APPENDICES

ANALYSIS OF THE POTENTIAL BENEFITS

RELATED TO IMPLEMENTATION OF

THE CALIFORNIA TOXICS RULE

June, 1997

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These appendices were prepared in support of the report: Analysis of the Potential Benefits Related to Implementation of the California Toxics Rule (U.S. EPA 1997) under the direction of Christine Ruf, U.S. EPA, Office of Policy, Planning and Evaluation, Office of Sustainable Ecosystems and Communities, and Diane Frankel, U.S. EPA, Region IX, San Francisco, California. Industrial Economics Inc. prepared the Appendices and performed much of the analysis and technical evaluation presented here.

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JUNE 1997

Appendix A

1994 ASSESSMENT OF CALIFORNIA WATER QUALITY BY REGION, FOR TOXICS

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Appendix A summarizes information on toxics water quality in California waters, and is based on the State's Water Quality assessment (WQA) database, developed and maintained by the State Water Resources Control Board (SWRCB). The WQA is a compilation of data from the State's nine regional Water Quality Control Boards and is organized by region and by waterbody type. It contains a range of information on surface water pollution, including the pollutants that adversely affect water quality, bodies of water that have been evaluated, the sources of pollution, the beneficial uses impaired, and an overall rating of water quality. The State relies on the WQA to develop the biennial water quality report required by section 305(b) of the Clean Water Act. The WQA was last updated in 1994. A description of the data and methodology used to develop these appendices is presented in Chapter 2, Characterization of Baseline Water Quality, *Analysis of the Potential Benefits Related to Implementation of the California Toxics Rule* (U.S. EPA, June 1997).

It is important to note that information on the extent to which California surface waters currently meet the proposed toxic water quality criteria is incomplete. Water quality conditions in many State waters have not been fully assessed, and assessments of waters that have been evaluated often do not contain monitoring data that is extensive or detailed enough to determine whether the waterbody meets all of the proposed criteria. According to water quality experts from U.S. EPA and the State of California, extrapolating information presented in these Appendices to all waters in the State may create a bias towards overestimating the extent of toxics contamination Statewide. These include assuming that the percentage of toxics impairment found in assessed waters was the same as the percentage of toxic impairment of waters throughout the State; that waters rated as medium impaired waters (those which partially support their uses) were conducted together with those rated as poor impaired waters (those which do not support their uses); and that waters listed as impaired in one data base, and associated with toxics in a second data base, were considered waters impaired by toxics.

Although the consensus of the U.S. EPA and State experts is that the above assumptions may have created a bias toward overestimating toxics contamination Statewide, they also stated that certain other assumptions used in the analysis may have created a bias in *underestimating* the extent of toxics contamination. For example, the assumption that the type and scope of all toxics of concern in all State waters appear in the WQA data base may underestimate the extent of toxics impairment because of the infrequency of ambient monitoring throughout the State, or because of the difficulty of detecting the ambient concentrations of certain toxic pollutants when their water quality criteria fall below the minimum detection limit. Consequently, because of all of the uncertainties associated with the WQA data base, State of California and U.S. EPA experts advise against an attempt to quantitatively estimate the magnitude of the bias in either direction.

Region 1: North Coast Region

Hydrologic Setting

The North Coast Region covers approximately 18,000 square miles in the northwest corner of California. It is bounded by the Pacific Ocean to the west, the California/Oregon border to the north, the Modoc National Forest and the Trinity Mountains to the east, and the Marin-Sonoma Area to the south. The topography consists mostly of rugged forested coastal mountains, divided by six major river systems: the Eel, Russian, Mad, Navarro, Gualala, and Noyo Rivers. The area along the eastern boundary is mostly National Forest land, with land use under the control of the National Forest Service. Major population areas center around Humboldt Bay in the northern portion of the basin and around Santa Rosa in the southern portion.[1]

The North Coast Region receives the highest levels of precipitation in the State. The North Coast Region constitutes only about 12 percent of the area of California but produces nearly 40 percent of the annual water runoff. The runoff contributes to river flow and storage in lakes and reservoirs; however, in combination with generally unstable soils, runoff has also created the hazard of damaging floods.[2]

Figure A-1 displays the major waterbodies of the North Coast Region.

Degree and Sources of Toxics Impairment

Excluding bay areas, North Coast Region waters are relatively free of toxic contamination. The types of toxic pollutants in the Region are limited to metals and pesticides, the primary sources of which are agriculture, industry, municipalities, and urban runoff. Analysis of the WQA database yields the following information:

- As summarized in Exhibit A-1, toxic pollutants impair a significant portion of the bays assessed, but very little of other waterbody types. Toxics impair 16,500 acres of bays (55 percent of assessed) but only 625 acres of estuaries (2 percent of assessed) and 16 miles of rivers and streams (less than 1 percent of assessed).

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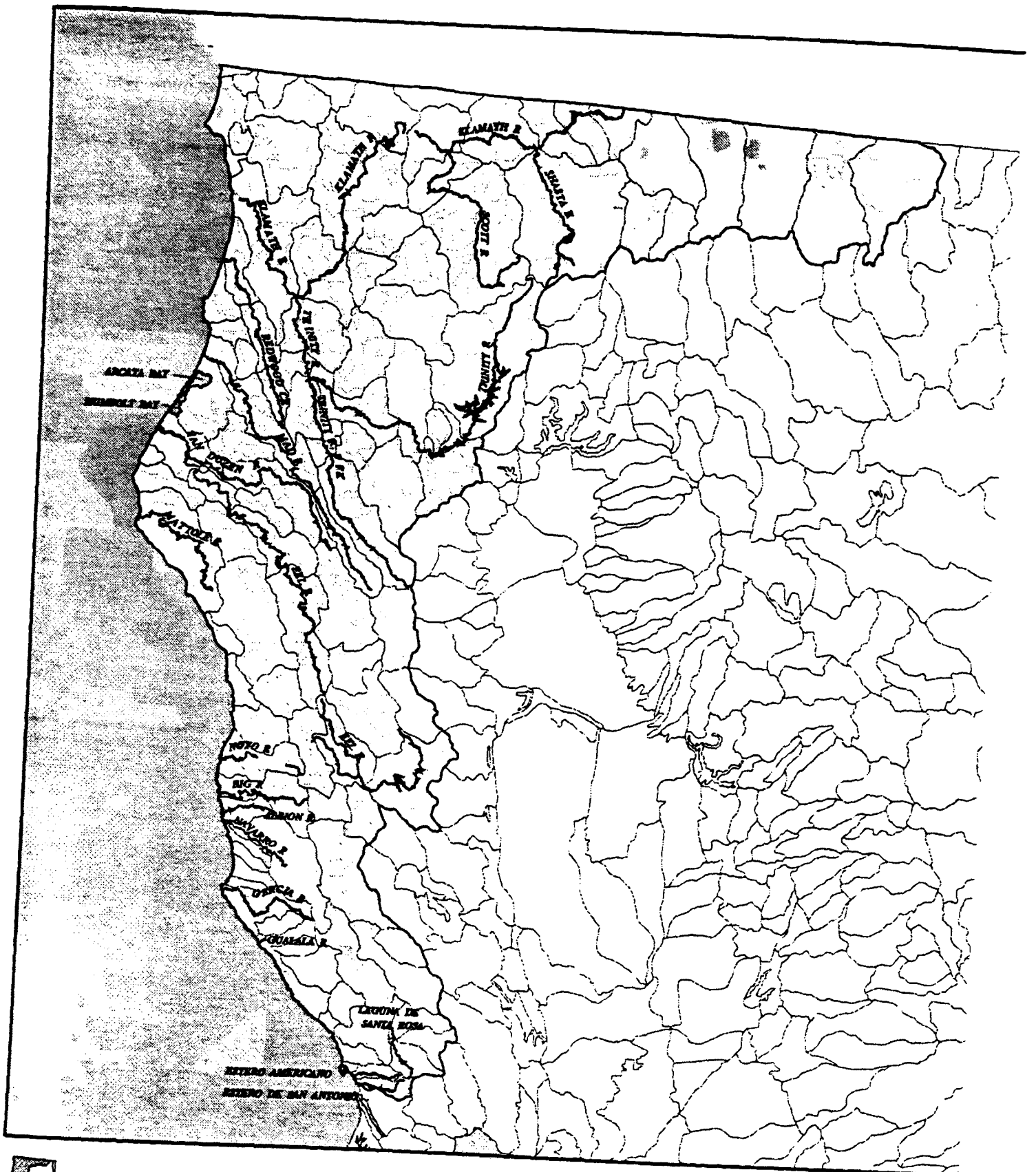
[1] *Water Quality Control Plan, North Coast Basin*; California Regional Water Quality Control Board, North Coast Region, Region 1, December, 1993, pp. I11-I12.

[2] Ibid.



NORTH COAST REGION(1)

Produced by
LKC
USEPA Region 9 GIS Center
Sept. 27 1995

0 10 20 30 MILES
0 10 20 30 KILOMETERS

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control I

Exhibit A-1 TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATERBODY AREA REGION 1: NORTH COAST REGION						
	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	16,500	625	0	16	0	0
Total Assessed	30,024	28,692	88,819	3,085	0	18,060
Share	54.96%	2.18%	0.00%	0.52%	NA	0.00%
Source: EPA analyses of 1994 WQA database.						

- Exhibit A-2 demonstrates that agriculture, industrial point sources, municipal treatment plants, and urban runoff all contribute to impairment of bay waters by toxics. Industrial dischargers are the principal source of toxics for the relatively small area of toxics-contaminated rivers, while mines also contribute to toxics impairment through discharges of metals.

Key Waterbodies Affected

Based on California's 1994 303(d) report, a number of the waterbodies affected by toxics in Region 1 are of significant priority. Twenty waterbodies in Region 1 appear on the priority list, six of which are affected by toxics. Exhibit A-3 presents the pollutant types, 303(d) report ranking, and area of impairment for those six waterbodies.[3] Included are the Estero Americano and Estero de San Antonio estuaries and the Klamath, Mad, Shasta, and Van Duzen rivers.[4] While not included on the 303(d) list, Arcata Bay and Humboldt Bay are included in Exhibit A-3 to reflect the areal extent and type of toxic pollution.

As shown, the Klamath River is listed as highest priority to the State (a ranking of "1"), but the area affected by toxics (according to the WQA database) is limited to only 1 mile of the river's 126 mile length. Based on 1996 data, the Klamath River was removed from the 303(d) list. The

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[3] The priority listings in the 303(d) report are determined by the Regional Water Boards and are a function of the intrinsic value of the waterbody and the degree of impairment. The rankings range form 1 to 5, with 1 representing highest priority waters. *California Report on Impaired Surface Waters*, Prepared as Required in Clean Water Act Section 303(d), May 1994.

[4] *California Report on Impaired Surface Waters, Clean Water Act Section 303(d)*, May 1994. Based on 1996 data, the Klamath River was removed from the 303(d) list.

Exhibit A-2

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 1: NORTH COAST REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	16,500	100%	625	100%	0	NA	0	0%	0	NA	0	NA
Hydro./Habitat Modification	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Industrial	16,500	100%	0	0%	0	NA	16	100%	0	NA	0	NA
Land Development	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Land Disposal	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Mining	0	0%	0	0%	0	NA	1	6%	0	NA	0	NA
Municipal	16,500	100%	0	0%	0	NA	0	0%	0	NA	0	NA
Other Nonpoint Sources	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Other Point Sources	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Storm Sewers	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Urban Runoff	16,500	100%	0	0%	0	NA	0	0%	0	NA	0	NA

Source: EPA analysis of 1994 WQA database.

WQA data suggest that toxics impair only small segments of the rivers ranked in the second and third tiers as well. In contrast, the WQA identifies the entire area of both the Estero Americano and Estero de San Antonio as impaired by toxics.

Based on other available information, the toxics-impaired waters from the 303(d) list are clearly not the only waterbodies in the North Coast Region affected by toxic pollutants. California's Bay Protection and Toxic Cleanup Program (BPTCP) lists toxic "hot spots" -- defined as areas of significant toxicity, high levels of bioaccumulation, and impairment of ecologic beneficial uses -- in key coastal waterbodies. While there are no known toxic hot spots identified in Region 1, many "potential" toxic hot spots (areas exhibiting elevated toxic concentrations in water or sediment) are listed. The areas cited as potential hot spots are the Smith River Estuary, Lake Earl, Crescent City Harbor, Klamath River Estuary, Redwood Creek Estuary, Stone Lagoon, Big Lagoon, Trinidad Coast, Little River Estuary, Mad River Estuary, Arcata Bay, Somoa Peninsula, Humboldt Bay, Eel River Estuary, and Mattole River Estuary.[5]

Exhibit A-3

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN THE NORTH COAST REGION (REGION 1)

Waterbody	Pollutants	303(d)Priority	Area Affected
Estero Americano	Metals	2	370 acres
Estero de San Antonio	Metals	2	255 acres
Klamath River[1]	Metals, Pesticides	1	1 mile
Mad River	Pesticides	2	3 miles
Shasta River	Pesticides	3	2 miles
Van Duzen River	Pesticides	2	2 miles
Arcata Bay	Metals, Pesticides	Not Listed	8,500 acres
Humboldt Bay	Metals, Pesticides	Not Listed	8,000 acres

Sources 303(d) list, WQA Data Base

[1] Based on 1996 data, the Klamath River was removed from the 303(d) list.

[5] *Bay Protection and Toxic Cleanup Program, Staff Report*; State Water Resources Control Board, State of California, November, 1993, p. 31, Figure 2.

Natural Resources and Beneficial Uses Affected

The surface waters of the Northern Coastal Region support diverse wildlife resources as well as a variety of beneficial human uses. Exhibit A-4 presents a summary of beneficial uses associated with the waterbodies on the 303(d) list (and the major toxics-impaired bays), as contained in the Region 1 Basin Report. The services and activities listed for each waterbody are based on the judgment of regional staff and are indicative of beneficial uses currently provided by the waterbody. They are not directly related to use designations as defined under the Clean Water Act.

As shown in Exhibit A-4, many of the Region 1 waterbodies on the 303(d) priorities list supply water for municipal and agricultural use, and all supply water for industry. All are also utilized for both contact and non-contact water recreation, including swimming, boating, camping, and nature-watching. All provide habitats for wildlife and most aid in the survival and maintenance of rare, threatened, or endangered plant or animal species. Many of the waterways also support fish spawning and migration, as well as groundwater recharge.

Exhibit A-4

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES

Waterbody	Beneficial Uses														
	Municipal Supply	Agriculture	Industrial	Commercial and Sport Fishing	Water Contact Recreation	Non-Contact Water Recreation	Groundwater Recharge	Freshwater Recharge	Wildlife Habitat	Freshwater Habitat	Saline Habitat	Fish Migration	Fish Spawning	Preservation of Biological Habitats of Special Significance	Supports Rare or Endangered Species
Estero Americano*			X	X	X	X			X		X	X	X	X	X
Estero de San Antonio*			X	X	X	X			X		X	X	X	X	X
Klamath River	X	X	X	X	X	X	X	X	X	X		X	X		X
Mad River	X	X	X	X	X	X	X		X	X		X	X		X
Shasta River	X	X	X		X	X	X	X	X	X		X	X		
Van Duzen River	X	X	X	X	X	X			X	X		X	X		X
Arcata Bay*			X	X	X	X			X		X	X	X	X	X
Humboldt Bay		X	X	X	X	X			X	X		X	X		X

Source *Water Quality Control Plan, North Coast Basin, Region 1*, California Regional Water Quality Control Board, December, 1993, Table 4

* The Region 1 Basin Report did not contain individual listings for these waterbodies; the listing for the estuary or bay category was therefore applied to the corresponding waters.

Region 2: San Francisco Bay Basin

Hydrologic Setting

Region 2, the San Francisco Bay Region, extends over approximately 1,620 square miles along the central coast of California.[6] The region is dominated by the San Francisco Bay system, a complex of several interconnected waterbodies. The key segments include Suisun Bay (including Grizzly and Honker Bays) to the east, Carquinez Strait, San Pablo Bay, and San Francisco Bay. Together, these bays cover approximately 470 square miles, or about 30 percent of the area of Region 2, making it the largest coastal embayment on the Pacific coast of the United States. The system functions as the only drainage outlet for the waters of the Central Valley, to the east. Figure A-2 shows the location of major waterbodies in Region 2.

The San Francisco Bay Region includes several other key waterbodies that add to the diversity of water resources in the area. To the north of Suisun Bay is Suisun Marsh, the largest brackish marsh in the United States, covering approximately 57,000 acres. In addition, a number of freshwater rivers and streams also drain to the Bay. Among the more significant are the Napa River to the north and the Guadalupe River and Alameda Creek to the south. Also to the north is Tomales Bay, a large (approximately 8,000 acres) and generally pristine estuary.

Because of their diversity, the water resources of the San Francisco Bay region support a wide array of wildlife. Many fish species use the waters for feeding and nursery grounds. In addition, anadromous fish and many species of waterfowl use the area as a migratory pathway. These natural resources and the variety of beneficial uses supported are described more fully below.

Degree and Sources of Toxics Impairment

The water resources of Region 2 are among those most affected by toxic pollution. Exhibit A-5 shows over two-thirds of the bays and about 60 percent of wetland areas are impaired by toxics.[7] Significant portions of assessed lakes and rivers are also impaired.

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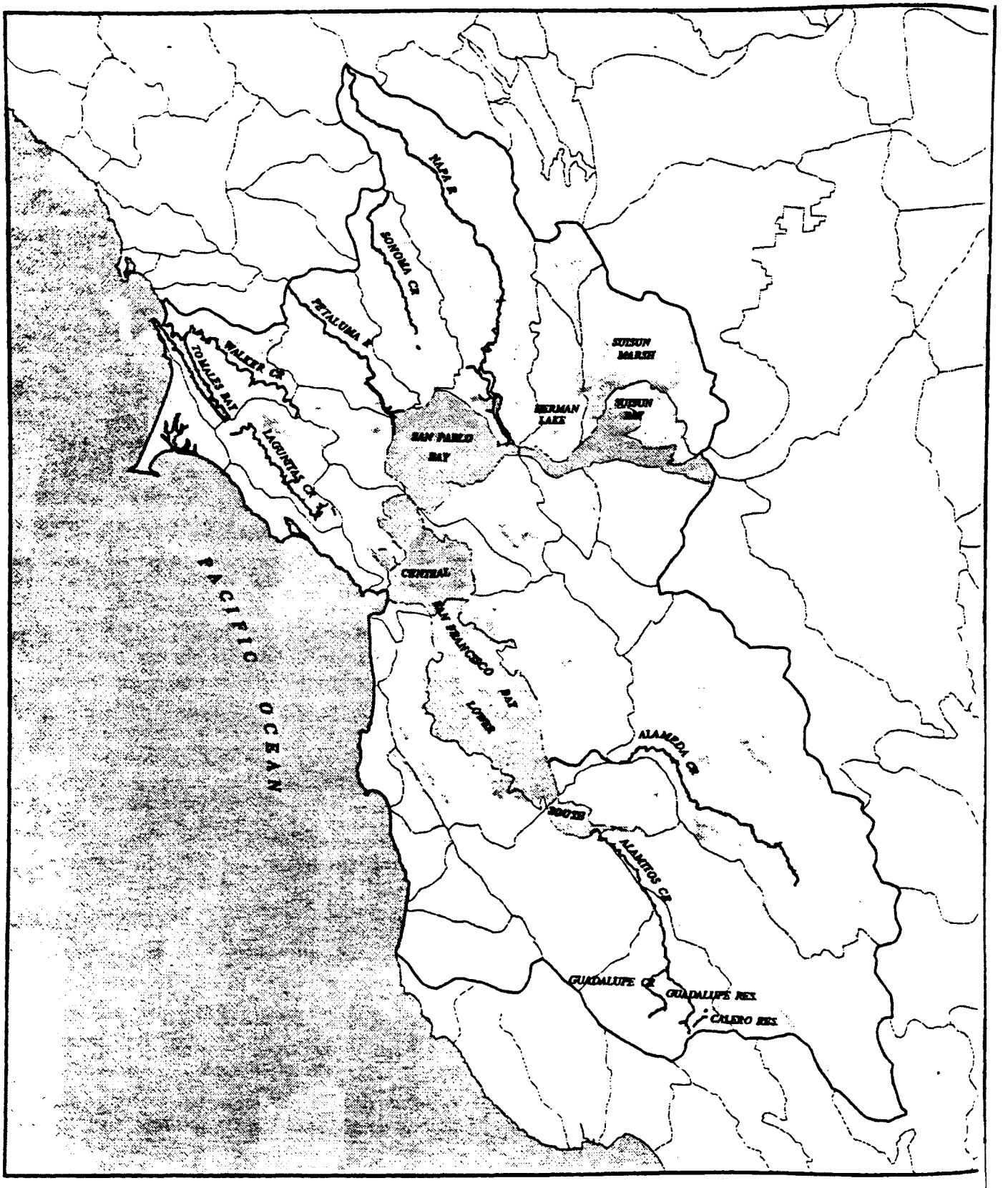
[6] Most of the discussion of the hydrologic setting of Region 2 is taken from two documents: *State of the Estuary: San Francisco Estuary Project*, U.S. EPA and the Association of Bay Area Governments, June, 1992; and *Water Quality Control Plan, San Francisco Bay Basin Region 2*, California Regional Water Quality Control Board, December, 1986.

[7] The impaired wetland acreage is all accounted for by the Suisun Marsh wetlands.



SAN FRANCISCO BAY REGION(2)

Produced by
LKC
USEPA Region 9 GIS Center
Sept. 27, 1995

0 5 10 15 MILES
0 5 10 15 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control

Exhibit A-5

TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATERBODY AREA
REGION 2: SAN FRANCISCO BAY REGION

	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	197,500	25	3,272	244	0	57,000
Total Assessed	285,341	26,833	16,281	619	0	95,055
Share	69.22%	0.09%	20.10%	39.42%	NA	59.97%

Source: EPA analysis of WQA database.

The sources that contribute to toxics pollution in Region 2 are varied. In many cases, the WQA data do not list sources contributing to pollution of Region 2 waters. Where data are available, they suggest that urban runoff and other nonpoint sources affect the greatest areas. Point sources are also cited, with municipal treatment plants affecting the Suisun Marsh wetlands and mining contributing to impairment of some lakes and rivers. Exhibit A-6 summarizes how the major categories of pollutant sources affect surface waters in Region 2.

Other information sources support the data found in the WQA data base. Exhibit A-7 summarizes loadings of key toxic pollutants to San Francisco Bay and the other waters of the delta estuary. Sources examined include municipal/industrial effluent, urban and non-urban runoff, deposition from the air, and loadings from the San Joaquin River (originating with point and nonpoint discharges in the Central Valley). As shown, non-urban runoff (runoff from agricultural land, forests, and other open areas) is a major contributor for a number of toxics, including arsenic, cadmium, chromium, copper, lead, mercury, and zinc. Urban runoff contributes significant shares of lead and PCBs. A large share of trace-element loadings can be traced to irrigation return flows and other nonpoint sources in the Central Valley, transported to San Francisco Bay via the San Joaquin River.[8]

Key Waterbodies Affected

Based on California's 303(d) list, a number of the waterbodies affected by toxics in Region 2 are of significant priority.[9] Exhibit A-8 presents information on the 15 waterbodies listed in the 303(d) report. Included are all major sections of San Francisco Bay, Tomales Bay, the Suisun Marsh wetlands, and a number of lakes and rivers. Metals are the most common source of the impairment, although trace elements and pesticides are also problematic.

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[8] An aquatic life criterion for selenium is already in effect for the Bay-Delta.

[9] *California Report on Impaired Surface Waters, Clean Water Act Section 303(d)*, May 1994.

Exhibit A-6

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 2: SAN FRANCISCO BAY REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	400	0%	0	0%	110	3%	25	10%	0	NA	0	0%
Hydro./Habitat Modification	0	0%	0	0%	0	0%	0	0%	0	NA	0	0%
Industrial	0	0%	25	100%	0	0%	0	0%	0	NA	0	0%
Land Development	0	0%	0	0%	0	0%	0	0%	0	NA	0	0%
Land Disposal	0	0%	25	100%	0	0%	0	0%	0	NA	0	0%
Mining	400	0%	0	0%	602	18%	75	31%	0	NA	0	0%
Municipal	0	0%	0	0%	0	0%	0	0%	0	NA	57,000	100%
Other Nonpoint Sources	67,700	34%	0	0%	2,240	68%	116	48%	0	NA	57,000	100%
Other Point Sources	0	0%	0	0%	0	0%	0	0%	0	NA	0	0%
Storm Sewers	0	0%	0	0%	0	0%	0	0%	0	NA	0	0%
Urban Runoff	24,500	12%	25	100%	430	13%	112	46%	0	NA	57,000	100%

Source: EPA analysis of WQA database.

Exhibit A-7

SUMMARY OF POLLUTANT LOADINGS TO THE BAY/DELTA ESTUARY FROM MAJOR SOURCES (Metric Tons/Year)

Pollutant	Municipal and Industrial Effluent	San Joaquin River	Urban Runoff	Total Nonurban Runoff	Atmospheric Deposition	Dredged Material
Arsenic	1.5 - 5.5	12	1.0 - 9.0	**10 - 120**	N/A	N/A
Cadmium	**1.8 - 4.0**	N/A	0.3 - 3.0	**0.52 - 6.0**	0.14 - 0.35	0.02 - 0.2
Chromium	12 - 13	66	3.0 - 15	**130 - 1500**	N/A	N/A
Copper	19 - 30	80	7.0 - 59	**51 - 580**	1.9 - 3.1	1.0 - 10
Lead	11 - 16	51 - 55	**30 - 250**	**31 - 360**	6.0 - 21	1.0 - 10
Mercury	**0.2 - 0.7**	N/A	0.026 - 0.15	**0.15 - 1.7**	N/A	0.01 - 0.1
Nickel	19 - 27	**51**	N/A	N/A	N/A	2.0 - 20
Selenium[1]	2.1	**4.2**	N/A	N/A	N/A	N/A
Silver	**2.7 - 7.2**	N/A	N/A	N/A	N/A	N/A
Zinc	77 - 80	164 - 175	34 - 268	**130 - 1450**	N/A	3.0 - 30
PCBs	N/A	N/A	**0.006 - 0.40**	N/A	N/A	0.00067 - 0.0067

Note: Values in bold face indicate the largest quantified source of each pollutant; multiple major sources are shown where ranks are relatively ambiguous. N/A = Data not available.

Source: *State of the Estuary: San Francisco Estuary Project*, U.S. EPA and the Association of Bay Area Governments, June, 1992, p. 172.

[1] An aquatic life criterion 5 μg/l for selenium is already in place for the Bay-Delta.

Exhibit A-8

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN SAN FRANCISCO BAY BASIN (REGION 2)

Waterbody	Pollutants	303(d) Priority	Area Affected
San Francisco Bay, Central	Metals, selenium [1]	1	67,700 acres
San Francisco Bay, Lower	Metals	1	79,900 acres
San Francisco Bay, South	Metals, trace elements [1]	1	24,500 acres
Suisun Bay	Metals, arsenic	n.a.	25,000 acres
Tomales Bay	Mercury	3	400 acres
Calero Reservoir	Mercury, arsenic, trace elements	4	350 acres
Guadalupe Reservoir	Nickel, trace elements	4	80 acres
Herman Lake	Mercury	5	110 acres
Alameda Creek	Trace elements	4	27 miles
Alamitos Creek	Mercury, trace elements	4	14 miles
Guadalupe River	Pesticides, other toxics	4	30 miles
Napa River	Metals	3	55 miles
Petaluma River	Metals	3	25 miles
Walker Creek	Mercury	4	25 miles
Suisun Marsh	Metals	1	57,000 acres

Sources: 303(d) list; WQA Data Base

1 An aquatic life criterion 5 μg/l for selenium is already in place for the Bay-Delta.

As shown, several waterbodies are listed as being of highest priority to the state (a rank of "1"). These include San Francisco Bay (Central, Lower, and South) and Suisun Marsh. All are affected by metals contamination, and portions of San Francisco Bay are impaired by trace elements. Other toxics-impaired waterbodies of medium priority include Tomales Bay, the Napa River, and the Petaluma River.

California's Bay Protection and Toxic Cleanup Program (BPTCP) provides yet another indicator of key waterbodies affected by toxic pollutants. The known toxic hot spots identified by this effort include Suisun Bay proper as well as several wetlands and smaller bays (Peyton Slough, Boynton Slough, Chadbourne Slough, and Honker Bay); Miller Creek (feeding the Central Bay); Castro Cove and Richmond Harbor (off of the Lower Bay); and Oakland Inner Harbor, Hunters Point, Redwood Creek, Dumbarton Bridge, and the area south of Dumbarton Bridge (South Bay). Region 2 also includes a number of other "potential" toxic hot spots identified by the monitoring program.[10]

Natural Resources and Beneficial Uses Affected

The surface waters of the San Francisco Bay Basin support diverse wildlife resources as well as a variety of beneficial human uses. Exhibit A-9 presents a summary of beneficial uses as reported in the Basin Report for Region 2.

As shown in Exhibit A-9, the majority of the waterbodies impaired by toxics are either freshwater habitat areas and/or wildlife areas. Many of the waters are also fish migration and spawning areas. The region is home to a variety of wildlife species that are in decline or listed as threatened or endangered. This is reflected in the beneficial use data as well as in other information sources.[11]

Increasing urbanization has limited natural habitat and is thought to threaten the wildlife of the region. While it is difficult to gauge the specific influence that toxic surface water pollution has had on the reduction in quantity and quality of wildlife habitat, it is clear that key species are exposed to toxics. Exhibit A-10 shows typical concentrations of selected toxic pollutants in various biota. As shown, toxic pollutants in several cases are present in biota tissue in concentrations exceeding alert levels. Most significantly, a number of metals are present in shellfish in concentrations that exceed general international guidelines on levels of concern (median international standards or MIS). Likewise, copper, mercury, selenium, DDT, and PCBs have been measured in fish at levels exceeding federal, state, and/or international standards. Elevated selenium is also present in some waterfowl tissue samples. Finally, there are a number of potentially problematic pollutants for which levels of concern have not been established.

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[10] *Bay Protection and Toxic Cleanup Program, Staff Report*; State Water Resources Control Board, State of California, November, 1993, p. 109, Figure 7.

[11] *State of the Estuary: San Francisco Estuary Project*, U.S. EPA and the Association of Bay Area Governments, June, 1992, p. 85.

Exhibit A-9

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES

Waterbody	Beneficial Uses														
	Agriculture	Municipal Supply	Groundwater Recharge	Industrial	Navigation	Water Contact Recreation	Non-Contact Water Recreation	Commercial Fishing	Freshwater Habitat	Wildlife Habitat	Supports Rare, Endangered Species	Marine Habitat	Fish Migration	Fish Spawning	Shellfish Harvesting
San Francisco Bay, Central				x	x	x	x	x		x	x		x	x	x
San Francisco Bay, Lower				x	x	x	x	x		x	x		x		x
San Francisco Bay, South				x	x	x	x	x		x	x		x		x
Suisun Bay				x	x	x	x	x		x	x		x	x	x
Tomales Bay						x	x	x		x	x	x	x	x	x
Calero Reservoir		x	x			x	x		x					x	
Guadalupe Reservoir		x	x				x		x					x	
Herman Lake				x			x		x	x				x	
Alameda Creek	x		x			x	x		x	x			x	x	
Guadalupe River						x		x	x	x					
Napa River	x	x			x	x	x		x	x	x		x	x	
Petaluma River					x	x		x	x	x	x	x	x		
Walker Creek									x	x	x		x	x	

Note Beneficial use data for Suisun Marsh and Alamitos Creek are not available
Source *Water Quality Control Plan, San Francisco Bay Basin Region 2*, California Regional Water Quality Control Board, December, 1986, Table II-1.

Exhibit A-10

CONCENTRATIONS OF SELECTED POLLUTANTS IN BAY/DELTA ESTUARY BIOTA
(ppm wet weight)

Pollutant	Mussel	Clam	Fish	Bird	Seal	Concentrations Exceeding Alert Levels*
Arsenic	1.16 - 2.16	--	0.13 - 1.20	--	--	Yes. Levels in some Bay shellfish exceed MIS.
Cadmium	0.11 - 4.91	--	0.03 - 0.48	4.17	<.06 - .33	Yes. Levels in some Bay shellfish exceed MIS.
Chromium	0.014 - 2.114	0.15 - 3.92	0.02 - 0.1 1.8 (striped bass)	--	--	Yes. Levels in some Bay shellfish exceed MIS.
Copper	0.314 - 4.395	10 - 100	1.3 - 30	7.14 - 13.86	3.0 - 8.7	Yes. Levels in some Bay shellfish exceed MIS. Levels in some Suisun Bay and Delta fish exceed MIS.
Lead	0.03 - 74	--	0.02 - 0.2	64 - 102	0.13 - 1.22	Yes. Levels in some Bay shellfish exceed MIS.
Mercury	0.01 - 0.46	--	0.13 - 0.94	0.16 - 0.6	0.40 - 3.65	Yes. Levels in some Bay shellfish and Delta fish exceed MIS.
Nickel	0.5 - 2.4	--	0.8	0.1	0.11-4.10	No alert levels established for tissue.
Selenium	0.19 - 0.66	0.3 - 1.30	0.28 - 22.0	24 - 58	2.07 - 6.49	Yes. Levels in some Bay shellfish exceed MIS. Levels in some Bay fish exceed MARL. Levels in some Bay ducks exceed MARL.
Silver	0.02 - 22.5	0.14 - 28.57	0.13 - 0.94	0.33 - 3.70	--	No alert levels established for tissue.
Tributylotin	0.120 - 2.960	--	--	--	--	No alert levels established for tissue.
Zinc	11.0 - 45.8	--	16.0 - 43.0	21.6	--	No alert levels established for tissue.
DDT and metabolites	<.002 - 3.21	--	0.020 - 5.18	--	5 - 34	Yes. Levels in some Delta fish exceed FDA action level.
PCB	0.009 - 0.657	--	0.05 - 6.99	--	0.05 - 330	Yes. Levels in some Bay and Delta fish exceed FDA action level.

Note: Concentrations are shown for wet weight; data originally given for dry weight have been converted by dividing by seven. For seals, trace element data represent concentrations in dry whole blood; data for DDT and PCB represent concentrations in blood plasma lipids.

* The alert levels referred to in this table are the maximum tissue residue levels that are protective of human health. They include: 1) the median international standard (MIS), which is a general guideline of what other nations consider to be elevated contaminant levels in fish and shellfish tissue; 2) the U.S. Food and Drug Administration (FDA) action levels, which represent maximum allowable concentrations for some toxic substances in human foods; and 3) the State Department of Health Service's maximum allowable residue levels (MARL), established to ensure that a consumer of specified fish or wildlife species does not exceed the permissible intake level for particular contaminants.

Apart from supporting wildlife, the 303(d) waterbodies identified above as being impaired by toxics also support recreation and other human activities. Data in the Basin Report for Region 2 indicate that virtually all the waters support some form of recreation. The major segments of the Bay system support both water contact recreation such as swimming and fishing as well as non-contact recreation such as boating and hiking.

The waters of Region 2 also support human uses beyond recreational activity. The major segments of the Bay are used for commercial fishing, shellfishing, and shipping, as well as for industrial applications such as cooling. The two reservoirs affected by toxics are used for municipal water supply, while Alameda Creek supplies irrigation water for agriculture.

Region 3: Central Coastal Region

Hydrologic Setting

Region 3, the Central Coastal Region, encompasses over 11,000 square miles, extending nearly 300 miles along the coast and ranging 40 miles inland. Included in the area are prime agricultural lands such as the Salinas, Santa Maria and Lompoc Valleys, areas of high rainfall like the Santa Cruz mountains in the west, and arid areas like the Carizo Plain to the east.[12] As shown in Figure A-3, significant waterbodies in this region are the Nacimiento Reservoir, the Salinas River, the Cuyama River, and the Santa Ynez River.

