# American River Watershed
# Mercury Total Maximum Daily Load

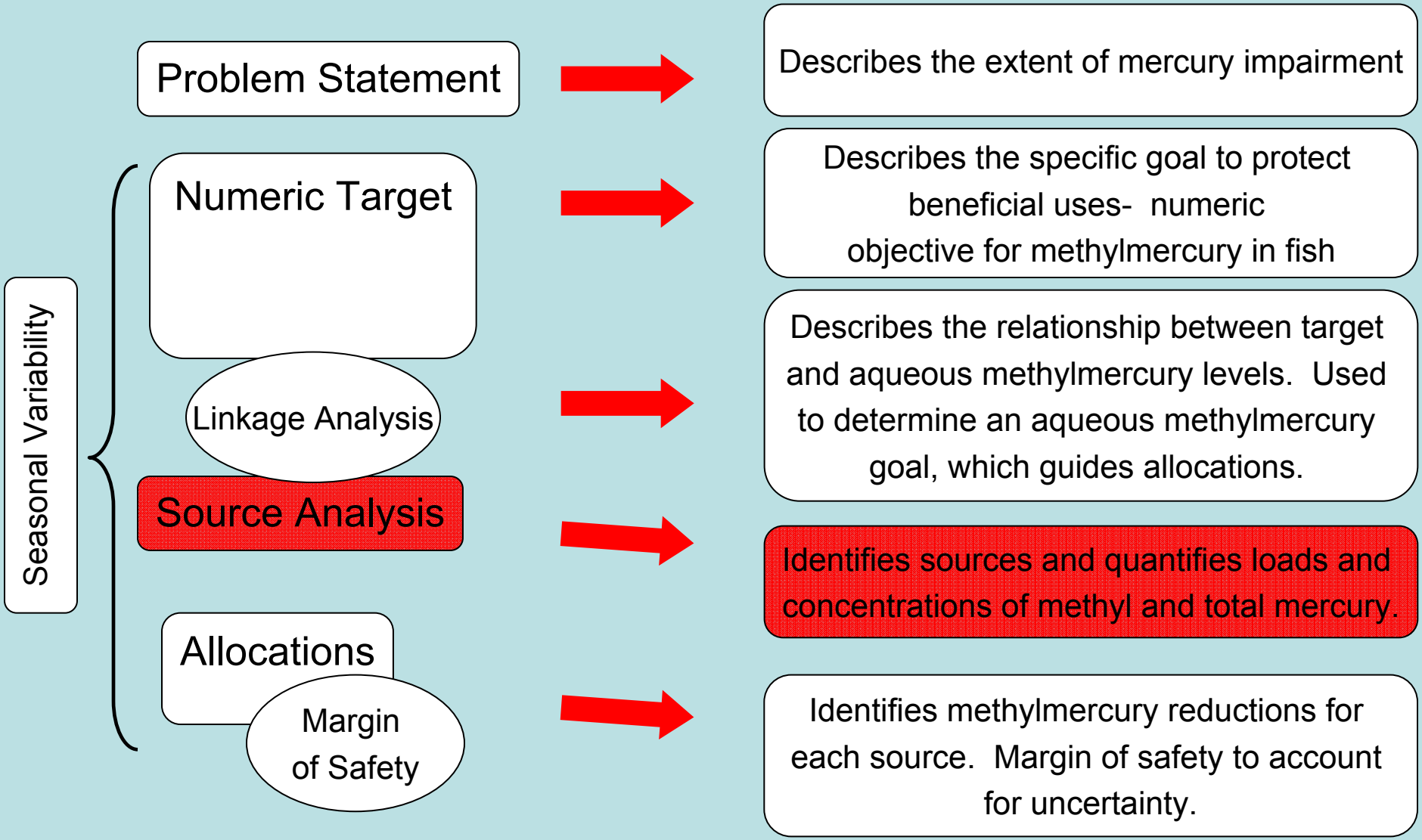
## Stakeholder Meeting

## Rancho Cordova – March 17, 2011

# Today's Topic

TMDL approach to mercury, methylmercury and sediment source assessment

# TMDL Elements- Scientific basis



# American River Watershed (ARW) Source Assessment

- Estimate total mercury (THg) and methylmercury (MMHg or MeHg) loads by source type or land cover types
- GIS for land cover types
- Local and regional data, literature review

# Sources

| | THg Sources | MeHg Sources |
|---|---|---|
| Nonpoint Sources | Atmospheric Dep. Runoff | Atmospheric Dep. Runoff |
| | Mines | Mines |
| | Upland Area Erosion | Upland Areas (Ag & native) |
| | Dredge Tailings | Dredge Tailings |
| | Springs | Springs |
| | **Bank erosion** | **Open Water Habitat** |
| | **Suction Dredging** | **Wetland Habitat** |
| Point Sources | Urban Runoff | Urban Runoff |
| | NPDES Facility Discharges | NPDES Facility Discharges |

# Losses

| THg Losses | MeHg Losses |
| --- | --- |
| Sediment Deposition | Sediment Deposition |
| Evasion | Photo-degradation |
| Water Diversions | Water Diversions |
| | Biota uptake |

*We will not review losses today.*

# Sources Assessment - Status

✓ ***Preliminary load estimates completed.***

| THg Sources | MeHg Sources |
|---|---|
| ✓ Atmospheric Dep. Runoff | ✓Atmospheric Dep. Runoff |
| ✓ Mines | ✓Mines |
| ✓ Springs | ✓Springs |
| Dredge Tailings | ✓Dredge Tailings |
| Bank Erosion | ✓Upland Areas (Ag & Native) |
| Upland Area Erosion | ✓Open Water Habitat |
| Suction Dredging | ✓Wetland Habitat |
| ✓ Urban Runoff | ✓Urban Runoff |
| ✓ NPDES Facility Discharges | ✓NPDES Facility Discharges |

# Source Assessment

***✓Load estimates are considered "preliminary" because:***

- We look forward to input from stakeholders experienced in the watershed
- Some loading rates may be updated once we obtain our sampling results
- Our literature review and search for existing data is ongoing…

# Source Assessment

**Load estimate methods make use of GIS land use coverages*

## THg Sources

Atmospheric Dep. Runoff *
Mines
Springs
Dredge Tailings *
Upland Areas (Ag & native) *
Bank Erosion
Suction Dredging

Urban Runoff *
NPDES Facility Discharges

## MeHg Sources

Atmospheric Dep. Runoff *
Mines *
Springs
Dredge Tailings *
Upland Areas (Ag & native) *
Open Water Habitat *
Wetland Habitat *
Urban Runoff *
NPDES Facility Discharges

# Land Use Coverage

**GIS Coverage Overlay**

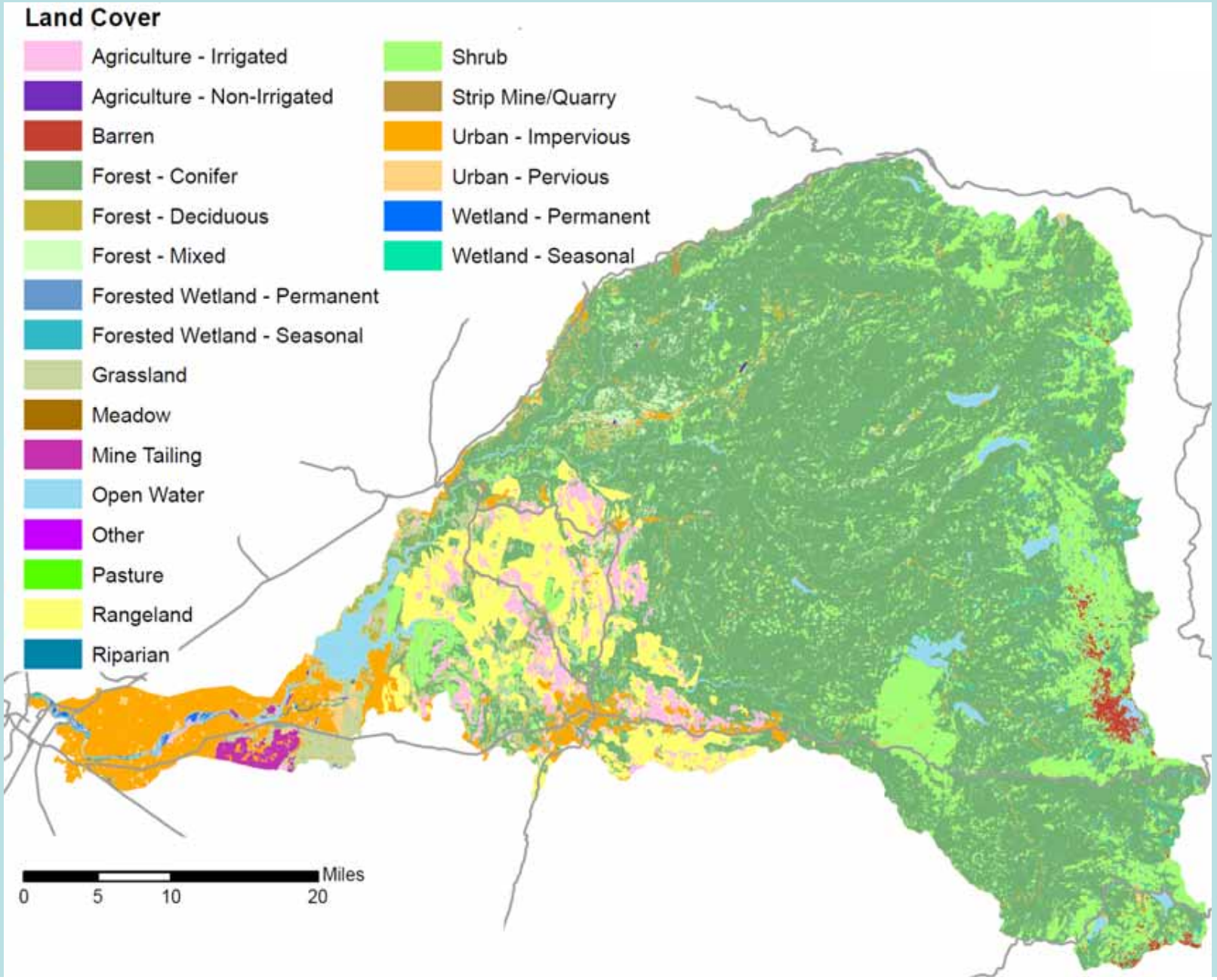
http://www.waterborne-env.com/risk_spatial.asp

1. National Wetlands Inventory (NWI)
2. Topographically Occurring Mine Symbols (TOMS)
3. Department of Water Resources (DWR)
4. Farmland Mapping and Monitoring Program (FMMP)
5. National Land Cover Data (NLCD)

# Data Preferences

- NWI – All Data
- TOMS – Strip Mine/Quarry
- DWR – Agricultural, Quarry, Riparian, Pasture, Meadow, Rangeland, Urban, Mine Tailings
- FMMP – Agricultural, Rangeland, Urban
- NLCD – All Data

# Resulting Seamless Coverage



# Sources

| | THg Sources | MeHg Sources |
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| | Upland Area Erosion | Upland Areas (Ag & native) |
| | Dredge Tailings | Dredge Tailings |
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| | Suction Dredging | Wetland Habitat |
| Point Sources | Urban Runoff | Urban Runoff |
| | NPDES Facility Discharges | NPDES Facility Discharges |

# Atmospheric THg Deposition

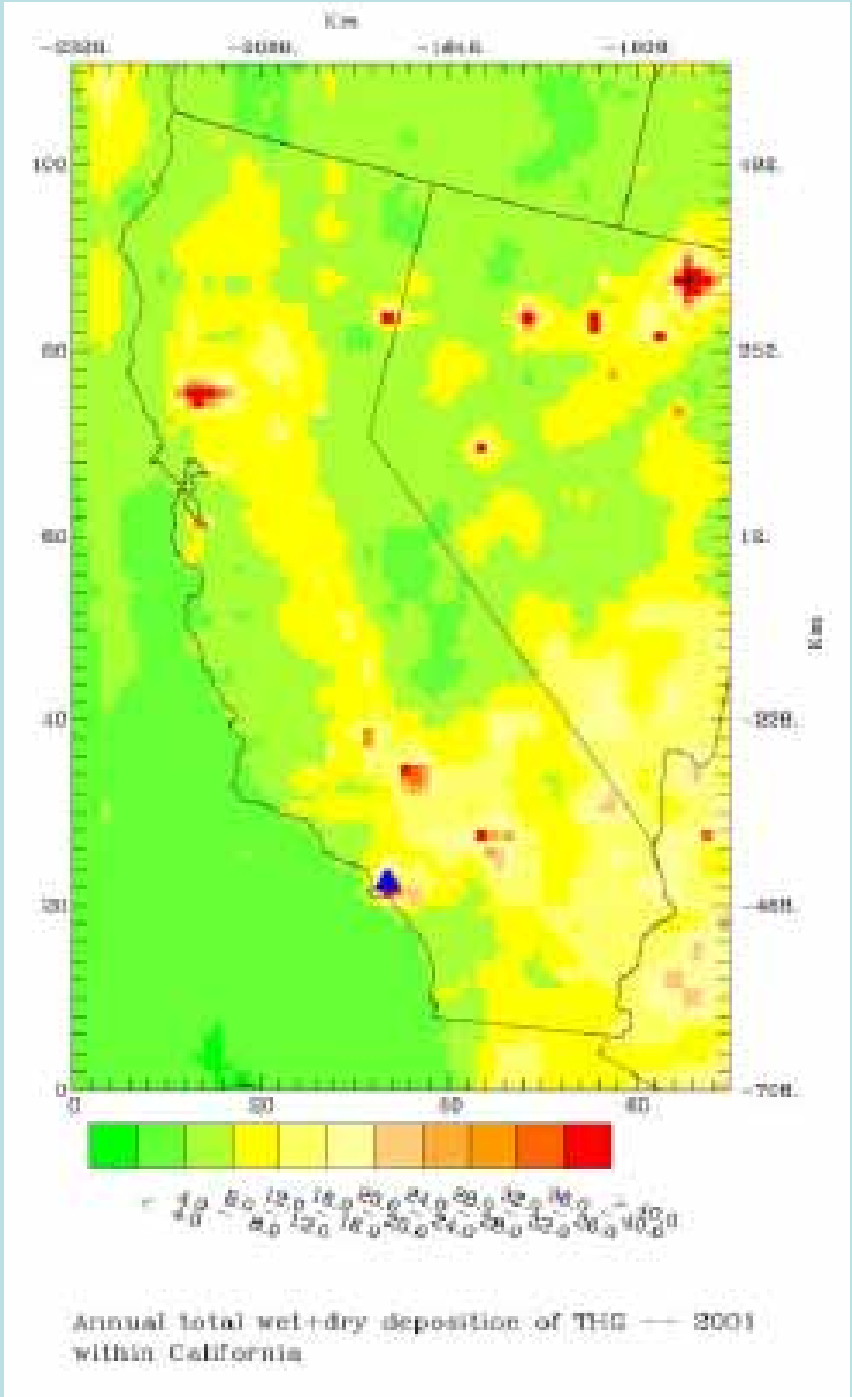
- Sources: Global & local
- Global, for example:
  - Coal-burning power plants in Asia
  - Worldwide gold and mercury production
  - Cement production
  - Volcanic emissions
  - Oceans
  - Biomass burning (e.g., forest fires and biofuel to produce energy)

# Atmospheric THg Deposition

- Sources: Global & local
- Local:
  - Municipal and industrial emissions
  - Historic mercury and gold mine sites
  - Forest fires
  - Naturally mercury-enriched geologic formations

# Atmospheric THg Deposition

- Sources: Global & local
- Key questions:
  - How much atmospheric mercury deposits in the American River Watershed?

