Characteristics of Effluents from Power Generating Stations in 1994

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Point source dischargers to the Southern California Bight (SCB) include municipal wastewater treatment facilities, power generating stations, and industrial dischargers. Since the early 1970s, 90% of the municipal wastewater effluents discharged directly to the Southern California Bight (SCB) have come from the four largest treatment facilities: Hyperion Treatment Plant (City of Los Angeles), Joint Water Pollution Control Plant (JWPCP) of the County Sanitation Districts of Los Angeles County, Wastewater Treatment Plants 1 and 2 of County Sanitation Districts of Orange County (CSDOC), and Point Loma Wastewater Treatment Plant (PLWTP) of the City of San Diego. Southern California Coastal Water Research Project (SCCWRP) has published annual effluent constituent concentrations and mass emission estimates for these four facilities for two decades (see *Characteristics of Effluents from Large Municipal Wastewater Treatment Plants in 1994* in this report). Effluent characteristics for small municipal wastewater treatment facilities (see *Characteristics of Effluents from Small Municipal Wastewater Treatment Plants in 1994* in this report), power generating stations, and industrial dischargers have been summarized less frequently. SCCWRP summarized flow of the power generating stations for 1970-71, 1987, and 1989 (SCCWRP 1973, 1989, 1990). As mass emissions from the large facilities continue to decline, inputs to the SCB from the small municipal wastewater facilities, power generating stations, and industrial dischargers may become more significant. Hence, we will summarize the mass emissions from these facilities more frequently. Effluents from industrial dischargers will be summarized in the future.

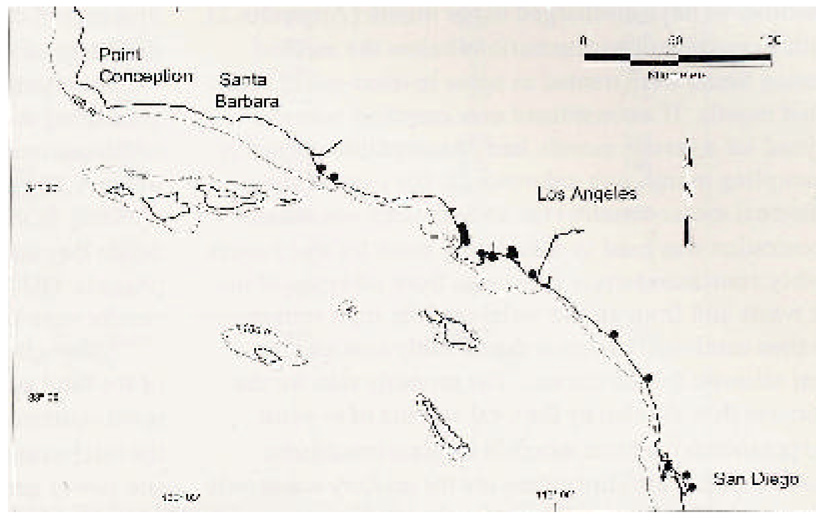

FIGURE 1. Locations of the power generating stations that discharged to the Southern California Bight in 1994.

In this report, we summarize effluent flows and constituent concentrations and estimate mass emissions from in-plant flow for the coastal power generating stations of Southern California for 1994, and discuss trends in flow from these facilities since 1970.

There are 15 power generating stations that discharge to the SCB (Figure 1; Appendix 1). All, except the San Onofre Nuclear Generating Station (SONGS), are conventional thermal power plants that use fossil fuels such as oil or natural gas (SCCWRP 1973). Whereas coastal municipal wastewater treatment facilities and industrial plants discharge effluent directly into the ocean, power generating stations discharge a low volume of treated in-plant wastes into a stream of once-through cooling water (seawater) that has circulated through the plant to cool condensers before entry into the receiving waters (MBC 1988). In-plant waste can consist of various types of waste such as boiler blowdown, metal cleaning waste, and sanitary waste. Generating stations may have more than one outfall (serial outfalls) that discharge various types of in-plant waste.

