Atmospheric and Environmental Research, Inc.

MEMORANDUM

TO: Brake Pad Partnership

FROM: Betty Pun

RE: Air deposition of copper from brake pad wear debris
(1) Final results of a 5-year simulation for the Castro Valley Creek subwatershed
(2) Estimates of copper air deposition to watersheds in the San Francisco Bay Area and to the San Francisco Bay

DATE: 6 March 2007

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(1) Air deposition of copper from brake pad wear debris - Final results of a 5-year simulation for the Castro Valley Creek subwatershed

A five-year simulation was performed to estimate the wet and dry air deposition fluxes of copper (Cu) in the Castro Valley Creek subwatershed. The methodology was described in Pun et al. (2006). Wet and dry deposition fluxes were calculated as the sum of regional and local components at 20 locations within the Castro Valley Creek subwatershed (see Figure 1).

The raw results of the simulation were transmitted in an excel spreadsheet to Tony Donigian at Aquaterra. Here we provide a summary of the simulated wet and dry deposition fluxes. Figure 2 shows time series of the local and regional components of the calculated dry deposition flux, spatially averaged across the 20 sites. The dry deposition flux was quite variable on a day-to-day basis. Large percentages of the dry deposition flux were attributable to local emissions within the Castro Valley Creek subwatershed. In fact, the local component of the dry deposition flux averaged 16.5 $\mu g/m^2/day$ over the five-year period between March 2000 and February 2005. The regional component of the dry deposition flux over the same period was only 0.804 $\mu g/m^2/day$, i.e., less than 5%.

Figure 3 shows the spatially averaged time series of the local and regional components of the calculated wet deposition flux in the Castro Valley Creek subwatershed. Wet deposition contributed sporadically to the total deposition flux. Unlike dry deposition, wet deposition was mostly attributed to regional emissions rather than local emissions. The regional component of wet deposition was 0.848 $\mu g/m^2/day$ averaged over five years, including days with and without precipitation. The average local component was only 0.301 $\mu g/m^2/day$. Even during the rainy season of December to March, the magnitude of the wet deposition flux was no larger than that of the dry deposition flux. Therefore, dry deposition dominated total deposition of copper in the Castro Valley Creek subwatershed.