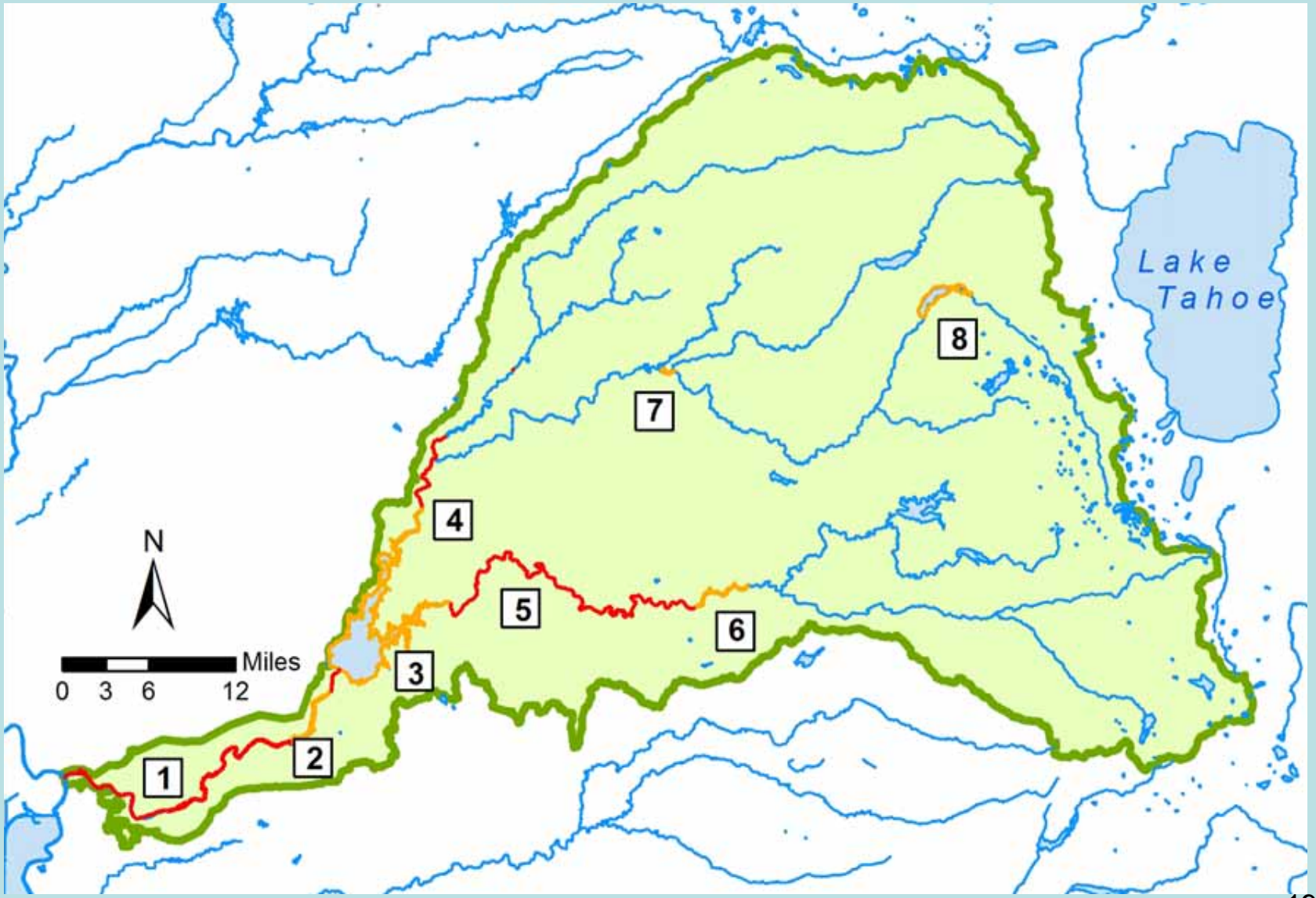



# REMSAD-simulated Total (Wet and Dry) Annual Mercury Deposition (g km-2) for California (USEPA, 2008)

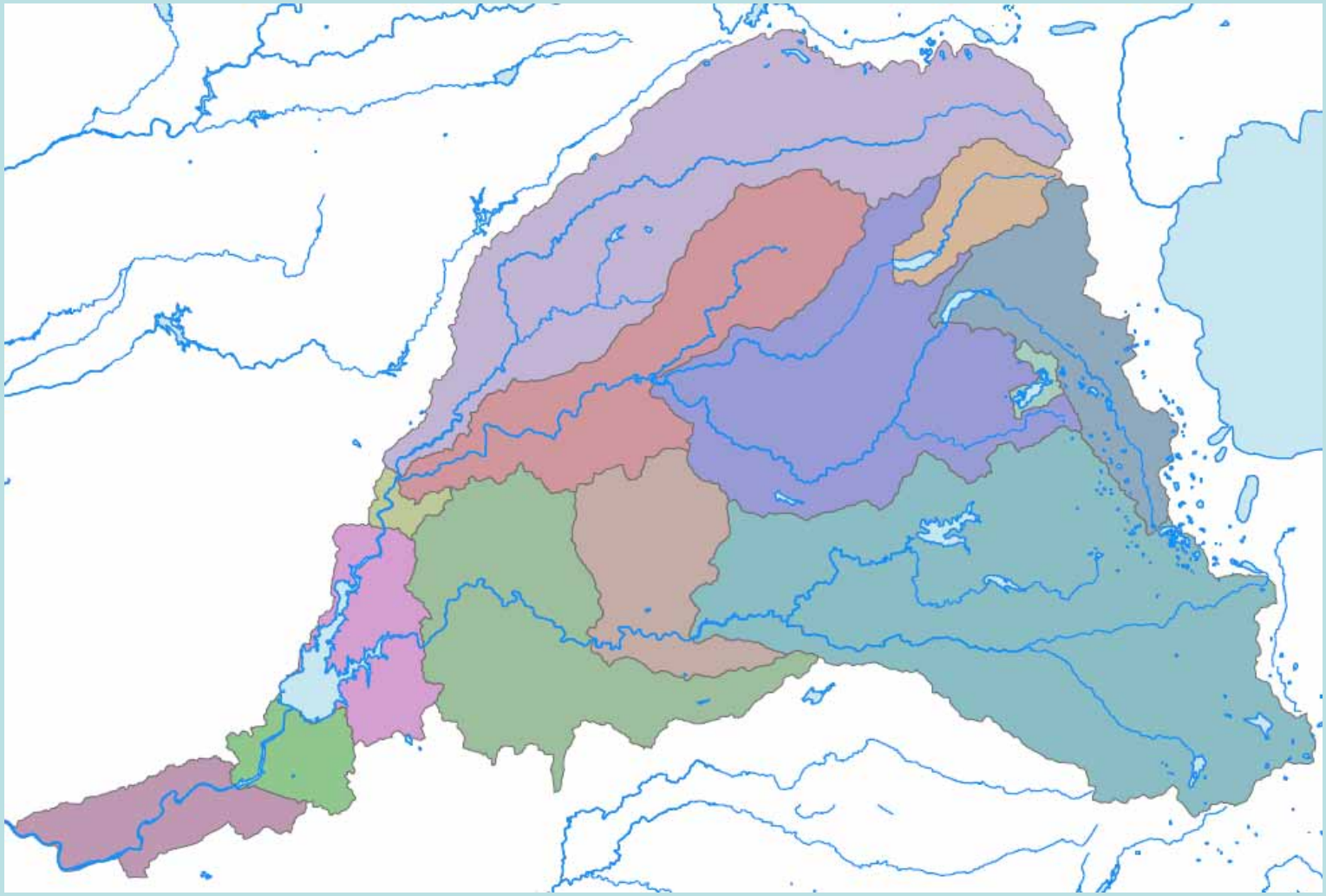
# Atmospheric Deposition

- Key questions:
  - How much atmospheric mercury deposits in the American River Watershed? - REMSAD Model output
  - **How much of what deposits is transported to the waterways?**
    - Literature values for mercury surface runoff:
      - 2 to 60% of atmospheric deposition to land
      - Extent of the mercury surface runoff affected by meteorological, soil, land use/land cover and scale characteristics of the watershed
    - ARW source assessment:
      - Identified area of different land covers in each watershed
      - Caltrans Highway Design Manual runoff coefficients calculation method

# 303(d) Listed Water Bodies



# Source Assessment Watersheds



# REMSAD Loading Rates:

- Western watersheds: 14 ug/m2/year
- Eastern watersheds: 6 ug/m2/year

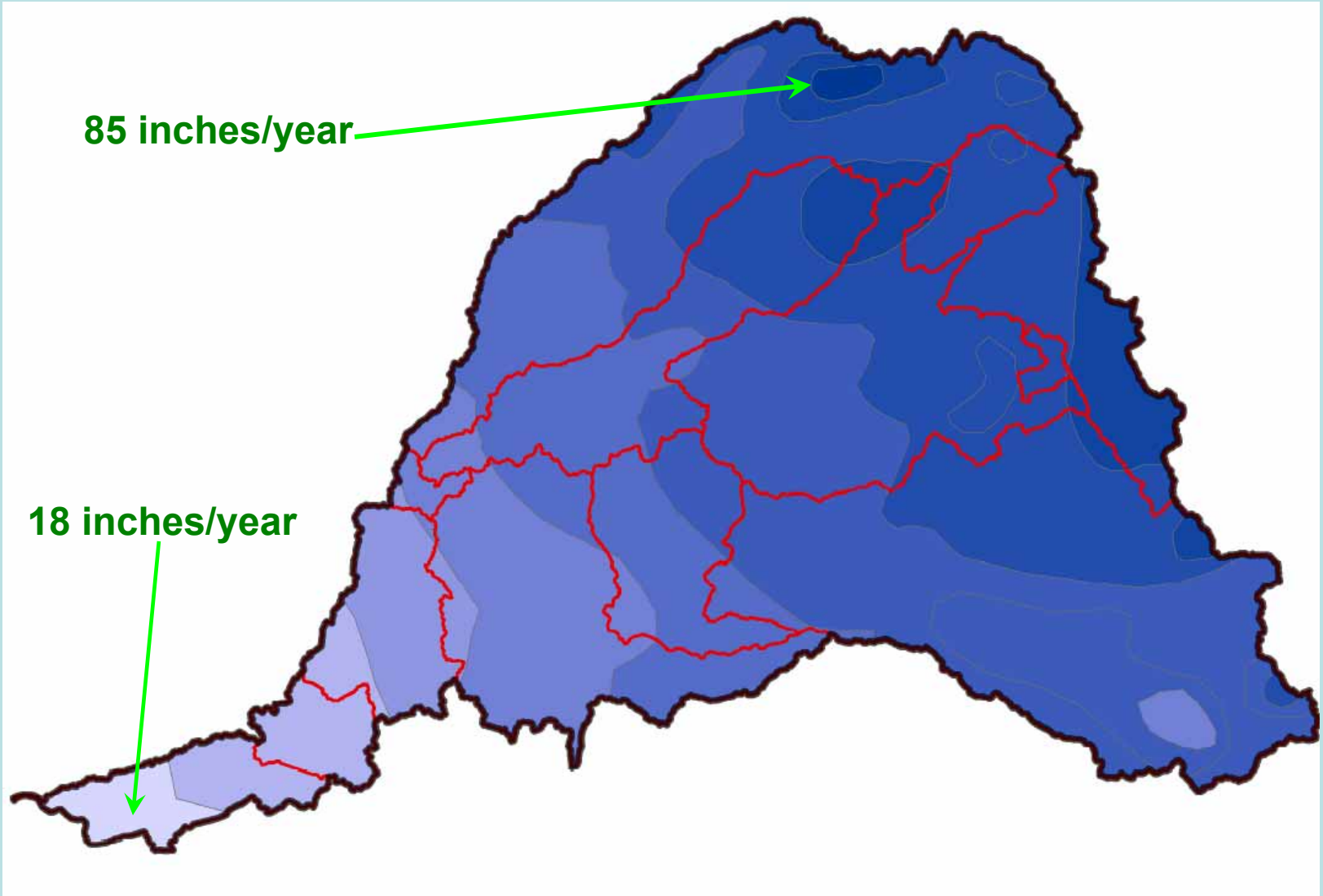
# Preliminary Atmospheric THg Deposition Runoff Results

| Watershed | REMSAD 2001 Dry + Wet Dep Runoff Annual Load (kg/yr) |
|---|---|
| 01 French Meadow Reservoir | 0.35 |
| 02 Hell Hole Reservoir | 0.84 |
| 03 Loon Lake | 0.07 |
| 04 Oxbow Reservoir | 2.18 |
| 05 Slab Creek Reservoir | 3.66 |
| 06 Chili Bar Reservoir | 0.76 |
| 07 North Fork u/s MF Confluence | 2.98 |
| 08 Middle Fork | 1.59 |
| 09 North Fork d/s MF confluence | 0.21 |
| 10 South Fork d/s Chili Bar Reservoir | 3.47 |
| 11 Folsom Lake | 1.79 |
| 12 Lake Natoma | 0.77 |
| 13 Lower American River | 1.73 |

# Literature Review: Wet Deposition

| Study [a] | Station [b] | Weighted Average THg Conc. (ng/L) for Collection Period | # of Samples | Collection Period | Annual Rainfall [c] (cm) | Deposition Rate [c] (ug/m2/yr) |
|---|---|---|---|---|---|---|
| **National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN) [from north to south)** | Yurok Tribe-Requa (CA20) | 3.5 | 117 | Aug. 2006 - Jul. 2010 | 165 | 5.8 |
| | **Covelo (CA97)** | **4.2** | 58 | Dec. 1997 - Oct. 2000 | 114 | 4.8 |
| | Reno (NV98) | 9.5 | 31 | Oct. 2006 - May 2008 | 19 | 1.8 |
| | **San Jose (CA72) [d]** | **9.1** | 146 | Jan. 2000 - Dec. 2006 | 36 | 3.3 |
| | Sequoia National Park (CA75) | 6.5 | 160 | Jul. 2003 - Jul. 2010 | 114 | 7.4 |
| | Converse Flats (CA94) | 9.4 | 67 | Apr. 2006 - Jul. 2010 | 70 | 6.6 |
| Coastal Pacific Rainwater Mercury Speciation Study | Monterey Bay (locations within a few km of Monterey Bay coastline) | 5.8 | 41 | 2007-2008 rainy season | 73 | 4.2 |
| **CalFed Atmospheric Mercury Deposition Studies** | Point Reyes Bird Observatory (near Bolinas) | 4.2 | 16 | Apr. 2004 - Jun. 2006 | 142 / 62 | 5.9 / 2.6 |
| | Twitchell Island (near Rio Vista) | 4.2 | 12 | Apr. 2004 - Jun. 2006 | 35 | 1.5 |
| | **Woodland (near Sacramento)** | **3.7** | 18 | Feb. 2005 - Apr. 2006 | 52 | 1.9 |
| Coastal Ca Precipitation Study (Steding and Flegal, 2002) | UC Santa Cruz Long Marine Laboratory | 6.0 | 17 | Feb. 2000 - Mar. 2001 | 74 | 4.0 |
| | Moffett Field [d] | 11.8 | 26 | Feb. 2000 - Mar. 2001 | 35 | 4.4 |
| San Francisco Bay Atmospheric Deposition Pilot Study (SFBADPS) | North Bay | 7.4 | 14 | Apr. 2000 – Jul. 2000 | 58 | 4.3 |
| | Central Bay | 6.6 | 16 | | 68 | 4.5 |
| | South Bay [d] | 9.7 | 29 | | 36 | 3.5 |
| | Bay-wide | 8.0 | 59 | | 53 | 4.2 |

# Long-term Average Precipitation



# Literature Review: Dry Deposition

| Study | Station | Collection Period | Deposition Rate (ug/m2/yr) | |
|---|---|---|---|---|
| San Francisco Bay Atmospheric Deposition Pilot Study (SFBADPS) | San Francisco Bay Area | Apr. 2000 – Jul. 2000 | 19 | |
| CalFed Atmospheric Mercury Deposition Studies | | | Winter | Summer |
| | Moss Landing (near Monterey) | Dec. 2004 - Jun. 2005 | 0.40 | 0.11 |
| | Woodland (near Sacramento) | July. 2005 - May 2006 | **1.1** | **3.4** |

