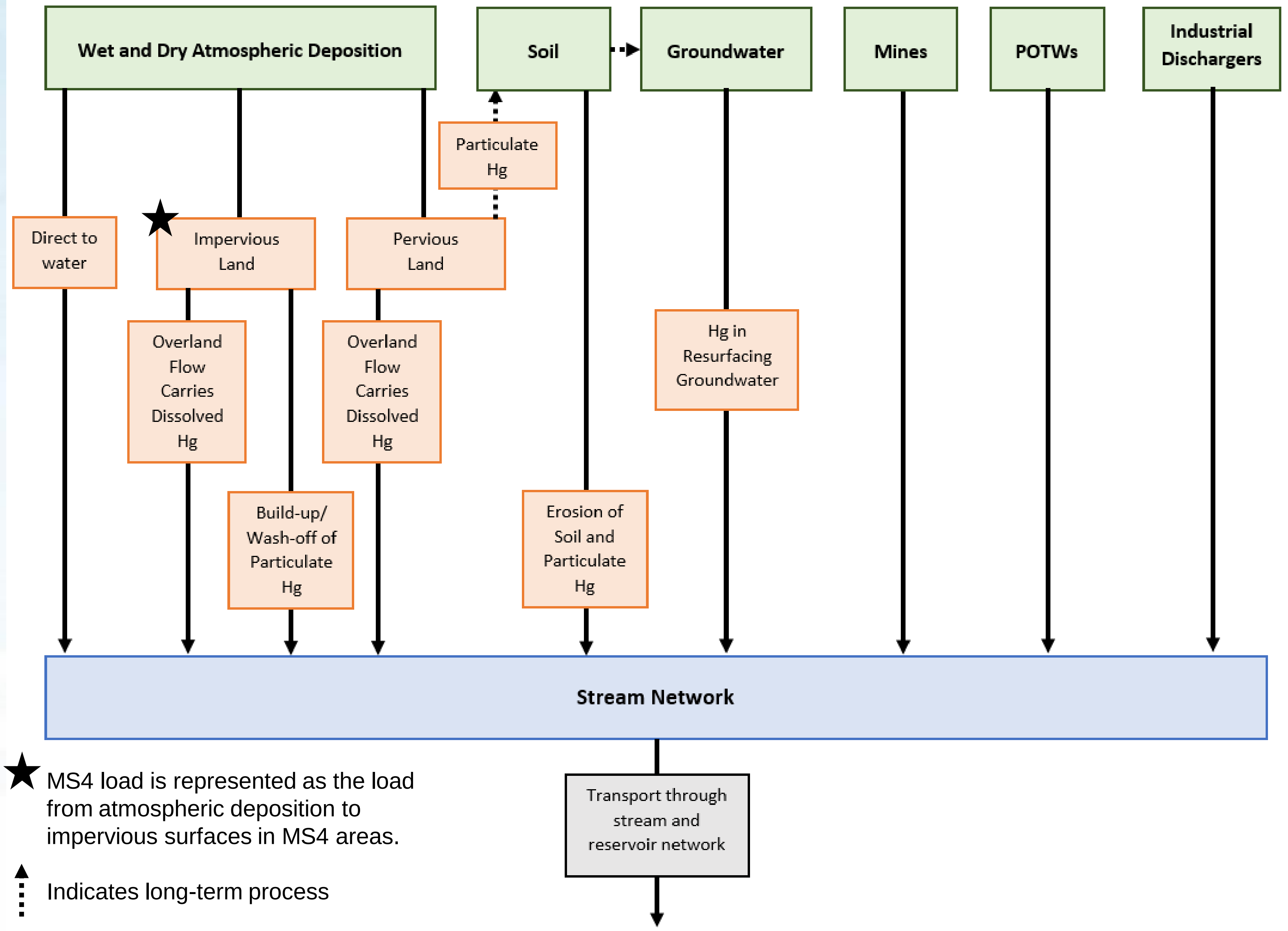
Most conservative target:
Northern Pikeminnow - 0.14 ng/L



Mass Balance Model Results

- Develop best estimates of loads by source from available data
- Account for losses in transit, including Hg volatilization and burial
- *Numbers presented below will change as additional data on point sources are processed!*