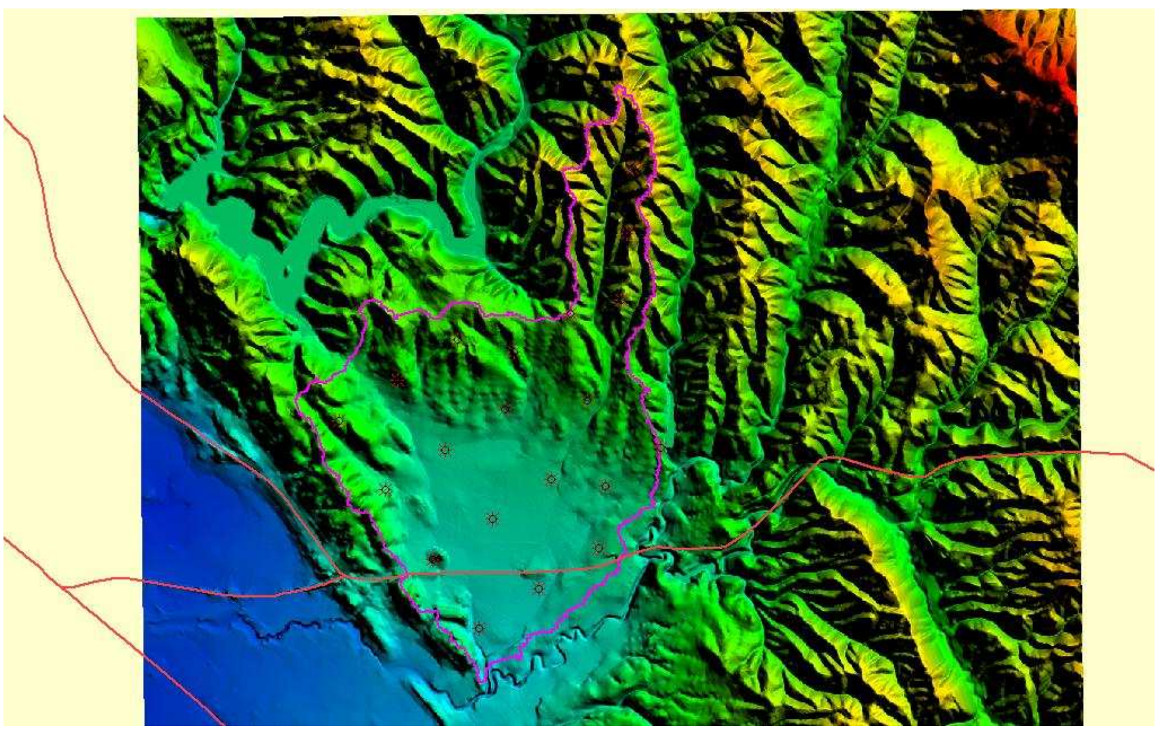
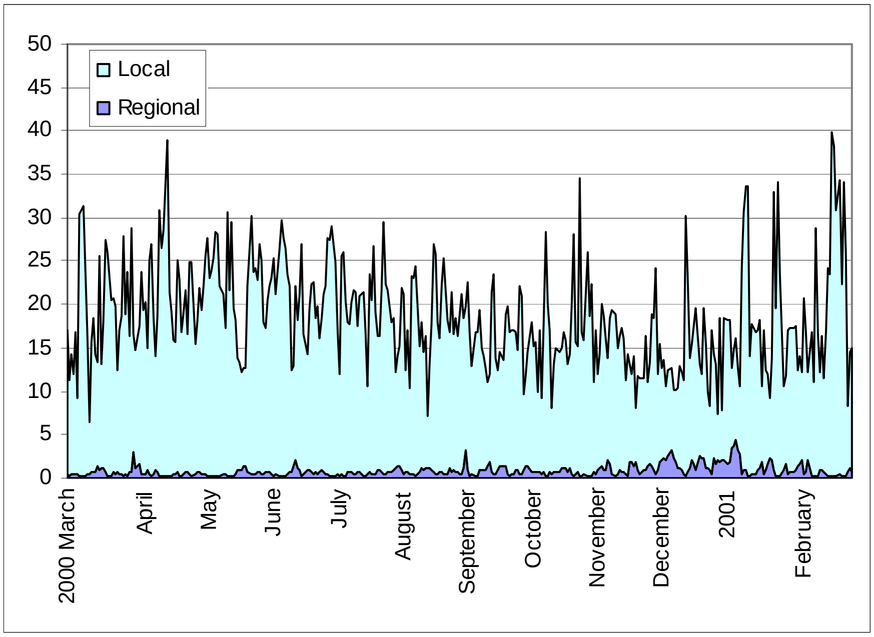


Figure 1. Locations of receptors for wet and dry deposition calculations within the Castro Valley Creek subwatershed.

(a) Dry deposition flux in μg/m^2/day for the period March 2000 – February 2001.



(b) Dry deposition flux in μg/m^2/day for the period March 2001 – February 2002.

