Urban Runoff Literature Review

A presentation to the TMDL group of the Regional Board

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Climate and Hydrology

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SFEI

Summary of Findings

- The discharge of water from small tributaries is about 4% of the total runoff entering the Bay (about the same as the area ratio (5%))
- The ten largest watersheds (ranging in size from 105 to 1,662 km^2) make up 75% of the area (Alameda, Coyote, Guadalupe, San Francisquito, Sonoma, Napa, Wooden Valley, Walnut, San Leandro, and San Lorenzo)
- Rainfall in the region varies from about 250 to 2,000 mm, 90% wet season
- There is an average of 58 to 67 rain days per year (>0.1 in)
- Annual rainfall varies from 200% of normal to 40% of normal
- The region undergoes periods of drought and flood that can last 4-8 years
- There are also longer term flood dominated and drought dominated periods that can last for several decades or more

- Between 87 and 99% of the annual runoff occurs from November to April
- Runoff can vary from 0% of annual rainfall during drought years to 75% of annual rainfall during wet years
- Inter-annual runoff variation is amongst the highest in the world and urbanization further increases the "flashiness" of runoff response adding to the difficulties of field monitoring and subsequent modeling an extrapolation
- The response time of small tributaries ranges from about 5 hours (100 km^2) to more than 12 hours for Alameda Creek (1,662 km^2)
- Urbanization increases flow volume, peek flow, and decreases the response time although there are complexities associated with basin configuration
- A regional scale water budget was constructed using the last 30 years of data and shows that annual runoff volume varies from 180 to 3,930 Mm^3 and averages 918 Mm^3