Mass Balance Model Framework

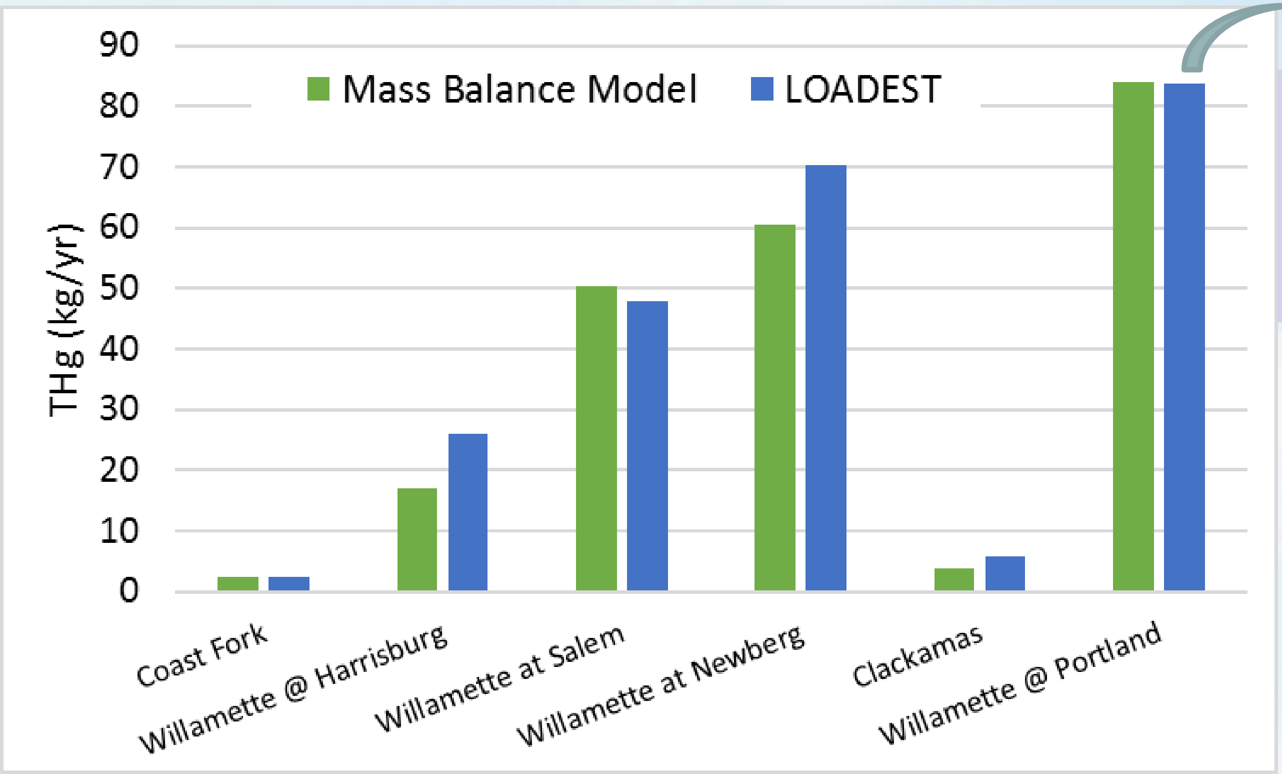


★ MS4 load is represented as the load from atmospheric deposition to impervious surfaces in MS4 areas.