MATERIALS AND METHODS

We obtained data on effluent characteristics of the power generating stations from the effluent monitoring data reports that are required by the Regional Water Quality Control Boards (Los Angeles, Santa Ana, and San

Diego Regions) under the National Pollutant Discharge Elimination System (NPDES) permits.

Constituent concentrations and mass emission estimates of total in-plant waste were calculated using constituent analyses and flow rate measurements of the in-plant waste.

Monthly contaminant mass emissions were estimated from the product of mean daily flow of a particular in-plant waste (e.g. low volume, mud sump, metal cleaning) and its respective constituent concentration in month *i* and the number of days discharged in the month (Appendix 2). Monthly constituent concentrations below the method detection limits were treated as zeros in mass calculations for that month. If a constituent concentration was not analyzed for a certain month, had unacceptable results, or the sampling month was unknown (in the case of some semiannual measurements) the annual mean constituent concentration was used in calculating mass for that month. Monthly constituent mass emissions from all types of in-plant waste and from all the serial outfalls for a station were then combined to obtain the monthly sum and the annual estimate for the station. The monthly sum for the station was then divided by the total volume of in-plant waste per month to obtain monthly in-plant constituent concentrations. Turbidity means are for sanitary waste only.

If our calculated annual mean for the total in-plant waste was below the method detection limit reported by the power plant, we reported the method detection limit as the annual mean. However, mass emissions were estimated for all months with measurable concentrations even though annual mean constituent concentrations may have been below detection limits.

SONGS, Encina, Station “B”, and South Bay report some of their constituent analyses results in pounds per day. When flow was available, these mass estimates were back-calculated to concentrations and then concentrations were used for mass estimates for months not measured; otherwise estimates in pounds per day were used.

RESULTS

In 1994, the total cooling water flow of the 15 coastal power generating stations was 7233 million gallons per day (mgd) (27.4×10^9 L/day) (Table 1). Daily flow rates varied over three orders of magnitude among the small facilities. The total daily in-plant waste flow of all the generating stations was 3 mgd (11.4×10^6 L/day) (Table 2a). The average daily flow of in-plant waste was 0.2 mgd. Discharge temperatures ranged from 16 to 51°C (60 to 124°F).

Eighty percent of the constituent concentrations and toxicity values varied by an order of magnitude or more among the power plants (Table 2a). At individual treatment plants, 73% of the annual mean constituents concentrations and toxicity values above method detection limits had coefficients of variation higher than 50%.

Mass emissions from in-plant waste also varied greatly among the power generating stations. Long Beach Generating Station (LBGS) had the highest emissions of suspended solids (Table 2b). Ormond Beach Generating Station had the highest emission of oil and grease. The four most common trace metals analyzed were copper, chromium, nickel, and zinc; Encina had the highest dicharge of chromium and nickel, SONGS had the highest discharge of copper, lead, and zinc.

The combined emission of all trace metals for the power generating stations was 1.78 metric tons (mt). The highest combined mass emission of an individual trace metal was below 1.28 mt for copper (Table 2b).

Only SONGS, Encina, Silvergate, Station “B”, and South Bay analyzed chlorinated and nonchlorinated phenols, DDTs, and PCBs in their in-plant waste; all results were below detection limits (Table 2b).

Although power generating stations accounted for 86% of the total volume of water discharged to the ocean by point sources, their in-plant flow comprised only 0.04% of the total treated effluent flow from municipal wastewater and power generating stations discharged to the SCB in 1994 (Table 3). In-plant waste from power generating stations accounted for <0.001 to 7% of the combined mass emissions of individual constituents discharged to the SCB, with most contributions of individual constituents being less than 1%. Contributions higher than 1% were for copper and lead.

DISCUSSION

The annual combined volume of cooling water discharged from the power generating stations increased 30% from 1970 to 1994 and 21% from 1989 to 1994 (Table 1) (SCCWRP 1973, 1989, 1990). The volume of cooling water declined from 1985 to 1988 since utilities started importing more power generated outside of Southern California (Figure 2).

The estimated monthly concentrations of some constituents varied substantially at individual power plants. Coefficients of variation higher than 100% generally were due to a high proportion of monthly concentrations below detection limits.

