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Progress Report for Mercury in Sediments of the Alviso and Eden Landing Salt Ponds – Results from Winter 2005 Sampling

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Overview

We collected sediment cores for analysis of total (THg) and methyl (meHg) mercury during winter 2005 from the Alviso and Eden Landing salt ponds as part of continuing monitoring to establish baseline concentrations in the sediments of the ponds comprising the South Bay Salt Pond Restoration Project. Results reported herein summarize efforts from winter 2005 and are presented with summaries from previous sampling conducted during late summer-early fall 2003 and 2004 (Miles et al. 2005).

The protocol set forth in the proposed scope of work for the monitoring study (Miles and Takekawa 2003, Stallings 2003) identified 2 main objectives: 1) establish a set of baseline concentrations of total and meHg in south bay salt ponds, primarily during late summer – early fall or winter, and 2) conduct additional sampling in ponds with highest baseline meHg concentrations, scheduled for changing water and salinity regimes, or characterized by important physical features. Results from ponds sampled during late summer – fall during 2003 and 2004 were reported previously (Miles et al. 2005) and, along with consultation with FWS, were used to determine ponds for sampling during winter 2005. Specifically,

- Ponds A3N, A12, and A13 were re-sampled because they contained surface sediments with the highest geometric mean concentrations of meHg during late summer – early fall.

- AB1, A5, and A7 are characterized by increasing depth associated with increasing distance from the south bay, causing exposed mudflats as water flow changes and higher methylation potential. Thus, we sampled 3 points (near, midway, and farthest from the bay) in order describe potential within pond variation in Hg concentrations associated with depth.

- Alviso ponds A9, A15, A17, A19, A20, and A21 were sampled to establish baseline Hg concentrations during winter. Water regime changes either have been conducted or soon will be conducted on these ponds.

- Finally, we collected sediment samples to obtain winter baseline THg and meHg concentrations in all Eden Landing Ponds (B1, B2, B4, B5, B6, B7, B8, B9, B10, B11, B12, B14, B1C, B2C, B4C, B5C, B6A, B6B, and B6C). In addition, 4 Eden Landing ponds were sampled in late summer – fall (B1, B2, B4, and B7).

- Concentrations of meHg in surface sediments from Alviso ponds A1, A2E, A2W, A3W, A5, A7, AB1, and AB2 sampled during late summer – fall 2004 were not available for inclusion in the January 2005 Progress Report. Results are included in this report which completes the baseline dataset for late summer – early fall.

Methods

Collection protocols and results for sediments collected during 2003 and 2004 were described previously (Miles et al. 2005). Briefly, we sampled 3 sites at each pond using a 2 cm diameter corer made of PVC pipe driven approximately 20 cm into the sediment. GPS coordinates and discrete water quality measurements (e.g. pH, temperature, salinity, Redox potential, dissolved oxygen) were recorded. For ponds sampled in multiple seasons or years, we collected sediment samples at the same sites to control for geographical variation whenever possible. Sites within ponds were generally 1) near an area of water exchange, 2) a distance of about halfway across the pond and 3) a distance at the far end of the pond away from water exchange. At each site, 3 surface sediment (0 – 5 cm) samples were collected approximately 5 – 10 m apart and placed in chemically clean jars (VWR Trace Clean 300 series ©). Previous analyses demonstrated significantly higher concentrations of THg and meHg in surface sediments compared to inner sediments (15 – 20 cm), so we only analyzed surface sediments. Site specific samples from Eden Landing ponds and Alviso ponds A19, A20, and A21 were composited into one sample per pond, while samples from all remaining Alviso ponds were left un-composited to enable examination of within pond Hg variation.

Battelle Marine Sciences Lab (Sequim, WA) conducted all Hg analyses. THg analyses followed EPA guidelines (1996; Method 1631, Appendix A, digestion and cold vapor)) and meHg analyses followed Bloom et al. 1989 and 1997. Limits of detection averaged 0.005 μg/g for THg and 0.014 ng/g for meHg. QA/QC criteria were met for THg and meHg: relative percent difference for duplicate samples ranged from 0 – 11 %, and recovery of matrix spikes ranged from 83 – 125 %. All concentrations reported herein are dry weight.

Preliminary Results

Alviso-winter 2005

We analyzed 31 sediment samples from the Alviso salt ponds collected from 3 February 2005 to 10 March 2005 (Appendix 1).

- Mercury concentrations were highest but also variable within pond A12; THg ranged from 0.27 to 4.2 μg/g, and meHg ranged from 1.8 to 9.0 ng/g (Figure 1). Notably, sample A12-4 was collected from recently dredged sediments and contained the lowest concentrations of THg and meHg.
- Sites A13-1 (1.5 μg/g) and A7-1 (1.7 μg/g) had concentrations of THg exceeding the US EPA criteria for contaminated sediments of 1.0 μg/g (Nichols et al 1991).
- Site A7-2 (0.9 μg/g) exceeded the Effects Range – Median (ERM) of 0.71 ug/g, (Long and Macdonald 1992). The ERM represents the 50th percentile of concentrations from other studies associated with toxic effects, is used as a general, non-absolute baseline.
- Nearly all non-composited sediments had THg concentrations exceeding the Effects Range – Low (ERL) of 0.15 μg/g (Long and Macdonald 1992). The ERL represents the 10th percentile of concentrations from other studies associated with toxic effects, and like the ERM, is used as a general, non-absolute baseline.
- In addition to A12, several sites in ponds A13, A15, A17, A9, A7, and A3N had relatively high meHg (> 2.0 ng/g). Furthermore, within pond concentrations of meHg were more variable than THg concentrations (Figures 2, 3).
- Logarithmic concentrations of THg were significantly correlated with meHg (P = 0.001), but similar to previous sampling the relationship was not strong (R^2 = 0.32) (Figure 4A).

Sediments from ponds A19, A20, and A21 were composited due to cost constraints. THg concentrations were either slightly above or below the ERL, and meHg did not appear substantially elevated (Figure 1).

Overall, water quality measurements (i.e., dissolved oxygen, pH, Redox potential) were not significantly correlated ($R^2 < 0.06$, $P \geq 0.27$) with either THg or meHg concentrations in non–composited samples from Alviso ponds. Water depth was positively (but not strongly) correlated with THg ($R^2 = 0.25$, $P = 0.02$), but not correlated with meHg (R^2 = 0.09, $P = 0.17$) (Figure 5). Within ponds AB1, A5, and A7 (the ponds hypothesized to have a strong depth – Hg association), no relation was apparent between depth and THg (Figure 6). However, meHg appeared to increase with depth in ponds AB1 and A5.

Eden Landing winter 2005

We analyzed 20 composite sediment samples from Eden Landing salt ponds collected from 11 January 2005 to 28 January 2005 (Appendix 2).

- Overall, THg concentrations were low (Figure 7).

- Pond B1C had the highest THg concentration (0.16 μg/g) followed by B1 and B11 (0.13 μg/g), while the concentration in B4C was lowest (0.05 μg/g).
- Concentrations of meHg were highest in B11 (3.1 ng/g) followed by B12 (2.8 ng/g) and B6B (2.3 ng/g), while B6C and B7 had lowest concentrations (0.3 ng/g).
- Similar to Alviso ponds, logarithmic concentrations of THg were significantly correlated with meHg ($P = 0.008$), but predictability the relationship was not strong ($R^2 = 0.33$) (Figure 4B).