On balance, most of the Central Coast region is considered to be relatively arid. The combination of low precipitation levels and a growing human population has led to the harnessing of many rivers and streams as storage reservoirs for municipal and agricultural purposes. The Nacimiento, San Antonio, and Huasana rivers have all been diverted or dammed to create the Nacimiento, San Antonio, and Twitchell reservoirs, respectively. The divergence of major waterways has led to reductions in aquatic habitats, ground water recharge, and other beneficial uses. Demand for water is increasing and competition for waters of adequate quality is expected to become more intense in the future.[13]

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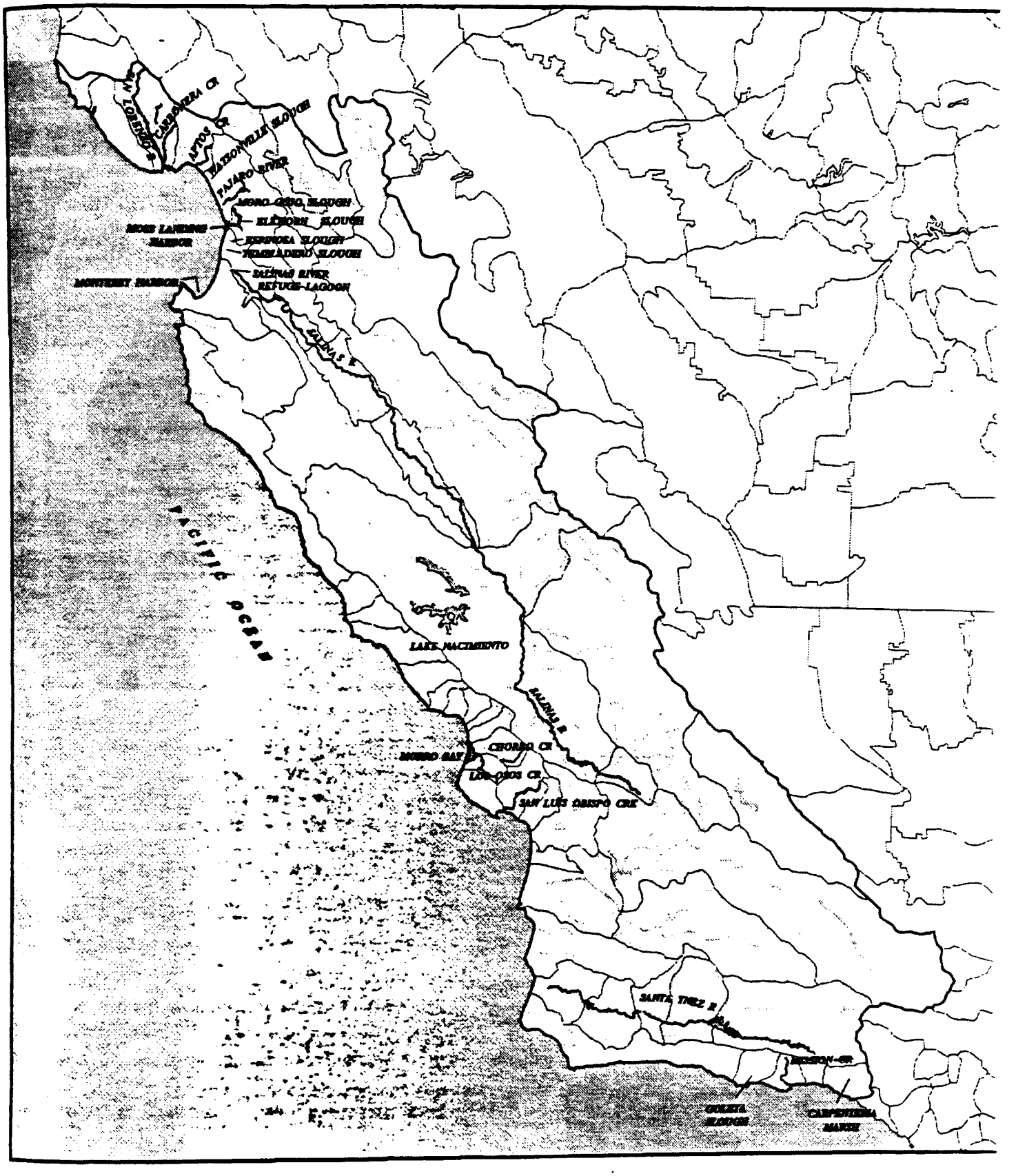
[12] *Water Quality Control Plan, Central Coast Basin*; California Regional Water Quality Control Board, Central Coast Region, Region 3, November, 1989, pp. I2-I3.

[13] Ibid.



CENTRAL COAST REGION(3)

Produced by
LEC
USEPA Region 9 GIS Center
Sept. 27, 1995

0 10 20 30 MILES
0 10 20 30 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board

Degree and Sources of Toxics Impairment

The Central Coastal Region waterbodies are impaired by a limited set of toxic pollutants from a variety of sources, dominated by pesticide and trace element contaminants from agricultural runoff. Analysis of the WQA database yields the following information:

- As summarized in Exhibit A-11, toxics impair a large area of most waterbody types, including 11,685 acres of lakes and reservoirs (47 percent of assessed), 1,747 acres of estuaries (36 percent of assessed), and 585 acres of wetlands (20 percent of assessed). However, the WQA database identifies only 233 river miles (7 percent of assessed) and 366 acres of bays (10 percent of assessed) as impaired by toxics.

Exhibit A-11

TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATERBODY AREA
REGION 3: CENTRAL COASTAL REGION

	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	366	1,747	11,685	233	0	585
Total Assessed	3,570	4,823	24,868	3,272	3,334	2,936
Share	10.25%	36.22%	46.99%	7.12%	0.00%	19.93%

Source: EPA analysis of WQA database.

- As shown in Exhibit A-12, agriculture is a primary source of toxic pollution and is associated with 100 percent of impaired wetland area, 58 percent of impaired estuary area, 33 percent of impaired river miles, and 11 percent of impaired bay area. Other significant sources of toxic pollutants are mining and unspecified nonpoint sources.

Key Waterbodies Affected

Based on California's 1994 303(d) report, a number of the waterbodies affected by toxics in Region 3 are of significant priority.[14] Eighteen waterbodies in Region 3 appear on the priority list, 14 of which are affected by toxics. Exhibit A-13 presents the pollutant types, 303(d) report ranking, and area of impairment for those 14 waterbodies. Included are the entire areas of the Nacimiento

[14] *California Report on Impaired Surface Waters, Clean Water Act Section 303(d)*, May 1994.

Exhibit A-12

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 3: CENTRAL COASTAL REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	40	11%	1,005	58%	0	0%	76	33%	0	NA	585	100%
Hydro./Habitat Modification	0	0%	0	0%	0	0%	20	9%	0	NA	0	0%
Industrial	0	0%	200	11%	0	0%	9	4%	0	NA	0	0%
Land Development	0	0%	430	25%	0	0%	20	9%	0	NA	100	17%
Land Disposal	0	0%	300	17%	0	0%	0	0%	0	NA	0	0%
Mining	74	20%	0	0%	5,960	51%	69	30%	0	NA	0	0%
Municipal	0	0%	0	0%	0	0%	20	9%	0	NA	0	0%
Other Nonpoint Sources	326	89%	1,247	71%	11,095	95%	93	40%	0	NA	335	57%
Other Point Sources	0	0%	0	0%	0	0%	0	0%	0	NA	0	0%
Storm Sewers	0	0%	705	40%	0	0%	0	0%	0	NA	235	40%
Urban Runoff	0	0%	705	40%	0	0%	19	8%	0	NA	335	57%

Source: U.S. EPA analysis of WQA database.

Reservoir, Elkhorn Slough, and Watsonville Slough, as well as large segments of the Goleta Slough and Salinas River. Pesticides are the most common cause of impairment of the waters listed, with metals, trace elements, and priority organics also identified as problem pollutants.

As Exhibit A-13 indicates, none of the Region 3 waterbodies listed have been designated as among the state's highest priorities (a rank of "1"), but the entire area of Elkhorn Slough and segments of Morro Bay and Carpinteria Marsh are contained in the second tier. Other toxics-impaired waterbodies of medium priority include the San Lorenzo River, Nacimiento Reservoir, Goleta Slough, and the Salinas River.

The pollutant types impairing priority waterbodies, and their respective sources, vary. The Nacimiento Reservoir is contaminated entirely by mercury associated with past and present mining activities. The Salinas River suffers from a variety of pesticides from agricultural sources. The Elkhorn Slough receives pesticides, herbicides, and metal pollutants from agricultural and other nonpoint sources, and the Goleta Slough receives toxic metals and priority organics from urban and industrial runoff.

Other information sources reveal that the number of toxics-impaired waterbodies in the Central Coastal Region are not limited to those on the 303(d) list. California's Bay Protection and Toxic Cleanup Program (BPTCP) provides an additional indicator for key coastal waterbodies affected by toxic pollutants. BPTCP lists areas of significant toxicity, high levels of bioaccumulation, and impairment of ecologic beneficial uses as toxic "hot spots". While there are no known toxic hot spots identified in Region 3, many "potential" toxic hot spots (areas exhibiting elevated toxic concentrations in water or sediment) are listed. All the enclosed bays and estuaries on the 303(d) list, except Carpinteria Marsh, were sited as potential toxic hot spots. Also listed are Santa Cruz Harbor, Harkins Slough, Pajaro River Estuary, Old Salinas River Estuary, Salinas Reclamation Canal, Carmel Bay, San Luis Obispo Creek, San Luis Harbor, and Santa Barbara Harbor.[15]

Additional information on toxic pollution in Region 3 is available from a workshop conducted in early 1994 under the Water Quality Protection Program (WQPP) for Monterey Bay National Marine Sanctuary which compiled a list of high priority waterbodies in the sanctuary and its watersheds that are affected by toxic pollutants. The WQPP provides a regional perspective on key waterbodies and generally concurs with lists compiled at a statewide level. High priority waterbodies include many on the 303(d) list, but also include the Pajaro River, Alisal Canal, and Carmel River.[16]

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[15] *Bay Protection and Toxic Cleanup Program, Staff Report*; State Water Resources Control Board, State of California, November, 1993, p. 109, Figure 7.

[16] *Comparison of the California Water Quality Assessment and the January 1994 Workshop Results*; Monterey Bay National Marine Sanctuary Water Quality Protection Program, April, 1995, p. 7, Table 4.

Exhibit A-13

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN CENTRAL COASTAL REGION (REGION 3)

Waterbody	Pollutants	303(d) Priority	Area Affected
Monterey Harbor	General Toxics	4	74 acres
Morro Bay	Mercury, other toxics	2	100 acres
Moss Landing Harbor	Pesticides, Herbicides	4	40 acres
Carpinteria Marsh	Priority Organics	2	80 acres
Elkhorn Slough	DDT	2	1,000 acres
Goleta Slough/ Estuary	Metals, Priority Organics	3	200 acres
Watsonville Slough	Pesticides, Herbicides, Trace Elements	4	300 acres
Nacimiento Reservoir	Mercury, other Metals	3	5,370 acres
Salinas River	Pesticides	3	50 miles
San Lorenzo River	Trace Elements	3	20 miles
Espinosa Slough	Pesticides, Priority Organics	4	160 acres
Moro Cojo Slough	Pesticides, Trace Elements	5	145 acres
Salinas River Refuge Lagoon (South)	Pesticides	4	50 acres
Tembladero Slough	Pesticides	3	75 acres

Sources: 303(d) list;WQA Data Base

Natural Resources and Beneficial Uses Affected

The surface waters of the Central Coastal Region support diverse wildlife resources as well as a variety of beneficial human uses. Exhibit A-14 presents a summary of beneficial uses in waters impaired by toxic pollutants, as contained in the Region 3 Basin Report. As shown in the exhibit, all of the Region 3 waterbodies listed on the 303(d) priorities list support both contact and non-contact water recreation. All support habitats for wildlife and most aid in the survival and maintenance of rare, threatened, or endangered plant or animal species. In addition, many of the waterways support fish spawning and migration, as well as shellfish harvesting.

The impact of toxic pollution on the beneficial uses listed in Exhibit A-14 is not always clear. In at least one case, however, the Nacimiento Reservoir, elevated levels of mercury in large-mouth bass have led the State of California to issue a fish consumption advisory.

Region 4: Los Angeles Basin

Hydrologic Setting

Region 4 encompasses nearly 4,000 miles of southwest California, extending from Rincon Point in westernmost Ventura County to the eastern tip of Los Angeles County. The region is extremely mountainous, and is interlaced with a complex network of rivers and streams that transport surface runoff from the mountains to the Pacific Ocean. Geographically, the region is bordered by the Santa Ynez mountains to the north, the Liebre-Sawmill mountains to the west, and the San Gabriel mountains to the south.

Large river systems comprise the majority of inland surface waters in the region. In the north, the Ventura River channels runoff from the Santa Ynez mountains. In the middle portion of the region, the Santa Clara River drains the San Gabriel, Santa Susana, and Liebre-Sawmill mountains. In the south, the Los Angeles and San Gabriel Rivers, as well as Ballona Creek, drain the Transverse Ranges. Figure A-4 shows the major rivers, lakes, and reservoirs of the region.[17]

The Pacific Ocean forms the western border of the region. Important features of the coastline include Santa Monica Bay in the north and Los Angeles and Long Beach Harbors in the south. The coast is also punctuated with smaller harbors, inlets, and beaches.

The region's waterbodies, particularly the bays and estuaries, provide habitat for a wide variety of wildlife and plant life. Several of the region's waters have been recognized as significant ecological areas (SEAs) that provide habitat for endangered species and unique recreational opportunities. These natural resources and the variety of beneficial uses they support are described more fully below.

Degree and Sources of Toxics Impairment

Of the Region 4 waterbodies assessed, bays and estuaries suffer disproportionately from toxics pollution. Over 90 percent of the assessed bays and estuaries in the Region are impaired by toxics. Conversely, the region's rivers, lakes, and reservoirs appear to be relatively free from impairment by toxics pollution. Exhibit A-15, derived from the WQA database, illustrates the percentage of waterbodies surveyed in each group that were found to be impaired by toxics.

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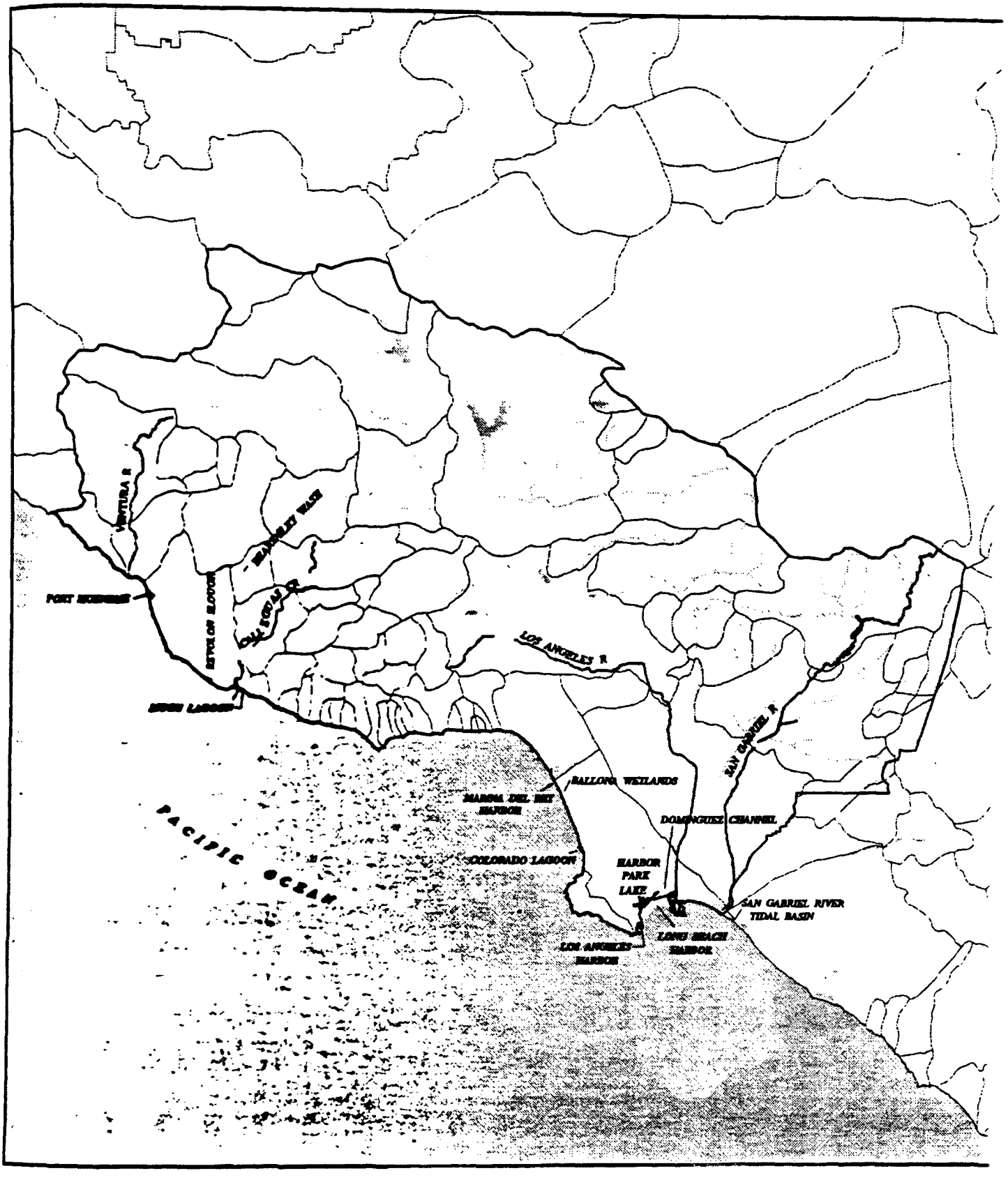
[17] *Los Angeles Region Water Quality Control Plan (Basin Plan)*, California Water Quality Control Board, June 1994.



LOS ANGELES REGION(4)

Produced by
LKC
USEPA Region 9 GIS Center
Sept. 27, 1995

0 5 10 15 MILES

0 5 10 15 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Bo

Exhibit A-14

NATURAL RESOURCES AND BENEFICIAL USES
ASSOCIATED WITH KEY WATERBODIES

Waterbody	Beneficial Uses													
	Municipal Supply	Agriculture	Industrial	Shellfish Harvesting	Ocean Commercial & Sport Fishing	Water Contact Recreation	Non Contact Water Recreation	Groundwater Recharge	Wildlife Habitat	Freshwater Habitat	Fish Migration	Fish Spawning	Preservation of Biological Habitats of Special Significance	Supports Rare or Endangered Species
Monterey Harbor			X	X	X	X	X							X
Morro Bay			X	X	X	X	X		X					X
Moss Landing Harbor			X	X	X	X	X		X					X
Carpinteria Marsh						X	X		X	X	X	X	X	X
Elkhorn Slough				X	X	X	X		X	X	X	X	X	X
Goleta Slough/ Estuary				X		X	X		X					X
Watsonville Slough						X	X		X	X		X	X	X
Nacimiento Reservoir	X	X				X	X	X	X	X		X		X
Salinas River	X	X	X			X	X	X	X	X	X	X		X
San Lorenzo River	X	X	X			X	X	X	X	X	X	X	X	X
Espinosa Slough						X	X		X	X				
Moro Cojo Slough						X	X	X	X	X		X	X	X
Salinas River Refuge Lagoon (South)						X	X		X	X	X		X	X
Tembladero Slough						X	X		X	X		X		X

Source: Water Quality Control Plan, Central Coastal Basin, Region 3, California Regional Water Quality Control Board, November, 1989, Table 2-2, Attachment E.

Exhibit A-15

TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATERBODY AREA
REGION 4: LOS ANGELES REGION

	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	14,070	1,678	461	115	0	0
Total Assessed	14,293	1,816	13,897	874	0	0
Share	98.44%	92.40%	3.32%	13.16%	NA	NA

Source: U.S. EPA analysis of WQA database.

The major sources of toxics pollution in the region include agricultural activities, hydro/habitat modification, municipal wastewater discharges, urban runoff, and other nonpoint discharges. Nonpoint source pollution has a wide-reaching impact, contributing to the impairment of a large share of affected waterbodies. In particular, estuaries and rivers are significantly affected by nonpoint discharges stemming from agricultural activities. Municipal point sources contribute significantly to toxic pollution of bays, while unspecified point sources are associated with pollution of both bays and estuaries. Industrial point sources affect a significant share of river miles, but are otherwise a minor contributor. Exhibit A-16 shows the impacts of different pollution sources on the waterbodies in the region.

Key Waterbodies Affected

Exhibit A-17 presents data on the significant waterbodies in Region 4 that are impaired by toxics, as identified in California's 1994 303(d) report. Most of the waters on the list are ranked as medium to low priority; only Mugu Lagoon achieved a rank of relatively high priority.

With respect to the areal extent of toxics contamination, Los Angeles Harbor and Mugu Lagoon are the largest waterbodies affected by toxics. The WQA database shows that both waterbodies are contaminated with pesticides and trace elements. Los Angeles Harbor is contaminated by PCBs, priority organics, and metals.

In addition, California's Bay Protection and Toxic Cleanup Program (BTPCT) provides another source of information on waterbodies affected by toxic pollution. The State's assessment of known and potential hot spots in Region 4 corresponds with the 303(d) list. Known hot spots include Mugu Lagoon, Santa Monica Bay, portions of Inner Los Angeles and Inner Long Beach Harbors, and San Pedro Bay. The State has also identified Port Hueneme Harbor, Marina Del Rey

Harbor, and portions of Inner Los Angeles and Long Beach Harbors as potential hot spots.[18] Additional waterbodies added to the 1996 303(d) list include the San Gabriel River (lower) and the Los Angeles River (upper).

Natural Resources and Beneficial Uses Affected

Toxics-impaired waters in Region 4 support a wide range of ecological and recreational uses. Exhibit A-18 summarizes beneficial use information from the Basin Report for Region 4.

As Exhibit A-18 shows, all of the impaired waterbodies provide opportunities for both contact recreational activities, including swimming and fishing, and non-contact activities such as boating and hiking. In addition, the affected waterbodies provide a source for industrial and agricultural water intake, support commercial shellfishing, and serve as navigation channels. Certain of these waters also contribute to groundwater recharge and freshwater replenishment.

Additionally, nearly all of the waterbodies provide wildlife habitat for fish, waterfowl, and other aquatic animals. In particular, several of the lagoons, estuaries, and woodlands provide refuge for rare and endangered species. Harbor Park Lake, one of the areas included on the 303(d) list, has been designated as a significant ecological area (SEA) by Los Angeles County. Waterbodies designated as SEAs contain unique habitats that support threatened or endangered species.

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[18] *Bay Protection and Toxic Cleanup Program, Staff Report*; State Water Resources Control Board, State of California, November 1993, p. 111, Figure 9

Exhibit A-16

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 4: LOS ANGELES REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	220	2%	1,500	89%	0	0%	33	29%	0	NA	0	NA
Hydro /Habitat Modification	2,100	15%	150	9%	0	0%	0	0%	0	NA	0	NA
Industrial	0	0%	12	1%	0	0%	56	49%	0	NA	0	NA
Land Development	0	0%	0	0%	0	0%	19	17%	0	NA	0	NA
Land Disposal	0	0%	0	0%	0	0%	0	0%	0	NA	0	NA
Mining	0	0%	0	0%	0	0%	1	1%	0	NA	0	NA
Municipal	10,700	76%	3	0%	0	0%	55	48%	0	NA	0	NA
Other Nonpoint Sources	13,785	98%	1,509	90%	461	100%	1	1%	0	NA	0	NA
Other Point Sources	12,890	92%	0	0%	0	0%	0	0%	0	NA	0	NA
Storm Sewers	0	0%	0	0%	0	0%	0	0%	0	NA	0	NA
Urban Runoff	2,739	19%	175	10%	0	0%	81	70%	0	NA	0	NA

Source: U.S. EPA analysis of WQA database.

Exhibit A-17

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN LOS ANGELES BASIN (REGION 4)

Waterbody	Pollutants	303(d) Priority	Area Affected
Mugu Lagoon	Pesticides, trace elements	2	1500 acres
Ballona Wetlands	Metals	3	150 acres
Colorado Lagoon	Pesticides, trace elements, lead	3	13 acres
Long Beach Harbor (Inner)	PCBs, PCP, pesticides, metals, priority organics	3	840 acres
Los Angeles Harbor (Inner)	PCBs, pesticides, metals, trace elements, priority organics	3	1260 acres
Ventura River (Lower)	Metals, priority and nonpriority organics	3	6 miles
Calleguas Creek	Pesticides	4	11 miles
Harbor Lake	PCBs, pesticides	4	50 acres
Los Angeles River (Upper)	Trace elements, priority and nonpriority organics	4	25 miles
Marina Del Rey Harbor	Pesticides, metals	4	354 acres
Revolon Slough	Pesticides	4	9 miles
San Gabriel River (Lower)	Metals, priority and nonpriority organics, unspecified toxics	4	18 miles
San Gabriel River Tidal Basin	Metals	4	3 miles
Port Hueneme (Harbor)	PCBs, metals, priority organics	5	121 acres
Beardsley Wash	Pesticides	unknown	5 miles
Dominguez Channel Tidal Basin	PCBs, pesticides, metals, priority organics	unknown	8 miles

Sources 1994 303(d) list; WQA Database

Exhibit A-18

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES

Watershed	MUN	IND	PROC	AGR	GWR	FRSH	NAV	REC1	REC2	COMM	WARM	COLD	EST	MAR	WILD	BIOL	RARE	MIGR	SPWN	SHELL	WET
Ballona Wetlands								X	X				X		X		X	X	X		X
Beardsley Wash	X					X			X	X			X			X					
Calleguas Creek	X			X	X	X		X	X		X	X			X		X				X
Colorado Lagoon								X	X	X	X				X					X	
Dominguez Channel Tidal Basin							X		X	X	X				X	X	X		X	X	X
Harbor Lake	X							X	X		X				X		X				X
Long Beach Harbor (Inner)		X					X	X	X	X				X			X			X	
Los Angeles Harbor (Inner)		X					X	X	X	X				X			X			X	
Los Angeles River (Upper)	X	X			X			X	X		X				X						X
Marina Del Rey Harbor							X	X	X	X				X	X					X	
Mugu Lagoon							X	X	X	X			X	X	X	X	X	X	X	X	X
Port Hueneme (Harbor)			X				X	X	X	X				X	X						
Revolon Slough	X	X		X	X			X	X		X				X						X
San Gabriel River (Lower)	X							X	X		X				X						
San Gabriel River Tidal Basin		X					X	X	X	X			X	X	X		X	X	X	X	
Ventura River (Lower)	X	X		X	X	X		X	X		X	X			X		X	X	X		X

Source: *Water Quality Control Plan, Los Angeles Basin, Region 4*, California Water Quality Control Board, June, 1994 Table 2-1.

Key

MUN = Municipal and Domestic Supply
IND = Industrial Service Supply
PROC = Industrial Process Supply
AGR = Agricultural Supply
GWR = Ground Water Recharge
FRSH Freshwater Replenishment
NAV Navigation

REC1: Water Contact Recreation
REC2: Non-Contact Recreation
COMM: Commercial and Sport Fishing
WARM Warm Freshwater Habitat
COLD Cold Freshwater Habitat
EST Estuarine Habitat
MAR Marine Habitat

WILD: Wildlife Habitat
BIOL: Preservation of Biological Habitat
RARE: Rare, Threatened, or Endangered Species
MIGR: Migration of Aquatic Organisms
SPWN: Spawning or Reproduction
SHELL: Shellfish Harvesting
WET Wetland Habitat

Region 5: Central Valley Region

Hydrologic Setting

The Central Valley Region extends approximately 400 miles from the California - Oregon border southward to the headwaters of the San Joaquin River.[18] It is bound by the Sierra Nevada Mountains on the east and the Coast Range and Klamath Mountains on the west. The Region encompasses over 50,000 square miles of land, about 40 percent of the total area of the State, including four major drainage basins. The southernmost basin is arid and contains little surface water. The other three basins -- the Sacramento River Basin, the Sacramento-San Joaquin Delta Basin, and the San Joaquin River Basin -- contain some of the most heavily utilized waterbodies in the State. Figure A-5 presents a map of the Central Valley Region.

The Sacramento River Basin is the northernmost section of Region 5. It covers nearly 26,500 square miles of land, varying in topography from valleys in the center of the basin to mountains on both the eastern and western sides. Precipitation falls mainly in the mountains, either as rain or snow. The basin encompasses the Sacramento River upstream of the City of Sacramento and the river's tributaries, including the Pit, Feather, and American Rivers.

The Sacramento-San Joaquin Delta Basin extends from the source of the Mokelumne River in the Sierra-Nevada mountains westward to the confluence of the Sacramento and San Joaquin rivers. The basin experiences hot dry summers and cool wet winters, with precipitation levels increasing to the east. The major waterbodies in the basin are the lower reaches of the Sacramento and San Joaquin Rivers and the many interconnected channels in the Delta.

The San Joaquin River Basin lies directly below the Delta Basin, extending from the Sierra Nevada mountains to the Coast range. Precipitation in the basin increases with elevation and is greater in the northern sections. The principal rivers are the San Joaquin and its major tributaries, including the Stanislaus, Tuolumne, and Merced.

Degree and Sources of Toxics Impairment

Agricultural activity, urbanization, and other factors have contributed to the impairment of Region 5's surface waters. Examination of the WQA database reveals the following information:

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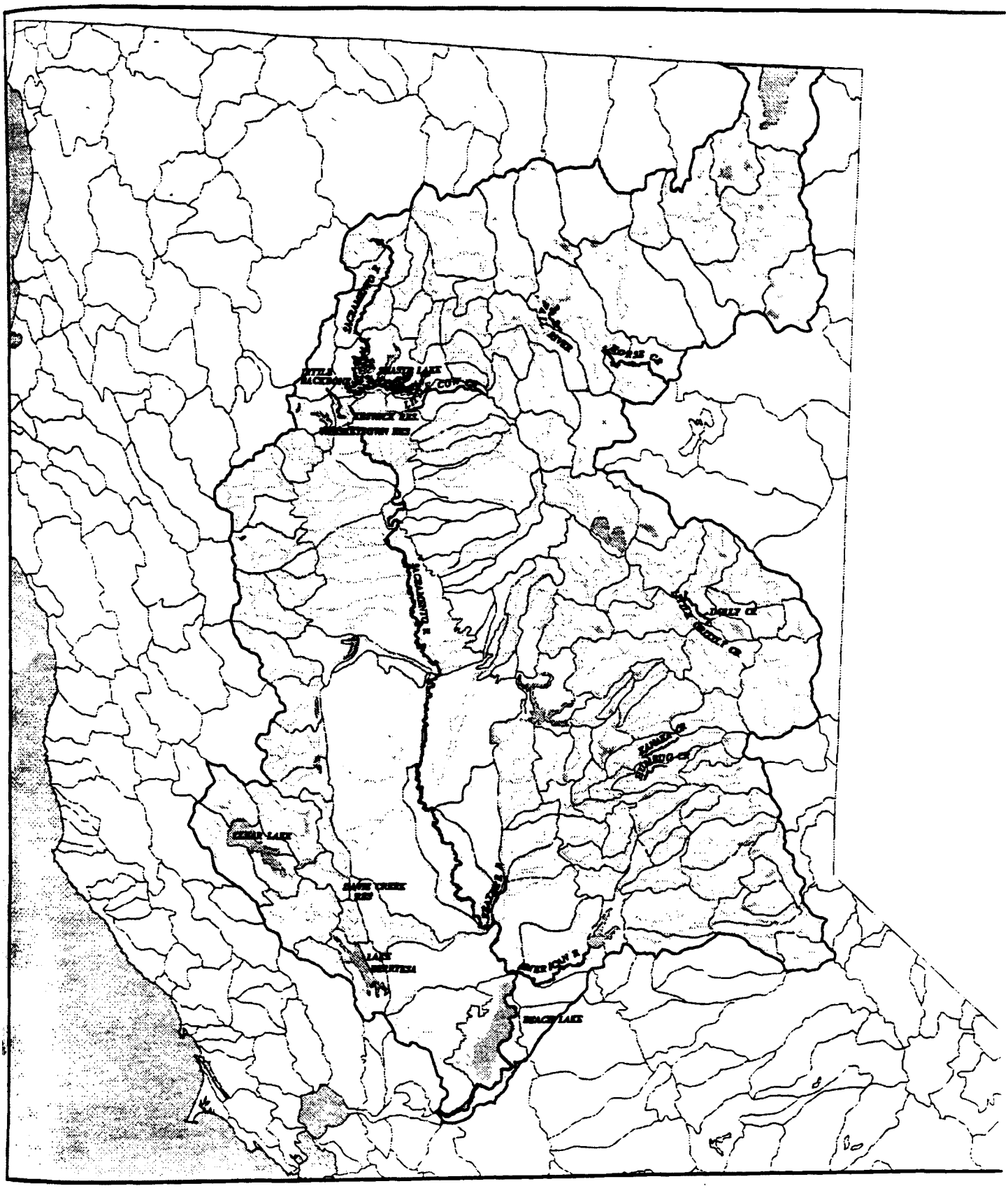
[18] Most of the discussion of the hydrologic setting of Region 5 is taken from two documents: *Water Quality Control Plan, Central Valley Region, Sacramento River and San Joaquin River Basins*, California Regional Water Quality Control Board, December, 1994; and *Draft California 305(b) Report on Water Quality*, State Water Resources Control Board, October 1994.