Estimated concentrations of in-plant waste constituents are only calculated as a frame of reference, not as the true concentration at the time of discharge. Estimates of concentrations of most of the constituents are based on calculating mass emissions from various sources of in-plant waste from different serial outfalls for each power plant. These were combined into one concentration. In

TABLE 1. Cooling water flows for power generating stations discharging to the Southern California Bight in 1970, 1987, 1989, and 1994.

	Cooling Water Flow[a] (mgd)			
Power Generating Station	1970[b]	1987[c]	1989[d]	1994
Mandalay Generating Station	230	200	167	201
Ormond Beach Generating Station	740	583	501	622
Scattergood Generating Station	180	273	71	343
El Segundo Generating Station	360	316	306	283
Redondo Generating Station	710	618	541	587
Harbor Generating Station	80	182	27	64
Long Beach Generating Station	60[e]	102	75	112
Haynes Generating Station	760	910	193	785
Alamitos Generating Station	840	930	683	718
Huntington Beach Generating Station	470	201	170	146
San Onofre Nuclear Generating Station	400	2310	2467	2436
Encina Power Plant	160[e]	404	400	462
Silvergate Power Plant	160[e]	3	5	2
Station “B” Power Plant	70[e]	2	1	1
South Bay Power Plant	360[e]	392	390	472
Total	5580	7425	5997	7233

[a]Values do not include in-plant waste.
[b]SCCWRP (1973).
[c]SCCWRP (1989).
[d]SCCWRP (1990).
[e]Estimated values for the year 1971.
mgd = million gallons per day (1 mgd= 3,785,000 liters/day).

reality, each serial outfall of a single power plant may have its own in-plant waste with different concentrations and each source of in-plant waste (metal cleaning, sanitary waste, boiler blowdown, etc.) may be added to the cooling water at different times. Also, concentrations are diluted (350 to 9700 times for 1994) by addition to the cooling water before it is discharged into the ocean.

Except for SONGS, Encina, Station “B”, and South Bay which analyze trace metals in their in-plant flow, many of the stations did not have any metal concentrations for in-plant waste. This is because the remaining power generating stations are required only to measure trace metals in certain types of in-plant waste such as metal cleaning wastes, oil recovery system wastes (LBGS), and boiler blowdown wastes. Frequently there will not be any discharge of that particular type of waste during the year.

In-plant flow of the power generating stations were a minor source of contaminants to the SCB during 1994. MBC (1988) also found the contribution of mass loadings from in-plant flow by generating stations during 1983-84 to the Santa Monica Bay to be small. Contributions of oil and grease, zinc, copper, nickel, chromium, lead, silver, and cadmium by Scattergood, El Segundo, and Redondo Generating Stations comprised only 0.02 to 0.2% of the combined mass emissions from various point and nonpoint sources to the bay.

CONCLUSIONS

Although power generating stations accounted for 86% of the water discharged to the ocean from point sources, their in-plant waste is not an important source of contaminants to the SCB. The in-plant flow of the power generating stations accounted for 0.04% of treated effluent flow and <0.001 to 7% of the mass emissons of individual constituents discharged to the SCB, with most contributions being less than 1%. The highest percent contributions by the plants were in copper and lead, but they still made up less than 10% of the input of these individual constituents to the SCB. Although the contribution of in-plant waste from power generating stations is currently low, their relative contribution may increase in the future as constituent emissions from the large municipal wastewater treatment facilities decrease.

TABLE 2. In-plant waste effluents from power generating stations discharging to the Southern California Bight in 1994.[a]

a) Flow and annual constituent concentrations[b].