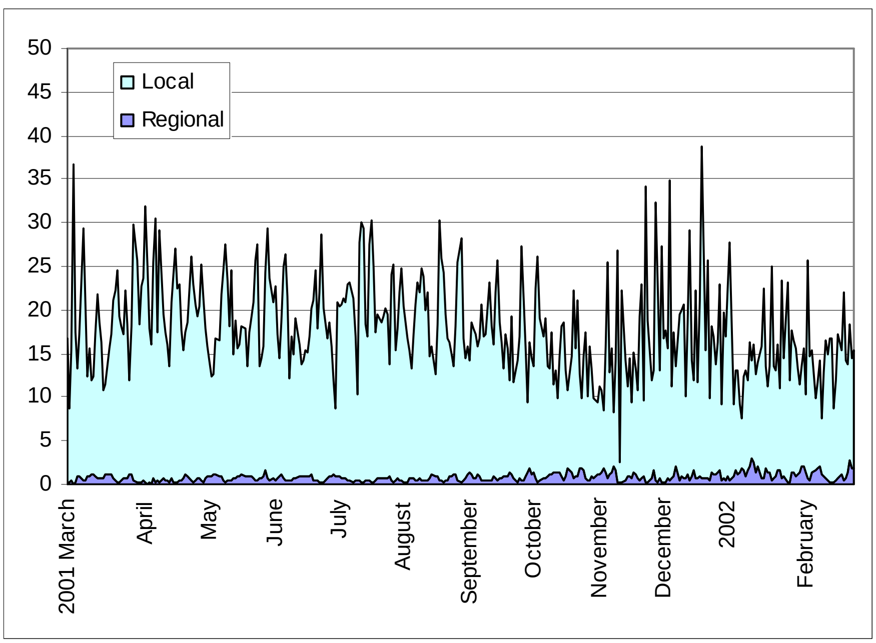
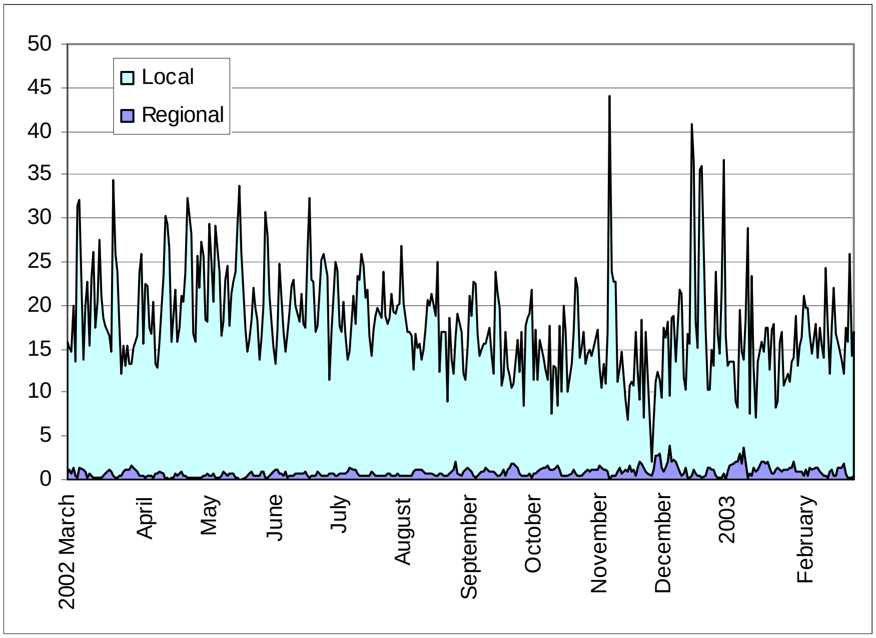


Figure 2 Time series of dry deposition flux spatially averaged across 20 sites within the Castro Valley Creek subwatershed.

(c) Dry deposition flux in μg/m^2/day for the period March 2002 – February 2003.



(d) Dry deposition flux in μg/m^2/day for the period March 2003 – February 2004.