Comparison among all seasons and ponds: 2003 – 2005.

For THg across all years and seasons:

- Alviso ponds A12, A13 (except winter), and A8 had concentrations above 1.0 μg/g in most seasons (Table 1, Figure 8).
- Alviso ponds A7 (late summer – fall 2004 and winter 2005), A10, A11, and A2W had concentrations at or exceeding the ERM.
- All years and seasons had concentrations at or exceeding the ERL except A21.
- In contrast, no Eden Landing pond contained THg concentrations exceeding 1.0 μg/g, and only B11 during late summer – fall 2004 and B1C during winter 2004 had concentrations exceeding the ERL (Table 2, Figure 8).
- THg concentrations did not differ significantly between seasons (paired t-test: $t = 1.2$, $P = 0.24$) among ponds sampled in both seasons ($n = 12$).

For meHg across all years and seasons:

- Alviso ponds A3N, A7 (except fall 2004), A12, A13, A11, A2W, and A9 had concentrations above the average meHg concentration for all Alviso samples ($\overline{x}$ = 2.6 ng/g) (Table 1, Figure 9).
- A3N had the highest elevated concentration (6.8 ng/g) in fall 2003, while samples from A1, A3W, and A5 had very low concentrations ($\leq$ 0.32 ng/g) in late summer-fall 2004.
- Notably, mean meHg concentrations in A5 were 9–fold higher in winter 2005 compared to late-summer – fall 2004, when methylation was expected to be higher.
- Eden Landing ponds B11, B12, B6B, B1, B1C, B14, and B4 had concentrations above the average concentration for all Eden Landing samples ($\overline{x}$ = 1.7 ng/g), and were generally lower than those in the Alviso ponds (Table 2, Figure 9).
- Pond B11 contained very elevated concentrations in late summer – fall 2003 ($\overline{x}$ = 10.7), but declined over 3–fold in winter 2005 ($\overline{x}$ = 3.1 ng/g).
- On average, however, meHg concentrations did not differ significantly between seasons (paired t-test: $t = 0.81$, $P = 0.43$) among ponds sampled in both seasons ($n = 12$).

- Percentages of THg comprised of meHg ranged from 0.03% to 1.5% in Alviso ponds (Table 1), and 0.2% to 6.9% in Eden Landing ponds (Table 2).

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Table 1. Summary results for concentrations (dry weight) of total Hg (THg) and methyl Hg (meHg) in surface sediments from salt ponds in the Alviso Salt Pond Complexes. Arithmetic (and geometric) means are calculated for non composited samples (n > 1).

Pond Complex	Year	season	Pond	*n*	THg (μg/g)	meHg (ng/g)	% meHg [a]
Alviso	2003	late summer - fall	A2E	3	0.487 (0.486)	0.788 (0.724)	0.15%
			A3N	3	0.438 (0.380)	6.793 (5.772)	1.52%
			A7	5	0.855 (0.810)	4.808 (2.825)	0.35%
			A8	3	1.362 (0.695)	2.063 (1.449)	0.21%
			A10	3	0.723 (0.722)	1.451 (1.425)	0.20%
			A11	3	0.690 (0.649)	2.834 (2.308)	0.36%
			A12	3	2.200 (1.697)	3.909 (3.344)	0.20%
			A13	3	1.454 (1.068)	3.299 (3.027)	0.28%
			A14	3	0.303 (0.276)	1.509 (1.435)	0.52%
			A16	3	0.441 (0.411)	1.382 (1.209)	0.29%
			Mean		*0.925 (0.635)*	*2.833 (1.954)*	0.32%
Alviso	2004	late summer - fall	A1	1	0.301	0.322	0.11%
			A2E	1	0.436	1.190	0.27%
			A2W	1	0.307	2.540	0.83%
			A3W	1	0.181	0.271	0.15%
			A5	1	0.736	0.233	0.03%
			A7	1	0.554	2.150	0.39%
			AB1	1	0.390	1.910	0.49%
			AB2	1	0.387	0.731	0.19%
			Mean	*1.168*	*0.412 (0.382)*	*1.168 (0.810)*	0.22%
Alviso	2004	winter	A12	4	1.594 (0.948)	4.525 (3.817)	0.40%
			A13	3	0.919 (0.832)	3.086 (3.075)	0.37%
			A15	3	0.533 (0.491)	2.237 (2.217)	0.45%
			A17	3	0.210 (0.204)	2.208 (1.939)	0.95%
			A19	1	0.1373	0.6828	0.50%
			A20	1	0.2539	1.6928	0.67%
			A21	1	0.1100	1.2175	1.11%
			A3N	3	0.295 (0.256)	3.286 (3.030)	1.18%
			A5	3	0.419 (0.407)	2.293 (2.115)	0.52%
			A7	3	0.960 (0.769)	3.230 (2.040)	0.27%
			A9	3	0.564 (0.560)	3.044 (2.585)	0.46%
			AB1	3	0.382 (0.380)	1.178 (0.989)	0.26%
			Mean		0.532 (0.363)	2.391 (1.911)	0.59%
Alviso - USFWS [b]	2002	late summer - fall	A1	3	0.313	na	
			AB1	3	0.563	na	
			A5	3	0.372	na	
			A9	3	0.479	na	
			A10	3	0.919	na	
			A16	3	0.533	na	

[a] based on geometric means for non-composited samples

[b] data from Maurer and Adelsbach (Phase 2 Environmental Site Assessment, USFW Environmental Contaminants Division, Sacramento CA). Samples collected in top 10-15 cm

na = not analyzed

Table 2. Summary results for concentrations (dry weight) of total Hg (THg) and methyl Hg (meHg) in surface sediments from salt ponds in the Eden Landing and Ravenswood Salt Pond Complexes. Arithmetic (and geometric) means are calculated for non composited samples ($n > 1$).

Pond Complex	Year	Season [a]	Pond	*n*	THg (μg/g)	meHg (ng/g)	% meHg [a]
Eden Landing	2003	late summer - fall	B2	3	0.136 (0.134)	0.751 (0.655)	0.5%
			B6A	3	0.070 (0.070)	0.128 (0.121)	0.2%
			B11	2	0.156 (0.156)	10.71 (10.71)	6.9%
			B12	2	0.067 (0.064)	2.083 (2.073)	3.2%
			Mean		*0.107 (0.098)*	*3.419 (1.150)*	*1.2%*
	2004	late summer - fall	B1	1	0.145	1.710	1.2%
			B2	1	0.142	0.616	0.4%
			B4	1	0.103	2.170	2.1%
			B7	1	0.080	0.467	0.6%
			Mean		*0.177 (0.114)*	*1.241 (1.016)*	*0.9%*
	2005	winter	B1	1	0.134	2.160	1.6%
			B1C	1	0.161	1.790	1.1%
			B2	1	0.118	1.240	1.1%
			B2C	1	0.070	0.535	0.8%
			B4	1	0.121	1.480	1.2%
			B4C	1	0.054	0.484	0.9%
			B5	1	0.091	0.819	0.9%
			B5C	1	0.116	0.413	0.4%
			B6	1	0.066	0.484	0.7%
			B6A	1	0.076	1.600	2.1%
			B6B	1	0.092	2.330	2.5%
			B6C	1	0.070	0.325	0.5%
			B7	1	0.090	0.256	0.3%
			B8	1	0.075	0.663	0.9%
			B8A	1	0.130	0.983	0.8%
			B9	1	0.091	2.240	2.5%
			B10	1	0.088	0.986	1.1%
			B11	1	0.128	3.070	2.4%
			B12	1	0.125	2.760	2.2%
			B14	1	0.091	1.680	1.9%
			Mean		*0.099 (0.096)*	*1.315 (1.033)*	*1.1%*
Ravenswood	2003	late summer - fall	R2	3	0.048 (0.044)	1.413 (0.882)	2.0%
			R4	3	0.041 (0.039)	0.368 (0.295)	0.8%
			Mean		*0.045 (0.041)*	*0.891 (0.510)*	*1.2%*