# Comparison is surprisingly good!

| Watershed | REMSAD 2001 Dry + Wet Dep Runoff Annual Load (kg/yr) | SUM Michelle's Wet Dep + CALFED Dry Dep Annual Runoff Load (kg/yr) | Difference with REMSAD |
|---|---|---|---|
| 01 French Meadow Reservoir | 0.35 | 0.66 | -86% |
| 02 Hell Hole Reservoir | 0.84 | 1.62 | -93% |
| 03 Loon Lake | 0.07 | 0.13 | -85% |
| 04 Oxbow Reservoir | 2.18 | 3.88 | -78% |
| 05 Slab Creek Reservoir | 3.66 | 6.31 | -72% |
| 06 Chili Bar Reservoir | 0.76 | 1.17 | -54% |
| 07 North Fork u/s MF Confluence | 2.98 | 5.19 | -74% |
| 08 Middle Fork | 1.59 | 2.68 | -69% |
| 09 North Fork d/s MF confluence | 0.21 | 0.12 | 43% |
| 10 South Fork d/s Chili Bar Reservoir | 3.47 | 2.06 | 41% |
| 11 Folsom Lake | 1.79 | 0.91 | 49% |
| 12 Lake Natoma | 0.77 | 0.37 | 52% |
| 13 Lower American River | 1.73 | 0.81 | 53% |

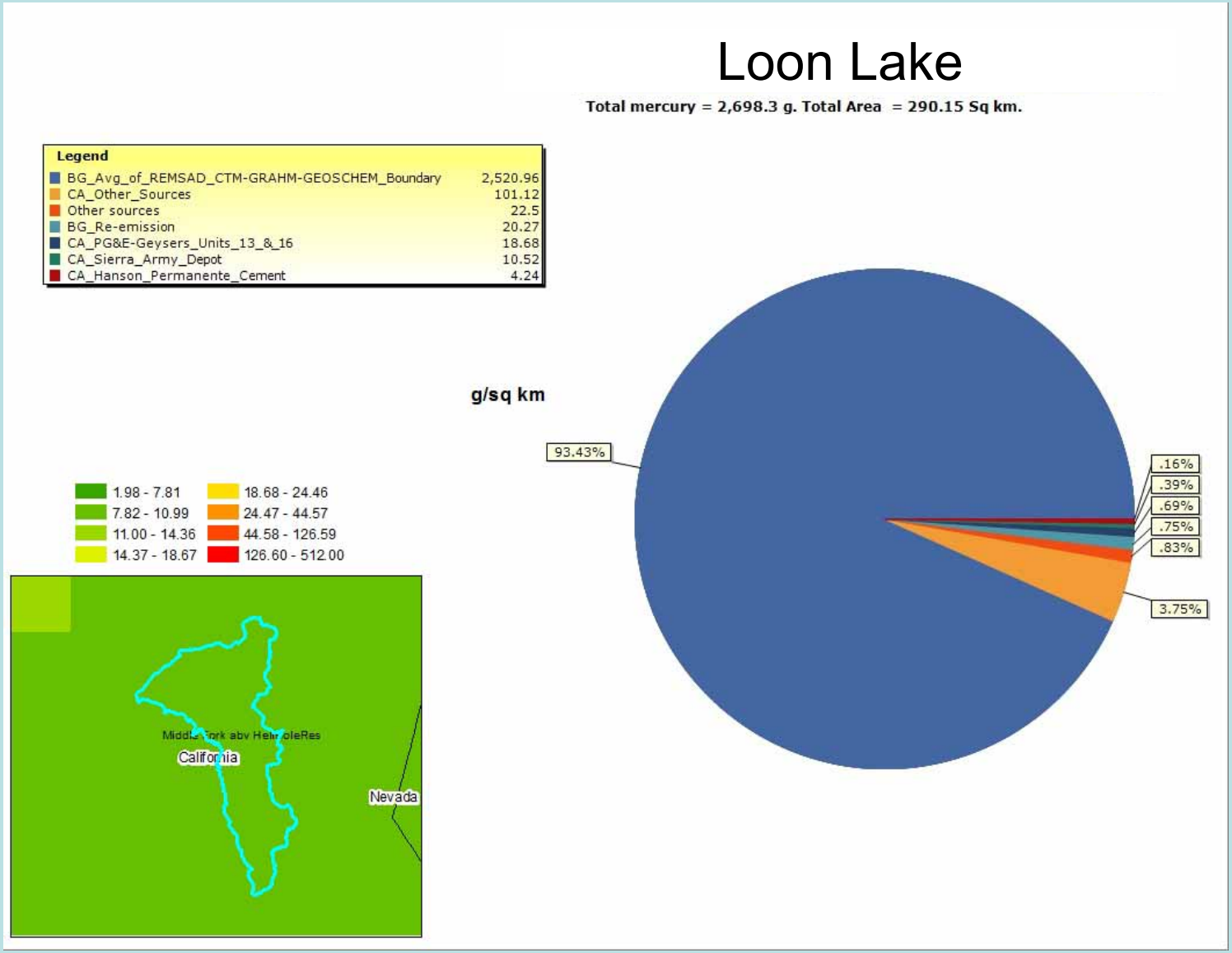
# Atmospheric Deposition Methods Comparison

- Not surprising that my method over-predicted loading to high precipitation areas, given I used Woodland wet dep concentrations
  - As noted in the literature, areas with elevated precipitation often have lower concentrations
- Not surprising that my methods under-predicted loading to western watersheds because I did not factor in local air emission sources

# Atmospheric Deposition

- Key questions:
  - How much atmospheric mercury deposits in the American River Watershed? - REMSAD Model output
  - How much of what deposits is transported to the waterways? Use runoff coefficients
  - Where does the mercury in atmospheric deposition come from?
    - Local versus global
    - Local point sources versus nonpoint sources

# REMSAD Model:
## Mercury Deposition Contribution Analysis



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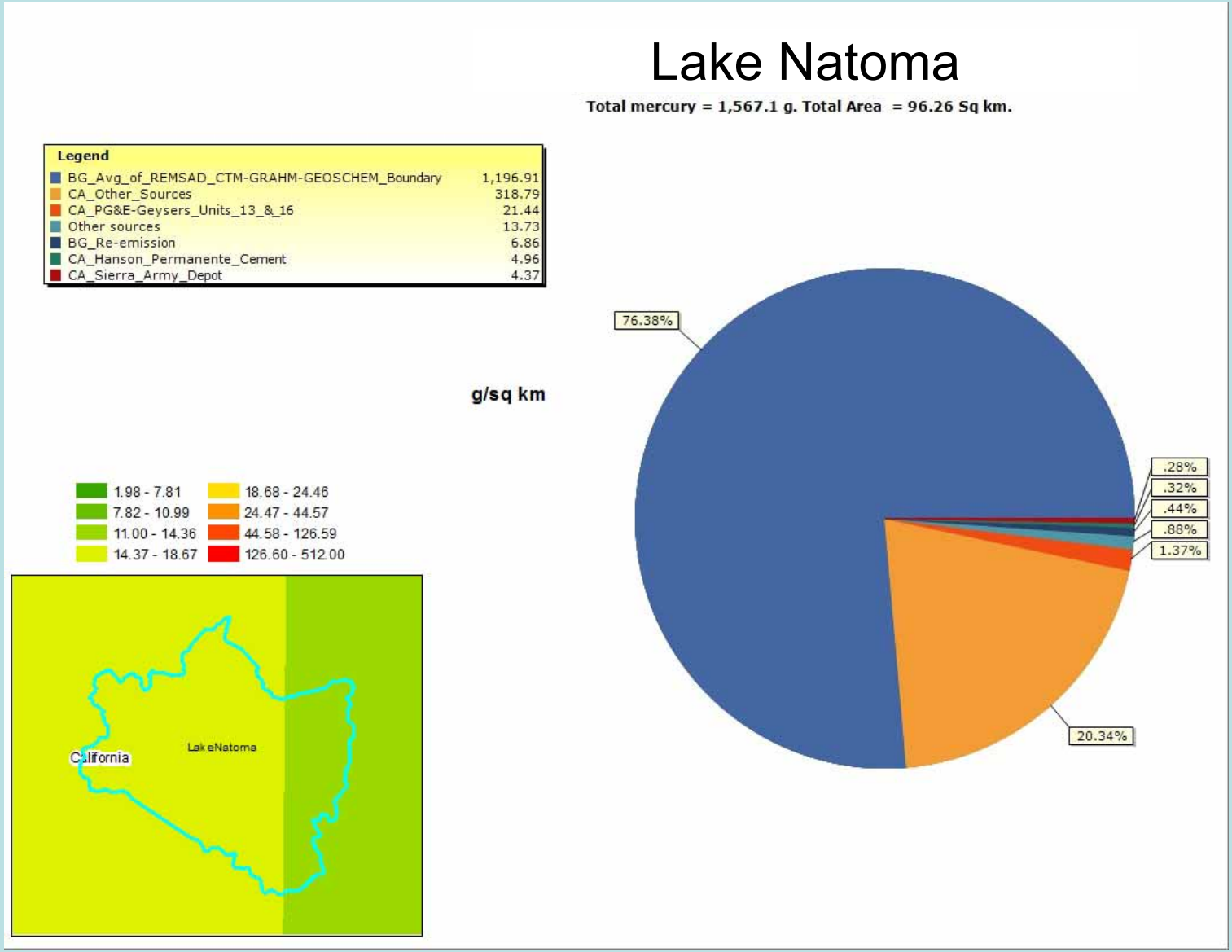

# THg Contributions from Historic Gold Mining Activity

- Key Questions:
  - How many historic mine sites are in the ARW?

# GIS Mine Site Coverages

- **MRDS**
  - Mineral Resources Data System: U.S. Geological Survey Digital Data Series DDS-20
  - Mines sites, commodity, and the under lying ore body
  - Status of the mine deposits: occurrence, prospect, **past and present producers**

# GIS Mine Site Coverages

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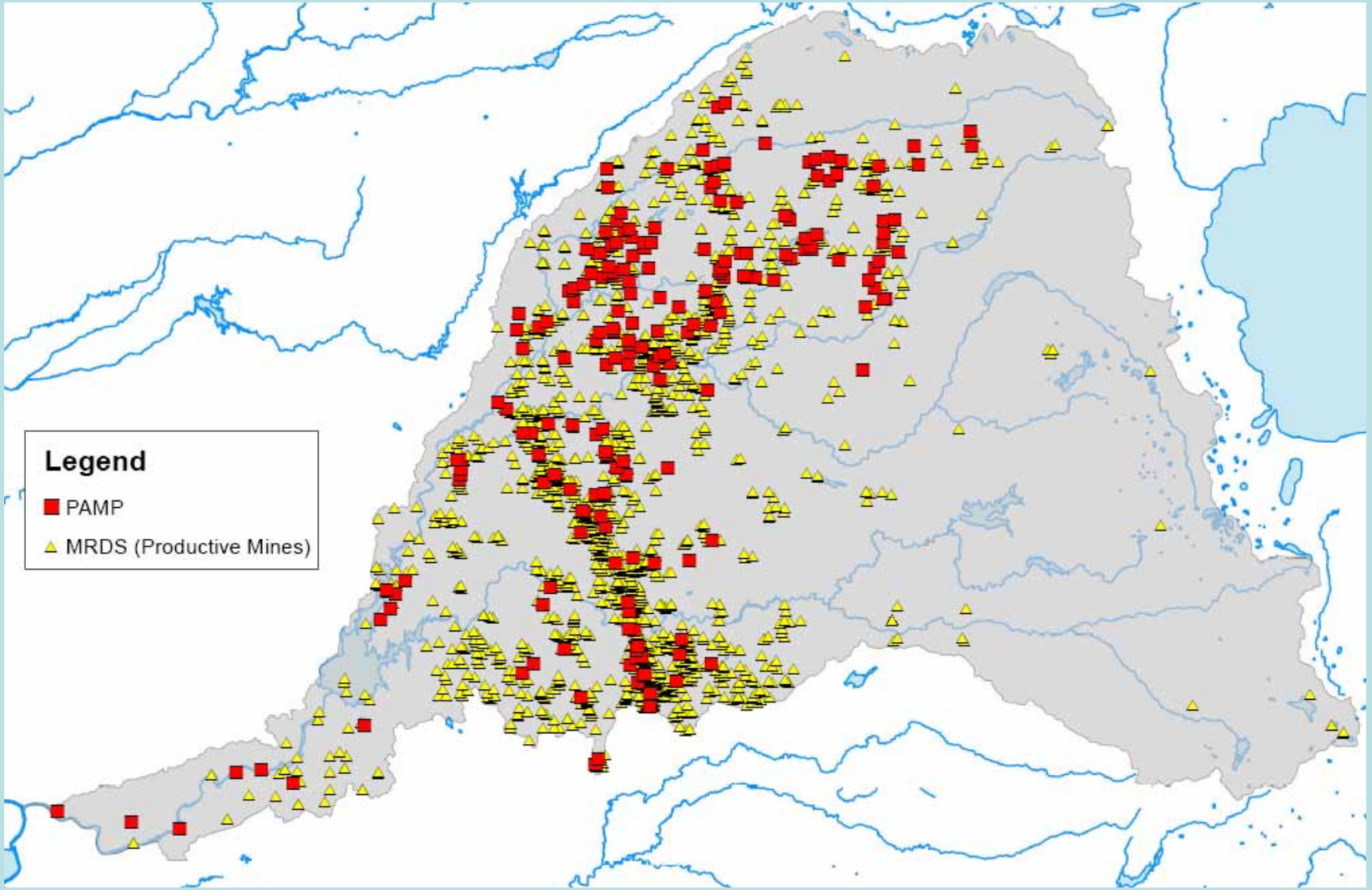
  - Mines sites, commodity, and the under lying ore body
  - Status of the mine deposits: occurrence, prospect, **past and present producers**
- **PAMP**
  - Principal Areas of Mine Pollution: Location of mining operations and their potential water-quality problems
  - Mines where production exceeded **$100,000** or where other factors indicated a high potential for water quality impacts.

# Identified ARW Gold Mines

Map includes only MRDS past and present producers, no occurrences or prospects.



