

# Effects of Historic Gold Mining on Water Quality and the Environment in California

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# Historic Gold Mining



- Tens of thousands of abandoned / inactive gold mines in California.
- Main contaminants of concern at hard-rock gold mines: **arsenic**, lead, and **mercury**.
- At placer gold mines, main contaminant is **mercury**.
- Some gold mines have **acid mine drainage** with elevated iron, aluminum, copper, zinc, cadmium, nickel, chromium, and other metals.

# Common Arsenic-rich Minerals in the Vicinity of Historic Gold Mines

Primary (Hydrothermal)

Secondary (Weathering)



Pyrite  
( $\text{FeS}_2$ )  
"Fool's Gold"  
1-10 wt% As



Scorodite  $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$   
Tens of wt% As



Iron oxyhydroxide  
("rust") containing arsenic  
(up to 10 wt% As)



Arsenopyrite ( $\text{FeAsS}$ )  
46 wt% As



Jarosite  $\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$   
Up to 1 wt% As

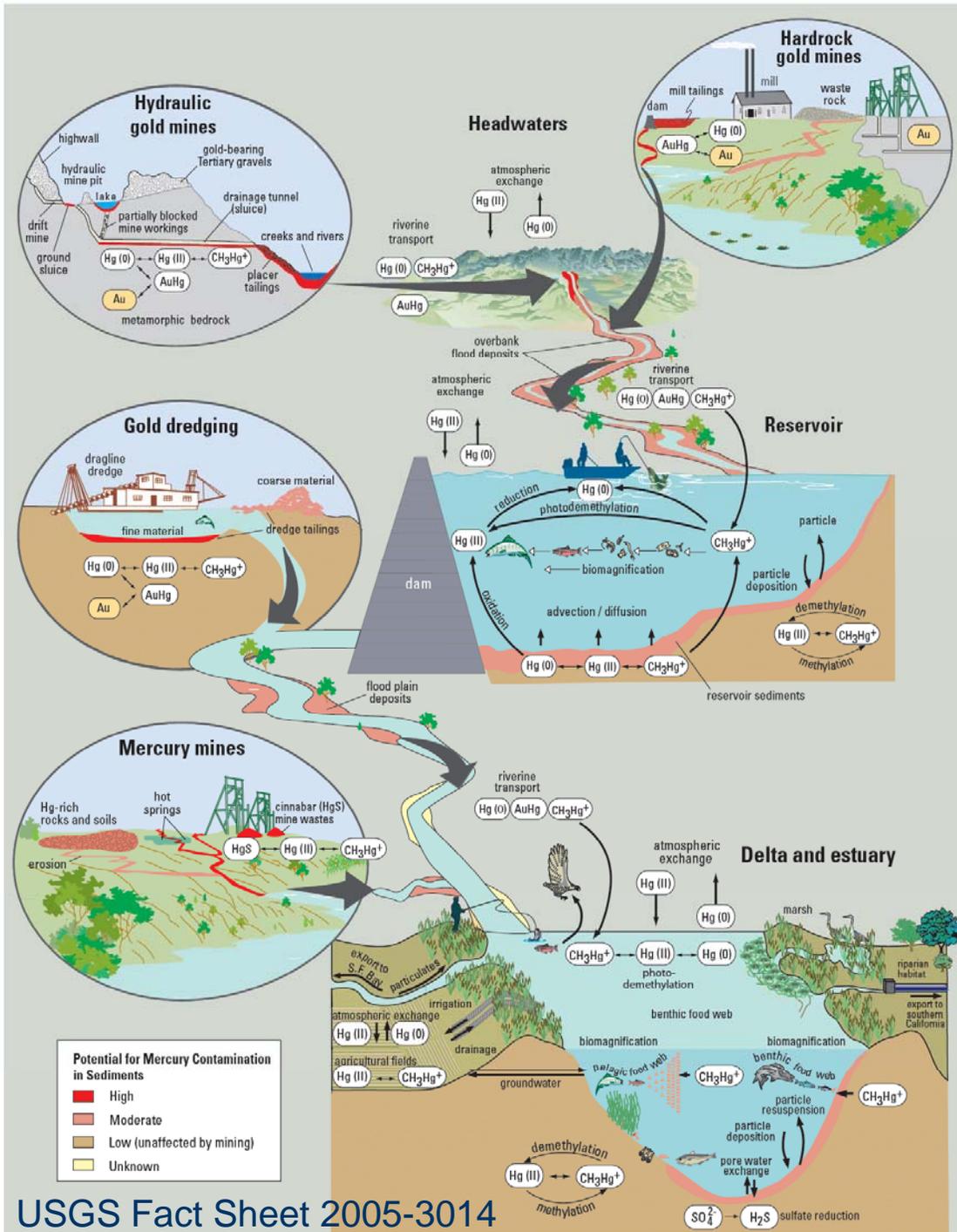
# Arsenic Speciation and Bioavailability

