Results of Aquatic Life Toxicity Studies Conducted During 1997-99 in the Upper Newport Bay Watershed[1]

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EXECUTIVE SUMMARY

This report covers the results of a US EPA 205(j)-funded project devoted to assessing aquatic life toxicity in the Upper Newport Bay watershed, located in Orange County, California. Also, a comprehensive review of the existing information on the water quality characteristics of Upper Newport Bay and its tributaries has been conducted. The 205(j) project is an expansion of an Evaluation Monitoring Demonstration Project concerned with demonstrating an approach for defining the significant water quality use impairments that are occurring in Upper Newport Bay and its tributaries.

REVIEW OF EXISTING WATER QUALITY INFORMATION FOR UPPER NEWPORT BAY AND ITS TRIBUTARIES

Presented below is the executive summary from a report by Lee and Taylor (1999a) devoted to the water quality characteristics of Upper Newport Bay and its tributaries. This report is part of an overall report by Lee and Taylor (1999a) devoted to this 205(j) supported study of the aquatic life toxicity of Upper Newport Bay and its tributaries. The complete report provides the backup information for those parts of this executive summary devoted to reviewing the water quality of Upper Newport Bay.

Aquatic Life Toxicity

Previous studies of stormwater runoff conducted in late 1992 and early 1993 on San Diego Creek waters as they enter Upper Newport Bay showed that aquatic life toxicity was found in the Creek waters. These studies were limited to two samples, where the cause of this toxicity was not identified. Further, chemical analysis of tributary waters and Bay waters has shown that the concentrations of some heavy metals with potential to cause aquatic life toxicity were present in excess of United States Environmental Protection Agency (US EPA) water quality criteria. Therefore, there is a potential that these exceedances of the water quality criteria may represent toxic conditions to aquatic life where they occur.

At the time of the initiation of the Evaluation Monitoring Demonstration Project in July 1996, further studies were needed to determine whether San Diego Creek waters entering Upper Newport Bay were toxic to aquatic life. If toxicity in the Creek waters was found, then the significance of this toxicity to aquatic life within San Diego Creek and Upper Newport Bay

[1] Reference as :Lee, G. F. and Taylor, S. “Results of Aquatic Life Toxicity Studies Conducted During 1997-99 in the Upper Newport Bay Watershed” Report to State Water Resources Control Board, Santa Ana Regional Water Quality Control Board, and Orange County Public Facilities and Resources Department to Meet the Requirements of the US EPA 205(j) Project G. Fred Lee & Associates and Robert Bean William Frost Associates. Irvine, CA October (1999).

should be evaluated. If the toxicity is judged to be significant in potentially impairing the beneficial uses of Upper Newport Bay and/or San Diego Creek waters, then the cause of this toxicity and the sources of constituents that cause the toxicity should be identified and, if possible, controlled at the source.

Studies conducted after the initiation of the Evaluation Monitoring Demonstration Project in July 1996 showed that the stormwater runoff in San Diego Creek as it enters Upper Newport Bay is toxic to *Ceriodaphnia dubia* (freshwater zooplankton) and *Americamysis bahia* (formerly *Mysidopsis bahia*), a marine zooplankton. About half of the toxicity was found to be likely due to the organophosphate pesticides, diazinon and chlorpyrifos, used in urban areas for structural, lawn and garden pest control. The other half of the toxicity was due to unknown causes and appeared to originate from agricultural and/or commercial sources such as commercial nurseries in the upper part of the San Diego Creek watershed. Additional information on the results of the toxicity studies conducted during this 205(j) project is presented below.

Excessive Bioaccumulation

A review of the 1980/early 1990 state of California Water Resources Control Board's (WRCB) Toxic Substances Monitoring (TSM) data for fish tissue concentrations for chlorinated hydrocarbon pesticides, PCBs and heavy metals shows that chlordane, DDT, dieldrin, PCBs and mercury have been present in San Diego Creek fish tissue at concentrations representing a potential human health threat to those who eat the fish. Generally, except for PCBs, the concentrations of chlorinated hydrocarbon pesticides and mercury present in fish taken from Upper Newport Bay were below those considered to be critical for the use of the organisms as human food.

Monitoring of San Diego Creek as it enters Upper Newport Bay shows that at least part of the chlorinated hydrocarbon pesticides and PCBs present in Upper Newport Bay aquatic life may

be derived from the input of these chemicals to the Bay via San Diego Creek. Further studies need to be done to determine if this is, in fact, the situation today. If it is, then forensic studies should be done to determine if there are specific sources of these chemicals within the San Diego Creek watershed that can be controlled to reduce the excessive bioaccumulation of hazardous chemicals that is occurring in San Diego Creek and Upper Newport Bay aquatic life.

At the initiation of the Evaluation Monitoring Demonstration Project, there was need for additional monitoring of fish from Upper Newport Bay and Lower San Diego Creek. This monitoring was needed to establish the current levels of fish tissue contamination relative to those that are potentially hazardous for the use of the fish as food. There is also need to better understand whether there is significant use of San Diego Creek fish as food for humans. It is likely that there is not a significant human health threat associated with eating fish from the Creek even if they contain excessive concentrations of chlorinated hydrocarbon pesticides, PCBs or mercury. This is due to the fact that there are limited waters in San Diego Creek during much of the year and the limited size of the fish normally present in the Creek. However, there may be a potential wildlife threat, especially to fish-eating birds and animals, due to the excessive concentrations of the chlorinated hydrocarbon pesticides, PCBs and/or mercury that could be present in San Diego Creek fish.

There is no information at this time on whether dioxins are present in Upper Newport Bay and San Diego Creek fish tissue at excessive concentrations for the use of fish as human food. Since problems of this type are being found in other waterbodies, such as San Francisco Bay, the concentrations of dioxins in fish taken from Upper Newport Bay and San Diego Creek should be examined.

No information is available on whether aquatic life within Upper Newport Bay and its tributaries is experiencing disease due to pathogenic organisms, carcinogens or other chemicals that cause tumors and/or other abnormal tissue growth. Also, no information is available as to whether there are any endocrine-active or other substances that impair the reproduction/behavior of aquatic organisms and waterfowl in Upper Newport Bay. This is an emerging area of increasing national/international water quality concern that could be significant in Upper Newport Bay. However, based on what is known from other areas, this is not likely a significant problem for aquatic life in Upper Newport Bay. Generally, where these problems have been found elsewhere, they are associated with major industrial wastewater inputs. There may be, however, problems of this type associated with past and possibly current pesticide/herbicide inputs to the Bay. The current pesticide/herbicide registration process does not adequately evaluate the potential for these types of chemicals to be adverse to aquatic life and wildlife.

The WRCB Toxic Substances Monitoring Program conducted additional sampling of Upper Newport Bay fish during the summer of 1997. As of the preparation of this report, these data are not available.

Sediment Toxicity

The 1994 Water Resources Control Board-US EPA EMAP/BPTCP studies have shown that the sediments of Upper Newport Bay are, at some locations, toxic to some forms of aquatic life. The cause of this toxicity has not been identified. Further, its significance in impairing the designated beneficial uses of Upper Newport Bay and associated waters is unknown. There is need to evaluate whether the toxicity found is of potential significance to Upper Newport Bay water quality. If it is judged significant, toxicity investigation evaluation (TIE) studies need to be conducted to try to determine the constituents responsible for the sediment toxicity and, through forensic studies, their sources.

Some attention has been given in previous studies to the chemical characteristics of Upper Newport Bay sediments. However, while Upper Newport Bay sediments, at some locations, contain elevated concentrations of heavy metals and some other constituents, it is not possible, from the information available, to determine whether these elevated concentrations are responsible for the aquatic life toxicity found in the sediments. It is well established that the relationship between the concentration of a constituent in sediments and its potential impact on sediments/water quality is tenuous. There are a wide variety of constituents in aquatic sediments such as sulfides, organic carbon, carbonates and hydrous metal oxides that detoxify heavy metals and other constituents, rendering them inert. Site-specific TIEs need to be conducted to determine the cause of the sediment-associated toxicity and the potential role, if any, that elevated heavy metals, pesticides, etc., have in causing this toxicity.

Several areas of Lower and Upper Newport Bay are listed as candidate toxic hot spots due to elevated concentrations of copper, lead, mercury, zinc, arsenic or chlordane. In accord with guidance provided by the WRCB Bay Protection and Toxic Cleanup Program (BPTCP) Policy the Santa Ana Regional Water Quality Control Board has listed the Rhine Channel in Lower Newport Bay as a high-priority toxic hot spot. This listing is due to the presence of heavy metals in the sediments of this area and will require cleanup of the contaminated sediments at a cost of approximately $10.5 million.

Eutrophication/Excessive Fertilization

Upper Newport Bay is experiencing excessive fertilization due to the input of aquatic plant nutrients (nitrogen and phosphorus compounds). Excessive fertilization is significantly impairing the beneficial uses of the Bay. It is manifested primarily as algal growth that appears in excessive amounts in mid-spring and lasts through early fall. It appears that nitrogen compounds (nitrate, nitrite and ammonia, as well as the part of the organic nitrogen that converts to ammonia/nitrate) are the key chemicals potentially limiting further algal growth within the Bay. The concentrations of available forms of phosphorus in Bay waters, at times, may become sufficiently low as to also limit algal growth in the Bay. Information available indicates that for most of the year, the current nitrate and other nitrogen compounds input to the Bay through San Diego Creek, as well as from other tributaries and local urban area street runoff and from possible groundwater input to the Bay, are surplus for that needed to support the algal growth occurring in Bay waters.

The information available shows that much of the nitrogen load to the Bay over the year has little or no influence on the excessive fertilization of the Bay because of the short residence time (10 day) of tributary waters and their associated nitrogen loads in the Bay. The nitrogen compounds added during late fall, winter and early spring do not generally cause excessive fertilization problems. They are flushed through the Bay before the excessive fertilization water quality problems begin in mid-spring.

An area that has not yet been adequately investigated is the role of the high nitrate (30 to 70 mg/L NO_3^--N) in the surficial groundwaters that enter San Diego Creek and its tributaries. In addition, subsurface flow into Upper Newport Bay is a possible source of nitrogen that is contributing to the excessive fertilization of the Bay.

The proposed IRWD Wetlands Water Supply Project involves diverting part of San Diego Creek waters through a wetlands area for nitrate removal (denitrification) before they enter Upper Newport Bay. It is unclear whether this project will significantly change the current situation relative to excessive algal growth to the point where the public would perceive a significant improvement in Bay water quality.

There is need to better understand nutrient (nitrogen and phosphorus) dynamics (aquatic chemistry), nutrient sources, and the factors controlling the excessive fertilization of Upper Newport Bay waters. Such understanding is important in order to explore the development of nutrient-control programs that will effectively control the eutrophication-related use impairments of Upper Newport Bay waters. This is particularly important in reference to the amount of nitrogen and/or phosphorus inputs to the Bay during the critical periods of the year that lead to the excessive fertilization problems-use impairments.

If further studies show that it is not possible, for economic or other reasons, to control the nutrient input to the Bay sufficiently to reduce the excessive fertilization occurring in the Bay, then aquatic plant harvesting approaches should be considered to improve the Bay's eutrophication-related water quality.

During 1998 the Santa Ana Regional Water Quality Control Board adopted Phase 1 total maximum daily loads (TMDLs) for nitrogen and phosphorus inputs to Upper Newport Bay. A monitoring program is being developed to evaluate the effectiveness of the nutrient input reductions on the excessive fertilization of Upper Newport Bay.

Dissolved Oxygen Depletion

It appears that there may be dissolved oxygen depletion problems in Upper Newport Bay associated with the excessive fertilization of the Bay. Further studies need to be done to be certain that the excessive fertilization of Bay waters does not lead to low dissolved oxygen problems that are adverse to aquatic life as part of the diel (night/day) changes in DO that occur in highly eutrophic waters.

Litter Accumulation

Litter is a significant cause of water quality deterioration/beneficial use impairment of Upper Newport Bay. The Orange County Public Facilities and Resources Department (OCPFRD) has initiated litter control programs that should reduce litter accumulation in the Bay. Further, Caltrans has extensive litter control programs (Adopt-A-Highway) in place on the facilities they operate.

Oil and Grease Accumulation

No oil and grease accumulation problems have been identified in Upper Newport Bay. Examination of the Bay for oil and grease accumulation problems should be conducted. If such problems are found, then the sources of the oil and grease that are accumulating in the area of concern should be identified through forensic studies and programs initiated to control the oil and grease at or near their source.

Sanitary Quality Impairment of Contact Recreation and Shellfish Harvesting

There are potentially significant sanitary quality (human disease) problems associated with contact recreation and shellfish harvesting in Upper Newport Bay. In addition to runoff from streets, there are spills of domestic wastewaters into the Bay and its tributaries due to blockage of the sanitary sewerage systems for the communities in the Bay watershed. Further, there may be illegal discharge of boaters' sanitary waste into the Bay waters. Of particular concern is the dumping of sanitary waste from boats in the Lower Bay which, through tidal currents, is carried into the Upper Bay. These sanitary wastes from human and animal sources can cause beach and shellfish bed closures due to excessive concentrations of human pathogen indicator organisms such as total and fecal coliforms. These organisms are used to indicate that potentially hazardous concentrations of enteric bacteria; cyst-forming protozoans, i.e., *Giardia* and *Cryptosporidium*; and enteroviruses are present in the Bay waters. These bacteria, protozoans and viruses can cause disease in people through contact with the water containing the organisms. It is possible that people today are acquiring diseases associated with contact recreation in Upper Newport Bay waters. The incidence of these diseases is not known.

There is need to better understand the current sources of human and animal fecal pathogen indicator organisms such as total and fecal coliforms, fecal streptococci, and other bacteria, as well as pathogens such as *Cryptosporidium* and selected enteroviruses in Bay waters. This is important in order to determine if it will be possible to improve the sanitary quality of Upper Newport Bay and, thereby, reduce the incidence of disease that could occur associated with contact recreation in the Bay.

In accord with the court consent decree, the Santa Ana Regional Water Quality Control Board must develop TMDLs for pathogen indicator organism input to Upper Newport Bay to protect shellfish harvesting and contact recreation. The Board has recently proposed an initial phase TMDL program for fecal coliform input to Upper Newport Bay.

Siltation, Excessive Sediment Accumulation and Turbidity
Upper Newport Bay contains excessive sediment due to erosion from its watershed. This sediment accumulation causes shoaling (reduction of water depth), which interferes with navigation. It also changes the depth of the Bay water and thereby alters the aquatic plant habitat so that macrophytes encroach into the open water areas. Extensive studies have been conducted on the sources of the erosional sediment, and programs have been implemented to control the erosion at the source as well as through trapping before San Diego Creek water enters Upper Newport Bay. The OCPFRD conducts an ongoing evaluation of sediment control program effectiveness and makes changes in the program as funds are available.

During 1997, the Santa Ana Regional Water Quality Control Board adopted Total Maximum Daily Loads (TMDLs) for sediment input to Upper Newport Bay for the purpose of limiting the shoaling of the Bay.

Impairment of Domestic Water Supply Water Quality
Since Upper Newport Bay is a marine waterbody, it is not a domestic water supply source. While San Diego Creek and its tributaries are freshwater and could, at some locations, recharge groundwaters, the groundwaters in some areas of the San Diego Creek watershed are polluted by past agricultural and industrial/military activities leading to high total dissolved solids (TDS), nitrate and, in some areas, chlorinated solvents. It does not appear, however, that the groundwater chlorinated solvent problems in the watershed are adverse to the beneficial uses of San Diego Creek or Upper Newport Bay.

It is not clear whether the poor water quality of San Diego Creek (due to groundwater discharge to the Creek, with elevated TDS and nitrate) is polluting groundwaters in other areas due to Creek and tributary recharge of the groundwater system. The shallow aquifer in the Irvine sub-basin contains high levels of TDS and nitrate. It is also apparent, however, that there is little interaction between the shallow aquifer and the principal aquifer, which has relatively good water quality and is used for domestic and agricultural purposes. The shallow aquifer consists primarily of fine-grained floodplain deposits, including massive silts and clays with one- to ten-foot-thick discontinuous lenses of sand and gravel. Vertical hydraulic conductivities of the clays/silts are less than 1 in./yr. Therefore, vertical movement of groundwater and subsequent recharge to the principal aquifer through the semiconfining layer between the aquifers may reasonably be considered of limited near-term significance.

Overall Upper Newport Bay Water Quality
Overall, Upper Newport Bay is experiencing significantly impaired water quality due to:

- Excessive bioaccumulation of hazardous chemicals in aquatic life tissue that causes the organisms to be a threat to those who use them as food
- Excessive fertilization that causes algal growth that impairs use of the Bay
- Excessive siltation that causes shoaling that impairs boating and changes the distribution of aquatic plant communities that develop in the Bay

- Excessive litter that impairs the use of Bay nearshore waters and associated lands
- Impairment of the sanitary quality of Upper Newport Bay, which increases the risk of disease to those who work and contact-recreate in Bay waters.

The occurrence and water quality significance of aquatic life (*Ceriodaphnia dubia* and *Americamysis bahia*) toxicity found in San Diego Creek as it enters Upper Newport Bay is the primary subject of the 205(j) project. A summary of these results is presented below.

AQUATIC LIFE TOXICITY IN UPPER NEWPORT BAY TRIBUTARIES DURING 1997 – 1999

The literature review originally conducted in the Evaluation Monitoring Demonstration Project and updated herein during the 205(j) project has shown that San Diego Creek stormwater runoff as it enters Upper Newport Bay is toxic to *Ceriodaphnia*. This toxicity was associated with and likely caused by two organophosphate (OP) pesticides, diazinon and chlorpyrifos. There was also appreciable *Ceriodaphnia* toxicity that could not be accounted for by the OP pesticides found in the samples. The cause of that toxicity is unknown.

Beginning with the 205(j) project, coupled with the second year of the Evaluation Monitoring Demonstration Project, it was possible to significantly expand the limited scope of the aquatic life toxicity studies that were conducted during the first year of the Evaluation Monitoring Demonstration Project. Beginning with the fall of 1997, seven stormwater runoff events were monitored for *Ceriodaphnia* toxicity in San Diego Creek as it enters Upper Newport Bay, as well as at several locations within the Creek's watershed. In addition, four dry weather flow samples of San Diego Creek and its tributaries were taken during the fall of 1997 through July 1999. The monitoring program was expanded to include the Santa Ana Delhi Channel, which is the next largest tributary to Upper Newport Bay. Further, the test organism suite was expanded to include *Americamysis bahia* (marine zooplankton). More than 230 toxicity tests have now been conducted on Upper Newport Bay tributary water and Bay water through January 1999. The following conclusions have evolved from this toxicity study program.

- ***Overall Conclusions.*** San Diego Creek stormwater runoff is toxic to *Ceriodaphnia* and mysids. It is not toxic to fathead minnow larvae or algae. While the OP pesticides (diazinon and chlorpyrifos) are not toxic to many forms of zooplankton, the full spectrum of organisms that are sensitive to OP pesticide toxicity is unknown.
- ***Cause of Toxicity.*** This toxicity is due to the OP pesticides diazinon and chlorpyrifos, and unknown constituents.
- ***Sources of Toxicity.*** The OP pesticide toxicity is likely derived from urban residential use for structural and lawn and garden pest control. There are also high concentrations of diazinon discharged to the Hines Channel upstream of Hines Channel at Irvine Boulevard, apparently from commercial nurseries, during stormwater runoff and during non-runoff periods. The unknown-caused toxicity is likely due, at least in part, to toxic constituents released to the Hines Channel by one or both commercial nurseries (Hines Nursery and El Modena Nursery) that border on this Channel and apparently discharge nursery-associated water to it. There is need to better understand the flows and releases of water from the nurseries during dry weather and stormwater runoff conditions.

There is also need to determine whether the unknown-caused toxicity is due to other sources within the Upper Newport Bay watershed.

- ***Water Quality Significance of Toxicity.*** The stormwater runoff mixing patterns of San Diego Creek stormwater runoff and Upper Newport Bay water are such that marine zooplankton that migrate into the mixed water lens that forms between the freshwater Creek water and the marine Bay water could be exposed for several days to toxic conditions. This exposure could cause the death of some zooplankton.

  Studies on the persistence of aquatic life toxicity and the organophosphate pesticides diazinon and chlorpyrifos in Upper Newport Bay during an extended rainfall runoff event that occurred in mid-January 1999 showed that there was a limited area near where San Diego Creek enters Upper Newport Bay that was toxic under laboratory conditions to *Americamysis bahia*. This laboratory-based toxicity, however, persisted for a shorter time than Bay organisms could experience through migration into the toxic waters.

  The water quality and ecological significance of the toxic conditions in San Diego Creek and Upper Newport Bay is unknown. It is possible that the OP pesticide-caused toxicity, while toxic to a limited number of types of zooplankton, is not significantly adverse to the fisheries and other higher trophic-level aquatic life-related beneficial uses of the Creek or the Bay.

  Further work needs to been done to define the conditions of potential zooplankton exposure to toxic conditions in Upper Newport Bay. There is need to better understand the mixing patterns of San Diego Creek stormwater runoff with the Bay waters during stormwater runoff events.

  Also, information is needed as to whether there are potentially ecologically significant marine zooplankton that would be expected to migrate into the mixed freshwater/marine lens during and following a stormwater runoff event.

- ***TIE Studies.*** It is suggested that no further funding of TIE work be done to identify the cause of the unknown-caused toxicity that is apparently derived from the nurseries. If nurseries are the source of the unknown-caused toxicity and they are regulated as other wastewater dischargers and commercial/industrial stormwater NPDES permittees, they will have to develop a pesticide use and water management program. This program would prohibit the discharge/release of toxic water to the State's waters. The focus of future TIE work should be on areas of aquatic life toxicity of unknown causes that appears to be due to constituents that are not directly related to the Hines Channel – nursery sources.

- ***Specific Sources of OP Pesticide Toxicity.*** Specific monitoring of a typical residential/ commercial area in the Upper Newport Bay watershed should be conducted to define the sources of the *Ceriodaphnia* toxicity and of the diazinon and chlorpyrifos found in stormwater runoff. It is suggested that a small residential subdivision be monitored to define the types of OP pesticide residential use, especially to determine if structural use of the OP pesticides is a significant source of the stormwater runoff toxicity.

  Also, specific monitoring of agricultural drains during stormwater runoff and non-runoff situations should be conducted to determine whether OP pesticide and other constituents are present that could cause *Ceriodaphnia/mysid* toxicity.

- ***"Toxicity" and "Pesticide" TMDLs Information Needs.*** There is need to obtain information that will help in developing appropriate "toxicity" and "pesticide" TMDLs by 2002. This is necessary in order that the Santa Ana Regional Water Quality Control Board can comply with the consent decree requiring TMDLs to be developed for "toxics" and "pesticides" in the Upper Newport Bay watershed and within the Bay by 2002. Since this will likely involve phased TMDLs, specific studies need to be conducted to define the principal sources of OP pesticide toxicity, diazinon, chlorpyrifos and unknown-caused toxicity with emphasis on residential, agricultural and commercial/nursery uses. Within each of these sources, percentage reductions can be developed to implement a Phase 1 TMDL. The TMDL will be evaluated by monitoring over a period of several years to determine the magnitude of toxicity and specific toxic constituent concentration reductions that occur. The Phase 1 TMDL would be followed by a revised estimate of the allowed toxicity and specific toxic constituent concentrations, and would be implemented as part of the Phase 2 TMDL.

OVERALL EVALUATION MONITORING PROGRAM - ACCOMPLISHMENTS AND PROGRESS

The Evaluation Monitoring Demonstration Project was established to show that an alternative approach to conventional stormwater runoff monitoring and BMP development could be initiated that more reliably assesses the water quality problems/use impairments caused by stormwater runoff-associated constituents in the receiving waters for the runoff. Conventional monitoring programs have shown that some heavy metals and other constituents are present in stormwater runoff to the Bay at concentrations above US EPA water quality criteria. However, these programs have not determined, for potentially toxic constituents such as heavy metals, whether the exceedance of the criterion values results in aquatic life toxicity in the runoff and receiving waters. If aquatic life toxicity is not present in a particular case where water quality standards are exceeded, then US EPA water quality criteria are overly protective when applied to waters like those in San Diego Creek and Upper Newport Bay.

The Evaluation Monitoring Program has defined, through a review of the water quality data and the literature, several issues that need to be further examined. These issues should be examined as part of a comprehensive evaluation of the impact of chemical constituents in stormwater runoff on the beneficial uses of Upper Newport Bay waters. Following conventional monitoring approaches, an exceedance of a water quality standard in stormwater runoff is assumed, by proxy and without verification, to represent a water quality use impairment that may require the public to spend funds to control it. The Evaluation Monitoring Program asks the following questions: "Is there toxicity in the stormwater runoff? If so, what is its cause and significance to the beneficial uses of a waterbody? What are the sources of the toxic constituents that are significantly adverse to the beneficial uses of the waterbody?" This is a more technically valid, cost-effective approach for developing water quality management programs than relying on conventional monitoring alone.

The conventional stormwater runoff monitoring approach and its associated receiving water monitoring focus on determining concentrations of chemical constituents that could, under some conditions, cause water quality problems. The conventional monitoring approach, however, fails to address the unregulated or under-regulated chemical constituents in stormwater runoff. In the conventional monitoring approach, it is necessary to try to extrapolate from the concentrations of a constituent found in runoff or receiving waters to estimate water quality problems in the receiving waters for the runoff of concern to the public. This extrapolation is tenuous, in that it requires a high degree of understanding of the relationship between the concentrations of a constituent found in runoff waters or receiving waters and their ability to adversely impact the beneficial uses of a waterbody. This extrapolation requires detailed, frequently unavailable information on the aqueous environmental chemistry of the constituent (transport and chemical transformations/kinetics and thermodynamics of toxic/available forms of constituents) and its aquatic toxicology/toxicity or uptake as a function of duration of exposure.

The Evaluation Monitoring approach, on the other hand, directly addresses the issue of whether there is a water quality problem due to toxic or bioaccumulatable constituents, identifies the cause of the toxicity and determines the sources, allowing the development of control programs. Such an approach allows for prioritization of water quality programs to focus on the most acute problems rather than giving all potential threats equal consideration. By using resources more efficiently, it is possible to make measurable gains in water quality management more rapidly.

The Upper Newport Bay Evaluation Monitoring Program, Phases I through III, and this 205(j)-supported effort, have proven to be valuable in defining the significant water quality problems that need further attention in managing the impacts of stormwater runoff from the Upper Newport Bay watershed.

ACRONYMS AND ABBREVIATIONS

AA	*Ampelisca abdita*
AET	apparent effect threshold
AMC	antecedent moisture content
ATSDR	Agency for Toxic Substances and Disease Registry
BMP	best management practice
BOD	biochemical oxygen demand
BPTCP	Bay Protection and Toxic Cleanup Program
COD	chemical oxygen demand
COE	U.S. Army Corps of Engineers
DIEPAMA	US EPA deionized moderately hard control water
DO	dissolved oxygen
DOC	dissolved organic carbon
DPR	Department of Pesticide Regulation
EDTA	Ethylenediaminetetraacetic acid
EHW	Extreme high water
ELISA	Enzyme linked immuno sorbent assay
EMA	Environmental Management Agency
EMAP	Environmental Monitoring and Assessment Program
EMAP/BPTCP	Environmental Monitoring and Assessment Program/Bay Protection and Toxic Cleanup Program
EPA	U.S. Environmental Protection Agency
ETC	Eastern Transportation Corridor
IRWD	Irvine Ranch Water District
MCL	maximum contaminant level
mg/L	milligrams per liter
MTBE	methyl tertiary butyl ether
MTRL	Maximum Tissue Residue Levels

ACRONYMS AND ABBREVIATIONS (continued)

NAE	National Academy of Engineering
NAS	National Academy of Science
NPDES	National Pollutant Discharge Elimination System
NURP	National Urban Runoff Program
OCEMA	Orange County Environmental Management Agency
OCHCA	Orange County Health Care Agency
OCPFRD	Orange County Public Facilities and Resources Department
PAHs	Polyaromatic hydrocarbons
PBO	piperonyl butoxide
ppt	parts per thousand
PGL	practical qualification limits
RA	*Rhepoxynius abronius*
RBF	Robert Bein, William Frost & Associates
SARWQCB	Santa Ana Regional Water Quality Control Board
SSEPAMH	Sierra Spring EPA moderately hard control water
SPPF	*Strongylocentrotus purpuratus*
TDS	total dissolved solids
TIE	toxicity investigation evaluation
TMDL	total maximum daily load
TSM	toxic substances monitoring
TUa	toxic units acute
UAA	use attainability analysis
UCD	University of California Davis
US EPA	United States Environmental Protection Agency
µg/L	micrograms per liter
VDR	volume of direct runoff
VOC	volatile organic compound

SECTION 1
EVALUATION MONITORING AS THE BASIS FOR THIS 205(J) PROJECT

Conventional "water quality" monitoring frequently involves measuring a suite of chemical constituents at various locations at a fixed sampling frequency over a period of a year or more. The data are then compared to US EPA water quality criteria and/or state standards based on these criteria. Exceedance of a criterion value is judged to represent an "impaired" waterbody which requires corrective action to eliminate the exceedance.

A critical review of the traditional stormwater runoff and many other water quality monitoring programs shows that it is not possible to reliably assess water quality use impairments to aquatic life resources based on chemical concentration measurements. Further, exceedance of a water quality criterion in an ambient water is rarely a reliable indicator of water quality use impairments of concern to the public. In an effort to address the deficiencies in traditional stormwater runoff water quality monitoring which focuses on assessing the concentrations of chemical constituents, an Evaluation Monitoring Demonstration Project (Silverado, 1997a) was initiated in the Upper Newport Bay watershed. Evaluation Monitoring focuses the monitoring resources on defining the real water quality use impairments that are occurring in a waterbody associated with urban area and highway stormwater runoff. Emphasis is given to assessing chemical impacts on beneficial uses, rather than assessing chemical concentrations or loads.

This project has been conducted using the Evaluation Monitoring approach for defining water quality impacts associated with urban area and highway stormwater runoff-associated constituents. This project focuses on assessing potential water quality impacts using an event-based monitoring program where highly directed sampling and analysis are used to:

- define whether potentially significant water quality problems exist that are caused by stormwater runoff-associated constituents that occur in the Upper Newport Bay watershed,
- explore the causes of these problems, focusing on aquatic life toxicity, and
- develop recommended approaches for controlling the significant water quality use impairments that are occurring in Upper Newport Bay due to stormwater runoff-associated constituents.

The demonstration of the need for and the feasibility of implementing Evaluation Monitoring as an alternative to conventional water quality monitoring and management serves as the background to the development of this 205(j) project. Additional information on Evaluation Monitoring is provided by Jones-Lee and Lee (1998a).

SECTION 2
CHARACTERISTICS OF THE UPPER NEWPORT BAY WATERSHED

The primary tributary of Upper Newport Bay is San Diego Creek. The San Diego Creek watershed is bounded on the north by the Santiago Hills (Loma Ridge) and to the south by the San Joaquin Hills. The major portion of the basin is comprised of the Tustin Plain, a broad alluvial valley occupying the central portion of the watershed. Figures 2-1 and 2-2 present the general features of the watershed with respect to San Diego Creek and Upper Newport Bay. The watershed has been greatly altered due to development. Most of the existing channel features were constructed in the early part of this century to accommodate farming. During the 1960s, easements for many of the principal streams were granted to the Orange County Flood Control District, and interim improvements were made to many of the channels.

The Newport Bay watershed includes an area of about 154 mi^2. The San Diego Creek watershed contains about 119 mi^2 with a mix of residential, commercial, industrial, recreational, and open space land uses. Other major tributaries of Upper Newport Bay include the Santa Ana Delhi Channel with a watershed of about 17 mi^2, Big Canyon Wash with a watershed of about 2 mi^2, and 16 mi^2 from other smaller tributaries. The Santa Ana Delhi Channel watershed includes commercial, industrial, recreational, and residential land uses, with roads and residential land uses predominant. The Big Canyon Wash watershed is comprised of commercial, recreational, open space, and residential land uses, with residential uses predominant. The remaining area is comprised of commercial and residential uses.

The San Diego Creek portion of the Upper Newport Bay watershed (119 mi^2) encompasses elevations that range from a high in the Santiago Hills of 1,775 ft to sea level at Upper Newport Bay. A large portion of the Tustin Plain generally has slopes of less than 1 percent, with steeper slopes occurring near the foothills. Existing land uses in the watershed include agricultural, open space, residential, commercial, industrial, and recreational. In general, the foothill areas remain as open space, with development generally occurring in the Tustin Plain along the western and eastern watershed boundaries and to the south. The central portion of the watershed retains the most agriculture, although this area is undergoing urbanization at a rapid pace. Table 2-1 summarizes the general land uses within the watershed.

Currently, it is estimated that less than 40 percent of the developed Upper Newport Bay watershed is impervious surface. The developed area represents about 50 percent of the total watershed area. Tettemer and Associates (1989) indicated that Orange County has estimated that the ultimate impervious surface in the watershed will be about 60 percent. Urbanization and improvement of the channel system have decreased the watershed runoff lag time, increased the peak discharge as compared to pre-development conditions, and enhanced the ability of the watershed and San Diego Creek to transport chemical constituents and sediment to Upper Newport Bay.

Numerous investigators have conducted hydrology studies within the San Diego Creek watershed for the entire area or specific subbasins. Estimates by Simons, Li and Associates (1987) of the flows for the 2 yr and 100 yr storm runoff are shown in Table 2-2. The discharges indicated have since been revised by Tettemer and Associates (1989), but have not changed significantly.

Table 2-1
Land Use—San Diego Creek Watershed

Land Use	% of Watershed	Area (mi^2)
Residential	15	17.9
Commercial	8	9.5
Industrial	6.3	7.5
Open Space/Vacant	23.1	27.5
Agriculture/Ranching	10	11.9
Public	0.3	0.4
Recreation	0.3	0.4
Transportation and Communication/Utility	1.2	1.4
Roads	35.8	42.6

Source: OCEMA, Survey Division (1990)

Table 2-2
Discharges for San Diego Creek

Location	Area (mi^2)	Q_{100} (cfs)	Q_2 (cfs)
Near Culver Dr.	42.9	18,050	3,700
At Jamboree Rd.	119.2	34,300	7,000

Source: Simons, Li and Associates (1987)

Table 2-2 provides tributary drainage areas and flow rates at locations coincident or near the stormwater runoff sampling point (San Diego Creek at Campus Drive) described in this report. The drainage area at each point represents the total watershed area that drains to the specified location. Two discharge frequency values are provided in the table, Q_{100} and $Q_{2.}$ The value for Q_{100} represents the discharge at the point indicated for a storm with a hypothetical return period of once every 100 yr. A storm of this magnitude has a 1 percent chance of occurring in any given year. A 100 yr return frequency represents the design return period used for San Diego Creek flood control improvements.

The 2 yr discharge rate represents a storm with a 50-percent chance of occurring in any given year. The 2 yr storm may approximate the “dominant” discharge, which generally is responsible for the geometry and shape of the streamcourse.

The flows and associated return frequencies indicated in the table can be used to assess the relative magnitude of the sampled storms, since the discharges given in the table are at locations that are either coincident with or near the sampling or stream gaging points used in this study.

San Diego Creek at Culver Drive is upstream of the Peters Canyon Channel confluence. Peters Canyon Channel drains an area of about 44.7 mi^2; the watershed is comprised of about 50 percent agricultural use and 50 percent urban areas. It is estimated that over half of the remaining agricultural area in the watershed is tributary to Peters Canyon Channel. San Diego

Creek at Jamboree Road represents the watershed outlet at Upper Newport Bay. The Creek discharges to Upper Newport Bay about 500 ft west of the Jamboree Road crossing.

The Santa Ana-Delhi Channel is the other primary tributary to Upper Newport Bay. Figure 2-1 shows Upper Newport Bay, including the location of the Santa Ana Delhi Channel. The Santa Ana Delhi Channel consists of four channels draining the watershed: Santa Ana-Delhi (Facility F01), Santa Ana Gardens (Facility F02), Paularino Channel (F03), and the Airport Storm Channel (F01S01). The Paularino Channel confluences with the Delhi Channel at the SR 55/SR 73 interchange. The Delhi Channel and the Airport Storm Channel confluence just downstream of the crossing of I-405. The Delhi Channel and the Santa Ana Gardens Channel confluence at Sunflower Avenue, near South Coast Plaza. Currently, the watershed is about 95 percent developed, with land uses apportioned as indicated in Table 2-3.

Table 2-3
Land Use- Santa Ana Delhi Channel

Land Use	% of Watershed	Area (mi^2)
Residential	33	5.6
Commercial	17	2.9
Industrial	8	1.4
Open Space/Vacant	5.6	1
Agriculture/Ranching	1.5	0.3
Public	1.2	0.2
Recreation	1.3	0.2
Transportation and Communication/Utility	3	0.5
Roads	30.4	5.2

Source: OCEMA, Survey Division (1990)

The most recent hydrology study for the Santa Ana-Delhi Channel was completed in 1985 (OCEMA, 1985). Much of the original channel system was designed to convey 65 percent of the 25 yr flow rate. Design (100 yr) flow rates for selected reaches are provided in Table 2-4.

Table 2-4
Discharges for Santa Ana Delhi Channel

Concentration Point	Area (mi^2)	Q_{100} (cfs)
At Newport Bay	17.4	8,700
Upstream of Paularino Channel (F03)	14.6	6,800
Upstream of Airport Storm Channel (F01S01)	10.9	5,750
Santa Ana Gardens Upstream of Delhi (F02)	4.1	2,300

Source: OCEMA, Survey Division (1990)

The remaining tributary areas to Upper Newport Bay are as estimated in Table 2-5. Comprehensive hydrology studies have not been completed for most of these smaller areas. Accordingly, hydrologic information is not provided.

Table 2-5
Watershed Areas for Other Tributaries, Newport Bay

Location	**Area (mi^2)**
Santa Ana Heights/Newport Heights	3.5
Newport Blvd./Turning Basin	1.5
East Costa Mesa Channel	~1.0
Fashion Island/Dunes	0.9
Bayside/Corona del Mar	0.6
Miscellaneous	10.0

Source: OCEMA, Survey Division (1990)

PHYSICAL AND HYDROLOGIC CHARACTERISTICS OF NEWPORT BAY

Lower Newport Bay extends westward about three miles behind the Balboa Peninsula to Newport Boulevard (see Figure 2-1). The Coast Highway divides the Bay into upper and lower basins. The lower basin is heavily urbanized, with numerous islands developed for residential use. The upper basin (about 1,000 acres) remains largely undeveloped within the nominal Bay boundaries, with the exception of about the lower one-third, which contains boat docks and other commercial facilities. The remaining area (752 acres) is operated as a State Ecological Reserve by the Department of Fish and Game.

The Upper Bay is characterized by a semidiurnal tidal pattern of two unequal highs and lows occurring each day. The maximum tidal range is about 9 ft (+7.2 ft MLLW to -1.8 ft MLLW), with little difference in absolute magnitude between the upper and lower Bays. Mudflats comprise the lower portion of the littoral zone below about 3.0 MLLW and are subject to daily inundation. Salt marsh occupies the mid and upper littoral zones up to the extreme high water (EHW) elevation. The salinity in the Upper Bay in 1959 was close to seawater (Gerstenberg, undated). The Bay is becoming progressively more estuarine in character, as freshwater inputs to the Bay increase.

Figure 2-1 Upper Newport Bay Area

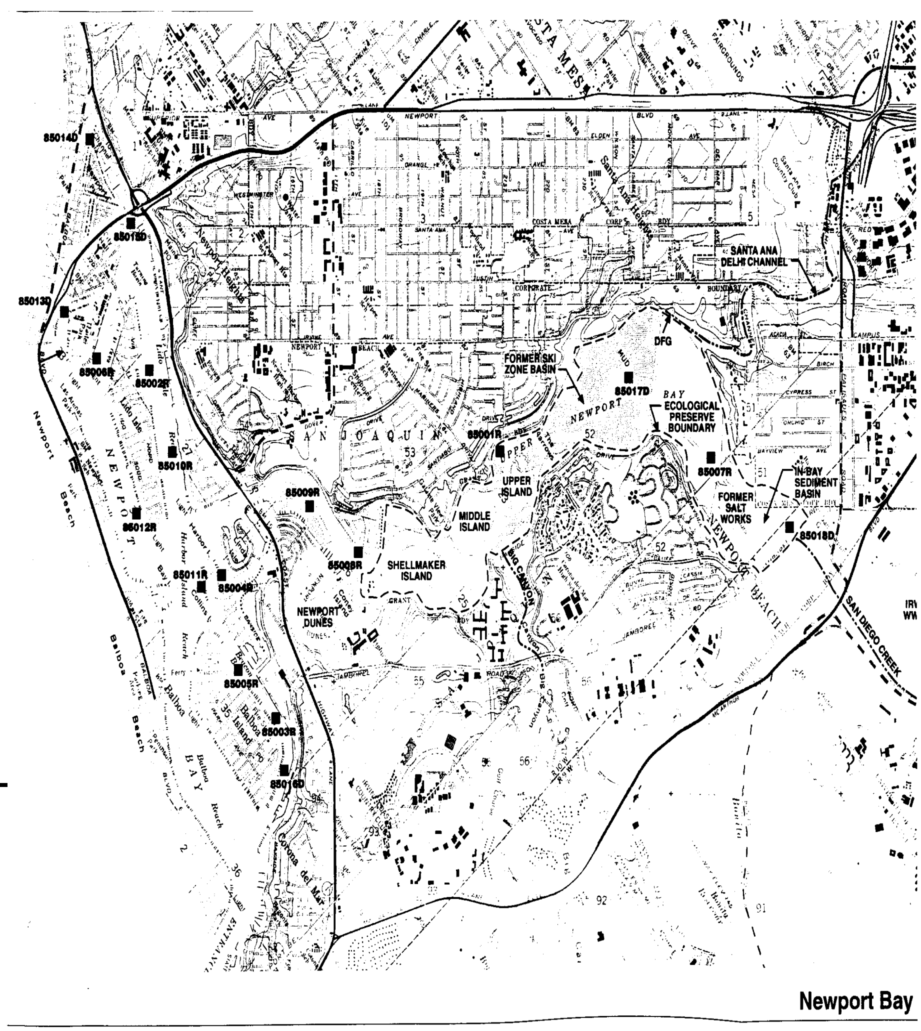
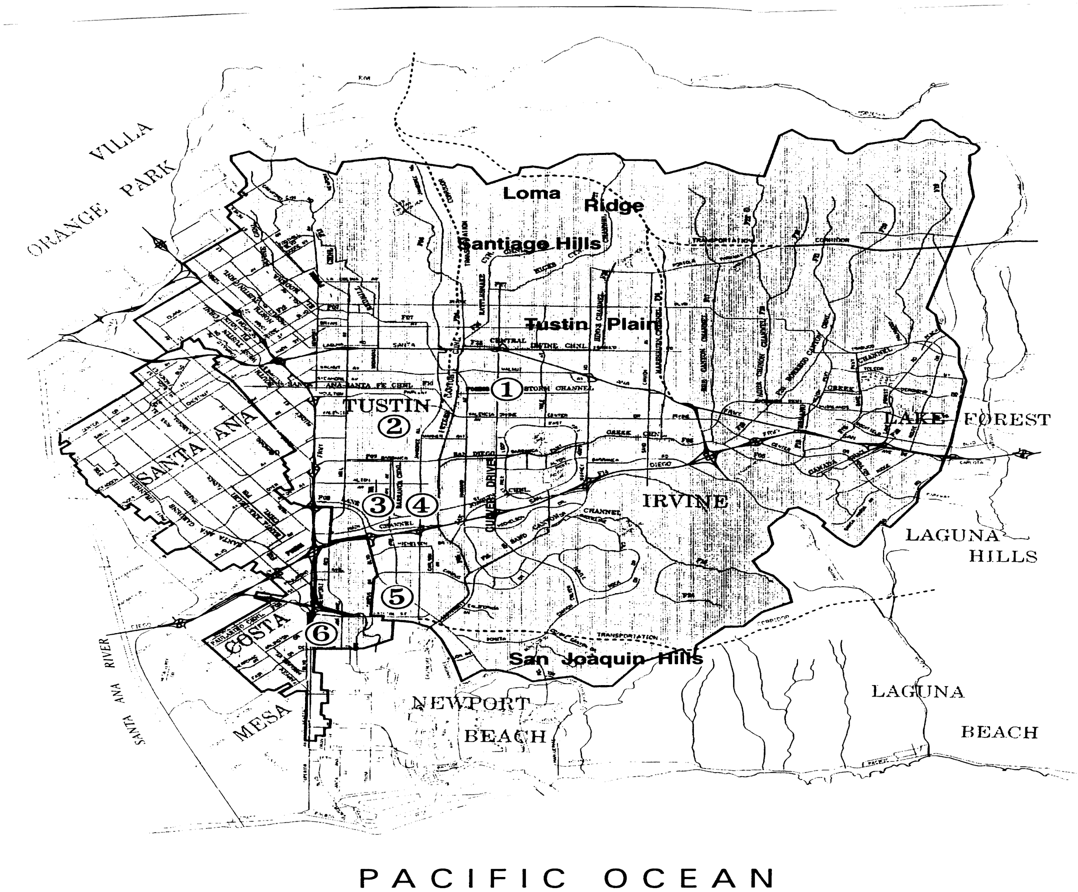


Figure 2-2
Upper Newport Bay Watershed



① Hines Channel @ Irvine Blvd
② Central Irvine Channel
③ Peters Canyon Channel @ Barranca Pkwy
④ San Diego Creek @ Culver Dr
⑤ San Diego Creek @ Campus Dr
⑥ Santa Ana Delhi Channel @ Mesa Dr

SECTION 3
AQUATIC LIFE TOXICITY IN UPPER NEWPORT BAY TRIBUTARIES DURING 1997 – 1999

During the fall of 1996, the Evaluation Monitoring Demonstration Project (Lee and Taylor, 1997a; Silverado, 1997a) reported that stormwater runoff in San Diego Creek at Campus Drive was toxic to *Ceriodaphnia*. The stormwater runoff contained sufficient concentrations of diazinon and chlorpyrifos (organophosphate pesticides – OP pesticides), as well as some unidentified toxic constituents, to be highly toxic to *Ceriodaphnia* during stormwater runoff events. A dry weather flow sample taken of San Diego Creek on November 19, 1996 between the two stormwater runoff events sampled (October 30, 1996 and November 21, 1996) was found to be non-toxic. Two US EPA grants, 205(j) and 319(h), were received to expand the Evaluation Monitoring Demonstration Project sampling to include additional sampling at San Diego Creek at Campus Drive, as well as at other locations within the Upper Newport Bay watershed. This report presents the results of the field studies conducted in the 205(j) grant-supported expanded Evaluation Monitoring Program. The studies were conducted to confirm aquatic life toxicity in tributaries to Upper Newport Bay and to begin to assess the water quality significance of this toxicity to the beneficial uses of Upper Newport Bay and its tributaries. Further, the studies were designed to facilitate 319(h) investigations to identify specific sources of the aquatic life toxicity within the Upper Newport Bay watershed and to investigate the cause of the unknown–caused toxicity found in the fall of 1996. The 319(h) project is beginning in the summer of 1999 and will extend over a 2-yr period.

A total of nine storm events were sampled during the 1997-99 winter seasons. Runoff from the first three storm events was sampled at San Diego Creek at Campus Drive. The storms occurred on September 25, November 12, and November 30, 1997. Subsequently, sampling locations were expanded to include Peters Canyon Channel at Barranca Parkway for storms occurring on December 6, 1997 and March 25, 1998. Sampling locations were further expanded to the Santa Ana Delhi Channel at Mesa Drive for the May 5 and May 12, 1998, storms. Sampling on November 8, 1999, further included sampling at Hines Channel at Irvine Boulevard and San Diego Creek at Harvard Avenue. Sampling on January 25-29, 1999, occurred at San Diego Creek at Campus Drive and at five stations in Upper Newport Bay.

A total of 6 dry weather low flow samples were collected. Dry weather flow sampling occurred on March 24, August 13, August 25, 1998 and July 21, 1999 at the Santa Ana Delhi Channel at Mesa, Hines Channel at Irvine Boulevard, the Central Irvine Channel just above where it confluences with Peters Canyon Channel at the I-5 crossing, Peters Canyon Channel at Barranca Parkway, and San Diego Creek at Campus Drive. The Peters Canyon at Barranca Parkway sample was taken just upstream of where Peters Canyon Channel confluences with San Diego Creek. "Dry weather" sampling took place on January 21, 1999, at San Diego Creek at Campus Drive, the Santa Ana Delhi Channel at Mesa Drive, and at Hines Channel at Irvine Boulevard. While this sample was intended to be a dry weather sample, and there was no measured precipitation from rain gages just before or on January 21, 1999, the specific conductivity of San Diego Creek at Campus Drive indicated that it was somewhat less than expected for a true dry weather sample. The County's ALERT precipitation gage minimum detection amount of rainfall is 0.04 in. At the time of sampling there was a light mist, which could have resulted in runoff from paved areas. The fact that this sample was toxic indicates that it may not be indicative of true dry weather conditions in San Diego Creek. "Dry weather" sampling also occurred on January 29, 1999, exclusively at San Diego Creek at Campus Drive. The January 29, 1999, "dry weather" – low flow sampling occurred immediately following the January 25-27, 1999, storm event and may have been influenced by that event.

BACKGROUND

Lee and Taylor (1997b) have presented a comprehensive review of the information available on Upper Newport Bay water quality. Upper Newport Bay is experiencing a number of significant designated beneficial use impairments. These include excessive fertilization, degraded sanitary quality that impairs contact recreation and shellfish harvesting, excessive litter, excessive bioaccumulation of hazardous chemicals, and excessive sediment accumulation. Constituents responsible for the use impairments include aquatic plant nutrients (nitrogen, and possibly phosphorus), sanitary quality indicator organisms – fecal and total coliforms, sediments resulting in significant sediment accumulation, and hazardous chemicals such as chlorinated hydrocarbon pesticides already present in the Bay and being contributed to the Bay. It also appears that there is sufficient heavy metal input to parts of Lower Newport Bay to cause significantly elevated concentrations of heavy metals in some Bay sediments. Further, the Lower Bay sediments have been found to be toxic to some forms of aquatic life.

An area of concern for which there was limited information at the time of initiation of this study was the input and impacts of potentially toxic chemical constituents such as heavy metals, pesticides, and other organics on the beneficial uses of Upper Newport Bay. Bailey *et al*. (1993) conducted toxicity tests on San Diego Creek and several other tributaries to Upper Newport Bay. They found that San Diego Creek, just above where it enters Upper Newport Bay and upstream of that point, as well as the Santa Ana-Delhi Channel, showed no significant toxicity compared to the controls for fathead minnow larvae. However, the tests conducted with *Ceriodaphnia* for San Diego Creek (Campus Drive and Culver Drive) and the Santa Ana-Delhi Channel waters caused complete mortality of the test organism. The testing with the alga *Selenastrum* showed no inhibition of algal growth.

In general, it can be concluded that in late 1992-early 1993 there were toxicants to *Ceriodaphnia* in stormwater runoff in several of the major tributaries of Upper Newport Bay. Bailey *et al.* (1993) did not identify the cause of this toxicity.

