Copper Released from Non-Brake Sources in the San Francisco Bay Area

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Executive Summary

Many human activities result in the release of copper to the environment. The Brake Pad Partnership is conducting a study whose purpose is to gain a better understanding of the sources of elevated copper concentrations in the San Francisco Bay. The overall effort includes assessing the magnitude of copper released in the Bay area, followed by modeling of the environmental fate and transport of these estimated releases. The primary objective of this report is to provide estimates of major releases of copper from non-brake sources in the Bay area for use in the Brake Pad Partnership's modeling effort. This report also presents the methodology for preparing the estimates. Copper releases from brake lining wear are the subject of a separate report.

The boundaries of the sub-watersheds to be modeled in this project were developed so that they suit the requirements of the models. As a result, the sub-watersheds discussed in this report may be subdivisions or aggregations of actual physical watersheds. References to sub-watersheds or Bay area sub-watersheds throughout this report indicate sub-watersheds as defined for this project. It is important to remember that the goal of the overall project is to estimate total loads to the San Francisco Bay and not to the individual sub-watersheds.

Estimates of releases of copper to surface waters and storm drains in the Bay area sub-watersheds in 2003 are summarized in Table ES-1. An estimated 8,600 kg of copper were released to surface waters and storm drains in the Bay watershed in 2003. This category of releases includes releases of copper from

- algaecide uses in nonagricultural rights of way, public health, and recreational areas,
- pool, spa, and fountain algaecides that are discharged to storm drains,
- industrial runoff,
- domestic water discharged to storm drains,
- architectural uses of copper, and
- pressure-treated wood used in marine construction in freshwater areas.

Table ES-1 shows that there is no single dominant source for this category of releases.

Table ES-2 shows the estimated releases of copper that occurred directly to Bay waters in 2003. Total estimated releases in this category in 2003 were 24,000 kg. This category of releases includes releases of copper from

- antifouling coatings on boats berthed in the Bay,
- copper-based algaecides used to treat shoreline waters, and
- pressure-treated wood used in marine construction.

Copper-based algaecides used to treat shoreline waters are a relatively insignificant source of copper that is released directly to Bay waters.

Air releases of copper in the Bay area include releases from brake lining materials (the subject of another report) and industrial air releases. Eleven facilities reported air releases of copper in the Toxic Chemical Release Inventory in 2003. These releases, which total 359 kg for the nine counties in the Bay area, are summarized in Table ES-3. The largest single reporter is San Francisco Drydock Inc., which reported nearly 200 kg of copper released to air in 2003.

Table ES-4 summarizes releases of copper to agricultural lands in the Bay area sub-watersheds in 2003. The estimated total for these releases is 20,000 kg/y. This category of releases includes releases of copper from

- agricultural uses of algaecides in water areas,
- non-algaecidal agricultural uses of copper-based pesticides,
- farm fertilizers.

The largest contributors to this category are copper pesticides applied to agricultural land and copper applied in farm fertilizers.

Table ES-5 summarizes releases of copper to permeable developed land in the Bay area sub-watersheds in 2003. The estimated total for these releases is 110,000 kg/y. This category of releases includes releases of copper from

- urban land applications of copper-based pesticides,
- pressure-treated lumber used in residential and commercial construction, and
- non-farm fertilizers.

The largest contributor by far to this category is copper pesticides applied to urban land.

Section 1 of this report is an introduction. Section 2 presents the estimation methodologies and results for releases of copper from various sources. This section begins with a discussion of themes relevant to estimating releases from all categories of sources, followed by subsections on architectural copper, copper in pesticides, copper in fertilizers, copper released from industrial facilities, and copper in domestic water discharged to storm drains. Section 3 provides a brief discussion of sources not included in this inventory, and Section 4 is a list of references.

Table ES-1 Estimates of copper released to storm drains and surface waters in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper in Algaecides Used in Nonagricultural Rights of Way, Recreation Areas, and Public Health, kg/y	Copper Released from Pool, Spa, and Fountain Algaecides, kg/y	Copper Released in Industrial Runoff, kg/y	Copper in Domestic Water Discharged to Storm Drains, kg/y	Architectural Releases of Copper, kg/y	Copper Released to Fresh Water from Pressure-Treated Wood Used in Marine Construction, kg/y	**Total Copper Released to Surface Waters and Storm Drains, kg/y**	Standard Uncertainty, kg/y
Upper Alameda	54	89	79	22	160	29	**433**	93
Santa Clara Valley Central	0	142	49	35	120	20	**365**	114
Castro Valley	0	14	3	4	9	0	**31**	11
East Bay North	95	99	58	24	120	0	**396**	115
Upper Colma	0	36	6	8	17	0	**67**	28
Marin South	0	51	26	13	61	0	**150**	42
Coyote	0	233	155	57	311	11	**767**	198
East Bay Central	26	356	282	88	554	29	**1,334**	312
East Bay South	1	75	83	19	162	11	**352**	72
Solano West	158	71	85	17	166	0	**497**	172
Napa	147	88	63	20	130	0	**449**	138
North Napa	13	12	6	3	13	0	**45**	19
North Sonoma	0	4	1	1	3	0	**8**	3
Marin North	0	33	20	8	46	0	**107**	28
Contra Costa Central	520	192	121	47	278	0	**1,159**	474
Petaluma	0	28	24	7	48	0	**108**	25
Santa Clara Valley West	0	292	202	71	431	0	**996**	251
Upper San Lorenzo	0	14	5	3	12	0	**35**	11
Contra Costa West	185	69	59	17	123	0	**452**	170
Peninsula Central	0	194	160	46	325	0	**725**	170
Sonoma	0	13	6	3	15	0	**38**	11
Upper San Francisquito	0	5	3	1	11	0	**20**	5
Upper Corte Madera	0	10	1	3	5	0	**19**	8
TOTAL	1,199	2,121	1,500	516	3,120	100	**8,556**	759

Table ES-2 Estimated copper released directly to San Francisco Bay waters in 2003.

Marina Name/County Shoreline	Degrees Latitude (North)	Degrees Longitude (West)	Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y	Copper Released to Bay Waters from Antifouling Coatings, kg/y	Copper in Algaecides Released to Shoreline Surface Waters, kg/y	**Total Copper Released to Bay Waters, kg/y**	Standard Uncertainty in Total Copper Released to Bay Waters, kg/y
Aeolian Yacht Club	37.75056	-122.20194	45	80		**125**	29
Alameda Marina	37.77519	-122.24768	259	338		**597**	153
Ballena Isle Marina	37.77000	-122.29000	246	238		**484**	139
Barnhill Marina	37.78981	-122.27543	33	5		**38**	18
Berkeley Marina	37.86473	-122.31311	537	991		**1,527**	346
Berkeley Marine Center	37.86831	-122.31822	29	45		**75**	18
Embarcadero Cove Marina	37.78250	-122.24333	59	105		**163**	37
Emery Cove Yacht Harbor	37.83750	-122.30750	210	389		**599**	136
Emeryville Marina	37.83816	-122.31326	200	205		**404**	114
Encinal Yacht Club	37.78251	-122.26344	0	0		**0**	0
Fifth Avenue Marina	37.78842	-122.26306	52	68		**120**	31
Fortman Marina	37.77660	-122.25960	237	311		**548**	140
Grand Marina	37.77820	-122.25246	195	358		**553**	126
Marina Village Yacht Harbor	37.78532	-122.26953	366	377		**743**	208
Marinemax	37.78696	-122.24970	11	20		**31**	7
Mariner Square	37.79142	-122.27650	24	35		**59**	15
Oakland Yacht Club/Pacific Marina	37.78369	-122.26474	110	110		**220**	62
Park Street Landing Marina	37.77196	-122.23837	12	23		**35**	8
Port of Oakland	37.79370	-122.27504	244	345		**589**	146
Portobello Marina/D Anna Yacht Ctr.	37.79099	-122.26453	32	32		**64**	18
San Leandro Marina	37.69770	-122.19110	222	349		**571**	137
Brickyard Cove Marina	37.90941	-122.37808	122	205		**326**	77
Channel Marina	37.92522	-122.37020	34	46		**80**	20
Keefe Kaplan Maritime Inc. (KKMI)	37.92420	-122.37473	10	18		**28**	6
Marina Bay Yacht Harbor	37.91423	-122.35458	415	585		**1,000**	249
Martinez Marina	38.02599	-122.13741	171	149		**319**	95
McAvoy Harbor	38.03905	-121.96094	146	394		**540**	109
Pittsburg Marina	38.03217	-121.88330	237	445		**682**	153
Point San Pablo Yacht Harbor	37.93000	-122.41000	103	36		**140**	55
Richmond Yacht Club	37.91174	-122.37917	120	182		**302**	73

Marina Name/County Shoreline	Degrees Latitude (North)	Degrees Longitude (West)	Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y	Copper Released to Bay Waters from Antifouling Coatings, kg/y	Copper in Algaecides Released to Shoreline Surface Waters, kg/y	**Total Copper Released to Bay Waters, kg/y**	Standard Uncertainty in Total Copper Released to Bay Waters, kg/y
Richmond Yacht Harbor Ltd.	37.92522	-122.37059	7	7		**14**	4
Rodeo Marina	38.03870	-122.27380	9	0		**9**	5
Sugar Dock Marina	37.92133	-122.37167	5	9		**14**	3
145 Marina	37.96918	-122.51266	5	7		**11**	3
American Oceanics	37.97000	-122.51000	8	1		**9**	4
Angel Island State Park	37.86902	-122.43339	1	0		**1**	1
Arques Shipyard and Marina	37.86750	-122.49717	43	12		**55**	23
Bel Marin Keys Yacht Club	38.0456	-122.3049	31	41		**72**	18
Cass Marina	37.86183	-122.48833	15	23		**37**	9
Clipper Yacht Harbor	37.86883	-122.49783	293	583		**875**	194
Corinthian Yacht Club	37.87187	-122.45602	45	64		**109**	27
Dolphin Marin and Lofts	37.97000	-122.51240	2	5		**7**	2
Galilee Harbor	37.86254	-122.48814	19	26		**45**	11
Hi Tide Boat Sales & Services	37.96733	-122.51233	5	0		**5**	3
Liberty Ship Marina	37.87	-122.5	26	41		**67**	16
Loch Lomond Marina	37.97334	-122.48248	253	436		**689**	160
Lowrie Yacht Harbor	37.96783	-122.50867	54	61		**115**	31
Marin Boat House	37.97000	-122.51183	6	7		**13**	3
Marin Yacht Club	37.97333	-122.49733	58	107		**165**	37
Marina Plaza Harbor	37.86650	-122.49550	50	92		**142**	32
Paradise Cay Yacht Harbor	37.90967	-122.47633	80	62		**141**	44
Pelican Harbor	37.86050	-122.48367	44	82		**126**	28
Richardson Bay Marina	37.87567	-122.50550	107	172		**279**	66
San Francisco Yacht Club	37.87267	-122.46350	91	61		**153**	50
San Rafael Yacht Club	37.96600	-122.51483	9	2		**11**	5
San Rafael Yacht Harbor	37.97000	-122.51267	68	91		**159**	40
Sausalito Marine	37.86081	-122.48483	29	27		**57**	16
Sausalito Yacht Harbor	37.85900	-122.48367	283	285		**568**	161
Schoonmaker Point Marina	37.86383	-122.49183	79	130		**208**	49
Shelter Cove Marina	37.9	-122.52	8	9		**18**	5
The Cove Apartments & Marina	37.88	-122.46	27	12		**39**	14
Trade Winds Marina	37.96697	-122.51208	15	21		**36**	9
Travis Marina	37.83267	-122.48367	40	36		**76**	22

Marina Name/County Shoreline	Degrees Latitude (North)	Degrees Longitude (West)	Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y	Copper Released to Bay Waters from Antifouling Coatings, kg/y	Copper in Algaecides Released to Shoreline Surface Waters, kg/y	**Total Copper Released to Bay Waters, kg/y**	Standard Uncertainty in Total Copper Released to Bay Waters, kg/y
Napa Valley Marina	38.21982	-122.31309	98	145		**243**	59
Napa Yacht Club			0	0		**0**	0
Fisherman's Wharf & Hyde St. Harbor	37.81000	-122.42000	88	41		**129**	47
Mission Creek Harbor	37.79	-122.39	27	16		**43**	15
Pier 39 Marina	37.81083	-122.40967	151	282		**433**	98
San Francisco Marina East Harbor	37.80733	-122.43583	167	185		**351**	96
San Francisco Marina West Harbor	37.80667	-122.44283	168	309		**477**	108
South Beach Harbor	37.78149	-122.38742	341	477		**819**	205
Treasure Island Marina	37.82000	-122.37021	49	69		**118**	29
Bair Island Marina	37.49858	-122.22097	46	86		**133**	30
Brisbane Marina	37.67454	-122.38096	283	526		**809**	183
Coyote Point Marina	37.59088	-122.31861	268	409		**677**	164
Docktown Marina	37.49583	-122.22050	74	82		**156**	43
Marine Collection LLC	37.66282	-122.37928	10	5		**15**	5
Oyster Cove Marina	37.66627	-122.38549	116	100		**216**	65
Oyster Point Marina	37.66257	-122.37495	289	64		**352**	154
Pete's Harbor	37.50167	-122.22500	128	112		**240**	72
Port of Redwood City Yacht Harbor	37.50317	-122.21317	90	164		**254**	58
South Bay Yacht Club	37.42683	-121.97917	7	2		**9**	4
Benicia Marina	38.05810	-122.17438	156	245		**402**	96
Glen Cove Marina	38.06767	-122.21357	102	157		**259**	62
Suisun City Marina	38.23449	-122.03800	76	133		**208**	48
Vallejo Marina	38.10885	-122.26722	390	444		**834**	225
Vallejo Yacht Club	38.10512	-122.26633	65	122		**188**	42
Gilardi's Lakeville Marina	38.19751	-122.54754	7	5		**12**	4
Petaluma Marina	38.23138	-122.61485	96	59		**155**	52
Port of Sonoma Marina	38.11637	-122.50353	138	45		**183**	74
Santa Clara County	37.45	-122.04			5	**5**	1
San Mateo County	37.57	-122.27			32	**32**	3
Contra Costa County	38.06	-122.03			1	**1**	0
Marin County	37.97	-122.45			847	**847**	77
Napa County	38.19	-122.29			427	**427**	39
TOTAL			9,721	13,281	1,312	**24,314**	902

Table ES-3 Air emissions of copper reported in the Toxic Chemical Release Inventory in the 9-county San Francisco region in 2003 (US EPA, 2005b).