Sediment Processes

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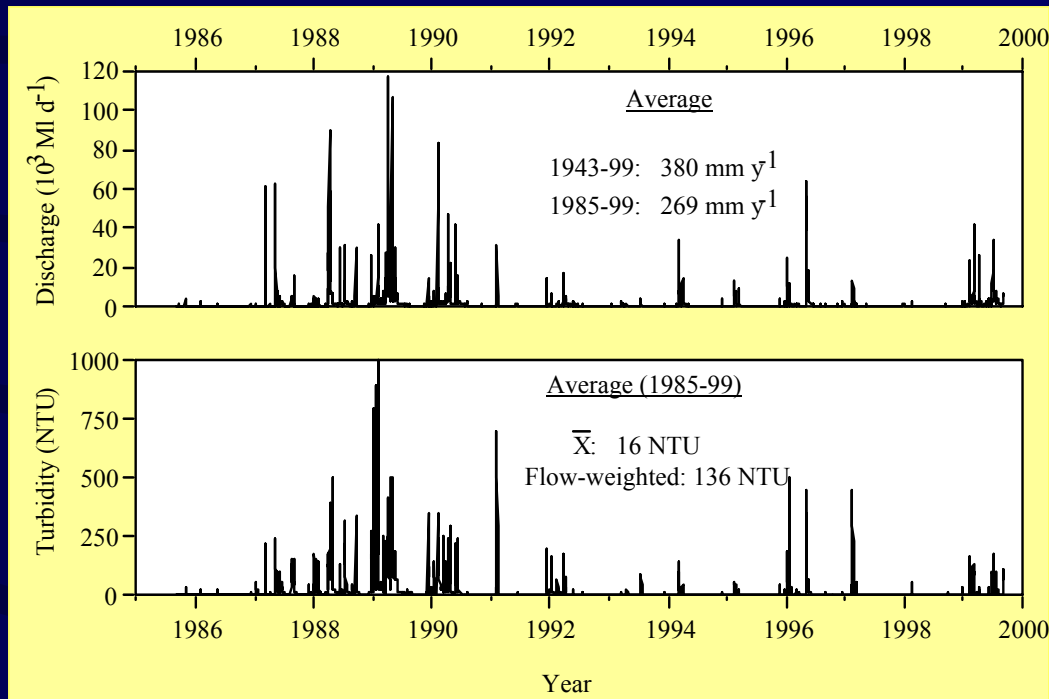
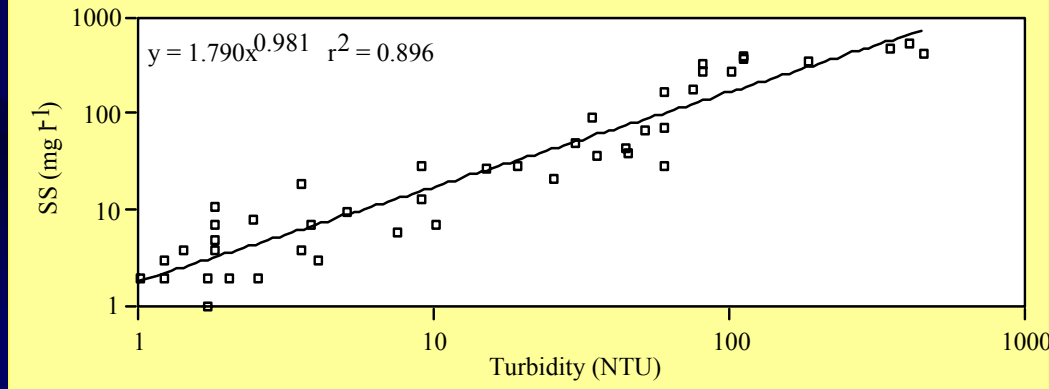
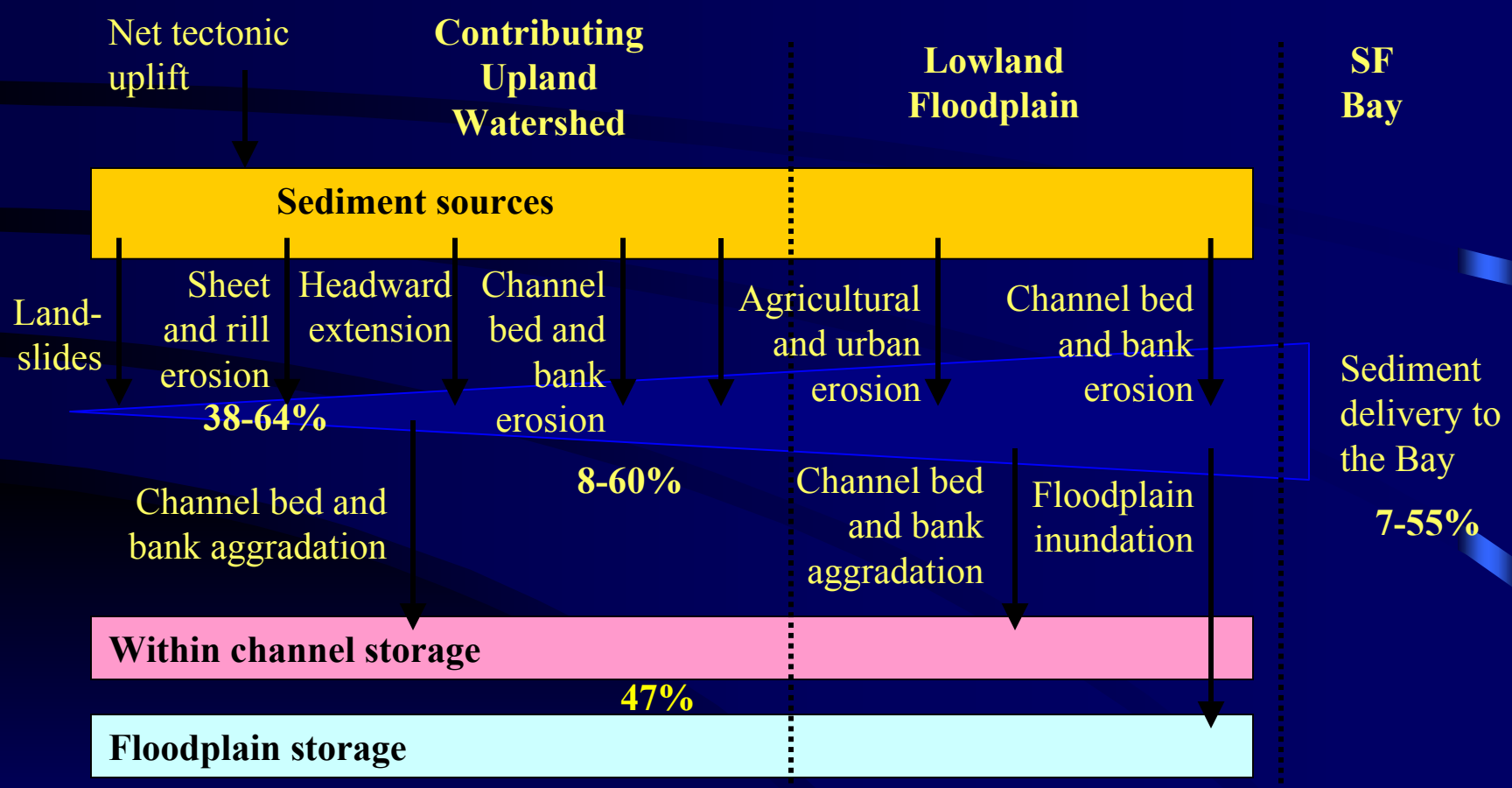
Why is an Understanding of Sediment Processes Important?