Beginning in the fall of 1997, an Evaluation Monitoring Demonstration Project was initiated to specifically assess whether constituents were present in runoff waters which are toxic to aquatic life. The samples taken in the fall of 1996 from San Diego Creek at Campus Drive, just above where the Creek discharges to Upper Newport Bay, were found to be highly toxic (about ten acute toxicity units, TUa) to *Ceriodaphnia* and non-toxic to fathead minnow larvae and the alga *Selenastrum*. These results confirmed the work of Bailey, *et al.* (1993) and identified the cause of about half of the toxicity in the stormwater runoff as it enters Upper Newport Bay as likely being due to the organophosphate pesticides, diazinon and chlorpyrifos. The other half of this toxicity was due to unidentified causes. This report presents the results of the expanded Evaluation Monitoring Program funded by the 205(j) grant devoted to assessing the presence of aquatic life toxicity in tributaries to Upper Newport Bay, sources of this toxicity, and its potential water quality significance.

SAMPLE COLLECTION AND ANALYSIS PROCEDURES

The samples were collected in prewashed bottles furnished by the University of California, Davis (UCD) Aquatic Toxicology Laboratory (Davis, CA), Pacific Eco-Risk Laboratory (Martinez, CA), and *AQUA*-Science (Davis, CA) (Neiter and Lee, 1998). At each site, samples were collected in three 1-gallon amber bottles early in the stormwater runoff event. For those situations where multiple samples were taken for chemical analyses for diazinon and chlorpyrifos during the runoff event, the samples were collected in small vials with a volume of approximately 40 ml. Field readings for electrical conductivity, pH and temperature were taken using a Hydac 900 portable meter, calibrated per manufacturer's instructions.

Samples were packed with blue ice in a cooler and shipped overnight for next morning delivery to the toxicity testing laboratories. Upon receipt at UCD the samples were stored in the dark under refrigeration at 4°C +/-1°C. According to L. Deanovic (personal communication, 1997), the UCD Aquatic Toxicology Laboratory found that diazinon and chlorpyrifos samples can be stored for several weeks under these conditions without significant loss of toxicity.

The samples were analyzed by the laboratory using the US EPA standard toxicity testing procedures described in the Quality Assurance Project Plan (QAPP) (Neiter and Lee, 1998). For freshwater samples, the procedures described by Lewis *et al*. (1994) were used in which the fathead minnow larvae *Pimephales promelas*, the zooplankton *Ceriodaphnia dubia,* and the alga *Selenastrum capricornutum* were used. For testing the potential toxicity impact to marine zooplankton, the salinity of the samples was increased to 20 ppt using Forty Fathoms® – bioassay grade and testing was done with *Americamysis bahia.* The mysid toxicity testing was done in accord with US EPA (1991) procedures. Mortality rates were examined for all but *Selenastrum capricornutum,* where growth rates were examined.

In order to determine whether the toxicity found was likely due to an organophosphate pesticide, piperonyl butoxide (PBO) was added to some of the duplicate tests. PBO interacts with organophosphate pesticides such as diazinon and chlorpyrifos to eliminate and/or reduce their toxicity (Bailey *et al*., 1996)

.Unless otherwise noted, 100 µg/L (ppb) of PBO were added to the test treatment where PBO was added.

The concentrations of diazinon and chlorpyrifos in the samples tested were evaluated using the ELISA (enzyme linked immuno sorbent assay) procedure, which has a detection limit for diazinon of about 30 ng/L and for chlorpyrifos of about 50 ng/L. The ELISA procedure is highly specific for the chemicals tested (VanEmon and Lopez-Avila, 1992, and Ferguson *et al*., 1993). Its use, combined with the use of PBO, is part of a toxicity investigation evaluation (TIE) for assessing whether the toxicity in a sample is likely due to an OP pesticide and, in particular, diazinon or chlorpyrifos.

An estimate of the total toxic units found was made by conducting toxicity tests using dilutions of the test sample using Sierra Spring EPA moderately hard control water (SSEPAMH) (Lewis *et al.* 1994).

Based on the experience of L. Deanovic (personal communication, 1998) of the University of California, Davis Aquatic Toxicology Laboratory, 425 ng/L of diazinon and 80 ng/L of chlorpyrifos represent about one acute toxic unit (TUa) each. The toxicities of these two OP pesticides have been found to be additive (Bailey *et al*., 1997). Based on the ELISA-measured diazinon and chlorpyrifos concentrations and the dilution series measured toxicity, with and without PBO addition, it is possible to estimate the amount of toxicity present in a sample that is not due to OP pesticides and/or diazinon and chlorpyrifos.

Table 3-1 summarizes the sampling activities conducted for this project, which extends from September 1997 through July 1999.

HYDROLOGIC ANALYSIS

A rainfall and runoff analysis has been performed to characterize the sampled storm events. Estimation of the storm recurrence interval using data at the sampling location is presented in this report.

Stream discharge data were collected at three points (from County of Orange stream gages) in order to determine the approximate storm return frequency and to illustrate the time during the runoff event that the samples were taken.

Stream hydrographs were analyzed from the following locations: San Diego Creek at Campus Drive, Peters Canyon Channel at Barranca Parkway, and the Santa Ana Delhi Channel at Mesa Drive. Sampling was completed for three storm events at the Santa Ana Delhi Channel, for four storm events at Peters Canyon Channel, and for seven storm events at San Diego Creek at Campus Drive.

Rainfall losses are comprised of depression storage, evaporation and infiltration. If these losses do not exceed the total rainfall, there is rainfall excess that becomes surface runoff, measured as volume of direct runoff (VDR). Rainfall losses are estimated in this analysis as one element of understanding the characteristics of the sampled storm event. The method used for computing losses, and, more significantly, the application of those losses to the storm hyetograph are not rigorous, but rather sufficiently accurate to provide the level of information required for this study. The constant loss rate method (phi index) used in this study (Gupta, 1989) will tend to underestimate losses at the beginning of the storm, and overestimate losses at the end of the storm.

Similarly, single rain gages were reviewed for the various watersheds and concentration points under consideration, rather than employing a more complex weighted average scheme from multiple gages. In general, areal and temporal variations are significant in determining runoff response to rainfall events, and the use of from 5 to 10 gages in a watershed the size of the San Diego Creek watershed to make accurate rainfall evaluations would be reasonable. However, for the purpose of this study, the analysis of single gages, coupled with validation from neighboring gages used for the various indicated runoff concentration points is sufficiently accurate to support the conclusions drawn in this study.

Lag time is defined as the time from the center of mass of the rainfall hyetograph to the center of mass of the storm hydrograph at a given location (concentration point). The lag time can be used to give a relative assessment of the portion of flow from areas more remote to the concentration point, and from pervious surfaces. For example, relatively longer lag times indicate that more of the upper portions of the watershed are contributing flow to the outlet. Conversely, a comparatively short lag time indicates that most flow may come from areas near the outlet.

The antecedent moisture condition (AMC) (Gupta, 1989) is an index of the soil condition with respect to runoff potential for a storm event. Category I indicates dry soil with little or no prior rain. Category II indicates average conditions (some prior rainfall), and Category III indicates saturated soils. Category I is associated with lower runoff potential from pervious areas, whereas Category III is associated with high runoff potential from pervious areas.

Table 3-1
Sampling Activities for September 1997-July 1999

Event Date	Sample Location	Description
9/25/97	Campus Dr./SDC	Peak flow – grab
11/13/97	Campus Dr./SDC	Early in storm – grab
11/30/97	Campus Dr./SDC	Time series – grab
12/6/97	Campus Dr./SDC	Time series – grab
	Barranca/PCC	Time series – grab
3/24/98	Campus Dr./SDC	Low flow – grab
	Barranca/PCC	Low flow – grab
	Mesa Dr./SAD	Low flow – grab
3/25/98	Campus Dr./SDC	Time series – grab
	Barranca/PCC	Time series – grab
	Mesa Dr./SAD	Time series – grab
5/5/98	Campus Dr./SDC	Peak flow – grab
	Barranca/PCC	Peak flow – grab
	Mesa Dr./SAD	Late storm – grab
5/12/98	Campus Dr./SDC	Time series – grab
	Barranca/PCC	Peak flow – grab
	Mesa Dr./SAD	Peak flow – grab
8/13-14/98	Campus Dr./SDC	Low flow – grab
	Irvine Blvd./HC	Low flow – grab
	I-5/CIC	Low flow – grab
	Barranca/PCC	Low flow – grab
	Mesa Dr./SAD	Low flow – grab
8/25/98	Campus Dr./SDC	Low flow – grab
	Irvine Blvd./HC	Low flow – grab
	Mesa Dr./SAD	Low flow – grab
11/8/98	Hines Channel	Late storm – grab
	Harvard Ave./SDC	Late storm – grab
	Barranca/PCC	Late storm – grab
	Campus Dr./SDC	Late storm – grab
	Mesa Dr./SAD	Late storm – grab
1/21/99	Hines Channel	Low flow – grab
	Mesa Dr./SAD	Low flow – grab
	Campus Dr./SDC	Low flow – grab
1/25/99	Campus Dr./SDC	Peak flow – grab
	UNBJAM	Bay sample – grab
	UNBSDC	Bay sample – grab
	UNBBCW	Bay sample – grab
1/26/99	Campus Dr./SDC	Early in storm – grab
1/27/99	Campus Dr./SDC	Late storm – grab
	UNBJAM	Late storm – grab
	UNBSDC	Late storm – grab
	UNBBCW	Late storm – grab

Table 3-1 (continued)

Event Date	Sample Location	Description
	UNBNSB	Late storm – grab
	UNBCHB	Late storm – grab
1/27/99	UNBPCH	Late storm – grab
1/29/99	Campus Dr./SDC	Low flow – grab
	UNBJAM	Low flow – grab
7/21/99	Campus Dr./SDC	Low flow - grab

Abbreviations:	SDC	San Diego Creek
	PCC	Peters Canyon Channel
	SAD	Santa Ana Delhi Channel
	HC	Hines Channel
	CIC	Central Irvine Channel
	UNBPCH	Upper Newport Bay Pacific Coast Highway Station
	UNBJAM	Upper Newport Bay Jamboree Station
	UNBBCW	Upper Newport Bay Big Canyon Wash Station
	UNBSDC	Upper Newport Bay San Diego Creek Station
	UNBNBS	Upper Newport Bay Newport Beach Station

SEPTEMBER 25, 1997, STORMWATER RUNOFF EVENT

The first storm of the 1997-98 precipitation season occurred on September 25, 1997. There had been no rainfall runoff in San Diego Creek since the previous winter. Late winter and early spring 1997 were extremely dry, with no precipitation occurring in the Orange County watershed.

Total rainfall of 0.56 in. fell at the Sand Canyon gage during the September 25, 1997 storm event. The duration of rainfall was about 7 hr, and the time of net rain (rainfall producing runoff) was about 2 hr.

The report of Lee and Taylor (1999a) provides the complete hydrologic data obtained in this study.

Campus Drive – San Diego Creek

The peak discharge at San Diego Creek at Campus Drive for the September 25, 1997, stormwater runoff event was 892 cfs. A storm recurrence interval rating curve was generated using data from Simons, Li and Associates (1987) at San Diego Creek at Campus Drive. The September 25, 1997, storm event is estimated to have a recurrence interval of about 1 yr. Storm recurrence intervals are probably larger because land uses in the San Diego Creek watershed have urbanized since 1987.

The volume of direct runoff (VDR) computed using rainfall data and a gaged hydrograph was determined to be 0.078 in. Subtracting the net rainfall (VDR) from the total rainfall gives a total loss of 0.48 in. Using a constant loss rate approach, an average loss of 0.069 in./hr is estimated, giving a time of net rain of 2 hr. The lag time for this storm (estimated from the hyetograph and the hydrograph) is about 11 hr.

This storm event typifies an average annual event for the watershed. As the first storm of the season, the antecedent moisture condition was low, and most rainfall on pervious surfaces was abstracted (infiltrated), rather than running off. Consequently, the runoff sampled at San Diego Creek at Campus Drive and the shape of the hydrograph primarily reflect runoff from directly connected impervious areas (urban areas). It is not unusual for all rainfall from relatively frequent events to be abstracted from pervious areas. Average loss rates may exceed 0.5 in./hr, with initial abstraction ranging from a few tenths of an inch for impervious areas to over 4 in. for pervious surfaces.

Sampling for the event occurred near the peak of the storm runoff hydrograph. The objective for this sampling event was to capture the "first flush" from the first significant runoff event of the season. Based on the total magnitude of rainfall, as is shown in Figure A1-1, it is likely that the sample is representative of flow from impervious surfaces in the vicinity of San Diego Creek at Campus Drive.

The September 25, 1997, storm sample toxicity was assessed using *Ceriodaphnia*, fathead minnow larvae and *Selenastrum*. The data obtained are presented in Table 3-2. Examination of the *Ceriodaphnia* toxicity data shows that there was 100-percent mortality of the *Ceriodaphnia* in the undiluted San Diego Creek sample on day 3. The San Diego Creek sample diluted by 50 percent with SSEPAMH water (standard dilution water) showed 100- percent mortality on day 7.

The undiluted (100 percent) San Diego Creek sample to which PBO was added showed no mortality to *Ceriodaphnia* over the 7-day test. These results indicate that the toxicity found was likely due to an organophosphate pesticide. The September 25, 1997, sample was found by ELISA testing procedures to contain 155 ng/L diazinon and 106 ng/L chlorpyrifos. The presence of these OP pesticides at these concentrations should cause the stormwater runoff to be toxic to *Ceriodaphnia*, with a total toxicity of between 1 and 2 acute toxic units (TUa). This level of toxicity is in accord with the toxic response found in the testing of *Ceriodaphnia*.

It is of interest that the high levels of unknown-caused toxicity (about 5 TUa) found in the stormwater runoff samples of San Diego Creek at Campus Drive in the fall of 1996 were not found in the September 25, 1997, sample. The difference is likely due to the fact that the September 25 storm was a somewhat smaller storm and had less precipitation and less runoff than the October 30, 1996, storm, which had a total precipitation of about 1 in. as opposed to about 0.6 in. for the September 25, 1997, event. As discussed subsequently, it has been found that a source of the unknown-caused toxicity is apparently located in the upper parts of the Peters Canyon Channel of the San Diego Creek watershed which drains primarily agricultural areas and nurseries. In order to get significant runoff from these areas, it is necessary to have a larger runoff event than occurred with the September 25, 1997, storm.

The data presented in Table 3-2 show that the September 25, 1997, sample of San Diego Creek water was non-toxic to fathead minnow larvae over the 7-day test period and to *Selenastrum* over the four-day test period. These results are similar to the results obtained for the October 30, 1996, sample taken of San Diego Creek at Campus Drive. That sample was also taken of the first rainfall runoff event of the season.

NOVEMBER 13, 1997, STORMWATER RUNOFF EVENT

The second stormwater runoff event of fall 1997 occurred on November 13. Total rainfall of 0.8 in. was measured at the Sand Canyon gage during this storm event. The time of rainfall was about 11 hr, and the time of net rain (rainfall producing runoff) was about 6 hr. This storm was somewhat larger than the September 25, 1997, storm in both magnitude and duration, with the antecedent moisture condition higher (possibly condition II) due to the previous rain. Accordingly, higher discharges and marginally lower loss rates were expected.

Campus Drive – San Diego Creek

The peak discharge recorded at San Diego Creek at Campus Drive was about 1,871 cfs. The storm recurrence interval rating curve (Figure A1-3) was used to estimate the storm frequency. The November 13, 1997, storm event at San Diego Creek at Campus Drive is estimated to have a recurrence interval of about 1.5 yr.

The VDR for this storm at San Diego Creek at Campus Drive was computed as 0.17 in. The total loss is the difference between the rainfall and the runoff, or 0.63 in. The average loss rate computed for this location is 0.057 in./hr. The estimated lag time is about 3 hr.

This storm and corresponding runoff was marginally above what could be characterized as an "average" event for the watershed, although the antecedent moisture condition was probably about "average" or above for the fall season. As compared to the first storm, runoff was up by 85 percent whereas rainfall was up by only about 40 percent, indicative of the higher antecedent moisture condition, higher rainfall intensity, and correspondingly lower loss rate.

The stormwater sample for this event was collected near the peak of the hydrograph. Runoff during this time is the result of rainfall excess with all of the effective portions of the basin contributing. As discussed in the Evaluation Monitoring Program Phase I report (Silverado, 1997a), it is difficult to quantify whether the timing of this sample represents the "first flush," since this concept is determined by the "pollutographs" for individual constituents, rather than the quantity or duration of flow that has passed a given point, or the quantity or duration of rainfall at a given time. Further, the concept becomes less discrete for larger watersheds where direct runoff from various parts of the watershed arrives at the sampling point at various times.

The toxicity results from the November 13, 1997, storm are presented in Table 3-3. The sample of San Diego Creek water at Campus Drive was highly toxic to *Ceriodaphnia*, with 100-percent mortality in one day. The addition of PBO to the sample slowed the time to reach 100 percent mortality to two days, but did not eliminate the toxicity. These results indicate that there was likely appreciable *Ceriodaphnia* toxicity due to non-organophosphate pesticides. The diazinon concentration (Table 3-4) for the November 13, 1997, sample was 462 ng/L, while the chlorpyrifos concentration was 161 ng/L. These results indicate that there are approximately 3 TUa of acute *Ceriodaphnia* toxicity in the November 13, 1997, sample based on diazinon and chlorpyrifos concentrations.

The November 13, 1997, sample was set up as a dilution series in order to estimate the total toxicity present in the sample. These data are presented in Table 3-5. Examination of these results shows that there was still toxicity to *Ceriodaphnia* over a 3-day test period at a 25-percent dilution of San Diego Creek water. These results indicate that there was between 4 and 8 TUa of *Ceriodaphnia* toxicity present in the November 13, 1997, San Diego Creek sample. Therefore, as with the fall 1996 samples, which had a similar runoff event magnitude to the November 13, 1997, sample, there was appreciable *Ceriodaphnia* toxicity in this sample that is due to unknown causes.

Table 3-2
Toxicity Test Results for San Diego Creek Water Samples
Collected September 25, 1997

7-day *Ceriodaphnia* Test [1,2]

Set up on 9/27/97

Treatment	Reproduction[3] (neonates/adult) X	se	Mortality (%)	Final pH @ 24 hr
Control	20.1[P]	0.9	0.0[P]	8.2
Control + PBO	20.5	0.9	0	8.2
San Diego Creek @ 100%	-	-	100 (3)	8.2
San Diego Creek @ 100% + PBO	36.1	3.9	0	8.2
San Diego Creek @ 50%	-	-	100 (7)	8.2

[P] The laboratory control met all US EPA criteria for test acceptability. 60% of the daphnids had a third brood.
[1]Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
[2]Standard US EPA feeding procedures were used during this test.
[3]Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The reproductive endpoint was analyzed using Dunnett's Test ($p<0.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.
(#) Denotes days to 100% mortality.

7-day *Pimephales* Test [1,2]

Set up on 9/27/97

Treatment	Growth[3] (mg) X	Se	Mortality[3] (%) x	se	Final pH @ 24 hr
Control	0.299[P]	0.013	20.0 [P]	9.1	8.3
San Diego Creek	0.282	0.010	25.0	6.5	8.2

[T]he laboratory control met all US EPA criteria for test acceptability.
[1]Four replicate beakers with 250 ml of sample and 10 minnows in each replicate.
[2]Minnows were fed three times daily.
[3]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

96-hr *Selenastrum* Test [1,2]

Set up on 9/27/97

Treatment	Cell Count[2, 3] (x 10^4) X	se [4]	% CV [5]	Final pH @ 96 hr
Control	98.4[P]	9.6	17.4	7.6
San Diego Creek	450.3	7.3	9.4	10.2

[T]he laboratory control met all US EPA criteria for test acceptability.
[1]Four replicate flasks with 100 ml of sample in each flask.
[2]Highlighted areas show a significant reduction in growth compared to the laboratory control.
[3]Cell count is measured in average number of cells/ml.
[4]Se equals standard error.
% CV = (standard deviation (sad)/mean)*100

Table 3-3
Toxicity Test Results for San Diego Creek Water Samples
Collected November 13, 1997

7-day *Ceriodaphnia* Test[1,2]

Set up on 11/14/97

Treatment	Reproduction [3] (neonates/adult)		Mortality (%)	Final pH @ 24 hr
	X	se		
Control (SSEPAMH)	27.4[P]	0.13	0[P]	8.6
Control + PBO (SSEPAMH	16.7	1.05	0	8.5
San Diego Creek 11/13/97	0	0	100(1)	8.1
San Diego Creek 11/13/97 + PBO	0	0	100(2)	8.0

[T]he laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
[1]Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
[2]Standard US EPA feeding procedures were used during this test.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.
(#) Denotes days to 100% mortality.

7-day *Pimephales* Test [1,2]

Set up on 11/14/97

Treatment	Growth (mg)		Mortality (%)[3]		Final pH @ 24 hr
	X	Se	x	se	
Control (DIEPAMH)	0.274[P]	0.009	0	0	8.0
San Diego Creek 11/13/97	0.245	0.013	7.5	4.8	7.9

[T]he laboratory control met all US EPA criteria for test acceptability.
[1]Four replicate beakers with 250 ml of sample and 10 minnows in each replicate.
[2]Minnows were fed three times daily.
[3]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

96-hr *Selenastrum* Test [1]

Set up on 11/14/97

Treatment	Cell Count[1] (x 10^4)		% CV	Final pH @ 96 hr
	X	se		
Control	133.5	15.5	23.2[NP]	7.5
San Diego Creek 11/13/97	209.1	23.5	22.4	9.4

[NP] The glass distilled control did not meet all US EPA criteria for test acceptability. The coefficient of variation was 23.2% in this treatment.
[1] Four replicate flasks with 100 ml of sample in each flask.
[2]Highlighted areas show a significant reduction in growth compared to the glass distilled control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

Table 3-4
Chemical Characteristics of San Diego Creek Water Collected November 13, 1997

Treatment	Diazinon[1] ELISA value (ng/L)	Chlorpyrifos[1] ELISA value (ng/L)	Lab pH	Lab EC [2] (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Ammonia (mg/L as NH_4)	Alkalinity (mg/L as $CaCO_3$)
Control for *Ceriodaphnia*	-	-	8.4	209	8.3	84	-	66
Control for *Pimephales*	-	-	8.4	260	8.2	80	-	58
Control for *Selenastrum*	-	-	7.9	91		-	-	-
San Diego Creek 11/13/97	462	161	8.3	441	8.2	140	0.2	82

[1]Detection limits for ELISA diazinon and chlorpyrifos are 30 ng/L and 50 ng/L, respectively. Diazinon and chlorpyrifos ELISA were conducted on 11/14/97.

[2]All EC values reported in this column were at 25^{o}C

Table 3-5
Results of 4-Day *Ceriodaphnia* Phase I TIE[1,2] on San Diego Creek Water Collected November 13, 1997

Set up on 11/15/97

Treatment	% Mortality for each day of the test[3]				Conclusions	Final pH @ 24hr
	1	2	3	4		
Control (SSEPAMH)	0	0	0	0	Control met all EPA criteria for test acceptability.	8.4
Control + PBO (SSEPAMH)	0	0	0	0	No artifactual toxicity detected in control blank.	8.4
100% San Diego Creek	100	100	100	100	Acute toxicity detected.	8.2
50% San Diego Creek	100	100	100	100	Acute toxicity detected	8.2
50% San Diego Creek + PBO	0	0	0	5	Significant decrease in mortality relative to ambient water suggests that a metabolically activated pesticide is responsible for toxicity.	8.2
25% San Diego Creek	0	16	89	95	Acute toxicity detected.	8.4
25% San Diego Creek + PBO	0	0	0	0	Significant decrease in mortality relative to ambient water suggests that a metabolically activated pesticide is responsible for toxicity.	8.4
12.5% San Diego Creek	0	0	5	5		8.4
6.25% San Diego Creek	0	0	0	0		8.4

[1]Four replicates with 18 ml of sample and five *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

NOVEMBER 30, 1997, STORMWATER RUNOFF EVENT

The November 30, 1997, rain event was the smallest rain event sampled during the 1997-98 study period. About 0.32 in. of rain fell at the Sand Canyon rain gage over a 4-hr period. The rainfall was unique in that one of the rain units occurred almost 8 hr after the primary series of rain units. The time of rainfall was about 4 hr, and the time of net rain was about 3 hr. This storm is another example of a "typical" event for the watershed, defined as an event that is likely to occur in any given year.

Campus Drive – San Diego Creek

The peak flow at San Diego Creek at Campus Drive was estimated to be about 840 cfs for this event. Using this estimated peak flow the runoff event would correspond to about a 1-yr storm.

The volume of direct runoff (VDR) was computed using the rainfall data and the gaged hydrograph as 0.035 in. Subtracting the net rainfall (VDR) from the total rainfall gives a total loss of 0.29 in. Using a constant loss rate approach, an average loss of 0.063 in./hr is estimated, giving a time of net rain of 3 hr. The lag time for this storm (estimated from the hyetograph and the hydrograph) is about 5 hr.

This storm event typifies an average annual runoff event for the watershed. The peak discharge at San Diego Creek at Campus Drive was comparable to the September 25, 1997, event. However the rainfall was almost one-quarter of an inch less. This is most likely directly attributable to the higher antecedent moisture condition associated with this storm.

Sampling for the event occurred near the peak flow of the hydrograph. Four samples were taken at San Diego Creek at Campus Drive. The first two were taken on the rising limb of the hydrograph. The third sample was taken on the falling limb and the last sample was taken when the flow had returned to baseflow. A sample at this point represents direct runoff contributed from all effective areas of the watershed. Given the storm size and intensity and computed watershed lag time, the effective areas of the watershed probably included most of the urban areas, certainly the urban areas that are west of I-5. See Figure 2-1.

Table 3-6 shows that the November 30, 1997, sample of San Diego Creek water at Campus Drive killed all *Ceriodaphnia* within 1 day. The addition of PBO to this sample extended the time for 100 percent mortality to 5 days. This sample was non-toxic to fathead minnow larvae. Table 3-7 shows that the November 30, 1997, sample was found to contain 226 ng/L of diazinon and 63 ng/L of chlorpyrifos. Since these two OP pesticides' toxicities are additive, this indicates that there was about 1 TUa of OP pesticide toxicity.

A dilution series of the San Diego Creek at Campus Drive November 30, 1997, sample was set up to estimate the total toxicity and the impact of PBO on reducing this toxicity. These results are presented in Table 3-8. Examination of the data presented in this table shows that 100 percent mortality was achieved in the first day for the undiluted sample and within three days for the 50-percent diluted sample. The addition of PBO to the 50-percent sample significantly reduced the toxicity, indicating the potential presence of OP pesticide toxicity. There were low levels of toxicity for the 25-percent sample beginning on the first day. The addition of PBO eliminated this toxicity. These results indicate that there were about 3 to 4 TUa of *Ceriodaphnia* toxicity in the November 30, 1997, sample. Therefore, as with many of the other samples, there was appreciable *Ceriodaphnia* toxicity due to unknown causes in the stormwater runoff as it enters Upper Newport Bay.

Table 3-6
Toxicity Test Results for San Diego Creek Water Samples
Collected November 11, 1997

7-day *Ceriodaphnia* Test[1,2]
Set up on 12/3/97

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Final pH @ 24 hr
	X	se		
Control (SSEPAMH)	22.7[P]	3.41	10[P]	8.5
Control + PBO (SSEPAMH)	11.7	1.64	0	8.5
San Diego Creek 11/30/97	0	0	100(1)	8.2
San Diego Creek 11/30/97 + PBO	0	0	100(5)	8.4

[P]The laboratory control met all US EPA criteria for test acceptability. 86% of the daphnids had a third brood.
[1]Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
[2]Standard US EPA feeding procedures were used during this test.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.
(#) Denotes days to 100% mortality.

7-day *Pimephales* Test[1,2]
Set up on 12/2/97

Treatment	Growth (mg)		Mortality[3] (%)		Final pH @ 24 hr
	x	Se	x	se	
Control (DIEPAMH)	0.346[P]	0.011	5	5	7.9
San Diego Creek 11/30/97	0.380	0.007	2.5	2.5	8.1

[P]The laboratory control met all US EPA criteria for test acceptability.
[1]Four replicate beakers with 250 ml of sample and 10 minnows in each replicate.
[2]Minnows were fed three times daily.
[3]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

A sample of the November 30, 1997, San Diego Creek stormwater runoff taken at Campus Drive was tested to determine if it contained constituents that are toxic to *Americamysis bahia* (mysids). The salinity of this sample was adjusted to 20 ppt using artificial sea salts (Forty Fathoms® – bioassay grade). The results are presented in Table 3-9. Examination of Table 3-9 shows that 70 percent mysid mortality occurred in three days, which increased to about 88 percent with a 7-day exposure. Table 3-10 presents the results of the dilution series of the November 30, 1997, sample obtained at San Diego Creek at Campus Drive.

The results of the 7-day test show that while 100 percent San Diego Creek water killed 50 percent of the mysids, when the sample was diluted to 50 percent, the toxicity was reduced to about 10-percent mortality. About the same level of toxicity was found in a 25-percent dilution of San Diego Creek water. However, the mortality in the 50- or 25-percent dilutions of San Diego Creek water was not statistically significantly different from that of the controls. These results indicate that there were about 1 to 2 TUa of mysid toxicity in the November 30, 1997, sample.

Table 3-7
Chemical Characteristics of San Diego Creek Water November 30, 1997

Treatment	Diazinon[1] ELISA value (ng/L)	Chlorpyrifos ELISA value (ng/L)	Lab pH	Lab EC [2] (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Control for *Ceriodaphnia*	-	-	8.1	217	8.4	80	66
Control for *Pimephales*	-	-	8.2	290	8.4	80	66
San Diego Creek 11/30/97	226	63	7.9	1155	8.3	308	96

[1]Detection limits for ELISA diazinon and chlorpyrifos are 30 ng/L and 50 ng/L respectively. Diazinon and chlorpyrifos ELISA were conducted on 12/4/97.

[2]All EC values reported in this column were at 25°C.

Table 3-8
Results of 4-Day *Ceriodaphnia* Phase I TIE[1,2] on San Diego Creek Water Collected November 30, 1997

Set up on 12/5/97

Treatment	% Mortality for each day of the test[3]				Conclusions	Final pH @ 24hr
	1	2	3	4		
Control (SSEPAMH)	0	0	0	0	Control met all US EPA criteria for test acceptability.	8.3
Control + PBO (SSEPAMH)	0	0	5	5	No artifactual toxicity detected in control blank.	8.3
100% San Diego Creek	95	100	100	100	Acute toxicity detected.	8.2
50% San Diego Creek	0	25	100	100	Acute toxicity detected.	8.3
50% San Diego Creek + PBO	0	5	5	5	Significant decrease in mortality relative to ambient water suggests that a metabolically activated pesticide is responsible for toxicity.	8.2
25% San Diego Creek	5	5	5	5	Acute toxicity detected.	8.3
25% San Diego Creek + PBO	0	0	0	0		8.2
12.5% San Diego Creek	0	0	0	0		8.3
6.25% San Diego Creek	0	0	0	0		8.4

[1]Four replicates with 18 ml of sample and five *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-9
Toxicity of the November 30, 1997, Campus Drive
San Diego Creek Water* to Americamysis bahia

Treatment	Mortality (%) 72-hr. Exposure	Mortality (%) 7-day Exposure
Control	0	2
San Diego Creek Water	70	87.5

*Salinity adjusted to 20 ppt with artificial sea salts.

Table 3-10
Results of 7-Day Mysid Toxicity Test Dilution Series
November 30, 1997, Campus Drive San Diego Creek Water

Treatment	Mortality (%)
Control	0
San Diego Creek Water – 100%	50*
San Diego Creek Water – 50%	10
San Diego Creek Water – 25%	10
San Diego Creek Water – 12.5%	5
San Diego Creek Water – 6.25%	0

*Statistically significant toxicity compared to controls at $p<0.05$.

The toxicity of this sample with 100 percent San Diego Creek water was lost upon dilution to 50 percent. Therefore, there were between 1 and 2 TUa of mysid toxicity in the salinity-adjusted San Diego Creek water taken from Campus Drive during the November 30, 1997, stormwater runoff event. This means that, while San Diego Creek water with the salinity adjusted to 20 ppt was toxic to mysids, mixing of this water with Upper Newport Bay marine waters on a one-to-one basis would cause the toxicity to disappear. The November 30, 1997, sample, therefore, was less toxic to mysids than to *Ceriodaphnia*. This is to be expected, since mysids are not particularly sensitive to diazinon. They are, however, more sensitive to chlorpyrifos than are *Ceriodaphnia*. According to Dr. Scott Ogle of Pacific Eco-Risk Laboratories of Martinez, California, 1 TUa of diazinon toxicity to *Americamysis bahia* is 4,500 ng/L. 1 TUa of chlorpyrifos to *Americamysis bahia* is 35 ng/L. The corresponding values for *Ceriodaphnia* are, for diazinon 425 ng/L, and for chlorpyrifos 80 ng/L.

Pacific Eco-Risk measurements of diazinon and chlorpyrifos in the November 30, 1997, sample using the ELISA procedure showed that diazinon was present at 278 ng/L and chlorpyrifos was present at 90 ng/L. Therefore, there was about 2.5 TUa of toxicity to mysids predicted in the November 30, 1997, sample. This predicted toxicity is somewhat higher than the measured toxicity, which was between 1 and 2 TUa. These results are expected, in that chlorpyrifos tends to sorb on particulates, which would be expected to reduce its toxicity. This would cause the measured toxicity to be less than that predicted, based on chlorpyrifos and diazinon measurements on unfiltered samples, since these measurements would measure the pesticides sorbed on the surface of particles.

The results of the diazinon and chlorpyrifos analyses on the November 30, 1997, sample by the two laboratories that ran the ELISA procedure on this sample were within reasonable agreement, where diazinon was measured by UCD at 226 ng/L and by Pacific Eco-Risk at 278 ng/L. For chlorpyrifos UCD measured 63 ng/L and Pacific Eco-Risk measured 90 ng/L.

DECEMBER 6, 1997, STORMWATER RUNOFF EVENT

The December 6, 1997, rain event was the largest rain event sampled (and recorded) during the 1997-99 study period. About 6.43 in. of rain fell at the Sand Canyon rain gage in less than 24 hr, about 0.8 in. above the County's defined 100-yr rainfall event. The rainfall was also unique in that most of the volume (3.5 in., or more than 50 percent) fell in just 2 hr. The time of rainfall was about 20 hr, and the time of net rain was about 2 hr. This storm did not necessarily constitute a 100-yr runoff event for all areas, since the antecedent moisture condition may not have corresponded to condition III, but rather was likely condition II, and other locations within the watershed may have experienced less rainfall than recorded at the Sand Canyon gage.

Campus Drive – San Diego Creek

The stream gage at San Diego Creek at Campus Drive malfunctioned during this event, likely due to the magnitude of runoff and corresponding stage in San Diego Creek. Consequently, a hydrograph and associated volume data were estimated. The methods that the County uses to reconstruct hydrographs in this watershed include consulting the field logbook for water level staff readings from the fluvial sediment monitoring program and comparing the data to the other gages in the watershed. The peak flow at San Diego Creek at Campus Drive was estimated to be 43,500 cfs. Using this estimated peak flow this runoff event would exceed a 100-yr recurrence interval for existing or ultimate watershed development conditions.

Sampling was completed at multiple times during the hydrograph in an effort to determine if the toxicity varied with flow and the time from the start of direct surface runoff. All of the samples were taken on the falling limb of the hydrograph beyond the inflection point of the hydrograph peak. Flow in this portion of the hydrograph represents detention storage, or flow that remains on the land surface and is running off once rainfall has stopped.

Barranca Parkway – Peters Canyon Channel

The peak discharge at Peters Canyon Channel at Barranca Parkway was recorded as 8,340 cfs. The estimated return period for this event is about 55 yr. There are significant hydraulic restrictions in the upstream watershed along Peters Canyon Channel, including construction of improvements to the channel associated with the Eastern Transportation Corridor. It is likely that the peak flow in Peters Canyon Channel was moderately attenuated due to flow restrictions and associated storage in these areas.

The calculated VDR at Barranca Parkway and Peters Canyon Channel is 2.76 in., for a total loss of about 3.7 in. The average loss rate for the storm is estimated to be 0.18 in/hr, approaching the theoretical maximum sustained average loss rate for much of the soil type in the watershed. The estimated lag time for this event is 2 hr.

In spite of the estimate of a 50 yr return period for reasons discussed above, it is likely that this storm produced a 100-yr runoff event for the Peters Canyon Channel. This runoff event was probably unique for the watershed during this monitoring period in that it is reasonably certain that all areas of the watershed were contributing runoff. The El Modena Channel tributary, which is highly urbanized and accounts for about 30 percent of the total Peters Canyon Channel watershed area, contributed about 20 percent of the flow volume during this storm. This is an indication that the open space and agricultural areas produced significant runoff.

Similar to the sampling completed at San Diego Creek at Campus Drive, a time-series of samples was collected at Barranca Parkway to provide data to help understand the potential variability of toxicity with respect to flow and time from the beginning of direct runoff. Four samples were taken on the falling limb of the hydrograph.

As shown in Table 3-11, the San Diego Creek sample taken on December 6, 1997, at Campus Drive showed 100-percent mortality to *Ceriodaphnia* in 2 days. The addition of PBO eliminated this toxicity, indicating that the toxicity was likely due to an OP pesticide. The December 6, 1997, sample was not toxic to fathead minnow larvae. Table 3-12 shows that diazinon was present at 257 ng/L with chlorpyrifos being present at 57 ng/L, indicating that there was about 1 TUa to *Ceriodaphnia* due to these two pesticides.

In order to evaluate the changes in concentration of diazinon and chlorpyrifos during a stormwater runoff event, samples were taken at various times during the December 6, 1997, event. The ELISA test data for the San Diego Creek at Campus Drive samples show that the sample collected on December 6, 1997, at 0910 hr had diazinon and chlorpyrifos concentrations of 215 ng/L and 89 ng/L, respectively, while the sample collected at 1320 hr had diazinon and chlorpyrifos concentrations of 257 ng/L and 57 ng/L, respectively. The San Diego Creek at Campus Drive sample collected at 1645 hr contained 195 ng/L of diazinon and 82 ng/L chlorpyrifos. It is evident that there were not major changes in the diazinon and chlorpyrifos concentrations during the December 6, 1997, stormwater runoff event.

Correspondingly, the sample of Peters Canyon Channel at Barranca Parkway at 1040 hr had diazinon and chlorpyrifos concentrations of 277 ng/L and 102 ng/L, respectively, while the sample taken at the same location at 1350 hr had concentrations of diazinon and chlorpyrifos of 426 ng/L and 94 ng/L, respectively. The Peters Canyon Channel at Barranca Parkway sample taken at 1715 hr had 202 ng/L and 84 ng/L concentrations of diazinon and chlorpyrifos, respectively. Therefore, except for one sample (Peters Canyon Channel at Barranca Parkway taken at 1350 hr) the data show that the concentrations of diazinon and chlorpyrifos were reasonably constant during the runoff event. The 1350 hr Peters Canyon Channel at Barranca Parkway sample which had a 426 ng/L diazinon concentration is somewhat elevated compared to the other samples taken at that location, although not significantly out of line from the other samples.

A sample of the San Diego Creek stormwater runoff collected at Campus Drive on December 6, 1997, was tested for mysid toxicity. Table 3-13 presents the results of this testing. The ELISA measurements on this sample showed that diazinon was present at 197 ng/L and chlorpyrifos was present at less than 50 ng/L, i.e., the test detection limit.

The results of the testing of the December 6, 1997, high flow San Diego Creek showed that the sample was toxic to mysids over a 7-day exposure period. A dilution series was not conducted on this sample.

Table 3-11
Toxicity Test Results for San Diego Creek Water Samples
Collected December 6, 1997

7-day *Ceriodaphnia* Test[1,2]

Set up on 12/9/97

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Final pH @ 24 hr
	X	se		
Control (SSEPAMH)	26.6[P]	3.9	10[P]	8.6
Control + PBO (SSEPAMH)	17.2	3.4	0	8.2
San Diego Creek 12/6/97	0	0	100(2)	8.3
San Diego Creek 12/6/97 + PBO	10.1	1.8	0	8.2

[P]The laboratory control met all US EPA criteria for test acceptability. 80% of the daphnids had a third brood.
[1]Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
[2]Standard US EPA feeding procedures were used during this test.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.
(#) Denotes days to 100% mortality.

7-day *Pimephales* Test[1,2]

Set up on 12/9/97

Treatment	Growth (mg)		Mortality[3] (%)		Final pH @ 24 hr
	X	se	x	se	
Control (DIEPAMH)	0.391[P]	0.014	0	0	7.9
San Diego Creek 12/6/97	0.427	0.023	0.06	0.04	8.2

[P]The laboratory control met all US EPA criteria for test acceptability.
[1]Four replicate beakers with 250 ml of sample and 10 minnows in each replicate.
[2]Minnows were fed three times daily.
[3]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

Table 3-12
Chemical Characteristics of San Diego Creek Water December 6. 1997

Treatment	Diazinon[1] ELISA value (ng/L)	Chlorpyrifos[1] ELISA value(ng/L)	Lab pH	Lab EC [2] (µmhos/cm)	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Control for *Ceriodaphnia*	-	-	8.2	220	7.7	80	66
Control for *Pimephales*	-	-	8.0	278	8.1	80	66
San Diego Creek 12/6/97	257	57	8.3	293	7.8	96	62

[1]Detection limits for ELISA diazinon and chlorpyrifos are 30 ng/L and 50 ng/L, respectively. Diazinon and chlorpyrifos ELISA were conducted on 12/9/97.

[2]All EC values reported in this column were at 25^{o}C

Table 3-13
Toxicity of the December 6, 1997, Campus Drive San Diego Creek Water* to *Americamysis bahia*
7-Day Exposure

Treatment	Mortality (%)
Control	5
San Diego Creek Water	62*

*Statistically significant toxicity compared to control at $p<0.05$.

A rainwater sample was collected in Irvine, California on the roof of the RBF building during the first part of the December 6, 1997, rainfall event. It was found to contain 13 ng/L diazinon and 23 ng/L chlorpyrifos. These concentrations are below the LC_{50} values, although there could be some toxicity to mysids in the rainwater sample, since chlorpyrifos is expected to show toxicity to *Americamysis bahia* at a few ng/L

MARCH 24, 1998, BASE FLOW STUDIES

January and February 1998 were extremely wet periods in Orange County, arising from El Niño, which produced frequent and substantial precipitation. No samples were taken during this time. It would be expected that there would have been limited pesticide use in residential and agricultural areas during this time because of the precipitation patterns. A sample of winter low flow conditions was taken at San Diego Creek at Campus Drive and the Santa Ana Delhi Channel at Mesa Drive on March 24, 1998. The previous rainfall event (0.86 in.) occurred on March 14, 1998. The estimated dry weather flow in San Diego Creek on March 24, 1998, at the time of sample collection was about 20 cfs. The estimated dry weather flow for the Santa Ana Delhi Channel on this day was 5 cfs.

Table 3-14 presents the results of the *Ceriodaphnia* and fathead minnow larvae toxicity testing that was conducted on the March 24, 1998, low flow sample. Examination of the Table 3-14 *Ceriodaphnia* toxicity test data shows that both San Diego Creek and the Santa Ana Delhi Channel were non-toxic to this organism. Similar results were obtained for the San Diego Creek sample taken at Campus Drive when fathead minnow larvae were used as the test organism. However, there was about 40-percent mortality of the fathead minnow larvae when exposed to Santa Ana Delhi Channel water. This is the first time during the testing in this project and in the Evaluation Monitoring Demonstration Project that toxicity to fathead minnow larvae was found. The Santa Ana Delhi Channel drains a considerable industrial/commercial area. It is possible that this toxicity was due to illegal or illicit industrial/commercial discharges to this channel. As discussed in a subsequent section, similar toxicity was found in the Santa Ana Delhi Channel water sampled in August 1998.

MARCH 25, 1998, STORMWATER RUNOFF EVENT

A total of 1.23 in. of rain was recorded at the Sand Canyon rain gage (San Diego Creek watershed) for the March 25, 1998, storm. The time of the rainfall was about 11 hr, and the time of net rain was about 5 hr.

A total of 1.35 in. of rain was recorded at the Santa Ana Delhi rain gage (Santa Ana Delhi channel watershed). The time of the rainfall was about 10 hr, and the time of net rain is estimated to be about 8 hr. The Santa Ana Delhi watershed is highly urbanized, which would be consistent with a longer time of net rain as compared to the less urbanized (on a percentage basis) San Diego Creek watershed.

Campus Drive – San Diego Creek

The peak discharge at San Diego Creek at Campus Drive for the March 25, 1998, storm was recorded as about 4,900 cfs. The recurrence interval for this event is estimated as about 2 yr.

The VDR for this storm was computed as 0.37 in. The total loss is about 0.86 in., obtained by subtracting the VDR from the total rainfall (1.2 in.). The average loss rate for this location is about 0.078 in/hr, and the estimated lag time is about 3 hr.

This storm is statistically above average annual, and produced moderate runoff at San Diego Creek at Campus Drive. The relatively high VDR as a percentage of total rain indicates a higher AMC and potentially more runoff from pervious areas, as compared to the average annual storm events.

Four samples were taken during this storm event at different times during the runoff hydrograph. One sample was taken prior to the peak and three samples were taken on the receding limb of the hydrograph. The sampling times selected can be used to determine if there are significant differences in the concentration of diazinon and chlorpyrifos over the duration of the runoff event.

Barranca Parkway – Peters Canyon Channel

The peak discharge recorded at Peters Canyon Channel at Barranca Parkway during this storm was about 3,990 cfs. The estimated storm recurrence interval is about 5 yr.

The VDR for this hydrograph is calculated to be 0.42 in. The total loss is about 0.81 in. The average loss rate for this location is about 0.074 in/hr. The estimated lag time is 2 hr.

In comparing the values given above to the San Diego Creek at Campus Drive location, it is apparent that more rainfall fell in the Peters Canyon Channel watershed as compared to the San Diego Creek watershed. This is correlated with the higher rainfall amount recorded at the Santa Ana Delhi gage which is geographically closer to the Peters Canyon Channel watershed than the Sand Canyon gage. The geometry of the Peters Canyon Channel watershed would appear to dominate the shape of the hydrograph at San Diego Creek at Campus Drive. The volume of runoff from the Peters Canyon Channel watershed is about 42 percent of the total volume of runoff at Campus Drive and San Diego Creek

Four samples were taken over the course of the hydrograph. All four of the samples occur on the receding limb, with the third and fourth samples occurring during base-flow following the runoff event.

Santa Ana Delhi Channel

The peak discharge recorded at Mesa Drive and the Santa Ana Delhi Channel was about 1,380 cfs. The estimated storm recurrence interval is about 2 yr. Hydrologic information for various storm recurrence intervals was not available. The VDR for this storm was computed as 0.67 in. The total loss for the storm was computed as 0.68 in. The average loss rate is estimated as 0.067 in./hr. The computed lag time for this storm is estimated as 3 hr.

Table 3-14
Toxicity Test Results on Prestorm Water Samples
Collected March 24, 1998

7-day *Ceriodaphnia* Test[1,2]

Set up on 3/26/98

Treatment	Reproduction[3] (neonates/adult)		Mortality (%)	Final pH @ 24 hr
	x	se		
Control	22.6[P]	1.6	0[P]	8.3
Control @ 2000 µmhos/cm	27.0	0.6	0	8.3
Santa Ana Delhi Channel	22.3	2.6	0	8.5
San Diego Creek @ Campus	26.7	1.1	0	8.6

[P]The laboratory control met all US EPA criteria for test acceptability. 80% of the daphnids had a third brood.
[1]Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
[2]Highlighted Standard US EPA feeding procedures were used during this test.
[3]Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The reproductive endpoint was transformed to rank and analyzed using Dunnett's Test ($p<0.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.

7-day *Pimephales* Test[1,2]

Set up on 3/26/98

Treatment	Growth[3] (mg)		Mortality[3] (%)		Final pH @ 24 hr
	X	se	x	se	
Control	0.428[P]	0.014	0[P]	0	7.6
Control @ 3000 µmhos/cm	0.552	0.013	0	0	8.3
Santa Ana Delhi Channel	0.619	0.072	40.0	14.72	8.2
San Diego Creek @ Campus	0.545	0.016	0	0	8.3

[P] The laboratory control met all US EPA criteria for test acceptability.
[1] Four replicate beakers with 250 ml of sample and 10 minnows in each replicate.
[2] Minnows were fed three times daily.
[3]Highlighted areas indicate a significant increase in mortality or decrease in growth relative to the laboratory control water. The growth and mortality endpoints were transformed to rank and analyzed using Dunnett's Test ($p<0.05$).

Given the highly urbanized nature of this watershed, it can be concluded that nearly the entire watershed was contributing flow at the hydrograph peak. The lag time is reduced as compared to the same watershed in an un-urbanized condition given that the majority of the channel system is improved and lined with concrete.

Four samples were taken during the March 25, 1998, stormwater runoff event. The first sampling occurs just prior to the hydrograph peak. The second sample was taken on the recession portion of the hydrograph. The final samples can be characterized as in the base-flow portion of the hydrograph.

The toxicity data obtained for the March 25, 1998, storm is presented in Table 3-15. As in the past, there was 100 percent mortality of *Ceriodaphnia* when tested with the San Diego Creek at Campus Drive sample. Mortality of 100 percent was achieved on day 4. There was also 100-percent mortality in the sample taken from Peters Canyon Channel at Barranca Parkway.

However, this mortality was achieved on day 1. The sample taken from the Santa Ana Delhi Channel was highly toxic to *Ceriodaphnia* with 100-percent mortality occurring on day 4.

Table 3-15 shows that there was no mortality or significant impact on the growth of fathead minnow larvae in the stormwater runoff at San Diego Creek at Campus Drive and Peters Canyon Channel at Barranca Parkway, as well as the Santa Ana Delhi Channel. These results may indicate illegal discharges to this channel as a source of the toxicity that was found under low flow conditions on March 24, 1998. The toxic constituents, however, were diluted below toxic levels in the March 25, 1998, stormwater runoff.

Table 3-15
Toxicity Test Results on Water Samples Collected during Storm
March 25, 1998

7-day *Ceriodaphnia* Test[1,2]
Set up on 3/26/98

Treatment	Reproduction[3] (neonates/adult)		Mortality[3](%)	Final pH @ 24 hr
	X	se		
Control	24.7[P]	0.8	0[P]	8.3
Control @ 1000 µmhos/cm	23.4	0.7	0	8.3
Peters Canyon Channel @ Barranca	-	-	100(1)	8.2
San Diego Creek @ Campus	-	-	100(4)	8.1
Santa Ana Delhi Channel	-	-	100(4)	7.7

[P]The laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
[1]Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
[2]Standard US EPA feeding procedures were used during this test.
[3]Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The reproductive endpoint was analyzed using Dunnett's Test ($p<0.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.
(#) Denotes days to 100% mortality.

7-Day *Pimephales* Test[1,2]
Set up on 3/27/98

Treatment	Growth[3] (mg)		Mortality[4] (%)		Final pH @ 24 hr
	X	se	x	se	
Control	0.405[P]	0.010	0[P]	0	7.0
Peters Canyon Channel @ Barranca	0.438	0.014	4.8	2.8	7.0
San Diego Creek @ Campus	0.461	0.031	7.8	4.8	7.0
Santa Ana Delhi Channel	0.413	0.006	7.5	4.8	7.4

[1]The laboratory control met all US EPA criteria for test acceptability.
[2]Four replicate beakers with 250 ml of sample and 10 minnows in each replicate.
[3]Minnows were fed three times daily.
[4]Highlighted areas indicate a significant increase in mortality or decrease in growth relative to the laboratory control water. The growth endpoint was analyzed using Dunnett's Test ($p<0.05$) and the mortality endpoint was transformed to rank and analyzed using Dunnett's Test ($p<0.05$).

