Characterization and Assessment of Storm Drain Sediments from Switzer Creek

March 20, 2009

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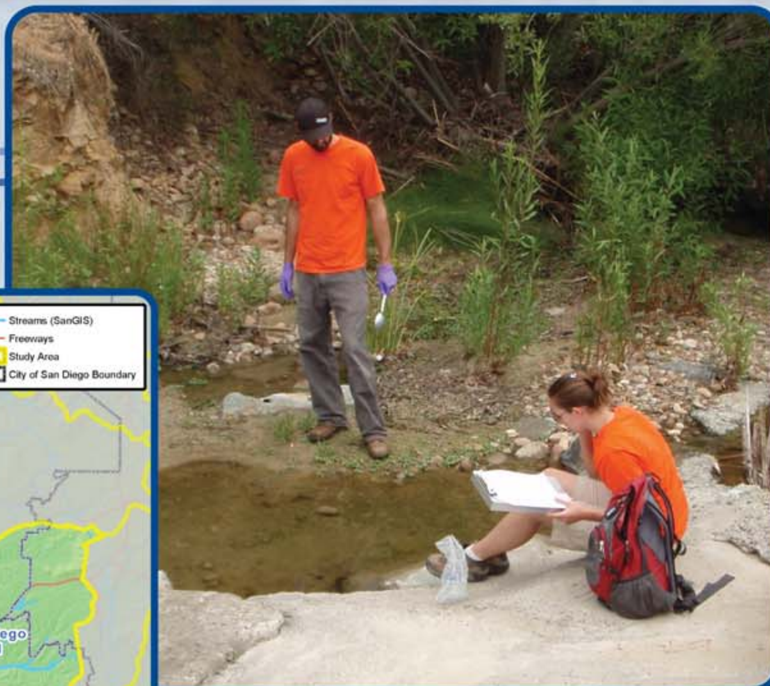

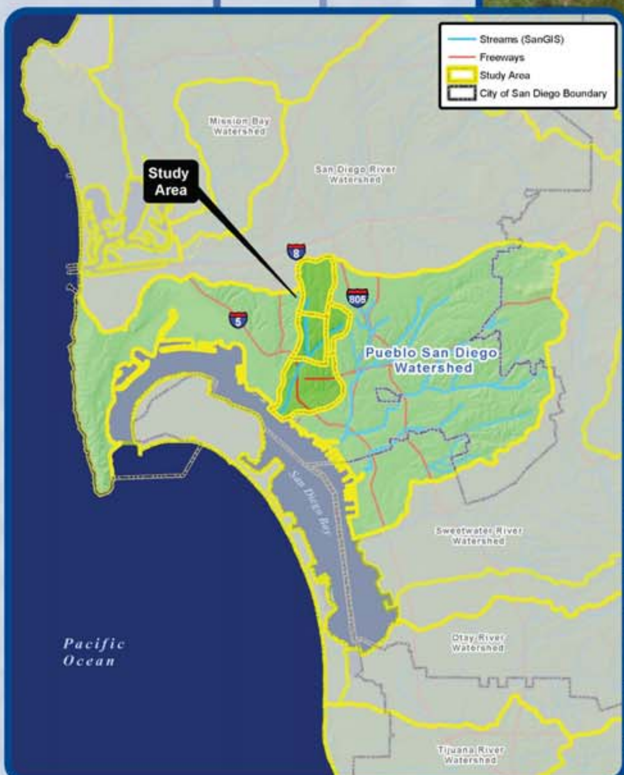

City of San Diego

think BLUE SAN DIEGO

Characterization and Assessment of Storm Drain Sediments from Switzer Creek

Final Report

Prepared for:

City of San Diego
9370 Chesapeake Drive, Suite 100, MS 1900
San Diego, CA 92123

Prepared by:
Weston Solutions, Inc.
2433 Impala Drive
Carlsbad CA, 92010

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LIST OF ACRONYMS

BPP	Brake Pad Partnership
COC	constituent of concern
CTR	California Toxics Rule
DDT	dichlorodiphenyltrichloroethane
DDT isomers	refers to the term of total DDT (DDT, DDE, DDD)
ERL	effect range – low
ERM	effect range – median
HU	hydrologic unit
MS4	municipal separate storm sewer system
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PCO	Pest Control Operator
PEL	probable effect level
TEL	threshold effect level
TMDL	total maximum daily load
US	United States
USEPA	United States Environmental Protection Agency
WESTON®	Weston Solutions, Inc.
WMA	watershed management area
WQO	water quality objective

EXECUTIVE SUMMARY

Weston Solutions, Inc. (WESTON®) under contract by the City of San Diego conducted a study within the Pueblo San Diego Watershed to characterize and assess storm drain sediments with a focus on pesticide distributions, specifically within the Switzer Creek Subwatershed. The study was designed to assess four sectors for prioritization and to potentially identify sources or sector areas of the watershed that contribute to constituent loads at the base of the watershed, which ultimately discharge to San Diego Bay. The study has a particular focus on pesticides that have been associated with toxicity at the mouth of Switzer Creek in San Diego Bay.

Currently, a total maximum daily load (TMDL) is being developed by the San Diego Regional Water Quality Control Board (RWQCB) for sediment toxicity for the mouths of Chollas Creek, Paleta Creek, and Switzer Creek. Switzer Creek was placed on the 2006 State Water Resources Control Board (SWRCB) Section 303(d) list for Chlordane, lindane/hexachlorocyclohexane (HCH), and polycyclic aromatic hydrocarbons (PAHs) (SWRCB, 2008). Monitoring data collected for model calibration and validation during the 2005–2006 Wet Weather Monitoring Season by the Southern California Coastal Water Research Project (SCCWRP) detected low concentrations of PAHs, Chlordane, and dichlorodiphenyltrichloroethane (DDT) in storm water runoff (SCCWRP, 2007).