- Suspended sediment loads from local tributaries currently forms about 40% of the sediment load entering the Bay annually and this may be rising
- Suspended sediment carries with it contaminants such as Hg, PCBs, PAHs, and OCs
- There is a great relationship between SSC and turbidity





Conceptual Model



Available Local Existing Concentration Data

- The USGS has measured suspended sediment concentrations in streams within the nine-county Bay Area over the past 40+ years at 26 locations.

- Three locations in Alameda County have >15 years of data.

- 18 locations have one or more full wet season of data.

- USGS is presently monitoring six locations:

1. Alameda Ck. at Niles
2. Cull Ck. above Cull Ck. Reservoir
3. San Lorenzo Ck. above Don Castro Reservoir
4. Arroyo de la Laguna near Pleasanton
5. Alameda Ck. below Welch Ck. near Sunol
6. Crow Ck. near Hayward

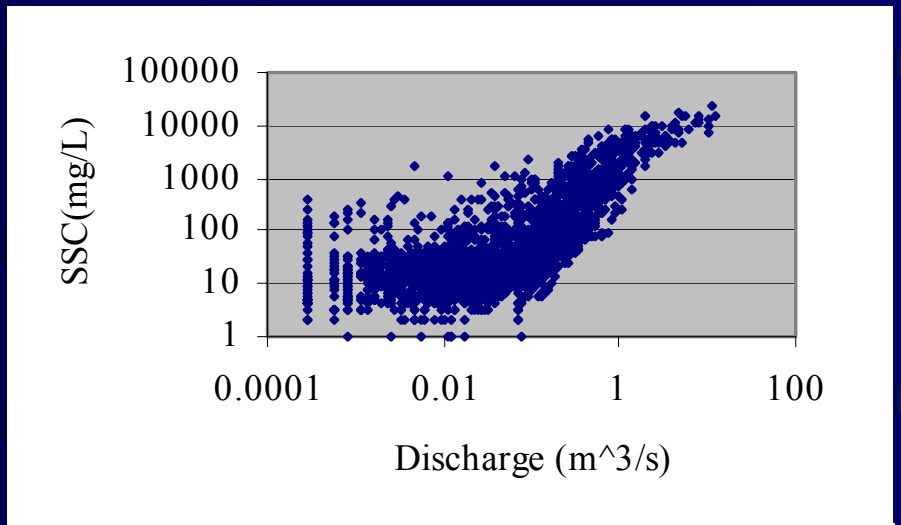
Suspended Sediment Character

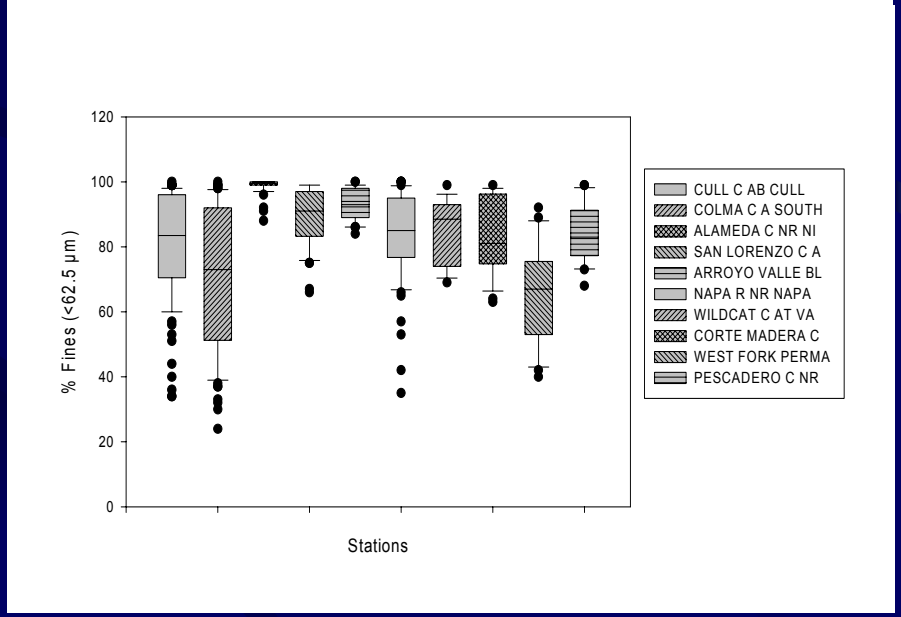
- Peaks in excess of 5,000 mg l^{-1} at 12 locations
- will make the use of surrogate techniques more difficult