While the Santa Ana Delhi Channel was non-toxic to *Ceriodaphnia* under low flow conditions for the sample taken on March 24, 1998, the sample taken during the following day's rainfall runoff event killed all *Ceriodaphnia* within four days. A dilution series of the sample from Peters Canyon Channel at Barranca Parkway was set up to estimate the total toxicity and the possibility of it being due to OP pesticides or other compounds that react with PBO. The dilution series results are presented in Table 3-16. All samples tested, including those that contain 100 µg/L of PBO were toxic to *Ceriodaphnia*, including the 6.25 percent dilution. These results indicate that there were at least 16 TUa to *Ceriodaphnia* in the March 25, 1998, Peters Canyon Channel sample collected at Barranca Parkway. The test conducted in the presence of PBO showed reduced toxicity. However, PBO did not eliminate the toxicity, indicating that there were other toxic constituents in the sample beyond those that interact with PBO.

Because of the high level of toxicity found, the March 25, 1998, sample was retested in a dilution series, with the data presented in Table 3-17. This time only 50 µg/L of PBO were used for those tests run with PBO. Again, high levels of *Ceriodaphnia* toxicity were found in all test conditions including down through the 12.5-percent diluted sample from Peters Canyon Channel at Barranca Parkway. PBO at 50 µg/L was able to neutralize a substantial part of this toxicity on the highly diluted samples. It is evident that there is substantial toxicity present in Peters Canyon Channel at the Barranca Parkway sampling station that is possibly due to OP pesticides. It also appears that there is some non-OP pesticide toxicity present in this sample. Further, it appears that the branch of Peters Canyon Channel that is sampled at Barranca Parkway accounts for a greater part of the toxicity than other parts of the San Diego Creek watershed, since the toxicity found at Peters Canyon Channel at Barranca Parkway appeared to be greater than that found at San Diego Creek at Campus Drive during the same runoff event.

Table 3-18 presents the ELISA-measured diazinon and chlorpyrifos in the March 24, 25, and 26, 1998, samples taken of the San Diego Creek at Campus Drive and Peters Canyon Channel at Barranca Parkway at various times during the runoff event. It also presents similar data for the Santa Ana Delhi Channel. Examination of Table 3-19 shows that only one of the San Diego Creek samples had a detectable concentration of chlorpyrifos. All others at San Diego Creek at Campus Drive, Peters Canyon Channel at Barranca Parkway, and Santa Ana Delhi Channel had non-detectable chlorpyrifos concentrations. The detection limit was about 50 ng/L.

Both the March 24, 1998, prestorm low flow San Diego Creek at Campus Drive and Santa Ana Delhi Channel samples had about 140 to 150 ng/L diazinon. This concentration is below the LC_{50} for the toxicity of diazinon to *Ceriodaphnia*, which is about 425 ng/L. It is also below the expected lower toxic level of about 200 ng/L. The concentrations of diazinon collected at San Diego Creek at Campus Drive at the various times of sampling, range from about 200 to about 460 ng/L, with the highest concentration occurring at 1730 hr on March 25, 1998. This sample was taken at the far right of the falling limb of the hydrograph. Examination of the data set from the samples taken at Peters Canyon Channel at Barranca Parkway shows that the highest concentrations of diazinon occurred at about 1300 hr near the peak of the hydrograph.

Table 3-16
Summary of 96-Hr *Ceriodaphnia* Dilution Series Test Conducted on Water Sample from Peters Canyon Channel at Barranca Parkway
Collected March 25, 1998

Set up on March 27, 1998[1,2]

Treatment	% Mortality for each day of the test[3]				Conclusions	Final pH @ 24hr
	1	2	3	4		
Control	0	0	0	0	Control met all US EPA criteria for test acceptability.	7.6
Control + PBO	0	0	15	100	Artifactual toxicity detected in the control blank.	8.0
100% Peters Canyon Channel @ Barranca	100	100	100	100	Toxicity detected.	8.2
100% Peters Canyon Channel @ Barranca + PBO	10	100	100	100	Delay in mortality relative to the ambient dilution suggests that the toxicity was due to a metabolically activated organophosphate pesticide.	8.2
50% Peters Canyon Channel @ Barranca	90	100	100	100	Toxicity detected.	8.0
50% Peters Canyon Channel @ Barranca + PBO	0	100	100	100	Delay in mortality relative to the ambient dilution suggests that the toxicity was due to a metabolically activated organophosphate pesticide.	8.0
25% Peters Canyon Channel @ Barranca	0	100	100	100	Toxicity detected.	8.0
25% Peters Canyon Channel @ Barranca + PBO	0	5	15	20	Decrease in mortality relative to the ambient dilution suggests that the toxicity was due to a metabolically activated organophosphate pesticide.	8.0
12.5% Peters Canyon Channel @ Barranca	0	5	70	90	Toxicity detected.	8.1
6.25% Peters Canyon Channel @ Barranca	0	0	5	15	Toxicity detected	8.1

[1]Four replicates with 18 ml of sample and five *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only four 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

The March 25 samples of the Santa Ana Delhi Channel taken at various times had diazinon concentrations ranging from 64 to about 200 ng/L, with the lowest concentration being in the last sample taken.

Overall, the diazinon and chlorpyrifos concentrations found in the San Diego Creek and the Santa Ana Delhi Channel samples taken of the March 25, 1998, storm show that, except for one sample, the concentrations were all less than the LC_{50} for *Ceriodaphnia*. It is clear that there is appreciable non-diazinon toxicity in this sample, some of which responds to PBO treatment.

Table 3-17
Summary of 96-Hr *Ceriodaphnia* Dilution Series Re-Test Conducted on Water Sample from San Diego Creek at Barranca Parkway
Collected March 25, 1998 - Retest

Set up on 4/1/98[1,2]

Treatment	% Mortality for each day of the test[3]				Conclusions	Final pH @ 24hr
	1	2	3	4		
Control	0	0	0	0	Control met all US EPA criteria for test acceptability.	8.2
Control + 50 ppb PBO	0	0	5	5	No artifactual toxicity detected in the control blank.	8.2
50% Peters Canyon Channel @ Barranca	100	100	100	100	Toxicity detected.	8.2
50% Peters Canyon Channel @ Barranca + 50 ppb PBO	0	25	100	100	Delay in mortality relative to the ambient dilution suggests that the toxicity was due to a metabolically activated organophosphate pesticide.	8.2
25% Peters Canyon Channel @ Barranca	0	100	100	100	Toxicity detected.	8.2
25% Peters Canyon Channel @ Barranca + 50 ppb PBO	0	5	5	5	Decrease in mortality relative to the ambient dilution suggests that the toxicity was due to a metabolically activated organophosphate pesticide.	8.2
12.5% Peters Canyon Channel @ Barranca	0	40	100	100	Toxicity detected.	8.2
12.5% Peters Canyon Channel @ Barranca + 50 ppb PBO	0	5	5	5	Decrease in mortality relative to the ambient dilution suggests that the toxicity was due to a metabolically activated organophosphate pesticide.	8.2

[1]Four replicates with 18 ml of sample and five *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

A sample of the San Diego Creek water obtained at Campus Drive on March 25, 1998, was sent to Pacific Eco-Risk Laboratories for toxicity testing using *Americamysis bahia*. The results are presented in Table 3-19. Two replicate tests were conducted (C and D). Both tests showed that San Diego Creek water obtained at Campus Drive on March 25, 1998, was non-toxic to *Americamysis bahia*. This is expected since the chlorpyrifos and diazinon concentrations in this sample represented less than 1 TUa.

Table 3-18
ELISA Data Summary for San Diego Creek Water Samples
Spring 1998

Sample	Time of Sampling (hr)	Sample Date	Diazinon (ng/L)	Chlorpyrifos (ng/L)
Santa Ana Delhi Channel		3/24/98	140	ND
San Diego Creek at Campus		3/24/98	148	ND
San Diego Creek at Campus	1140	3/25/98	196	ND
San Diego Creek at Campus	1730	3/25/98	462	50
San Diego Creek at Campus	2300	3/25/98	294	ND
San Diego Creek at Campus	0900	3/26/98	250	ND
Peters Canyon Channel @ Barranca	1300	3/25/98	367	ND
Peters Canyon Channel @ Barranca	1710	3/25/98	288	ND
Peters Canyon Channel @ Barranca	2240	3/25/98	378	ND
Peters Canyon Channel @ Barranca	0925	3/26/98	266	ND
Santa Ana Delhi Channel	1220	3/25/98	202	ND
Santa Ana Delhi Channel	1750	3/25/98	192	ND
Santa Ana Delhi Channel	2215	3/25/98	155	ND
Santa Ana Delhi Channel	0830	3/26/98	64	ND
Santa Ana Delhi Channel		5/5/98	170	ND
San Diego Creek at Campus		5/5/98	136	ND
San Diego Creek at Campus		5/13/98	96	57
Santa Ana Delhi Channel		5/13/98	375	ND

ND means concentration <50 ng/L

Table 3-19
***Americamysis bahia* Toxicity Test Results for March 25, 1998,**
Stormwater Runoff -San Diego Creek at Campus Drive

Stormwater Treatment	Mortality % (days)
Control	0
San Diego Creek – 100% (C)	12.5 (7)
San Diego Creek – 100% (D)_	10 (7)

Los Angeles County Samples. During the course of a study on aquatic life toxicity of stormwater runoff to Upper Newport Bay in Orange County, California, it was discovered that some toxicity tests on stormwater runoff conducted in the Los Angeles Basin by the Los Angeles County Department of Public Works were toxic. However, this toxicity was apparently not due to organophosphate pesticides. Further, it was indicated that the OP pesticides diazinon and chlorpyrifos were not being detected in the Los Angeles County samples of stormwater runoff. This was somewhat surprising, in that studies in the San Francisco Bay region; Sacramento/Stockton region; Davis, and Orange County, California, have found organophosphate pesticide-associated toxicity in stormwater runoff from urban areas. In order to address this issue, cooperative arrangements were made between the Los Angeles Regional Water Quality Control Board staff (Xavier Swamikannu), the Los Angeles Department of Public Works staff, and the University of California, Davis Aquatic Toxicology Laboratory. A set of stormwater runoff samples were collected in the Los Angeles County area in order to compare the toxicity results in these samples using toxicity test procedures identical to those used in the Orange County studies.

The Los Angeles County Department of Public Works collected a set of samples from various streams/rivers in the Los Angeles area for the March 25, 1998, storm. The results are presented in Table 3-20. Examination of the data presented in Table 3-20 shows that the samples of Ballona Creek at Beloit Street; Culver City; Project 156 at Concord Street; Glendale; and Coyote Creek at Spring Creek in Long Beach were all acutely toxic to *Ceriodaphnia* in 2 to 6 days. The land uses of the watersheds above the sampling locations for these three stations are predominantly residential.

The Malibu Creek sample taken at Piuma Rd. in unincorporated Los Angeles County, while not acutely toxic, i.e., causing mortality, did impair *Ceriodaphnia* reproduction. The watershed at this sampling point is primarily vacant land. Both the LA River at Wardlow in Long Beach and the San Gabriel River at the San Gabriel River Parkway in Pico Rivera showed no toxicity to *Ceriodaphnia* in the 7-day test. The land use in the LA River in the Wardlow watershed has substantial vacant land with about 30 percent of the land being residential. The San Gabriel River at San Gabriel River Parkway watershed has over 66 percent vacant land. From the limited data available it appears that the residential areas in the Los Angeles region contributed higher levels of *Ceriodaphnia* toxicity to stormwater runoff than the watersheds which primarily consist of vacant land. This would be expected since the primary uses of OP pesticides in an urban setting are associated with residential areas.

Examination of the ELISA test results for these samples (Table 3-20) showed that Coyote Creek had about 586 ng/L diazinon and 102 ng/L chlorpyrifos. As expected, this sample was highly toxic to *Ceriodaphnia*. Ballona Creek had 298 ng/L diazinon and about 50 ng/L chlorpyrifos. This sample would also be expected to be toxic to *Ceriodaphnia*, although less toxic than the Coyote Creek sample. The Project 156 sample contained 375 ng/L diazinon and less than 50 ng/L chlorpyrifos. No ELISA testing was done on the LA River at Wardlow and the San Gabriel River samples, since they were nontoxic. Therefore, there was less than one toxic unit of *Ceriodaphnia* toxicity based on ELISA-measured diazinon and chlorpyrifos in this sample. This sample, however, did show 100 percent kill of *Ceriodaphnia* in 6 days. It is possible that the toxicity found in this sample, as well as the other samples, may also be due, at least in part, to constituents other than diazinon and chlorpyrifos.

DePoto (personal communication, 1998) of the LA Department of Public Works, helped explain some of the apparent discrepancies between the previously-reported results and the results obtained in this study. The failure to detect diazinon and chlorpyrifos in previous studies was due to the use of an analytical method for these chemicals that had detection limits for diazinon of 250 ng/L and 1,000 ng/L for chlorpyrifos. Subsequently, more sensitive analytical procedures were used for measurements of these pesticides in the LA County stormwater monitoring program. No results are available at this time using the more sensitive analytical procedures.

Both the Los Angeles River and the San Gabriel River in the Los Angeles area were monitored in the fall of 1997 for dry weather and wet weather toxicity to sea urchin fertilization by SCCWRP (1997, 1998). The fall 1997 dry weather flow sample was nontoxic to sea urchin fertilization. However, two stormwater runoff events, one occurring in November and the other in December 1997, both suppressed sea urchin fertilization (were toxic). The cause of this toxicity is unknown. Also, no measurements were made of OP pesticide concentrations in the runoff samples.

Table 3-20
Toxicity Test Results for Los Angeles Area Water Samples
Collected March 25, 1998

7-day *Ceriodaphnia* Test[1,2]
Set up on March 26, 1998

Treatment	Reproduction[3] (neonates/adult)		Mortality[3] (%)	Final pH @ 24 hr
	x	se		
Control	24.7[P]	0.8	0[P]	8.3
Control @ 1000 µmhos/cm	23.4	0.7	0	8.3
San Gabriel River @ San Gabriel River Pkwy., City of Pico Rivera	25.6	1.5	0	8.5
Malibu Creek @ Piuma Rd., unincorporated area of Malibu	16.8	1.0	0	8.4
Ballona Creek @ Beloit St., Culver City	-	-	100(5)	8.2
Project 156 @ Concord St., City of Glendale	-	-	100(6)	7.6
LA River Wardlow @ Wardlow Rd., City of Long Beach	30.0	1.4	0	8.0
Coyote Creek @ Spring St., City of Long Beach	-	-	100(2)	8.2

[P]The laboratory control met all US EPA criteria for test acceptability. 100% of daphnids had a third brood.
[1]Ten replicates with 15 ml of sample and one *Ceriodaphnia* each.
[2]Standard US EPA feeding procedures were used during this test.
[3]Highlighted areas indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The reproductive endpoint was analyzed using Dunnett's Test ($p<0.05$) and the mortality endpoint was analyzed using Fisher's Exact Test.
(#) Denotes days to 100% mortality.

ELISA Data for Los Angeles Area Water Samples
Collected March 25, 1998

Location	Diazinon (ng/L)	Chlorpyrifos (ng/L)
Ballona Creek @ Beloit St., Culver City	298	50
Project 156 @ Concord St., City of Glendale	375	<50
Coyote Creek @ Spring St., City of Long Beach	586	102
San Gabriel River @ San Gabriel River Pkwy., City of Pico Rivera	ND*	ND
LA River Wardlow @ Wardlow Rd., City of Long Beach	ND	ND
Malibu Creek @ Piuma Rd., unincorporated area of Malibu	ND	ND

*ND means not determined because sample was non-toxic

Overall, it is concluded that the Los Angeles County stormwater runoff is, as expected, toxic to *Ceriodaphnia*, with a toxicity at least in part due to the OP pesticides diazinon and chlorpyrifos. It should be noted that stormwater runoff in the San Diego area has also been found by Kinnetic Laboratories (1995) to be toxic to *Ceriodaphnia*, with a pattern similar to that observed for OP pesticides. The presence of these chemicals in San Diego stormwater runoff, however, was not confirmed in those studies. It therefore may be concluded that stormwater runoff in the southern California urban areas is toxic to *Ceriodaphnia,* and this toxicity is due at least in part to diazinon and chlorpyrifos.

MAY 5, 1998, STORMWATER RUNOFF EVENT

A total of 0.99 in. of rain was recorded at the Sand Canyon rain gage (San Diego Creek watershed) for the May 5, 1998, storm. The time of the rainfall was about 10 hr, and the time of net rain was about 4 hr.

The Santa Ana Delhi rain gage recorded a total of 0.84 in. of rain for this storm event. The total rainfall occurred over a 2-hr period, resulting in a time of net rainfall of 2 hr.

Campus Drive – San Diego Creek

The peak discharge recorded at Campus Drive and San Diego Creek for this event was 3,161 cfs. The May 5 storm event is estimated to have a return interval of about 2 yr. The hydrograph for this storm is more peaked as compared to the previous events due to the relatively short duration of rainfall.

The VDR was computed using the gaged hydrograph as about 0.18 in. The loss for this storm at San Diego Creek at Campus Drive is estimated as 0.66 in. using the Santa Ana Delhi rain gage. The estimated constant loss rate for this storm is 0.33 in./hr, confirming the time of net rain for the storm of 2 hr. The estimated lag time for this storm is 4 hr.

This storm event is characteristic of 1- to 2-yr return events in that it has a relatively short duration and time of net rain. The runoff hydrograph also has a relatively short time base (about 7 hr), and the slope of the rising and falling limbs are steep compared to other runoff events for the season. This is an indication of a highly urbanized watershed with runoff from impervious surfaces.

A single sample was collected from the May 5 storm event. The sample was collected at nearly the time of the peak flow on the hydrograph as shown on Figure A6-3. The peak of the hydrograph represents the arrival of flow from all parts of the basin, or from that portion of the basin receiving the highest concentration of rainfall and runoff.

Barranca Parkway – Peters Canyon Channel

The peak discharge recorded at Peters Canyon Channel at Barranca Parkway for this event was 1,832 cfs. The estimated storm recurrence interval is about 2 yr.

The volume of direct runoff (VDR) for this storm at this location is about 0.16 in.. The total loss for the storm at this location is estimated as about 0.68 in. for an average loss rate of about 0.34 in./hr. The estimated lag time for this hydrograph is about 4 hr.

The shape of the hydrograph at Peters Canyon Channel at Barranca Parkway is similar to that at Culver Drive with relatively steep slopes on the rising and falling limbs of the hydrograph. The hydrograph shape is characteristic of a short duration rainfall over the entire watershed**.**

A single sample was collected for this event at nearly the exact peak discharge point of the hydrograph.

Santa Ana Delhi Channel

The peak discharge recorded at Irvine Avenue along the Santa Ana Delhi Channel for the May 5, 1998, storm was 1,210 cfs. The return period for this event was estimated as about 1 yr.

The VDR for this storm at the Delhi Channel was computed as 0.26 in. The total loss for the storm is estimated as 0.58 in., or about 0.29 in./hr. The estimated lag time for this hydrograph is about 4 hr.

The watershed upstream of this sampling point is more urban than that of either San Diego Creek at Campus Drive or Peters Canyon Channel at Barranca Parkway. This is reflected in the average loss rate at this location which is less than that at either San Diego Creek at Campus Drive or Peters Canyon Channel at Barranca Parkway by about 17 percent. Accordingly, more of the runoff may be expected to be from impervious surfaces.

A single sample was collected during this runoff event on the receding limb of the hydrograph. Table 3-21 presents the results of the *Ceriodaphnia* toxicity testing for the May 5, 1998, stormwater runoff event. San Diego Creek at Campus Drive showed 100 percent toxicity to *Ceriodaphnia* beginning on day 2. The same sample with 100 µg/L PBO was non-toxic to *Ceriodaphnia* indicating the likely presence of OP pesticides at sufficient concentrations to be toxic to this organism. However, examination of the ELISA test results for the May 5 San Diego Creek sample taken at Campus Drive shows only 136 ng/L of diazinon and non-detectable amounts of chlorpyrifos. It appears that there was appreciable toxicity due to unknown causes in this sample.

MAY 12, 1998, STORMWATER RUNOFF EVENT

The May 12 storm event produced a total of 1.11 in. as recorded at the Sand Canyon gage. This event was similar to the May 5 storm event in that two rain units (1 hr rain periods) were responsible for nearly all of the precipitation and a significant portion of the direct runoff, accounting for about 0.75 in., or 67 percent of the rain total. The time of rainfall is 13 hr but the time of net rain is estimated as 2 hr.

A total of 1.15 in. of rain was recorded at the Santa Ana Delhi rain gage. The Santa Ana Delhi rain gage also indicates that a significant portion of the rainfall occurred during two rainfall periods, although a single rainfall period earlier in the storm also contributed to runoff. The total rainfall time was 5 hr and the time of net rain is estimated as 3 hr.

Campus Drive – San Diego Creek

The peak discharge recorded at San Diego Creek for this storm was 4,361 cfs. The return period for this event is estimated as about 2 yr.

The VDR for the storm was calculated as 0.42 in., with a total storm loss of 0.69 in.. The average loss rate for this location is about 0.086 in./hr. The estimated lag time is about 3 hr. Given the multiple peak configuration of the hydrograph, and the relatively wide time-lapse between rain units on the hyetograph, estimation of the lag time was somewhat difficult.

The hydrograph exhibits a multi-peaked configuration in response to the rainfall pattern. This type of hydrograph configuration can also be an indication of a watershed with limited storage (for example, urbanized with improved watercourses).

Table 3-21
Summary of *Ceriodaphnia* Toxicity in San Diego Creek Samples Collected May 5, 1998[1,2]

Set up on 5/6/98

Treatment	% Mortality for each day of the test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Control				0	Control met all US EPA criteria for test acceptability.	8.3
Control + PBO				0	No artifactual toxicity present in control blank.	8.3
San Diego Creek at Campus		100	100	100	Toxicity detected.	8.2
San Diego Creek at Campus + PBO				0	Decrease in mortality with the addition of PBO suggests that the toxicity was caused by a metabolically activated compound.	8.1
Santa Ana Delhi Channel				0	No toxicity detected.	7.9
Santa Ana Delhi Channel + PBO				0		7.9

[1] Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2] Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3] Highlighted cells indicate areas of significant interest. No statistical analyses were done.

ELISA Diazinon and Chlorpyrifos Data

Sample	Sample Date	Diazinon (ng/L)	Chlorpyrifos (ng/L)
San Diego Creek at Campus	5/5/98	136	<50
Santa Ana Delhi Channel	5/5/98	170	<50

Five samples were taken during this event. The first and second samples were taken at the end of the receding limb of the first peak on the hydrograph. The third sample was taken near the start of direct runoff for the second hydrograph peak.

Barranca Parkway - Peters Canyon Channel

The peak discharge recorded at Peters Canyon Channel at Barranca Parkway for the May 12-13, 1998, storm was 1,304 cfs. The return period for this storm event is estimated as about 1 yr.

The VDR for the storm was calculated as 0.29 in. with a total loss of about 0.82 in. The computed average loss rate for the storm is 0.16 in./hr. The lag time is difficult to estimate, given the multiple-peak configuration of the storm and the corresponding clustered rainfall units on the hyetograph. The estimated lag time is about 2 hr.

The sample was taken near the second peak of the first runoff event.

Santa Ana Delhi Channel

The peak discharge recorded at the Santa Ana Delhi Channel at Irvine Avenue for the May 12-13 event was 887 cfs. This peak discharge corresponds to a storm return period of about 1-yr.

The VDR for the storm was calculated as 0.45 in. with a total loss of about 0.7 in.. The estimated average loss rate is 0.14 in./hr. Similar to the other locations for this storm, the lag time is difficult to estimate, but is about 2 hr.

Three samples were taken for this event. The first is located at the point just before the second precipitation event. The second is located at the end of the second precipitation event. Finally, the third sampling point is located at the start of the return to base flow.

The toxicity data for the May 12-13, 1998, stormwater runoff event is presented in Tables 3-22 and 3-23. The stormwater runoff sample of San Diego Creek waters collected at Campus Drive was acutely toxic to *Ceriodaphnia* within 1 day. The addition of 100 µg/L of PBO did not remove this toxicity. The Santa Ana Delhi Channel samples were non-toxic to *Ceriodaphnia* over the 7-day test period. This sample had 375 ng/L of diazinon and non-detect (less than 50 ng/L) chlorpyrifos.

Table 3-23 presents the results of the dilution series toxicity testing of the San Diego Creek sample taken at Campus Drive. As shown, this sample was toxic to *Ceriodaphnia* where all organisms were killed within 1 day in the undiluted (100), 50 and 25 percent dilutions. While the addition of PBO to the undiluted and 50-percent samples did not remove or decrease the toxicity, the 25-percent San Diego Creek water diluted sample, with the addition of PBO, reduced the rate of 100 percent kill from 1 to 3 days. The 6.25-percent San Diego Creek diluted sample was non-toxic over the 4-day test period. These results indicate that there were between 8 to 16 toxic units of *Ceriodaphnia* toxicity in this sample.

The ELISA testing of the San Diego Creek sample taken at Campus Drive found 96 ng/L of diazinon and 57 ng/L of chlorpyrifos. This would be expected to be equivalent to about one toxic unit of *Ceriodaphnia* toxicity. Since over 8 toxic units of *Ceriodaphnia* toxicity were found in the toxicity test, the May 12, 1998, stormwater runoff event contained large amounts of *Ceriodaphnia* toxicity due to unidentified cause(s). As discussed below, further toxicity identification evaluation work was done on this sample in an attempt to determine the cause(s) of this toxicity.

A time series set of samples was taken of San Diego Creek at Campus Drive and of Santa Ana Delhi Channel at Mesa Drive during the May 12–13 stormwater runoff event. This data is presented in Table 3-24.

Examination of the data presented in Table 3-24 shows that the diazinon and chlorpyrifos concentrations were essentially constant during the runoff event. There was no detectable first flush characteristic.

The May 12, 1998, San Diego Creek at Campus Drive stormwater runoff sample was tested for *Americamysis bahia* toxicity after the salinity had been adjusted to 20 ppt using artificial sea salt. The results of these tests are presented in Table 3-25.

Examination of the results presented in Table 3-25 shows that the May 12, 1998, San Diego Creek at Campus Drive sample with the salinity adjusted to 20 ppt was toxic to *Americamysis bahia* at the 25-percent dilution. These results indicate that there were between 4 and 8 toxic units of mysid toxicity in this sample. Since this sample was found to contain about 57 ng/L chlorpyrifos, which represents about 1.6 toxic units of mysid toxicity, there was appreciable toxicity in the sample to mysids that is due to unknown constituents.

Table 3-22
Summary of 7-Day *Ceriodaphnia* Toxicity Tests on Water Samples Collected May 12, 1998

Set up on 5/14/98

Treatment	Reproduction[1] (neonates/adult)		Mortality (%)	Final pH @ 24 hr
	X	Se		
Control	28.2[P]	0.4	0[P]	8.3
Control + PBO	19.7	1.3	0	8.3
San Diego Creek at Campus	*	*	100 (1)	7.9
San Diego Creek at Campus + PBO	*	*	100 (1)	7.8
Santa Ana Delhi Channel	33.2	0.7	0	8.3
Santa Ana Delhi Channel + PBO	27.7	1.6	0	8.2

[P] The laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.

[1]Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The morality endpoint was analyzed using Fisher's Exact Test.

(#) Number in parentheses indicates days to 100% mortality.

* Due to significant mortality observed in these samples, reproduction was not calculated.

Table 3-23
Summary of *Ceriodaphnia* 96-Hr Toxicity for Water Samples Collected May 12, 1998[1,2]

Set up on 5/16/98

Treatment	% Mortality for each day of the test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Control				0	Control met all US EPA criteria for test acceptability.	8.3
Control + PBO				0	No artifactual toxicity present in control blank.	8.3
100% San Diego Creek @ Campus	100	100	100	100	Toxicity detected.	8.0
100% San Diego Creek @ Campus + PBO	100	100	100	100	No delay in mortality with the addition of PBO suggests that either toxicity was not due to a metabolically activated compound or that the concentration of the metabolically activated compound was too high to be alleviated by PBO.	8.1
50% San Diego Creek @ Campus	100	100	100	100	Toxicity detected.	8.2
25% San Diego Creek @ Campus	100	100	100	100	Toxicity detected	8.3
25% San Diego Creek @ Campus + PBO		45	100	100	Delay in mortality suggests that the toxicity was at least in part due to a metabolically activated compound.	8.3
12.5% San Diego Creek @ Campus		100	100	100	Toxicity detected.	8.3
6.25% San Diego Creek @ Campus				0	No toxicity detected.	8.3

[1] Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2] Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3] Highlighted cells indicate areas of significant interest. No statistical analyses were done.

AUGUST 1998 BASE FLOW STUDIES

In August 1998 several samples were taken in the Upper Newport Bay watershed of the San Diego Creek and its tributaries' base flow in order to evaluate the potential toxicity during summer base flow conditions. The base flow in San Diego Creek is derived primarily from groundwater discharge to the creek. In addition, there are wastewater inputs from nurseries, irrigation tail water from agricultural activities, and fugitive water associated with over watering or improper watering of lawns and other landscape areas.

Table 3-24
Summary Of San Diego Creek and Santa Ana Delhi Channel for the May 12, 1998, Time Series ELISA Results

Site	Sample Date	Sample Time (hr)	Diazinon (ng/L)	Chlorpyrifos (ng/L)
San Diego Creek at Campus	5/12/1998	1900	375	65
San Diego Creek at Campus	5/13/1998	0710	375	57
San Diego Creek at Campus	5/13/1998	1205	371	57
San Diego Creek at Campus	5/13/1998	1740	253	58
Santa Ana Delhi at Mesa	5/13/1998	0645	96	41
Santa Ana Delhi at Mesa	5/13/1998	1145	203	36
Santa Ana Delhi at Mesa	5/13/1998	1800	104	55

Table 3-25
***Americamysis bahia* Toxicity Test Results for May 12, 1998, Stormwater Runoff San Diego Creek at Campus Drive**

Stormwater Treatment	Mortality (%)
Control	0
San Diego Creek – 100%	100*
San Diego Creek – 50%	100*
San Diego Creek – 25%	65*
San Diego Creek – 12.5%	5
San Diego Creek – 6.5%	5

* Significantly less than the control treatment at $p<0.05$.

A sample of San Diego Creek at Campus Drive, Peters Canyon Channel at Barranca Parkway, Hines Channel at Irvine Boulevard, Central Irvine Channel just upstream of where it confluences with Peters Canyon Channel at the I-5 crossing and the Santa Ana Delhi Channel was taken on August 13, 1998. The locations of these channels are shown in Figure 2-2. Because of the high total salt content of San Diego Creek water under base flow conditions, it was necessary to dilute the Creek water with the reference water to keep the total salts below an electrical conductivity of 2,000 µmhos/cm. Total salt concentrations above this specific conductance value are toxic to *Ceriodaphnia*.

The August 13, 1998, base flow San Diego Creek sample taken at Campus Drive diluted to 66 percent of the original sample was non-toxic to *Ceriodaphnia* (Table 3-26). The analysis of this sample by *AQUA*-Science using ELISA procedures showed a diazinon concentration of 117 ng/L. The chlorpyrifos concentration for this sample was 67 ng/L. These concentrations of OP pesticides could be just under a toxic concentration to *Ceriodaphnia*. It is possible that the undiluted sample would have been toxic due to OP pesticides. Similar toxicity and OP pesticide analytical results were obtained in the fall of 1996 and in the spring of 1998 for base flow conditions for San Diego Creek at Campus Drive.

Sixty-eight percent dilution of Peters Canyon Channel at Barranca Parkway water, sampled on August 13, 1998, killed all *Ceriodaphnia* within 5 days. This toxicity was eliminated through the addition of 100 µg/L of PBO. The undiluted sample of Peters Canyon at Barranca Parkway was found by *AQUA*-Science to contain 470 ng/L diazinon, and 57 ng/L chlorpyrifos. These concentrations of these OP pesticides would be expected to be toxic to *Ceriodaphnia*.

The samples from Hines Channel at Irvine Boulevard and Central Irvine Channel at the point just upstream of the confluence with Peters Canyon Channel at the I-5 crossing, which were taken upstream of the Peters Canyon Channel at Barranca Parkway sampling station, killed all *Ceriodaphnia* within one day. The addition of PBO to the Central Irvine Channel sample extended the kill time to 2 days. It is evident from these results that there is appreciable *Ceriodaphnia* toxicity in the upper parts of the San Diego Creek watershed that are drained by the Peters Canyon Channel and its tributaries, which is partly neutralized by the addition of PBO. It appears that the primary source of this toxicity is a discharge(s) to the Hines Channel, where, through dilution, i.e., increased groundwater flow, the toxicity is reduced in downstream stations along Peters Canyon Channel to the point where San Diego Creek at Campus Drive is non-toxic.

The sample taken of the Santa Ana Delhi Channel diluted to 2,000 µmhos/cm (74 percent of the originally sampled water) was non-toxic to *Ceriodaphnia* (Table 3-26). This result is similar to that found on the March 24, 1998, low flow sample taken at this location. The August 13 sample was found by *AQUA*-Science to contain 85 ng/L of diazinon and 5 ng/L of chlorpyrifos. These concentrations would not be expected to be toxic to *Ceriodaphnia*.

Table 3-27 presents the toxicity test results using fathead minnow larvae for the August 13, 1998, sample taken at Peters Canyon Channel at Barranca Parkway, Hines Channel and Central Irvine Channel. These samples were all non-toxic to fathead minnow larvae including potentially affecting their growth. Therefore, as with past sampling of the San Diego Creek at Campus Drive, no toxicity to fathead minnow larvae has been found during this study. Unfortunately, the Santa Ana Delhi Channel sample taken on August 13 broke in shipping, and therefore it was not possible to determine if the fathead minnow toxicity found in the March 24, 1998, low flow sample of Santa Ana Delhi Channel water was present in August 1998.

Table 3-27 presents the toxicity results for the testing of *Selenastrum* using the August 13, 1998, sample. While it appears that the Hines Channel at Irvine Boulevard was toxic to *Selenastrum*, since the algal cell count at 4 days was considerably less than the control, the coefficient of variation for the control and test samples were sufficiently high that the differences between the Hines Channel at Irvine Boulevard and the control were not statistically significant. Because of the high variability in the August 13, 1998, toxicity test results to *Selenastrum*, the August 13 Hines Channel at Irvine Boulevard sample, which had been stored in the dark under refrigeration at 4°C, was set up again and the test repeated (the results are presented in Table 3-28). This time a statistically significant difference in the test results were obtained, indicating that Hines Channel at Irvine Boulevard was toxic to *Selenastrum.*

Table 3-26
Summary of 7-Day *Ceriodaphnia* Toxicity Tests on Water Samples Collected August 13, 1998

Set up on 8/14/98

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH @ 24 hr
	x	se		
Control	23.5[P]	0.9	0[P]	8.3
Control + PBO	13.6	0.9	0	8.2
Control @ 2000 µmhos/cm	13.6	0.9	20	8.2
Control @ 2000 µmhos/cm + PBO	12.3	1.9	10	8.2
San Diego Creek at Campus (diluted to 2000 µmhos/cm - 66% dilution)	11.6	1.9	0	8.5
San Diego Creek at Campus (diluted to 2000 µmhos/cm - 66% dilution) + PBO	23.5	1.8	0	8.5
Peters Canyon Channel at Barranca (diluted to 2000 µmhos/cm – 68% dilution)	*	*	100 (5)	8.6
Peters Canyon Channel at Barranca (diluted to 2000 µmhos/cm – 68% dilution) + PBO	26.9	1.3	0	8.5
Hines Channel at Irvine Creek Dr.	*	*	100 (1)	8.1
Hines Channel at Irvine Creek Dr. + PBO	*	*	100 (1)	8.1
Central Irvine Channel	*	*	100 (1)	8.3
Central Irvine Channel + PBO	*	*	100 (2)	8.3
Santa Ana Delhi Channel (diluted to 2000 µmhos/cm - 74% dilution)	25.2	2.6	10	8.5
Santa Ana Delhi Channel (diluted to 2000 µmhos/cm - 74% dilution) + PBO	26.5	1.5	0	8.4

[P] The laboratory control met all US EPA criteria for test acceptability. 100% of the daphnids had a third brood.

[1] Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The reproduction endpoint was analyzed using Dunnett's Test and the mortality endpoint was analyzed using Fisher's Exact Test.

* Due to significant mortality observed in these samples reproduction was not calculated.

(#) Number in parenthesis indicates days to 100% mortality.

Table 3-29 presents the dilution series *Ceriodaphnia* toxicity test results for the Hines Channel and Central Irvine Channel August 13, 1998, sample. The Hines Channel samples at dilutions less than 3.13 percent were all toxic to *Ceriodaphnia*. This toxicity was eliminated by the addition of PBO. These results strongly point to the presence of an OP pesticide as a cause of the toxicity. Based on the toxicity test results, a measured *Ceriodaphnia* toxicity of 16 to 32 toxic units was found in this sample. This is the highest value found during the course of this study.

Table 3-27
Summary of Toxicity Tests on Water Samples
Collected August 13, 1998

7-day *Pimephales* Toxicity Tests

Set up on 8/14/98

Treatment	Growth[1] (mg)		Mortality[1] (%)		Final pH @ 24 hr
	X	Se	X	se	
Control	0.346[P]	0.012	0[P]	0.0	8.0
Peters Canyon Channel At Barranca	0.412	0.010	0.0	0.0	8.6
Hines Channel at Irvine Creek Dr.	0.396	0.008	0.0	0.0	8.0
Central Irvine Channel	0.401	0.005	0.0	0.0	8.2

[P] The laboratory control met all US EPA criteria for test acceptability.
[1] Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

96-hr *Selenastrum* Toxicity Tests

Set up on 8/14/98

Treatment	Cell Count[1] (x 10^4)		% CV	Final pH @ 96 hr
	x	se		
Control	214.8[NP]	39.6	36.9	9.4
San Diego Creek at Campus	222.0	16.4	14.7	8.5
Peters Canyon Channel at Barranca	367.1	23.7	12.9	9.2
Santa Ana Delhi Channel	356.1	21.4	14.3	9.1
Hines Channel at Irvine Creek Dr.	13.9	0.5	7.3	9.4
Central Irvine Channel	189.5	3.5	3.7	8.8

[NP]The laboratory control did not meet all US EPA criteria for test acceptability. The coefficient of variation was 36.9% in this treatment.
[1]Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

Table 3-28
Summary of 96-Hr *Selenastrum* Toxicity Re-Test on Water Sample
Collected August 13, 1998

Set up on 8/ 20/98

Treatment	Cell Count[1] (x 10^4)		% CV	Final pH @ 96 hr
	x	se		
Control	196.5[P]	16.4	16.7	8.1
Hines Channel at Irvine Creek Dr.	28.1	3.7	26.0	8.6

[P]The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 16.7% in this treatment.
[1]Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

The August 13 Hines Channel and Central Irvine Channel samples were sent to *AQUA*-Science for diazinon and chlorpyrifos analysis using the ELISA procedure. The Hines Channel sample was found to contain about 10,000 ng/L of diazinon. The August 13, 1998, samples from Hines Channel and Central Irvine Channel were also sent to APPL, Inc., Fresno, California, for dual column GC analysis using US EPA 8141 Special Low-Level procedures. The results are presented in Table 3-30. Diazinon was found to be present in this sample at 12,000 ng/L. Therefore, there was reasonably good agreement between the APPL results using GC procedures and the *AQUA*-Science results using ELISA procedures. This same sample was found by APPL to contain about 67 ng/L chlorpyrifos. *AQUA*-Science found 47 ng/L of chlorpyrifos in the August 13, 1998, Hines Channel sample.

The Central Irvine Channel sample was found by APPL to contain 620 ng/L of diazinon, and 260 ng/L of chlorpyrifos. *AQUA*-Science found 281 ng/L of chlorpyrifos and 840 ng/L of diazinon. These concentrations of these OP pesticides translate to a potential *Ceriodaphnia* toxicity of 28 toxic units in the Hines Channel water at Irvine Boulevard based on APPL results. The Central Irvine Channel water just above where this Channel confluences with Peters Canyon Channel had about 5 toxic units of *Ceriodaphnia* toxicity. It is evident that this very high concentration of diazinon and chlorpyrifos were responsible, at least in part, for the high level of toxicity found in the Hines Channel and the Central Irvine Channel.

The high levels of *Ceriodaphnia* toxicity found in the August 13 samples taken from the upper part of the San Diego Creek watershed prompted a re-sampling of these locations on August 25, 1998. This was also a low flow sample and there was no precipitation between the August sampling events. The *Ceriodaphnia* toxicity results are presented in Table 3-31. Again, as has been found previously, San Diego Creek at Campus Drive and Santa Ana Delhi Channel at Mesa were non-toxic to *Ceriodaphnia*. However, the Hines Channel at Irvine Creek dry weather flow sample with and without PBO killed all *Ceriodaphnia* within 1 day.

Table 3-32 presents the results of the fathead minnow larvae testing using the August 25, 1998, sample. This time the Santa Ana Delhi Channel sample was non-toxic to fathead minnow larvae. The March 24, 1998, low flow sample taken of the Santa Ana Delhi Channel indicated potential industrial/commercial discharge of a toxicant to the base flow of this Channel. This was not present in the August 25, 1998, sample. However, the sample of Hines Channel water at Irvine Boulevard taken on August 25, 1998, showed 11 percent mortality to fathead minnow larvae and, for the first time, the San Diego Creek sample at Campus Drive was toxic to fathead minnow larvae with approximately 4 percent mortality found in the 7-day test.

Table 3-33 presents the results of the dilution series toxicity testing of *Ceriodaphnia* conducted on the August 25, 1998, sample of Hines Channel water. These results show that this sample was acutely toxic to *Ceriodaphnia* in a four-day test period with a dilution of 12.5 percent. The 25-percent sample of Hines Channel water was acutely toxic to *Ceriodaphnia*, where all test organisms were killed within 1 day. The addition of PBO to the Hines Channel sample neutralized most but not all of the toxicity found. These results indicate that the Hines Channel water obtained on August 25, 1998, had greater than 8 toxic units of *Ceriodaphnia* toxicity.

Table 3-29
Summary of *Ceriodaphnia* Toxicity for Water Samples Collected August 13, 1998[1,2]

Set up on 8/17/1998

Treatment	% Mortality for Each Day of the Test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Control				0[P]	The laboratory control met all US EPA criteria for test acceptability.	8.2
Control + PBO			0	0	No artifactual toxicity in laboratory control blank.	8.3
6.25% Hines Channel	100	100	100	100	Toxicity detected	8.3
6.25% Hines Channel + PBO	5	5	5	5	Decrease in mortality with the addition of PBO suggests that toxicity was due to a metabolically activated organophosphate pesticide.	8.3
3.13% Hines Channel	10	65	80	100	Toxicity detected	8.3
1.57% Hines Channel				0		8.3
1.57% Hines Channel + PBO		5	5	5		8.3
0.78% Hines Channel				0	No toxicity detected.	8.3
0.39% Hines Channel				0		8.3
100% Central Irvine Channel	100	100	100	100	Toxicity detected	8.5
50% Central Irvine Channel	100	100	100	100	Toxicity detected	8.4
50% Central Irvine Channel + PBO				0	Decrease in mortality with the addition of PBO suggests that toxicity was due to a metabolically activated organophosphate pesticide.	8.4
25% Central Irvine Channel	80	100	100	100	Toxicity detected	8.4

Table 3-29 continued

12.5% Central Irvine Channel				35	Toxicity detected	8.4
12.5% Central Irvine Channel + PBO				0	Decrease in mortality with the addition of PBO suggests that toxicity was due to a metabolically activated organophosphate pesticide.	8.3
6.25% Central Irvine Channel				20		8.4
3.13% Central Irvine Channel			5	5	No toxicity detected.	8.4

[P]The laboratory control met all US EPA criteria for test acceptability.
[1] Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-30
Results of Chemical Analysis of Water Samples
Collected August 13, 1998
(GC By APPL., Inc.)

Sample Location	Analyte[1]	Concentration (ng/L)
Hines Channel at Irvine Creek Dr.	Chlorpyrifos	66
	Diazinon	12,000
	Merphos	180
	Methyl trithion	1,500
	Prowl	1,000
	Benomyl	600
Central Irvine Channel	Chlorpyrifos	260
	Diazinon	620
	Dimethoate	82
	Pendimethalin	920
	Benomyl	600

[1]Analytes not listed were not detected using the US EPA 8141 with low-level detection.

Table 3-31
Summary of 7-Day *Ceriodaphnia* Toxicity Tests on Water Samples Collected August 25, 1998

Set up on 8/26/98

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH @ 24 hr
	x	se		
Control	15.6[P]	1.8	0[P]	8.5
Control + PBO	6.1	0.9	0	8.4
Control – 2000 µmhos/cm	17.5	0.7	0	8.4
San Diego Creek at Campus (diluted to 2000 µmhos/cm - 69% dilution)	23.3	2.7	0	8.6
San Diego Creek at Campus (diluted to 2000 µmhos/cm - 69% dilution) + PBO	23.1	2.0	0	8.6
Santa Ana Delhi Channel (diluted to 2000µmhos/cm - 75% dilution)	28.7	0.9	0	8.6
Santa Ana Delhi Channel (diluted to 2000 µmhos/cm - 75% dilution) + PBO	14.3	2.8	20	8.6
Hines Channel at Irvine Creek Dr.	*	*	100 (1)	8.2
Hines Channel at Irvine Creek Dr. + PBO	*	*	100 (1)	8.2

[P]The laboratory control met all US EPA criteria for test acceptability. 90% of the daphnids had a third brood.
[1]Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The reproduction endpoint was analyzed using Dunnett's test and the mortality endpoint was analyzed using Fisher's Exact Test.
*Due to significant mortality observed in these samples reproduction was not calculated.
(#) Number in parenthesis indicates days to 100% mortality.

Table 3-32
Summary of Toxicity Tests Conducted on Water Samples
Collected August 25, 1998

7-day *Pimephales* Toxicity Tests

Set up on 8/26/98

Treatment	Growth[1] (mg/individual)		Mortality[1] (%)		Final pH @ 24 hr
	X	se	x	se	
Control	0.417[P]	0.013	2.5[P]	3.0	8.1
San Diego Creek at Campus	0.473	0.025	3.9	4.0	8.4
Hines Channel at Irvine Creek Dr.	0.313	0.012	11.0	5.0	8.1
Santa Ana Delhi Channel	0.495	0.020	0.0	0.0	8.6

[P]The laboratory control met the criteria for test acceptability.

[1]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

96-hr *Selenastrum* Toxicity Tests

Set up on 8/26/98

Treatment	Cell Count [1] ($x10^4$)		% CV	Final pH @ 96 hr
	x	se		
Control	169.0[P]	2.9	17.1	7.6
San Diego Creek at Campus	73.4	2.5	6.9	8.6
Hines Channel at Irvine Creek Dr.	25.7	2.1	16.1	8.7
Santa Ana Delhi Channel	226.8	3.4	3.0	8.8

[P] The laboratory control met all US EPA criteria for test acceptability. The coefficient of variation was 17.1% in this treatment.

[1]Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

Table 3-33
Summary of *Ceriodaphnia* Toxicity for Water Samples Collected August 25, 1998[1,2,]

Set up on 8/29/98

Treatment	% Mortality for Each Day of the Test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Control				0[P]	The laboratory control met all criteria for test acceptability.	8.3
Control + PBO			0	0	No artifactual toxicity in laboratory control blank.	8.3
1.57% Hines Channel				0		8.3
3.13% Hines Channel				0	No toxicity detected	8.3
6.25% Hines Channel				0		8.2
6.25% Hines Channel + PBO			5	5		8.3
12.5% Hines Channel				50	Toxicity detected	8.3
25% Hines Channel	100	100	100	100		8.3
25% Hines Channel + PBO			10	15	Decrease in mortality with the addition of PBO suggests that toxicity was due to the presence of a metabolically activated organophosphate pesticide.	8.3

[P]The laboratory control met all US EPA criteria for test acceptability.
[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done

AQUA-Science, Davis, California, reported that the August 25, 1998, sample of Hines Channel water had 97 ng/L of chlorpyrifos and 2,500 ng/L of diazinon which translates to about five *Ceriodaphnia* acute toxicity units. APPL analysis of the same sample reported chlorpyrifos at 110 ng/L and diazinon at 2,500 ng/L. The chlorpyrifos present in this sample could cause about 1 toxic unit of *Ceriodaphnia* toxicity. Therefore, the potential toxicity of this sample to *Ceriodaphnia* was in the order of 7 toxic units. It is evident that, as with other samples taken during this study period, there is appreciable toxicity in the San Diego Creek watershed. Substantial amounts of the *Ceriodaphnia* toxicity found in the San Diego Creek watershed is due to unidentified causes.

As shown in Table 3-34, APPL found detectable concentrations of dimethoate at 7.1 µg/L, malathion at 0.2 µg/L, merphos at 0.14 µg/L, prowl (pendimethalin) at 1.2 µg/L, stirophos at 0.14 µg/L, and benomyl at 0.5 µg/L in the August 25 sample taken from the Hines Channel. Twenty-six other pesticides that are normally measured in the US EPA 8141 Special Low-Level list were present at less than detection limits, which, in general, were between 0.1 and 0.5 µg/L.

Also, 23 carbamate pesticides that are measured by US EPA method 632 were present at less than detection limits for this method. APPL found metalaxyl at 30 µg/L. Further, the August 25 sample contained ridomil and oryzalin in readily detectable amounts. These amounts, however, were not quantified. As discussed in a subsequent section of this report, except for possibly benomyl, diazinon and chlorpyrifos, none of the other pesticides that were found in the August 25 sample would be expected to be toxic to *Ceriodaphnia*.

Table 3-34
Analysis of Hines Channel Sample

Project: Upper Newport Bay Toxicity
Sample ID: 082698 GFL 3
Sample Collection Date: 5/25/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 28485

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)		PQL (µg/L)
Azinphosmethyl	Not detected		1.0
Bolstar	Not detected		0.10
Chlorpyrifos	0.11	Y	0.05
Coumaphos	Not detected		0.10
Def	Not detected		0.10
Demeton-6	Not detected		0.20
Diazinon	2.5	Y	0.25
Dichlorvos	Not detected		0.20
Dimethoate	7.1	Y	1.0
Diphenamid	Not detected		0.10
Disulfoton	Not detected		0.10
Ethion	Not detected		0.10
Ethoprop	Not detected		0.10
Fensulfothion	Not detected		0.20
Fenthion	Not detected		0.10
Malathion	0.20	Y	0.10
Merphos	0.14		0.10
Methidathion	Not detected		0.10
Methyl Trithion	Not detected		0.20
Mevinphos	Not detected		0.70
Naled	Not detected		0.50
Parathion, ethyl	Not detected		0.10
Parathion, methyl	Not detected		0.10
Phorate	Not detected		0.10
Phosalone	Not detected		0.10
Phosmet	Not detected		1.0
Prometon	Not detected		0.10
Prowl	1.2	Y	0.50
Ronnel	Not detected		0.10
Simazine	Not detected		0.50
Stirophos	0.14		0.10
Trichloronate	Not detected		0.10
Trifluralin	Not detected		0.10
Surrogate:Tributylphosphate	118		60-150%
Surrogate:Triphenylphosphate	124		76-140%

Y=Percent D>25%

Table 3-34 (continued)

US EPA Method 632

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	0.5	0.4
Bromacil	Not detected	0.4
Carbaryl	Not detected	0.07
Carbofuran	Not detected	0.07
Chloropropham	Not detected	3.5
Chloroxuron	Not detected	0.4
Diuron	Not detected	0.4
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	0.4
Methiocarb	Not detected	0.4
Methomyl	Not detected	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	0.4
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate recovery	400#	40-140%

Recovery is outside QC limits

Table 3-32 also presents the results of the 96-hr *Selenastrum* toxicity test, which showed that the Santa Ana Delhi Channel water stimulated the growth of *Selenastrum*. San Diego Creek at Campus Drive and Hines Channel at Irvine Boulevard showed statistically significant toxicity to *Selenastrum*, with the highest toxicity found in the Hines Channel sample. It appears that chemicals toxic to *Selenastrum* are being discharged to Hines Channel which are somewhat diluted by the time they reach San Diego Creek at Campus Drive. A number of the pesticides found by APPL are normally used as herbicides. The concentrations of several of these herbicides found by APPL such as pendimethalin would be expected to be toxic to some forms of algae.