This study was intended to address the following questions:

1. **What is the spatial distribution of pesticides and other relevant COCs in sediment in Switzer Creek?**

2. **Are areas of Switzer Creek impacted in specific areas related to current and historical pesticide use?**

3. **Do sediment concentrations exceed published sediment guidelines or LC_{50}s for target species?**

These questions were answered through conducting sediment sampling throughout Switzer Creek. Sediment samples were collected in the Switzer Creek Watershed from four sector areas based on land use and drainage area to assess the distribution of pesticides and potentially identify sources (Figure ES-1). The results should provide the City of San Diego information to support the development of a TMDL at the mouth of Switzer Creek for sediment toxicity and to develop management strategies for reducing constituent loads.

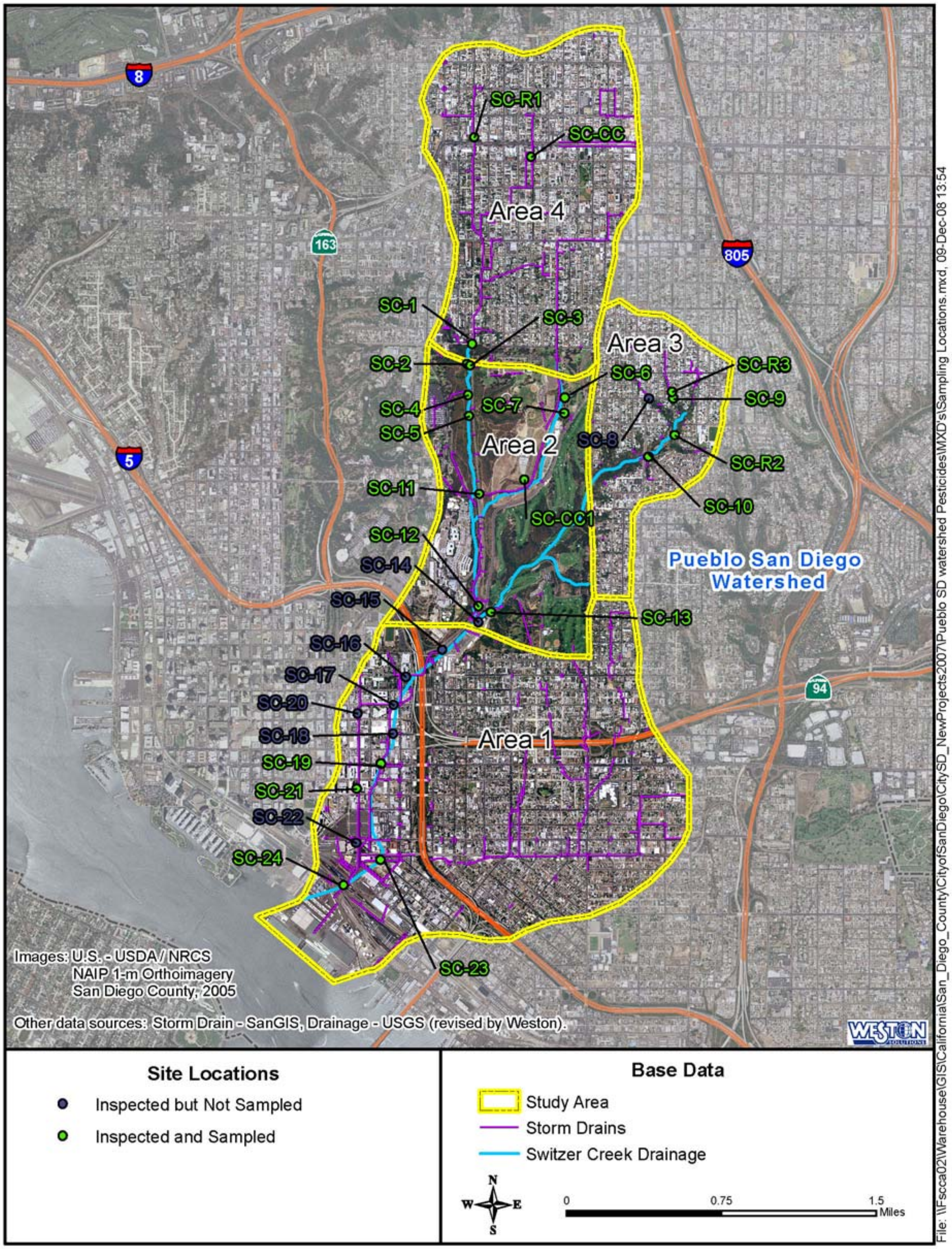


Figure ES-1. 2008 Switzer Creek Sediment Sample Locations and Sector Areas

Based on the sample results assessed, the following study questions were addressed:

1. **What is the spatial distribution of pesticides and other relevant COCs in sediment in Switzer Creek?**

The pesticides Chlordane, DDT isomers, and synthetic pyrethroids were highest in and most frequently detected in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential) which coincide with residential and commercial land uses. Although DDT and its degradation isomers were detected, the concentrations are indicative of historical usage and not indicative of recent application. DDT isomers are generally persistent and have long half lives in soil. The compound 4,4-DDT was detected during the initial sample event, but was not detected during follow-up sampling which further confirms evidence of historical pesticide use and not recent application. Organophosphate pesticides were rarely detected and demonstrates that the USEPA ban on these pesticides is effective.