- FWMC calculated in excess of 3000 mg l^{-1} at 2 locations, 1,000 mg l^{-1} at 9 out of 17 locations and are greater than 374 mg l^{-1} at all locations.

- At locations where there have been sufficient measurements, grains in suspension are between 67 and 100% finer than 0.62 mm (silts and clays).
- Surrogate technologies are likely to work well for these grain sizes

Cull Ck. above Cull Ck. Reservoir





Seasonal Loads Character

	Cull Creek (wet season 1996-2000)	Napa River (WY 1979)	Wildcat Creek (WY 1978-1979)
October	(%)	(%)	0
November	0	0	0.3
December	0.1	3.1	2.4
January	4.2	7.4	40.8
February	53.1	76.7	74.9
March	96.4	89.5	96.7
April	99.8	99.6	99.99
May		99.9	99.995
June		99.92	99.997
July		99.95	99.998
August		99.97	99.999
September		99.99	100

Inter-annual Loads Character

- Non urban / less urban watersheds

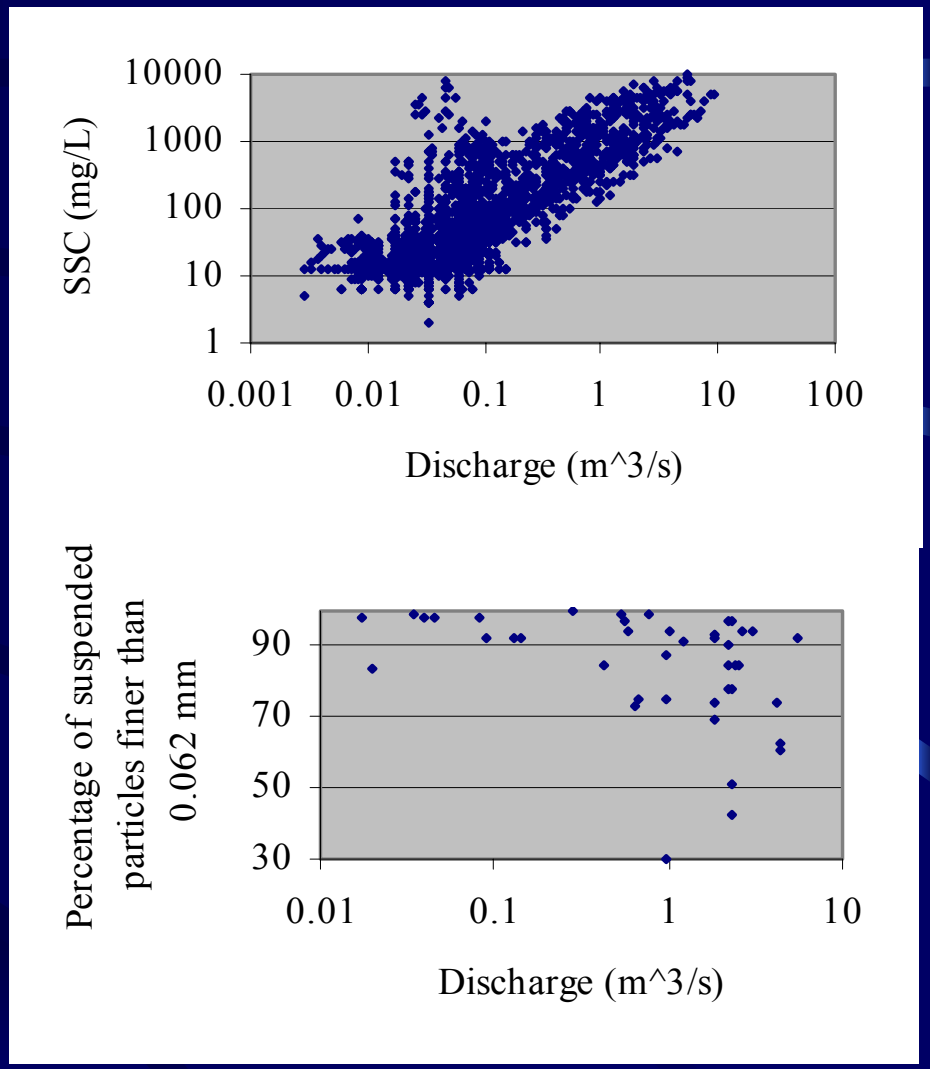
- 3 to 4 orders of magnitude annual variation