CENTRAL VALLEY REGION(5R)

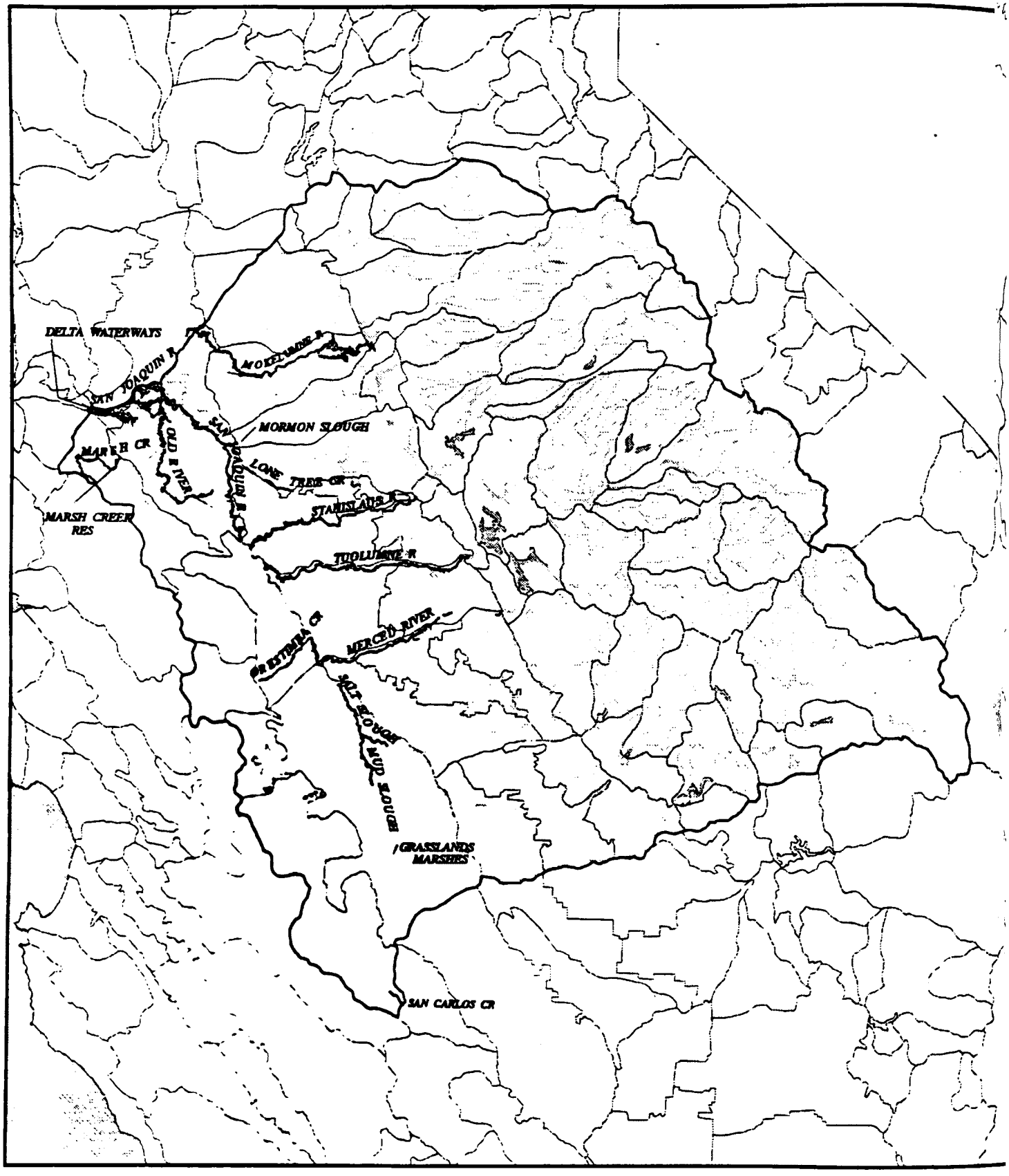
Produced by
LKC
USEPA Region 9 GIS Center
Sept. 27, 1995

0 10 20 30 MILES

0 1020 30 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Boa



CENTRAL VALLEY REGION(5S)

Produced by
LKC
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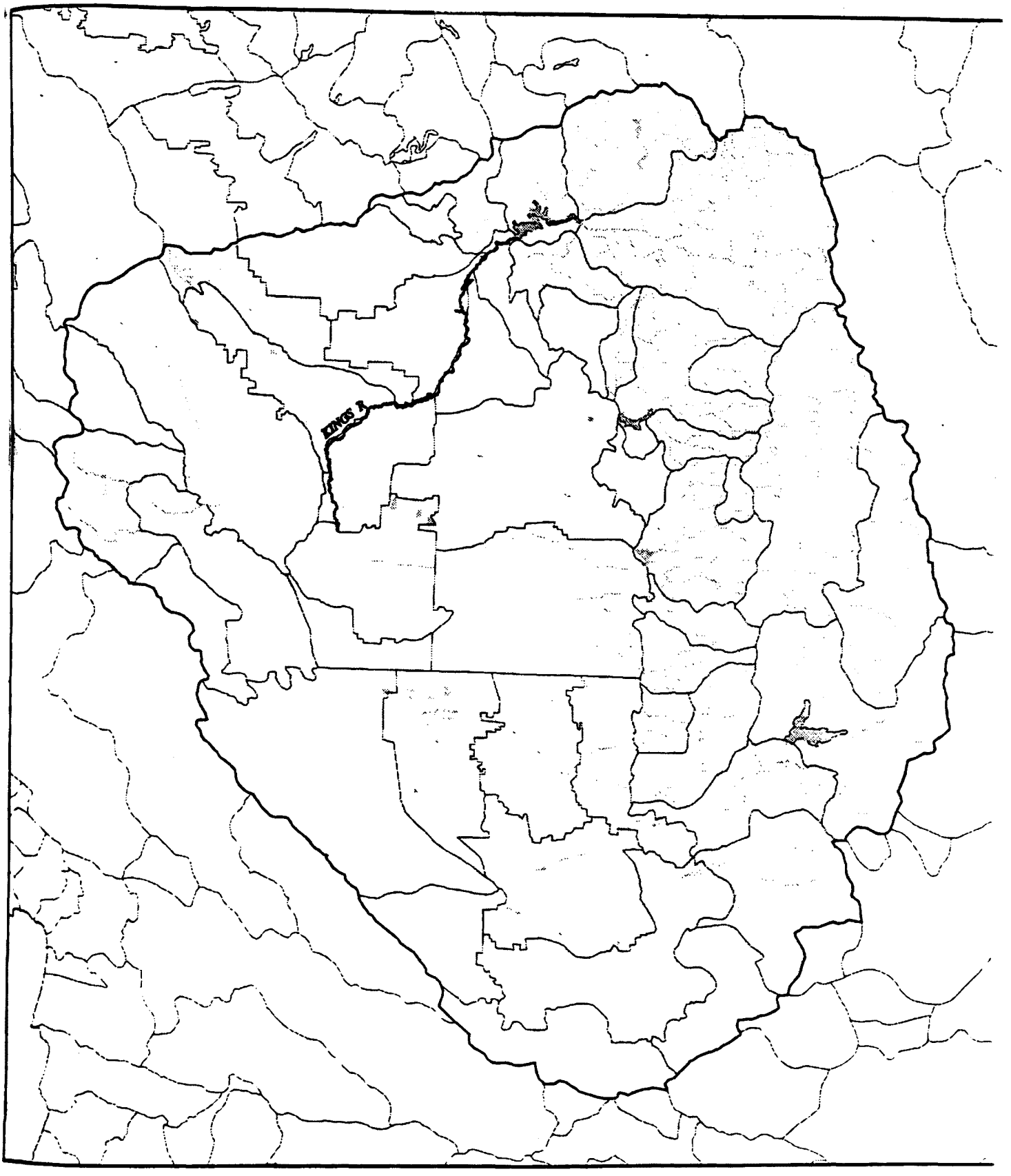
Sept. 27, 1995

0 10 20 30 MILES
0 10 20 30 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board



CENTRAL VALLEY REGION(5F)

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Sept. 27, 1995

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board

- As summarized in Exhibit A-19, toxics impair a significant area of Region 5 waterbodies, including 48,000 acres of estuaries (100 percent of assessed), 120,156 acres of lakes and reservoirs (23 percent of assessed), 1,217 miles of rivers (21 percent of assessed), and 8,227 acres of wetlands (16 percent of assessed).[19]

- Exhibit A-20 shows that agriculture and mining are the most significant sources of toxic pollutants. Agriculture affects large portions of estuaries, rivers, and wetlands, while mining discharges affect estuaries, lakes, and rivers. Unspecified nonpoint sources, hydrologic modification, municipalities, storm sewers, and urban runoff also add to toxic impairment.

Exhibit A-19

TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATERBODY AREAS
REGION 5: CENTRAL VALLEY REGION

	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	0	48,000	120,156	1,217	0	8,227
Total Assessed	0	48,000	514,074	5,770	0	51,242
Share	NA	100.00%	23.37%	21.09%	NA	16.06%

Source: EPA analysis of WQA database

Key Waterbodies Affected

Based on California's 303(d) report, many of the waterbodies impaired by toxics in Region 5 are of significant priority. Twenty-eight waterbodies in Region 5 appear on the 303(d) priorities list, 26 of which are impaired by toxics. Exhibit A-23 presents the pollutant types, 303(d) report ranking, and area of impairment for the 26 toxics-impaired waterbodies.[20]

As shown in Exhibit A-21, the Delta Waterways, Clear Lake, the lower sections of the American and Feather Rivers, and sections of the Sacramento River are all listed as highest priority to the State. Metals, pesticides, and unspecified toxics combine to impair these waters. Shasta Lake and the Grasslands Marshes lie in the second tier of state priorities, while Berryessa Lake, Whiskeytown Reservoir and the lower section of the Stanislaus River fall into the third highest category. Fifteen other waterbodies were ranked as lower priority.

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[19] The Delta Waterways account for the entire area of assessed estuaries.

[20] *California Report on Impaired Surface Waters, Clean Water Act Section 303(d)*, May 1994.

Exhibit A-20

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 5: CENTRAL VALLEY REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	0	NA	48,000	100%	0	0%	533	44%	0	NA	8,226	100%
Hydro./Habitat Modification	0	NA	48,000	100%	0	0%	0	0%	0	NA	0	0%
Industrial	0	NA	0	0%	295	0%	186	15%	0	NA	0	0%
Land Development	0	NA	0	0%	0	0%	19	2%	0	NA	0	0%
Land Disposal	0	NA	0	0%	0	0%	0	0%	0	NA	0	0%
Mining	0	NA	48,000	100%	97,386	81%	690	57%	0	NA	2	0%
Municipal	0	NA	48,000	100%	0	0%	185	15%	0	NA	0	0%
Other Nonpoint Sources	0	NA	48,000	100%	10,576	9%	514	42%	0	NA	1	0%
Other Point Sources	0	NA	0	0%	0	0%	0	0%	0	NA	0	0%
Storm Sewers	0	NA	0	0%	0	0%	185	15%	0	NA	0	0%
Urban Runoff	0	NA	48,000	100%	295	0%	178	15%	0	NA	0	0%

Source: U.S. EPA analysis of WQA database.

Exhibit A-21

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN THE CENTRAL VALLEY REGION (REGION 5)

Waterbody	Pollutants[1]	303(d) Priority	Area Affected
Delta Waterways	Pesticides, Metals, Unspec. Toxics	1	48,000 acres
Beach Lake	Pesticides, Metals	5	295 acres
Berryessa Lake	Metals	3	20,700 acres
Clear Lake	Metals	1	43,000 acres
Davis Creek Res.	Metals	5	290 acres
Keswick Res.	Metals	4	450 acres
Marsh Creek Res.	Metals	5	375 acres
Shasta Lake	Metals	2	20 acres
Whiskeytown Res.	Unspec. Toxics	3	3,251 acres
American River, Lower	Pesticides, Metals, Unspec. Toxics	1	23 miles
Feather River, Lower	Pesticides, Metals, Unspec. Toxics	1	60 miles
Kings River, Lower	Pesticides, Metals, Trace Elements	4	30 miles
Little Backbone Creek	Metals	5	1 mile
Little Grizzly Creek	Metals	5	10 miles
Merced River, Lower	Pesticides, Unspec. Toxics	4	60 miles
Mokelumne River, Lower	Metals	4	28 miles
Mud Slough	Pesticides, Trace Elements, Unspec. Toxics	4	16 miles
Sacramento River, Shasta Dam to Red Bluff	Metals, Unspec. Toxics	1	50 miles
Sacramento River, Red Bluff to Delta	Pesticides, Metals, Unspec. Toxics	1	185 miles
Sacramento Slough	Metals, Unspec. Toxics	5	1 mile
Salt Slough	Pesticides, Trace Elements, Unspec. Toxics	4	15 miles
Stanislaus River, Lower	Pesticides, Unspec. Toxics	3	48 miles
Tuolumne River, Lower	Pesticides, Unspec. Toxics	4	32 miles
Grasslands Marshes	Trace Elements	2	8,224 acres
Mormon Channel	Pesticides, Metals	5	1 acre
Mormon Slough	Pesticides, Metals	5	1 acre

Sources: 1994 303(d) list;WQA Database

[1] An aquatic life criterion of 5 μg/l for selenium is already in effect in portions of Region 5.

Natural Resources and Beneficial Uses Affected

The surface waters of the Central Valley Region are essential to the diverse human activities and wildlife resources in the Region. The Sacramento and San Joaquin Rivers alone furnish over 50 percent of the State's water supply. Together, the Region's waters support one of the most productive agricultural centers, a growing population, and many wild and scenic areas. Exhibit A-22 presents a summary of the beneficial uses associated with the toxics-impaired waterbodies listed in the 303(d) report.[21]

As shown in Exhibit A-22, all of the waterbodies listed in the 303(d) report for which beneficial use information exists support both contact and non-contact water recreation, including swimming, boating, hiking, and nature-watching. The American and Kings River are noted as popular recreational areas, and the upper reaches of the Kings River are classified as Wild and Scenic, protecting these reaches from the construction of dams and other water diversion devices.[22] All but the Kings River supply water to municipalities, and most are used for agricultural purposes. Many of the waterbodies supply industry, while a few serve as navigational channels.

All of the waterbodies listed in the 303(d) report also support wildlife habitats. Most are also areas of fish spawning, while many serve as paths for fish migration. In particular, the Sacramento River is home to rare and endangered species of salmon.

Region 6: Lahontan Region

Hydrologic Setting

Region 6, the Lahontan Basin, runs nearly 570 miles along California's eastern boundary and encompasses over 33,000 square miles of area. Its topography is diverse and includes the highest (Mount Whitney) and the lowest (Death Valley) points in the contiguous United States. Also included are the eastern slopes of the Warner, Sierra Nevada, San Bernardino, Tehachapi, and San Gabriel mountains, as well as topographic depressions such as the Madeline Plains and the Bridgeport, Owens, and Victor Valleys. The Region lies generally in a rain shadow, but mountainous areas receive high levels of precipitation (up to 70 inches per year), mostly as snow. Runoff from the mountains, generally from intermittent streams formed by melting snow, carries significant amounts of toxic metals to the larger waterbodies of the Region. The high natural concentration of toxics exacerbates the effects of toxic pollutants from human activity.[23]

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[21] The Region 5 Basin Report provided most of the beneficial use information but lacked individual listings for many of the water bodies contained on the 303(d) report. The WQA SITEDATA file was employed to augment the Basin Report.

[22] *Draft California 305(b) Report on Water Quality*; State Water Resources Control Board, October 1994, pp. 12-13.

[23] *Water Quality Control Plan, Central Coast Basin*; California Regional Water Quality Control Board, Lahontan Region, Region 6, October, 1994, pp. I3-I5.

Exhibit A-22

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES

Waterbody	Beneficial Uses									
	Municipal Supply	Agriculture	Industrial	Water Contact Recreation	Non-Contact Water Recreation	Freshwater Habitat	Fish Migration	Fish Spawning	Wildlife Habitat	Navigation
Delta Waterways	X	X	X	X	X	X	X	X	X	X
Beach Lake*	X	X	X	X	X	X	X	X	X	X
Berryessa Lake	X	X	X	X	X	X		X	X	
Clear Lake	X	X		X	X	X		X	X	
Davis Creek Res.				X	X	X		X	X	
Keswick Res.*	X	X	X	X	X	X	X	X	X	
Marsh Creek Res.*	X	X		X	X	X		X	X	
Shasta Lake	X	X	X	X	X	X		X	X	
Whiskeytown Res.	X	X	X	X	X	X		X	X	
American River, Lower	X	X	X	X	X	X	X	X	X	
Feather River, Lower	X			X	X	X		X	X	
Kings River, Lower*		X		X	X	X			X	
Little Backbone Creek*	X	X		X	X	X		X	X	
Little Grizzly Creek*	X			X	X	X	X	X	X	
Merced River, Lower	X	X	X	X	X	X	X	X	X	
Mokelumne River, Lower		X	X		X	X	X	X	X	
Mud Slough*	X	X		X	X	X	X	X	X	
Sacramento River, Shasta Dam to Red Bluff	X	X	X	X	X	X	X	X	X	X
Sacramento River, Red Bluff to Delta	X	X	X	X	X	X	X	X	X	X
Sacramento Slough**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Exhibit A-22

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES (continued)

	Beneficial Uses									
Waterbody	**Municipal Supply**	**Agriculture**	**Industrial**	**Water Contact Recreation**	**Non-Contact Water Recreation**	**Freshwater Habitat**	**Fish Migration**	**Fish Spawning**	**Wildlife Habitat**	**Navigation**
Salt Slough*	X	X		X	X	X	X	X	X	
Stanislaus River, Lower	X	X	X	X	X	X	X	X	X	
Tuolumne River, Lower	X	X		X	X	X	X	X	X	
Grasslands Marshes*	X	X		X	X	X	X	X	X	
Mormon Channel**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mormon Slough**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

* The Region 5 Basin Report did not contain individual listings for these waterbodies. The beneficial uses were taken from the WQA database, SITEDATA.

** Neither the Region 5 Basin report nor the WQA contained beneficial use listings for these waterbodies.

Sources: *Water Quality Control Plan, Central Valley Region, Sacramento River and San Joaquin River Basins*, California Regional Water Quality Control Board, December, 1994, Table II-1.
Water Quality Assessment Catalog, State Water Quality Control Board, December, 1994.

The waterbodies in the Lahontan Region have proven essential to urban development in the area; a number of the Region's waterbodies are diverted to supply energy and drinking water for the cities of Los Angeles and Reno, Nevada. The Region's 700 lakes are utilized for many human beneficial uses and include a number of saline lakes, such as Alkali Lake and Honey Lake. In addition, Lahontan Region waterbodies attract millions of visitors for recreation each year. Much of the Region is in public ownership, with land use controlled by the Los Angeles Department of Water and Power, the National Park Service, Bureau of Land Management, and other Federal and State agencies.[24] Figure A-6 shows the location of major waterbodies in Region 6.

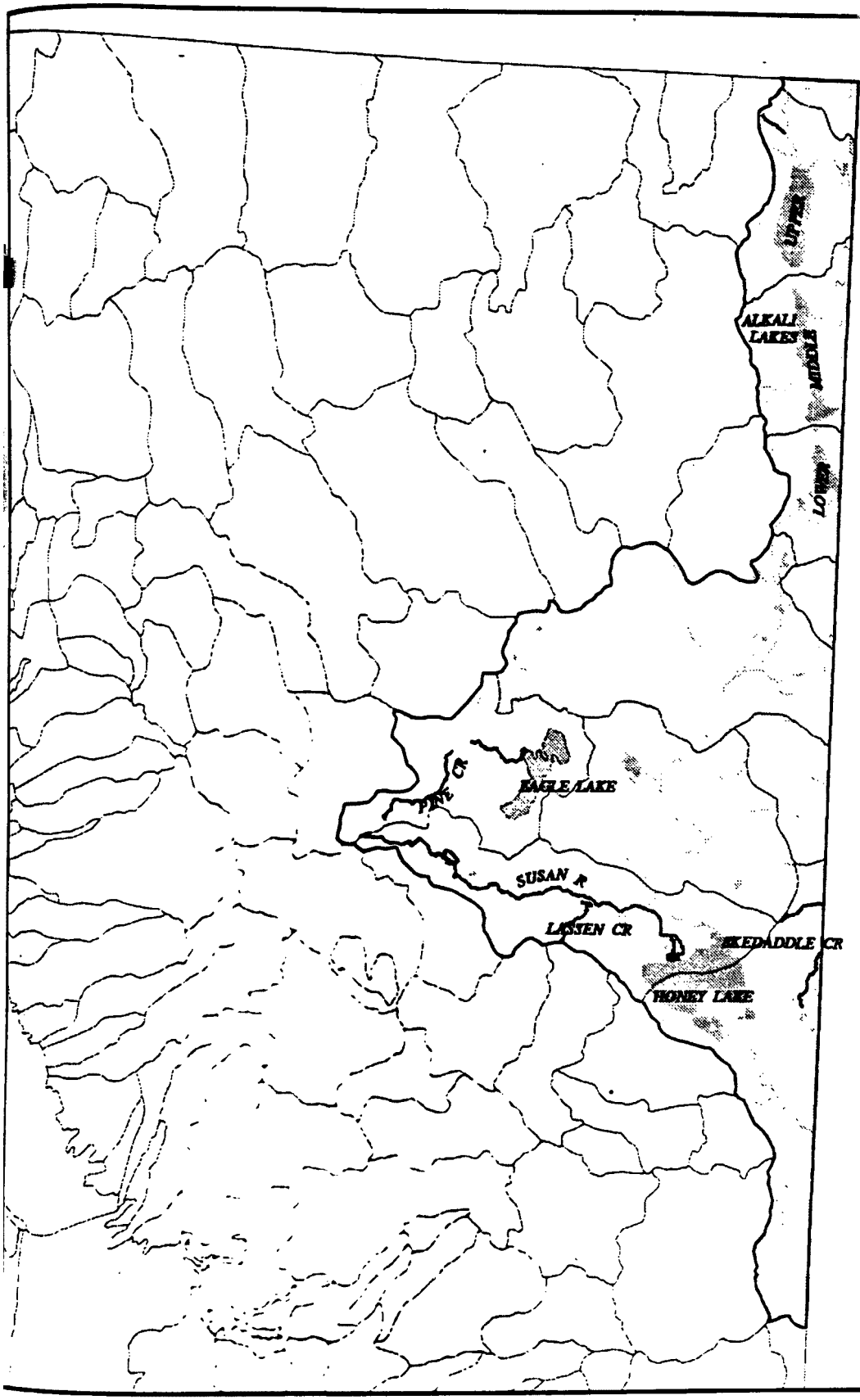
Degree and Sources of Toxics Impairment

Much of the toxic pollution found in Region 6 waterbodies originates in the many mountain streams that serve as tributaries to the Region's major rivers and lakes. Many desert waters also have naturally high concentrations of toxic metals, including selenium. Additional toxics, including metals, pesticides, priority organics, and trace elements, result from human activities, particularly land development, agriculture, and urban development. The high natural baseline, combined with human contributions, leads to a large areal extent of toxic impairment. Examination of the WQA database reveals the following information:

- As summarized in Exhibit A-23, toxics impair a significant portion of most of the waterbody types assessed, including 35,878 acres of lakes and reservoirs (19 percent of assessed), 66,182 acres of saline lakes (34 percent of assessed), and 372 miles of rivers and streams (13 percent of assessed). However, only 468 acres of wetlands (1 percent of assessed) are considered to be impaired by toxics.

- Exhibit A-24 demonstrates that natural sources are among the primary contributors to toxic pollution in Region 6, particularly for rivers, lakes, and reservoirs. In addition, agricultural activities are associated with the impairment of 34 percent of affected rivers and streams and 100 percent of affected saline lakes, while land development is connected with the impairment of 70 percent of affected lakes and reservoirs area and 16 percent of affected saline lakes. Mining contributes significantly to river contamination. The relatively small area of wetlands that is impaired by toxics is affected by urban runoff and miscellaneous nonpoint sources.

[24] Ibid.



LAHONTAN REGION(6SLT-A)

Produced by
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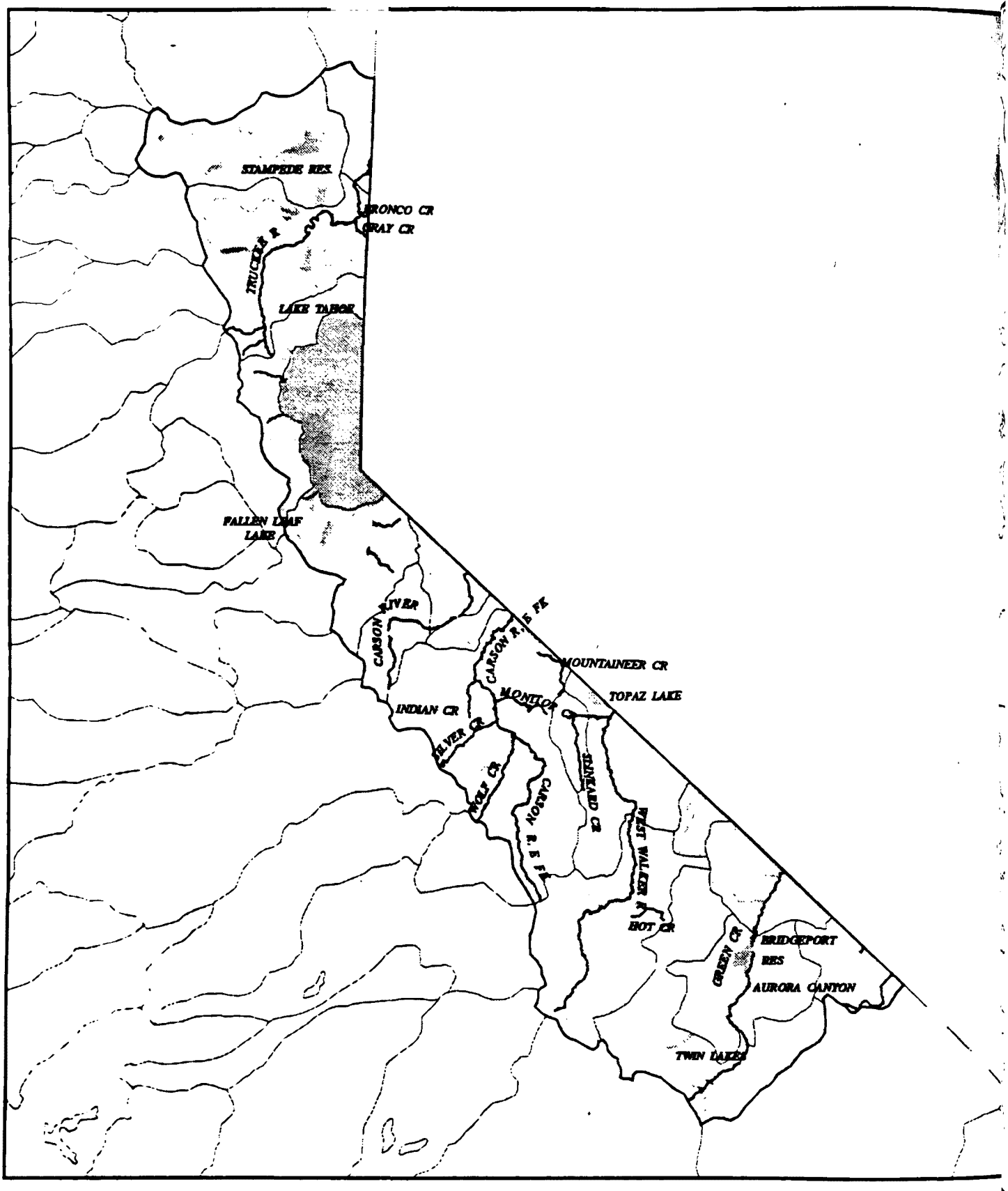
Sept. 27, 1995

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board



LAHONTAN REGION(6SLT-B)

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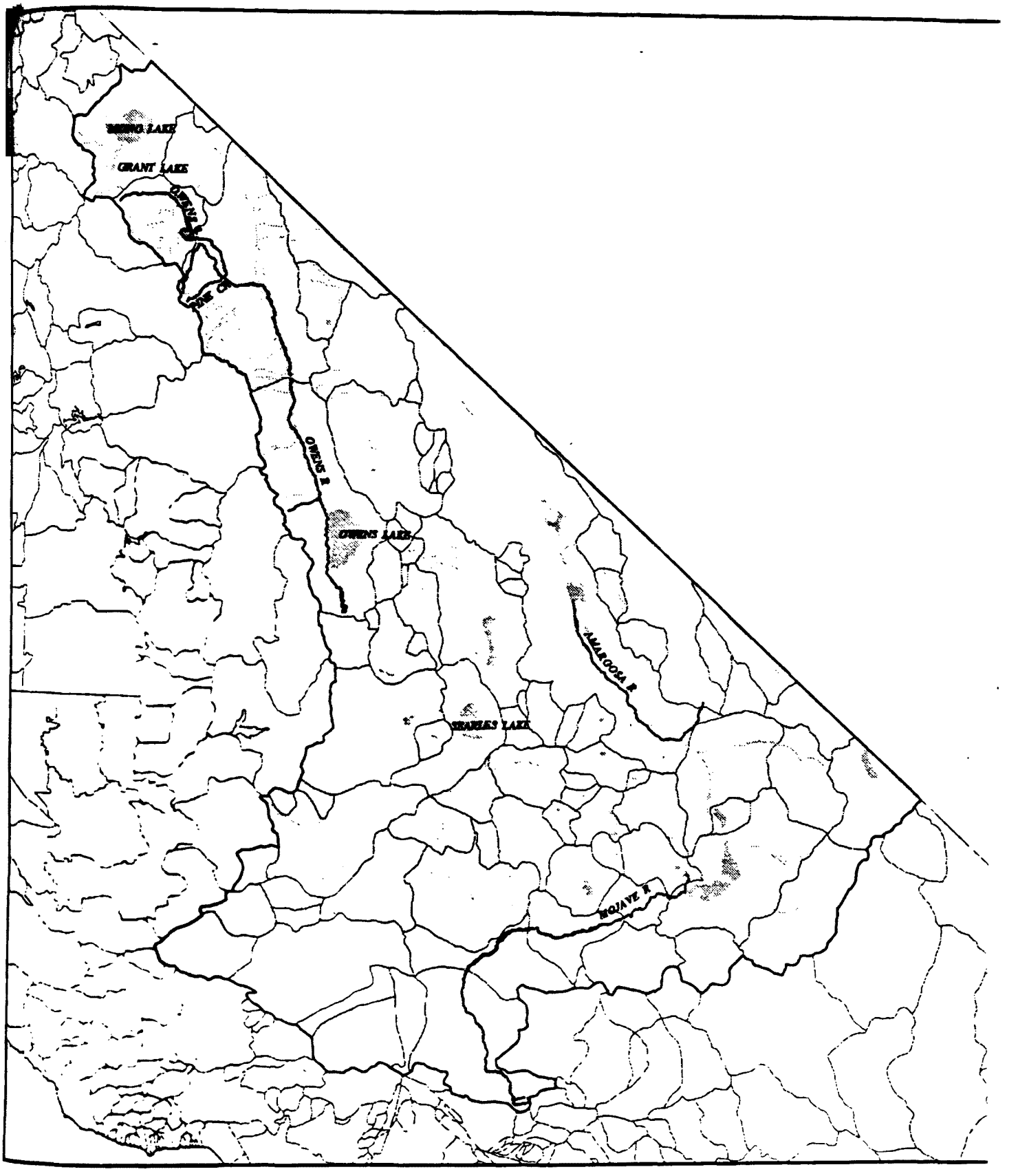
0 5 10 15 MILES

0 5 10 15 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board



LAHONTAN REGION(6V)

Produced by
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Sept. 27, 1995

0 15 30 45 MILES

0 15 30 45 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board

Exhibit A-23

TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATERBODY AREA
REGION 6: LAHONTAN REGION

	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	0	0	35,878	372	66,182	468
Total Assessed	0	0	189,059	2,893	193,082	43,545
Share	NA	NA	18.98%	12.86%	34.28%	1.07%

Source: U.S. EPA analysis of the WQA database.

Key Waterbodies Affected

Based on California's 303(d) report, a number of the waterbodies affected by toxics in Region 6 are of significant priority. Twenty-seven waterbodies in Region 6 appear on the priority list, 14 of which are affected by toxics. Exhibit A-25 presents the pollutant types, 303(d) report ranking, and area of impairment for these 14 waterbodies. Included are the Truckee River, Owens River, Honey Lake, Eagle Lake, Topaz Lake, and a small segment of Lake Tahoe.[25] Metals and trace elements are the most common types of toxics, with pesticides and priority organics also present.

As shown in Exhibit A-25, Lake Tahoe is listed as among the state's highest priorities (a ranking of "1"), but the area affected by toxics (according to the WQA database) is limited to only 0.1 percent of the total area of the lake. In contrast, the WQA data suggest that toxics impair the entire assessed area of the waterbodies ranked in the second tier, including Eagle Lake, Owens River, Truckee River, and Honey Lake.

[25] *California Report on Impaired Surface Waters, Clean Water Act Section 303(d)*, May 1994. Based on 1996 data, Lake Tahoe has been removed from the 303(d) list.

Exhibit A-24

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 6: LAHONTAN REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	0	NA	0	NA	2,300	6%	127	34%	66,182	100%	0	0%
Hydro./Habitat Modification	0	NA	0	NA	0	0%	0	0%	0	0%	0	0%
Industrial	0	NA	0	NA	0	0%	0	0%	0	0%	0	0%
Land Development	0	NA	0	NA	25,000	70%	7	2%	10,855	16%	0	0%
Land Disposal	0	NA	0	NA	0	0%	1	0%	0	0%	0	0%
Mining	0	NA	0	NA	2,300	6%	94	25%	0	0%	0	0%
Municipal	0	NA	0	NA	0	0%	4	1%	0	0%	0	0%
Other Nonpoint Sources	0	NA	0	NA	35,878	100%	245	66%	10,855	16%	468	100%
Other Point Sources	0	NA	0	NA	0	0%	4	1%	0	0%	0	0%
Storm Sewers	0	NA	0	NA	0	0%	0	0%	0	0%	0	0%
Urban Runoff	0	NA	0	NA	4,670	13%	117	31%	0	0%	468	100%

Source: U.S. EPA analysis of WQA database.
* Natural Sources are a subset of Other Nonpoint Sources.

Natural Resources and Beneficial Uses Affected

The waterbodies of the Lahonton Basin support a diverse wildlife population, including species and subspecies of plants and animals exclusive to the Region. Notable fish species include the Eagle Lake trout, Lahontan and Paute cutthroat trout, and Mojave Chub. Exhibit A-26 summarizes available information on the beneficial uses supported by Region 6 waters that have been identified as impaired by toxic pollutants. As the exhibit indicates, all of the waterbodies included on the 303(d) priority list are categorized as either freshwater or inland saline habitats, and all support wildlife. Most are fish spawning areas, while many support fish migration and rare or endangered species. Eagle Lake and Lake Tahoe are both considered essential for the preservation of biological habitats of special significance.[26]

In addition to providing important wildlife habitat, all of the freshwater resources listed in Exhibit A-26 supply water to municipalities. The waters of the Truckee, Carson and Walker Rivers, and of Lake Tahoe, are allocated among water users in California and Nevada, while water from the Owens and Mono Rivers is diverted, via the Los Angeles Aqueduct, for use in the Los Angeles area. Most of the waterbodies also support agriculture, while many are used for navigation. Only four of the waters are utilized for industrial purposes.

Many of the waters identified in Exhibit A-26 play a critical role in the Lahontan Region's tourist economy. According to the Basin Report, all of the waterbodies support both contact and non-contact water recreation, including swimming, boating, hiking, and nature-watching. Most of the waterbodies also support commercial and sport fishing. Segments of the East Fork Carson and West Walker Rivers are included in the State Wild and Scenic River system, which prohibits the construction of dams and other water diversion facilities on the specified waterbodies. Lake Tahoe and Eagle Lake are noted tourist sites, while the Truckee river is a popular rafting stream and wild trout fishery. Tributaries of the Owens river also support heavy recreational use.

[26] Based on 1996 data, Lake Tahoe is no longer on the 303(d) list.

Exhibit A-25

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN THE LAHONTON REGION (REGION 6)

Waterbody Name	Pollutants	303(d) Priority	Area Affected
Eagle Lake (2)	Metals	2	25,000 acres
Fallen Leaf Lake	Trace Elements	3	1,410 acres
Lake Tahoe[1]	Metals, Pesticides	1	160 acres
Topaz Lake	Trace Elements	4	2,300 acres
Bryant Creek	Metals, Trace Elements	5	10 miles
Carson River, E. Fork	Metals, Trace Elements	3	46 miles
Carson River, W. Fork	Trace Elements	4	6 miles
East Walker River	Metals, Priority Organics	3	8 miles
Owens River	Trace Elements	2	120 miles
Susan River	Metals, Trace Elements	4	7 miles
Truckee River	Metals, Trace Elements, Priority Organics	2	106 miles
West Walker River	Metals, Trace Elements	3	1 mile
Alkali Lake, Lower	Trace Elements	3	10,855 acres
Honey Lake	Trace Elements	2	55,327 acres

Sources: 303(d) list; 1994 WQA Data Base

[1] Based on 1996 data, Lake Tahoe is no longer on the 303(d) list.

Exhibit A-26

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES

Waterbody	Beneficial Uses														
	Municipal Supply	Agriculture	Industrial	Commercial and Sport Fishing	Navigation	Water Contact Recreation	Non-Contact Water Recreation	Groundwater Recharge	Wildlife Habitat	Freshwater Habitat	Inland Saline Habitat	Fish Migration	Fish Spawning	Preservation of Biological Habitats of Special Significance	Supports Rare or Endangered Species
Eagle Lake (2)	X	X		X	X	X	X	X	X	X		X	X	X	X
Fallen Leaf Lake	X			X	X	X	X		X	X			X		
Lake Tahoe	X	X		X	X	X	X	X	X	X		X	X	X	
Topaz Lake	X	X		X	X	X	X	X	X	X			X		
Bryant Creek	X	X				X	X	X	X	X					
Carson River, E. Fork	X	X		X	X	X	X	X	X	X			X		X
Carson River, W. Fork	X	X	X	X	X	X	X	X	X	X			X		X
East Walker River	X	X	X	X	X	X	X	X	X	X			X		X
Owens River	X	X		X	X	X	X	X	X	X		X	X		
Susan River	X	X	X		X	X	X	X	X	X		X	X		
Truckee River	X	X	X	X		X	X	X	X	X		X	X		X
West Walker River	X	X		X		X	X	X	X	X		X	X		
Alkali Lake, Lower						X	X		X		X		X		X
Honey Lake		X		X		X	X	X	X	X	X				

Source: Water Quality Control Plan, Lahontan Basin, Region 6, California Regional Water Quality Control Board, October, 1994, Table 2-1.

Region 7: Colorado River Basin

Hydrologic Setting

Region 7, the Colorado River Basin, encompasses approximately 20,000 square miles of southeast California.[27] It is bordered on the north and west by several mountain ranges, on the south by Mexico, and on the east by the Colorado River and the state of Arizona. As shown in Figure A-7, the major waterbodies in this region are the Colorado River, the Salton Sea, and a variety of smaller rivers and conduits that feed the Salton Sea.

The hydrologic features of Region 7 are heavily influenced by the Colorado River and agricultural activity in the area. Water from the Colorado River is used to irrigate land in the Palo Verde Valley, the Imperial Valley, and the Coachella Valley.