# # of Identified ARW Gold Mine

| | No of Mines | |
|---|---|---|
| **Watershed** | **MRDS** | **PAMP** |
| 01 French Meadow Reservoir | 3 | |
| 02 Hell Hole Reservoir | 1 | |
| 04 Oxbow Reservoir | 29 | 9 |
| 05 Slab Creek Reservoir | 15 | |
| 06 Chili Bar Reservoir | 44 | 6 |
| 07 North Fork u/s MF Confluence | 206 | 70 |
| 08 Middle Fork | 196 | 62 |
| 09 North Fork d/s MF confluence | 1 | |
| 10 South Fork d/s Chili Bar Reservoir | 227 | 37 |
| 11 Folsom Lake | 20 | 2 |
| 12 Lake Natoma | 17 | 1 |
| 13 Lower American River | 11 | 1 |

# THg Contributions from Historic Gold Mining Activity

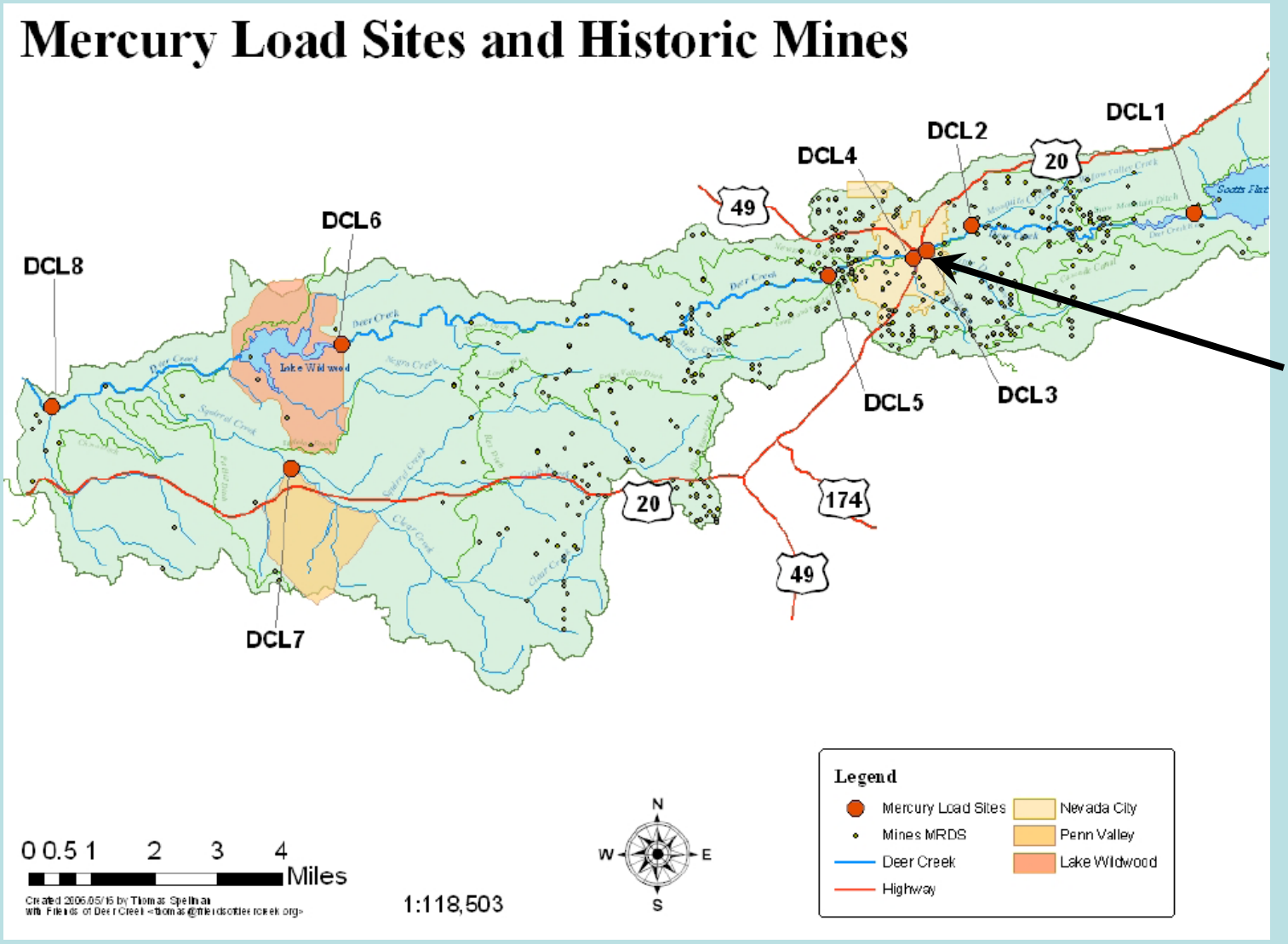
- Key Questions:
  - How many historic mine sites are in the ARW?
  - How much mercury did the sites contribute?
  - How much mercury do the sites still contribute?

# Per Mine Loading Estimates

| | Loading Per Mine kg/year |
|---|---|
| **Study** | **MRDS** |
| 2002 DTMC estimate for Feather River [Yuba River, Cottonwood Creek] | 0.05 [0.02, 0.12] |

# Deer Creek Watershed Mercury Survey

## Friends of Deer Creek, 2008




**DCL3:**
Little Deer Ck

**DCL4:**
Gold Run Ck

# Deer Creek Watershed Mercury Survey

## Friends of Deer Creek, 2008

Table 9. Total mercury load estimates for the eight principal water sampling sites for each storm-event.

| Deer Creek Total mercury Load Estimates (g/day) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | 9/15/05 | 12/1/05 | 12/28/05 | 12/31/05 | 2/2/06 | 2/27/06 | 3/25/06 | 4/3/06 | 5/11/06 | 6/29/06 | Average | Stdev |
| *DCL1* | 0.07 | 0.00 | 0.64 | 11.97 | 0.97 | 0.43 | 3.33 | 11.60 | 0.28 | 0.26 | 2.95 | 4.75 |
| *DCL2* | 0.04 | 7.07 | 11.48 | 69.11 | 5.04 | 7.03 | 44.61 | 136.23 | 0.36 | 0.08 | 28.10 | 44.32 |
| *DCL3 (LDC)* | 0.01 | 21.27 | 69.61 | 505.11 | 0.89 | 8.86 | 82.50 | 98.33 | 0.06 | 0.03 | 78.67 | 154.60 |
| *DCL4 (GR)* | **0.26** | 69.56 | 75.04 | 282.99 | 3.12 | 17.87 | 95.36 | 86.77 | 0.45 | **0.85** | 63.23 | 86.62 |
| *DCL5* | 0.14 | **76.74** | 155.74 | 1037.62 | 11.23 | 56.79 | 231.18 | 667.15 | 1.09 | 0.48 | 223.81 | 350.83 |
| *DCL6* | 0.01 | 57.10 | **818.44** | **3674.10** | **33.99** | **100.65** | **1445.61** | **1408.37** | 0.98 | 0.04 | 753.93 | 1181.93 |
| *DCL7 (SC)* | | 20.43 | 75.53 | 159.14 | 11.61 | 23.13 | 89.63 | 181.67 | 0.32 | 0.11 | 62.40 | 69.03 |
| *DCL8* | 0.01 | | 145.92 | 883.41 | 21.03 | 38.06 | 158.95 | 315.62 | **1.51** | 0.04 | 173.84 | 286.47 |
| **Bold = highest load for sampling event** | | | | | | | | | | | | |
| Highlighted = site where the load increases with an unaccounted source | | | | | | | | | | | | |

# Per Mine Loading Estimates

| | # of Mines | | Loading Per Mine kg/year | |
|---|---|---|---|---|
| **Study** | **PAMP** | **MRDS** | **PAMP** | **MRDS** |
| 2002 DTMC estimate for Feather River [Yuba River, Cottonwood Creek] | na | na | na | **0.05** [0.02, 0.12] |
| Michelle's estimate based on Deer Creek Survey WY2006 LDC and Gold Run watershed loads [FODC, 2008] [WY2006=very wet year] | 5 | 62 | 0.88 | **0.07** |

# The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area USGS, 2010

## South Yuba River at Jones Bar:

| Year | THg g/yr | Water Year Index |
|---|---|---|
| 2001 | 510 | Dry |
| 2002 | 1,900 | Dry |
| 2003 | 3,500 | Above Normal |
| **Average** | **1970** | |

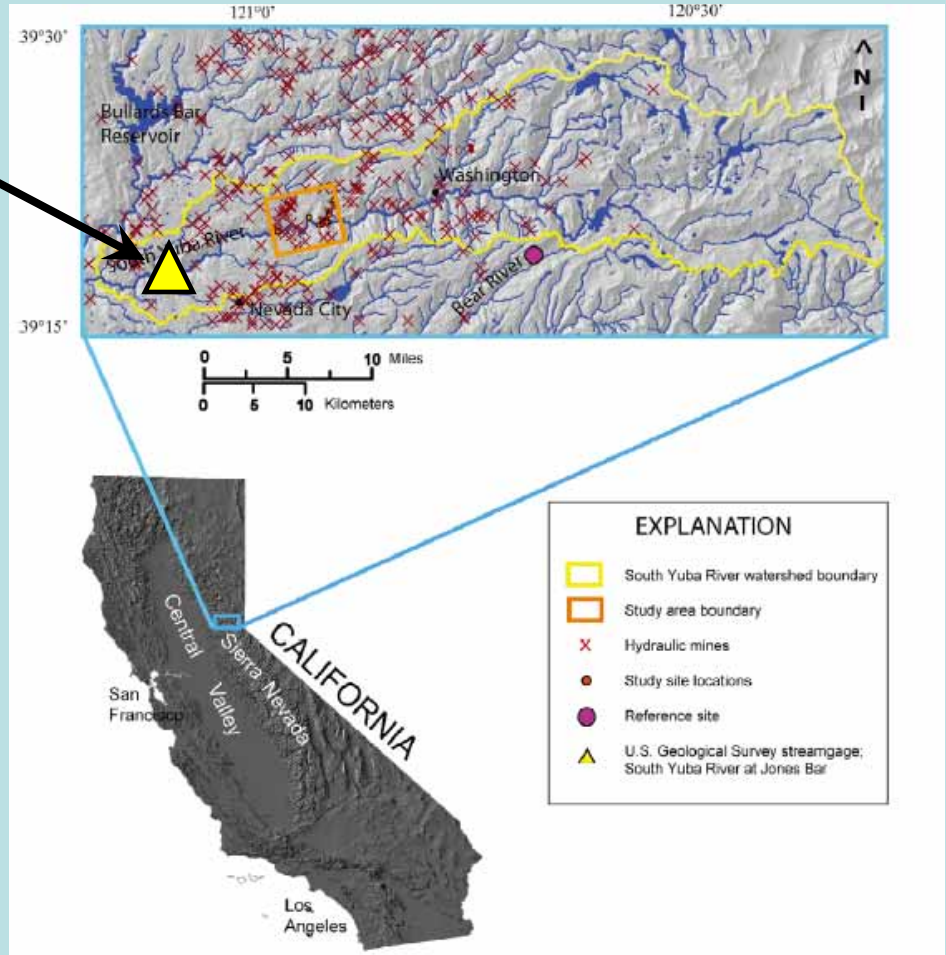



Figure 1. Maps showing location of (A) the South Yuba River watershed in California's Sierra Nevada, with a detailed view of the location of the study area and hydraulic mines within the South Yuba River watershed and (B) the locations of hydraulic pits (Yeend, 1974) and sampling sites within the study area, with a detailed view of the high-resolution aerial photo of the focused study area of the South Yuba River–Humbug Creek (SYR-HC) confluence. Source: MAS/MILS (Minerals Availability System/Mineral Information Location System) database compiled by the former U.S. Bureau of Mines, now archived by the USGS.

# Per Mine Loading Estimates

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|---|---|---|---|---|
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| 2002 DTMC estimate for Feather River [Yuba River, Cottonwood Creek] | na | na | na | **0.05** [0.02, 0.12] |
| Michelle's estimate based on Deer Creek Survey WY2006 LDC and Gold Run watershed loads [FODC, 2008] [WY2006 = very wet year] | 5 | 62 | **0.88** | **0.07** |
| Michelle's estimate based on South Yuba River 2001-2003 loads [Fleck et al., 2010] [WY-2001-2003 = relatively dry period] | 44 | 239 | **0.045** | **0.008** |

# Range of Per Mine Loads for ARW Estimates

| | THg Loading Per Mine kg/year | |
|---|---|---|
| Year Type | PAMP | MRDS |
| Wet Year | 0.88 | 0.07 |
| Dry Year | 0.045 | 0.008 |

***Combination of THg loads in modern mine site surface runoff & adit discharges, as well as in-channel legacy THg ***that are being transported by stream and river flows****

# Preliminary Estimate of Range of THg Loads from Gold Mines

| | Estimated THg Load from Mines (kg/year) | |
|---|---|---|
| **Watershed** | **Low** | **High** |
| 01 French Meadow Reservoir | 0.024 | 0.21 |
| 02 Hell Hole Reservoir | 0.008 | 0.070 |
| 04 Oxbow Reservoir | 0.23 | 7.92 |
| 05 Slab Creek Reservoir | 0.12 | 1.05 |
| 06 Chili Bar Reservoir | 0.27 | 5.28 |
| 07 North Fork u/s MF Confluence | 1.65 | 61.6 |
| 08 Middle Fork | 1.57 | 54.56 |
| 09 North Fork d/s MF confluence | 0.008 | 0.07 |
| 10 South Fork d/s Chili Bar Reservoir | 1.67 | 32.56 |
| 11 Folsom Lake | 0.09 | 1.76 |
| 12 Lake Natoma | 0.05 | 1.19 |
| 13 Lower American River | 0.05 | 0.88 |

# Sources

| | THg Sources | MeHg Sources |
|---|---|---|
| Nonpoint Sources | Atmospheric Dep. Runoff | Atmospheric Dep. Runoff |
| | Mines | Mines |
| | Upland Area Erosion | Upland Areas (Ag & native) |
| | Dredge Tailings | Dredge Tailings |
| | Bank erosion | Springs |
| | Springs | Open Water Habitat |
| | Suction Dredging | Wetland Habitat |
| Point Sources | Urban Runoff | Urban Runoff |
| | NPDES Facility Discharges | NPDES Facility Discharges |

# THg Loads from Upland Area Erosion & Dredge Tailings

Estimate method:

Sediment Mercury Concentration

X

Sediment Load

# Literature Review:
# Mercury in Native Soil

| Study | Soil Type | THg Conc (mg/kg) |
|---|---|---|
| Negrey et al, 2000 (draft) | Folsom Lake Watershed Soil | 0.03 |
| Heyvaert et al, 2000 | Lake Tahoe sediment cores baseline | 0.033 |
| Ashley & Rytuba, 2008 | Clear Creek (Trinity Mountains) metamorphic and granitic pebbles, Nomlaki Tuff, and Tehama formation conglomerates | 0.01 - 0.03 |
| Hornberger et al, 1999 | San Francisco Bay sediment cores baseline | 0.06 |
| Taylor, 1964 | Crustal abundance (basalt & granite averages) | 0.08 |
| Bradford et al., 1996 | Surface soil sample collected in the SF AR watershed* | 0.21 |

* The Kearney Foudnation Special Report describes trace element analyses of surface soil samples collected in 1967, mostly from agricultural fields distant from known point sources of contamination. The latitude/longitude coordinates for the site in the South American River watershed place it near the Marshall Gold Discovery State Historic Park.

# Literature Review:
# Mercury in Dredge Tailings

| Study | Location | Material* | THg Conc (mg/kg) |
|---|---|---|---|
| Ashley & Rytuba, 2008 | Clear Creek (Trinity Mountains) | Fine sediments intermixed with cobbles in dredge stacker tailings | ~0.01 - 0.05 |
| | | Sand and mud from dredge pond deposits | 0.09 - 1.1 |
| Stillwater Science, 2004 | Merced River (lower) | Fines intermixed with gravel and cobbles | 0.004 - 0.09 |
| | | Fine sediments in ponds in the swales between stacker tailings | 0.075 - 0.138 |

* Dredge mining practices resulted in dredge stacker tailings comprised of cobbles that were not exposed to mercury during dredging being deposited on top of silts/sands deposited in dredge ponds that were exposed to mercury. However, later gravel mining and dredging activities can mix up what were once stratified layers.