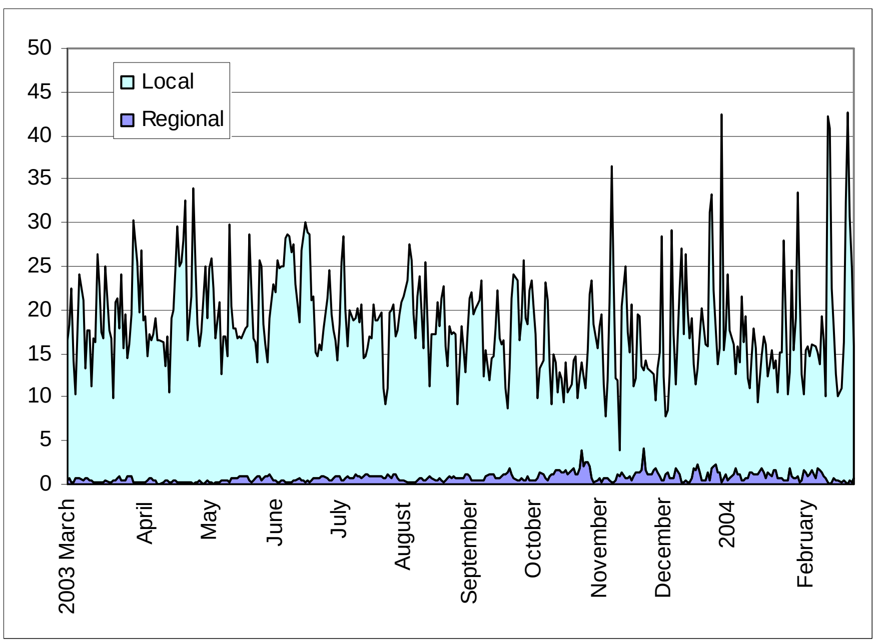


Figure 2 Time series of dry deposition flux spatially averaged across 20 sites within the Castro Valley Creek subwatershed (continued).

(e) Dry deposition flux in μg/m^2/day for the period March 2004 – February 2005.

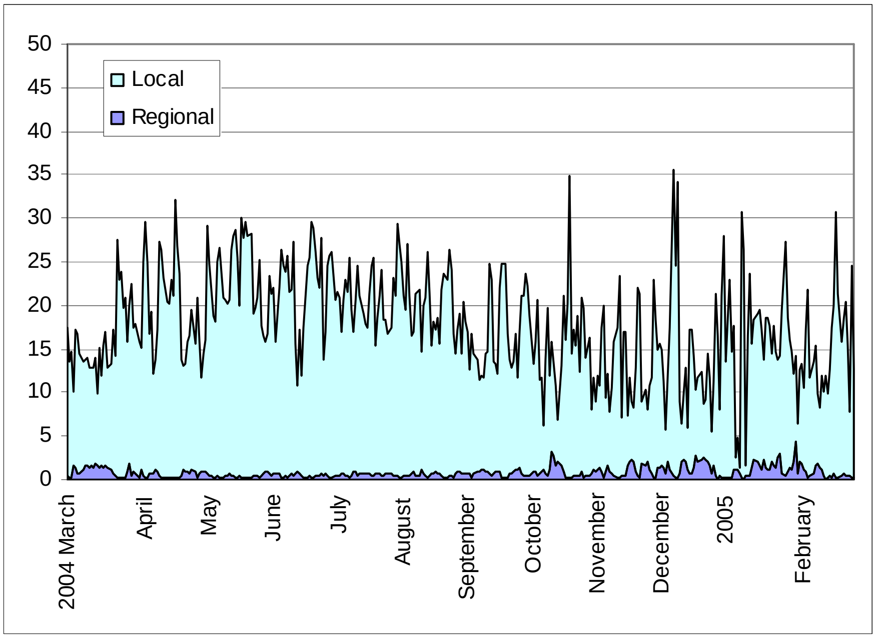
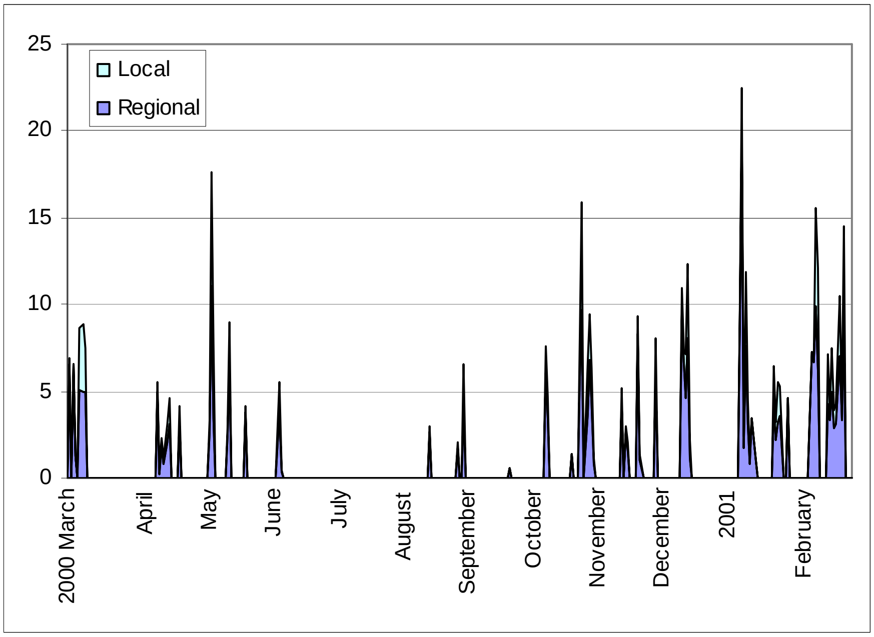