Indicates long-term process

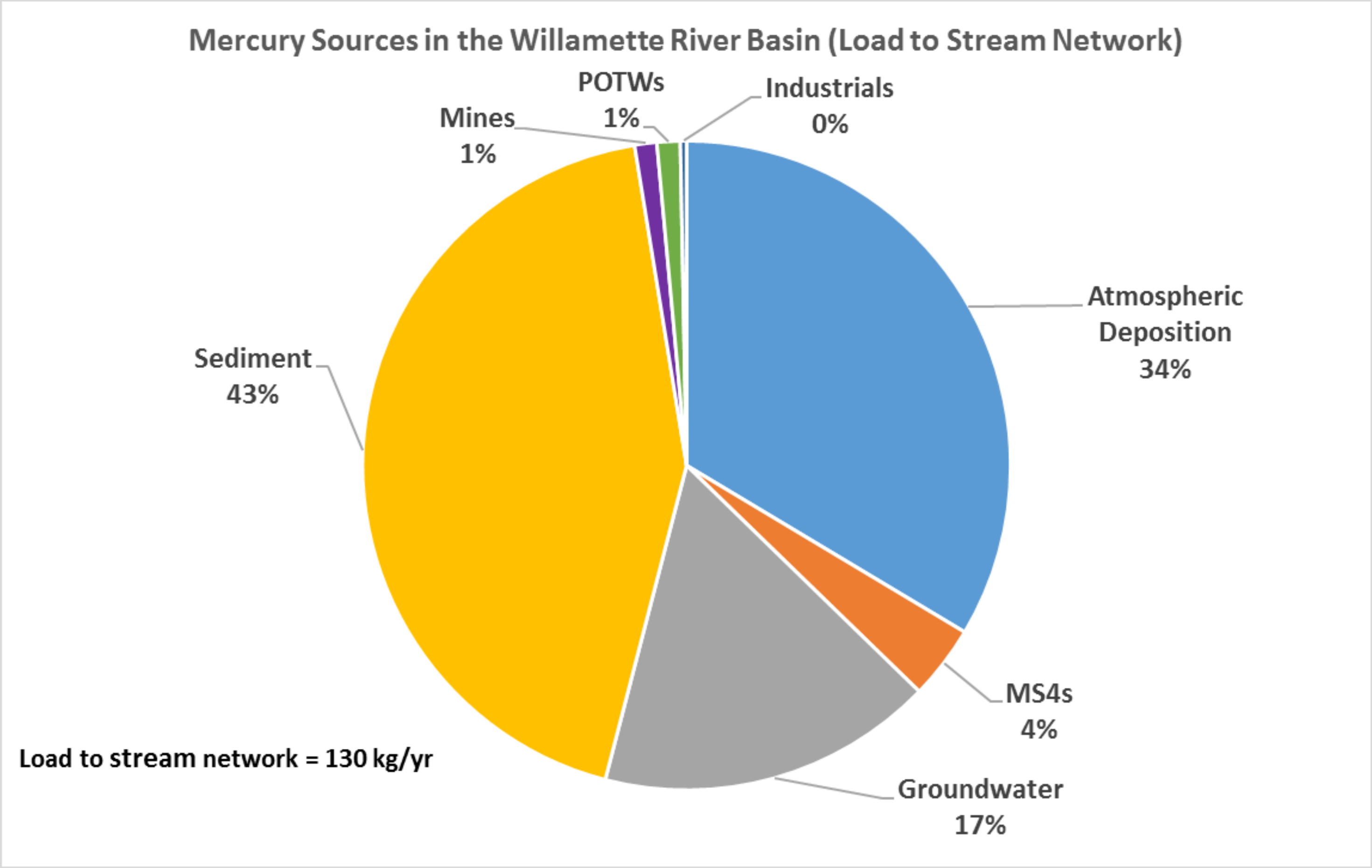
Calibration to LOADEST

- LOADEST: USGS tool to estimate loads from continuous flow and sparse concentration data
- Mass Balance Model and LOADEST agree with THg decay rate of 0.08 per day – midpoint of range suggested for rivers by WASP model developer Robert Ambrose



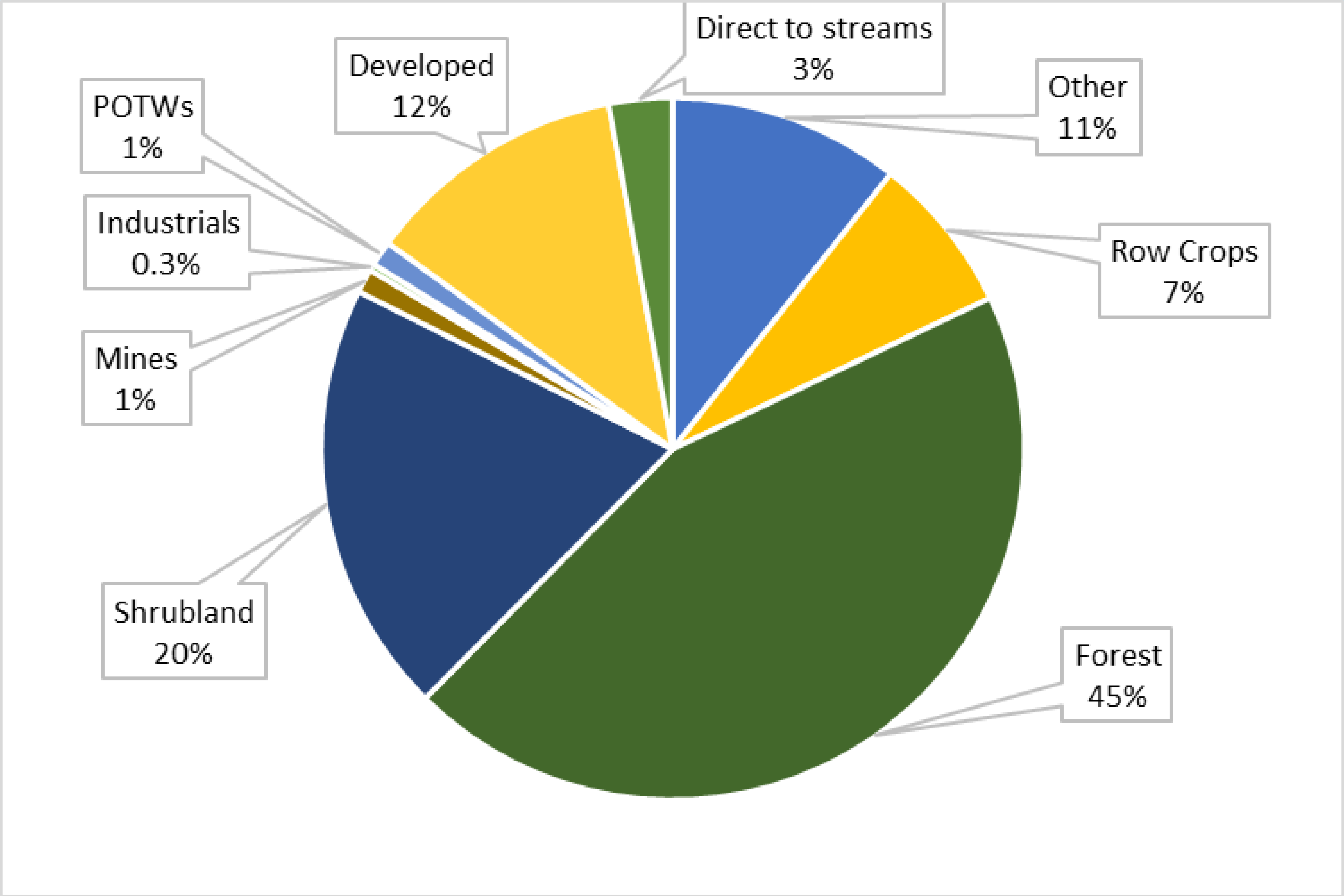
At Portland gage (1411720),
LOADEST: 83.7 kg/yr
Mass Balance: 83.9

