Santa Rosa Subregional Long-Term Wastewater Project

ECOLOGICAL RISK ASSESSMENT

SANTA ROSA SUBREGIONAL LONG-TERM WASTEWATER PROJECT

Prepared for

City of Santa Rosa
and
U.S. Army Corps of Engineers

June 1996

Prepared by

PARSONS ENGINEERING SCIENCE, INC.
8000 CENTRE PARK DRIVE, SUITE 200, AUSTIN, TEXAS 78754 (512) 719-6000

For

HARLAND BARTHOLOMEW & ASSOCIATES, INC.

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EXECUTIVE SUMMARY

The City of Santa Rosa is preparing an Environmental Impact Report/Environmental Impact Statement (EIR/EIS) to determine the effect of bringing the existing system into compliance with disposal regulations and increasing treated wastewater flow from 18 to 21 million gallons per day at general plan buildout in approximately the year 2010. The city has evaluated five primary alternatives with numerous subalternatives to address the projected increased production of reclaimed water: 1) retention of existing discharge conditions (no-project alternative); 2) reuse of reclaimed water for agricultural use in South County; 3) West County agricultural irrigation; 4) transfer to geyser recharge area by pipeline; and 5) increased discharge to the Russian River, directly or through the Laguna de Santa Rosa.

A risk assessment was undertaken to evaluate potential adverse effects to ecological resources associated with the reclaimed water management alternatives. The risk characterization was based on the use of ecological quotients, the ratio of expected exposure concentrations in water, sediment, soils, and organism tissues to benchmark values indicative of potential adverse effects on organisms.

CONCEPTUAL SITE MODEL AND EXPOSURE ASSESSMENT

Two main routes of exposure were identified for evaluation of ecological risk to terrestrial and aquatic organisms: direct contact with the media (surface soil, water, and sediment) and indirect exposure by dietary intake. Specific ecological receptors were selected to evaluate potential effects on aquatic biota and wildlife exposure through food ingestion. Key ecological receptors, representative of various trophic levels, included red-legged frog, steelhead trout, mallard duck, harbor seal, and great blue heron.

Exposure Analysis for Soil. For evaluation of future exposure of vegetation and soil organisms during irrigation, soil concentrations were assumed to be equal, on a mass basis, to chemical concentrations in the reclaimed water. Dietary intake of chemical substances was determined by: 1) concentration in the food source; 2) the food ingestion rate of the consumer organism; and 3) the fraction of the diet that the organism is expected to obtain from the site. Concentrations in diet were estimated from concentrations detected in soils using transfer factors that account for the potential accumulation of a chemical in organism tissues at each transfer step of the food chain.

Exposure Analysis for Surface Water. Detected concentrations of chemical substances were used as the exposure values for aquatic organisms. For wildlife exposure through food consumption, potential fish tissue concentrations were obtained from analytical data collected in August 1994 from the Kelly Farm Wetlands Demonstration Project.

Exposure Analysis for Sediments. Exposure to contaminants in sediments through direct contact and pore water was evaluated for aquatic invertebrates and rooted aquatic macrophytes such as cattails. The analysis of dietary exposure of wildlife was based on the use of transfer factors similar to those used for the terrestrial food chain.

CHARACTERIZATION OF ECOLOGICAL EFFECTS

In the evaluation of potential effects on terrestrial wildlife, benchmarks were based on toxicological data for individual test species. Benchmarks for evaluation of potential effects of chemicals on terrestrial vegetation and soil invertebrates were obtained from various sources including screening reference values developed by the Oak Ridge National Laboratory (ORNL). These screening benchmarks identify soil concentrations with low potential for effects on biota, based on toxicological data for several test species.

For aquatic organisms, state and federal criteria for protection of aquatic life were used as the primary benchmark values. For chemical substances lacking EPA criteria, secondary reference values developed by ORNL were used as benchmarks. The evaluation of potential effects on sediment-associated organisms was based on sediment quality guidelines developed by EPA for organic chemicals, and on threshold concentrations for potential effects of metals on organisms compiled by the National Oceanic and Atmospheric Administration.

RISK QUANTIFICATION

Risk Assessment Methodology. The assessment of ecological risk was based on the calculation of the ecological quotient (EQ). The quotient is calculated as the ratio between exposure concentration for a given chemical substance and an applicable benchmark value that identifies possible adverse effect levels on ecological receptors. The characterization of potential effects on receptor organisms was based on the following guidelines (Barnthouse, et al., 1986; EPA, 1989b; Watkin and Stelljes, 1993; Menzie et al., 1993):

1. No risk for adverse effects is expected for EQ values equal to, or less than, 1;
2. Low risk potential for effects is indicated by EQ values between 1 and 10;
3. A potential for significant adverse effects is indicated by EQ values greater than 10; EQs in excess of 100 identify a very high probability for adverse effects on ecological receptors and biological communities.

Six major pathways were evaluated for the potential exposure of aquatic organisms and wildlife to the reclaimed water discharge: 1) direct exposure to the discharge in Santa Rosa Creek and the Laguna de Santa Rosa; 2) exposure of organisms associated with the Russian River; 3) exposure of rooted vegetation, sediment organisms and waterfowl to sediments in the Laguna de Santa Rosa and the Russian River; 4) exposure of aquatic organisms and wildlife in storage reservoirs; 5) exposure of soil organisms and terrestrial vegetation by reclaimed water application to irrigation fields; and 6) potential releases from pipelines along the transfer route to the geysers injection area.

Reclaimed Water Discharge to Laguna de Santa Rosa. Based on the ecological quotient calculations, no risk was identified for direct exposure of aquatic organisms to chemical substances found at detectable levels in the reclaimed water (EQ value smaller than 1) with the exception of cyanide (EQ of 2.3). For the consumption of fish by the great blue heron, a low potential for adverse effects was identified for aluminum, chromium, and zinc under the assumption of high levels of bioaccumulation in fish tissues (EQs of 3.2 and 2.7, respectively). No potential risk was identified for any other metals or organic substances.

Discharge to the Russian River. Based on the EQ calculations, no risk to aquatic organisms was identified for direct exposure of aquatic organisms in the Russian River at any of the discharge scenarios (EQ less than 1). Low EQ values were also obtained utilizing specific benchmarks for direct exposure of tadpoles to stream water. EQ values were greater than 1.0 for consumption of fish by the harbor seal. No risk was identified using benchmark values for protection of other aquatic organisms of concern such as the California freshwater shrimp and migratory salmonid species.

Exposure to Sediments. Calculated EQs for potential accumulation of eleven constituents in Russian River sediments showed little or no potential for adverse effects on aquatic vegetation, sediment organisms, or waterfowl. For all discharge scenarios, exposure concentrations of metals, pesticides, and other organic substances in sediments were well below available benchmark values for potential adverse effects on multiple organisms.

Reclaimed Water Storage. Based on the ecological quotient calculations, no potential risk was identified for direct exposure of aquatic life to organic chemicals and metals found at detectable levels in reclaimed water. A low potential risk to aquatic organisms (EQ of 2.3) was identified for cyanide. For the potential exposure of aquatic vegetation, sediment-associated organisms, and water fowl to reservoir sediments, detected values were below available benchmark values, as indicated by EQs below the threshold value of 1.

Reclaimed Water Reuse in Agriculture. The EQs calculated for exposure of vegetation and soil organisms to reclaimed water were below a threshold value of 1, indicating no risk for potential adverse effects on either type of organism. For the exposure of freshwater organisms to agricultural runoff, EQ values were below the threshold value indicative of potential adverse effects. In the case of discharge of agricultural runoff into the tidally-influenced esteros, EQ values were below the threshold value of 1 for all constituents with the exception of copper. The expected reclaimed water concentrations in the runoff moderately exceeded available benchmarks for potential effects of copper on marine organisms. A low EQ was calculated for this metal (EQ of 3.2), indicating a low probability of actual effects on receptor organisms.

Reclaimed Water Transfer to Geysers Area. For all organic and inorganic chemicals detected in the reclaimed water, calculated EQ values were below the threshold value of 1 indicative of potential adverse effects on freshwater organisms.

ECOLOGICAL RISK EVALUATION

Summary of Ecological Quotients. The following table summarizes the ecological quotients calculated for increased flow of reclaimed water from the Santa Rosa regional facility on aquatic and terrestrial organisms under various exposure scenarios.

No organic compounds present in the reclaimed water were identified as a potential concern for the exposure of aquatic organisms and wildlife under various discharge alternatives. Ecological quotients were near or below a value of 1.0, indicating that the expected exposure concentrations in water, sediment, soils, and organism tissues were lower than the benchmark values for potential adverse effects on receptor organisms. Ecological quotients greater than one were identified for cyanide, copper, chromium, aluminum, and zinc.

Chemicals of Potential Concern. The following inorganic chemicals were identified as having a low risk probability under the following exposure scenarios: 1) cyanide for the direct exposure of aquatic organisms in the proposed storage reservoirs and in Laguna de Santa Rosa under the assumption of chronic exposure to undiluted reclaimed water; 2) copper for the exposure of aquatic organisms in esteros as a result of agricultural irrigation with reclaimed water; 3) aluminum for dietary intake by waterfowl and other fish-eating organisms assuming high levels of bioaccumulation of those metals in fish tissues; and 4) in the Laguna de Santa Rosa, chromium and zinc were a concern for dietary intake by waterfowl at a 100% exposure to reclaimed water, but not at the average exposure conditions (17% reclaimed water).

A low risk probability for adverse effects was identified for exposure of aquatic organisms to cyanide in the Laguna de Santa Rosa and storage reservoirs. Calculated ecological quotients were well below the threshold value of 10, indicative of probable risk levels, even under the assumption of chronic exposure to undiluted reclaimed water.

Exposure to aluminum through fish ingestion appears to have a low risk for adverse effects on piscivorous organisms such as the great blue heron or the harbor seal. The presence of elevated tissue concentrations of aluminum in Russian River organisms, however, has already been documented on a regular basis for the area upstream of the Laguna de Santa Rosa confluence.

Copper concentrations potentially present in runoff from agricultural areas irrigated with reclaimed water were identified as having a low risk for adverse effects on aquatic organisms. The significance of the potential copper exposure of organisms in the esteros is low because mixing with seawater is expected to significantly reduce the actual expo sure concentrations. For dissolved copper, the average concentration in the undiluted reclaimed water is similar to those historically reported for Estero Americano.

Conclusion. The ecological risk evaluation showed little or no risk associated with the increased discharge of reclaimed water into the Laguna de Santa Rosa, Russian River, and agricultural runoff discharge. A low risk was identified for three chemical substances under conservative assumptions of potential toxicity and exposure conditions. No significant potential for adverse effects on organisms was identified for the increased reclaimed water production from the Santa Rosa Subregional facility.

Summary of Ecological Quotients for Exposure of Aquatic Organisms and Wildlife to Treated Effluent from the Santa Rosa Regional Facility

	CUMULATIVE ECOLOGICAL QUOTIENT VALUES (AVERAGE EXPOSURE)			CHEMICALS OF POTENTIAL CONCERN		
	Volatile Organics	Semi-volatiles / Pesticides	Metals / Cyanides	Low Risk 1 < EQ < 10	Probable Risk 10 < EQ < 100	Reference Table
LAGUNA DE SANTA ROSA						
Undiluted Reclaimed Water						
Risk to aquatic life	0.73	0.18	3.27	Cyanide	-	6.2
Risk to amphibians	0.16	0.01	0.14	-	-	6.0
Great Blue Heron - fish ingestion	0.00	0.04	8.02	Al, Cr, Zn	-	6.3
Great Blue Heron - water ingestion	0.03	0.00	0.00	-	-	6.4
Short-tailed shrew - water ingestion	0.03	0.00	0.03	-	-	6.4
Sediment						
Risk to aquatic organisms	0.00	1.69	0.00	-	-	6.10
Risk to vegetation	0.00	0.01	0.00	-	-	6.10
Risk to mallard duck by food ingestion	0.00	0.07	0.00	-	-	6.11
RUSSIAN RIVER WATER						
Reclaimed Water Diluted to 20%						
Risk to aquatic life	0.14	0.04	1.41	-	-	6.5
Risk to amphibians	0.03	0.00	0.17	-	-	6.5
Great Blue Heron - fish ingestion	0.00	0.00	0.75	-	-	6.6
Harbor Seal - fish ingestion	0.00	0.00	9.28	Aluminum	-	6.6
Great Blue Heron - water ingestion	0.00	0.01	0.00	-	-	6.7
Short-tailed shrew - water ingestion	0.00	0.00	0.02	-	-	6.7
Reclaimed Water Diluted to 10%						
Risk to aquatic life	0.07	0.02	0.71	-	-	6.8
Risk to amphibians	0.01	0.00	0.09	-	-	6.8
Great Blue Heron - fish ingestion	0.00	0.00	0.38	-	-	6.8
Harbor Seal - fish ingestion	0.00	0.00	4.64	Aluminum	-	6.8
Great Blue Heron - water ingestion	0.00	0.00	0.00	-	-	6.8
Short-tailed shrew - water ingestion	0.00	0.00	0.01	-	-	6.8
Reclaimed Water Diluted to 5%						
Risk to aquatic life	0.03	0.01	0.35	-	-	6.8
Risk to amphibians	0.01	0.00	0.04	-	-	6.8
Great Blue Heron - fish ingestion	0.00	0.00	0.19	-	-	6.8
Harbor Seal - fish ingestion	0.00	0.00	2.32	Aluminum	-	6.8
Great Blue Heron - water ingestion	0.00	0.00	0.00	-	-	6.8
Short-tailed shrew - water ingestion	0.00	0.00	0.00	-	-	6.8
Reclaimed Water Diluted to 1%						
Risk to aquatic life	0.01	0.00	0.07	-	-	6.8
Risk to amphibians	0.00	0.00	0.01	-	-	6.8
Great Blue Heron - fish ingestion	0.00	0.00	0.04	-	-	6.8
Harbor Seal - fish ingestion	0.00	0.00	0.47	-	-	6.8
Great Blue Heron - water ingestion	0.00	0.00	0.00	-	-	6.8
Short-tailed shrew - water ingestion	0.00	0.00	0.00	-	-	6.8
Sediments at 20%						
Risk to aquatic organisms	0.00	0.11	0.00	-	-	6.12
Risk to vegetation	0.00	0.00	0.00	-	-	6.12
Risk to mallard duck by food ingestion	0.00	0.01	0.00	-	-	6.13

	CUMULATIVE ECOLOGICAL QUOTIENT VALUES (AVERAGE EXPOSURE)			CHEMICALS OF POTENTIAL CONCERN		
	Volatile Organics	Semi-volatiles / Pesticides	Metals / Cyanides	Low Risk 1 < EQ < 10	Probable Risk 10 < EQ < 100	Reference Table
STORAGE RESERVOIR						
Water						
Risk to aquatic life	0.73	0.18	3.27	Cyanide	-	6.2
Risk to amphibians	0.16	0.01	0.14	-	-	6.2
Sediments						
Risk to aquatic organisms	0.00	0.00	0.77	-	-	6.14
Risk to vegetation	0.00	0.00	2.28	-	-	6.14
Risk to mallard duck by food ingestion	0.00	0.01	0.00	-	-	6.15
RECLAIMED WATER USE IN IRRIGATION FIELDS						
Direct Exposure						
Risk to vegetation	0.00	0.00	0.00	-	-	6.16
Risk to soil organisms	0.00	0.01	0.00	-	-	6.16
Run-off from Irrigation Fields						
Risk to freshwater organsims	0.00	0.02	3.88	-	-	6.17
Risk to aquatic organisms in esteros	0.00	0.00	6.90	Copper	-	6.18
RECLAIMED WATER TRANSFER BY PIPELINE						
Direct Exposure						
Risk to freshwater organisms exposed during accidental effluent release.	0.04	0.07	1.44	-	-	6.19

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1. INTRODUCTION

The Laguna Subregional Wastewater Treatment Plant is an activated sludge tertiary treatment facility which serves the City of Santa Rosa and surrounding districts in Sonoma County, California. The plant is currently permitted for discharge of 18 million gallons per day (mgd) using a combination of direct discharge from storage ponds to the Russian River via the Laguna de Santa Rosa, plus urban irrigation, agricultural irrigation, and discharge/reuse through created wetlands. The City of Santa Rosa is preparing an Environmental Impact Report/Environmental Impact Statement (EIR/EIS) to determine the impact of future increases in the release of treated wastewater to a flow of 21 mgd at general plan buildout in about the year 2010.

An ecological risk assessment of representative sites under the various alternatives was undertaken to evaluate potential adverse effects to ecological resources as a result of the increased discharge of treated wastewater. The primary objective of the ecological risk assessment was to identify and characterize the potential risks posed to environmental receptors as a result of the alternative wastewater releases. The assessment was also used for the overall characterization of the various areas potentially affected as the basis for evaluating each of the discharge alternatives under consideration. This document presents the results of the ecological risk evaluation for potential effects of the increased reclaimed water discharge.

1.1 PROJECT ALTERNATIVES

The City of Santa Rosa has developed five primary alternatives with numerous subalternatives for management of the projected increased production of reclaimed water. The alternatives are: 1) retention of current discharge conditions (no project); 2) west county reclamation; 3) south county reclamation; 4) geysers steamfield recharge; and 5) discharge to the Russian River. The following are brief descriptions of each alternative. Detailed descriptions of these alternatives and their subalternatives are included elsewhere in the EIR/EIS documents.

Alternative 1: Operation of the Existing System (No Project Construction)

Approximately 5,300 acres of land located in the Santa Rosa Plain are irrigated using reclaimed water from the Laguna Plant. Both agricultural and urban irrigation sites are included in the system, although the majority of sites and acreage are in agricultural use. Irrigation, which occurs from March through November, uses reclaimed water supplied directly by the Laguna Plant and water stored in ponds. Reclaimed water storage occurs mostly in the fall when the irrigation demand decreases and the water flow in the Russian River is too low to allow wastewater discharges.

Reclaimed water from the treatment facility that is not stored or used in irrigation is discharged to the Russian River via the Laguna de Santa Rosa. Treated wastewater may be discharged to the Laguna from numerous points. The actual volume and frequency of discharge at any given location may vary due to operational and seasonal considerations, including irrigation needs, storage levels, and weather conditions.

The subregional system is also responsible for the operation and management of three wetland areas: the Kelly Farm Demonstration Wetland, constructed in 1992, the LaFranchi marsh, and the Joint Wetlands pond that will be operational in the near future. The wetlands are supplied with reclaimed water from the Laguna Plant and are monitored by the system as part of a demonstration project.

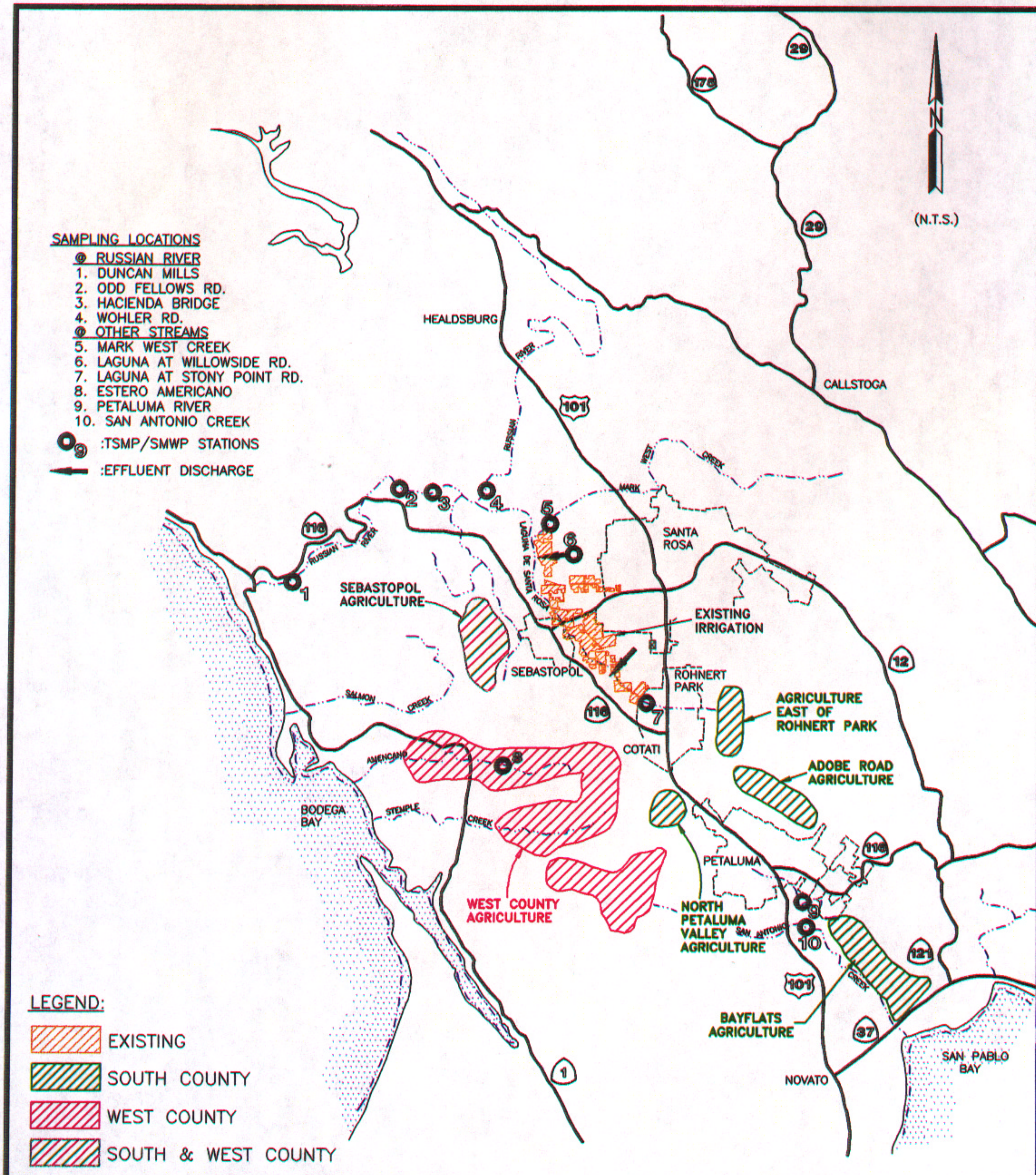
Alternatives 2 and 3: South County and West County Irrigation

Although these two alternatives cover different parts of Sonoma County, the general operation of their respective reclamation systems will be nearly identical. There are three primary components to the reclamation system: agricultural irrigation lands, storage reservoirs, and Russian River discharge via the Laguna de Santa Rosa. Stream discharge is limited to the season from October to mid-May. The design discharge rates considered for the project are 1, 5, 10, and 20 percent of Russian River flow. These design discharge rates determine the system requirements for agricultural irrigation land and storage reservoir volume.

Reclaimed water for both agricultural irrigation alternatives would be sent from the treatment plant to one or more of the proposed storage reservoirs, and delivered to the irrigation fields via a distribution pipeline network. The existing reclamation system and agricultural irrigation in the Laguna de Santa Rosa is expected to continue operation. The West County alternative covers approximately 21,400 acres of irrigation fields in the Sebastopol area, Estero Americano, Stemple Creek, and various other small irrigation areas. The South County Alternative encompasses 15,200 acres in six main locations: Lakeville, Adobe Road, North Petaluma Valley, Baylands, Sebastopol, and an area east of Rohnert Park. Actual irrigation areas would be smaller, depending on the amount of river discharge. Figure 1.1 shows the location of the proposed irrigation areas.

Alternative 4: Geysers Geothermal Steamfield Recharge

This alternative proposes the delivery of most reclaimed water through a pipeline to a geysers area located northeast of Healdsburg in northern Sonoma County. Some of the water will be used in the existing Laguna reclamation system, including the existing Laguna irrigation fields. More water would be available for delivery to the geysers during the winter months. The maximum required storage volume (about 1,203 million gallons) is less than the total available storage volume of the existing storage system (about 1,500 million gallons). About 80 percent of the annual reclaimed water would be delivered to the geysers and about 20 percent to the existing Laguna irrigation system.



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Santa Rosa
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FIGURE 1.1.
LOCATION OF PROPOSED IRRIGATION AREAS

ALTER 6/06/96

Alternative 5: Direct Discharge to the Russian River

The direct Russian River discharge subalternatives include two options: 1) continued discharge into the Laguna from existing storage ponds and 2) direct discharge from Delta Pond into the Russian River. Both would occur at a design rate of up to 20% of river flow. The direct discharge could occur at existing discharge points or through new pipelines to the Russian River. Reclaimed water production is balanced with the irrigation demand to determine the actual discharge to the Russian River. The water balance for stream discharge is based on the 95th percentile of the reclaimed water production rate. The proposed discharge season is October 1 through May 15.

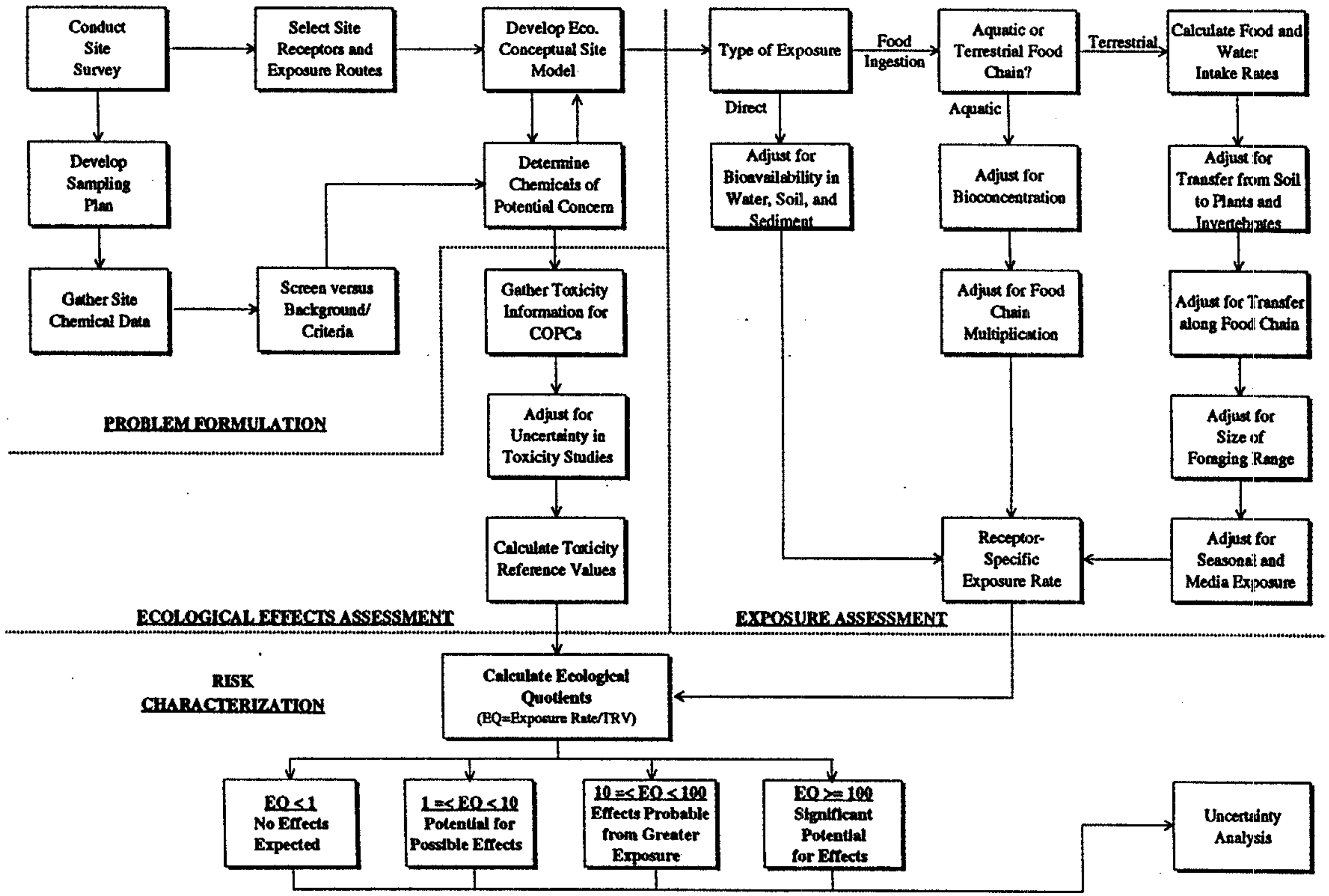
1.2 RISK ASSESSMENT METHODOLOGY

The ecological risk assessment for the increased reclaimed water discharge was based on site, field, and laboratory data, and available toxicology literature for plant and animal species potentially present in the vicinity of the wastewater discharge, the storage ponds, and the irrigation fields. This study was conducted in accordance with the following guidelines by the U.S. Environmental Protection Agency (EPA): *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual* (EPA, 1989b); *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference* (EPA, 1989b); and *Framework for Ecological Risk Assessment* (EPA, 1992a). The assessment of ecological risk encompassed five components whose implementation sequence is illustrated in Figure 1.2. These components are:

- *Site characterization*, the description of potentially-exposed aquatic and terrestrial ecosystems, and the identification of representative plant and animal communities;
- *Development of a conceptual site model*, the formulation of exposure scenarios including exposure pathways and ecological receptors based on site characterization;
- *Exposure assessment*, an evaluation of the exposure conditions and transfer factors, both by direct contact with the media, and through food and water ingestion;
- *Characterization of ecological effects*, the selection of reference values for potential effects (benchmarks), and the extrapolation of these values to the site ecoreceptors; and
- *Risk characterization*, the use of ecological quotients and the evaluation of uncertainty associated with the risk assessment.

The risk evaluation focused on potential adverse effects on individual species, not at the population level. Quantitative characterizations of ecological communities are not warranted in the initial phase of a risk assessment unless a significant potential for adverse effects is identified with the use of screening benchmarks.

FIGURE 1.2
ECOLOGICAL RISK ASSESSMENT PROCESS



2. SITE CHARACTERIZATION

The following section presents a brief description of biological communities in terrestrial and aquatic habitats potentially exposed to reclaimed water from the Santa Rosa Subregional facility. A more detailed description of biological communities, based on multiple documents developed in support of the EIR/EIS document, is presented in Appendix A.

2.1 AGRICULTURAL IRRIGATION

The maximum acreage for the South County Reclamation and the West County Reclamation including the Sebastopol area is 12,400 acres. The dominant vegetative communities are the result of heavy agricultural use. Pastoral communities are common in the region, and much of the Stemple and Americano watersheds have been altered for the production of forage species. The riparian communities associated with the proposed irrigation areas of Americano and Stemple Creek watersheds are greatly influenced by cattle grazing and subsequent nutrient input.

Areas considered sensitive due to high plant and animal diversity are the riparian and oak woodland communities. Oak woodlands, a diminishing community, are found near the headwaters of all three creeks and provide a suitable habitat for a variety of bird and mammal species.

2.2 RESERVOIR SITES

Reservoirs create unique aquatic habitats at the expense of removing existing terrestrial habitat. Due to the general practices of dairy farming, the most common vegetative community at potential reservoir sites is pastoral. Sparse riparian areas are located adjacent to creeks at the bottom of the drainage basins.

Wildlife associated with the reservoir are expected to be similar to wildlife species associated with the irrigation areas. However, the reservoir will also provide habitat for a variety of aquatic species and waterfowl.