Facility	City	Facility-Reported Latitude	Facility-Reported Longitude	Preferred Latitude	Preferred Longitude	**Reported Release, kg/y**	Standard Uncertainty, kg/y
Isola USA Corp	Fremont	372024	1242236	37.469698	121.918306	**4**	1
Titan PCB West Inc	Fremont	373028	1215650	37.508333	121.936111	**114**	38
New United Motor Manufacturing Inc	Fremont	372924	1215630	37.484722	121.941667	**5**	2
Pressure Cast Products Corp	Oakland	374620	1221259	37.772222	122.216389	**2**	1
Communications & Power Industries Inc Eimac Div	San Carlos	373052	1201604	37.514444	122.267778	**20**	7
San Francisco Drydock Inc	San Francisco	374540	1222245	37.761111	122.379167	**195**	64
South Bay Circuits Inc	San Jose	371653	1215038	37.281389	121.843889	**5**	2
Viko Technology Inc Adaptive Circuits Div	San Jose	372146	1215314	37.366667	121.851667	**2**	1
ECS Refining	Santa Clara	372140	1225640	37.3615	121.9382	**9**	3
Pycon Inc	Santa Clara	373330	1215929	37.383822	121.955817	**2**	1
Sprig Circuits Inc	Vacaville	382100	1220000	38.417222	121.970833	**1**	0.3
Total						**359**	

Table ES-4 Estimates of copper released to agricultural land in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper in Algaecides Applied to Agricultural Water Areas, kg/y	Copper in Pesticides Applied to Agricultural Land, kg/y	Copper Applied in Farm Fertilizers, kg/y	**Total Copper Released to Agricultural Land, kg/y**	Standard Uncertainty, kg/y
Upper Alameda	0	107	621	**728**	455
Santa Clara Valley Central	0	20	65	**85**	48
Castro Valley	0	0	0	**0**	0
East Bay North	0	0	0	**0**	0
Upper Colma	0	0	0	**1**	0
Marin South	0	0	0	**0**	0
Coyote	0	291	944	**1,235**	704
East Bay Central	0	8	61	**69**	44
East Bay South	0	12	83	**95**	61
Solano West	0	897	1,423	**2,321**	1,155
Napa	0	1,895	1,093	**2,988**	1,351
North Napa	0	4,636	2,676	**7,312**	3,306
North Sonoma	6	894	342	**1,242**	573
Marin North	0	94	3	**97**	54
Contra Costa Central	0	30	66	**96**	51
Petaluma	4	613	230	**848**	391
Santa Clara Valley West	0	17	55	**72**	41
Upper San Lorenzo	0	0	0	**0**	0
Contra Costa West	0	11	24	**35**	19
Peninsula Central	0	0	0	**0**	0
Sonoma	16	2,239	856	**3,111**	1,434
Upper San Francisquito	0	15	31	**45**	24
Upper Corte Madera	0	0	0	**0**	0
TOTAL	27	11,780	8,573	**20,380**	4,164

Table ES-5 Estimates of copper released to permeable developed land in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper in Pesticides Applied to Urban Land, kg/y	Copper Released from Treated Wood Used in Residential and Commercial Construction, kg/y	Copper Applied in Non-Farm Fertilizers, kg/y	**Total Copper Released to Permeable Developed Land, kg/y**	Standard Uncertainty, kg/y
Upper Alameda	4,346	145	23	**4,514**	1,852
Santa Clara Valley Central	6,796	229	36	**7,062**	2,931
Castro Valley	682	23	4	**708**	295
East Bay North	4,872	161	26	**5,059**	2,057
Upper Colma	1,680	56	9	**1,745**	711
Marin South	2,496	83	13	**2,591**	1,056
Coyote	11,165	377	60	**11,602**	4,816
East Bay Central	17,066	578	92	**17,736**	7,382
East Bay South	3,609	122	19	**3,751**	1,563
Solano West	3,525	114	18	**3,657**	1,459
Napa	4,674	134	21	**4,830**	1,728
North Napa	647	17	3	**666**	217
North Sonoma	198	7	1	**206**	84
Marin North	1,607	53	8	**1,668**	680
Contra Costa Central	9,865	311	49	**10,225**	3,984
Petaluma	1,385	46	7	**1,439**	586
Santa Clara Valley West	13,979	471	75	**14,525**	6,022
Upper San Lorenzo	676	23	4	**702**	293
Contra Costa West	3,531	111	18	**3,660**	1,427
Peninsula Central	9,114	302	48	**9,464**	3,859
Sonoma	655	22	3	**680**	277
Upper San Francisquito	222	7	1	**231**	94
Upper Corte Madera	507	17	3	**526**	214
TOTAL	103,296	3,408	541	**107,245**	13,166

1 Introduction

Many human activities result in the release of copper to the environment. The Brake Pad Partnership is conducting a study whose purpose is to gain a better understanding of the sources of elevated copper concentrations in the San Francisco Bay. The overall effort includes assessing the magnitude of copper released in the Bay area, followed by modeling of the environmental fate and transport of these estimated releases. The primary objective of this report is to provide estimates of major releases of copper from non-brake sources in the Bay area for use in the Brake Pad Partnership's modeling effort. This report also presents the methodology for preparing the estimates. Copper releases from brake lining wear are the subject of a separate report.

This report contains separate release estimates for the following categories of releases of copper:

- architectural copper
- copper in pesticides
- copper in fertilizer
- copper releases from industrial facilities (including releases in runoff)
- copper in domestic water discharged to storm drains

With a few exceptions, these categories of releases are taken from “Copper Sources in Urban Runoff and Shoreline Activities” (hereafter referred to as the urban runoff report) prepared by TDC Environmental for the Clean Estuary Partnership in November of 2004. Sources estimated in the urban runoff report to contribute less than one thousand pounds of copper per year in urban runoff (those from fuel combustion, wood burning, and vehicle fluid leaks) were not inventoried for this report. Also, copper released from soil erosion will be calculated by the runoff model and was not estimated. In addition to sources found in the urban runoff report, an estimate of copper released from fertilizers was developed for this inventory. A more detailed discussion of sources not included in this inventory effort is given in Section 3 of this report.

In many cases, approaches for estimating releases that are described in the urban runoff report were adopted in this study. A report titled "Work Plans for Estimating Non-Brake Releases of Copper in the San Francisco Bay Area Watershed" contains supplementary information about the methodology pursued in the creation of the estimates of releases presented in this report. Interested readers can access this document at
www.suscon.org/brakepad/pdfs/ FINALWorkPlanEstimatingCopperLoadingNonBrakeSources04-27-05.pdf

2 Estimates for Individual Categories of Releases

Some of the strategies for developing release estimates apply to all or most of the release categories. These commonalities are presented in this section.

Multimedia Estimates

Multimedia emission estimates of copper are given in this report, so that releases to pervious surfaces such as soil, fresh water (both storm drains and surface waters), marine water, and air were identified separately. Releases were estimated for the 23 sub-watersheds that lie within the San Francisco Bay watershed.

Study Area

The boundaries of the sub-watersheds to be modeled in this project were developed so that they suit the requirements of the models. As a result, the sub-watersheds discussed in this report may be subdivisions or aggregations of actual physical watersheds. References to sub-watersheds or Bay area sub-watersheds throughout this report indicate sub-watersheds as defined for this project. It is important to remember that the goal of the overall project is to estimate total loads to the San Francisco Bay and not to the individual sub-watersheds.

Figure 2-1 shows the sub-watersheds within the San Francisco Bay watershed. San Francisco County drains almost exclusively to the ocean as opposed to the Bay and is not generally included in the inventories presented in this report. An exception is made for air emissions of copper in San Francisco County, as they have a high potential for transport to the Bay or to portions of the Bay area that drain to the Bay. Also, a very small portion of Santa Cruz County falls within the watershed. This area is neglected for purposes of creating the copper release inventories. Thus, the 9-county region that is referred to in this report when discussing air emissions includes the following counties: San Francisco, San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Napa, Sonoma, and Marin Counties. The 8-county region that is referred to when discussing releases includes all of those counties except for San Francisco County.

General Methodology

Information that can be used to estimate releases is almost without exception available for areas bordered by political boundaries as opposed to physical ones such as watersheds. For this project, data for estimating emissions were gathered with the highest geographic resolution possible. For some categories of releases, the data are county-based; for others, they are state- or nationally-based. Emissions for the portion of the county (or state or country) within the sub-watersheds were then apportioned based on population, land use, or some other appropriate factor.

Population counts and other weighting factors such as land use areas for each sub-watershed area by county, for the counties, and for the state were provided by URS Corporation, a member of the Bay modeling team. Tables 2-1 through 2-6 include some of the data that were needed to estimate releases by sub-watershed. Population data for these tables were taken from the 2000 census and land use/land cover data are from the 1992 NLCD data set. The agricultural land use area in these tables includes crop categories only (orchards/vineyards/other, row crops, and small grains). The residential land use area includes low intensity residential, high intensity residential, and urban/recreational grasses. Industrial/commercial/transportation is a single aggregated category of land use. Other land use categories do not appear in the tables because they are not helpful in making release estimates of copper.

A number of assumptions were made in order to conduct the inventories of copper releases. These assumptions are stated in the report. In cases where there was more than one source of data for a given value, the value judged to be superior in terms of factors including peer-review of the reference, geography, sample size, and timeliness was used. If several values were available in different references that were determined to be of equal quality, a value that is representative of all of them was chosen.

Standard uncertainties were estimated for each of the values obtained, following the strategies outlined in NIST, 2005. In a few cases, a standard deviation of a sample was calculated and used as the standard uncertainty. However, in most cases, it was possible to determine only a potential range of possible values for a given variable, where the true value was equally likely to be anywhere in the range (a uniform distribution). In these cases, the point value was calculated to be the midpoint of the range and the standard uncertainty is equal to half of the range divided by the square root of three. (Half of the range divided by the square root of three corresponds to the square root of the variance, or the second central moment, of a uniform distribution, and the square root of the variance is, by definition, the standard deviation in statistical terms.)

Developing an estimated standard uncertainty for each variable was onerous, but it was necessary so that the uncertainties in each intermediate value could be combined in order to develop a sense for the standard uncertainty in the final calculated results. One way to estimate the standard uncertainty in a value that is calculated using the function $f(x_1, x_2,\ldots,x_n)$ is to apply the Kline-McClintock equation to that function. The Kline-McClintock equation is the first term in the Taylor series approximation for the propagation of uncertainty and can be used when variables are not co-related. It is

$$u_R = \sqrt{\left(u_1 \frac{\partial f}{\partial x_1}\right)^2 + \left(u_2 \frac{\partial f}{\partial x_2}\right)^2 + \ldots + \left(u_n \frac{\partial f}{\partial x_n}\right)^2}$$

where u is uncertainty, R is the resulting value, and n is the number of variables in the function. For example, if

$$f(x, y, z) = R = axyz$$

where a is a constant, then

$$\frac{\partial R}{\partial x} = ayz$$

$$\frac{\partial R}{\partial y} = axz$$

$$\frac{\partial R}{\partial z} = axy$$

and

$$u_R = \sqrt{\left(ayzu_x\right)^2 + \left(axzu_y\right)^2 + \left(axyu_z\right)^2}$$

If

$$f(x, y, z) = R = ax + by + cz$$

where *a*, *b*, and *c* are constants, then

$$\frac{\partial R}{\partial x} = a$$

$$\frac{\partial R}{\partial y} = b$$

$$\frac{\partial R}{\partial z} = c$$

and

$$u_R = \sqrt{\left(au_x\right)^2 + \left(bu_y\right)^2 + \left(cu_z\right)^2}$$

The Kline-McClintock equation was used to estimate the uncertainty in calculated results for this project.

Standard uncertainties are useful not only for calculating a standard uncertainty in a calculated value but because they can be used to provide a range of values that apply to a desired confidence interval. For a 95% confidence interval, the range of values provided for the final result is 95% likely to contain the true (actual) value. This 95% confidence interval would be described as a point value plus or minus two times the standard uncertainty for that value. A 67% confidence interval is one that includes the point value plus or minus the standard uncertainty. (This assumes that the probability distribution characterized by a function's result and its standard uncertainty is approximately normal, and the uncertainty result is a reliable estimate of the standard deviation of the result.)

Figure 2-1 Sub-watersheds in the San Francisco Bay watershed (Cooke, 2005c).

Table 2-1 County, state, and national data used to apportion releases to the San Francisco Bay watershed.

Area	2000 Population (% in watershed)		Area, m^2 (% in watershed)		Area by Land Use Category, m^2: Agricultural (% in watershed)[1]		Area by Land Use Category, m^2: Residential (% in watershed)[2]		Area by Land Use Category, m^2: Commercial/ Industrial/ Transportation (% in watershed)[3]	
United States	290,809,777	(2%)								
California*	33,871,648	(15%)	409,874,161,860	(2%)	31,725,542,200	(1%)	9,173,708,900	(18%)	3,017,909,600	(12%)
Alameda County*	1,443,741	(100%)	1,953,699,152	(90%)	32,377,500	(81%)	370,398,100	(100%)	111,510,000	(100%)
Contra Costa County*	948,816	(83%)	1,964,595,501	(59%)	146,006,100	(4%)	390,201,000	(87%)	64,098,900	(83%)
Marin County*	247,289	(95%)	1,412,412,634	(30%)	126,900	(93%)	111,232,200	(93%)	12,347,100	(95%)
Napa County*	124,279	(98%)	2,041,071,836	(54%)	151,664,800	(96%)	36,727,200	(95%)	7,490,700	(98%)
San Francisco County*	776,733	(0%)	127,205,702	(0%)	0	(0%)	84,504,600	(0%)	20,382,300	(0%)
San Mateo County*	707,161	(84%)	1,194,501,487	(40%)	10,487,700	(11%)	234,374,500	(86%)	43,065,000	(97%)
Santa Clara County*	1,682,585	(95%)	3,377,679,385	(71%)	150,470,900	(27%)	528,315,700	(95%)	105,190,000	(92%)
Solano County*	394,542	(71%)	2,300,256,594	(38%)	611,600,200	(8%)	128,275,600	(74%)	38,932,200	(76%)
Sonoma County*	458,614	(24%)	4,118,178,208	(18%)	234,120,500	(23%)	122,115,900	(28%)	24,449,400	(28%)
8-County area	6,007,027	(86%)	18,362,394,797	(49%)	1,336,854,600	(24%)	1,921,640,200	(87%)	407,083,300	(88%)
9-County area	6,783,760	(76%)	18,489,600,499	(48%)	1,336,854,600	(24%)	2,006,144,800	(84%)	427,465,600	(84%)
San Francisco Bay watershed	5,135,779	(100%)	8,913,383,406	(100%)	324,270,900	(100%)	1,672,962,300	(100%)	354,911,400	(100%)

*From Cooke, 2005b.

Table 2-2 Population in sub-watersheds of the San Francisco Bay watershed (Cooke, 2005a and 2005c).

Sub-watershed	POPULATION WITHIN COUNTY, 2000									
	Sonoma	Solano	Santa Clara	San Mateo	San Francisco	Napa	Marin	Contra Costa	Alameda	TOTAL
Upper Alameda	0	0	223	0	0	0	0	48,103	171,322	219,648
Santa Clara Valley Central	0	0	347,650	0	0	0	0	0	0	347,650
Castro Valley	0	0	0	0	0	0	0	0	35,023	35,023
East Bay North	0	0	0	0	0	0	0	85,046	158,852	243,897
Upper Colma	0	0	0	84,318	0	0	0	0	0	84,318
Marin South	0	0	0	0	0	0	125,179	0	0	125,179
Coyote	0	0	571,147	0	0	0	0	0	0	571,147
East Bay Central	0	0	0	0	0	0	0	18,285	857,207	875,492
East Bay South	0	0	1,749	0	0	0	0	0	183,665	185,414
Solano West	0	172,236	0	0	0	520	0	0	0	172,755
Napa	2	107,613	0	0	0	95,852	0	0	0	203,467
North Napa	8	0	0	0	0	24,997	0	0	0	25,005
North Sonoma	9,927	0	0	0	0	2	0	0	0	9,929
Marin North	0	0	0	0	0	0	80,582	0	0	80,582
Contra Costa Central	0	0	0	0	0	0	0	471,163	2	471,165
Petaluma	66,505	0	0	0	0	0	2,946	0	0	69,451
Santa Clara Valley West	0	0	669,727	44,512	0	0	0	0	0	714,239
Upper San Lorenzo	0	0	0	0	0	0	0	2	34,716	34,718
Contra Costa West	0	0	0	0	0	0	0	167,549	1,179	168,728
Peninsula Central	0	0	0	457,375	0	0	0	0	0	457,375
Sonoma	32,834	0	0	0	0	1	0	0	0	32,835
Upper San Francisquito	0	0	147	10,998	0	0	0	0	0	11,144
Upper Corte Madera	0	0	0	0	0	0	25,414	0	0	25,414
City of San Francisco					776,733					776,733
SAN FRANCISCO BAY AREA WATERSHED TOTAL	109,275	279,849	1,590,642	597,203	0	121,372	234,121	790,147	1,441,965	5,164,575
9-COUNTY TOTAL	458,614	394,542	1,682,585	707,161	776,733	124,279	247,289	948,816	1,443,741	6,783,760

Table 2-3 Land area of sub-watersheds in the San Francisco Bay watershed (Cooke, 2005a and 2005c).

Sub-watershed	AREA WITHIN COUNTY (m^2)								
	Sonoma	Solano	Santa Clara	San Mateo	Napa	Marin	Contra Costa	Alameda	TOTAL
Upper Alameda	0	0	569,667,660	0	0	0	156,839,820	923,910,443	1,650,417,923
Santa Clara Valley Central	0	0	368,720,232	0	0	0	0	0	369,367,983
Castro Valley	0	0	0	0	0	0	0	14,236,851	14,236,851
East Bay North	0	0	0	0	0	0	38,683,529	52,795,508	91,479,037
Upper Colma	0	0	0	28,260,219	0	0	0	0	28,260,219
Marin South	0	0	0	0	0	113,110,758	0	0	113,136,276
Coyote	0	0	966,384,393	0	0	0	0	0	966,384,393
East Bay Central	0	0	0	0	0	0	53,391,891	466,575,698	520,087,677
East Bay South	0	0	2,216,535	0	0	0	0	191,618,628	193,835,164
Solano West	0	773,412,422	0	0	123,046,394	0	0	0	896,458,817
Napa	973,992	96,218,658	0	0	415,235,611	0	0	0	512,428,261
North Napa	855,776	0	0	0	565,375,144	0	0	0	566,230,920
North Sonoma	151,776,894	0	0	0	165,608	0	0	0	151,942,501
Marin North	0	0	0	0	0	185,472,023	0	0	185,472,023
Contra Costa Central	0	0	0	0	0	0	653,816,114	270,654	654,086,768
Petaluma	298,210,466	0	0	0	0	84,043,122	0	0	382,253,589
Santa Clara Valley West	0	0	484,864,703	16,416,015	0	0	0	0	501,538,211
Upper San Lorenzo	0	0	0	0	0	0	826,636	102,221,067	103,047,703
Contra Costa West	0	0	0	0	0	0	261,468,003	781,737	262,249,740
Peninsula Central	0	0	0	348,556,751	0	0	0	0	348,556,751
Sonoma	278,867,641	35,347	0	0	197,270	0	0	0	279,100,257
Upper San Francisquito	0	0	13,138,177	84,666,471	0	0	0	0	97,804,648
Upper Corte Madera	0	0	0	0	0	47,394,139	0	0	47,394,139
SAN FRANCISCO BAY AREA WATERSHED TOTAL	730,684,768	869,666,427	2,404,991,700	477,899,456	1,104,020,027	430,020,043	1,165,025,994	1,752,410,586	8,935,769,853

Table 2-4 Agricultural land use in the sub-watersheds of the San Francisco watershed (Cooke, 2005a and 2005c).