THg Loads by Type



Note: A majority of the sediment and groundwater loads ultimately originate from historic atmospheric deposition of mercury.

THg Loads by Land Use



Notes: Shrubland is primarily disturbed forest. “Other” includes pasture and hay along with native grass, barren land, & wetlands

Example THg Load Analysis for Upper Willamette (HUC 17090003; kg/yr)

- Tables for each HUC and major reservoir, for both at-source and delivered loads

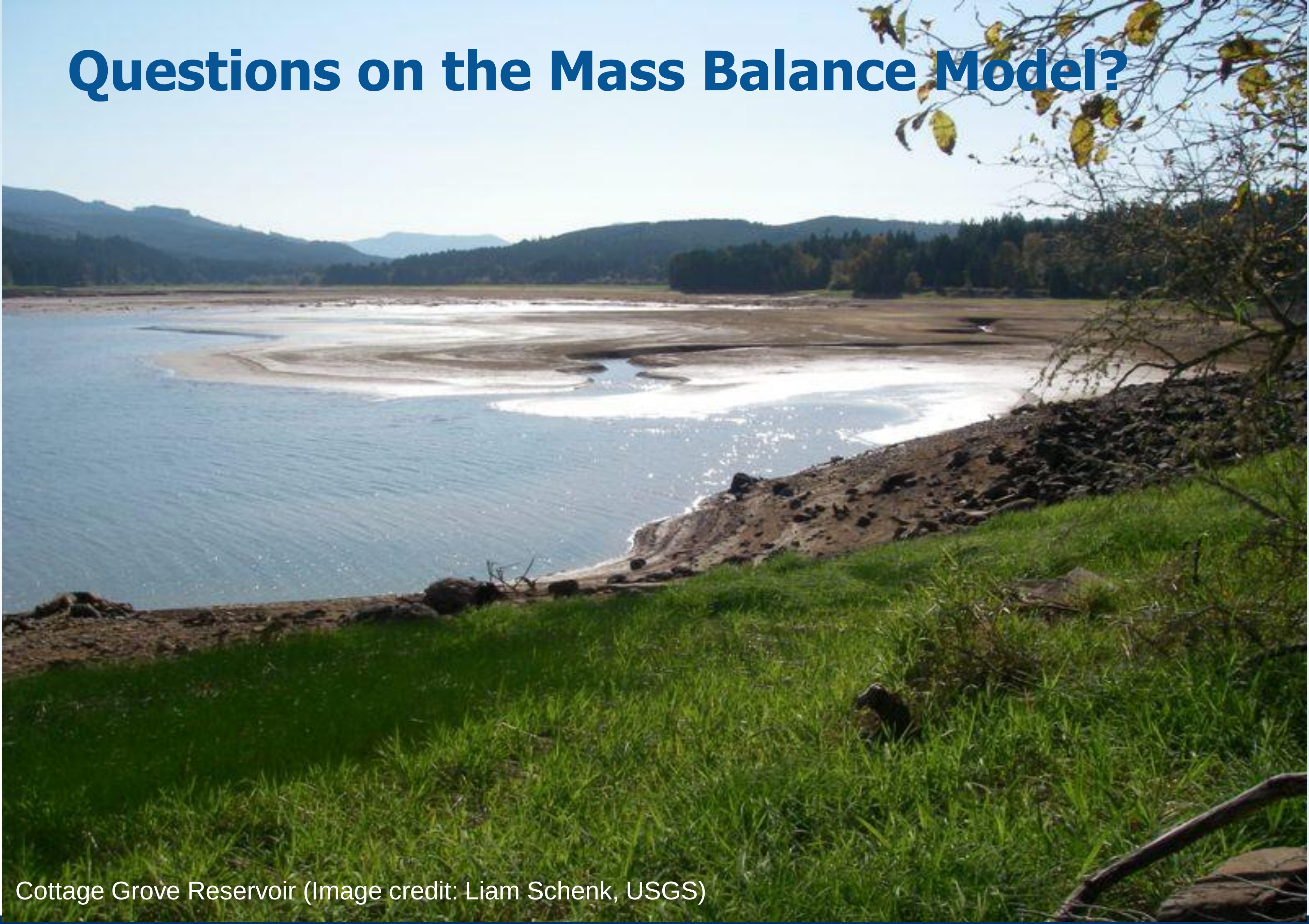
	At-source			
	Atmospheric Deposition	Sediment Erosion	Groundwater	Total
Row Crops	0.61	2.50	0.32	3.43
Forest	1.18	5.45	0.84	7.48
Shrub	0.82	4.59	0.35	5.76
Developed	1.83	0.98	0.13	2.93
Other	1.50	1.87	1.06	4.43
Direct to streams	0.76			0.76
MS4s	0.94			0.94
POTWs				0.21
Industrial dischargers				0.17
Mines				0.00
TOTAL	7.65	15.38	2.70	26.11