[a] based on geometric means for non-composited samples

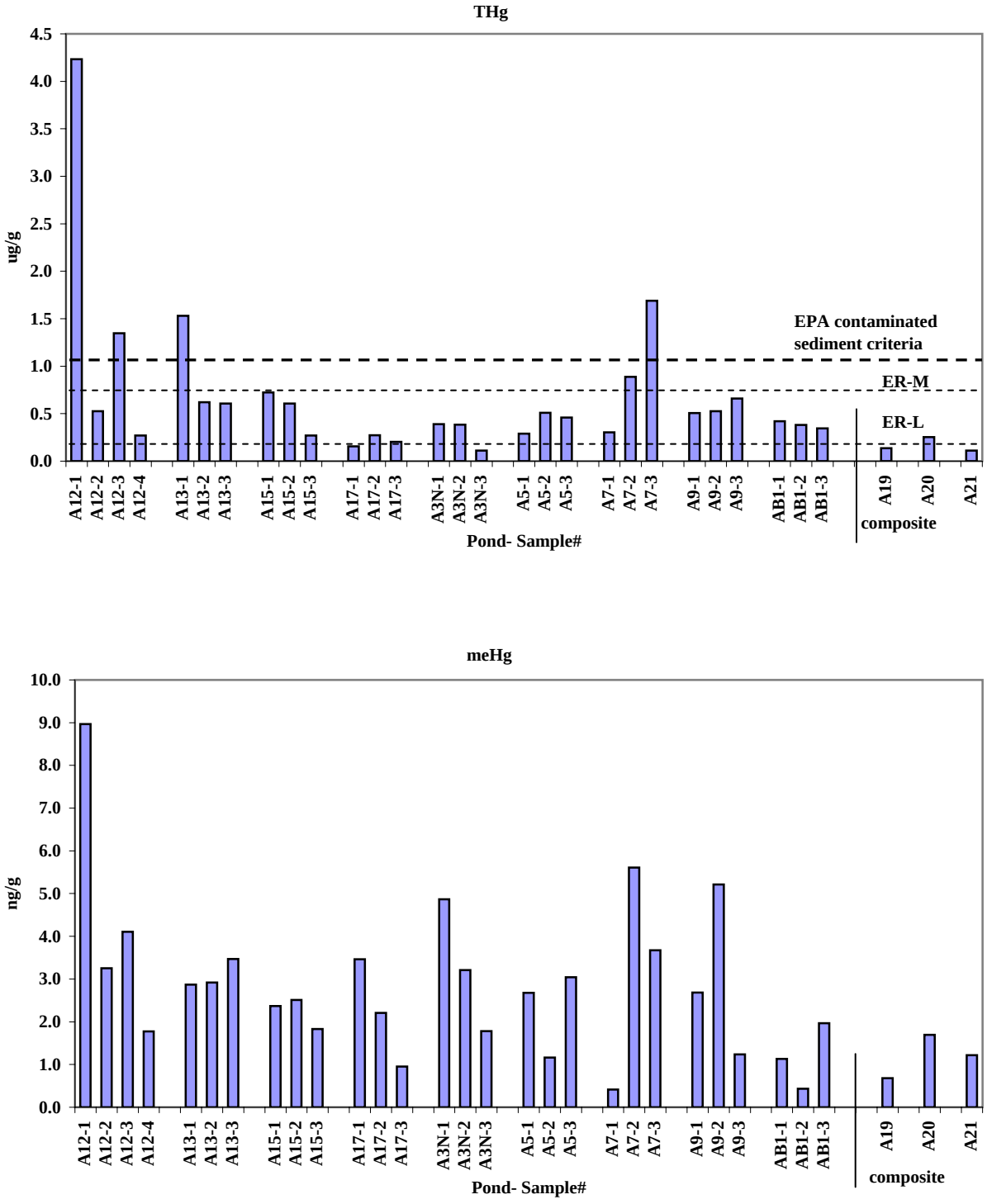


Figure 1. Concentrations of THg and meHg from site specific and composite sediment samples from Aviso salt ponds, winter 2005. Baseline biological effect levels for THg are indicated by doted lines: 1.0 ng/g = US EPA criteria for contaminated sediment, 0.71 µg/g = Effects Range-Median (ER-M), 0.15 µg/g = Effects Range-Low (ER-L).

Figure 2. Concentrations of THg in surface sediment samples from Alviso Salt Ponds during February and March 2005. Points represent sampling locations except A19, 20, and 21 which were composite samples. Water exchange points taken from the Salt Pond ISP.