Sub-watershed	AGRICULTURAL AREA WITHIN COUNTY (m^2)								
	Sonoma	Solano	Santa Clara	San Mateo	Napa	Marin	Contra Costa	Alameda	TOTAL
Upper Alameda	0	0	279,000	0	0	0	2,452,500	20,766,600	23,498,100
Santa Clara Valley Central	0	0	2,449,800	0	0	0	0	0	2,449,800
Castro Valley	0	0	0	0	0	0	0	0	0
East Bay North	0	0	0	0	0	0	0	0	0
Upper Colma	0	0	0	18,900	0	0	0	0	18,900
Marin South	0	0	0	0	0	0	0	0	0
Coyote	0	0	35,693,100	0	0	0	0	0	35,693,100
East Bay Central	0	0	0	0	0	0	13,500	2,277,000	2,290,500
East Bay South	0	0	43,200	0	0	0	0	3,111,300	3,154,500
Solano West	0	50,537,700	0	0	3,296,700	0	0	0	53,834,400
Napa	68,400	2,700	0	0	41,262,300	0	0	0	41,333,400
North Napa	20,700	0	0	0	101,182,500	0	0	0	101,203,200
North Sonoma	12,925,800	0	0	0	3,600	0	0	0	12,929,400
Marin North	0	0	0	0	0	105,300	0	0	105,300
Contra Costa Central	0	0	0	0	0	0	2,490,300	0	2,490,300
Petaluma	8,700,300	0	0	0	0	12,600	0	0	8,712,900
Santa Clara Valley West	0	0	2,068,200	900	0	0	0	0	2,069,100
Upper San Lorenzo	0	0	0	0	0	0	0	0	0
Contra Costa West	0	0	0	0	0	0	917,100	0	917,100
Peninsula Central	0	0	0	10,800	0	0	0	0	10,800
Sonoma	32,362,200	0	0	0	27,900	0	0	0	32,390,100
Upper San Francisquito	0	0	12,600	1,157,400	0	0	0	0	1,170,000
Upper Corte Madera	0	0	0	0	0	0	0	0	0
SAN FRANCISCO BAY AREA WATERSHED TOTAL	54,077,400	50,540,400	40,545,900	1,188,000	145,773,000	117,900	5,873,400	26,154,900	324,270,900
9-COUNTY TOTAL	234,120,500	611,600,200	150,470,900	10,487,700	151,664,800	126,900	146,006,100	32,377,500	1,336,854,600

Table 2-5 Residential land use in the sub-watersheds in the San Francisco Bay watershed (Cooke, 2005a and 2005c).

Sub-watershed	RESIDENTIAL/URBAN AREA WITHIN COUNTY (m^2)								
	Sonoma	Solano	Santa Clara	San Mateo	Napa	Marin	Contra Costa	Alameda	TOTAL
Upper Alameda	0	0	218,700	0	0	0	15,110,100	61,531,200	76,860,000
Santa Clara Valley Central	0	0	113,288,400	0	0	0	0	0	113,350,500
Castro Valley	0	0	0	0	0	0	0	10,795,500	10,795,500
East Bay North	0	0	0	0	0	0	26,065,800	33,708,600	59,774,400
Upper Colma	0	0	0	19,317,600	0	0	0	0	19,317,600
Marin South	0	0	0	0	0	52,890,300	0	0	52,891,200
Coyote	0	0	134,801,100	0	0	0	0	0	134,801,100
East Bay Central	0	0	0	0	0	0	10,377,900	197,658,900	208,096,200
East Bay South	0	0	444,600	0	0	0	0	56,329,200	56,773,800
Solano West	0	58,060,800	0	0	213,300	0	0	0	58,274,100
Napa	18,900	36,740,700	0	0	27,042,300	0	0	0	63,801,900
North Napa	0	0	0	0	7,751,700	0	0	0	7,751,700
North Sonoma	4,214,700	0	0	0	0	0	0	0	4,214,700
Marin North	0	0	0	0	0	36,290,700	0	0	36,290,700
Contra Costa Central	0	0	0	0	0	0	220,281,300	0	220,281,300
Petaluma	16,563,600	0	0	0	0	2,474,100	0	0	19,037,700
Santa Clara Valley West	0	0	251,110,800	10,549,800	0	0	0	0	261,662,400
Upper San Lorenzo	0	0	0	0	0	0	0	10,795,500	10,795,500
Contra Costa West	0	0	0	0	0	0	66,592,800	471,600	67,064,400
Peninsula Central	0	0	0	154,647,900	0	0	0	0	154,647,900
Sonoma	13,039,200	0	0	0	0	0	0	0	13,039,200
Upper San Francisquito	0	0	1,071,900	17,729,100	0	0	0	0	18,801,000
Upper Corte Madera	0	0	0	0	0	12,254,400	0	0	12,254,400
SAN FRANCISCO BAY AREA WATERSHED TOTAL	33,836,400	94,801,500	500,935,500	202,244,400	35,007,300	103,909,500	338,427,900	371,290,500	1,680,577,200

Table 2-6 Industrial/commercial/transportation land use in the sub-watersheds of the San Francisco Bay watershed (Cooke, 2005a and 2005c).

Sub-watershed	INDUSTRIAL/COMMERCIAL/TRANSPORTATION AREA WITHIN COUNTY (m^2)								
	Sonoma	Solano	Santa Clara	San Mateo	Napa	Marin	Contra Costa	Alameda	TOTAL
Upper Alameda	0	0	5,400	0	0	0	2,484,000	16,370,100	18,859,500
Santa Clara Valley Central	0	0	11,700,000	0	0	0	0	0	11,700,900
Castro Valley	0	0	0	0	0	0	0	824,400	824,400
East Bay North	0	0	0	0	0	0	7,659,900	6,318,000	13,977,900
Upper Colma	0	0	0	1,507,500	0	0	0	0	1,507,500
Marin South	0	0	0	0	0	6,138,900	0	0	6,142,500
Coyote	0	0	37,251,900	0	0	0	0	0	37,251,900
East Bay Central	0	0	0	0	0	0	145,800	67,490,100	67,643,100
East Bay South	0	0	189,900	0	0	0	0	19,807,200	19,997,100
Solano West	0	20,430,000	0	0	0	0	0	0	20,430,000
Napa	16,200	9,293,400	0	0	5,892,300	0	0	0	15,201,900
North Napa	0	0	0	0	1,423,800	0	0	0	1,423,800
North Sonoma	185,400	0	0	0	0	0	0	0	185,400
Marin North	0	0	0	0	0	4,762,800	0	0	4,762,800
Contra Costa Central	0	0	0	0	0	0	29,088,000	0	29,088,000
Petaluma	5,178,600	0	0	0	0	632,700	0	0	5,811,300
Santa Clara Valley West	0	0	47,007,900	1,398,600	0	0	0	0	48,406,500
Upper San Lorenzo	0	0	0	0	0	0	0	1,208,700	1,208,700
Contra Costa West	0	0	0	0	0	0	14,125,500	900	14,126,400
Peninsula Central	0	0	0	38,342,700	0	0	0	0	38,342,700
Sonoma	1,541,700	0	0	0	0	0	0	0	1,541,700
Upper San Francisquito	0	0	177,300	582,300	0	0	0	0	759,600
Upper Corte Madera	0	0	0	0	0	216,000	0	0	216,000
SAN FRANCISCO BAY AREA WATERSHED TOTAL	6,921,900	29,723,400	96,332,400	41,831,100	7,316,100	11,750,400	53,503,200	112,019,400	359,409,600

2.1 Architectural Copper

Releases from this category were estimated using the approach taken in the urban runoff report. Using this methodology, the surface area of copper roofs, composition shingles containing copper biocide, and copper gutters was calculated and then multiplied by factors that identify the amount of copper released per unit of surface area for each type of material. Use of copper as a biocide in composition shingles is a pesticidal application of copper, but it is expected that most of the copper biocide used in manufacturing copper shingles does not appear in California's pesticide usage and sales reports. Because of this and because the release estimation methodologies for copper roofing and shingles containing copper are similar, these pesticidal releases are inventoried in this section rather than in the pesticide section of the report.

Roofing is estimated to occupy 30% of residential land use and 50% of other developed land (Barron, 2001). Copper roofs are used in 0.05% of residences and 0.3% of industrial buildings (Barron, 2001). It is estimated that 0.03% of residential roofs are covered in composition shingles treated with copper biocide (Barron, 2001). Additionally, copper gutters are used on 0.06% of residences and 0.3% of industrial buildings (Barron, 2001). The estimated surface area of gutters is 3.25% of roof area (Barron, 2001).

The loss of copper in runoff from architectural fixtures decreases with increasing rainfall pH until the pH reaches a level of 4.8, where further increases in pH have no effect on the loss rate (CDA, 2003). Another strong influence on copper runoff rates from architectural features is the atmospheric concentration of chloride ions. The copper in runoff is higher in marine environments where chloride concentrations are high both because the corrosion rate is faster and because the dominant corrosion products are more soluble in water than the corrosion products found in inland areas (He et al, 2001). Similarly, the copper in runoff from architectural features is higher in urban areas than in rural areas because pollutants in urban areas increase the rate of corrosion (Wallinder and Leygraf, 2001). Finally, copper in runoff from architectural features increases as annual precipitation increases.

The Bay area has elevated atmospheric chloride concentrations (National Atmospheric Deposition Program, 2005). Also, most of the copper roofs in the Bay area are found in urbanized areas. However, the pH of rainfall in the Bay area is generally higher than 6 and the precipitation rate is low (35 cm/yr).

Values used to estimate architectural releases of copper are summarized in Table 2.1-1. The emission factor selected for estimating releases of copper from copper roofs is 1.8 g/m^2/y. This factor is based on the concentration of copper in runoff from a roof exposed to marine conditions (He et al, 2001) and the rainfall rate in the Bay area. It is intended to reflect the elevated levels of chloride ions that are found in the San Francisco Bay area. The potential range of release rates was assumed to be 1.0 to 2.6 g/m^2/y so that the standard uncertainty in this value is 0.5 g/m^2/y.

The emission factor selected for estimating releases of copper from composition shingles treated with copper biocide is 0.2 g/m^2/yr. This factor is based on field tests of panels covered with algae-resistant composition shingles over seven rainfall events in Palo Alto (Barron, 2001). The standard uncertainty in this value is the standard deviation of the average values for the seven rainfall events and is 0.1 $g/m^2/y$.

The emission factor selected for estimating releases of copper from copper gutters is based on a study of gutters of varying ages in the Palo Alto area in the late 1990s (Uribe and Associates, 1999). The point value for the emission factor from this study is 4 $g/m^2/y$. It was assumed that the actual value for the release rates has a 100% likelihood of falling between 2 and 6 $g/m^2/y$, so that the standard uncertainty is 1 $g/m^2/y$.

The roof area fractions discussed earlier in this section are specific to land use data developed by the Association of Bay Area Governments (ABAG, 2003). The ABAG land use data set closely matches the data provided in Tables 2-1, 2-5, and 2-6 for residential use but not for commercial uses. In fact, the ABAG values for commercial land use area are two to three times larger than the values given in Tables 2-1 and 2-6. In order to apply the roof fractions, the commercial/industrial/transportation land use area has to be adjusted to be more in line with ABAG values.

According to ABAG, the area of land in the 9-county region devoted to commercial/industrial/institutional uses is 267,630 acres (ABAG, 2003), which is equivalent to 1,083 km^2. This compares to land use area of 427 km^2 for the 9-county area from Table 2-1. This means that a correction factor of 2.5 must be applied to the commercial/industrial/transportation land use values of Tables 2-1 and 2-6 before calculating roof area.

The surface area of each sub-watershed that is devoted to residential and industrial/commercial/transportation structures was used to apportion the copper releases. The standard uncertainty in the surface area of each sub-watershed that is devoted to the two types of land use was assumed to be 3% of the land use area.

The estimated standard uncertainty in the fraction of surface area occupied by each type of architectural feature is taken as half of the point value divided by the square root of three.

Most residential copper roofs in the Bay Area are installed on multifamily structures, and higher density residential developments are more likely to be directly connected to storm drains or surrounded by impervious surfaces than single-family homes (Moran, 2005a). Therefore, these releases were assumed to occur to surface waters and storm drains for the purposes of modeling.

Estimates of copper released in runoff from architectural features are given in Table 2.1-2. The total estimated release of copper from architectural features in the greater Bay watershed is 3,100 kg/y.

Table 2.1-1 Values used to estimate releases of copper from architectural copper.

Architectural Feature	Fraction That Is Roof	Standard Uncertainty in Fraction That Is Roof	Fraction of Roof That Is Gutter	Standard Uncertainty in Fraction of Roof That Is Gutter	Fraction That Is Copper	Standard Uncertainty in Fraction That Is Copper	Emission Factor, $g/m^2/y$	Standard Uncertainty in Emission Factor, $g/m^2/y$
Residential copper roofs	0.3	0.03			0.0005	0.0001	1.8	0.5
Residential roofs with copper-impregnated composition shingles	0.3	0.03			0.0003	0.00009	0.2	0.1
Residential copper gutters	0.3	0.03	0.0325	0.009	0.0006	0.0002	4	1
Industrial/commercial/transportation copper roofs	0.5	0.03			0.003	0.0009	1.8	0.5
Industrial/commercial/transportation copper gutters	0.5	0.03	0.0325	0.009	0.003	0.0009	4	1

Table 2.1-2 Estimates of architectural releases of copper in the San Francisco Bay area by sub-watershed.

Watershed	Architectural Releases of Copper, kg/y	Standard Uncertainty in Architectural Releases of Copper, kg/y
Upper Alameda	160	25
Santa Clara Valley Central	120	21
Castro Valley	9	2
East Bay North	120	19
Upper Colma	17	3
Marin South	61	10
Coyote	311	48
East Bay Central	554	85
East Bay South	162	25
Solano West	166	25
Napa	130	20
North Napa	13	2
North Sonoma	3	1
Marin North	46	8
Contra Costa Central	278	47
Petaluma	48	7
Santa Clara Valley West	431	69
Upper San Lorenzo	12	2
Contra Costa West	123	19
Peninsula Central	325	51
Sonoma	15	3
Upper San Francisquito	11	3
Upper Corte Madera	5	1
TOTAL	3,120	

2.2 Copper in Pesticides

Pesticide use reports are available statewide (CA DPR, 2005a) and by county (CA DPR, not dated, various counties) and pesticide sales data are available statewide (CA DPR, 2005b). All but one of the 19 currently registered copper-based pesticide products appear in the California use and/or sales reports. Data in these reports are generally given in terms of active ingredient. Sales reporting requirements for pesticides include sales for use in the manufacture of products that contain pesticides. Use reporting sometimes includes use in the manufacture of products that contain pesticides. However, once a pesticide is formulated into a consumer product such as marine antifouling paint, pressure-treated wood, or composition shingles with biocide, its use and sales are no longer required to be reported.

Note that release estimates for copper incorporated as a biocide in composition shingles appear in the architectural section of this report. This is because it is expected that most of the use of copper in composition shingles containing copper does not appear in California pesticide reporting. Also, the means for estimating this source of copper releases is similar to the means for estimating other sources of architectural copper releases.

Pesticide use reporting applies to agricultural use and to use by licensed professional pesticide applicators. The difference between adjusted sales and adjusted reported use can be assumed to include everything else, including the amount of active ingredient applied by commercial, institutional, industrial, and household consumers.

In the pesticide sales reports, sales are disclosed only for pesticides that have three or more registrants. Seven copper-based pesticides in California have reported use with no reported sales. They are copper ammonium carbonate, copper carbonate (basic), copper ethylenediamine complex, cupric oxide, copper oxychloride sulfate, copper salts of fatty and rosin acids, and cuprous thiocyanate. Another copper-based pesticide, copper 8-quinolinolate, had no reported sales or use in 2003. The sales for these pesticides can be estimated either based on their sales history or based on their labeling information, coupled with information on usage.