Example THg Load Analysis for Upper Willamette (continued)

- Delivered loads include upstream HUCs

	Delivered			
	Atmospheric Deposition	Sediment Erosion	Groundwater	Total
Row Crops	0.55	2.23	0.31	3.09
Forest	4.40	6.06	3.35	13.81
Shrub	1.67	5.00	0.73	7.39
Developed	1.98	0.93	0.13	3.04
Other	2.30	1.80	1.18	5.29
Direct to streams	1.06			1.06
MS4s	0.90			0.90
POTWs				0.19
Industrial dischargers				0.24
Mines				0.72
TOTAL	12.86	16.02	5.70	35.74

Questions on the Mass Balance Model?



Cottage Grove Reservoir (Image credit: Liam Schenk, USGS)

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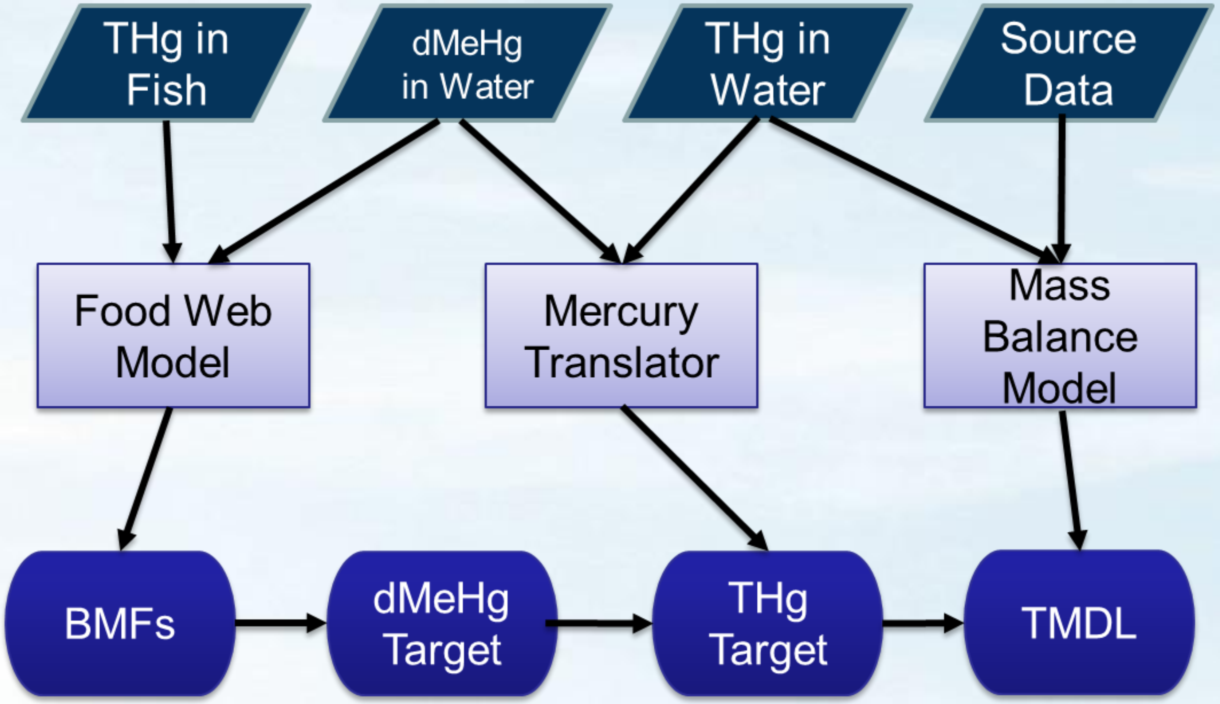
TMDL AND ALLOCATION OPTIONS

Note: Material in this section is presented for example only by Tetra Tech and does not represent the official views of DEQ or EPA. Load estimates are not final and are subject to change. The final allocation approach will depend on policy decisions to be made by DEQ.