	Mandalay		Ormond Beach		Scattergood		El Segundo		Redondo		Harbor		Long Beach	
Constituent	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
In-plant flow (mgd)	0.06	27	0.50	19	0.21	42	0.16	0.98	0.44	43	0.026	76	0.62	17
In-plant flow (million L/day)	0.2	27	1.9	19	0.81	42	0.59	0.98	1.68	43	0.99	76	2.3	17
Suspended solids (mg/L)	8	47	6.11	41	11	86	10	67	6.2	78	1.9	78	26.5	23
Settleable solids(mL/L)	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-
BOD (mg/L)	-	-	-	-	-	-	0.1	154	-	-	-	-	-	-
Oil & Grease (mg/L)	5	33	6.43	37	<3	-	4.4	76	5.2	43	<3	-	5.2	72
Ammonia-N (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyanide (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity (NTU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxicity (TU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromium (mg/L)	-	-	-	-	0.9	346	-	-	-	-	-	-	-	-
Copper (mg/L)	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-
Lead (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel (mg/L)	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-
Selenium (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zinc (mg/L)	-	-	-	-	9.7	60	-	-	-	-	-	-	-	-
Phenols (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorinated[f]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nonchlorinated[f]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DDT (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

b) Estimated flow volume and constituent mass emissions.

Constituent	Mandalay	Ormond Beach	Scattergood	El Segundo	Redondo	Harbor	Long Beach	Haynes
In-plant flow (L x 10^9/yr)	0.079	0.68	0.29	0.21	0.61	0.036	0.85	0.15
Suspended solids (mt)	0.67	4.2	3.6	2.7	3.4	0.07	23	2.3
BOD (mt)	-	-	-	0.02	-	-	-	0.02
Oil & Grease (mt)	0.40	4.3	0.07	0.95	2.9	-	4.1	0.001
Ammonia-N (mt)	-	-	-	-	-	-	-	-
Cyanide (kg)	-	-	-	-	-	-	-	-
Arsenic (kg)	-	-	-	-	-	-	-	-
Cadmium (kg)	-	-	-	-	-	-	-	-
Chromium (kg)	-	-	0.14	-	-	-	-	0.01
Copper (kg)	-	-	0.01	-	-	-	-	0.09
Lead (kg)	-	-	-	-	-	-	-	-
Mercury (kg)	-	-	-	-	-	-	-	-
Nickel (kg)	-	-	0.006	-	-	-	-	-
Selenum	-	-	-	-	-	-	-	-
Silver (kg)	-	-	-	-	-	-	-	-
Zinc (kg)	-	-	2.4	-	-	-	-	0.10
Phenols (kg)	-	-	-	-	-	-	-	-
Chlorinated[f]	-	-	-	-	-	-	-	-
Nonchlorinated[f]	-	-	-	-	-	-	-	-
DDT (kg)	-	-	-	-	-	-	-	-
PCB (kg)	-	-	-	-	-	-	-	-

[a]Silvergate Power Plant did not have any in-plant waste during 1994.
[b]The number of significant figures of concentration are those reported by the power generating stations.
[c]Includes only retention basin data. Data does not include yard drains or boiler blowdown wastes.
[d]Calculated from estimates of discharges given in units of pounds per day.
[e]Only includes chromium VI.
[f]EPA method 604 or 625 (GC/MS method).
[g]Maximum detection limit reported.
[h]The mass emissions used to back calculate concentrations may have been misreported 1000 times too high (David Kay, Southern California Edison Company, Rosemead, CA, pers. comm. 1996).
[i]Only includes 2,4,6-trichlorophenol and pentachlorophenol.
BOD=biochemical oxygen demand; CV=coefficient of variation; mgd=million gallons per day; nd=not detectable; NTU=nephelometric turbidity units; TUa=toxicity units.