- **Chemical species** vital to hazard assessment
  - Arsenides, arsenites, arsenates – range in solubility
- **Aqueous fluids critical** (pathway into body)
  - drinking water (ingestion)
  - gastric and intestinal fluids (ingestion)
  - lung fluids (inhalation)
  - recreational water bodies (dermal absorption)
- **USGS studies have assisted other agencies**
  - Lava Cap Mine, Nevada County (USEPA/DTSC)
  - Mesa de Oro, Amador County (USEPA / DTSC)
  - Kelly / Rand / Johannesburg, Kern County (BLM)

# Mercury Sources, Transport, and Bioaccumulation

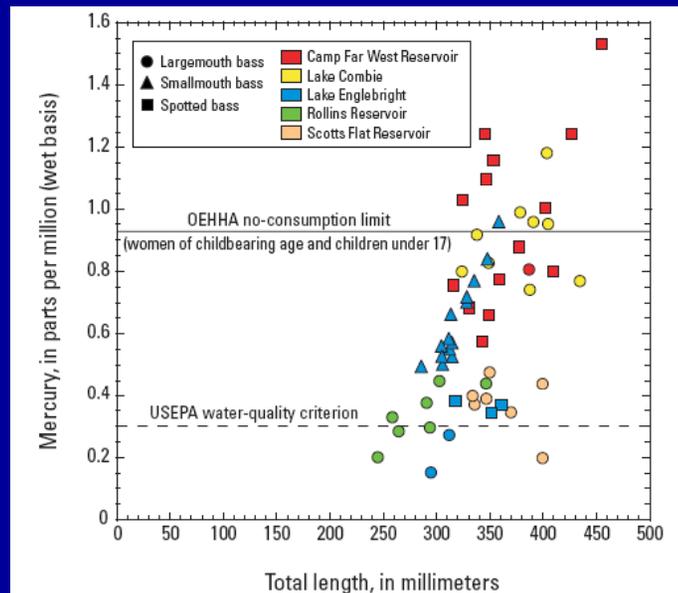
## ENVIRONMENTS:

- Mercury mines – Coast Ranges
- Hydraulic and hard-rock gold mines – Sierra Nevada
- Mountain streams above reservoirs
- Foothill reservoirs
- Rivers below reservoirs – gold dredging environments
- Floodplains
- San Francisco Bay-Delta estuary