Unfortunately, sales of some retail products sold at “big box” stores are inadequately disclosed (CA DPR, 2004). These stores dominate sales of pesticides to consumers. Estimated consumer sales were adjusted upwards by a factor of 20% in order to correct for unreported sales (Brank, 2005). This factor is the midpoint of a range from 0-40%, and the standard uncertainty in this correction factor is half of the range divided by the square root of three, or 10%. Only those portions of active ingredients that are susceptible to under-reporting (those that did not appear in usage reports) were adjusted. Because the adjustment factor applies to products in aggregate, it is important to remember when examining the release estimates presented in this section that the adjustment is intended to give a more accurate estimate of total releases of copper and that each individual active ingredient is not affected uniformly by under-reporting of sales.

As Table 2.2-1 shows, a large portion of the sales of products containing copper metal, mixed copper ethanolamine complexes, copper hydroxide, and copper sulfate (pentahydrate) do not have reported uses. These four active ingredients, all of which are found in consumer products, are responsible for essentially all of the estimated releases that are due to unreported sales.

Cuprous oxide also shows a substantial correction for under-reporting of sales, but as is described in a later section, the estimated releases of copper from this active ingredient are not based on its sales.

Use is also known to be under-reported. Reported uses of copper-based pesticides were adjusted upwards by 10% to correct for under-reporting. This correction factor is taken from a study by the California Department of Pesticide Regulation (CA DPR), where it was found that about 90% of the sales were reported as used over a five-year period for a group of pesticides whose usage was required to be entirely reported (Wilhoit, 2005). This assumes that under-reporting of copper-based pesticides is similar to under-reporting for the group of pesticides in the CA DPR study. For calculating the standard uncertainty of this adjustment factor, it was assumed that 67% of pesticides fall within a range of 80-100% fully reported, so that the standard uncertainty in the correction factor is 10%. Reported uses for copper pesticides in California are given in Table 2.2-1, along with adjusted uses. As with the adjustment for unreported sales, the usage adjustment for this group of active ingredients is intended to provide a more accurate estimate of total releases of copper from pesticides, but it is recognized that the usage of individual active ingredients is not under-reported uniformly.

2.2.a Pesticides Applied to Land in Urban Areas

Estimates for this category were made by assuming that unreported uses of copper-based pesticides sold in California that are not used as algaecides, as antifouling coatings, or as root killer are applied to land in urban areas. While this is not strictly the case, it is generally true and this methodology is expected to provide the best possible estimates of applications of copper in copper-based pesticides to urban land.

The use of copper in antifouling paints is estimated in this section not because it is a good indicator of releases of copper from that source, but because the use of copper in this category of pesticides helps with the development of an estimate for pesticides applied to urban land. Pool, spa, and fountain algaecide and antifouling coating uses as well as root killer uses are not necessarily required to be reported and must be estimated.

Five hundred million board feet of treated lumber are manufactured each year in California (WWPI, 2004). While there are some products registered for use in California for manufacturing treated lumber that list copper metal and copper ethanolamine complexes (mixed) as active ingredients, there was no reported usage of these compounds in the manufacture of treated lumber in 2003. There were 88,000 lb of cupric oxide and 319 lb of copper carbonate (basic) reported as being used in the manufacture of treated lumber in California in 2003. Estimating the amount of copper that is used to manufacture treated lumber in California is problematic, but the reported values for copper use probably fall far short of the amount of copper actually used in the manufacture of treated lumber. Statewide sales of cupric oxide are not disclosed, making it impossible to assess the magnitude of unreported uses of this compound.

In the absence of more complete information, it was assumed that cupric oxide is the primary copper compound used for treating lumber in California. This means that any unreported uses of copper carbonate (basic), copper ethanolamine complexes (mixed), and copper metal for treating lumber were neglected, so that unreported uses of these compounds were assumed to be applied to urban land or used as algaecides in swimming pools, spas, and fountains. The description of the methodology for estimating releases of copper from treated lumber, given in section 2.2d of this report, shows that the estimated releases of copper from treated wood products are not dependent on the reported use of copper in the manufacture of treated lumber.

A statewide estimate of cuprous oxide use in marine antifouling coatings can be made by assuming that any unreported uses of cuprous oxide are used in antifouling coatings (paints). Adjusted reported sales of this pesticide in California were 1,800,000 lb copper in 2003, while adjusted reported use on boats and piers is approximately 6,100 lb Cu/yr. Other adjusted reported uses of this active ingredient, most of which are agricultural, totaled 310,000 lb copper. Thus, use of cuprous oxide in marine antifouling coatings was estimated to be 1,500,000 lb Cu, which is 240 times larger than adjusted reported use.

Sales are not reported for cuprous thiocyanate because there is only one registrant. In order to estimate use of this active ingredient, it was assumed that the use of cuprous thiocyanate as an antifouling coating is reported at the same rate as the use of cuprous oxide as an antifouling coating. Adjusted reported statewide use of cuprous thiocyanate for boats and piers was 6.5 lb copper in 2003. Multiplying this value by 240 yields an estimate of 1,500 lb Cu/yr.

Copper hydroxide is registered for antifouling coating use, but is used for that purpose in only two products where it is present in low concentrations (TDC, 2004). Therefore, its use as a marine antifouling coating was neglected.

Finally, the use of copper in copper sulfate (pentahydrate) as a root killer must be estimated. Sales of root killer products containing this compound have been banned in the nine Bay area counties, but are still allowed in the remainder of California. Use of these products as root killer can be estimated by using the reduction in sewered copper in Palo Alto after the ban on sales of root killer products containing this active ingredient was instituted. A reduction of 370 lb of copper per year was observed for a population base of 226,300 (Moran, 2005b). The population of California outside of the nine-county Bay area is 26,637,987, so the statewide estimated use of copper for root control in products containing copper sulfate (pentahydrate) is 44,000 lb Cu/yr.

Table 2.2-2 summarizes the estimated breakdown of unreported uses of copper-based pesticides in California in 2003. The first column in this table is the same as the last column of Table 2.2-1. Unreported uses of the six copper pesticides that were not assigned to antifouling coatings or root killer uses and that can be used as algaecides were divided evenly between algaecidal applications and applications to urban land. These six pesticides are copper metal, copper carbonate (basic), copper ethanolamine complexes (mixed), copper ethylenediamine complex, copper sulfate (pentahydrate), and copper triethanolamine complex.

Table 2.2-2 also gives the standard uncertainties in the estimated use as pool, spa, and fountain algaecides and the estimated applications to urban land. The uncertainty for the six copper-based pesticides that can be used as algaecides is particularly large because their possible use as algaecide includes a range from 0% to 100% of the unreported uses that were not assigned to antifouling coatings or root killer uses. Standard uncertainties in Table 2.2-2 also include the uncertainty in estimated unreported uses, which in turn is based on the uncertainty in adjusted reported usage and adjusted reported sales.

Some usage of copper-based algaecides for pools, spas, and fountains and some usage of copper-based pesticides applied to urban land are reported. Table 2.2-3 shows the reported usage of copper-containing pesticides by county for the eight counties in the Bay watershed. Footnotes for this table explain how the data in the pesticide usage reports was used to obtain these values. Note that total adjusted reported use in this table is equal to the sum of total adjusted reported use in agriculture, industrial water treatment, nonagricultural water areas plus estimated use on urban land, in pools, spas, and fountains, and as an algaecide in nonagricultural rights of way, recreaction areas, and public health.

It should be noted that uses of copper for structural pest control are included in the urban land use estimate. (For the six algaecides, half of these adjusted reported uses in structural pest control are included in the urban land use estimate and half are included in pool, spa, and fountain algaecides.) Statewide, adjusted reported use of copper in copper pesticides for structural pest control was 4,700 lb in 2003. These uses are included with the urban land estimate because it is expected that they would behave much more like landscaping uses than uses of copper in treated lumber.

The ratio of population in each sub-watershed to California's population was applied to the statewide estimates of unreported uses of copper based-pesticides on urban land from Table 2.2-2 in order to determine the portion of copper in unreported copper pesticides that is used in urban areas in each sub-watershed. This was added to county estimates from Table 2.2-3, which were apportioned to the sub-watersheds using the ratio of population in each sub-watershed to the county's population. Results, along with their standard uncertainties, are given in Table 2.2-4. The standard uncertainties in Table 2.2-4 include the uncertainty in basing sub-watershed releases on population ratios. This uncertainty is based on a range of half the population to 1.5 times the population of the sub-watersheds.

Table 2.2-4 shows that in the San Francisco Bay watershed, an estimated 100,000 kg of copper in pesticides were applied to urban land in 2003. All of these releases in Table 2.2-4 are assumed to be to permeable developed land.

One would expect reported nonagricultural uses of copper-based pesticides to be somewhat proportionate to unreported uses on urban land and in pools, spas, and fountains. In other words, if a county has comparatively large reported nonagricultural uses of an active ingredient, comparatively large nonagricultural unreported uses of that active ingredient might be expected in that county as well. Therefore, one means of testing the appropriateness of apportioning unreported uses of copper-based pesticides on urban land and in pools, spas, and fountains as if they were uniform throughout California is to determine if reported nonagricultural uses in the eight Bay watershed counties are proportionate to statewide nonagricultural uses based on population. Eighteen percent of California's population lives in the eight Bay watershed counties. The four active ingredients with the highest unreported uses assigned to urban land are copper, copper ethanolamine complexes, copper hydroxide, and copper sulfate (pentahydrate). For copper, only 2% of California's nonagricultural uses occur in the 8-county region. Copper sulfate (pentahydrate) is similar, with 3% of California's nonagricultural uses occurring in the 8-county region. However, 34% of the state's nonagricultural uses of copper ethanolamine complexes occurs in the 8-county region, as do 18% of the state's nonagricultural uses of copper hydroxide. Overall, reported nonagricultural uses of copper-based pesticides in the eight Bay watershed counties appears to be proportionate to statewide reported nonagricultural usage.

2.2.b Agricultural Land Applications

The next step in estimating copper releases from copper-containing pesticides in the watershed is to estimate agricultural land applications of copper pesticides within each sub-watershed. Copper use reports for the eight counties in the watershed were used. Adjusted usage values (excluding use as algaecide, if any) are shown in Table 2.2-5. The portion of agricultural area in each county that falls within each sub-watershed was used to assign agricultural releases to the sub-watersheds.

Results for the sub-watersheds are given in Table 2.2-6. The standard uncertainties in these values were estimated as half of the range from zero to twice as much as the average application per unit of agricultural land, divided by the square root of three. Using 1992 land use data to apportion 2003 uses introduces an error that tends to overestimate agricultural applications within the Bay watershed. This is because agricultural land within the Bay watershed portion of the counties has been converted to urban uses at a higher rate than agricultural land within the counties in general. However, this error is assumed to be small compared to the uncertainty associated with apportioning releases based on agricultural land use area as if releases were uniform throughout all agricultural land within the counties. In the greater Bay watershed, an estimated 12,000 kg of copper in pesticides were applied to agricultural land in 2003. All of these releases are assumed to be applied to agricultural land.

2.2.c Algaecide Treatment of Surface Waters

The pesticides in this category are copper metal, copper carbonate (basic), copper ethanolamine complexes (mixed), copper ethylenediamine complex, copper sulfate (pentahydrate), and copper triethanolamine complex. Reported usage in industrial water was not included in this category, because it is assumed that those uses are captured in the section on industrial runoff and industrial releases to surface waters.

Adjusted reported agricultural water area uses of copper-based algaecides in the 8-county region are given in Table 2.2-7. Uses of algaecides in agricultural water areas are treated as a release to land because they are applied to waters that are subsequently applied to land rather than to surface waters that subsequently flow to the Bay. They were apportioned amongst the sub-watersheds based on agricultural land use area. As with applications of copper-based pesticides to agricultural land, using 1992 land use data to apportion 2003 uses introduces an error that tends to overestimate agricultural applications within the Bay watershed. This is because agricultural land within the Bay watershed portion of the counties has been converted to urban uses at a higher rate than agricultural land within the counties in general. However, this error is assumed to be small compared to the uncertainty associated with apportioning releases based on agricultural land use area as if releases were uniform throughout all agricultural land within the counties. Estimates by sub-watershed are given in Table 2.2-8. The estimated copper released in algaecide treatments of agricultural surface waters in the greater San Francisco Bay watershed was 27 kg in 2003. For uses in agricultural water areas, the uncertainty in the adjustment factor (which accounts for under-reporting) can be neglected because it is far outweighed by the uncertainty associated with apportioning the values among the sub-watersheds. This apportioning uncertainty is estimated as half of the range from zero to twice as much as the average application per unit of agricultural land, divided by the square root of three.

Use of copper-based algaecides in nonagricultural water areas in the eight-county area is assumed to occur entirely within the watershed and along the shoreline of the bays in the watershed. Values for adjusted reported use are given in Table 2.2-9. This table provides geographic coordinates for the center of each county's shoreline. The total estimated releases to the shorelines of the three bays in the San Francisco Bay watershed were 1,300 kg in 2003. Three of the counties had no reported uses of copper-based algaecides in nonagricultural water areas in 2003. They are Alameda, Solano, and Sonoma Counties. Also, estimated shoreline releases in Contra Costa County are quite small. The standard uncertainty in the estimates in Table 2.2-9 is based on the uncertainty in the correction factor for usage reporting. This uncertainty does not take into account reported copper use, if any, for treating drinking water reservoirs (which would not be a direct release to the Bay).

Estimates for those portions of adjusted reported uses of algaecides in rights of way (nonagricultural), public health, and recreation area categories were taken as the midpoint of a range from zero to total adjusted reported use in these categories. Again, these values are not adjusted to reflect use, if any, of copper-based algaecides for treating drinking water reservoirs. Also, the scientific literature suggests that copper in algaecides applied to water conveyance channels is relatively quickly removed into sediments, and discharges to receiving waters may be significantly lower than the load estimates. Table 2.2-7 gives county-specific estimates of these releases, which will be modeled as releases to surface water (these values were also given in Table 2.2-3). These values were apportioned amongst the sub-watersheds based on population. Results are given in Table 2.2-10. The total estimated releases of copper from algaecide uses in rights of way (nonagricultural), public health, and recreation areas were 1,200 kg in 2003. Four counties had no reported uses of copper-based algaecides in these categories in 2003. They are Sonoma, Santa Clara, San Mateo, and Marin Counties. The uncertainty in county-specific estimates is based on half of the possible range (from zero to 100% of adjusted reported usage) divided by the square root of three. In order to obtain the uncertainty in the release estimates, this uncertainty was combined with the uncertainty in apportioning the releases by population, which was taken as half of the range of half the population to 1.5 times the population of each sub-watershed, divided by the square root of three. The uncertainty in the magnitude of these releases is quite large.

2.2.d Pressure-Treated Wood Preservatives

There are several treatments for lumber that prevent decay. These include creosote, pentachlorophenol, oil-based treatments, and water-based treatments. There is an oil-based treatment that includes copper naphthenate as an active ingredient, but the majority of wood treatments that contain copper are water-based. Also, most of the water-based treatment formulations contain copper. The copper in the water-based treatments is intended to remain in the wood, but some of it leaches out over time. Chromated copper arsenate (CCA) has historically been the most common water-based wood treatment preservative, but concerns about arsenic leaching have led to bans in many applications. Substitutes for CCA usually contain copper and are generally less effectively fixed in the wood. Unfortunately, very little research has been conducted to determine the rate of copper leaching from treated wood, and what has been conducted focuses on CCA. This inventory relies on results from studies of CCA.

In this inventory, releases of copper from treated wood are divided into two subcategories: 1) copper released from pressure-treated wood used in residential and commercial construction, and 2) copper released from pressure-treated wood used in marine construction. These two types of releases have very different fates. Copper leached from pressure-treated wood used in residential and commercial construction is assumed to be released to permeable developed land, while copper leached from pressure-treated wood used in marine construction is released directly to the water the structure is in. Copper releases from treated wood applications other than residential and commercial and marine construction are not expected to be important because they generally depend on non-copper based treatments or because they comprise a small proportion of the treated wood market. For instance, most utility poles are treated with pentachlorophenol and most railroad ties are treated with creosote (Smith, 2003). Road and highway uses comprise only 1% of treated wood uses in California, and markets for other uses of treated wood, which are not described in sufficient detail to include in the inventory, are 10% of the total use of treated wood in California (Smith, 2003).

Loss rates of copper from treated wood depend on the type of preservative used, the type of wood, the surface area of the wood, and environmental factors including acidity, exposure to moisture, temperature, and salinity. Researchers have estimated that it would take about 180 years to leach all the copper from CCA-treated wood posts and pilings submerged in water (Rice et al., 2002). The average lifetime for pressure-treated lumber is 15 to 25 years (CDA, 2003; Rice et al, 2002).