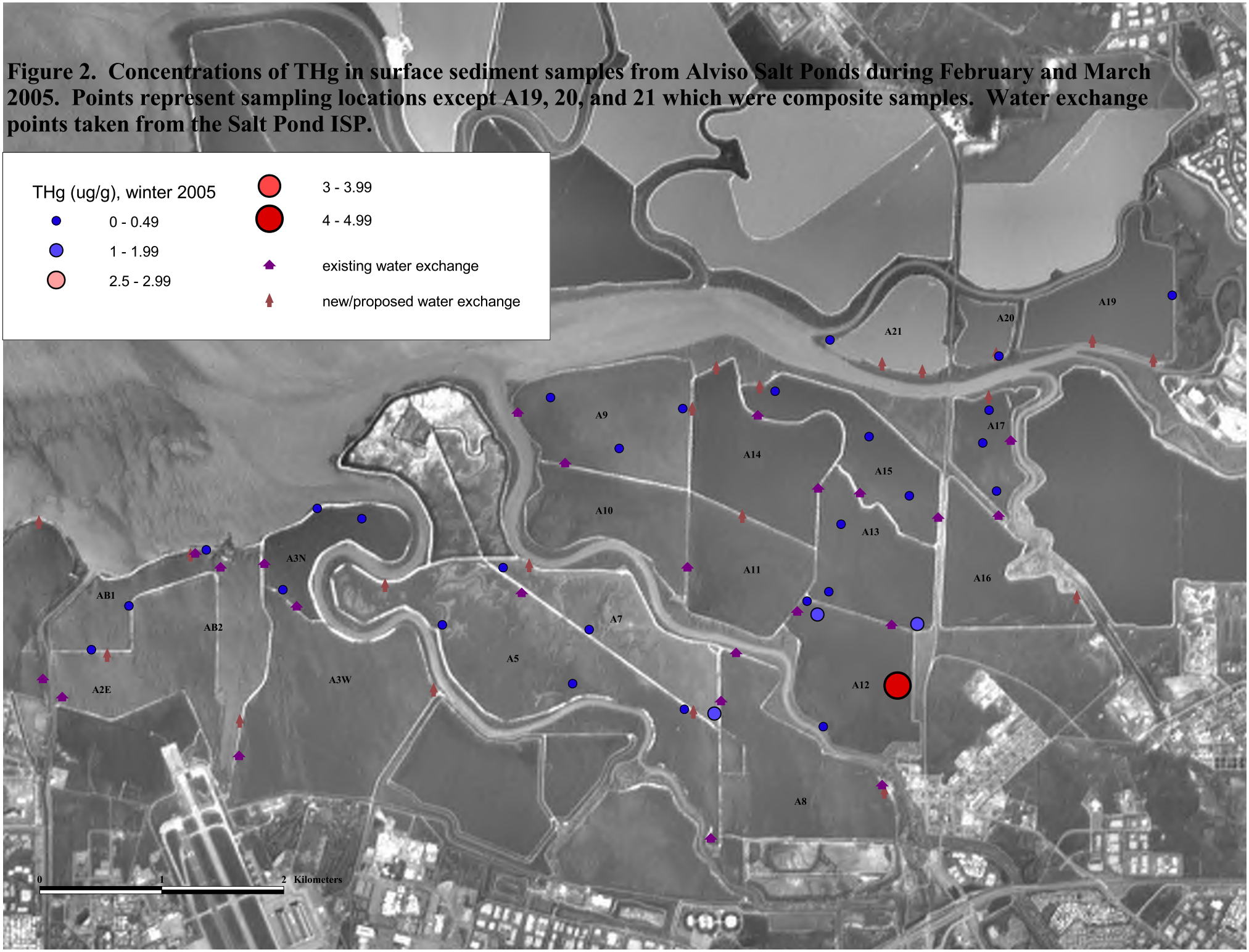
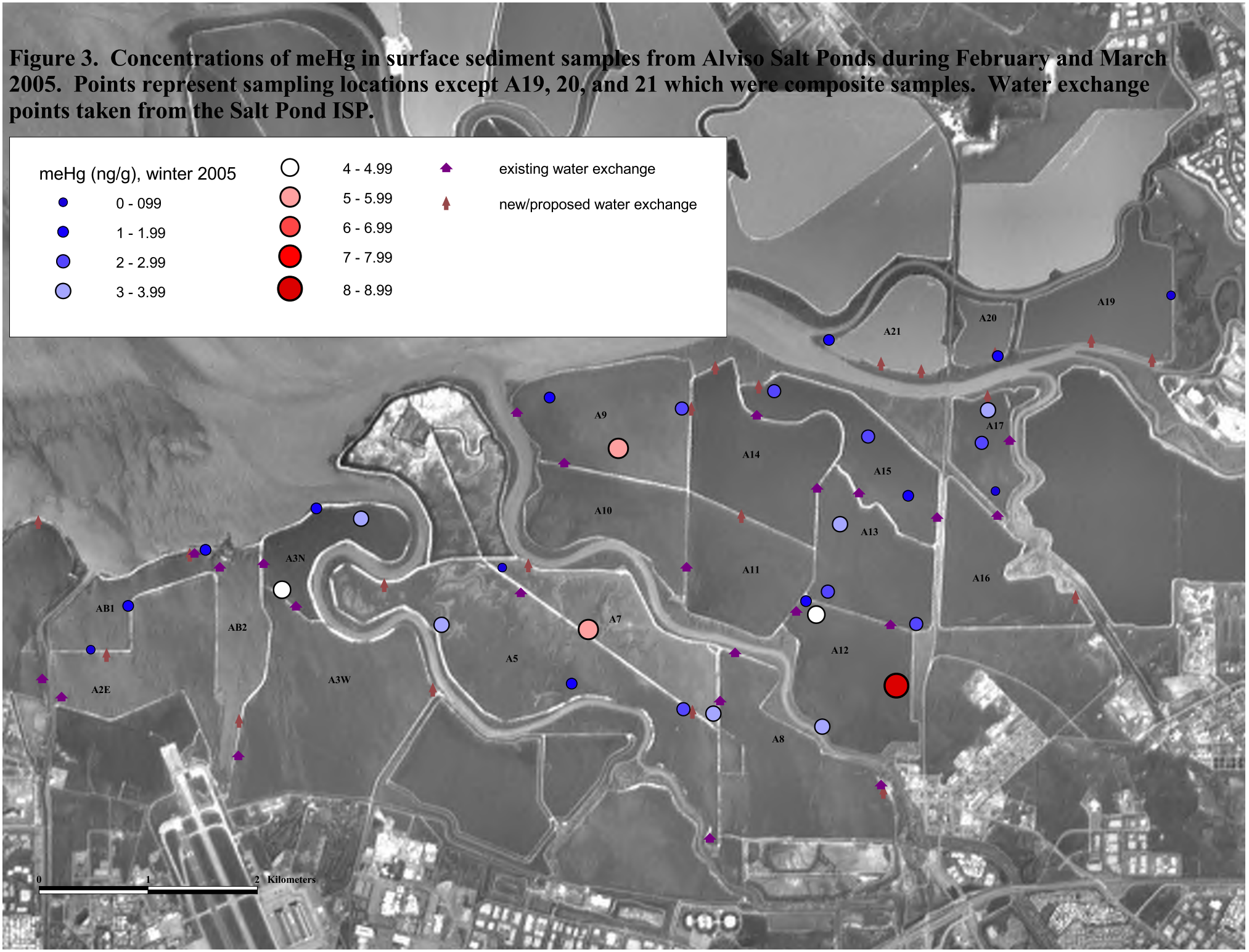


Figure 3. Concentrations of meHg in surface sediment samples from Alviso Salt Ponds during February and March 2005. Points represent sampling locations except A19, 20, and 21 which were composite samples. Water exchange points taken from the Salt Pond ISP.