# Understanding Mercury Bioaccumulation – Food Web / Water Quality Studies (1 of 3)

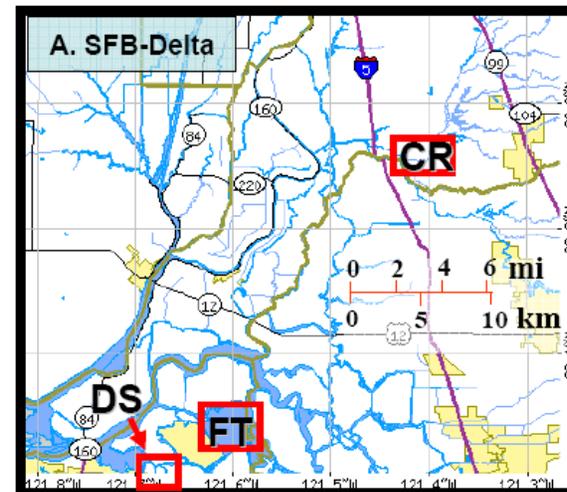
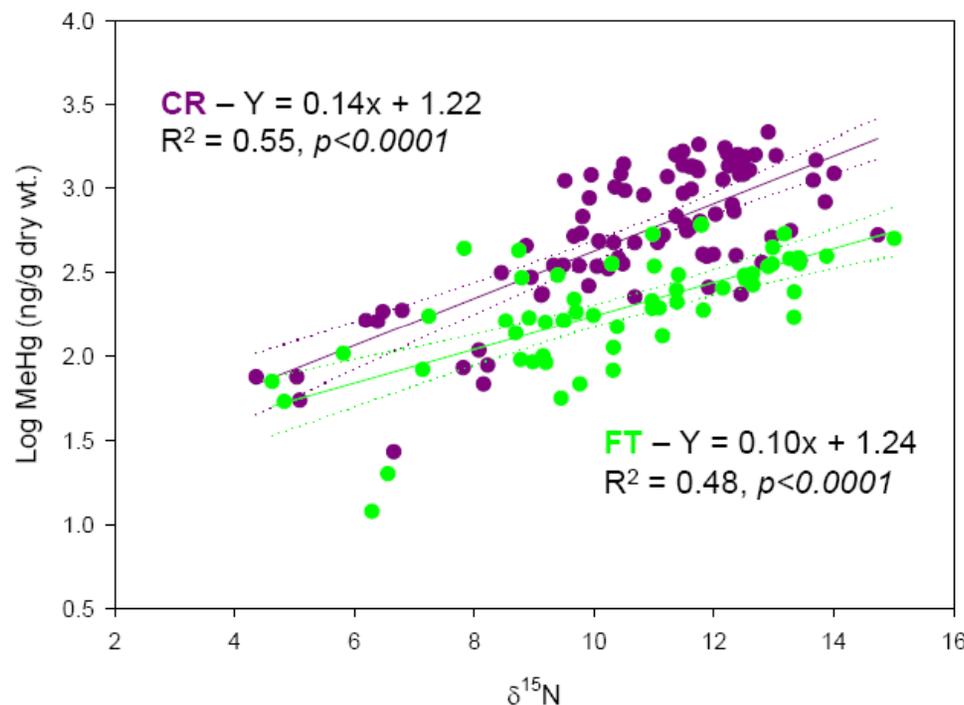
- **Bear River** (USGS / SWRCB / BLM / FS / NCRCD):
  - Fish tissue data → public health advisories
  - Load estimates for Hg, MeHg → mass balances
  - Seasonality of MeHg in water and zooplankton



Greenhorn Creek

# Understanding Mercury Bioaccumulation – Food Web / Water Quality Studies (2 of 3)

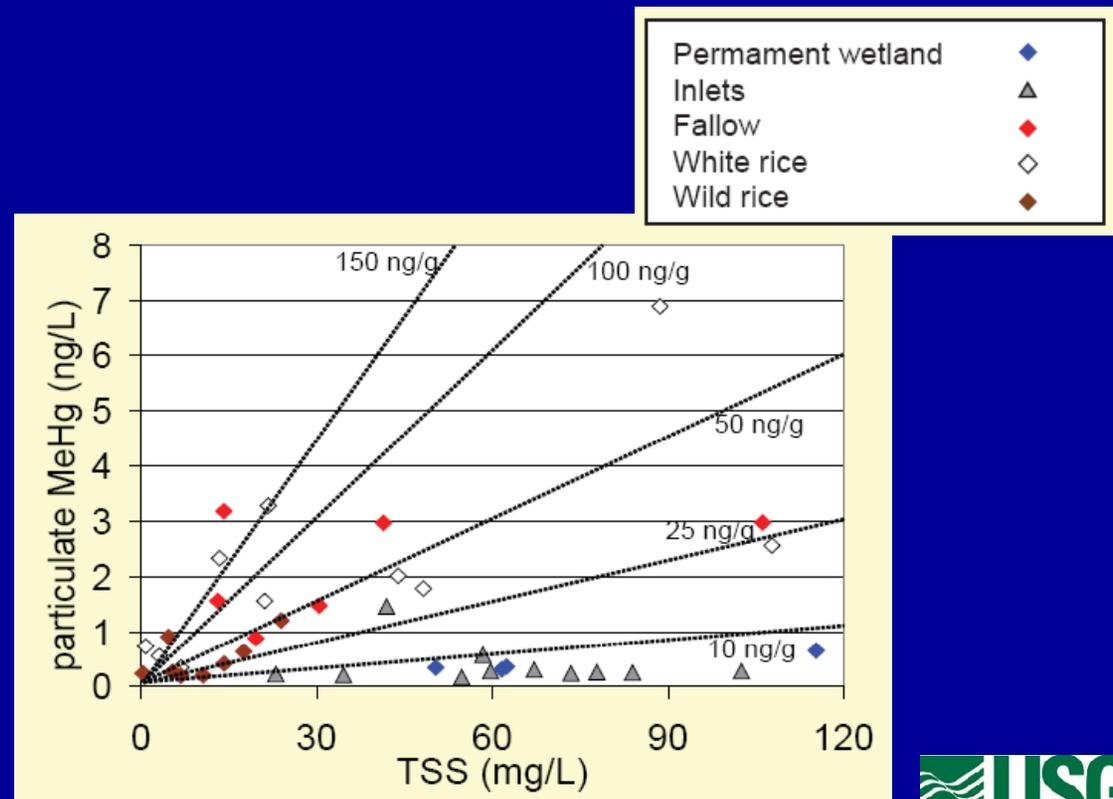
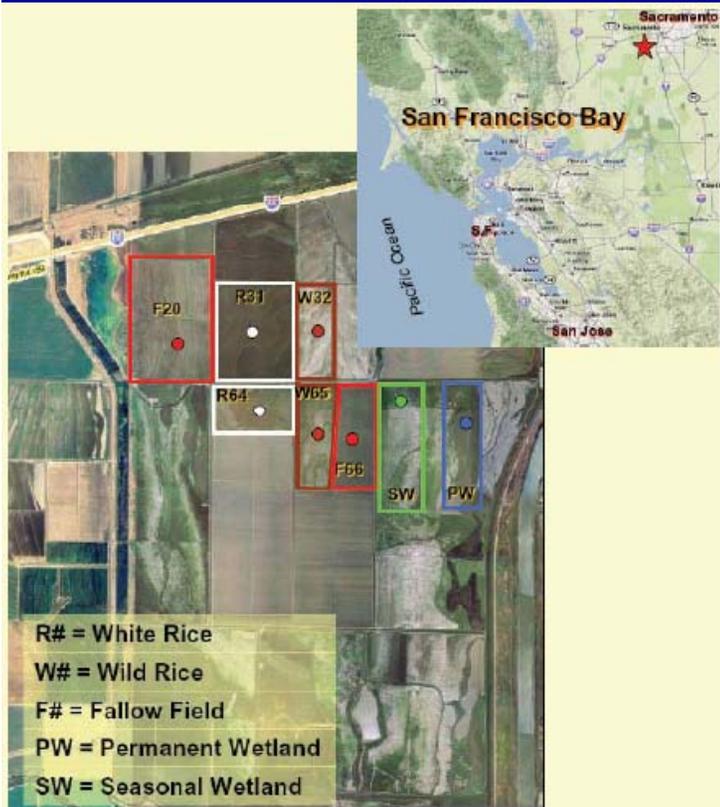
- Cosumnes River, Petaluma River & Central Delta (CALFED-ERP):
  - Higher MeHg (water, sediment, and biota) in Cosumnes R. and Petaluma R. compared to Central Delta