# Methods to Estimate Sediment Loads

- Soil loss from upland areas:
  Revised Universal Soil Loss Equation (RUSLE)
- Surface runoff from dredge tailings:
  RUSLE
- Channel bank erosion of dredge tailings and native material: Literature review combined with estimate of length of eroding reaches from USGS topo maps, aerial photographs, and site visits (focus on lower American River)

# Soil Loss Estimation: RUSLE

- Revised Universal Soil Loss Equation

$$A = R*K*LS*C*P$$

A = Soil Loss (tons per acre per year )

R = Rain Erosivity Factor: erosive power of rainfall

((ft * tons * in) /(ac * yr * hr) )

K = Soil Erodibility Factor: extent that the soil resists erosive forces

((tons * ac * hr) / (ft * tons * in * ac) )

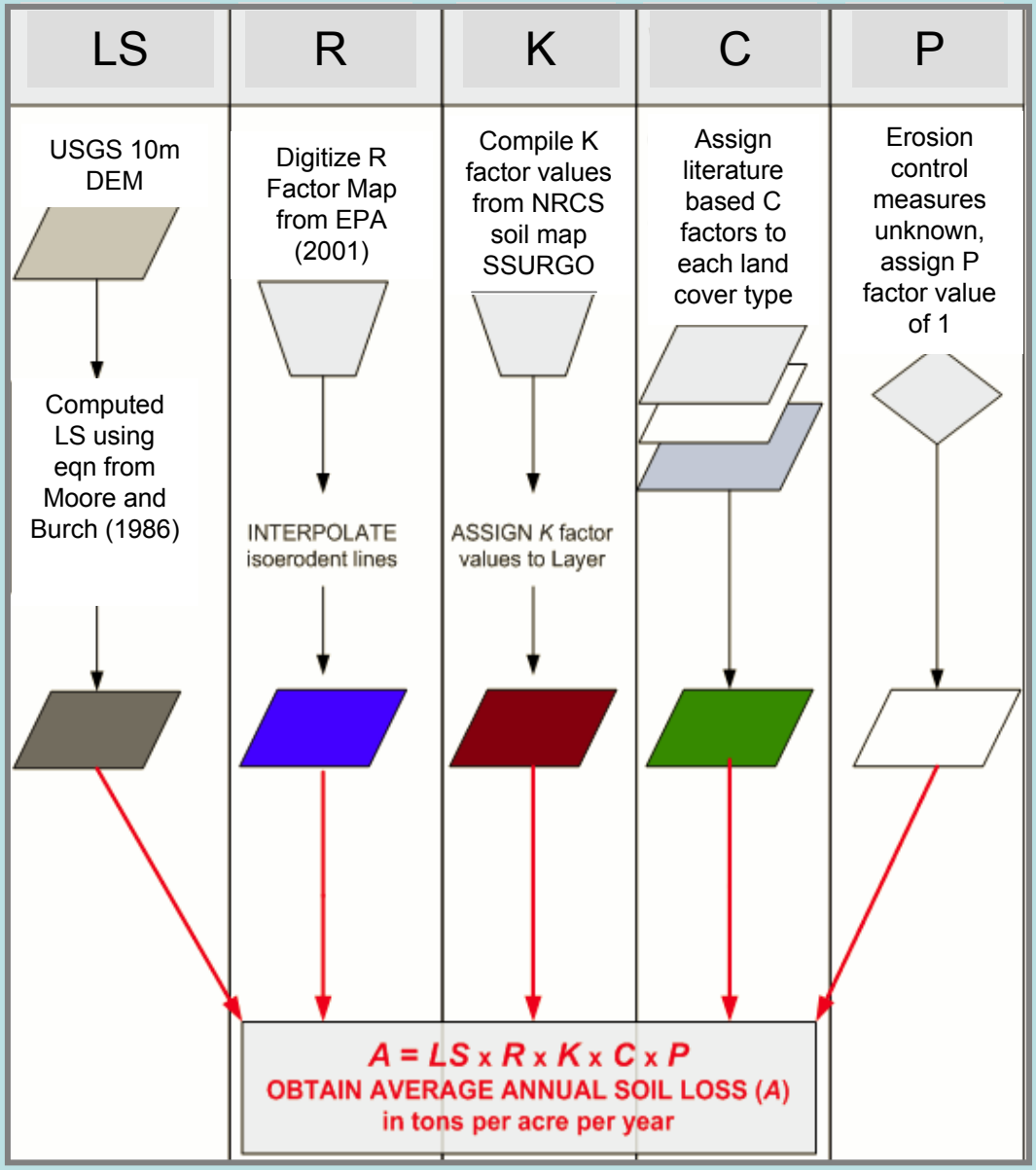
LS = Slope Length Factor: slope length and gradient

C = Cover Factor: vegetation type/density

P = Practice Factor: land management operations

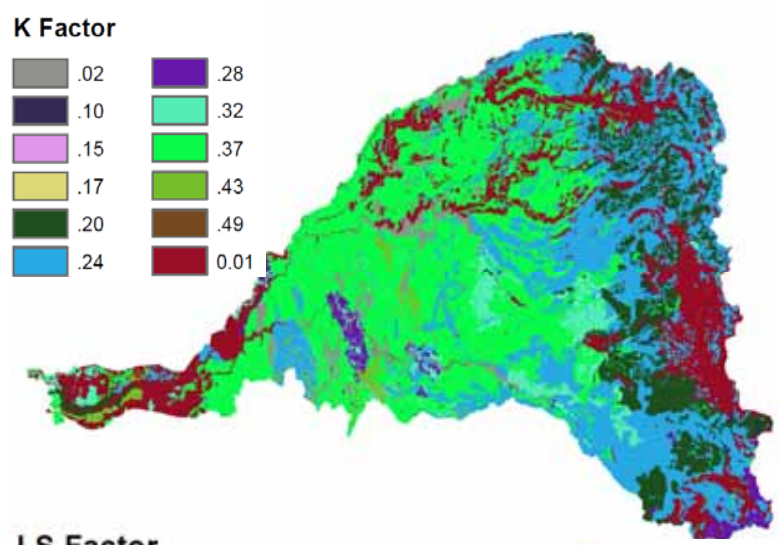
NOTE: LS, C, and P Factors are used as adjustment factors for the real world conditions as compared to the experiment field plot conditions and are therefore dimensionless.

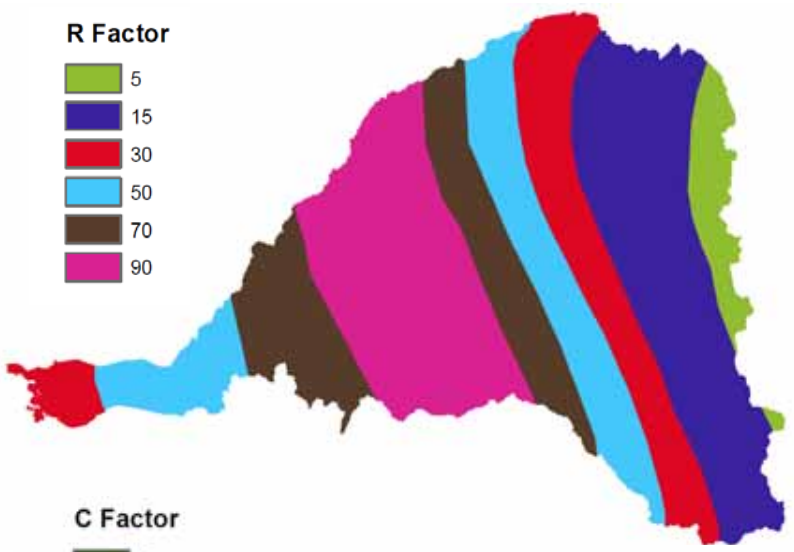
# Using GIS to Calculate Soil Loss

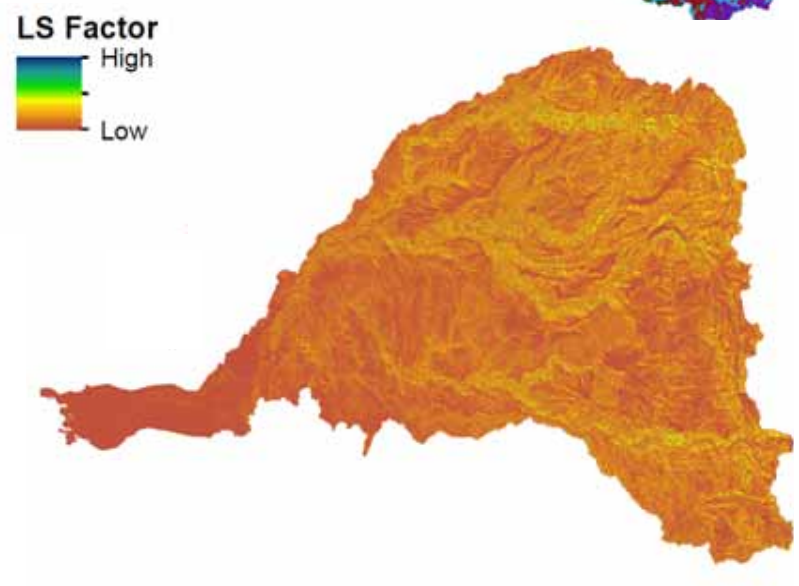


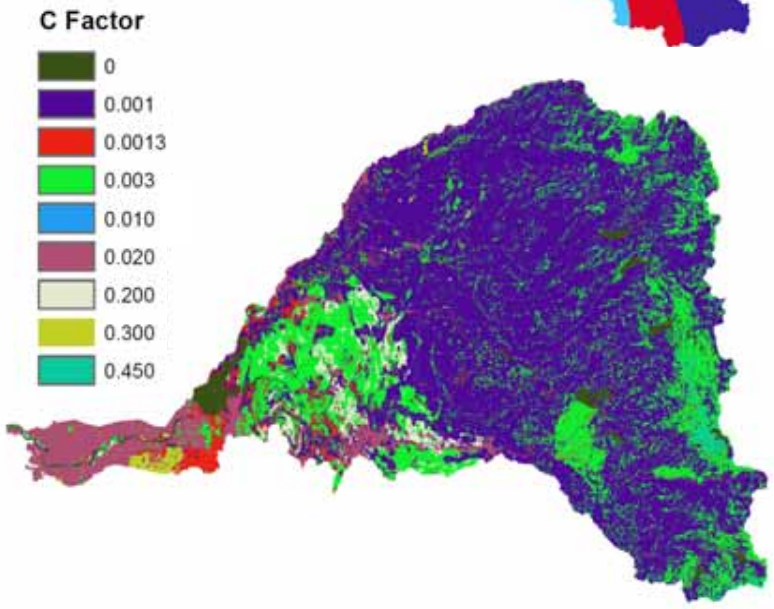

Modified from:
Khosrowpanah et al, 2007

# Maps of RUSLE Factors

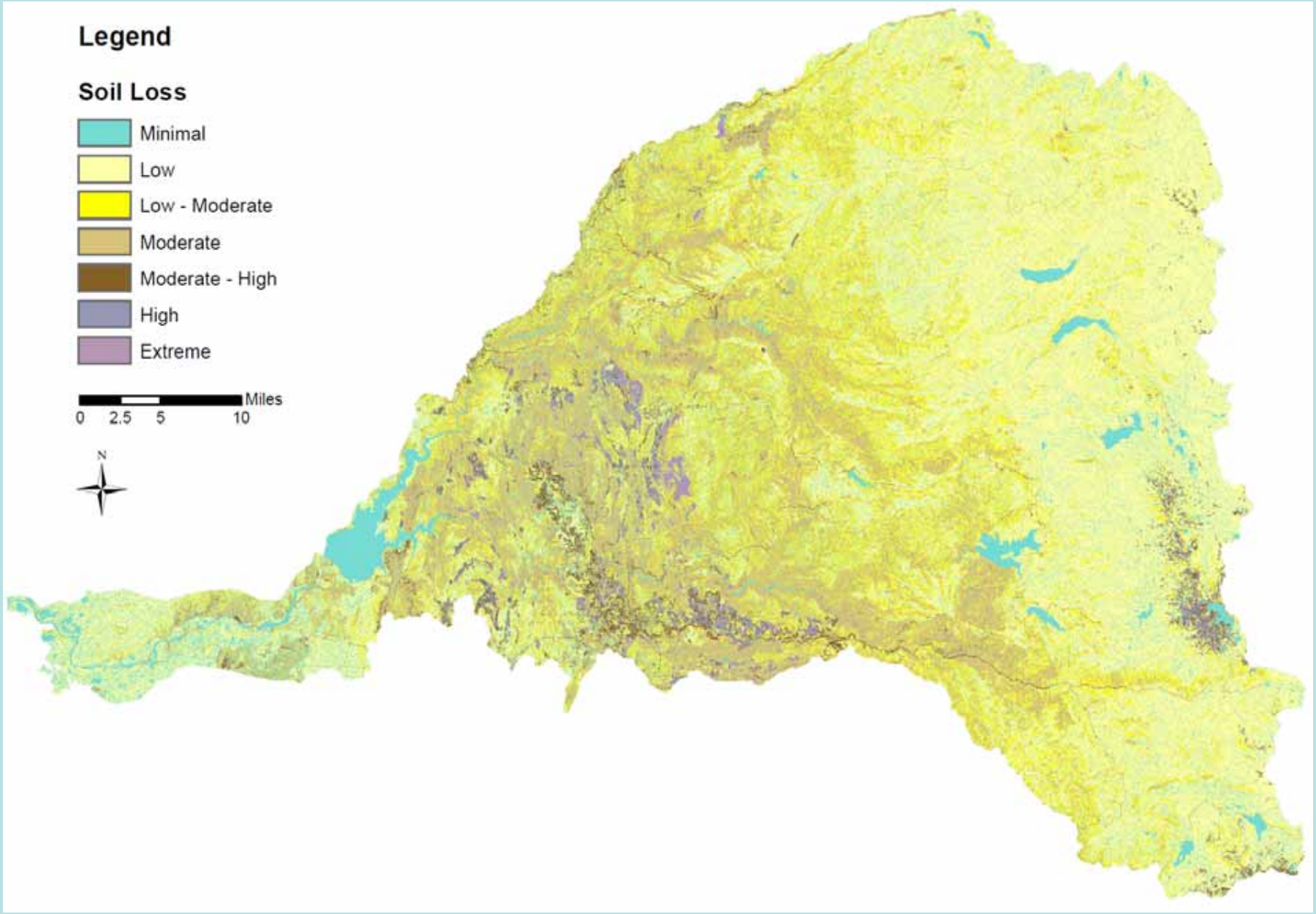


# Soil Loss Map

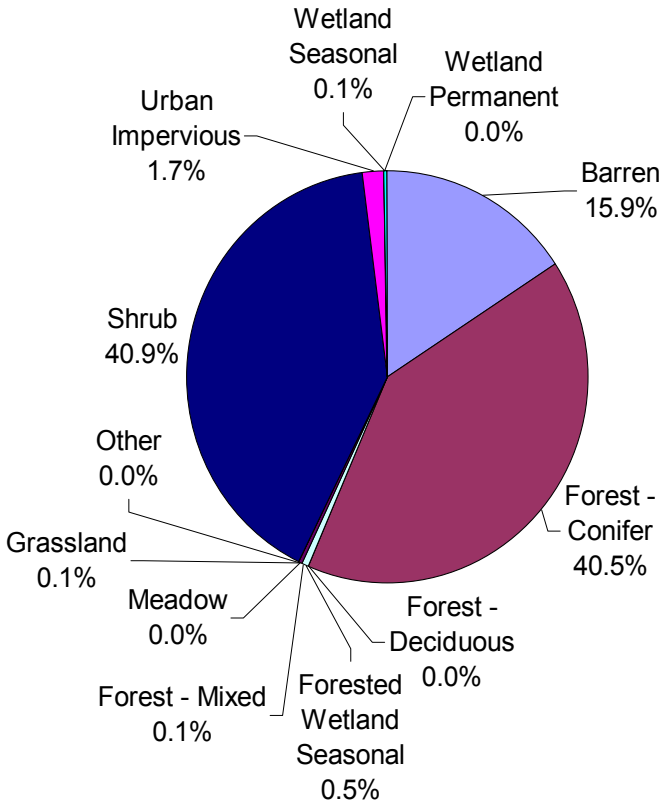


# French Meadows Soil Loss

**Average Annual Soil Loss by Land Use**

| Land Cover | Soil Loss (tons/acre) |
|---|---|
| Barren | 99 |
| Forest - Conifer | 1.4 |
| Forest - Deciduous | 1.6 |
| Forested Wetland Seasonal | 0.9 |
| Forest - Mixed | 2.0 |
| Grassland | 1.2 |
| Meadow | 0.02 |
| Other | 0.00 |
| Shrub | 3.6 |
| Urban Impervious | 16 |
| Wetland Permanent | 0.3 |
| Wetland Seasonal | 1.1 |