For this report, results from a United States Forest Service study of two-by-six wood treated with CCA to a retention of 6.4 kg/m^3 were used to model releases of copper from residential and commercial construction. Most treated wood used in residential and commercial construction in California is treated with water-based preservatives, (Smith, 2003), and 6.4 kg/m^3 CCA, the concentration that is applied to wood that is intended to have contact with soil, is the most common treatment retention (USFS, 2001). The Forest Service study found that 12.57 mg of copper leached from 0.001446 m^3 of two-by-six after exposure to an amount of misted water that corresponds to 813 mm of rainfall (USDA, 2001). Rainfall in the Bay area is 35 cm/y, which yields a leaching rate of 3.7 g copper per cubic meter of treated wood used in residential and commercial construction per year. The standard uncertainty in this value is based on the standard deviation presented in the Forest Service report and is 0.5 g copper per cubic meter per year.

Recently purchased lumber was used in the Forest Service study and it is known that the leaching rate of copper from treated wood decays over time. Researchers have found high leaching rates upon initial exposure to water as poorly fixed copper leaches out. Once the poorly fixed copper is released, leaching drops to a low and constant rate over the remaining lifetime of the lumber (Lebow, 1996; Albuquerque et al, 1996; Merkle et al, 1993). However, information on the decay in leaching rate is insufficient for including in calculations. Instead, the number of years over which leaching occurs at the rate of 3.7 g/m^3 will be taken as the midpoint of a range from 1 year (where copper leaches out a rate of 3.7 g/m^3 for one year and does not leach after that) to 20 years (where copper leaches out at a rate of 3.7 g/m^3 for all 20 years that the wood is in service), with an uncertainty of half of that range divided by the square root of three.

Some of the releases of copper from pressure-treated lumber occur from portions of the lumber that are buried underground or that are in service in areas protected from precipitation. These releases are not likely to be entrained in runoff. It was assumed that a range from 10% to 40% of the copper leached from treated lumber cannot reach surface runoff, with a point value of 25%. The uncertainty in this estimate is half of the range divided by the square root of three, or 9%.

Each year in California, approximately 34.5 million cubic feet of wood that were treated with water-based preservatives are placed into service (Smith, 2003). Of that amount, 62% is used in residential and commercial construction (Smith, 2003).

Point values and standard uncertainties used to calculate releases of copper from treated lumber used in residential and commercial construction are summarized in Table 2.2-11. The uncertainty in apportioning statewide releases of copper to the sub-watersheds based on population is based on a range of half the population to 1.5 times the population, and the standard uncertainty in the volume of treated wood used in residential and commercial construction is estimated to be 10% of the value.

Results are given in Table 2.2-12. The estimated copper released from treated lumber used in residential and commercial construction in 2003 in the greater San Francisco Bay watershed is 3,400 kg/y. This category of releases is assumed to occur entirely to permeable developed land.

Copper releases from treated lumber used in marine construction are estimated differently because of the lack of a reasonably representative leaching study. Because of its submersion in water and higher treatment retentions, the rate of loss of copper from treated wood used in marine construction is expected to be higher than the loss rate of copper from treated wood used in residential and commercial construction. However, less treated lumber is used in marine construction than in residential and commercial construction.

Most treated wood pilings used in marine construction are treated with CCA, ammoniacal copper zinc arsenate (ACZA), or creosote (Smith, 2003). Information on the market share of each type of treatment for marine construction could not be found, so it was assumed that treatments containing copper are used on a possible range of 20% to 90% of wood used in marine construction. This yields a fraction of 0.6 with a standard uncertainty of 0.2.

The treatment retention for wood used in saltwater decking for docks and marinas is 9.6 kg/m^3 CCA, and the treatment retention for wood used for saltwater immersion at docks and marinas is 40 kg/m^3 (AWPA, 1996). In California, 425,000 cubic feet of treated wood used in pilings, 1,133,000 cubic feet of treated lumber, and 249,000 cubic feet of treated timber are used in marine construction each year (Smith, 2003). (Although the word "marine" is used, this includes freshwater construction.) A range for the weighted average treatment retention for marine construction was calculated by assuming that pilings in marine construction are treated to a retention of 40 kg/m^3 CCA, that lumber in marine construction is treated to a retention of 9.6 kg/m^3 CCA, and that timber in marine construction is treated to a retention of either 9.6 kg/m^3 or 40 kg/m^3. Various formulations of CCA have copper concentrations ranging from 18.1% to 19.6% (Lebow, 1996; USFS, 2000). The possible range for the copper concentration in treated wood used for marine construction is from 3.0 kg/m^3 to 4.1 kg/m^3, with a midpoint of 3.6 kg/m^3 and a standard uncertainty of 0.3 kg/m^3.

In the absence of better information, it was assumed that 20% to 60% of the copper in treated wood used for marine construction has leached out of the wood at the time the wood is removed from service. This yields a point value of 0.4 with a standard uncertainty of 0.1. The average lifetime for treated wood is taken as a range from 15 to 25 years, for a point value of 20 years. This means that if the introduction of copper in treated wood used for marine construction is assumed to be constant over the last 20 years, then the amount of copper leached per year from all treated wood in marine construction service is equal to 40% of the copper introduced in new construction each year.

Copper releases from marine construction were apportioned to specific locations within the bay watershed based on the fraction of California's berths at each location. It was assumed that the amount of wood used in marine construction at each marina is proportional to the number of berths at each marina. The total number of berths in California was taken from a report on the needs of California's boating facilities (California Department of Boating and Waterways, 2002) and the number of berths at each marina in the watershed was taken from a report prepared by the San Francisco Estuary Project for the California Department of Boating and Waterways (McDowell and Patton, 2004). The authors of the latter report surveyed marinas in the region in order to identify the number of pump-out facilities and dump stations required to serve the needs of the area's boaters. This report included two marinas that are outside of the watershed: Bolinas Rod and Boat Club and Pillar Point Harbor. It also included seven marinas that are in freshwater locations within the watershed: Velma Million Marina in the Coyote sub-watershed, Lake Chabot Marina and Lake Merritt Boating Center in the East Bay Central sub-watershed, Central Park/Lake Elizabeth in the East Bay South sub-watershed, Vasona Lake in the Santa Clara Valley Central sub-watershed, and Del Valle Park Company and Shadow Cliffs Regional Recreation Area in the Upper Alameda sub-watershed. Copper releases from the marinas in the freshwater locations were included in releases to surface waters for the sub-watershed in which they are located.

The standard uncertainty associated with using the number of berths in the pump-out survey to apportion copper releases from marine construction is expected to be negligible compared to the substantial uncertainties associated with other values used to calculate the release estimates.

The values used to estimate copper releases from marine construction are summarized in Table 2.2-13, along with their standard uncertainties. Table 2.2-14 gives estimates of the releases of copper from treated lumber used in marine construction for the 90 marinas in bay waters, along with their geographic coordinates and an assessment of the standard uncertainty in each release estimate. An estimated 9,700 kg/y of copper was released to bay waters from pressure-treated lumber used in marine construction in 2003. Table 2.2-15 provides estimates of releases of copper from treated lumber used in marine construction for the seven marinas whose releases were apportioned to surface waters in the sub-watersheds. These releases are small, totaling 100 kg/y for the watershed.

2.2.e Antifouling Coatings

Antifouling coatings (paints) are designed to deter growth of aquatic life on submerged boat and structure surfaces. Table 2.2-3 shows that the statewide estimate of the copper portion of the coatings used in 2003 is 1,500,000 lb. However, along with the pesticides used in treated lumber and unlike most other pesticides, all of the copper in these coatings is not released directly to the environment. Instead, it leaches out of the coating over time in a process that does not go to completion.

The copper released from antifouling coatings was estimated by using an emission factor of 1.8 lb Cu/boat/yr (0.8 kg Cu/boat/y). This factor is intended to represent releases from a 40-foot boat, which is assumed to be the average length of boat in wet storage. This emission factor is based on values obtained in a number of studies whose results vary over a range of approximately 1.3 lb Cu/boat/yr to 2.3 lb Cu/boat/yr (CA RWQCB, 2005). Half of this range divided by the square root of three, or 0.3 lb Cu/boat/yr (0.1 kg Cu/boat/y), is the estimate of the standard uncertainty in this emission factor.

The estimated number of boats berthed at each marina was derived from values found in a survey of marinas in the San Francisco Bay area (McDowell and Patton, 2004). This survey was conducted primarily to quantify the number of pump-out and dump stations required to serve the needs of boats in the area. The total number of boats in wet storage was not sought in the survey; instead, the survey was intended to quantify the number of boats with marine sanitation devices (MSDs) requiring pump-out facilities and the number of boats with portable toilets. In the survey, the number of boats in each category at each marina is provided as an estimate. For the purposes of estimating the standard uncertainty in the number of boats with MSDs requiring pump-outs and the number of boats with portable toilets, it was assumed that the true value for the number of boats falls within 10% of the surveyed value. Also, it was assumed that the two categories of boats included in the pump-out survey comprise most of the boats in wet storage in the area. A factor of 1.1 was applied to the number of boats in the survey to account for boats that do not have MSDs requiring pump-outs and that do not have portable toilets. This correction factor was assumed to fall within a range from 1 to 1.2, so that the standard uncertainty in the correction factor is 0.1.

For a few marinas, the number of boats was listed in the survey report as "unknown," "some," or "few." Estimates of the number of boats at these marinas were derived by applying the ratio of the number of boats to the number of permanent slips at all marinas in the area. For boats with MSDs, this ratio was 0.61 boats/permanent slip, and for boats with portable toilets, this ratio was 0.11 boats/permanent slip.

Marinas in the bay along with the estimated number of boats and estimated releases of copper from antifouling coatings to Bay waters are summarized in Table 2.2-16. This table provides the geographic coordinates of each marina, along with the standard uncertainty in the estimate of copper released. An estimated 13,000 kg of copper was released directly to Bay waters from antifouling coatings in 2003. The pump-out survey listed no boats at marinas in freshwater areas of the Bay watershed.

It is recognized that boats berthed at marinas are generally intended to move about in bay waters or out of the bay. Also, boats that are underway may release copper at higher rates than boats that are berthed. However, the bulk of the boats spend the majority of their time at or near the marinas, and associating the releases of copper from antifouling coatings with marina locations is probably the most appropriate means of identifying the location of these releases.

2.2.f Pool, Spa, and Fountain Algaecides

Algaecides used in pools, spas, and fountains can be discharged to storm drains when the pools, spas, or fountains are drained and when their filters are backwashed.

Many uses of copper-based algaecides are not reported because they are applied by commercial, institutional, industrial, and household consumers. Also, some of the reported uses are reported in categories that may or may not be algaecide applications. Table 2.2-2 provides an estimate of the unreported uses of pool, spa, and fountain algaecides for California and Table 2.2-3 provides estimates of their use based on reported usage by county. These tables show that estimates for pool, spa, and fountain use, which are based on possible fractions of use of these compounds as algaecides, is highly uncertain. The fraction of California’s population in each sub-watershed was used to apportion statewide unreported uses and the fraction of each county's population in each sub-watershed was used to apportion countywide estimated uses in order to estimate the total pool, spa, and fountain algaecide used in each sub-watershed.

In arriving at estimated releases of this source of copper to storm drains, it was assumed that 5% of the use of these algaecides is released to storm drains rather than being sewered or trapped in filter media that is subsequently disposed of in a landfill. The standard uncertainty in the fraction released to storm drains is 3%.

Table 2.2-17 gives estimates of copper released to storm drains from pool, spa, and fountain algaecides in the Bay area in 2003. Total estimated releases are 2,100 kg/y. The uncertainties in the estimates presented in this table include the uncertainty in the use estimates along with the uncertainty in the fraction that is released to storm drains and the error in assuming that swimming pools, spas, and fountains are uniform throughout California and throughout the counties on a per capita basis. The uncertainty in basing values on sub-watershed population is assumed to reflect a range from half the sub-watershed population to 1.5 times the sub-watershed population.

In a study of swimming pool discharges in Contra Costa County in 1999, the total copper concentration in filter backwash at five public pools ranged from 120 ppb to 7,850 ppb, with an average concentration of 2,549 ppb (URS, 2000). This same study provides estimates of the number and size of pools in the county. There are an estimated 50,000 private pools in Contra Costa County, with an average pool volume of 26,250 gal, and 12,000 public pools in the county, with an average pool volume of 280,715 gal and an average filter backwash rate of 34,600 gal/yr. The study also estimates that 39% of private pools discharge to storm drains, while 5% of public pools discharge to storm drains.

The copper concentration and the filter backwash discharge volume of private pools were not measured or estimated in the URS study. If, however, the private pools have a filter backwash discharge rate that is scalable by volume to the filter backwash discharge rate of public pools and if their filter backwash has a copper concentration similar to that of public pools, then the data can be used to estimate a release rate of copper from swimming pools (both public and private) to storm drains in Contra Costa County. (Copper concentration measurements from the URS study indicate that the water in private pools is higher in copper than the water in public pools.)

The resulting estimate of copper discharged from swimming pools to storm drains in Contra Costa County is 29 kg/y to 2,500 kg/y, with an average of 800 kg/y. Estimated pool, spa, and fountain discharges of copper to storm drains in the portion of Contra Costa County that is within the San Francisco Bay watershed using the methodology described earlier in this section is 340 kg/y, with a standard uncertainty of approximately 250 kg/y. Eighty-three percent of the population of Contra Costa County lives in the San Francisco Bay watershed. Thus, the results from the two methods for estimating releases of copper from pools, spas, and fountains have some overlap, but the magnitude of some of the copper concentrations measured in pool filter backwash indicates that this source may be substantially larger than the estimate provided in this report.

The highest copper concentrations in filter backwash were observed in the backwash of pools equipped with a diatomaceous earth filter. In fact, the average copper concentration of filter backwash from public pools equipped with diatomaceous earth filters is twenty times larger than that of public pools equipped with sand filters. The reason for this difference is not known. Possibilities include a copper contribution from diatomaceous earth or superior adsorption of copper onto sand filter media. The fraction of public and private pools that are equipped with diatomaceous earth filters is not known.

Table 2.2-1 Adjustments for under-reported sales and usage of copper pesticides in California in 2003. Values are in pounds of copper.

Active Ingredient	Reported Sales (CA DPR, 2005b)	Adjusted Reported Sales	Reported Usage (CA DPR, 2005a)	Adjusted Reported Usage	Estimated Unreported Uses[f]
Copper	360,606	414,717	81,863	90,050	324,667
Copper 8-quinolinoleate		98[a]			98
Copper ammonium carbonate		3[b]	3	3	0
Copper ammonium complex	14,441	16,302	4,667	5,134	11,168
Copper carbonate, basic		8,716[c]	4,459	4,905	3,810
Copper ethanolamine complexes, mixed	191,469	226,341	15,549	17,104	209,238
Copper ethylenediamine complex		5,252[b]	4,775	5,252	0
Copper hydroxide	2,701,598	2,823,913	1,900,020	2,090,022	733,890
Copper naphthenate	16,934	19,288	4,693	5,162	14,126
Copper octanoate	57	68			68
Copper oxide (ic)		79,889[b]	72,627	79,889	0
Copper oxide (ous)	1,518,069	1,758,864	285,539	314,093	1,444,771
Copper oxychloride	83,276	87,187	57,927	63,720	23,467
Copper oxychloride sulfate		283,829[b]	258,027	283,829	0
Copper salts of fatty and rosin acids		1,286[b]	1,169	1,286	0
Copper sulfate (basic)	611,359	620,584	513,852[e]	565,238	55,346
Copper sulfate (pentahydrate)	1,748,062	1,866,483	1,050,872[e]	1,155,959	710,524
Cuprous thiocyanate		1,632[d]	86	94	1,538
Copper triethanolamine complex	116	139			139
Total	7,245,986	7,833,887	4,256,128	4,681,740	3,532,852

[a] Reported sales of copper 8-quinolinoleate were 455 lb active ingredient in 2001, or 80 lb of copper. This value is used to estimate 2003 sales of this product (in any event, this is not a high-volume pesticide).

[b] Because labeling information indicates that all usage is reported and because sales of these active ingredients are not reported, total adjusted statewide reported uses or total statewide estimated uses are used to estimate sales of these products. They are not expected to have unreported urban or agricultural uses.

[c] Copper carbonate sales estimated using ratio of sales (8,136 lb copper) to total reported usage (4,490 lb copper) from 2002 and applying to 2003 reported usage (4,905 lb copper).

[d] Adjusted sales for boat/pier usage estimated as 240 multiplied by adjusted reported use on boat/pier (this is the ratio of estimated cuprous oxide use on boats to reported cuprous oxide use on boats).

[e] Corrected for 533 pounds of nonagricultural water area usage that were reported for copper sulfate (basic) but that should have been reported for copper sulfate (pentahydrate) (136 lb copper).

[f] This column is equal to adjusted reported sales less adjusted reported usage.

Table 2.2-2 Estimated applications of unreported uses of copper-containing pesticides in California in 2003. Values are in pounds of copper.