Haynes		Alamitos		Huntington Beach[b]		San Onofre[c]		Encina		Station "B"		South Bay	
Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
0.13	51	0.074	10	0.04	70	0.6	2	0.1	66	0.002	162	0.076	42
0.47	51	0.28	10	0.2	70	2	2	0.5	66	0.006	162	0.29	42
10	58	15	42	13	28	6.9	24	2	149	19	104	2.4	72
<0.1	-	<0.1	-	-	-	<0.1	-	-	-	-	-	-	-
<2	-	0.2	67	-	-	-	-	-	-	-	-	-	-
<3	-	3	57	3.4	55	2	60	0.6	245	0.9	109	1.7	71
-	-	-	-	-	-	<100	-	1.75[d]	141	0.45[d]	-	0.06[d]	141
-	-	-	-	-	-	nd	-	<40[d]	-	11[d]	-	<20[d]	-
-	-	-	-	-	-	14	91	-	-	-	-	-	-
-	-	-	-	-	-	0	-	-	-	0	-	-	-
-	-	-	-	-	-	nd	-	8.5[d]	58	<2[d]	-	<2[d]	-
-	-	-	-	-	-	nd	-	<2[d,g]	-	3[d]	-	<1[d]	-
<20	-	-	-	-	-	0.9[e]	71	40[d]	141	4[d,e]	-	15[d]	24
<10	-	-	-	-	-	1,284[h]	69	107[d]	99	25[d]	-	79[d]	57
-	-	-	-	-	-	329[h]	67	38[d]	30	11[d]	-	22[d]	39
-	-	-	-	-	-	nd	-	1[d]	141	0.3[d]	-	<10[d,g]	-
<40	-	-	-	-	-	1.4	62	58[d]	90	10[d]	-	9[d]	0.8
-	-	-	-	-	-	nd	-	-	-	-	-	-	-
-	-	-	-	-	-	21	62	<2[d,g]	-	<10[d]	-	<1[d]	-
3	77	-	-	-	-	118	43	11[d]	141	110[d]	-	68[d]	60
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	nd	-	<7[d,g]	-	<3.6[d]	-	<3.6[d]	-
-	-	-	-	-	-	nd	-	<85[d,g]	-	<42[c]	-	<42[d]	-
-	-	-	-	-	-	nd	-	<1[d,g]	-	<0.02[d]	-	<0.09[d,g]	-
-	-	-	-	-	-	nd	-	<7[d,g]	-	<0.05	-	<0.60[d,g]	-

Alamitos	Huntington Beach[b]	San Onofre[c]	Encina	Station "B"[c]	South Bay	Total
0.10	0.058	0.78	0.17	0.002	0.10	4.1
1.5	0.78	5.4	0.25	0.03	0.25	48
0.02	-	-	-	-	-	0.06
0.35	0.21	1.5	0.07	0.002	0.16	15
-	-	0.02	0.28	0.001	0.005	0.31
-	-	-	-	0.025	-	0.025
-	-	-	1.4	-	-	1.4
-	-	-	-	0.006	-	0.006
-	-	0.83[e]	6.6	0.01[e]	1.5	9.1
-	-	1,250[h]	18	0.06	8.5	1,277
-	-	320[h]	6.3	0.03	2.2	329
-	-	-	0.17	0.0007	-	0.17
-	-	1.2	9.6	0.02	1.0	12
-	-	-	-	-	-	0
-	-	19	-	-	-	19
-	-	107	1.7	0.25[i]	7.3	119
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

TABLE 3. Comparison of constituent mass emissions from power generating stations, and large (>150 mgd) and small (<25 mgd) municipal wastewater treatment facilities that discharged to the Southern California Bight in 1994.

	Mass Emissions				Percent of Total		
Constituent	Power Plants (n=15)	Large POTWs[a] (n=4)	Small POTWs[b] (n=15)	Total	Power Plants	Large POTWs	Small POTWs
Total flow (mgd)	7,236[c] (3[d])	1,069	131	8,436	86[c] (0.04[d])	13	2
Suspended solids (mt)	48	68,126	1,737	69,911	0.07	97	2
BOD (mt)	0.06	132,257	2,207	134,464	<0.001	98	2
Oil & Grease (mt)	15	18,534	377	18,926	0.08	98	2
Ammonia-N (mt)	0.31	41,106	3,118	44,224	<0.001	93	7
Cyanide (kg)	0.025	12,000	2,200	14,200	<0.001	85	15
Arsenic (kg)	1.4	4,000	400	4,401	0.03	91	9
Cadmium (kg)	0.006	700	900	1,600	<0.001	44	56
Chromium (kg)	9.1	6,700	1,600	8,309	0.1	81	19
Copper (kg)	1,277[e]	49,000	3,200	53,477	2	92	6
Lead (kg)	329[f]	1,300	2,800	4,429	7	29	63
Mercury (kg)	0.17	30	8	38	0.4	79	21
Nickel (kg)	12	28,000	4,900	32,901	0.004	85	15
Silver (kg)	19	5,700	1,400	7,119	0.3	80	20
Zinc (kg)	119	72,000	11,000	83,119	0.1	87	13
DDT (kg)	nd	7.9	0.07	8	-	99	1
PCB (kg)	nd	nd	0.09	0.09	-	-	-