Copper and lead were highest in Area 1 (Downtown) while zinc was highest in Area 4 (Residential & El Cajon Blvd.). Cadmium was relatively low in comparison to copper, lead, and zinc. However, cadmium, copper, and zinc were highest in Area 4 (Residential & El Cajon Blvd.) and Area 2 (Balboa Park). Lead was highest in Area 1 (Downtown) receiving water locations. PAHs were highest in Area 1 (Downtown) and Area 2 (Balboa Park). PCBs were rarely detected.

2. **Are areas of Switzer Creek impacted in specific areas related to current and historical pesticide use?**

This question was answered by the elevated detections of DDT isomers, Chlordane, and synthetic pyrethroids in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential), which have primarily residential land uses. Synthetic pyrethroids were detected in all areas. However, organophosphate pesticides were rarely detected or were just above the detection limit. DDT isomers and Chlordane were historically used for pesticide control. Currently, synthetic pyrethroids are the most commonly used pesticides to control ants, termites, and mosquitoes. Because DDT and Chlordane are banned compounds, the elevated levels detected in areas 4 and 3 suggest that these pesticides were previously applied in areas not subject to environmental exposures until soil excavations, erosion, or building demolition occurred in recent years. Re-sampling of several sites in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential) to confirm detections of 4,4-DDT showed no detections of 4,4-DDT and generally lower concentrations of the breakdown products DDE and DDD.

Synthetic pyrethroids are the most readily available retail pesticides and it stands to reason that elevated detections of these compounds would be expected. However, their route to the storm drain network likely occurs through improper applications to impervious surfaces subject to washoff. Applications of these pesticides to impervious surfaces can occur through lawn and garden products, professional pest control operators (PCOs), and via broadcast spraying to control mosquitoes.

3. Do sediment concentrations exceed published sediment guidelines or LC_{50}s for target species?

Based on the data assessed, it is evident that DDT isomers, Chlordane, synthetic pyrethroids, and metals (copper, lead, and zinc), are being detected at levels above published sediment guidelines in the Switzer Creek Watershed. Although PAHs and infrequent detections of PCBs, Diazinon, and Chlorpyrifos were noted, these compounds were below the effects level expected to cause lethal effects to freshwater or marine organisms.

The results of this study demonstrate that Chlordane, DDT isomers, synthetic pyrethroids, copper, lead, and zinc should be classified as COCs in the Switzer Creek Watershed. Because the watershed is similar to many urbanized settings within the City and County of San Diego, it stands to reason that storm drain sediment results would likely be similar in other watersheds. Synthetic pyrethroids are a known issue on a statewide basis and have been detected in storm water runoff in most areas of San Diego County. The California Storm Water Quality Association (CASQA) Pesticide Subcommittee is actively working with the Department of Pesticide Regulation to provide information and recommendations during the pyrethroid re-registration process, with the ultimate goal of preventing these compounds form entering the MS4 or receiving waters.

Recommendations

Management actions focused in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential) may help to reduce the use and detections of legacy pesticides in these areas. Increased education and outreach combined with household hazardous waste disposal events may help to eradicate stored sources of these pesticides. Promoting integrated pest management techniques may also be useful. Alternatively, promotion of Ecowise Certified PCOs (Ecowise, 2008) may help to influence other PCOs to operate in a more environmentally friendly manner. Additionally, pre-termiticide applications of these compounds are long lasting and may be a result of building renovations and soil excavations in older areas of the watershed and may be detected for some time. Enforcement of construction site erosion controls or BMPs may help to stabilize sediments from these activities. Because most of the COCs are associated with sediment transport, BMPs focused on controlling sediments from entering the storm drain system may be beneficial at reducing sediment concentrations of these compounds. The City of San Diego is currently evaluating the effectiveness of aggressive street sweeping in the Pueblo San Diego Hydrologic Unit with a focus in Chollas Creek. Mechanical street sweepers, vacuum assisted street sweepers, and regenerative air street sweepers are being assessed for their effectiveness at reduce pollutant loadings that include sediment, pesticides, metals, and other constituents. Lastly, efforts focused at removing sediment from storm drain catchments prior to the storm season will help to reduce the amount of sediment able to be mobilized during the wet weather season.

1.0 INTRODUCTION

The purpose of this study is to characterize and assess storm drain sediments with a focus on pesticide distributions within the Pueblo San Diego Watershed, specifically within the Switzer Creek Subwatershed. The study was designed to assess four sectors for prioritization and to potentially identify sources or sector areas of the watershed that contribute to constituent loads at the base of the watershed, which ultimately discharge to San Diego Bay. The study has a particular focus on pesticides that have been associated with toxicity at the mouth of Switzer Creek in San Diego Bay. Weston Solutions, Inc. (WESTON®) was contracted by the City of San Diego to perform this study during Summer 2008.

Currently, a total maximum daily load (TMDL) is being developed by the San Diego Regional Water Quality Control Board (RWQCB) for sediment toxicity for the mouths of Chollas Creek, Paleta Creek, and Switzer Creek. Switzer Creek was placed on the 2006 State Water Resources Control Board (SWRCB) Section 303(d) list for Chlordane, lindane/hexachlorocyclohexane (HCH), and polycyclic aromatic hydrocarbons (PAHs) (SWRCB, 2008).