Active Ingredient	Estimated Unreported Uses[a]	Estimated Unreported Uses Used as Antifouling Coating	Estimated Unreported Uses Used as Root Killer	Fraction of Estimated Unreported Uses That Is Used as Pool, Spa, and Fountain Algaecide	Estimated Unreported Uses That Are Used As Pool, Spa, and Fountain Algaecide	Standard Uncertainty in Estimated Unreported Uses That Are Used As Pool, Spa, and Fountain Algaecide	Estimated Unreported Uses Applied to Urban Land	Standard Uncertainty in Estimated Unreported Use Applied to Urban Land
Copper	324,667			0.5	162,334	97,535	162,334	97,535
Copper 8-quinolinoleate	98						98	33
Copper ammonium carbonate	0						0	0
Copper ammonium complex	11,168						11,168	2,092
Copper carbonate, basic	3,810			0.5	1,905	1,836	1,905	1,836
Copper ethanolamine complexes, mixed	209,238			0.5	104,619	62,308	104,619	62,308
Copper ethylenediamine complex	0			0.5	0	0	0	0
Copper hydroxide	733,890						733,890	382,817
Copper naphthenate	14,126						14,126	2,490
Copper octanoate	68						68	9
Copper oxide (ic)	0						0	0
Copper oxide (ous)	1,444,771	1,444,771					0	0
Copper oxychloride	23,467						23,467	11,784
Copper oxychloride sulfate	0						0	0
Copper salts of fatty and rosin acids	0						0	0
Copper sulfate (basic)	55,346						55,346	89,874
Copper sulfate (pentahydrate)	710,524		43,553	0.5	333,486	228,098	333,486	228,098
Cuprous thiocyanate	1,538	1,538					0	0
Copper triethanolamine complex	139			0.5	70	41	70	41
Total	3,532,852	1,446,309	43,553		602,413		1,440,577	

[a]After adjusting for under-reporting of sales and under-reporting of usage.

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Table 2.2-3 Reported applications of copper-based pesticides in the San Francisco Bay watershed counties in 2003 and their estimated use as algaecides in pools, spas, and fountains, as public applications of algaecides, and on urban land. Values are in pounds of copper.

County	Total Adjusted Reported Use	Total Adjusted Reported Use in Agriculture, Industrial Water Treatment, and Nonagricultural Water Areas	Estimated Applications to Urban Land[a]	Standard Uncertainty in Estimated Applications to Urban Land	Estimated Pool, Spa, and Fountain Algaecide Use[b]	Standard Uncertainty in Estimated Pool, Spa, and Fountain Algaecide Use	Estimated Algaecidal Use in Nonagricultural Rights of Way, Recreation Areas, and Public Health[c]	Standard Uncertainty in Estimated Use in Nonagricultural Rights of Way, Recreation Areas, and Public Health
Alameda	824	259	414	60	128	46	22	13
Contra Costa	9,674	3,859	3,351	917	162	82	2,302	844
Marin	3,155	2,793	329	34	32	17	2	1
Napa	18,471	16,224	1,790	262	319	172	138	78
San Mateo	2,062	495	925	377	642	376	0	0
Santa Clara	3,757	2,715	801	94	241	84	0	0
Solano	21,663	19,870	914	355	85	37	793	346
Sonoma	36,580	35,872	623	61	85	35	1	1
TOTAL	96,185	82,086	9,148		1,693		3,258	

[a] For products that do not have algaecidal applications, this value includes adjusted reported uses in landscape maintenance, public health, recreation areas, nonagricultural rights of way, and structural pest control. For products that have algaecidal applications, this value includes half of the adjusted reported uses in landscape maintenance, public health, recreation areas, nonagricultural rights of way, and structural pest control.

[b] For products that have algaecidal applications, this value includes half of the adjusted reported uses in landscape maintenance and structural pest control.

[c] For products that have algaecidal applications, this value includes half of the adjusted reported uses in public health, recreation areas, and nonagricultural rights of way.

Table 2.2-4 Estimates of copper in pesticides applied to urban land in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper in Pesticides Applied to Urban Land, kg/y	Standard Uncertainty in Copper in Pesticides Applied to Urban Land, kg/y
Upper Alameda	4,346	1,850
Santa Clara Valley Central	6,796	2,928
Castro Valley	682	295
East Bay North	4,872	2,055
Upper Colma	1,680	710
Marin South	2,496	1,054
Coyote	11,165	4,810
East Bay Central	17,066	7,373
East Bay South	3,609	1,561
Solano West	3,525	1,457
Napa	4,674	1,726
North Napa	647	217
North Sonoma	198	84
Marin North	1,607	679
Contra Costa Central	9,865	3,979
Petaluma	1,385	585
Santa Clara Valley West	13,979	6,015
Upper San Lorenzo	676	292
Contra Costa West	3,531	1,425
Peninsula Central	9,114	3,854
Sonoma	655	277
Upper San Francisquito	222	94
Upper Corte Madera	507	214
TOTAL	103,296	

Table 2.2-5 Reported agricultural use of copper-containing pesticides in the San Francisco Bay watershed counties, 2003 (does not include applications to agricultural water areas).

Species	Adjusted Reported Agricultural Usage, lb Cu								TOTAL
	Alameda	Contra Costa	Marin	Napa	San Mateo	Santa Clara	Solano	Sonoma	
Copper								18	18
Copper ammonium complex				0			68	1	70
Copper hydroxide	256	3,431	74	13,075	279	2,673	19,312	23,204	62,306
Copper oxide (ous)		92		449			388	2,750	3,679
Copper oxychloride			149				57	441	647
Copper oxychloride sulfate		256		1,758		23		8,962	10,999
Copper salts of fatty and rosin acids	3	39		2	4		18	95	161
Copper sulfate (basic)		18	26			1	27	144	215
Copper sulfate (pentahydrate)		22		0	5	6		2	35
Total	259	3,857	249	15,285	288	2,703	19,870	35,618	78,128

Table 2.2-6 Estimates of copper in pesticides applied to agricultural land in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper in Pesticides Applied to Agricultural Land, kg/y	Standard Uncertainty in Copper in Pesticides Applied to Agricultural Land, kg/y
Upper Alameda	107	62
Santa Clara Valley Central	20	12
Castro Valley	0	0
East Bay North	0	0
Upper Colma	0	0
Marin South	0	0
Coyote	291	168
East Bay Central	8	5
East Bay South	12	7
Solano West	897	518
Napa	1,895	1,094
North Napa	4,636	2,677
North Sonoma	894	516
Marin North	94	54
Contra Costa Central	30	17
Petaluma	613	354
Santa Clara Valley West	17	10
Upper San Lorenzo	0	0
Contra Costa West	11	6
Peninsula Central	0	0
Sonoma	2,239	1,293
Upper San Francisquito	15	8
Upper Corte Madera	0	0
TOTAL	11,780	

Table 2.2-7 Releases of copper-based algaecides to surface waters in the 8-county San Francisco Bay area in 2003. Values are in pounds of copper.

County	Use in Nonagricultural Rights of Way, Recreation Areas, and Public Health			Adjusted Reported Use in Agricultural Water Area
	Total Adjusted Reported Usage for Six Pesticides that Have Algaecidal Uses	Estimated Use as Algaecide	Uncertainty in Estimated Use as Algaecide	
Alameda	45	22	13	0
Santa Clara	0	0	0	0
San Mateo	0	0	0	0
Contra Costa	4,603	2,302	844	0
Marin	4	2	1	0
Napa	276	138	78	0
Solano	1,586	793	346	0
Sonoma	3	1	1	254
TOTAL	6,517	3,258		254

Table 2.2-8 Estimates of copper in algaecides applied to agricultural water areas in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper in Algaecides Applied to Agricultural Water Areas, kg/y	Standard Uncertainty in Copper in Algaecides Applied to Agricultural Water Areas, kg/y
Upper Alameda	0	0
Santa Clara Valley Central	0	0
Castro Valley	0	0
East Bay North	0	0
Upper Colma	0	0
Marin South	0	0
Coyote	0	0
East Bay Central	0	0
East Bay South	0	0
Solano West	0	0
Napa	0	0
North Napa	0	0
North Sonoma	6	4
Marin North	0	0
Contra Costa Central	0	0
Petaluma	4	2
Santa Clara Valley West	0	0
Upper San Lorenzo	0	0
Contra Costa West	0	0
Peninsula Central	0	0
Sonoma	16	9
Upper San Francisquito	0	0
Upper Corte Madera	0	0
TOTAL	27	10

Table 2.2-9 Estimates of copper in algaecides released to shoreline surface waters in the San Francisco Bay watershed counties in 2003.

County	Degrees Latitude (North)*	Degrees Longitude (West)*	Copper in Algaecides Released to Shoreline Surface Waters, kg/y	Standard Uncertainty in Copper in Algaecides Released to Shoreline Surface Waters, kg/y
Alameda			0	0
Santa Clara	37.45	-122.04	5.0	0.5
San Mateo	37.57	-122.27	32	3
Contra Costa	38.06	-122.03	1	0.1
Marin	37.97	-122.45	847	77
Napa	38.19	-122.29	427	39
Solano			0	0
Sonoma			0	0
TOTAL			1,312	

* These coordinates (Carleton, 2006) are intended to represent the centerline of the county's shoreline. Pesticide usage data do not permit finer geographic resolution.

Table 2.2-10 Estimates of copper in algaecides used in nonagricultural rights of way, recreation areas, and public health in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper in Algaecides Used in Nonagricultural Rights of Way, Recreation Areas, and Public Health, kg/y	Standard Uncertainty in Copper in Algaecides Used in Nonagricultural Rights of Way, Recreation Areas, and Public Health, kg/y
Upper Alameda	54	45
Santa Clara Valley Central	0	0
Castro Valley	0	0
East Bay North	95	80
Upper Colma	0	0
Marin South	0	1
Coyote	0	0
East Bay Central	26	19
East Bay South	1	2
Solano West	158	158
Napa	147	116
North Napa	13	16
North Sonoma	0	0
Marin North	0	0
Contra Costa Central	520	445
Petaluma	0	0
Santa Clara Valley West	0	0
Upper San Lorenzo	0	0
Contra Costa West	185	158
Peninsula Central	0	0
Sonoma	0	0
Upper San Francisquito	0	0
Upper Corte Madera	0	0
TOTAL	1,199	

Table 2.2-11 Values used to calculate copper releases from pressure-treated wood used in residential and commercial construction.

Variable	Value	Standard Uncertainty
Treated wood used in CA for residential and commercial construction, m^3/y	761,583	76,158
Fraction not susceptible to runoff	0.25	0.09
Emission factor, kg $Cu/m^3/y$	0.0037	0.0005
Number of years Cu is released at emission factor rate	10.5	5.5

Table 2.2-12 Estimates of copper released from pressure-treated wood used for residential and commercial construction in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper Released from Pressure-Treated Wood Used in Residential and Commercial Construction, kg/y	Standard Uncertainty in Copper Released from Pressure-Treated Wood Used in Residential and Commercial Construction, kg/y
Upper Alameda	145	91
Santa Clara Valley Central	229	144
Castro Valley	23	15
East Bay North	161	101
Upper Colma	56	35
Marin South	83	52
Coyote	377	237
East Bay Central	578	363
East Bay South	122	77
Solano West	114	72
Napa	134	84
North Napa	17	10
North Sonoma	7	4
Marin North	53	33
Contra Costa Central	311	195
Petaluma	46	29
Santa Clara Valley West	471	296
Upper San Lorenzo	23	14
Contra Costa West	111	70
Peninsula Central	302	190
Sonoma	22	14
Upper San Francisquito	7	5
Upper Corte Madera	17	11
TOTAL	3,408	

Table 2.2-13 Values used to estimate copper releases from pressure-treated wood used in marine construction.

Variable	Value	Standard Uncertainty
Treated wood used for marine construction in California, m^3/y	51,161	5,116
Fraction of treated wood used for marine construction that was treated using compounds that contain copper	0.6	0.2
Copper concentration in treated wood used for marine construction, kg/m^3	3.6	0.3
Fraction of copper leached from treated wood at time of removal from service	0.4	0.1
Total berths in California	82,328	negligible

Table 2.2-14 Number of permanent slips and estimated copper releases from pressure-treated lumber at marinas in San Francisco Bay waters.

Marina Name	Number of Permanent Slips[a]	Degrees Latitude (North)[a]	Degrees Longitude (West)[a]	Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y	Standard Uncertainty in Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y
Aeolian Yacht Club	93	37.75056	-122.20194	45	24
Alameda Marina	530	37.77519	-122.24768	259	137
Ballena Isle Marina	504	37.77000	-122.29000	246	131
Barnhill Marina	68	37.78981	-122.27543	33	18
Berkeley Marina	1,100	37.86473	-122.31311	537	285
Berkeley Marine Center	60	37.86831	-122.31822	29	16
Embarcadero Cove Marina	120	37.78250	-122.24333	59	31
Emery Cove Yacht Harbor	430	37.83750	-122.30750	210	112
Emeryville Marina	409	37.83816	-122.31326	200	106
Encinal Yacht Club	0	37.78251	-122.26344	0	0
Fifth Avenue Marina	107	37.78842	-122.26306	52	28
Fortman Marina	486	37.77660	-122.25960	237	126
Grand Marina	400	37.77820	-122.25246	195	104
Marina Village Yacht Harbor	750	37.78532	-122.26953	366	195
Marinemax	22	37.78696	-122.24970	11	6
Mariner Square	50	37.79142	-122.27650	24	13
Oakland Yacht Club/Pacific Marina	225	37.78369	-122.26474	110	58
Park Street Landing Marina	25	37.77196	-122.23837	12	6
Port of Oakland	500	37.79370	-122.27504	244	130
Portobello Marina/D Anna Yacht Ctr.	65	37.79099	-122.26453	32	17
San Leandro Marina	455	37.69770	-122.19110	222	118
Brickyard Cove Marina	250	37.90941	-122.37808	122	65
Channel Marina	70	37.92522	-122.37020	34	18
Keefe Kaplan Maritime Inc. (KKMI)	20	37.92420	-122.37473	10	5
Marina Bay Yacht Harbor	850	37.91423	-122.35458	415	220
Martinez Marina	350	38.02599	-122.13741	171	91
McAvoy Harbor	300	38.03905	-121.96094	146	78
Pittsburg Marina	485	38.03217	-121.88330	237	126
Point San Pablo Yacht Harbor	212	37.93000	-122.41000	103	55
Richmond Yacht Club	246	37.91174	-122.37917	120	64
Richmond Yacht Harbor Ltd.	15	37.92522	-122.37059	7	4

Marina Name	Number of Permanent Slips[a]	Degrees Latitude (North)[a]	Degrees Longitude (West)[a]	Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y	Standard Uncertainty in Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y
Rodeo Marina	18	38.03870	-122.27380	9	5
Sugar Dock Marina	10	37.92133	-122.37167	5	3
145 Marina	10	37.96918	-122.51266	5	3
American Oceanics	16	37.97000	-122.51000	8	4
Angel Island State Park	2	37.86902	-122.43339	1	1
Arques Shipyard and Marina	89	37.86750	-122.49717	43	23
Bel Marin Keys Yacht Club	63	38.0456[b]	-122.3049[b]	31	16
Cass Marina	30	37.86183	-122.48833	15	8
Clipper Yacht Harbor	600	37.86883	-122.49783	293	156
Corinthian Yacht Club	93	37.87187	-122.45602	45	24
Dolphin Marin and Lofts	5	37.97000	-122.51240	2	1
Galilee Harbor	38	37.86254	-122.48814	19	10
Hi Tide Boat Sales & Services	10	37.96733	-122.51233	5	3
Liberty Ship Marina	54	37.87[c]	-122.5[c]	26	14
Loch Lomond Marina	518	37.97334	-122.48248	253	134
Lowrie Yacht Harbor	110	37.96783	-122.50867	54	29
Marin Boat House	12	37.97000	-122.51183	6	3
Marin Yacht Club	118	37.97333	-122.49733	58	31
Marina Plaza Harbor	103	37.86650	-122.49550	50	27
Paradise Cay Yacht Harbor	163	37.90967	-122.47633	80	42
Pelican Harbor	90	37.86050	-122.48367	44	23
Richardson Bay Marina	220	37.87567	-122.50550	107	57
San Francisco Yacht Club	187	37.87267	-122.46350	91	49
San Rafael Yacht Club	18	37.96600	-122.51483	9	5
San Rafael Yacht Harbor	140	37.97000	-122.51267	68	36
Sausalito Marine	60	37.86081	-122.48483	29	16
Sausalito Yacht Harbor	580	37.85900	-122.48367	283	150
Schoonmaker Point Marina	161	37.86383	-122.49183	79	42
Shelter Cove Marina	17	37.9[c]	-122.52[c]	8	4
The Cove Apartments & Marina	55	37.88[c]	-122.46[c]	27	14
Trade Winds Marina	30	37.96697	-122.51208	15	8
Travis Marina	81	37.83267[d]	-122.48367	40	21
Napa Valley Marina	200	38.21982	-122.31309	98	52
Napa Yacht Club	0[e]			0	0
Fisherman's Wharf & Hyde St. Harbor	180	37.81000	-122.42000	88	47