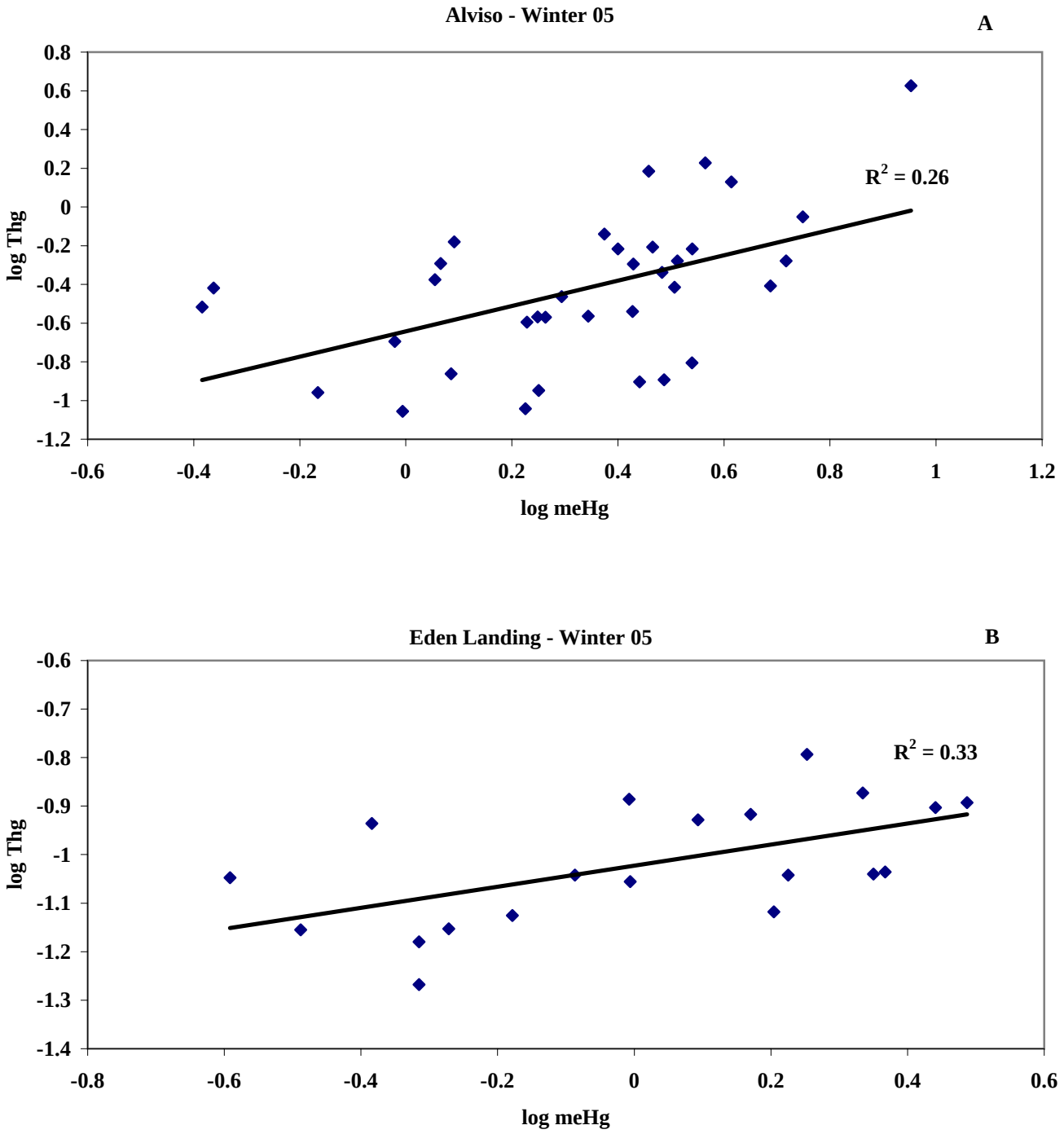


Figure 4. Correlations between log transformed concentrations of THg and meHg in Alviso (A) and Eden Landing (B) salt ponds sampled during winter 2005.

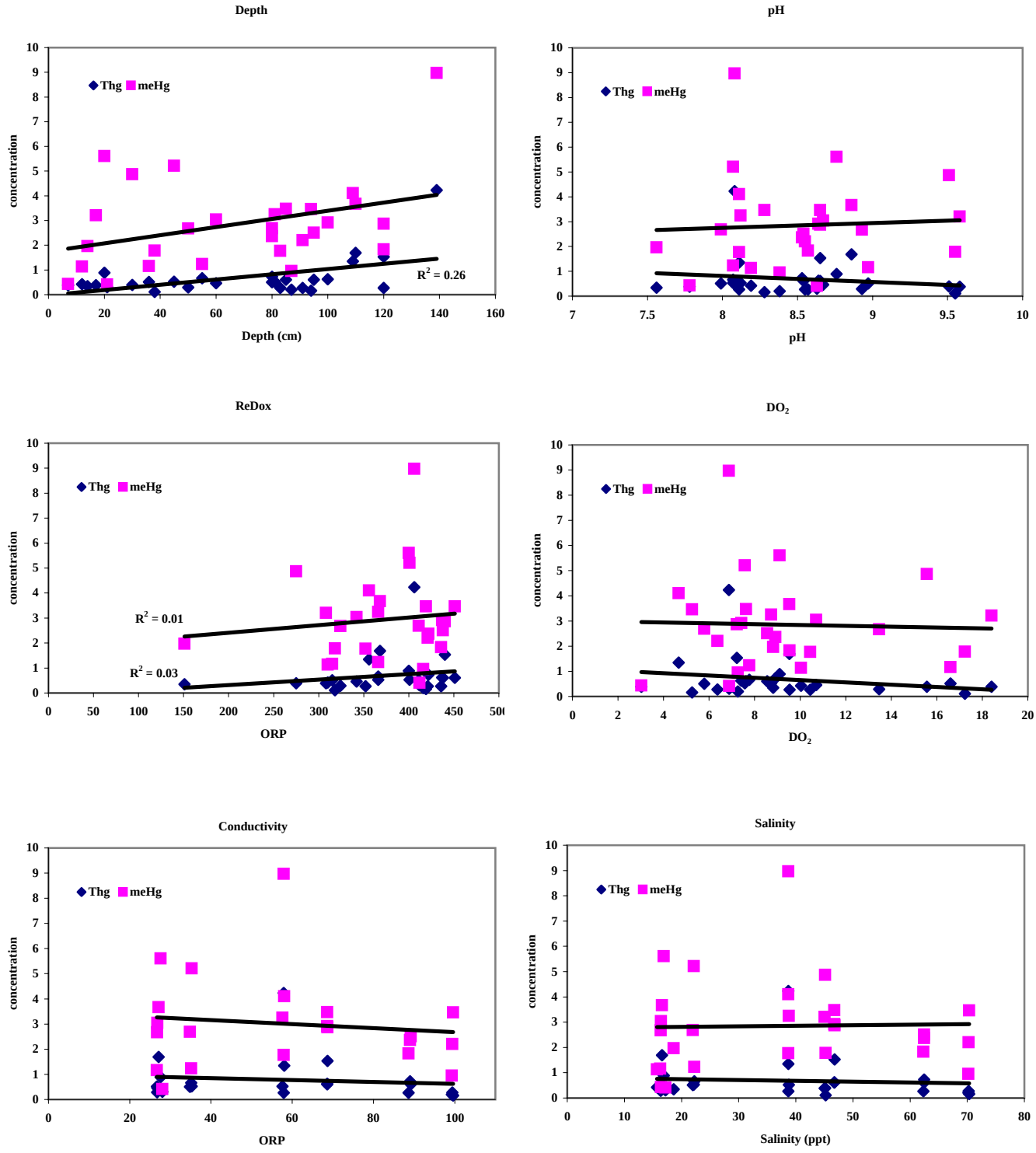


Figure 5. Correlations between water chemistry and concentrations of THg and meHg in site specific (non composited) sediment samples from Alviso salt ponds, winter 2005. Only depth vs. THg was significant ($P < 0.001$).