2.3 THE LAGUNA DE SANTA ROSA

The Laguna de Santa Rosa is a tributary to the Russian River. In times of heavy rain, overflow from the river backs up into the Laguna, creating a marsh that is used by many plant and animal species. The Laguna is used as a migratory route by steelhead trout.

The Laguna area can be separated into five communities that vary in physical characteristics that influence the presence of plant and wildlife species: grassland, woodland, riparian, marsh, and anthropogenic communities. The grassland area is predominantly made up of annual, non-native grass and weed species. Woodland communities are dominated by oak species with an understory of grass and forbs common to grassland areas. Anthropogenic communities in the vicinity of the Laguna de Santa Rosa include cropland, plantation, and pasture.

Riparian communities exist in areas along the banks of streams and rivers. Thick overstories and thickets provide foraging habitat and bedding and nesting areas for wildlife species.

Laguna freshwater marsh communities contain wetland plants that are adapted to and require saturated soil. These communities are dominated by tules, rushes, cattails, and sedges. Marsh communities, due to their unique vegetative composition, also provide foraging and nesting sites for many mammalian and avian species such as mink, otter, raccoon, American coot, and great blue heron.

Sensitive areas located around the Laguna include the valley foothill riparian, freshwater emergent wetland, and valley oak woodland communities. These habitats were once widely distributed throughout the region, but their presence is now rare.

2.4 RUSSIAN RIVER

The Russian River, 110 miles in length, drains 1,485 square miles of Sonoma and Mendocino Counties. The river and its estuaries provide resources for twenty-seven native fish species, including the steelhead trout, which utilizes tributaries of the Laguna de Santa Rosa as spawning grounds.

The Russian River has unique riparian communities characterized by woody species near the source and estuarine species near the mouth. Vegetation is sparse along the river stem compared to its tributaries. In the upper reaches of the river, the riparian community increases in diversity due to a transition from the riparian community to a woodland. Typical riparian species include sedges, rushes, and tules, as well as larger woody plants, such as cottonwood and willow.

Wildlife in the river area includes terrestrial animals such as mule deer, otter, badger, and small rodents. The Pacific harbor seal occurs frequently in the estuarine area near the mouth of the river. Bird species found along the river include osprey in the estuarine areas, and golden eagle, hawks, and woodpeckers in riparian areas. Fish species include steelhead trout, king/chinook salmon, silver/coho salmon, and Pacific lamprey. Sensitive areas of concern include both the riparian and aquatic communities associated with the river below the proposed point of discharge. The estuary associated with the Russian River provides habitat for a variety of invertebrates and vertebrates.

2.5 ESTEROS AMERICANO AND DE SAN ANTONIO

The Esteros Americano and de San Antonio are seasonal estuaries that encompass marine, brackish, and freshwater habitats. The uplands surrounding the esteros are composed primarily of annual grassland or pastoral land intermingled with coastal prairie, coastal scrub, and seasonal brackish marsh. These habitats merge with open water creating a complex ecosystem that supports a diverse flora and fauna.

Fourteen different vegetative communities can be observed in this area. The five main communities are open water areas, seasonal brackish marsh, coastal scrub, coastal prairie, and annual grassland. Annual grassland is the dominant plant community, comprising 30,684 acres. Coastal scrub areas are characterized by low-lying shrubs adapted to high winds and salt spray. Twenty-four different species of shrubs can be found in the scrub area, in which spatial distribution depends on the degree of ecological succession. Prairie species, subject to harsh westerly winds, salt spray, and fires, are dominated by California fescue and Pacific reedgrass.

The open water habitat is dominated by algae species. Both esteros contain eelgrass, a flowering plant that provides unique habitat for waterfowl, fish, anthropods, and mollusks. In the seasonal brackish marsh, spring rains create a freshwater environment that becomes saline as sand bars block the mouths of the esteros and freshwater evaporates. Pickle weed and salt grass occur on the border areas. Further inland from the coast, less salt-tolerant species such as wild oats, soft chess, and velvet grass are found.

Open water habitats (pelagic zone) support a variety of invertebrates and vertebrates that reside in the sandy/muddy bottom (benthic zone). Gobies, sculpins, and flatfishes are common benthic species. Schooling fishes such as herring, smelt, silversides, and seasonal predators such as bass and small sharks are found in the pelagic zone.

The seasonal brackish marsh and open water areas support many bird species including species that feed along the shoreline such as mallard, gull, great blue heron, and predatory species such as northern harrier and white-tailed kite. The coastal scrub provide a habitat for mammal species that is utilized for reproduction, foraging, and cover by the raccoon, striped skunk, gray fox, and long-tailed weasel. The species diversity decreases in the grassland area, where rodent species, foraging bird and mammal species, and predatory birds are common.

The esteros are unique habitats that have protected status under the federal National Marine Sanctuary Act. Both esteros have species which are considered threatened or endangered, including six sensitive or rare plant species found in the seasonal brackish marsh area and in coastal scrub vegetation. Special-status grassland wildlife includes the ferrugienous hawk and badger. The Estero Americano supports the following special status bird species, which are of special concern over the whole area: golden eagle, sharp-shinned hawk, northern harrier, white-tailed kite, peregrine falcon, and bald eagle.

3. CONCEPTUAL SITE MODEL

3.1 EXPOSURE PATHWAYS

Two main routes of exposure were identified for evaluation of ecological risk to the site's terrestrial and aquatic organisms: direct contact with the media (surface soil, water, and sediment) and exposure by dietary intake. These routes are discussed below for each media. Figures 3.1 and 3.2 present conceptual site models that identify main exposure pathways and typical ecological receptors for reclaimed water use in irrigation and stream discharge.

3.1.1 Surface Soils

Direct Exposure. Vegetation, the base of the herbivore food chain, is primarily exposed to soil constituents by uptake of contaminants through the root system. Some chemical substances are largely retained in underground plant tissues while others are translocated, to a variable extent, in shoots, leaves, fruits, and seeds.

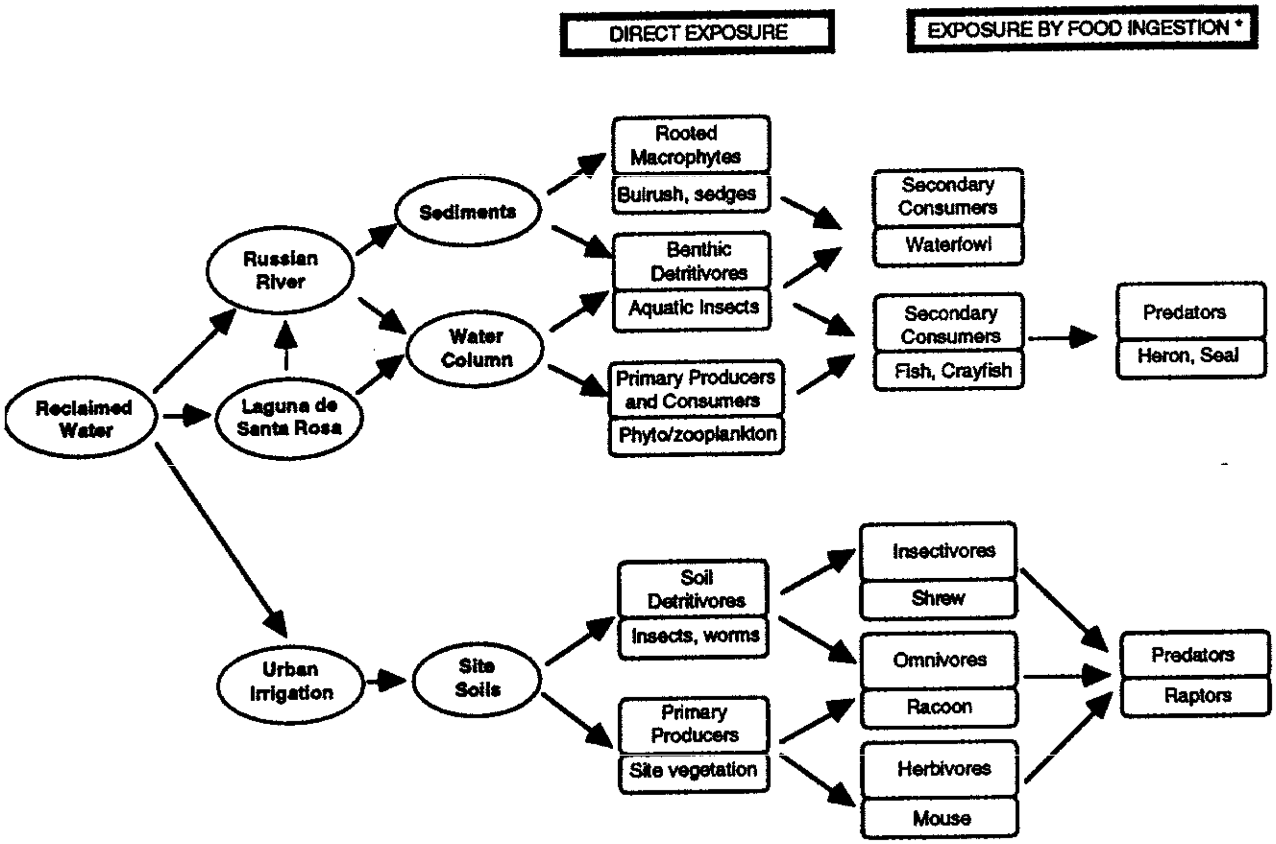
Soil microorganisms and other invertebrates are directly exposed to soil constituents. For earthworms and insects, the exposure route is a combination of dietary intake and dermal contact. These two types of exposure are not considered independent in the risk assessment because, in practice, toxicological effect levels (benchmarks) documented in laboratory and field tests are directly related to soil concentrations and include both exposures.

Dietary Exposure. For terrestrial vertebrates, dietary exposure is considered the primary exposure route for chemical substances. Dermal contact, an additional exposure mechanism for burrowing organisms, is not included in the risk assessment because, currently, there are no adequate data to quantify potential exposure through dermal contact or potential effects to wildlife through this exposure route.

Numerous insectivorous species such as shrews and various bird species potentially present in the site vicinity depend on soil invertebrates as their main food source. Large grazers such as deer and other ground-dwelling herbivores derive their diet primarily from herbaceous vegetation, while squirrels and seed-eating birds are likely to be more dependent on arboreal vegetation where present. Omnivores such as robins and raccoons rely on both the herbivore and the detritivore/insectivore food chains as a food source. Predators associated with the Sonoma County area include red-tailed hawk, northern harrier, great horned owl, and foxes.

FIGURE 3.1

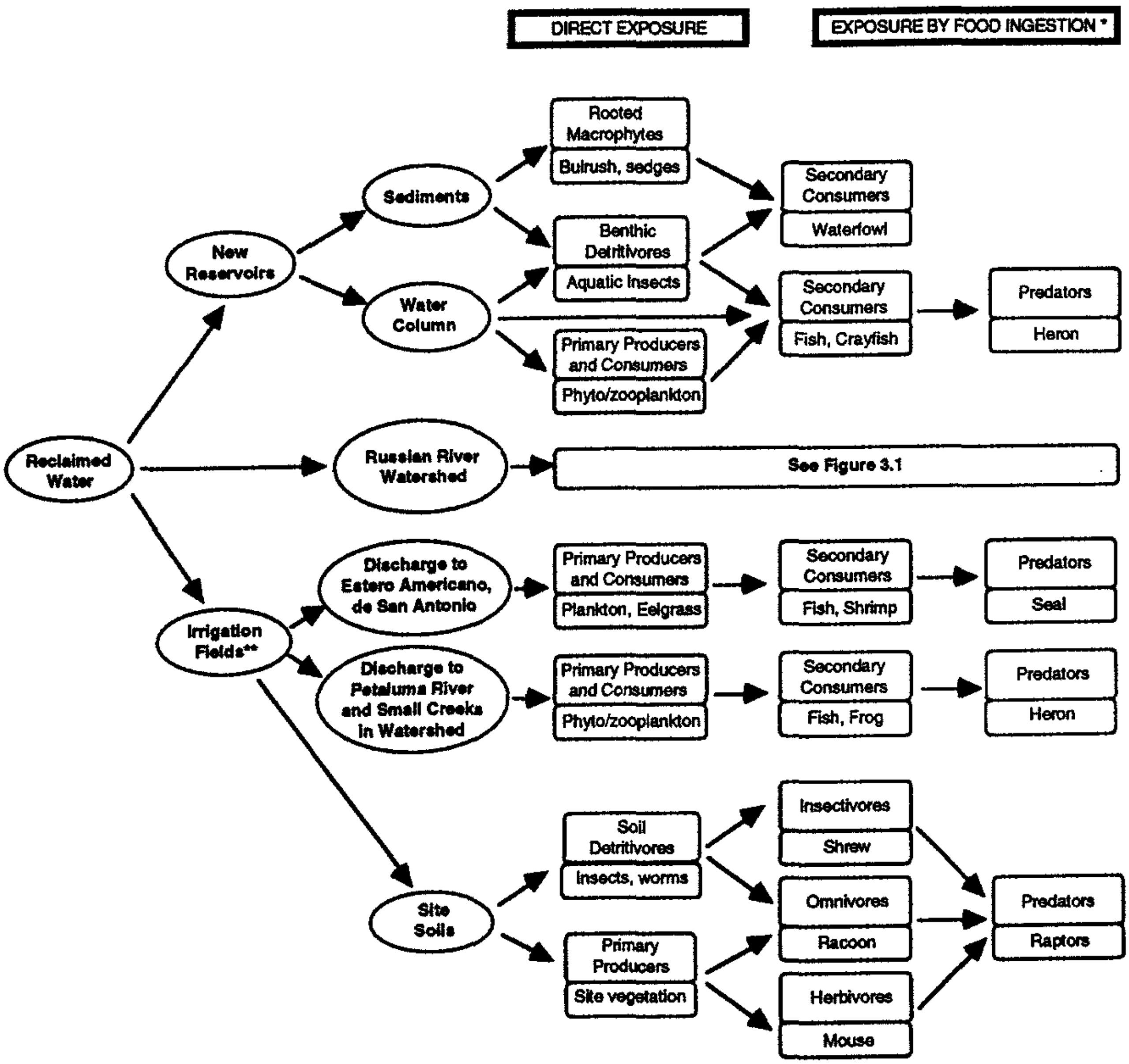
EXPOSURE PATHWAYS AND ECOLOGICAL RECEPTORS FOR DISCHARGES TO LAGUNA DE SANTA ROSA AND THE RUSSIAN RIVER



* Direct exposure to water also applies to all aquatic organisms, and wildlife by water intake.

FIGURE 3.2

EXPOSURE PATHWAYS AND ECOLOGICAL RECEPTORS FOR WEST COUNTY AND SOUTH COUNTY RECLAMATION



* Direct exposure to water also applies to all aquatic organisms, and wildlife by water intake.

** *South County: Sebastopol, Adobe Road, North Petaluma Valley, Lakeville, and East of Rohnert Park;* West County: Sebastopol, Estero Americano, Stemple Creek, others.

3.1.2 Surface Waters

Aquatic organisms may be continuously exposed to chemical substances in surface waters both by direct contact and through consumption of prey organisms. For an aquatic ecosystem, the direct accumulation of chemical substances in organism tissues from the water is usually referred to as bioconcentration. Often, this term is also used for the concentration of chemicals in tissues from other media such as sediments. Tissue concentration resulting from a combined exposure of direct contact with the water and food ingestion is referred to as bioaccumulation (EPA, 1994). Biomagnification refers to an increase in tissue levels from one trophic level to the next higher level.

Small fish and aquatic macroinvertebrates derive their diets from sediment-associated organisms (benthos) and/or microorganisms suspended in the water column (plankton). Those organisms, in turn, support consumer organisms at higher trophic levels of the aquatic food chain such as predatory fish and piscivorous birds. Common, primarily piscivorous birds inhabiting the Sonoma County area include the osprey, kingfishers, and great blue heron.

3.1.3 Sediments

Direct exposure to chemical substances present in the sediment applies to sediment-associated organisms, both microorganisms and macroinvertebrates. Organisms present in sediments, in turn, support a detritivore food chain that serves as an exposure pathway up to piscivorous birds through fish consumption.

Aquatic vegetation is also exposed to substances in sediments through direct contact. Rooted aquatic plants, such as cattails, have the highest potential for exposure. This vegetation is expected to provide a fraction of the diet of the mallard duck and other herbivores.

3.1.4 Agricultural Runoff

Wastewater applied to irrigation areas is expected to percolate into surface soils with a minimum transfer via subsurface flow to nearby surface waters. No direct exposure to subsurface flow is expected to occur, as reclaimed water constituents are likely to be retained in the irrigated soils (Merritt Smith Consulting, 1996b).

3.2 ECOLOGICAL RECEPTORS

Organisms potentially exposed to contaminants in any media are commonly referred to as ecological receptors or ecoreceptors. Typical ecoreceptors for various exposure pathways are identified in Figures 3.1 and 3.2. For direct exposure to soil, water, and sediments, the risk evaluation is based on reference values for potential effects on assemblages of species, reference values derived from combined toxicological data for several species, or EPA or state water quality criteria.

Specific ecological receptors were selected to evaluate terrestrial wildlife exposed through food ingestion because toxicological data are usually limited to species widely used in laboratory tests, such as the rat or mouse. The use of specific ecoreceptors for evaluation of dietary intake allows the extrapolation of test data to a site organism taking into account its potential for exposure (i.e., food ingestion rate, mobility) and sensitivity to individual contaminants. In addition, extra safety factors are added to protect threatened and endangered species.

The following species, representative of various trophic levels, were selected as ecological receptors for the assessment of risk through the terrestrial and aquatic food chains :

1. Deer mouse, predominantly herbivorous;
2. Shrew, insectivorous;
3. Raccoon (ringtail), omnivorous;
4. Muskrat, herbivorous;
5. Mule deer, herbivorous;
6. Harbor seal, piscivorous, diet includes both plant and animal matter;
7. Red-legged frog, insectivorous;
8. Tidewater goby, insectivorous;
9. Steelhead trout, insectivorous/piscivorous;
10. Sunfish, insectivorous;
11. California quail, primarily insectivorous;
12. Red-tailed hawk, carnivorous;
13. Mallard duck, aquatic omnivore;
14. Osprey, piscivorous;
15. Great blue heron, primarily piscivorous.

These species have been reported at each area in the various biological assessments, or are common species of the plant communities dominant in the area. In the selection of ecological receptors, the following criteria were used:

1. Common or likely occurrence in the site vicinity based on predominant plant communities;
2. Use of species with a relatively low mobility (for a given trophic level) likely to be frequently or continuously exposed to chemical substances;
3. Use of species having exposure information (such as food and water intake rates, foraging area, diet composition) and/or toxicological values to reduce the

need for data extrapolation. EPA (1993b) has summarized exposure factors for selected species of mammals, birds, reptiles, and amphibians widely distributed throughout the United States; and

4. Threatened or endangered species likely present at the site.

The use of commonly-occurring species from various trophic levels as ecological receptors is a screening method for potential effects for site organisms intended to reduce the uncertainty in the risk analysis. When potential adverse effects are identified for a specific ecoreceptor, a potential risk is also assumed for other wildlife species having similar diet composition and mobility, and for endangered, threatened, or special-status species potentially present in the site vicinity.

4. EXPOSURE ASSESSMENT

The following sections describe the general approaches for estimating the exposure of receptors to the alternative evaluations. These approaches use site information and information from other sources, as noted below. Volatile organics (VOCs) are not considered in this assessment. VOCs would not be present in the wastewater following residence in the storage ponds.

4.1 EXPOSURE ANALYSIS FOR SOIL

4.1.1 Direct Exposure

In the absence of actual soil concentrations, reclaimed water concentrations are converted to soil concentrations (i.e., mg/l to mg/kg) and used as the direct exposure values for soils. This approach is conservative because it assumes that wastewater constituents, once applied to soils, are completely available for uptake by organisms. Site-specific soil properties, however, might reduce the bioavailability of contaminants. In the case of metals such as cadmium, copper, lead, mercury, and zinc, their uptake by vegetation and potential toxicity have been related to multiple soil parameters including composition, pH, redox potential, and content of organic material (EPA, 1983). The exposure assessment for metals assumes that the metal is present in its most toxic form, typically in the inorganic form used in most toxicological tests.

4.1.2 Exposure by Dietary Intake

Dietary Intake Calculation. Exposure to a chemical substance by dietary intake is determined by: 1) its concentration in the food source; 2) the food ingestion rate (FIR) of the consumer organism; and 3) the fraction of the diet that the organism actually obtains from the site.

The dietary fraction derived from the site is typically quantified using a mobility factor (MF), the ratio between the site surface area and the organism's foraging/feeding range. Large mammals and raptors have extensive foraging ranges and are likely to obtain only a fraction of their diet from a single location, while low mobility organisms such as invertebrates and small wildlife have a higher degree of exposure because most or all of their diet is derived from the site. For seasonally-occurring species, the mobility factor not only accounts for the foraging range, but also for the fraction of time during which exposure is likely.

Based on the three previously described parameters, the dietary exposure for an organism can be calculated as:

$$\text{Dietary Exposure} = \text{Concentration in Diet} \times (\text{FIR} \times \text{MF})$$

where,

> Dietary exposure is expressed as a daily dose per unit body weight (mg/kg/day);
>
> Concentration in diet is given in mg/kg (dry-weight basis);
>
> FIR is the daily food or water consumption as a fraction of the organism's weight (kg food or water per kg body weight per day); and
>
> MF is the mobility factor (hectare/hectare).

Data on foraging ranges and food and water intake rates for the selected ecological receptors, obtained by EPA (1993b), are listed in Table 4.1. Values selected for the risk assessment are the midpoint of reported ingestion rate data, and the lowest value of the reported foraging ranges. Table 4.1 also summarizes the predominant diet composition of selected receptor organisms.

Contaminant Concentrations in Diet. When the concentration of a chemical compound in various types of foods is known, its dietary concentration can be calculated based on the relative contribution of each type of food to the organism's diet. The nomenclature used for identification of the concentration of chemical substances in five major food sources, and their relative contribution to an organism's diet (as "f_i" the fraction in the total food ingested) are tabulated below.

	Concentration in Food Source	Relative Contribution to the Diet	Dietary Transfer Factor
Soil/sediments	C_S	f_S	-
Vegetation	C_V	f_V	TF_V
Insects/invertebrates	C_I	f_I	TF_I
Herbivores	C_H	f_H	TF_H
Small carnivores	C_C	f_C	TF_C

For a species whose diet includes multiple foods sources, the dietary concentration of a chemical substance is calculated as:

$$\text{Concentration in Diet} = f_S C_S + f_V C_V + f_I C_I + f_H C_H + f_C C_C$$

where,

$$f_S + f_V + f_H + f_I + f_C = 1$$

For species with diets composed predominately of only one or two food sources, the contributions of other food sources become negligible. For predatory organisms such as

Table 4.1. Wildlife Exposure Factors For Ecological Risk Assessment

	Weight (kg)	Food Ingestion * (g/g/day)	Diet Composition (percent) Plant Material	Inverte-brates	Vertebrate Prey	Water Intake (g/g/day)	Foraging Range ** (hectares)
BIRD SPECIES							
Great Blue Heron							
Reported range	2 - 2.2	0.18			100	0.05	0.6 - 8.4
Exposure value		0.18			100	0.05	0.6
Mallard Duck							
Reported range	1 - 1.2	0.05	10 - 92	8 - 90		0.06	110 - 620
Exposure value		0.05	50	50		0.06	110
Red-Tailed Hawk							
Reported range	1 - 1.2	0.09-0.11			100	0.60	60 - 1,770
Exposure value	1	0.10			100	0.06	60
MAMMALS							
Harbor Seal							
Reported range	50 - 110	0.05-0.08		0-20	0-100	0.005-0.064	>7,800
Exposure value		0.05			100	0.003	7,800
Vagrant Shrew***							
Reported range	0.01 - 0.02	0.49-0.62	8 - 17	83 - 92		0.22	0.1 - 1.8
Exposure value		0.56	10	90		0.22	0.1
Deer Mouse							
Reported range	0.02 - 0.03	0.18-0.22	33 - 93	7 - 66		0.19-0.34	0.01-0.13
Exposure value		0.20	70	30		0.26	0.01

SOURCE: Summary of exposure factors by EPA (1993).

* Midpoints of the reported ranges are used as exposure values.

** The lowest reported range is used as a conservative exposure value.

*** Data for vagrant shrew from EPA (1993) for exposure factors.

raptors that rely on herbivores and small carnivores as their main food source, the dietary concentration simplifies to:

$$f_S = f_V = f_I = 0$$

$$\text{Concentration in Predator's Diet} = f_H C_H + f_C C_C$$

Dietary Transfer Factors. Because organism tissues are not routinely monitored during initial phases of an ecological risk assessment, the concentration of chemical substances in the diet of site wildlife are often unknown. To evaluate potential effects on wildlife by food ingestion, the concentration in the diet can be estimated from concentrations detected in soils using a unitless transfer factor (**TF**). These transfer factors are empirical values that account for the potential accumulation of a chemical in organism tissues at each transfer step of the food chain.

Based on the use of transfer factors, whose derivation is discussed below, the concentration of a chemical substance in tissues of four types of organisms can be estimated from the soil concentration (**C_S**) as follows:

Concentration in Vegetation Tissues:	$C_V = C_S \times TF_V$
Concentration in Invertebrate Tissues:	$C_I = C_S \times TF_I$
Concentration in Herbivore Tissues:	$C_H = C_V \times TF_H$
	$C_H = C_S \times (TF_V \times TF_H)$
Concentration in Small Carnivore Tissues:	$C_C = C_I \times TF_C$
	$C_C = C_S \times (TF_C \times TF_I)$

For an omnivore organism whose food is derived from multiple food sources, the concentration of a chemical substance in its tissues (**C_O**) can be estimated as:

$$C_O = f_S C_S + f_V C_V + f_I C_I + f_H C_H + f_C C_C$$

Replacing the concentration in diet as a function of soil concentration using dietary transfer factors

$$C_O = f_S C_S + f_V TF_V C_S + f_I TF_I C_S + f_H C_S (TF_H \times TF_V) + f_C C_S (TF_C \times TF_I)$$

Rearranging the equation as a function of the soil concentration (C_S), the concentration in the tissues of the omnivore organism is finally obtained as:

$$C_O = C_S [\, f_S + f_V TF_V + f_I TF_I + f_H (TF_H \times TF_V) + f_C (TF_C \times TF_I)\,]$$

Tables 4.2 and 4.3 list transfer factors used in the exposure rate calculations for organic compounds and metals, respectively. These values were obtained from reported data or were calculated using empirical equations relating potential bioaccumulation to the tendency of the substance to accumulate in fat tissues (as measured by the octanol-water partition coefficient, K_{ow}). A default value of 1 was used when estimates of the transfer factors were unavailable or when the potential for bioaccumulation of a given chemical was known to be low. This default value indicates that concentrations of a chemical in the consumer organism tissues are similar to those found in the food source. For volatile organics, a default value of 0.1 was used as transfer factor of 0.1. This value is the minimum food chain multiplier reported by EPA (1994) for contaminants with a very low bioavailability.

Soil to Vegetation Transfer. Transfer of organic substances from soil to vegetation tissues was calculated from the octanol/water partition coefficient using the following empirical equations for roots and foliage:

$$\log (TF_V \text{ for net root uptake}) = 2.0 - 0.11 \log K_{ow}$$

$$\log (TF_V \text{ for foliage}) = 1.588 - 0.578 \log K_{ow}$$

Net root uptake is based on experimental data relating the uptake of multiple pesticides by barley roots to their octanol/water partition coefficient (Table 3.6 of Bell, 1992). For foliage, a geometric correlation equation was obtained from data on bioconcentration of twenty-nine chemicals in cattle-feed grasses as a function of K_{ow} (Travis and Arms, 1988).

Transfer factors from soil to plant tissues (TF_V) for metals were calculated from concentration ranges in plant tissues, as summarized by Baes et al. (1984). The transfer factor was obtained by dividing the midpoint of the reported ranges for vegetative tissues by the average concentration of the element in natural soils. Data for non-vegetative tissues (fruits and tubers), which have lower levels of metal bioconcentration than vegetative tissues (Baes et al., 1984), were not used in the TF_V calculations.

Soil to Invertebrate Transfer. Transfer of metals from soil to tissues of invertebrates (TF_I) was obtained from bioaccumulation data for earthworms in sludge-amended soils (Pietz et al., 1984). For organic compounds, TF_I were obtained from various studies relating tissue levels in earthworms and other invertebrates to soil concentrations of polycyclic aromatic hydrocarbons (Marquenie et al. 1987), pesticides (Wheatley and Hardman, 1968; Beyer and Krynitski, 1989), PCBs (Diercxsens et al., 1985), pentachlorophenol (Haque and Ebing, 1988), and dioxins (Reinecke and Nash, 1984) (Table 4.2).