Marina Name	Number of Permanent Slips[a]	Degrees Latitude (North)[a]	Degrees Longitude (West)[a]	Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y	Standard Uncertainty in Copper Released to Bay Waters from Pressure-Treated Wood Used in Marine Construction, kg/y
Mission Creek Harbor	55	37.79[c]	-122.39[c]	27	14
Pier 39 Marina	310	37.81083	-122.40967	151	80
San Francisco Marina East Harbor	342	37.80733	-122.43583	167	89
San Francisco Marina West Harbor	344	37.80667	-122.44283	168	89
South Beach Harbor	700	37.78149	-122.38742	341	182
Treasure Island Marina	100	37.82000	-122.37021	49	26
Bair Island Marina	95	37.49858	-122.22097	46	25
Brisbane Marina	580	37.67454	-122.38096	283	150
Coyote Point Marina	550	37.59088	-122.31861	268	143
Docktown Marina	152	37.49583	-122.22050	74	39
Marine Collection LLC	20	37.66282	-122.37928	10	5
Oyster Cove Marina	237	37.66627	-122.38549	116	61
Oyster Point Marina	592	37.66257	-122.37495	289	154
Pete's Harbor	263	37.50167	-122.22500	128	68
Port of Redwood City Yacht Harbor	185	37.50317	-122.21317	90	48
South Bay Yacht Club	15	37.42683	-121.97917	7	4
Benicia Marina	320	38.05810	-122.17438	156	83
Glen Cove Marina	209	38.06767	-122.21357	102	54
Suisun City Marina	155	38.23449	-122.03800	76	40
Vallejo Marina	800	38.10885	-122.26722	390	207
Vallejo Yacht Club	134	38.10512	-122.26633	65	35
Gilardi's Lakeville Marina	14	38.19751	-122.54754	7	4
Petaluma Marina	196	38.23138	-122.61485	96	51
Port of Sonoma Marina	282	38.11637	-122.50353	138	73
TOTAL	19,928			9,721	

[a] Unless otherwise specified, from McDowell and Patton, 2004.
[b] From www.calsign.com/mining/countydata/marin1.htm for a feature called Bel Marin Keys.
[c] From melissadata.com for marina address given in pump-out survey.
[d] Assigned the lowest latitude of any of the marinas in Richardson Bay.
[e] Number of slips listed as "unknown" in survey. Assumed to be zero.

Table 2.2-15 Estimated copper releases from treated lumber at freshwater marinas in the San Francisco Bay watershed.

Watershed	Copper Released to Surface Waters from Pressure-Treated Wood Used in Marine Construction, kg/y	Standard Uncertainty in Copper Released to Surface Waters from Pressure-Treated Wood Used in Marine Construction, kg/y
Upper Alameda	29	12
Santa Clara Valley Central	20	10
Castro Valley	0	0
East Bay North	0	0
Upper Colma	0	0
Marin South	0	0
Coyote	11	6
East Bay Central	29	12
East Bay South	11	6
Solano West	0	0
Napa	0	0
North Napa	0	0
North Sonoma	0	0
Marin North	0	0
Contra Costa Central	0	0
Petaluma	0	0
Santa Clara Valley West	0	0
Upper San Lorenzo	0	0
Contra Costa West	0	0
Peninsula Central	0	0
Sonoma	0	0
Upper San Francisquito	0	0
Upper Corte Madera	0	0
TOTAL	100	

Table 2.2-16 Estimated number of boats and estimated copper releases from antifouling coatings at marinas in San Francisco Bay waters.

Marina Name	Estimated Number of Boats	Standard Uncertainty in Estimated Number of Boats	Degrees Latitude (North)[a]	Degrees Longitude (West)[a]	Copper Released to Bay Waters from Antifouling Coatings, kg/y	Standard Uncertainty in Copper Released to Bay Waters from Antifouling Coatings, kg/y
Aeolian Yacht Club	98	12	37.75056	-122.20194	80	16
Alameda Marina	413	48	37.77519	-122.24768	338	67
Ballena Isle Marina	291	34	37.77000	-122.29000	238	47
Barnhill Marina	6	1	37.78981	-122.27543	5	1
Berkeley Marina	1211	141	37.86473	-122.31311	991	196
Berkeley Marine Center	56	6	37.86831	-122.31822	45	9
Embarcadero Cove Marina	128	15	37.78250	-122.24333	105	21
Emery Cove Yacht Harbor	476	56	37.83750	-122.30750	389	77
Emeryville Marina	250	30	37.83816	-122.31326	205	41
Encinal Yacht Club	0	0	37.78251	-122.26344	0	0
Fifth Avenue Marina	83	10	37.78842	-122.26306	68	14
Fortman Marina	380	43	37.77660	-122.25960	311	61
Grand Marina	438	51	37.77820	-122.25246	358	71
Marina Village Yacht Harbor	461	54	37.78532	-122.26953	377	75
Marinemax	24	3	37.78696	-122.24970	20	4
Mariner Square	42	5	37.79142	-122.27650	35	7
Oakland Yacht Club/Pacific Marina	134	15	37.78369	-122.26474	110	22
Park Street Landing Marina	28	3	37.77196	-122.23837	23	5
Port of Oakland	422	48	37.79370	-122.27504	345	68
Portobello Marina/D Anna Yacht Ctr.	39	5	37.79099	-122.26453	32	6
San Leandro Marina	427	50	37.69770	-122.19110	349	69
Brickyard Cove Marina	250	30	37.90941	-122.37808	205	41
Channel Marina	56	6	37.92522	-122.37020	46	9
Keefe Kaplan Maritime Inc. (KKMI)	22	3	37.92420	-122.37473	18	4
Marina Bay Yacht Harbor	715	82	37.91423	-122.35458	585	116
Martinez Marina	182	21	38.02599	-122.13741	149	29
McAvoy Harbor	481	54	38.03905	-121.96094	394	77
Pittsburg Marina	544	61	38.03217	-121.88330	445	87
Point San Pablo Yacht Harbor	44	5	37.93000	-122.41000	36	7
Richmond Yacht Club	222	25	37.91174	-122.37917	182	36
Richmond Yacht Harbor Ltd.	9	1	37.92522	-122.37059	7	1

Marina Name	Estimated Number of Boats	Standard Uncertainty in Estimated Number of Boats	Degrees Latitude (North)[a]	Degrees Longitude (West)[a]	Copper Released to Bay Waters from Antifouling Coatings, kg/y	Standard Uncertainty in Copper Released to Bay Waters from Antifouling Coatings, kg/y
Rodeo Marina	0	0	38.03870	-122.27380	0	0
Sugar Dock Marina	11	1	37.92133	-122.37167	9	2
145 Marina	8	1	37.96918	-122.51266	7	1
American Oceanics	1	0	37.97000	-122.51000	1	0
Angel Island State Park	0	0	37.86902	-122.43339	0	0
Arques Shipyard and Marina	14	2	37.86750	-122.49717	12	2
Bel Marin Keys Yacht Club	50	6	38.0456[b]	-122.3049[b]	41	8
Cass Marina	28	3	37.86183	-122.48833	23	4
Clipper Yacht Harbor	712	83	37.86883	-122.49783	583	115
Corinthian Yacht Club	78	9	37.87187	-122.45602	64	13
Dolphin Marin and Lofts	6	1	37.97000	-122.51240	5	1
Galilee Harbor	32	4	37.86254	-122.48814	26	5
Hi Tide Boat Sales & Services	0	0	37.96733	-122.51233	0	0
Liberty Ship Marina	50	6	37.87[c]	-122.5[c]	41	8
Loch Lomond Marina	533	61	37.97334	-122.48248	436	86
Lowrie Yacht Harbor	74	9	37.96783	-122.50867	61	12
Marin Boat House	8	1	37.97000	-122.51183	7	1
Marin Yacht Club	131	16	37.97333	-122.49733	107	21
Marina Plaza Harbor	113	13	37.86650	-122.49550	92	18
Paradise Cay Yacht Harbor	75	9	37.90967	-122.47633	62	12
Pelican Harbor	100	12	37.86050	-122.48367	82	16
Richardson Bay Marina	210	24	37.87567	-122.50550	172	34
San Francisco Yacht Club	75	8	37.87267	-122.46350	61	12
San Rafael Yacht Club	2	0	37.96600	-122.51483	2	0
San Rafael Yacht Harbor	111	13	37.97000	-122.51267	91	18
Sausalito Marine	33	4	37.86081	-122.48483	27	5
Sausalito Yacht Harbor	349	40	37.85900	-122.48367	285	56
Schoonmaker Point Marina	159	18	37.86383	-122.49183	130	26
Shelter Cove Marina	12	1	37.9[c]	-122.52[c]	9	2
The Cove Apartments & Marina	14	2	37.88[c]	-122.46[c]	12	2
Trade Winds Marina	26	3	37.96697	-122.51208	21	4
Travis Marina	44	5	37.83267[d]	-122.48367	36	7
Napa Valley Marina	178	21	38.21982	-122.31309	145	29
Napa Yacht Club	0[e]	0			0	0
Fisherman's Wharf & Hyde St. Harbor	50	6	37.81000	-122.42000	41	8

Marina Name	Estimated Number of Boats	Standard Uncertainty in Estimated Number of Boats	Degrees Latitude (North)[a]	Degrees Longitude (West)[a]	Copper Released to Bay Waters from Antifouling Coatings, kg/y	Standard Uncertainty in Copper Released to Bay Waters from Antifouling Coatings, kg/y
Mission Creek Harbor	20	2	37.79[c]	-122.39[c]	16	3
Pier 39 Marina	344	41	37.81083	-122.40967	282	56
San Francisco Marina East Harbor	226	25	37.80733	-122.43583	185	36
San Francisco Marina West Harbor	378	43	37.80667	-122.44283	309	61
South Beach Harbor	583	68	37.78149	-122.38742	477	95
Treasure Island Marina	84	10	37.82000	-122.37021	69	14
Bair Island Marina	106	12	37.49858	-122.22097	86	17
Brisbane Marina	643	76	37.67454	-122.38096	526	105
Coyote Point Marina	500	57	37.59088	-122.31861	409	80
Docktown Marina	100	12	37.49583	-122.22050	82	16
Marine Collection LLC	7	1	37.66282	-122.37928	5	1
Oyster Cove Marina	122	15	37.66627	-122.38549	100	20
Oyster Point Marina	78	9	37.66257	-122.37495	64	13
Pete's Harbor	137	16	37.50167	-122.22500	112	22
Port of Redwood City Yacht Harbor	200	23	37.50317	-122.21317	164	32
South Bay Yacht Club	2	0	37.42683	-121.97917	2	0
Benicia Marina	300	35	38.05810	-122.17438	245	49
Glen Cove Marina	192	22	38.06767	-122.21357	157	31
Suisun City Marina	162	19	38.23449	-122.03800	133	26
Vallejo Marina	542	62	38.10885	-122.26722	444	87
Vallejo Yacht Club	150	17	38.10512	-122.26633	122	24
Gilardi's Lakeville Marina	7	1	38.19751	-122.54754	5	1
Petaluma Marina	72	8	38.23138	-122.61485	59	12
Port of Sonoma Marina	56	6	38.11637	-122.50353	45	9
TOTAL	16,232				13,281	

[a] Unless otherwise specified, from McDowell and Patton, 2004.
[b] From www.calsign.com/mining/countydata/marin1.htm for a feature called Bel Marin Keys.
[c] From melissadata.com for marina address given in pump-out survey.
[d] Assigned the lowest latitude of any of the marinas in Richardson Bay.
[e] Number of slips listed as "unknown" in survey. Assumed to be zero.

Table 2.2-17 Estimates of copper released from copper-based algaecides used in pools, spas, and fountains in the San Francisco Bay area sub-watersheds in 2003.

Watershed	Copper Released from Pool, Spa, and Fountain Algaecides, kg/y	Standard Uncertainty in Copper Released from Pool, Spa, and Fountain Algaecides, kg/y
Upper Alameda	89	69
Santa Clara Valley Central	142	109
Castro Valley	14	11
East Bay North	99	76
Upper Colma	36	27
Marin South	51	39
Coyote	233	179
East Bay Central	356	274
East Bay South	75	58
Solano West	71	54
Napa	88	66
North Napa	12	9
North Sonoma	4	3
Marin North	33	25
Contra Costa Central	192	148
Petaluma	28	22
Santa Clara Valley West	292	224
Upper San Lorenzo	14	11
Contra Costa West	69	53
Peninsula Central	194	147
Sonoma	13	10
Upper San Francisquito	5	4
Upper Corte Madera	10	8
TOTAL	2,121	

2.3 Copper in Fertilizers

Approximately 10% of the 54 million tons of commercial fertilizers used in the United States in 1996 were used in California (US EPA, 1999). Table 2.3-1 shows farm and non-farm fertilizer application by broad category of fertilizer in California in 1996. The standard uncertainty in these values is estimated to be half of the value divided by the square root of three. This estimate is meant to include errors in the data and in the gap between the year that the data represent and the year 2003.

The amount of copper in fertilizer varies from 0 to 39 g/kg. The average concentration of copper in fertilizer by fertilizer category is shown in Table 2.3-1. As this table shows, the uncertainty in these averages is large.

Farm uses of fertilizer were assigned to the sub-watersheds based on the ratio of the agricultural land use in the sub-watershed to the agricultural land use in California. Non-farm uses were assigned to sub-watersheds based on the fraction of California's population living within the sub-watershed. The uncertainties in apportioning according to land use fraction and population are estimated as half of a range of 0.5 to 1.5 of land use or population, whichever is appropriate, divided by the square root of three.

In some agricultural applications, fertilizers are tilled into the soil after application and are not entirely available for incorporation into runoff. The fraction available for runoff in agricultural applications was based on a range from 50-100%, and the uncertainty was estimated to be half of this range divided by the square root of three.

The amount of copper that is applied in fertilizers in the Bay sub-watersheds, along with the standard uncertainty in these values, is given in Table 2.3-2. Estimated copper in farm fertilizers applied to the sub-watersheds in the Bay area in 2003 is 8,600 kg/y. These applications are to agricultural land. Estimated copper in non-farm fertilizers applied to the sub-watersheds in the Bay area in 2003 is 540 kg/y. These applications are to permeable developed land.

Table 2.3-1 Values used to calculate copper loading from fertilizer use.

Fertilizer Type	Application Type	Fertilizer Applied in California in 1996, kg[1]	Standard Uncertainty in Fertilizer Applied, kg	Average Copper Concentration, mg/kg[2]	Standard Uncertainty in Average Concentration, mg/kg[3]	Copper Applied in Fertilizer in California, kg/y	Standard Uncertainty in Copper Applied, kg/y
Multinutrient	Farm	1,162,687,000	335,638,826	4	4	4,644	4,367
Multinutrient	Non-farm	316,487,000	91,361,927	4	4	1,264	1,189
N	Farm	1,706,091,000	492,506,049	4	4	6,824	7,103
N	Non-farm	0	0	4	4	0	0
P_2O_5	Farm	223,074,000	64,395,917	49	47	10,933	10,927
P_2O_5	Non-farm	0	0	49	47	0	0
K_2O	Farm	130,149,000	37,570,780	0.3	0.3	39	42
K_2O	Non-farm	0	0	0.3	0.3	0	0
Organic	Farm	78,781,000	22,742,116	114	117	8,996	9,580
Organic	Non-farm	0	0	114	117	0	0
Secondary and micronutrient[4]	Farm	1,593,276,000	459,939,164	649	405	1,033,697	711,086
Secondary and micronutrient[4]	Non-farm	3,520,000	1,016,136	649	405	2,284	1,571
Liming	Farm	621,915,000	179,531,396	86	39	53,196	28,714
Liming	Non-farm	0	0	86	39	0	0
TOTAL	Farm	5,515,973,000				1,118,330	711,863
TOTAL	Non-farm	320,007,000				3,548	1,970

[1] From US EPA, 1999.

[2] Derived from data in US EPA, 1999. Data on copper concentrations in non-farm fertilizers are not available; copper concentrations found in farm fertilizers was used for non-farm applications. Concentrations for P_2O_5 include concentrations of rock phosphates and TSP.

[3] Standard deviation in population-weighted averages from various data sources except for N, where there was only one concentration measured, and K_2O, where data on only one population was available. The values in this column are an attempt to estimate the standard deviations for the average concentration of copper in populations of fertilizers, not the standard deviation in the copper concentration of a population of individual fertilizers.

[4] Eliminated two samples with very high copper concentrations (19,400 mg/kg and 39,000 mg/kg) when obtaining average concentration and standard uncertainty in average concentration for this group of fertilizers.