The Salton Sea was formed early in this century by overflow from the Colorado River and now is fed primarily by irrigation drainage from the Imperial and Coachella Valleys. It is California's largest inland waterbody, covering approximately 220,000 acres, and supports a number of wildlife species and recreational activities (see below). Agricultural drainage is transported to the Salton Sea via several natural and man-made conduits. The Alamo River, New River, and Coachella Valley Storm Water Channel are the Sea's major water sources and are fed primarily by agricultural runoff. San Felipe Creek and Salt Creek are natural waterways that also feed the Salton Sea.

Degree and Sources of Toxics Impairment

Unlike many of California's other water regions, toxics pollution in the Colorado River Basin is relatively homogenous in nature and source: pesticide and trace element contamination caused by agricultural drainage. Analysis of the WQA database yields the following information:

- Of the total river miles assessed in Region 7, approximately 60 percent (1,433 miles) are impaired by toxics.
- Where pollutants are specified in the database, pesticides account for essentially all of the toxic pollution that impairs rivers, while trace elements (primarily selenium) are the primary pollutants for the Salton Sea.
- Agriculture is listed as the source of toxic pollution for nearly 100 percent of the Region's impaired waters. Border pollution from Mexico (agricultural runoff and municipal sewage) is a minor contributor as well.

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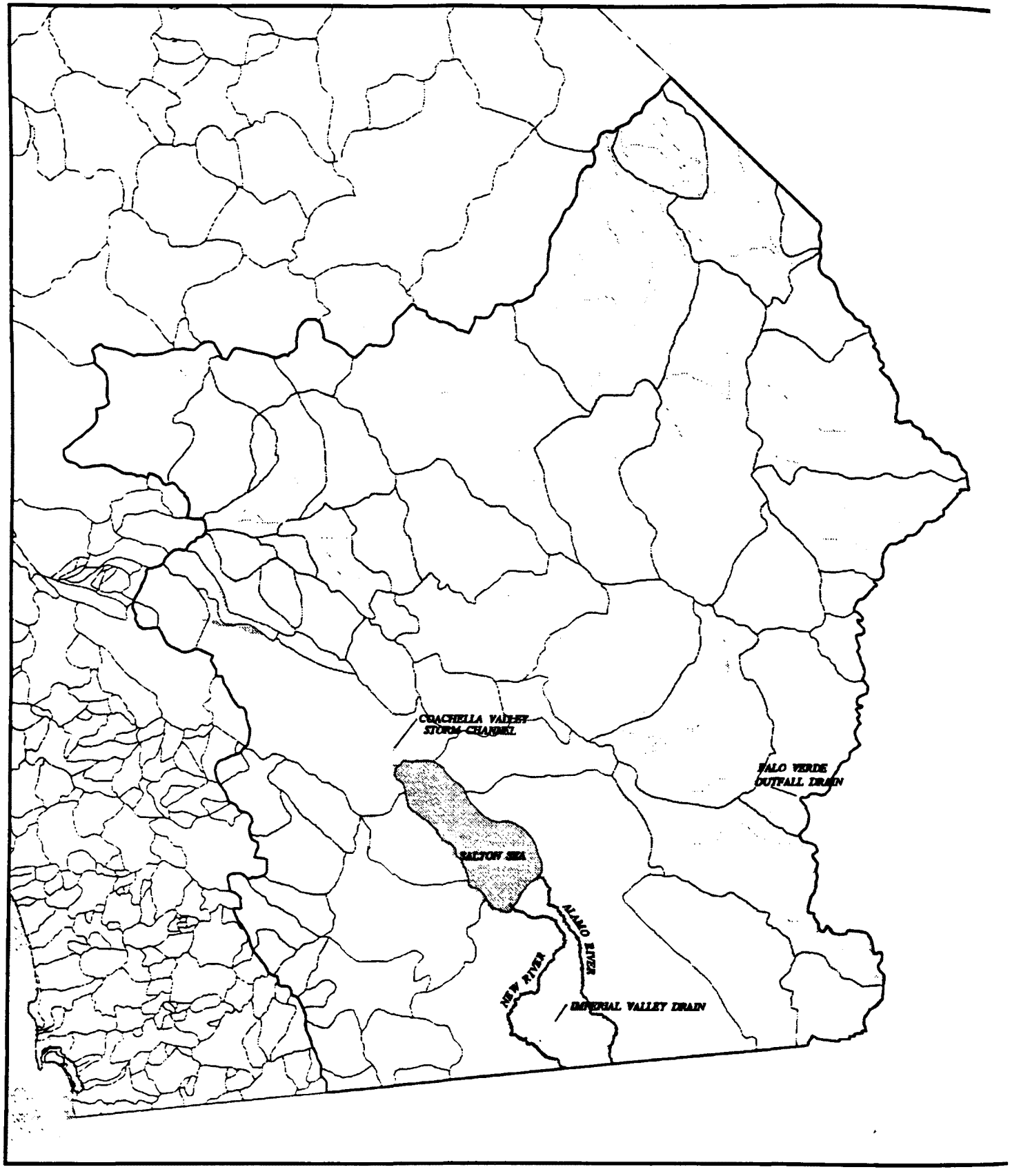
[27] *Water Quality Control Plan - Colorado River Basin Region,* State Water Resources Control Board, California Regional Water Quality Control Board, Colorado River Basin Region, November 17, 1993.



COLORADO RIVER BASIN REGION(7)

Produced by
LKC
USEPA Region 9 GIS Center
Sept. 27, 1995

0 10 20 30 MILES

0 10 20 30 KILOMETERS

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board

Key Waterbodies Affected

Available water quality data indicate that, apart from the Salton Sea, the extent of waters impaired by toxics in Region 7 is relatively limited. Exhibit A-27 presents information on the Region 7 waterbodies that California's 303(d) report identifies as impaired.[28] These include the Salton Sea as well as several rivers or channels that carry agricultural runoff. Despite the fact that these waters are identified in the 303(d) report, only the Salton Sea is listed as being of "high priority" (based on beneficial uses and severity of pollution) relative to other state waters.[29]

With respect to the areal extent of toxics contamination, the Salton Sea and the Imperial Valley Drains are the two most significant waterbodies impaired. The WQA database indicates that trace elements (including selenium) are the most significant toxics problem in the Salton Sea. This is consistent with a 1986-1987 U.S. Geological Survey investigation of the area that found elevated concentrations (a median of 19 ppb) of selenium in tile drain effluent. The study also found elevated selenium and boron in aquatic bird tissues.[30] The WQA database indicates that both trace elements and pesticides are present in the Imperial Valley Drains.

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[28] *California Report on Impaired Surface Waters, Clean Water Act Section 303(d)*, May 1994.

[29] According to the WQA data, the Colorado River itself has no toxic pollution. Salinity levels, however, are high in the lower portions of the river. In addition, the flow of the Colorado has been greatly diminished by diversions for agricultural, industrial and municipal use (*Running Dry: Why Some of the World's Great Rivers No Longer Reach the Sea*, World Watch, May/June, 1995.)

[30] *An Overview of Irrigation Drainwater Techniques, Impacts on Fish and Wildlife Resources, and Management Options*, U.S. Fish and Wildlife Service, May 1992, p. 63.

Exhibit A-27

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN COLORADO RIVER BASIN (REGION 7)

Waterbody	Pollutants	303(d) Priority	Area Affected
Salton Sea	Trace elements	1	220,000 acres
Alamo River	Pesticides, Selenium	4	52 miles
Coachella Valley Storm Channel	Pesticides	5	20 miles
Imperial Valley Drains	Pesticides, Selenium	5	1,305 miles
New River	Pesticides, Trace elements	5	60 miles
Palo Verde Outfall Drain	Pesticides	5	16 miles

Sources 303(d) list; 1994 WQA database.

Natural Resources and Beneficial Uses Affected

The surface waters of the Colorado River Basin, including those impaired by toxics pollution, support diverse wildlife resources as well as a variety of beneficial human uses. Exhibit A-28 summarizes beneficial use information from the Basin Report for Region 7. As shown, all of the waterbodies impaired by toxics support habitat, fish, and wildlife.[31] Moreover, all support some form of rare, threatened or endangered species. The Basin Report for Region 7 provides the following additional information on fish and wildlife in the Region:

- **Fish:** Virtually all fish species found in Region 7 have been introduced into the Region. The irrigation canals support large- and smallmouth bass, catfish, bullhead, bluegill, sunfish, crappie, carp, striped bass and other species. The Salton Sea supports large sportfish, including orangemouth corvina, gulf croaker, sargo, and tilapia.

[31] Regional officials list the Salton Sea as a warm freshwater habitat for lack of a more precise categorization The Salton Sea is actually of somewhat greater salinity than ocean water. Personal communication with Kenneth Coulter, Senior Engineering Geologist, California Regional Water Quality Control Board, Colorado River Basin Region, July 27, 1995.

- **Waterfowl:** The Salton Sea National Wildlife Refuge and state waterfowl management areas are located in and around the Salton Sea. Currently, more than 90,000 migratory waterfowl, as well as other aquatic birds, use the refuge each year.[32]

- **Rare, Threatened, Endangered Species:** Critical species supported by surface water in the Region include the desert pupfish, razorback sucker, Yuma clapper rail, black rail, least Bell's vireo, yellow billed cuckoo, and desert tortoise.

- **Mammals and Reptiles:** Large portions of Region 7 are inhabited by rodents, coyotes, foxes, and assorted reptiles.

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[32] *An Overview of Irrigation Drainwater Techniques, Impacts on Fish and Wildlife Resources, and Management Options*, p. 63.

Exhibit A-28

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES

Waterbody	Beneficial Uses						
	Aquaculture	Water Contact Recreation	Non-Contact Water Recreation	Freshwater Replenishment	Warm Freshwater Habitat	Wildlife Habitat	Supports Rare, Endangered Species
Salton Sea	x	x	x		x	x	x
Alamo River		x	x	x	x	x	x
Coachella Valley Storm Channel		x	x	x	x	x	x
Imperial Valley Drains		x	x	x	x	x	x
New River		x	x	x	x	x	x

Note: Beneficial use information not available for Palo Verde Outfall Drain.
Source: WQA data, as summarized in *Water Quality Control Plan Colorado River Basin Region*, p. 2-12 through 2-13.

The ecological impacts attributable to pollution in Region 7's surface waters include adverse effects on waterfowl. Concentrations of selenium are highest in the drainage channels and tests have found elevated tissue concentrations in birds and other species that feed in these areas. In addition, the Salton Sea was the site of one of the largest bird kills on record (approximately 180,000 eared grebes), although this event was associated with red algae blooms partially caused by nonpoint source runoff, rather than direct exposure to toxics.[33]

Apart from supporting wildlife, the Region's impaired surface waters are used for recreation and other human activities. The WQA database shows that the beneficial use of these waters include swimming, fishing, and non-contact recreation such as boating and hiking.[34] It should be noted that all the affected rivers are used for the collection and transport of agricultural drainage; however, the Clean Water Act does not recognize this application as a beneficial use.

Toxics contamination in the region has had an impact on recreational activity in recent years, but only to a small degree. Because of selenium levels in the Salton Sea, a fish consumption advisory is in effect. Recreational anglers and sensitive subpopulations such as pregnant women are encouraged to limit intake of fish caught in the Salton Sea. Regional officials note that the advisory is highly conservative, and that recreational fishing is still popular in the area. Furthermore, a number of other recreational activities are freely pursued; for example, no beach closures have ever been issued for the Salton Sea.[35]

Region 8: Santa Ana River Basin

Hydrologic Setting

The Santa Ana River Basin is approximately 2,800 square miles in size and is located just south of Los Angeles and north of San Diego.[36] It is bounded by the San Gabriel and San Bernardino mountains to the north and east, the San Jacinto Mountains in the southeast, and the Pacific Ocean to the west. As the Region's name suggests, the Santa Ana River and its tributaries

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[33] Personal communication with Kenneth Coulter, Senior Engineering Geologist, California Regional Water Quality Control Board, Colorado River Basin Region, July 27, 1995.

[34] CWA, 40 CFR Section 131.10 (a).

[35] Personal communication with Kenneth Coulter, Senior Engineering Geologist, California Regional Water Quality Control Board, Colorado River Basin Region, July 27, 1995.

[36] The majority of the material on Region 8 was taken from the *Water Quality Control Plan - Santa Ana River Basin*, State Water Resources Control Board, California Regional Water Quality Control Board, Santa Ana River Basin Region, January 1995.

comprise the largest waterbody system in the area, which also includes the San Jacinto River and other rivers that interlace the mountains. Lake Elsinore in the south and Lake Mathews in the center of the Region are its largest standing waterbodies (see Figure A-8).

The climate in the Santa Ana River Basin is dry and warm. The region receives an average of only 15 inches of rainfall per year, and is technically classified as "near-desert". The attractive climate has encouraged settlement, making the Region the most densely populated in California. Moreover, the area continues to grow. A 1985 land use report for the upper Santa Ana basin indicates that the amount of land used for agricultural activities declined by 30 percent from 1975 to 1984, while land use for urban and suburban development increased by 23 percent during that period.[37]

The search for adequate water to supply the needs of such a densely populated area has affected the hydrology of the Region. In particular, the Santa Ana, San Jacinto, and other rivers have been diverted for use in irrigation and urban water supplies. These activities have resulted in a cessation of the groundwater recharge cycle; in some areas, artesian wells no longer pump water to the surface. At the same time, the area has been forced to exploit its remaining groundwater reservoirs as surface water sources dry up. Despite the use of sophisticated water retrieval techniques to access remaining local water supplies, the Region now must import over half of its water from other sources to meet the needs of the population. As a result, the Santa Ana River is an effluent-dominated river system; as its upstream waters are siphoned for other uses, downstream outfalls have become the largest contributor to the river's flow. These conditions contribute to elevated concentrations of pollutants, which have been only partially addressed by recent efforts to improve pretreatment and reduce the quantity of pollutants entering the Region's waters.

Degree and Sources of Toxics Impairment

Based on areal extent of impairment, toxics have the greatest impact on the bays and estuaries of Region 8. All of the bays whose waters have been assessed are impaired by toxics. Similarly, of the estuaries assessed, 91 percent are contaminated with toxics. Wetlands and rivers appear to be relatively less polluted, revealing rates of contamination of roughly 3 and 11 percent, respectively. Exhibit A-29 presents the percentages of assessed waters in Region 8 that have been found to be toxic-impaired.

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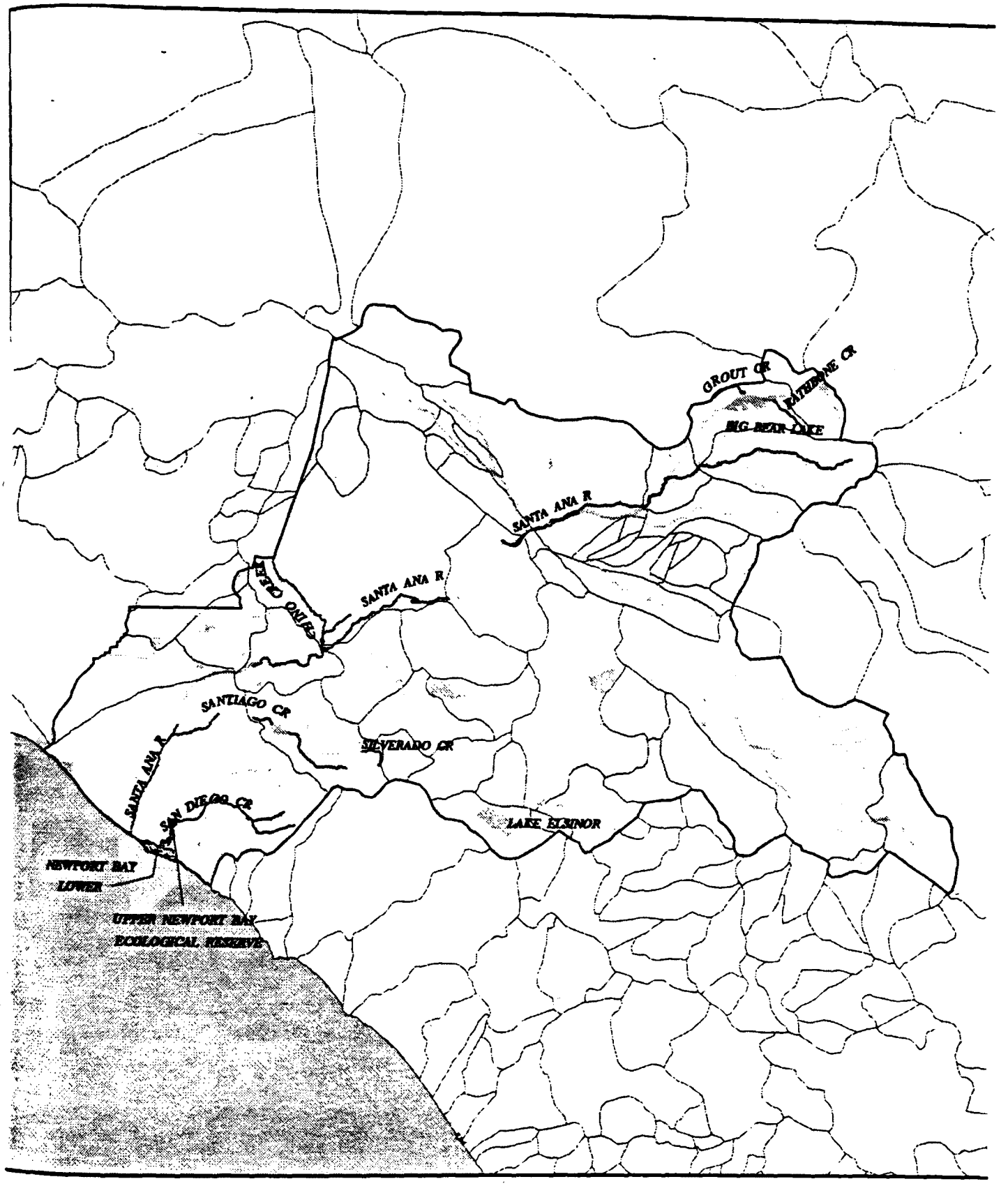
[37] *Upper Santa Ana River Drainage Area Land Use Survey, 1984*, California Department of Water Resources, Southern District, June 1985, Table 3, pp. 11



SANTA ANA REGION(8)

Produced by
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Sept. 27, 1995

0 5 10 15 MILES

0 5 10 15 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board

Exhibit A-29

TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATERBODY AREA
REGION 8: SANTA ANA RIVER REGION

	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	1,030	2,726	4,100	49	0	400
Total Assessed	1,030	2,996	15,167	463	0	15,017
Share	100.00%	90.99%	27.03%	10.58%	NA	2.66%

Source: EPA analysis of WQA database.

The primary source of toxics pollution in Region 8 is nonpoint source runoff from both urban and agricultural areas. Land development has contributed significantly to the impairment of estuaries and lakes, while land disposal has primarily affected wetlands. Aside from the effects of mining on lakes and reservoirs and the effects of POTWs on rivers, point source contamination is minor. Exhibit A-30 shows the impacts of different point and nonpoint sources on the various waterbodies in the region.

Key Waterbodies Affected

Exhibit A-31 presents data on the Region 8 waterbodies that appear on California's 303(d) list and are impaired by toxics (based on WQA data). Included are two portions of the Santa Ana River, as well as Lake Elsinore and certain Pacific coastal harbors. As shown, most of the waters are of lower priority (although several did not receive a ranking in the 303(d) list). Metals and pesticides are the most common categories of pollutants affecting these waters. The California Bay Cleanup Program lists several potential "toxic hot spots" in the Santa Ana basin. These include Anaheim Bay, Huntington Harbor, Bolsa Bay, and Newport Bay.[38]

Natural Resources and Beneficial Uses Affected

As shown in Exhibit A-32, the toxic-impaired waters of Region 8 provide a variety of beneficial services to the area. All of the waterbodies listed provide recreational opportunities for both contact activities, such as swimming and fishing, and non-contact activities such as boating and hiking. Certain of these waters also provide for commercial and recreational fin- and shellfishing.

[38] *Bay Protection and Toxic Cleanup Program, Staff Report*; State Water Resources Control Board, State of California, November 1993, p. 111, Figure 9.

Exhibit A-30

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 8: SANTA ANA REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	700	68%	752	28%	0	0%	12	24%	0	NA	400	100%
Hydro./Habitat Modification	0	0%	0	0%	0	0%	0	0%	0	NA	0	0%
Industrial	0	0%	0	0%	0	0%	0	0%	0	NA	0	0%
Land Development	0	0%	752	28%	1,500	37%	0	0%	0	NA	0	0%
Land Disposal	0	0%	0	0%	0	0%	0	0%	0	NA	400	100%
Mining	0	0%	0	0%	500	12%	0	0%	0	NA	0	0%
Municipal	0	0%	0	0%	0	0%	12	24%	0	NA	0	0%
Other Nonpoint Sources	1,030	100%	1,974	72%	4,100	100%	16	33%	0	NA	400	100%
Other Point Sources	20	2%	0	0%	0	0%	0	0%	0	NA	0	0%
Storm Sewers	0	0%	752	28%	0	0%	0	0%	0	NA	0	0%
Urban Runoff	350	34%	1,974	72%	2,600	63%	24	49%	0	NA	400	100%

Source: U.S. EPA analysis of WQA database.

Several of the waterbodies listed in Exhibit A-32 also contribute to water supplies in the area. The majority of freshwater entities are identified as a source for groundwater replenishment. Several of these waterbodies provide water for municipal systems and agricultural enterprises.

Region 8 waters that are impaired by toxics also support a variety of wildlife. All of the surveyed waterbodies provide either salt- or freshwater habitat for aquatic organisms, including some rare and endangered species. Certain of the waters are spawning areas for fish and other aquatic wildlife. In addition, Anaheim Bay and the Upper Newport Bay Ecological Reserve are designated as biological habitats of special significance that require special protection.

Exhibit A-31

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN SANTA ANA RIVER BASIN (REGION 8)

Waterbody	Pollutants	303(d) Priority	Area Affected
Upper Newport Bay Ecological Reserve	Pesticides, trace elements	2	1500 acres
Anaheim Bay	Metals, pesticides	3	180 acres
Big Bear Lake	Metals	3	2970 acres
Newport Bay, Lower	PCBs, pesticides, metals, trace elements	3	700 acres
Lake Elsinore	Various toxics	4	2600 acres
Santa Ana River, Reaches 3 and 4	Metals, various toxics	4	30 miles
Grout Creek	Metals	NA	2 miles
Huntington Harbor	Pesticides, metals	NA	150 acres
Knickerbocker Creek	Metals	NA	2 miles
San Diego Creek, Reaches 1 and 2	Pesticides, metals, various toxics	NA	12 miles

Sources: 303(d) list 1994 WQA Database

Exhibit A-32

NATURAL RESOURCES AND BENEFICIAL USES ASSOCIATED WITH KEY WATERBODIES

Waterbody	MUN	AGR	GWR	NAV	REC1	REC2	COMM	WARM	COLD	BIOL	WILD	RARE	SPWN	MAR	SHEL	EST
Anaheim Bay					X	X				X	X	X	X	X		X
Big Bear Lake	X	X	X		X	X		X	X		X	X				
Lake Elsinore					X	X		X			X					
Grout Creek	X		X		X	X			X		X		X			
Huntington Harbor				X	X	X	X				X	X	X	X	X	
Knickerbocker Creek	X		X		X	X			X		X					
Newport Bay, Lower				X	X	X	X				X	X	X	X	X	
San Diego Creek, Reaches 1 and 2			X		X	X		X			X					
Santa Ana River, Reaches 3 and 4		X	X		X	X		X			X	X				
Upper Newport Bay Ecological Reserve					X	X	X			X	X	X	X	X	X	X

Key:
- MUN = Municipal and Domestic Supply
- AGR = Agricultural Supply
- GWR = Ground Water Recharge
- NAV Navigation
- REC1 Water Contact Recreation
- REC2: Non-Contact Recreation
- COMM: Commercial and Sport Fishing
- WARM Warm Freshwater Habitat
- COLD: Cold Freshwater Habitat
- EST. Estuarine Habitat
- MAR. Marine Habitat
- WILD: Wildlife Habitat
- BIOL: Preservation of Biological Habitat
- RARE: Rare, Threatened, or Endangered Species
- SPWN: Spawning or Reproduction
- SHELL: Shellfish Harvesting

Source: *Water Quality Control Plan - Santa Ana River Basin*, State Water Resources Control Board, California Regional Water Quality Control Board, Santa Ana River Basin Region, January 1995, pp. 3-7 to 3-24.

Region 9: San Diego Basin

Hydrologic Setting

The San Diego Basin (Region 9) forms the southwest corner of California and encompasses nearly 3,900 square miles of surface area. The Region is bound to the west by the Pacific Ocean, and to the east by the Laguna Mountains and mountains located in the Cleveland National Forest. To the north lies a hydrologic divide that begins near Laguna Beach and extends inland through El Toro; to the south is the United States and Mexico border.[39] Figure A-9 shows the location of major waterbodies in Region 9.

Topographically, the San Diego Region is divided into a coastal plain, a central mountain-valley area, and an eastern mountain-valley area. The San Diego Region is characterized as semi-arid; precipitation is lowest on the coast, higher inland. In general, Region 9 water resources are limited, with only about 20,000 acres of bays and estuaries, 15,000 acres of lakes, and about 600 miles of rivers assessed in the WQA database. Scarcity of rainfall and increased urbanization of the Region have led to increased amounts of water importation from eastern sections of the state and alterations in many of the region's stream flows.

Degree and Sources of Toxic Impairments

The effects of toxic pollutants in Region 9 are greatest in the San Diego Bay area. The areal extent of toxics impairment in Region 9 is limited, with most pollution the result of increasing urbanization. The WQA data support the following observations:

- As summarized in Exhibit A-33, only 38 of the 576 river miles assessed (6.6 percent) are impaired by toxics. Toxics impair a small percentage of bays (2.2 percent of assessed) and estuaries (14.4 percent of assessed) as well.

- Exhibit A-34 demonstrates that industry, storm sewers, and miscellaneous nonpoint sources are the principal sources of toxic pollutants in bays, while land disposal activities have led to the contamination of estuaries. Toxic pollution in rivers is associated with agricultural and urban runoff, as well as industrial sources.

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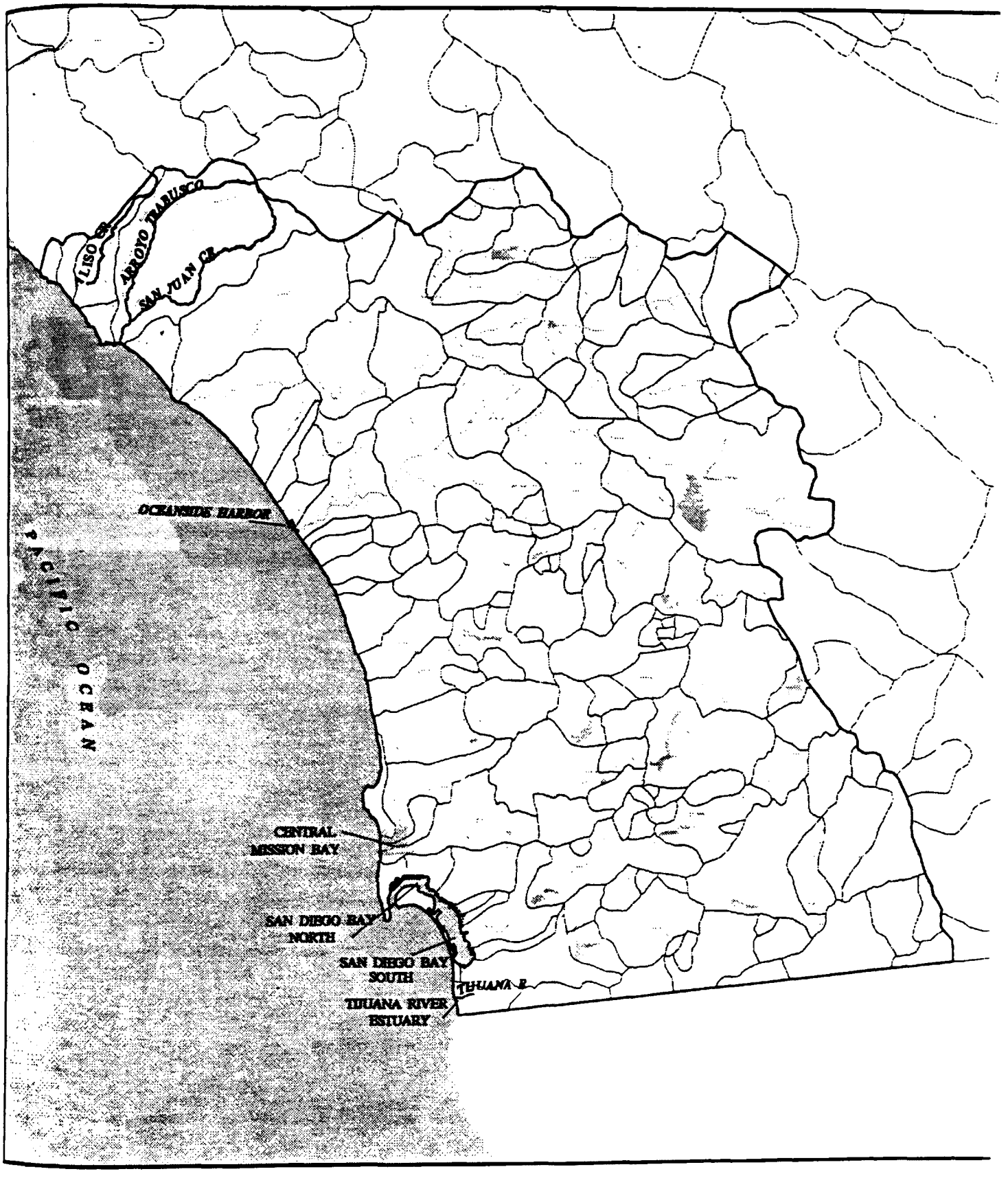
[39] *Water Quality Control Plan, San Diego Basin (Region 9)*; California Regional Water Quality Control Board, San Diego Region, September, 1994, p. 1-3.



SAN DIEGO REGION(9)

Produced by
LKC
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Sept. 27, 1995

0 5 10 15 MILES

0 5 10 15 KILOMETERS

EPA

SOURCES:
Streams: RF3 USEPA 1992
Impaired Waterbodies: State Water Resource Control Board 303(d) list 5-18-94
Hydrologic Sub-basins: Calif. State Water Resources Control Board

Exhibit A-33

TOXICS-IMPAIRED SHARE OF TOTAL ASSESSED WATER BODY AREA
REGION 9: SAN DIEGO REGION

	Bays (acres)	Estuaries (acres)	Lakes & Reservoirs (acres)	Rivers & Streams (miles)	Saline Lakes (acres)	Wetlands (acres)
Toxics-Impaired	308	937	0	38	0	0
Total Assessed	13,965	6,523	15,185	576	0	0
Share	2.21%	14.36%	0.00%	6.60%	NA	NA

Source: U.S. EPA analysis of WQA database.

Key Waterbodies Affected

Based on California's 303(d) report, a number of the waterbodies affected by toxics in Region 9 are of significant priority.[40] Fifteen waterbodies in Region 9 appear on the priority list, seven of which are affected by toxics. Exhibit A-35 presents the pollutant types, 303(d) report ranking, and area of impairment for these seven waterbodies. Included are the North and South sections of San Diego Bay, Oceanside Harbor, Central Mission Bay, and the Tijuana River. Metals are a contaminant in all of the waterbodies, with pesticides, trace elements, and priority organics also present in some areas.

The North and South sections of San Diego Bay were rated among the state's highest 301(d) priorities. The North section receives metals, pesticides, and priority organics from industrial sources and, to a limited extent, storm sewers. Industry also discharges toxic metals to the South section, accompanied by priority organics from nonpoint sources. The State has also assigned relatively high 301(d) priority to the Tijuana River Estuary (ranked in the second tier), while Central Mission Bay, Oceanside Harbor, Arroyo Trabuco Creek, and the Tijuana River are all considered medium priority.

California's Bay Protection and Toxic Cleanup Program (BPTCP) provides an additional indicator for key coastal waterbodies affected by toxic pollutants. BPTCP lists areas of significant toxicity, high levels of bioaccumulation, and impairment of ecologic beneficial uses as toxic "hot spots". While there are no known toxic hot spots identified in Region 9, many "potential" toxic hot spots (areas exhibiting elevated toxic concentrations in water or sediment) are listed. The Tijuana River Estuary was the only waterbody included on the 303(d) list not considered a potential hot spot; conversely, Central San Diego Bay is targeted by BPTCP, but is not on the 303(d) list.[41]

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[40] *California Report on Impaired Surface Waters, Clean Water Act Section 303(d)*, May 1994.

[41] *Bay Protection and Toxic Cleanup Program, Staff Report*; State Water Resources Control Board, State of California, November, 1993, p. 111, Figure 9.

Exhibit A-14

MAJOR SOURCES OF TOXIC POLLUTANTS
REGION 9: SAN DIEGO REGION

	Bays (acres)	Share of Total Toxics-Impaired Area	Estuaries (acres)	Share of Total Toxics-Impaired Area	Lakes & Reservoirs (acres)	Share of Total Toxics-Impaired Area	Rivers & Streams (miles)	Share of Total Toxics-Impaired Area	Saline Lakes (acres)	Share of Total Toxics-Impaired Area	Wetlands (acres)	Share of Total Toxics-Impaired Area
Agriculture	0	0%	1	0%	0	NA	11	29%	0	NA	0	NA
Hydro./Habitat Modification	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Industrial	305	99%	1	0%	0	NA	6	16%	0	NA	0	NA
Land Development	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Land Disposal	0	0%	936	100%	0	NA	0	0%	0	NA	0	NA
Mining	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Municipal	1	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Other Nonpoint Sources	308	100%	1	0%	0	NA	2	5%	0	NA	0	NA
Other Point Sources	0	0%	0	0%	0	NA	0	0%	0	NA	0	NA
Storm Sewers	165	54%	0	0%	0	NA	0	0%	0	NA	0	NA
Urban Runoff	63	20%	1	0%	0	NA	6	16%	0	NA	0	NA

Source: U.S. EPA analysis of WQA database.

Natural Resources and Beneficial Uses Affected

Exhibit A-36 summarizes available information on the beneficial uses supported by Region 9 waters that are identified as impaired by toxic pollutants. As the exhibit shows, all of the waterbodies impaired by toxics are either freshwater or marine habitats, and most support rare, threatened, or endangered plant or animal species. All are also wildlife habitats, and several are recognized as aiding in the preservation of biological habitats of special significance.

In addition to supporting wildlife and maintaining ecosystems, the toxic-impaired waterbodies are also used for contact and non-contact water recreation, including swimming, fishing, boating, and camping. In addition, all of the marine waterbodies support commercial fishing and shellfish harvesting. Many of the waterbodies are also used as a source of water for industrial purposes.

Exhibit A-35

PRINCIPAL WATERBODIES IMPAIRED BY TOXIC POLLUTION IN SAN DIEGO REGION (REGION 9)

Waterbody Name	Pollutants	303(d) Priority	Area Affected
Central Mission Bay	Metals, pesticides	3	1 acre
Oceanside Harbor	Metals, pesticides, trace elements	4	1 acre
San Diego Bay, North	Metals, pesticides, priority organics	1	239 acres
San Diego Bay, South	Metals	1	4 acres
Tijuana River Estuary	Metals, pesticides	2	1 acre
Arroyo Trabuco Creek	Metals	5	1 mile
Tijuana River	Metals, pesticides, trace elements	5	7 miles

Sources 303(d) list;1994 WQA Data Base

Exhibit A-36

NATURAL RESOURCES AND BENEFICIAL USES
ASSOCIATED WITH KEY WATERBODIES

Waterbody	Agriculture	Industrial	Shellfish Harvesting	Ocean Commercial & Sport Fishing	Water Contact Recreation	Non-Contact Water Recreation	Marine Habitat	Wildlife Habitat	Freshwater Habitat	Fish Migration	Fish Spawning	Preservation of Biological Habitats of Special Significance	Supports Rare or Endangered Species
Central Mission Bay		X	X	X	X	X	X	X		X			X
Oceanside Harbor		X	X	X	X	X	X	X		X	X		X
San Diego Bay, North		X	X	X	X	X	X	X		X		X	X
San Diego Bay, South		X	X	X	X	X	X	X		X		X	X
Tijuana River Estuary			X	X	X	X	X	X		X		X	X
Arroyo Trabuco	X	X			X	X		X	X				
Tijuana River		X			X	X		X	X				X

Source: Water Quality Control Plan, San Diego Basin, Region 9, California Regional Water Quality Control Board, September, 1994, Tables 2-2, 2-3.