Transfer to Vertebrate Tissues. A single transfer factor ($TF_H = TF_C$) was used to account for accumulation of chemical substances from prey organisms (invertebrates,

Table 4.2. Transfer Factors for Calculation of Potential Bioaccumulation of Organic Compounds

		TRANSFER FACTORS FOR TERRESTRIAL FOOD CHAIN					BIOACCUMULATION FROM AQUATIC FOOD CHAIN ***					
	log Kow****	From Soils to Aboveground Plant Tissues* (TFv)		From Soils to Invertebrate Tissues (TFi)		From Food Source to Vertebrates ** (TFc)	Bioconcentration From Water BCF (L/kg)	Food Chain Multipliers Trophic Level 2	Trophic Level 3	Trophic Level 4	Bioaccumulation In Fish Tissue BAF (L/kg)	Ratio of Trophic Level 4 to Trophic Level 3
Volatile Organic Compounds												
Trichloroethane		0.13 - 0.45	(1)			1.0		0.1	0.1	0.1		1.0
Toluene	2.7	0.5	(2)			1.0		0.1	0.1	0.1		1.0
Polycyclic Aromatic Hydrocarbons												
Anthracene	4.5	0.3		0.05	(5)	1.0	30	1.1	1.1	1.1	33	1.0
Benzo(a)anthracene	5.9	0.2		0.12	(5)	2.1	30	3.3	7.5	16.0	225	2.1
Benzo(b)fluoranthene	6.6	0.2		0.32	(5)	2.2	30	19.2	45.0	100.0	1,350	2.2
Benzo(k)fluoranthene	6.9	0.2		0.25	(5)	2.2	30	19.2	45.0	100.0	1,350	2.2
Benzo(g,h,i)perylene	7.0	0.2		0.24	(5)	2.2	30	19.2	45.0	100.0	1,350	2.2
Benzo(a)pyrene	6.4	0.2		0.34	(5)	3.0	30	8.2	25.0	75.0	750	3.0
Chrysene	5.8	0.2		0.18	(5)	2.1	30	3.3	7.5	16.0	225	2.1
Fluoranthene	5.2	0.3		0.08	(5)	1.9	30	2.8	5.9	11.0	177	1.9
Indeno(1,2,3-cd)pyrene	7.7	0.1		0.42	(5)	2.2	30	19.2	45.0	100.0	1,350	2.2
Naphthalene	3.4	0.1	(1)	0.12	(5)		10					
Phenanthrene	4.6	0.3		0.12	(5)	1.0	30	1.2	1.2	1.2	36	1.0
Pyrene	5.2	0.3		0.09	(5)	1.1	30	1.5	1.8	2.0	54	1.1
Other Semivolatile Organics												
Bis(2-ethylhexyl)phthalate	4.2	0.3				1.3	130	1.7	2.5	3.2	325	1.3
Di-n-butyl phthalate	4.1	0.4				1.0	89	1.1	1.1	1.1	98	1.0
Hexachlorobenzene	5.5	0.3				3.2	8,690	6.8	21.0	67.0	182,490	3.2
Pentachlorophenol	5.0	0.3		22.0	(6)	1.4	11	1.9	3.0	4.3	33	1.4
2,3,7,8-TCDD (dioxin)	6.1	<0.01	(3)	14.5	(7)	2.2	5,000	19.2	45.0	100.0	225,000	2.2
Pesticides and PCBs												
Aldrin	5.5	0.2		1 - 4	(8)	1.9	4,670	2.8	5.9	11.0	27,553	1.9
Chlordane	6.4	0.2				1.9	14,100	2.8	5.9	11.0	83,190	1.9
BHC - mixed isomers	5.3	0.3		1.5 - 4.2	(8)	1.6	130	2.2	3.7	5.8	481	1.6
BHC - gamma (lindane)	3.7	0.4		1.5 - 4.2	(8)	1.0	130	1.0	1.0	1.0	130	1.0
4,4'-DDT	6.4	0.2		5.0	(9)	2.5	53,600	15.0	39.0	98.0	2,090,400	2.5
Dieldrin	6.2	0.2		8.0	(9)	1.0	4,670	1.2	1.3	1.3	6,071	1.0
Endrin	4.6	0.3				1.0	3,970	1.2	1.3	1.3	5,161	1.0
Heptachlor	5.4	0.3		10.0	(9)	1.0	11,200	1.1	1.1	1.1	12,320	1.0
Methoxychlor	4.3	0.3				1.3		1.7	2.5	3.2		1.3
Toxaphene	3.3	0.4				1.1	13,100	1.4	1.5	1.6	19,650	1.1
PCB (Araclor 1016, 1032)	5.9	0.2		6.0	(10)	2.1	31,200	3.3	7.5	16.0	234,000	2.1
PCBs (Araclor 1254, 1260)	6.5	0.004 - 0.01	(4)	6.0	(10)	2.2	31,200	19.0	45.0	100.0	1,404,000	2.2

* Unless otherwise indicated, TFv from octanol/water partition coefficient (Kow), using a correlation equation for net uptake of pesticides by barley roots (Bell, 1992; Table 3.6): log (net root uptake) = 2.0 - 0.11 log Kow.
** Expected diet-associated increase in concentration from fish to piscivorous birds (trophic levels 3 and 4 of the aquatic food chain) (EPA, 1994).
*** Bioconcentration factors for fish tissue (3% lipid content) from EPA, Region IV, "304(a) Criteria Toxic Substance Spreadsheet" (EPA, 1995); food chain multipliers from Water Quality Standards Handbook (EPA, 1994).
**** Log Kow values from Table 1 of Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish, EPA, 1989.

1. Experimental growth of vegetables and other crops in 30 to 50-day tests (Bell, 1992).
2. Experimental data on corn, bean, and other crops (Overcash et al., 1982).
3. Monitoring data for thirteen plant species at a Superfund site in St. Louis, Missouri (Bell, 1992).
4. Data on beet and turnip growth in sediment-amended soils contaminated with Arochlor 1248, 1254, and 1260 (Sawhney & Hankin
5. Marquerie et al., 1987 (32-day survival of the earthworm Eisenia foetida in contaminated soils).
6. Haque & Ebing, 1988 (test species: Lumbricus terrestris).
7. Reinecke & Nash, 1984 (7-day bioaccumulation data and 85-day survival tests of two earthworm species).
8. Wheatley & Hardman, 1968 (chlorinated insecticide residues in earthworms from agricultural soils).
9. Beyer & Krynitsky, 1989 (long-term monitoring of insecticide residues in earthworms).
10. Diercxsens et al., 1985 (PCBs in soils treated with compost).

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Table 4.3. Transfer Factors for Calculation of Potential Bioaccumulation of Metals

	TERRESTRIAL FOOD CHAIN			AQUATIC FOOD CHAIN****		
	From Soils to Aboveground Plant Tissues* (TFv)	From Soils to Invertebrate Tissues** (TFi)	From Food Source to Vertebrates*** (TFc)	Bioconcetration Factor (L/kg)	Bioaccumulation Factor (L/kg)	Reference
Aluminum	0.01		1.0	231	231	EPA 440/5-80-023, 1980
Antimony	0.6		1.0	1	1	EPA 440/5-80-029, 1980
Arsenic	<0.05		1.0	44	44	EPA, 1995
Beryllium				19	19	EPA 440/5-80-024, 1980
Boron	2.5 - 210		1.0	1	1	Default value
Cadmium	0.26 - 4.8	19.0	1.0	64	64	EPA 440/5-84-032, 1885
Chromium	< 0.02	0.1	1.0	16	16	EPA, 1995
Cobalt	< 0.07		1.0	1	1	Default value
Copper	0.1 - 0.55	0.4	1.0	36	36	EPA, 1995
Lead	0.01 - 0.9	0.1	1.0	49	49	EPA, 1995
Mercury****	1 - 2	13.0	3.5	9,000	60,000	Peterson and Nebeker (1992)
Molybdenum	0.18 - 1.5		1.0	1	1	Default value
Nickel	< 0.13	0.1	1.0	47	47	EPA, 1995
Selenium	< 0.35		1.0	6	2,600	EPA (1993)
Silver	1.3		1.0	1	1	Default value
Tin	0.01		1.0	1	1	Default value
Vanadium	< 0.2		1.0	1	1	Default value
Zinc	0.2 - 0.6	3.8	1.0	47	47	EPA, 1995

* Metals bioaccumulation at typical soil concentrations (data summarized by Baes et al., 1984; Tables 2.6 to 2.10, Fig 2.16).

** Data for earthworms in sludge-amended soils (Pietz et al., 1984). Mercury TF from insect data in contaminated areas (USFWS, 1987; Table 6).

*** TFs for insects, deer, and mink, based on concentration ratios between mercury-contaminated areas and reference sites (USFWS, 1987; Table 6).

**** BCFs for metals from EPA (1995) or EPA's ambient water quality criteria documents; BAFs for selenium and methylmercury from Peterson and Nebeker (1992) and EPA (1993e), respectively.

small vertebrates) to their consumer organisms. A default value of 1 was used for metals, with the exception of mercury, which is known to biomagnify in high trophic levels of the food chain (EPA, 1993b). For organic substances, the transfer factors TF_H and TF_C were calculated as a function of the octanol/water partition coefficient using data developed by EPA (1994) for the aquatic food chain. Table 4.2 lists transfer values that represent the expected increase in tissue concentrations from secondary consumers such as small fish (food chain multiplier for trophic level 3) to predatory fish and piscivore birds (food chain multiplier for trophic level 4).

Direct Soil and Sediment Ingestion. For many wildlife species, diets may include the incidental ingestion of soil and sediments. Typically, the ingestion rate is less than 10 percent of the diet for most wildlife species and has been excluded from the risk calculations. The exposure to contaminants by direct soil/sediment ingestion may be significant for shorebirds feeding on mud-dwelling invertebrates, such as sandpipers, and for insectivores feeding extensively on earthworms such as the woodcock (EPA, 1993b).

4.2 EXPOSURE ANALYSIS FOR SURFACE WATER

4.2.1 Direct Exposure of Aquatic Organisms

The total concentration of a substance in water has been traditionally considered the exposure concentration for potential effects to aquatic organisms. For metals, however, this procedure overestimates the potential real risk because only the dissolved fraction is bioavailable, and potentially toxic, to aquatic organisms. The metals fraction that is present in the particulate form or that is tightly bound to chelating chemicals present in natural waters is typically not bioavailable. Following EPA's new policy and guidance, the dissolved concentration is used in the risk assessment as the metals fraction that is potentially toxic to aquatic organisms (EPA, 1994).

4.2.2 Exposure by Dietary Intake

In aquatic systems, chemical substances accumulate in organism tissues as a result of both direct exposure to the water and exposure through food consumption. This potential for accumulation in organism tissues is used in the risk assessment to estimate potential transfer from fish tissues to piscivorous birds and mammals.

For the evaluation of chemical transfer from the reclaimed water to piscivorous organisms, potential tissue concentrations in fish were obtained from data of mosquito fish collected from Kelly Farm Ponds wetlands demonstration project in August 1994. This pilot-scale project was conducted over a four year period to determine potential bioaccumulation of metals and organic substances in fish, invertebrate, and wetland vegetation tissues during a long-term exposure to reclaimed water from the Santa Rosa Regional Wastewater Treatment facility (Table 4.4).

Table 4.4 Metals in Organism Tissue at the Kelly Farms Demonstration Wetlands

	Tissue Concentration at KFDW (mg/kg dry wt.)*			
	Cattail Rhizomes	Bulrush Seeds	Crayfish	Mosquitofish
Aluminum	1,183	35	449	1,232
Arsenic	0.3	<0.06	0.77	0.33
Cadmium	<0.20	<0.06	<0.15	<0.26
Chromium	4.09	0.3	1.88	4.94
Copper	7.38	4.35	85.7	6.79
Lead	1.24	0.27	0.94	1.06
Mercury	<0.040	0.017	0.05	0.11
Nickel	7.1	3.6	4.5	4.9
Selenium	<0.40	0.2	0.59	0.84
Silver	0.92	0.8	0.6	1.36
Zinc	15.4	5	62.2	142.2

* Data from Merritt Smith Consulting (1995e)

For the risk evaluation, tissue levels in fish from the Laguna de Santa Rosa were assumed to be equal to average tissue concentrations detected in Kelly Farm Ponds. This assumption is conservative because it indicates that fishes in the Laguna are continually exposed to undiluted reclaimed water. In the average, reclaimed water will only contribute 17 percent to the Laguna flow (Merritt Smith Consulting, 1996b). For exposure to reclaimed water in the Russian River, the tissue concentration was assumed to decrease in direct proportion to the minimum dilution level of the reclaimed water. Concentrations of chemicals expressed on a dry-weight basis were recalculated as fresh-weight concentrations using a moisture content of 80 percent in fish tissues. This value is typical of the moisture content in mosquito fish collected from Kelly Farm Ponds.

4.2.3 Water Intake by Terrestrial Organisms

Exposure of terrestrial organisms by water consumption is a direct function of the intake rate. Water intake rates for selected ecological receptors were summarized by EPA (1993b) along with other exposure factors selected for the risk assessment (Table 4.1).

4.2.4 Exposure Analysis for Irrigation Water

The evaluation of potential effects on aquatic organisms from agricultural runoff was based on the modeling of irrigation drainage for various project alternatives (Questa

Consulting Engineers, 1995b). The analysis of runoff quality was limited to metals and two widely-utilized pesticides in the region: the herbicide 2,4-D and the insecticide carbaryl. Organic substances present in the reclaimed water from the Santa Rosa facility are expected to be retained in the soils of the irrigation fields (Merritt Smith Consulting, 1996b).

4.3 Exposure Analysis for Sediments

4.3.1 Direct Exposure

Exposure to contaminants in sediments through direct contact and pore water applies to aquatic invertebrates and rooted aquatic macrophytes such as cattails. Evaluation of potential effects on riparian vegetation was performed under the assumption of complete availability of chemical substances present in the sediment for uptake by the plant root system (bioavailability). For sediment-associated organisms (benthos), the effects evaluation accounted for the potential bioavailability using the following procedures.

For non-polar organic compounds, a reduced bioavailability results from an elevated content of organic matter that retains potential contaminants by sorption to particulate material. Little or no reduction in bioavailability is expected for sediment with a content of organic carbon (a parameter commonly used to estimate organic matter content) less than 0.5 percent (EPA, 1994). In the assessment of risk to sediment-associated organisms, reference values for potential effects on non-polar organic compounds were calculated for an organic carbon content of 1 percent for ravine sediments and reservoirs. See Section 5.5 for further discussion of organic carbon content and its effects on sediment concentrations.

For exposure of sediment-associated organisms to metals in sediments, a 100-percent bioavailability was assumed. This approach is conservative because reduced availability, and thus potential toxicity to organisms, has been reported for sediments with a significant content of acid volatile sulfides (Persch et al., 1995). In addition, this assumption is also conservative for uptake by plants, because most metals in soils and sediments above pH of 7.5 are not taken up by the plants and thus not toxic or bioaccumulative (EPA, 1983).

4.3.2 Exposure by Dietary Intake

The analysis of dietary exposure of wildlife (such as the mallard duck) to aquatic vegetation and invertebrate organisms was based on the use of transfer factors previously described for the terrestrial food chain: TF_v for the sediment-to-plant transfer, and TF_i for the sediment-to-invertebrate transfer. Factors used in the exposure calculations were obtained from data on soil organisms and terrestrial vegetation (Table 4.2).

5. CHARACTERIZATION OF ECOLOGICAL EFFECTS

The initial phase for assessment of ecological risk is the comparison of contaminant concentrations in soil, water, and sediment to reference values that identify threshold levels below which adverse effects on organisms are unlikely. These reference values for potential effects on site organisms are referred to as benchmarks. For evaluation of effects on organisms by direct exposure, benchmarks are expressed simply as the concentration of a chemical substance in the medium. For evaluation of exposure through food or water ingestion, benchmarks for specific chemical substances are dietary doses associated with various adverse levels documented under experimental conditions.

Currently, there are no universally-accepted methods for deriving benchmarks used in risk assessment. For different locations and exposure scenarios, multiple approaches and benchmark values have been used in the evaluation of ecological risk. Commonly used benchmarks document toxicological endpoints for individual species and, less frequently, potential effects on several test species or assemblages of organisms. The following section describes the benchmark derivation methods and rationale for their use in the assessment of potential ecological risk.

In the evaluation of potential effects on terrestrial wildlife, benchmarks were based on toxicological data for individual tests species summarized by Opresko et al. (1994). Benchmarks for evaluation of potential effects of contaminants on terrestrial vegetation and soil invertebrates were obtained from various sources including screening reference values used by the Environmental Sciences Division of the Oak Ridge National Laboratory (ORNL) to evaluate the need for remediation at hazardous waste sites within the jurisdiction of the U.S. Department of Energy (Will and Suter, 1994a, 1994b). These screening benchmarks identify soil concentrations with low potential for effects on biota, based on toxicological data for several test organisms.

For aquatic organisms, state and federal criteria for protection of aquatic life (marine and freshwater, where appropriate) were used as the primary benchmark values (EPA, 1991a). For chemical substances lacking EPA criteria, secondary reference values developed by ORNL were used as benchmarks (Suter and Mabrey, 1994). The evaluation of potential effects on sediment-associated organisms was based on sediment quality guidelines developed by EPA for organic chemicals (EPA, 1994) and on threshold concentrations for potential effects on organisms compiled by the National Oceanic and Atmospheric Administration (NOAA, 1994).

5.1 BENCHMARKS FOR EFFECTS ON VEGETATION

Benchmarks for screening of potential effects of metals on terrestrial plants, listed in Table 5.1, were developed by Will and Suter (1994) based on a summary of reported low-effect levels on vegetation growth and production. Will and Suter ranked reported data, and used the 10th percentile of the data distribution as a screening benchmark intended to provide a 90-percent level of protection for plant communities. When phytotoxicity data were insufficient for calculation of a 10th percentile, the lowest effect level reported was used as the benchmark value. In some cases, low-effect concentrations were obtained by extrapolation from lethal effects data (low-effect level = 20% LC_{50}).

Benchmarks for potential effects of organic substances on vegetation used in the risk assessment are environmental quality criteria developed by the Canadian Council of Ministers of the Environment (CCME, 1991) (Table 5.2). These criteria are defined as numerical limits for contaminants in soils intended to maintain, improve, or protect environmental quality and human health at contaminated sites. The environmental quality criteria are not solely based on phytotoxicity data, but were used as screening benchmarks for potential effects because they are conservative values considered protective not only of plant communities, but also soil organisms and the entire food chain dependent upon the soil.

Environmental quality criteria for organic substances other than pesticides, listed in Table 5.2, apply to the parkland/commercial/residential land use scenario. These values are intended to protect soil-dependent biota and to result in soils capable of supporting ornamental and native flora (CCME, 1991). Alternative environmental quality criteria have also been developed by CCME for the agricultural and industrial land use scenarios. In addition to organic substances, EQCs were also used for four metals (chromium, silver, vanadium, and zinc), because screening benchmarks calculated by Will and Suter (1994a) were below the typical concentrations in U.S. soils.

Benchmark values for pesticides are maximum application rates resulting in no-apparent effect levels (NOEL) on crops, reported by EPA (1983). These values were extrapolated to soil concentrations assuming a 6-inch penetration in the soil, and negligible pesticide degradation or accumulation (Table 5.2). When unavailable, a NOEL was obtained by extrapolation of low-effect levels (NOEL = 10% LOEL).

5.2 BENCHMARKS FOR EFFECTS ON SOIL ORGANISMS

Benchmarks for screening of potential effects on earthworms and other soil organisms, listed in Tables 5.1 and 5.2, were obtained primarily from two main sources: benchmarks developed by the ORNL for metals, phenolic compounds, and chlorobenzenes (Will and Suter, 1994b); and earthworm toxicity data for volatile and semivolatile organics reported by Neuhauser et al. (1985). Additional benchmarks for pesticides were obtained from

Table 5.1 Benchmarks for Direct Exposure of Organisms to Metals in Soils

	VEGETATION*		SOIL ORGANISMS **		REFERENCE CONCENTRATIONS
-	10th Percentile of Ranked LOELs (mg/kg)	Remediation Criteria (mg/kg)	Low LOEL For Microorganisms (mg/kg)	Low LOEL For Earthworms (mg/kg)	Average in U.S. Soils*** (mg/kg)
Aluminum	50	-	600	-	47000
Antimony	5	20		-	0.5
Arsenic	10	30	100	60	5.2
Barium	500	500	3,000	-	440
Beryllium	10	4	-	-	0.6
Boron	0.5	-	20	-	-
Cadmium	3	5	20	20	-
Chromium- total	1	250	10	0.4	37
Chromium- hexavalent	-	8	-	-	-
Cobalt	20	50	1,000	-	6.7
Copper	100	100	100	50	17
Lead	50	500	900	500	16
Lithium	2	-	10	-	
Managenese	500	-	100	-	
Mercury	0.3	2	30	0.1	0.06
Molybdenum	2	10	200	-	0.6
Nickel	30	100	90	200	13
Selenium	1	3	100	70	0.3
Silver	2	20	50	-	-
Thallium	1	-	-	-	
Tin	50	50	2,000	-	0.9
Titanium	-	-	1,000	-	
Vanadium	2	200	20	-	58
Zinc	50	500	100	200	48

* Screening benchmarks based on potential phytotoxicity (10th percentile of ranked low-effect data) from Will and Sutter (1994a); soil remediation criteria for parkland and residential land use (CCME, 1991). Values were derived as protetive of vegetation and soil organisms, and food chain dependent upon them.
** Screening benchmarks by Will and Sutter (1994b). Values are based on potential toxicity by direct exposure to soils (10th percentile of ranked low-effect data).
*** Data as summarized by NOAA (1994).

Table 5.2. Benchmarks for Direct Exposure of Organisms to Organic Compounds in Soils

	SOIL ORGANISMS			VEGETATION			
	Benchmark * (mg/kg)	Calculation Method		Benchmark* (mg/kg)	Calculation Method	Test Species	
Volatile Organic Compounds							
Benzene	65	1% LC50	(2)				
Carbon tetrachloride	106	1% LC50	(2)				
Chlorinated aliphatic hydrocarbons							
Chlorobenzene	40	Multispecies LOEL	(3)	10	1% EC50	Lettuce	(6)
Chloroform	73	1% LC50	(2)				
1,2 Dichloropropane	42	1% LC50	(1)				
Ethylbenzene	31	1% LC50	(2)				
Methylene chloride	204	1% LC50	(2)				
Styrene				3.2	1% EC50	Lettuce	(6)
Toluene	50	1% LC50	(2)	200	Multispecies LOEL	Several	(8)
Trichloroethylene	70	1% LC50	(2)				
1,1,1 Trichloroethene	55	1% LC50	(2)	10	1% EC50	Lettuce	(6)
Xylenes				10	1% EC50	Lettuce	(6)
Polycyclic Aromatic Hydrocarbons							
Acenaphthene	1	1% LC50	(2)	0.25	1% EC50	Lettuce	(6)
Fluoranthene	22	1% LC50	(2)				
Fluorene	2	1% LC50	(1)				
Naphthalene	47	1% LC50	(2)	1	1% EC50	Lettuce	(6)
Phenanthrene							
Pyrene							
Other PAHs (each)							
Other Semivolatile Organics							
Bis(2-ethylhexyl)phthalate	1,400	1% LC50	(2)	200	Multispecies LOEL	Several	(8)
Diethylphthalate	49	1% LC50	(2)	1.3	1% EC50	Lettuce	(6)
Dimethylphthalate	32	1% LC50	(1)				
Di-n-butylphthalate	78	1% LC50	(2)	1.3	1% EC50	Lettuce	(6)
Dioctylphthalate	180	1% LC50	(2)				
Hexachlorobenzene	1,000	Multispecies LOEL	(3)	10	1% EC50	Lettuce	(6)
4-Nitrophenol	7	Multispecies LOEL	(3)				
Pentachlorophenol	4	Multispecies LOEL	(3)	0.08	1% EC50	Lettuce	(6)
Phthalic acid esters (each)							
Phenol	30	Multispecies LOEL	(3)	1.68	1% EC50	Lettuce	(6)
Phenols - non chlorinated (each)				20	Multispecies LOEL	Several	(8)
Phenols - chlorinated (each)							
PCDD, PCDF (dioxins and furans)							
2,4,6 Trichlorophenol	10	Multispecies LOEL	(3)				
TCDD (dioxin)	5	NOEL	(5)				
Pesticides and PCBs							
Aldrin				25	NOEC	Beans	(7)
Chlordane				1.8	10% LOEC	Beans	(7)
4,4'-DDT	2.25	NOEL	(4)	2.3	10% LOEC	Soybean	(7)
Endosulfan				10	1% EC50	Lettuce	
Endrin	0.45	10% LOEL	(4)	7.5	10% LOEC	Tomatoes	(7)
Heptachlor				6	10% LOEC	Sudan grass	(7)
Methoxychlor				12.5	NOEC	Beans	(7)
PCBs				40	Multispecies LOEL	Several	(8)

* Reported no-effect levels (NOEL), or values extrapolated as10% LOEL, or 1% LC50. Extrapolation factors by Ford et al. (1992).

** Soil remediation criteria for three land uses (CCME, 1991). Values were derived as protective of vegetation, and soil organisms, and the food chain dependent upon them.

1. Neuhauser et al., 1985a (2-week survival test of the earthworm Eisenia foetida in artificial soil).
2. Neuhauser et al., 1985a (48-hour contact tests of Eisenia foetida. Results were extrapolated to soil concentrations based on earthworm survival data for 1,2 dichloropropane for volatiles; fluorene for PAHs; and dimethylphthalate for phthalates).
3. Screening benchmarks by Will and Sutter (1994b). Values are based on potential toxicity by direct exposure to soils (10th percentile of ranked low-effect data).
4. Thompson, 1971 (number of earthworms in soil test plots).
5. Reinecke & Nash, 1989 (7-day bioaccumulation data and 85-day survival tests of two earthworm species).
6. Effect concentration 50% inhibiting of lettuce seedlings in 14-day tests (Hulzebos, 1993).
7. Maximum surface application rates resulting in no-apparent effects (NOEL) or low-effect levels (LOEL) on crops (EPA, 1977). Data were recalculated as soil concentrations assuming negligible pesticide degradation, a 6-inch penetration in soils, and a 1.5 soil specific gravity (1 kg/ha = 450 ug/kg).
8. The 10th percentile of ranked low-effect data for various species (Will and Sutter, 1994b).

studies reporting no-observed-effect concentrations on earthworm species during exposure to contaminated soils (Reinecke and Nash, 1984; Thompson, 1971).

Benchmarks for effects of metals, phenolic substances, and chlorobenzenes on soil and litter invertebrates were obtained from Will and Suter (1994b). Using the methodology previously described for development of screening benchmarks for vegetation, Will and Suter (1994b) developed separate benchmarks for soil microbial organisms (M-benchmarks) and for earthworms (E-benchmarks). Both types of benchmarks represent the 10th percentile of the ranked data on lowest-observed-effect concentrations (or the lowest LOEL available when less than 10 data points were available). For the risk assessment, the lowest of the two reference values reported by Will and Suter (M-benchmark or E-benchmark) was selected as the screening benchmark value for potential effects on soil organisms. For two metals, chromium and mercury, benchmarks for microorganisms were used because the lowest benchmark (based on earthworm data) was below typical concentrations in U.S. soils.

Benchmarks for several organic compounds are toxicity data reported by Neuhauser et al. (1985) for the earthworm *Eisenia foetida* in acute exposure tests. Reported test results, expressed as a soil concentration resulting in 50 percent mortality (LC_{50}) were divided by an extrapolation factor of 100 to obtain a no-observed-effect concentration (extrapolation factor from Ford et al., 1992). Data reported by Neuhauser et al. (1985) for 1,2 dichloropropane, fluorene, and dimethylphthalate were obtained by direct testing in soils (14-day exposures), while data for other organic compounds were obtained in 48-hour filter-paper contact tests. The contact-test data were converted to a soil concentration based on the ratio of LC_{50} values between each target compound and values for the three reference compounds tested in soils: 1,2 dichloropropane for volatile organics, fluorene for polycyclic aromatic hydrocarbons, and dimethylphthalate for phthalates.

5.3 BENCHMARKS FOR EFFECTS ON WILDLIFE

Benchmarks for screening of potential effects on mammals and birds by dietary ingestion are summarized in Tables 5.3 and 5.4, respectively. Values selected as benchmarks represent no observed adverse effect levels (NOAEL) by dietary intake reported for a selected test species. In the selection of benchmarks, preference was given to toxicological data documenting effects on reproduction and development associated with chronic exposures. Most NOAELs used in the risk evaluation, summarized by Opresko et al. (1994), are data obtained using laboratory mice, rats, and mallard ducks as test organisms. Other toxicological data used in benchmark development were obtained from summary documents by EPA (1993e), Extoxnet (1993), Hill and Camardese (1986), Hudson et al. (1984), Sax (1984), and US Fish and Wildlife Service (USFWS, 1986a).

For chemical compounds without reported chronic NOAELs, extrapolations were made from subchronic tests, and from tests documenting two other effect levels: the lowest observed adverse effect level (LOAEL) and the lethal dose to 50 percent of the test

Table 5.3. Screening Benchmarks for Potential Effects on Mammals by Dietary Intake

	Benchmark for Food Ingestion (mg/kg bw/d)	Extra-polation Factor *	Experimental Conditions				
			Dose (mg/kg bw/d)	Test Species	Effect and Exposure **	Test Endpoints	Ref. ***
Volatile Organic Compounds							
Acetone	10	10	100	Rat	NOAEL / Subchronic	Physiology	(1)
Benzene	53	5	264	Mouse	LOAEL / Chronic	Reproduction	(1)
2-Butanone	34	100	3,400	Rat	LD50 / Acute	Survival	(3)
Carbon tetrachloride	16	1	16	Rat	NOAEL / Chronic	Reproduction	(1)
Chlorobenzene	22	100	2,190	Rat	LD50 / Acute	Survival	(8)
Chloroform	15	10	150	Rat	NOAEL / Subchronic	Physiology	(1)
1,2-Dichloroethane	50	1	50	Mouse	NOAEL / Chronic	Reproduction	(1)
1,1-Dichloroethylene	30	1	30	Rat	NOAEL / Chronic	Growth, physiology	(1)
1,2-Dichloroethylene	45	10	452	Mouse	NOAEL / Subchronic	Growth, survival	(1)
Ethyl acetate	90	10	900	Rat	NOAEL / Subchronic	Growth, survival	(1)
Ethylbenzene	35	100	3,500	Rat	LD50 / Acute	Survival	(3)
Methanol	50	10	500	Rat	NOAEL / Subchronic	Physiology, survival	(1)
Methylene chloride	5.9	1	5.9	Rat	NOAEL / Chronic	Physiology	(1)
4-Methyl 2-pentanone	25	10	250	Rat	NOAEL / Subchronic	Physiology	(1)
1,1,2,2-Tetrachloroethylene	2.0	10	20	Mouse	NOAEL / Subchronic	Physiology	(1)
Toluene	52	5	260	Mouse	LOAEL / Chronic	Reproduction	(1)
1,1,1-Trichloroethane	1,000	1	1,000	Mouse	NOAEL / Chronic	Reproduction	(1)
Trichloroethylene (TCE)	5.0	20	100	Mouse	LOAEL / Subchronic	Physiology	(1)
Vynil chloride	0.3	5	1.70	Rat	LOAEL / Chronic	Longevity	(1)
Xylene (Total)	2.1	1	2.06	Mouse	NOAEL / Chronic	Reproduction	(1)
Polycyclic Aromatic Hydrocarbons							
Benzo(a)pyrene	2.0	5	10	Mouse	LOAEL / Chronic	Reproduction	(1)
Fluoranthene	20	100	2,000	Mouse, rat	LD50 / Acute	Survival	(6)
Naphthalene	18	100	1,780	Mouse, rat	LD50 / Acute	Survival	(6)
Phenanthrene	7.0	100	700	Mouse, rat	LD50 / Acute	Survival	(6)
Miscellaneous Organics							
Bis(2-ethylhexyl)phthalate	18	1	18.3	Mouse	NOAEL / Chronic	Reproduction	(1)
Cyanide	14	5	68.7	Rat	LOAEL / Chronic	Reproduction	(1)
Diethylphthalate	4,580	1	4,580	Mouse	NOAEL / Chronic	Reproduction	(1)
Di-n-butylphthalate	550	1	550	Mouse	NOAEL / Chronic	Reproduction	(1)
Di-n-hexylphthalate	110	5	550	Mouse	LOAEL / Chronic	Reproduction	(1)
Hexachlorobenzene	120	1	120	Rat	NOAEL / Chronic	Reproduction	(4)
Pentachlorophenol	0.5	100	50	Rat	LD50 / Acute	Survival	(3)
Phenol	5.3	100	530	Rat	LD50 / Acute	Survival	(3)
Dioxins and Furans							
Hexachloro dibenzofuran	0.0002	10	0.0016	Rat	NOAEL / Subchronic	Growth, physiology	(1)
Pentachloro dibenzofuran	0.0002	10	0.0016	Rat	NOAEL / Subchronic	Growth, physiology	(1)
Tetrachloro dibenzodioxin	0.000001	1	0.000001	Rat	NOAEL / Chronic	Reproduction	(1)
Pesticides and PCBs							
Aldrin	0.20	1	0.20	Rat	NOAEL / Chronic	Reproduction	(1)
BHC - mixed isomers	0.32	5	1.60	Rat	NOAEL / Chronic	Reproduction	(1)
BHC - beta	0.40	10	4.00	Rat	NOAEL / Subchronic	Growth, physiology	(1)
Carbaryl	8.50	100	850	Rat	LD50 / Acute	Survival	(8)
Chlordane	4.6	1	4.58	Mouse	NOAEL / Chronic	Reproduction	(1)
4,4'-DDT	0.50	1	0.50	Rat	NOAEL / Chronic	Reproduction	(7)
Dieldrin	0.04	5	0.20	Rat	LOAEL / Chronic	Reproduction	(1)
Endosulfan	0.15	10	1.50	Rat	NOAEL / Subchronic	Growth, physiology	(1)
Endrin	0.18	5	0.92	Mouse	LOAEL / Chronic	Reproduction	(1)
Heptachlor	0.80	1	0.80	Rat	NOAEL / Chronic	Reproduction	(1)
Lindane (gamma BHC)	8.0	1	8.00	Rat	NOAEL / Chronic	Reproduction	(1)
Malathion	10	100	1,000	Rat	LD50 / Acute	Survival	(4)
Methoxychlor	4.0	1	4.00	Rat	NOAEL / Chronic	Reproduction	(1)
Toxaphene	8.0	1	8.00	Rat	NOAEL / Chronic	Reproduction	(1)
PCB - Aroclor 1254	0.14	10	1.35	Mouse	NOAEL / Subchronic	Reproduction	(1)

Table 5.3, continued

	Benchmark for Food Ingestion (mg/kg bw/d)	Extra-polation Factor *	Experimental Conditions Dose (mg/kg bw/d)	Test Species	Effect and Exposure **	Test Endpoints	Ref. ***
Herbicides							
2,4-D	3.8	100	375	Rat	LD50 / Acute	Survival	(4)
2,4-DB	20	100	1,960	Rat	LD50 / Acute	Survival	(4)
Dicamba	17	100	1,707	Rat	LD50 / Acute	Survival	(4)
Dichloroprop (2,4-DP)	8.0	100	800	Rat	LD50 / Acute	Survival	(4)
Dinoseb	0.40	100	40	Rat	LD50 / Acute	Survival	(4)
MCPA	15	1	15	Rat	NOAEL / Chronic	Growth	(4)
MCPB	6.8	100	680	Rat	LD50 / Acute	Survival	(4)
MCPP	9.3	100	930	Rat	LD50 / Acute	Survival	(4)
2,4,5-T (Silvex)	6.5	100	650	Rat	LD50 / Acute	Survival	(4)
Metals							
Aluminum	3.9	5	19.3	Mouse	LOAEL / Chronic	Reproduction	(1)
Antimony	0.25	5	1.25	Mouse	LOAEL / Chronic	Longevity	(1)
Arsenic	0.25	5	1.26	Mouse	LOAEL / Chronic	Reproduction	(1)
Barium	5.1	1	5.06	Rat	NOAEL / Chronic	Growth, physiology	(1)
Beryllium	0.66	1	0.66	Rat	NOAEL / Chronic	Growth, longevity	(1)
Cadmium	0.50	5	2.52	Mouse	LOAEL / Chronic	Reproduction	(1)
Chromium III	4,000	1	4,000	Rat	NOAEL / Chronic	Longevity, reproduction	(1)
Chromium VI	3.3	1	3.28	Rat	NOAEL / Chronic	Growth	(1)
Copper	9.4	100	940	Rat	LD50 / Acute	Survival	(3)
Lead	8.0	1	8.0	Rat	NOAEL / Chronic	Reproduction	(1)
Lithium	50	1	50.0	Rat	NOAEL / Chronic	Reproduction	(1)
Managnese	88	1	88.0	Rat	NOAEL / Chronic	Reproduction	(1)
Mercury - inorganic	13	1	13.2	Mouse	NOAEL / Chronic	Longevity, physiology	(1)
Mercury - methyl	0.03	1	0.032	Rat	NOAEL / Chronic	Reproduction	(1)
Nickel	40	1	40.0	Rat	NOAEL / Chronic	Reproduction	(1)
Selenium	0.15	5	0.75	Mouse	LOAEL / Chronic	Reproduction	(1)
Silver	0.50	100	50	Mouse	LD50 / Acute	Survival	(3)
Strontium	263	1	263	Rat	NOAEL / Chronic	Growth, physiology	(1)
Thallium	0.04	20	0.74	Rat	LOAEL / Subchronic	Physiology	(1)
Uranium	3.1	1	3.07	Mouse	NOAEL / Chronic	Reproduction	(1)
Vanadium	1.0	5	5.00	Rat	LOAEL / Chronic	Reproduction	(1)
Zinc	160	1	160	Rat	NOAEL / Chronic	Reproduction	(1)
Zirconium	0.35	5	1.74	Mouse	LOAEL / Chronic	Longevity	(1)

* Benchmarks are calculated as the dose divided by extrapolation factors to no-effect levels according to guidelines by Ford et al. (1992).