Figure 2 Time series of dry deposition flux spatially averaged across 20 sites within the Castro Valley Creek subwatershed (continued).

(a) Wet deposition flux in $\mu g/m^2/day$ for the period March 2000 – February 2001.



(b) Wet deposition flux in $\mu g/m^2/day$ for the period March 2001 – February 2002.

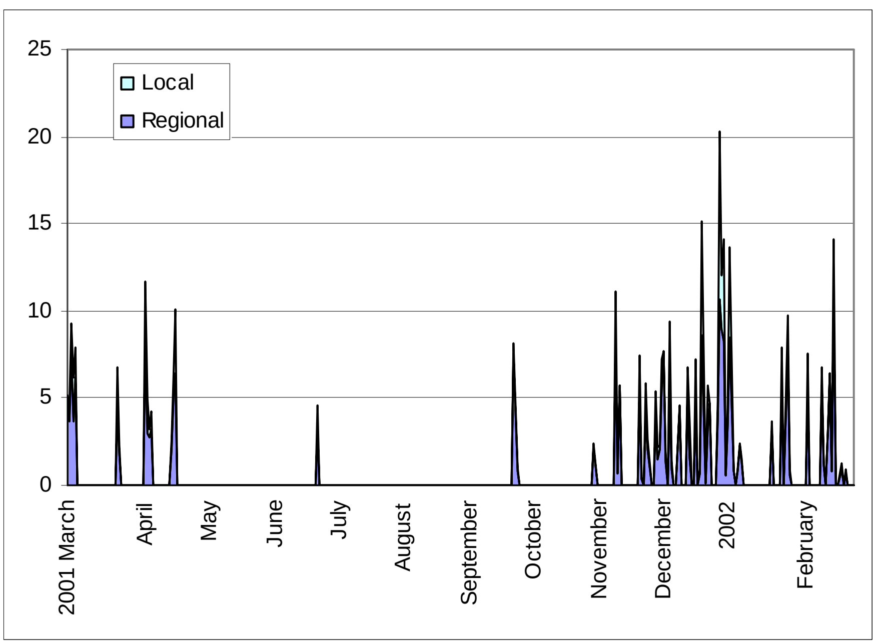
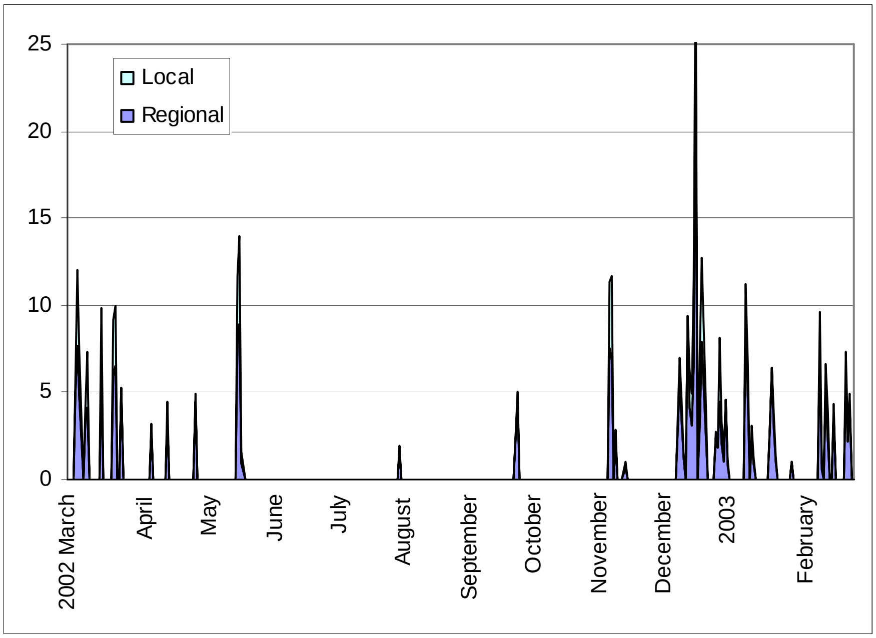