Monitoring data collected for model calibration and validation during the 2005–2006 Wet Weather Monitoring Season by the Southern California Coastal Water Research Project (SCCWRP) detected low concentrations of PAHs, Chlordane, and dichlorodiphenyltrichloroethane (DDT) in storm water runoff (SCCWRP, 2007). Polychlorinated biphenyls (PCBs) and lindane were not detected during any of the three storms monitored during the 2005–2006 Wet Weather Monitoring Season. Chlordane and DDT isomers are organochlorine pesticides previously used for termite, ant, and mosquito control, but were banned from use in the United States (US). DDT was banned for use in the US in 1972, but is still used in some countries for malaria control. The United States Environmental Protection Agency (USEPA) banned all uses of Chlordane in 1988. PAHs are a group of over 100 different analytes that are formed as a result of incomplete combustion of oils, gas, coal, and other organic products. Following the development of the model calibration and validation, model runs suggested that many of the constituents of concern (COCs) were correlated with total suspended solids (TSS) concentrations found in storm water runoff. The SCCWRP report further recommended that best management practices (BMPs) associated with reducing sediment loads would likely be beneficial to reduce constituent loads. Based on the findings of the Switzer Creek modeling studies, the Switzer Creek Sediment Study focused on identifying areas with high sediment concentrations in areas susceptible to contributing to sediments in storm water runoff.

The work for this project will support the TMDL implementation monitoring for Switzer Creek and will provide valuable information with regard to pesticide use by drainage area. This work will help to identify the spatial distribution of pesticide pollutants in sediment in Switzer Creek.

Some historical monitoring work has been conducted in the area. Monitoring that was conducted in 2005–2006 supported the hypothesis that the majority of detected pollutants are associated with sediment transport. Additionally, nearby Chollas Creek 2005–2007 monitoring data have shown that toxicity to *Hyalella azteca* is linked to synthetic pyrethroids (WESTON, 2007a). Synthetic pyrethroids are commercially available compounds used for insect control and are predominantly associated with sediments in storm water runoff. Recent monitoring in Chollas

Creek has also demonstrated decreasing concentrations of Diazinon, and there has been an observed shift in pesticide use to the synthetic pyrethroid class of compounds (WESTON, 2008a). Land use in Chollas Creek is similar to that of Switzer Creek. A recent study by UC Davis scientists has indicated that synthetic pyrethroids in San Diego Bay marine sediments and storm water from Switzer Creek were linked to toxicity to *Eohaustorius estuarius* (Anderson et al., 2007). This also supports the evidence that previous toxicity may no longer be due to only the historical pollutants of concern. Review of the Switzer, Chollas, and Paleta Creek TMDL Monitoring and Modeling Reports (SCCWRP, 2007) indicated that total Chlordane was highest and most variable in Switzer Creek. Additionally, historical pesticide operations were most prevalent in the Pueblo San Diego Watershed, where Switzer Creek is located. Therefore, this effort was conducted in Switzer Creek since historical pesticide operations were more widespread in this watershed, and results appear more variable.

This project was intended to address the following questions:

1. **What is the spatial distribution of pesticides and other relevant COCs in sediment in Switzer Creek?**

2. **Are areas of Switzer Creek impacted in specific areas related to current and historical pesticide use?**

3. **Do sediment concentrations exceed published sediment guidelines or LC_{50}s for target species?**

These questions were answered through conducting sediment sampling throughout Switzer Creek. Sediment samples were collected in the Switzer Creek Watershed to assess the distribution of pesticides and potentially identify sources. The results should provide the City of San Diego information to support the development of a TMDL at the mouth of Switzer Creek for sediment toxicity and to develop management strategies for reducing constituent loads.

2.0 STUDY LOCATION

Switzer Creek is located entirely within City of San Diego limits and is shown on Figure 2-1. Switzer Creek is in the San Diego Mesa Hydrologic Area (HA) (908.20) in the Pueblo Watershed (Hydrologic Unit (HU) 908.00) and is part of the San Diego Bay Watershed Management Area (WMA). Switzer Creek drains directly into San Diego Bay.

San Diego Bay is the largest estuary in San Diego County and has extensively been developed as a port. The Pueblo San Diego Watershed is the smallest watershed in the San Diego Bay WMA, covering approximately 36,000 acres (WESTON, 2008b). The Pueblo San Diego Watershed is also the most developed and most densely populated watershed in the San Diego Bay WMA. A map of Switzer Creek land uses is presented on Figure 2-2.

The Switzer Creek Watershed is highly urbanized and has been extensively developed in the downtown areas of San Diego. Land use in the watershed is primarily residential (40.1%) and transportation (28.1%). Over half of the municipal separate storm sewer system (MS4) is underground and exists as a network of pipes and connections. The central portion of the watershed is uniquely different and is comprised of parks and recreation (7.2%). Other land uses include public facility (6%), vacant and undeveloped (5%), commercial (5%), military (4.1%), industrial (2.4%), and commercial recreation (1.7%). The majority of land is privately owned, with only a small percentage owned by government. Most of the Switzer Creek Watershed falls under City of San Diego and Port of San Diego jurisdiction.