** NOAEL: no observed adverse effect level; LOAEL: lowest observed adverse effect level; LD50: lethal dose to 50% of the organisms. Chronic exposures evaluate critical stages of the organism's life cycle.

*** Data from multiple sources summarized by (1) Opresko et al., 1994; (2) Hudson et al., 1984; (3) Sax, 1986; (4) Extoxnet, 1993; (5) Ford et al, 1992; (6), USFWS, 1986; (7) EPA, 1993; (8) Vershueren, 1983.

Table 5.4 Screening Benchmarks for Potential Effects on Birds by Dietary Intake

	Benchmark for Food Ingestion (mg/kg bw/d)	Extra-polation Factor *	Experimental Conditions				
			Dose (mg/kg bw/d)	Test Species	Effect and Exposure **	Test Endpoints	Ref. ***
Volatile Organic Compounds							
Acetone	40	100	4,000	Japanese quail	LD50 / Acute	50% Survival	(5)
Carbon tetrachloride	5.0	100	500	Japanese quail	LD50 / Acute	50% Survival	(5)
1,2-Dichloroethane	17.2	1	17.2	Chicken	NOAEL / Chronic	Reproduction	(1)
Xylene (Total)	20	100	2,000	Japanese quail	LD50 / Acute	50% Survival	(5)
Polycyclic Aromatic Hydrocarbons							
Phenanthrene	200	20	4000	Mallard duck	LOAEL / Subchronic	Survival, growth	(6)
Miscellaneous Organics							
bis(2-ethylhexyl)phthalate	1.11	1	1.11	Ringed dove	NOAEL / Chronic	Reproduction	(1)
Di-n-butylphthalate	0.22	5	1.11	Ringed dove	LOAEL / Chronic	Reproduction	(1)
Hexachlorobenzene	0.57	100	56.80	Japanese quail	LD50 / Acute	50% Survival	(4)
Pentachlorophenol	5.13	100	513	Japanese quail	LD50 / Acute	50% Survival	(5)
Pentachloro nitrobenzene	7.07	1	7.07	Chicken	NOAEL / Chronic	Reproduction	(1)
Dioxins and Furans							
Tetrachloro dibenzodioxin (TCDD)	0.000014	1	0.000014	Ring-necked pheasant	NOAEL / Chronic	Reproduction	(1)
Tetrachloro dibenzofuran (TCDF)	0.00001	20	0.00010	Chicken	LOAEL / Subchronic	Survival, growth	(1)
Pesticides and PCBs							
Aldrin	0.062	100	6.20	Japanese quail	LD50 / Acute	50% Survival	(5)
BHC - mixed isomers	0.563	1	0.563	Japanese quail	NOAEL / Chronic	Reproduction	(1)
BHC - beta	1.180	100	118	Pheasant	LD50 / Acute	50% Survival	(2)
Carbaryl	10.0	100	1,000	Japanese quail	LD50 / Acute	50% Survival	(5)
Chlordane	2.14	1	2.14	Red-winged blackbird	NOAEL / Chronic	Survival, growth	(1)
4,4'-DDE	0.859	100	85.90	Japanese quail	LD50 / Acute	50% Survival	(5)
4,4'-DDT	0.12	1	0.12	Mallard duck	NOAEL / Chronic	Reproduction	(7)
Dieldrin	0.077	1	0.077	Barn owl	NOAEL / Chronic	Reproduction	(1)
Endosulfan	10.0	1	10.00	Gray partridge	NOAEL / Chronic	Reproduction	(1)
Endrin	0.30	1	0.30	Mallard duck	NOAEL / Chronic	Reproduction	(1)
Heptachlor	20.8	100	2,080	Mallard duck	LD50 / Acute	50% Survival	(2)
Lindane (gamma BHC)	4.00	5	20.00	Mallard duck	LOAEL / Chronic	Reproduction	(1)
Malathion	1.67	100	167	Pheasant	LD50 / Acute	50% Survival	(2)
Methoxychlor	20.0	100	2,000	Mallard, quail	LD50 / Acute	50% Survival	(2)
Toxaphene	0.53	100	52.90	Japanese quail	LD50 / Acute	50% Survival	(5)
PCBs - Aroclor 1242	0.41	1	0.41	Screech owl	NOAEL / Chronic	Reproduction	(1)
Aroclor 1254	1.45	1	1.45	Mallard duck	NOAEL / Chronic	Reproduction	(7)
Herbicides							
2,4-D	6.7	100	668	Japanese quail	LD50 / Acute	50% Survival	(4)
MCPA	20.0	100	2,000	Bobwhite quail	LD50 / Acute	50% Survival	(4)
2,4,5-T (Silvex)	5.0	100	500	Pheasant	LD50 / Acute	50% Survival	(2)
Inorganic Compounds							
Aluminum	111	1	111	Ringed dove	NOAEL / Chronic	Reproduction	(1)
Arsenic	5.14	1	5.14	Mallard duck	NOAEL / Chronic	Survival	(1)
Barium	20.8	10	208	Chicken	NOAEL / Subchronic	Survival	(1)
Cadmium	15.2	1	15.20	Mallard duck	NOAEL / Chronic	Reproduction	(1)
Chromium III	1.0	1	1.00	Black duck	NOAEL / Chronic	Reproduction	(1)
Copper	33.2	1	33.20	Chicken	NOAEL / Chronic	Growth	(1)
Fluoride	7.8	1	7.80	Screech owl	NOAEL / Chronic	Reproduction	(1)
Lead	3.85	1	3.85	American kestrel	NOAEL / Chronic	Reproduction	(1)
Mercury - inorganic	5.09	100	509	Japanese quail	LD50 / Acute	50% Survival	(5)
Mercury - methyl	0.013	5	0.064	Mallard duck	LOAEL / Chronic	Reproduction	(1)
Nickel	77.4	1	77.4	Mallard duck	NOAEL / Chronic	Survival, growth	(1)
Selenium	0.50	1	0.50	Mallard duck	NOAEL / Chronic	Reproduction	(1)
Thallium	0.24	100	23.7	Pheasant	LD50 / Acute	50% Survival	(2)
Uranium	16.0	10	160	Black duck	NOAEL / Subchronic	Survival, growth	(1)
Vanadium	11.4	1	11.4	Mallard duck	NOAEL / Chronic	Survival, growth	(1)
Zinc	15.0	20	300	Mallard duck	LOAEL / Subchronic	Survival, growth	(1)

* Benchmarks are calculated as the dose divided by extrapolation factors to no-effect levels according to guidelines by Ford et al. (1992).

** NOAEL: no observed adverse effect level; LOAEL lowest observed adverse effect level; LD50: lethal dose to 50% of the organisms. Chronic exposures evaluate critical stages of the organism's life cycle.

*** Data from multiple sources summarized by (1) Opresko et al., 1994; (2) Hudson et al., 1984; (3) Sax, 1986; (4) Extoxnet, 1993; (5) Hill & Camardese, 1986; (6) USFWS, 1986; (7) EPA, 1993.

organisms (LD_{50}). Extrapolation factors, based on guidelines by Ford et al. (1992), are as follows:

Chronic NOAEL	= 20% Chronic LOAEL
	= 10% Subchronic NOAEL
	= 5% Subchronic LOAEL
	= 1% LD_{50}

Site-specific extrapolations of benchmarks from tests species to selected ecological receptors are discussed in the last section of the ecological effects characterization.

5.4 BENCHMARKS FOR EFFECTS ON AQUATIC ORGANISMS

Benchmarks for aquatic life were obtained from federal ambient water quality criteria (AWQC) developed by EPA for chronic exposures to contaminants (EPA, 1991a). These criteria are regulatory values intended to protect fish and other aquatic life. The AWQC were derived by EPA from toxicological data documenting no-observed effect levels for the set of most sensitive fish and invertebrate species. Tables 5.5 and 5.6 lists chronic AWQC promulgated by EPA including some criteria proposed but not yet formally adopted by the agency. Freshwater criteria for cadmium, chromium, copper, lead, nickel, and zinc were calculated for site-specific hardness using predictive equations developed by EPA (1991).

Because an extensive toxicological database is required for AWQC development, water quality criteria are mostly available for metals and pesticides. To increase the number of reference values used for screening of contaminants in the ecological risk evaluation, secondary chronic values (SCV) were used as benchmark values when AWQC were unavailable. The SCV, developed by the Oak Ridge National Laboratory (Suter and Mabrey, 1994), are intended to provide an aquatic life protection level that, in 80 percent of the cases, matches the protection levels associated with federal AWQC.

The most stringent of the following four parameters was used by Suter and Mabrey (1994) as secondary chronic values: 1) the lowest chronic values for fish and daphnids, 2) chronic toxicity tests for fish and daphnids documenting the 20-percent effect concentration (EC_{20}), 3) the estimated EC_{20} for selected sensitive aquatic species, and 4) the concentration estimated to cause a 20 percent reduction in recruitment abundance of largemouth bass. The methods employed by Suter and Mabrey are based on the draft Great Lakes Water Quality Initiative Tier II method developed by EPA.

SCVs reported by ORNL were used as benchmarks in the risk assessments when AWQC were unavailable. SCVs were also used as benchmarks for chlordane, DDT, heptachlor, and PCBs because their AWQC are based on human health protection from ingestion of

Table 5.5 Screening Benchmark Values for Metals in Water and Sediment Quality

	CAS Number	WATER QUALITY AQUATIC LIFE CRITERIA (ug/L) * — Freshwater Criteria — EPA's Acute Criteria	Chronic Criteria — EPA	Chronic Criteria — Secondary		Marine Criteria — Acute Value	Marine Criteria — Chronic Value	SEDIMENT CRITERIA (ug/kg) — Equilibrium Partitioning Approach**	Screening Level Concentration ***
Metals/Other Inorganics									
Aluminum		750	87					NA	
Antimony (1)	7440360		30	104			500	150	
Arsenic (Total)	7440382							57	8,200
Arsenic III	22569728	360	190			69	36	NA	
Arsenic V				8.1				NA	
Barium				3.8				NA	
Beryllium	7440417			5.3	(3)			NA	
Boron				547				NA	
Cadmium (2)	7440439	3.9	1.1			43	9.3	5.1	1,200
Chromium (Total)	1333820							260	81,000
Chromium III (2)	1308141	1,737	207					NA	
Chromium VI	7440473	16	11			1100	50	NA	
Cobalt				3.1				NA	
Copper (2)	7440508	17.7	11.8			2.9	2.9	390	34,000
Cyanide	57125	22	5.2			1.0	1.0		
Lead (2)	7439921	81.6	3.2			220	8.5	450	46,700
Mercury (Total)	7439976			1.3	(4)	2.1		0.41	150
Molybdenum				239				NA	
Nickel (2)	7440020	1,418	158			75	8.3	140	20,900
Selenium	7782492	20	5	35		300	71	NA	
Silver	7440224	4.06				2.3	0.92	6.1	1,000
Thallium	7440280			18				NA	
Tin				73.7				NA	
Zinc (2)	7440666	117	106			95	86	410	150,000

NOTES:

* Federal criteria from EPA (1991); secondary chronic value (SCV) from Hull and Suter (1994).

** Values indicate the apparent effects threshold (NOAA, 1994).

*** Empirically-derived low-effect level (ER-L) for sediment-associated organisms (NOAA, 1994).

(1) Proposed criteria

(2) Water quality criteria are dependent on water hardness. Reference value in mg/L $CaCO_3$: 100

(3) LOELs reported by EPA (1991) were used as alternative secondary criteria.

(4) EPA's values based on tissue residue were replaced by SCV for aquatic life protection.

Table 5.6 Screening Benchmark Values for Organic Substances in Water and Sediment Quality

	CAS Number	Log Kow ****	WATER QUALITY AQUATIC LIFE CRITERIA (ug/L) * *Freshwater Criteria* EPA's Acute Criteria	*Freshwater Criteria* Chronic Criteria EPA	*Freshwater Criteria* Chronic Criteria Secondary	*Marine Criteria* Acute Value	*Marine Criteria* Chronic Value	SEDIMENT CRITERIA (ug/kg) *Equilibrium* Partitioning Approach**	*Screening* Level Concentration ***
Volatile Organic Compounds									
Acetone	67641	-0.20			11,200			71	
Acrolein	107028	0.90			21 (3)			1.61	
Acrylonitrile	107131	1.20			2,600 (3)			393	
Benzene	71432	2.11			45.5			54	
Benzidine		1.81			3.86			2.32	
Carbon disulfide	75150	2.20			8.9			13	
Carbon tetrachloride	56235	2.80			229			1296	
Chlorobenzene	108907	3.79			127			6755	
Chloroform	67663	1.90			188			139	
1,1-Dichloroethane	75343	1.78			46.6			26	
1,2-Dichloroethane	75343	1.45			1100			293	
1,1-Dichloroethylene	75354	1.50			196			58	
1,2-Dichloroethylene	540590	1.90			31.2			23	
1,3-Dichloropropane	26638197	2.30			25.6			47	
Ethylbenzene	100414	3.15			389			4860	
2-Hexanone	591786				99			-	
4-Methyl-2-pentanone	108101	1.20			164			25	
Methylene Chloride	75092	1.30			2240			425	
1,1,2,2-Tetrachloroethane	79345	2.39			125			280	
Tetrachloroethylene	127184	3.40			71.3			1569	
Toluene	108883	2.21			176			262	
1,1,1-Trichloroethane	71556	2.47			62.1			166	
1,1,2-Trichloroethane	79005	2.18			715			994	
Trichloroethylene	79016	2.40			354			810	
Xylene (Total)	1330207	3.20			86			1203	
Semivolatile Organics: PAHs									
Acenaphthene	83329	3.92	80	23				1642	16
Acenaphthylene	208968	4.07							44
Anthracene	120127	4.54			0.0013			0.38	85
Benzo(a)anthracene	56553	5.91			0.027			174	261
Benzo(a)pyrene	50328	6.42			0.014			287	430
Chrysene	218019	5.79							384
Dibenzo(a,h)anthracene	53703	6.50							63
Fluoranthene	206440	5.22					16	6200 (5)	600
Fluorene	86737	4.38							19
Methylnaphthalene (Total)	1321944				2.1			0.02	70
Naphthalene	91203	3.36			23.4			470	160
Phenanthrene (1)	85018	4.57		6.3	3.2		4.6	1800 (5)	240
Pyrene	129000	5.18							685
Total PAHs									4,020

Table 5.6, continued

	CAS Number	Log Kow ****	WATER QUALITY AQUATIC LIFE CRITERIA (ug/L) * Freshwater Criteria: EPA's Acute Criteria	Freshwater Chronic Criteria: EPA	Freshwater Chronic Criteria: Secondary		Marine Criteria: Acute Value	Marine Criteria: Chronic Value	SEDIMENT CRITERIA (ug/kg) Equilibrium Partitioning Approach**	Screening Level Concentration ***
Other Semivolatile Organics										
Benzoic Acid	65850				41.6				-	
Benzyl alcohol	100516				58				-	
Dibenzofuran	132649	4.10			20.4				2189	
2,4-Dichlorophenol	120832	3.08			365	(3)			3892	
Diethyl phthalate	131113	1.40			220				52	
Di-n-butyl phthalate	84742	4.13			32.7				3755	
2,4-Dinitrotoluene	121142	2.00			230	(3)			213	
Di-n-octyl phthalate	117840	8.06			708				593325833	
bis(2-Ethylhexyl)phthalate (1)	117817	4.20	400	360			400	360	48438	
Hexachlorobenzene (1)	118741	5.47		3.68					8773	
2-Methylphenol (o-cresol)	95487				72.2				-	
Nitrophenols		2.91			163				1183	
N-Nitrosodimethylamine	62759	-0.60			24.5				0.06	
Pentachlorophenol (2)	87865	5.00	20	0	117		13	7.9	4.15	
Phenol	108952	1.46			2560	(3)			698	
2,4,5-Trichlorophenol (1)	95954	3.40		63				11	1386	
2,4,6-Trichlorophenol	88062	3.69			970	(3)			41145	
Pesticides and PCBs										
Aldrin		7.40	3				1.3			
Chlordane	57749	6.42	2.4		0.17	(4)	0.09		3480	
4,4'-DDT	50293	6.36	1.1		0.04	(4)	0.13		715	1.6
Dieldrin	60571	6.20	2.5				0.71		11 (5)	
Endosulfan	115297	3.60	0.22	0.056			0.034	0.0087	1.94	
Endrin	72208	4.56	0.18	0.0023			0.037	0.0023	4.2 (5)	
Heptachlor	76448	5.44	0.52		0.029	(4)	0.053	0.0036	65	
Heptachlor epoxide	1024573	5.40	0.52		0.029	(4)	0.053	0.0036	59	
Lindane (gamma-BHC)	58899	3.72	2	0.08			0.16	0.03	3.63	
Malathion	121755	2.89		0.1				0.1	0.69	
Mirex	2385855	6.89		0.001				0.001	59	
Methoxychlor	72435	4.30		0.03				0.03	5.06	
Parathion	56352	3.81	0.065	0.013					0.72	
PCBs (Total)	1336363	6.20			0.19	(4)		0.03	2364	23
Toxaphene	8001352	3.30	0.73	0.0002			0.21	0.0002	0.004	
2,3,7,8-TCDD	1746016	6.10			0.00001	(3)			0.10	

* Federal criteria from EPA (1991); secondary chronic value (SCV) from Hull and Suter (1994).

** Sediment quality benchmark (SQB) calculated for organic substances were calculated from water quality criteria (WQC) using the equilibrium-partitioning approach (EPA, 1993f):
SQB (ug/kg) = WQC (ug/L) x Koc x OC; where, OC = % organic carbon in the sediments, and log Koc = 0.00028 + 0.983 log Kow. % OC= 1

*** Empirically-derived low-effect level (ER-L) for sediment-associated organisms (NOAA, 1994).

**** Log Kow values from Table 1 of Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish, EPA, 1989.

(1) Proposed criteria

(2) pH-dependent criteria. Reference value: 7.8

(3) LOELs reported by EPA (1991) were used as alternative secondary criteria.

(4) EPA's values based on tissue residue were replaced by SCV for aquatic life protection.

(5) Sediment quality criteria formally adopted by EPA (1994).

residues in fish tissues, not on protection of aquatic life. For chemical compounds lacking secondary chronic values, LOEL values reported by EPA (1991) were used as alternative benchmarks for the risk assessment.

For exposure of amphibians to contaminants in water, toxicological data on tadpoles were obtained from EPA's Aquatic Information Retrieval (AQUIRE) database. Table 5.7 lists benchmark values for the exposure of amphibians to metals and organic substances.

5.5 BENCHMARKS FOR EFFECTS ON SEDIMENT-ASSOCIATED ORGANISMS

Two main approaches have been used in development of guidelines for protection of sediment-associated organisms: 1) the equilibrium-partitioning approach (EqP method), adopted by EPA as basis for development of sediment quality guidelines for nonpolar organic compounds (EPA, 1993c, 1994), and 2) the screening-level concentration (SLC) approach, a method that empirically relates an extensive sediment contaminant database to reported effect levels on sediment-associated organisms (Long and Morgan, 1990).

Sediment quality screening benchmarks used in the risk assessments were based on the EqP approach for organic chemicals. Data obtained with the use of the SLC approach were used for all metals (Table 5.5), and for those organic substances lacking water quality criteria (Table 5.6). The basis for benchmark derivation is presented below.

Equilibrium Partitioning Approach. This methodology extrapolates the use of ambient water quality criteria (AWQC) to the sediment pore water under the assumption that chemical substances exert toxicity only to the extent that they desorb from the sediments and become bioavailable. The concentration and bioavailability of nonpolar organics in the pore water have been found to be consistently related to the fraction of organic carbon in the sediment (f_{oc}). For sediments with organic carbon content exceeding 0.5 percent, the bioavailable fraction of a chemical can be predicted from its partitioning, at equilibrium, between the particulate organic matter and the sediment pore water (EPA, 1993c). The predictive equation is:

$$\text{Bioavailable concentration} = \text{Total sediment concentration} / (f_{oc} \times K_{oc})$$

where, K_{oc} is the sediment/organic carbon partition coefficient, generally estimated from the more accurately-measured octanol/water partition coefficient, K_{ow}, as:

$$\log K_{oc} = 0.00028 + 0.983 \log K_{ow}$$

The sediment quality benchmark (SQB) for a given chemical was then calculated by application of the AWQC to the total sediment concentration as:

$$SQB = AWQC \times f_{oc} \times K_{oc}$$

Table 5.7 Benchmarks for Potential Effects on Amphibians

Chemical	Chronic Toxicity Value* (mg/L)	LC_{50} 96-hour (mg/L)	LC_{50} ** (mg/L)	Test Species: Common Name	Test Species: Scientific Name	Reference ***
Dissolved Metals						
Aluminum	47.46	1800		African clawed toad	*Xenopus laevis*	AQUIRE # 311700
Antimony						
Arsenic	0.07	0.249		Six-digit frog	*Rana hexadactyla*	AQUIRE # 311438
Beryullium						
Boron						
Cadmium	0.28	1.58		Answering frog	*Microhyla ornata*	Jayaprakash and Madhyastha, 1987
Chromium III						
Chromium VI						
Cobalt	0.48		3.3			Plowman et al., 1991
Copper	0.65	5.04		Answering frog	*Microhyla ornata*	Jayaprakash and Madhyastha, 1987
Lead	2.58	33.28		Six-digit frog	*Rana hexadactyla*	AQUIRE # 311438
Manganese	1.43	14.84				Jayaprakash and Madhyastha, 1987
Mercury	0.22	1.12		Answering frog	*Microhyla ornata*	Jayaprakash and Madhyastha, 1987
Molybdenum						
Nickel	2.11	25.32		Common indian toad	*Bufo Bufo japonicus*	AQUIRE # 312339
Selenium						
Silver	0.01	0.025		Six-digit frog	*Rana hexadactyla*	AQUIRE # 311438
Thallium						
Vanadium						
Zinc	1.93	22.41		Answering frog	*Microhyla ornata*	Jayaprakash and Madhyastha, 1987
Organic Compounds						
Chlorobenzene	0.01	0.4		Western chorus frog	*Pseudaeris triseriata triseria*	AQUIRE # 212891
Chloromethane	1.60	40		Common indian toad	*Bufo Bufo japonicus*	AQUIRE # 216288
Pesticides						
Heptachlor	0.01		0.44	Fowler's toad	*Bufo woddhousei fowlesi*	AQUIRE # 212891

* Chronic toxicity value was derived from the 50 percent lethal concentration at 96 hours (LC50 hour) using the equations:
Lowest chronic value, metallic: log CV = 0.73 log LC50 - 0.70; nonmetallic: log CV = 1.07 log LC50 - 1.51 (Suter and Mabrey, 1994).
** Exposure duration not reported.
*** AQUIRE reference numbers refer to EPA's on-line database "Aquatic Toxicity Information Retrieval System".

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Site-specific f_{OC} was calculated based on measured total organic carbon (TOC). The SQB method can also be used for nonpolar organic chemicals with no AWQC and K_{ow} values greater than 2 and less than 5.5. Examples of SQBs based on the EqP method are listed in Table 5.6, along with sediment quality criteria formally proposed by EPA for acenaphthene, fluoranthene, phenanthrene, dieldrin, and endrin.

Screening-Level Concentration (SLC). The SLC methodology empirically relates observations on the health and community structure of sediment-associated macroorganisms to multiple data on sediment contamination. Unlike the EqP approach, the SLC associates the concentration of a given chemical to the species composition and abundance of macroorganisms under natural conditions. The SLC method, however, is not necessarily indicative of a cause-and-effect relationship for a given chemical because observed effects might be biased by the presence of unmeasured contaminants in the sediment, or by the cumulative effect of various chemical substances.

Using an extensive database for marine and estuarine sediments compiled by the National Oceanic and Atmospheric Administration (NOAA), Long and Morgan (1990) derived two concentrations of sediment-sorbed contaminants indicative of potential adverse effects on organisms: the Effects Range-Low (ER-L) and Effects Range-Medium (ER-M). These values represent the 10th and 50th percentiles of the range of concentrations at which adverse effects were reported for each individual chemical substance. For the risk assessments, the ER-L reported by Long and Morgan (1990) was used as a benchmark for screening potential effects on sediment-associated organisms. Because ER-L represents the low end of sediment concentrations with documented adverse effects, this benchmark is assumed to be protective of sediment-associated organisms (a nominal 90 percent protection level).

5.6 BENCHMARK EXTRAPOLATION

Benchmarks are often unavailable for a target chemical or a specific ecological receptor because toxicological data are limited to relatively few chemical compounds tested with laboratory organisms and plants. For the risk assessment, benchmark values were extrapolated between chemical compounds, and from test organisms to selected ecological receptors. The extrapolation criteria are described below.

Extrapolation Between Chemicals. When benchmarks for a specific chemical were not available, the value was obtained from a surrogate compound. When available, data from a closely-related chemical was used as the benchmark in the risk assessment. In cases where this information was unavailable, the compound with the lowest toxicity concentration value reported within a given chemical group was used as a surrogate compound. Surrogate compounds were used for the following chemical groups: volatile organics, polycyclic aromatic hydrocarbons, chlorinated benzenes, pesticides, and herbicides.

Extrapolation Between Organisms. Benchmarks for dietary intake by terrestrial wildlife are largely based on toxicity testing of selected organisms. Among mammals, the most tested organisms are the laboratory rat and mouse. Commonly tested bird species include the mallard duck and various quail species.

Because receptor species might have higher or lower sensitivities to a given contaminant than the test species, data extrapolation is required. There is no unified approach in the scientific community for extrapolation of toxicological data between species, but it is commonly accepted that the uncertainty of the extrapolation increases as the taxonomic difference between the species increases.

The extrapolation method used for wildlife uses the uncertainty factors developed by Ford et al. (1992) based on comparison of toxicological data for mammals. The uncertainty values to be used in the risk assessments are as follows:

- An extrapolation factor of 2 for intraspecies differences;
- An extrapolation factor of 4 between species of the same genus or between closely-related species;
- An extrapolation factor of 8 for families within the same taxonomic order (i.e., between rodents); and,
- An extrapolation factor of 16 for organisms in taxonomic orders within the same class (i.e., between a rodent and an ungulate).

Ford et al. (1992) presented the rationale for selection of the uncertainty values, and provided toxicological data on various mammalian species showing that typical inter-species variation factors (the ratio of highest to lowest LC_{50} reported) were typically less than 5. For nineteen out of twenty chemicals evaluated, the observed intraspecies variations were within the uncertainty factor of 16 proposed for organisms in different taxonomic orders. For aquatic organisms, considerably higher uncertainty factors have been proposed by Calabrese and Baldwin (1993) based on toxicological data for fish and macroinvertebrates (factors of 60 for families within the same taxonomic order and 100 for orders within a taxonomic class). For extrapolation of benchmarks to endangered or special-status species, an additional uncertainty factor of 2 has been proposed as an increased level of protection to the species (Ford et al., 1992; Calabrese and Baldwin, 1993).