Figure 3. Time series of wet deposition flux spatially averaged across 20 sites within the Castro Valley Creek subwatershed.

(c) Wet deposition flux in $\mu g/m^2/day$ for the period March 2002 – February 2003.



(d) Wet deposition flux in $\mu g/m^2/day$ for the period March 2003 – February 2004.

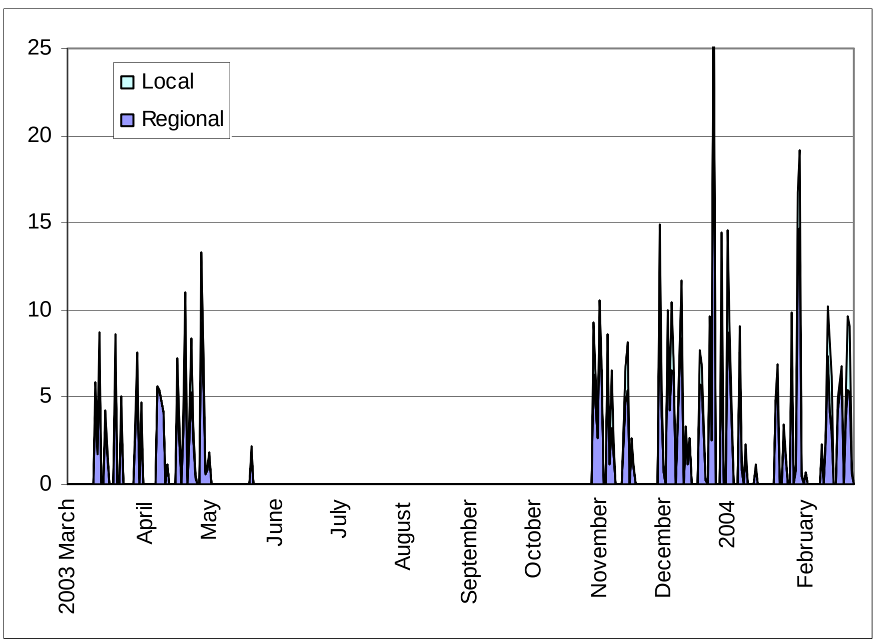


Figure 3. Time series of wet deposition flux spatially averaged across 20 sites within the Castro Valley Creek subwatershed (continued).

(e) Wet deposition flux in μg/m^2/day for the period March 2004 – February 2005.