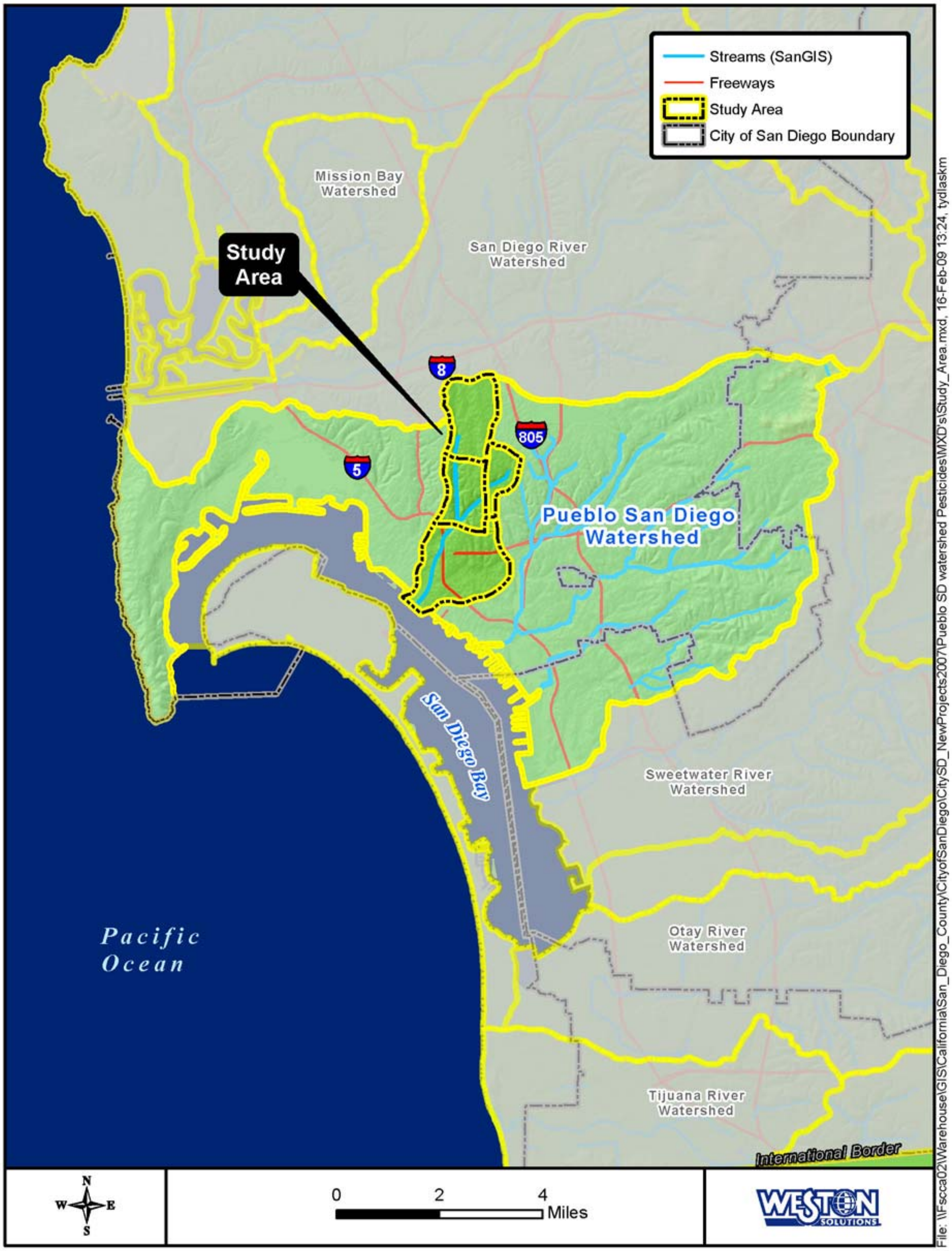


Figure 2-1. Location of Switzer Creek Study Area

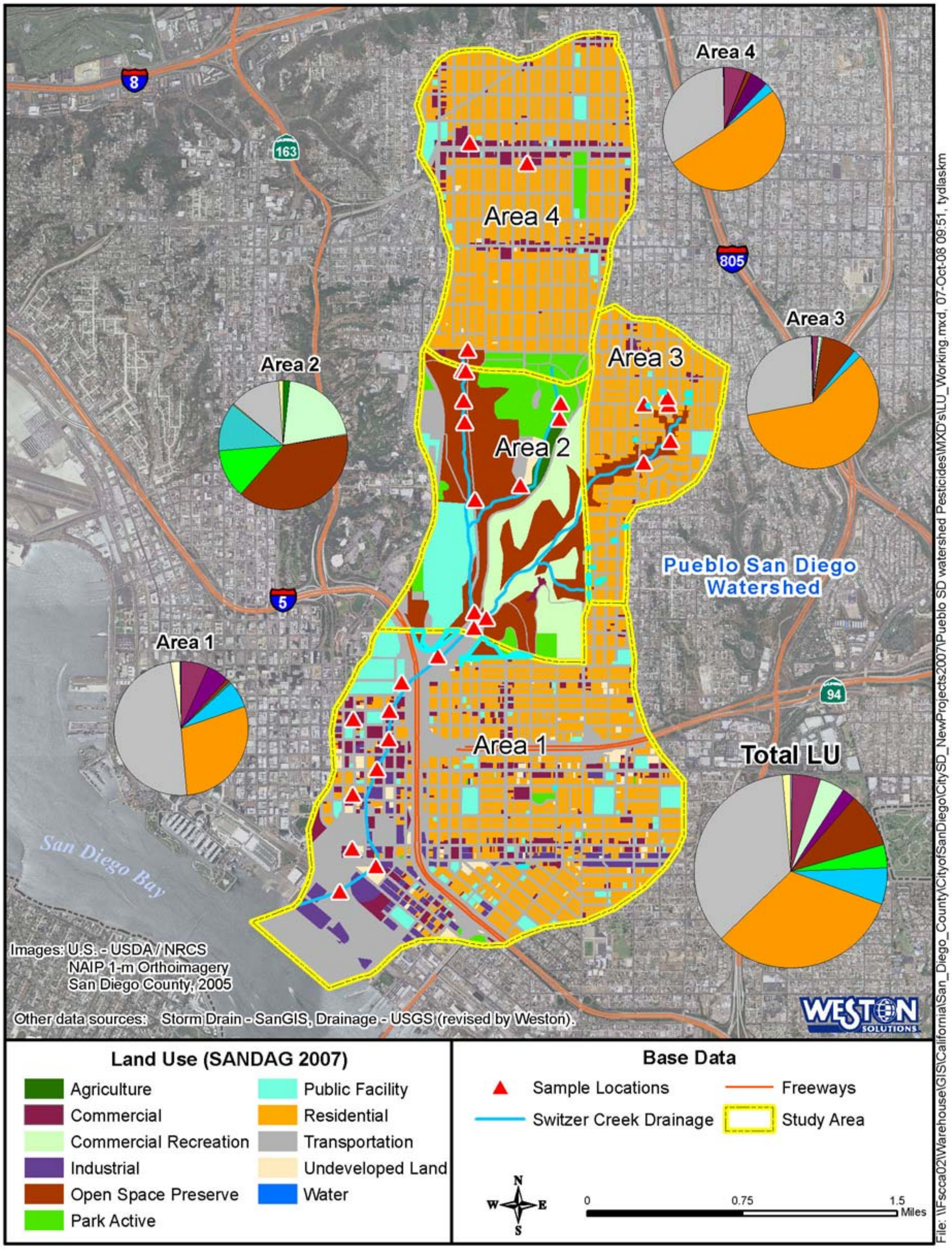


Figure 2-2. Switzer Creek Land Use and Sample Locations

Average rainfall for the Pueblo San Diego Watershed is light, with an average rainfall of 10.5 inches in coastal areas to 13.5 inches in the eastern portion of the watershed (WESTON, 2008b).

Most of the beneficial uses for Pueblo San Diego Watershed lie in its coastal water and inland surface waters. Beneficial uses by category are presented in Table 2-1.

Table 2-1. Pueblo San Diego Watershed List of Beneficial Uses

Beneficial Uses	Inland Surface Waters	Coastal Waters (excluding Pacific Ocean)[a]	Pacific Ocean	Reservoirs and Lakes	Ground-waters
Municipal and domestic supply					●
Agricultural supply					
Industrial service supply		●	●		
Industrial process supply					
Groundwater recharge					
Freshwater replenishment					
Hydropower generation					
Navigation		●	●		
Contact water recreation	O	●	●		
Non-contact water recreation	●	●	●		
Commercial and sport fishing		●	●		
Warm freshwater habitat	●				
Cold freshwater habitat					
Estuarine habitat		●	●		
Wildlife habitat	●	●			
Biological habitats of special significance		●	●		
Rare, threatened, or endangered species		●	●		
Marine habitat		●	●		
Migration of aquatic organisms		●	●		
Aquaculture			●		
Shellfish harvesting		●	●		
Spawning, reproduction, and/or early development		●	●		

(a) = San Diego Bay
● = Existing
O = Potential
Note: Beneficial uses vary by HU basin number. Please refer to the basin plan for individual HUs.
Source: RWQCB, 1994.

3.0 CONSTITUENTS OF CONCERN SUMMARY

This section presents a summary of the constituents of potential concern (COPC) found in many highly urbanized areas. The list is not fully inclusive of all economic or toxicological information available, but provides a general summary of why these compounds may be found in urban environments and what their ecological relevance is.

The following COPCs and physical parameters were assessed under this study:

- Metals (focus on cadmium, copper, lead, and zinc).
- Organochlorine pesticides (DDT isomers, Chlordane, and others).
- Organophosphate pesticides (Diazinon, Chlorpyrifos, and Malathion).