An elevated extrapolation factor was applied to nearly all benchmarks used for wildlife species because toxicity of chemical substances is typically tested in laboratory animals rather than on ecological receptors used in the risk assessment. This approach assumes that the ecological receptors are sixteen times more sensitive to a particular chemical than mice, rabbits, quails, and other species commonly used in laboratory tests.

6. QUANTIFICATION OF POTENTIAL RISK

6.1 RISK ASSESSMENT METHODOLOGY

The assessment of ecological risk for the increased discharge of reclaimed water from the Santa Rosa wastewater reclamation facility was based on the calculation of the ecological quotients (EQs). The quotient is a quantitative estimate of possible risk calculated as the ratio between exposure concentration for a given chemical substance and an applicable benchmark value that identifies possible adverse effect levels on ecological receptors. Because several uncertainties are associated with their calculation, EQs only provide order-of-magnitude estimates of the potential for adverse effects, not exact measurements of actual effects on receptor organisms. For the risk assessments, the characterization of potential effects of chemical substances on receptor organisms was based on the following guidelines proposed by Barnthouse et al. (1986) and adopted in subsequent evaluations of ecological risk (EPA, 1989a; Watkin and Stelljes, 1993; Menzie et al., 1993):

1. Adverse effects are not expected for EQ values equal to, or less than, 1;
2. A low potential for environmental effects is indicated by EQ values between 1 and 10;
3. A significant potential for adverse effects is indicated by EQ values greater than 10; EQs in excess of 100 identify a very high probability for adverse effects on ecological receptors and biological communities.

Because contaminants could act in combination to produce greater adverse effects (additive action), cumulative EQ values were calculated for major chemical categories. This approach conservatively assumes that all individual compounds have an additive effect and that their interaction does not result in a reduced potential toxicity (no antagonistic effects).

EQs were calculated for typical and maximum exposure conditions at the site. These exposure scenarios are represented by the average and maximum concentrations detected or anticipated under various alternatives in soil, sediment, and surface water. Average values were calculated on the basis of detected concentrations plus one-half of the analytical quantitation limit for non-detect values.

Ecological risk was evaluated for six major pathways identified for the potential increased exposure of aquatic organisms and wildlife to the discharge from the Santa Rosa wastewater reclamation facility:

1. Direct exposure to the reclaimed water in Santa Rosa Creek and the Laguna de Santa Rosa;

2. Exposure of organisms associated with the Russian River, by direct discharge or through the Laguna de Santa Rosa;
3. Exposure of rooted vegetation, sediment organisms, and waterfowl to sediments in the Laguna Santa Rosa and the Russian River;
4. Exposure of aquatic organisms and wildlife in storage reservoirs;
5. Exposure of soil organisms and terrestrial vegetation by reclaimed water application to irrigation fields (South County, West County, and Sebastopol irrigation areas); and
6. Potential releases from pipelines along the transfer route to the geysers injection area.

Ecological risks for each of these major exposure pathways are discussed below, along with the assumptions used in the exposure analysis. In all cases, the risk methodology was based on the use of ecological quotients that compare expected exposure concentrations in the various media (water, sediments, soils) to specific benchmarks indicative of potential adverse effects on organisms.

6.2 DISCHARGE TO LAGUNA DE SANTA ROSA

6.2.1 Exposure Scenarios

The potential exposure of aquatic organisms and wildlife of Santa Rosa Creek and Laguna de Santa Rosa to chemical substances was evaluated under the assumption that future water quality in these streams will be similar to the current quality of undiluted reclaimed water. This is a conservative exposure scenario because the typical contribution of the reclaimed water to the flow in those two stream will be considerably lower than 100 percent. According to the hydrological model developed for the project (Merritt Smith Consulting, 1996b), a 100-percent contribution of the reclaimed water to the Santa Rosa Creek and the Laguna is not expected to occur. For the maximum design discharge (equivalent to 20 percent of the Russian River flow), the expected average contributions of the reclaimed water to the Laguna and Santa Rosa Creek flows are 17 and 35 percent, respectively. Table 6.1 summarizes the average and high-estimates (50th and 95th percentiles) of reclaimed water contribution to the flow of Santa Rosa Creek, Laguna de Santa Rosa, and the Russian River under four discharge scenarios (design discharges of 1, 5, 10, and 20 percent).

6.2.2 Transfer Pathways

Three transfer pathways were considered for the potential exposure of organisms to constituents in reclaimed water:

1. Direct exposure of aquatic organisms;
2. Stream water ingestion by wildlife species; and

Table 6.1 Estimated Percent Contribution of Reclaimed Water to the Flow of Santa Rosa Creek, Laguna de Santa Rosa, and the Russian River

	Current (No Project)	Discharge to Laguna (as % Russian River flow) 1%	5%	10%	20%	Direct Discharge to Russian River
Santa Rosa Creek						
50th percentile *	29	0	6	11	35	0
95th percentile *	75 **	9 **	49	67	81**	2 **
Laguna at River Road						
50th percentile *	13	0	3	5	17	0
95th percentile *	53 **	4 **	26	43	61**	0.6 **
Russian River at Oddfellows Rd.						
50th percentile *	2	0	0.3	0.6	3	2***
95th percentile *	10	0.5 **	5	10	15	10***

* All values are based on daily averages; dry year for 95th percentile: 1976; average year for 50th percentile: 1961. Data from hydrology model (Merritt Smith Consulting, 1996b).

** Highest 95th percentile value occured in 1961, not 1976.

*** Values at the direct discharge location rather than at Oddfellows Rd.

3. Exposure of piscivorous birds and mammals by fish consumption.

Tadpoles were identified as key receptor organisms for the direct exposure pathway, given the potential presence of endangered frog species in the Laguna and Russian River. For the potential use of the stream as a drinking water source, two common wildlife species were evaluated: the great blue heron and a shrew species. The great blue heron was also selected as the key ecological receptor for potential contaminant transfer via fish consumption. For the risk assessment it was assumed that fish consumption from Laguna de Santa Rosa represents fifty percent of total food intake of the heron given the high mobility of the species and its seasonal change in feeding grounds. This assumption was incorporated in the exposure calculations as a mobility factor of 0.5.

In addition to organisms commonly associated with the Laguna de Santa Rosa, an additional assessment of risk was conducted for chronic exposure of endangered, threatened, or other special-status aquatic species to the reclaimed water. The risk analysis for these organisms was based on the use of more conservative benchmark values, equivalent to one half of the values applicable to other stream organisms. The use of this protection factor for environmentally-sensitive species has been proposed by Ford et al. (1992), and Calabrese and Baldwin (1993).

Aquatic endangered/threatened species potentially associated with Laguna de Santa Rosa include the red-legged frog (*Rana aurora*) and California freshwater shrimp (*Syncaris pacifica*). If present, both species could be chronically exposed to reclaimed water at various concentrations. Freshwater marshes of the Laguna are also a potential habitat for endangered plant species which include various species of sedges and rushes.

6.2.3 Ecological Risk

Ecological quotient calculations for evaluation of potential risks on aquatic organisms and wildlife from exposure to the reclaimed water are presented in Tables 6.2, 6.3, and 6.4 for the direct exposure scenario, fish ingestion, and water intake, respectively.

Direct Exposure. Based on the ecological quotient calculations, no potential risk was identified for direct exposure of aquatic organisms to four groups of chemical substances found at detectable levels in the undiluted reclaimed water: volatile organics, semivolatile organics, pesticides, and metals (Table 6.2). EQs for these substances were below a threshold value of 1 indicative of potential adverse effects on aquatic life. Low EQ values were also calculated for the direct exposure of tadpoles to undiluted reclaimed water indicating that, similarly to other aquatic organisms, there is a low potential for adverse effects of reclaimed water constituents on amphibians (Table 6.2). An EQ value greater than 1 was calculated for a single compound, cyanide. This value indicates a possible risk to sensitive aquatic species by exposure to cyanide.

Water Ingestion. In terms of exposure of wildlife species by direct water ingestion, no potential adverse effects were identified for use of undiluted reclaimed water as sole

Table 6.2 Risk to Freshwater Organisms from Chronic Exposure to Undiluted Reclaimed Water

	EXPOSURE CONCENTRATION		GENERAL RISK TO AQUATIC LIFE			RISK TO AMPHIBIANS (tadpoles)		
	Surface Water Average (mg/L)	Detection Frequency	Benchmark * (mg/L)		Ecological Quotient for Surface Water **	Benchmark * (mg/L)		Ecological Quotient for Surface Water **
Volatile Organic Compounds								
Acetone	0.01060	2 / 14	11.2		0.00	139	(e)	0.00
Bromodichloromethane	0.00220	22 / 23	0.125	(a)	0.02	1.6	(d)	0.00
Bromomethane	0.00043	1 / 16	0.0089	(a)	0.05	1.6	(d)	0.00
Carbon Disulfide	0.00513	3 / 14	0.0089		0.58	110		0.00
Chlorobenzene	0.00038	1 / 19	0.127		0.00	0.01		0.04
Chloroform	0.00990	22 / 23	0.186		0.05	1.6	(d)	0.01
Chloromethane	0.00069	1 / 19	0.125	(a)	0.01	1.6		0.00
Dibromochloromethane	0.00062	4 / 22	0.125	(a)	0.00	NA		
1,4-Dichlorobenzene	0.00075	10 / 13	0.127	(b)	0.01	0.01	(b)	0.08
Ethyl Benzene	0.00040	1 / 19	0.389		0.00	0.01	(b)	0.04
Methylene Chloride	0.00133	5 / 19	2.24		0.00	1.6	(d)	0.00
Tetrachloroethene	0.00039	2 / 19	0.125		0.00	1.6	(d)	0.00
Toluene	0.00040	2 / 19	0.176		0.00	139	(e)	0.00
1,1,1-Trichloroethane	0.00037	1 / 19	0.062		0.01	1.6	(d)	0.00
Xylenes	0.00039	1 / 18	0.086		0.00	139		0.00
			Cumulative EQ		*0.73*	*Cumulative EQ*		*0.16*
			EQ for ETS ****		1.47	EQ for ETS ****		0.33
Semivolatiles / Pesticides								
Bis(2-Ethylhexyl)phthalate	0.00510	5 / 19	0.36		0.01	NA		
Diethylphthalate	0.00140	2 / 19	0.22		0.01	NA		
Aldrin	0.00002	3 / 19	0.00029	(c)	0.06	0.01	(c)	0.00
alpha-BHC	0.00002	2 / 19	0.0024		0.01	0.01	(c)	0.00
Endosulfan II	0.00001	1 / 19	0.00056		0.02	0.01	(c)	0.00
gamma-BHC	0.00003	5 / 19	0.0008		0.03	0.01	(c)	0.00
Heptachlor	0.00002	1 / 19	0.00029		0.07	0.01		0.00
			Cumulative EQ		0.18	Cumulative EQ		0.01
			EQ for ETS ****		0.37	EQ for ETS ****		0.02
Cyanide and Dissolved Metals * **								
Cyanide	0.01200	3 / 6	0.0052		2.31	NA		
Aluminum	0.01100	2 / 8	0.087		0.13	47.46		0.00
Arsenic	0.00250	8 / 8	0.19		0.01	0.072		0.03
Copper	0.00600	8 / 8	0.012		0.50	0.65		0.01
Nickel	0.00300	6 / 8	0.158		0.02	2.11		0.00
Silver	0.00100	2 / 8	NA			0.013		0.08
Zinc	0.03200	8 / 8	0.106		0.30	1.93		0.02
			Cumulative EQ		3.27	Cumulative EQ		0.14
			EQ for ETS ****		6.54	EQ for ETS ****		0.28

NA: Not Available

* Surrogate chemicals: (a) Tetrachloroethane, (b) Chlorobenzene, (c) Heptachlor, (d) Chloromethane, and (e) Xylenes.

** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value.

*** Antimony, Beryllium, Cadmium, Chromium III, Cobalt, Lead, Mercury, Molybdenum, Selenium, Thallium, and Vanadium concentrations were below analytical detection limits.

**** Ecological quotients for endangered, threatened, or special-status species are calculated using a more stringent benchmark (one-half of the value used for other species).

Table 6.3 Risk to Heron from Consumption of Fish Continually Exposed to Undiluted Reclaimed Water

	EXPOSURE ASSESSMENT			RISK FOR FISH INGESTION	
		Tissue Concentration * (mg/kg/dry wt.)	Exposure Rate ** (mg/kg/d)	Benchmark (mg/kg/d)	Ecological Quotient ***
Semivolatiles / Pesticides					
Bis(2-Ethylhexyl)phthalate		NA	NA	1.11	
Diethylphthalate		NA	NA	NA	
Aldrin	<	0.008	0.000	0.062	0.04
alpha-BHC	<	0.008	0.000	0.56	0.00
Endosulfan II	<	0.008	0.000	10	0.00
gamma-BHC	<	0.008	0.000	4	0.00
Heptachlor				21	
				Cumulative	**0.04**
Dissolved Metals* **					
Aluminum		1,232	22.18	111	3.20
Arsenic		0.325	0.01	5.14	0.02
Cadmiun		0.26	0.00	15.2	0.00
Chromium III		4.94	0.09	1	1.42
Copper		6.80	0.12	33.2	0.06
Lead		1.10	0.02	3.85	0.08
Mercury		0.11	0.00	5.09	0.01
Nickel		4.90	0.09	77.4	0.02
Selenium		0.84	0.02	0.5	0.48
Silver		1.36	0.02	NA	
Zinc		142	2.56	15	2.73
				Cumulative	**8.02**

Exposure Factors for G. Blue Heron	
Fish Ingestion Rate (g/g/d)	0.18
Wet weight / Dry weight Ratio	5.00
Benchmark Extrapolation Factor	16
Mobility Factor	0.5

ND: Not Detected
NA: Not Available
* Only parameters with detectable levels are included. Tissue for mosquitofish collected from Kelly Farms Wetlands Demonstration Project (Tables 3 and 4, HBA, 1995).
** Exposure rate = Concentration in water x BAF x Food ingestion rate x Mobility factor / (Wet wt./ Dry wt. Ratio)
*** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value. To adjust the benchmark value for the target species, the ecological quotient value is divided by *an inter-species extrapolation factor shown in the insert below.*

Table 6.4 Risk to Wildlife from Direct Ingestion of Undiluted Reclaimed Water

CONCENTRATION 100%	Maximum Concentration in Surface Water (mg/L) *	BENCHMARKS (mg/kg/d)				ECOLOGICAL QUOTIENTS **	
		Mammals		*Birds*		*Shrew*	*Heron*
Volatile Organic Compounds							
Acetone	0.050	10		40		0.00	0.00
Bromodichloromethane	0.011	2	(a)	17.2	(b)	0.00	0.00
Bromomethane	0.001	2	(a)	17.2	(b)	0.00	0.00
Carbon Disulfide	0.037	2	(a)	17.2	(b)	0.01	0.01
Chlorobenzene	0.001	22		17.2	(b)	0.00	0.00
Chloroform	0.044	15		17.2	(b)	0.00	0.00
Chloromethane	0.005	2	(a)	17.2	(b)	0.00	0.00
Dibromochloromethane	0.002	2	(a)	17.2	(b)	0.00	0.00
1,4-Dichlorobenzene	0.001	2	(a)	17.2	(b)	0.00	0.00
Ethyl Benzene	0.001	35		17.2	(b)	0.00	0.00
Methylene Chloride	0.006	5.9		17.2	(b)	0.00	0.00
Tetrachloroethene	0.001	2		17.2	(b)	0.00	0.00
Toluene	0.001	52		20	(c)	0.00	0.00
1,1,1-Trichloroethane	0.001	1000		NA		0.00	0.00
Xylenes	0.001	2.1		20		0.00	0.00
				Cumulative		**0.03**	**0.03**
Semivolatiles / Pesticides							
Bis(2-Ethylhexyl)phthalate	0.0060	18		1.11		0.00	0.00
Diethylphthalate	0.0070	4580		1.11	(d)	0.00	0.00
Aldrin	0.0000	0.2		0.062		0.00	0.00
alpha-BHC	0.0000	0.32		0.563		0.00	0.00
Endosulfan II	0.0000	0.15		10		0.00	0.00
gamma-BHC	0.0001	8		4		0.00	0.00
Heptachlor	0.0000	0.8		21		0.00	0.00
				Cumulative		**0.00**	**0.00**
Cyanide and Dissolved Metals ***							
Cyanide	0.030	14		NA		0.00	0.00
Aluminum	0.040	3.9		111		0.01	0.01
Arsenic	0.003	0.25		5.14		0.01	0.01
Copper	0.013	9.4		33.2		0.00	0.00
Nickel	0.005	40		77.4		0.00	0.00
Silver	0.005	0.5		NA		0.01	0.01
Zinc	0.058	160		15		0.00	0.00
				Cumulative		**0.03**	**0.00**

NA: Not Available

* Water concentrations of antimony, beryllium, cadmium, chromium III, cobalt, lead, mercury, molybdenum, selenium, thallium, and vanadium were *below analytical detection limits. Exposure rates used in the* ecological quotient calculations were obtained from the surface water value as: water concentration X ingestion rate X mobility factor.

** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value. To adjust the benchmark value for the target species, *the ecological quotient value is divided by* an inter-species extrapolation factor shown in the insert below.

Surrogate Chemicals : (a) Tetrachloroethane; (b) 1,2 - Dichloroethane; (c) Xylenes; and (d) Bis(2 - ethylhexyl)phthalate.

Water Intake Rates (g/g/d)	
Short-tailed shrew	0.05
Great blue heron	0.05
Benchmark extrapolation factor	16.00

source of drinking water by three common wildlife species (Table 6.4). All EQ values for water ingestion were below the threshold value of 1, even those calculated for the maximum detected concentrations.

Fish Consumption. For the consumption of fish by the great blue heron, a potential for adverse effects was identified for aluminum, chromium, and zinc under the assumption of high levels of bioaccumulation in fish tissues (Table 6.3). No potential risk was identified for other metals or organic substances.

Risk for Special-Status Species. Table 6.2 lists ecological quotients calculated for two aquatic species of concern potentially present in Laguna de Santa Rosa: the red-legged frog and the California freshwater shrimp. Risk calculations for these species were based on the use of benchmarks calculated as half of the values used for evaluation of effects on other aquatic organisms. Calculated EQ values for amphibians were less than 1, indicating than exposure concentrations to undiluted reclaimed water were below available benchmark values for amphibians. The risk values for amphibians were largely based on benchmarks for metals, but also included two volatile substances and a pesticide (Table 6.2).

In terms of protection of the California freshwater shrimp, no potential risk was identified for any metals, volatile and semivolatile organic compounds, or pesticides found at detectable concentrations in the reclaimed water (Table 6.2). Only cyanide had EQ values significantly greater than 1, indicating a potential risk to sensitive aquatic species under the assumption of a chronic exposure to undiluted reclaimed water. Such high exposure concentrations are expected to occur in Laguna de Santa Rosa only on an occasional basis as reclaimed water dilution to less than 35 percent is expected for average flow conditions in Santa Rosa Creek and the Laguna de Santa Rosa (Table 6.1).

6.3 DISCHARGE TO THE RUSSIAN RIVER

6.3.1 Exposure Scenarios

For the Russian River, potential ecological risks were evaluated for a design concentration of 20 percent. This future contribution of the reclaimed water to the Russian River flow is likely to occur only occasionally during very dry-weather conditions when there is a minimum potential for in-stream dilution. Under typical flow conditions, concentrations in the Russian River will be considerably smaller than those indicated by the design discharge values. For the maximum design discharge of 20 percent, the reclaimed water is expected to contribute an average of 3 percent to the stream flow (50th percentile value of a normal hydrologic year). The discharge is expected to contribute less than 1 percent of the average flow of the Russian River for the 5 and 10 percent design alternatives (Table 6.1).

6.3.2 Transfer Pathways

Similarly to the risk analysis for the Laguna de Santa Rosa, three transfer pathways were considered for the potential exposure of Russian River organisms to reclaimed water constituents: direct exposure of aquatic organisms, water ingestion from the stream by wildlife species, and exposure by fish consumption by piscivorous birds and mammals.

For the direct exposure pathway, tadpoles were identified as key receptor organisms given the potential presence of endangered frog species in the Laguna and Russian River. Use of the stream as a drinking water source was evaluated for two common wildlife species (the great blue heron and the shrew).

The harbor seal and the great blue heron were selected as the key ecological receptors for potential contaminant transfer via fish consumption. Herons are seasonal inhabitants of the stream, while populations of harbor seals are known to consume fish from the Russian River mouth. For the risk assessment, it was assumed that fish consumption from the Russian River represents 50 percent of total food intake of both the heron and the seal given the high mobility of both species. In addition, the exposure of the prey organisms to reclaimed water is expected to occur only during 6 months of the year, thus reducing the potential for bioaccumulation in tissues. These two assumptions were incorporated in the exposure calculations as a mobility factor of 0.25 (0.5 for mobility times 0.5 for exposure period).

The risk assessment for chronic exposure of endangered, threatened, or other special-status aquatic species to the reclaimed water was based on more conservative benchmark values, equivalent to half of the value used for other stream organisms. Aquatic endangered/threatened species potentially associated with the Russian River include the red-legged frog (*Rana aurora*) and the California freshwater shrimp (*Syncaris pacifica*). An additional species of concern is the steelhead trout which utilizes tributaries of the Russian river as spawning habitat.

6.3.3 Risk Evaluation

Ecological quotient calculations for discharge into the Russian River at the design discharge of 20 percent are presented in Tables 6.5, 6.6, and 6.7 for the direct exposure of aquatic organisms, wildlife exposure by fish ingestion, and exposure by water intake, respectively. Table 6.8 presents a summary of ecological quotients for four discharge alternatives (design discharges of 1, 5, 10, and 20 percent in the Russian River).

Direct Exposure. Based on the EQ calculations, no significant risk to aquatic organisms was documented for direct exposure of aquatic organisms to the Russian River combination at any of the discharge scenarios (Table 6.8). All ecological quotients were near or below a threshold value of 1 for all constituents. Low EQ values were

Table 6.5 Risk to Freshwater Organisms from Chronic Exposure to Reclaimed Water Diluted in Russian River Water

CONCENTRATION 20%	EXPOSURE CONCENTRATION Surface Water Average (mg/L)	Detection Frequency	GENERAL RISK TO AQUATIC LIFE Benchmark (mg/L)		Ecological Quotient for Surface Water *	RISK TO AMPHIBIANS (tadpoles) Benchmark (mg/L)		Ecological Quotient for Surface Water *
Volatile Organic Compounds								
Acetone	0.002	2 / 14	11.2		0.00	139	(e)	0.00
Bromodichloromethane	0.000	22 / 23	0.125	(a)	0.00	1.6	(d)	0.00
Bromomethane	0.000	1 / 16	0.125	(a)	0.00	1.6	(d)	0.00
Carbon Disulfide	0.001	3 / 14	0.0089		0.12	111		0.00
Chlorobenzene	0.000	1 / 19	0.127		0.00	0.102		0.00
Chloroform	0.002	22 / 23	0.188		0.01	1.6	(d)	0.00
Chloromethane	0.000	1 / 19	0.125	(a)	0.00	1.6		0.00
Dibromochloromethane	0.000	4 / 22	0.125	(a)	0.00	NA		
1,4-Dichlorobenzene	0.000	10 / 13	0.127	(b)	0.00	0.01	(b)	0.02
Ethyl Benzene	0.000	1 / 19	0.0389		0.00	0.01	(b)	0.01
Methylene Chloride	0.000	5 / 19	2.24		0.00	1.6	(d)	0.00
Tetrachloroethene	0.000	2 / 19	0.125		0.00	1.6	(d)	0.00
Toluene	0.000	2 / 19	0.176		0.00	139	(e)	0.00
1,1,1-Trichloroethane	0.000	1 / 19	0.062		0.00	1.6	(d)	0.00
Xylenes	0.000	1 / 18	NA			139		0.00
			Cumulative		0.14	Cumulative		0.03
Semivolatiles / Pesticides								
Bis(2-Ethylhexyl)phthalate	0.001	5 / 19	0.36		0.00	NA		
Diethylphthalate	0.000	2 / 19	0.22		0.00	NA		
Aldrin	0.000	3 / 19	0.00029	(c)	0.01	0.01	(c)	0.00
alpha-BHC	0.000	2 / 19	0.0024		0.00	0.01	(c)	0.00
Endosulfan II	0.000	1 / 19	0.00056		0.00	0.01	(c)	0.00
gamma-BHC	0.000	5 / 19	0.0008		0.01	0.01	(c)	0.00
Heptachlor	0.000	1 / 19	0.00029		0.01	0.01		0.00
			Cumulative		0.04	Cumulative		0.00
Cyanide and Dissolved Metals **								
Cyanide	0.002	3 / 6	0.0052		0.46	NA		
Aluminum	0.002	2 / 8	0.087		0.03	47.46		0.00
Arsenic	0.005	8 / 8	0.19		0.02	0.072		0.06
Copper	0.005	8 / 8	0.012		0.43	0.649		0.01
Nickel	0.005	6 / 8	0.158		0.03	2.11		0.00
Silver	0.001	2 / 8	NA			0.013		0.08
Zinc	0.046	8 / 8	0.106		0.44	1.93		0.02
			Cumulative		1.41	Cumulative		0.17

NA: Not Available

Surragate Chemicals: (a) Tetrachloroethane, (b) Chlorobenzene, (c) Heptachlor, (d) Chloromethane, and (e) Xylenes.

* The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value.

** The potential for adverse effects of metals is quantified as an incremental risk above background concentrations. Antimony, Beryllium, Cadmium, Chromium III, Cobalt, Lead, Mercury, Molybdenum, Selenium, Thallium, and Vanadium concentrations were below analytical detection limits.

Table 6.6 Risk to Heron and Harbor Seal from Consumption of Fish Exposed to Reclaimed Water Diluted in Russian River Water

DESIGN DISCHARGE 20%		EXPOSURE ASSESSMENT Tissue Concentration * (mg/kg dry wt.)	Exposure Rate ** (mg/kg/d)	RISK FOR FISH INGESTION BY HERON Benchmark (mg/kg/d)	Ecological Quotient ***	RISK FOR FISH INGESTION BY HARBOR SEAL Benchmark (mg/kg/d)	Ecological Quotient ***
Semivolatiles							
Bis(2-Ethylhexyl)phthalate		NA	NA	1.11		18	
Diethylphthalate		NA	NA	NA		4580	
Aldrin	<	0.002	0.000	0.062	0.00	0.2	0.00
alpha-BHC	<	0.002	0.000	0.56	0.00	0.32	0.00
Endosulfan II	<	0.002	0.000	10	0.00	0.15	0.00
gamma-BHC	<	0.002	0.000	4	0.00	8	0.00
Heptachlor	<	0.002	0.000	21	0.00	0.8	0.00
			0.000	**Cumulative**	**0.00**	**Cumulative**	**0.00**
			0.000				
Dissolved Metals **			0.000				
Aluminum		246.400	2.218	111	0.32	3.9	9.10
Arsenic		0.065	0.001	5.14	0.00	0.25	0.04
Cadmium		0.052	0.000	15.2	0.00	0.5	0.01
Chromium (total)		0.988	0.009	1	0.14	NA	
Copper		1.360	0.012	33.2	0.01	9.4	0.02
Lead		0.220	0.002	3.85	0.01	8	0.00
Mercury		0.022	0.000	5.09	0.00	13	0.00
Nickel		0.980	0.009	77.4	0.00	40	0.00
Silver		0.272	0.002	NA		0.5	0.08
Zinc		28.400	0.256	15	0.27	160	0.03
				Cumulative	**0.75**	**Cumulative**	**9.28**

ND: Not Detected

NA: Not Available

* Only parameters with detectable levels are included. Tissue for mosquitofish collected from Kelly Farms Wetlans Demonstration Project (Tablse 3 and 4, HBA, 1995) assuming a 20% exposure level to the effluent.

** Exposure rate = Concentration in water x BAF x Food ingestion rate x Mobility factor

*** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value. To adjust the benchmark value for the target species, the ecological quotient value is divided by an inter-species extrapolation factor shown in the insert below.

Exposure Factors for G. Blue Heron	
Fish Ingestion Rate (g/g/d)	0.18
Benchmark extrapolation factor	16
Mobility Factor	0.25
Wet weight/ Dry weight ratio	5

Exposure Factors for Harbor Seal	
Fish Ingestion Rate (g/g/d)	0.05
Benchmark extrapolation factor	16
Mobility Factor	0.25
Wet weight/ Dry weight ratio	5

Table 6.7 Risk to Wildlife from Intake of Reclaimed Water Diluted in Russian River Water

CONCENTRATION	AVERAGE CONCENTRATION *	BENCHMARKS (mg/kg/d)				ECOLOGICAL QUOTIENTS **	
- 20%	Surface Water (mg/L)	Mammals		Birds		Shrew	Heron
Volatile Organic Compounds							
Acetone	0.00210	10		40		0.00	0.00
Bromodichloromethane	0.00048	2	(a)	17.2	(b)	0.00	0.00
Bromomethane	0.00009	2	(a)	17.2	(b)	0.00	0.00
Carbon Disulfide	0.00100	2	(a)	17.2	(b)	0.00	0.00
Chlorobenzene	0.00008	22		17.2	(b)	0.00	0.00
Chloroform	0.00220	15		17.2	(b)	0.00	0.00
Chloromethane	0.00014	2	(a)	17.2	(b)	0.00	0.00
Dibromochloromethane	0.00012	2	(a)	17.2	(b)	0.00	0.00
1,4-Dichlorobenzene	0.00015	2	(a)	17.2	(b)	0.00	0.00
Ethyl Benzene	0.00008	35		17.2	(b)	0.00	0.00
Methylene Chloride	0.00027	5.9		17.2	(b)	0.00	0.00
Tetrachloroethene	0.00008	2		17.2	(b)	0.00	0.00
Toluene	0.00008	52		20	(c)	0.00	0.00
1,1,1-Trichloroethane	0.00007	1000		NA		0.00	
Xylenes	0.00008	2.1		20		0.00	0.00
				Cumulative		0.00	0.00
Semivolatiles							
Bis(2-Ethylhexyl)phthalate	0.007000	18		1.11		0.00	0.01
Diethylphthalate	0.000280	4580		1.11	(d)	0.00	0.00
Aldrin	0.000003	0.2		0.062		0.00	0.00
alpha-BHC	0.000004	0.32		0.563		0.00	0.00
Endosulfan II	0.000002	0.15		10		0.00	0.00
gamma-BHC	0.000005	8		4		0.00	0.00
Heptachlor	0.000004	0.8		21		0.00	0.00
				Cumulative		0.00	0.01
Cyanide and Dissolved Metals ***							
Cyanide	0.002	14		NA		0.00	
Aluminum	0.002	3.9		111		0.00	0.00
Arsenic	0.005	0.25		5.14		0.01	0.00
Copper	0.005	9.4		33.2		0.00	0.00
Nickel	0.005	40		77.4		0.00	0.00
Silver	0.001	0.5		NA		0.00	
Zinc	0.046	160		15		0.00	0.00
				Cumulative		0.02	0.00

Water Intake Rates (g/g/d)	
Short-tailed shrew	0.05
Great blue heron	0.05
Benchmark extrapolation factor	16

NA: Not Available

* Water concentrations of antimony, beryllium, cadmium, chromium III, cobalt, lead, mercury, molybdenum, selenium, thallium, and vanadium were below analytical detection limits. Exposure rates used in the ecological quotient calculations were obtained from the surface water value as the water concentration X ingestion rate X mobility factor.

*** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value.

To adjust the benchmark value for the target species, the ecological quotient value is divided by an inter-species extrapolation factor shown in the insert.

Surrogate Chemicals : (a) Tetrachloroethane, (b) 1,2 - Dichloroethane, (c) Xylenes, and (d) Bis(2 - ethylhexhl)phthalate.

Table 6.8 Cumulative Ecological Quotients for Exposure of Aquatic Organisms and Wildlife to Reclaimed Water Diluted in Russian River Water.

Design Discharge of Reclaimed Water (as percent of Russian River Flow)	Exposure Route: Direct Exposure to Water – Aquatic Life	Direct Exposure to Water – Amphibians	Water Ingestion – Shrew	Water Ingestion – Heron	Fish Ingestion – Heron	Fish Ingestion – Seal
1 percent						
Volatile Organics	0.01	0.00	0.00	0.00		
Semivolatiles / Pesticides	0.00	0.00	0.00	0.00	0.00	0.00
Metals / Cyanide	0.07	0.01	0.00	0.00	0.04	0.47
5 percent						
Volatile Organics	0.03	0.01	0.00	0.00		
Semivolatiles / Pesticides	0.01	0.00	0.00	0.00	0.00	0.00
Metals / Cyanide	0.35	0.04	0.00	0.00	0.19	2.32
10 percent						
Volatile Organics	0.07	0.01	0.00	0.00		
Semivolatiles / Pesticides	0.02	0.00	0.00	0.00	0.00	0.00
Metals / Cyanide	0.71	0.09	0.01	0.00	0.38	4.64
20 percent						
Volatile Organics	0.14	0.03	0.00	0.00		
Semivolatiles / Pesticides	0.04	0.00	0.00	0.01	0.00	0.00
Metals / Cyanide	1.41	0.17	0.02	0.00	0.75	9.28

also obtained for direct exposure of tadpoles to stream water indicating that, similarly to other aquatic organisms, there is a low potential for adverse effects of constituents on amphibians inhabiting the lower reaches of the Russian River (Table 6.5).

Water Ingestion. In terms of exposure of wildlife species by routine water ingestion, no potential risk was detected for any of the species evaluated (short-tailed shrew and great blue heron). For all discharge scenarios, up to 20 percent concentration, EQ values were below the threshold value of 1 indicative of potential adverse effects on common wildlife species (Table 6.7).

Fish Consumption. Most ecological quotients calculated for wildlife exposure by fish consumption were lower that the threshold value of 1. EQs greater than this value were identified for the consumption of fish by the harbor seal. This low risk was associated with the estimated concentration of aluminum, chromium, and zinc in fish tissues. The significance of this risk for aluminum is discussed in Section 7.

Risk to Special-Status Species. Table 6.9 lists EQ values applicable to aquatic species of concern potentially present in the Russian River for 20 percent discharge into the Russian River (maximum exposure scenario). Average EQ values based on conservative benchmark values for protection of amphibians of special concern, such as the red-legged frog, were below a threshold of 1 for all constituents found at detectable concentrations. Similarly, little or no risk (low EQ values) was identified using benchmark values for protection of other aquatic organisms of concern such as the California freshwater shrimp and migratory salmonoid species. These benchmarks, derived from toxicological data for freshwater invertebrates and cold-water fish, are expected to be protective of shrimp and salmonoid species in the Russian River. Based on the low risk to special-interest aquatic species at the maximum discharge of 20 percent into the Russian River, no significant risk is expected for the 1, 5, and 10 percent design discharge.

6.4 EXPOSURE TO SEDIMENTS

6.4.1 Exposure Scenarios

The evaluation of risk associated with exposure of aquatic organisms to sediments was conducted for the discharge of reclaimed water into the Russian River at target (maximum) concentrations of 1, 5, 10, and 20 percent. The evaluation was based on the potential accumulation of nine organic substances and two metals (barium and arsenic) in sediments of the lower section of the Laguna de Santa Rosa and in the Russian River below the confluence with the Laguna. The expected concentrations of those substances in sediments for the maximum discharge alternative (20 percent design discharge) are listed in Table 6.10. The basis for calculation of expected sediment concentrations is presented in detail in the *Sediment Quality Characterization Report* developed for the Santa Rosa wastewater reclamation project (Merritt Smith, 1996).

Table 6.9 Risk to Freshwater Endangered Species from Chronic Exposure to Reclaimed Water Diluted to 20 Percent in Russian River Water

DESIGN DISCHARGE 20%	EXPOSURE CONCENTRATION		GENERAL RISK TO AQUATIC LIFE			RISK TO AMPHIBIANS (tadpoles)		
	Surface Water Average (mg/L)	Detection Frequency	Benchmark * (mg/L)		Ecological Quotient for Surface Water **	Benchmark * (mg/L)		Ecological Quotient for Surface Water **
Volatile Organic Compounds								
Acetone	0.002	2 / 14	5.6		0.00	69.5	(e)	0.00
Bromodichloromethane	0.000	22 / 23	0.0625	(a)	0.01	0.8	(d)	0.00
Bromomethane	0.000	1 / 16	0.0625	(a)	0.00	0.8	(d)	0.00
Carbon Disulfide	0.001	3 / 14	0.0045		0.23	55.5		0.00
Chlorobenzene	0.000	1 / 19	0.0635		0.00	0.005		0.02
Chloroform	0.002	22 / 23	0.094		0.02	0.8	(d)	0.00
Chloromethane	0.000	1 / 19	0.0625	(a)	0.00	0.8		0.00
Dibromochloromethane	0.000	4 / 22	0.0625	(a)	0.00	NA		
1,4-Dichlorobenzene	0.000	10 / 13	0.0635	(b)	0.00	0.005	(b)	0.03
Ethyl Benzene	0.000	1 / 19	0.1945		0.00	0.005	(b)	0.02
Methylene Chloride	0.000	5 / 19	1.12		0.00	0.8	(d)	0.00
Tetrachloroethene	0.000	2 / 19	0.0625		0.00	0.8	(d)	0.00
Toluene	0.000	2 / 19	0.088		0.00	69.5	(e)	0.00
1,1,1-Trichloroethane	0.000	1 / 19	0.031		0.00	0.8	(d)	0.00
Xylenes	0.000	1 / 18	0.043		0.00	69.5		0.00
			Cumulative		0.27	Cumulative		0.07
Semivolatiles / Pesticides								
Bis(2-Ethylhexyl)phthalate	0.001	5 / 19	0.18		0.01	NA		
Diethylphthalate	0.000	2 / 19	0.11		0.00	NA		
Aldrin	0.000	3 / 19	0.000145	(c)	0.02	0.005	(c)	0.00
alpha-BHC	0.000	2 / 19	0.0012		0.00	0.005	(c)	0.00
Endosulfan II	0.000	1 / 19	0.00028		0.01	0.005	(c)	0.00
gamma-BHC	0.000	5 / 19	0.0004		0.01	0.005	(c)	0.00
Heptachlor	0.000	1 / 19	0.000145		0.03	0.005		0.00
			Cumulative		0.08	Cumulative		0.00
Cyanide and Dissolved Metals ***								
Cyanide	0.002	3 / 6	0.0026		0.92	NA		
Aluminum	0.002	2 / 8	0.0435		0.05	23.73		0.00
Arsenic	0.005	8 / 8	0.095		0.05	0.036		0.13
Copper	0.005	8 / 8	0.006		0.87	0.325		0.02
Nickel	0.005	6 / 8	0.079		0.06	1.055		0.00
Silver	0.001	2 / 8	NA			0.0065		0.15
Zinc	0.046	8 / 8	0.053		0.88	0.965		0.05
			Cumulative		2.82	Cumulative		0.35

NA: Not Available

* Surragate Chemicals: (a) Tetrachloroethane, (b) Chlorobenzene, (c) Heptachlor, (d) Chloromethane, and (e) Xylenes.

** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value.

** The potential for adverse effects of metals is quantified as an incremental risk above background concentrations.
Antimony, Beryllium, Cadmium, Chromium III, Cobalt, Lead, Mercury, Molybdenum, Selenium, Thallium, and Vanadium concentrations were below analytical detection limits.

Table 6.10 Risk to Aquatic Vegetation and Benthic Invertebrates from Exposure to Sediment in the Lower Laguna de Santa Rosa

	EXPOSURE CONCENTRATION AT 20% DESIGN DISCHARGE (mg/kg/d) *	ECOLOGICAL QUOTIENTS FOR VEGETATION **						ECOLOGICAL QUOTIENTS FOR SEDIMENT ORGANISMS **					
		Benchmark (mg/kg)	Surrogate Chemical	DESIGN DISCHARGE 1%	5%	10%	20%	Benchmark (mg/kg)	Surrogate Chemical	DESIGN DISCHARGE 1%	5%	10%	20%
Volatile Organic Compounds													
Chlorobenzene	0.0001	10		0.00	0.00	0.00	0.00	1.582		0.00	0.00	0.00	0.00
		Cumulative		**0.00**	**0.00**	**0.00**	**0.00**	**Cumulative**		**0.00**	**0.00**	**0.00**	**0.00**
Semivolatiles / Pesticides													
1,4-dichlorobenzene	0.0020	10	Chlorobenzene	0.00	0.00	0.00	0.00	0.719	Chlorobenzene	0.00	0.00	0.00	0.00
Bis-(2-ethylhexyl)phthalate	1.1530	200		0.00	0.00	0.00	0.01	9,900,000		0.00	0.00	0.00	0.00
Diethylphthalate	0.0004	1.3		0.00	0.00	0.00	0.00	42		0.00	0.00	0.00	0.00
Aldrin	0.0100	25		0.00	0.00	0.00	0.00	0.011	Dieldrin	0.15	0.30	0.45	0.91
alpha-BHC	0.0002	6	Heptachlor	0.00	0.00	0.00	0.00	0.0035	gamma-BHC	0.01	0.02	0.03	0.05
gamma-BHC	0.0001	6	Heptachlor	0.00	0.00	0.00	0.00	0.0035	gamma-BHC	0.00	0.01	0.01	0.01
Endosulfan II	0.0003	10		0.00	0.00	0.00	0.00	0.0015		0.03	0.06	0.09	0.17
Heptachlor	0.0033	6		0.00	0.00	0.00	0.00	0.0061		0.09	0.18	0.26	0.54
		Cumulative		**0.00**	**0.00**	**0.01**	**0.01**	**Cumulative**		**0.28**	**0.56**	**0.84**	**1.69**
Metals													
Arsenic	0.0036	10		0.00	0.00	0.00	0.00	57		0.00	0.00	0.00	0.00
Barium	0.0101	500		0.00	0.00	0.00	0.00	NA					
		Cumulative		**0.00**	**0.00**	**0.00**	**0.00**	**Cumulative**		**0.00**	**0.00**	**0.00**	**0.00**

NA: Not Available

* Exposure concentrations were calculated for maximum reclaimed water discharges of 1, 5, 10, 20% in the Russian River.

** The ecological quotient is calculated as the ratio of the exposure concentration to the benchmark value.

Rooted aquatic vegetation and sediment organisms were evaluated for potential adverse effects by direct exposure to sediments. For indirect exposure to sediment constituents via food ingestion, the mallard duck was selected as a typical ecological receptor. This species' diet includes both wetland vegetation, such as cattails, and aquatic invertebrates. For the risk assessment it was assumed that, as a worst-case scenario, the mallard would derive all its diet from the Russian River or the lower reach of Laguna de Santa Rosa. This assumption was incorporated in the exposure calculations using a mobility factor of 1.

6.4.2 Risk Evaluation for the Laguna de Santa Rosa

Table 6.10 lists the expected concentrations of two metals and nine organic substances in sediments of the Laguna de Santa Rosa under various discharge scenarios. Ecological quotients for potential adverse effects associated with direct exposure of aquatic vegetation and invertebrates to sediment constituents are also presented in Table 6.10. Table 6.11 lists EQ values for indirect exposure of aquatic birds by food ingestion.

Calculated EQ values for exposure of rooted aquatic plants to sediment constituents were well below threshold value of 1 for all expected discharge conditions (Table 6.10). These low EQ values indicate that exposure to the sediments poses little or no risk for potential adverse effects on wetland vegetation.

In terms of potential adverse effects on sediment organisms, little or no risk was identified for exposure to reclaimed water constituents, as indicated by EQ values below a threshold value of 1 (Table 6.10). Ecological quotients below 1 were also calculated for the indirect exposure of waterfowl to sediment constituents at average concentrations (Table 6.11).

6.4.3 Risk Evaluation for the Russian River

Table 6.12 lists the expected concentrations of two metals and nine organic substances in sediments of the Russian River downstream of Laguna de Santa Rosa under various discharge scenarios. Table 6.12 also presents the ecological quotients for potential adverse effects of sediment constituents on aquatic vegetation and sediment-associated invertebrates. Table 6.13 summarizes EQ values for indirect exposure of waterfowl to sediment constituents by ingestion of invertebrates and aquatic vegetation.

Calculated EQs for potential accumulation of eleven constituents in Russian River sediments showed little or no potential for adverse effects on aquatic vegetation, sediment organisms, or water fowl. For all discharge scenarios, exposure concentrations of metals, pesticides, and other organic substances in sediments were significantly below available benchmark values for potential adverse effects on various organisms. This low risk is indicated by EQ values smaller than 1 for exposure of vegetation (Table 6.12), sediment organisms (Table 6.12), and waterfowl by food ingestion (Table 6.13).

Table 6.11 Risk to Aquatic Birds from Exposure to Sediment in the Lower Laguna de Santa Rosa

	EXPOSURE ASSESSMENT				ECOLOGICAL QUOTIENT FOR MALLARD DUCK **					
	CONCENTRATION (mg/kg) AT 20% DISCHARGE *	TRANSFER FACTORS (TF)		EXPOSURE RATE	Benchmark	Extrapolation	DESIGN DISCHARGE			
		Vegetation	Invertebrates	(mg/kg/d)	(mg/kg/d)	Factor	1%	5%	10%	20%
Volatile Organic Compounds										
Chlorobenzene	0.0001	1	1	0.00	NA	16				
					Cumulative		0.00	0.00	0.00	0.00
Semivolatiles / Pesticides										
1,4-dichlorobenzene	0.0020	1	1	0.00	NA	16				
Bis-(2-ethylhexyl)phthalate	1.1530	0.3	1	0.00	1.11	16	0.03	0.04	0.04	0.05
Diethylphthalate	0.0004	1	1	0.00	NA	16				
Aldrin	0.0100	0.2	2.5	0.00	0.062	16	0.00	0.01	0.01	0.02
alpha-BHC	0.0002	0.3	1	0.00	NA	16				
gamma-BHC	0.0001	0.4	2.85	0.00	4.00	16	0.00	0.00	0.00	0.00
Endosulfan II	0.0003	1	1	0.00	10.0	16	0.00	0.00	0.00	0.00
Heptachlor	0.0033	0.3	10	0.00	21	16	0.00	0.00	0.00	0.00
					Cumulative		0.04	0.04	0.05	0.07
Metals										
Arsenic	0.0036	0.05	1	0.00	5.14	1	0.00	0.00	0.00	0.00
Barium	0.0101	1	1	0.00	20.8	16	0.00	0.00	0.00	0.00
					Cumulative		0.00	0.00	0.00	0.00

NA: Not Available

* Exposure concentrations were calculated for maximum reclaimed water discharges of 1, 5, 10, 20% in the Russian River.

** Exposure rate = Sediment concentration * mobility factor * ingestion rate * transfer factors (proportional to diet composition)

*** The ecological quotient is calculated as the ratio of the exposure concentration to the benchmark value.

Exposure data for mallard duck

Mobility Factor	Ingestion Rate (g/g/day)	Wet wt / Dry wt. Ratio	Diet Composition	
			Vegetation	Invertebrates
0.500	0.05	5.0	0.5	0.5

Table 6.12 Risk to Vegetation and Benthic Invertebrates from Exposure to Russian River Sediment at Various Reclaimed Water Discharge Concentrations

	EXPOSURE CONCENTRATION AT 20% DESIGN DISCHARGE (mg/kg)*	ECOLOGICAL QUOTIENT FOR VEGETATION **						ECOLOGICAL QUOTIENT FOR AQUATIC ORGANISMS **					
		Benchmark (mg/kg)	Surrogate Chemical	DESIGN DISCHARGE 1%	5%	10%	20%	Benchmark (mg/kg)	Surrogate Chemical	DESIGN DISCHARGE 1%	5%	10%	20%
Volatile Organic Compounds													
Chlorobenzene	0.0000	10		0.00	0.00	0.00	0.00	1.582		0.00	0.00	0.00	0.00
		Cumulative		0.00	0.00	0.00	0.00	Cumulative		0.00	0.00	0.00	0.00
Semivolatile / Pesticides													
1,4-dichlorobenzene	0.0001	10	Chlorobenzene	0.00	0.00	0.00	0.00	0.719	Chlorobenzene	0.00	0.00	0.00	0.00
Bis-(2-ethylhexyl)phthalate	0.2720	200		0.00	0.00	0.00	0.00	9,900,000		0.00	0.00	0.00	0.00
Diethylphthalate	0.0000	1.3		0.00	0.00	0.00	0.00	42		0.00	0.00	0.00	0.00
Aldrin	0.0006	25		0.00	0.00	0.00	0.00	0.011	Dieldrin	0.03	0.03	0.03	0.05
alpha-BHC	0.0000	NA						0.0035	gamma-BHC	0.00	0.00	0.00	0.00
gamma-BHC	0.0000	NA						0.0035	gamma-BHC	0.00	0.00	0.00	0.00
Endosulfan II	0.0000	10		0.00	0.00	0.00	0.00	0.0015		0.01	0.01	0.01	0.01
Heptachlor	0.0002	6		0.00	0.00	0.00	0.00	0.0061		0.02	0.02	0.03	0.03
		Cumulative		0.00	0.00	0.00	0.00	Cumulative		0.05	0.05	0.08	0.11
Metals													
Arsenic	0.0003	10		0.00	0.00	0.00	0.00	57		0.00	0.00	0.00	0.00
Barium	0.0064	500		0.00	0.00	0.00	0.00	NA					
		Cumulative		0.00	0.00	0.00	0.00	Cumulative		0.00	0.00	0.00	0.00

NA: Not Available

* Exposure concentrations were calculated for maximum reclaimed water dishcarges of 1, 5, 10, 20% in the Russian River.

** The ecological quotient is calculated as the ratio of the exposure concentration to the benchmark value.

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Table 6.13 Risk to Aquatic Birds from Exposure to Russian River Sediment at Various Reclaimed Water Dishcarge Concentrations

	EXPOSURE ASSESSMENT				ECOLOGICAL QUOTIENT FOR MALLARD DUCK **					
	CONCENTRATION (mg/kg) AT 20% DISCHARGE *	TRANSFER FACTORS (TF) Vegetation	TRANSFER FACTORS (TF) Invertebrates	EXPOSURE RATE (mg/kg/d)	Benchmark (mg/kg/d)	Extrapolation Factor	DESIGN DISCHARGE 1%	5%	10%	20%
Volatile Organic Compounds										
Chlorobenzene	0.0000	1	1	0.00	NA	16				
					Cumulative		**0.00**	**0.00**	**0.00**	**0.00**
Semivolatile / Pesticides										
1,4-dichlorobenzene	0.0001	1	1	0.00	NA	16				
Bis-(2-ethylhexyl)phthalate	0.2720	0.3	1	0.00	1.11	16	0.01	0.01	0.01	0.01
Diethylphthalate	0.0000	1	1	0.00	NA	16				
Aldrin	0.0006	0.2	2.5	0.00	0.062	16	0.00	0.00	0.00	0.00
alpha-BHC	0.0000	0.3	1	0.00	NA	16				
gamma-BHC	0.0000	0.4	2.85	0.00	4.00	16	0.00	0.00	0.00	0.00
Endosulfan II	0.0000	1	1	0.00	10.0	16	0.00	0.00	0.00	0.00
Heptachlor	0.0002	0.3	10	0.00	21	16	0.00	0.00	0.00	0.00
					Cumulative		**0.01**	**0.01**	**0.01**	**0.01**
Metals										
Arsenic	0.0003	0.05	NA	0.00	5.14	1	0.00	0.00	0.00	0.00
Barium	0.0064	NA	NA	0.00	20.8	16	0.00	0.00	0.00	0.00
					Cumulative		**0.00**	**0.00**	**0.00**	**0.00**

NA: Not Available

* Exposure concentrations were calculated for maximum effluent concentrations of 1, 5, 10, 20% in the Russian River.

** Exposure rate = Sediment concentration * mobility factor * ingestion rate * transfer factors (proportional to diet composition)

*** The ecological quotient is calculated as the ratio of the exposure concentration to the benchmark value.

Exposure data for mallard duck

Mobility Factor	Ingestion Rate (g/g/day)	Wet wt / Dry wt. Ratio	Diet Composition Vegetation	Diet Composition Invertebrates
0.500	0.05	5.0	0.5	0.5

6.5 RECLAIMED WATER STORAGE

6.5.1 Exposure Scenarios

Monitoring data for reclaimed water of the Santa Rosa reclamation facility were used as the basis for assessment of ecological risk to aquatic organisms in proposed storage reservoirs. This approach assumes that future water quality in the reservoirs will be similar to the reclaimed water quality. Water quality data were evaluated in terms of potential effects on aquatic organisms by direct exposure.

The assessment of potential effects associated with exposure to sediments in storage reservoir was based on the use of monitoring data for existing storage ponds of the Santa Rosa water reclamation facility. This approach implies that future sediment conditions in the reservoirs will be similar to, or better than, those in existing ponds because reclaimed water quality has improved in recent years and will be maintained following expansion of the wastewater treatment facility. Among five storage ponds for which monitoring data are currently available, Meadowlane Pond was selected for evaluation of potential effects of sediments. The selection was based on the largest amount of available data on sediment quality.

Constituents in sediments were evaluated for potential effects on aquatic vegetation, sediment organisms, and waterfowl. For the evaluation, the mallard duck was selected as typical ecoreceptor assuming that, throughout the year, vegetation and invertebrates in the reclaimed water storage reservoirs will provide fifty percent of the organism's diet (mobility factor of 0.5).

6.5.2 Risk Evaluation for Exposure to Water

The ecological quotients for exposure of aquatic organisms to undiluted reclaimed water stored in ponds are summarized in Table 6.2. Based on the ecological quotient calculations, no potential risk was identified for direct exposure of aquatic organisms to organic chemicals and metals found at detectable levels in the reclaimed water (Table 6.2). All EQs for these compounds were below the threshold value of 1 indicative of potential adverse effects. A potential but low risk was identified for cyanide which had more elevated EQ values based on average concentrations (Table 6.2).

6.5.3 Risk Evaluation for Exposure to Sediments

Tables 6.14 and 6.15 list ecological quotients calculated for twelve metals found at detectable concentrations in sediments of Meadowlane Pond. No organic substances were found in sediments at this location, or at the Kelly Farm Wetland project where priority pollutants were also analyzed.

Table 6.14 Risk to Aquatic Vegetation and Benthic Invertebrates from Sediment Constituents in Storage Reservoirs

	EXPOSURE CONCENTRATION *		RISK ASSESSMENT FOR VEGETATION		RISK ASSESSMENT FOR AQUATIC ORGANISMS	
	Average (mg/kg)	Detection Frequency	Benchmark (mg/kg)	Ecological Quotient **	Benchmark (mg/kg)	Ecological Quotient **
Metals						
Antimony	3.20	1 / 7	NA		150	0.02
Barium	34.78	4 / 4	750.00	0.05	NA	
Beryllium	0.56	1 / 5	10.00	0.06	NA	
Cadmium	0.96	4 / 12	3.00	0.32	5	0.19
Chromium (hexavalent)	0.39	1 / 8	NA		NA	
Chromium (trivalent)	7.16	5 / 5	NA		81	0.09
Chromium, total	1.17	3 / 6	250.00	0.00	260	0.00
Cobalt	15.64	3 / 7	20.00	0.78	NA	
Copper	6.15	8 / 12	100.00	0.06	390.0	0.02
Lead	9.82	2 / 7	50.00	0.20	450.0	0.02
Nickel	10.93	4 / 6	30.00	0.36	140.0	0.08
Silver	1.95	2 / 6	20.00	0.10	6.1	0.32
Vanadium	66.40	1 / 5	200.00	0.33	NA	
Zinc (ICP)	11.88	12 / 12	500.00	0.02	410	0.03
			Cumulative	**2.28**	**Cumulative**	**0.77**

NA: Not Available

* Sediment data for Meadowlane Pond

** The ecological quotient is calculated as the ratio of the exposure concentration to the benchmark value.

Table 6.15 Risk to Aquatic Birds from Exposure to Sediment Constituents in Storage Reservoirs

	SEDIMENT CONCENTRATION *		EXPOSURE ASSESSMENT			RISK ASSESSMENT		
	Average (mg/kg)	Detection Frequency	Transfer Factors (TF) Vegetation	Transfer Factors (TF) Invertebrates	Exposure ** (mg/kg/d)	Benchmark (mg/kg/d)	Extrapolation Factor	Ecological Quotients for Mallard Duck ***
Metals								
Antimony	3.20	1 / 7	1.00	1.00	0.0160	NA	NA	
Barium	34.78	4 / 4	1.00	1.00	0.1739	20.8	16	0.13
Beryllium	0.56	1 / 5	1.00	1.00	0.0028	NA	16	
Cadmium	0.96	4 / 12	2.50	19.00	0.0515	15.2	2	0.01
Chromium (hexavalent)	0.39	1 / 8	1.00	1.00	0.0019	NA	NA	
Chromium (trivalent)	7.16	5 / 5	1.00	1.00	0.0358	NA	NA	
Chromium, total	1.17	3 / 6	0.01	0.10	0.0003	1	16	0.01
Cobalt	15.64	3 / 7	0.04	1.00	0.0407	NA	16	
Copper	6.15	8 / 12	0.30	0.40	0.0108	33.2	16	0.01
Lead	9.82	2 / 7	0.50	0.10	0.0147	3.9	16	0.06
Nickel	10.93	4 / 6	0.07	0.10	0.0046	77.4	16	0.00
Silver	1.95	2 / 6	1.00	1.00	0.0098	NA	16	
Vanadium	66.40	1 / 5	0.10	1.00	0.1826	11.4	2	0.03
Zinc (ICP)	11.88	12 / 12	0.40	3.80	0.1247	15	2	0.02
						Cumulative		**0.26**

NA: Not Available

* Sediment data for Meadowlane Pond

** Exposure rate = Sediment concentration * mobility factor * ingestion rate * transfer factors (proportional to diet composition)

*** The ecological quotient is calculated as the ratio of the exposure concentration to the benchmark value.

Exposure data for mallard duck

Mobility Factor	Ingestion Rate (g/g/day)	Wet wt / Dry wt Ratio	Diet Composition Vegetation	Diet Composition Invertebrates
0.500	0.05	5	0.5	0.5

For the potential exposure of aquatic vegetation and sediment-associated organisms to metals, average detected values were typically below available benchmark values, as indicated by EQs below the threshold value of 1 (Table 6.14). For dietary exposure of the mallard duck to metals in Meadowlane Pond sediments, calculated EQ values were low, less than 1 for exposure values based on both average and maximum concentrations (Table 6.15).

6.6 Reclaimed Water Reuse in Agriculture

6.6.1 Exposure Scenarios

Two main pathways for contaminant transfer were evaluated for the use of reclaimed water in agricultural irrigation: exposure of vegetation and soil organisms by direct application, and discharge of agricultural runoff into streams from excess irrigation.

For all irrigation sites, the exposure of vegetation and soil organisms was based on assumption that, on a mass-basis, soil concentrations will be similar to, or lower than, concentrations currently present in undiluted reclaimed water. The evaluation of potential effects on aquatic organisms from agricultural runoff was based on the modeling of irrigation drainage for various project alternatives (Questa Consulting Engineers, 1995b). The analysis of runoff quality was limited to metals and two widely-utilized pesticides in the region: the herbicide 2,4-D and the insecticide carbaryl. Organic substances present in the reclaimed water from the Santa Rosa facility are expected to be retained in the soils of the irrigation fields (Merritt Smith, 1996).

Three regional agricultural areas were evaluated for the use of reclaimed water in irrigation: South County, West County, and the Sebastopol area. Irrigation areas included in the West County alternative are located along Americano Creek and Stemple Creek. The lower reaches of both creeks, the Estero Americano and Estero de San Antonio are tidal embayments several miles long. Salinity in the esteros has marked seasonal variations, from freshwater conditions following heavy rainfall events to marine or hypersaline during the dry-weather conditions predominant throughout the year.

Green Valley Creek and Atascadero Creek, tributaries of the Russian River, are the primary receptors of runoff from irrigation fields in the Sebastopol area. The South County alternative includes irrigation areas East of Rohnert Park, and at Adobe Road, North Petaluma, Lakeville, and the Bayflats along San Pablo Bay. Receiving streams potentially receiving agricultural runoff include the Petaluma River, Tolay Creek, and various other small creeks that flow into the Petaluma Plain. Receiving waters with estuarine or marine characteristics include tidal sloughs associated with the mouth of the Petaluma River.

6.6.2 Risk Evaluation for Irrigation

Table 6.16 summarizes ecological quotients for direct application of reclaimed water in irrigation fields. The EQs calculated for exposure of vegetation and soil organisms to undiluted reclaimed water are below a threshold value of 1, indicating little or no risk for potential adverse effects on either type of organisms.

6.6.3 Risk Evaluation for Agricultural Runoff

Tables 6.17 and 6.18 list EQs for the exposure of freshwater and marine organisms to agricultural runoff. For freshwater organisms, organic chemicals in the reclaimed water had EQ values below the threshold value indicative of potential adverse effects (Table 6.17). These EQ values indicate that two pesticides commonly used in agricultural fields have a very low risk for effects on freshwater organisms, even in dry-weather conditions when there is a low potential for in-stream dilution. A low risk for adverse effects was also identified for the exposure to metals in the runoff. Only mercury was likely to moderately exceed applicable benchmarks for protection of aquatic life. The calculated EQ value of 1.1, however, indicates a very low probability of actual effects on stream organisms.

In the case of agricultural runoff discharge into the tidally-influenced esteros, EQ values were below the threshold value of 1 for all but one constituent in agricultural runoff. These values indicate that exposure to most constituents found in the reclaimed water have a low potential for adverse effects on aquatic organisms inhabiting the esteros. Only copper had concentrations in undiluted reclaimed water which exceeded available benchmarks for potential effects on marine organisms (Table 6.18). Relatively low EQ numbers were calculated for this metal, indicating a low probability of actual effects on receptor organisms.

6.7 Reclaimed Water Pipeline to Geysers Area

6.7.1 Exposure Scenarios

This project alternative entails piping reclaimed water from Delta Pond to an injection area located north of the City of Santa Rosa. The exposure scenario addresses the potential water release due to pipeline breakage and subsequent short-term exposure of freshwater organisms in one or various creeks along the pipeline alignment.