A. SFB-Delta: Map showing the three sampling regions: Frank's Tract (FT), Dutch Slough (DS) and Cosumnes River (CR).

# Understanding Mercury Bioaccumulation – Food Web / Water Quality Studies (3 of 3)

- **Yolo Bypass (USGS / SWRCB / CDFG / SJSF):**
  - First detailed study of Hg methylation and bio-accumulation in rice fields & non-agricultural wetlands



# Ecological Effects of Mercury

- SF Bay studies show negative effects of Hg on bird survival
  - Black-necked stilt Hg higher in dead chicks
  - Forster's tern – Hg higher in eggs that fail to hatch
    - Nearly 60% of breeding population at high risk from Hg
  - Effects of Hg on many other bird species that breed in SF Bay and Delta not yet studied
  - Toxicity thresholds for Hg not established
- Data needed on fish, mammals & reptiles

# High-Priority Information Gaps

- 1) Arsenic speciation and bioavailability
  - Mine wastes and natural deposits
- 2) Mercury contamination in dredged materials
  - Spoils from historic gold dredging, settling basins, reservoirs, shipping channels, flood control
  - Suction dredging impacts in contaminated rivers
  - BMPs to minimize releases of Hg and MeHg
- 3) Mercury cycling in agricultural environments
- 4) Mercury in atmospheric deposition
  - Uncertain contribution to reactive Hg loads
- 5) Mercury in fish and birds
  - Data for additional public health advisories
  - Assessment of ecological effects
  - Long-term monitoring to assess trends

# Opportunities for Partnership and Collaboration

- USGS Cooperative Water Program
  - matches non-federal funds, ~\$5M/yr in Calif.
- Other USGS programs in Water Resources, Geology, and Biological Resources
- Collaborative projects with other agencies
  - **Federal:** BOR, USFWS, BLM, USFS, USEPA
  - **State:** CALFED/CBDA, DFG, DWR, UCs, DOC/AMLU, SWRCB, RWQCBs, SNC
  - **Local:** RCDs, water agencies, sanitation districts, cities, counties, non-profit foundations