Calculating Needed Reductions

- Reduce median THg concentrations by HUC to meet target based on NPM of 0.14 ng/L THg
- Use median to represent typical concentration over time for chronic bioaccumulation
- Assume load reductions correspond to concentration reductions

Needed Reduction =
1 – Target/Median THg



Reductions based on NPM Target

Catchment	Count	Median THg Concentration (ng/L, 2002-2017)	Percent Reduction based on NPM
17090001	27	0.86	84%
17090002	122	3.39	96%
17090003	130	1.01	86%
17090004	13	1.00	86%
17090005	25	0.92	85%
17090006	0	1.00	86%
17090007	78	1.23	89%
17090008	10	1.13	88%
17090009	14	0.88	84%
17090010	18	2.67	95%
17090011	15	1.00	86%
17090012	130	2.15	94%

Note: No observed data are available for HUC 17090006 (South Santiam) so calculations are performed using concentrations from adjacent HUC 17090004 (Mckenzie).

TMDL Algebra

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

where:

WLA = Waste Load Allocation – the portion of the loading to the water body assigned to each existing and future permitted point source of the pollutant;

LA = Load Allocation – the portion of the pollutant loading assigned to existing and future nonpoint sources of the pollutant;

Σ = Summation across multiple items;

MOS = Margin of Safety – an accounting of the uncertainty of the pollutant load and the quality of the water body.

Example of Potential Calculations

- Use Upper Willamette (17090003) as example
- To address mercury bioaccumulation, first calculate the annual loading capacity
  - Annual loads determine typical exposure concentration
  - Daily TMDL allocations must sum to be less than or equal to the annual loading capacity
- Loading capacity = average annual delivered load (Mass Balance model) x (1 - required reduction)
- 84.02 kg/yr x (1 – 86%) = 5.46 kg/yr for Upper Willamette
  - This includes loads derived from 3 upstream HUC8s

At-source Loading Capacity

- ► Translate to at-source loads to derive allocations
- ► Assume same percent reductions apply to at-source loads within the target HUC8
- ► For Upper Willamette: 26.11 kg/yr x (1 – 86%) = 3.60 kg/yr
  - Equivalent to 9.86 g/day
  - Not adjusted for potential higher reduction rates in upstream HUC8s (e.g., 96% reduction in Coast Fork HUC8)
  - This can be used as part of the Margin of Safety

TMDL: Daily Load Expression

- *Friends of the Earth vs. EPA* (2006) stated that “daily means daily” and all TMDLs and associated WLAs and LAs must contain a daily load expression
- For THg, it is really the annual load that counts
- Simply dividing the average annual load by 365 yields a load that will frequently be exceeded even when the annual load target is met
- EPA draft guidance suggests assigning a daily expression of the load conditional on flow and a daily limit based on the upper percentiles of flow
  - Similar to permit limits for average monthly and daily maximum load

TMDL: Daily Load Expression

- ► Suggest using the 95th percentile flow (for a given season) times the concentration target, converted to kg/d as the daily maximum limit
- ► Days with loads greater than this limit would not be compliant with TMDL
- ► Wet and dry seasons at Portland gage have 95th percentile flows of 116,000 and 27,965 cfs, respectively
- ► Based on 0.14 ng/L target, this yields maximum daily load limits of 39.7 and 9.6 kg/d at Portland
- ► Proposed approach meets the letter of the law, but allows implementation to focus on what counts – the average annual load

Margin of Safety (MOS)

- All TMDLs are required to include an MOS
- MOS can be **explicit** or **implicit** (based on conservative assumptions)
- Suggest an implicit MOS, based on the following:
    1. Target based on NPM, which is not frequently consumed
    2. TMDL is based on the median of the distribution of target levels, which is lower than the average of the distribution
    3. Target based on THg concentration in fish, whereas Oregon criterion is for MeHg in fish
    4. At-source reductions by HUC8 are not adjusted for cases where greater reductions are assigned to upstream HUCs

WLAs for Traditional Point Sources Based on Tt Literature Review

- POTWs and Industrials (not MS4s)
- EPA guidance: "*Where point sources are contributing a very small amount of the total mercury load, allocation proportional to their relative contribution is typical…*"
- This approach is used in approved statewide TMDLs for NC, FL, MN, and the New England states, with PS fractions from 0.5 to 2.1%
- Estimated traditional point source contribution in the WRB is <1.5% (will be adjusted down based on new data)

Hypothetical WLAs for Traditional Point Sources – Upper Willamette from Tt Literature Review

- Existing conditions: 1.44% of THg load
- Assign 1.44% of loading capacity (incorporates 86% reduction)
- Resulting sum is 0.128 g/d
- Divided among POTWs (Eugene [MWMC], Corvallis, Albany-Millersburg) and Industrials