APPENDIX B

CALIFORNIA FISH TISSUE CONTAMINANT DATA BASES

B1: Freshwater

B2: San Francisco Bay

FISH TISSUE DATABASES

To analyze the baseline health risks faced by anglers in California in support of the California Toxics Rule, we constructed two fish tissue contaminant databases. The first database includes information on contaminant concentrations in fish from rivers and lakes located throughout California. We apply these data to the analysis of health risks faced by California's freshwater anglers. The second database contains information on contaminant concentrations in fish from San Francisco Bay. These data serve as the basis for a case study of potential health risks facing anglers who consume fish caught in enclosed bays and estuaries, as represented by the health risks faced by anglers consuming fish from San Francisco Bay.

B1: Freshwater Fish Tissue Database

Fish Tissue Data Source

The freshwater database contains fish tissue contaminant information collected by California's Toxic Substances Monitoring Program (TSMP). The TSMP is administered by the State Water Resources Control Board and is conducted jointly with the California Department of Fish and Game. This on-going program monitors the occurrence of toxic pollutants in California's waters through sampling and analysis of fish tissue. Since its inception in 1976, more than 70 species of fish have been sampled under the TSMP. Samples of largemouth bass, channel catfish, and carp -- all species which are commonly caught and consumed by California's angling population -- have been collected with the highest frequency. Fish tissue samples are collected between May and December of each year, thereby minimizing the potential impacts of seasonal variation on contaminant concentrations. Each sample is analyzed for up to 10 metals and 68 organic compounds.

Although the TSMP collects freshwater tissue samples throughout the state, sampling locations are targeted to waterbodies with known or suspected water quality impairments. The data, therefore, may not provide a representative assessment of overall water quality. To the extent that California's anglers fish in less contaminated lakes and streams, the TSMP data may overstate contaminant concentrations in the fish they consume. Exhibit B-1 provides a list of the TSMP sampling locations included in the freshwater database.

A review of the TSMP sampling stations included within this analysis indicates that the program's potential bias may not be significant. First, across the entire state, approximately 53 percent of the waterbodies (encompassing 51 percent of the fish tissue samples) included in the freshwater analysis comply with applicable water quality standards and designated use criteria. Second, each of the California Water Quality Control Board regions samples impaired water bodies at different rates. Regions 4, 6, and 8, for example, collect between 75 and 95 percent of their samples from impaired water bodies. The six remaining regions collect between eight and 38 percent of their samples from impaired sources. Analysis of sample size by region, however, indicates that regions with a large number of impaired samples are not likely to exert a disproportionate impact on average tissue concentrations because the number of samples collected in these regions is generally equal to or less than the number of samples collected in other regions.

Similarly, comparison of TSMP sampling locations to areas where California's OEHHA has issued health advisories warning against fish consumption shows that less than three percent of the samples (12 out of more than 360 samples) used in this analysis were collected from locations where advisories have been issued. These results also suggest that any bias toward higher fish tissue contaminant levels introduced by this targeted sampling effort may be limited.

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 1

Station Name	Sampled for	
	Metals	Organics
Beaughton Creek d/s Highway 97 Bridge	X	X
Big Sulfur Creek	X	X
Carrville Pond	X	X
Hardscrabble Creek	X	
Indian Creek	X	
Iron Gate Reservoir	X	X
Janes Creek	X	X
Klamath River u/s Copco Reservoir	X	X
Lake Mendocino	X	X
Lake Pillsbury	X	
Lake Pillsbury/Eel River Arm	X	
Lake Sonoma	X	X
Lost River/Canal D	X	X
Mark West Creek	X	X
Russian River/Odd Fellows Park Bridge	X	X
Shasta River	X	X
Smith River	X	
Trinity River/East Fork	X	X
Trinity River/Willow Creek	X	X
Trinity River d/s Burnt Ranch		X

Region 2

Station Name	Sampled for	
	Metals	Organics
Alameda Creek/Niles Canyon Road	X	X
Alamitos Creek d/s Almaden Reservoir	X	
Almaden Reservoir	X	
Bear Gulch Reservoir	X	X
Coyote Creek/Brokaw Road	X	X
Coyote Creek/Percolation Pond	X	
Lake Chabot	X	X
Los Gatos Creek	X	
Napa River/Napa	X	X
New York Slough	X	X
Santa Fe Dam Park	X	X
Stevens Creek	X	X

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 2 (continued)

Station Name	Sampled for	
	Metals	Organics
Stevens Creek Reservoir	X	X
Vasona Lake	X	X
Walker Creek	X	
Walnut Creek	X	X

Region 3

Station Name	Sampled for	
	Metals	Organics
Alisal Slough u/s Tembladero Slough		X
Bean Creek/Conference Drive	X	X
Bean Creek/Graham Hill Road	X	X
Big Sur River	X	
Bixby Creek	X	
Chorro Creek	X	X
Chorro Creek u/s Chorro Reservoir	X	X
El Estero	X	X
Elkhorn Slough		X
Goleta Slough West/Tecolotico Creek	X	
Jameson Lake	X	X
Klau Mine Pond	X	
Lake Nacimiento/Dip Creek	X	
Lake Nacimiento/Las Tablas	X	
Lake San Antonio/San Antonio River	X	
Little Sur River	X	
Los Osos Creek u/s Los Osos	X	X
Nacimiento Lake	X	X
Oso Flaco Lake	X	X
Roberts Lake	X	X
Salmon Creek	X	
San Lorenzo River/Big Trees	X	X
San Luis Obispo Creek d/s SLO	X	X
San Luis Obispo Creek u/s SLO	X	X
Small Twin Lake	X	X
Waddel Creek	X	
Watsonville Slough/Lee Road		X
Whale Rock Reservoir	X	X

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 4

Station Name	Sampled for	
	Metals	Organics
Arroyo Conejo	X	X
Arroyo Conejo d/s Forks	X	X
Ballona Creek	X	X
Calabasas Lake	X	X
Calleguas Creek	X	X
Casitas Lake	X	X
Echo Park Lake	X	X
El Dorado Park Lake	X	X
Eleanor Lake	X	X
Harbor Park Lake	X	X
Legg Lake	X	X
Lincoln Park Lake	X	X
Lindero Lake	X	X
Los Angeles River/Sepulveda Basin	X	X
Malibou Lake	X	X
Malibu Creek	X	X
Oxnard Drainage Ditch 2		X
Peck Road Lake	X	X
Puddingstone Reservoir	X	X
Revolon Slough	X	X
Rio de Santa Clara/Oxnard Drain	X	X
San Gabriel River	X	X
San Gabriel River/Coyote Creek	X	X
Santa Clara River/Santa Paula	X	
Sherwood Lake	X	X
Simms Pond	X	X
Ventura River	X	X
Westlake Lake	X	X

Region 5

Station Name	Sampled for	
	Metals	Organics
American River N.F./Highway 49	X	
American River d/s Folsom Reservoir	X	
American River d/s Highway 160 Bridge	X	X
American River d/s Watt Avenue Bridge	X	X

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 5 (continued)

Station Name	Sampled for	
	Metals	Organics
Bounde Creek/Norman-Princeton Road	X	X
Bullards Bar Reservoir/Willow Cr		X
Bullards Bar Reservoir/Willow Cr	X	
Butte Creek/Colusa Highway	X	X
Cache Creek	X	
Cache Creek d/s Davis Creek	X	X
Camp Far West	X	
Camp Far West/Rock Creek Arm	X	
Central Drain/Norman-Princeton Road	X	X
Colusa Drain/Abel Road	X	X
Colusa Drain/Yolo-Colusa County Line	X	X
Courtright Reservoir/Dusy Creek	X	X
Cross Canal	X	
Dallas Warner Reservoir	X	
Dry Creek/Spenceville	X	
Feather River d/s Highway 99 Bridge	X	X
Feather River d/s Oroville Reservoir	X	
Glenn-Colusa Canal	X	X
Huntington Lake/Rancherio Creek	X	X
Kern River/Bakersfield	X	
Lake Kaweah	X	
Lake Wildwood	X	
Logan Creek/Norman-Princeton Road	X	X
Mendota Pool	X	X
Merced River/Hatfield St Recreation Area	X	
Mud Slough	X	
New Hogan Reservoir	X	
Paradise Cut/Tracy		X
Pardee Reservoir	X	
Reclamation Slough		X
Rollins Reservoir	X	
Sacramento River/Hood	X	X
Sacramento River/Keswick	X	
Sacramento Slough	X	
Salt Slough	X	X

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 5 (continued)

Station Name	Sampled for	
	Metals	Organics
San Joaquin River/Mossdale	X	X
San Joaquin River/Newman	X	
San Joaquin River/Vernalis	X	X
Stanislaus River		X
Stockton Deep Water Channel		X
Sycamore Slough/Knights Landing	X	X
Sycamore Slough/Yolo-Colusa County Line	X	X
Willow Creek/Norman-Princeton Road	X	X
Wishon Reservoir N.F./Kings River	X	X
Yuba River N.F. d/s Bullards Bar Res	X	

Region 6

Station Name	Sampled for	
	Metals	Organics
Bishop Creek Canal d/s Bishop	X	X
Boca Reservoir	X	X
Bodie Creek/Flying M Club	X	
Carson River W.F. d/s Paynesville	X	X
Convict Lake	X	
Crowley Lake	X	X
Deep Creek u/s Mojave River	X	X
Donner Lake	X	X
Eagle Lake	X	
East Walker River/Bridgeport	X	X
Grant Lake	X	X
Grass Valley Lake	X	X
Gull Lake	X	
Haiwee Reservoir	X	
Hot Creek	X	
Hot Creek d/s Hatchery	X	
June Lake	X	
Lake Tahoe/Homewood	X	
Little Rock Creek Reservoir	X	
Long Valley Creek/Honey Lake	X	X
Lundy Lake	X	
Mammoth Creek	X	

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 6 (continued)

Station Name	Sampled for	
	Metals	Organics
Martis Creek d/s Martis Creek Reservoir	X	
McGee Creek	X	
Monitor Creek	X	
Owens River Gorge	X	X
Pine Creek/Bishop	X	
Robinson Creek	X	
Sabrina Lake	X	
Silverwood Lake	X	
Slinkard Creek	X	X
Squaw Creek	X	X
Stampede Reservoir	X	X
Susan River d/s Piute Creek	X	X
Topaz Lake	X	
Trout Creek/Tahoe d/s Meeks Lumber	X	
Trout Creek/Tahoe u/s Meeks Lumber	X	X
Trout Creek/Truckee d/s Meeks Lumber	X	
Trout Creek/Truckee u/s Meeks Lumber	X	
Twin Lakes	X	
Virginia Creek/Dog Town	X	

Region 7

Station Name	Sampled for	
	Metals	Organics
Alamo River/Brawley	X	X
Alamo River/Calipatria	X	X
Alamo River/Holtville	X	X
Alamo River/International Boundary		X
Central Drain	X	X
Colorado River/International Boundary	X	X
Colorado River/Needles	X	X
Colorado River u/s Imperial Dam	X	X
Fig Drain	X	X
Fig Lake	X	X
Fig Lake Outlet	X	X
Greeson Drain	X	X
Holtville Main Drain	X	X

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 7 (continued)

Station Name	Sampled for	
	Metals	Organics
New River/International Boundary	X	X
New River/Westmorland	X	X
Palo Verde Outfall Drain	X	X
Pumice Drain	X	X
Reservation Main Drain	X	X
Rose Drain	X	X
South Central Drain	X	X
Verde Drain	X	X
Wiest Lake	X	X

Region 8

Station Name	Sampled for	
	Metals	Organics
Big Bear Lake	X	X
Bolsa Chica Channel/Westminster Ave		X
Canyon Lake	X	X
Chino Creek d/s Euclid Ave		X
E.G.G. Wintersburg Channel/Gothard St		X
Prado Lake	X	X
Santa Ana River/Hamner Ave	X	X
Santa Ana River/Prado Dam	X	X
Santa Ana River/USGS Gage	X	X

Region 9

Station Name	Sampled for	
	Metals	Organics
BLM Reservour/Buena Vista Mine	X	
Cannon Lake/Carlsbad	X	X
Escondido Creek/Country Club Drive	X	X
Escondido Creek/Elfin Forest Park	X	X
Forester Creek/Billy Mitchel Road	X	X
Guajome Lake	X	X
Keys Creek	X	X
Lake Hodges	X	X
Lake Mission Viejo	X	X
Lake San Marcos	X	X

Exhibit B-1

FRESHWATER FISH TISSUE SAMPLING LOCATIONS BY CALIFORNIA STATE WATER RESOURCES CONTROL BOARD REGION

Region 9 (continued)

Station Name	Sampled for	
	Metals	Organics
Los Penasquitos Creek/Highway 15	X	X
O'Neill Lake	X	X
Oso Reservoir	X	X
Otay River/Apache Service Pond	X	X
Rainbow Creek	X	X
San Diego River/Mission Center Drive	X	X
San Diego River/Old Mission Dam	X	X
San Luis Rey River/Foussat Road	X	X
San Luis Rey River/Highway 15	X	X
San Luis Rey River/Highway 76	X	X
San Luis Rey River/Pankey Road	X	X
San Marcos Creek		X
San Marcos Creek/Gibralter	X	X
Santa Margarita River/Willow Glen Road	X	X
Santee Lake No. 5	X	X
Sweetwater Reservoir	X	X

Abbreviations:
d s Downstream
u s Upstream
N F North Fork
W F West Fork

Freshwater Database Structure

The freshwater database provides information on contaminant concentrations for five metals and 26 organic compounds. Exhibit B-2 lists the contaminants included. The contaminants were selected for inclusion in the database based on the following three criteria:

(1) The proposed water quality standards contained human health or aquatic life criteria for the contaminant;

(2) TSMP samples were analyzed for the contaminant; and

(3) The contaminant was observed above method detection limits (MDLs) in at least one tissue sample.

Exhibit B-2

CONTAMINANTS INCLUDED IN THE FRESHWATER DATABASE

Metals	Organics
Copper	Aroclor 1248
Mercury	Aroclor 1254
Nickel	Aroclor 1260
Selenium	Dieldrin
Zinc	Endrin
	Endosulfan I
	Endosulfan II
	Endosulfan Sulfate
	HCH-alpha
	HCH-gamma
	Hexachlorobenzene
	Toxaphene
	o,p'-DDT
	p,p'-DDT
	o,p'-DDE
	p,p'-DDE
	o,p'-DDD
	p,p'-DDD
	p,p'-DDMU
	alpha-Chlordane
	gamma-Chlordane
	Cis-Chlordane
	Trans-Chlordane
	Cis-Nonachlor
	Trans-Nonachlor
	Oxychlordane

In addition to the criteria listed above, the freshwater database includes only those samples collected between 1988 and 1993. Data were limited to this period to best reflect current water quality conditions. In addition, all tissue concentrations in the database are measured in fish fillets without skin -- the most commonly consumed portion of fish caught by anglers.

The database includes more than 360 composite samples of 32 different species of fish. Each composite contains tissue from an average of six fish of a single species. The number of fish per composite sample ranges from one to 65. As a result, the number of fish samples actually incorporated into the analysis is substantially greater than the number of composites.

We have grouped the composite samples into one of five general species categories based on family level taxonomy. These categories include bass, trout, catfish, panfish, and other. The species included within each of these groupings are listed in Exhibit B-3. For each species category the number of samples and the number of samples containing contaminants at concentrations above the MDL are summarized in Exhibit B-4.

San Francisco Bay Fish Tissue Database

Fish Tissue Data Source

In 1994, California's Water Resources Control Board - San Francisco Bay Region undertook a study of contaminant levels in edible fish tissues collected from San Francisco Bay.[1] The main goal of the study was to identify the contaminants, fish species, and geographic areas within San Francisco Bay that pose the greatest health risk to Bay anglers. The San Francisco Bay fish tissue database constructed for this analysis contains a subset of the contaminant data collected during the 1994 study.

The San Francisco Bay study includes fish tissue samples collected from 16 stations located throughout the Bay. Thirteen of these stations were classified as "geographically discrete," or stations providing contaminant data for well-defined areas of the Bay. These stations were selected to obtain data that were proximate to commonly fished shorelines and piers, and either known to be contaminated or thought to be contaminant free. Furthermore, the stations were selected because, together, they provide geographic coverage of the entire Bay. Three additional sampling locations

[1] *Contaminant Levels in Fish Tissue from San Francisco Bay*, Final Draft Report, December, 1994.

Exhibit B-3

FRESHWATER SPECIES CATEGORIES

Common Name	Genus	Species
BASS:		
Largemouth bass	*Micropterus*	*salmoides*
Smallmouth bass	*Micropterus*	*dolomieu*
White bass	*Morone*	*chrysops*
TROUT:		
Brook trout	*Salvelinus*	*fontinalis*
Brown trout	*Salmo*	*trutta*
Coast cutthroat trout	*Oncorhynchus*	*clarki clarki*
Eagle lake trout	*Oncorhynchus*	*mykiss aquilarum*
Kokanee	*Oncorhynchus*	*nerka*
Lahontan cutthroat trout	*Oncorhynchus*	*clarki henshawi*
Rainbow trout	*Oncorhynchus*	*mykiss*
Steelhead rainbow trout	*Oncorhynchus*	*mykiss gairdneri*
CATFISH:		
Black bullhead	*Ameiurus*	*melas*
Brown bullhead	*Ictalurus*	*nebulosus*
Channel catfish	*Ictalurus*	*punctatus*
Flathead catfish	*Pylodictis*	*olivaris*
White catfish	*Ameiurus*	*catus*
Yellow bullhead	*Ictalurus*	*natalis*
PANFISH:		
Bluegill	*Lepomis*	*macrochirus*
Green sunfish	*Lepomis*	*cyanellus*
Redear sunfish	*Lepomis*	*microlophus*
Sacramento perch	*Archoplites*	*interruptus*
White crappie	*Pomoxis*	*annularis*
OTHER:		
Carp	*Cyprinus*	*carpio*
Goldfish	*Carassius*	*auratus*
Hardhead	*Mylopharodon*	*conocephalus*
Hitch	*Lavinia*	*exilicauda*
Mozambique tilapia	*Tilapia*	*mossambica*
Redbelly tilapia	*Tilapia*	*zillii*
Sacramento squawfish	*Ptychocheilus*	*grandis*
Sacramento sucker	*Catostomus*	*occidentalis*
Santa ana sucker	*Catostomus*	*santaanae*
Striped mullet	*Mugil*	*cephalus*

Exhibit B-4

SUMMARY OF FRESHWATER FISH TISSUE OBSERVATIONS

Pollutant	Total		Bass		Trout		Catfish		Panfish		Other	
	Number of Samples	Number of Samples Above MDL[1]	Number of Samples	Number of Samples Above MDL	Number of Samples	Number of Samples Above MDL	Number of Samples	Number of Samples Above MDL	Number of Samples	Number of Samples Above MDL	Number of Samples	Number of Samples Above MDL
Copper	12	11	3	2	4	4	0	0	1	1	4	4
Mercury	369	359	108	108	78	75	71	70	35	35	77	71
Nickel	50	2	12	0	11	0	8	1	9	1	10	0
Selenium	289	283	77	76	76	76	40	36	32	32	64	63
Zinc	12	12	3	3	4	4	0	0	1	1	4	4
Total Chlordane[2]	247	72	64	10	36	5	47	21	24	1	76	35
Total DDT[3]	247	190	64	42	36	22	47	47	24	9	76	70
Dieldrin	247	50	64	0	36	0	47	20	24	1	76	29
Total Endosulfan[4]	233	41	62	1	35	0	42	16	22	0	72	24
Endrin	247	2	64	0	36	0	47	0	24	0	76	2
HCH alpha	247	6	64	0	36	0	47	4	24	0	76	2
HCH gamma	247	21	64	3	36	1	47	6	24	1	76	10
Hexachlorobenzene	247	24	64	0	36	0	47	8	24	0	76	16
Total PCBs[5]	249	41	64	7	37	2	47	12	24	1	77	19
Toxaphene	247	26	64	0	36	0	47	9	24	0	76	17

[1] MDL = Method Detection Limit
[2] Total Chlordane = alpha-Chlordene + gamma-Chlordene + cis-Chlordane + trans-Chlordane + cis-Nonachlor + trans-Nonachlor + Oxychlordane
[3] Total DDT = o,p'-DDT + p,p'-DDT + o,p'-DDE + p,p'-DDE + o,p'-DDD + p,p'-DDD + p,p'-DDMU
[4] Total Endosulfan = Endosulfan I + Endosulfan II + Endosulfan Sulfate
[5] Total PCBs = Aroclor 1248 + Aroclor 1254 + Aroclor 1260

were classified as "non-discrete regions," or areas of open bay. These regions were used to collect shark samples and were defined as North Bay, Central Bay, and South Bay. Exhibit B-5 lists all 16 sampling locations. (See Exhibit 3-12 for a map of these locations).

The study's collection protocol targeted fish species with high probability of catch and consumption by Bay area anglers, and high potential for contaminant accumulation due to feeding behavior or habitat range. Specific species collected included white croaker, shiner surfperch, walleye surfperch, white surfperch, leopard shark, brown smoothhound shark, striped bass, sturgeon, and halibut.

Fish collected at each station were combined into single-species composite samples for chemical analysis. Depending on the species, the number of fish required to obtain a standard 200 gram composite varied. White croaker, walleye surfperch, and white surfperch required five fish for a composite. Shiner surfperch required 20 fish. Composites of shark, halibut, sturgeon, and striped bass each required three fish.

Contaminant analyses were conducted on fish fillets. To reflect common fish preparation methods, white croaker and all surfperch fillets analyses included the skin; shark, halibut, sturgeon, and striped bass were analyzed without skin. Each composite sample was analyzed for trace metals, polychlorinated biphenols (PCBs), pesticides, and polycyclic aromatic hydrocarbons (PAHs). Selected samples were analyzed for dioxins and furans.

B2: San Francisco Bay Database Structure

The San Francisco Bay database includes contaminant concentrations for five metals, PCBs, 21 pesticides, three PAHs, and Dioxin. The contaminants included in the database are listed in Exhibit B-6. To be included in the database, each contaminant satisfied the following three criteria:

(1) The proposed water quality standards contained human health or aquatic life criteria for the contaminant;

(2) The San Francisco Bay study analyzed for the contaminant; and

(3) The contaminant was observed above MDLs in at least one tissue sample.

Exhibit B-5

SAN FRANCISCO BAY STUDY SAMPLING LOCATIONS

Discrete Sampling Locations:

1. San Mateo Bridge	(West shoreline near pier)
2. Dumbarton Bridge	(East shoreline near pier)
3. Fremont Forebay	(East of the Freemont Landfill)
4. Richmond Inner Harbor	(Friendship Shamada Park)
5. Berkeley Pier	
6. Oakland Inner Harbor	(Fruitvale)
7. Oakland Middle Harbor Pier	
8. Double Rock	(Candlestick)
9. Islais Creek Channel	
10. Point Molate	(San Pablo Strait)
11. Rodeo Pier	(Carquinez Stait)
12. San Francisco Pier #7	(Municipal Pier)
13. Vallejo Pier-Mare Island Straight	(Knight Island)

Non-Discrete Sampling Regions:

14. South Bay	(South of Oakland Bay Bridge)
15. Central Bay	(Between Oakland and San Rafael Bridges)
16. North Bay	(North of San Rafael Bridge)

Exhibit B-6

CONTAMINANTS INCLUDED IN THE SAN FRANCISCO BAY DATABASE

Metals	Organics
Cadmium Copper Mercury Silver Zinc	PCBs 5, 8, 18, 28, 29, 31, 44, 49, 52, 66, 70, 74, 87, 85, 97, 99, 101, 105, 110, 118, 128, 132, 137, 138, 149, 151, 153, 156, 157, 158, 170, 174, 177, 180, 183, 187, 189, 194, 195, 201, 203, 206, 209 Dieldrin HCH-alpha HCH-beta HCH-gamma Heptachlor Heptachlor Epoxide Hexachlorobenzene o,p'-DDT p,p'-DDT o,p'-DDE p,p'-DDE o,p'-DDD p,p'-DDD p,p'-DDMU p,p'-DDMS gamma-Chlordene Cis-Chlordane Trans-Chlordane Cis-Nonachlor Trans-Nonachlor Oxychlordane Fluoranthene Fluorene Pyrene Dioxin (as 2,3,7,8-TCDD)

More than 450 individual fish from seven species comprise the 64 composite samples included in the San Francisco Bay database developed for this analysis. We have grouped the composite samples into one of four general species categories based on family level taxonomy. These categories include white croaker, perch, striped bass, and shark. The species included within each grouping are listed in Exhibit B-7. For each species category, the number of samples and the number of samples containing contaminants at concentrations above the MDL are summarized in Exhibit B-8. Samples of halibut and sturgeon were collected during the San Francisco Bay study but are not included in our database due to limited sample sizes.

Exhibit B-7

SAN FRANCISCO BAY SPECIES CATEGORIES

Common Name	Genus	Species
WHITE CROAKER:		
White croaker	*Genyonemus*	*lineatus*
PERCH:		
Shiner surfperch	*Cymatogaster*	*aggregata*
Walleye surfperch	*Hyperprosopon*	*argenteum*
White surfperch	*Phanerodon*	*furcatus*
STRIPED BASS:		
Striped bass	*Morone*	*saxatilis*
SHARK:		
Brown smoothhound shark	*Mustelus*	*henlei*
Leopard shark	*Triakis*	*semifasciata*

Exhibit B-8

SAN FRANCISCO BAY FISH TISSUE OBSERVATIONS

Pollutant	Total		White Croaker		Surf Perch		Striped Bass		Shark	
	Number of Samples	Number of Samples Above MDL[1]	Number of Samples	Number of Samples Above MDL	Number of Samples	Number of Samples Above MDL	Number of Samples	Number of Samples Above MDL	Number of Samples	Number of Samples Above MDL
Cadmium	64	14	25	4	18	2	9	1	12	7
Copper	64	64	25	25	18	18	9	9	12	12
Mercury	64	64	25	25	18	18	9	9	12	12
Silver	64	5	25	0	18	4	9	0	12	1
Zinc	64	64	25	25	18	18	9	9	12	12
Total Chlordane[2]	64	61	25	25	18	18	9	9	12	9
Total DDT[3]	64	64	25	25	18	18	9	9	12	12
Total PCBs[4]	64	64	25	25	18	18	9	9	12	12
Dieldrin	64	49	25	24	18	14	9	9	12	2
HCH alpha	64	22	25	18	18	3	9	1	12	0
HCH beta	64	1	25	1	18	0	9	0	12	0
HCH gamma	64	17	25	12	18	0	9	5	12	0
Heptachlor	64	4	25	3	18	0	9	1	12	0
Heptachlor Epoxide	64	12	25	8	18	1	9	3	12	0
Hexachlorobenzene	64	23	25	13	18	3	9	7	12	0
Fluoranthene	64	10	25	0	18	9	9	1	12	0
Fluorene	64	4	25	1	18	2	9	1	12	0
Pyrene	64	1	25	0	18	0	9	1	12	0
Dioxin	17	9	9	8	3	0	2	1	3	0

1 MDL = Method Detection Limit
2 Total Chlordane = gamma-Chlordene + cis-Chlordane + trans-Chlordane + cis-Nonachlor + trans-Nonachlor + Oxychlordane
3 Total DDT = o,p'-DDT + p,p'-DDT + o,p'-DDE + p,p'-DDE + o,p'-DDD + p,p'-DDD + p,p'-DDMS + p,p'-DDMU
4 Total PCBs = PCB congeners 5 + 8 + 18 + 28 + 29 + 31 + 44 + 49 + 52+ 66 + 70 + 74 + 87 + 85 + 97 + 99 + 101 + 105 + 110 + 118 + 128 + 132 + 137 + 138 + 149 + 151 + 153 + 156 + 157 + 158 + 170 + 174 + 177 + 180 + 183 + 187 + 189 + 194 + 195 + 201 + 203 + 206 + 209

APPENDIX C

FISH CONSUMPTION RATES

FISH CONSUMPTION RATES

The quantity of fish consumed is an important factor in this report's analysis of health risks associated with current levels of toxic contaminants in tissue of non-commercially caught freshwater and San Francisco Bay fish. Since the analysis evaluates the risks for anglers, the consumption rate reflects the habits of this segment of the population, rather than those of the population as a whole. EPA estimates fish consumption among the general population at 6.5 grams per person per day; however, studies of consumption rates among anglers estimate substantially higher rates for this specific group. EPA offers default values to be used in evaluating potential risks from fish consumption, but recommends using local consumption data whenever they are available.[1]

Following EPA's guidance, we have conducted this analysis based on the results of a 1994 survey of fish consumption patterns among anglers in Santa Monica Bay that provides recent estimates of consumption rates for California anglers.[2] Specifically, we assumed that a "typical" California angler would consume between 21.4 and 49.6 grams of fish per day. This range is bounded by the median (21.4 g/day) and the mean (49.6 g/day) from the Santa Monica Bay study. Since this range covers the central portion of the study's fish consumption distribution, we assumed that the vast majority of California anglers would consume fish within these rates. We present all estimates of individual and population risks based on this range.

We also provide individual risk estimates for anglers at the high end of the fish consumption distribution. Based on the Santa Monica Bay study, we use the 90th percentile consumption rate of 107.1 g/day to represent these high consumption anglers. The 90th percentile value may also be representative of subgroups of anglers, such as those relying on their fish catch for subsistence, or those from a specific ethnic group, whose diets contain substantially more fish than other anglers'.

These values are listed along with those from several other studies in Exhibit C-1. This exhibit shows that the consumption rates from the Santa Monica Bay Study are within the range of other reported values.

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[1] See USEPA, *Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories, Volume 1: Fish Sampling and Analysis,* Office of Water, EPA 823-R-93-002, August 1993.

[2] Santa Monica Bay Restoration Project, *Santa Monica Bay Seafood Consumption Study,* prepared by Southern California Coastal Water Research Project and MBC Applied Environmental Sciences, June 1994.

Exhibit C-1

SELECTED FISH CONSUMPTION ESTIMATES

Source	Consumption Rate (g/day)
Santa Monica Bay Study of anglers[1]	
mean	49.6
median	21.7
90th percentile	107.1
California Office of Environmental Health Hazard Assessment (average value used in assessing human health risks)[2]	23
USEPA default values for recreational anglers[3]	
median	30
90th percentile	140
Sport-Caught Fish in Michigan[4]	
Low-income minority	43.1
Other minority	11.1
Other sport fishers	16.7

Sources

[1] *Santa Monica Bay Seafood Consumption Study*, June 1994.

[2] California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, "Food Consumption Value," Memorandum from R.K. Brodberg to Dave Morry, May 24, 1995.

[3] USEPA, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, August 1993*.

[4] West, et al., 1993, as reported in USEPA's *Regulatory Impact Analysis of the Final Great Lakes Water Quality Guidance*, March 1995.

APPENDIX D

SUPPLEMENTAL INFORMATION FOR THE

ANGLER RISK ASSESSMENT

SUPPLEMENTAL INFORMATION FOR THE ANGLER RISK ASSESSMENT

This appendix provides background information for the calculation of angler cancer and noncancer risks. In addition, it describes the specific carcinogenic and noncarcinogenic effects of contaminants that pose potentially significant risks to freshwater and/or San Francisco Bay anglers. Much of the text presented in this appendix has been adapted from EPA's March 1995 *Regulatory Impact Analysis of the Final Great Lakes Water Quality Guidance.*

CARCINOGENIC EFFECTS: NON-THRESHOLD CALCULATIONS AND SUBSTANCE-SPECIFIC CARCINOGENIC EFFECTS[1]

Part of EPA's assessment of carcinogenic substances is a rating of the "weight of evidence" concerning carcinogenicity. The evidence from human and animal studies is cross-tabulated into one of five categories: (1) sufficient evidence, (2) limited evidence, (3) inadequate evidence, (4) no data concerning carcinogenicity, and (5) no evidence of carcinogenicity. The classification scheme is presented in Exhibit D-1.

Exhibit D-1

EPA CLASSIFICATION SCHEME FOR CARCINOGENS

Group	Description
A	Human carcinogen; sufficient human evidence.
B1	Probable human carcinogen; limited human evidence.
B2	Probable human carcinogen; sufficient animal evidence, inadequate or no human evidence, or no human data.
C	Possible human carcinogen; limited animal evidence, inadequate or no human evidence, or no human data.
D	Not classifiable as to human carcinogenicity; inadequate human and animal evidence or no data available.
E	Evidence of noncarcinogenicity for humans.

Source: U.S. EPA, *Guidelines for Carcinogen Risk Assessment,* 51 FR 33992-34054, 1986.

[1] For more detailed information on EPA's method for estimating cancer risks, see U.S. EPA, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual,* December 1989.

In addition to the qualitative rating assigned to potentially carcinogenic substances, EPA develops substance-specific cancer slope factors (CSFs) for potential carcinogens. A CSF gives the increase in lifetime cancer risk for an individual continuously exposed to a substance, from birth to death, per unit increase in the substance's concentration.[2] CSFs provide estimates of risks associated with low-dose exposure to suspected or known carcinogens. They are estimated from data on high dose human exposures and/or high dose laboratory exposure to animals. The CSF for an agent with an "A" rating will be based -- at least in part -- on human data, while one with a "B2" rating will be based entirely on animal data.

Generating a Cancer Slope Factor

In deriving a CSF, EPA evaluates available toxicological information about a chemical and selects an appropriate data set. In choosing appropriate data sets, human data of high quality are preferred to animal data. If animal data are used, the species that responds most similarly to humans is preferable. If there is no clear choice among species for which data exist, data for the most sensitive species is given the greatest emphasis. Occasionally, when no single study is judged to be most appropriate, EPA may derive a CSF based on the geometric mean of slope factors from several studies that collectively support the estimate.

Concept of Nonthreshold Effects

Carcinogens are assumed to have no threshold, i.e., there is no level of exposure that does not pose some probability, however small, of generating a carcinogenic response. Therefore, the development of a CSF usually involves extrapolating from the high doses administered to experimental animals to the lower exposure levels expected for human exposure in the environment. Because the extrapolation of the dose-response is to a range where data are not available, the actual CSFs are uncertain. Hence, a large margin of safety is built into the slope factors. Generally, EPA takes a conservative approach in estimating a CSF by calculating the slope factor as the highest value that can be justified with 95 percent confidence. Thus, given the data, it is unlikely that the CSF is greater than that reported.

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[2] U.S. EPA, *Integrated Risk Information System,* 1995.

Assessing Carcinogenic Risks

A substance-specific CSF is multiplied by the substance-specific daily dose to estimate the incremental probability of a person developing cancer over a lifetime (70 years) as a result of exposure to the potential carcinogen. A cancer risk of 1×10^{-6} implies a probability of one in a million of developing cancer. Risk managers generally consider a cancer risk of 1×10^{-6} sufficient to protect the general population.

Combined Risks for Multiple Substances

To determine the overall potential for carcinogenic effects from exposure to more than one substance, the sum of substance-specific cancer risks is calculated. This risk summation assumes that there are no antagonistic or synergistic interactions and that all substances produce the same effect (i.e., cancer). If these assumptions are incorrect, the actual multiple-substance risk may be over- or under-estimated.

Carcinogenic Effects Associated with Fish Tissue Contaminants

A summary of the carcinogenic effects for contaminants that pose potentially significant cancer risks to freshwater or San Francisco Bay anglers is provided below. Unless otherwise indicated, descriptions of the carcinogenic effects of these contaminants are based on data obtained from EPA's *Integrated Risk Information System, Forth Quarter, 1996.*

Chlordane -- Chlordane is classified as a B2 probable human carcinogen. Although human carcinogenicity data are inadequate, there is sufficient evidence of carcinogenicity in studies in which benign and malignant liver tumors were induced in four strains of mice of both sexes, as well as in male rats. This compound is structurally related to other known liver carcinogens. The quantitative estimate of the CSF, 1.3 $(mg/kg\text{-}day)^{-1}$, is derived from the geometric mean of several data sets, based on the incidence of liver tumors in mice and rats.

DDT -- DDT is classified as a B2 probable human carcinogen. No case studies or epidemiological investigations are available concerning the carcinogenic effects of DDT in humans following oral exposure. However, DDT is one of the most widely studied pesticides in animals,

and numerous carcinogenicity studies are available for several animal species. The CSF of 0.34 $(mg/kg\text{-}day)^{-1}$ is derived from the geometric mean of several data sets, based on the incidence of liver tumors in mice and rats after exposure to 4,4'-DDT.