Table 2.3-2 Estimates of copper released from fertilizers applied in the San Francisco Bay area sub-watersheds.

Watershed	Copper Applied in Farm Fertilizers, kg/y	Standard Uncertainty in Copper Applied in Farm Fertilizers, kg/y	Copper Applied in Non-Farm Fertilizers, kg/y	Standard Uncertainty in Copper Applied in Non-Farm Fertilizers, kg/y
Upper Alameda	621	450	23	14
Santa Clara Valley Central	65	47	36	23
Castro Valley	0	0	4	2
East Bay North	0	0	26	16
Upper Colma	0	0	9	6
Marin South	0	0	13	8
Coyote	944	684	60	37
East Bay Central	61	44	92	57
East Bay South	83	60	19	12
Solano West	1,423	1,032	18	11
Napa	1,093	792	21	13
North Napa	2,676	1,940	3	2
North Sonoma	342	248	1	1
Marin North	3	2	8	5
Contra Costa Central	66	48	49	31
Petaluma	230	167	7	5
Santa Clara Valley West	55	40	75	47
Upper San Lorenzo	0	0	4	2
Contra Costa West	24	18	18	11
Peninsula Central	0	0	48	30
Sonoma	856	621	3	2
Upper San Francisquito	31	22	1	1
Upper Corte Madera	0	0	3	2
TOTAL	8,573		541	

2.4 Copper Releases from Industrial Facilities

2.4.a Industrial Runoff and Industrial Releases to Surface Waters

Industrial runoff releases go directly to storm water drains. The estimate for releases of copper to the Bay watershed from this source, 3,300 lb/yr, is taken from the urban runoff report (TDC Environmental, 2004). This value was calculated by extrapolating copper released in industrial runoff as measured in a study in Santa Clara County to the Bay watershed based on the number of acres of facilities filing notices of intent under the State Water Resources Control Board's industrial general permit for urban storm water runoff (Grotte, 1996; SCVURP, 1997;Moran, 2005c). This value is apportioned to the sub-watersheds based on industrial/transportation/commercial land use acreage within each sub-watershed.

The uncertainty in the urban runoff result includes uncertainty in the monitoring data that the emission factor is based on, uncertainty in land use values, and uncertainty in extrapolating the monitored sites to all industrial sites. The monitoring data this value is based on was collected nearly a decade ago and the uncertainty in this value must reflect this, along with the inherent uncertainty in applying monitored data to long-term estimates of releases. This uncertainty was estimated as half of a range from 1,700 to 4,900 lb/yr, divided by the square root of three, or 900 lb/yr.

Land use values for industrial uses in the sub-watersheds include transportation and commercial uses. There is error in apportioning to the sub-watersheds by a category that includes facilities that are not part of the group of facilities the release estimates are based on. However, it is assumed that this error is negligible compared to the error in extrapolating data from monitored sites to all industrial sites. The uncertainty in extrapolating monitored sites to all industrial sites is based on half of a range of half of industrial acreage within each sub-watershed to 1.5 times the industrial acreage, divided by the square root of three.

Point values and standard uncertainties for copper in industrial runoff are given by sub-watershed in Table 2.4-1. The uncertainty associated with applying data from monitored sites to all industrial sites and the uncertainty in the release estimate of 3,300 lb/yr contribute equally to the standard uncertainty in the values of Table 2.4-1. Note that these releases are direct to storm drains.

The Toxic Chemical Release Inventory (TRI) is a database containing facility-reported release data for many chemicals. One of the reported chemicals is copper, either as elemental copper or copper in copper compounds. TRI-reported releases capture only a subset of industrial releases. Facilities are not required to report copper releases to the TRI unless they fall into manufacturing and certain other industrial classifications, have more than ten employees, and either process more than 25,000 lb/yr of copper or "otherwise use" more than 10,000 lb/yr of copper. Also, TRI reporting requirements apply only if copper is present in any facility stream at a concentration greater than 1%, regardless of the total amount of copper emitted. TRI data include information on receiving streams and facility location, along with the percentage of releases that are in storm water. In 2002, TRI-reported releases to surface waters in the 8-county region were 320 lb (US EPA, 2005). In 2003, these reported releases dropped to 39 pounds.

Three refineries that reported no copper releases to water in 2003 reported a total of 247 lb in 2002. These refineries are ConocoPhillips San Francisco Refinery, Chevron Products Co Richmond Refinery, and Shell Oil Products US Martinez Refinery. Valero Refining Co California Benicia Refinery reported 20 pounds released to water in 2002 and one pound in 2003. Other than these four refineries, facilities in the 8-county region are fairly consistent in their reporting of copper discharges to surface waters over this two-year period.

It was felt that because TRI-reported releases in the 8-county region are minimal, the effort of determining how much of the 39 pounds that are reported as released to surface waters in 2003 is entrained in storm water (and should not be included because it would result in double-counting of industrial releases of storm water) was not worthwhile.

2.4.b Industrial Air Emissions

TRI-reported air emissions of copper from 17 facilities in the 9-county region were 1,707 lb (776 kg) in 2002. This is several times larger than the value of 410 lb (186 kg) copper from 53 facilities reported by the Bay Area Air Quality Management District (BAAQMD) for 2001. However, TRI-reported releases dropped to 789 lb (359 kg) in 2003. Seven facilities that reported air releases of copper in 2002 did not report such releases in 2003. These facilities include four refineries (Chevron Products Co Richmond Refinery, ConocoPhillips San Francisco Refinery, Shell Oil Products US Martinez Refinery, and Valero Refining Co California Benicia Refinery) that together reported air releases of 427 lb (194 kg) of copper in 2002, and Waukesha Electric Systems Inc, a facility that reported 251 lb (114 kg) of copper released to air in 2002. The single largest reporter for both years is San Francisco Drydock Inc.

Part of the explanation for the discrepancy between the BAAQMD data and the TRI data is due to differences in reporting requirements. For example, only facilities releasing more than 463 lb/y (210 kg/y) of copper are required to report releases to the BAAQMD. As discussed in the previous subsection of this report, TRI-reported releases also capture only a subset of industrial releases. Thus, the number of facilities emitting copper to air is likely far larger than either the TRI or the BAAQMD database include. However, offsetting this potential for under-reporting is that many of the simplest emission estimation methodologies are conservative and result in estimated emissions that are larger than actual emissions.

Table 2.4-2 summarizes the 2002 TRI air emission data. This information will not be used in modeling of copper emissions to air, but comparing it to 2003 data provides insight into the potential for uncertainty in the values. Of the 17 facilities that reported copper releases to air in 2002, four were refineries, one was an organic chemical manufacturer, one was a secondary nonferrous metals manufacturer, one was a maker of aluminum die-cast parts, one was a non-electronic transformer manufacturer, one was a commercial lighting fixture manufacturer, one was an electron tube manufacturer, four made cathode ray television picture tubes, one made electronic components not elsewhere classified, one made motor vehicles and car bodies, and one was a ship building and repair facility. Clearly, not all facilities in these industrial classification categories are reporting releases of copper to air.

Table 2.4-3 gives 2003 TRI air emission data for copper, including information on the latitude and longitude of reporting companies. The latitude and longitude data can be used to accommodate these releases spatially during modeling. Some of these facilities may fall outside of the greater watershed boundary.

BAAQMD data is not available by facility or facility address. Thus, it is impossible to know what BAAQMD values are duplicated by TRI reporting or what sub-watersheds to assign the BAAQMD releases to.

A comparison of 2001 TRI data on air releases for the Great Lakes states and 2001 air toxics data published by the Great Lakes Commission (GLC) sheds some light on the uncertainty in reported industrial air emissions. This comparison suggests that in the aggregate, TRI-reported releases for the industry categories listed in Table 2.4-2 range from twice as high as GLC air toxics data to a third of GLC air toxics data.

It was hoped that data on county business patterns might allow a second means of estimating industrial air emissions of copper in the Bay area by assuming emissions per employee in the Great Lakes states are roughly the same as they are in California for some industry categories. The Great Lakes air toxics and TRI data are collected by Standard Industrial Classification (SIC) code. However, since 1998, county business patterns have been collected not by SIC code but by NAICS code, and there is no one-to-one correspondence between the two classification systems for many industry categories. Employment trends in the Great Lakes region are too volatile to apply four-year old data on employees and hope to achieve anything meaningful. Also, the Great Lakes air toxics data do not clearly include a universal set of reporting facilities for copper.

TRI-reported values for the year 2003, as presented in Table 2.4-3, will be used as point estimates of industrial copper emissions to air. The standard uncertainty in these values is assumed to be 33% of the point value.

Table 2.4-1 Estimates of copper released in industrial runoff in the San Francisco Bay area sub-watersheds.

Watershed	Copper Released in Industrial Runoff, kg/y	Standard Uncertainty, kg/y
Upper Alameda	79	31
Santa Clara Valley Central	49	19
Castro Valley	3	1
East Bay North	58	23
Upper Colma	6	2
Marin South	26	10
Coyote	155	62
East Bay Central	282	112
East Bay South	83	33
Solano West	85	34
Napa	63	25
North Napa	6	2
North Sonoma	1	0
Marin North	20	8
Contra Costa Central	121	48
Petaluma	24	10
Santa Clara Valley West	202	80
Upper San Lorenzo	5	2
Contra Costa West	59	23
Peninsula Central	160	64
Sonoma	6	3
Upper San Francisquito	3	1
Upper Corte Madera	1	0
TOTAL	1,500	

Table 2.4-2 TRI-reported air emissions of copper in the 9-county San Francisco Bay region in 2002 (for comparison with 2003 TRI-reported releases) (US EPA, 2005a).

Facility Name	SIC Code Description	Reported Air Emissions, kg/y
Shell Chemical Co. Martinez Catalyst Plant	Industrial organic chemicals nec	0.01
Chevron Products Co Richmond Refinery	Petroleum refining	32
ConocoPhillips San Francisco Refinery	Petroleum refining	114
Shell Oil Products US Martinez Refinery	Petroleum refining	47
Valero Refining Co California Benicia Refinery	Petroleum refining	0
ECS Refining	Secondary nonferrous metals	6
Pressure Cast Products Corp	Aluminum die-castings (1987)	2
Waukesha Electric Sys. Inc.	Transformers except electronic	114
Shaper Lighting	Commercial lighting fixtures	1
Communications & Power Industries Inc Eimac Div	Electron tubes	27
Pycon Inc	Cathode ray television picture tubes (disc. 1987 3671)	2
South Bay Circuits Inc	Cathode ray television picture tubes (disc. 1987 3671)	116
Sprig Circuits Inc	Cathode ray television picture tubes (disc. 1987 3671)	1
Viko Technology Inc Adaptive Circuits Div	Cathode ray television picture tubes (disc. 1987 3671)	2
Isola USA Corp	Electronic components nec	2
New United Motor Manufacturing Inc	Motor vehicles and car bodies	114
San Francisco Drydock Inc	Ship building and repairing	195
TOTAL		776

Table 2.4-3 TRI-reported air emissions of copper in the 9-county San Francisco Bay region in 2003 (US EPA, 2005b)

Facility	City	Facility-Reported Latitude	Facility-Reported Longitude	Preferred Latitude	Preferred Longitude	Reported Release, kg/y	Standard Uncertainty, kg/y
Isola USA Corp	Fremont	372024	1242236	37.469698	121.918306	4	1
Titan PCB West Inc	Fremont	373028	1215650	37.508333	121.936111	114	38
New United Motor Manufacturing Inc	Fremont	372924	1215630	37.484722	121.941667	5	2
Pressure Cast Products Corp	Oakland	374620	1221259	37.772222	122.216389	2	1
Communications & Power Industries Inc Eimac Div	San Carlos	373052	1201604	37.514444	122.267778	20	7
San Francisco Drydock Inc	San Francisco	374540	1222245	37.761111	122.379167	195	64
South Bay Circuits Inc	San Jose	371653	1215038	37.281389	121.843889	5	2
Viko Technology Inc Adaptive Circuits Div	San Jose	372146	1215314	37.366667	121.851667	2	1
ECS Refining	Santa Clara	372140	1225640	37.3615	121.9382	9	3
Pycon Inc	Santa Clara	373330	1215929	37.383822	121.955817	2	1
Sprig Circuits Inc	Vacaville	382100	1220000	38.417222	121.970833	1	0.3
Total						359	

2.5 Copper in Domestic Water Discharged to Storm Drains

This source consists of domestic water that contains copper because it has passed through copper pipes. An example of these discharges is domestic water that is lost to storm drains during irrigation. The methodology from the urban runoff report was used for estimating these releases. This approach is to extrapolate copper discharged to storm drains as measured in a study in Santa Clara County to the Bay area based on population. Copper in domestic water in the Santa Clara County study was found to be 0.0004 lb Cu/person/yr (derived from TDC Environmental, 2004).

Note that this methodology is expected to produce an upper bound estimate because it is based on tap water concentrations of copper. It is likely that domestic water discharges to storm drains pass through less copper piping than tap water does. In fact, in many cases, irrigation water passes through no copper piping. A lower bound for the emission factor was assumed to be an order of magnitude smaller, or 0.00004 lb Cu/person/yr. The midpoint of this range (0.0002 lb Cu/person/yr) was used to produce the estimate of copper released to storm drains from domestic water discharges, and the standard uncertainty is half of the range divided by the square root of three, or 0.0001 lb Cu/person/yr. The uncertainty in extrapolating this to all domestic water discharges within the Bay area is assumed to be relatively negligible.

Table 2.5-1 provides estimates of copper in domestic water discharged to storm drains in 2003 for the sub-watersheds, along with the standard uncertainty in these estimates. These releases are direct to storm drains. They total 516 kg in the greater Bay watershed.

Table 2.5-1 Estimates for copper in domestic water discharged to storm drains in the San Francisco Bay area sub-watersheds.

Watershed	Copper in Domestic Water Discharged to Storm Drains, kg/y	Standard Uncertainty, kg/y
Upper Alameda	22	10
Santa Clara Valley Central	35	16
Castro Valley	4	2
East Bay North	24	12
Upper Colma	8	4
Marin South	13	6
Coyote	57	27
East Bay Central	88	41
East Bay South	19	9
Solano West	17	8
Napa	20	10
North Napa	3	1
North Sonoma	1	0.5
Marin North	8	4
Contra Costa Central	47	22
Petaluma	7	3
Santa Clara Valley West	71	34
Upper San Lorenzo	3	2
Contra Costa West	17	8
Peninsula Central	46	22
Sonoma	3	2
Upper San Francisquito	1	1
Upper Corte Madera	3	1
TOTAL	516	

3 Sources Not Included in this Inventory

Release estimates for sources whose contribution to copper in urban runoff to the Bay were estimated to be minimal in the urban runoff report were not developed for this inventory. These sources include fuel combustion, which was estimated to release 10 to 200 lb/yr of copper to air in the nine Bay area counties each year (TDC Environmental, 2004). Another source that falls into this category is wood burning, which was estimated to release 340 lb/yr of copper to air in the nine Bay area counties (TDC Environmental, 2004). The final source identified as minor in the urban runoff report is vehicle fluid leaks. An estimated 600 lb/yr of copper is released due to vehicle fluid leaks (mostly coolant dumping, but some coolant leaks as well) in the nine-county Bay area (TDC Environmental, 2004).

Also, copper released from soil erosion will be calculated by the runoff model and was not estimated in this inventory.

Copper runoff from landfills was not inventoried because modern landfills are regulated under the Resource Conservation and Recovery Act (RCRA) and landfill leachate is managed and treated either on-site or routed to sewer. Old landfills in the Bay area are regulated under programs for closed landfills and have been controlled since the 1980s. Demolition debris that was dumped around the edges of San Francisco after the 1906 earthquake is now covered and paved, and is surrounded by engineered fill.

Brush-type DC motors and generators (including car and truck alternators) use copper in their commutators. Some wear of the commutator occurs during operation. Copper released from commutator wear escapes to the environment, but the magnitude of these releases is expected to be small in comparison to copper releases from vehicle brake wear.

There is a potential for copper to be released from the exposed copper that provides power to electrically powered public transit systems, either as mechanically abraded particles or as very small particulate matter that is generated when arcing occurs between the contacts. Copper releases from electrically powered public transit systems were not inventoried because they are expected to be small. BART has not prepared any studies of the losses of copper from its conducting surfaces, and to the author’s knowledge, no such studies exist in the literature. The only location in the Bay area where public transit relies on exposed overhead copper wires is a small area in San Francisco where runoff drains to sewer and is treated before discharge. Also, BART is required to treat the wash off water from their trains before discharging it to the sewer, so copper that adheres to the trains is removed and treated before discharge.

Copper losses from the brake lining materials of electrically powered public transit systems are also expected to be small. The manufacturer of the brake pads used for BART trains has indicated that the copper/brass content of the pads is less than one percent by weight (Kahr, 2004).

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