NOVEMBER 8, 1998, STORMWATER RUNOFF EVENT

A total of 0.64 in. of rain was recorded at the Campus Drive rain gage (San Diego Creek watershed) for the November 8, 1998, storm. The time of the rainfall was about 5 hr, and the time of net rain was about 3 hr.

A total of 0.83 in. of rain was recorded at Peters Canyon Channel at Barranca Parkway rain gage for this storm. The time of rainfall was 5 hr and the time of net rain (for Peters Canyon Channel upstream of San Diego Creek) was 2 hr. The Peters Canyon Channel watershed is largely un-urbanized in the upstream portions. This would account for the higher rainfall loss and corresponding shorter time of net rain in this watershed as compared to either San Diego Creek at Campus Drive or the Santa Ana Delhi Channel at Irvine Avenue.

A total of 0.8 in. of rain was recorded at the Santa Ana Delhi rain gage (Santa Ana Delhi Channel watershed). The time of the rainfall was about 5 hr, and the time of net rain is estimated to be about 3 hr.

Campus Drive – San Diego Creek

The peak discharge at San Diego Creek at Campus Drive for the November 8 storm was recorded as about 2,728 cfs. The recurrence interval for this event is estimated as about 1 yr.

The VDR for this storm was computed as 0.377 in. The total loss is about 0.263 in., computed by subtracting the VDR from the rainfall (0.64 in.). The average loss rate for this location is about 0.0526 in./hr, and the estimated lag time is about 4 hr.

This storm is statistically below average annual, and produced modest runoff at San Diego Creek at Campus Drive. The relatively low VDR as a percentage of total rain indicates a lower AMC and potentially less runoff from pervious areas as compared to the average annual storm events.

The sample time on the hydrograph was 1100 hr on the receding limb of the hydrograph.

Barranca Parkway – Peters Canyon Channel

The flow meter malfunctioned at this location. Therefore, hydrologic information is not available at this time.

It is apparent that more rainfall fell in the Peters Canyon Channel watershed as compared to the San Diego Creek watershed as recorded by the Barranca Parkway gage.

Santa Ana Delhi Channel

The peak discharge recorded at Mesa Drive and the Santa Ana Delhi Channel was about 1,400 cfs. The estimated storm recurrence interval is about 1 yr. Hydrologic information for various storm recurrence intervals was not available. The VDR for this storm was computed as 0.12 in. The total loss for the storm was computed as 0.68 in. The average loss rate is estimated as 0.136 in./hr. The computed lag time for this storm is estimated as 2 hr.

Given the highly urbanized nature of this watershed, more rainfall was converted to runoff as compared to the Peters Canyon Channel watershed. The Peters Canyon Channel watershed is greater than twice the size of the Santa Ana Delhi watershed (44.7 mi^2 vs. 17 mi^2), yet the Santa Ana Delhi watershed produced a greater volume of runoff (by about 4 times). The lag time is relatively short given that the majority of the channel system is improved and lined with concrete. The sample was taken on the recession portion of the hydrograph (Figure A8-5) just above base flow.

Table 3-35 presents the results of the 7-day *Ceriodaphnia* toxicity tests conducted on the samples taken from the San Diego Creek watershed on November 8, 1998. Examination of the data presented in this table shows that San Diego Creek at Campus Drive and Harvard Avenue, with and without PBO at 100 µg/L, killed all *Ceriodaphnia* within 1 day. Similar results were obtained for the Hines Channel with and without PBO. The Santa Ana Delhi Channel water killed 100 percent of the *Ceriodaphnia* within 4 days. This sample with 100 µg/L of PBO only killed 20 percent of the *Ceriodaphnia* in seven days. These results indicate that the toxicity present in Santa Ana Delhi Channel was likely due in part to organophosphate pesticides, where PBO at 100 µg/L significantly reduced the toxicity of the sample.

Table 3-36 presents the results of the testing of stormwater runoff collected on November 8, 1998, using fathead minnow larvae. None of the samples tested, which included San Diego Creek at Campus Drive and Harvard Avenue, Peters Canyon at Barranca Parkway, Hines Channel and the Santa Ana Delhi Channel, was toxic to fathead minnow larvae over the 7-day test.

Selenastrum toxicity data obtained for the samples collected on November 8, 1998, are presented in Table 3-36. None of the samples collected was toxic to *Selenastrum*. Several, such as the San Diego Creek at Campus Drive and Harvard Avenue, Peters Canyon Channel at Barranca Parkway, and Hines Channel, significantly stimulated the growth of *Selenastrum*.

Table 3-35
Summary of Results of 7-day *Ceriodaphnia* Toxicity Tests
on Samples from San Diego Creek Watershed
Collected November 8, 1998

Set up on 11/11/1998

Treatment	Reproduction[1] (neonates/adult)		Mortality[1,2] (%)	Final pH @ 24 hr
	X	Se		
Laboratory Control	21.3[P]	0.9	0[P]	8.3
Laboratory Control + PBO	12.1	1.5	0	8.3
San Diego Creek at Campus	*	*	100 (1)	7.9
Peters Canyon Channel at Barranca	*	*	100 (1)	7.8
Peters Canyon Channel at Barranca + PBO	*	*	100 (1)	7.8
Harvard Ave	*	*	100 (1)	7.9
Harvard Ave + PBO	*	*	100 (1)	7.4
Hines Channel	*	*	100 (1)	7.2
Hines Channel + PBO	*	*	100 (1)	8.0
Santa Ana Delhi Channel	*	*	100 (4)	8.0
Santa Ana Delhi Channel + PBO	46.2	2.6	20	8.0

[P]The laboratory control met the US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
[1]Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproduction endpoint was analyzed using Dunnett's Test.
[2]Numbers in parentheses represent days to 100% mortality.
*Due to significant mortality observed in these samples, reproduction was not calculated.

Table 3-36
Summary of Toxicity Tests Conducted
on Samples from San Diego Creek Watershed
Collected November 8, 1998

7-day *Pimephales* Toxicity Tests

Set up on 11/11/1998

Treatment	Growth[1] (mg)		Mortality[1] (%)		Final pH @ 24 hr
	x	Se	mean	standard error	
Laboratory Control	0.413[P]	0.009	2.5 [P]	3.0	8.1
San Diego Creek at Campus	0.386	0.003	5.0	3.0	8.0
Peters Canyon Channel at Barranca	0.381	0.011	4.5	5.0	7.8
Harvard Ave	0.358	0.016	0.0	0.0	7.9
Hines Channel	0.436	0.013	0.0	0.0	7.2
Santa Ana Delhi Channel	0.385	0.005	2.5	3.0	7.8

[P]The laboratory control met the US EPA criteria for test acceptability.

96-hr *Selenastrum* Toxicity Tests

Treatment	Cell Count[1] (x 10^4)		% CV	Final pH @ 96 hr
	X	se		
Laboratory Control	150.9[P]	6.5	8.6	8.7
San Diego Creek at Campus	351.7	6.9	3.6	10.4
Peters Canyon Channel at Barranca	252.6	10.1	7.9	10.5
Harvard Ave	323.4	5.6	3.5	10.4
Hines Channel	314.9	18.9	12.0	10.4
Santa Ana Delhi Channel	145.6	3.2	4.4	8.0

[P]The laboratory control met the US EPA criteria for test acceptability. The coefficient of variation was 8.6% in this treatment.

[1]Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

Table 3-37 presents the dilution series testing with *Ceriodaphnia* to determine the amount of total toxicity present in the sample and the ability of PBO to reduce this toxicity. The San Diego Creek sample taken at Campus Drive, even when diluted to 6.25 percent, killed 100 percent of the *Ceriodaphnia* within 2 days. When diluted to 3.13 percent, the toxicity was eliminated over a 4-day period. These results indicate that the sample of San Diego Creek water taken at Campus Drive on November 8, 1998, contained between 16 and 32 TUa. Further, 100 µg/L of PBO did not significantly reduce the toxicity of the samples, even to the highly diluted samples. These results indicate that there were constituents other than organophosphate pesticides in the sample responsible for the toxicity.

A similar type of testing arrangement was conducted on Peters Canyon Channel; the data are presented in Table 3-37. This sample was slightly less toxic to *Ceriodaphnia* than the San Diego Creek sample, in that the 6.25-percent Peters Canyon Channel sample required 4 days to kill 100 percent of the *Ceriodaphnia*. The total toxic units in this sample were between 16 to 32 TUa. A similar set of results (Table 3-37) was obtained for Harvard Avenue, which also contained from 16 to 32 TUa.

The Hines Channel sample also showed similar results with the same level of toxicity, i.e., 16 to 32 TUa. The 100 µg/L PBO added to the 25-percent Hines Channel sample did not significantly reduce the toxicity of the sample.

Another set of the November 8 samples was set up for toxicity testing on November 18, 1998, ten days after collection. These data are presented in Table 3-38. It is of interest to find that the toxicity of a 12.5 percent San Diego Creek sample collected on November 8 but tested on November 18 still killed 100 percent of the *Ceriodaphnia* in 1 day. The addition of 100 µg/L of PBO significantly reduced this toxicity. Similar results were obtained for Peters Canyon Channel at Barranca Parkway, as well as San Diego Creek at Harvard Avenue and the Hines Channel. These results indicate that the toxicity in these samples was likely due to a combination of an organophosphate pesticide and non-OP pesticide-caused toxicity. Passing the Hines Channel sample through a C8 solid phase extraction column did not reduce the toxicity, while the San Diego Creek sample taken at Campus Drive C8 solid phase extracted water had lower toxicity, indicating that part of the toxicity present at San Diego Creek at Campus Drive was removed on a C8 solid phase column. The alleviation of some of the toxicity with the C8 column extraction suggests that toxicity is due in part to a non-polar organic chemical.

Testing was done on the Hines Channel sample collected on November 8, 1998, using the C8 solid phase column, PBO, and the addition of EDTA. As shown in the data on Table 3-39, none of these treatments decreased the toxicity of the Hines Channel water to *Ceriodaphnia* in a 4-day test. The failure of EDTA to affect the toxicity indicates that the toxicity was not likely due to a heavy metal.

Table 3-37
Summary of *Ceriodaphnia* 96-hr PBO TIE Conducted on Water Samples from San Diego Creek Watershed Collected November 8, 1998 [1,2]

Set up on 11/13/98

Treatment	% Mortality for each Day of the Test [3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.3
Laboratory Control + PBO				5	No artifactual toxicity present in control blank.	8.3
25% San Diego Creek at Campus	100	100	100	100	Toxicity detected.	8.2
25% San Diego Creek at Campus + PBO	100	100	100	100	No alleviation of toxicity with the addition of PBO suggests that either the toxicant is not a metabolically activated OP pesticide, or there is too much metabolically activated OP pesticide present in the sample to be alleviated by PBO.	8.1
12.5% San Diego Creek at Campus	100	100	100	100	Toxicity detected down to the 6.25% dilution.	8.2
6.25% San Diego Creek at Campus	10	100	100	100		8.2
3.13% San Diego Creek at Campus				0	No toxicity detected.	8.3
1.57% San Diego Creek at Campus				0		8.3
25% Peters Canyon Channel at Barranca	100	100	100	100	Toxicity detected.	8.2
25% Peters Canyon Channel at Barranca + PBO	100	100	100	100	No alleviation of toxicity with the addition of PBO suggests that either the toxicant is not a metabolically activated OP pesticide, or there is too much metabolically activated OP pesticide present in the sample to be alleviated by PBO.	8.2
12.5% Peters Canyon Channel at Barranca	55	100	100	100	Toxicity detected down to the 6.25% dilution.	8.2
6.25% Peters Canyon Channel at Barranca	5	40	90	100		8.2
3.13% Peters Canyon Channel at Barranca			5	5	No toxicity detected.	8.5

Table 3-37 continued

25% Harvard Ave	100	100	100	100	Toxicity detected.	8.4
25% Harvard Ave + PBO	100			100	No alleviation of toxicity with the addition of PBO suggests that either the toxicant is not a metabolically activated OP pesticide, or there is too much metabolically activated OP pesticide present in the sample to be alleviated by PBO.	8.4
12.5% Harvard Ave	100	100	100	100	Toxicity detected down to the 6.25% dilution.	8.5
6.25% Harvard Ave	10	100	100	100		8.5
3.13% Harvard Ave				0	No toxicity detected.	8.6
25% Hines Channel	100	100	100	100	Toxicity detected.	8.2
25% Hines Channel + PBO	95	100	100	100	No alleviation of toxicity with the addition of PBO suggests that either the toxicant is not a metabolically activated OP pesticide, or there is too much metabolically activated OP pesticide present in the sample to be alleviated by PBO.	8.3
12.5% Hines Channel	100	100	100	100	Toxicity detected down to the 6.25% dilution.	8.5
6.25% Hines Channel		100	100	100		8.5
3.13% Hines Channel		5	5	5	No toxicity detected.	8.6

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-38
Summary of *Ceriodaphnia* 96-hr PBO TIE Conducted on Water Samples from San Diego Creek Watershed Collected November 8, 1998 [1,2]

Set up on 11/18/98

Treatment	% Mortality for each Day of the Test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control				0	Control met all US EPA criteria for test acceptability.	8.4
Laboratory Control + PBO				0	No artifactual toxicity present in control blank.	8.4
12.5% Campus	100	100	100	100	Toxicity detected.	8.3
12.5% Campus + PBO			20	20	Alleviation of toxicity with the addition of PBO suggests that the toxicity may at least in part be due to a metabolically activated OP pesticide.	8.3
12.5% Peters Canyon Channel at Barranca	100	100	100	100	Toxicity detected.	8.3
12.5% Peters Canyon Channel at Barranca + PBO		5	5	5	Alleviation of toxicity with the addition of PBO suggests that the toxicity may at least in part be due to a metabolically activated OP pesticide.	8.2
12.5% Harvard Ave	65	100	100	100	Toxicity detected.	8.4
12.5% Harvard Ave + PBO				0	Alleviation of toxicity with the addition of PBO suggests that the toxicity may at least in part be due to a metabolically activated OP pesticide.	8.3
12.5% Hines Channel	100	100	100	100	Toxicity detected.	8.3
12.5% Hines Channel + PBO		10	10	10	Alleviation of toxicity with the addition of PBO suggests that the toxicity may at least in part be due to a metabolically activated OP pesticide.	8.1
Hines Channel C8 Solid Phase Extracted Water	100	100	100	100	Toxicity detected.	7.8
Campus C8 Solid Phase Extracted Water		60	60	60	Toxicity detected.	8.2

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-39
Summary of *Ceriodaphnia* 96-hr PBO TIE Conducted on Water Samples from Hines Channel
Collected November 8, 1998 [1,2]

Set up on 11/22/98

Treatment	% Mortality for Each Day of the Test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control			5	10	Control met the US EPA criteria for test acceptability.	8.3
Hardness-Adjusted Laboratory Control (492 mg/L as $CaCO_3$)				0	No artifactual toxicity in control blanks.	8.3
Hardness-Adjusted Laboratory Control C8 Blank				0		8.3
Hardness-Adjusted Laboratory Control C8 Blank + PBO				60	Toxicity detected in control blank.	8.3
Hardness-Adjusted Laboratory Control C8 Blank + 250 mg/L EDTA			5	5	No artifactual toxicity in control blanks.	8.1
Hardness-Adjusted Laboratory Control C8 Blank + 500 mg/L EDTA				0		7.7
Hines Channel	100	100	100	100	Toxicity detected.	8.2
Hines Channel C8 Solid Phase Extracted Water	60	100	100	100	No alleviation of toxicity with C8 extraction suggests that the toxicity was not due to a non-polar organic chemical.	8.2
Hines Channel C8 Solid Phase Extracted Water + PBO	45	100	100	100	Due to high mortality in the control blank, these results cannot be interpreted.	8.0
Hines Channel C8 Solid Phase Extracted Water + 250 mg/L EDTA	35	100	100	100	No alleviation of toxicity with the addition of EDTA suggests that the toxicity was not due to a metal.	8.0
Hines Channel C8 Solid Phase Extracted Water + 500 mg/L EDTA	30	100	100	100		7.5

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-40 presents a summary of the results of the dual-column GC analysis conducted by APPL Laboratory on the November 8, 1998, stormwater runoff samples collected in the Upper Newport Bay watershed. The complete data sets are presented in Tables 3-41 through 3-51. Samples were analyzed from San Diego Creek at Campus Drive and Harvard Avenue, Peters Canyon Channel at Barranca Parkway, Hines Channel in the San Diego Creek watershed, and at the Santa Ana Delhi Channel. The Hines Channel samples were found to contain 4,100 ng/L of diazinon. Peters Canyon Channel at Barranca Parkway, which is downstream of the Hines Channel, contained 670 ng/L of diazinon, and San Diego Creek at Campus Drive contained less than 50 ng/L of diazinon. The San Diego Creek at Campus Drive result seems anomalous, compared to diazinon concentrations found at this location in the past, and the fact that there were high concentrations of diazinon found in upstream San Diego Creek samples on this sampling date.

The Hines Channel, Peters Canyon Channel and San Diego Creek at Campus Drive samples contained between 140 and 500 ng/L of chlorpyrifos. Carbaryl was found in the Hines Channel sample at 5,100 ng/L, Peters Canyon Channel at Barranca Parkway sample at 3,400 ng/L, and San Diego Creek at Campus Drive at 3,100 ng/L. Methomyl was found in the Hines Channel sample, just downstream from the two nurseries, at 12,000 ng/L. The Peters Canyon Channel at Barranca Parkway sample had 14,000 ng/L, and San Diego Creek at Campus Drive had 6,200 ng/L. Fensulfothion was found in the Peters Canyon Channel at Barranca Parkway sample at 320 ng/L and less than 200 ng/L at the Hines Channel and San Diego Creek at Campus Drive samples. One hundred and twenty ng/L of malathion was found in the Hines Channel sample, with Peters Canyon Channel at Barranca Parkway and San Diego Creek at Campus Drive containing less than 100 ng/L. Methiocarb was also present in the Hines Channel sample at 2,500 ng/L. However, at Peters Canyon Channel at Barranca Parkway and San Diego Creek at Campus Drive it was present at less than the detection limit of 400 ng/L.

Based on these results, it appears that the pesticide primarily responsible for the toxicity in the November 8 samples from the San Diego Creek watershed, which receives drainage/runoff from the nurseries located upstream from Hines Channel, is methomyl, with from 6,000 to 12,000 ng/L present. The *Ceriodaphnia* estimated 96-hr LC_{50} for methomyl is about 1,400 ng/L. Therefore, the San Diego Creek sample collected on November 8, 1998, had about 4.5 TUa due to methomyl. The Hines Channel sample had 8.5 TUa due to methomyl. While carbaryl was present in large amounts, ranging from 3,100 to 5,100 ng/L, the 96-hr LC_{50} for carbaryl is about 5,560 ng/L. Therefore, carbaryl was not likely responsible for the *Ceriodaphnia* toxicity found in these samples.

The Santa Ana Delhi Channel water contained 2,200 ng/L of diuron, and typically less than detection limits for other measured pesticides, except for 130 ng/L of carbaryl and 90 ng/L of malathion.

Based on the information available, the Hines Channel sample, which was found to contain 16 to 32 *Ceriodaphnia* TUa based on toxicity testing, it is found that 20 of these units could be accounted for by methomyl, diazinon, and chlorpyrifos. The San Diego Creek sample, which also contained from 16 to 32 *Ceriodaphnia* TUa, was found to contain an estimated 10 TUa due to chlorpyrifos and methomyl. However, the analysis for diazinon, which was reported as less than the detection limit, 50 ng/L, was likely in error.

Table 3-40
Concentrations of Pesticides Runoff Samples from
Upper Newport Bay Watershed
Collected November 8, 1998
(concentrations in ng/L)

Pesticide	San Diego Creek @ Campus Dr	Peters Canyon Channel @ Barranca	Hines Channel	Santa Ana Delhi Channel	San Diego Creek @ Harvard
Benomyl	500	<400	2,000	<400	700
Carbaryl	3,100	3,400	5,100	130	5,100
Chlorpyrifos	500	430	140	<50	400
Diazinon	**<50**	670	4,100	<50	<50
Dimethoate	<100	290	110	<100	<100
Diuron	<800	<800	<2,000	2,200	<5,000
Fensulfothion	<200	320	<200	<200	<200
Malathion	<100	<100	120	90	<100
Methiocarb	<400	<400	2,500	<400	<400
Methomyl	6,200	14,000	12,000	<70	<70
Pendimethalin	60	180	530	<100	<100

Analyses conducted by APPL Laboratories, Inc., Fresno, CA

The November 8, 1998, sample was the first major runoff event for the fall of 1998. It contained elevated concentrations of pesticides, compared to those found at other times and other years' first fall runoff. In the previous year the TUa for San Diego Creek at Campus Drive was about 10. The TUa for San Diego Creek at Campus Drive on November 8, 1998, was between 16 and 32 units. It is evident that there may have been substantial unknown-caused toxicity in the November 8, 1998, samples that were taken from the Hines Channel, Peters Canyon Channel at Barranca Parkway and San Diego Creek at Campus Drive.

Table 3-52 presents the results of the field and laboratory measurements of electrical conductivity, pH, lab DO, hardness, and alkalinity for these samples. There was nothing unusual about this data set.

Part of the November 8, 1998, stormwater runoff sample collected from San Diego Creek at Campus Drive was sent to Pacific Eco-Risk Laboratory for toxicity testing with *Americamysis bahia*. Table 3-53 presents the results of this testing. As shown in Table 3-53, there was 100 percent kill of *Americamysis bahia* within one day. The same sample was set up again in a dilution series. The results are shown in Table 3-53. The results show 100 percent mortality within seven days for all dilutions tested. This means that the sample contained in excess of 16 TUa for *Americamysis bahia*. It is of interest to find that the November 8, 1998, stormwater runoff sample collected at San Diego Creek at Campus Drive was highly toxic to both *Ceriodaphnia* and *Americamysis bahia*.

Table 3-41
Analysis of San Diego Creek at Campus Drive
(Initial Analysis)

Project: UCD ATL
Sample ID: 111098 GLF-C
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8141 Special Low-Level List

Analyte Result (µg/L)		PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	Not detected	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	Not detected	0.05
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	Not detected	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	Not detected	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	156 #	60-150 %
Surrogate: Tnphenylphosphate	126	76-140 %

= Recovery is outside QC limits.

Table 3-42
Analysis of San Diego Creek at Campus Drive
(Repeat Analysis)

Project: UCD ATL
Sample ID: 111098 GLF-C
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8141 SPECIAL LOW-LEVEL LIST

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.50	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	Not detected	0.05
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	Not detected	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	0.06 J	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	156 #	60-150%
Surrogate: Triphenylphosphate	126	76-140%

J = Estimated value, below quantitation limit.

= Recovery is outside QC limits.

Table 3-43
Analysis of Peters Canyon Channel at Barranca Parkway

Project: UCO ATL
Sample ID: 111098 GLF-B
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.43 Y	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	0.67	0.25
Dichlorvos	Not detected	0.20
Dimethoate	0.29	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	0.32 Y	0.20
Fenthion	Not detected	0.10
Malathion	Not detected	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	0.18 Y	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	141	60-150 %
Surrogate: Triphenylphosphate	136	76-140 %

Y = Percent D > 25%.

Table 3-44
Analysis of Santa Ana Delhi Channel

Project: UCD ATL
Sample ID: 111098 GLF-SAD
Sample Collection Date: 11/08/98
Sample Extraction Date:

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
11/17/98ARF: 29000

US EPA 8141 Special Low-Level List

Analyte	Result (μg/L)	PQL (μg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	Not detected	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	Not detected	0.05
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	0.09 J Y	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	Not detected	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	311 #	60-150 %
Surrogate: Triphenylphosphate	102	76-140 %

J = Estimated value, below quantitation limit.
# = Recovery is outside QC limits.
Y = Percent D > 25%.

Table 3-45
Analysis of Hines Channel

Project: UCD ATL
Sample ID: 111098 GLF-HN
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.14	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	4.1	1.25
Dichlorvos	Not detected	0.20
Dimethoate	0.11	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	0.12 Y	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	0.53	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	78.9	60-150 %
Surrogate: Triphenylphosphate	83.3	76-140 %

Y = Percent D > 25%.

Table 3-46
Analysis of San Diego Creek at Harvard Avenue

Project: UCD ATL
Sample ID: 111098 GLF-HD
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.40	0.25
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	Not detected	0.05
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	Not detected	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	Not detected	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate:Tributylphosphate	198 #	60-150 %
Surrogate:Tnphenylphosphate	140	76-140 %

= Recovery is outside QC limits.

Table 3-47
Analysis of Peters Canyon Channel at Barranca Parkway

Project: UCD ATL
Sample ID: 111098 GLF-B
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	Not detected	0.4
Bromacil	Not detected	0.4
Carbaryl	3.4	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	0.8
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	5
Methiocarb	Not detected	0.4
Methomyl	14	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	5
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	125	40-140 %

Table 3-48
Analysis of San Diego Creek at Campus Drive

Project: UCD ATL
Sample ID: 111098 GLF-C
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	0.5	0.4
Bromacil	Not detected	0.4
Carbaryl	3.1	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	0.8
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	5
Methiocarb	Not detected	0.4
Methomyl	6.2	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	5
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	87.5	40-140 %

Table 3-49
Analysis of Santa Ana Delhi Channel

Project: UCD ATL **APPL Inc.**
Sample ID: 111098 GLF-SAD **4203 West Swift Avenue**
Sample Collection Date: 11/08/98
Fresno, CA 93722
Sample Extraction Date: 11/17/98 **ARF: 29000**

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	Not detected	0.4
Bromacil	Not detected	0.4
Carbaryl	0.13	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	2.2	0.4
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	5
Methiocarb	Not detected	0.4
Methomyl	Not detected	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	5
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	89.1	40-140 %

Table 3-50
Analysis of Hines Channel

Project: UCD ATL
Sample ID: 111098 GLF-HN
Sample Collection Date: 11/08/98
Sample Extraction Date: 11/17/98

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8321A

Analyte	Result (μg/L)	PQL (μg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	2.0	0.4
Bromacil	Not detected	0.4
Carbaryl	Not detected	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	2
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	0.4
Methiocarb	2.5	0.4
Methomyl	12	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	5
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	520 #	40-140 %

= Recovery is outside QC limits.

Table 3-51
Analysis of San Diego Creek at Harvard Avenue

Project: UCD ATL	**APPL Inc.**
Sample ID: 111098 GLF-HD	**4203 West Swift Avenue**
Sample Collection Date: 11/08/98	**Fresno, CA 93722**
Sample Extraction Date: 11/17/98	**ARF: 29000**

US EPA 8321A

Analyte	Result (μg/L)	PQL(μg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	0.7	0.4
Bromacil	Not detected	0.4
Carbaryl	5.1	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	20
Diuron	Not detected	5
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	10
Methiocarb	Not detected	0.4
Methomyl	Not detected	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	5
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	71.7	40-140 %

Table 3-52
Summary of Chemical Characteristics of Water Samples from San Diego Creek Watershed - Collected November 8, 1998

Treatment	Field Temp (°C)	pH		EC µmhos/cm		Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
		Field	Lab	Field	Lab			
Laboratory Control (EPAMH)			8.2		284	8.4	84	60
Laboratory Control (SSEPAMH)			8.1		220	8.7	88	70
Laboratory Control (Glass Distilled)			8.4		90	8.9		
San Diego Creek at Campus	17.5	7.3	8.0	519	505	8.0	168	74
Peters Canyon Channel at Barranca	17.8	7.5	7.9	600	670	8.2	212	56
Harvard Ave	17.1	8.0	8.0	501	497	8.6	164	68
Hines Channel	16.8	7.2	7.2	1127	1144	8.6	516	48
Santa Ana Delhi Channel	17.5	6.9	7.8	339	318	8.4	104	42

Table 3-53
Toxicity Test Results for San Diego Creek, Campus Drive Water Samples Collected November 8, 1998 for *Americamysis bahia* Survival #1

Stormwater Treatment	Mortality % (Days)
Control	0
100%	100(1)
San Diego Creek – 50%	100*

* Significantly less than the control treatment at $p<0.05$.

***Americamysis bahia* Survival #2 - Retest**

Stormwater Treatment	Mortality % (Days)
Control	0
100%	100(1)
50%	100(1)
25%	100(1)
12.5%	100(2)
6.25%	100(4)

JANUARY 21, 1999, "DRY WEATHER"

On January 21, 1999, samples were taken at San Diego Creek at Campus Drive, Hines Channel and Santa Ana Delhi Channel to represent "dry weather" flow conditions during mid-winter.

Samples of this type had not been taken previously. While the sample was intended to be a dry-weather sample, there was a slight mist preceding and occurring at the time of the sampling. This mist, while not resulting in measurable precipitation at the rain gage locations, likely caused runoff from paved areas to the Creek. Evidence for this is discussed below in the review of the specific conductivity data, which shows that the San Diego Creek water was diluted considerably from its normal dry weather total salt content.

Table 3-54 presents the results of the 7-day *Ceriodaphnia* toxicity tests for the January 21, 1999, samples taken at San Diego Creek at Campus Drive, Hines Channel and Santa Ana Delhi Channel. The San Diego Creek at Campus Drive and Hines Channel samples caused 100-percent mortality of *Ceriodaphnia* within 1 day. The Santa Ana Delhi Channel caused 90-percent mortality over the 7-day test period. Table 3-54 presents the results of the toxicity testing using fathead minnow larvae for the January 21, 1999, "dry weather" sample. The results from this sampling show that San Diego Creek at Campus Drive, Hines Channel and Santa Ana Delhi Channel were not toxic to fathead minnow larvae.

Table 3-54 presents the results of the 96-hr *Selenastrum* toxicity test for the January 21, 1999, sample. The San Diego Creek samples at Campus Drive and Santa Ana Delhi Channel both showed a slight stimulation of algal numbers during the test period. The Hines Channel, just downstream from the two nurseries, showed a statistically significant depression in algal growth, suggesting that the nurseries, or other upstream sources, were apparently discharging an herbicide(s) that was toxic to *Selenastrum*.

Since toxicity was found in the dry weather samples at San Diego Creek and Hines Channel in the January 21, 1999, sample, a 96-hr dilution series toxicity test of San Diego Creek and Hines Channel waters collected on January 21, 1999, was conducted. These results are presented in Table 3-55. The San Diego Creek sample taken at Campus Drive, with 100 percent (no dilution) and 50 percent (dilution) was highly toxic to *Ceriodaphnia*, with 100-percent kill occurring in 1 or 2 days, respectively. A 25-percent dilution of the San Diego Creek sample taken at Campus Drive on January 21, 1999, showed essentially no toxicity in 4 days. This indicates that the sample contained a total of 2 to 4 TUa for *Ceriodaphnia*. The 12.5-percent dilution San Diego Creek sample at Campus Drive showed a slight toxicity, possibly indicating the presence of pyrethroids, although this value is not statistically significant.

The 6.25-percent dilution of the Hines Channel sample collected on January 21, 1999, killed all *Ceriodaphnia* within 1 day. Sixty-three percent of the *Ceriodaphnia* were killed in 4 days in the 3.13-percent dilution Hines Channel sample. These results indicate that the Hines Channel water sampled on January 21, 1999, had between 32 and 64 TUa for *Ceriodaphnia*. This toxicity is similar to the dry weather toxicity that was found in the August 1998 sampling of Hines Channel just downstream of the nurseries.

The January 21, 1999, sample was set up again on February 6, 1999, after being stored in the dark just above freezing, to examine *Ceriodaphnia* toxicity in another dilution series to see how well the toxicity persisted under these conditions. These data are presented in Table 3-55. Examination of these data shows that the toxicity of the San Diego Creek sample taken on January 21, 1999, at Campus Drive, that had stood in the dark 15 days, still killed 100 percent of the *Ceriodaphnia* within one day. The addition of PBO to the sample did reduce the toxicity so that a 3-day period was needed to kill 100 percent of the *Ceriodaphnia*. It appears that there may be a fraction of the toxic constituents that are slowly degraded. However, appreciable toxicity persists for at least 15 days under the conditions of storage used (4°C).

Table 3-55 shows the results of a similar study of the impact of storage on the January 21, 1999, sample obtained from the Hines Channel showing that even after standing for 16 days, the 12.5 percent Hines Channel sample killed 100 percent of the *Ceriodaphnia* within one day. The addition of PBO did reduce the rate of kill for 100 percent of the test organisms to 2 days. Again, as with the San Diego Creek samples taken on January 21, 1999, the Hines Channel toxicity was highly persistent under cold, dark conditions.

Table 3-56 presents the results of the chemical analyses of the San Diego Creek at Campus Drive, Hines Channel, and Santa Ana Delhi samples that were obtained on January 21, 1999. The electrical conductivity of these samples shows that they are diluted somewhat from normal dry-weather flow samples of San Diego Creek. Dry-weather flow in San Diego Creek typically has an electrical conductivity of between 2,000 and 2,600 µmhos/cm. These results indicate that there was some runoff into San Diego Creek at the time of the January 21, 1999, sampling and, therefore, this sampling event cannot be characterized as a dry-weather flow sample, but one that more represents a sample that is taken in the middle of winter, when there is a small amount of runoff to San Diego Creek, likely primarily from paved areas.

Table 3-56 presents the results of the pesticide chemical analyses of the San Diego Creek sample taken at Campus Drive and Hines Channel. The complete APPL laboratory data analyses for these samples are presented in Tables 3-57, 3-58, 3-59, and 3-60. The Hines Channel sample was found to contain 670 ng/L of chlorpyrifos and 1,400 ng/L of diazinon. It also contained 290 ng/L of methomyl, 11,000 ng/L of carbaryl, and 1,600 ng/L of benomyl. While the San Diego Creek samples taken at Campus Drive contained 70 ng/L of chlorpyrifos, 570 ng/L of diazinon and 370 ng/L of carbaryl, there were non-detectable amounts of methomyl. It appears that the nurseries and other dischargers, if there are any, above the Hines Channel sampling point were sources of several OP and carbamate pesticides for San Diego Creek. As in the August 1998 dry-weather sampling, there was appreciable dilution/loss of the pesticides found at the Hines Channel sampling point by the time the pesticides present at that sampling point reached San Diego Creek at Campus Drive.

Table 3-54
Summary of Results of Toxicity Tests Conducted on Water Samples from San Diego Creek Watershed Collected January 21, 1999

7-day *Ceriodaphnia* Tests

Set up on 1/22/99

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH @ 24 hr
	X	se		
Laboratory Control	21.8[P]	1.8	0[P]	8.5
Laboratory Control at 2000 µmhos/cm	18.5	0.8	0	8.6
San Diego Creek at Campus	*	*	100 (1)	8.3
Hines Channel	*	*	100 (1)	8.2
Santa Ana Delhi Channel	*	*	90 (7)	8.4

[P]The laboratory control met the US EPA criteria for test acceptability. 100% of the daphnids had a third brood.
[1]Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).
* Due to significant mortality observed in these samples, reproduction was not calculated.
(#) Number in parentheses represents days to 100% mortality.

7-day *Pimephales* Tests

Set up on 1/22/99

Treatment	Growth[1] (mg/individual)		Mortality (%)[1]		Final pH @ 24 hr
	X	se	mean	standard error	
Laboratory Control	0.361[P]	0.015	5.0[P]	3.0	8.2
San Diego Creek at Campus	0.412	0.011	0	0	8.2
Hines Channel	0.407	0.024	5.0	3.0	7.7
Santa Ana Delhi Channel	0.431	0.028	2.5	3.0	8.5

[P]The laboratory control met the US EPA criteria for test acceptability.
[1]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

96-hr *Selenastrum* Tests

Set up on 1/22/99

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH @ 96 hr
	X	se		
Laboratory Control	206.9[P]	9.3	9.0	8.7
San Diego Creek at Campus	292.3	16.6	11.3	9.5
Hines Channel	9.4	1.5	31.5	8.4
Santa Ana Delhi Channel	284.5	9.9	6.9	9.5

[P]The laboratory control met the US EPA criteria for test acceptability. The coefficient of variation was 9.0% in this treatment.
[1]Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

Table 3-55
Summary of Results of *Ceriodaphnia* 96-hr Dilution Series Toxicity Tests Conducted on Water Samples from San Diego Creek Watershed Collected January 21, 1999 [1,2]

Set up on 1/27/99

Treatment	% Mortality for Each Day Of The Test [3]				Conclusions	Final pH @ 24 Hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.2
100% San Diego Creek at Campus	100	100	100	100	Toxicity detected down to a 50% dilution. LC50 = 30.6%	8.3
50% San Diego Creek at Campus	5	100	100	100		8.3
25% San Diego Creek at Campus				10		8.3
12.5% San Diego Creek at Campus		5	5	5		8.2
6.25% Hines Channel	100	100	100	100	Toxicity detected down to a 3.13% dilution. LC50 = 2.7%	8.2
3.13% Hines Channel			37	63		8.2
1.56% Hines Channel				0		8.2
0.78% Hines Channel		5	5	5		8.3

Set up on 1/27/99

Treatment	% Mortality for each day of the test [3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.3
Laboratory Control + 100 µg/L PBO				11	No artifactual toxicity present in method blank.	8.4

Set up on 1/27/99

Treatment	% Mortality for each day of the test [3]				Conclusions	Final pH at 24 hr
	1	2	3	4		
100% San Diego Creek at Campus	100	100	100	100	Toxicity detected.	8.4
100% San Diego Creek at Campus + PBO		10	100	100	Mortality delayed with the addition of PBO suggesting that toxicity was partly due to the presence of a metabolically activated OP pesticide.	8.4

Table 3-55 (continued)

Set up on 2/6/99

Treatment	Mortality for each day of the test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.4
Laboratory Control + 100 µg/L PBO				0	No artifactual toxicity present in method blank.	8.5
12.5% Hines Channel	100	100	100	100	Toxicity detected.	8.5
12.5% Hines Channel + PBO		100	100	100	Mortality delayed a day with the addition of PBO suggesting that toxicity was partly due to the presence of a metabolically activated OP pesticide.	8.4

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

These results point to the nurseries being a year-round source of substantial amounts of OP and carbamate pesticides that persist in potentially significant concentrations through the San Diego Creek tributaries to Upper Newport Bay. Based on the pesticide data presented in Table 3-56, the Hines Channel waters collected on January 21, 1999, had about 11.5 TUa due to chlorpyrifos, diazinon, and carbaryl. The samples of San Diego Creek taken at Campus Drive had about 2 TUa due to diazinon and chlorpyrifos. Based on these results and the results of the toxicity tests, there was appreciable unknown-caused toxicity in the Hines Channel sample taken on January 21. There may also have been some unknown-caused toxicity in the San Diego Creek sample taken on that day.

JANUARY 25-29, 1999, STORMWATER RUNOFF EVENT

The January 25-29, 1999, runoff event was a multi-day storm with relatively small amounts of rain recorded over the period. The largest 1-hr rain unit (rainfall occurring over a 1-hr unit period) was 0.12 in., with many of the rain units as small as 0.4 in.

A total rainfall of 0.8 in. fell at the Campus Drive gage during this storm. The duration of rainfall was about 14 hr spread over a period of about 48 hr, and the time of net rain (rainfall producing runoff) was also about 14 hr.

Table 3-56
Summary of Chemical Characteristics of Water Samples from San Diego Creek Watershed Collected January 21, 1999

Treatment	Field Temp °C	pH		EC (µmhos/cm)		Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
		Field	Lab	Field	Lab			
Laboratory Control (EPAMH)			8.3		226	8.1	96	60
Laboratory Control (SSEPAMH)			8.3		226	7.6	88	66
Laboratory Control (Glass Distilled)			7.6		126	8.4		
San Diego Creek at Campus	17.5	7.9	8.2	1358	1387	7.8	204	158
Hines Channel	22.2	8.1	8.1	1515	1417	8.3	368	80
Santa Ana Delhi Channel	16.8	7.7	8.2	1647	1587	7.8	336	214

Location	Chemical Concentration (ng/L)								
	Chlor-pyrifos	Diazi-non	Diphen-amid	Methyl Trithion	Prowl	Simazine	Benomyl	Carbaryl	Metho-myl
Hines Channel	670	1,400	130	580	720	600	1,600	11,000	290
San Diego Creek at Campus	70	570	50	< 200	< 100	310	400	370	< 70

Analysis by APPL Laboratories, Inc., Fresno, CA

Table 3-57
Analysis of Water Sample from Hines Channel

Project: UCD ATL GFL
Sample ID: 012199 H-GFL
Sample Collection Date: 1/21/99
Sample Extraction Date: 1/28/99

APPL, Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29000

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.67	0.50
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	1.4	0.05
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	0.13 Y	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	Not detected	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	0.58	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	0.72	0.50
Ronnel	Not detected	0.10
Simazine	0.60	0.50
Tnchloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	111%	60-150%
Surrogate: Triphenylphosphate	97.7%	76-140%

Y = Percent D > 25%

Table 3-58
Analysis of Water Sample from San Diego Creek at Campus Drive

Project: UCD ATL GFL
Sample ID: 012199 C-GFL
Sample Collection Date: 1/21/99
Sample Extraction Date: 1/28/99

APPL, Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29475

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.07	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	0.57 Y	0.50
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	0.05 J	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	Not detected	0.10
Ronnel	Not detected	0.10
Simazine	0.31 J	0.50
Trichioronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	1300% #	60-150%
Surrogate: Triphenylphosphate	107%	76-140%

J = Estimated value, below quantitation limit
# = Recovery is outside QC limits
Y = Percent D > 25%

Table 3-59
Analysis of Water Sample from Hines Channel

Project: UCD ATL GFL
Sample ID: 012199 H-GFL
Sample Collection Date: 1/21/99
Sample Extraction Date: 2/1/99

APPL, Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29475

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocaib	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	1.6	0.4
Bromacil	Not detected	0.4
Carbaryl	11	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	0.8
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	0.4
Methiocarb	Not detected	0.4
Methomyl	0.29	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	0.4
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	453% #	40-140%

= Recovery is outside QC limits

Table 3-60
Analysis of Water Sample from San Diego Creek at Campus Drive

Project: UCD ATL GFL
Sample ID: 012199 C-GFL
Sample Collection Date: 1/21/99
Sample Extraction Date: 2/1/99

APPL, Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29475

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	0.4	0.4
Bromacil	Not detected	0.4
Carbaryl	0.37	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	5
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	5
Methiocarb	Not detected	0.4
Methomyl	Not detected	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	5
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	124%	40-140%

Campus Drive – San Diego Creek

The peak discharge at San Diego Creek at Campus Drive for the January 25-29 stormwater runoff event was 2,629 cfs. The storm event is estimated to have a recurrence interval of less than 1 yr.

The volume of direct runoff (VDR) computed using rainfall data and a gaged hydrograph was determined to be 0.32 in. Subtracting the net rainfall (VDR) from the total rainfall gives a total loss of 0.48 in. Using a constant loss rate approach, an average loss of 0.034 in./hr is estimated. The lag time for this storm is difficult to estimate, given the number of small rain units spaced over a multi-day period, but is estimated to be about 3 hr.

This storm event occurred over an extended period of time (two days) with several 1-hr rain units. Runoff from the storm was moderate, however, given the antecedent moisture condition from previous rain. Nevertheless, the majority of surface runoff from this event can most likely be attributed to impervious surfaces. The event can also be classified as "typical" for any given year in terms of the total depth of rain.

Sampling for the event occurred both in Upper Newport Bay and at San Diego Creek at Campus Drive. A total of five samples were taken at San Diego Creek at Campus Drive during the runoff event. The samples are fairly evenly distributed across the hydrograph. The storm peak, occurring at about midnight on January 27, was not sampled. While the January 25 sample was near the peak of the hydrograph for that runoff event, the other sampling was just above base flow and did not occur at the time of the peaks in the hydrograph for the subsequent runoff events.

Table 3-61 presents the results of the 7-day *Ceriodaphnia* toxicity tests for the San Diego Creek samples taken on January 25 at 1000 hr and January 25 at 1530 hr, as well as on the January 26 sampling which occurred at 0935 hr. All three samples killed 100 percent of the *Ceriodaphnia* within 1 day. Dilution series of these toxicity tests were conducted for the January 25-26 samples to determine the magnitude of the toxicity found. The 25-percent dilution of the January 26 sample of San Diego Creek taken at Campus Drive killed all *Ceriodaphnia* with 2 days, while the 12.5-percent dilution of this sample taken at this date was non-toxic. These results indicate that the sample taken on January 26, 1999, at San Diego Creek at Campus Drive had from 4 to 8 TUa.

Table 3-61
Summary of Results of 7-day *Ceriodaphnia* Toxicity Tests
Conducted on Water Samples from San Diego Creek Watershed
Collected January 25-26, 1999[2]

Set up on 1/27/99

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH @ 24 hr
	X	se		
Laboratory Control	22.2[P]	0.6	0[P]	8.4
Laboratory Control at 2,000 μmhos/cm	19.6	1.6	0	8.3
San Diego Creek at Campus 1/25/99 at 1000 hr	*	*	100 (1)	8.1
San Diego Creek at Campus 1/25/99 at 1530 hr	*	*	100 (1)	8.2
San Diego Creek at Campus 1/26/99	*	*	100 (1)	8.5

[P]The laboratory control met the US EPA criteria for test acceptability. 90% of the daphnids had a third brood.
[1]Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).
[2]The samples were collected on the date and at the time indicated in the table.
* Due to significant mortality observed in these samples, reproduction was not calculated.
(#) Number in parenthesis represents days to 100% mortality.

Table 3-62 also presents a subsequently conducted dilution series testing for the San Diego Creek at Campus Drive samples collected on January 25 and 26 that was set up, again, after storage in the dark on February 5, i.e., 15 days after collection. These samples showed that the 50-percent dilution of the San Diego Creek sample taken at Campus Drive on January 25 and 26 killed 100 percent of the *Ceriodaphnia* within 1 day. The addition of 100 µg/L of PBO reduced the rate of kill from 1 to 2 days, thereby indicating that at least part of the toxicity is due to OP pesticides. Similar toxicity test results were obtained with a 50-percent dilution of the San Diego Creek sample taken on January 25, 1999, at 1530 hr and the January 26, 1999, sample. There was appreciable toxicity in this sample throughout this runoff event.

Table 3-63 presents a summary of the chemical characteristics of the January 25 and January 26 samples taken at San Diego Creek at Campus Drive. These results show 960 ng/L of diazinon on January 25 at 1000 hr, 910 ng/L of diazinon on January 25 at 1530 hr, and 880 ng/L of diazinon on January 26. This concentration of diazinon represents about 2 TUa of diazinon. There were also elevated concentrations of several other pesticides, including carbaryl at about 1 TUa. There was also appreciable benomyl

Table 3-62
Summary of Results of *Ceriodaphnia* 96-hr Dilution Series Toxicity Tests Conducted on Water Samples from San Diego Creek Watershed Collected January 25-26, 1999 [1,2,4]

Set up on 1/31/99

Treatment	Mortality for each day of the test [3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.3
25% San Diego Creek at Campus 1/25/99 at 1000 hr	100	100	100	100	Toxicity detected at 25% dilution. LC50 = 14.4%	8.3
12.5% San Diego Creek at Campus 1/25/99 at 1000 hr		5	10	20		8.3
6.25% San Diego Creek at Campus 1/25/99 at 1000 hr	5	10	10	10		8.3
3.13% San Diego Creek at Campus 1/25/99 at 1000 hr				0		8.3
25% San Diego Creek at Campus 1/25/99 at 1530 hr	80	100	100	100	Toxicity detected at 25% dilution. LC50 = 18.8%	8.3
12.5% San Diego Creek at Campus 1/25/99 at 1530 hr				0		8.3
6.25% San Diego Creek at Campus 1/25/99 at 1530 hr				0		8.3
3.13% San Diego Creek at Campus 1/25/99 at 1530 hr				0		8.3
25% San Diego Creek at Campus 1/26/99	95	100	100	100	Toxicity detected at 25% dilution. LC50 = 18.6%	8.4
12.5% San Diego Creek at Campus 1/26/99				0		8.3
6.25% San Diego Creek at Campus 1/26/99			5	5		8.3

Table 3-62 (continued)

Set up on 2/5/99

Treatment	Mortality for each day of the test[3] 1	2	3	4	Conclusions	Final pH @ 24 hr
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.3
Laboratory Control + 100 µg/L PBO				5	No artifactual toxicity present in method blank.	8.4
50% San Diego Creek at Campus 1/25/99 at 1000 hr	100	100	100	100	Toxicity detected.	8.3
50% San Diego Creek at Campus 1/25/99 at 1000 hr + PBO	0	100	100	100	Delay in mortality suggests that toxicity may have been partly due to the presence of a metabolically activated OP pesticide.	8.3
50% San Diego Creek at Campus 1/25/99 at 1530 hr	100	100	100	100	Toxicity detected.	8.3
50% San Diego Creek at Campus 1/25/99 at 1530 hr + PBO	0	100	100	100	Delay in mortality suggests that toxicity may have been partly due to the presence of a metabolically activated OP pesticide.	8.2
50% San Diego Creek at Campus 1/26/99	100	100	100	100	Toxicity detected.	8.3
50% San Diego Creek at Campus 1/26/99 + PBO	75	100	100	100	Delay in mortality suggests that toxicity may have been partially due to the presence of a metabolically activated OP pesticide.	8.4

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.
[4]The site was sampled on the date and at the time indicated in the table.

Table 3-63
Summary of Chemical Characteristics of Water Samples from San Diego Creek Watershed Collected January 25-26, 1999

Treatment	Field Temp (°C)	pH		EC (μmhos/cm)		Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
		Field	Lab	Field	Lab			
Laboratory Control (SSEPAMH)			8.2	220		8.2	88	66
San Diego Creek at Campus 1/25/99 at 1000 hr	13.6	7.7	8.1	425	376	8.2	136	56
San Diego Creek at Campus 1/25/99 at 1530 hr	14.8	7.6	8.0	510	477	8.2	172	62
San Diego Creek at Campus 1/26/99	13.4	8.4	8.3	1150	935	8.2	328	118

Location 1/25/99	Chemical Concentration (ng/L)										
	Diazinon	Malathion	Prowl	Simazine	Methidathion	Trifluralin	Benomyl	Carbaryl	Diuron	Methomyl	Chlorpyrifos
San Diego Creek at Campus at 1000 hr	960	490	250	300	120	190	1,600	5,400	800	230	<50
San Diego Creek at Campus at 1530 hr	910	380	200	370	120	180	1,500	4,600	2,000	610	<50
San Diego Creek at Campus 1/26/99	880	290	160	280	< 100	< 100	1,000	2,600	1,700	410	<50

Analysis by APPL Laboratories, Inc., Fresno, CA

at 1,000 to 1,600 ng/L. At this time no information is available on the toxicity of benomyl to *Ceriodaphnia*. However, based on the toxicity of benomyl to *Daphnia magna*, the concentrations of benomyl found would not be expected to be toxic to *Ceriodaphnia*. It is somewhat surprising that the chlorpyrifos concentrations in these samples were less than the detection limit of about 50 ng/L based on the analysis by APPL Laboratories.

It was of interest to find that the concentrations of the OP pesticides and their toxicity over the period January 25 through 26 did not change significantly independent of the time of sampling relative to the sampling position on the hydrograph.