Hypothetical WLAs for MS4s from Tt Literature Review

- MS4 permits for municipal stormwater also require WLAs – but behave more like nonpoint
- Calculate revised reduction after adjusting for the traditional point source WLAs
  - For Upper Willamette, adjusted reduction is 86.2%
- Apply this reduction to existing estimated MS4 concentration and multiply times estimated long-term average flow
- For Eugene MS4, the reduced MS4 concentration is 0.64 ng/L and the WLA is 0.36 g/d

Hypothetical LAs for Nonpoint Sources (NPS) from Tt Literaure Review

- Calculation is similar to MS4s
  - Apply revised reduction to estimated average flow-weighted concentration
  - Combine reduced concentration and flow estimates to obtain load
  - Going through concentration decouples different NPS groups from load estimates of other groups
- Can be summarized per HUC8 by source type and/or land use
- Form basis for implementation strategies

Hypothetical LAs for NPS – Upper Willamette from Tt Literature Review

- Target THg Concentrations (ng/L) for NPS

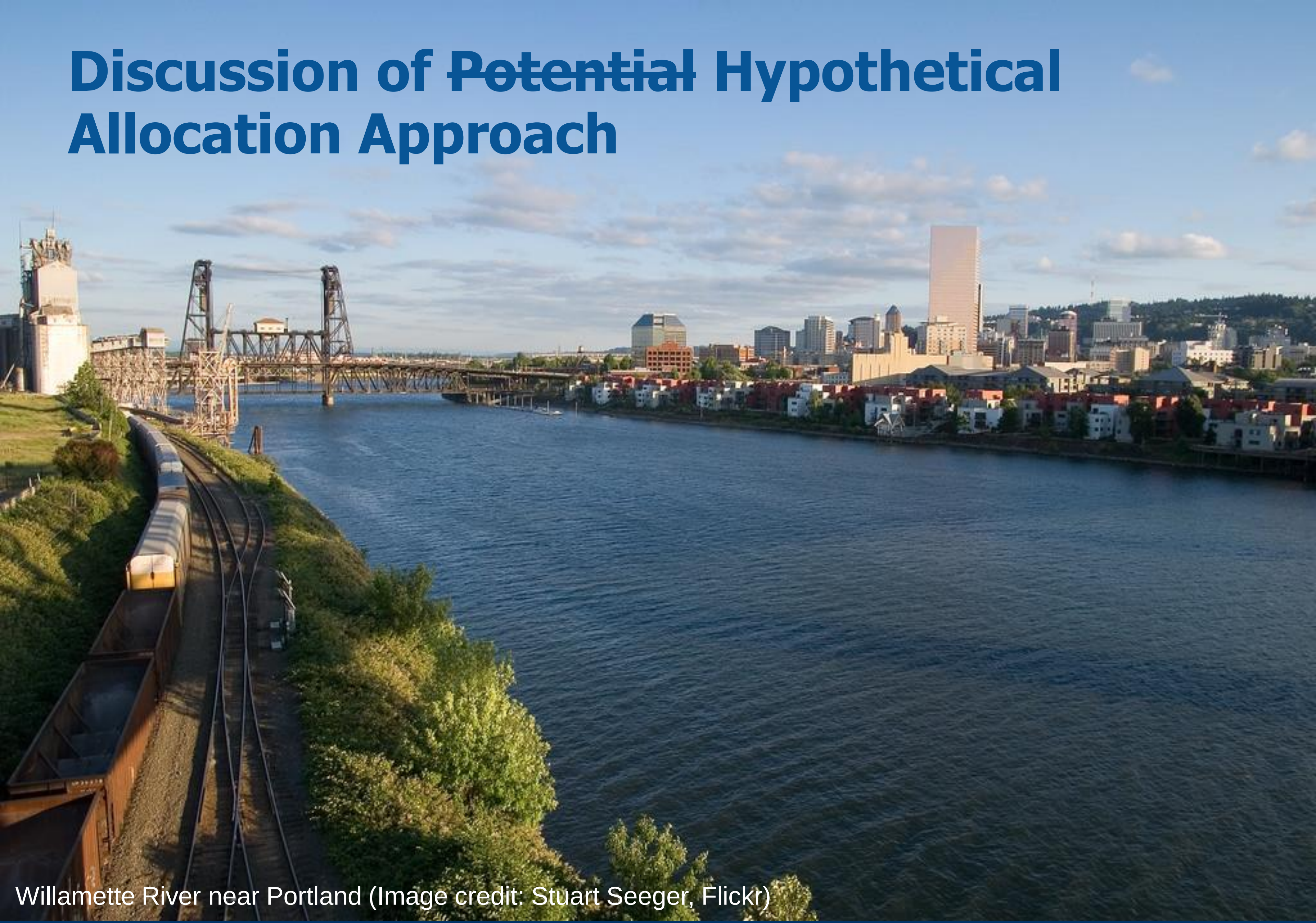
HUC8	Atmospheric Deposition	Groundwater	Sediment Erosion	Mines
17090003	0.82	0.20	2.78	0

- LAs for NPS (g/d)

HUC8	Atmospheric Deposition	Groundwater	Sediment Erosion	Mines	Total Loading Capacity
17090003	2.54	1.02	5.82	0.00	9.86

Note: Concentrations calculated for atmospheric deposition include direct atmospheric deposition to waterbodies, atmospheric deposition to pervious and impervious land (outside MS4 boundaries) transported to the stream network via overland flow, and dry atmospheric deposition to impervious surfaces.