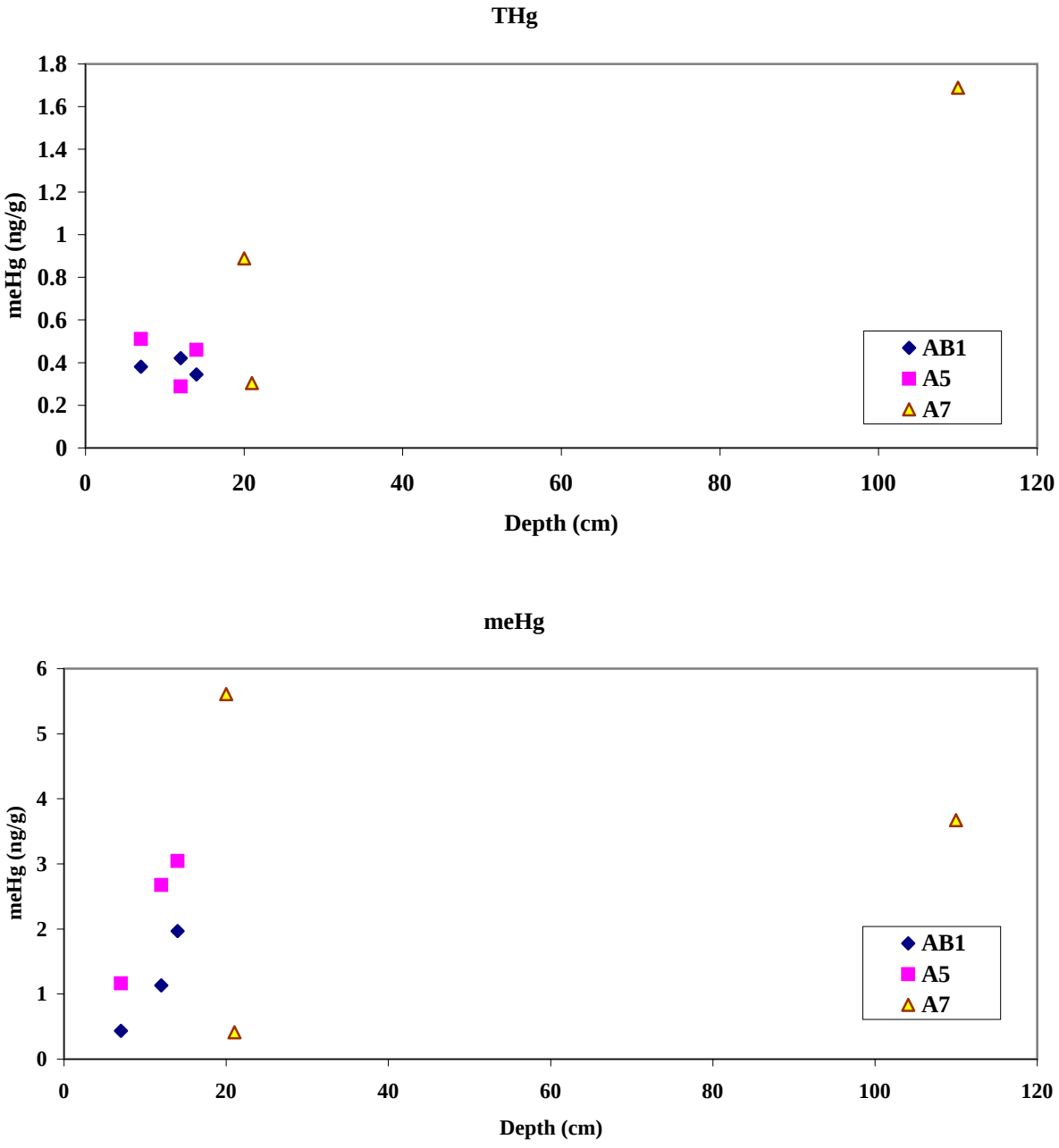
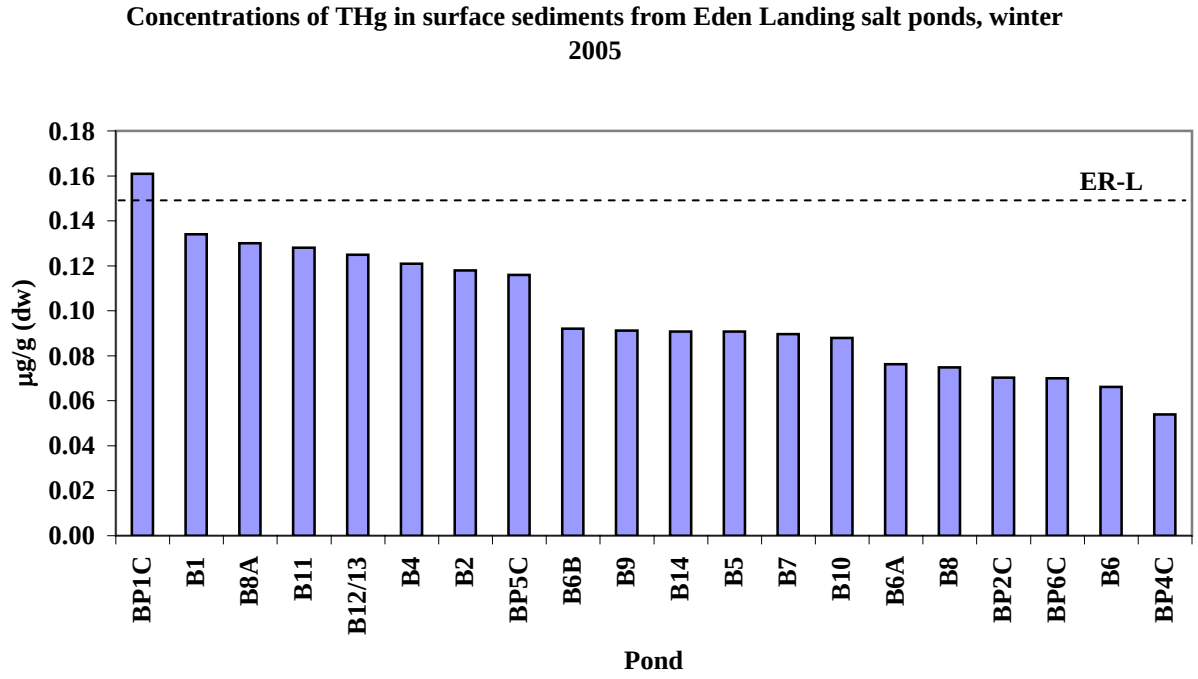


Figure 6: Simple graphical relations between water depth and concentrations of THg and meHg in Alviso ponds AB1 A5, and A7.