A third storm front passed through the San Diego Creek at Campus Drive area on January 27, which was sampled near the base of the descending arm of the runoff event at 800 hr on January 27. Table 3-64 presents the results of the toxicity tests, showing that this sample caused 100 percent mortality to *Ceriodaphnia* within 1 day. A dilution series of the sample of San Diego Creek taken at Campus Drive was set up. Table 3-64 presents the results of this dilution series, showing that a 50-percent dilution of the San Diego Creek water taken on January 27 at Campus Drive killed 100 percent of the *Ceriodaphnia* within one day, while a 25-percent dilution sample killed all *Ceriodaphnia* within three days. A 12.5-percent dilution sample of San Diego Creek taken at Campus Drive was non-toxic to *Ceriodaphnia* over 4 days. Therefore, there was between 4 and 8 TUa of *Ceriodaphnia* toxicity in the January 27 sample.

The 50 percent dilution of the January 27 sample of San Diego Creek water taken at Campus Drive was set up again on February 5 with and without PBO. Table 3-64 shows that the 50-percent dilution sample of San Diego Creek water taken at Campus Drive, after standing for 8 days, still killed 100 percent of the *Ceriodaphnia* within 1 day. The addition of 100 µg/L of PBO reduced this toxicity to 60 percent over 4 days, indicating that PBO did delay and reduce the toxicity of this sample. Table 3-65 presents a summary of the chemical characteristics of this sample, showing that it is similar in character to other samples taken during the course of this study.

An additional sample of San Diego Creek water at Campus Drive was taken on January 29, a little over two days since the last rainfall runoff event in the San Diego Creek watershed. The toxicity data on this sample are presented in Table 3-66, which shows that the San Diego Creek water taken at Campus Drive on January 29 killed 100 percent of the *Ceriodaphnia* within 6 days. These results indicate that there was still some toxicity in San Diego Creek waters several days after the last stormwater runoff event occurred. The chemical characteristics of this sample are presented in Table 3-66, indicating, from the electrical conductivity data, that the sample had considerable normal dry-weather flow characteristics due to the elevated salt inputs from groundwater. The January 27 sample had a specific conductivity of 511 µmhos/cm, while the January 29 sample had a specific conductivity of 1,870 µmhos/cm, about three times greater than the January 27 sample.

Table 3-64
Summary of Results of *Ceriodaphnia* Toxicity Tests
Conducted on Water Samples from San Diego Creek Watershed
Collected January 27, 1999

7-day *Ceriodaphnia* Tests

Set up on 1/30/99

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH @ 24 hr
	X	Se		
Laboratory Control	21.2[P]	0.8	0[P]	8.3
San Diego Creek at Campus	*	*	100 (1)	8.2

[P]The laboratory control met the US EPA criteria for test acceptability. 100% of the daphnids had a third brood.

[1]Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).

*Due to significant mortality observed in these samples, reproduction was not calculated.

(#) Number in parenthesis represents days to 100% mortality.

96-hr *Ceriodaphnia* Dilution Tests

Set up on 2/1/99

Treatment[1,2]	% Mortality for each day of the test[3]				Conclusions	Final pH @24 hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.3
100% San Diego Creek at Campus	100	100	100	100	Toxicity detected down to 25% dilution. LC50 = 18.6%	8.2
50% San Diego Creek at Campus	100	100	100	100		8.3
25% San Diego Creek at Campus		30	100	100		8.4
12.5% San Diego Creek at Campus				0		8.4
6.25% San Diego Creek at Campus		15	15	15		8.4

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.

[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.

[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-64 (continued)

96-hr Ceriodaphnia Dilution Tests

Set up on 2/5/99

Treatment [1,2]	**% Mortality for each day of the test** [3]				**Conclusions**	**Final pH @ 24 hr**
	1	**2**	**3**	**4**		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.3
Laboratory Control + 100 µg/L PBO				5	No artifactual toxicity present in method blank.	8.4
50% San Diego Creek at Campus	100	100	100	100	Toxicity detected.	8.4
50% San Diego Creek at Campus + PBO			50	60	Delay in mortality with the addition of PBO suggests that toxicity may have been partly due to the presence of a metabolically activated OP pesticide.	8.4

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-65
Summary of Chemical Characteristics of Water Samples From San Diego Creek Watershed
Collected January 27, 1999

Treatment	**Field Temp (°C)**	**PH**		**EC (µmhos/cm)**		**Lab DO (mg/L)**	**Total Hardness (mg/L as $CaCO_3$)**	**Alkalinity (mg/L as $CaCO_3$)**
		Field	**Lab**	**Field**	**Lab**			
Laboratory Control (SSEPAMH)			8.3		220	8.4	88	66
San Diego Creek at Campus	10.2	8.0	8.1	511	499	8.1	168	66

Table 3-66
Summary of 7-Day Ceriodaphnia Toxicity Test From
San Diego Creek at Campus Drive
Sample Collected on January 29, 1999

Set up on 2/1/99

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH @24 hr
	x	se		
Laboratory Control	19.6[P]	1.5	0P	8.4
Laboratory Control at 2000 µmhos/cm	14.0	2.1	0.0	8.5
San Diego Creek at Campus	*	*	100 (6)	8.7

[P] The control met all EPA criteria for test acceptability. 100% of the daphnids had a third brood.
* Due to significant mortality observed in these samples, reproduction was not calculated.
(#) Number in parentheses represents days to 100% mortality

Treatment	Field Temp (^{0}C)	pH		EC (µmhos/cm)		Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
		Field	Lab	Field	Lab			
Lab Control (SSEPAMH)			8.2		227	8.2	88	66
San Diego Creek at Campus	15.8	8.5	8.3	1870	2050	8.3	628	188

IN-BAY SAMPLING

January 25, 1999, Bay Sampling Study

In-Bay sampling occurred on 3 days: January 25, 27, and 29, 1999. Salinity measurements were taken at various stations (see Figure 2-1) and at various depths for each of the 3 days. Three stations were sampled on January 25 (UNBJAM, UNBSDC and UNBBCW), five stations were sampled on January 27 (UNBJAM, UNBSDC, UNBBCW, UNBNSB, and UNBCHB), and four stations were sampled on January 29 (UNBJAM, UNBSDC, UNBBCW, and UNBNSB).

The storm hydrograph at San Diego Creek at Campus Drive exhibits a small peak during this time period of about 1200 cfs, in response to a set of rainfall units occurring from about 0300 hr on January 25 to about 0900 hr on the same day. A total of about 0.4 in. of rain fell during this period.

The first set of samples was taken on January 25 at 1225 hr. The tide was low at 1044 hr and moving toward a high tide at 1643 hr. The condition with the tide moving from low to high would tend to create a counter-current to the storm flows and also tend to promote mixing. The fresh water (stormwater) discharge at the Jamboree Station (UNBJAM) at the time of the sample is estimated to be about 725 cfs.

The LTI numeric mixing model (see discussion in Section 4) predicts that, with a discharge (725 cfs), the water at the Jamboree Station would be partially to fully mixed. The salinity/depth data is presented by Lee and Taylor (1999a). A plot of salinity vs. depth for the given discharge indicates that the water is stratified up to a depth of about 0.5 m, and partially mixed to a depth of 4 m. The salinity at the surface was about 1 ppt, increasing to about 27 ppt at a depth of 4 m.

Sampling on January 25 at the San Diego Creek Bay Station (UNBSDC) occurred at 1345 hr. Note there are two San Diego Creek stations. One of these is San Diego Creek at Campus Drive, which is upstream of Upper Newport Bay. The other is the San Diego Creek Bay Station, which is within the Bay. The tide condition was midpoint moving from low tide (1044 hr) to high tide (1643 hr). The discharge to the Bay at this time was about 266 cfs. The LTI model predicts that this location should be nearly fully mixed. The salinity/depth plot indicates stratification under about 0.2 m, with a rapidly increasing salinity gradient as the depth increases further. The salinity at the surface is about 1.9 ppt, increasing to about 25 ppt at a depth of 4.2 m.

The January 25, 1999, sampling at the Big Canyon Wash Station (UNBBCW) occurred earlier than either the San Diego Creek or Jamboree Stations due to logistics. The Big Canyon Wash station was sampled at 1200 hr. The tide was trending from low to high at this time. Flow would be expected to be diluted by this station given the modest inflow rate (about 420 cfs).

The salinity data indicate that the surface stratification seen at the Upper Bay stations is gone. Salinity at the surface is 11 ppt, much higher than at the other two locations, rising to about 28 ppt near the bottom. The effects of the surface water flows on salinity were less pronounced at this station.

In summary, the data indicate that a veneer of fresher water existed near the surface (to a depth of about 0.2 m) on the January 25 sample within the Bay to the San Diego Creek Bay Station. This fresher water lens was largely dissipated by the time the flow reached the Big Canyon Wash station.

The data obtained in the January 25-29 study of the persistence of aquatic life toxicity and diazinon and chlorpyrifos in Upper Newport Bay during an extended stormwater runoff event is presented in Table 3-67. The multi-component storm that occurred over this period, had three distinct runoff periods. In general, the San Diego Creek water at Campus Drive during the period January 25 through 29 contained a total salt content (specific conductivity) of about 376 to 1870 µmhos/cm (µS/cm), which is typical for the range for San Diego Creek at Campus Drive during runoff events. The San Diego Creek water was about the same temperature as the marine waters of the Bay. Therefore, the density stratification was due largely to salinity differences between the fresh San Diego Creek water entering the Bay and the Bay waters which had salinities near the bottom at the Pacific Coast Highway station (UNBCH) of 30 ppt.

Examination of the salinity profiles for January 25 shows that the Jamboree sampling station (UNBJAM) just downstream of where San Diego Creek enters Upper Newport Bay, during a flood tide situation, exhibited a narrow band of fresher water floating on top of marine water. Just below this fresher water lens, the salinity profile showed a gradual decrease in salinity from 5 ppt to about 26 ppt over the 4-m depth at the station. A similar profile is shown at the San Diego Creek Bay station (UNBSDC) on January 25. By the Big Canyon Wash station (UNBBCW), the fresher water lens had been mixed into the water column, since the surface water at this location had a salinity of about 11 ppt. Therefore, the zone of expected toxicity would be the Bay surface waters up-Bay of Big Canyon Wash (UNBBCW).

Examination of Table 3-67 shows that the San Diego Creek at Campus Drive water samples taken at 1000 hr (C2) and 1530 hr (C3) on January 25, 1999, just upstream of where San Diego Creek enters Upper Newport caused 100 percent mortality of mysids within two days. It is important to note that there was no mortality within one day: therefore, at least 1 to 2 days of exposure is needed for this water to kill *Americamysis bahia*.

The Jamboree surface station (UNBJAM) (Jamboree Surface JS) also showed 100-percent mortality of mysids within 2 days. The Jamboree bottom station (Jamboree Bottom JB) showed 82 percent mortality over 5 days of exposure. Since this bottom station had 26.7 ppt salinity, it is apparent that there was mixing of some of the San Diego Creek water with the approximately 30-ppt salinity marine waters. This mixing was not sufficient, however, to dilute the toxic constituents in the fresh water input below toxic levels or there is toxicity present in the Jamboree near-bottom waters from other sources such as the sediments.

Table 3-68 presents the results of the dilution series testing of the January 25, 1999, San Diego Creek stormwater runoff sample (C2) using *Americamysis bahia*. Examination of this table shows that there were between 2 and 4 TUa of mysid toxicity in this sample over the 7-day test period. Therefore, there appears to be an inconsistency between the level of toxicity found in the January 25 C2 sample and the January 25 Jamboree Bottom JB sample, where toxicity was present in the Jamboree Bottom sample with a salinity near that of undiluted marine water. As discussed below, a similar pattern was found on the January 27 sampling, where the Jamboree JB station (UNBJAM) bottom waters showed some toxicity at an elevated salinity above what would be expected to be toxic. This issue is discussed further below.

Table 3-68 also presents data on the effect of the January 25 San Diego Creek stormwater runoff sample (C2) on *Americamysis bahia* weight. These results show that a 25-percent dilution of this sample caused a statistically significant decrease from the controls in mean mysid weight over the 7-day test period. No information is available on how the toxicity in the sample affected mysid larval weights over shorter periods of exposure than 7 days.

The January 25, 1999, surface San Diego Creek Bay sample (UNBSDC) (San Diego Creek SDC) taken further down the Bay caused 38 percent mysid mortality in 6 days, which was statistically significant from the controls (Table 3-67). This sample had approximately 2 ppt salinity. The Big Canyon Wash (UNBBCW) (Big Canyon Wash BCW) surface sample obtained on January 25 was not toxic to *Americamysis bahia* over the 7-day test period. Therefore, as expected, with respect to the surface San Diego Creek water entering Upper Newport Bay forming a fresher water lens, the toxic San Diego Creek water was diluted sufficiently with nontoxic marine waters by the time it reached the Big Canyon Wash station to be nontoxic. These results tend to contradict the results for the January 25 Jamboree Bottom sample, which was found to be toxic with less dilution of the San Diego Creek water entering Upper Newport Bay than was found at the Big Canyon Wash Bay station.

The backup data for the APPL Laboratories analysis of the January 25-26 samples are presented in Tables 3-69 through 3-74. Examination of the diazinon and chlorpyrifos concentrations found in the January 25 samples presented in Table 3-67 shows that the San Diego Creek freshwater entering the Bay (samples C2 and C3) had about 640 ng/L diazinon and about 100 ng/L chlorpyrifos. The surface sample diazinon had been diluted to about 350 ng/L by the time it reached the surface Big Canyon Wash (UNBBCW) sampling location. Chlorpyrifos was also diluted by about a factor of 2 in the surface waters from San Diego Creek as it enters Upper Newport Bay to the Big Canyon Wash station.

Table 3-67
Results of Toxicity Testing and Chemical Analyses of Upper Newport Bay Waters During the January 25-29 Stormwater Runoff Event
***Americamysis Bahia* Used as a Test Organism**
Samples Collected January 25, 1999

Sample Location Designation	Depth (m)	Time	Salinity	Temp (C)	Mortality % (days)	Diaz ng/L	Chlorp ng/L	Est Tua
San Diego Creek Campus C2	0.1	1000	376 (µS/cm)	13.6	100 (2)	638	102	2.9
C3	0.1	1530	477 (µS/cm)	14.8	100 (2)	720	132	3.8
C26 1/26/99	0.1	0935	935 (µS/cm)	13.5	--	560	60	1.7
Jamboree Surface JS	0.1	1225	1 ppt	13.0	100 (2)	468	42	1.2
Jamboree Bottom JB	4.0	1225	26.7 ppt	14.6	82 (5)	197	2	0
Jamboree J-0.1m	0.1	1225	1 ppt	13.0	--	445	30	0.9
Jamboree J-0.7m	0.7	1225	6.7 ppt	13.4	--	--	--	--
Jamboree J-1.7m	1.7	1225	10.4 ppt	13.8	--	--	--	--
San Diego Creek SDC	0.1	1345	1.9 ppt	13.6	38 (6)	357	--	--
San Diego Creek SDC	0.2	1345	6.7 ppt	13.6	--	--	--	--
San Diego Creek SDC	1.5	1345	15 ppt	14.0	--	295		--
Big Canyon Wash BCW	0.1	1200	11 ppt	14.0	8 (7) (not ss)	357	55	1.6
San Diego Creek Campus C27	0.1	800	511 (µS/cm)	10.2	98 (3)	640	48	1.4
Jamboree Surface JS	0.1	1330	2.4 ppt	12.3	90 (4)	468	42	1.2
Jamboree Bottom JB	3.1	1330	21.4 ppt	13.3	68 (5)	243	20	0.6
Jamboree J 0.1m	0.1	1330	2.4 ppt	12.3	--	445	58	1.7
Jamboree J 1.0m	1.0	1330	7.5 ppt	10.8	--	407	86	2.4

Table 3-67 (continued)
Samples Collected on January 27, 1999

Sample Location Designation	Depth (m)	Time	Salinity	Temp (C)	Mortality % (days)	Diaz ng/L	Chlorp ng/L	Est TUa
San Diego Creek SDC	0.1	1430	4.3 ppt	11.7	70 (6)	357	42	1.2
San Diego Creek SDC	0.5	1430	5.6 ppt	12.1		384	54	1.5
San Diego Creek SDC	1.5	1430	12.2 ppt	12.2	--	295	38	1
Big Canyon Wash BCW	0.1	1500	3.6 ppt	12.8	42 (6)	352	58	1.7
Big Canyon Wash BCW	0.7	1500	5.6 ppt	12.3	--	372	36	1
Big Canyon Wash BCW	3.1	1500	21.4 ppt	13.1	--	227	14	0.4
North Star Beach NSB	0.1	1530	8.3 ppt	12.8	--	306	27	0.8
Pacific Coast Hwy PCH	0.1	950	9.8 ppt	11.8	--	324	39	1
Pacific Coast Hwy PCH	4.0	950	29.9 ppt	12.1	--	317	14	0.4
San Diego Creek Campus C29	0.1	1315	1870 (µS/cm)	15.7	18 (7) (not ss)	233	23	0.7
Jamboree Surface JS29	0.1	915	7.5 ppt	12.1	--	432	15	0.4
Jamboree Bottom JB29	4.8	915	28.2 ppt	12.8	--	197	2	0

-- No analysis conducted, (not ss) means not statistically different from the controls at $p<0.5$

The Jamboree Bottom sample (UNBJAM) (Jamboree JB) was essentially free of chlorpyrifos, while the surface sample at that point had 42 ng/L of chlorpyrifos; which represents approximately 1 TUa for chlorpyrifos toxicity to *Americamysis bahia* over a 7-day exposure. All of the diazinon concentrations presented in Table 3-67 would be non-toxic to *Americamysis bahia*, since the LC_{50} for *Americamysis bahia* is about 4,500 ng/L. Therefore, the toxicity found is likely due to chlorpyrifos and other unknown toxicants in the San Diego Creek water as it enters Upper Newport Bay.

It is somewhat surprising that the January 25 Big Canyon Wash surface sample, which was found in this testing to be nontoxic, had a projected 1.5 TUa for *Americamysis bahia* based on the chlorpyrifos concentrations. It appears that possibly some of the chemically measured chlorpyrifos was nontoxic, likely due to sorption on the particulates in the stormwater runoff. Ankley *et al*. (1994) reported that chlorpyrifos was detoxified when it was attached to organic carbon particles. It is unclear whether this same situation would occur with attachments to clay surfaces with low organic carbon, which is likely the situation for a substantial part of the suspended sediment that is added to Upper Newport Bay.

Table 3-68
Toxicity of the January 25, 1999, San Diego Creek at Campus Drive "C2" Stormwater Runoff Sample to *Americamysis bahia*

January 25 "C2" Sample Treatment	Mean % Mortality
Control	5
100%	100 *
50%	100 *
25%	10
12.5%	5
6.25%	20

* Significantly less than the Control treatment at $p < 0.05$.

Effect of the January 25, 1999, San Diego Creek at Campus Drive "C2" Stormwater Runoff Sample on *Americamysis bahia* Weight

January 25 "C2" Sample Treatment	Mean Mysid Weight
Control	0.27
100%	-(100% kill)
50%	-(100% kill)
25%	0.19 *
12.5%	0.21
6.25%	0.20

* Significantly less than the Control treatment at $p < 0.05$.

Table 3-69
Analysis of San Diego Creek at Campus Drive

Project: UCD ALT
Sample ID: 012599 GFL-C2
Sample Collection Date: 1/25/99
Sample Extraction Date: 2/13/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29640

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	Not detected	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	0.96 Y	0.25
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	0.49 Y	0.10
Merphos	Not detected	0.10
Methidathion	0.12 Y	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	.Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	0.25 Y	0.10
Ronnel	Not detected	0.10
Simazine	0.30 J	0.50
Trichloronate	Not detected	0.10
Trifluralin	0.19 Y	0.10
Surrogate: Tributylphosphate	830 #	60-150 %
Surrogate: Triphenylphosphate	111	76-140 %

J = Estimated value, below quantitation limit. Y = Percent D > 25%.

= Recovery is outside QC limits.

Table 3-70
Analysis of San Diego Creek at Campus Drive

Project: UCD ALT
Sample ID: 012599 GFL-C3
Sample Collection Date: 1/25/99
Sample Extraction;2/24/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
APPL ID AP75389

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	Not detected	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	0.91	0.25
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	0.38 Y	0.10
Merphos	Not detected	0.10
Methidathion	0.12	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	0.20 Y	0.10
Ronnel	Not detected	0.10
Simazine	0.37 J	0.50
Trichloronate	Not detected	0.10
Trifluralin	0.18 Y	0.10
Surrogate: Tributylphosphate	528 #	60-150 %
Surrogate: Triphenylphosphate	105	76-140 %

J = Estimated value, below quantitation limit.

= Recovery is outside QC limits.

Y = Percent D > 25%.

Table 3-71
Analysis of San Diego Creek at Campus Drive

Project: UCD ALT
Sample ID: 012699 GFL-C26
Sample Collection Date: 1/26/99
Sample Extraction Date: 2/13/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29640

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	Not detected	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	0.88	0.25
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	0.29 Y	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	0.16 Y	0.10
Ronnel	Not detected	0.10
Simazine	0.28 J	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	388 #	60-150 %
Surrogate: Triphenylphosphate	104	76-140 %

J = Estimated value, below quantitation limit.

= Recovery is outside QC limits.

Y = Percent D > 25%.

Table 3-72
Analysis of San Diego Creek at Campus Drive

Project: UCD ALT
Sample ID: 012599 GFL-C2
Sample Collection Date: 01/25/99
Sample Extraction Date: 2/16/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29640

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	1.6	0.4
Bromacil	Not detected	0.4
Carbaryl	5.4	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	0.8	0.4
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	0.4
Methiocarb	Not detected	0.4
Methomyl	0.23	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	1
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	135	40-140 %

Table 3-73
Analysis of San Diego Creek at Campus Drive

Project: UCD ALT
Sample ID: 012599 GFL-C3
Sample Collection Date: 01/25/99
Sample Extraction Date: 2/16/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29640

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	1.5	0.4
BromaciI	Not detected	0.4
Carbaryl	4.6	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	2.0	0.4
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	2
Methiocarb	Not detected	0.4
Methomyt	0.61	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	0.4
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	130	40-140 %

Table 3-74
Analysis of San Diego Creek at Campus Drive

Project: UCD ALT
Sample ID: 012699 GFL-C26
Sample Collection Date: 01/26/99
Sample Extraction Date: 2/16/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29640

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	1.0	0.4
Bromacil	Not detected	0.4
Carbaryl	2.6	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	1.7	0.4
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	2
Methiocarb	Not detected	0.4
Methomyl	0.41	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	0.4
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	130	40-140 %

Therefore, the January 25, 1999, stormwater runoff event caused an area of Upper Newport Bay near where San Diego Creek enters the Bay to be toxic to aquatic life with a sensitivity to chlorpyrifos similar to that of *Americamysis bahia*. However, a toxic exposure to the OP pesticides could require a period of time greater than aquatic life present in the toxic waters could experience during a stormwater runoff event. Table 3-67 presents data for a San Diego Creek at Campus Drive sample taken on January 26, 1999 (C26). While no toxicity measurements were made on this sample, the diazinon and chlorpyrifos present were somewhat less than that found the previous day. There were, however, almost 2 TUa of chlorpyrifos toxicity to mysids based on the LC_{50} value present in the January 26 sample.

The January 26 sample was taken just at the beginning of the ascending part of the second stormwater runoff event that occurred in the January 25 through 29 sampling period. It is likely that the 60 to 100 ng/L of chlorpyrifos present in the afternoon of January 25 (1530 hr) (C3), on the descending part of the first runoff event hydrograph, and the January 26 (C26) sample taken on the ascending part of the second runoff event represent the concentrations of chlorpyrifos in San Diego Creek waters as they enter Upper Newport Bay.

January 27, 1999, Bay Sampling Study

The sampling procedure was repeated for January 27 from about 1000 hr to 1530 hr. The tide during this time was trending low, low, or trending high (after 1247 hr). The storm hydrograph was generally in the receding limb during this time period, following the peak flow for this multi-day event (2629 cfs) which occurred at about 2400 hr on January 27. The largest single unit rainfall (rainfall occurring over a 1-hr unit period) occurred during this time, and was about 0.12 in. in an hour. Several smaller rain units of about 0.04 in. were clustered around the primary rain unit.

Salinity profiles were recorded for five stations on January 27, 1999. The first profile was recorded at 1005 hr at the Coast Highway Station (UNBCHB). The tide was trending lower at this time, and the sampling time followed the maximum discharge for the storm event. The estimated discharge entering Upper Newport Bay at the time of sampling was about 90 cfs. The salinity profile is consistent with other salinity profiles obtained downstream of Big Canyon Wash, with salinity decreasing from 9.8 ppt at 0.1 m to 29.9 ppt at 4 m. It is evident that the freshwater input to the Bay from San Diego Creek and local sources associated with the January 25, 26, and 27 stormwater runoff events is being appreciably mixed and diluted with the marine waters by the time it reaches the Pacific Coast Highway Bridge.

Salinity profiles for the other Stations for this date show stratification associated with the input of San Diego Creek freshwater to the Bay. The profiles for the upper four stations -- Jamboree Station (UNBJAM), San Diego Creek Bay Station (UNBSDC), and Big Canyon Wash Station (UNBBCW), Northstar Beach (UNBNSB) and Coast Highway Stations (UNBCHB) show that the freshwater input to the Bay on January 25, 26, and 27, 1999, from San Diego Creek occurs as a fresher water lens for the Jamboree, San Diego Creek Bay, and Big Canyon Wash stations. The surface water salinities for these stations at the time of sampling were less than 2 to 4 ppt. Below this fresher water lens, which was less than 1 m thick (usually less than 0.5 m thick), the salinity increased at these stations to about 15 to 20 ppt at the bottom, indicating that the San Diego Creek freshwater inputs had been mixed to some extent with the marine Bay waters to the bottom.

Tide does not appear to have a readily discernable effect on the salinity profiles. Potentially greater mixing would be expected during a rising tide, assuming a constant flow.

Samples collected on January 27, 1999, showed (Table 3-67) that San Diego Creek at Campus Drive (C27) contained about 640 ng/L diazinon, and 48 ng/L chlorpyrifos, for a total TUa to mysids, based on these constituents, of about 2. Examination of the salinity profiles for the January 27, 1999, samples showed that at the Jamboree station (UNBJAM) there was an appreciable fresher water lens, now about 0.7 m thick, which increased to a salinity of about 21 ppt at the bottom, which at the time of sampling was a little over 3 m. At the San Diego Creek Bay station (UNBSDC) the fresher water lens was present for about 0.5 m from the surface.

There was appreciable mixing of marine waters into the freshwater input at the Jamboree sampling location, since the salinity was about 2.5 ppt in the fresher water lens. By the San Diego Creek sampling station the salinity in this fresher water lens was about 5 ppt, and the bottom waters at this station at a depth of about 2.4 m had a salinity of about 14 ppt.

The January 27 sample at Big Canyon Wash sampling station (UNBBCW) showed that the salinities near the surface were about 4 ppt and gradually increased to about 21 ppt at a little over 3 m. By the Northstar Beach station (UNBNSB), further down the Bay, on January 27 the salinity of the surface waters had increased to about 8 ppt and then increased to 30 ppt at a depth of about 2.8 m. While at the Pacific Coast Highway Bridge (UNBCHB) the surface salinity on January 27 was 10 ppt, with a gradual increase to about 30 ppt at the bottom 4-m depth. Therefore, there was appreciable mixing of what appear to be non-toxic marine waters with the San Diego Creek water, resulting in significant dilution of the San Diego Creek water throughout the Bay, including the uppermost reaches of Upper Newport Bay, within 2 days after the rainfall event began.

The toxicity of the January 27, 1999, sample showed (Table 3-67) 98 percent mortality of *Americamysis bahia* within 3 days in San Diego Creek water at Campus Drive (C27). The Jamboree Surface waters (UNBJAM) (Jamboree Surface JS) exhibited a 90-percent mortality within 4 days, while the Jamboree Bottom (JB) exhibited 68-percent mysid mortality over 5 days, indicating that there was sufficient mixing of San Diego Creek water to the bottom at the Jamboree station, where the salinity was 21.4 ppt, to still show some toxicity. It appears that there is another source of toxicity that causes the bottom samples at the Jamboree JB station to be toxic with elevated salinities. A possible explanation is that the stormwater runoff event scoured the Upper Bay sediments sufficiently so that a toxic constituent(s) present in the sediments was mixed into the water column causing the near-bottom waters to become toxic to mysids.

Examination of the diazinon and chlorpyrifos concentrations at these stations (Table 3-67) shows that San Diego Creek waters entering Upper Newport Bay had about 2 mysid TUa due to chlorpyrifos, about 1.6 mysid TUa in the surface waters at Jamboree Surface station (JS), and 0.8 mysid TUa at the Jamboree Bottom station (JB). These results are indicative of the presence of potential chlorpyrifos toxicity and possible other toxicants in these waters.

The samples of surface water taken on January 27, 1999, at the San Diego Creek Bay station (UNBSDC) and Big Canyon Wash Bay station (UNBBCW) showed a readily discernible toxicity over 6 days, with 70- and 42-percent mysid mortality, respectively. However, it is important to emphasize that toxicities of this magnitude, especially over this period of time, reflect a relatively low level of toxicity in terms of the exposure that marine organisms might experience by entering the fresher water lens present in the Bay.

There is some evidence that part of the chlorpyrifos present in these samples may not be in a toxic form. The TUas, based on using a 35 ng/L LC_{50} for *Americamysis bahia,* are greater than the measured mysid toxicity found. This could be expected, based on the fact that chlorpyrifos tends to sorb to particulates, and this sorption should make the chlorpyrifos less toxic. Further, there are likely other toxicants in the samples which are causing part of this toxicity. Their tendency for sorption and other factors that influence their persistence in toxic forms is unknown.

January 29, 1999, Bay Sampling Study

The direct surface runoff from the January 25 through 27 storm had largely subsided by the time the samples were taken on January 29, 1999. Sampling at four stations was completed from about 0915 hr to 1125 hr on this day. The estimated discharge to the Bay at the time of sampling was low, about 18 cfs. The tide during this period was receding, which could tend to promote stratification. However, given the low discharge of San Diego Creek, only a small near-surface fresher water lens near the Jamboree Station was, as expected, found.

The salinity data indicates that there had been appreciable mixing of the recent freshwater inputs into the Bay water column down to the Big Canyon Wash station. There were, however, appreciable salinity gradients on January 29 for the Jamboree station and the San Diego Creek Bay station. The Northstar Beach station showed complete mixing, top to bottom, of the freshwater inputs to the Bay at the time of sampling. The Jamboree Station shows a marginal stratification for the top 0.1 m with a salinity of 7.5 ppt, increasing to about 17 ppt by a depth of 0.2 m. The remaining data indicate that salinity varies from about 17 ppt (at 0.3 m) to about 28 ppt (at about 5 m).

The set of samples collected on January 29, 1999, well down on the hydrograph for this stormwater runoff event, showed (Table 3-67) that San Diego Creek at Campus Drive (C29) was back to almost normal TDS with a specific conductivity of 1,870 µmhos/cm (µS/cm). The surface water at Jamboree Surface station (JS29) had 7.5 ppt salinity, with a bottom water salinity of 28.2 ppt. While there was readily measurable diazinon of 432 and 197 ng/L at Jamboree Bay sampling station surface and bottom, respectively, the chlorpyrifos concentrations were 15 and 2 ng/L, respectively, indicating that there was less than 1 mysid TUa expected for San Diego Creek water as it enters Upper Newport Bay and within the Bay. The San Diego Creek water (C29) was found to be nontoxic to *Americamysis bahia* on January 29, 1999. This is in accord with what would be expected, based on the concentrations of chlorpyrifos found and the characteristics of the water.

Therefore, it is evident that, while potentially toxic concentrations of chlorpyrifos were found in the surface waters of San Diego Creek as it enters Upper Newport Bay on January 25, 26, and 27, 1999, this toxicity did not persist over large areas of the Bay for a sufficient period of time to likely be adverse to marine zooplankton that would migrate into the surface fresher water areas, except possibly near the Jamboree Sampling Station. The January 25-27, 1999, stormwater runoff event is unusual, in that the runoff would be toxic for approximately 3 days. A more typical runoff event of 1 day's duration would not likely cause the persistence of toxic conditions for three days.

July 21, 1999, San Diego Creek Sample

A dry weather flow sample of San Diego Creek water was collected on July 21, 1999. The toxicity test results for this sample are presented in Table 3-75. The data in this table show that 100 percent of the *Ceriodaphnia* were killed within 5 days. This same sample was set up again with and without PBO. The data presented in Table 3-75 show that this time 100 percent of the *Ceriodaphnia* were killed within 4 days. The addition of PBO eliminated this toxicity.

The July 21, 1999, dry weather flow sample was also tested for toxicity to fathead minnow larvae and the algae *Selenastrum*. Table 3-76 shows that there was no toxicity to fathead minnow larvae. However, as shown in Table 3-77, there was apparent toxicity to *Selenastrum* in four days. That same sample was set up again. This time (see Table 3-77) there was no toxicity to *Selenastrum*.

The chemical testing for electrical conductivity, pH, hardness and alkalinity (see Table 3-78) shows that the values were all within the range expected. The APPL Laboratories GC scan of the San Diego Creek sample collected on July 21, 1999 is presented in Tables 3-79 and 3-80. As shown, all OP and carbamate pesticides that are normally included in the US EPA GC 8141 and 8321A scans were below detectable levels.

Overall, it can be concluded that the dry weather flow sample of San Diego Creek taken on July 21, 1999, showed a low level toxicity to *Ceriodaphnia* and was nontoxic to fathead minnow larvae and *Selenastrum*. The August 1998 sample of San Diego Creek water taken at Campus Drive could have also shown a low level of toxicity, although because of the high salt content this sample had to be diluted to 66 percent. With this dilution, it was nontoxic to *Ceriodaphnia*.

Table 3-75
Summary of 7-Day *Ceriodaphnia* Toxicity Test Conducted on Samples Collected from Upper Newport Bay Watershed on July 21, 1999

Set up on 7/23/99

Treatment	Reproduction[1] (neonates/adult)		Mortality[1] (%)	Final pH @ 24 hr
	X	se		
Laboratory Control	23.6[P]	1.3	0[P]	8.3
San Diego Creek at Campus	*	*	100 (5)	8.6

[P] The laboratory control met all EPA criteria for test acceptability. 90% of the daphnids had a third brood.

[1] Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the Laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's Test ($p<.05$).

Table 3-75 (continued)
Summary of *Ceriodaphnia* 7-Day Phase I TIE Conducted on Samples Collected from San Diego Creek at Campus on July 21, 1999[1,2]

Set up on 8/5/99

Treatment	% Mortality for each day of the test[3]							Conclusions	Final pH
	1	2	3	4	5	6	7		@ 24 hr
Laboratory Control			5	10	10	10	15	Control met all EPA criteria for test acceptability.	8.4
Laboratory Control + 100 ppb PBO			5	5	5	5	5	No artifactual toxicity present in control blank.	8.3
San Diego Creek at Campus		5	24	100	100	100	100	Toxicity detected.	8.6
San Diego Creek at Campus + 100 ppb PBO							0	Alleviation of toxicity with the addition of PBO suggests that toxicity was caused by a metabolically activated organophosphorus pesticide.	8.6

[1] Four replicates with 18 ml of sample and five *Ceriodaphnia* each.

[2]Daphnids were fed the standard EPA amount of food for only 4 hr/day.

[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-76
Summary of 7-Day *Pimephales* Toxicity Test Conducted on Samples Collected from Upper Newport Bay Watershed on July 21, 1999

Set up on 7/22/99

Treatment	Growth[1] (mg/indiv)		Mortality (%)[1]		Final pH @24 hr
	x	se	X	se	
Laboratory Control	0.258[P]	0.009	1.3[P]	1.3	8.0
San Diego Creek at Campus	0.331	0.006	0.0	0.0	8.5

[P]The laboratory control met the criteria for test acceptability.

[1]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test (p<.05).

Table 3-77
Summary of 96-Hr *Selenastrum* Toxicity Test Conducted on Samples Collected from Upper Newport Bay Watershed on July 21, 1999

Set up on 5/22/99

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH @ 96 hr
	X	se		
Laboratory Control	90.8[P]	4.2	9.3	7.9
San Diego Creek at Campus	24.5	3.3	27.0	9.0

[P] The laboratory control met all EPA criteria for test acceptability. The coefficient of variation was 9.3% in this treatment.

[1] Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test (p<.05).

Summary of 96-Hr *Selenastrum* Re-Test Conducted on Samples Collected from Upper Newport Bay Watershed on July 21, 1999

Set up on 5/27/99

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH
	X	se		@ 96 hr
Laboratory Control	76.0[P]	3.8	16.0	8.5
San Diego Creek at Campus	116.7	5.5	9.4	8.8

[P] The laboratory control met all EPA criteria for test acceptability. The coefficient of variation was 9.3% in this treatment.

[1] Highlighted areas indicate a significant reduction in growth compared to the laboratory control.

Table 3-78
Summary of Chemical Characteristics Measurements on Samples COLLECTED FROM UPPER NEWPORT BAY WATERSHED ON JULY 21, 1999

Treatment	Field Temp (°C)	pH Field	pH Lab	EC (µmhos/cm) Field	EC (µmhos/cm) Lab	Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Laboratory Control (EPAMH)			8.4		273	8.1	80	74
Laboratory Control (SSEPAMH)			8.3		212	7.5	88	66
Laboratory Control Distilled)			7.8		228	8.8	0	6
San Diego Creek at Campus Campus	27	8.6	8.7	2.9E3	2.4E3	7.8	620	208

Table 3-79
Analysis of San Diego Creek at Campus Drive

Project: UPPER NEWPORT
Sample ID: 072199GFL-C
Sample Collection Date: 7/21/99
Sample Extraction Date: 8/2/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 30844

US EPA 8141 Special Low-Level List

Analyte	Result (μg/L)	PQL (μg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	Not detected	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	Not detected	0.05
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	Not detected	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	Not detected	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	66.6%	60 - 150
Surrogate: Triphenylphosphate	63.3% #	76 - 140

= Recovery is outside QC limits.

Table 3-80
Analysis of San Diego Creek at Campus Drive

Project: UPPER NEWPORT
Sample ID: 072199GFL-C
Sample Collection Date: 7/29/99
Sample Extraction Date: 8/3/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 30844

US EPA 8321A

Analyte	Result (μg/L)	PQL (μg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	Not detected	0.4
Bromacil	Not detected	0.4
Carbaryl	Not detected	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	0.4
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	0.4
Methiocarb	Not detected	0.4
Methomyl	Not detected	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	0.4
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	92.5%	40 – 140%

YORBA LINDA, CA, RESIDENTIAL STORMWATER RUNOFF TOXICITY

As part of the Evaluation Monitoring Demonstration Project, samples were taken of Yorba Linda, CA, residential stormwater runoff in the Santa Ana River watershed. The general watershed characteristics and land uses along the Santa Ana River are provided here as background for the toxicity testing that was completed on March 15, 1999, in Yorba Linda, CA.

The lower Santa Ana River flows about 31 mi from Prado Dam through the Santa Ana Canyon and the cities of Yorba Linda, Orange, Anaheim, Santa Ana, Fountain Valley, Costa Mesa, and Huntington Beach before discharging into the Pacific Ocean. About 60 percent of the drainage area tributary to the lower River lies within the Santa Ana Mountains and the Chino Hills; the remaining area lies within the coastal plain that extends to the Pacific Ocean. Several tributaries join the lower Santa Ana River, principal among these is Santiago Creek, with a watershed of about 103 mi^2. The average slope of the lower Santa Ana River from Prado Dam to the ocean is about 15 ft/mi. Figure 3-1 shows the lower Santa Ana River watershed.

Land use within the Santa Ana River watershed varies greatly, with nearly all types of uses from commercial/industrial to park and open space represented. Mountain areas are expected to remain largely undeveloped; however, valley areas within the watershed will probably approach complete urbanization. Table 3-81 provides estimates for watershed area and percent impervious for current and future estimated "build out" conditions (US ACOE, 1988) within the Santa Ana River watershed.

Table 3-81
Land Use – Santa Ana River Watershed

Concentration Point	Area (mi^2)	Percent Impervious	
		Existing Condition	Future Condition
Santa Ana River at Prado Dam	2,255	11	20
Prado Dam to Weir Canyon Rd.	35.8	5.8	10.4
Prado Dam to Pacific Ocean	60.1	21.5	29
Santiago Creek Watershed	102.7	3	10.5
Santa Ana River Watershed at Ocean	2450	10.8	19.6

US ACOE, 1988

An extensive amount of hydrologic analysis has been performed within the Santa Ana River watershed, the most comprehensive of which was completed by the Los Angeles District Corps of Engineers in association with the Santa Ana River Mainstem Improvement Project. Completion of the Mainstem Project, which includes the construction of the Seven Oaks Dam in the San Bernardino Mountain foothills and the raising of Prado Dam, will alter the discharges along the Santa Ana River. Consequently, discharges have been provided in Table 3-82 for "with project" and "without project," representing future (with the Mainstem Project and full urbanization) and current (with current urbanization) conditions, respectively. The Mainstem Project is expected to be completed by the year 2005.

Table 3-82 indicates the discharges for selected storm return periods from 100 yr to 2 yr. The discharges indicated represent the estimated magnitude of runoff from a rainfall event that has a chance of occurring every "n" years. Release rates from Prado Dam are higher for more frequent return intervals in the after-project condition due to the assumed full urbanization upstream; interim condition flows that occur when the Mainstem Project is complete but the watershed has not yet fully urbanized, would be less than the values indicated.

Figure 3-1 Lower Santa Ana Watershed

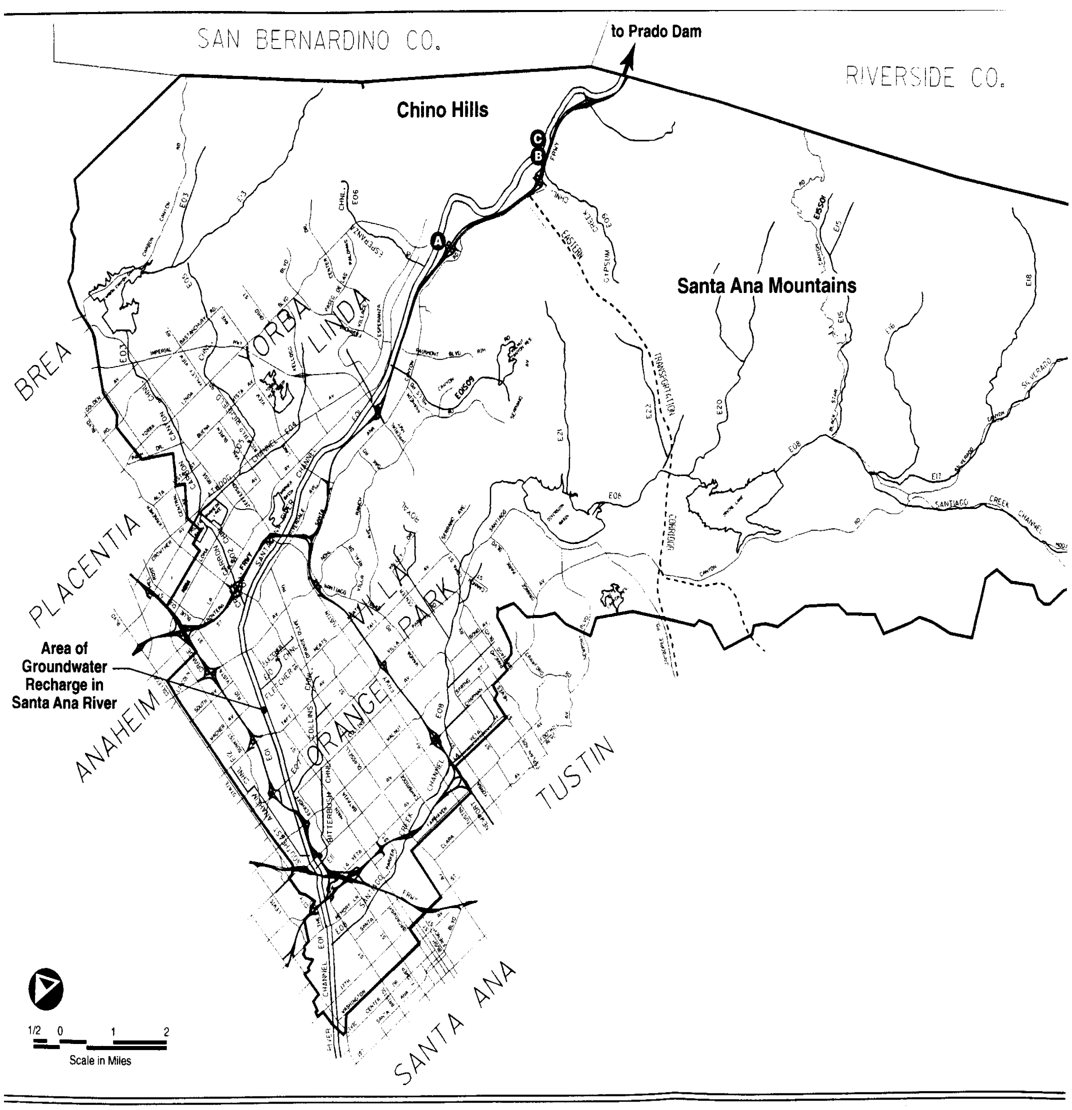


Table 3-82
Discharge Analysis
Lower Santa Ana River
(ft^3/sec)

Location	Q_{100}	Q_{25}	Q_{10}	Q_2	$A_{total(sq.mi.)}$
At Prado Dam (inflow, w/o project)	230,000	72,000	28,000	2,800	2,255
At Prado Dam (inflow, with project)	230,000	75,000	30,000	3,100	2,255
At Prado Dam (outflow, w/o project)	50,000	5,600	3,100	600	2,255
At Prado Dam (outflow, with project)	30,000	22,000	11,000	2,200	2,255
At Imperial Highway (w/o project)	50,000	6,000	3,500	700	2306
At Imperial Highway (with project)	36,000	25,000	13,000	3,800	2306
At Santa Ana (w/o project)	45,000	17,000	12,000	1,800	2447
At Santa Ana (with project)	42,000	27,500	18,000	4,700	2447

$A_{total(sq\ mi)}$ = Total area in square miles

US ACOE, 1998

The water quality characteristics of the Santa Ana River will be highly dependent on the release of water from Prado Dam. The flood protection capacity of Prado Dam will be increased from a present 70-year event to an estimated 190-year event with the Mainstem Project. For water surface elevations lower than elevation 490 National Geodetic Vertical Datum (NGVD) (reservoir pool elevation), releases are normally made to accommodate downstream groundwater recharge capabilities. For water surface elevations higher than elevation 490 NGVD, releases are a function of reservoir water surface elevations only. Releases from the reservoir range from a minimum outflow of 50 cfs to 1,500 cfs (depending on pool elevation) to a future maximum of 30,000 cfs at the spillway crest corresponding to a reservoir pool elevation of 563 NGVD. Sustained releases above 2,500 cfs have historically caused severe invert degradation and damage to downstream habitat in the Santa Ana River. The maximum current scheduled normal release is 5,000 cfs. Releases greater than 5,000 cfs would result from spillway flow (USACOE, 1988).

Once the Santa Ana River Mainstem Project is completed (including improvements to the lower Santa Ana River), the maximum scheduled release would increase to 30,000 cfs. Sustained releases of up to 2,000 cfs from Prado Dam for several days after major storm events are not uncommon. According to Risk Sciences (1993), the management of the Santa Ana River for flood control is significantly detrimental to the aquatic life resources of the Santa Ana River in between 17th Street in Santa Ana and Prado Dam (Reach 2). The high-flow releases from Prado Dam are significantly deleterious to maintaining suitable aquatic life habitat in the Santa Ana River in Reach 2.

Little information is available regarding the magnitude of floods occurring prior to 1850. Historical references indicated that medium to large floods occurred in 1825, 1844, 1840, 1850, 1959, 1862, 1867, 1976, 1884, 1886. 1889, 1894, 1903, 1910, 1914, 1916, 1921, 1922, 1927, 1938, 1943, 1965, 1966, 1969, 1978, 1980 and 1983. Following the historical floods of the 1800s and early 1900s, considerable changes have occurred in the drainage basin. Runoff characteristics of the majority of the valley areas have been changed by urbanization and agriculture. The mountain areas have remained relatively unchanged, although several small reservoirs, detention dams, and debris basins have been constructed at the canyon mouths. However, mountain runoff today would be similar to that incurred in the past, since these small structures would have little effect on major floods on the main stem of the Santa Ana River above Prado Dam. Valley runoff would be considerably higher in both peak and volume because of the increase in impervious cover due to development and channelization of flows.

The storm of February/March of 1938 was one of the most severe general storms of record for southern California. Ground conditions were conducive to runoff. The storm of January 1943 was the most severe of its kind on record. Local thunderstorms resulted in short-period precipitation of near record-breaking magnitude for the southern California coastal region. The January/February storms of 1969 brought extremely heavy precipitation to the southern California area. The storms of February and March of 1978 brought moderate to heavy precipitation into southern California. Storms and floods of 1983 were the climax of a season of repeated moderate-to-heavy storms across southern California, resulting from the strongest El Nino phenomenon in many decades.

The Santa Ana River Basin encompasses about 2,450 mi^2 (1,568,000 acres), excluding areas tributary to Baldwin Lake and Perris Reservoir that do not generally contribute runoff to the Santa Ana River (USACOE, 1988). About 2,255 mi^2 (1,443,200 acres) of the watershed are upstream of Prado Dam, with the remaining 195 mi^2 (124,800 acres) below Prado Dam. About 2284.5 square miles of area concentrates at the Gypsum Canyon sampling site. The area tributary to the sampling point at the Weir Canyon sampling site is 2,290.8 mi^2. The residential area tributary to the storm drain at Camino de Bryant, encompasses about 0.30 mi^2 (192 acres). See Figure K-2 for the residential drainage study area.

About 23 percent of the watershed is within the San Gabriel and San Bernardino Mountains (563.5 square miles), about 9 percent (220.5 mi^2) in the San Jacinto Mountains and about 5 percent (122.5 mi^2) in the Santa Ana Mountains. The remaining watershed area consists of broad alluvial valleys and foothill areas. The maximum elevation in the watershed reaches 11,502 ft at San Gorgonio Mountain in the San Bernardino Mountains, which contain the headwaters of the Santa Ana River. The Santa Ana River has an average gradient of about 240 ft/mi in the mountains and about 20 ft/mi near Prado Dam (USACOE, 1988).

The SARWQCB (1995) divides the Santa Ana River into various reaches. Reach 2 of the Santa Ana River is between 17th Street in Santa Ana and Prado Dam. This SARWQCB report characterizes Reach 2 as having beneficial uses that include agricultural water supply; groundwater recharge; water contact recreation; noncontact recreation; warm freshwater habitat;

groundwater recharge; wildlife habitat; and rare, threatened, and endangered species. This reach of the river is excepted from direct municipal water supply use, and does not support cold water fisheries; preservation of biological habitats of special significance; and spawning, reproduction, and development of fish and wildlife.

The SARWQCB (1995) characterizes Reach 2 of the Santa Ana River and near Gypsum Canyon as deep in many places with some rocky substrate and rapid sections that support a variety of organisms. Further, Santa Ana River flows are a significant source of groundwater recharge in the lower basin, which provides domestic water supplies for more than 2 million people. The river flows account for more than 70 percent of the total recharge. Additional information on the water quality characteristics of the Santa Ana River in Reach 2 is provided in Risk Sciences reports (1993).