**Percent of Total Soil Loss by Land Use**



# Sources

| | THg Sources | MeHg Sources |
|---|---|---|
| Nonpoint Sources | Atmospheric Dep. Runoff | Atmospheric Dep. Runoff |
| | Mines | Mines |
| | Upland Area Erosion | Upland Areas (Ag & native) |
| | Dredge Tailings | Dredge Tailings |
| | Springs | Springs |
| | Suction Dredging | Open Water Habitat |
| | | Wetland Habitat |
| Point Sources | Urban Runoff | Urban Runoff |
| | NPDES Facility Discharges | NPDES Facility Discharges |

# Literature Review:
# THg in Spring Flows

| Study | Region | THg Conc. Range [Average] (ng/l) |
|---|---|---|
| SRWP & CVRWQCB Data, 2000-2006 | Mill Creek outflow | 1.0 - 406 [33] |
| CVRWQCB Data, 2006 | Coast Range springs (51) | <MDL (0.2 ng/l) to 3461 [8.9] |
| Goff et al., 2001 | The Geyers / Clear Lake Region springs | <MDL (20 ng/l) to 7100 |
| Ball et al., 2006 | Yellowstone Geyers | 1.6 - 2100 |

# Spring Locations & Flows

- Database of Low-Temperature Geothermal Springs and Wells (Youngs, 1994) – locations & flows
  - Listed only 1 spring in the entire ARW, Wentworth Spring, **6 L/min** (liters per minute)
  - Listed 5 springs in the Mill Creek watershed with flows of 11, 19, 38, 323, 400 L/min, and an average of **158 L/min**
- GIS coverage of named spring locations

# Spring Locations & Flows

- GIS coverage of named spring locations

| Watershed | # of Named Springs |
|---|---|
| 01 French Meadows Reservoir | 1 |
| 02 Hell Hole Reservoir | 4 |
| 04 Oxbow Reservoir | 17 |
| 08 Middle Fork | 1 |
| 07 North Fork u/s MF Confluence | 11 |
| 05 Slab Creek Reservoir | 11 |

# Per Spring Loading Estimates

| | Low | High | | | | |
|---|---|---|---|---|---|---|
| Wentworth Spring flow (L/min) | 6 | 158 | Average Mill Creek springs flow (L/min) | | | |
| Average Coast Range springs THg conc. (ng/l) | 8.9 | 33 | Mill Creek average THg conc. (ng/l) | | | |
| **Low THg load rate (g/yr/spring)** | **0.028** | **2.7** | **High THg load rate (g/yr/spring)** | | | |

# Estimate of Range of THg Loads from Springs

| Watershed | # of Named Springs | Low (g/yr) | High (g/yr) |
|---|---|---|---|
| 01 French Meadows Reservoir | 1 | 0.028 | 2.7 |
| 02 Hell Hole Reservoir | 4 | 0.11 | 11 |
| 04 Oxbow Reservoir | 17 | 0.48 | 47 |
| 08 Middle Fork | 1 | 0.028 | 2.7 |
| 07 North Fork u/s MF Confluence | 11 | 0.31 | 30 |
| 05 Slab Creek Reservoir | 11 | 0.31 | 30 |

# Suction Dredging

- Use of portable suction dredge with SCUBA and Hookah Air systems allows individuals to use suction dredges underwater like “vacuum cleaners” to excavate sediment and recover gold from rivers and streams
- CDFG issued on average ~3,650 suction dredge permits per year for 15 years prior to current moratorium established in July 2009

# THg Loads Mobilized by Suction Dredging…

- Are inherently included in the previously described Gold Mine-related load estimates:
  - Combination of THg loads in modern mine site surface runoff & adit discharges, as well as in-channel legacy THg **that are being transported by stream and river flows***
  - Suction dredging took place in the watersheds that were the basis of the Gold Mine-related load estimates

# Estimate of Range of THg Loads Mobilized by Suction Dredging: *In Progress*

Use information from:

- CDFG's 2011 Suction Dredge Permitting Program SDEIR (Subsequent Draft Environmental Impact Report)
- USGS's 2010 report, The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area, Nevada County, California: Concentrations, Speciation, and Environmental Fate—Part 1. Field Characterization (Fleck, Alpers and others)

# Suction Dredging Frequency & Location Information:

CDFG's 2011 Suction Dredge Permitting Program SDEIR

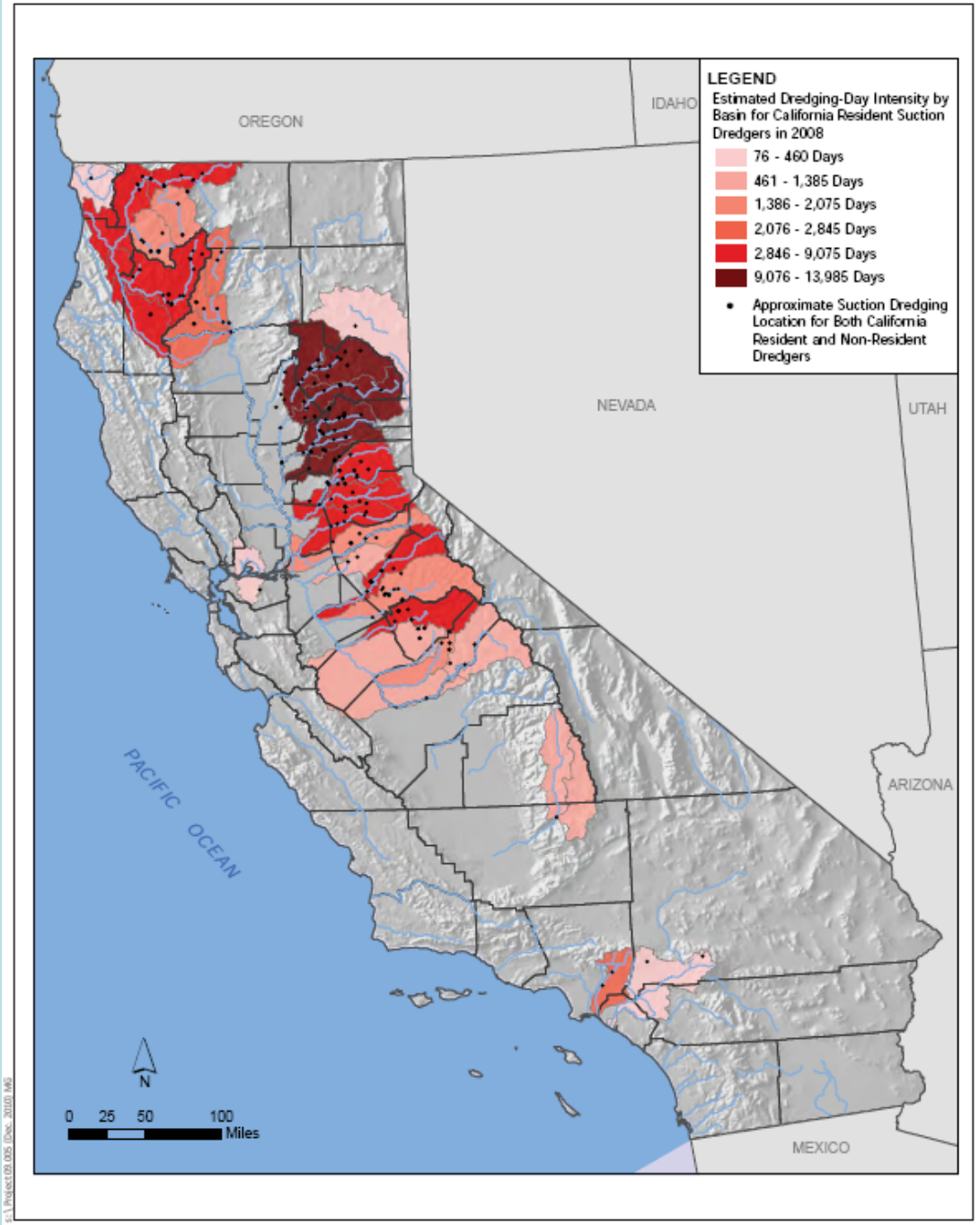



Figure 3-5: Dredging-Day Intensity by Basin for California Resident Suction Dredgers, 2008

# Amount of THg Potentially Mobilized by a Suction Dredge: Transported by The Effects of Sediment and Mercury Mobilization in the South Yuba River and Humbug Creek Confluence Area (USGS, 2010 – Part 1)


Figure 3. Photographs of dredge test in South Yuba River, California, on October 11, 2007. (A) Dredge in operation at first location (hours 0–2); plume of suspended sediment downstream of dredge is visible, (B) Streambed of second dredge location after 1 hour of dredging (hours 2–3), with the excavated 'dredged' streambed pit (outlined in red) and the pile of accumulated sediment 'tails' discharged from the sluice box (outlined in green) both visible.

- In-stream dredge test
- Comprehensive characterization of grain size distribution, Hg speciation, and mineralogy of bed and suspended sediment
- A determination of the past and current sources of sediment in the study area
- An assessment of Hg bioaccumulation in the local invertebrate population
- A comparison of potential Hg transport caused by natural storm disturbances with potential Hg mobilization caused by suction dredging as a method of Hg removal at the study site

# USGS, 2010:
# Calculated rates of potential mercury mobilization by suction dredging for various materials sampled at the South Yuba River - Humbug Creek confluence area

Table 10C. Calculated rates of potential mercury mobilization by suction dredging for various materials sampled at the South Yuba River - Humbug Creek confluence area: Sediment properties used in calculation: Rates of sediment and mercury dredged using revised dredge performance rates from Keene Engineering, Inc. (2010).

[**Abbreviations**: OBL, overburden layer; FCZ, first contact zone; CSL, compact sediment layer; BRC, bedrock contact; HMD-CF, hydraulic mining debris cliff face; THg, total mercury; Hg(II)R, reactive mercury; kg/m³, kilogram per cubic meter; µg/kg, microgram per kilogram; kg/hr, kilogram per hour; m³/hr, cubic meter per hour; mg/hr, milligram per hour; in., inch; HP, horsepower; hr, hour; ", inch; <, less than; >, greater than; mg, milligram; g/m³, gram per cubic centimeter; %, percent

| Dredge nozzle diameter (in.) | Engine HP | Dredge-engine | PIT 1 | | | | HMD-CF | | | | PIT 2 OBL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | sediment m³/hr | sediment kg/hr | THg mg/hr | $Hg(II)_R$ mg/hr | sediment m³/hr | sediment kg/hr | THg mg/hr | $Hg(II)_R$ mg/hr | sediment m³/hr | sediment kg/hr | THg mg/hr | $Hg(II)_R$ mg/hr |
| 2 | 2.5 | 2" / 2.5HP | 0.000027 | 0.07 | 0.02 | 0.00006 | 0.0031 | 8 | 10 | 0.3 | 0.001 | 3 | 0.4 | 0.01 |
| 2.5 | 3.5 | 2.5" / 4HP | 0.000034 | 0.09 | 0.02 | 0.00008 | 0.0038 | 10 | 12 | 0.4 | 0.001 | 3 | 0.5 | 0.01 |
| 3 | 4 | 5" / 5HP | 0.000067 | 0.18 | 0.05 | 0.00016 | 0.0077 | 20 | 25 | 0.8 | 0.003 | 7 | 0.9 | 0.03 |
| 4 | 6 | 4" / 6.5HP | 0.000103 | 0.27 | 0.08 | 0.00024 | 0.0118 | 31 | 38 | 1 | 0.004 | 10 | 1.4 | 0.05 |
| 5 | 9 | 5" / 9HP | 0.000204 | 0.54 | 0.15 | 0.00048 | 0.0233 | 62 | 74 | 2 | 0.01 | 20 | 2.8 | 0.09 |
| 6 | 14 | 6" / 14HP | 0.000240 | 0.64 | 0.18 | 0.00056 | 0.0274 | 73 | 88 | 3 | 0.01 | 24 | 3.3 | 0.11 |
| 8 | 46 | 8" / 46HP | 0.000511 | 1.36 | 0.37 | 0.00119 | 0.0584 | 155 | 187 | 6 | 0.02 | 51 | 7.1 | 0.22 |
| 10 | 95 | 10" / 95HP | 0.001093 | 2.90 | 0.80 | 0.00255 | 0.1248 | 331 | 399 | 12 | 0.04 | 109 | 15.1 | 0.48 |
| Dredge Nozzle diameter (in.) | Engine HP | Dredge-Engine | PIT 2 FCZ | | | | PIT 2 CSL | | | | PIT 2 BRC | | | |
| | | | sediment m³/hr | sediment kg/hr | THg mg/hr | $Hg(II)_R$ mg/hr | sediment m³/hr | sediment kg/hr | THg mg/hr | $Hg(II)_R$ mg/hr | sediment m³/hr | sediment kg/hr | THg mg/hr | $Hg(II)_R$ mg/hr |
| 2 | 2.5 | 2" / 2.5HP | 0.001 | 3.1 | 4.8 | 0.02 | 0.002 | 6 | 67 | 3 | 0.003 | 7 | 77 | 13 |
| 2.5 | 3.5 | 2.5" / 4HP | 0.001 | 3.8 | 6.0 | 0.03 | 0.003 | 8 | 84 | 3 | 0.003 | 9 | 96 | 17 |
| 3 | 4 | 5" / 5HP | 0.003 | 7.7 | 12 | 0.05 | 0.006 | 16 | 168 | 7 | 0.007 | 17 | 193 | 33 |
| 4 | 6 | 4" / 6.5HP | 0.004 | 12 | 18 | 0.08 | 0.009 | 25 | 258 | 10 | 0.010 | 27 | 296 | 51 |
| 5 | 9 | 5" / 9HP | 0.01 | 23 | 36 | 0.15 | 0.018 | 48 | 510 | 20 | 0.020 | 53 | 585 | 101 |
| 6 | 14 | 6" / 14HP | 0.01 | 27 | 42 | 0.18 | 0.022 | 57 | 600 | 24 | 0.023 | 62 | 688 | 119 |
| 8 | 46 | 8" / 46HP | 0.02 | 59 | 90 | 0.38 | 0.046 | 121 | 1,279 | 50 | 0.050 | 132 | 1,467 | 253 |
| 10 | 95 | 10" / 95HP | 0.05 | 125 | 193 | 0.81 | 0.098 | 259 | 2,731 | 107 | 0.106 | 282 | 3,133 | 540 |

# Sources

| | THg Sources | MeHg Sources |
|---|---|---|
| Nonpoint Sources | Atmospheric Dep. Runoff | Atmospheric Dep. Runoff |
| | Mines | Mines |
| | Upland Area Erosion | Upland Areas (Ag & native) |
| | Dredge Tailings | Dredge Tailings |
| | Springs | Springs |
| | Suction Dredging | Open Water Habitat |
| | | Wetland Habitat |
| Point Sources | Urban Runoff | Urban Runoff |
| | NPDES Facility Discharges | NPDES Facility Discharges |

# Urban Runoff

## Sacramento MS4's Mercury Load Estimates

## (Larry Walker Associates, 2009)

| | Lake Natoma Watershed | Lower American River Watershed |
|---|---|---|
| TSS (tonnes) | 471 | 4330 |
| THg (g/yr) | 218 | 2003 |
| MeHg (g/yr) | 2.3 | 21 |
| Hg:TSS | 0.46 | Hg:TSS |
| Natoma Urban Area (acres) | 11,555 | 30,567 |
| **THg Loading Rate (mg/acre/year)** | **19** | **66** |
| **MeHg Loading Rate (mg/acre/year)** | **0.20** | **0.69** |