The evaluation of potential effects of released reclaimed water on aquatic organisms was based on the assumption that the discharge to streams occurs without a significant dilution from the receiving waters. Consequently, the risk evaluation was based on short-term exposure of aquatic organisms to reclaimed water constituents. Benchmarks for the risk evaluation were obtained from EPA's ambient water quality criteria that are applicable to acute, short-term exposures of freshwater organisms.

Table 6.16 Risk to Vegetation and Soil Organisms from Exposure to Soils *Irrigated with Undiluted Reclaimed Water*

	EXPOSURE CONCENTRATION		RISK ASSESSMENT FOR VEGETATION			RISK ASSESSMENT FOR SOIL ORGANISMS		
	Average (mg/kg)	Detection Frequency	Benchmark* (mg/kg)		Ecological Quotient**	Benchmark* (mg/kg)		Ecological Quotient**
Volatile Organic Compounds								
Acetone	0.01060	2 / 14	10	(a)	0.00	31	(c)	0.00
Bromodichloromethane	0.00220	22 / 23	10	(a)	0.00	31	(c)	0.00
Bromomethane	0.00043	1 / 16	10	(a)	0.00	31	(c)	0.00
Carbon Disulfide	0.00513	3 / 14	10	(a)	0.00	31	(c)	0.00
Chlorobenzene	0.00038	1 / 19	10		0.00	40		0.00
Chloroform	0.00990	22 / 23	10	(a)	0.00	73		0.00
Chloromethane	0.00069	1 / 19	10	(a)	0.00	31	(c)	0.00
Dibromochloromethane	0.00062	4 / 22	10	(a)	0.00	31	(c)	0.00
1,4-Dichlorobenzene	0.00075	10 / 13	10	(a)	0.00	31	(c)	0.00
Ethyl Benzene	0.00040	1 / 19	10	(a)	0.00	31		0.00
Methylene Chloride	0.00133	5 / 19	10	(a)	0.00	204		0.00
Tetrachloroethene	0.00039	2 / 19	10	(a)	0.00	31	(c)	0.00
Toluene	0.00040	2 / 19	200		0.00	50		0.00
1,1,1-Trichloroethane	0.00037	1 / 19	10		0.00	55		0.00
Xylenes	0.00039	1 / 18	10		0.00	31	(c)	0.00
			Cumulative		**0.00**	**Cumulative**		**0.00**
Semivolatiles / Pesticides								
Bis(2-Ethylhexyl)phthalate	0.00510	5 / 19	200		0.00	NA		
Diethylphthalate	0.00140	2 / 19	1.3		0.00	NA		
Aldrin	0.00002	3 / 19	25		0.00	0.01	(c)	0.00
alpha-BHC	0.00002	2 / 19	6	(b)	0.00	0.01	(c)	0.00
Endosulfan II	0.00001	1 / 19	6	(b)	0.00	0.01	(c)	0.00
gamma-BHC	0.00003	5 / 19	6	(b)	0.00	0.01	(c)	0.00
Heptachlor	0.00002	1 / 19	6		0.00	0.01		0.00
			Cumulative		**0.00**	**Cumulative**		**0.01**
Cyanide and Dissolved Metals ***								
Cyanide	0.01200	3 / 6	NA			NA		
Aluminum	0.01100	2 / 8	50		0.00	600		0.00
Arsenic	0.00250	8 / 8	10		0.00	60		0.00
Copper	0.00600	8 / 8	100		0.00	50		0.00
Nickel	0.00300	6 / 8	30		0.00	200		0.00
Silver	0.00100	2 / 8	2		0.00	50		0.00
Zinc	0.03200	8 / 8	50		0.00	200		0.00
			Cumulative		**0.00**	**Cumulative**		**0.00**

NA: Not Available

* Surrogate chemicals: (a) Chlorobenzene, (b) Heptachlor, and (c) Heptachlor

** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value.

*** Antimony, Beryllium, Cadmium, Chromium III, Cobalt, Lead, Mercury, Molybdenum, Selenium, Thallium, and Vanadium concentrations were below analytical detection limits.

Table 6.17 Risk to Freshwater Organisms from Chronic Exposure to Dissolved Metals and Pesticides in Irrigated Percolate Water

	EXPOSURE CONCENTRATION	GENERAL RISK TO AQUATIC LIFE	
	Highest Average in Surface Water*	Benchmark (mg/L)	Ecological Quotient Surface Water**
Dissolved Metals			
Arsenic	0.0068	0.19	0.04
Cadmium	0.0010	0.0011	0.92
Chromium	0.0025	0.207	0.01
Copper	0.0057	0.012	0.48
Lead	0.0013	0.0032	0.41
Mercury	0.0001	0.00013	1.08
Nickel	0.0066	0.158	0.04
Selenium	0.0033	0.005	0.65
Silver	0.0006	NA	
Zinc	0.0271	0.106	0.26
		Cumulative	**3.88**
Pesticides			
2,4 - D	0.0020	10	0.00
Carbaryl	0.0001	0.005	0.02
		Cumulative	**0.02**

NA : Not Available

* Highest average value of all sites in the Americano, Stemple, and Tolay Creeks. Data from Questa (1995b).

** Ratio of exposure concentration to benchmark value.

Table 6.18 Risk to Aquatic Organisms in Esteros from Chronic Exposure to Dissolved Metals and Pesticides in Irrigated Percolate Water

	EXPOSURE CONCENTRATION*	GENERAL RISK TO AQUATIC LIFE	
	Highest Average in Surface Water**	Benchmark (mg/L)	Ecological Quotient Surface Water
Dissolved Metals			
Arsenic	0.00650	0.0360	0.18
Cadmium	0.00080	0.0093	0.09
Chromium***	0.00160	0.0500	0.03
Copper	0.01230	0.0029	4.24
Lead	0.00170	0.0085	0.20
Mercury	0.00020	NA	
Nickel	0.00580	0.0083	0.70
Selenium	0.00270	0.0710	0.04
Silver	0.00070	0.0009	0.76
Zinc	0.05700	0.0860	0.66
		Cumulative	**6.90**
Pesticides			
2,4 - D	0.00000	2	0.00
Carbaryl	0.00000	0.006	0.00
		Cumulative	**0.00**

NA : Not Available

* Exposure concentration was estimated as 50 percent additional flow contribution to the esteros by the creek.

** Highest average value of all sites in the Americano, Stemple, and Tolay Creeks. Data from Questa (1995b).

*** Benchmark value for hexavalent chromium.

6.7.2 Risk Evaluation

Table 6.19 lists EQs for the short-term exposure of aquatic organisms to undiluted reclaimed water released from the pipelines. For all organic and inorganic chemicals, calculated EQ values were below the threshold value of 1 indicative of potential adverse effects on freshwater organisms (Table 6.19). These EQ values indicate that the reclaimed water release has a very low risk for effects on stream organisms, even at low-flow conditions when there is a minimum potential for dilution.

Table 6.19 Risk to Freshwater Organisms from Acute Exposure to Undiluted Reclaimed Water Released from Pipelines

	EXPOSURE CONCENTRATION		GENERAL RISK TO AQUATIC LIFE		
	Surface Water (mg/L)	*Detection* Frequency	*Benchmark* * (mg/L)		Ecological Quotient for Surface Water **
Volatile Organic Compounds					
Acetone	0.011	2 / 14	200		0.00
Bromodichloromethane	0.002	22 / 23	NA	(a)	
Bromomethane	0.000	1 / 16	NA	(a)	
Carbon Disulfide	0.005	3 / 14	0.159		0.03
Chlorobenzene	0.000	1 / 19	2.27		0.00
Chloroform	0.010	22 / 23	3.36		0.00
Chloromethane	0.001	1 / 19	NA	(a)	
Dibromochloromethane	0.001	4 / 22	NA	(a)	
1,4-Dichlorobenzene	0.001	10 / 13	NA	(b)	
Ethyl Benzene	0.000	1 / 19	6.97		0.00
Methylene Chloride	0.001	5 / 19	25.6		0.00
Tetrachloroethene	0.000	2 / 19	0.99		0.00
Toluene	0.000	2 / 19	3.15		0.00
1,1,1-Trichloroethane	0.000	1 / 19	0.62		0.00
Xylenes	0.000	1 / 18	1.54		0.00
			Cumulative EQ		**0.04**
Semivolatiles / Pesticides					
Bis(2-Ethylhexyl)phthalate	0.005	5 / 19	0.36		0.01
Diethylphthalate	0.001	2 / 19	3.95		0.00
Aldrin	0.000	3 / 19	0.003	(c)	0.01
alpha-BHC	0.000	2 / 19	0.044		0.00
Endosulfan II	0.000	1 / 19	0.0022		0.00
gamma-BHC	0.000	5 / 19	0.002		0.01
Heptachlor	0.000	1 / 19	0.00052		0.04
			Cumulative EQ		**0.06**
Cyanide and Dissolved Metals ***					
Cyanide	0.012	3 / 6	0.022		0.55
Aluminum	0.011	2 / 8	0.75		0.01
Arsenic	0.003	8 / 8	0.36		0.01
Copper	0.006	6 / 8	0.017		0.35
Nickel	0.003	6 / 8	1.42		0.00
Silver	0.001	2 / 8	0.0041		0.24
Zinc	0.032	8 / 8	0.117		0.27
			Cumulative EQ		**1.44**

NA: Not Available

* Surrogate chemicals: (a) Tetrachloroethane, (b) Chlorobenzene, (c) Heptachlor, (d) Chloromethane, and (e) Xylenes.

** The ecological quotient is calculated as the ratio of exposure concentration to the benchmark value.

*** Antimony, Beryllium, Cadmium, Chromium III, Cobalt, Lead, Mercury, Molybdenum, Selenium, Thallium, and Vanadium concentrations were below analytical detection limits.

**** Ecological quotients for endangered, threatened, or special-status species are calculated using a more stringent benchmark (one-half of the value used for other species).

7. ECOLOGICAL RISK EVALUATION

7.1 SUMMARY OF ECOLOGICAL QUOTIENTS

Table 7.1 summarizes cumulative valves of ecological quotients calculated for six exposure pathways previously discussed (Sections 6.2 through 6.7). No metals or any organic substances present in the reclaimed water were identified as a potential concern for the exposure of aquatic organisms and wildlife to reclaimed water constituents under various discharge alternatives with the exception of cyanide, aluminum, copper, and zinc.

The lack of a probable risk is indicated by ecological quotients below a value of 1.0. This threshold EQ value indicates that the expected exposure concentrations in water, sediment, soils, and organism tissues are lower than benchmark values indicative of potential adverse effects on receptor organisms.

7.2 CHEMICALS OF POTENTIAL CONCERN

On the basis of average concentrations, four inorganic chemicals were identified as having a low risk probability as indicated by EQ values greater than 1 but below a value of 10. These chemicals are:

- Cyanide for the direct exposure of aquatic organisms in the proposed storage reservoirs and in Laguna de Santa Rosa under the assumption of chronic exposure to undiluted reclaimed water (average EQ value of 2.3);
- Copper for the exposure of aquatic organisms in esteros as a result of agricultural irrigation with reclaimed water (average EQ value of 4.2); and
- Zinc and chromium for dietary intake by waterfowl in the Laguna de Santa Rosa assuming a high level of bioaccumulation in fish tissues (average EQs of 2.7 and 1.4, respectively).
- Aluminum for dietary intake of fish by piscivorous organisms assuming high levels of bioaccumulation of the metal in fish tissues. The risk was characterized as low both for the Russian River at the 5%, 10%, and 20% design discharges (average EQ of 9.0 for the harbor seal at the mouth of the Russian River); and for waterfowl in Laguna de Santa Rosa assuming consumption of fish chronically exposed to undiluted reclaimed water (average EQ of 3.2 of great blue heron).

The significance of the ecological risk for the chemicals of potential concern (COPC) identified is discussed below.

Table 7.1 Cumulative Ecological Quotients for Exposure of Aquatic Organisms and Wildlife to Treated Effluent from the Santa Rosa Regional Facility

	CUMULATIVE ECOLOGICAL QUOTIENT VALUES (AVERAGE EXPOSURE)			CHEMICALS OF POTENTIAL CONCERN		
	Volatile Organics	Semi-volatiles / Pesticides	Metals / Cyanides	Low Risk 1 < EQ < 10	Probable Risk 10 < EQ < 100	Reference Table
LAGUNA DE SANTA ROSA						
Undiluted Reclaimed Water						
Risk to aquatic life	0.73	0.18	3.27	Cyanide	-	6.2
Risk to amphibians	0.16	0.01	0.14	-	-	6.0
Great Blue Heron - fish ingestion	0.00	0.04	8.02	Al, Cr, Zn	-	6.3
Great Blue Heron - water ingestion	0.03	0.00	0.00	-	-	6.4
Short-tailed shrew - water ingestion	0.03	0.00	0.03	-	-	6.4
Sediment						
Risk to aquatic organisms	0.00	1.69	0.00	-	-	6.10
Risk to vegetation	0.00	0.01	0.00	-	-	6.10
Risk to mallard duck by food ingestion	0.00	0.07	0.00	-	-	6.11
RUSSIAN RIVER WATER						
Reclaimed Water Diluted to 20%						
Risk to aquatic life	0.14	0.04	1.41	-	-	6.5
Risk to amphibians	0.03	0.00	0.17	-	-	6.5
Great Blue Heron - fish ingestion	0.00	0.00	0.75	-	-	6.6
Harbor Seal - fish ingestion	0.00	0.00	9.28	Aluminum	-	6.6
Great Blue Heron - water ingestion	0.00	0.01	0.00	-	-	6.7
Short-tailed shrew - water ingestion	0.00	0.00	0.02	-	-	6.7
Reclaimed Water Diluted to 10%						
Risk to aquatic life	0.07	0.02	0.71	-	-	6.8
Risk to amphibians	0.01	0.00	0.09	-	-	6.8
Great Blue Heron - fish ingestion	0.00	0.00	0.38	-	-	6.8
Harbor Seal - fish ingestion	0.00	0.00	4.64	Aluminum	-	6.8
Great Blue Heron - water ingestion	0.00	0.00	0.00	-	-	6.8
Short-tailed shrew - water ingestion	0.00	0.00	0.01	-	-	6.8
Reclaimed Water Diluted to 5%						
Risk to aquatic life	0.03	0.01	0.35	-	-	6.8
Risk to amphibians	0.01	0.00	0.04	-	-	6.8
Great Blue Heron - fish ingestion	0.00	0.00	0.19	-	-	6.8
Harbor Seal - fish ingestion	0.00	0.00	2.32	Aluminum	-	6.8
Great Blue Heron - water ingestion	0.00	0.00	0.00	-	-	6.8
Short-tailed shrew - water ingestion	0.00	0.00	0.00	-	-	6.8
Reclaimed Water Diluted to 1%						
Risk to aquatic life	0.01	0.00	0.07	-	-	6.8
Risk to amphibians	0.00	0.00	0.01	-	-	6.8
Great Blue Heron - fish ingestion	0.00	0.00	0.04	-	-	6.8
Harbor Seal - fish ingestion	0.00	0.00	0.47	-	-	6.8
Great Blue Heron - water ingestion	0.00	0.00	0.00	-	-	6.8
Short-tailed shrew - water ingestion	0.00	0.00	0.00	-	-	6.8
Sediments at 20%						
Risk to aquatic organisms	0.00	0.11	0.00	-	-	6.12
Risk to vegetation	0.00	0.00	0.00	-	-	6.12
Risk to mallard duck by food ingestion	0.00	0.01	0.00	-	-	6.13

	CUMULATIVE ECOLOGICAL QUOTIENT VALUES (AVERAGE EXPOSURE)			CHEMICALS OF POTENTIAL CONCERN		
	Volatile Organics	*Semi-volatiles / Pesticides*	*Metals / Cyanides*	Low Risk 1 < EQ < 10	Probable Risk 10 < EQ < 100	Reference Table
STORAGE RESERVOIR						
Water						
Risk to aquatic life	0.73	0.18	3.27	Cyanide	-	6.2
Risk to amphibians	0.16	0.01	0.14	-	-	6.2
Sediments						
Risk to aquatic organisms	0.00	0.00	0.77	-	-	6.14
Risk to vegetation	0.00	0.00	2.28	-	-	6.14
Risk to mallard duck by food ingestion	0.00	0.01	0.00	-	-	6.15
RECLAIMED WATER USE IN IRRIGATION FIELDS						
Direct Exposure						
Risk to vegetation	0.00	0.00	0.00	-	-	6.16
Risk to soil organisms	0.00	0.01	0.00	-	-	6.16
Run-off from Irrigation Fields						
Risk to freshwater organsims	0.00	0.02	3.88	-	-	6.17
Risk to aquatic organisms in esteros	0.00	0.00	6.90	Copper	-	6.18
RECLAIMED WATER TRANSFER BY PIPELINE						
Direct Exposure						
Risk to freshwater organisms exposed during accidental effluent release.	0.04	0.07	1.44	-	-	6.19

7.3 RISK EVALUATION

Cyanide

Cyanide was identified as a potential risk for aquatic organisms in the Laguna de Santa Rosa, and reclaimed water storage reservoirs. In both cases the assessment identified a low risk probability for adverse effects, as calculated ecological quotients were well below the threshold value of 10 indicative of probable risk levels. Based on current reclaimed water quality, cyanide levels in the Laguna de Santa Rosa and storage reservoirs are likely to moderately exceed toxicological levels for sensitive aquatic species.

The exceedance of the EQ threshold value, however, was low, indicating that the probability for actual adverse effects is low, even under the assumption of chronic exposure to undiluted reclaimed water (average cyanide concentration of 0.012 mg/L). Reported toxicity values for chronic exposure of freshwater organisms to cyanide range from 0.0018 to 0.0034 mg/L for invertebrate species and from 0.008 to 0.016 mg/L for fish species (EPA, 1985e).

Zinc and Chromium

The risk for wildlife exposure to zinc and chromium by fish consumption appears not to be significant as elevated tissue concentrations of those two metals are unlikely to occur. These elevated tissue concentrations apply to fish chronically exposed to undiluted reclaimed water, an exposure condition not likely to occur even during extended dry-weather conditions. The expected average exposures of aquatic organisms to reclaimed water constituents in Laguna de Santa Rosa are below 17 percent (Table 6.1).

Aluminum

Aluminum was identified as having a low potential for adverse effects on piscivorous organisms based on the detected levels of metals in fish tissues (1995) of the Kelly Farm Wetlands Demonstration Project.

Exposure to aluminum through fish ingestion appears to have a low risk for adverse effects on piscivorous organisms such as the great blue heron and the harbor seal. For the latter species, an ecological quotient greater than 9 was calculated for exposure of individuals that, on a seasonal basis, derive one half of their diet from fish inhabiting the mouth of the Russian River. The potential for actual adverse effects of aluminum in tissues of Russian River organisms is low for three reasons: 1) the screening benchmarks for effects on mammal species have a low reliability; 2) the average exposure of fish to reclaimed water is expected to be less than 3 percent; and 3) elevated aluminum concentrations in organism tissues have already been documented on a seasonal basis for the area upstream of the converge of the Laguna de Santa Rosa.

Toxicological Benchmark. The benchmark used for evaluation of potential effects on mammals has a low reliability when applied to the harbor seal. The reference value of 111 mg/kg/day for potential adverse effects was obtained from a single study in which three consecutive generations of mice were administered aluminum salts dissolved in water. No effects on the number of litters or number of offspring per litter were observed for a single dietary dose tested, but growth of generations two and three was reduced (Opresko et al, 1994). This screening benchmark value was applied to the harbor seal for ingestion of fish assuming that the seal is sixteen times more sensitive to aluminum than the mouse (benchmark extrapolation factor of 16). The extrapolation also assumes that aluminum present in fish tissues is as readily available for absorption as the salts dissolved in drinking water administered to laboratory mice.

Average Exposure. Nominal reclaimed water discharges of 1, 5, 10, and 20 percent were used to estimate fish exposure in the Russian River. These maximum discharge values apply to extreme dry-weather conditions that do not represent long-term exposure conditions of aquatic organisms to reclaimed water. A better indicator of the expected long-term exposure is the average discharge value (50th percentile) of reclaimed water which ranges from 0.2 to 3 percent of the Russian River flow (Table 6.1).

Current Exposure Levels to Aluminum. Since 1990, the State Mussel Watch Monitoring Program has reported elevated concentrations of aluminum in tissues of organisms of the Russian River, both in the downstream section of the river (Wohler Road sampling site) and outside the area of influence of the project (upstream section of the river, prior to the confluence of Laguna de Santa Rosa). The monitoring program has also documented elevated concentrations of aluminum in clam tissues throughout the region, including the Laguna de Santa Rosa at the sampling sites located upstream of the reclaimed water discharge locations (Laguna at Stony Point Road) (Merritt Smith Consulting, 1995a).

Tissue concentrations for the transplanted freshwater clam (Asian clam), listed below, are similar or greater than the tissue values reported for crayfish and mosquitofish in Kelly Farm Ponds (449 mg/kg and 1,232 mg/kg, respectively). The regular monitoring of Asian clam tissues, a common inhabitant of the Russian River, indicates that seals and herons are routinely exposed to dietary concentrations of aluminum that exceed those expected in aquatic organisms continually exposed to undiluted reclaimed water. The maximum exposure regime of Russian River fish to reclaimed water is only 3 percent on the basis of average flow (Table 6.1).

Copper

Copper concentrations potentially present in runoff from agricultural areas irrigated with reclaimed water were identified as having a low potential for adverse effects on aquatic organisms. The ecological quotient was more elevated for the esteros because marine organisms appear to have a greater sensitivity to copper than freshwater organisms.

	Aluminum Concentration in Asian Clam Tissue (mg/kg dry wt)*				
	3/20/90	**1/30/91**	**4/7/92**	**3/30/93**	**10/11/94**
Russian River					
Upstream of the Laguna's Confluence (at Wohler Bridge)	1,251	NA	5,700	970	670
Downstream of the Laguna (at Hacienda Bridge)	780	NA	1,900	1,500	790
Laguna de Santa Rosa					
Upstream of reclaimed water discharge (at Stony Point Rd)	1,055	360	1,300	400	420
Downstream from discharge (at Wohler Rd)	977	570	900	2,400	460

* Data of the State Mussel Watch Program

The significance of the potential exposure of organisms in the esteros to copper will depend on the degree of mixing of agricultural runoff and receiving waters. Mixing with seawater is expected to significantly reduce the actual concentrations at which estuarine organisms are exposed to reclaimed water constituents. For dissolved copper, concentrations in the undiluted reclaimed water (ranging from 0.006 to 0.013 mg/L) are similar to those of Estero Americano where historically reported concentrations range up to 0.036 mg/L with an average value of 0.0058 mg/L (Surface Water Quality Report, Table WQ-21). For the Estero de San Antonio the reported average values range from 0.003 to 0.004 mg/L.

7.4 RISK UNCERTAINTY EVALUATION

Table 7.2 lists the uncertainties for the assessment of ecological risk associated with the increased reclaimed water discharge from the Santa Rosa Regional Water Reclamation Facility. A qualitative analysis was made of these uncertainties in the quantification of ecological risk. This analysis was based on the potential magnitude of underestimating or overestimating the risk of adverse effects to organisms using four uncertainty categories: low, moderate, high, and unknown potential. A low uncertainty qualifies the risk with an estimated one-order of magnitude error, or less. High uncertainties refer to risk estimates with potential errors greater than two orders of magnitude. Moderate uncertainties are defined by the intermediate range of potential errors between one and two orders of magnitude in the risk estimates.

In general, assumptions used in the evaluation of exposures and potential adverse effects are conservative and tend to overestimate actual risk values. Extrapolation factors and transfer factors for potential bioaccumulation of chemical substances were selected to provide an elevated level of protection for sensitive ecological receptors. The applicability of these factors to the specific site conditions, however, is largely unknown.

Table 7.2 Uncertainties for Ecological Risk Assessment

	Potential Magnitude		
Source of Uncertainty	For Overestimating Risk	For Underestimating Risk	For Overestimating or Underestimating Risk
Selection of Receptor Species			
1. Large numbers of species are present at the site which may be more or less sensitive than receptors selected.			Unknown
2. Exposure/bioaccumulation pathways could be different from theoretical ones discussed.			Unknown
Selection of Assessment Endpoints/Benchmarks			
1. Effects endpoints were based primarily on lethal and sublethal effects using uncertainty factors to estimate a no-observable effect levels.			Unknown
2. Benchmarks use laboratory studies and assume 100% of the chemical substance is bioavailable and in most toxic form.	Moderate/high		
3. Metals in soil are less available for plant uptake in pH > 6.5.	Moderate		
4. Similar compounds were used to estimate benchmarks using an uncertainty factor.			Unknown
Determination of Exposure Concentrations			
1. Assumes no detoxification or depuration of COPC from prey to predator, and 100 percent assimilation.	Moderate		
2. Extrapolation from low to high dose and from one species to another introduces uncertainties.			Unknown
3. Environmental sampling locations may not be representative of conditions at the source area.		Moderate	
4. Bioconcentration/bioaccumulation factors could be different than those chosen; limited organism tissue data were available.			Unknown
5. Most receptors were assumed to derive all their food from the sites.	Moderate		

Table 7.2, continued

Source of Uncertainty	Potential Magnitude: For Overestimating Risk	Potential Magnitude: For Underestimating Risk	Potential Magnitude: For Overestimating or Underestimating Risk
Calculation of Ecological Quotients			
1. Risks are summed for multiple compounds within a group.	Moderate		Unknown
2. Some chemicals were not included in the calculations due to lack of benchmarks.		Moderate	

Notes:

Low - The effects from the uncertainty are estimated to be less than one order of magnitude.
Moderate - The effects from the uncertainty are estimated to be between one and two orders of magnitude.
High - The effects from the uncertainty are estimated to be greater than two orders of magnitude.
Unknown - The effects from the uncertainty are not determined due to numerous variables.

8. SUMMARY AND CONCLUSIONS

8.1 RISK ASSESSMENT METHODOLOGY

Overview

An ecological risk assessment of various project alternatives was conducted to evaluate whether the increased discharge of reclaimed water would result in potential adverse effects to ecological resources. The ecological risk assessment was based on site, field, and laboratory data collected, and on available toxicology literature of chemicals of potential concern to plant and animal species in vicinity of the reclaimed water discharge, storage, and irrigation sites. The ecological risk assessment included five components.

- Site characterization, the identification of potentially exposed aquatic and terrestrial ecosystems, and representative plant and animal communities;
- Development of a conceptual site model, the formulation of exposure scenarios and identification of exposure pathways and ecological receptors;
- Exposure assessment, the evaluation of exposure conditions and transfer factors, both by direct contact with the media, and through food and water ingestion;
- Characterization of ecological effects, the selection of reference values for potential effects (benchmarks), and their extrapolation to the site ecoreceptors; and
- Risk characterization, the use of ecological quotients and the evaluation of uncertainty associated with the risk assessment.

Risk Quantification

The quantification of ecological risk was based on the calculation of the ecological quotients (EQs), the ratio between exposure concentration for a given chemical substance and an applicable benchmark value that identifies possible adverse effect levels on ecological receptors. The characterization of potential effects of chemical substances on receptor organisms was based on the following guidelines proposed by Barnthouse et al. (1986), EPA (1989a), Watkin and Stelljes (1993), and Menzie et al. (1993). These guidelines characterize the risk probability on an order-of-magnitude basis:

1. Adverse effects are not expected for EQ values equal to, or less than, 1;
2. A low potential for effects is indicated by EQ values between 1 and 10;
3. A significant potential for adverse effects is indicated by EQ values greater than 10; EQs in excess of 100 identify a very high probability for adverse effects on ecological receptors and biological communities.

Exposure Pathways

Ecological risk was evaluated for six major pathways identified for the potential increased exposure of aquatic organisms and wildlife to the discharge from the Santa Rosa reclamation facility:

1. Direct exposure to the reclaimed water in Santa Rosa Creek and the Laguna de Santa Rosa;
2. Exposure of organisms associated with the Russian River, by direct discharge or through the Laguna de Santa Rosa;
3. Exposure of rooted vegetation, sediment organisms and waterfowl to sediments in the Laguna Santa Rosa and the Russian River;
4. Exposure of aquatic organisms and wildlife in storage reservoirs;
5. Exposure of soil organisms and terrestrial vegetation by reclaimed water application to irrigation fields (South County, West County, and Sebastopol irrigation areas); and
6. Potential releases from transfer pipelines along the route to the geysers injection area.

8.2 ECOLOGICAL RISK EVALUATION

No organic substances were identified as a potential concern to biological communities in terrestrial and aquatic habitats potentially exposed to reclaimed water use. Ecological quotients for reclaimed water constituents were near or below a value of 1.0, indicating that the expected exposure concentrations in water, sediment, soils, and organism tissues were lower than the benchmark values for potential adverse effects on receptor organisms.

Three inorganic chemicals were identified as having a low risk probability: 1) cyanide for the direct exposure of aquatic organisms in the proposed storage reservoirs and in Laguna de Santa Rosa under the assumption of chronic exposure to undiluted reclaimed water; 2) copper for the exposure of aquatic organisms in esteros as a result of increased agricultural irrigation; and 3) aluminum for dietary intake by waterfowl and the harbor seal in the mouth of the Russian River, assuming a high level of bioaccumulation in fish tissues. Zinc and chromium also had EQ values greater than 1.0 for fish ingestion by waterfowl in the Laguna de Santa Rosa, assuming continuous exposure to undiluted reclaimed water. However, values lower than 1.0 are obtained on the basis of exposure to the expected contribution of reclaimed water to the Laguna, an average of 17 percent.

Cyanide. Cyanide was identified as a potential risk for aquatic organisms in the Laguna de Santa Rosa and storage reservoirs, but in both cases the assessment identified a low probability for adverse effects. Calculated ecological quotients were well below the threshold value of 10 indicative of probable risk levels, even under the assumption of chronic exposure to undiluted reclaimed water.

Aluminum. Exposure to aluminum through fish ingestion has a low risk for adverse effects on piscivorous organisms such as the great blue heron or the harbor seal. The potential for adverse effects associated with aluminum present in Russian River organisms, however, is low. Elevated aluminum concentrations have already been documented on a seasonal basis for the Russian River upstream of the convergence of Laguna de Santa Rosa. Since 1990, the State Mussel Watch Monitoring Program has documented elevated concentrations of aluminum in clam tissues, both in the mouth and upstream sections of the Russian River.

Copper concentrations potentially present in runoff from agricultural areas irrigated with reclaimed water were identified as having a low potential for adverse effects on aquatic organisms. The significance of the potential exposure of organisms in the esteros to copper will depend on the degree of mixing of agricultural runoff and receiving waters. Mixing with seawater is expected to significantly reduce the actual exposure concentrations for estuarine organisms. For dissolved copper, the average concentration in reclaimed water is similar to those historically reported for Estero Americano.

In conclusion, the ecological risk evaluation showed little or no risk associated with the increased discharge of reclaimed water into the Russian River and with streams receiving irrigation runoff. In some instances, a low risk was identified for three chemical substances under conservative assumptions of potential toxicity and exposure conditions. No significant potential for adverse effects on species in the project area was identified for the increased reclaimed water production from the Santa Rosa Subregional facility.