- Urbanized areas (if Colma Ck is a good indicator)

- 1 to 2 orders of magnitude annual variation

- Colma Ck. has low discharge variability, and high and variable SSC

Colma Ck., South San Francisco



Summary and Ramifications for Sampling Contaminants

- Peak SSC are high but a turbidity threshold sampling technique can overcome this problem.
- Grain sizes vary during floods but are in the range of acceptability for surrogate techniques.
- Existing USGS sediment gauging provides an opportunity to sample for contaminants.
- Several long term data collection sites could be used to interpret less intensive sampling sites and for testing the best extrapolation methods
- Studies that select for a certain time (for example 3 years) may fail to sample the range of sediment and contaminant response to climatic variation and therefore fail to estimate the average or range of annual loads.

- The solution is to selectively sample certain floods for contaminants over a less defined period of time (for example – it may take 4 years or five years

Mercury Literature Review

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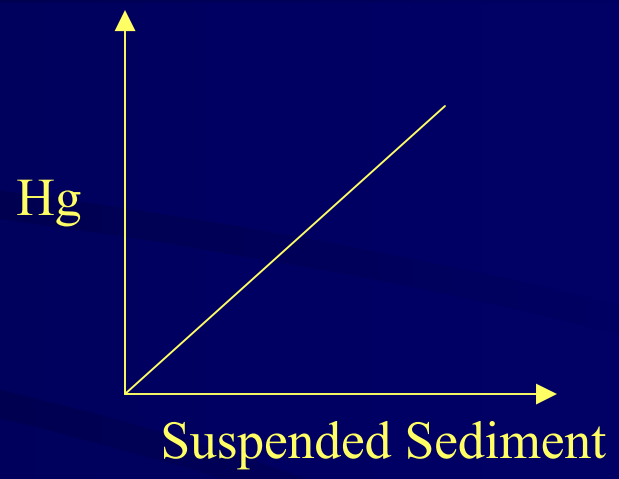
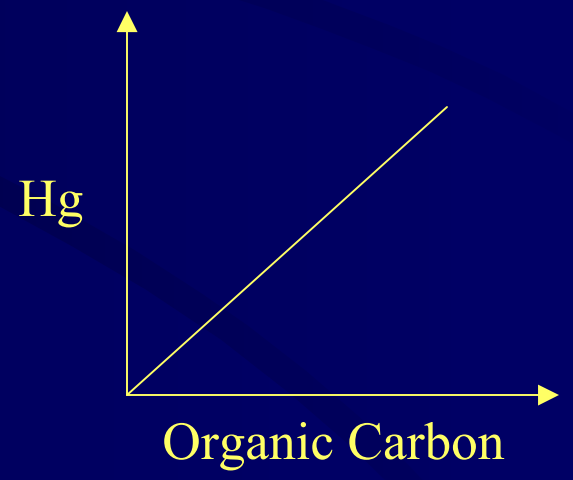
Hg Sources in the Watersheds

- There are 16 historic mine locations in the Bay Area.
- Ultramafic serpentinite rocks that are found in all nine counties.
- Hg is used in the urban environment in common everyday products and devices. This suggests that urban areas with high population will also be likely to have high mercury loads.
- Hg is transported from naturally occurring deposits and contaminated locations in dissolved, colloidal, and particulate forms.
- Particulate mercury is conventionally reported as the mass that does not pass through a 0.4 or 0.45µm filter paper. The colloidal fraction can be partitioned out using ultra-filtration leaving the truly dissolved fraction that passes through 0.0015-0.005 µm pore size