Dieldrin -- Dieldrin is a B2 probable human carcinogen with a unit risk factor of 16 $(mg/kg\text{-}day)^{-1}$. There is inadequate evidence of human carcinogenicity for this contaminant. Two studies of workers exposed to aldrin and dieldrin reported no increased incidence of cancer. However, both studies were limited in their ability to detect an excess of cancer deaths because exposure levels for workers were not quantified. In addition, the number of workers studied was small, the mean age of the cohort was young, the number of expected deaths was not calculated, and the duration of exposure and of latency was relatively short. EPA's basis for its B2 classification is the carcinogenicity of dieldrin in seven strains of mice when dieldrin is administered orally. Dieldrin is also structurally related to other compounds (aldrin, chlordane, heptachlor, heptachlor epoxide, and chlorendic acid) that produce tumors in rodents. Therefore, EPA classifies the animal carcinogenicity data for this contaminant as "sufficient." At different dose levels, the effects range from benign liver tumors, to liver carcinomas with transplantation confirmation, to pulmonary metastases.

Dioxin -- The EPA has classified dioxin (2,3,7,8-TCDD) as a B2 probable human carcinogen when considered alone, and a B1 carcinogen (limited human evidence in addition to sufficient animal evidence of carcinogenicity) when considered in association with phenoxyherbicides and/or chlorophenols. The estimated CSF for dioxin is based on a study showing increased incidence of tumors of the lungs, liver, hard palate, and nasal turbinates in female rats maintained on diets containing dioxin for two years. The EPA estimated the CSF from the results of two different pathologic examinations that produced differences in tumor incidence, and hence, slightly different values.[3] The final slope factor of 1.5×10^5 $(mg/kg\text{-}day)^{-1}$, is the average based on these separate calculations.[4]

PCBs -- PCBs have been classified as B2 probable human carcinogens based on a 1996 study that found liver tumors in female rats exposed to Aroclors 1260, 1254, 1242, and 1016, and in male rats exposed to Aroclor 1260. Human data are currently inadequate yet suggestive of carcinogenic

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[3] Agency for Toxic Substances and Disease Registry, *Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin*, June 1989.

[4] US EPA, *Health Effects Assessment Summary Tables: Annual Update FY-1994*, March 1994.

effects in the liver and lungs via ingestion, inhalation, or dermal exposure. The CSF for PCBs of 2.0 $(mg/kg\text{-}day)^{-1}$ used in this analysis is based on EPA's 1996 guidance for assessment of health risks resulting from exposure to PCBs.[5] EPA's guidance recommends a tiered approach that uses PCB CSFs ranging from 0.04 to 2.0 mg/kg-day depending on the characteristics of the exposure pathway and congener composition of the PCB mixture. EPA notes that bioaccumulated congeners ingested through the food chain (e.g., consumption of recreationally caught fish) tend to exhibit the highest chlorine content and persistence. Therefore, EPA recommends using the highest PCB CSF of 2.0 mg/kg-day for food chain exposure pathways where environmental processes tend to increase risk.

The data regarding occupational and accidental exposures of humans to PCBs are inconclusive due to confounding exposures, lack of exposure quantification, and small sample sizes. In one such study, male workers at a capacitor manufacturing plant in Italy exhibited a statistically significant increase in gastrointestinal tract cancer over local and national rates. Hematologic cancer incidence in female workers exceeded local but not national rates. Another study of 2,588 capacitor plant workers in New York and Massachusetts with occupational exposure to Aroclor 1254, 1242, and 1016, showed a statistically significant increase in death from cancer of the liver, gall bladder, and biliary tract.

An occupational cohort study of 3,588 capacitor plant workers in Indiana analyzed the health effects of varying levels of exposure to Aroclor 1242 and 1016. At the end of the follow-up period, workers showed a significant increase in malignant melanomas compared to national rates. A cohort study of 142 male Swedish capacitor plant workers who had been exposed to PCBs for an average of 6.5 years did not indicate any excess mortality of cancer incidence; however, the follow-up time was limited and the cohort was small.[6]

Statistically significant excess risk of liver cancer has been reported in a 16-year follow-up of patients who consumed PCB-contaminated rice oil in the Yusho, Japan incident. However, there were a number of serious limitations in this study. First, there was a lack of information concerning job histories or the potential influence of alcoholism or smoking. Second, the information

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[5] USEPA, National Center for Environmental Assessment, Office of Research and Development. *PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures*, EPA/600/P-96/001F, September 1996.

[6] Agency for Toxic Substances and Disease Registry, *Toxicological Profile for Selected PCBs (Aroclor-1260,-1254,-1248,-1242,-1232,-1221, and -1016)*, June 1989.

concerning the diagnosis of liver cancer was obtained from the victims' families and may not have been independently verified by health professionals. Additionally, there were confounding exposures to polychlorinated dibenzofurans and polychlorinated quinones; thus, the findings are considered tentative. In general, although studies of humans exposed to PCBs are suggestive of excess risk of liver cancer, the available epidemiological data do not indicate a consistent tumorigenic effect.

There also are a large number of animal studies that review the carcinogenic potential of PCBs. A recent study of Sprague-Dawley rats compared carcinogenicity across different Aroclors, dose levels, and sexes. Statistically significant increased incidences of liver adenomas or carcinomas were found in female rats for all Aroclors and in male rats for Aroclor 1260. This study also investigated tumor progression after exposure ended (stop-studies). Aroclors 1254 and 1242 resulted in tumor incidences that were nearly proportional to exposure duration, while stop-study tumor incidences for Aroclor 1016 were zero. The stop-study associated with Aroclor 1260 resulted in a greater cancer incidence than the lifetime exposure.

A long-term bioassay of Aroclor 1260 with rats produced hepatocellular carcinomas when 100 ppm was administered for 630 days to 200 animals. In another study, female rats surviving at least 29 months had a 91 percent incidence of liver carcinomas; however, male rats had only a four percent incidence rate.

Toxaphene -- Toxaphene is classified as a B2 probable human carcinogen based on inadequate human evidence and sufficient animal evidence. Oral exposure to this chemical has resulted in dose-related increases in liver carcinomas in mice and thyroid tumors in rats. Based on these data, EPA's estimated CSF is 1.1 $(mg/kg\text{-}day)^{-1}$.

NONCARCINOGENIC EFFECTS: THRESHOLD CALCULATIONS AND SUBSTANCE-SPECIFIC HEALTH EFFECTS[7]

Unlike carcinogenic effects, noncarcinogenic effects are assumed to occur only at exposures above a threshold concentration below which protective mechanisms and function reserve capacities prevent reactions to exposure. Therefore, a range of exposures exists from zero to some finite value

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[7] For more detailed information on EPA's method for estimating noncancer risks, see U.S. EPA, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual*, December 1989.

that can be tolerated by the individual without the manifestation of an adverse effect. The reference dose (RfD) is an estimate of a daily exposure level for humans, including sensitive subgroups, that is not likely to cause adverse effects during a lifetime of exposure. To develop an RfD, it is necessary to identify the upper bound of a tolerance range for the most sensitive populations.

Derivation of an Oral Reference Dose

To develop an oral RfD, EPA examines all available toxicity studies for a substance following oral exposure. If adequate human data are available, this information is used as the basis of the RfD. Otherwise, animal study data are used. When choosing the appropriate human or animal study to use in deriving the RfD, EPA must make judgements regarding the relevance and quality of the available experimental studies. In addition, EPA must identify the effect characterized by the "lowest observed adverse effect" (LOAEL), which is referred to as the critical toxic effect, and serves as the basis for the RfD.

After the study and critical toxic effect have been selected, EPA identifies the exposure level that represents the highest exposure level tested in the study at which the critical effect was not observed. This highest "no observed adverse effect level" (NOAEL) is used to develop the RfD.

Applying Uncertainty Factors

The RfD is derived from the NOAEL by consistent application of the following uncertainty factors (UF):

- A factor of 10 is used to account for variation in biological response to exposure among the general population and is intended to protect sensitive subgroups, such as the elderly, from adverse effects.

- A factor of 10 is used when extrapolating from animals to humans to account for interspecies variability.

- A factor of 10 is used when a NOAEL derived from a subchronic rather than a chronic study is used as the basis for a chronic RfD.

- A factor of 10 is used when a LOAEL rather than a NOAEL is used as the basis for an RfD.

In addition to the UFs listed above, a modifying factor (MF) ranging from greater than zero to 10 is used to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire toxicity database for the substance not specifically addressed by the preceding UFs. The default value for the MF is 1.0.

Calculation of the Reference Dose

To calculate the RfD, the appropriate NOAEL (or LOAEL if a suitable NOAEL is not available) is divided by the product of all of the applicable uncertainty factors and the modifying factor. The calculation is as follows:

$$RfD = NOAEL \text{ or } LOAEL/(UF_1 \times UF_2 \ldots \times MF)$$

Oral RfDs are expressed in units of mg/kg-day.

Accessing the Potential for Noncarcinogenic Effects

The RfD assumes that there is an exposure threshold below which adverse effects will not occur. If the exposure level (dose) exceeds this level, adverse effects could potentially occur. This potential for adverse systemic effects is characterized by the hazard quotient (HQ). The HQ is calculated according to the following equation:

$$HQ = Dose/RfD$$

The greater the value of the HQ above one, the greater the potential for adverse effects. However, the HQ is not a statistical probability; a ratio of 0.001 does not mean that there is a one in one thousand chance of the effect occurring. Furthermore, the potential for adverse effects does not increase linearly as the RfD is approached or exceeded.

Risks for Exposure to Multiple Substances

To determine the overall potential for noncarcinogenic effects from exposure to more than one substance, EPA has developed a hazard index (HI) approach. Under this approach, EPA assumes that simultaneous exposure to several substances below their respective threshold levels could result in an adverse health effect. Thus, the HI is equal to the sum of the HQs.

Noncarcinogenic Effects Associated with Fish Tissue Contaminants

A summary of the critical systemic effects associated with exposure to the four contaminants that pose potentially significant noncancer risks to freshwater or San Francisco Bay anglers is provided below. These contaminants are the only ones among those considered in this analysis that have an HQ greater than 0.5 under the typical or 90th percentile fish consumption rate scenarios.[8]

Chlordane – The oral RfD for chlordane is based on a chronic study in which rats were fed chlordane at various dietary levels. The critical systemic effect observed was liver lesions in females, at 0.27 mg/kg-day. The RfD of 6.0×10^{-5} mg/kg-day is based on a NOEL of 0.06 mg/kg-day and an uncertainty factor of 1,000. An uncertainty factor of 100 was used to account for the inter- and intraspecies differences; and an additional factor of 10 was used to account for the lack of an adequate reproduction study and an adequate chronic study in a second mammalian species, and the generally inadequate sensitive endpoints studied in the existing studies.

DDT – The oral RfD for DDT was determined from a chronic study in which rats were fed DDT in their diet for 27 weeks. The critical effect was liver lesions. The RfD of 5×10^{-4} mg/kg-day is based on a NOEL of 0.05 mg/kg-day and an uncertainty factor of 100. An uncertainty factor of 100 was selected to account for uncertainty associated with interspecies conversion and to protect sensitive human subpopulations.

Dioxin – The oral reference dose for dioxin is based on a three generation reproductive study in Sprague-Dawley rats receiving 0.001, 0.1 or 0.01 μg 2,3,7,8-TCDD/kg-day. The lowest observable effect level (LOEL) was 0.001 μg 2,3,7,8-TCDD/kg-day based on a reduction in

[8] We have included contaminants with HQs as low as 0.5. Given the uncertainties in the risk estimates, an HQ as low as 0.5 suggests that exposure to a contaminant may be high enough to produce an adverse health effect.

gestation index, decreased fetal weight, increased liver to body weight ratio, and increased incidence of dilated renal pelvis. An uncertainty factor of 1,000 was applied to account for interspecies variation and for the use of a LOAEL, resulting in an RfD of 1×10^{-9} mg/kg-day.[9]

Mercury -- The mercury RfD is derived from a study of citizens in rural Iraq that were exposed to mercury-treated seed grain that was mistakenly used in bread. Adults and children who consumed bread for two to three months showed latent toxicity, with infants exposed during gestation being the most sensitive group. Infants exposed during fetal development exhibited cerebral palsy, altered muscle tone, deep tendon reflexes, and delayed developmental milestones. Adults exhibited neurological signs including paresthesia, ataxia, reduced visual fields, and hearing impairment. Using mercury concentrations in hair and assumptions of steady-state conditions and first-order kinetics, the study estimated that the individuals had a dietary intake of 65 μg/L mercury per day. The resulting oral RfD of 1.0×10^{-4} mg/kg-day includes an uncertainty factor of 10.

PCBs -- The liver is a principal site of systemic PCB toxicity in animals. Liver effects have been observed in numerous studies with exposed rats, mice, guinea pigs, rabbits, dogs, and monkeys, but rats have been tested most extensively. The effects appear to be reversible at low doses and are similar among species. Nonmalignant proliferative lesions were observed in the liver at high frequencies of PCB-treated rats and mice. Liver alterations were observed in monkeys fed diets containing 2.5 and 5.0 ppm Aroclor 1248. However, these effects were examined by autopsy in only one animal per dose level. In addition, rats exposed to Aroclor 1254 for four to 12 weeks experienced thyroid alterations. Thyroid effects also appeared to be reversible after cessation of exposure.[10]

Studies of PCB-exposed workers provide inconsistent but suggestive evidence for subclinical increases in serum enzymes that are indicators of possible liver damage. Liver dysfunction has not been demonstrated in PCB-exposed workers.

The RfD for PCBs is based on toxicity studies of the effects of long-term exposure to Aroclor 1254 on monkeys. Based on the LOAEL for changes in immune response, periocular tissue, and nail bed formation, EPA has developed an RfD of 2×10^{-5} mg/kg-day.

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[9] Agency for Toxic Substances and Disease Registry, *Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin*, June 1989.

[10] Agency for Toxic Substances and Disease Registry, *Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016)*, June 1989.

APPENDIX E

ECOLOGY AND ECOLOGICAL EFFECTS

This appendix was adopted from Chapter 2, **Ecological Risk and Decision Making Workshop (1995)**, U.S. Environmental Protection Agency, Office of Sustainable Communities and Ecosystems, Office of Policy, Planning and Evaluation, Washington, D.C. 20460

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Summary of Ecology Unit:

Time Allotted

Approximately 2 hours are allowed for discussion and lecture.

Summary of the Unit

This unit presents a general overview of ecology to provide participants with the basic concepts and terminology underlying ecological risk assessments. The information includes a discussion of the types of stressors and related ecological effects.

Key Concepts

- Ecosystems are complex and dynamic, composed of interacting networks of **biotic** and **abiotic** components.
- **Principal ecological components** are individuals, populations, communities, and ecosystems.
- Critical to the function of an ecosystem is the flow of energy and nutrients through the system's producers and consumers.
- **Stressors** can affect individual organisms, population growth, community structure and function, and ecosystem processes.
- Interactions among individuals in a population, and among populations in a community influence the **significance** of a stressor's ecological effects.
- The combination of stressor, environmental, and biological characteristics dictates the nature, extent, and magnitude of ecological effects.

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ECOLOGY AND ECOLOGICAL EFFECTS UNIT

ECOLOGY AND ECOLOGICAL EFFECTS

- **Basic Concepts in Ecology**
- **Ecological Effects of Stressors**

There are certain concepts that are important to understand to improve appreciation of ecological risk assessments. This unit will provide a brief review of ecological concepts, and the ecological effects of man-made activities and natural stressors.

Basic Concepts in Ecology

Ecology — *oikos* ("house") *logos* ("governing rules")

Focus — the primary levels of ecological organization: species, populations, communities, and ecosystems.

Basic Concepts in Ecology

The term "ecology" comes from the Greek phrase *oikos* ("house") *logos* ("governing rules"), literally "the rules of the house." The "rules" refer to the array of relationships and interconnections through which organisms interact with their environments.

Organisms do not live in isolation but occur in systems that exhibit a certain structure and function, such that the behavior of the whole is greater than the sum of the parts and therefore, very difficult to predict.

- Just as the cell and the entire individual organism represent levels of a system, so do populations of individuals of the same species and communities of populations characterizing ecosystems (Howell, 1994).
- Ecology is the study of systems in which there are interactions among living organisms, and between those organisms and the landscapes they inhabit. These relationships and interactions can generally be characterized in the following manner:
  - Among individuals within a population;
    - Social interactions among members of a wolf pack, or breeding behavior among stoneflies in a mountain stream.
  - Between individuals of different populations;
    - Predator-prey interactions between wolves and moose, or the importance of spottail shiners in the diet of green herons.

Basic Concepts in Ecology (Continued)

- Between organisms and their physical surroundings;
  - The relationship between gopher holes and soil microorganisms, or the influence of river water levels and muskrat populations.

This unit focuses on four primary levels of ecological systems:

- Species;
- Population;
- Community; and
- Ecosystem.

In doing so, the materials introduce and define some of the ideas and terms commonly used in ecology.

SPECIES

A group of actually or potentially interbreeding organisms that are reproductively isolated from other organisms.

Two animals of the same species will not necessarily look exactly alike. Widely distributed species often have different physical or behavioral characteristics. As a familiar example, consider the species *homo sapiens*. Humans exhibit considerable variety in skin, hair and eye color, size, etc. This same type of variety also occurs in plant and animal species.

POPULATIONS

Populations are groups of organisms of the same species occupying a particular space over a given interval of time.

Populations are the next step up the **systems hierarchy** from the individual organism.

Population structure is the relative proportion of individuals within each stage, e.g., eggs, larva, juveniles, and adults, or category, e.g., male or female.

A maximum **population size** can be reached for a limited area and time frame, given specific and limited amounts of food, shelter, living space, and other resources. This carrying capacity varies from month to month or even day to day with the seasons and other environmental circumstances.

Population density primarily is a function of three factors: birth rate, death rate, and distribution over time and space.

Each organism occupies only areas that meet its requirements for life. As a result, a population generally has a patchy distribution.

HABITAT—WHERE AN ORGANISM LIVES

Habitat provides factors necessary for survival, such as:

- **Hiding places**
- **Nesting and birthing sites**
- **Shelter from ambient weather conditions**
- **Cover for the growth and survival of shade-tolerant species of vegetation**
- **Structural features needed for song perches**
- **Food source**

In a general sense, a **habitat** can be thought of as the **"address" of an organism.**

Habitat structure provides much of what is needed to sustain life. Habitats also need to be a particular size and often, of a particular configuration to meet the living requirements of a particular species. Habitat size and shape will vary depending on the quality of the habitat and the requirements of the species.

- For example, species that live at the edge of forests (transitional belts between the interior forest and a different adjacent landscape) require a much different habitat type than interior forest species.
- For forest interior plants, the minimum area depends on the size at which moisture and light conditions become sufficient enough to support shade-tolerant species.

Terrestrial habitats are often described in terms of vegetational type, such as a pine forest or a grassland.

Freshwater habitats are broadly classified as standing water or running water.

Literally standing between freshwater and marine habitats, and heavily influenced by both, are **estuarine habitats.**

Marine habitats are generally classified as coastal and open ocean.

COMMUNITIES

Populations of different species live and interact with one another in complex associations called communities.

A **community** is an organized **assemblage or association of populations** in a prescribed area or a specific habitat (Howell, 1994). No species in nature exists in isolation from all others. Communities, more specifically **biotic communities**, are associations of interacting populations and are often defined by the nature of their interactions or by their location.

Communities can be considered on both large- and small-scale levels. Since most species are distributed independently according to environmental gradients (e.g., moisture or light levels, temperature, etc.), no clear-cut boundaries delineate communities. A community could be identified as existing within an entire forest or as existing within a hollow tree. Other examples of small-scale communities could be a decaying log, a pile of dead leaves, or the gut of a deer. The adaptations of populations to their habitats, and the interactions between and among populations determine the nature of a community.

Each community is composed of certain organisms that are characteristic of particular habitats. For example:

- Egrets in salt marsh habitats in eastern North America;
- Saguaro cactus in desert habitats in the southwestern United States; or
- Cattails in freshwater marshes.

Although the species within a community are, to some extent, replaceable by others over space and time, their **functions** in the community are relatively fixed.

NICHE

A niche is the role or function of a species in a community.

Ecological niche is the role or function of a species in its community. The niche is the expression of the relationship of an individual organism or population to the rest of the community.

An organism's ecological niche is expressed as its **"job" in its give-and-take with its environment**. More specifically, an animal's activity pattern, its feeding location, and its place in a food web—what it eats and what eats it—contribute to a description of its niche. For example:

- Red-eyed vireos hunt for food in trees; ovenbirds hunt on the ground.
- Red-tailed hawks are active by day; screech owls are active at night.

Some birds of related species within the same family occupy separate niches in parts of the same kind of tree.

- Bay-breasted, blackburnian, black-throated green, cape may, and yellow-rumpled warblers each live in a different zone or part of a spruce tree. Each species nests in a different part of the tree and at a different height above the ground. Each species gathers insects in a different part of the tree. These birds sometimes overlap in the *physical space* they occupy in or about the tree, but their *niches* do not (Terres, 1980).

This example points out the importance of the diversity of species. Each species performs a particular function, and the loss of a species will disrupt the community. This becomes especially important when endangered species are at risk, because there is little or no reserve capacity for those species to fill vacated niches and maintain community function.

Plants may form niches according to light levels. For example, in a tropical rain forest different plants live at different heights—canopy (tall trees), understory trees, shrub layer, and ground layer of vegetation. Plants living in each layer of the forest have adapted to different light levels.

SUCCESSION

The gradual replacement of one community by another as environmental conditions change.

Communities exist in a continual state of flux. Organisms die and others are born to take their place. When a habitat is disturbed—for example, by clear cutting, fire, or hurricane—the community slowly rebuilds. The sequence of changes initiated by disturbance is called succession. The creation of any new habitat—a plowed field, a temporary pond left by heavy rains—invites a host of species particularly adapted to be good pioneers or to colonize the newly disturbed sites.

Succession is the process whereby the pioneering species adapted to the disturbed habitat are progressively replaced by other species, and so on, until the community reaches its former structure and composition. For example, consider the following sequence of events:

- An oak-hickory community is burned.
- Annual and perennial herbs (pioneers) invade that area.
- Pine seeds blow in.
- The pines and herbs compete for resources.
- Within 30 years, the burned area has become a stand of pines.
- The forest floor (under the pines) shows many oak and hickory seedlings (pine seedlings grow poorly in shade while competing for nutrients).
- A well-developed oak-hickory understory exists within 50 years.
- Oaks and hickories replace the pines as they die.
- Within 200 years, the burned area once again becomes an oak-hickory forest.

This example illustrates that the microenvironment beneath a plant community differs significantly from that in the open. Temperature, humidity, soil moisture, and light are all affected by the canopy.

- A stable community consists of species whose seedlings can survive in its unique microenvironment while seedlings of other species cannot.

Succession (Continued)

- If the stable community is removed by some disturbance, leaving the soil exposed to full sunlight, the first species that colonize the site are not those of the old community; rather, they are seedlings of species adapted to grow in full light intensity.

Succession has been classified into two types (primary, secondary) according to its origin. The terminal community is known as the climax, although subtle changes in species composition continue after reaching the climax growth form. **Primary succession** is the establishment and development of plant communities in newly formed habitats previously without plants. **Secondary succession** is the return of an area to its natural vegetation following a major disturbance. The characteristics of the dominant species change during succession:

- Early-stage species are opportunistic, and capitalize on their high dispersal ability to colonize newly created or disturbed habitats rapidly. These species, which include dandelions and milkweed, typically have small wind-dispersed seeds. The seeds can remain dormant in soils of forested or shrub-covered areas for years until fire or treefalls create the bare soil conditions they need for germination and growth of the early-stage species.

- Climax species disperse and grow more slowly. Their shade tolerance as seedlings, and large size as mature plants give them a competitive edge over early successional species.

It should be noted that communities do not always return to the climax state following a disturbance, especially if there is an increasing impact of humans on the environment. In some cases, humans might have modified an area so extensively that the natural disturbance and succession regimes can no longer exist.

An example can be seen in some of the southwestern portions of the United States, as well as the many other arid or semi-arid regions of the world. In these areas, where local climates would normally allow grassland to maintain itself, the influence of disturbances, such as overgrazing by livestock, have led to the long-term conversion of productive, arable grassland to desert. The same community in a region with a true desert climate would be a natural condition; however, in "desertified" regions it can be seen as a "disclimax"—a disturbance-caused climax community.

PRINCIPLES OF EVOLUTION

- **No two individuals are exactly alike**
- **There is competition for survival**
- **Some individuals have traits better suited for survival in a particular environment**

Evolution consists of changes in the genetic makeup of a population over time. This process occurs because of several facts:

- All organisms show **variation**—no two individuals are exactly alike.
- All organisms **produce more offspring than can survive** to adulthood.
- There is **competition** for survival within and among species or populations for energy, sunlight, food, nutrients, water, space, and mates.
- Under given conditions, **individuals with certain characteristics have a better chance of survival and reproduction** than others because they can use the environment to better advantage.
- Some of those **characteristics are inheritable** over long time spans—geologic time or less.

The result is **natural selection**. The commonly used phrase to describe natural selection is "survival of the fittest." However, this refers to genetic lines and not individuals. Fighting for survival is only a small part of competition in natural selection.

- Darwin's finches on the Galapagos Islands of the Pacific developed a great variety of bill shapes, behaviors and other features to facilitate feeding on different types of food (bugs, seeds, flowers, etc.). These characteristics were developed to adapt to various environmental conditions, such as temperature, moisture chemistry, light, etc.

Principles of Evolution (Continued)

Artificial selection is the intentional breeding of a species such as livestock, pets, plants, etc. It may also be the unintentional spread of a species or characteristics, such as resistance of insects to pesticides, or bacteria to antibiotics. This results in very complex, self-sustaining communities finely adapted to the environment in which they live. When it is that finely tuned, disturbances to the environment can have a tremendous impact, from which they may or may not recover.

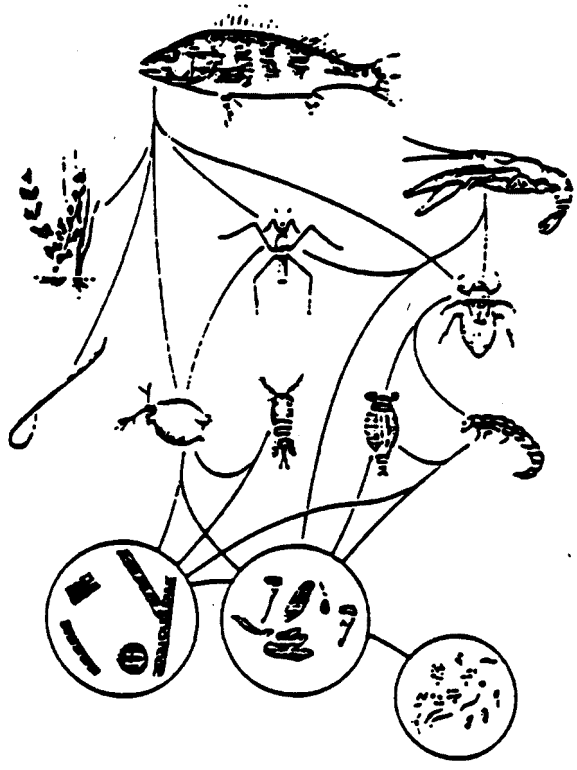
For most of its history, the human species was subject to the forces of natural selection. This has changed for several reasons:

- A cultural evolution led to technology, freeing humans to a great extent from the effects of natural selection.
- Humans are still part of ecosystems, but we are now almost always the dominant factor, subjecting other species to an array of stresses to which they are not adapted.
- For many species, even communities, the rate of introduction of new human stressors (physical, chemical or biological) far outstrips the rate with which they can evolve adaptations.
- A shift is occurring on the planet from self-sustaining communities that have evolved over very, very long periods of time, to very recently created communities that require artificial inputs of energy and materials, e.g., agriculture.

If long-term or unprecedented environmental changes occur, the response by a species or population will be:

- Extinction;
- Survival unchanged; or
- Evolution or adaptation.

FOOD WEB



Food Web

A food chain is the transfer of energy from one species to another. However, no organism lives wholly on another, and many organisms share several different food sources. Consequently, food chains interlink and form food webs (see diagram).

The term food web more accurately describes the complex, interrelated system of pathways through which the flow of energy takes place in nature. A food web is the total set of feeding relationships among and between species.

Food Web (Continued)

The food web hierarchy is described by **feeding, or trophic, levels**:

- **Producers**—Producers, primarily green plants, are the trophic level that supports all others.
- **Consumers**—Consumers rely on producers as an energy source. Most consumers belong to one of three groups:
  - **Herbivores**, which consume plants.
  - **Carnivores**, which consume meat.
  - **Omnivores**, which consume both meat and plants.

Many species are omnivores, living on mixed diets of plant and animal material. For example, black bears feed on berries, nuts, insects, rodents, and other plant and animal material.

Many species **change their feeding habits seasonally** or have different food requirements at different life stages. For example, seeds, nuts, and acorns are staple food items for turkeys during most of the year, but in summer, turkeys eat grasshoppers, other insects, frogs, toads, snakes, and other animals.

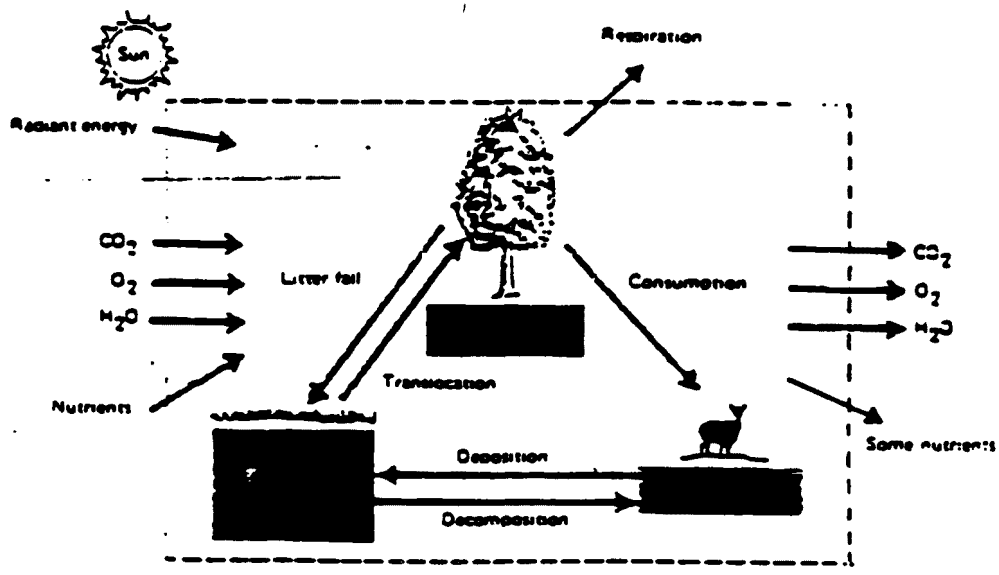
Trophic Levels and Energy Level

Consumers can be categorized into trophic levels. All organisms that share the same general source of nutrition are said to be at the same trophic level. Consumers belonging to more than one trophic level are called omnivores.

Energy decreases as trophic levels increase—at each step in the food chain, energy is lost in respiration, and less energy is available for the next level up. Caloric energy stored by plants is passed through the community through successive transfers between plants and herbivores, and prey and predators. At each step in the food chain, a considerable portion of the potential energy transferred in the food is lost as heat. The longer the food chain, the more restricted the amount of energy that will reach the terminal members. As a result, we rarely find food chains of more than four or five steps in natural situations. Furthermore, the number of organisms involved in the populations through which this energy passes becomes smaller with each new link.

ECOSYSTEM

Generalized ecosystem diagram illustrating the systematic nature of ecosystems and major components of the system



An **ecosystem** includes the **physical environment** and its **component plant and animal populations**. In the simplest of terms, all ecosystems consist of **three basic components**: the producers, the consumers, and abiotic (or nonliving) matter (Smith, 1990).

- **Producers** and consumers make up the **biotic (or living)** components of an ecosystem and include plants, algae, bacteria, and animals. As covered previously, populations of these organisms grouped into recognizable aggregations are known as communities.

- **Producers** are the energy-capturing base of the system. Producers are largely **green plants** that are able to fix (or transform) the energy of the sun and manufacture food from simple inorganic and organic substances.

Ecosystem (Continued)

- **Consumers** use (eat) the food stored by the producers, rearrange it (through digestion), and finally decompose the complex materials into simple, inorganic substances (assimilation into body tissues).

The structural elements of an ecosystem are the species, population, community, habitat, and food chain. The functional elements include niche and the flow of energy through the system's producers and consumers.

ABIOTIC FACTORS

Soils, sediment, water, solar radiation, nutrients, and minerals.

Ecosystems are not closed systems, existing within neatly defined boundaries. For example, picture a stream flowing through a deciduous forest, then a grassland, then, gradually, a salt marsh, ultimately emptying into a bay. Obvious **gradations exist** along this kind of continuum, yet the **ecosystems are identifiable by general landscape characteristics**.

The **elements that differentiate ecosystems** are abiotic components that make up the physical environment, such as soils, **sediment**, **water** (moisture, salinity), solar radiation, and nutrients. These elements determine the types of organisms that can inhabit a particular ecosystem.

PHOTOSYNTHESIS

The process by which plants convert light energy into chemical energy, which is stored as glucose.

Ecosystems operate because light energy from the sun is absorbed by **photosynthetic organisms** (plants, algae, and photosynthetic bacteria) and transformed into chemical energy in the form of glucose.

- Glucose is a sugar and an organic compound. Compounds that contain carbon and hydrogen are called organic compounds. The glucose is used to synthesize (or produce) carbohydrates, amino acids, proteins, fatty acids, fats, vitamins, pigments, etc.

Non-photosynthetic organisms (i.e., animals) get energy by eating this sugar or other substances, such as carbohydrates, that the plants make from it.

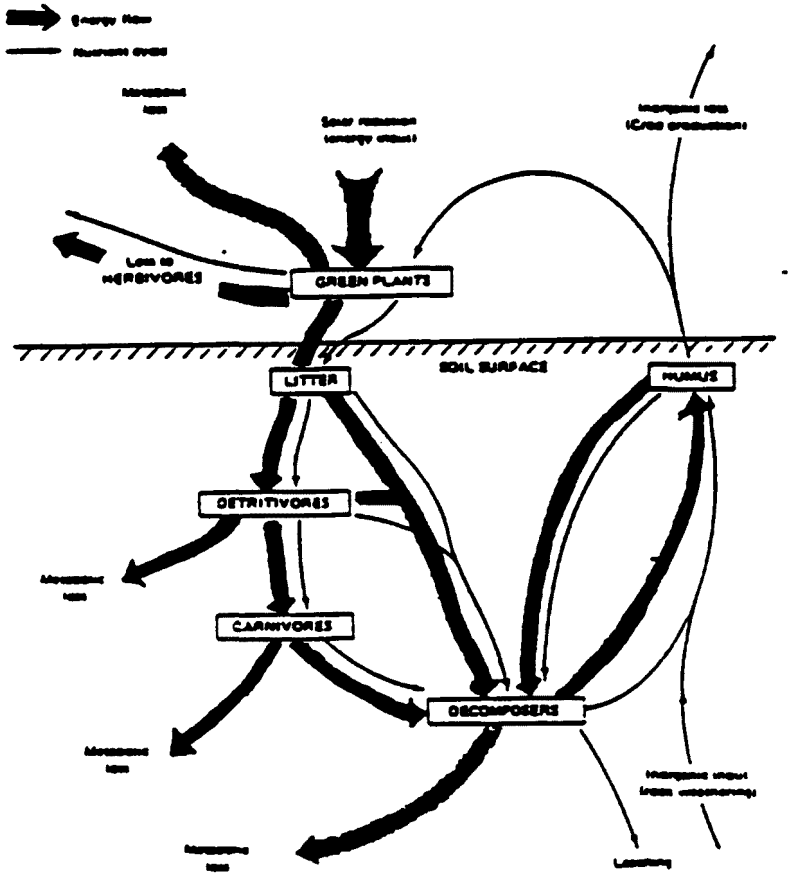
- When an animal eats a plant, the animal gets energy and the carbon-compound that is storing the energy. The animal uses the compound as a source of carbon to synthesize the substances it needs. In other words, photosynthesis is important for generating both energy and essential substances in an ecosystem.

Photosynthetic organisms are **producers**, and non-photosynthetic organisms are **consumers** (because they must consume producers to obtain energy).