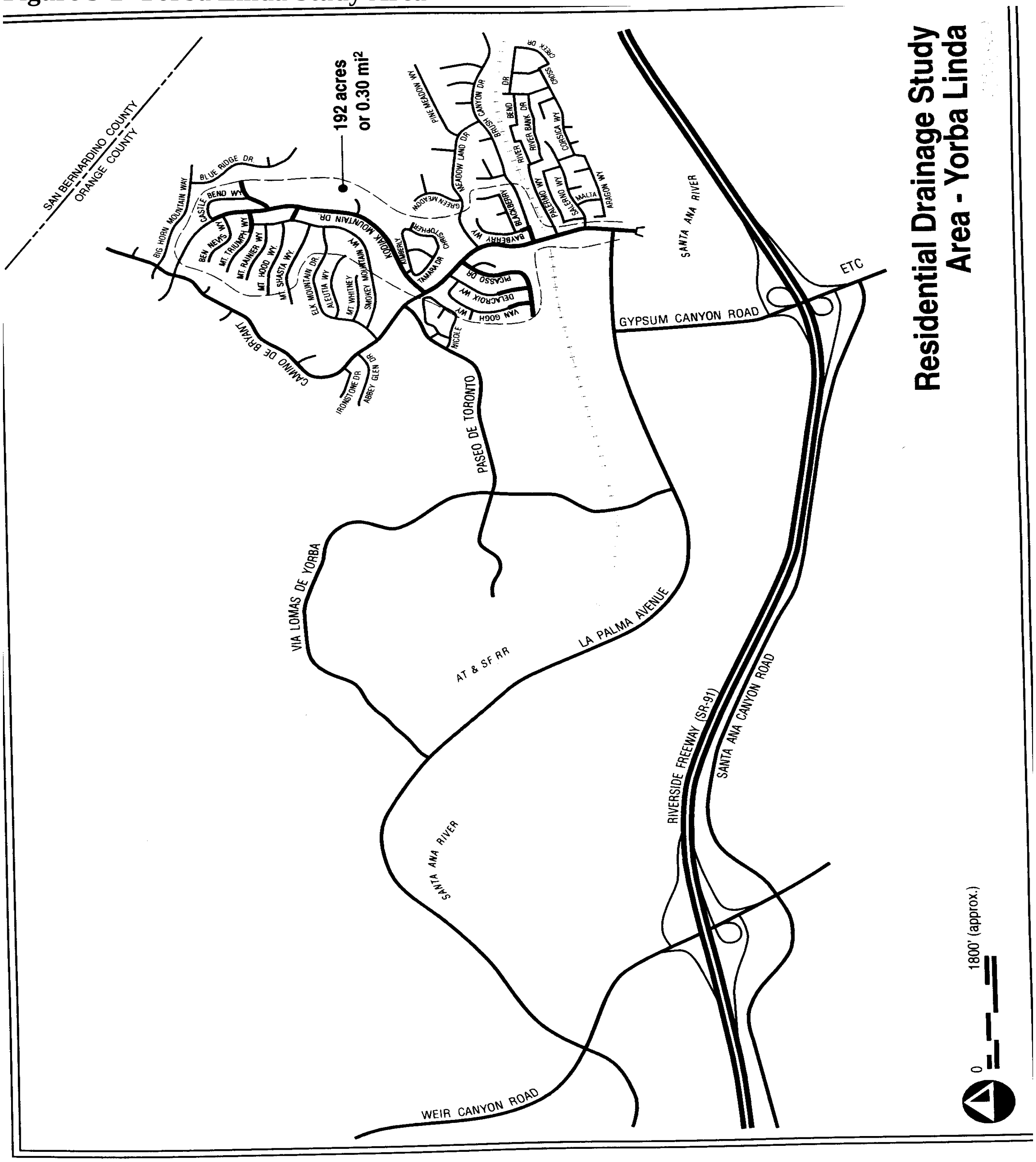
Toxicity Testing in the Lower Santa Ana River

Three sampling stations were used during the sample collection on March 15, 1999, along the Santa Ana River. Station locations are shown in Figure 3-2. These stations were at Weir Canyon Road, Gypsum Canyon Road and Camino de Bryant. The Weir Canyon Road station is located at the bridge on Weir Canyon Road that passes over the Santa Ana River, bounded by State Route 91 or Riverside/Artesia Freeway to the south and La Palma Avenue to the north. The immediate vicinity is just west of Featherly Park in a commercial area of Yorba Linda, near a shopping center and car dealership, with residential development within close proximity. Samples were taken by bucket from the center of the bridge span.

The Gypsum Canyon Road station is located at the bridge on Gypsum Canyon Road that passes over the Santa Ana River, crossing over the center of Featherly Regional Park at the widest portion of the park and close to the campgrounds in the park. The sampling station on Gypsum Canyon is bounded by State Route 91 on the south and La Palma Avenue on the north. Samples were taken by bucket from the center of the bridge span. Housing developments are in the near vicinity. The sampling at this station did not likely include the runoff from the residential development that discharged to the Santa Ana River just upstream on the west side of the river. This discharge did not have sufficient distance to mix across the river before the Gypsum Canyon Road bridge sampling.

The Camino de Bryant station is located about 30 yards southeast of the La Palma Avenue/Camino de Bryant intersection. A storm drain discharging from a residential area to the north of La Palma Avenue was sampled at this station. The size of the pipe at the outfall is 48 in. in diameter. The drainage area of the residential area draining into this pipe is about 0.30 mi^2 (192 ac).

Figure 3-2 Yorba Linda Study Area



The drainage area (192 acres or 0.30 mi^2) is primarily comprised of single family residences built along a steep hillside area. The homes are generally at a density of 5-7 homes per acre, with a total of approximately 960 to 1350 homes. About 30 percent (approximately 58 acres) of the drainage area remains as natural open space, consisting of steep hillsides with natural grassland cover.

March 15, 1999 Stormwater Sampling Event

A total of 0.36 inches of rain was recorded in Yorba Linda at Device ID 1165 for the March 15, 1999, storm. The time of the rainfall was about 4 hr.

Due to the storage of Prado Dam, and the large watershed of the Santa Ana River at this location (2,255 mi^2), it is not practical to compute the storm's average loss rate, volume of direct runoff, or lag time. Estimates of these parameters would require the analysis of many rain gages throughout the watershed, as well as information regarding the change in storage of the primary flood control reservoirs.

The sample time was 1138 hr at Weir Canyon Road, 1300 hr at Camino de Bryant and 1400 hr at Gypsum Canyon Road.

The Weir Canyon sample site is about 3 mi upstream of Imperial Highway and 6.5 mi downstream of Prado Dam. The Gypsum Canyon sample site is approximately 4.7 mi upstream of Imperial Highway and 4.8 mi downstream of Prado Dam. The residential sample site at Camino de Bryant is approximately 5.3 mi upstream from Imperial Highway and 4.2 mi downstream of Prado Dam.

The peak discharge at the USGS station just below Prado Dam for the March 15 storm was recorded as about 390 cfs. The discharge hydrograph shows that the recurrence interval for this storm is estimated to be less than 1 yr.

The shape of the hydrograph results from the release of stormwater runoff from Prado Dam. Flows less than about 1,500 cfs are generally a function of pool elevation in the reservoir and the outlet structure's hydraulic characteristics. The hydrograph exhibits an attenuated and relatively modest rate of flow increase and decrease associated with the flow passing through the reservoir pool and outlet works. The rising limb has a gradual slope; peak flows persist for 12 hr, followed by a gradually sloped declining limb.

The peak discharge for the March 15, 1999, storm recorded at the Orange County Water District gages at the Imperial Highway Station was about 420 cfs. The estimated storm recurrence interval is less than 1 year.

The hydrograph at this location is the result of additional attenuation along the Santa Ana River of the outflow hydrograph from Prado Dam, with flow added from tributaries along the Santa Ana Canyon. Local creek and storm drain confluence can have a significant effect on the main river flow due to the relatively modest release rate from Prado Dam. This can be a significant factor influencing water quality if the flow in the Santa Ana River below Prado Dam is dominated by local stormwater runoff.

The lower Santa Ana River functions somewhat independently of the upper watershed for frequent storm events. Releases from Prado Dam tend to be relatively constant and drawn from storage in the reservoir pool. The release from Prado Dam in some ways is similar to a base flow, with contributions from tributaries along the lower Santa Ana River directly additive.

The samples collected on March 15, 1999, were tested for toxicity to *Ceriodaphnia*, fathead minnow larvae, and *Selenastrum*. The results are presented in Table 3-83. The toxicity testing using *Ceriodaphnia* showed 100-percent kill within 1 day in the Camino de Bryant residential area runoff sample. The Santa Ana River sample taken at Gypsum Canyon Road was nontoxic to *Ceriodaphnia* over a 7-day period. This sample was taken downstream of where the Camino de Bryant discharges to the Santa Ana River. However, it is unlikely that the Camino de Bryant residential stormwater runoff input had mixed across the river so that it would influence the characteristics of the river at the point of sampling on the Gypsum Canyon bridge.

The Santa Ana River sample taken at Weir Canyon Road showed a low level of toxicity to *Ceriodaphnia*, which was manifested as 80-percent kill on the seventh day. The Weir Canyon Road sample was taken downstream of where the Camino de Bryant, as well as other residential areas, discharge stormwater to the Santa Ana River. It is evident that the nontoxic base flow of the Santa Ana River was able to significantly dilute the stormwater runoff to the river from residential areas along the river. The toxicity testing with fathead minnow larvae and the alga *Selenastrum* showed that the Santa Ana River, as well as the Camino de Bryant runoff sample, was nontoxic to these two types of organisms.

Table 3-84 presents the results of a dilution series testing of *Ceriodaphnia* toxicity for the Camino de Bryant sample. The 12.5-percent Camino de Bryant sample killed all *Ceriodaphnia* within two days. When 100 µg/L PBO was added to the 12.5-percent Camino de Bryant sample, the 100-percent kill was delayed 1 day, to 3 days. These results indicate that there is appreciable toxicity in these samples that is likely not due to an OP pesticide. As shown in Table 3-84, the 6.25-percent Camino de Bryant sample still showed toxicity to *Ceriodaphnia*, while the 3.13-percent sample was nontoxic to *Ceriodaphnia*. These results indicate that there was between 16 and 32 TUa of *Ceriodaphnia* toxicity in this sample.

This level of acute *Ceriodaphnia* toxicity is unusual for urban stormwater runoff from residential areas. Typically in the San Francisco Bay area, and in Sacramento and Stockton, California, stormwater runoff from urban residential areas contains 1 to 2 TUa of *Ceriodaphnia* toxicity. It is evident that there was a substantial amount of *Ceriodaphnia* toxicity in the March 15, 1999, sample that is atypical of what is expected for urban stormwater runoff, based on the results from other areas. Table 3-85 presents a summary of the chemical characteristics of the samples taken on March 15, 1999. The results of the chemical analyses do not show any unusual characteristics for the parameters determined.

Tables 3-86, 3-87, 3-88 and 3-89 present the results of the dual column GC analysis of the Camino de Bryant (Table 3-86 and 3-87) and the Santa Ana River at Weir Canyon Road (Tables 3-88 and 3-89) for the OP and carbamate pesticides. Table 3-86 shows that the Camino de Bryant stormwater runoff sample collected on March 15, 1999, contained 400 ng/L of chlorpyrifos and 1,600 ng/L of diazinon. This sample also contained 300 ng/L of malathion, as well as 500 ng/L of propoxur. This is the first time that propoxur has been detected in any of the stormwater runoff samples collected in these studies. Propoxur is a carbamate pesticide that is used for structural pest control, as well as on some agricultural crops. It is not particularly toxic to *Daphnia magna*, and therefore would not be expected to be toxic to *Ceriodaphnia* at the concentrations found in this study.

The Santa Ana River at Weir Canyon Road contained about 30 ng/L chlorpyrifos and 350 ng/L of diazinon. These concentrations are just on the edge of that necessary to be toxic to *Ceriodaphnia* over extended periods of time.

Based on the pesticides found in the Camino de Bryant stormwater runoff sample, there is an estimated 4.4 TUa of chlorpyrifos and 3.5 TUa of diazinon. The malathion and propoxur are present at nontoxic concentrations. Therefore, the total estimated TUa, based on diazinon and chlorpyrifos, is about 9 TUa units. Since the total measured TUa using the toxicity test dilution series is 16 to 32 units, there is a large amount of unknown-caused toxicity in this sample.

There is need to follow up on the sampling in the Yorba Linda residential area, to determine the constituents responsible for this unknown-caused toxicity. Also, additional studies of this type need to be done on strictly residential stormwater runoff in the Upper Newport Bay watershed.

Table 3-83
Summary of Results of Toxicity Tests Conducted on Water Samples Collected from Santa Ana River (SAR) Watershed on March 15, 1999

7-day *Ceriodaphnia* Toxicity Tests

Set up on 3/17/99

Treatment	Reproduction[1] (neonates/adult)		% Mortality for each day of test[1]							Final pH @ 24 hr
	mean	Standard error	1	2	3	4	5	6	7	
Laboratory Control	21.3[P]	0.7	0	0	0	0	0	0	0	8.3
SAR at Weir Canyon Road	*	*	0	0	0	0	0	0	80	8.6
SAR at Gypsum Canyon Road	26.9	2.6	0	0	0	0	0	0	0	8.4
SAR at Camino de Bryant	*	*	100	100	100	100	100	100	100	8.4

[P]The laboratory control met the US EPA criteria for test acceptability. 100% of the daphnids had a third brood.

[1]Highlighted cells indicate a significant reduction in reproduction or increase in mortality relative to the laboratory control water. The mortality endpoint was analyzed using Fisher's Exact Test. The reproductive endpoint was analyzed using Dunnett's test ($p<0.05$).

* Due to significant mortality observed in these samples, reproduction was not calculated.

7-day *Pimephales* Toxicity Tests

Treatment	Growth[1] (mg/individual)		Mortality (%)[1]		Final pH @24 hr
	mean	standard error	mean	standard error	
Laboratory Control	0.313[P]	0.011	2.5[P]	3.0	7.9
SAR at Weir Canyon Road	0.298	0.011	13.0	10.0	8.4
SAR at Gypsum Canyon Road	0.295	0.025	2.5	3.0	8.4
SAR at Camino de Bryant	0.308	0.014	7.5	3.0	8.2

[P]The laboratory control met the US EPA criteria for test acceptability.

[1]Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

4-day *Selenastrum* Toxicity Tests

Treatment	Cell Count (x 10^4)[1]		% CV	Final pH @ 96 hr
	Mean	standard error		
Laboratory Control	186.9[P]	9.1	9.7	7.6
SAR at Weir Canyon Road	351.9	7.8	4.4	9.6
SAR at Gypsum Canyon Road	337.4	6.2	3.7	9.4
SAR at Camino de Bryant	312.3	6.9	4.4	10.1

[P]The laboratory control met the US EPA criteria for test acceptability. The coefficient of variation was 9.7% in this treatment.

[1]Highlighted areas indicate a significant reduction in growth compared to the laboratory control. Cell counts were analyzed using Dunnett's Test ($p<0.05$).

Table 3-84
Summary of *Ceriodaphnia* 96-hr TIE Conducted on Water Samples Collected from the Santa Ana River at Camino de Bryant on March 15, 1999[1,2]

PBO Tests

Set up on 3/19/99

TREATMENT	% Mortality for each day of the test[3]				Conclusions	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.2
Laboratory Control + 100 μg/L PBO			5	5	No artifactual toxicity present in control blank.	8.3
12.5% Camino de Bryant	5	100	100	100	Toxicity detected.	8.3
12.5% Camino de Bryant + 100 μg/L PBO		70	100	100	No decrease in mortality with addition of PBO suggests that toxicity was not due to a metabolically activated OP pesticide.	8.3

Dilution Series

TREATMENT	% Mortality for each day of the test[3]				CONCLUSIONS	Final pH @ 24 hr
	1	2	3	4		
Laboratory Control				0	Control met the US EPA criteria for test acceptability.	8.4
25% Camino de Bryant	100	100	100	100	Toxicity detected.	8.4
12.5% Camino de Bryant	50	100	100	100		8.4
6.25% Camino de Bryant		19	71	81		8.4
3.13% Camino de Bryant		5	5	5	No toxicity detected.	8.5
1.57% Camino de Bryant				0		8.5

[1]Four replicates with 18 ml of sample and 5 *Ceriodaphnia* each.
[2]Daphnids were fed the standard US EPA amount of food for only 4 hr/day.
[3]Highlighted cells indicate areas of significant interest. No statistical analyses were done.

Table 3-85
Summary of Chemical Characteristics of Water Samples
Collected from the Santa Ana River (SAR) Watershed on March 15, 1999

Treatment	Field Temp	pH		EC (μmhos/cm)		Lab DO (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
		Field	lab	Field	lab			
Lab Control (EPAMH)			8.1		295	8.0	80	64
Lab Control (SSEPAMH)			8.1		218	8.0	86	68
Lab Control (Glass Distilled)			7.4		94	8.1	0	4
SAR at Weir Canyon Road	15.2	8.4	8.3	830	864	8.4	272	190
SAR at Gypsum Canyon Road	16.1	8.1	8.3	930	892	8.1	280	103
SAR at Camino de Bryant	17.2	8.1	8.2	1170	1117	7.9	352	128

Table 3-86
Analysis of Water Sample from Camino de Bryant Stormwater Runoff

Project: Santa Ana River
Sample ID: GFL-RR 031599
Sample Collection Date: 3/15/99
Sample Extraction Date: 3/26/99
Sample Analysis Date: 4/7/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29948
APPL ID AP76964

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.40	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	1.6	0.50
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	0.30 Y	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
$Parathion_1$ ethyl	Not detected	0.10
$Parathion_1$ methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	Not detected	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Trifluralin	Not detected	0.10
Surrogate: Tributylphosphate	123 %	60-150 %
Surrogate: Triphenylphosphate	102 %	76-140 %

Y = Percent D > 25 %

Table 3-87
Analysis of Water Sample from Camino de Bryant Stormwater Runoff

Project: Santa Ana River
Sample ID: GFL-RR 031599
Sample Collection Date: 3/15/99
Sample Extraction Date: 3/26/99
Sample Analysis Date: 4/26/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29948
APPL ID: AP76964

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	Not detected	0.4
Bromacil	Not detected	1
Carbaryl	Not detected	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	I
Fenuron	Not detected	0.4
Fluometuron	Not detected	1
Linuron	Not detected	0.4
Methiocarb	Not detected	0.4
Methomyl	Not detected	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	1
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	0.5	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	90.5 %	40-140 %

Table 3-88
Analysis of Water Sample from Santa Ana River Collected at Weir Canyon Road

Project: Santa Ana River
Sample ID: GFL-DS 031599
Sample Collection Date: 3/15/99
Sample Extraction Date: 3/26/99
Sample Analysis Date: 4/7/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29948
APPL ID AP76963

US EPA 8141 Special Low-Level List

Analyte	Result (µg/L)	PQL (µg/L)
Azinphosmethyl	Not detected	1.0
Bolstar	Not detected	0.10
Chlorpyrifos	0.03 J	0.05
Coumaphos	Not detected	0.10
Def	Not detected	0.10
Demeton-s	Not detected	0.20
Diazinon	0.35 Y	0.05
Dichlorvos	Not detected	0.20
Dimethoate	Not detected	0.10
Diphenamid	Not detected	0.10
Disulfoton	Not detected	0.10
Ethion	Not detected	0.10
Ethoprop	Not detected	0.10
Fensulfothion	Not detected	0.20
Fenthion	Not detected	0.10
Malathion	Not detected	0.10
Merphos	Not detected	0.10
Methidathion	Not detected	0.10
Methyl Trithion	Not detected	0.20
Mevinphos	Not detected	0.70
Naled	Not detected	0.50
Parathion, ethyl	Not detected	0.10
Parathion, methyl	Not detected	0.10
Phorate	Not detected	0.10
Phosalone	Not detected	0.10
Phosmet	Not detected	1.0
Prometon	Not detected	0.10
Prowl	Not detected	0.10
Ronnel	Not detected	0.10
Simazine	Not detected	0.50
Trichloronate	Not detected	0.10
Tnfluralin	Not detected	0.10
Surrogate: Tributylphosphate	124 %	60-150 %
Surrogate: Triphenylphosphate	97.7 %	76-140 %

J = Estimated value, below quantitation limit
Y=Percent D>25%

Table 3-89
Analysis of Water Sample from Santa Ana River Collected at Weir Canyon Road

Project: Santa Ana River
Sample ID: GFL-DS 031599
Sample Collection Date: 3/15/99
Sample Extraction Date: 3/26/99
Sample Analysis Date: 4/25/99

APPL Inc.
4203 West Swift Avenue
Fresno, CA 93722
ARF: 29948
APPL ID: AP76963

US EPA 8321A

Analyte	Result (µg/L)	PQL (µg/L)
Aldicarb	Not detected	0.4
Aminocarb	Not detected	0.4
Barban	Not detected	3.5
Benomyl (Carbendazim)	Not detected	0.4
Bromacil	Not detected	0.4
Carbaryl	Not detected	0.07
Carbofuran	Not detected	0.07
Chloroxuron	Not detected	0.4
Chlorpropham	Not detected	3.5
Diuron	Not detected	0.4
Fenuron	Not detected	0.4
Fluometuron	Not detected	0.4
Linuron	Not detected	0.4
Methiocarb	Not detected	0.4
Methomyl	Not detected	0.07
Mexacarbate	Not detected	3.5
Monuron	Not detected	0.4
Neburon	Not detected	0.4
Oxamyl	Not detected	0.4
Propachlor	Not detected	3.5
Propham	Not detected	3.5
Propoxur	Not detected	0.4
Siduron	Not detected	0.4
Tebuthiuron	Not detected	0.4
Surrogate: Oryzalin	93.4 %	40-140 %

SECTION 4
DISCUSSION

This section presents a summary of the study results obtained in this project. Also presented are the results obtained in the 1996 monitoring of San Diego Creek as it enters Upper Newport Bay. The 1996 data are included, since they are part of the overall study that is being conducted devoted to demonstrating the use of the Evaluation Monitoring approach. This section also presents a discussion of the interpretation of the water quality significance of the toxicity found, and provides guidance on the future studies that should be conducted.

SUMMARY OF STUDY RESULTS

The 1996 (Silverado, 1997a and Lee and Taylor, 1997a) monitoring of Upper Newport Bay stormwater runoff from San Diego Creek showed that the Creek waters contain constituents which are highly toxic to some zooplankton, such as *Ceriodaphnia*. During 1996-98, eleven stormwater runoff events were monitored. Table 4-1 presents a summary of the *Ceriodaphnia* toxicity results that have been found in the Upper Newport Bay watershed since the initiation of the Evaluation Monitoring Demonstration Project in the summer of 1996. Examination of this table shows that, with few exceptions, the undiluted sample of San Diego Creek water during a stormwater runoff event, obtained at Campus Drive just before where the Creek enters Upper Newport Bay killed all *Ceriodaphnia* in the test system within one day. Table 4-1 also presents a summary of the dilution series tests that were run on some of the samples, as well as an estimate of the total toxicity found in the sample in the "Measured TUa" column. Many of the samples of San Diego Creek taken at Campus Drive have at least three, and often greater than eight, acute toxic units (TUa) to *Ceriodaphnia*. This means that up to a ten-fold dilution of San Diego Creek water taken at Campus Drive during a stormwater event could be toxic to *Ceriodaphnia*.

Table 4-2 presents the results of toxicity testing that was done using *Americamysis bahia* as the test organism, where a standard sea salt mixture was added to San Diego Creek water to bring the salinity to 20 ppt. The toxicity results presented in Table 4-2 are from samples of San Diego Creek water taken at Campus Drive. The undiluted San Diego Creek sample was also toxic to *Americamysis bahia*. This indicates that there is a potential for marine zooplankton to be killed by OP pesticides and possibly other pollutants when the San Diego Creek water mixes with the marine waters in Upper Newport Bay during a stormwater runoff event.

The toxicity testing of San Diego Creek water at Campus Drive using *Ceriodaphnia* during dry weather flow conditions during 1996 and 1997 were found to be non-toxic, indicating that the toxicity was associated with land runoff from residential, commercial and/or rural areas. In general, with the exception of the samples taken on August 25, 1998, under dry weather flow conditions, no toxicity to fathead minnow larvae or algae has been found in San Diego Creek waters at Campus Drive.

Table 4-1
Summary of *Ceriodaphnia* Toxicity Test Results for
Upper Newport Bay Watershed Stormwater Runoff and Dry Weather Flow

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
10/30/96	San Diego Creek @ Campus	7	100 (1)	> 8	> 3
10/30/96	San Diego Creek @ Campus	1	100		
10/30/96	San Diego Creek @ Campus + PBO	1	100 (1)		
10/30/96	San Diego Creek @ Campus 100%	4	100 (1)		
10/30/96	San Diego Creek @ Campus 50%	4	100 (1)		
10/30/96	San Diego Creek @ Campus 50% + PBO*	4	5		
10/30/96	San Diego Creek @ Campus 50% + 200 µg/L PBO*	4	5		
10/30/96	San Diego Creek @ Campus 25%	4	100 (2)		
10/30/96	San Diego Creek @ Campus 25% + PBO*	4	0		
10/30/96	San Diego Creek @ Campus 25% + 200 µg/L PBO*	4	60		
10/30/96	San Diego Creek @ Campus 12.5%	4	5		
11/19/96	San Diego Creek @ Campus Base Flow	7	0	0	0
11/19/96	San Diego Creek @ Campus +PBO Base Flow	7	0		
11/21/96	San Diego Creek @ Campus	1	100 (1)	> 8	> 3
11/21/96	San Diego Creek @ Campus + PBO	1	100 (1)		
11/21/96	San Diego Creek @ Campus 100%	4	100 (1)		
11/21/96	San Diego Creek @ Campus 65%	4	100 (1)		
11/21/96	San Diego Creek @ Campus 65% + PBO	4	100 (1)		
11/21/96	San Diego Creek @ Campus 50%	4	100 (1)		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
11/21/96	San Diego Creek @ Campus 25%	4	100 (1)		
11/21/96	San Diego Creek @ Campus 25% + PBO	4	100 (3)		
11/21/96	San Diego Creek @ Campus 12.5%	4	100 (2)		
9/25/97	San Diego Creek @ Campus 100%	7	100 (3)	> 2	> 1.1
9/25/97	San Diego Creek @ Campus 100% + PBO	7	0		
9/25/97	San Diego Creek @ Campus 50%	7	100 (7)		
11/13/97	San Diego Creek @ Campus	7	100 (1)	4 to 8	~2
11/13/97	San Diego Creek @ Campus + PBO	7	100 (2)		
11/13/97	San Diego Creek @ Campus 100%	4	100 (1)		
11/13/97	San Diego Creek @ Campus 50%	4	100 (1)		
11/13/97	San Diego Creek @ Campus 50% + PBO	4	5		
11/13/97	San Diego Creek @ Campus 25%	4	95		
11/13/97	San Diego Creek @ Campus 25% + PBO	4	0		
11/13/97	San Diego Creek @ Campus 12.5%	4	5		
11/13/97	San Diego Creek @ Campus 6.25%	4	0		
11/30/97	San Diego Creek @ Campus	7	100 (1)	3 to 4	3 to 4
11/30/97	San Diego Creek @ Campus + PBO	7	100 (5)		
11/30/97	San Diego Creek @ Campus 100%	4	100 (2)		
11/30/97	San Diego Creek @ Campus 50%	4	100 (3)		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
11/30/97	San Diego Creek @ Campus 50% + PBO	4	5		
11/30/97	San Diego Creek @ Campus 25%	4	5		
11/30/97	San Diego Creek @ Campus 25% + PBO	4	0		
11/30/97	San Diego Creek @ Campus 12.5%	4	0		
11/30/97	San Diego Creek @ Campus 6.25%	4	0		
12/6/97	San Diego Creek @ Campus	7	100 (2)		
12/6/97	San Diego Creek @ Campus + PBO	7	0		
3/24/98 (prestorm)	Santa Ana Delhi Channel Base Flow	7	0		
3/24/98	San Diego Creek @ Campus	7	0		
3/25/98	Peters Canyon Channel @ Barranca	7	100 (1)	~16	
3/25/98	San Diego Creek @ Campus	7	100 (4)		
3/25/98	Santa Ana Delhi Channel	7	100 (4)		
3/25/98	Peters Canyon Channel @ Barranca 100%	4	100 (1)		
3/25/98	Peters Canyon Channel @ Barranca 100% + PBO	4	100 (2)		
3/25/98	Peters Canyon Channel @ Barranca 50%	4	100 (2)		
3/25/98	Peters Canyon Channel @ Barranca 50% + PBO	4	100 (2)		
3/25/98	Peters Canyon Channel @ Barranca 25%	4	100 (2)		
3/25/98	Peters Canyon Channel @ Barranca 25% + PBO	4	20		
3/25/98	Peters Canyon Channel @ Barranca 12.5%	4	90		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
3/25/98	Peters Canyon Channel @ Barranca	4	100 (1)	>16	
3/25/98	Peters Canyon Channel @ Barranca 50%	4	100 (1)		
3/25/98	Peters Canyon Channel @ Barranca 50% +50µg/L PBO	4	100 (3)		
3/25/98	Peters Canyon Channel @ Barranca 25%	4	100 (2)		
3/25/98	Peters Canyon Channel @ Barranca 25% +50µg/L PBO	4	5		
3/25/98	Peters Canyon Channel @ Barranca 12.5%	4	100 (3)		
3/25/98	Peters Canyon Channel @ Barranca 12.5% +50µg/L PBO	4	5		
3/25/98	Peters Canyon Channel @ Barranca 6.25%	4	15		
3/25/98	San Gabriel River @ San Gabriel River Pkwy., City of Pico Rivera	7	0		
3/25/98	Malibu Creek @ Piuma Rd., unincorporated area of Malibu	7	0 – impaired reproduction		
3/25/98	Ballona Creek @ Beloit St., Culver City	7	100 (5)		
3/25/98	Project 156 @ Concord St., City of Glendale	7	100 (6)		
3/25/98	LA River Wardlow @ Wardlow Rd., City of Long Beach	7	0		
3/25/98	Coyote Creek @ Spring St., City of Long Beach	7	100 (2)		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
5/5/98	San Diego Creek @ Campus	4	100 (2)		
5/5/98	San Diego Creek @ Campus + PBO	4	0		
5/5/98	Santa Ana Delhi	4	0		
5/5/98	Santa Ana Delhi + PBO	4	0		
5/12/98	San Diego Creek @ Campus	7	100 (1)	8 to 16	> 8
5/12/98	San Diego Creek @ Campus + PBO	7	100 (1)		
5/13/98	Santa Ana Delhi Channel	7	0		
5/13/98	Santa Ana Delhi Channel + PBO	7	0		
5/12/98	San Diego Creek @ Campus	4	100 (1)		
5/12/98	San Diego Creek @ Campus + PBO	4	100 (1)		
5/12/98	San Diego Creek (50%) @ Campus	4	100 (1)		
5/12/98	San Diego Creek (25%) @ Campus	4	100 (1)		
5/12/98	San Diego Creek (25%) @ Campus +PBO	4	100 (3)		
5/12/98	San Diego Creek (12.5%) @ Campus	4	100 (2)		
5/12/98	San Diego Creek (6.25%) @ Campus	4	0		
8/13/98	San Diego Creek @Campus (diluted to 2000 µmhos/cm - 66% dilution)	7	0		
8/13/98	San Diego Creek @ Campus (diluted to 2000 µmhos/cm - 66% dilution) + PBO	7	0		
8/13/98	Peters Canyon Channel @ Barranca (diluted to 2000 µmhos/cm - 68% dilution)	7	100 (5)		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
8/13/98	Peters Canyon Channel @ Barranca (diluted to 2000 μmhos/cm - 68% dilution) + PBO	7	0		
8/13/98	Hines Channel @ Irvine Creek Dr.	7	100 (1)	16 to 32	~1
8/13/98	Hines Channel @ Irvine Creek Dr. + PBO	7	100 (1)		
8/13/98	Central Irvine Channel	7	100 (1)		
8/13/98	Central Irvine Channel + PBO	7	100 (2)		
8/13/98	Santa Ana Delhi Channel (diluted to 2000 μmhos/cm - 74% dilution)	7	10 Impaired Reproduction		
8/13/98	Santa Ana Delhi Channel (diluted to 2000 μmhos/cm - 74% dilution) + PBO	7	0 Impaired Reproduction		
8/13/98	Hines Channel 6.25%	4	100 (1)		
8/13/98	Hines Channel 6.25% + PBO	4	5		
8/13/98	Hines Channel 3.13%	4	100 (4)		
8/13/98	Hines Channel 1.57%	4	0		
8/13/98	Hines Channel 1.57% + PBO	4	5		
8/13/98	Hines Channel 0.78%	4	0		
8/13/98	Hines Channel 0.39%	4	0		
8/13/98	Central Irvine Channel	4	100 (1)		
8/13/98	Central Irvine Channel 50%	4	100 (1)		
8/13/98	Central Irvine Channel 50% + PBO	4	0		
8/13/98	Central Irvine Channel 25%	4	100 (2)		
8/13/98	Central Irvine Channel 12.5%	4	35		
8/13/98	Central Irvine Channel 12.5% + PBO	4	0		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100%)	Measured TUa	Ratio TUa(measured): TUa(expected)
8/13/98	Central Irvine Channel 6.25%	4	20		
8/13/98	Central Irvine Channel 3.13%	4	5		
8/25/98	San Diego Creek @ Campus (diluted to 2000 µmhos/cm - 69% dilution)	7	0		
8/25/98	San Diego Creek @ Campus (diluted to 2000µmhos/cm - 69% dilution) + PBO	7	0		
8/25/98	Santa Ana Delhi Channel (diluted to 2000 µmhos/cm - 75% dilution)	7	0		
8/25/98	Santa Ana Delhi Channel (diluted to 2000 µmhos/cm - 75% dilution) + PBO	7	20		
8/25/98	Hines Channel	7	100 (1)	>8	~1
8/25/98	Hines Channel + PBO	7	100 (1)		
8/25/98	Hines Channel 25%	4	100 (1)		
8/25/98	Hines Channel 25% + PBO	4	15		
8/25/98	Hines Channel 12.5%	4	50		
8/25/98	Hines Channel 6.25%	4	0		
8/25/98	Hines Channel 6.25% + PBO	4	5		
8/25/98	Hines Channel 3.13%	4	0		
8/25/98	Hines Channel 1.57%	4	0		
11/8/98	San Diego Creek at Campus	7	100 (1)	16 to 32	2.5 to 5
11/8/98	Peters Canyon Channel at Barranca	7	100 (1)	16 to 32	2.5 to 5
11/8/98	Peters Canyon Channel at Barranca + PBO	7	100 (1)		
11/8/98	Harvard Ave.	7	100 (1)	16 to 32	3 to 6
11/8/98	Harvard Ave. + PBO	7	100 (1)		
11/8/98	Hines Channel	7	100 (1)	16 to 32	1.5 to 3
11/8/98	Hines Channel + PBO	7	100 (1)		
11/8/98	Santa Ana Delhi Channel	7	100 (4)		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
11/8/98	Santa Ana Delhi Channel + PBO	7	20		
11/8/98	25% San Diego Creek at Campus	4	100 (1)		
11/8/98	25% San Diego Creek at Campus + PBO	4	100 (1)		
11/8/98	12.5% San Diego Creek at Campus	4	100 (1)		
11/8/98	6.25% San Diego Creek at Campus	4	100 (2)		
11/8/98	3.13% San Diego Creek at Campus	4	0		
11/8/98	1.57% San Diego Creek at Campus	4	0		
11/8/98	25% Peters Canyon Channel at Barranca	4	100 (1)		
11/8/98	25% Peters Canyon Channel at Barranca + PBO	4	100 (1)		
11/8/98	12.5% Peters Canyon Channel at Barranca	4	100 (2)		
11/8/98	6.25% Peters Canyon Channel at Barranca	4	100 (4)		
11/8/98	3.13% Peters Canyon Channel at Barranca	4	5		
11/8/98	25% Harvard Ave.	4	100 (1)		
11/8/98	25% Harvard Ave. + PBO	4	100 (1)		
11/8/98	12.5% Harvard Ave.	4	100 (1)		
11/8/98	6.25% Harvard Ave.	4	100 (2)		
11/8/98	3.13% Harvard Ave.	4	0		
11/8/98	25% Hines Channel	4	100 (1)		
11/8/98	25% Hines Channel + PBO	4	100 (2)		
11/8/98	12.5% Hines Channel	4	100 (1)		
11/8/98	6.25% Hines Channel	4	100 (2)		
11/8/98	3.13% Hines Channel	4	5		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
11/8/98	12.5% San Diego Creek at Campus	4	100 (1)		
11/8/98	12.5% San Diego Creek at Campus + PBO	4	20	>8	
11/8/98	12.5% Peters Canyon Channel at Barranca	4	100 (1)		
11/8/98	12.5% Peters Canyon Channel at Barranca + PBO	4	5		
11/8/98	12.5% Harvard Ave.	4	100 (2)		
11/8/98	12.5% Harvard Ave. + PBO	4	0		
11/8/98	12.5% Hines Channel	4	100 (1)		
11/8/98	12.5% Hines Channel + PBO	4	10		
11/8/98	Hines Channel C8 Solid Phase Extracted Water	4	100 (1)		
11/8/98	San Diego Creek at Campus C8 Solid Phase Extracted Water	4	60		
1/21/99	San Diego Creek at Campus	7	100 (1)	2 to 4	>1
1/21/99	Hines Channel	7	100 (1)	32 to 64	>1
1/21/99	Santa Ana Delhi Channel	7	90		
1/21/99	100% San Diego Creek at Campus	4	100 (1)		
1/21/99	50% San Diego Creek at Campus	4	100 (2)		
1/21/99	25% San Diego Creek at Campus	4	10		
1/21/99	12.5% San Diego Creek at Campus	4	5		
1/21/99	6.25% Hines Channel	4	100 (1)		
1/21/99	3.13% Hines Channel	4	63		
1/21/99	1.56% Hines Channel	4	0		
1/21/99	0.78% Hines Channel	4	5		
1/21/99	100% San Diego Creek at Campus	4	100 (1)		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
1/21/99	100% San Diego Creek at Campus + PBO	4	100 (3)		
1/21/99	12.5% Hines Channel	4	100 (1)		
1/21/99	12.5% Hines Channel + PBO	4	100 (2)		
1/25/99	San Diego Creek at Campus (1000 hr)	7	100 (1)		
1/25/99	San Diego Creek at Campus (1530 hr)	7	100 (1)		
1/26/99	San Diego Creek at Campus	7	100 (1)	4 to 8	2 to 4
1/25/99	25% San Diego Creek at Campus (1000 hr)	4	100 (1)		
1/25/99	12.5% San Diego Creek at Campus (1000 hr)	4	20		
1/25/99	6.25% San Diego Creek at Campus (1000 hr)	4	10		
1/25/99	3.13% San Diego Creek at Campus (1000 hr)	4	0		
1/25/99	25% San Diego Creek at Campus (1530 hr)	4	100 (2)		
1/25/99	12.5% San Diego Creek at Campus (1530 hr)	4	0		
1/25/99	6.25% San Diego Creek at Campus (1530 hr)	4	0		
1/25/99	3.13% San Diego Creek at Campus (1530 hr)	4	0		
1/26/99	25% San Diego Creek at Campus	4	100 (2)		
1/26/99	12.5% San Diego Creek at Campus	4	0		
1/26/99	6.25% San Diego Creek at Campus	4	5		
1/26/99	3.13% San Diego Creek at Campus	4	0		
1/25/99	50% San Diego Creek at Campus (1000 hr)	4	100 (1)		

Table 4-1 (continued)

Date	Location (Treatment)	Duration of Test (days)	% Mortality[1,2] (days to 100% kill)	Measured TUa	Ratio TUa(measured): TUa(expected)
1/25/99	50% San Diego Creek at Campus (1000 hr) + PBO	4	100 (2)		
1/25/99	50% San Diego Creek at Campus (1530 hr)	4	100 (1)		
1/25/99	50% San Diego Creek at Campus (1530 hr) + PBO	4	100 (2)		
1/26/99	50% San Diego Creek at Campus	4	100 (1)		
1/26/99	50% San Diego Creek at Campus + PBO	4	100 (2)		
1/27/99	San Diego Creek at Campus	7	100 (1)	4 to 8	2 to 4
1/27/99	100% San Diego Creek at Campus	4	100 (1)		
1/27/99	50% San Diego Creek at Campus	4	100 (1)		
1/27/99	25% San Diego Creek at Campus	4	100 (3)		
1/27/99	12.5% San Diego Creek at Campus	4	0		
1/27/99	6.25% San Diego Creek at Campus	4	15		
1/27/99	50% San Diego Creek at Campus	4	100 (1)		
1/27/99	50% San Diego Creek at Campus + PBO	4	60		
1/29/99	San Diego Creek at Campus	7	100 (6)		
7/21/99	San Diego Creek at Campus	7	100 (5)		

1 100% sample unless otherwise indicated
2 Number in parenthesis indicates number of days to 100% mortality
* 100 µg/L PBO added unless noted otherwise

In March 1998 toxicity was found to fathead minnow larvae in Santa Ana Delhi Channel water under low flow conditions, indicating the possibility of illegal or illicit discharges to this Channel. Also, fathead minnow larvae toxicity was found in Hines Channel at the Irvine Boulevard sampling station in the August 1998 samples. This sampling station is just downstream from two large commercial nurseries which may have discharges or fugitive waters containing toxic constituents entering the channel. The toxicity to *Ceriodaphnia* found in the January 21, 1999, low flow sample was likely due to runoff from areas where the toxicants were used, as well as discharges from upstream sources such as the commercial nurseries. While the January 21, 1999, sample was intended to be a dry weather low flow sample, the fact that the specific conductance of the sample was lower than normal low flow conditions indicates that there was some dilution of the San Diego Creek base flow with surface runoff.

Table 4-2
Summary *of Americamysis bahia* Toxicity Tests for
San Diego Creek Stormwater Runoff at Campus Drive

Date	Location (Treatment)	% Mortality[1,2] (days)	Measured TUa	Calculated TUa Based on Chlorpyrifos Concentrations	Ratio TUa (measured): TUa(expected)
11/30/97	San Diego Creek	88 (7)	1 to 2	2.5	~1
11/30/97	San Diego Creek 100%	50 (7)			
11/30/97	San Diego Creek 50%	10 (7)			
11/30/98	San Diego Creek 25%	10 (7)			
11/30/97	San Diego Creek 12.5%	5 (7)			
11/30/97	San Diego Creek 6.25%	0 (7)			
12/6/97	San Diego Creek	62 (7)		2	
3/25/98	San Diego Creek (C) 100%	12 (7)		0	
3/25/98	San Diego Creek (D) 100%	10 (7)		0	
5/12/98	San Diego Creek 100%	100 (1)	4 to 8	2	2 to 4
5/12/98	San Diego Creek 50%	100 (2)			
5/12/98	San Diego Creek 25%	65 (3)			
5/12/98	San Diego Creek 12.5%	5 (7)			
5/12/98	San Diego Creek 6.25%	5 (7)			
11/8/98	San Diego Creek	100 (1)	>16	6	>2.6
11/8/98	San Diego Creek 100%	100 (1)			
11/8/98	San Diego Creek 50%	100 (1)			
11/8/98	San Diego Creek 25%	100 (1)			
11/8/98	San Diego Creek 12.5%	100 (2)			
11/8/98	San Diego Creek 6.25%	100 (4)			
1/25/99	San Diego Creek C2 100%	100 (2)	3	1	>3
1/25/99	San Diego Creek C2 50%	100 (3)			
1/25/99	San Diego Creek C2 25%	10 (7)			
1/25/99	San Diego Creek C2 12.5%	5 (7)			
1/25/99	San Diego Creek C2 6.25%	20 (7)			

[1]100% sample unless otherwise indicated
[2]Number in parenthesis indicates number of days to 100% mortality

The first stormwater runoff event of the fall 1998/99 season, which occurred on November 8, 1998, showed similar results in terms of toxicity levels to *Ceriodaphnia* and lack of toxicity to fathead minnow larvae and *Selenastrum* (algae), to those that were found in the first fall and subsequent stormwater runoff event sampled in 1996, 1997, and 1998. The November 8, 1998, samples of San Diego Creek water taken at various locations were found to contain from 16 to 32 *Ceriodaphnia* TUa. In addition to having high levels of diazinon and chlorpyrifos, these samples contained a variety of other OP pesticides and carbamate pesticides. The sample of San Diego Creek water just above where it enters Upper Newport Bay was found to contain in excess of 16 TUa for *Americamysis* (*Mysidopsis).*

A dry weather sample taken of San Diego Creek at Campus Drive in January 1999, after several months of no appreciable runoff, was found to be highly toxic to *Ceriodaphnia*. This sample contained a variety of OP pesticides and carbamate pesticides that had not been found at this location in the previous studies.

Table 4-3 presents a summary of information on the respective toxicities (LC_{50}) of diazinon, chlorpyrifos, methomyl, carbaryl, and malathion to *Ceriodaphnia* and *Americamysis bahia*. These values are used to estimate the toxic units of the samples based on the concentrations of diazinon and chlorpyrifos and the other pesticides for which there are LC_{50} data measured in the samples. They represent the concentrations of the constituent that are roughly equal to one acute toxic unit.

The Table 4-1 data for *Ceriodaphnia* toxicity indicate that the addition of PBO to the San Diego Creek samples, especially those that have been diluted somewhat, reduced the amount of *Ceriodaphnia* toxicity. This is an indication that the toxicity found is due, at least in part, to OP pesticides.

Table 4-4 presents the results of the ELISA and GC analysis of the Upper Newport Bay watershed samples that have been collected in this study. The data in this table show that, frequently, the concentrations of diazinon and chlorpyrifos in the San Diego Creek waters as they enter Upper Newport Bay that contain stormwater runoff are sufficient, individually and/or when mixed, to be toxic to *Ceriodaphnia*.

Table 4-3
Toxicity of Diazinon and Chlorpyrifos to
Ceriodaphnia dubia* and *Americamysis bahia

Constituent	*Ceriodaphnia* LC_{50} (ng/L)	*Americamysis bahia* LC_{50} (ng/L)
Diazinon	450	4,500
Chlorpyrifos	80	35
Methomyl	5,560	-
Carbaryl	3,500 – 5,200	-
Malathion	1,400	-

- No information available.

Table 4-4 also presents the expected acute *Ceriodaphnia* toxic units (TUa) based on the sum of the diazinon and chlorpyrifos concentrations, plus other pesticides for which LC_{50} data were available, divided by the LC_{50} for the respective compounds. Examination of Table 4-4, calculated expected TUa values, shows that, frequently, the sum of the diazinon and chlorpyrifos concentrations should result in several acute toxic units for *Ceriodaphnia* in San Diego Creek water as it enters Upper Newport Bay.

The November 30, 1997, San Diego Creek at Campus Drive sample contains sufficient chlorpyrifos to cause about 2 TUa to *Americamysis bahia*. A similar situation exists for the May 12, 1998 San Diego Creek at Campus Drive sample, where there is an expected 1.5 TUa to *Americamysis bahia* due to chlorpyrifos. The concentrations of diazinon found in this study at the San Diego Creek at Campus Drive sampling point are not sufficient to be toxic to *Americamysis bahia* (see Table 4-3). The data presented in Table 4-2 show that there is appreciable toxicity to *Americamysis bahia* in the San Diego Creek water during a stormwater runoff event that cannot be accounted for based on the chlorpyrifos concentrations measured in the sample that was tested for toxicity. The cause of this toxicity to *Americamysis bahia* is, at this time, unknown. However, as discussed in subsequent sections, it appears that it may be due to toxic constituents discharged from one or more large commercial nurseries present in the headwaters of the San Diego Creek watershed.

During several of the stormwater runoff events that have been monitored during 1998-99, samples were taken at several times during the runoff to evaluate potential changes in diazinon and chlorpyrifos concentrations during the runoff event. The results of these analyses are presented in Table 4-4. They show that, in general, the grab samples of San Diego Creek water collected at Campus Drive taken during a runoff event are representative of what is found over the runoff event (hydrograph).

Table 4-1 presents the ratio of the measured TUa based on *Ceriodaphnia* toxicity testing using dilutions of the San Diego Creek sample to the expected toxicity based on using the LC_{50} values for diazinon and chlorpyrifos, summed for additive toxicity. Examination of this column in Table 4-1 shows that in most of the samples where dilutions of the San Diego Creek water taken at the Campus Drive testing was done, that there is appreciable toxicity to *Ceriodaphnia* that cannot be accounted for based on the concentrations of diazinon and chlorpyrifos. These results are somewhat different than what is being found in stormwater runoff in the San Francisco Bay area, and in the Sacramento/Stockton area, for urban stormwater runoff toxicity to *Ceriodaphnia*. In the San Francisco Bay and Sacramento/Stockton areas, the diazinon and chlorpyrifos concentrations typically account for the measured *Ceriodaphnia* toxicity found. The principal difference between the Upper Newport Bay/San Diego Creek situation and that of the San Francisco Bay and Sacramento/Stockton urban creeks, is that the San Diego Creek stormwater not only contains runoff from residential areas, but also contains runoff from agricultural areas, as well as several large commercial nurseries.

In an effort to begin to address the nature and source of the unidentified *Ceriodaphnia* toxicity found at the San Diego Creek at Campus Drive sampling location, selective sampling was initiated in the spring of 1998 within the San Diego Creek watershed. It was observed that the samples of stormwater runoff taken at Peters Canyon Channel where Barranca Parkway crosses the Channel had higher concentrations of unknown-caused toxicity than were found in the San Diego Creek samples taken at Campus Drive. This observation led to conducting additional TIE work on the Peters Canyon Channel at Barranca Parkway samples. Dr. Jeff Miller, of *AQUA*-Science, Davis, CA, was provided samples of Peters Canyon Channel at Barranca Parkway stormwater runoff for the purpose of conducting more extensive TIEs to try to determine the cause of the unknown toxicity. This work included fractionating the sample using various column chromatography techniques and subjecting the fractions to GC/MS analysis. The more comprehensive TIE investigations did not provide definitive results on the cause of the unknown *Ceriodaphnia* toxicity. It appears to be due to a number of chemicals. This issue is discussed further in a subsequent section.

In an effort to define possible sources of the unknown-caused toxicity, limited scope forensic studies were done in the Peters Canyon Channel watershed in which dry weather flow samples were taken during August, 1998 to specifically target potential discharges of pesticides from several large commercial nurseries located in this watershed. Nurseries are known to use large amounts of a variety of conventional and exotic (less commonly used) pesticides. One of the sampling stations selected for dry weather sampling on August 13, 1998, was the Hines Channel at the Irvine Boulevard crossing. This sampling station is just downstream of two large commercial nurseries, one of which (Hines Nursery) is located on each side of the Channel just upstream of the sampling location. The other (El Modena Nursery) discharges runoff waters into a channel which apparently, based on the information currently available, contributes flow to the Hines Channel. At this time, the flow patterns have not been fully defined, since they occur, in part, in below-ground pipes. It should also be noted that the nurseries use a low-flow re-circulation system to recycle fugitive irrigation water.