Hg Transport in the Watersheds

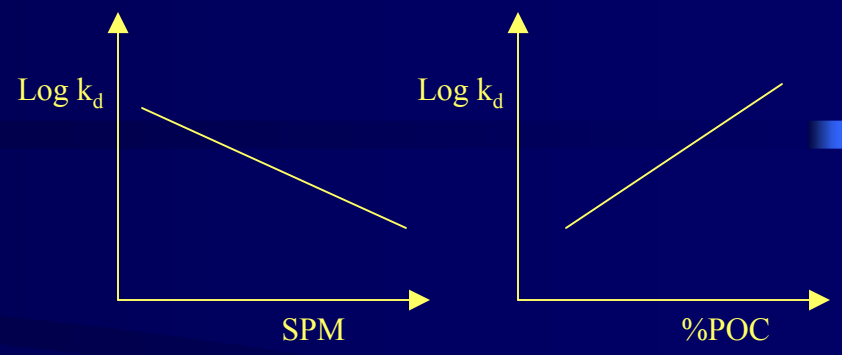
- Based on studies in other parts of the US, particulate Hg is between 69 and 99% of total Hg in the water column of contaminated streams.
- In agricultural watersheds particulate Hg may only form 37-50% of the total mercury load and organic carbon seems to play a role in transport.
- Given that colloidal transport make up part of the "dissolved phase" and colloidal material is detectable using optical sensors, surrogate techniques are likely to be applicable to loading studies for Hg under most circumstances.
- Field and laboratory techniques must be "Clean". This issue will pose a challenge or potential barrier to the use of automated field sampling for mercury. Manual collection be necessary, and extrapolation using relationships with suspended sediment or turbidity are likely to be appropriate.





Hg Transport in the Watersheds 2

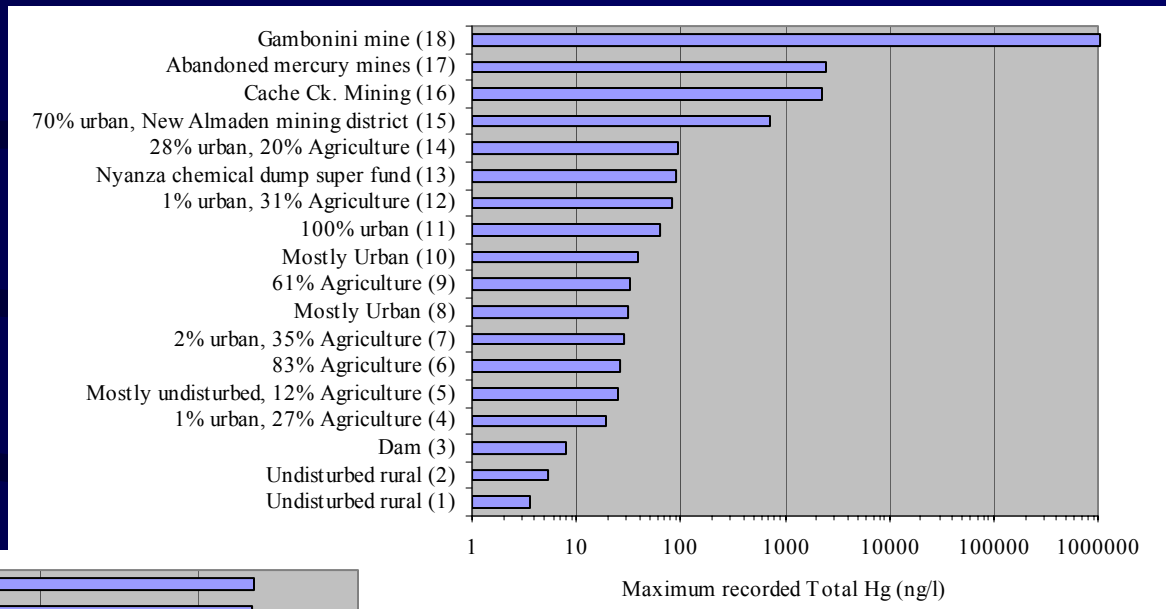
- Concentrations of suspended particulate matter and %OC in particles has been found to influence the partitioning of mercury between dissolved and particulate forms.