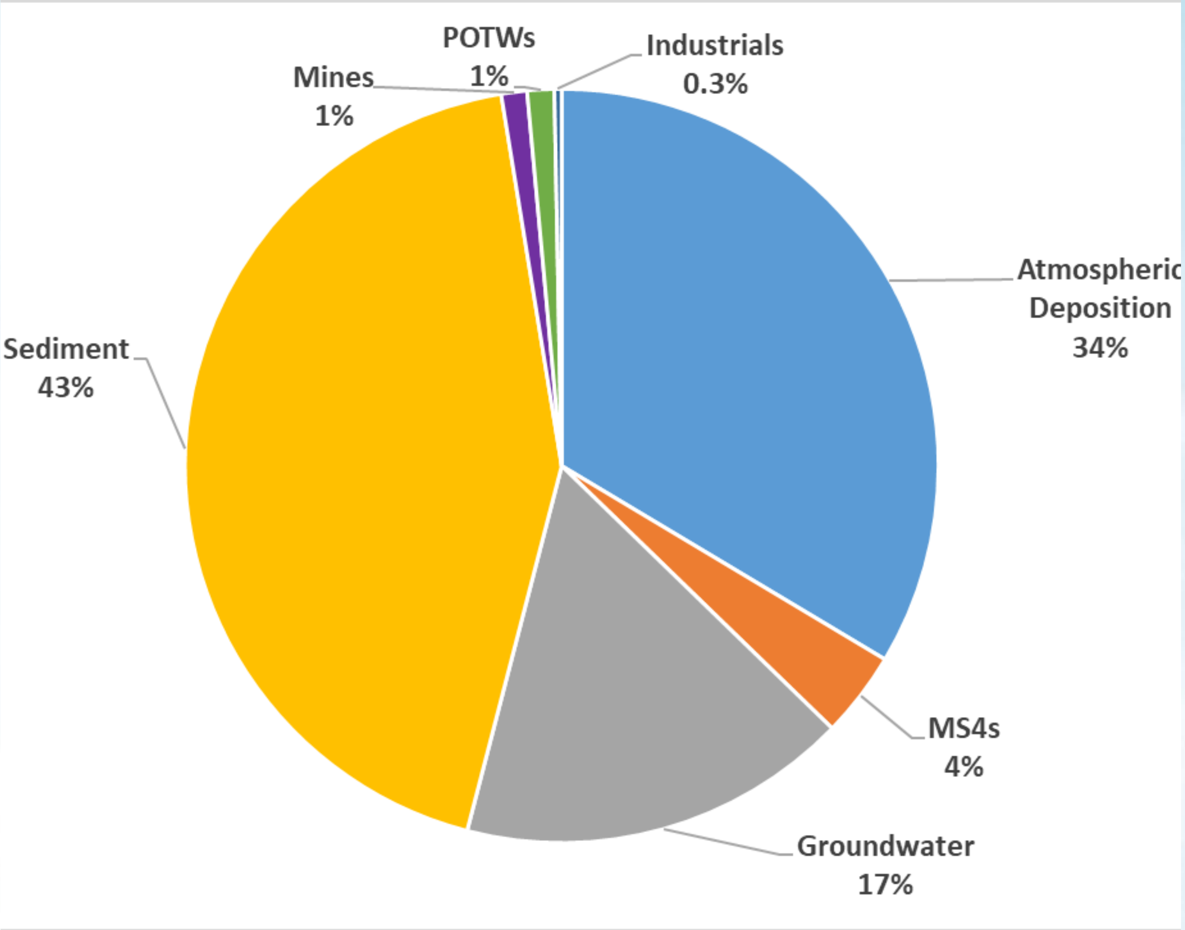
Discussion of ~~Potential~~ Hypothetical Allocation Approach



Willamette River near Portland (Image credit: Stuart Seeger, Flickr)

EXTRA SLIDE

Role of Atmosphere Deposition



- ► For HUC 17090003, reduce atmospheric deposition from 18.1 to 2.5 g/d
- ► MS4 load also mostly from atmospheric deposition
- ► Erosion-related loads reflect centuries of atmospheric deposition

➢ Oregon can't control global atmospheric load, but can address the fraction of the load that reaches streams