# Urban Runoff Loads

| Watershed | Urban Acreage | THg (g/yr) | MeHg (g/yr) |
|---|---|---|---|
| 01 French Meadow Reservoir | 73 | 4.8 | 0.051 |
| 02 Hell Hole Reservoir | 5 | 0.303 | 0.0032 |
| 04 Oxbow Reservoir | 660 | 44 | 0.46 |
| 05 Slab Creek Reservoir | 4,624 | 305 | 3.19 |
| 06 Chili Bar Reservoir | 2,898 | 191 | 2.00 |
| 07 North Fork u/s MF Confluence | 6,028 | 398 | 4.2 |
| 08 Middle Fork | 2,884 | 190 | 1.99 |
| 09 North Fork d/s MF confluence | 1,308 | 86 | 0.90 |
| 10 South Fork d/s Chili Bar Reservoir | 12,953 | 855 | 8.9 |
| 11 Folsom Lake | 5,663 | 374 | 3.9 |
| 12 Lake Natoma | 11,555 | 218 | 2.3 |
| 13 Lower American River | 30,567 | 2,003 | 21 |

# Urban Runoff Alternative Method

- Estimate Precipitation Runoff Volume
- Multiple by median THg and MMHg concentrations reported in Sacramento MS4 study

| Watershed | Median THg Conc (ng/l) | Median MeHg Conc (ng/l) |
|---|---|---|
| Lower American River urban runoff | 24 | 0.22 |
| Natoma Urban Runoff | 3.6 | 0.13 |

# Urban Runoff Load Comparison

| | | Alternative 1 | | Alternative 2 | |
|---|---|---|---|---|---|
| **Watershed** | **Urban Acreage** | **THg (g/yr)** | **MeHg (g/yr)** | **THg (g/yr)** | **MeHg (g/yr)** |
| 01 French Meadow Reservoir | 73 | 4.8 | 0.051 | 10.0 | 0.092 |
| 02 Hell Hole Reservoir | 5 | 0.303 | 0.0032 | 0.627 | 0.0057 |
| 04 Oxbow Reservoir | 660 | 44 | 0.46 | 85 | 0.77 |
| 05 Slab Creek Reservoir | 4,624 | 305 | 3.19 | 515 | 4.7 |
| 06 Chili Bar Reservoir | 2,898 | 191 | 2.00 | 272 | 2.5 |
| 07 North Fork u/s MF Confluence | 6,028 | 398 | 4.2 | 603 | 5.5 |
| 08 Middle Fork | 2,884 | 190 | 1.99 | 281 | 2.6 |
| 09 North Fork d/s MF confluence | 1,308 | 86 | 0.90 | 92 | 0.84 |
| 10 South Fork d/s Chili Bar Reservoir | 12,953 | 855 | 8.9 | 1036 | 9.5 |
| 11 Folsom Lake | 5,663 | 374 | 3.9 | 293 | 2.7 |
| 12 Lake Natoma | 11,555 | 218 | 2.3 | 76 | 2.7 |
| 13 Lower American River | 30,567 | 2,003 | 21 | 1,253 | 11 |

# NPDES Facility Discharges

| NPDES # | Agency | Facility Type | Latitude | Longitude | MeHg Load (g/yr) | THg Load (g/yr) |
|---|---|---|---|---|---|---|
| CA0083861 | Aerojet Interim GW WTP | WTP (GW) | 38.616667 | -121.242777 | 0.09[a, b] | 18[a, c] |
| CA0004111 | Aerojet Sacramento Facility | Heating/Cooling | 38.621000 | -121.231100 | no data | no data |
| CA0078875 | CA DGS Office of State Publishing | Misc | 38.602000 | -121.494100 | 0.004[a, b] | 0.63[a] |
| CA0079529 | Colfax WWTP | Mun WWTP | 39.075000 | -120.941667 | 0.036 | 0.86 |
| CA0004774 | DFG Nimbus Fish Hatchery | Aquaculture | 38.634100 | -121.228600 | 3.4 | 127 |
| CA0078956 | Placerville Hangtown Creek WWTP | Mun WWTP | 38.733333 | -120.841667 | 0.011[b] | 0.92 |
| CA0078841 | Sierra Pacific Industries Camino Lumber Mill | Lumber | 38.745280 | -120.678610 | no data | no data |
| CA0084905 | USBR Sliger Mine | Mines | 38.940994 | -120.932769 | 0.017 | 3.7 |

[a]From Table B.5 NDPES 13267 Report. Bosworth, *et al* . March 2010.

[b]Load based from concentration data where all results were less than MDL. Used 1/2 MDL to calculate load.

[c]No total mercury concentration data available. Load estimate was derived from similar treatment facilities.

# Sources

| | THg Sources | MeHg Sources |
|---|---|---|
| Nonpoint Sources | Atmospheric Dep. Runoff | Atmospheric Dep. Runoff |
| | Mines | Mines |
| | Upland Area Erosion | Upland Areas (Ag & native) |
| | Dredge Tailings | Dredge Tailings |
| | Springs | Springs |
| | Suction Dredging | Open Water Habitat |
| | | Wetland Habitat |
| Point Sources | Urban Runoff | Urban Runoff |
| | NPDES Facility Discharges | NPDES Facility Discharges |

# Methylmercury (MMHg) in Wet Deposition

| Location | Source | Ratio MeHg:THg in Rainfall |
|---|---|---|
| California - Monterey | Gill, 2008 | 3.4% |
| California - Woodland | Conaway et al., 2010 | 3.7% |
| Other studies around t | Bloom and Watras, 1989<br>Ebinghaus et al., 1999<br>Nguyen et al., 2005<br>Lawson and Mason, 2001<br>Mason et al., 1997 and 2000<br>Munthe et al., 1995 | 0.25% - 6%, typically <1.5% except in Great Lakes Area (up to 18%) and Sweden (3%) |
| | **ARW:** | **1%** |
| | | **3%** |

# MMHg Loads in Wet Deposition

| Watershed | Wet Dep. Runoff Volume (acre-feet/year) | Wet Dep. THg Load (kg/yr) | MMHg Load (1%) (g/yr) | MMHg Load (3%) (g/yr) |
|---|---|---|---|---|
| 01 French Meadow Reservoir | 78,958 | 0.39 | 3.9 | **12** |
| 02 Hell Hole Reservoir | 200,857 | 0.99 | 9.9 | **30** |
| 03 Loon Lake | 15,161 | 0.07 | 0.7 | **2.2** |
| 04 Oxbow Reservoir | 452,774 | 2.23 | 22 | **67** |
| 05 Slab Creek Reservoir | 704,450 | 3.48 | 35 | **104** |
| 06 Chili Bar Reservoir | 111,879 | 0.55 | 5.5 | **17** |
| 07 North Fork u/s MF Confluence | 577,522 | 2.85 | 28 | **85** |
| 08 Middle Fork | 291,737 | 1.44 | 14 | **43** |
| 09 North Fork d/s MF confluence | 7,490 | 0.04 | 0.4 | **1.1** |
| 10 South Fork d/s Chili Bar Reservoir | 155,767 | 0.77 | 7.7 | **23** |
| 11 Folsom Lake | 58,557 | 0.29 | 2.9 | **8.7** |
| 12 Lake Natoma | 8,399 | 0.04 | 0.4 | **1.2** |
| 13 Lower American River | 8,728 | 0.04 | 0.4 | **1.3** |

***We will evaluate a second method using REMSAD wet deposition THg loading rates once we obtain the rates.***

# Per Spring MMHg Loading Estimates

| | Low | High | |
|---|---|---|---|
| Wentworth Spring flow (L/min) | 6 | 158 | Average Mill Creek springs flow (L/min) |
| Mill Creek average MMHg conc. (ng/l) | 0.14 | 0.31 | Average Coast Range springs MMHg conc. (ng/l) |
| **Low MMHg load rate (g/yr/spring)** | **0.00044** | **0.026** | **High MMHg load rate (g/yr/spring)** |

# Estimate of Range of MMHg Loads from Springs

| Watershed | # of Named Springs | Low (g/yr) | High (g/yr) | Average (g/yr) |
|---|---|---|---|---|
| 01 French Meadows Reservoir | 1 | 0.0004 | 0.03 | 0.01 |
| 02 Hell Hole Reservoir | 4 | 0.002 | 0.1 | 0.1 |
| 04 Oxbow Reservoir | 17 | 0.01 | 0.4 | 0.2 |
| 08 Middle Fork | 1 | 0.0004 | 0.03 | 0.01 |
| 07 North Fork u/s MF Confluence | 11 | 0.005 | 0.3 | 0.1 |
| 05 Slab Creek Reservoir | 11 | 0.005 | 0.3 | 0.1 |

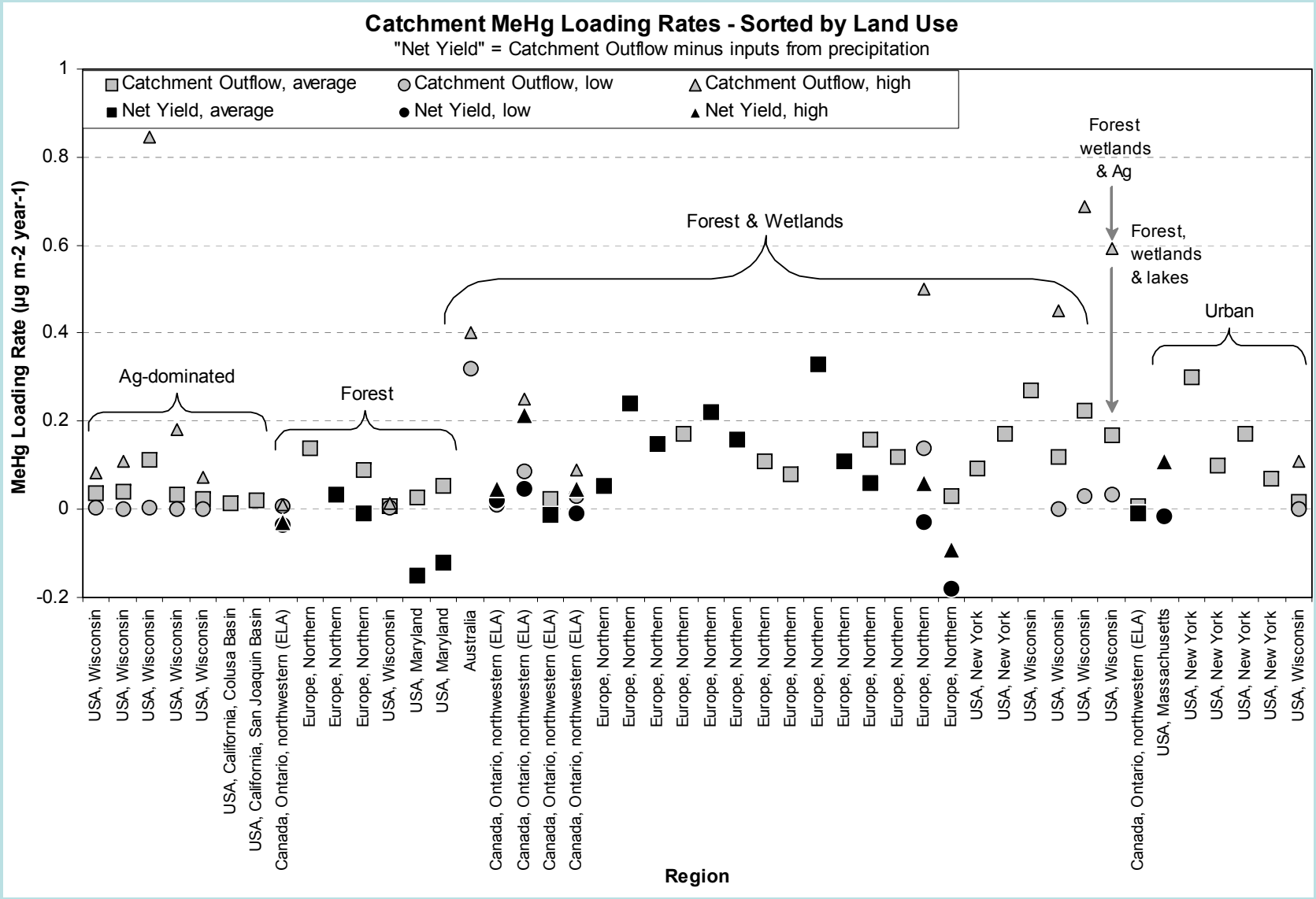
# Sources

| | THg Sources | MeHg Sources |
|---|---|---|
| Nonpoint Sources | Atmospheric Dep. Runoff | Atmospheric Dep. Runoff |
| | Mines | Mines |
| | Upland Area Erosion | Upland Areas (Ag & native) |
| | Dredge Tailings | Dredge Tailings |
| | Springs | Springs |
| | Suction Dredging | Open Water Habitat |
| | | Wetland Habitat |
| Point Sources | Urban Runoff | Urban Runoff |
| | NPDES Facility Discharges | NPDES Facility Discharges |

# Literature Review:

# MMHg Loading Rates by Land Use

*Do not cite – Already out of date!*



# Literature Review:

# MMHg Loading Rates by Land Use

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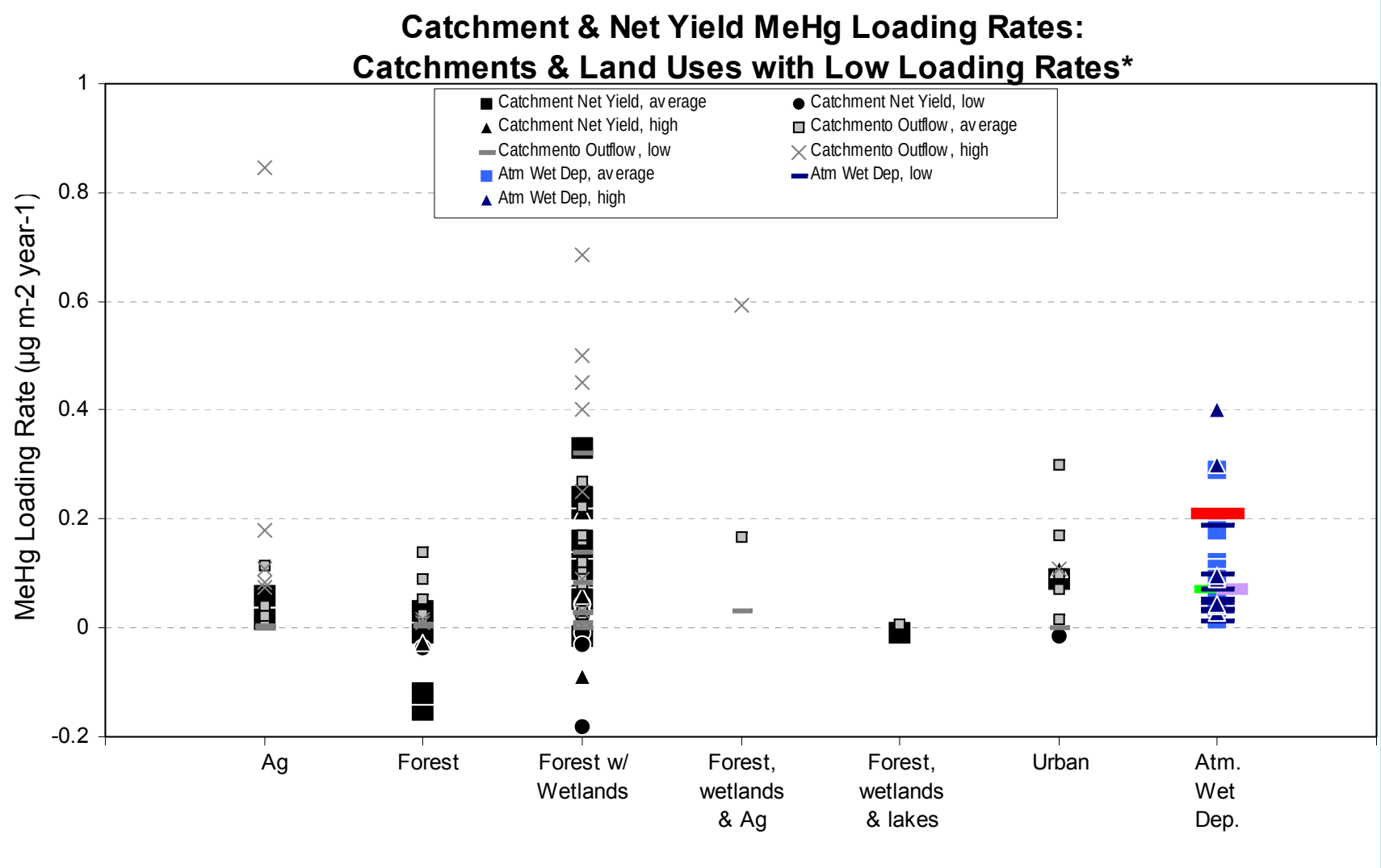