In summary, organisms need energy to survive, and they need a source of carbon in order to synthesize carbon-containing substances, such as proteins and fats.

- Photosynthesis supplies both needs by converting light energy into chemical energy, and by combining carbon dioxide (CO_2) gas and water to form glucose, an organic compound. Glucose, then, is a source of energy and organic carbon for making all the other substances organisms need for survival.

DECOMPOSITION



Decomposition

Organisms living in any ecosystem require a continual supply of **energy** and **nutrients** in order to survive. Photosynthesis provides the energy, and decomposition provides the nutrients.

Decomposition of organic matter, such as what occurs to fallen leaves and logs, or roadkilled possums, consists of breaking down organic compounds and returning basic chemical elements, such as carbon, to the soil. The organisms most commonly associated with decomposition are bacteria and fungi. These microorganisms secrete enzymes into plant and animal matter, causing them to decompose.

- Bacteria are the major decomposers of animal matter.
- Fungi are the major decomposers of plant material.

Once one group has exploited the material to its capabilities, another group of bacteria and fungi able to use the remaining material move in. In this way, a succession of microorganisms acts on the organic material until it is finally reduced to inorganic nutrients. Detritivores are invertebrates that aid decomposition by fragmenting leaf litter, etc. Examples of detritivores, from smallest to largest size, are as follows:

- Protozoans;
- Mites, springtails, potworms;
- Nematodes, caddisfly larvae, mayfly nymphs; and
- Snails, earthworms, millipedes.

NUTRIENTS AND BIOGEOCHEMICAL CYCLES

Nutrients are essential to plants and animals and are used over and over again, cycling between organisms and the environment.

For an ecosystem to function, nutrients must be available to plants, and must be present in a consumer's diet. Of the many elements required, these eight are the most important:

- Carbon: A basic part of all organic compounds, such as glucose. In the ecosystem, it exists as carbon dioxide, carbonates, and fossil fuel, and as a part of living tissue.
- Hydrogen: Also a basic part of organic compounds and an important component of water.
- Oxygen: A by-product of photosynthesis. It is used by microbes in the decomposition process, and is used by animals in cellular respiration. Three major sources of oxygen are carbon dioxide, water, and molecular oxygen.
- Nitrogen: An essential element of protein and DNA. It makes up about 79% of the atmosphere as molecular nitrogen, but most plants can use it in a changed form, such as nitrates or nitrites.
- Phosphorus: An element involved in photosynthesis. It plays a major role in energy transfer in plants and animals.
- Sulfur: Like nitrogen, a basic constituent of protein.
- Calcium: Element necessary for proper acid-base relationships, blood clotting, contraction and relaxation of the heart muscle, etc.
- Magnesium: Element that helps certain enzymes function and is crucial to protein synthesis in plants

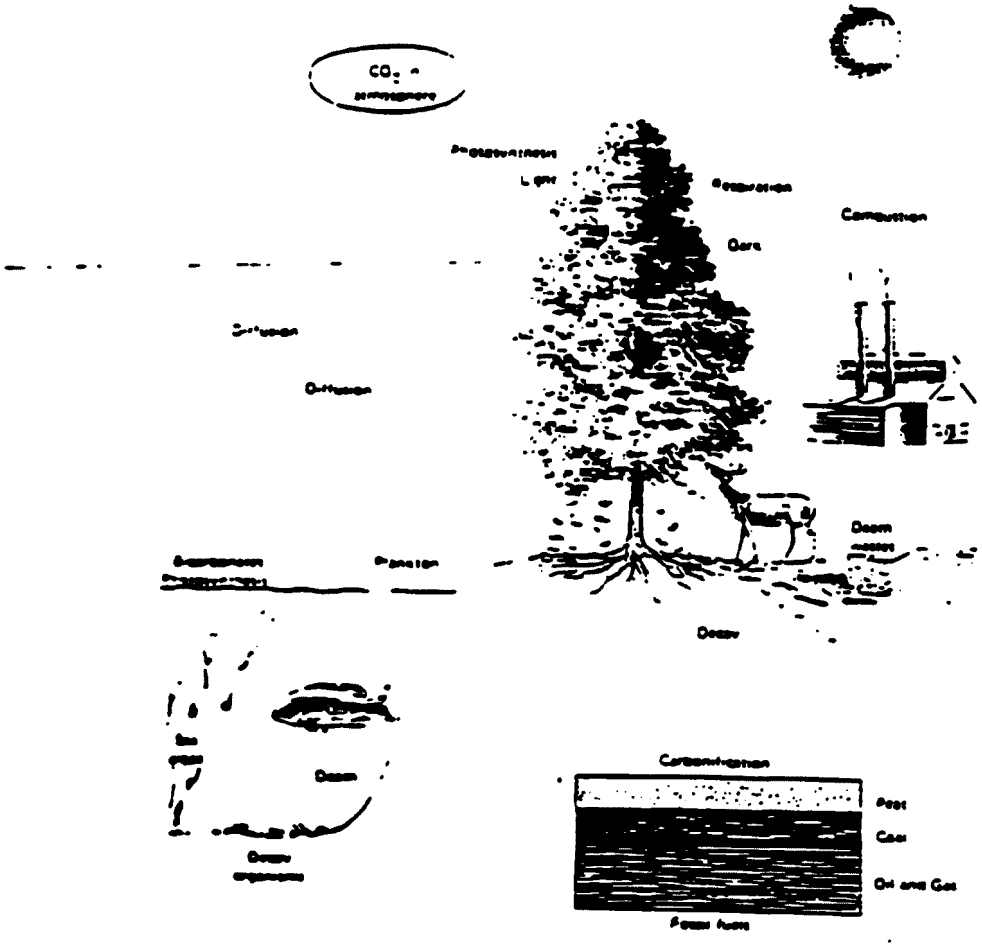
Nutrients and Biogeochemical Cycles (Continued)

These chemical elements are not destroyed upon the death of an organism. They can be used over and over again, being transferred from organisms to the environment and back to the organisms, in more or less circular paths, called **cycles**. Each element that is a nutrient follows its own unique pathway, called a **biogeochemical cycle** or **nutrient cycle**, through the abiotic and biotic components of an ecosystem.

In contrast to energy, which is in constant supply from the sun, nutrients exist on earth in fixed amounts. Life evolved the means to use mineral nutrients, release them to the abiotic environment, and then use them again. Although energy eventually leaves the earth as heat, and nutrients remain on earth to be recycled, the pathways of both are closely tied together. For some nutrients, going back and forth between the physical environmental and living organisms entails changing from an inorganic element or compound to an organic compound.

The **nitrogen cycle** is one specific example of the many biogeochemical cycles. Gaseous nitrogen is converted into ammonia, nitrates and nitrites by specific microorganisms. Plants convert these nutrients into proteins, DNA, and other organic compounds. Animals obtain these nutrients by eating plants or other animals. When plants and animals die, certain decomposer bacteria convert the nitrogen-containing organic compounds back into ammonia, nitrates, nitrites, and gaseous nitrogen beginning the cycle over again.

CARBON CYCLE



Carbon Cycle

The **carbon cycle** is another critical biogeochemical cycle. The recycling of carbon between the abiotic and biotic elements of an ecosystem is linked inseparably to the flow of energy through photosynthesis and respiration. The abiotic part of the carbon cycle involves carbon dioxide, a gas that makes up a small percentage of the atmosphere (0.03 percent) and is dissolved in the waters of the earth.

- Producers convert solar energy into chemical energy, which they use to convert the carbon in carbon dioxide into glucose.
- As plants respire (at night), they convert some of the carbon in organic compounds back to carbon dioxide, which is released into the environment.
- The rest of the converted carbon is stored in new plant tissue, which is transferred along a food chain.
- At each link in the food chain, more of the carbon converted by the producer is released by a consumer as carbon dioxide.
- The release of converted carbon by respiration replaces much of the carbon incorporated into glucose during photosynthesis.
- In breaking down organic waste and dead organisms, detritivores and bacteria return carbon to the physical environment in the form of carbon dioxide.

MAJOR TYPES OF ECOSYSTEMS

Terrestrial:	**Grasslands, deserts, coniferous forests, deciduous forests, alpine, tundra, rainforest**
Aquatic:	**Lakes and ponds, streams and rivers, wetlands, estuaries, open sea**

There are two major types of ecosystems: terrestrial and aquatic.

Examples of terrestrial ecosystems include:

▸ Rainforest	Amazon, northeastern Australia
▸ Deserts	Mojave and Sahara
▸ Grasslands	Serengeti, Great Plains of the U.S.
▸ Deciduous Forests	New England maples, Colorado aspens
▸ Coniferous Forests	Rocky Mountains, Mt. St. Helens
▸ Alpine	Swiss Alps
▸ Tundra	Greenland, Siberia

Aquatic ecosystems—freshwater and saltwater—include the following:

▸ Lakes and Ponds	Great Lakes, Walden Pond
▸ Streams and Rivers	Ohio River
▸ Wetlands	Florida Everglades
▸ Estuaries	Chesapeake Bay
▸ Open Sea	Pacific Ocean
▸ Coral Reefs	Australian Great Barrier Reef

ECOLOGICAL EFFECTS of STRESSORS

- **Stressor Types**
- **Kinds of Ecological Effects**
- **Factors Influencing Ecological Effects**

Ecological Effects of Stressors

We just concluded a discussion of a few basic terms and concepts necessary to develop a cursory understanding of the fundamentals of ecology. This section continues in the same manner by providing an overview of the characteristics of man-made or anthropogenic stressors and their ecological effects.

A definition and description of the types of stressors that commonly are addressed during an ecological risk assessment will be provided. Such stressors are those we (humans) have control over.

Next, we will discuss some stressor characteristics, followed by examples of the kinds of ecological effects caused by stressors.

The section concludes with a brief discussion of the ecological significance of the effects caused by anthropogenic stressors.

STRESSOR TYPES

• Chemical Stressors	Industrial chemicals, pesticides, fertilizers, smog, auto exhaust, radionuclides, etc.
• Physical Stressors	Logging, dredging/filling wetlands, road construction, etc.
• Biological Stressors	Introduced organisms and microorganisms such as starlings, gypsy moths, multiflora rose, genetically engineered microorganisms, etc.

Ecological risk assessments evaluate the **effects** caused by three general types (or categories) of **stressors**–chemical, physical, and biological.

Chemical stressors include hazardous waste, industrial chemicals, pesticides, and fertilizers. These stressors are by far the most frequently investigated during ecological risk assessments. This is evident in the focus of most of the major pieces of environmental legislation and the EPA programs developed to enforce such legislation. For example,

- CERCLA—Uncontrolled hazardous waste (Superfund).
- RCRA—Controlled hazardous waste.
- FIFRA—Pesticide registration.
- TSCA—Manufacture and use of toxic substances.
- CWA—Discharge from municipal wastewater treatment plants and industrial facilities.

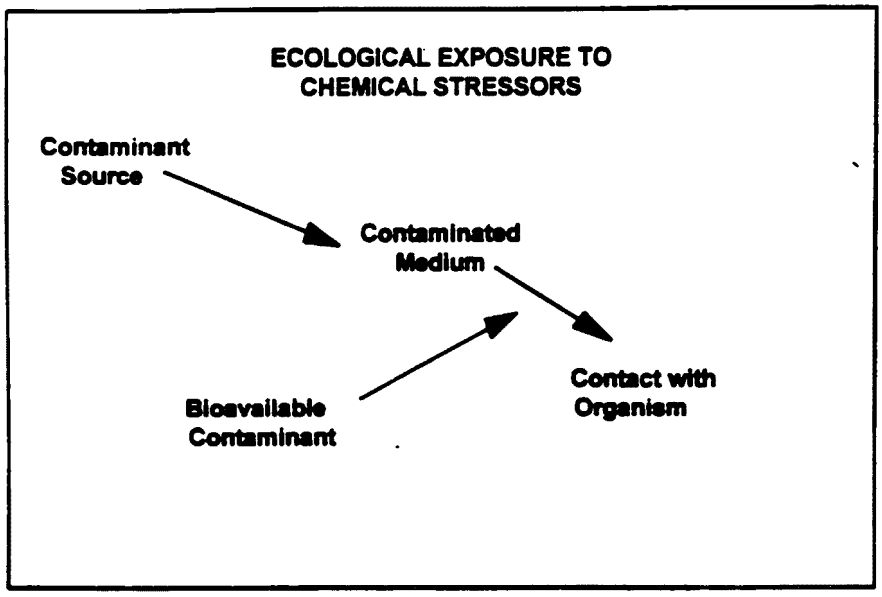
Physical stressors are activities that directly remove or alter habitat. Ranging from tilling soil to logging, road construction, and the building of shopping malls, these stressors often are the most destructive because they can result in total habitat loss as soils are compacted and organisms are lost.

EPA's regulatory authority with regard to physical stressors pertains to filling waters of the U.S. including wetlands (Section 404 of CWA), e.g., placing fill in water for constructing a bulkhead to shore-up waterfront property.

Biological stressors are organisms or microorganisms that are introduced, or released, (intentionally or accidentally) to habitats in which they did not evolve naturally. These organisms often are called "exotics." Biological stressors become a concern when they compete against native species, replace them, and become pests.

Stressor Types (Continued)

With regard to ecological concerns, **EPA's jurisdiction** over biological stressors is limited essentially to the regulation of **genetically engineered microorganisms** under the auspices of FIFRA and TSCA (for use in commerce). The federal agencies primarily responsible for regulating exotics are the U.S. Department of Agriculture and the U.S. Fish and Wildlife Service.



Exposure is the route and extent of contact between a **chemical stressor** and the ecological component. Exposure includes three aspects:

- *The chemical must reach the organism.* This means that some medium must be contaminated, such as air, water, soil, sediment, or other organisms.
- *The chemical must be in a form that can cause effects.* This is known as **bioavailability**.
- *The chemical must reach a site on or in the organism where the chemical can cause effects.* This means that the organism must breathe, eat, drink, touch, or be touched by the contaminated medium.

Depending on the physical and chemical properties of contaminants, they are incorporated into the cycles of the atmosphere, soil, and/or water, where ecological components become exposed. Once in the environment, chemicals can undergo changes and/or move from one medium to another. This is called **fate and transport**.

Chemical stressors can be altered by physical and chemical processes. For example:

- Light energy can alter a substance through a process called **photolysis**.
- Some substances react with water in a process known as **hydrolysis**. To illustrate, acetic anhydride, which is corrosive and causes burns, is hydrolyzed to acetic acid (vinegar), a food substance.

Exposure (Continued)

- Contaminants can react with other chemicals in the environment to produce new compounds. For example, under the right conditions lead will bond with sulfide ions in sediment to form an insoluble, nontoxic mineral, lead sulfide (galena).

THE NATURE OF CHEMICAL STRESSORS

Bioavailable chemicals exist in a form that organisms can take up.

No bioavailability equals no uptake and therefore no effect.

Before a chemical stressor can induce an effect in an organism or become incorporated into its tissues, the **chemical stressor must be bioavailable.** That is to say, it must exist in a form that the organism will absorb.

The **total amount of a substance** detected in contaminated media **is not necessarily bioavailable.** A portion of the chemical stressor might be sorbed (or adhered) to soil or sediment particles, or to particles suspended in the water column or atmosphere. Some or all of the chemical might be chemically bound as an insoluble salt or other biologically unavailable compound.

- Only the bioavailable portion of the total amount of contaminant in the environment is relevant to an ecotoxicity evaluation. **No bioavailability equals no uptake and therefore no effect.**

- The **bioavailability** of a substance can **change with changes in environmental conditions.** For example, an increase in the acidity of water or soil can increase the bioavailability of metals.

Biologically unavailable chemical stressors in ingested soil, sediment, or water may **become bioavailable during the digestive process.** For example, a squirrel might inadvertently ingest lead-contaminated soil in the process of opening an acorn. If the lead in the soil is not bioavailable (i.e., is strongly sorbed to the soil particle), it can become bioavailable when the acid in the squirrel's stomach causes the lead to dissociate (or desorb) from the soil particles. The lead is now available for uptake into the animal's bloodstream.

BIOCONCENTRATION

BIOACCUMULATION

BIOMAGNIFICATION

When evaluating the potential for toxic effects from chemical stressors, we have to consider bioconcentration, bioaccumulation, and biomagnification as factors. Note that these are **factors**, not **effects**. Even if a chemical stressor is present at low concentrations in the environment, it might still pose a threat to ecological components if it bioconcentrates or bioaccumulates, and especially if it biomagnifies.

Bioconcentration - The absorption of a chemical by an organism to levels greater than the surrounding environment.

Bioaccumulation - Uptake and retention of a chemical by an organism through feeding and bioconcentration.

Biomagnification - Increased concentration as a contaminant passes up the food chain.

A classic case of biomagnification is DDT. During the years of its use, the pesticide DDT caused eggshell thinning in numerous birds of prey, including hawks and eagles. DDT occurred at low concentrations in water as a result of runoff from agricultural fields. Because DDT is very persistent and because it accumulates in fat tissue, it biomagnified in the food chain, beginning with aquatic plants and invertebrates, through fish, to fish-eating birds. The lower concentrations occurring at the bottom of the food chain produced no adverse effects, but the high concentrations in the birds caused eggshell thinning and reduced reproductive success.

Bioconcentration, Bioaccumulation, Biomagnification (Continued)

A **bioconcentration factor (BCF)** is the concentration of the chemical in the organism, divided by the exposure concentration. It is often used in ecological risk assessments to help characterize exposure.

BCFs for *Daphnia magna* (Water Flea)

Substance	BCF
Benzo(a)pyrene	12762
Bis(2-ethylhexyl)phthalate	5200
Manganese chloride	911

Bioconcentration varies among chemicals. Bioconcentration, bioaccumulation, and biomagnification depend on both the chemical and the species exposed to the chemical. As shown in the above table, bioconcentration in one species varies with the chemical. Also, bioconcentration of the same chemical varies with the species. Environmental conditions also affect bioconcentration and bioaccumulation, so in site-specific risk assessments, we may sometimes want to calculate site-specific bioconcentration factors.

THE NATURE OF PHYSICAL STRESSORS

The severity of the impact of a physical stressor depends primarily upon:

- **The size of the affected area.**
- **The frequency of the disturbance.**
- **The intensity, or physical force, of the distributing event.**

All **ecosystems** are **dynamic** and possess some degree of **resilience** to recover from a disturbance. Natural disturbance is a normal part of ecosystem functioning. Occasional disturbances that cause fluctuations in community structure and function are as much a part of natural processes as is the cycling of nutrients. However, the addition of human-caused physical stressors often pushes a system's resilience to its limits because they tend to be more frequent, more intense, and tend to impact larger areas than do natural disturbances. In other words, they represent new types of disturbances to which the system has not evolved adaptations.

The extent to which this combination is overwhelming depends on the **size** of the affected **area**, the **frequency of disturbance**, and the **intensity of the disturbing event**. Generally speaking, larger and more frequent physical stressors result in more extensive and longer-lasting effects. Massive and intensive disturbances can sometimes take centuries to recover. Sometimes recovery is apparent within years, a relatively short period of time.

- Whether a two-lane country road or a superhighway, road construction means **habitat loss**. Often wetlands are filled, hilltops are removed, and other changes are made. The movement of heavy machinery results in the compaction of soil. During construction, rain washes exposed soil into streams and other bodies of water. Also, use of the road will introduce some **chemical stressors**, such as oil and gas residues, and road salt in northern climates.

- **Surface mining** removes habitat and increases erosion. Removing topsoil often exposes iron- and sulfur-bearing strata to rain, resulting in highly **acidic runoff** that renders nearby water bodies lifeless. Surface mining also exposes water tables, adding to the volume of runoff.

The Nature of Physical Stressors (Continued)

- **Clear-cutting**, a common form of timber harvesting, removes large blocks of forested habitat. The erosion associated with logging occurs both from the newly exposed forest floor and from improperly constructed logging roads.

- Clearing and plowing fields for **agriculture** disturbs the structure of the soil, exposing it to erosion by water and wind. Water erosion often carries soil, fertilizers, and pesticides to nearby streams and rivers.

THE NATURE OF BIOLOGICAL STRESSORS

Biological stressors are living organisms (including microorganisms) accidentally or intentionally introduced to an ecosystem.

Unlike chemical and physical stressors, biological stressors can reproduce, adapt, and spread, adding new dimensions to the ecological assessment process.

Biological stressors are known as "exotics" because they have not evolved along with the organisms that make up a particular biotic community.

These stressors add another dimension to the ecological risk assessment process because they are living and reproducing organisms that require the consideration of active biological and mechanical transport, passive transport, or both.

- Microorganisms, some invertebrates, and some seeds have nearly the same capability for transport; they are carried in the guts of animals, by wind, and by water.
- Mechanical transport (e.g., ships, trucks, airplanes) is as effective as biological transport in moving organisms over long distances. Upon arrival in a suitable habitat, biological stressors use nutrient and energy sources to grow and reproduce.

KINDS OF EFFECTS CAUSED BY CHEMICAL STRESSORS

- **Organism Level—Mortality, behavioral changes, physiological impairment (e.g., growth, reproduction).**
- **Population Level—Decreased birth rates, increased mortality rates, increased dispersion, local extinction.**
- **Community/Ecosystem Level—Structural changes (e.g., population loss), functional changes (e.g., niche loss), habitat destruction.**

Effects are measured and evaluated in terms of organisms, populations, communities, and ecosystems. For the most part, community-level effects translate into ecosystem effects, because communities make up the biological portion of an ecosystem.

Organism Level. Chemical stressors matter because of their effects on populations, and, indirectly, on communities, but chemical stressors act by their immediate effects on individual organisms (Moriarty, 1983). Effects on individuals range from **rapid death through sublethal effects** to no observable effects. These effects may be indirect, occurring as a result of elimination of prey base or habitat alteration. In the case of threatened and endangered species, effects influencing a few individuals are likely to be significant because they are at or near to the point of no return.

Population Level. Usually, effects become ecologically significant when they affect the survival, productivity, or function of a significant number of individuals such that **population size is reduced, population structure is altered, or total function is impaired** (Cockerham and Shane, 1994).

- **Population size** can be reduced if stressors reduce mating success or egg production; reduce survival of offspring or reproductive-age adults; increase susceptibility to predation, parasitism, and disease; affect recruitment through altered immigration or emigration rates; or reduce development or maturation rates.
- **Population structure** can be altered if stressors differentially affect one age group or developmental stage, reduce development or maturation rates, or differentially affect one sex.
- **Ecological function** can be reduced if stressors impair photosynthesis, reduce organisms' efficiency in converting food into energy, or cause organisms to slow or stop performing activities such as decomposition of leaf litter or fixation of nitrogen.

Kinds of Effects Caused by Chemical Stressors (Continued)

Community/Ecosystem Level. Community/ecosystem-level effects are often the direct result of stressors affecting the ability of populations to interact with one another.

Two examples of a stressor affecting a population's ability to interact with other populations are an **impaired ability to avoid predators** and a **decreased ability to prey on lower trophic levels.**

A population can suffer from indirect effects due to a stressor altering the dynamics of populations with which it interacts, such as reduction in the abundance of a predator due to toxic effects on prey.

Stressors can result in changes in **structural** properties of a community, such as the **number of species or trophic levels**, or changes in the functional properties of an ecosystem, such as photosynthesis.

Lethal and Sublethal Effects

Adverse effects on living organisms can be either lethal or sublethal.

- Lethal—Mortality of individuals due to exposure to chemical stressors.
- Sublethal—Other adverse effects. These include reproductive impairment, disruption of certain functions such as growth or photosynthesis, and induction of behavioral abnormalities such as hyper- or hypo-activity.

Frequently, the type of sublethal effect is characteristic of the chemical stressor of concern. For instance, lead and mercury are associated with behavioral abnormalities in mammals.

Toxicity varies among chemicals. Toxicologists measure the lethal effects of a chemical by exposing test animals to various concentrations or doses of the chemical and counting how many organisms die in a specified period of time.

Kinds of Effects Caused by Chemical Stressors (Continued)

Lethality is usually expressed as the median lethal concentration or dose (LC_{50} or LD_{50}) which is the concentration or dose at which 50 percent of an exposed population dies. Notice that the lower the LC_{50} or LD_{50}, the more toxic is the chemical. It takes less to kill 50 percent of the population. As the table shows, lethal concentrations vary among chemicals for a particular species.

Lethal effects are measured by **Median Lethal Concentration (LC_{50})** and **Median Lethal Dose (LD_{50})**.

LC_{50}s for *Daphnia magna*	
Substance	LC_{50}
Aroclor 1248	2.6
Cadmium chloride	65
Carbon disulfide	2100
Sodium arsenite	5278

As with lethal effects, ecotoxicologists test for sublethal effects by exposing organisms to different concentrations or doses of a chemical, and counting how many exhibit the adverse effect. Sublethal effects are frequently reported as follows:

- **Median effects concentrations or doses (EC_{50}s or ED_{50}s)** indicate the exposure at which 50 percent of exposed organisms exhibited the effect being evaluated by the investigation.
- **Lowest Observed Adverse Effects Level** or **Concentrations (LOAELs** or **LOAECs)** indicate the lowest exposure at which adverse effects were initially observed.
- **No Observed Adverse Effect Levels** or **Concentrations (NOAELs** or **NOAECs)** indicate the highest exposure at which effects were not observed.

Sometimes the word "adverse" is left out, making these acronyms LOEL or LOEC and NOEL or NOEC. The following tables show how sublethal effects vary according to the chemical, the species, and the effect.

Kinds of Effects Caused by Chemical Stressors (Continued)

LOAECs for Phenanthrene

Species/Effects	LOAEC (in µg/l)
Daphnia pulex/reproduction	110
Daphnia pulex/growth	360
Selenastrum capricornutum (alga)/population growth	800,000

LOAECs for Di-n-octyl phthalate in Fathead Minnows

Effect	LOAEC (in µg/l)
Reduced Growth	8300
Reduced Hatching	1760

CHEMICAL STRESSORS: AN EXAMPLE

Nutrient Loading (Eutrophication)

The biological overproduction in aquatic ecosystems primarily as a result of increased nitrogen and phosphorus from agricultural drainage, partially treated sewage and other wastes, etc.

Images of hazardous waste come to mind first when considering chemical stressors. However, there are other kinds of chemical stressors that are widespread and more damaging in terms of ecological impacts. One example is **nutrient loading or eutrophication,** which is the biological overproduction in aquatic ecosystems.

Treated sewage, drainage from agricultural lands, river basin development, runoff from urban areas, and other factors, commonly increase the rate of nitrogen and phosphorus loading to aquatic ecosystems, and are the major causes of **biological overproduction, or eutrophication.**

Nitrogen and phosphorus are required in limited amounts by algae and aquatic plants. However, excess amounts of these nutrients act as fertilizers and cause photosynthetic rates to increase dramatically. The corresponding growth forms dense algal populations, increases turbidity and sedimentation, reduces the lighted region where photosynthesis occurs, and prevents the growth of submerged aquatic vegetation.

Increased sedimentation reduces growth rates or resistance to disease, prevents successful development of eggs and larvae, modifies natural movement or migration patterns, reduces the natural availability of food, and results in more oxygen being consumed in the lower reaches of the water column and the sediments during the decomposition of organic matter. The result often is a **depletion** or almost complete absence of **dissolved oxygen** in the lower reaches of the water column.

CHEMICAL STRESSORS: ANOTHER EXAMPLE

Acid Deposition

The release of sulfur dioxide and nitrogen oxide to the atmosphere (primarily as a result of fossil fuel combustion), where they form sulfuric and nitric acid, which then falls back to earth in all forms of precipitation.

The **major industrial sources** of acid deposition are internal combustion engine, utility plants, etc. These industrial sources produce **sulfur dioxide** and **nitrogen oxides** which are the precursors of acid deposition. These substances readily react in aerosols to generate sulfuric and nitric acid, respectively. These acids and their precursors are picked up and transported from one locale to others by the prevailing winds. Deposition then occurs in precipitation in all its forms.

Eighty percent of sulfur dioxide released into the atmosphere is attributed to human activity—100 percent in some regions. Of that, 85 percent is attributed to fossil fuel combustion. Nitrogen oxides also come from combustion, the most notable source being motor vehicles.

For **terrestrial ecosystems**, the effects of acid deposition have been implicated in declines and **die-back in forests**. In **aquatic systems**, changes in pH, or the acidity or alkalinity of a solution, can affect communities of bacteria, algae, invertebrates, and fish, **altering species composition and productivity**, reducing numbers, and impairing reproduction and decomposition. Acidic conditions can mobilize metals from a bound form in which they are largely non-toxic to a free form in which they are toxic and readily available to organisms.

Acid deposition is thought to be the major cause of the destruction of populations of fish and other aquatic organisms in many lakes, particularly in the northeastern United States (Cockerham and Shane, 1994).

KINDS OF EFFECTS CAUSED BY PHYSICAL STRESSORS

Erosion	Removal and transport of soil material by water and wind.
Siltation	Soil that is removed by erosion makes its way to streams and rivers.
Increased Light Intensity	Vegetation removal results in higher soil and water temperature and lower soil moisture and relative humidity.

Disturbances create conditions for **erosion** by destroying plants, their roots, and soil organic matter. Arid and semiarid climates are especially prone to wind erosion. The soil in such areas has little moisture to hold it together, and the small quantity of vegetation that grows in such areas does not provide stems and leaves extensive enough to block the wind, or roots extensive enough to hold soil in place.

Examples of natural causes: Water flow (rivers and streams), heavy rains, flooding, drought followed by rain storms or strong winds.

Examples of man-made causes: Agricultural practices (such as irrigation, plowing, clearing of land, grazing), removal of vegetation (timber harvesting), construction of roads, buildings, etc.

One of the major ecological problems associated with erosion is **siltation**. Siltation results in the deposition of excess soil where stream and river currents are slow, smothering plants and bottom-dwelling organisms, and covering important fish habitat. Some fish, such as salmon, require clean gravel streambeds in which to spawn. For them, the effects of siltation could result in the loss of critical breeding habitat. Salmon lay their eggs in the small spaces between rocks on streambeds. Water circulating around the eggs supplies them with oxygen which is dissolved in the water. If the spaces become filled with silt, water circulation around the eggs will decrease and the young will fail to develop.

When the **vegetation** along a stream or other water body is removed (e.g., by clear-cutting, house construction etc.), the amount of sunlight reaching the water increases. As a result, water temperatures can increase significantly, possibly having lethal effects on some of the resident aquatic organisms.

HABITAT FRAGMENTATION

Physical stressors, such as road construction, logging, dredging wetlands, etc., break larger areas of habitat into smaller patches, or fragments.

Habitat fragments can ultimately become so isolated that they function much like islands.

Wildlife corridors are "natural highways" that link habitat fragments, thereby allowing certain species to survive a partial loss of habitat.

In addition to disturbing or destroying the immediate habitat(s), activities such as road construction, logging, dredging wetlands, and agriculture, whittle away piecemeal at larger, relatively intact areas. This results in **habitat fragmentation**, the breaking up of larger areas into smaller patches or fragments of habitat.

When **habitat patches become isolated** from similar habitat by different, relatively inhospitable terrain, they essentially **become islands**.

If fragmentation **continues**, the remaining area is reduced to a critical size below which the **habitat** will not provide the **requirements** of many of the original species, and a number of them will disappear.

Many species of **terrestrial wildlife** can live in fragmented habitats only if **corridors** link enough fragments to provide both habitat requirements and interactions with others of the same species to perpetuate viable populations.

KINDS OF EFFECTS CAUSED BY BIOLOGICAL STRESSORS

Introduced organisms act as biological stressors through predation, parasitism, pathogenesis, and competition for resources.

Exotic organisms include domestic species, accidentally introduced species, non-native game and fish species, biocontrol agents, and, quite recently, species modified by bioengineering. Through competition, predation, and pathogenesis (disease), exotic organisms have extinguished native species or reduced them, and have drastically changed the character of the invaded communities (Suter, 1993).

- Outbreaks of insects, such as the introduced gypsy moth and spruce budworm, defoliate large areas of forest, which results in the death or reduced growth of affected trees. The degree of gypsy moth mortality can range from 10 to 30 percent in hardwood forests to 100 percent in spruce and fir stands.

- When two introduced species of plankton-feeding fish, the alewife and rainbow smelt, proliferated in Lake Michigan, seven native species of fish with similar food habits declined drastically (Crowder et al., 1981).

- Japanese honeysuckle, a garden escapee, and multiflora rose, widely planted in the past for soil conservation purposes, have invaded old fields and forest edges, crowding out native plants and affecting the structure and composition of animal life.

- Virulent tree diseases have markedly changed the composition of North American forests. The chestnut blight, introduced into North America from Europe, nearly exterminated the American chestnut and removed it as a major component of the forests of eastern North America. With its demise, oaks and birch increased (Smith, 1990).

ECOLOGICAL SIGNIFICANCE OF EFFECTS

- Nature and magnitude of effects
- Spatial and temporal patterns of effects
- Recovery potential

Ecological significance of effects or the types and extent of effects is an important consideration in assessing ecological risk.

Nature and Magnitude of Effects

The **nature** of effects relates to the relative significance of effects especially when the effects of stressors on several ecosystems within an area were assesssed. It is important to characterize the types of effects associated with each ecosystem and where the greatest impact is likely to occur.

Magnitude of effect will depend on the ecological context, e.g., life history characteristics. Long-lived vertebrates such as large mammals, predatory birds, and whales are more sensitive to mortality imposed on adults that are short-lived, highly fecund (fertile) organisms such as quail and anchovies (Cockerham and Shane, 1994).

Spatial and Temporal Patterns of Effects

Spatial and **temporal** patterns of effects consider whether effects occur on large scales (e.g., acid rain) or will be localized, and whether effects are short-term or long-term. Some effects take decades to manifest themselves (e.g., ozone depletion effects on marine ecosystems).

Recovery Potential

Recovery relates to how easy it is to adapt to changes. For example, rainforests which are complex, highly evolved ecosystems may take longer to adapt to perturbations than a pine forest, which can recover relatively quickly from disturbances by rapidly re-seeding.

NATURAL VS. HUMAN STRESSORS AND RECOVERY

It is important to remember that natural disturbances bring about diversity of the landscape. Wind, moving water, drought, fire, and animal activity yield variation in habitats. These natural disturbances also cause changes in the availability of open space for species to colonize. Ecosystems are adapted to disturbances that have occurred with some frequency over the evolutionary history of the ecosystem and will usually eventually recover and return to their original state.

Humans may introduce stressors to which the ecosystem has not been exposed during its evolutionary history (synthetic chemicals, exotic species). Human-caused disturbances are usually more frequent, more intense and impact larger areas. These larger-scale disturbances can have subtle as well as dramatic impacts on a habitat. They often result in a situation that is overwhelming from which the ecosystem never recovers. Recovery is sometimes apparent within years. However, a massive and intense disturbance can cause an ecosystem to take centuries to recover. Even then, the original or "natural" ecosystem may never recur.

Key Concepts

- Ecosystems are complex and dynamic, composed of interacting networks of biotic and abiotic components.
- Principal ecological components are species, populations, communities, and ecosystems.
- Critical to the function of an ecosystem is the flow of energy and nutrients through the systems's producers and consumers.

Key Concepts (Continued)

- Stressors can affect individual organisms, population growth, community structure and function, and ecosystem processes.
- Interactions among individuals in a population, and among populations in a community influence the significance of a stressor's ecological effects.
- The combination of stressor, environmental, and biological characteristics dictates the nature, extent, and magnitude of ecological

Optional Exercise:

The following exercise illustrates how stressors affect a population.

A SIMPLE SIMULATION MODEL
Hypothetical What-If Population

Stage	Initial Number	Maturation Time	Percent Survival	Percent Females	Eggs/ Female/Month
Eggs	300	1 mo.	50		
Larvae	200	1 mo.	50		
Adults	100		50 per mo.	50	10

To illustrate the effects of stressors on populations, we will use a very simple simulation model. We'll call our organism *Hypothetical what-if*, or the What-If Bug.

The What-If Bug has three stages: an egg, a larva, and an adult. The eggs and larva each take one month to complete their development, and 50 percent survive to the next developmental stage (egg to larva, larva to adult). Adult survival is 50 percent per month. In other words, of the original 100 adults in our example, 50 will be alive at the end of 1 month, 25 at the end of 2 months, and so on. One lucky individual will live to the ripe old age of 7 months. The What-If Bug has a sex ratio of 0.5; that is, 50 percent of the adult population is female. Every month, each female lays 10 eggs.