- Synthetic pyrethroid pesticides (Bifenthrin, Permethrin, and others).
- PAHs.

Metals (focus on cadmium, copper, lead, and zinc)

Cadmium

Cadmium (Cd) has an estimated crustal abundance of approximately 0.2 mg/kg (Kennedy, 2003). Cadmium is found in all rocks and soils at low levels and has also been found in some fertilizers. Most cadmium used in the US is derived from the production of other metals, such as, lead, copper, and zinc. Most cadmium (75%) is used for nickel–cadmium batteries. Other uses of cadmium include pigments (12%), coatings and plating (8%), stabilizers for plastics (4%), and non-ferrous alloys and others (1%). Cadmium is also linearly related to zinc concentrations in tires because cadmium is present as an impurity in zinc oxide used for the manufacture of tires (Kennedy, 2003).

Water quality objectives (WQOs) for dissolved cadmium are based on the California Toxics Rule (CTR) and vary depending on the hardness concentration from the sample collected. At a hardness of 100 mg $CaCO_3$/L, the dissolved lead CTR acute WQO is 4.265 µg/L, and the chronic WQO is 2.25 µg/L. Cadmium is relatively insoluble and is rarely found in detectable concentrations in storm water runoff.

Copper

Copper (Cu) has an estimated crustal abundance of approximately 55 mg/kg (Kennedy, 2003). Copper commonly substitutes in minerals, such as plagioclase and apatite, and ranges from 10 mg/kg in granite to 100 mg/kg in basalt (Kennedy, 2003). Copper has a specific gravity of 8.96. Copper is an essential element for all higher living organisms. However, dissolved copper is considered toxic to aquatic organisms (e.g., algae, salmon, and other marine species) even in minute concentrations. WQOs for dissolved copper are based on the CTR and vary depending on the hardness concentration from the sample collected. At a hardness concentration of 100 mg $CaCO_3$/L, the dissolved copper CTR acute WQO is 13.4 µg/L. The saltwater numeric criteria for dissolved copper for the Shelter Island Yacht Basin Dissolved Copper TMDL is set at 4.8 µg/L for the acute criteria. In comparison, the Federal Safe Drinking Water Act maximum contaminant level goal for total or dissolved copper is set at 1,300 µg/L.