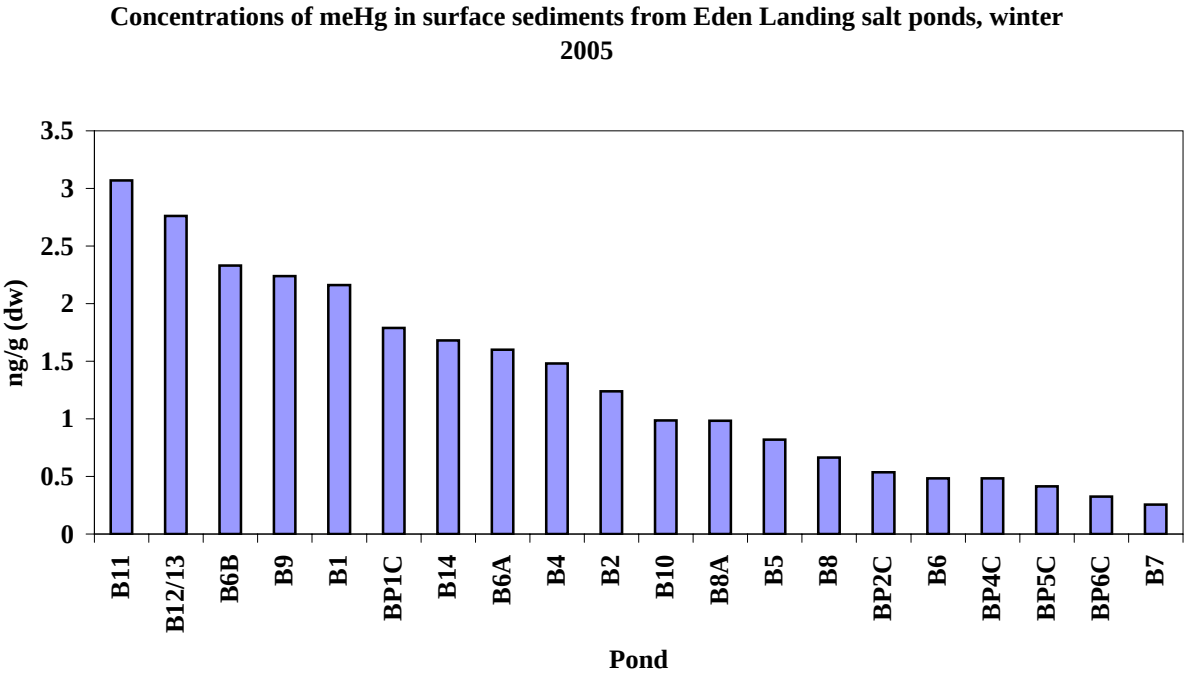


Figure 7. Concentrations of THg and meHg in composite surface sediment samples collected from Eden Landing salt ponds, winter 2005. ER-L = Effects Range-Low.

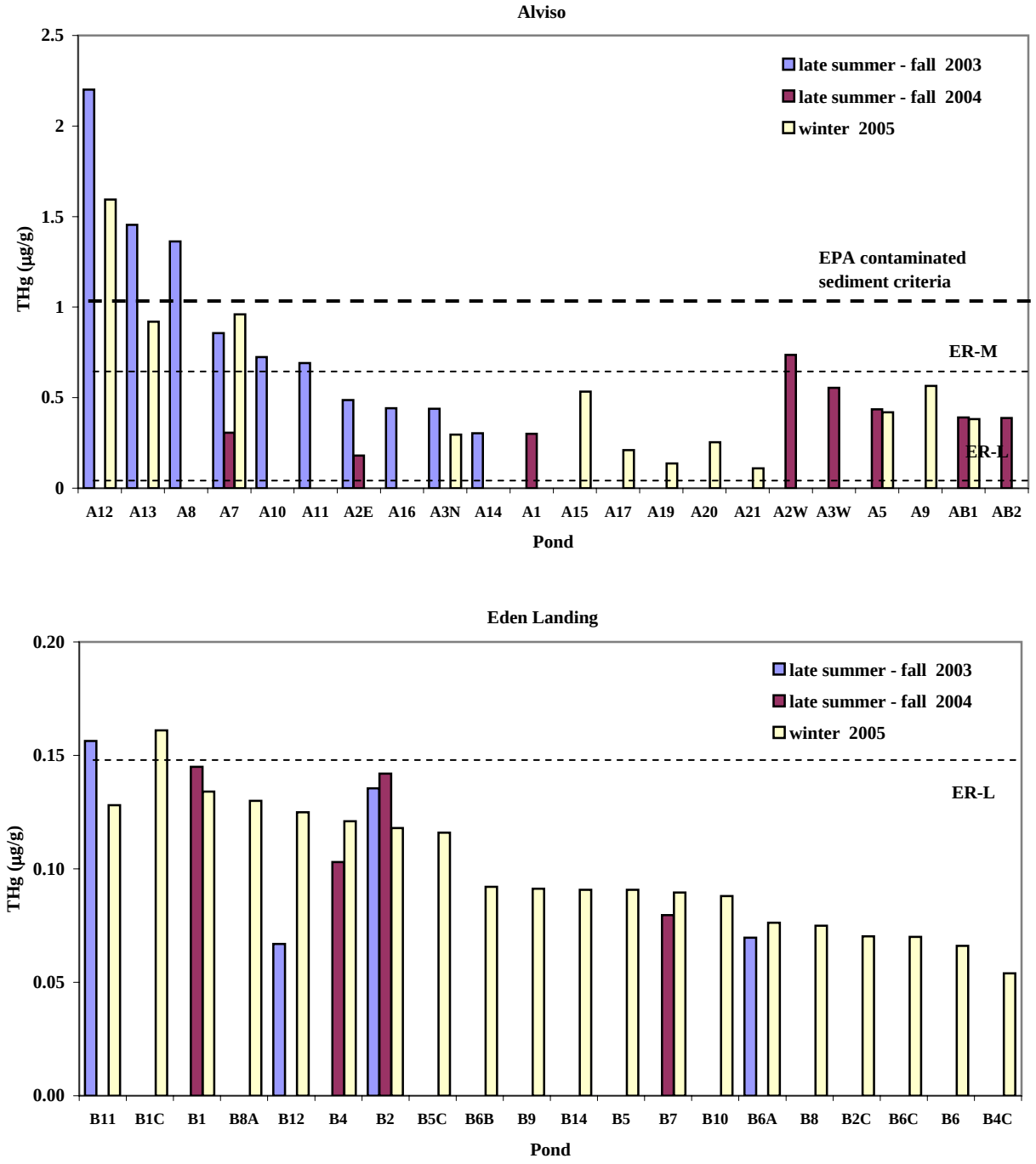


Figure 8. THg concentrations (mean or single composite value) in Alviso and Eden Landing pond surface sediments, fall 2003 - winter 2005. Note y-axis varies between pond complexes. Baseline biological effect levels for THg are indicated by doted lines: 1.0 ng/g = US EPA criteria for contaminated sediment, 0.71 mg/g = Effects Range-Median (ER-M), 0.15 mg/g = Effects Range-Low (ER-L).