Our simulations start out with 300 eggs, 200 larvae, and 100 adults. We then run the simulation for 25 "months," first with the parameters shown here, then changing one parameter to see the effect of reduced survival of a life stage, reduced egg production, or changes in the sex ratio. The next four figures show the effects of hypothetical stressors on our hypothetical population.

- In the first figure, we reduce egg survival from 50 percent to 45, 40, and 35 percent.
- In the second figure, we reduce adult survival in the same manner.
- In the third figure, we reduce eggs per female from 10 to 9.7 and 5 eggs per female.
- In the fourth figure, we vary two parameters simultaneously. Both adult survival and the percent of the population that is female are reduced from 50 percent to 45, 40, and 35 percent.

Let's look at the results. You will note that the top curve in each graph represents the initial conditions that we presented earlier. All the curves represent the total population (eggs, larvae, and adults) over the 25- month period.

Optional Exercise (Continued)

Egg Survival

Assume that the What-If Bug lays its eggs in soil contaminated with a chemical that is slightly toxic. Suppose that the toxic effects of the contaminant only reduce egg survival from its normal 50 percent to 45 percent. The graph in Figure 1 shows that the population at the end of 25 months is about half what it would be with no additional egg mortality, down from about 2400 to about 1200. If the contaminant causes egg survival to decrease to 40 percent, the population does not grow at all, and if egg survival drops to 35 percent, the population declines.

EGG SURVIVAL

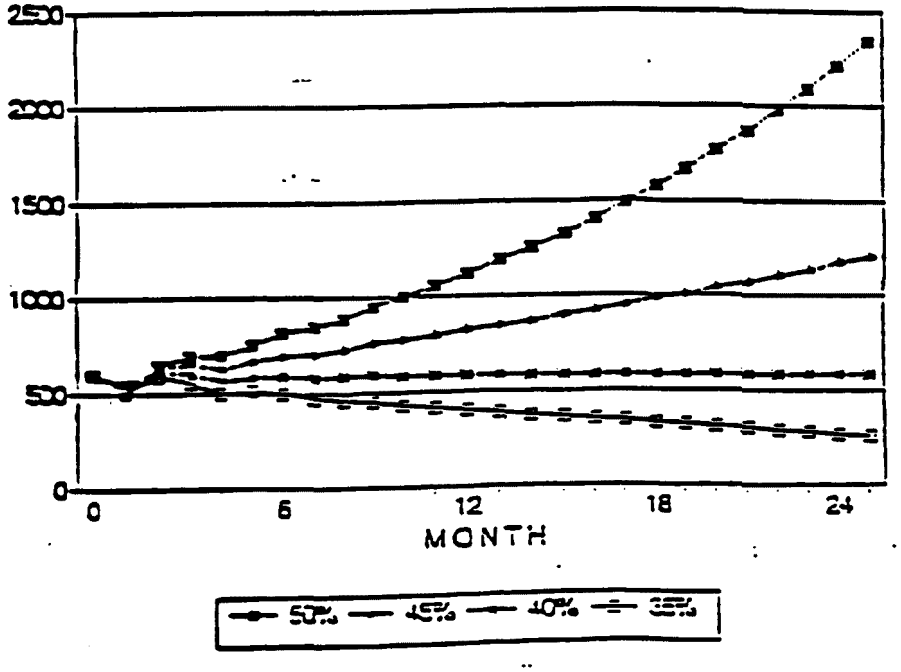


Figure 1. Number of eggs of What-If Bug surviving over 25 months

Optional Exercise (Continued)

Adult Survival

The adult What-If Bug feeds on flowers that grow along pesticide-treated vegetable fields. Drift from the pesticide spraying lands on the flowers, killing some What-If Bugs (Figure 2).

- The population fails to grow at all when adult survival declines just to 45 percent.
- Reductions in survival to 40 and 35 percent result in significant decline in the population.

ADULT SURVIVAL

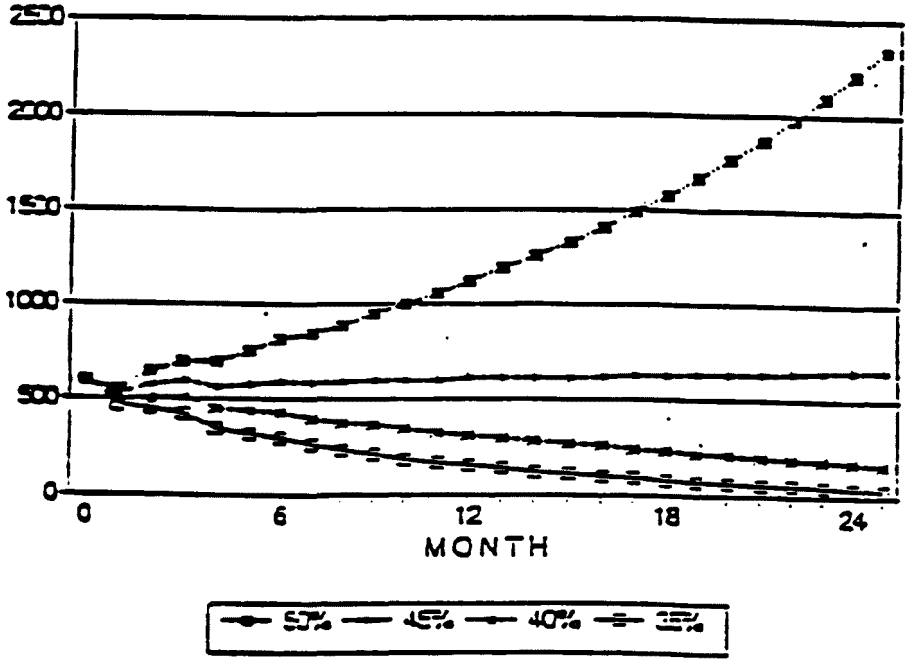


Figure 2. Number of adult What-If Bugs surviving over 25 months

Optional Exercise (Continued)

Eggs per Female

Along the roadway, another flower serves as a food source for adult What-If bugs. The soil is so compacted at this site that the plants provide less nutrition and the female bugs produce fewer eggs.

- Figure 3 shows that a reduction to nine eggs per female causes the population to grow at about half the rate if egg production remains at 10 per female.
- At five eggs per female, the population is heading for extinction.

EGGS PER FEMALE

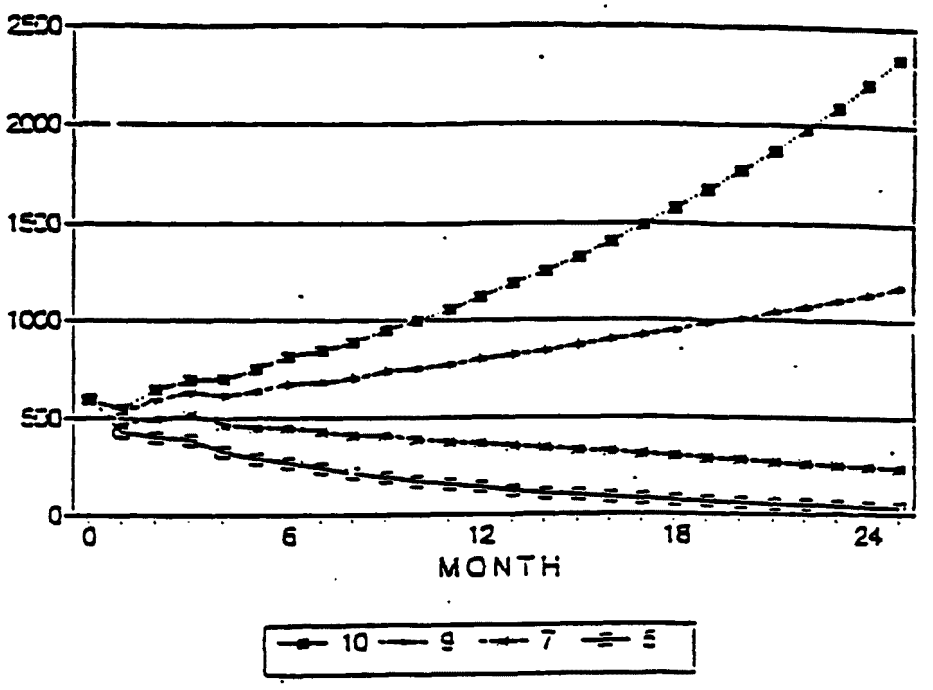


Figure 3. Number of eggs per female What-If Bug over 25 months

Optional Exercise (Continued)

Adult Survival and Percent Females

The What-If bug survives best in partially shaded environments where the temperature is moderate in summer. Females are more susceptible than males to high temperatures, but both suffer some additional mortality. In Figure 4 both adult survival and the percent of the population that is female were reduced. To keep things simple, we used the same numbers for each: 50, 45, 40, and 35 percent.

- As seen in Figure 4, with just a 5 percentage point decline in the two parameters, the population declines. At 40 and 35 percent, the population is quickly becoming extinct.

ADULT SURVIVAL/% FEMALE

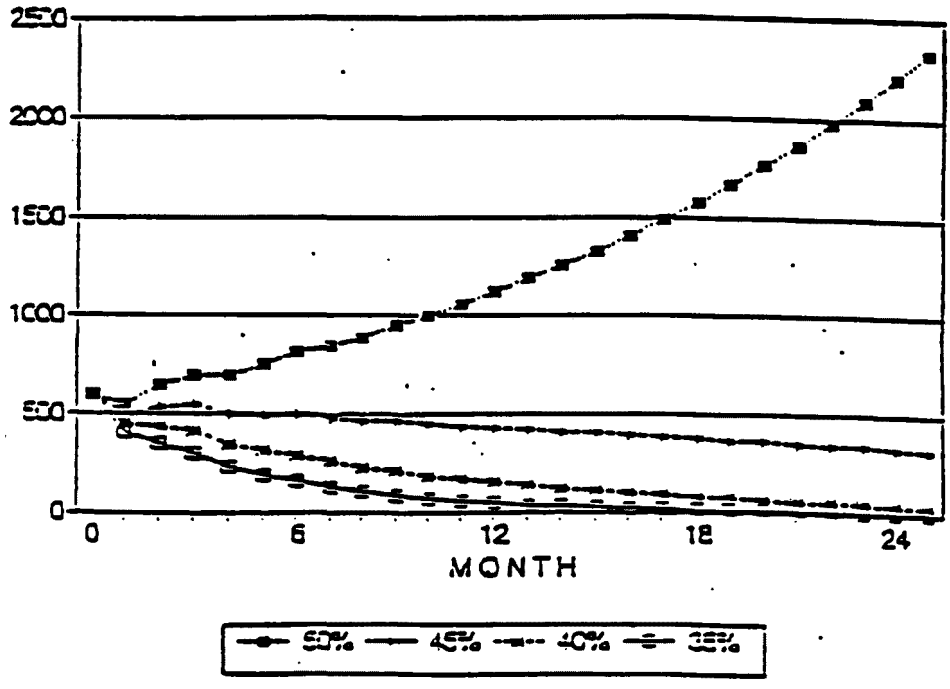


Figure 4. Survival of adult What-If Bugs when percent females change over 25 months

Optional Exercise (Continued)

The figures show that small differences in survival, reproductive rates, and sex ratios can produce large differences in population size over the long term.

- You may have noticed that in some of the curves the population increased at first, then declined. How far into the future can/should we consider when looking at effects?

- In several instances, the population increased, but not as much as with the original parameters. Should a population actually decrease before the effects are considered significant? How much is too much?

APPENDIX F

LOADINGS DATA USED IN THE

APPORTIONMENT ANALYSIS

This Appendix presents loadings data used in Chapter 7 of the California Toxics Rule (CTR) Benefits Report to apportion benefits between point and nonpoint sources of pollutants in the proposed CTR. Data are taken from NOAA, (June 1988) **The National Coastal Pollutant Discharge Inventory: Estimates for San Francisco Bay**, Data Summary, Ocean Assessment Division, National Oceanic and Atmospheric Administration, and J.A. Davis et al, (1991) **Status and Trends Report on Pollutants in the San Francisco Estuary**, prepared by the San Francisco Bay-Delta Aquatic Habitat Institute for the San Francisco Estuary Project, U.S. EPA.

LOADINGS TO SAN FRANCISCO BAY
NOAA DATA

	POINT SOURCES			NONPOINT SOURCES						TOTAL
	WASTEWATER TREATMENT PLANTS	DIRECT INDUSTRIAL DISCHARGES	POWER PLANTS	URBAN RUNOFF	CROPLAND RUNOFF	FORESTLAND RUNOFF	PASTURE / RANGELAND RUNOFF	IRRIGATION RETURN FLOW	UPSTREAM SOURCES	ALL SOURCES
Arsenic	17.24	0.91	-	6.35	31.75	9.98	47.17	-	45.36	158.76
Cadmium	11.79	0.91	-	1.81	0.91	-	1.81	-	64.41	81.65
Chromium	26.31	5.44	0.91	10.89	246.76	109.77	471.74	1.81	395.54	1,269.16
Copper	48.08	4.54	2.72	43.55	110.68	48.08	210.47	-	536.15	1,004.26
Lead	35.38	6.35	-	183.25	56.25	29.03	132.45	-	124.29	567.00
Mercury	4.31	0.07	-	0.11	0.34	0.14	0.52	0.00	4.28	9.77
Zinc	132.45	9.98	0.91	196.86	266.72	118.84	530.71	1.81	1,508.66	2,766.94
Chlorinated Hydrocarbon Pesticides	0.56	0.00	-	0.05	0.41	-	-	0.08	-	1.10
	SOURCE TOTALS	308.85					5,549.80			5,858.65

Notes: 1) All values are in metric tons per year.
2) The NOAA data show large mercury loadings associated with riverine inputs to the Bay. We classified 46.34 percent of these riverine loadings as point sources given that upstream mines are the likely original source of the mercury. The 46.34 percent figure can be found in Exhibit 7-4.

Source: NOAA, The National Coastal Pollutant Discharge Inventory: Estimates for San Francisco Bay, Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, June 1988.

LOADINGS TO SAN FRANCISCO BAY
DAVIS DATA

		POINT SOURCES				NONPOINT SOURCES								TOTAL	
		MUNICIPAL & INDUSTRIAL DISCHARGES		URBAN RUNOFF		NONURBAN RUNOFF		UPSTREAM SOURCES		DREDGED MATERIAL		ATMOSPHERIC DEPOSITION		ALL SOURCES	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound		
Arsenic		1.50	5.50	1.00	9.00	10.00	120.00	12.00	12.00	-	-	-	-	24.50	146.50
Cadmium		1.80	4.00	0.30	3.00	0.52	6.00	-	-	0.02	0.20	0.14	0.35	2.78	13.55
Chromium		12.00	13.00	3.00	15.00	130.00	1,500.00	66.00	66.00	-	-	-	-	211.00	1,594.00
Copper		19.00	30.00	7.00	59.00	51.00	580.00	80.00	80.00	1.00	10.00	1.90	3.10	159.90	762.10
Lead		11.00	16.00	30.00	250.00	31.00	360.00	51.00	55.00	1.00	10.00	6.00	21.00	130.00	712.00
Mercury		0.20	0.70	0.03	0.15	0.15	1.70	-	-	0.01	0.10	-	-	0.39	2.65
Nickel		19.00	27.00	-	-	-	-	51.00	51.00	2.00	20.00	-	-	72.00	98.00
Selenium		2.10	2.10	-	-	-	-	5.30	5.30	-	-	-	-	7.40	7.40
Zinc		77.00	80.00	34.00	268.00	130.00	1,450.00	164.00	175.00	3.00	30.00	-	-	408.00	2,003.00
	SOURCE TOTALS	**143.60**	**178.30**	75.33	604.15	352.67	4017.70	429.30	444.30	7.03	70.30	8.04	24.45	**1,015.97**	**5,339.20**
							872.37	**5,160.90**							

Notes: 1) All values are in metric tons per year.

Source: Davis, J.A., et al., Status and Trends Report on Pollutants in the San Francisco Estuary, prepared by the San Francisco Bay-Delta Aquatic Habitat Institute for the San Francisco Estuary Project, U.S. EPA, March 1991

LOADINGS TO SANTA MONICA BAY
NOAA DATA

	POINT SOURCES				NONPOINT SOURCES							TOTAL
	WASTEWATER TREATMENT PLANTS	DIRECT INDUSTRIAL DISCHARGES	POWER PLANTS		URBAN RUNOFF	CROPLAND RUNOFF	FORESTLAND RUNOFF	PASTURE / RANGELAND RUNOFF	IRRIGATION RETURN FLOW	UPSTREAM SOURCES		ALL SOURCES
Arsenic	15.88	0.27	-		0.91	-	-	0.91	-	-		17.96
Cadmium	9.25	0.45	-		-	-	-	-	-	-		9.71
Chromium	89.81	0.45	-		0.91	-	-	10.89	-	-		102.06
Copper	123.02	2.81	4.35		4.54	-	-	10.89	-	-		145.60
Lead	59.06	2.81	-		19.96	-	-	10.89	-	-		92.72
Mercury	0.53	0.04	0.00		0.01	-	0.00	0.07	-	-		0.65
Zinc	226.34	7.53	-		21.77	-	0.91	42.64	-	-		299.19
Chlorinated Hydrocarbon Pesticides	0.77	-	-		0.01	0.00	-	-	-	-		0.77
	SOURCE TOTALS	**543.38**				**125.28**						**668.66**

Notes: 1) All values are in metric tons per year.

Source: NOAA, The National Coastal Pollutant Discharge Inventory: Estimates for Santa Monica Bay, San Pedro Bay, and San Diego Bay, Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, July 1988.

LOADINGS TO SAN DIEGO BAY
NOAA DATA

	POINT SOURCES				NONPOINT SOURCES							TOTAL
	WASTEWATER TREATMENT PLANTS	DIRECT INDUSTRIAL DISCHARGES	POWER PLANTS		URBAN RUNOFF	CROPLAND RUNOFF	FORESTLAND RUNOFF	PASTURE / RANGELAND RUNOFF	IRRIGATION RETURN FLOW	UPSTREAM SOURCES		ALL SOURCES
Arsenic	6.17	0.27	-		0.91	-	-	-	-	-		7.35
Cadmium	9.89	1.18	-		-	-	-	-	-	-		11.07
Chromium	16.69	1.18	-		0.91	-	-	-	-	-		18.78
Copper	26.40	2.45	1.09		4.54	-	-	-	-	-		34.47
Lead	10.70	2.54	-		19.05	-	-	-	-	-		32.30
Mercury	0.11	0.02	-		0.01	0.00	0.00	-	-	-		0.15
Zinc	90.81	4.99	-		20.87	0.91	0.91	-	-	-		118.48
Chlorinated Hydrocarbon Pesticides	0.14	-	-		0.00	0.01	-	-	-	-		0.15
	SOURCE TOTALS	174.63				48.11						222.74

Notes: 1) All values are in metric tons per year.

Source: NOAA, The National Coastal Pollutant Discharge Inventory: Estimates for Santa Monica Bay, San Pedro Bay, and San Diego Bay, Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, July 1988.

LOADINGS TO SAN PEDRO BAY
NOAA DATA

	POINT SOURCES			NONPOINT SOURCES						TOTAL
	WASTEWATER TREATMENT PLANTS	DIRECT INDUSTRIAL DISCHARGES	POWER PLANTS	URBAN RUNOFF	CROPLAND RUNOFF	FORESTLAND RUNOFF	PASTURE / RANGELAND RUNOFF	IRRIGATION RETURN FLOW	UPSTREAM SOURCES	ALL SOURCES
Arsenic	12.16	0.27	0.18	1.81	-	-	-	-	-	14.42
Cadmium	18.23	0.27	0.18	-	-	-	-	-	-	18.69
Chromium	32.11	0.27	0.18	2.72	-	1.81	-	-	-	37.10
Copper	50.98	0.27	5.72	13.61	-	1.81	-	-	-	72.39
Lead	22.95	0.27	0.18	61.69	-	1.81	-	-	-	86.91
Mercury	0.22	0.00	0.00	0.03	-	0.01	0.00	-	-	0.27
Zinc	182.26	0.36	0.27	68.04	-	8.16	0.00	-	-	259.10
Chlorinated Hydrocarbon Pesticides	0.36	0.00	-	0.02	0.01	-	-	-	-	0.38
	SOURCE TOTALS	**327.71**				**161.55**				**489.27**

Notes: 1) All values are in metric tons per year.

Source: NOAA, The National Coastal Pollutant Discharge Inventory: Estimates for Santa Monica Bay, San Pedro Bay, and San Diego Bay, Data Summary, Ocean Assessments Division, National Oceanic and Atmospheric Administration, July 1988.

LOADINGS TO MONTEREY BAY
NOAA DATA

	POINT SOURCES			NONPOINT SOURCES						TOTAL
	WASTEWATER TREATMENT PLANTS	DIRECT INDUSTRIAL DISCHARGES	POWER PLANTS	URBAN RUNOFF	CROPLAND RUNOFF	FORESTLAND RUNOFF	PASTURE / RANGELAND RUNOFF	IRRIGATION RETURN FLOW	UPSTREAM SOURCES	ALL SOURCES
Arsenic	0.98	1.07	-	0.50	0.63	0.35	0.07	-	-	3.60
Cadmium	0.44	0.80	-	0.14	0.08	0.01	0.00	-	-	1.49
Chromium	1.60	1.89	-	0.70	14.42	3.65	0.72	-	-	22.97
Copper	1.49	0.54	-	3.27	6.00	1.12	0.22	-	-	12.64
Lead	2.44	5.37	-	13.80	3.22	1.08	0.21	-	-	26.12
Mercury	0.10	0.05	-	0.01	0.04	0.00	-	-	-	0.20
Zinc	5.76	5.38	-	15.31	15.40	4.35	0.86	-	-	47.07
	SOURCE TOTALS	**27.92**			**86.17**					**114.08**

Notes: 1) All values are in metric tons per year.

Source: NOAA, The National Coastal Pollutant Discharge Inventory, Summary of Pollutant Discharges in West Coast Study Area by Estuarine Watershed, circa 1982/1984; obtained on disk from Mr. Percy Pacheco, Office of Ocean Resources Conservation and Assessment.

LOADINGS TO HUMBOLDT BAY
NOAA DATA

	POINT SOURCES				NONPOINT SOURCES					TOTAL
	WASTEWATER TREATMENT PLANTS	DIRECT INDUSTRIAL DISCHARGES	POWER PLANTS	URBAN RUNOFF	CROPLAND RUNOFF	FORESTLAND RUNOFF	PASTURE / RANGELAND RUNOFF	IRRIGATION RETURN FLOW	UPSTREAM SOURCES	ALL SOURCES
Arsenic	0.32	0.35	-	0.23	-	0.14	0.08	-	0.94	2.07
Cadmium	0.43	-	-	0.06	-	0.01	0.01	-	0.55	1.06
Chromium	0.78	8.61	-	0.32	-	3.46	1.94	-	11.88	26.98
Copper	1.15	1.18	-	1.48	-	1.73	0.97	-	7.21	13.73
Lead	0.54	1.67	-	6.29	-	0.69	0.39	-	1.83	11.41
Mercury	0.00	0.00	-	0.00	-	0.00	-	-	0.09	0.10
Zinc	4.06	7.00	-	6.98	-	2.57	1.44	-	18.96	41.00
	SOURCE TOTALS	**26.10**				**70.27**				**96.37**

Notes: 1) All values are in metric tons per year.

Source: NOAA, The National Coastal Pollutant Discharge Inventory, Summary of Pollutant Discharges in West Coast Study Area by Estuarine Watershed, circa 1982/1984; obtained on disk from Mr. Percy Pacheco, Office of Ocean Resources Conservation and Assessment.

LOADINGS TO SACRAMENTO RIVER
CVRWQCB DATA

	POINT SOURCES		NONPOINT SOURCES		TOTAL
	NPDES	MINES	URBAN RUNOFF	AGRICULTURAL DRAINAGE	ALL SOURCES
Arsenic	0.38	1.72	2.40	4.90	9.40
Cadmium	0.01	1.81	0.22	0.19	2.23
Copper	1.15	63.91	8.16	16.65	89.88
Lead	0.38	0.56	12.70	1.71	15.35
Zinc	10.12	261.18	59.42	41.25	371.97
	SOURCE TOTALS	**341.22**		**147.61**	**488.83**

Notes: 1) All values are in metric tons per year.

Source: Central Valley Regional Water Quality Control Board, Mass Emission Strategy - Load Estimates, no date.

LOADINGS TO SAN JOAQUIN RIVER
CVRWQCB DATA

	POINT SOURCES		NONPOINT SOURCES		TOTAL
	NPDES	MINES	URBAN RUNOFF	AGRICULTURAL DRAINAGE	ALL SOURCES
Arsenic	0.08	0.00	0.68	1.86	2.62
Cadmium	0.00	0.01	0.05	0.09	0.14
Copper	0.24	0.00	1.95	6.44	8.64
Lead	0.08	0.00	2.27	0.65	3.00
Zinc	2.14	0.27	15.88	15.15	33.44
	SOURCE TOTALS	**2.83**		**45.01**	**47.84**

Notes: 1) All values are in metric tons per year.

Source: Central Valley Regional Water Quality Control Board, Mass Emission Strategy - Load Estimates, no date.

APPENDIX G

COMPARISON OF POSSIBLE POINT SOURCE INDUSTRIAL PCB DISCHARGERS IN CALIFORNIA AND THE GREAT LAKES REGION BY SIC CODE

This Appendix compares industries (as organized by SIC codes) reporting PCB discharges in the Great Lakes region and the existence and number of similar industries in California. This data was developed in support of the document: **Assessment of Compliance Costs Resulting from Implementation of the Final Great Lakes Water Quality guidance**, prepared for the U.S. Environmental Protection Agency, March 13, 1995, prepared by SAIC.

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
10	METAL MINING							
		1011	IRON ORES	0	0			1
		1021	COPPER ORES	0	4			1
		1081	METAL MINING SERVICES	0	0			1
14	NONMETALLIC MINERALS							
		1422	CRUSHED AND BROKEN LIMESTONE	15	2			4
		1440	SAND AND GRAVEL	204	1			2
20	FOOD AND KINDRED PRODUCTS							
		2050	BAKERY PRODUCTS	424	0			1
		2063	BEET SUGAR	9	1			3
		2087	FLAVORING EXTRACTS AND SYRUPS	47	0			1
24	LUMBER AND WOOD PRODUCTS							
		2493	RECONSTITUTED WOOD PRODUCTS	27	3			2

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
25	FURNITURE AND FIXTURES							
		2500	FURNITURE AND FIXTURES	1764	0			7
		2522	OFFICE FURNITURE, EXCEPT WOOD	77	0			3
		2591	DRAPERY HARDWARE AND BLINDS AND SHADES	88	0			1
26	PAPER AND ALLIED PRODUCTS							
		2600	PAPER AND ALLIED PRODUCTS	634	0			2
		2611	PULP MILLS	4	5		4	
		2621	PAPER MILLS	9	0		1	13
		2631	PAPERBOARD MILLS	15	0			7
		2640	NOT LISTED	N/A	0			1
		2650	PAPERBOARD CONTAINERS AND BOXES	243	0			1
		2651	NOT LISTED	N/A	0			1
		2670	MISC. CONVERTED PAPER PRODUCTS	363	0			1

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				[illegible]	[illegible]	TRI	PCS	MI+WISC
		[illegible]	[illegible]	[illegible]	1			1
27	PRINTING AND PUBLISHING							
		2700	PRINTING AND PUBLISHING	8423	0			1
		2710	NEWSPAPERS	690	0			3
		2750	COMMERCIAL PRINTING	5219	0			2
		2782	BLANKBOOKS AND LOOSELEAF BINDERS	64	0			1
		2790	PRINTING TRADE SERVICES	567	0			1
28	CHEMICALS AND ALLIED PRODUCTS							
		2800	CHEMICALS AND ALLIED PRODUCTS	1367	0			2
		2810	INDUSTRIAL INORGANIC CHEMICALS	125	0			2
		2813	INDUSTRIAL GASSES	52	2			1
		2819	INDUSTRIAL INORGANIC CHEMICALS, NEC	65	18	1		
		2820	PLASTICS MATERIALS AND SYNTHETICS	57	0			2

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
		2830	DRUGS	217	0			4
		2840	SOAP, CLEANERS, AND TOILET GOODS	337	0			1
		2850	PAINTS AND ALLIED PRODUCTS	190	0			2
		2851	PAINTS AND ALLIED PRODUCTS	190	2			2
		2860	INDUSTRIAL ORGANIC CHEMICALS	57				4
		2865	CYCLIC CRUDES AND INTERMEDIATES	12				2
		2870	AGRICULTURAL CHEMICALS	81				1
		2890	MISC. CHEMICAL PRODUCTS	303				2
		2891	ADHESIVES AND SEALANTS	76	1			2
		2899	CHEMICAL PREPARATIONS, NEC	167	8		1	3
29	PETROLEUM AND COAL PRODUCTS							
		2900	PETROLEUM AND COAL PRODUCTS	222	0			1
		2911	PETROLEUM REFINING	32	30	1		2

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
30	RUBBER AND MISC PLASTIC PRODUCTS							
		3053	GASKETS, PACKING AND SEALING DEVICES	80	0			1
		3069	FABRICATED RUBBER PRODUCTS, NEC	196	0			3
		3079	N/A	N/A	0			4
		3080	MISC PLASTICS PRODUCTS, NEC	1736	0			11
32	STONE, CLAY, AND GLASS PRODUCTS							
		3220	GLASS AND GLASSWARE, PRESSED OR BLOWN	88	0			3
		3221	GLASS CONTAINERS	12	4			1
		3241	CEMENT, HYDRAULIC	22	0	1		5
		3273	READY-MIXED CONCRETE	436	5			1
		3274	LIME	3	0	1		1
		3290	MISC. NONMETALLIC MINERAL PRODUCTS	194	0			1

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
		3295	MINERALS, GROUND OR TREATED	36	0			5
		3297	NONCLAY REFRACTORIES	7	1			2
33	PRIMARY METAL INDUSTRIES							
		3312	BLAST FURNACES AND STEEL MILLS	7	3			6
		3313	ELECTROMETALLURGICAL PRODUCTS	3	0	1		1
		3316	COLD FINISHING OF STEEL SHAPES	16	0			5
		3317	STEEL PIPES AND TUBES	24	0			1
		3320	IRON AND STEEL FOUNDRIES	89	0			1
		3321	GRAY AND DUCTILE IRON FOUNDRIES	39	1	2		10
		3322	MALLEABLE IRON FOUNDRIES	0	0			2
		3334	PRIMARY ALUMINUM	3	0		2	
		3339	PRIMARY NONFERROUS METALS, NEC	10	0			1
		3340	SECONDARY NONFERROUS METALS	37	0			4

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
		3341	SECONDARY NONFERROUS METALS	37	0		1	1
		3354	ALUMINUM EXTRUDED PRODUCTS	31	1			1
		3360	NONFERROUS FOUNDRIES (CASTINGS)	216	0			1
		3365	ALUMINUM FOUNDRIES	82	1			1
		3366	COPPER FOUNDRIES	41	0			2
		3369	NONFERROUS FOUNDRIES, NEC	9	0			1
		3398	METAL HEAT TREATING	79	1			6
34	FABRICATED METAL PRODUCTS							
		3400	FABRICATED METAL PRODUCTS	4657				5
		3442	METAL DOORS, SASH AND TRIM	193	0			1
		3443	FABRICATED PLATE WORK (BOILER SHOPS)	182	2			
		3449	MISC. METAL WORK	61	0			1
		3460	METAL FORGING AND STAMPING	433	0			1

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name		Great Lakes establishments reporting PCB Discharges			
					PCS CA Firms	TRI	PCS	MI+WISC
		1	IRON AND STEEL FOUNDRIES		0			6
		3465	AUTOMOTIVE STAMPINGS	29	0			13
		3471	PLATING AND POLISHING	561	0			4
		3479	METAL COATING AND ALLIED SERVICES	308	2			1
		3490	MISC. FABRICATED METAL PRODUCTS	816	0			9
		3499	FABRICATED METAL PRODUCTS, NEC	384	0			1
35	INDUSTRIAL MACHINERY AND EQUIPMENT							
		3510	ENGINES AND TURBINES	39	0			5
		3519	INTERNAL COMBUSTION ENGINES, NEC	31	1		1	
		3530	CONSTRUCTION AND RELATED MACHINERY	272	0			2
		3540	METALWORKING MACHINERY	958	0			1
		3544	SPECIAL DIES, TOOL JIGS, AND FIXTURE	575	0			1
		3545	MACHINE TOOL ACCESSORIES	192	0			1

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				[illegible] CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
		3560	SPECIAL INDUSTRY MACHINERY	513	0			3
		3566	SPEED CHANGERS, DRIVES, AND GEARS	27	0			1
		3570	COMPUTER AND OFFICE EQUIPMENT	651	0			1
		3580	REFRIGERATION AND SERVICE MACHINERY	328	0			1
		3585	REFRIGERATION AND HEATING EQUIPMENT	97	1			
		3590	INDUSTRIAL MACHINERY	3517	0			1
36	ELECTRONIC AND OTHER ELECTRONIC EQUIPMENT							
		3612	TRANSFORMERS, EXCEPT ELECTRONIC	28	1	1		
		3620	ELECTRICAL INDUSTRIAL APPARATUS	287	0			1
		3621	MOTORS AND GENERATORS	50	1	1		1
		3630	HOUSEHOLD APPLIANCES	60	0			1
		3651	HOUSEHOLD AUDIO AND VIDEO EQUIPMENT	97	0			1

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI/WISC
37	TRANSPORTATION EQUIPMENT							
		3710	MOTOR VEHICLES AND EQUIPMENT	648	0			3
		3711	MOTOR VEHICLES AND CAR BODIES	57	1			15
		3714	MOTOR VEHICLE PARTS AND ACCESSORIES	451	0		2	46
		3790	MISC. TRANSPORTATION EQUIPMENT	115	0			1
38	INSTRUMENTS AND RELATED PRODUCTS							
		3812	SEARCH AND NAVIGATION EQUIPMENT	163	0			1
		3840	MEDICAL INSTRUMENTS AND SUPPLIES	752	0			1
		3843	DENTAL EQUIPMENT AND SUPPLIES	259	0			1
39	MISC. MANUFACTURING INDUSTRIES							
		3940	TOYS AND SPORTING GOODS	512	0			1
		3970	NOT LISTED	N/A	0			1
		3990	MISC. MANUFACTURES	1054	0			1

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Census CA Firms	PCS CA Firms	TRI	PCS	MI+WISC
42	TRUCKING AND WAREHOUSING							
		4230	TRUCKING TERMINAL FACILITIES	N/A	0			1
47	TRANSPORTATION SERVICES							
		4785	INSPECTION AND FIXED FACILITIES	4	0			1
49	ELECTRIC, GAS, AND SANITARY SERVICES							
		4911	ELECTRIC SERVICES	319	55			21
		4952	SEWERAGE SYSTEMS	221	275		24	
		4953	REFUSE SYSTEMS	371	16		1	
50	WHOLESALE TRADE--DURABLE GOODS							
		5013	MOTOR VEHICLE SUPPLIES AND NEW PARTS; WHOLESALE TRADE	2758	1			3
65	REAL ESTATE							
		6512	NONRESIDENTIAL BUILDING OPERATORS	4495	24			5

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				Consu	Fire	PCS CA Firms	TRI	PCS	MI+WISC
[illegible]								
		7215	COIN OPERATED LAUNDRIES AND CLEANING	1158		0			1
76	MISC REPAIR SERVICES								
		7699	REPAIR SERVICES, NEC	3582		0			1
80	HEALTH SERVICES								
		8060	HOSPITALS	199		0			3
		8070	MEDICAL AND DENTAL LABORATORIES	2463		0			1
		8091	HEALTH AND ALLIED SERVICE, NEC	N/A		0			
87	ENGINEERING AND MANAGEMENT SERVICES								
		8730	RESEARCH AND TESTING SERVICES	2155		0			10
		8731	COMMERCIAL PHYSICS RESEARCH	802		1			1
		8734	TESTING LABORATORIES	615		0			1

Great Lakes--California PCB Cross Reference

Major SIC Number	MAJOR NAME	Minor SIC Number	MINOR Name	Great Lakes establishments reporting PCB Discharges				
				CA Firms	PCS Co. Firms	TRI	PCS	MI+WISC

Notes
PCS is Permit Compliance System
TRI is toxics release inventory
MI+WISC is the sum of establishments with PCBs reported to the Michigan and Wisconsin toxics programs.
Derived from the US Bureau of the Census 1992 Economic Census.