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APPENDIX A

SITE CHARACTERIZATION

This site characterization provides an overview of the different ecological communities present in terrestrial and aquatic habitats potentially exposed to reclaimed water from the Santa Rosa Subregional facility. Each characterization contains vegetative and wildlife communities, environmentally sensitive areas, and species of special concern. The purpose of characterizations is to recognize possible ecological receptors, pathways, and exposure scenarios for each plant and wildlife community located in each region. These descriptions, limited to dominant and unique flora and fauna, are based on multiple surveys conducted in support of the EIR/EIS document. A complete list of documents cited below is presented in Section 9.

A.1 AGRICULTURAL IRRIGATION

A.1.1 Vegetative Communities

The proposed agricultural irrigation sites are located in the south and west areas of Sonoma County and extend southward into the northwest portion of Marin County. Proposed irrigation sites for the South County Reclamation Alternative (South County Alternative) are the areas surrounding Tolay Creek, the Petaluma River, and extending southwest to San Pablo Bay. The West County Reclamation Alternative (West County Alternative) sites include the Americano and Stemple Creek watersheds, which both have different vegetative communities based on topography, soil type, and the availability of freshwater. Irrigation of the Sebastopol area is an option for both alternatives. Anthropogenic (human-made) influences have altered native plant communities through the introduction of new plant species and cultivation practices.

For both irrigation alternatives the extent of the irrigation areas will depend on the percentage of reclaimed water discharge into the Russian River. Both acreage scenarios include present, interim, and future irrigation plans under both normal and low volume conditions. The West County alternative encompasses approximately 21,400 acres: 6,700 acres in Americano Creek, 11,100 acres in Stemple Creek, 2,600 acres in the Sebastopol area, and 1,000 acres of miscellaneous locations. The South county alternative is composed of approximately 15,200 acres located in Lakeville area (6,100 acres), east of Rohnert Park (2,300 acres), Adobe Road area (900 acres), north of Petaluma (800 acres), Baylands (2,500 acres), and Sebastopol area (2,600 acres).

The dominant vegetative communities at these locations are the result of heavy agricultural use. Currently, the primary agricultural commodity for both alternative areas is dairy farming; however, other agriculture uses are being developed. Pastoral communities are common in the region and much of the Stemple and Americano watersheds have been altered for the production of forage species. This vegetative community is characterized by the presence of few native species, with weedy species scattered throughout. Some of the more common species present include milk thistle (*Silybum marianum*), soft chess (*Bromus mollis*), slender wild oat (*Avena barbata*), and Italian rye grass (*Lolium multiflorum*) (EIP, 1990). Other less common anthropogenic communities found in the irrigation areas are agrestal and plantation communities. Agrestal communities are characterized by areas that are consistently plowed for the production of crops (e.g., corn). EIP Associates (1990) found agrestal communities to be less important today than in the past for both the Stemple Creek and Americano Creek watersheds. Vineyards and orchards comprise plantation communities located mainly east of the watersheds, with the exception of several blue gum (*Eucalyptus* sp.) plantations (HBA, 1996b).

The riparian communities associated with the proposed irrigation areas of Americano and Stemple Creek watersheds are greatly influenced by cattle grazing and subsequent nutrient input. However, when grazing is prevented, native riparian vegetation quickly re-establishes, creating usable wildlife habitat. These communities include rushes and sedges intermixed with grasses. Where cattle grazing is limited for longer periods of time, the transition to a riparian woodland occurs, allowing for willow (*Salix* sp.) and cottonwood (*Populus* sp.) to become established (HBA, 1996b).

A.1.2 Wildlife

The presence of wildlife within the irrigation areas is a product of available habitat. Historical and current observations of important habitat features in Americano and Stemple creeks included valley oak and coastal oak woodlands (Maron, 1994). These woodlands provide shelter and a valuable food source for a variety of mammal and bird species. However, due to anthropogenic influences, both woodland communities are largely limited to the Laguna de Santa Rosa and outside the irrigation areas of the West County Alternative (EIP, 1990). The dominant vegetation found in these watersheds is currently pastoral grasslands used for dairy cattle production (USDA, 1990).

The most sensitive and important habitats in these areas are the riparian communities adjacent to all three creeks. This habitat provides refuge for a variety of birds such as mallard (*Anas platyrhynchos*), red-winged blackbird (*Agelaius phoeniceus*), red-tailed hawk (*Buteo jamaicensis*), Brewer's blackbird (*Euphagus cyanocephalus*), and great egret (*Casmerodius albus*). Common mammals associated with the riparian and adjacent pastoral communities include the following: opossum (*Didelphis virginiana*), vole (*Clethrionomys* sp.), mule deer (*Odocoileus hemionus*), deer mouse (*Peromyscus maniculatus*), and Botta's pocket gopher (*Thomomys bottae*). Amphibian and reptile species associated with the riparian community are bullfrog (*Rana catesbeiana*), California newt (*Taricha torosa*), western aquatic garter snake (*Thamnophis conchii aquaticus*), and western fence lizard (*Sceloporus occidentalis*).

A.1.3 Environmentally Sensitive Areas

Areas considered sensitive due to increased plant and animal diversity are the riparian and oak woodland communities. The irrigation sites have limited riparian woodlands, making them sensitive to anthropogenic influences. When undisturbed, the riparian areas contain the highest diversity of plant and animal species relative to pastoral communities within the region. Furthermore, this vegetation type, which was once widespread, still supports threatened and endangered species. Oak woodlands, another diminishing community, are found near the headwaters of all three creeks and provide suitable habitat for a variety of bird and mammal species.

A.1.4 Special Status Species

Avian species of special concern include the yellow warbler (*Dendroica petechia brewsteri*) and the yellow breasted chat (*Icteria virens*). Both species use the riparian areas associated with Stemple Creek (Maron, 1994). The osprey (*Pandion haliaetus*) is known to frequent the irrigation areas and is a listed State species of special concern. The bald eagle (*Haliaeetus leucocephalus*) is a federally threatened species occasionally sighted at Estero Americano, an estuary located at the mouth of the Americano Creek (Maron, 1994).

Aquatic species of special concern are the red-legged frog (*Rana aurora*) (federally proposed as endangered), western pond turtle (*Clemmys marmorata*) (federal category 2 candidate), and the California freshwater shrimp (*Syncaris pacifica*) (state and federally-listed as endangered). All three species have limited spatial distribution due to habitat loss within the region.

A.2 RESERVOIR SITES

Reservoirs create unique aquatic habitats at the expense of removing existing terrestrial habitat. The reservoir characterization focuses on the potential aquatic and terrestrial habitat resulting from the construction of a proposed reservoir. Because of available data, the Bloomfield Reservoir site, located north of Americano Creek, was used to determine the establishment of possible plant and animal communities after the construction.

A.2.1 Vegetative Communities

Due to the general practices of dairy farming, the most common vegetative community at potential reservoir sites is pastoral. Sparse riparian areas are located adjacent to creeks at the bottom of the drainage basins. The most common species within the pastoral community are annual bluegrass (*Poa annua*), clover (*Trifolium* sp.), and milk thistle, and adjacent slopes have scattered, dense stands of gorse (*Ulex europaeus*). The riparian community is estimated to be approximately 5 acres for the Bloomfield site and consists of willow, blackberry (*Rubus ursinus*), and wax myrtle (*Myrica californica*) (HBA, 1996a).

The physical and chemical features of the selected reservoirs (i.e., basin morphometry, residence time, and nutrient input) will determine the biological community composition. Increased water availability may expand riparian vegetation along the reservoir edges. This expansion may be hindered by land management influences such as cattle grazing. The management of the reservoir will play a direct role in what type of vegetation is established. Rapid changes in depth for irrigation purposes is likely to hinder development of extensive riparian vegetation.

Typical riparian species will include rushes (*Juncus* sp.), sedges (*Carex* sp.), and cattails (*Typha latifolia*). Areas with little anthropogenic influence will develop into woody riparian vegetation that may include willow and cottonwood (HBA, 1996b).

A.2.2 Wildlife

Wildlife associated with the reservoir will be similar to wildlife species associated with the irrigation areas; however, the reservoir will also provide habitat for a variety of aquatic species (i.e., phytoplankton, zooplankton, crayfish, and fish). Furthermore, waterfowl would be able to utilize this area, along with other species such as arthropods, mollusks, amphibians, and reptiles. Bird species found at reservoirs may include mallard, red-winged blackbird, great egret, and Brewer’s blackbird. Mammal species found at reservoirs may include opossum, vole, mule deer, deer mouse, and Botta’s pocket gopher. Amphibian and reptile species may include bullfrog, California newt, and aquatic garter snake (HBA, 1996b; Merritt Smith Consulting, 1995c, 1996c).

A.3 THE LAGUNA DE SANTA ROSA

The Laguna de Santa Rosa is a tributary to the Russian River which drains a watershed encompassing approximately 255 square miles. This large, marshy area acts as a flood control basin and, in times of heavy rain, overflow from the river backs up into the Laguna creating a lake that is used by many plant and animal species (Reilly and Smith, 1990). The Laguna is also used as a migratory route by steelhead trout and other fish species which spawn in the upper reaches of Mark West and Santa Rosa Creeks (CH2M Hill, 1992; Merritt Smith Consulting, 1996b).

Land use within this watershed is primarily agricultural; however, other areas which have been less impacted retain native flora and fauna species. The Laguna has high levels of bacteria, phytoplankton and nutrients that are associated with livestock, wildlife, and other sources (Merritt Smith Consulting, 1996b; USDA, 1990).

A.3.1 Vegetative Communities

The Laguna area can be separated into five communities that vary in physical characteristics that influence the presence of plant and wildlife species. Grassland, woodland, riparian, marsh, and anthropogenic communities comprise the Laguna area. Vernal pools, found in the grassland and woodland areas, create habitat for specialized species that exist within very specific conditions (HBA, 1996a).

The grassland area is predominantly made up of annual, non-native grass and weed species that are well-suited for grazing. Grassland species include soft chess, foxtail fescue (*Festuca dertonesis*), Italian rye grass, slender wild oat, and forbs such as cut-leaf geranium (*Geranium dissectum*), vetch (*Vicia sativa*), and hairy cat's ear (*Hypocharis radicata*). In spring, the area is in bloom with many native wildflower species that disappear in late summer to be replaced by tarweed species, including *Hemizona* sp., *Madia* sp. and *Holocarpa virgata* (HBA, 1996a).

Woodland communities are dominated by oak species with an understory of grass and forbs common to grassland areas. These communities are mostly associated with irrigated pasture and vernal pools. Grazing of the seedling trees has slowed the natural replacement of the woodlands. Typical oak species include California black oak (*Quercus kelloggii*), coast live oak (*Q. agrifolia*), and Gary oak (*Q. garryana*), with valley oak (*Q. lobata*) being the dominating species. Typical herbaceous species include soft chess and slender wild oat as well as cut-leaf geranium and vetch (HBA, 1996a).

Riparian communities exist in areas along the banks of streams and rivers. This community is the product of the river bank's physical characteristics. For example, sedges and rushes are present in areas with little slope, while cottonwood and willow are associated with steep banks. Thick overstories and thickets provide foraging habitat and bedding and nesting areas for many wildlife species.

The Laguna riparian communities are diverse as indicated by the many wildlife species utilizing them. Typical vegetation includes willow, cottonwood, Oregon ash (*Fraxinus latifolia*), valley oak, box elder (*Acer negundo*), and black walnut (*Juglans hindsii*). Understory species include gooseberry (*Ribes divaricatum*), hedge mustard (*Sisymbrium officinale*), stinging nettle (*Urtica* sp.), honeysuckle (*Lonicera* sp.), blackberry, and yellow monkey flower (*Mimulus gutatus*) (Madrone, 1977; Reilly and Smith, 1990).

Laguna freshwater marsh communities contain obligate wetland plants. These plants are adapted to and require saturated soil. The acreage of freshwater marsh land in this area is decreasing as the land is drained for agricultural uses and/or flood control projects. These communities are dominated by tules (*Scirpus* sp.), rushes, cattails, and sedges (EIP, 1990).

Anthropogenic communities in the vicinity of the Laguna de Santa Rosa include cropland, plantation, and pasture. Plant species present in these communities include predominantly weedy annuals and perennials. Anthropogenic communities are increasing and replacing other native communities as agricultural activities are expanded. Typical species include slender wild oat, Italian rye grass, foxtail fescue, and rip-gut brome, as well as forbs like cut-leaf geranium, vetch, and hairy cat's ear (EIP, 1990).

Vernal pools exist primarily in the grassland areas. Vernal pools occur where impervious soils block the downward percolation of rainwater, creating pools of water. The pools usually fill with rain during the winter months and do not lose water until evaporation exceeds precipitation (usually during the spring months). This combination of wet and dry cycles allows only very specialized species to become established. The non-native species typical of the grassland areas do not readily establish themselves in these areas due to the extreme physical changes. Typical vernal pool species include Howell's bentgrass (*Alopecurus howellii*), white brodiaea (*Brodiaea hyacinthina*), bracted allocarya (*Allocarya bracteata*), marsh lasthenia (*Lasthenia glaberrima*), and pennyroyal (*Mentha pulegium*) (Madrone, 1977; Reilly and Smith, 1990).

A.3.2 Wildlife

Grassland wildlife is similar to that found in the grasslands of the potential reservoir sites. Bird species found in grasslands include meadowlark (*Sturnella neglecta*), killdeer (*Charadrius vociferus*), white-crowned western sparrow (*Zonotrichia leucophrys*), goldfinch (*Carduelis* sp.), housefinch (*Carpodacus mexicanus*), and red-winged blackbird. Raptor species that forage in grasslands include red-tailed hawk, white-tailed kite (*Elanus leucurus*), American kestrel (*Falco sparverius*), rough-legged hawk (*Buteo lagopus*), and ferruginous hawk (*Buteo regalis*). Typical mammalian species found in grassland areas include mule deer, vole, Botta's pocket gopher, gray fox (*Urycyon cinereoargenteus*), and black-tailed jack rabbit (*Lepus californicus*) (HBA, 1996a).

Woodland communities provide nesting and foraging areas for various avian and mammalian species. Wildlife species inhabiting woodlands can include raptors such has hawks and the golden eagle, a State species of special concern. Raptors feed upon small mammals such as house mice (*Mus musculus*), black-tailed jack rabbit, and California ground squirrel (*Spermophilus beecheyi*). Larger predatory mammal species include fox and coyote (*Canis latrans*) (HBA, 1996a, 1996b).

Riparian areas also provide nesting, breeding, and foraging habitat for a variety of wildlife. Migratory birds utilize the areas for feeding, resting, and breeding habitat. Bird species that utilize riparian areas include yellow-rumped warbler (*Dendroica coronata*), woodpeckers (*Picoides* sp.), nuthatch (*Sitta carolinensis*), flycatchers (*Empidonax* sp.), mallard, belted kingfisher (*Ceryle alcyon*), great blue heron (*Ardea herodias*), and song sparrow (*Melospiza melodia*) (HBA, 1996a, 1996b). Mammal and fish species include raccoon (*Procycon lotor*), striped skunk (*Mephitis mephitis*), green sunfish (*Lepomis cyanellus*), and mosquitofish (*Gambusia affinis*) (Merritt Smith Consulting, 1995c, 1995d).

Marsh communities, due to their unique vegetative composition, provide foraging and nesting sites for many mammalian and avian species. Mammalian species located in marshes include mink (*Mustela vison*), otter (*Lutra canadensis*), and raccoon (CH2M Hill, 1990). Marsh bird species include American coot (*Fulica americana*), red-winged blackbird, great blue heron, black phoebe (*Sayornis nigricans*), and song sparrow. Other species commonly found in marshes include green sunfish, mosquitofish, crayfish, and aquatic garter snake. The aquatic community associated with marshes also provides suitable habitat for many frogs and pond turtles (CH2M Hill, 1990; Thorp and Covich, 1991).

Anthropogenic wildlife communities are limited due to the relatively uniform nature of the Laguna de Santa Rosa area. Species composition varieties will change slightly depending on the associated land use (i.e., cropland, pasture, or plantation). Typical residents include rodent species such as deer mice, voles, Botta's pocket gopher, and house mice. Bird species that utilize pastures and croplands for foraging and cover include short-eared owl (*Asio flammeus*) and ringneck pheasant (*Phasianus colchicus*) (EIP, 1992).

Vernal pools typically receive an influx of wildlife species from neighboring areas that take advantage of the water and plant resources (EIP, 1990). There are many endemic species associated specifically with the pools (e.g., vernal pool crustaceans). Their distribution is limited to the temporary aquatic environment provided by the pool habitat (CH2M Hill, 1990).

A.3.3 Environmentally Sensitive Areas

Sensitive areas located around the Laguna include the valley foothill riparian, freshwater emergent wetland, and valley oak woodland communities. All three areas represent habitats that were once widely distributed throughout the state; however, due to anthropogenic influences, these habitats are now considered rare.

A.3.4 Special Status Species

Endangered species and species of special concern occur within the various vegetative communities of the Laguna area. Endangered and threatened species found in grassland areas include Clara Hunt's milk vetch (*Astragalus clarinus*), Tiburon tarplant (*Hemizonia multicaulis, spp. vernalis*), Petaluma popcorn flower (*Plagiobothrys mollis, var. vestitus*), and showy Indian clover (*Trifolium amoenum*) (EIP, 1990). Wildlife species of special concern found in the Laguna area include the golden eagle, badger, and the burrowing owl (EIP, 1990).

Woodland communities are dominated by the valley oak. Although dominant in this association, throughout California the valley oak is considered a sensitive species that is characterized as having limited distribution and therefore in need of monitoring (EIP, 1992). Clara Hunt's milk vetch, badger, and golden eagle occur in and around woodland communities.

An endangered plant species found in the riparian community is the Sonoma alopecurus (*Alopecurus aequalis var. sonomensis*). Because of low numbers and reduced habitat, the ringtail is considered a State species of special concern.

The freshwater marsh provides habitat for endangered species such as Sonoma alopecurus, Thurber's reedgrass (*Calamagrostis crassiglumis*), swamp haerbell (*Campanula californica*), white sedge, Pitkin marsh Indian paintbrush (*Castilleja uliginosa*), Pitkin Marsh lily (*Lilium pitkinense*), Douglas pogogyne (*Pogogyne douglasii* spp. *parviflora*), California beaked-rush (*Rhynchospora globularis*), round-headed beaked rush (*Rhynchospora globularis var. globularis*), and Kenwood Marsh checkerspot (*Sidalcea oregana spp. valida*) (EIP, 1990). Wildlife species of special concern associated with this area include the ringtail (CH2M Hill, 1990; Reilly and Smith, 1990).

Anthropogenic areas such as pastures and agriculture fields are used by the northern harrier, a State species of concern (HBA, 1996a, 1996b).

Endangered plant species associated with vernal pools in the area include Baker's blennosperma (*Blennosperma bakeri*), Boggs Lake hedge hyssop (*Gratiola heterosepala*), Burke's goldfields (*Lasthenia burkei*), legenere (*Legenere limosa*), Sebastopol meadowfoam (*Limnanthes vinculans*), and Douglas pogogyne (HBA, 1996a, 1996c).

A.4 RUSSIAN RIVER

The Russian River, 110 miles in length, drains 1,485 square miles of both Sonoma and Mendocino Counties. The river and its estuaries provide resources for forty-six fish species, of which twenty-seven are native. The principal tributaries that serve as a spawning grounds for steelhead trout are Mark West Creek, Santa Rosa Creek, Dry Creek, and Maacama Creek. Due to high average water temperatures and the lack of shelter in the form of vegetation, boulders, or undercut banks in the river, spawning activity takes place only in the upper reaches of the Laguna and river tributaries (Merritt Smith, 1995).

Hydrology of the river is partially determined by rainfall and reservoir management within the region. Flood events are common during winter and spring seasons, while summer conditions cause periodic drying along certain areas of the river. Aquatic plant and animal species have adapted to these abrupt seasonal changes in flow and water level through increased tolerance and reproductive timing (EIP, 1990).

A.4.1 Vegetative Communities

The Russian River has unique riparian communities characterized by woody species near the source and estuarine species near the mouth. The source area contains species typical of other riparian habitat within the project area. According to EIP Associates (1990), vegetation is sparse along the river stem compared to its tributaries. The riverbank, throughout the course of the river, can influence the degree of vegetative diversity and the rate of transition into other surrounding vegetative communities. A gradually sloping bank allows for more emergent macrophytes to become established, while steep slopes tend to have only woody vegetation. In the upper reaches of the river, the riparian community increases in diversity due to a transition from the riparian community to a woodland.

Typical riparian species include sedges, rushes, and tules, as well as larger woody plants like cottonwood and willow. On either side of the river there are grassland areas utilized for agricultural purposes. Runoff from these areas provides an additional water source for the riparian community (EIP, 1990).

A.4.2 Wildlife

Wildlife in the river area varies from large terrestrial animals to small aquatic invertebrates. Terrestrial animals include mule deer, otter, badger, and small rodents. The Pacific harbor seal (*Phoca vitulina*) occurs frequently in the estuarine area near the mouth of the river. Bird species found along the river include osprey in the estuarine areas, golden eagle, and hawks, woodpeckers, nuthatches (*Sitta* sp.), and flycatchers (*Empidonax* sp.) in riparian areas. The occurrence of these species is dependent on the extent of habitat for foraging and nesting available along the course of the river.

Fish species include anadromous and non-anadromous species. Each species uses the river for habitat, feeding, and/or spawning. Native anadromous species include steelhead trout (*Oncorhynchus mykiss*), king/chinook salmon (*Oncorhynchus tshawytscha*), silver/coho salmon (*O. kisutch*), and Pacific lamprey (*Lampetra tridentatus*). Native non-anadromous fish species include minnows, perch, and sculpins. Non-native anadromous species include American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*).

River bottom dwellers range from gastropods to arthropods, all feeding on detritus and other food sources. Snails, clams, and insect larvae utilize the sediment for nutritional sources as well as protection from predators (Merritt Smith Consulting, 1995a).

A.4.3 Sensitive Areas

Sensitive areas of concern include both the riparian and aquatic communities associated with the river below the proposed point of discharge. These limited habitats provide unique resources for a variety of flora and fauna, which have adapted to both the physical and chemical characteristics of the area. For example, without emergent macrophytes, surface area for periphyton growth would be reduced, causing a decrease in the food source for macroinvertebrates. This bottom-up reaction would ultimately reduce populations of higher vertebrates within the water column.

The estuary associated with the Russian River provides habitat for a variety of invertebrates and vertebrates. Because of the high diversity and the decline of available habitat, the associated estuary is considered a sensitive area.

A.4.4 Special Status Species

Species of concern include the steelhead trout, golden eagle, ringtail, badger, and northern harrier, as well as white sedge and round-headed beaked rush. The chinook salmon, a State endangered fish species, is also of special concern due to diminishing spawning habitat (EIP, 1992; EIP, 1990).

A.5 ESTEROS AMERICANO AND DE SAN ANTONIO

The Esteros Americano and de San Antonio are "seasonal estuaries" that encompass marine, brackish, and freshwater habitats. They are termed seasonal due to the sand bar barriers that form seasonally, blocking their connection to the ocean. The uplands surrounding the esteros are composed primarily of annual grassland or pastoral land intermingled with coastal prairie, coastal scrub, and seasonal brackish marsh. These habitats merge with open water creating a diverse flora and fauna (Madrone, 1977; Maron, 1994).

A.5.1 Vegetative Communities

Fourteen different vegetative communities can be observed in this area. The five main communities are open water areas, seasonal brackish marsh, coastal scrub, coastal prairie, and annual grassland, which comprises the largest area (Madrone, 1977).

The open water habitat is dominated by algae species. A total of sixty-four algal species have been found between the two esteros, thirty-eight in the Americano and twenty-six in the de San Antonio, including the classes Clorophyta, Phaeophyta, and Rhodophyta. Both esteros contain eelgrass beds, a flowering plant that provides unique habitat for waterfowl, fish, arthropods, and mollusks. Epiphytic microalgae grow on the grass blades and provide an important food source (EIP, 1994).

A seasonal brackish marsh is also termed a euryhaline marsh. This characterization is derived from the wide range of salt tolerance in the plant community as a result of seasonal fluctuations in salinity. Spring rains create a freshwater environment that soon becomes saline as the mouths of the esteros are blocked and the freshwater evaporates. Pickle weed (*Salicornica virginica*) and salt grass (*Distichlis spicata*) occur on the border areas, while frankenia (*Frankenia grandifolia*) is found in better drained areas. Further inland from the coast, less salt-tolerant species such as wild oats, soft chess, and velvet grass (*Holcus lanatus*) are found (Madrone, 1977).

Coastal scrub areas are characterized by low-lying shrubs adapted to high winds and salt spray. In areas secluded from the wind and spray, these shrubs may grow to greater heights. Twenty-four different species of shrubs can be found in the scrub area depending on the degree of succession. Arid tolerant, primary species include California sage brush (*Artemisia californica*), coyote brush (*Baccharis pilularis var. consanguinea*), and bracken fern (*Pteridium aquilinum var. pubescens*). Secondary succession results in a community that supports native blackberry (*Rubus ursinus*) and yerba buena (*Satureja* *douglasii*). A fully mature coastal scrub may contain nine bark (*Physocarpus capitatus*), thimble berry (*Rubus parriflorum var. velutinus*), salmon berry (*Rubus spectabilis var. franciscanus*), and hazelnut (*Crylus cornuta, var. californica*). Other species such as snowberry (*Symphoricarpos rivularis*), ocean spray (*Holodiscus discolor*), and blue blossom (*Ceanothus thyrsiflorus*) also occur within this association (Madrone, 1977).

Closely associated with the species of the coastal scrub are coastal prairie species. Like the shrubs of the scrub areas, prairie species are stunted from harsh westerly winds, salt spray, and fires. The dominant species of this area include California fescue (*Festuca californica*) and Pacific reedgrass (*Calamagrostis nutkaensis*). Other subdominants include tufted hairgrass (*Deschampia edespitosa* ssp. *holieformis*), needlegrass (*Stipa pulchra*), California bromegrass (*Bromus marginatus*), iris (*Iris douglasiana*), and lupine (*Lupinus arboreus*) (Madrone, 1977).

Annual grassland is the dominant plant community, comprising 30,864 acres (Maron, 1994). Grassland acreage is increasing due to clearing, grazing, and other anthropogenic activities. The native species that once dominated the area have been replaced by non-native species. In areas that are heavily grazed, wild oats, soft chess, Italian ryegrass, and pineapple weed (*Matricaria matricarioides*) dominate. In areas that are more lightly grazed, native species intermingle with non-native species. Coast fiddleneck (*Amsinckia spectabilis*), Brodiaea (*Brodiaea* sp.), goldfield (*Lasthenia chrysostoma*), owl's clover (*Orthocarpus* sp.), checkerbloom (*Sidalcea malvaeflora*), and yarrow (*Achillea borealis var. californica*) can be found together with California poppy (*Eschscholzia californica*) near the banks of the esteros (Madrone, 1977).

A.5.2 Wildlife

Open water habitats support a variety of invertebrates and vertebrates that reside in the sandy/muddy bottom (Maron, 1994). Protozoans, cnidarians, rotifers, and annelids are found within the open water habitat and provide a food base for aquatic and wildlife communities. Within benthic zones, populations of fishes include various species of gobies, sculpins, and flatfishes. Schooling fishes such as herring, smelt, silversides, and seasonal predators such as bass and small sharks are found in the pelagic zone (Maron, 1994).

The seasonal brackish marsh and open water areas support many bird species, including the red-necked northern phalarope (*Phalaropus lobatus*), willet (*Catoptrophorus semipalmatus*), yellowlegs (*Tringa* sp.), dowitcher (*Limnodromus* sp.), mallard, gull (*Larus* sp.), great blue heron, and great egret. These species feed along the shoreline and in marsh areas as well as in open water areas. Predatory species such as northern harrier and white-tailed kite hunt in seasonal brackish marshes (Madrone, 1977).

A shift in wildlife species composition occurs in the transition from upland to scrub areas. The physical characteristics of the coastal scrub provide a different habitat than the marsh. Mammal species utilize the grasses and low-lying shrubs for reproduction, foraging, and cover. The raccoon, striped skunk, gray fox, and long-tailed weasel (*Mustela frenata*) occur in these areas (Madrone, 1977).

The coastal prairie succeeds out of the scrub area creating a variety of habitats for various species. Gray fox, brush rabbit (*Sylvilagus bachmani*), and mule deer have been observed in this area. Smaller foraging birds are also present in this area, including goldfinch, meadowlark (*Sturnella neglecta*), house finch, and white-crowned sparrow. Predatory birds such as American kestrel, red-tailed hawk, and white-tailed kite prey on a variety of prairie mammal and bird species (Madrone, 1977).

The species diversity decreases in the grassland area, although rodent species as well as predatory bird species increase in grasslands. Red-tailed hawks and white-tailed kites, along with other predatory birds such as American kestrel, golden eagle, rough-legged hawk, and ferruginous hawk, combine to form a diverse assemblage of predators. Foraging bird species include meadowlark, killdeer, white-crowned sparrow, goldfinch, and red-winged blackbird. Mammal species include mule deer, vole, pocket gopher, badger, and gray fox (Madrone, 1977).

A.5.3 Sensitive Areas

The esteros are sensitive areas that lie in what is termed the California coastal zone as defined by the Coastal Zone Management Act of 1976. This designation requires the local communities to carefully plan future land uses in an effort to further protect the esteros from development (Madrone, 1977). Furthermore, the esteros have obtained federal protective status and have been placed under the National Marine Sanctuary.

A.5.4 Special Status Species

Both esteros have species which are considered threatened or endangered. Threatened and endangered species occur in the Estero Americano more frequently than the Estero de San Antonio.

The seasonal brackish marsh area supports three sensitive or rare plant species. Mason's lilaeopsis (*Lilaeopsis masonii*), delta tule pea (*Lathyrus jepsonii* spp. *jepronii*), and Suisun marsh aster (*Aster chilensis var. lentus*) are all considered sensitive plant species by the state (HBA, 1996c).

Coastal scrub vegetation potentially supports sensitive or rare species such as Thurber's reed grass (*Calamagrostis crassiglumis*), Bolanders' reed grass (*C. bolanderi*), and yellow larkspur (*Delphinium luteum*) (HBA, 1996c).

Coastal prairie and coastal scrub support many of the same sensitive plant species. Pt. Reyes bent grass (*Agrostis clivicola var. punta-reyensis*) and coast lily (*Lilium maritimum*) are located in both the prairie and scrub areas. The California sedge (*Carex* *californica*) is a sensitive plant species that also occurs in the prairie area (EIP, 1992). Bent-flowered fiddleneck (*Amsinckia lunaris*), dwarf downingia (*Downingia humilis*), and Tiburon tarplant (*Hemizonia multicaulis*) are three of the sensitive plant species found in the grassland area. Special-status grassland wildlife includes the ferringous hawk and badger (HBA, 1996c).

The tidewater goby (*Eacyclogobius newberryi*), found in the shallow areas of the Estero de San Antonio, is a federally endangered species considered a California species of special concern.

The Estero Americano supports the following special status bird species which are of special concern over the whole area: golden eagle, sharp-shinned hawk (*Accipiter straiatus*), northern harrier, white-tailed kite (*Elanus leucurus*), peregrine falcon (*Falco peregrinus*), prairie falcon (*Falco mexicanus*), and bald eagle (HBA, 1996a). For more detailed species information refer to other existing biological assessments.