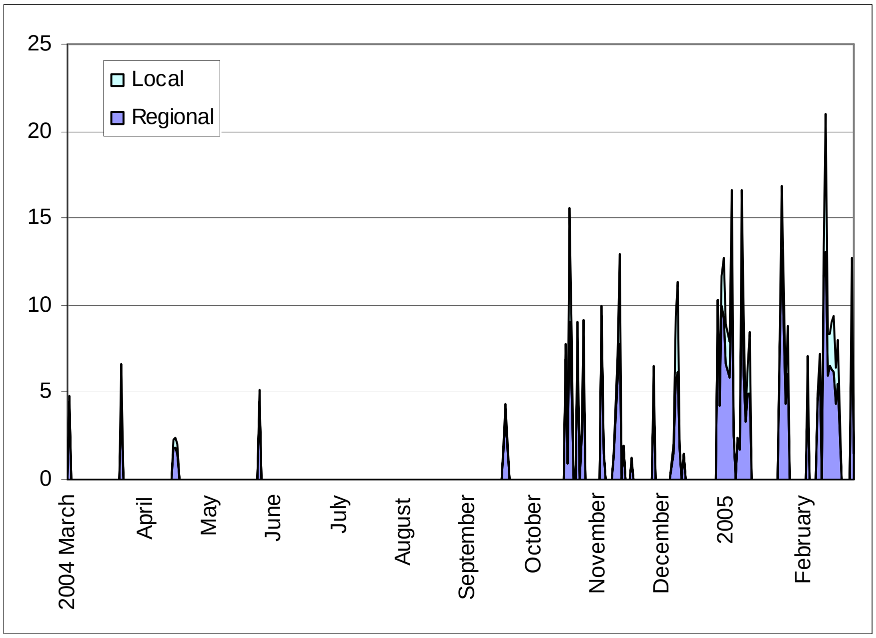


Figure 3. Time series of wet deposition flux spatially averaged across 20 sites within the Castro Valley Creek subwatershed (continued).

(2A) Estimates of copper air deposition to watersheds in the San Francisco Bay Area

Air deposition fluxes for 23 watersheds and the city of San Francisco were estimated using a scaling methodology. This methodology is based on the air deposition modeling results and copper emission flux data. For each watershed (or City of San Francisco), the emission flux was calculated by dividing the emission rate for the watershed (or City of San Francisco) (Rosselot, 2006a) by the surface area of the watershed (or City of San Francisco) (Rosselot, 2006b). Results are presented in Table 1.

Airborne copper release rates from brake lining wear are obtained from Table ES-4 of Rosselot (2006a). Total airborne copper release from brake pad lining, including those from the City of San Francisco, is 47,033 kg Cu / year. In addition, industrial sources also release 358 kg Cu / year into the air. Therefore, a total Cu release rate (TE) of 47,392 kg / yr is used in the calculations.

The total area within the San Francisco Bay watersheds is 8,935,769,853 m^2 (Rosselot, 2006b; Table 2-3). Because emissions from the City of San Francisco is included in TE, the city area of 127,205,702 m^2 (Rosselot, 2006b; Table 2-1) is also included in the total area term (TA). Therefore, 9,062,975,553 m^2 is used as TA in the calculations.

For each watershed i, a local emission term (LE_i) is obtained from Rosselot (2006a). The local emission flux (LEF_i) is defined using the local watershed area (LA_i) from Rosselot (2006b).

$LEF_i = LE_i / LA_i$

The regional emission term (RE_i) with respect to watershed i is defined as:

$RE_i = TE - LE_i$

The area corresponding to the regional emissions (RA_i) is

$RA_i = TA – LA_i$

The regional emission flux term is defined as

$REF_i = RE_i / RA_i$

A scaling factor for local deposition flux (LSF_i) is defined as the ratio of the local emission flux from watershed i and the local emission flux from the Castro Valley Creek subwatershed.

$LSF_i = LEF_i / LEF_{CVC}$

Similarly, a scaling factor for the regional deposition flux (RSF_i) is defined as the ratio of the regional emission flux as seen by watershed i and the regional emission flux as seen by the Castro Valley Creek subwatershed.