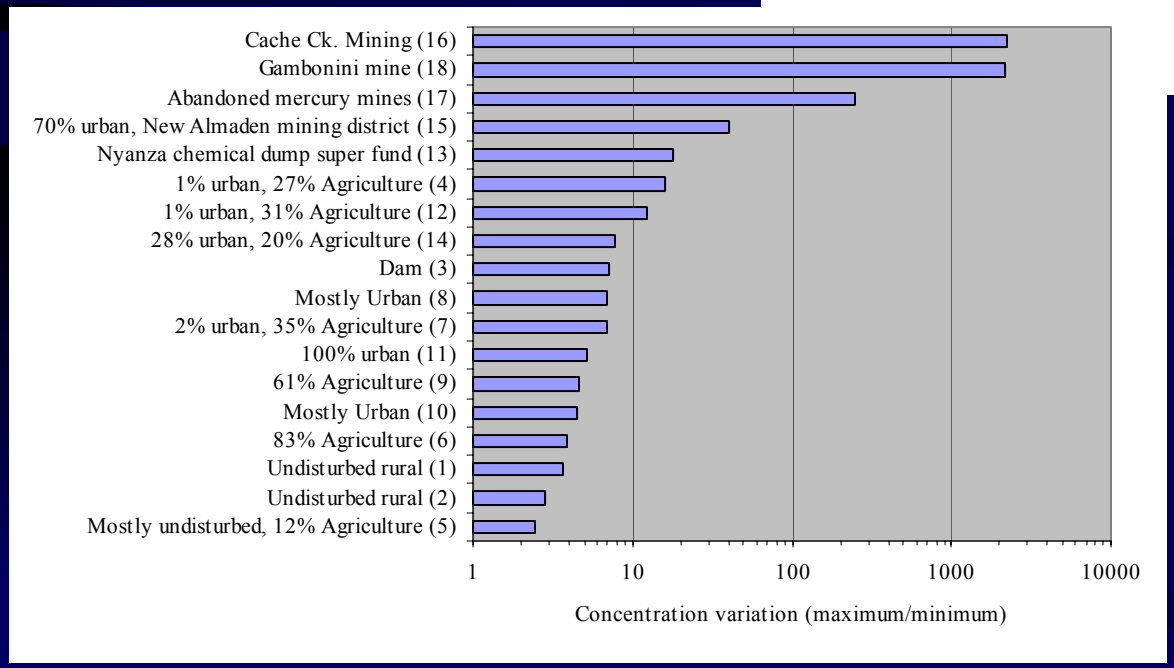


- Catastrophic events such as large rainstorms, and landslides or tailings dam failures can occur. These "rare events" may cause the majority of loads.
- Total mercury concentration can be expected to vary by 2-3 orders of magnitude during storm events.
- Total mercury concentrations in undisturbed rural watersheds are likely to be 3-10 ng l^{-1}.
- Hg concentration is likely to be 30 times greater in urban and mixed urban and agricultural watersheds and more than 500 times greater at historic mine sites