Table 4-4
Summary of Diazinon and Chlorpyrifos Concentrations in Upper Newport Bay Watershed

Date	Location (Time – hr)	Diazinon (ng/L)	Chlorpyrifos (ng/L)	Expected TUa*
10/30/96	San Diego Creek @ Campus	370	157	3
11/19/96	San Diego Creek @ Campus Base Flow	164	ND	0.5
11/21/96	San Diego Creek @ Campus	359	133	2.5
9/25/97	San Diego Creek @ Campus	155	106	1.5
11/13/97	San Diego Creek @ Campus	462	161	3
11/30/97	San Diego Creek @ Campus	226[1]	63[1]	1
11/30/97	San Diego Creek @ Campus	278[2]	90[2]	2
12/06/97	Peters Canyon Channel @ Barranca	251	57	1
12/06/97	Peters Canyon Channel @ Barranca (1040)	277	102	2
12/06/97	Peters Canyon Channel @ Barranca (1350)	426	94	2
12/06/97	Peters Canyon Channel @ Barranca (1715)	202	84	2
12/06/97	San Diego Creek @ Campus (1320)	257[1]	57[1]	1
12/06/97	San Diego Creek @ Campus (1320)	197[2]	<50[2]	<1
12/06/97	San Diego Creek @ Campus (0910)	215	89	1.5
12/06/97	San Diego Creek @ Campus (1645)	195	82	1.5
12/06/97	Rain Water (0910)	13	23	0.3
3/24/98	Santa Ana Delhi Base Flow	140	ND	0.3
3/24/98	San Diego Creek @ Campus Base Flow	148	ND	0.3
3/25/98	San Diego Creek @ Campus (1140)	196	ND	0.4
3/25/98	San Diego Creek @ Campus (1730)	462	50	1.5
3/25/98	San Diego Creek @ Campus (2300)	294	ND	0.5
3/26/98	San Diego Creek @ Campus (0900)	250	ND	0.5
3/25/98	Peters Canyon Channel @ Barranca (1300)	367	ND	0.8
3/25/98	Peters Canyon Channel @ Barranca (1710)	288	ND	0.5
3/25/98	Peters Canyon Channel @ Barranca (2240)	378	ND	0.8
3/26/98	Peters Canyon Channel @ Barranca (0925)	266	ND	0.5
3/25/98	Santa Ana Delhi (1220)	202	ND	0.5
3/25/98	Santa Ana Delhi (1750)	192	ND	0.5
3/25/98	Santa Ana Delhi (2215)	155	ND	0.3
3/26/98	Santa Ana Delhi (0830)	64	ND	0.1
3/25/98	Ballona Creek **	298	50	1.3
3/25/98	Project 156 **	375	ND	0.8
3/25/98	Coyote Creek **	586	102	2.6
5/5/98	Santa Ana Delhi	170	ND	0.4
5/5/98	San Diego Creek @ Campus	136	ND	0.3

Table 4-4 (continued)

Date	Location (Time – hr)	Diazinon (ng/L)	Chlorpyrifos (ng/L)	Expected TUa*
5/13/98	Santa Ana Delhi	375	ND	0.8
5/13/98	Santa Ana Delhi (0645)	96	41	0.7
5/13/98	Santa Ana Delhi (1145)	203	36	0.9
5/13/98	Santa Ana Delhi (1800)	104	55	0.9
5/12/98	San Diego Creek @ Campus	96	57	0.8
5/12/98	San Diego Creek @ Campus (1900)	375	65	1.6
5/13/98	San Diego Creek @ Campus (0710)	375	57	1.5
5/13/98	San Diego Creek @ Campus (1205)	371	57	1.5
5/13/98	San Diego Creek @ Campus (1740)	253	58	1.3
5/25/98	Hines Channel	2,500	110	6.9
8/13/98	San Diego Creek @ Campus[3] Base Flow	117	67	1.1
8/13/09	Peters Canyon Channel @ Barranca[3] Base Flow	470	57	1.8
8/13/98	Central Irvine Channel[3]	840	281	5.4
8/13/98	Central Irvine Channel[2]	620	260	4.6
8/13/98	Hines Channel[3]	10,000	47	23
8/13/98	Hines Channel[2]	12,000	67	28
8/13/98	Santa Ana Delhi[3]	85	5	0.2
8/25/98	San Diego Creek @ Campus[2]	492	11	1.2
8/25/98	Central Irvine Channel[3]	620	260	4.6
8/25/98	Hines Channel[2]	2,500	97	6.8
8/25/98	Hines Channel[3]	2,500	110	7
8/25/98	Santa Ana Delhi[2]	340	18	1
11/8/98	San Diego Creek at Campus	<50	500	6
11/8/98	Peters Canyon Channel at Barranca	670	430	7
11/8/98	Hines Channel	4,100	140	11
11/8/98	Santa Ana Delhi Channel	<50	<50	<1
11/8/98	Harvard Ave.	<50	400	5
1/21/99	Hines Channel	1,400	670	11.5
1/21/99	San Diego Creek at Campus	570	70	2
1/25/99	San Diego Creek at Campus (1000)	960	<50	2
1/25/99	San Diego Creek at Campus (1530)	910	<50	2
1/26/99	San Diego Creek at Campus	880	<50	2
1/27/99	San Diego Creek at Campus	640	48	1.5

ND = Not Detected. Detection limits for ELISA analyses are 50 ng/L for chlorpyrifos and 30 ng/L for diazinon.
[1]UCD
[2]Pacific Eco-Risk
[3]*AQUA*-Science
*Based on LC_{50} values for toxicity to *Ceriodaphnia*
**Los Angeles County, CA

As shown in Table 4-4, the August 13, 1998, sample of Hines Channel analyzed by two different analytical procedures and labs had from 10,000 to 12,000 ng/L of diazinon, representing a potential *Ceriodaphnia* toxicity of 23 to 28 TUa. Because of this very high concentration of diazinon, the Hines Channel at Irvine Boulevard was sampled again on August 25, 1998. This time the diazinon was present at 2,500 ng/L. The same analytical result was obtained by both labs using two different procedures. It was also found that there was enough chlorpyrifos in these samples to be highly toxic to *Ceriodaphnia*. The total predicted diazinon plus chlorpyrifos toxicity for the August 25 sample was 7 TUa. The August 13, 1998, sample of the Hines Channel, as well as the August 25, 1998, sample of Hines Channel water, as expected, killed all *Ceriodaphnia* in one day. Both the August 13 and August 25 samples were taken under dry weather flow conditions which apparently represented flow derived from primarily the El Modena Nursery and/or possibly groundwater flow into the channel. Further work on the hydrology of this system upstream of the Hines Channel sampling point at Irvine Boulevard is needed. A dilution series of the August 13, 1998, sample of Hines Channel water showed that the 3.13% dilution of this sample killed all *Ceriodaphnia* in 4 days. The 1.57 percent sample of Hines Channel water did not kill *Ceriodaphnia* during the 4-day test period. This indicates that the measured *Ceriodaphnia* TUa was about 32. Since the August 13, 1998, Hines Channel water had an expected 25 *Ceriodaphnia* TUa, based on diazinon and chlorpyrifos concentrations, apparently there was appreciable toxicity in this sample due to unknown causes.

The November 8, 1998 study of the Upper Newport Bay watershed of the first major stormwater runoff event for the fall of 1998 showed somewhat similar results to the August 1998 studies, where high concentrations of OP pesticides and aquatic life toxicity were found in Hines Channel just downstream from the nurseries. In excess of 16 TUa of *Ceriodaphnia* toxicity was found in the November 8, 1998, Hines Channel runoff waters. About 20 TUa could be accounted for based on diazinon, chlorpyrifos and methomyl. It is evident that there is need to confirm that these nurseries are the source of the high levels of aquatic life toxicity that have been repeatedly found in these studies. It is of interest to find that the addition of PBO to the 1.57 percent Hines Channel sample collected on August 13, 1998, caused a low level of toxicity to *Ceriodaphnia* that was not found in the same dilution of this sample without PBO. A similar result was found for the Santa Ana Delhi Channel sample collected on August 25, 1998. This is a possible indication of a PBO-activated toxicity such as that associated with pyrethoid. It would not be surprising to find nurseries and/or agriculture using pyrethoid-based pesticides to control certain types of pests in their nursery stock or crops.

The August 13, 1998, Hines Channel sample was nontoxic to fathead minnow larvae. It did, however, show toxicity to the algae, *Selenastrum.* It appears that the nurseries and/or other dischargers to the Hines Channel may be using an herbicide(s) that is toxic to *Selenastrum*. The pesticides used by several of the nurseries in the Upper Newport Bay watershed are discussed in a subsequent section of this report.

The August 25, 1998, sample of Hines Channel water, however, as well as the San Diego Creek at Campus Drive sample, were both toxic to fathead minnow larvae. This is the only time that toxicity to fish larvae was found during this study in the San Diego Creek watershed. The San Diego Creek sample taken at Campus Drive on July 21, 1999, had a low level of toxicity to *Ceriodaphnia* and was nontoxic to fathead minnow larvae and algae. The March 1998 Santa Ana Delhi dry weather flow sample was toxic to fathead minnow larvae; however the August 25, 1998, Santa Ana Delhi sample, which was also a dry weather flow sample, was nontoxic to fathead minnow larvae.

A review of the August 13, 1998, and August 25, 1998, dry weather flow conditions samples taken at the Hines Channel, Central Irvine Channel, and San Diego Creek at Campus Drive locations presented in Table 4-1, shows that the toxicity decreased from the Hines Channel downstream to the San Diego Creek sampling location. This reflects a situation where the primary source of toxicity is upstream of the Hines Channel at Irvine Boulevard.

Overall, the August 1998 dry weather flow sampling of the San Diego Creek watershed, focusing on the Peters Canyon Channel, the Central Irvine Channel, and the Hines Channel established that high levels of *Ceriodaphnia* toxicity are present immediately downstream of two large commercial nurseries. The sampling at other times during the past year indicated that this situation is likely occurring year-round, and that the Hines Channel is likely one of the sources, if not the primary source of unknown-caused toxicity that is found during stormwater runoff events at the San Diego Creek at Campus Drive sampling point, as well as at the Peters Canyon Channel sampling point at Barranca Parkway.

The two nurseries (Hines Nursery and El Modeno Nursery) are near the headwaters of the Hines Channel. Based on field reconnaissance and the results of the toxicity testing and chemical analysis, it is possible that the El Modeno Nursery and the Hines Nursery are contributing substantial toxic constituents that are being carried with some dilution into Upper Newport Bay. It is also possible, however, that orchards in the headwaters area of Hines Channel may also be contributing toxic constituents to the channel. In addition, agricultural drains and possibly groundwater discharge to the channel are likely sources of constituents that cause *Ceriodaphnia* toxicity. This situation needs further investigation. The stormwater runoff sampling that has been conducted since the fall of 1996 at various locations in the San Diego Creek watershed has demonstrated that with each stormwater runoff event, there is appreciable *Ceriodaphnia* and *Mysidopsis (Americamysis bahia)* toxicity contributed from the San Diego Creek watershed to Upper Newport Bay. Substantial parts of this toxicity (on the order of 50 percent) are likely due to diazinon and chlorpyrifos. The remainder of the toxicity is due to causes unknown at this time, which apparently are related to commercial nursery use of chemicals for pest control or other purposes, as well as agricultural use of pesticides. The Hines Channel discharges, which are believed to be due to nursery sources, contain high concentrations of diazinon, and contain chlorpyrifos at toxic levels. Further, the Hines Channel water in August 1998 and January 21, 1999, was found to contain substances that were toxic to *Selenastrum*.

Further, while of limited scope, the studies of Bailey *et al*. (1993), which showed *Ceriodaphnia* toxicity in stormwater runoff to Upper Newport Bay, indicate that the OP pesticide-caused aquatic life toxicity problem that now exists in the Upper Newport Bay watershed is a longstanding problem that has been occurring for many years. The water quality significance of the toxicity, from one or more nurseries and/or agricultural use located in the headwaters of the Hines Channel, is an issue that needs to be addressed. There is need to do more detailed sampling on other channels in the San Diego Creek watershed during various runoff conditions to determine if this type of problem is occurring elsewhere in the San Diego Creek watershed.

INVESTIGATION OF THE CAUSE OF THE UNKNOWN-CAUSED TOXICITY

In an effort to try to gain guidance on what could be causing this unknown-caused toxicity, the Orange County Agricultural Commissioner's office was contacted for information on pesticides used in the Peters Canyon Channel watershed. This information is provided in Table 4-5. A review of Table 4-5 shows that a wide variety of pesticides are used in the Upper Newport Bay watershed. Many of these contain active agents for which there is no information on their toxicity to *Ceriodaphnia*. Because of the extensive use of such a variety of pesticides, the information on their use provided by the Orange County Agricultural Commissioner is of limited assistance in helping to identify the potential cause of the unknown-caused toxicity found in Peters Canyon Channel at the Barranca Parkway sampling station.

Since the commercial nurseries seem to be an important source of pesticides and aquatic life toxicity, the California Department of Pesticide Regulation 1995, 1996 and 1997 pesticide use database was examined with respect to the amounts and types of pesticides used by three large commercial nurseries in the San Diego Creek watershed. These tables show that a wide variety of pesticides are used by these nurseries, where some of the use is extensive. These tables also show that each nursery may have a significantly different mixture of types of pesticides used and the amounts used.

The total amounts of pesticides used in Orange County during 1997. based on the DPR database. shows over 1.8 million lb of pesticides were used in Orange County during 1997. This use does not include the pesticides that the public purchased over the counter without reporting the use. It is estimated that about half of Orange County pesticide use takes place in the Upper Newport Bay watershed. A review is underway in an attempt to determine, based on DPR reported Orange County 1997 pesticide use and their toxicity to *Daphnia magna* and *Mysidopsis bahia,* if any of the pesticides could be responsible for the unknown-caused toxicity found in stormwater runoff samples found in this study.

Table 4-6 presents a listing of the pesticides that have been found in the San Diego Creek stormwater runoff and dry weather flow during the 1996-1999 studies. At this time, *Ceriodaphnia* toxicity appears to be due in part to diazinon, chlorpyrifos and methomyl. Further, several of the samples taken just downstream from the nurseries near Hines Channel contained sufficient concentrations of carbaryl to be potentially toxic to *Ceriodaphnia*.

In order to assess whether the other pesticides that have been found in San Diego Creek water are the potential cause of the unknown-caused toxicity, a review of the US EPA Office of Pesticides Programs (OPP) Pesticide Ecotoxicity Database has been conducted. The US EPA Office of Pesticide Programs requires that pesticide manufacturers test pesticides for their toxicity to *Daphnia magna* and *Americamysis bahia* (*Mysidopsis bahia*), as well as several other organisms. OPP does not require the use of *Ceriodaphnia* as a test organism. Keehner (personal communication 1999), of the OPP staff indicated that the sensitivity of *Ceriodaphnia* to pesticides is within a factor of two of *Daphnia magna* toxicity. A compilation of the US EPA OPP aquatic life toxicity information contained in its Pesticide Ecotoxicity Database that is pertinent to this study is presented Lee and Taylor (1999a)..

A comparison of the pesticide concentrations found in the San Diego Creek water (Table 4-6 and elsewhere in this report) shows that diazinon is at times present in San Diego Creek water or its tributaries at concentrations that would be expected to be toxic to *Daphnia magna*, as well as *Daphnia pulex*. Also, the concentrations found are frequently greater than the concentrations found to be toxic to the amphipod *Gammarus fasciatus*. The daphnids and *Gammarus* are the most sensitive organisms to diazinon toxicity that the US EPA has included in its Pesticide Ecotoxicity Database. The concentrations of diazinon found would not be expected to be toxic to fish larvae and a number of other organisms for which the US EPA has toxicity data. A comparison of the toxicity data in Tables 4-3 and 4-6 shows that *Daphnia magna* has about one-half the sensitivity to diazinon toxicity as *Ceriodaphnia dubia*, confirming the factor of 2 relationship mentioned by Keehner.

Table 4-5
Agricultural Pesticides Used Within the San Diego Creek Watershed

Pesticide Trade Name	Active Chemical Ingredient(s)
Princep Caliber 90	Simazine
Roundup	Glyphosphate
Activator 90	No chemical information
Buffercide	No chemical information
Gramoxone Extra	Paraquat Dichloride
Silwet L-77	No chemical information
LI 700	No chemical information
Pyrellin E.C.	Pyrethrins, rotenone and other related
Neemix 4.5 Bothanical Agri	Azadirachtin
Xentari Biological Insecticide	Bacillus thurgiensis (berliner), subst aizawai serotype H-7
Miller NU – Film – P	No chemical information
Tenn – Cop 5E	Copper salts of fatty and rosin acids
Javelin WG Biological Insecticide	Bacillus thuringiensis (berliner), subsp kurstaki, strain SA-11
Micro Flo Captec 4L	Captan, captan and other related
Stik	No chemical information
Drexel Captan 50W	Captan, captan and other related
Du Pont Lannate Insecticide	Methomyl
Unifilm B	No chemical information
Rovral 4 Flowable	Iprodione
Dipel 2X Worm Killer Wettab	Bacillus thuringiensis (berliner) subsp kurstaki, serotype 3A,3B
Goal 2XL Herbicide	Osyfluorfen
Unifilm 707 N.F.	No chemical information
MVP II Bioinsecticide	Encapsulated delta endotoxin of bacillus thuringiensis var. karstaki
Brigade WSB Insecticide/Mit	Bifenthrin
Clean Crop Carbaryl Bait	Carbaryl
Agri-Mek 0.15 EC Miticide/I	Avermectin
Uni-Par	Petroleum oil
Vapam HL Soil Fumagant	Metam-sodium
Leaf Act 80B Buffer Stread	No chemical information
First Choice Thiram 65% Wet	Thiram
Champ Formula 2 Flowable	Copper hydroxide
Ridomil Gold EC	Mefenoxam
Admire 2 Flowable	Imidacloprid
Tatto C Suspension Concentrate	Chlorothalonil, propamocarb hydrochloride
Colton Hydrated Lime	Calcium hydroxide
Clean Crop Thiolux Dry Flow	Sulfur
Basicop	Copper sulfate
Bravo 720	Chlorothalonil
Du Pont Manzate 200 DF Fungicide	Mancozeb
Quadris Flowable Fungicide	Azoxystrobin

Pesticide Trade Name	Active Chemical Ingredient(s)
Ambush Insecticide	Permethrin
Provado 1.6 Flowable	Imidacloprid
Lasso Herbicide	Alachlor
Du Pont Benlate SP Fungicide	Benomyl
Clean Crop Malathion 8 Aqua	Malathion
Ornalin FL Liquid Flowable	Vinclozolin

Chlorpyrifos is much more toxic to *Daphnia magna* than diazinon. Also, chlorpyrifos is highly toxic to *Mysidopsis bahia*, with a 96-hr LC_{50} of 35 ng/L. Chlorpyrifos is also highly toxic to *Gammarus*. Further, it is somewhat more toxic to various types of fish than diazinon. While chlorpyrifos is more toxic to fish than diazinon, based on the concentrations found, it would not be expected to be toxic to fish in San Diego Creek or Upper Newport Bay.

Methomyl at some of the concentrations found in this study are in excess of the LC_{50} values for the toxicity to *Daphnia magna*. Like the other OP pesticides, methomyl would not be expected to be toxic to fish in San Diego Creek or Upper Newport Bay.

The information provided for the toxicity of carbaryl to *Daphnia magna* shows that it is considerably less toxic than diazinon and chlorpyrifos. There were, however, some samples of San Diego Creek water near the nursery discharges which contain carbaryl at potentially toxic levels to *Daphnia magna*.

Table 4-6
OP and Carbamate Pesticides Found in Upper Newport Bay/San Diego Creek Watershed Samples During 1996-1999

(Concentrations are the highest value found by APPL Laboratory, Fresno, CA using US EPA 8141 Special Los-Level List and US EPA 8321A procedures.)

diazinon	12,000 ng/L
chlorpyrifos	670 ng/L
dimethoate	290 ng/L
fensulfothion	320 ng/L
benomyl	2,000 ng/L
carbaryl	11,000 ng/L
methomyl	14,000 ng/L
diuron	2,200 ng/L
oryzalin (surfalan)	30 µg/L
metalaxyl (ridomil)	10 µg/L
simazine	3,200 ng/L
dimethoate	7,100 ng/L
malathion	490 ng/L
merphos	140 ng/L
prowl	1,200 ng/L
stirophos	140 ng/L
trifluralin	190 ng/L
methidathion	1,500 ng/L
diphenamid	130 ng/L
methyl trithion	580 ng/L
methiocarb	2,500 ng/L

The concentrations of benomyl found in this study are below the concentrations that would be expected to be toxic to *Daphnia magna*, *Mysidopsis bahia* and the other organisms for which the US EPA OPP has LC_{50} data.

The fungicide metalaxyl and the insecticides dimethoate and propoxur were present in San Diego Creek or stormwater runoff from a Yorba Linda residential area below concentrations which would be toxic to *Daphnia magna* and other aquatic life. The concentrations of malathion, while below those that are expected to be toxic to *Daphnia magna*, could be toxic to *Gammarus*.

The concentrations of the herbicides diuron, oryzalin, pendimethalin, trifluralin and simazine found in San Diego Creek waters during stormwater runoff would not be expected to be toxic to any of the aquatic life for which the US EPA OPP has LC_{50} data.

It is of interest to find that propetamphos, which is used as an alternate OP pesticide for diazinon and chlorpyrifos in residential areas, is somewhat less toxic to *Daphnia magna* than diazinon.

The toxicity data for several of the pyrethroid pesticides show that several of these pesticides are as toxic as the OP pesticides to *Daphnia magna* and *Mysidopsis*. However, at this time there is no indication, based on PBO activation, that any of the pyrethroid pesticides are present at potentially toxic concentrations in San Diego Creek water. Further studies are needed to confirm this preliminary observation.

APPL Labs reported finding several pesticides in the GC scans which are not registered for use in California. These include fensulfothion, merphos, methidathion, diphenamid, methyl trithion and methyl chlorpyrifos. It appears that there may have been problems with these analyses, where a GC peak was inappropriately assigned to a pesticide, or there may have been illegal use of these pesticides.

Overall, based on a review of the OP and carbamate pesticides found in San Diego Creek water using US EPA standard low level GC scans compared to the US EPA OPP Pesticide Ecotoxicity Database, none of the pesticides found appears to be responsible for the unknown-caused toxicity repeatedly found in this study. Further TIE work will be needed to identify the cause of this unknown-caused toxicity.

REGULATING AQUATIC LIFE PESTICIDE-CAUSED TOXICITY

One of the issues that will likely influence the control of the aquatic life toxicity in Upper Newport Bay and its tributaries is that the Santa Ana Regional Water Quality Control Board has listed San Diego Creek Reach 1 (lower reach) on the 1998 303(d) list of impaired waterbodies due to the presence of "pesticides" in the Creek waters. This Board has listed San Diego Creek Reach 2 (upper reach) on the 303(d) list because of "unknown toxicity." Both of these listings are given a high priority for Total Maximum Daily Load (TMDL) development. According to the TMDL process, the Reach 1 TMDL for the control of pesticides is to be completed by January 1, 2002. The unknown toxicity TMDL for Reach 2 has the same completion date.

Regulatory Requirements. The US EPA Region 9, as part of settling a lawsuit filed by an environmental group concerned about protecting the beneficial uses of Upper Newport Bay, entered into a consent decree which requires that TMDLs be developed for all Santa Ana Regional Board-listed Upper Newport Bay use impairments within a limited specified time period. If the Santa Ana Regional Water Quality Control Board does not meet this extremely short timetable for developing a TMDL for such complex issues as control of toxics, the US EPA

Region 9 will develop the TMDL and impose the requirements on the Santa Ana Regional Board for enforcement.

The 1998 303(d) list developed for the Upper Newport Bay Ecological Reserve, which is the upper part of the Upper Bay, includes the development of TMDLs for "pesticides" as a high-priority item that is to be completed by January 1, 2002. Toxicity is not listed as a use impairment of the Upper Newport Bay. However, in discussing this matter with H. Smythe of the Santa Ana Regional Water Quality Control Board, the listing of Upper Newport Bay as impaired by pesticides is based on the work of Bailey *et al.* (1993), in which they found *Ceriodaphnia* toxicity to be due to unknown causes. It is now clear from the studies conducted in this project that diazinon and chlorpyrifos are the cause of at least a substantial part of this toxicity. However, a significant part of the toxicity at times is due to unknown causes, which may not be due to pesticides.

The development of a TMDL for pesticides and pesticide-caused toxicity will be difficult and is controversial. The controversy stems from the fact that pesticides are regulated differently than other toxicants. While several Regional Water Quality Control Board Basin Plans have a toxicity control requirement of "no toxics in toxic amounts," the Santa Ana Regional Water Quality Control Board (1995) requirements for the control of toxicity include:

"*Toxic Substances*

> *Toxic substances shall not be discharged at levels that will bioaccumulate in aquatic resources to levels which are harmful to human health.*
>
> *The concentrations of toxic substances in the water column, sediments or biota shall not adversely affect beneficial uses."*

The application of this Basin Plan requirement to pesticides is controlled by a Management Agency Agreement (MAA) between the California EPA Department of Pesticide Regulation and the State Water Resources Control Board. The initial phase of the MAA (DPR, 1997) focuses on achieving voluntary control of the use of pesticides associated with agricultural use to control the runoff and aerial drift of pesticides from agricultural applications, which results in pesticides entering the State's waters in sufficient concentrations to be toxic to aquatic life. Ciba *et al*. (undated) have discussed what they term best management practices for protecting water quality in California from pesticides used as a dormant spray in orchards. That approach is now being evaluated by DPR. Further, the Central Valley Regional Water Quality Control Board and DPR have begun to develop the Sacramento/Feather River O-P Pesticide Management Strategy. This strategy focuses on developing the information that can be used by the Central Valley Regional Board in developing a TMDL to manage diazinon-caused aquatic life toxicity in the Sacramento and Feather Rivers associated with the use of diazinon as a dormant spray in orchards.

US EPA OPP Regulatory Approach. The US EPA Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) pesticide use regulations governing restricting the use of pesticides can allow aquatic life toxicity to non-target organisms provided that this does not cause significant adverse impacts on the beneficial uses of a waterbody. In addition, the State Water Resources Control Board's (WRCB, 1997a) draft approach for implementation of the California Toxics Rule (CTR) proposed to allow aquatic life toxicity in the state's waters provided it is not significantly adverse to the beneficial uses of the waterbody. Therefore, there is a fundamental conflict between Clean Water Act requirements of no toxics in toxic amounts, as currently required in some regional board basin plans, and the pesticide use regulations governing aquatic life toxicity control due to pesticides, as well as the SWRCB's proposed toxicity control under the CTR. The latter two focus on controlling aquatic life toxicity that is significantly adverse to the beneficial uses of a waterbody. At this time it is not clear that the SWRCB's (WRCB, 1997a) proposed approach will be adopted in the final regulations governing the implementation of the CTR. Further, in several years, based on the MAA, if toxicity is still present in the State's waters due to pesticide applications in agricultural use, the regional water quality control boards will become responsible for controlling the pesticide-caused aquatic life toxicity through appropriate regulatory means. Such control could potentially include curtailment of pesticide use for certain purposes.

Fox (1999) has recently discussed the approach that the current US EPA administration is using with respect to regulating pesticide-caused aquatic life toxicity. He states,

> *"Since pesticides are also transported to receiving streams in sheet flow from agricultural and residential areas, non-point source control measures are expected to be an important component of water quality protection. This essentially relies on usage of best management practices by pesticide applicators.*
>
> *Given the variable nature of non-point source pollution, these approaches are the most pragmatic way for the Office of Water to address toxicity from registered pesticides. Of course, the primary responsibility for pesticide control lies with OPP. Local water quality issues are typically addressed by the governing State or Tribe, with EPA support as needed."*

Food Quality and Protection Act. An emerging area that could significantly influence the use of OP pesticides is the Food Quality and Protection Act (FQPA) that was adopted by the U.S. Congress in August 1996. The FQPA replaced the Delaney clause governing the evaluation of the public health hazards associated with pesticide use. According to the FQPA, by August 1999 the US EPA was to develop a revised approach for determining the health hazards associated with pesticide use considering the potential for cumulative impacts. While the OP pesticides diazinon and chlorpyrifos are not particularly toxic to people, because of their widespread use, the cumulative exposure to people may be judged to be excessive, and thereby represent a health threat. If this occurs, then through the FQPA there could be a significant curtailment in OP pesticide use.

Probabilistic Ecological Risk Assessment. An approach that is being explored as a possible regulatory tool for controlling OP pesticide caused aquatic life toxicity is based on conducting a probabilistic ecological risk assessment. This approach has been applied to the regulation of organophosphate pesticide aquatic life toxicity. Novartis (1997) and Giesy *et al*. (1999), on behalf of Dow AgroSciences, have developed probabilistic risk assessments for assessing the water quality significance of *Ceriodaphnia* toxicity associated with the use of the OP pesticides diazinon and chlorpyrifos. These risk assessments purport to show that, based on the information available, there is a potential impact of OP pesticide toxicity on aquatic life resources of a waterbody. However, this impact is within the promoted level of aquatic life toxicity that is claimed to be acceptable; i.e., 10 percent of the species within a waterbody can be killed 10 percent of the time without significant adverse impact on ecosystem functioning

(SETAC, 1994). The OP pesticide ecological risk assessment work that has been done thus far confirms what was known from the exceedance of a water quality standard approach, that there are potentially significant water quality problems associated with the OP pesticide aquatic life toxicity that need to be better understood before it can be concluded that this toxicity is not significantly detrimental to the designated beneficial uses of a waterbody.

Further, such issues as additive and synergistic effects of various toxicants, including other OP pesticides, are thus far ignored in the probabilistic risk assessments that have been conducted. Basically, the probabilistic risk assessment shows that the cladoceran *Ceriodaphnia* is highly sensitive to OP pesticide toxicity. It is not, however, the most sensitive organism known. The amphipod *Gammarus fasciatus* is about twice as sensitive to diazinon toxicity as *Ceriodaphnia dubia* (Novartis, 1997). A similar situation exists with respect to chlorpyrifos, where the amphipod *Gammarus fasciatus* is about twice as sensitive to chlorpyrifos as some cladocerans. There is potential, through further study, that other organisms will be found to have even greater sensitivity to diazinon and chlorpyrifos toxicity than *Ceriodaphnia*. This points to the need to better understand the ecological role of cladocerans such as *Ceriodaphnia* and amphipods in providing food for key higher trophic-level aquatic organisms of concern to the public.

While an ecological risk assessment is an interesting initial step in an evaluation of the potential water quality significance of OP pesticide toxicity, at this time ecological risk assessment falls far short of providing the information needed to assert that the toxic pulses caused by OP pesticides that occur in receiving waters for urban area and some agricultural area stormwater runoff are not adverse to key aquatic organisms of concern to the public. Further, and most importantly, as discussed by Solomon (1996), the ecological risk assessment approach places a great demand for high-quality data far beyond that available.

A possible way that ecological risk assessment can be an effective regulatory tool is to fund the studies needed to evaluate the potential ecological significance of pulses of OP pesticide toxicity associated with urban and agricultural stormwater runoff events, as well as agricultural drainage-tailwater.

Ecological risk assessment can be a reliable base for developing regulatory approaches for chemicals in the environment as they may impact aquatic/terrestrial ecosystems. However, in order to use this approach, there must be a substantial database of information which rarely, if ever, exists. It is inappropriate for chemical companies and pesticide users to expect that regulatory agencies and members of the public who do not use these chemicals will pay for the studies or wait for the studies to be done until regulatory decisions are made. The OP pesticide aquatic life toxicity problem has been known for many years. Little has been done, however, to obtain the necessary information to properly evaluate the ecological significance of the OP pesticide-caused toxicity associated with urban area stormwater runoff and agricultural runoff/drainage.

Lee *et al*. (1999) have recently reviewed the regulatory issues for control of aquatic life toxicity due to the OP pesticides, with particular reference to the Upper Newport Bay situation. As discussed below, there is considerable uncertainty at this time about the regulatory approach that will be used to control aquatic life toxicity in urban and agricultural stormwater runoff.

Amounts of Pesticides Used in Orange County During 1995-1997 for Pesticides Detected in San Diego Creek Stormwater Runoff. A key component of regulating stormwater runoff-associated OP pesticide-caused aquatic life toxicity is an understanding of how these pesticides are used. Silverado (1997a) and Lee and Taylor (1997a) reported, based on California Department of Pesticide Regulation (DPR) data, that on the order of 60,000 lb/yr of diazinon and chlorpyrifos were applied in the Upper Newport Bay watershed during 1995. Recently, DPR has published the 1996 and 1997 pesticide use reports for the state of California. These publications have been examined to determine the amount of pesticides used by commercial applicators within Orange County, California during 1995, 1996, and 1997 for those pesticides which were found in this study in stormwater runoff in San Diego Creek and its tributaries.

A review of the information provided shows pesticide use by commercial applicators that was recorded with the Orange County Agricultural Commissioner. The public can purchase unrestricted amounts of diazinon and chlorpyrifos from their garden supply stores. The Orange County Agricultural Commissioner's Office (Hill, 1997) estimated that at least as much diazinon and chlorpyrifos are used in urban areas by the public as are applied by commercial applicators. It is also estimated by Lee and Taylor (1997a) that about half of the use of pesticides within Orange County occurs within the Upper Newport Bay watershed.

In 1995 about 21,500 lb of diazinon were used in the County by commercial applicators. During 1996, about 16,400 lb of diazinon were used by commercial applicators within the County, with 85 percent of this use for structural purposes. In 1997, 21,600 lb of diazinon were used within the County, with 87 percent used for structural purposes. For chlorpyrifos, 41,700 lb were used in the County by commercial applicators in 1995, with 75,400 lb used in 1996, and 73,600 lb in 1997. The 1996/97 usage of chlorpyrifos represents a significant increase in the amount of chlorpyrifos used compared to 1995. Of the 73,600 and 75,400 lb of chlorpyrifos used in 1996/97 by commercial applicators, 95 percent was used for structural purposes.

Methomyl has been found to be present in stormwater runoff in the Upper Newport Bay watershed at potentially toxic concentrations. In 1995 about 4,100 lb were applied to agricultural lands. In 1996 about 3,100 lb of methomyl were applied to agricultural lands, with 3,000 lb being applied for the same purpose in 1997.

The 1995 use of carbaryl was 5,600 lb, in 1996, 3,200 lb, and in 1997, 5,600 lb, with most of the use in all three years for agricultural purposes. The use of malathion in 1996 (4,700 lb) and 1997 (4,300 lb) was about half that used in 1995 (9,100 lb). The use of pendimethalin, an herbicide used primarily on rights-of-way and for landscaping, amounted to 3,400 lb in 1995, 8,400 lb in 1996, and 5,500 lb in 1997. The use of another herbicide, simazine, in 1995 was 13,200 lb, in 1996 was 6,300 lb, and in 1997 was 11,000 lb; with the dominant use in all three years being for agricultural purposes. Approximately 5,900 lb of diuron and 13,200 lb of oryzalin (both herbicides) were applied within the County in 1995, 5,500 lb of diuron and 13,400 lb of oryzalin were used in 1996, and 10,600 lb of diuron and 16,700 lb of oryzalin in 1997, primarily for right-of-way purposes.

There are several other pesticides that have been found in the studies of San Diego Creek water. These include dimethoate, that had a use of about 2,000 lb in both 1995 and 1996, and 1,400 lb in 1997, with use primarily for agricultural and nursery purposes. Approximately 2,000 lb of benomyl was used in 1995, 1,100 lb in 1996, and 1,500 lb in 1997 for agricultural purposes in Orange County.

It is of interest to find that trifluralin and methiocarb were both detected in stormwater runoff in San Diego Creek during these studies. During 1995, 171 lb of trifluralin was used; in1996, approximately 100 lb; and in 1997, 101 lb. In 1995, 254 lb of methiocarb were used, with 170 lb used in 1996 and 576 lb in 1997 within the County.

Propetamphos was applied by commercial applicators for structural purposes, with 1,800 lbs applied during 1995, 1,500 lb in 1996, and 1,400 lb in 1997. As discussed elsewhere in this report, propetamphos is of interest, since this is an OP pesticide that is only applied by commercial applicators in urban areas. It is an OP pesticide that is not measured in conventional OP pesticide GC scans.

The fungicide, maneb, is of interest because it is highly toxic to fish. It has not been found in stormwater runoff in San Diego Creek. Approximately 1.2 million lb were applied in California during 1995; however, only about 10 lb were applied in Orange County in 1995, with 30 lb applied in 1996 and 100 lb in 1997.

Propoxur, a pesticide that is used for structural purposes, was found in March 1999 stormwater runoff from a Yorba Linda subdivision; 81 lb of Propuxur were applied in Orange County in 1995, with only 56 lb applied in 1996, and 61 lb applied in 1997. There is need for more recent data to determine whether there has been a significant increased use of this pesticide in recent years to account for finding it in stormwater runoff from a residential area in 1999. The concentrations found were well below those that are reported for toxicity to *Daphnia magna*.

Pyrethroids are of interest, as they are used as an alternative to the OP pesticides. Their use is increasing in many parts of the state. They are also of interest because they have high levels of toxicity to many of the same forms of aquatic life as are highly sensitive to diazinon and chlorpyrifos. The stormwater runoff analyses that have been conducted in this study have not included the measurement of pyrethroids, although there has been some indication of a PBO activation of toxicity to *Ceriodaphnia*, which is indicative of the presence of pyrethroid pesticides. While in 1995 over 300,000 lb of permethrin was applied in California, in 1996 about 10,000 lb and in 1997 11,000 lb were applied in Orange County, with most of the application for structural purposes. A review is underway at this time as to the possibility of directly measuring permethrin and several of the other pyrethroid pesticides in stormwater runoff in San Diego Creek waters.

It is evident that for some pesticides, such as chlorpyrifos, there are significant year-to-year variations in the amounts that are used within Orange County. It is also evident that some pesticides that are used in relatively small amounts of a few hundred pounds are being found in San Diego Creek waters associated with stormwater runoff events. Based on the concentrations of diazinon and chlorpyrifos found in the fall of 1996, fall and winter 1997-98, and fall and winter 1998-99 in stormwater runoff in San Diego Creek waters at Campus Drive, only a few pounds of the over 60,000 lb of diazinon and chlorpyrifos used in the Upper Newport Bay watershed each year is needed in runoff to cause the levels of aquatic life toxicity and diazinon and chlorpyrifos concentrations found in stormwater runoff to Upper Newport Bay.

Further, as reported by Silverado (1997a) and Lee and Taylor (1997a), based on the work of Scanlin (1997) in Alameda County, California, and the unreported work done by Dr. G. Fred Lee in El Macero, California during 1998, normal registered use/application of these pesticides by commercial applicators on residential properties can be a significant source of pesticide runoff from these properties. There is a substantial potential for residential use of these pesticides in excess of label specifications leading to over-application of the pesticides which contributes to the aquatic life toxicity problem that is being found in urban stormwater runoff throughout California. Therefore, the control of urban stormwater runoff-caused *Ceriodaphnia* toxicity will be extremely difficult to achieve without significantly curtailing the use of these pesticides for residential, commercial and agricultural purposes. While it would be possible to curtail the use of these pesticides, there is no assurance that the substitute pesticides would necessarily be any more compatible with the environment than diazinon and chlorpyrifos.

NEED FOR EVALUATION OF WATER QUALITY/ECOLOGICAL SIGNIFICANCE OF AQUATIC LIFE TOXICITY IN SAN DIEGO CREEK AND ITS TRIBUTARIES

The studies conducted during the fall of 1996, 1997-98 and 1998-99 show high levels of aquatic life toxicity in San Diego Creek and in various tributaries to the Creek. Very high levels of toxicity were found in the Hines Channel area, which is a tributary of Central Irvine Channel, which in turn is a tributary of Peters Canyon Channel. As shown in Figure 2-2, Peters Canyon Channel is a tributary of San Diego Creek. From the data collected during August, 1998 under low flow conditions, it appears that San Diego Creek above Peters Canyon Channel confluence is of lower toxicity since it diluted the toxicity found in Peters Canyon Channel at the Barranca Parkway, which is just above where this Channel confluences with San Diego Creek. The November 1998 studies included sampling of San Diego Creek above this point of confluence at Harvard Avenue. The high levels of toxicity found at San Diego Creek at Harvard Avenue in this stormwater runoff event indicate that there are significant sources of aquatic life toxicity in the main stem of San Diego Creek. This part of the watershed contains a large commercial nursery and several smaller nurseries. The waters just downstream of this nursery have not yet been sampled. They will be sampled in a follow-on study beginning in the fall of 1999.

One of the issues that must be addressed is the water quality/ecological significance of *Ceriodaphnia* and other aquatic organism toxicity, including fathead minnows and possibly *Selenastrum* in the Hines Channel, Central Irvine Channel, Peters Canyon Channel, San Diego Creek above Harvard Avenue, as well as other tributaries of San Diego Creek, under low flow, as well as stormwater flow conditions. While the beneficial uses of these waters are listed as aquatic life-related habitat by the Santa Ana Regional Water Quality Control Board in this Board's Basin Plan, the aquatic life-related resources of the waters in these channels are severely impacted by habitat characteristics. There is need to assess the potential improvement in the beneficial uses of these waters if the high levels of aquatic life toxicity that have been found under both low flow and high flow conditions were eliminated. It is likely that the high levels of toxicity found on two different sampling days in August 1998, as well as in the November 1998 and January 1999 stormwater runoff event samples, are detrimental to the aquatic life resources of these channels and, therefore, the apparent discharge of toxic constituents from one or both of the nurseries in their wastewater and fugitive water discharges/releases, as well as stormwater runoff from the nurseries and agricultural tailwater and stormwater runoff, will likely be found to need to be controlled.

EVALUATION OF THE WATER QUALITY SIGNIFICANCE OF STORMWATER RUNOFF *CERIODAPHNIA*/MYSID TOXICITY TO UPPER NEWPORT BAY

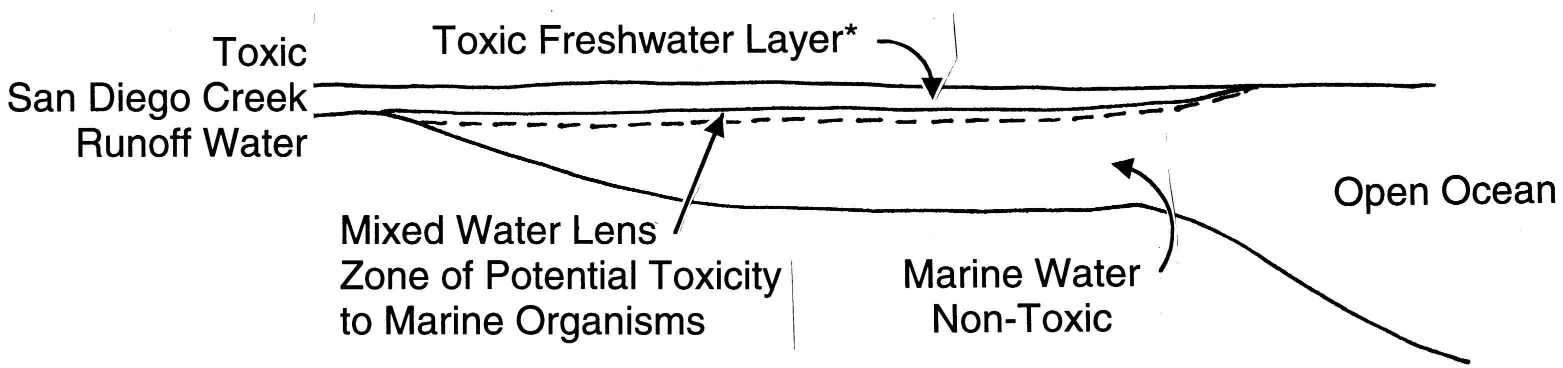
Associated with each stormwater runoff event to Upper Newport Bay is a pulse of toxic water that has a potential to kill certain zooplankton with a sensitivity to OP pesticides similar to *Ceriodaphnia* and mysids. Novartis (1997) and 1999 US EPA OPP Pesticide Ecotoxicity

Database have compiled information on the diazinon-caused LC_{50}s for various freshwater and marine organisms. Based on the information available at this time, *Ceriodaphnia* is one of the most sensitive organisms to diazinon toxicity. Based on the review of Menconi and Paul (1994) and 1999 US EPA OPP Pesticide Ecotoxicity Database there is no evidence from the literature that the organophosphate pesticides at the concentrations being found in this study in San Diego Creek waters as they enter Upper Newport Bay are toxic to adult or larval fish. There is, however, some limited uncorroborated work that chlorpyrifos is toxic to the Korean prawn, *Palaemon macrodactylus*, at 10 ng/L (Earnest, 1970).

The Korean prawn is not a native species in the United States but has been introduced to the San Francisco Bay and the Sacramento/San Joaquin River Delta. According to S. Dawson (personal communication, 1998) of the Santa Ana Regional Water Quality Control Board, the Korean prawn has not been found in Upper Newport Bay. Further work needs to be done to determine if the limited scope study, which indicates a potential for OP pesticide toxicity to certain types of shrimp, is reliable. Also, work needs to be done to determine if Upper Newport Bay has organisms that are key parts of the food web for the overall ecosystem that could be impacted by OP pesticide toxicity and/or the unknown-caused toxicity found in this study.

Since the zooplankton present in San Diego Creek water will be killed due to salinity in Upper Newport Bay as the Creek water mixes with the 30 ppt salinity marine waters, the water quality significance of the toxic pulses becomes one of assessing whether there are marine organisms present in the Bay waters that will be mixed into, or migrate into, the San Diego Creek waters that are present as a fresher water lens on top of the Bay marine waters during and following a stormwater runoff event. This relationship is shown in Figure 4-1. If it is assumed that 10 TUa of acute toxicity is present in San Diego Creek water as it enters Upper Newport Bay, then under these conditions the toxic waters that could affect marine zooplankton are those with a salinity less than 3 ppt. Any salinity greater than this amount would dilute the 10 TUa San Diego Creek water to non-toxic levels.

Figure 4-1
Upper Newport Bay OP Pesticide Aquatic Life Toxicity Situation



Toxic Freshwater Mixes with Non-Toxic Marine Water

* Under "Steady State" Conditions with Minimum Flow of 1500 cfs. At Lower Flow Rates, Bay May Be Only Partially Stratified, or, in Upper Bay, Fully Mixed, with Unknown Toxicity.

During the fall 1998/January 1999 studies an excess of 16 TUa for *Ceriodaphnia* and mysids was found in stormwater runoff to Upper Newport Bay. This means that the expected lower-most salinity, which should be toxic to organisms with mysid sensitivity, would be about 6 to 10 ppt. Salinities greater than this amount would not be expected to be toxic to mysids.

A fundamental issue that needs to be assessed is whether there is a significant amount of water present in Upper Newport Bay associated with stormwater runoff events with salinities less than 3 to 10 ppt that would persist for at least 2 to 3 days. Another issue is whether marine zooplankton could be mixed into, or migrate into the freshwater marine water lens with salinities less than 3 ppt and stay in this lens. This assumes that the zooplankton persisted for a sufficient period of time to receive a toxic exposure to the toxic constituents in the San Diego Creek water that has been diluted by the Bay's marine waters. In order to review this situation an analysis of the currently available information on the mixing of San Diego Creek waters with Upper Newport Bay waters has been undertaken. Further, the January 1999 in-Bay studies reported in Section 3 provide information on the presence of aquatic life toxicity in Upper Newport Bay as influenced by a series of stormwater runoff events.

MIXING OF SAN DIEGO CREEK AND UPPER NEWPORT BAY – NUMERIC MODEL

The water quality and ecological significance of the toxicity identified in San Diego Creek and the Santa Ana Delhi Channel stormwater runoff in Upper Newport Bay is a function of the level of mixing that occurs between the runoff waters and the Bay water. Conductivity data from the County of Orange municipal stormwater monitoring effort in the Bay would tend to suggest that stratification occurs during significant runoff events, wherein freshwater remains as a "lens" on the surface of the Bay marine waters. The stratification of Upper Newport Bay during stormwater runoff events was investigated by Limno-Tech (1998) as part of a study devoted to defining the fate and persistence of nutrients associated with low flows and stormwater runoff input to Upper Newport Bay.

Limno-Tech (LTI) conducted an investigation of the quantity of water necessary to cause significant salinity stratification in Newport Bay (creation of a freshwater "lens"). Their analysis incorporated an estuarine stratification classification system using salinity stratification and water circulation patterns. This classification system was developed by Hansen and Rattray (1996). The system involves the calculation of two parameters at two points along a main estuary channel. The two locations chosen were an upper station near San Diego Creek (UNSBC) and a lower bay station near Harbor Island (HIR).

The two parameters used in this classification system are for stratification and circulation, and are described as follows:

1) Stratification parameter = Delta S/S_o

   Delta S = time averaged difference in salinity between surface and bottom water (ppt)

   S_o = cross-section mean salinity (ppt)

2) Circulation parameter = U_s/U_f

   U_s = net non-tidal sectional surface velocity (ft/sec)

   U_f = mean fresh water velocity through the section (ft/sec) = R/A

R = fresh water (river) inflow rate (ft^3/sec)

A = cross-sectional area of the estuary through the point being used to calculate the circulation pattern and stratification parameters based on a mean tide surface elevation (ft^2)

Data for this analysis were obtained from the Irvine Ranch Water District Wetlands Water Supply Project Monthly Water Column Monitoring Reports, published literature, the County of Orange Municipal Stormwater Program, and the Army Corps of Engineers.

While electronic data were available for conductivity but not for salinity, the stratification system requires salinity data. LTI used an empirical relationship between conductivity and salinity to estimate salinity in the Bay. To verify the relationship between salinity and conductivity, they compared selected values spanning the range of conductivity for predicted salinity compared to measured salinity. A 1:1 relationship was observed (R^2=0.99); it was decided that it was valid to use the empirical relationship to predict salinity from measured conductivity.

The Hansen and Rattray's estuarine classification scheme was interpreted as follows:

Stratification Parameter	Bay Stratification Status
<0.1	Not Stratified
0.1 – 1.0	Partially Stratified
>1.0	Highly Stratified

Figures 4-2 and 4-3 plot observed stratification parameter versus measured San Diego Creek flows for the most upstream (Jamboree) and downstream (Harbor Island Reach) stations in the Bay. Figure 4-3 shows that the Jamboree station is at least partially stratified (stratification parameter > 0.1) the majority of the time, regardless of Creek flows. For San Diego Creek flows above 50 cfs, the Jamboree station is typically stratified (either partially or fully). Figure 4-3 shows that the Harbor Island Reach station becomes partially stratified at flows above 25 cfs and does not become fully stratified until San Diego Creek flows are on the order of 1,000–1,500 cfs.

In summary, the Upper Bay area appears to be well mixed during low flow conditions, defined as 50 cfs and under, and partially stratified (and mixed) for San Diego Creek flows up to about 1,000 cfs. Above 1,000 cfs, the Upper Bay becomes fully stratified, depending on tide conditions. In reviewing County of Orange conductivity data, it also appears reasonable to assume that the lower Bay is largely unaffected by flows of less than about 50 cfs (urban runoff) from San Diego Creek and the Santa Ana Delhi Channel and is fully mixed. These conclusions are valid regardless of tidal stage. Between Creek discharges of 50 cfs and about 1,500 cfs, the influence of tide would appear to be important, and partial stratification (mixed condition) occurs in the Lower and Upper Bay, depending on tide conditions. Above about 1,500 cfs, the Bay would appear to be fully stratified at all locations and for all tide conditions. The LTI report upon which these conclusions are based is provided in Lee and Taylor (1999a).