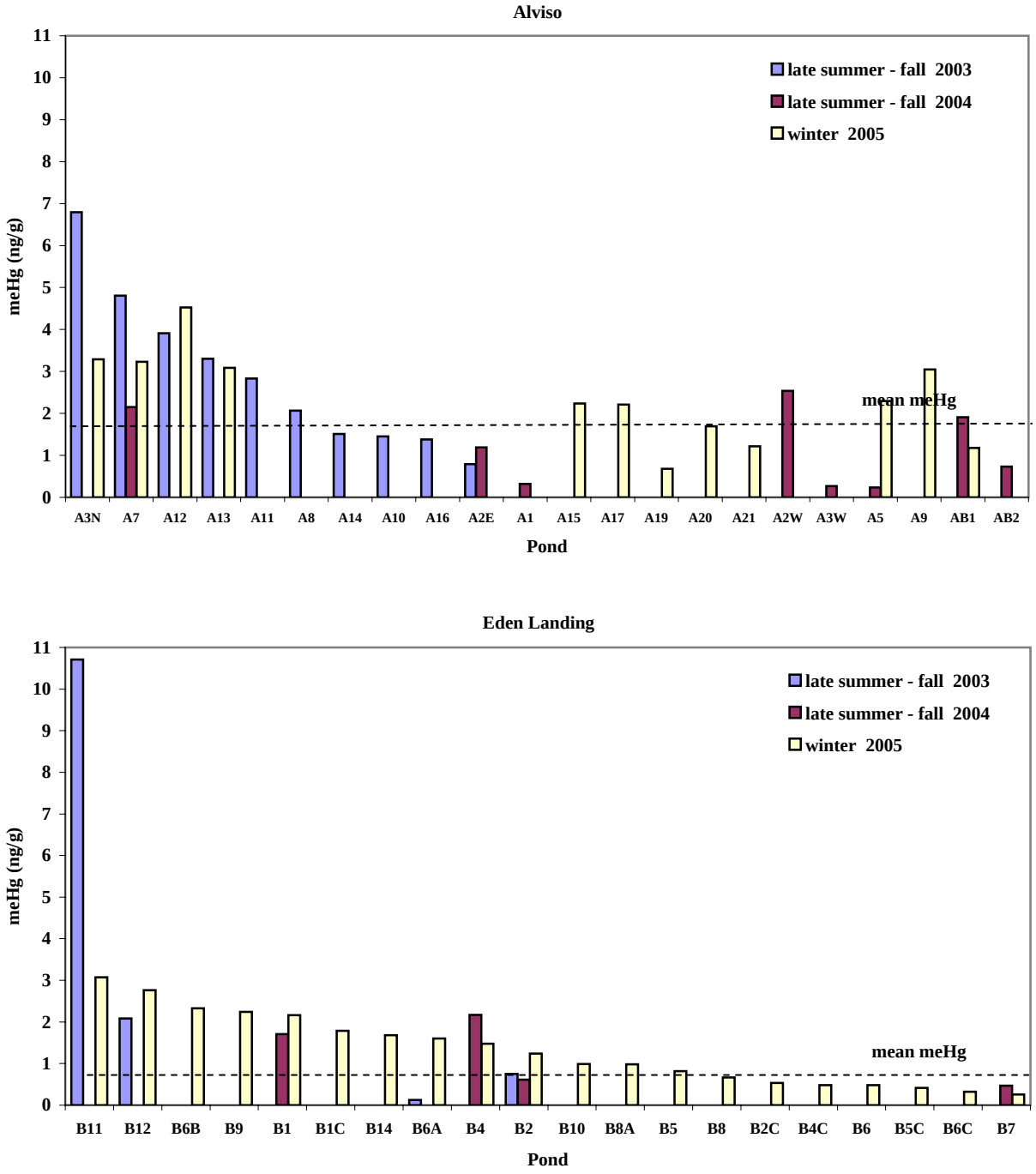
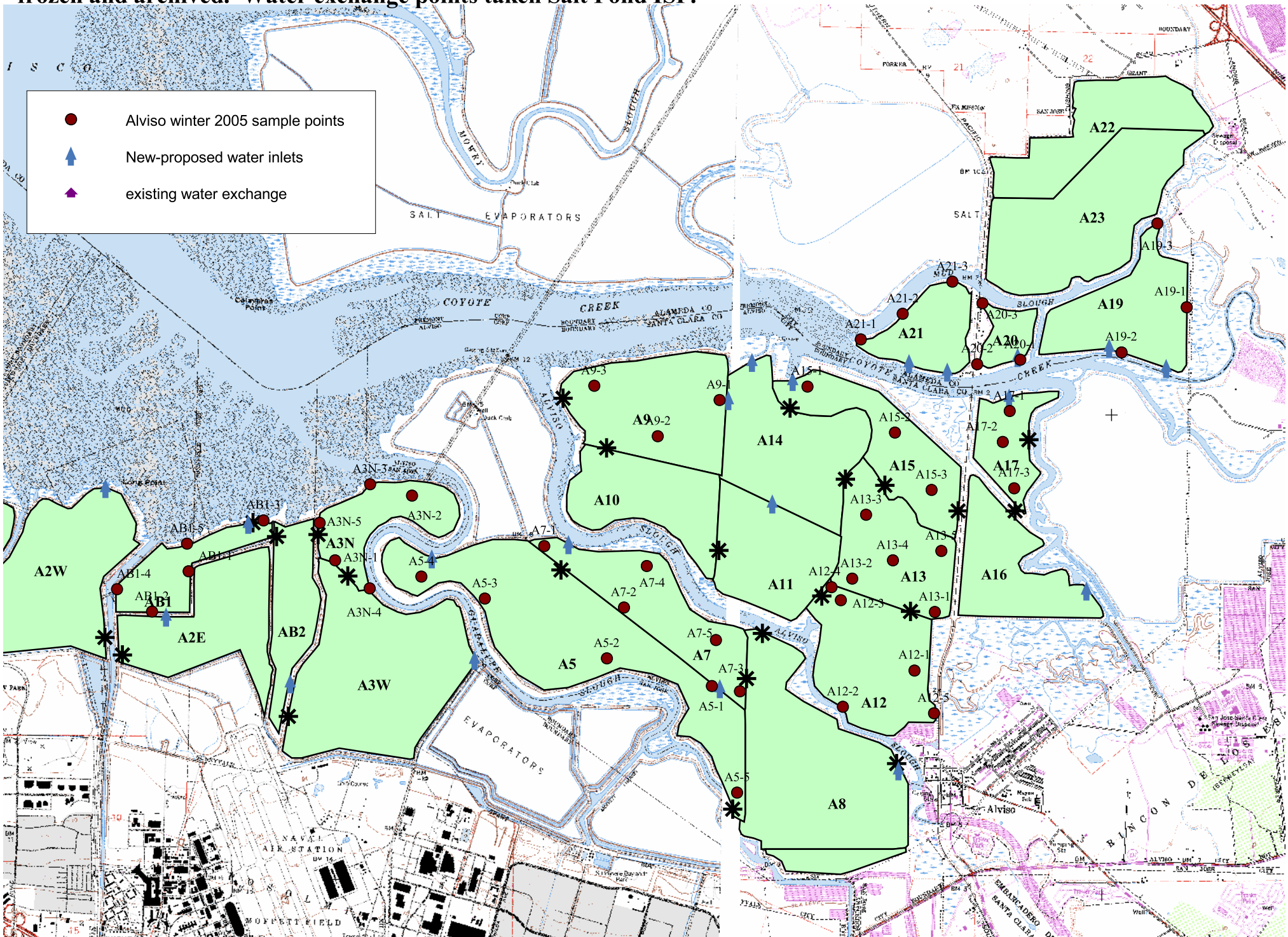


Figure 9. MeHg concentrations (mean or single composite value) in Alviso and Eden Landing pond surface sediments, fall 2003 - winter 2005. Baseline biological effect levels for THg are indicated by doted lines: 1.0 ng/g = US EPA criteria for contaminated sediment, 0.71 mg/g = Effects Range-Median (ER-M), 0.15 mg/g = Effects Range-Low (ER-L).

Appendix 1. Sediment sampling locations for Hg analysis in Alviso sat ponds, winter 2005. Note 1-2 additional samples in ponds AB1, A3N, A13, A5, and A7 were collected which were not analyzed for Hg but were frozen and archived. Water exchange points taken Salt Pond ISP.



Appendix 2. Sediment sampling locations for Hg analysis in Eden Landing salt ponds, late summer-fall 2004 and winter 2005. Water exchange points taken from Salt Pond ISP.