# Literature Review:

# MMHg Loading Rates by Land Use

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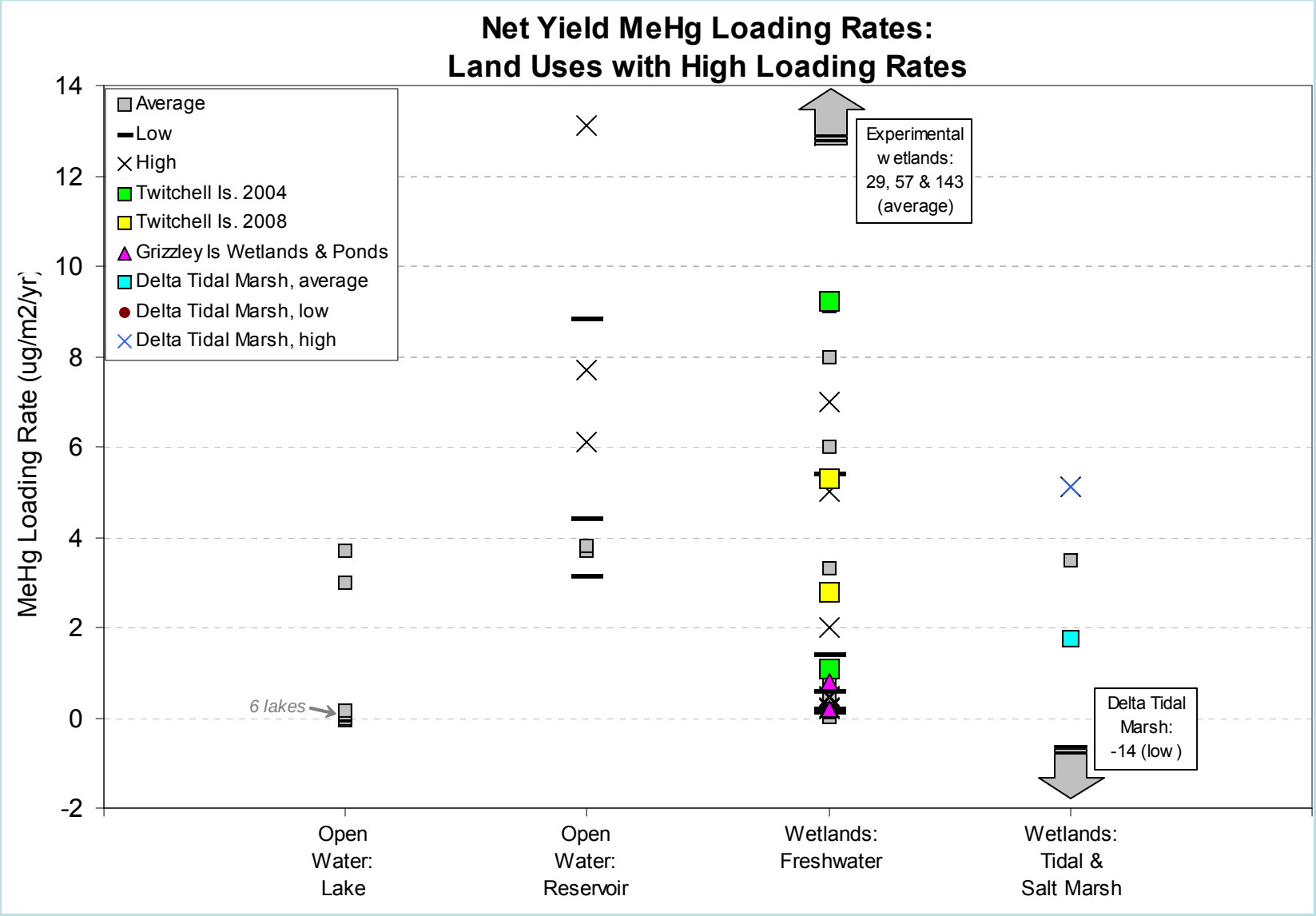


| Land Cover | Estimated Loading Rates (ug/m2/yr) |
|---|---|
| Open Water - Reservoirs | 5 |
| Wetland (Permanent) & Meadows | 4 |
| Open Water | 1 |
| Open Water - Pond | 1 |
| Wetland - Seasonal | 1 |
| Forested Wetland | 0.2 |
| Open Water - Riverine | 0.2 |
| Mine sites | 0.1 |
| Riparian | 0.1 |
| Forest | 0.04 |
| Agriculture - Irrigated | 0.02 |
| Grassland | 0.02 |
| Pasture | 0.02 |
| Shrub | 0.02 |
| Agriculture - Non-Irrigated | 0.01 |
| Barren & Other | 0.01 |
| Rangeland | 0.01 |

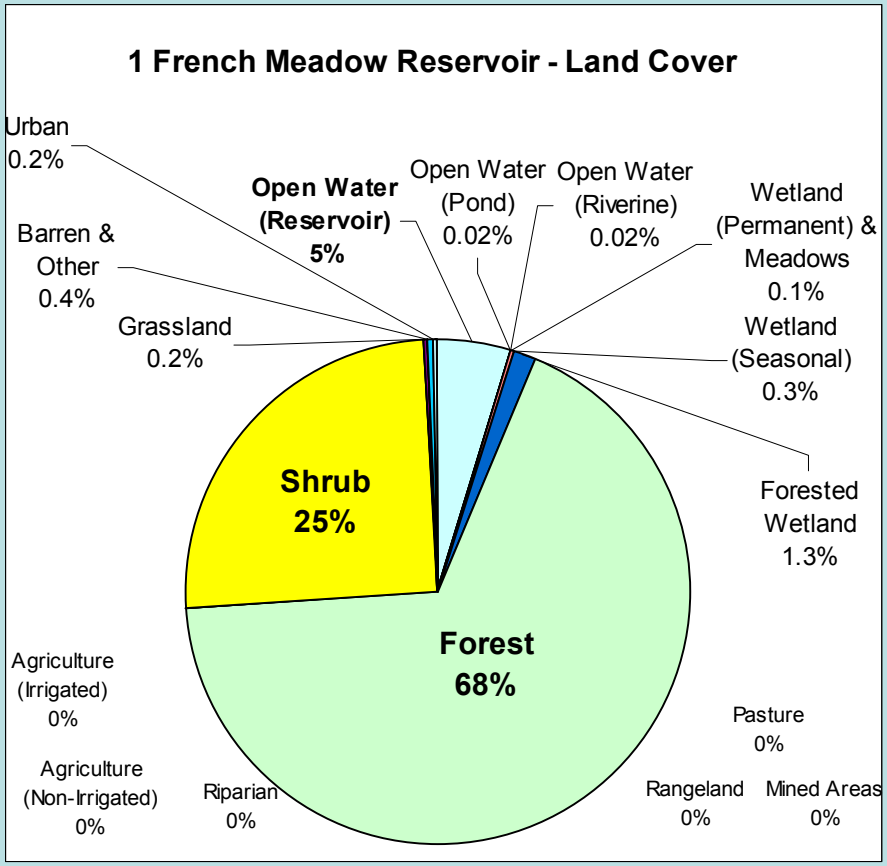
MMHg loading rates used to develop a preliminary estimate of watershed nonpoint source loads

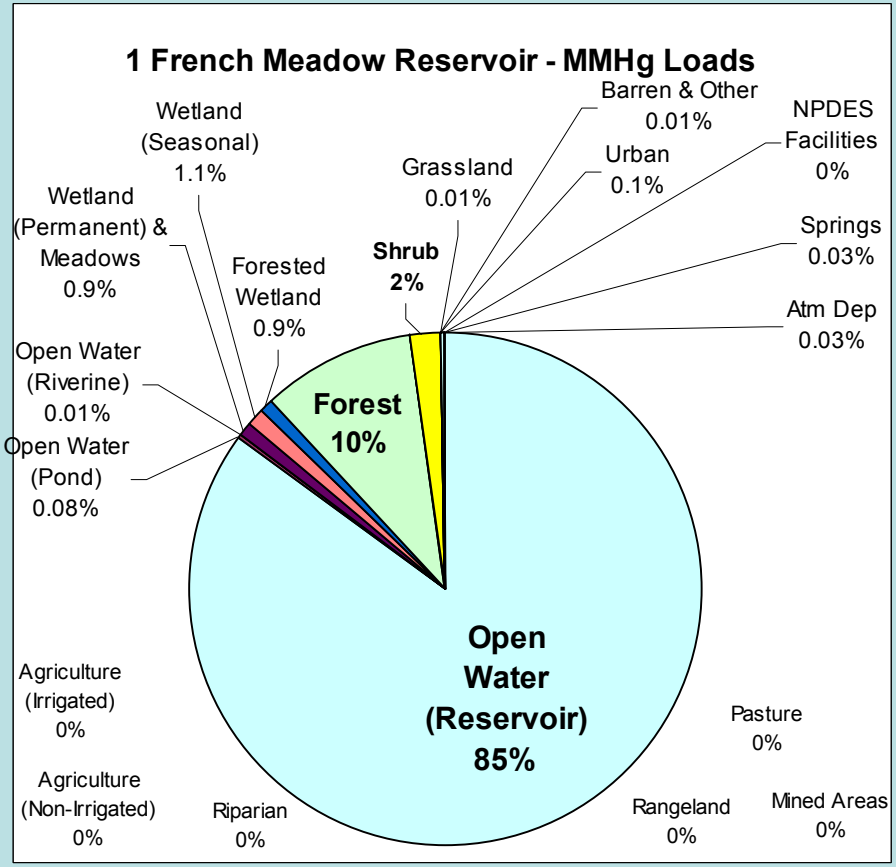
<u>METHOD</u>:

MMHg Loading Rate $_{\text{Land Use}}$
X
Acreage $_{\text{Land Use}}$

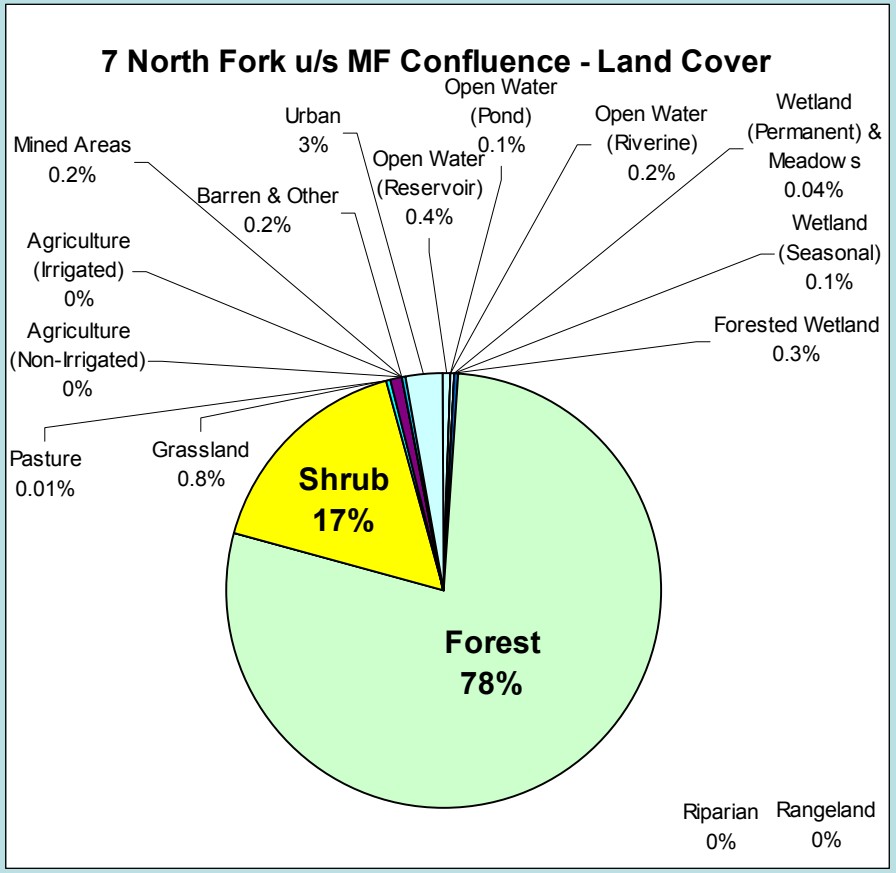
*For each Watershed*

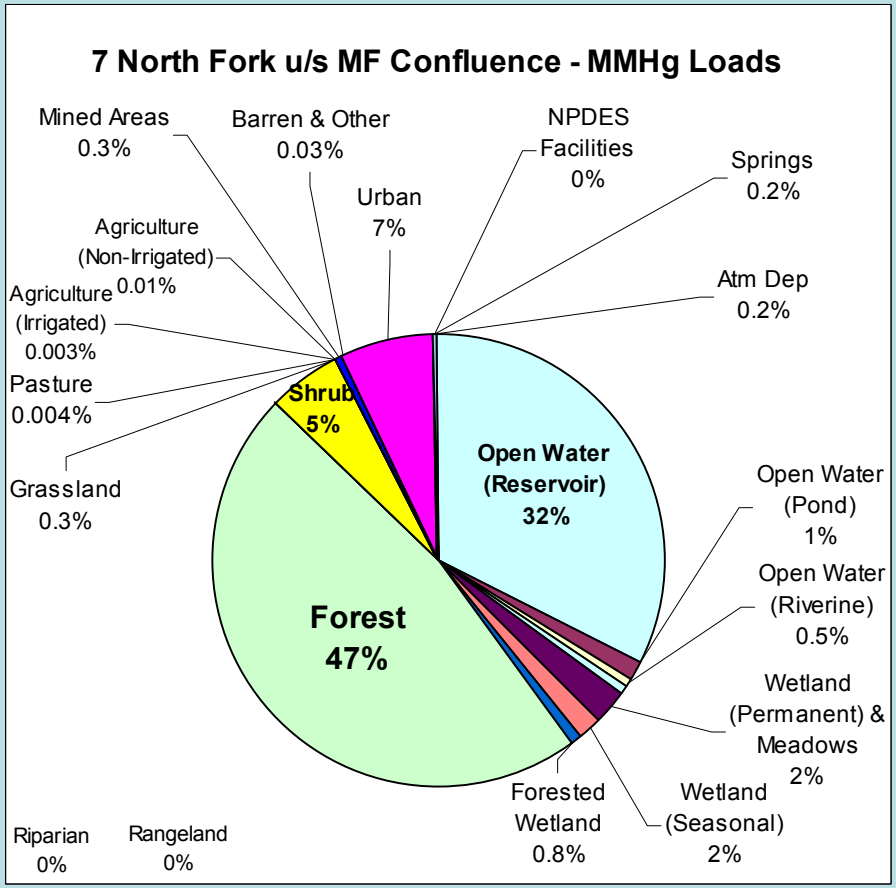
# Preliminary MMHg Loads



# Preliminary MMHg Loads



# Source Analysis Next Steps

- Finish soil loss and THg load estimates for Upland Area Erosion and Dredge Tailings, and THg load estimates for Suction Dredging
- Update source analysis as needed based on new sampling results and other information
- Incorporate loss processes (loads lost to photo-degradation, sedimentation, etc.)

# April 2011 Meeting

- Topics:
  - Overall TMDL approach
  - Implementation ideas and considerations
  - Straw proposal incorporating stakeholder comments and including implementation options
- The April meeting will not be a CEQA meeting

# Contact Information

- American River Watershed TMDL/BPA Webpage:
  http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/american_river_hg/index.shtml
- Questions or Comments:
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