$$RSF_i = REF_i / REF_{CVC}$$

The local and regional wet deposition fluxes (LWD_i and RWD_i) for a given watershed i are then defined as:

$$LWD_i = LWD_{CVC} \times LSF_i$$
$$RWD_i = RWD_{CVC} \times RSF_i$$

where LWD_{CVC} and RWD_{CVC} are the model-estimated average wet deposition of Cu for Castro Valley Creek subwatershed ($RWD_{CVC} = 0.848$ and $LWD_{CVC} = 0.301$ $\mu g/m^2/day$). The total wet deposition flux for the watershed (Table 1) is calculated as the sum

$$WD_i = LWD_i + RWD_i$$

A similar procedure is employed for dry deposition flux (DD_i), where the local and regional dry deposition fluxes (RDD_i and LDD_i) are calculated as

$$LDD_i = LDD_{CVC} \times LSF_i$$
$$RDD_i = RDD_{CVC} \times RSF_i$$

where the local and regional deposition fluxes in the Castro Valley Creek subwatershed are $RDD_{CVC} = 0.804$ and $LDD_{CVC} = 16.5$ $\mu g/m^2/day$, respectively. The total dry deposition flux for the watershed (Table 1) is calculated as the sum

$$DD_i = LDD_i + RDD_i$$

(2B) Estimates of copper air deposition to the San Francisco Bay

For deposition onto the San Francisco bay, the local component of the dry and wet deposition fluxes are assumed to be zero. The bay is only influenced by the regional components of wet and dry deposition fluxes. Therefore, the wet deposition flux to the San Francisco Bay (Table 1) is calculated as the average of the regional components of the wet deposition fluxes to the individual watersheds. Similarly, the dry deposition flux to the San Francisco Bay (Table 1) is calculated as the average of the regional components of the dry deposition fluxes to the individual watersheds.

Table 1. Estimated dry and wet air deposition fluxes of copper.

Watershed	**Dry deposition ($\mu g/m^2/day$)**	**Uncertainty in Dry deposition ($\mu g/m^2/day$)**	**Wet deposition ($\mu g/m^2/day$)**	**Uncertainty in Wet deposition ($\mu g/m^2/day$)**
Upper Alameda	1.84	1.24	1.02	0.68
Santa Clara Valley Central	7.45	4.99	0.95	0.64
Castro Valley	17.30	11.59	1.15	0.77
East Bay North	18.71	12.54	1.15	0.77
Upper Colma	24.41	16.35	1.27	0.85
Marin South	9.51	6.37	1.00	0.67
Coyote	4.99	3.35	0.93	0.62
East Bay Central	12.02	8.06	0.98	0.65
East Bay South	7.22	4.84	0.96	0.64
Solano West	2.13	1.43	0.94	0.63
Napa	3.46	2.32	0.92	0.62
North Napa	1.15	0.77	0.91	0.61
North Sonoma	1.23	0.82	0.87	0.58
Marin North	4.23	2.83	0.92	0.61
Contra Costa Central	5.67	3.80	0.93	0.62
Petaluma	1.98	1.33	0.90	0.60
Santa Clara Valley West	10.89	7.30	0.97	0.65
Upper San Lorenzo	3.08	2.06	0.90	0.60
Contra Costa West	5.16	3.45	0.93	0.62
Peninsula Central	11.14	7.47	0.99	0.67
Sonoma	1.57	1.05	0.89	0.59
Upper San Francisquito	1.72	1.15	0.88	0.59
Upper Corte Madera	5.03	3.37	0.93	0.62
City of San Francisco	24.42	16.36	1.23	0.82
San Francisco Bay	0.81	0.54	0.85	0.57

* uncertainty estimates due to uncertainty in the brake pad wear debris source term copper content (±67%), which was determined to be a dominant source of uncertainty in the air deposition modeling results (Pun et al., 2006)

References

Rosselot, , K.S., 2006a. Copper Released from Brake Lining Wear in the San Francisco Bay Area, final report, Brake Pad Partnership, January 2006.

Rosselot, , K.S., 2006b. Copper Released from Non-Brake Sources in the San Francisco Bay Area, final report, Brake Pad Partnership, January 2006.

Pun, B.K.; K. Lohman, C. Seigneur, 2006. Air Deposition Modeling of Copper from Brake Pad Wear Debris in Castro Valley Creek Watershed, final report, July 2006.