Copper is a common consumer product used in building construction (e.g., plumbing, architectural copper roofs, mailboxes, and railings), electrical and electronic products (e.g., wiring and cables), metal plating and alloys, antifouling paints, and sandblasting material. Copper is also used as an algaecide and fungicide for swimming pool treatments and as a wood preservative. As of 2008, the USEPA announced it is taking legal action to ban the use of acid copper chromate (ACC) in wood preservatives for residential use. Copper has also been shown to erode from overhead trolley wires from electric trains (Kennedy, 2003). Additionally, a recent study conducted by the City of San Diego found that air conditioning condensate was also a source of copper discharges to areas susceptible to urban runoff (IEA Memo, 2008).

Copper is used in brake pads as an additive to prevent brake disk screeching and is a functional product required to meet braking safety standards. Copper in brake pads has been extensively studied in recent years by the Brake Pad Partnership (BPP). The BPP is an organization of government regulators, brake pad manufacturers, storm water management agencies, and environmentalists. The brake pad manufacturers have agreed to change their product formulations "if brake pad wear debris is found to impair water quality" (Sustainable Conservation, 2006). The BPP has a technical library of over 197 studies related to the fate and transport of copper associated with brake wear debris.

Copper slag is used for sandblasting as an economical choice of abrasive grain for shipyards and contractors. Shipyard related industries are concentrated in the areas around downtown San Diego. These facilities may include the use of copper slag and copper based paints in their processes.

Lead

Lead (Pb) has the highest atomic number (82) of all stable elements. The main lead mineral is called galena (lead sulfide), which contains approximately 86% lead. It is estimated that 50% of the lead used today comes from recycling. Lead is not an essential element to living organisms and is known historically to be toxic to both humans and aquatic organisms. Lead has been shown to damage the nervous system and cause brain and blood disorders. It is detrimental to the development of young children. While lead awareness has significantly increased and exposure to public health has significantly decreased, lead is still commonly found in the environment. The USEPA suggests the primary sources of lead exposure in the urban environment are:

- Deteriorating lead-based paint.
- Lead contaminated dust.
- Lead contaminated residential soil.

The USEPA's Lead Awareness Program continues to work to protect human health and the environment against the dangers of lead. Information regarding lead can be found on the USEPA website (http://www.epa.gov/lead/). The Federal Safe Drinking Water Act sets the drinking water action level for lead at 15 µg/L, and the maximum contaminant level goal is 0 µg/L. WQOs for dissolved lead are based on the CTR and vary depending on the hardness concentration from the sample collected. At a hardness of 100 mg $CaCO_3$/L, the dissolved lead CTR acute WQO is 64 µg/L, and the chronic WQO is considerably lower at 2.5 µg/L.

Lead has been widely used in the transportation industry, primarily for lead acid batteries, solder, bearings, and wheel balancing weights. Lead is a soft malleable metal also used as lead shot, fishing weights, sailboat keels for ballast, leaded glass, and television glass. Lead has been used historically in paint and is commonly found in homes built prior to 1978. Many older homes will often have larger concentrations of lead in soil in the areas directly adjacent to the home where paint chips will degrade and eventually slough off. In some cases, homeowners and remodelers have used mechanical sanders to remove this older paint, unaware of the hazards involved in releasing this material to the atmosphere as inhalable articulates. Lead was also used in gasoline to prevent engine knock. The use of leaded gasoline peaked during the 1970s but was eventually phased out during the 1980s. Many researchers have shown that lead in soil is primarily a residual effect of the historic use of leaded gasoline and that storm water containing lead is likely a result of the erosion of soils near roadways. The concentration of lead in soil is steadily decreasing over time. Total lead in Chollas Creek has also shown a significant decreasing trend (WESTON, 2006).

Zinc

Zinc (Zn) is the 23rd most abundant element in the earth's crust (USGS, 2006). It is the fourth most common metal used, behind iron, aluminum, and copper. In the US, approximately two-thirds of zinc is produced from ores (primary zinc), and the remaining one-third is produced from scrap and residues (secondary zinc). Zinc uses range from metal products to rubber and medicines. Approximately three-fourths of zinc used is consumed as metal (mainly as a coating to protect iron and steel from corrosion (galvanized metal)), as alloying metal to make bronze and brass, as a zinc-based die-casting alloy, and as rolled zinc. The remaining one-fourth is consumed as zinc compounds mainly by the rubber, chemical, paint, and agricultural industries. Zinc is also a necessary element for proper growth and development of humans, animals, and plants; it is the second most common trace metal, after iron, naturally found in the human body. Though, in its dissolved form, it has been shown to cause toxic responses to aquatic organisms in elevated concentrations (Councell et al., 2004). The USEPA has set the maximum water quality goal for zinc at 120 µg/L. The WQO for zinc is based on the CTR and varies depending on the hardness concentration from the sample collected. At a hardness of 100 mg $CaCO_3$/L, the dissolved zinc CTR acute WQO is 117 µg/L. In comparison, the Federal Safe Drinking Water Act does not regulate the concentration of zinc in drinking water. California sets the secondary (aesthetic) maximum contaminant level, which is not enforceable, at 5,000 µg/L.