Hg Character for Different Land Uses

Concentration in different land uses



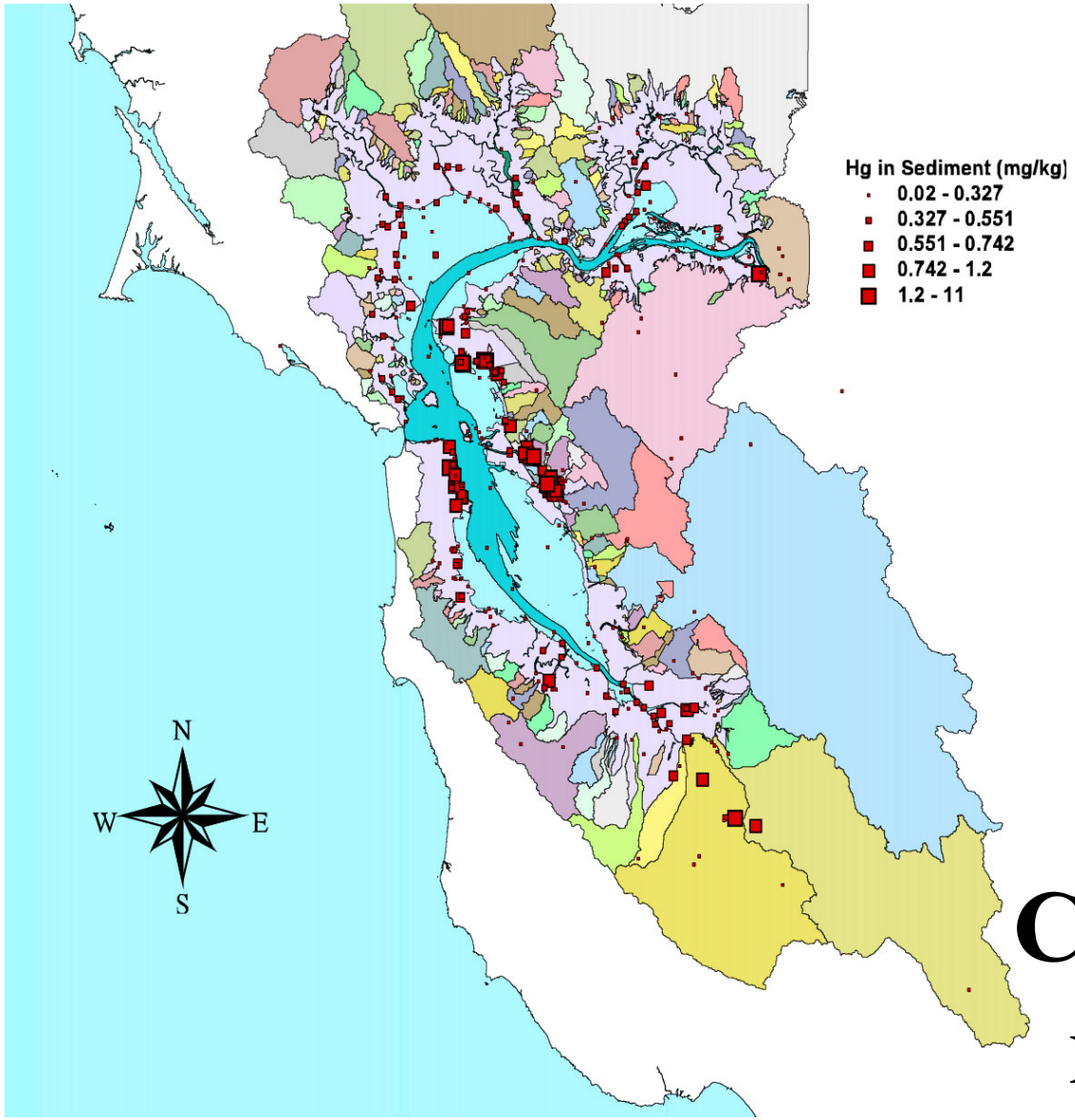


Concentration variation in different land uses

Loads Variation

- Monthly loads in the Central Valley have been found to vary by 129 to 292 times from the wettest month to the driest month.
- Daily loads in watersheds can vary by upward of 1000 times.
- Given the relationship between Hg and suspended sediment, it is likely that 90% or more of the annual load will be transported during the wet season during short lived flood events.

DRAFT Average concentrations of mercury in sediment (mg/kg).
Pilot RMP 1991-1992, RMP 1993-1999, BPTCP 1994-1997, BADALEMP 1994-1997, Stormdrain Sediment Study 2000 (Gunther et al. 2001, KLI 2001), San Leandro Bay Study 1998 (Daum et al. 2000), CALFED 1999.



Concentrations in Sediments

Recommendations for the Use Bed Sediment Concentrations

- The ratio of concentrations in suspended sediment : bed sediment were found to be 0.2 to 31.4

Given the variety of chemical and geomorphic processes that may occur during the source activation, transport, deposition, and period of time since deposition we recommend:

- The use of bed sediment concentrations for watershed characterization has a low sensitivity
- Bed sediment concentrations will not be useful as a trend indicator
- The use of bed sediment data for loads calculations will have indeterminable errors and bias

Summary and Recommendations

<u>Where to measure</u>

Given the distribution of mercury sources and climatic influences, it is recommended that sampling for loads concentrate on:

1. Guadalupe River (for mining and urban loads characterization)
2. Napa River (for mining and rural / background loads characterization)

Should resources be available, further studies should be initiated in:

3. Petaluma (for mining and rural / background loads characterization)
4. Carquinez (for mining loads characterization under low rainfall conditions)
5. San Mateo (for mining and urban loads characterization)
6. Alameda (for urban loads characterization under low rainfall conditions)

When to measure?

- November and April
- First flush process when studying both urban and rural watersheds
- Studies should be reactive given watersheds in the Bay Area are "flashy"
- Monthly intervals throughout the year using (similar to the USGS Central Valley sampling program) for seasonal and spatial characterization

What to measure?

Given watersheds in the Bay Area have very high suspended sediment concentrations and loads, mercury studies should concentrate resources on:

- Total Hg
- Particulate Hg
- SSC, TOC, POC, DOC

Given the direct impact of methyl Hg, studies should supply more limited resources to determining what proportion of total mercury loads are in methylated forms:

- Particulate methyl mercury
- Dissolved methyl mercury