[a]Hyperion Wastewater Treatment Plant (City of Los Angeles), Joint Water Pollution Control Plant (County Sanitation Districts of Los Angeles County), Wastewater Treatment Plants 1 and 2 (County Sanitation Districts of Orange County), and Point Loma Wastewater Treatment Plant (City of San Diego).
[b]See *Characteristics of Effluents from Small Municipal Wastewater Facilities in 1994* in this report.
[c]Combined discharge (includes cooling water and in-plant waste effluent flow).
[d]Inplant waste effluent.
[e]This value may be about 1,250 kg too high due to a possible reporting error (see Table 2b - San Onofre).
[f]This value may be about 320 kg too high due to a possible reporting error (see Table 2b - San Onofre).
BOD=biochemical oxygen demand.
mgd=millions of gallons per day (1 mgd=3,785,000 L/day).
mt=metric tons.
nd=nondetectable.
POTWs=publicly owned treatments works.

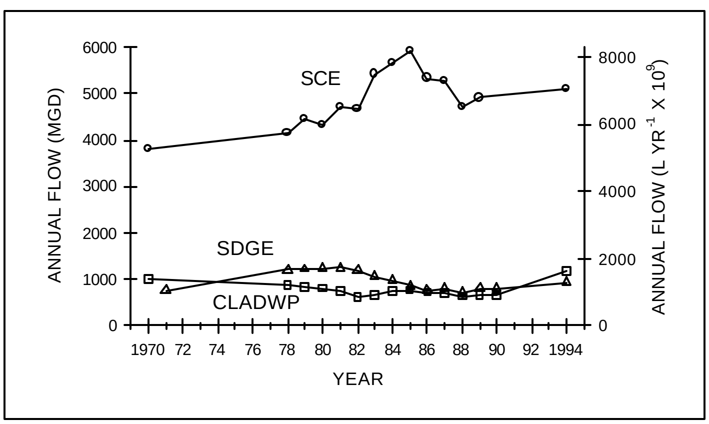

FIGURE 2. Cooling water flow from coastal power generating stations in Southern California from 1970 to 1994 (MGD = millions of gallons per day). CLADWP = City of Los Angeles, Department of Water and Power; SCE = Southern California Edison Company; SDGE = San Diego Gas and Electric Company.

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APPENDIX 1.

Names, locations, and organizations of the power generating stations that discharged to the Southern California Bight in 1994.

Power Generating Station	Location	Organization
LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD		
Mandalay Generating Station	Oxnard	SCE
Ormond Beach Generating Station	Port Hueneme	SCE
Scattergood Generating Station	El Segundo	CLADWP
El Segundo Generating Station	El Segundo	SCE
Redondo Generating Station	Redondo Beach	SCE
Harbor Generating Station	Los Angeles Harbor	CLADWP
Long Beach Generating Station	Long Beach Harbor	SCE
Haynes Generating Station	Long Beach	CLADWP
Alamitos Generating Station	Long Beach	SCE
SANTA ANA REGIONAL WATER QUALITY CONTROL BOARD		
Huntington Beach Generating Station	Huntington Beach	SCE
SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD		
San Onofre Nuclear Generating Station (SONGS)	San Onofre	SCE
Encina Power Plant	Carlsbad	SDGE
Silvergate Power Plant	San Diego Bay	SDGE
Station "B" Power Plant	San Diego Bay	SDGE
South Bay Power Plant	San Diego Bay	SDGE

APPENDIX 2.
Mass Emission Equation

Annual mass emissions (ME) of constituents were estimated from:

$$ME = \sum_{i=1}^{12} (F_i C_i D_i)$$

where

F_i = mean daily flow in month *i*:
C_i = constituent concentration in month *i*, or annual mean concentration (for months not measured); and
D_i = number of days in month *i*.