Figure 4-2. Jamboree Station

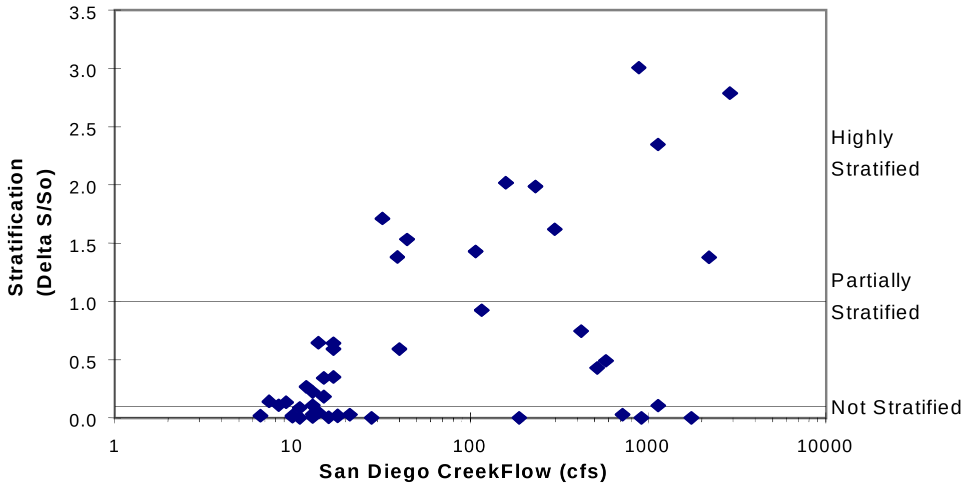
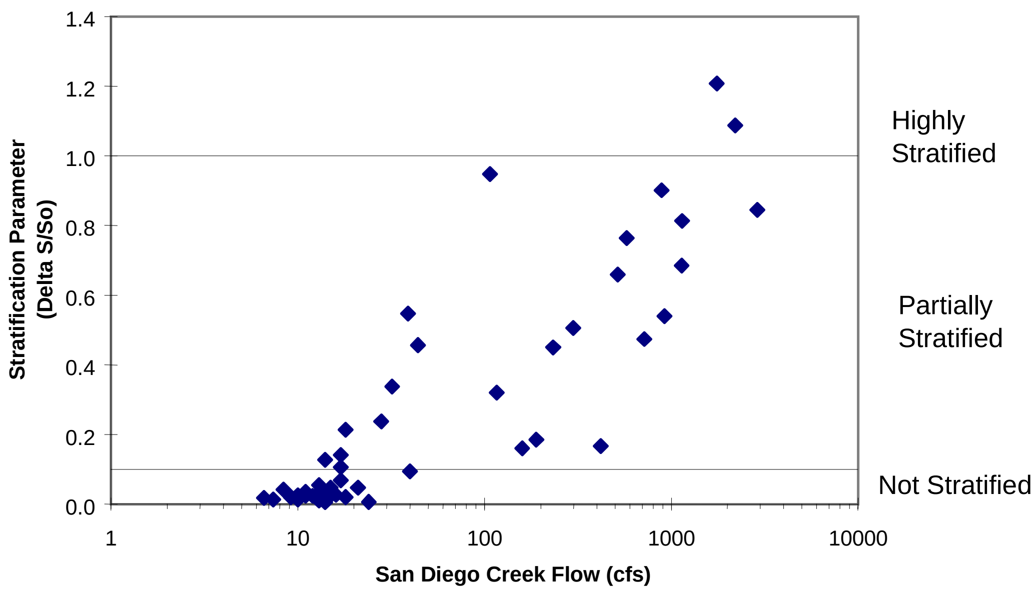


Figure 4-3. Harbor Island Reach Station



Preliminary conclusions may be drawn relative to the sampled storm events using the stratification analysis of the Bay. Table 4-7 provides a description of the estimated time that the Bay would be stratified versus the time it would be mixed for selected storm events during the 1997-98 season.

The stormwater runoff is assumed to remain in a relatively confined prism as it moves through the Bay. The data and analysis compiled did not explicitly examine the question of the potential for lateral mixing of the stratified freshwater plume. This assumption will need to be verified through actual in-Bay testing.

Table 4-7
Estimated Time of Stratification during Sampled Storm Events

Storm Date	Location	Period Flow Is Stratified (hr)[2]	Period Flow Is Mixed (hr)	Total Time of Runoff (hr)
09/25/97	Campus	18	9	27
11/13/97	Campus	24	9	33
11/30/97	Campus	19	10	29
12/6/97	Campus	45	4	49
03/25/98	Campus	36	6	42
05/05/98	Campus	28	13	41
05/12/98	Campus	60	3	63
11/08/98	Campus	12	20	32
01/25-29/99	Campus	43	32	75
03/25/98	Santa Ana Delhi Channel	13	9	22
05/05/98	Santa Ana Delhi Channel	6	18	24
5/12/98	Santa Ana Delhi Channel	18	24	42
11/08/98	Barranca	6	10	16

[1] Stratified here is defined as any flow above 50 cfs.

If the flow is stratified or partially so above 50 cfs, then the time when it is more fully mixed with the Bay waters and the dilution during this time may become critical from the perspective of potential harm to organisms in the water from the measured toxicity. An estimate of the relative volumes of stormwater runoff versus Bay water for these low-flow conditions may be made by assuming a control volume in the Bay and computing the total stormwater runoff volume during the period when the flow is likely to be mixed.

The LTI report provided estimates of a flow ratio parameter as part of its analysis. The value is a ratio of tidally induced flow to river flow. Such a flow ratio provides a good estimate of the dilution and associated toxicity of the stormwater runoff and Bay water. The tidal prism represents the mass of water that moves in and out of the estuary with the tide. The tidal prism is a reasonable control volume to use as a basis to assess dilution of the stormwater runoff within the estuary.

The flow ratio estimates were prepared for various average flow rates over a 12.5-hr cycle, generally consistent with the time of mixed flow given in Table 4-7. Table 4-8 provides a range of flow ratios (F) using tidal prism value estimates from the US Army Corps of Engineers (US ACOE, 1993). Use of an average of the flow ratio values for any given flow is a reasonable assumption to compute dilution of the San Diego Creek runoff water in the Bay.

The OCPFRD and the ACOE funded Resource Management Associates (RMA) to develop a model that would predict sediment deposition. The model was expanded to predict salinity profiles. This model will be explored by researchers from this study when the model is available for use.

Table 4-8
Flow Ratios Given Various Tidal Prism Volumes

Tidal Prism Value (P)	SDC Average Flow (cfs)	Flow Ratio (F)
$P=1.65(10^7)\ m^3$	1967	0.16
	156	0.01
	22	0.002
$P=2.6(10^6)\ m^3$	1967	0.99
(U.S. Army Corps, 1993)	156	0.076
	22	0.0109
$P=1.15(10^7)$	1967	0.225
J. DeGeorge (1998)	156	0.017
	22	0.0025

Values of “F” that approach 1 in the table do not indicate that the volume of storm flow equals the volume of salt water. These values should not be interpreted to mean that the entire estuary is comprised of storm flow. Rather, this would indicate a highly stratified condition where an estimate of dilution (mixing) of the volume of the estuary (or tide prism) would not be appropriate. It should be noted that the table above does not include the contribution of the Santa Ana Delhi Channel, which is about 6 percent of the area of the San Diego Creek watershed.

Upper Newport Bay marine waters typically exhibit a salinity of about 30 ppt. During a portion of a storm event, as discussed above, there will be a zone in the Bay waters where the salinity drops significantly. The time this zone will exist depends on several variables. A salinity of about 3 ppt or less is considered critical with respect to mysid mortality based on the salinity threshold and an assumed toxicity of 10 toxic units associated with the incoming stormwater discharge.

The extent and time of mixed versus stratified flow in the Bay is highly variable, depending on the volume of stormwater entering the Bay versus the tide stage, the time of direct runoff of the stormwater hydrograph, and the peak discharge of the stormwater hydrograph, and to a lesser extent the temperature differential of the Bay and stormwater, the amount of sediment in the stormwater, and the shape of the hydrograph. In addition, lateral mixing of storm flow and Bay waters is impacted by wind direction and magnitude. The information provided in Table 4-7 can be used as an indicator to determine if a potential problem exists for exposure of marine organisms to stormwater runoff that has been determined to be toxic.

It is reasonable to assume that a substantial zone of water in the range of 3 ppt of salinity or less would occur during full or partial mixing of storm flow with Bay water. Conditions with full stratification may be less problematic for marine organisms, since they are not originally present in the stormwater runoff and may tend to not migrate into the freshwater lens. Therefore, if the critical time is assumed to be during the hours when the flow is estimated to be fully mixed, it can be seen from the data in Table 4-7 that this time occurs on average about 10.5 hr per storm event (using 1997-98 storm season data). The average time of direct storm runoff into the Bay (again using 1997-98 data) is about 37 hr per storm. This average contact time (10.5 hr) is potentially significant relative to toxicity to marine organisms in the Bay. Based on this analysis, it is clear that the toxicity from San Diego Creek and the Santa Ana Delhi Channel could impact some forms of aquatic life in Upper Newport Bay.

Using salinity gradients as a measure of mixing San Diego Creek water with Upper Newport Bay water in order to estimate the persistence of the toxic constituents and toxicity in the Bay following a runoff event assumes that the toxic constituents measured in the laboratory test of toxicity will be conservative, i.e., remain unaltered, in Upper Newport Bay. Since chlorpyrifos is likely the constituent of greatest concern, and since it tends to sorb on particulates, it is possible that part of the chlorpyrifos entering the Bay will be in non-toxic forms. This conclusion is based on the fact that the WRCB BPTCP/EMAP studies of Upper Newport Bay conducted in 1994 (Anderson *et al*., 1997) found chlorpyrifos in the Bay sediments near where San Diego Creek enters Upper Newport Bay. The January 1999 in-Bay studies reported in Section 3 found that the mysid toxicity that has been found in San Diego Creek waters as they enter Upper Newport Bay is apparently affected by sorption or other reactions which affect its fate, persistence and magnitude of toxicity.

MIXING OF SAN DIEGO CREEK AND UPPER NEWPORT BAY (IN-BAY SAMPLING) – JANUARY 25-29, 1999

A sampling program was conducted January 25–29, 1999, to investigate salinity profiles at various locations in the Bay during a selected stormwater runoff event. Selected sampling was conducted for the presence of diazinon, chlorpyrifos and aquatic life toxicity at various locations within the Bay as a part of the in-Bay investigation. The data for this study were presented and discussed in Section 3.

The in-Bay study was designed to evaluate and further refine the work previously developed by Limno-Tech (LTI) (Limno-Tech, 1998) relative to the conditions under which Newport Bay becomes stratified (freshwater in a defined lens on top of marine water, discussed above). Stratification occurs when the large tributaries to the Bay (San Diego Creek, and to a lesser extent the Santa Ana Delhi Channel) discharge stormwater to the Bay.

A target stormwater runoff event that resulted in runoff from San Diego Creek of at least 1,500 cfs was desired to allow validation of the LTI estimates. However, storm events of lesser magnitude would also be acceptable for study, given that the runoff in San Diego Creek from a storm with a recurrence interval of 1 year is about 1,300 cfs. Storms with numerically lower recurrence intervals are more significant from a stormwater quality and receiving water impact perspective. The initial sampling plan was based on the following criteria:

- Samples were to be taken in the Upper Bay at selected stations. Each station is defined as a cross section, taken normal to the stormwater flow.

- Up to five stations have been identified in the Upper Bay as possible sampling locations: one near the entrance of San Diego Creek to the Bay (Jamboree Road, OCPFRD Station No. 1 "UNBJAM"), OCPFRD Station No. 2 San Diego Creek (UNBSDC), one about mid-way between Jamboree Road and the Pacific Coast Highway bridge at Big Canyon Wash (OCPFRD Station No. 3 "UNBBCW"), one near North Star Beach (OCPFRD Station No. 4, UNBNSB) and the fifth near the Pacific Coast Highway bridge (OCPFRD Station No. 6 "UNBCHB"). OCPFRD Station No. 5 was not selected for use with the study.

- Three locations were identified at each station. Two locations were near each shore, the third location in the middle of the Bay. Nearshore locations were selected to be in estimated active flow areas, as opposed to ineffective flow areas (i.e., in small channels on the leeward side of islands). Four samples were to be taken at each location. The samples were to be taken at various depths and be spaced between the surface and the sediments of the Bay, dependent on the salinity profiles. Tide and wind were noted for each of the samples.

- Salinity was to be measured at each sampling location. Samples for toxicity testing, when taken, were to be collected at the center Bay locations.

- Sampling was to be carried out at several times over the runoff hydrograph. At least one sampling time was to be completed when the inflow from San Diego Creek was estimated to be below 1500 cfs. The other sampling sets were to be taken at other times during the runoff hydrograph.

- It was anticipated that for some storms, as many as 108 salinity measurements could be made. The number of samples to be taken for toxicity and diazinon and chlorpyrifos measurements will be determined based on the data obtained.

The actual sampling program was adjusted somewhat from that originally planned in response to the conditions encountered in the field. The most significant change was the elimination of multiple sampling locations at each station. The depth of the Bay in the nearshore areas was too shallow to allow boat access regardless of tide conditions; consequently, a single sample was taken in the main Bay channel at each identified Bay station. Further, samples at additional depths were generally taken (not limited to four depths) to better define the depth salinity profile. Finally, not all stations were sampled if it was apparent that no fresh water mixing was occurring. For example, if stations in the upper portion of the Bay showed essentially 100% sea water (high salinity), samples were not taken further down-Bay (toward the ocean) at the remaining stations. The changes to initial program in the field are summarized below.

- Sample locations at each cross section (Station) were reduced to one (single point in the main channel), due to shallow water conditions;

- The number of salinity readings with respect to depth at each station was increased to a minimum of 5 and a maximum of about 14, depending on the depth;

- Not all five stations were sampled depending on the salinity readings that were obtained from the upstream Stations. If salinity readings were high, stations further downstream in the Bay were not sampled;

- Sample times were adjusted to coincide with the storm characteristics. The storm occurred over 2 days, with runoff over 4 days, and was generally less intense (return period of less than 1 yr).

The results of the January 25–29, 1999, in-Bay studies were presented and discussed in Section 3 Results. Presented below is a discussion of the relationship of the data obtained to that predicted by the LTI model.

The LTI numeric model predicts that flows from San Diego Creek will generally be mixed for discharges less than about 1,500 cfs, regardless of tide. The results of the in-Bay sampling generally support this conclusion. Stratification in which a fresher water lens is observed near the discharge point of San Diego Creek with the Bay at shallow depths (0.1 to 0.2 m) for nearly any of the discharges sampled were found. However, this fresher water lens stratification is generally not observed for the sampled event downstream of the Big Canyon Wash Station, which is located about midway in the Upper Bay (see Figure 2-1). There was appreciable vertical gradient in salinity at almost all stations. The San Diego Creek stormwater flows become "mixed" as depth increases, with typical salinity ranging from 10 ppt to 20 ppt. The LTI model indicates that stratification can occur for flows less than 100 cfs at the Jamboree Station, but that the potential for stratification for flows less than about 1,000 cfs decreases with the distance downstream from the Jamboree Station. Again, dilution of the freshwater inputs appeared to be pronounced by the Big Canyon Wash Station, and fairly consistent for Bay stations downstream of this point for the sampled storm event sequence.

The results indicate that salinity of less than about 5 ppt can persist in the Upper Bay (generally upstream of the Big Canyon Wash Station) for several days. For the January 25-27, 1999, event, salinity at a depth to 0.1 m was less than 5 ppt for about 4 days, and less than 10 ppt for the entire event time of 5 days. The sampled event is significant in that it is typical of the conditions that would be expected on a routine basis for storm events in the watershed; however, the event duration is somewhat atypical. Based on the author's review of local rainfall data, the storm interevent time for the Newport Bay area during an average winter is about 5 days (during January, February, March). The sampled storm event exhibited two primary rainfall sequences about one day apart. As indicated on Figure A1-3, a runoff event with a 1-yr recurrence interval represents a flow to the Bay from San Diego Creek of about 3,000 cfs. Average events for any given year will have peak discharges less than this value, with magnitudes consistent with the sampled event.

HYDROLOGIC CONSIDERATIONS IN MANAGING SAN DIEGO CREEK AND UPPER NEWPORT BAY AQUATIC LIFE TOXICITY

Table 4-9 summarizes the hydrologic information for the San Diego Creek watershed. The data shown below are useful to assist in characterizing the storms relative to each other, and also with respect to other storm years. The data in Table 4-9 can be used when reviewing the storm hydrographs to aid in better understanding the nature of the rainfall event and the resulting runoff. The hydrograph shape is influenced by climatic factors and physiographic factors. Climatic factors include duration of the storm event (hyetograph), rainfall intensity and areal distribution. Physiographic factors include the slope of the watershed land surface and channels, and the size, shape and land use of the watershed. For any rainfall event, losses such as storage and initial abstraction must be satisfied before any runoff may begin.

The columns for peak flow and return period provide an assessment of the relative magnitude of the storm. Generally, most storms would be expected to have a recurrence interval of about one year. As shown in Table 4-9, the 1997-98 storm season was an exceptional year, with several storms exceeding the annual benchmark and one exceeding a 100-yr return period. As such, the 1997-98 storm season provides a good overall picture of the range of flows experienced in the watershed. The storms with relatively larger magnitudes would be expected to cause runoff from all portions of the watershed, as opposed to the smaller storms, which may produce runoff primarily from the impervious areas. The rainfall/runoff events recorded in 1996 are similar in nature to those recorded in the fall of 1997, with generally smaller storms and higher loss rates. The November 21, 1996, storm was notable for its fairly large total loss, a reflection of the duration of the storm (about 19 hours). Note that the method used to compute return period for the 1996 storms is not directly comparable to that used for the 1997 and later storms.

The Volume of Direct Runoff (VDR), total loss and average loss and total rainfall parameters are also good indicators of where runoff was produced in the watershed for the given storm event. The storms with a high loss rate and low VDR may reflect more runoff from impervious areas. Conversely, events with a relatively higher VDR as compared to the total loss may reflect more contribution from the pervious watershed areas (such as agricultural land). The storm average loss rate may also be indicative of the relative intensity of the storm, with higher average loss rates reflecting higher rainfall rates.

The lag time is an indicator of the watershed response to the rainfall event. A longer lag time indicates either a more protracted rainfall event, or a larger magnitude event that resulted in runoff contribution from all areas of the watershed. Conversely, shorter lag times result from more urbanized watersheds where runoff response is relatively quick and more runoff is generated from impervious areas. Hydrographs tend to be relatively steep in urban watersheds, both in the ascending and descending limbs for this type of storm as compared to an event that received significant contribution from pervious areas, which would tend to have a longer lag time and flatter slopes on the rising and falling limbs of the hydrograph. High-intensity rainfall and urbanization both increase the peak flow and shorten the watershed lag time.

Table 4-9
Summary of Hydrologic Information on the San Diego Creek Watershed Developed During the Study Period

Storm/Location	Peak Flow (cfs)	Return Period (yr)	VDR (in.)	Total Loss (in.)	Average Loss (in./hr)	Total Rainfall (in.)
October 30, 1996						
Campus Drive/SDC	1150	1.6[1]	0.12	0.81	0.27	0.93
November 21, 1996						
Campus Drive/SDC	1100	2.5[1]	0.2	2.48	0.13	2.68
September 25, 1997						
Campus Drive/SDC	892	1	0.078	0.48	0.069	0.56
November 13, 1997						
Campus Drive/SDC	1,871	1.5	0.17	0.63	0.057	0.8
November 30, 1997						
Campus Drive/SDC	840	1	0.035	0.29	0.063	0.32
December 6, 1997						
Campus Drive/SDC	43,500	100+	N/A	N/A	N/A	6.43
Barranca Parkway/PCC	8,900	50	2.76	3.7	0.18	6.43
March 25,1998						
Campus Drive/SDC	4,900	2	0.37	0.86	0.78	1.23
Barranca Parkway/PCC	3,990	5	0.42	0.81	0.074	1.23
Irvine Avenue/SAD	1,550	2	0.67	0.68	0.067	1.35
May 5, 1998						
Campus Drive/SDC	3,161	2	0.18	0.66	0.33	.99
Barranca Parkway/PCC	1,832	2	0.16	0.68	0.34	.99
Irvine Avenue/SAD	1,210	1	0.26	0.58	0.29	.84
May 12, 1998						
Campus Drive/SDC	4,361	2	0.42	0.69	0.086	1.11
Barranca Parkway/PCC	1,304	1	0.29	0.82	0.16	1.11
Irvine Avenue/SAD	887	1	0.45	0.7	0.14	1.15

Table 4-9 (continued)

Storm/Location	Peak Flow (cfs)	Return Period (yr)	VDR (in.)	Total Loss (in.)	Average Loss (in./hr)	Total Rainfall (in.)
November 8, 1998						
Campus Drive/SDC	2727.5	1	0.377	0.263	0.0526	0.64
Barranca Parkway/PCC [2]						
Irvine Avenue/SDC	673.7	1	0.22	0.58	0.116	0.80
January 25-29, 1999						
Campus Drive/SDC	2629	2	0.32	0.47	0.023	0.79

NOTES:

cfs Cubic feet per second
yr Years
in. Inches
in./hr Inches per hour
hr Hours
SDC San Diego Creek
PCC Peters Canyon Channel
SAD Santa Ana Delhi Channel

[1]The return periods computed for these storms used gaged hydrographs at Culver Drive, which is not directly comparable to the current year estimates which use a frequency relations graph generated for Campus Drive at San Diego Creek.

[2] The streamgage at Barranca malfunctioned during this storm. Therefore, hydrologic data are not available for this storm at this time.

SECTION 5
EVALUATION OF THE WATER QUALITY SIGNIFICANCE OF HEAVY METALS IN URBAN AREA AND HIGHWAY STORMWATER RUNOFF

One of the areas of particular concern in urban area and highway stormwater runoff water quality management is the need to treat the stormwater runoff to control the concentrations of heavy metals in the runoff waters. As reported by Lee (1998a), typically, copper, lead, and zinc are present in urban area street and highway stormwater runoff at concentrations above US EPA worst-case-based water quality criteria and state standards based on these criteria. OCEMA (1996, 1998) has reported the concentrations of several heavy metals in San Diego Creek water as it enters Upper Newport Bay at concentrations above water quality standards. It is, therefore, of interest to examine whether part of the toxicity found in this study was due to heavy metals.

There was discussion during the July 1998 Stormwater Quality Task Force meeting about the potential significance of vehicular traffic as a source of heavy metals that cause stormwater runoff from urban area streets and highways to be toxic to some forms of aquatic life. There have been a number of studies of urban area street and highway stormwater runoff in the San Francisco Bay area (Hansen & Associates, 1995) and the Central Valley Sacramento/Stockton area (Connor, 1995) which have demonstrated that the heavy metals in this runoff are in non-toxic forms. As part of the 1998 205(j) studies, special purpose TIEs were conducted on the November 8, 1998, San Diego Creek stormwater runoff as it entered Upper Newport Bay, for the purpose of determining whether any of the toxicity present in the samples could be due to heavy metals. From the information available, it appears that vehicular traffic is not a source of toxic forms of heavy metals. However, at the July 1998 Stormwater Quality Task Force meeting, Dr. Michael Stenstrom indicated that his information did not support the position that heavy metals derived from vehicular traffic are in non-toxic forms.

It seems unlikely that the studies conducted in San Francisco Bay, the Sacramento/Stockton area and Orange County, which demonstrate that heavy metals in urban area and highway stormwater runoff are not toxic, would not also be applicable to the Los Angeles region as well. It should be noted that there can be toxic heavy metals in urban area stormwater runoff. However, the metals are not derived from urban area streets and highways, but from industrial properties.

In a stormwater runoff water quality management program, it is important to critically examine the cause of toxicity which is apparently due to heavy metals to determine whether or not heavy metals or, for that matter, any constituents in urban area street and highway runoff are in toxic forms that are significantly adverse to the beneficial uses of the waterbody. This must be done through properly conducted toxicity tests using a suite of sensitive organisms where the response of the test could be related to beneficial use impacts. This issue is important, especially when using certain types of tests, such as a sea urchin fertilization test, since the use of this test can result in false positives, wherein an impairment of fertilization is shown, but does not subsequently translate to a reduction in the number of echinoderms at some sites. There are other factors that influence the fertilization of echinoderms that can affect the test results. Much of the heavy metal toxicity data (Bay, *et al.,* 1996) from the Los Angeles area is based on the sea urchin fertilization test.

At the July 1998 Stormwater Quality Task Force meeting, Dr. Steve Bay discussed the use of toxicity investigation evaluations (TIEs) to determine the potential cause of toxicity. This topic was also addressed by Stenstrom at this meeting. The comment was made after this discussion that caution must be exercised in doing a partial TIE as reported on by Bay and Stenstrom in identifying the real toxicants responsible for a particular toxicity. The addition of EDTA and the associated decrease in toxicity is not adequate proof that heavy metals at elevated concentrations in a stormwater runoff sample or in ambient water receiving stormwater runoff is a cause of the toxic response observed. A TIE must include Phase III confirmation to be certain that zinc or some other heavy metal or, for that matter, an organic that is a suspected cause of toxicity is the real cause of toxicity. Failure to follow these approaches could lead to erroneous conclusions about the need to control heavy metals in urban area and highway stormwater runoff. It should not be assumed that because there is an elevated concentration of a potentially toxic constituent relative to a water quality standard that the constituent is responsible for the toxicity.

One of the areas of particular concern with respect to heavy metals in stormwater runoff from urban area streets and highways as they may impact the beneficial uses of waterbodies is the copper situation in San Francisco Bay. As reported by Lee and Jones-Lee (1997a), while copper, associated with its use in some automobile brake pads, is apparently a significant source of the elevated copper that is present in San Francisco Bay area stormwater runoff, there are significant questions about whether this copper, which contributes to exceedances of site-specific water quality standards in San Francisco Bay waters, is adversely impacting the beneficial uses of these waters. It is likely that the copper derived from auto brake pads is in a non-toxic form and remains in this form in the stormwater runoff and Bay waters. Further, many waterbodies, such as San Francisco Bay, are well known to have significant detoxification capacity which renders toxic forms of constituents, such as copper, non-toxic.

Dr. Sam Luoma's discussions at the July 1998 Stormwater Quality Task Force meeting of the copper situation in south San Francisco Bay, as influenced by the City of Palo Alto's domestic wastewater discharges to the Bay, demonstrate that it is possible to overload the copper detoxification capacity of the system. His data show that during the time when the wastewater treatment plant was discharging large amounts of copper, there were likely adverse impacts on the clam population and on other organisms in the vicinity near the discharge. The situation today is that the copper that is accumulating in clam tissue appears to be derived primarily from stormwater runoff. The amount of that runoff-derived copper that is present in the clams is below the level that appears to be adverse to them.

There is considerable concern about the appropriateness of a TMDL for copper for San Francisco Bay, which could readily cost the public in that region hundreds of millions to a billion dollars to comply with water quality standards in the stormwater runoff. The goal of the TMDLs is to achieve the copper criterion/standard in the stormwater runoff so that no more than one exceedance of this criterion/standard occurs every 3 years in runoff waters. While there has been discussion about requiring the removal of copper from auto brake pads, such removal, while reducing the frequency of exceeding water quality objectives, will not eliminate the exceedance of the US EPA criteria - water quality site-specific objective developed for copper in San Francisco Bay. The Bay waters would continue to have these exceedances if all urban area and highway stormwater runoff inputs to the Bay were terminated. This arises from the presence of copper in the Bay sediments. While the copper in sediments is not especially high and, in fact, is apparently less than normal crustal abundance, it still is sufficient to cause exceedances of the site-specific water quality objectives for the Bay.

The San Francisco Estuary Institute (SFEI) has been testing Bay waters over the past several years for toxicity using the same organism that was used to establish the national water quality criterion for copper. SFEI has found that these waters are not toxic to this organism, even though the copper concentrations exceed the site-specific criterion. Further, SFEI studies have indicated that while there is toxicity in the Bay sediments, this toxicity does not correlate well with copper concentrations in the sediments.

Horne (1998a) has reported on the speciation (chemical forms) of copper present in stormwater runoff to San Francisco Bay. He found that urban stormwater runoff and San Francisco Bay waters contain considerable copper complexing capacity. Complexes are a special form of a metal species that results when the electropositive charge of a metal ion interacting with a ligand or ligand-containing molecule, i.e., one with an excess pair of electrons, forms a bond which changes the chemical characteristics of the metal. Many, but not all, complexes of heavy metals are non-toxic. Typically, as discussed by Allen and Hansen (1996), copper complexes with natural organic matter have been found to be non-toxic. Horne's work suggests that the dissolved copper in San Francisco Bay is in a non-toxic form because of complexation with organics. This type of situation is well known in the aquatic chemistry/aquatic toxicology literature.

The work of Horne is in accord with what would be predicted, based on the work that has been done over the last 20 years on the aqueous environmental chemistry of copper (Allen and Hansen, 1996). This situation is another example of the importance of appropriately incorporating aquatic chemistry/toxicology into assessing the water quality impacts of constituents in urban area and highway stormwater runoff on the beneficial uses of receiving waters.

It is recommended that, rather than implementing a TMDL for copper which would control the input of copper from stormwater runoff to San Francisco Bay or Upper Newport Bay and many other waterbodies, stormwater and wastewater dischargers to the Bay fund studies to search for yet-unknown problems due to copper or for other constituents. These constituents, such as copper, lead and zinc, while not now shown to be adverse to the beneficial uses of the Bay, could be adverse through some subtle, as yet undetected, response. It should be noted that this response would not likely be related to the current national criterion or site-specific objective for copper. If such problems are found, then control programs could be developed to control the constituents that are responsible for the recently detected problems at their source.

It is important not to assume that what is found in the San Francisco Bay will be applicable to all urban area and highway stormwater runoff. There can be situations where the ambient waters coupled with the stormwater runoff do not have sufficient complexing capacity so that the copper in the runoff would be in a toxic-available form when mixed into the receiving waters. These situations, however, would not be expected in Upper Newport Bay because of the characteristics of the Bay waters due to their high suspended solids and the high algal and other aquatic plant productivity in the Upper Bay.

Elevated concentrations of a potentially toxic constituent above the US EPA water quality criterion for that constituent should only be used to indicate that under worst-case conditions there could be aquatic life toxicity. Toxicity tests which include TIE evaluations, including Phase III, to confirm that a particular constituent is, in fact, responsible for toxicity, are an indication that the constituent is responsible for a **potential** adverse impact. This is much more reliable for assessing potential use impairments than the exceedance of a chemically-based water quality standard that is frequently used today.

While, from the information available, it appears that urban area street and highway stormwater runoff heavy metals, such as copper, zinc, cadmium and lead, are not a cause of aquatic life toxicity, urban area residential and commercial street stormwater runoff is highly toxic to some forms of aquatic life. As discussed herein, the cause of much of this toxicity is the residential and commercial use of organophosphate pesticides, diazinon and chlorpyrifos, that are used for structural (termites and ants) and lawn and garden pest control.

As discussed in the review of Upper Newport Bay water quality Lee and Taylor (`1999b) a heavy metal that may be causing low levels of aquatic life toxicity in urban area stormwater runoff is chromium VI. The concentrations of dissolved chromium in urban area stormwater runoff are sufficient, if the chromium is present as chromium VI, to be toxic to several forms of zooplankton.

SECTION 6
RECOMMENDATIONS FOR FUTURE STUDIES

The results from the Evaluation Monitoring Demonstration Project and this 205(j) Project have defined several areas that need additional studies to further define the magnitude of the aquatic life toxicity problem that exists in the Upper Newport Bay watershed and the Bay. Of particular importance is the need to conduct specific investigations of the fate/persistence of toxicity of the OP pesticides diazinon and chlorpyrifos. Also of concern is the persistence of the unknown-caused toxicity in the Bay. Information on the persistence of the aquatic life toxicity in the Bay is a key component of evaluating the potential water quality/ecological significance of the toxicity discharged to the Bay with each stormwater runoff event.

The other major area of needed future studies is the definition of the sources of the known (OP and carbamate pesticide) and unknown-caused toxicity. Of particular importance is an assessment of the relative magnitude of the contributions of toxicity from residential, agricultural and commercial nurseries that persist in the tributary waters to the Bay and within the Bay. Also there is need to define the specific uses and formulations of pesticides and other chemicals in each of these known principal sources that lead to the greatest loss of toxic components to stormwater runoff that persists in the Bay.

This project considers aquatic life toxicity as an entity that may need to be controlled, irrespective of whether the cause of the toxicity is identified. As discussed in Section 4 of this report, after considerable toxicity investigation evaluation (TIE) efforts, there is still substantial toxicity caused by unidentified constituents. It was not possible in this study, with the funds available, to identify the specific constituents responsible for all of the unknown-caused toxicity. However, as demonstrated in this project, through toxicity, diazinon and chlorpyrifos forensic-based studies of samples taken in various parts of the watershed during dry weather flow and runoff events, it is possible to determine the source of the unknown-caused toxicity without specifically identifying the chemicals responsible. The commercial nurseries that discharge/release water to the Hines Channel have been tentatively identified as potentially significant sources of the unknown-caused toxicity. Also, the March 15, 1999, Yorba Linda residential stormwater runoff sample shows that potentially there are large amounts of unknown-caused toxicity from this and, by extension, possibly other residential areas in the region.

Through the use of US EPA toxicity reduction evaluation (TRE) approaches, the nurseries and, for that matter, other identified sources of unknown-toxicity can be required to control this toxicity through the elimination of certain chemical applications and/or modification of water management practices. Therefore, in accord with the TMDL toxicity control requirements, the development of toxicity control approaches for the unknown-caused toxicity should be a key component of future studies.

The development of the needed information through the recommended follow-up studies will provide the technical base of information that the Santa Ana Regional Water Quality Control Board can use to formulate the Phase I total maximum daily loads (TMDLs) for toxicity, diazinon and chlorpyrifos. The following section presents a summary of the components of the recommended follow-up studies.

EVALUATION OF THE WATER QUALITY/ECOLOGICAL SIGNIFICANCE OF THE STORMWATER RUNOFF TOXICITY

The water quality/ecological significance of the stormwater runoff-associated *Ceriodaphnia*/ mysid toxicity is a key factor that could be highly influential in determining the need for the control of the use of the OP pesticides and other toxic constituents that are now causing San Diego Creek and its tributaries to be toxic to *Ceriodaphnia* and certain other forms of aquatic life during stormwater runoff events. A key issue that must be resolved is whether the regulation of this toxicity will be based on its likely causing a significant adverse impact to the beneficial uses of the tributary waters, as well as in the Bay. If the toxicity is judged to be of water quality significance to the aquatic life-related beneficial uses of the Bay and/or its tributaries, then the degree of toxic constituent control needed to protect the designated beneficial uses and the corresponding level of restriction on use of the pesticides or other chemicals responsible for the toxicity will need to be assessed.

The information presented on the current degree of mixing of San Diego Creek water with Upper Newport Bay water during and following a stormwater runoff event shows that there are conditions where marine zooplankton could receive an acute toxic exposure, provided that there are marine organisms that migrate into the low (less than 3 to 5 ppt) salinity San Diego Creek water/marine water lens and stay in this area for a day or more. The initial Bay toxicity pesticide fate/persistence studies conducted in January 1999 verify the persistence of San Diego Creek water-derived toxicity in the Bay following a stormwater runoff event near where the Creek waters mix with the Bay waters in the upper end of the Bay. This is an area that needs further study to define the conditions under which this situation occurs, and especially its water quality/ecological significance.

One of the issues that needs to be investigated is whether there is a significant potential for marine zooplankton to receive a toxic exposure due to the stormwater runoff-associated toxicity. If the decision to regulate the toxicity is based on the existence of significant adverse impacts to the aquatic life beneficial uses of the Bay, then there is need to determine whether there are marine zooplankton that migrate into the low-salinity toxic San Diego Creek/Bay marine waters and stay in these waters for one or more days. As discussed in Section 4, the current regulatory requirements are unclear as to whether OP and other pesticide-caused toxicity will be regulated based on significant adverse impacts or simply based on the presence of toxicity. If toxicity that causes significant adverse impacts to the beneficial uses of the Bay is the regulatory approach adopted, then studies will need to be conducted that involve trawling for zooplankton in the potentially toxic fresh water/marine water lens. The purpose of these studies is to determine the types of organisms present in the areas where the toxicity is present for sufficient duration to be potentially adverse to aquatic life.

If potentially significant marine zooplankton are present in the Bay toxic waters, then caged organism and/or laboratory studies will need to be conducted to determine if the organisms found in the potentially toxic waters of the Bay are sensitive to the conditions that are toxic to the standard test organism used in these studies, mysids. The caged organism studies where exposure occurs during a runoff event would provide information on whether the marine zooplankton that migrate into the potentially toxic fresh water/marine water lens are killed during the period of time that this lens exists.

If it is established that there are marine zooplankton that are likely killed by the toxic conditions that occur in stormwater runoff events, then an assessment will need to be made on whether the potentially impacted zooplankton are important components of the Upper Newport Bay ecosystem. If they are important, then a reduction in toxicity would lead to significantly improved aquatic life-related beneficial uses of the Bay, where key organisms in the Bay Waters depend on Upper Newport Bay as important nursery grounds for larval forms of the organisms.

Consideration should also be given to whether there are fresh water zooplankton that enter Upper Newport Bay in a stormwater runoff event that could survive in Upper Newport Bay when the stormwater runoff is mixed with the Bay waters. It is expected that most of the San Diego Creek zooplankton will be killed by the salinity of the Bay when the Creek and Bay waters mix. As a result, the toxicity found in San Diego Creek to its zooplankton will most likely need to focus on toxicity to freshwater zooplankton that occurs during the transport of the zooplankton to the Bay during runoff events.

An area of particular concern is the very high levels of *Ceriodaphnia* toxicity that were found in August 1998 dry weather flow in the Hines Channel just downstream from the two commercial nurseries. Since, as discussed in Section 4, other nurseries in other parts of the Upper Newport Bay watershed are also using a wide variety of pesticides, it is likely that they will also be contributing to the aquatic life toxicity in the runoff/discharge waters from the nurseries.

From the limited information that is available, it appears that groundwater and other dry weather flows input to the Hines Channel and downstream channels diluted the high levels of toxicity found in Hines Channel just downstream of the two commercial nurseries. It should be noted, however, that at this time no sampling of agricultural irrigation return water (tail water) for aquatic life toxicity has been conducted. It is possible that at some time during the year, but not necessarily at all times, agricultural tail water in the Upper Newport Bay watershed could also be highly toxic to *Ceriodaphnia* and other forms of aquatic life. This is an area that needs to be investigated in subsequent studies.

The US EPA OPP and California Department of Pesticide Regulation regulatory process for curtailing pesticide use depends on demonstrating that the Upper Newport Bay ecosystem is currently being significantly impaired by the OP and other pesticides. Because of the difficulty in establishing a clear relationship between pesticide-caused toxicity and impaired beneficial uses, it is likely that the TMDL for control of toxicity and diazinon and chlorpyrifos will need to be based on a Phase I assumed percent reduction of the total toxic loads and the OP pesticide loads to Upper Newport Bay by each of the major sources – urban residential, agricultural and commercial nurseries – as well as any other toxicity sources that are identified through further studies.

This study, like other studies of OP pesticide-caused aquatic life toxicity, focused on toxicity to *Ceriodaphnia* and *Americamysis*. As discussed in Section 4, the amphipod *Gammarus fasciatus* is more sensitive to diazinon and chlorpyrifos toxicity than *Ceriodaphnia*. At this time, the US EPA and states are developing sediment quality guidelines that are designed to protect benthic organisms such as amphipods from aquatic life toxicity. It is likely that the toxic pulses associated with stormwater runoff events are killing benthic organisms such as *Gammarus.* There is need to determine whether this is occurring and if so, its water quality/ecological significance to the beneficial uses of San Diego Creek and the upper parts of Upper Newport Bay which were found to be toxic during the January 1999 stormwater runoff events.

SOURCES OF TOXICITY AND OP PESTICIDES, DIAZINON AND CHLORPYRIFOS

Independent of the regulatory approach adopted in the TMDLs that will be implemented by 2002, there is need for information on the sources of known and unknown-caused toxicity, diazinon and chlorpyrifos that leads to aquatic life toxicity in Upper Newport Bay tributaries, as well as the Bay. The Evaluation Monitoring Demonstration Project and this 205(j) Project have focused the sampling and toxicity assessment on San Diego Creek at Campus Drive as it enters Upper Newport Bay. Selected sampling of other Bay tributaries such as the Santa Ana Delhi Channel as well as within the San Diego Creek watershed has been conducted. In the future, associated with the Santa Ana Regional Water Quality Control Board's need for information on the sources of aquatic life toxicity and diazinon and chlorpyrifos, a more detailed, systematic sampling of the stormwater runoff events should be conducted. This sampling program should be designed to define the major sources and loads of toxicity and diazinon and chlorpyrifos for San Diego Creek and its tributaries. Funding has been made available by the US EPA, through a 319(h) grant, to initiate an Upper Newport Bay and San Diego Creek toxicity, diazinon and chlorpyrifos source identification and load characterization study. This study will start in the fall of 1999.

Since residential use of the OP pesticides, diazinon and chlorpyrifos, is the primary use in the Upper Newport Bay watershed, a special purpose study program should be conducted to determine the potential significance of various residential uses, structural for termite and ant control versus lawn and garden pest control, as a source of stormwater runoff-associated toxicity. As delineated in DPR (1995-1997) pesticide use data for Orange County, by far the greatest use of the OP pesticides diazinon and chlorpyrifos applied by commercial applicators is for structural purposes. At this time, however, it is unclear whether such uses represent significant sources of OP pesticides that lead to stormwater runoff toxicity. It is possible that, if properly applied by a commercial applicator, the OP pesticides used for termite and ant control do not represent a significant source of stormwater runoff-associated toxicity. However, it is likely that any use of the OP pesticides for lawn and garden pest control by commercial applicators and/or the public can lead to stormwater runoff-associated toxicity. Therefore, it will be important to determine at several locations within the Upper Newport Bay watershed the significance of various residential uses of the OP pesticides as a cause of aquatic life toxicity in stormwater runoff. These studies should involve measurement of stormwater runoff-associated pesticides and toxicity on residential properties where a controlled application of the pesticides has taken place.

This project has focused on the OP pesticides diazinon and chlorpyrifos as a potential cause of the *Ceriodaphnia* toxicity found in the stormwater runoff that is measured at San Diego Creek as it enters Upper Newport Bay. Since there have been readily measurable amounts of unknown causes of toxicity in stormwater runoff in the Upper Newport Bay watershed, some samples of the San Diego Creek stormwater runoff have been submitted for dual column GC analysis in order to determine whether there are other OP pesticides or carbamate pesticides that are causing *Ceriodaphnia* toxicity. It was through this approach that methomyl, a carbamate pesticide, was discovered at sufficient concentrations in San Diego Creek as it enters Upper Newport Bay during fall 1996-98 stormwater runoff events, to be acutely toxic to *Ceriodaphnia*. Methomyl was used in the Upper Newport Bay watershed in 1995-97 for agricultural purposes on cabbage, corn, strawberries, lettuce, beans and tomatoes.

There could be a variety of other OP as well as other types of pesticides used in the Upper Newport Bay watershed by residential, agricultural and commercial institutions including nurseries which are responsible for the *Ceriodaphnia* and mysid toxicity that is found in San Diego Creek as it enters Upper Newport Bay. It has been found that only a small amount of pesticide loss (about a pound or so over the year) from the point of application compared to the total pesticide applied can account for the *Ceriodaphnia*/mysid toxicity found in this study in San Diego Creek stormwater runoff. While typically pesticide investigation programs focus on large uses of pesticides, some of the smaller uses could be important sources causing *Ceriodaphnia*/ mysid toxicity. As an example, about 3,000 to 4,000 lb/yr of methomyl was applied to agricultural crops in Orange County in 1995-97, yet methomyl was detected as a potential toxicant above the LC_{50} for *Ceriodaphnia* in San Diego Creek water as it enters Upper Newport Bay.

Propetamphos is an example of an OP pesticide that is being used in the Upper Newport Bay watershed for residential pest control purposes that could be responsible for part of the unknown-caused toxicity in San Diego Creek as it enters Upper Newport Bay. This pesticide can only be used by commercial applicators. In 1990 over 7,800 lb were applied for structural pest control in Orange County, while in 1996 and 1997 about 1,400 lb were applied each year for this purpose. It has been found that the conventional US EPA GC scan for OP pesticides is not typically set up to detect this chemical. As discussed in Section 4, propetamphos appears to be slightly less toxic to *Daphnia magna* than diazinon. At this time, there is no information on its toxicity to *Ceriodaphnia* or *Americamysis*. Therefore, propetamphos is one of possibly many OP pesticides that could be present in residential stormwater runoff that could be contributing to the unknown-caused *Ceriodaphnia* toxicity in the Upper Newport Bay watershed.

It will be important in the Upper Newport Bay pesticide source studies to examine each of the sources of *Ceriodaphnia* and mysid toxicity to determine whether there is unknown-caused toxicity that cannot be accounted for by diazinon and chlorpyrifos. This type of study could reveal that there are a variety of other OP as well as other pesticides used in residential, agricultural and commercial nurseries that are contributing to the *Ceriodaphnia*/mysid toxicity problem that is occurring in San Diego Creek water as it enters Upper Newport Bay.

A new area of potential concern with respect to pesticide impacts on San Diego Creek and Upper Newport Bay is the recent finding that fire ants have become established in Orange County. This could lead to the use of one or more pesticides as part of an effort to try to eradicate fire ants before they spread further through the County. It will be important to keep track of what pesticides are used and where and when this use takes place in any fire ant control program. Also it may be desirable to do some stormwater runoff monitoring from areas that are treated for fire ant control.

FUTURE TIE STUDIES

Toxicity investigation evaluations (TIEs) have been used throughout the Evaluation Monitoring Demonstration Project and this 205(j) Project to gain insight into the cause of the *Ceriodaphnia* and mysid toxicity that is found in San Diego Creek watershed stormwater runoff as it enters Upper Newport Bay. The use of PBO with the ELISA testing is a highly directed, fairly specific TIE for OP pesticides and, in particular, diazinon and chlorpyrifos. Further, the expanded conventional TIE that was conducted on the San Diego Creek stormwater runoff collected at Campus Drive for the November 8, 1998, storm, demonstrated that heavy metals are not likely a significant cause of the toxicity that was found in this sample. There is, however, a substantial amount of the *Ceriodaphnia* and mysid toxicity that, at this time, is due to unknown causes. As reported by Dr. J. Miller (See Lee and Taylor 1999a Appendix B), efforts to identify the cause of this toxicity have thus far proven to be unsuccessful. Therefore, one of the issues that needs to be addressed is what further work should be done to identify the cause of the unknown-caused toxicity.

A substantial part of the unknown-caused toxicity appears to be derived from the use of pesticides and other chemicals by one or both commercial nurseries that are located just upstream of the Hines Channel sampling point. It appears from the data available that part of the unknown-caused toxicity that has been measured at the San Diego Creek at Campus Drive station and the Peters Canyon Channel at Barranca Parkway station is derived from the Hines Channel and likely the commercial nurseries and/or upstream agricultural areas. The set of samples that was obtained in the San Diego Creek watershed on November 8, 1998, provides information on other potential sources of unknown-caused toxicity.

As discussed in Section 4, it was hoped that a review of the pesticides used at the commercial nurseries would provide insight into the cause of the unknown-caused toxicity. However, there are so many different types of pesticides used by the commercial nurseries, that the information on pesticide use provides little in the way of help to identify the cause of the unknown-caused toxicity found just downstream from two of these nurseries.

The testing of the November 8, 1998, runoff waters for toxicity to *Ceriodaphnia* showed that San Diego Creek at Campus Drive and Harvard Avenue, Peters Canyon Channel at Barranca Parkway and Hines Channel were highly toxic, where 12.5% dilution killed all *Ceriodaphnia* in 24 hr. PBO only partially neutralized this toxicity on the highly diluted samples. The total *Ceriodaphnia* toxicity in these samples was on the order of 16 TUa. This is the first time that San Diego Creek above where it confluences with Peters Canyon Channel has been tested in this study. It is of interest to find that there were high levels of *Ceriodaphnia* toxicity in the main stem of San Diego Creek above where it confluences with Peters Canyon Channel and, most importantly, that there were high levels of *Ceriodaphnia* toxicity that could not be neutralized by PBO, indicating that there is a source(s) of unknown-caused toxicity in the San Diego Creek watershed that is not associated with the Hines Channel.

As discussed in Section 4, the attempt to use the US EPA OPP Pesticide Ecotoxicity Database for the pesticides that have been found in San Diego Creek stormwater runoff to identify the cause of some of the unknown-caused toxicity proved unsuccessful. From the information available, it appears that this toxicity is due to non-measured OP or carbamate pesticides, other pesticides, or other chemicals.

The watershed studies that should be conducted should attempt to identify other sources of unknown-caused toxicity, as well as to quantify how much of the unknown-caused toxicity that is present in the Peters Canyon Channel and its tributaries branch of the San Diego Creek watershed is derived from the Hines Channel. Also, studies need to be conducted on the sources of the unknown-caused toxicity in San Diego Creek above where it confluences with the Peters Canyon Channel.

There is need to determine if any further efforts should be made to identify, through more comprehensive TIEs, the specific chemicals responsible for the unknown-caused toxicity that is present in the Hines Channel just downstream from the commercial nurseries and agricultural areas. Full TIEs may not identify all or even a substantial part of the cause of the unknown-caused toxicity found in the samples in the Hines Channel sampling location and are relatively expensive to run. Further it is likely that the pesticide or other chemical mix that is responsible for the unknown-caused toxicity changes from season to season and could change from year to year, as pesticide use is modified.

Further TIE work should be devoted to examining the cause(s) of the unknown-caused toxicity if any is found in the stormwater runoff from the residential areas as well as from agricultural areas. The Yorba Linda March 15, 1999, stormwater runoff sample points to the importance of conducting studies of this type. For those situations where substantial amounts of unknown-caused toxicity are found in stormwater runoff for more restricted types of land use, more comprehensive TIEs should be used to try to identify the cause(s) of this toxicity. The planning and implementation of this effort should be closely coordinated with the Santa Ana Regional Water Quality Control Board to best use the limited funds available.

An important aspect of further TIE work is an understanding of the uncertainty that exists in assessing the magnitude of the unknown-caused toxicity present in a sample. The approach that has been used to estimate the toxicity due to the organophosphate pesticides, which involved dividing the ELISA-measured concentrations by the LC_{50} and adding the two quotients to assess the known toxicity, is subject to considerable variability. The LC_{50}s for *Ceriodaphnia* or mysids are not fixed, precise values, but are subject to a number of factors that can influence their magnitude. These include the inherent variability in the toxicity tests used, as well as an ambient water effect on toxicity associated with how toxicity by a chemical such as diazinon is manifested to a test organism such as *Ceriodaphnia* in various types of ambient waters.

The ambient water effects can be either positive or negative, depending on the constituents in the water. Dr. J. Miller of *AQUA*-Science (personal communication, 1998) has recently indicated that he is finding enhanced toxicity of diazinon to *Ceriodaphnia* in certain ambient waters, compared to the toxicity found in standard laboratory waters. Such findings would reduce the magnitude of the unknown toxicity in a sample, proportionate to the enhanced toxicity associated with the ambient water effects on toxicity. The net result is that the so-called known toxicity that is obtained by the procedures used in this investigation can easily vary ±1 or more toxic units.

There is also considerable uncertainty about the magnitude of the total toxicity present in the sample, based on the dilution series toxicity testing that is done. Another factor is that many of the analytical procedures used to identify unknown toxic components in a sample yield variable results, especially at low concentrations of constituents.

These factors result in a situation where any efforts to try to identify unknown-caused toxicity through a TIE procedure should only be directed toward samples that repeatedly show at least a 3-toxic-unit difference between the total toxicity measured in a sample through a dilution series and the estimated toxicity based on dividing the measured concentrations of diazinon and chlorpyrifos by the LC_{50} values.

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