Sources of zinc in the air and water include fertilizer, cement production, and transportation activities (e.g., combustion exhaust, galvanized parts, fuel and oil, brake wear, and tire wear). Zinc chromate primer is commonly used in the marine and aircraft industries. Zinc oxide is used in the vulcanization process of tires and rubber (estimated at 1% by weight). In urban environments, several studies reviewed by Councell et al. (2004) reported positive correlations of zinc to traffic volume, primarily as tire-wear. Researchers concluded that 60% of the total zinc load in south San Francisco Bay was attributable to tire-wear debris. There is less information related to zinc contamination from fan belt wear from automobiles. It stands to reason that the density of cars, trucks, and other industrial motors, including ventilation fans, air compressors, and other machinery using rubber belts, may also be a significant source of zinc containing particulates. However, further investigation is needed to determine the contribution of fan belt wear to atmospheric deposition.

Galvanized metal is also used in numerous products that have the potential to release zinc containing particulates to the atmosphere. These products include fences, sign posts, guardrails, and galvanized metal roofs, which are frequently observed in the San Diego region industrial areas. Galvanized roofs have been shown to release elevated concentrations of zinc in storm water runoff captured directly from these sources. Other sources of galvanized products include scrap metal recycling and auto dismantling operations. Several automotive dismantling facilities have been observed in the area of Commercial Street and directly west of the north fork of Chollas Creek.

Organochlorine pesticides (DDT isomers, Chlordane, and others)

Organochlorine pesticides are chlorine-based compounds used for a broad spectrum of pest control. These compounds have the potential to bioaccumulate and biomagnify in organisms. Rain can wash freshly sprayed pesticides into creeks, where they will eventually make their way to rivers, estuaries, and the ocean. Previously applied organochlorine pesticides also have the potential to be released to the environment during redevelopment and grading due to long degradation rates of these compounds. Organochlorine pesticides are solely anthropogenic in origin and many have been banned from urban use, as described below.

DDT

DDT is one of the most renowned chlorinated organic insecticides. Dichlorodiphenyldichloro-ethylene (DDE) and dichlorodiphenyldichloroethane (DDD) are the major metabolites (isomers) and breakdown products of DDT in the environment. DDT and its isomers can last for up to and beyond 30 years in soil. During the 1940s, DDT was used extensively to control mosquito populations and subsequently control malaria in many areas throughout the world. As the first of the modern pesticides, it was overused and soon led to the discovery of the phenomena of insect resistance to pesticides, bioaccumulation, and biomagnification. While the DDT family is the best known organochlorine pesticide, it is only one of a large number of related compounds used for a variety of pest control needs. In the 1970s and 1980s, applications of DDT were banned in most developed countries, although its limited use in disease vector control continues in certain parts of the world where malaria persists.

The history of DDT offers one of the classic examples of bioaccumulation resulting in biomagnification. The toxic pollutant bioaccumulated within each organism and then biomagnified through the food web to very high levels in piscivorous avian species, such as bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), peregrine falcons (*Falco peregrinus*) and brown pelicans (*Pelecanus occidentalis*). Biomagnified levels of DDT were high enough that the birds' eggshells became abnormally thin. As a result, adults broke the shells of their unhatched offspring during incubation causing high levels of mortality and subsequent population decline (Stephenson et al., 1995).

Large quantities of DDTs have historically been discharged into coastal waters of Los Angeles—most of which emanated from Montrose Chemical Corporation of Torrance, California (formerly the world’s largest manufacturer of DDT)—and were discharged through the MS4 ocean outfall. Since 1970 (i.e., when the use of DDT was banned and Montrose Chemical Corporation halted production), discharges from the ocean outfalls have dramatically decreased. However, the legacy of this point source contamination is still observed in sediment and biota. DDT has also been known to be stored for long periods of time and is infrequently found in residential homes.

Chlordane
Chlordane is a manufactured chemical used as a pesticide in the US from 1948–1988. Technical Chlordane is not a single chemical, but is a mixture of pure Chlordane mixed with many related chemicals. It does not occur naturally in the environment and is solely related to anthropogenic uses. Until 1983, Chlordane was used as a pesticide on crops like corn and citrus and on home lawns and gardens and was also used to control termites. Because of concern regarding damage to the environment and harm to human health, the USEPA banned all uses of Chlordane in 1983, except to control termites. In 1988, USEPA banned all uses (ATSDR, 1995). Chlordane is highly insoluble, readily attaches to soil particles, and has a long degradation rates. Chlordane was commonly used for pre-termiticide applications prior to pouring cement building foundations for homes and buildings. This compound has been known to become mobilized to the environment during redevelopment or renovation of older buildings and homes and possibly during fires when a home's interior components become exposed.

Organophosphate Pesticides (Diazinon, Chlorpyrifos, and Malathion)
Organophosphate pesticides affect the nervous system by disrupting the enzyme that regulates acetylcholine, a neurotransmitter. Most organophosphates are insecticides. They were developed during the early 19th century, but their effects on insects, which are similar to their effects on humans, were discovered in 1932. Some of these pesticides are very poisonous (they were used in World War II as nerve agents). However, they usually are not persistent in the environment (USEPA, 2008).

Diazinon
Diazinon is the common name of an organophosphorus pesticide previously used to control pest insects in soil, on plants, and on fruit and vegetable field crops. Various Diazinon formulations were widely used in agriculture and for structural pest control, besides being used on lawns and home gardens. Important target pests for Diazinon applications included cockroaches, aphids, scales, mites, ants, crickets, fleas and ticks, flies, grubs, and, in the western US, yellow jackets. Diazinon is a synthetic chemical that does not occur naturally in the environment. Pure Diazinon is a colorless and practically odorless oil. Preparations used in agriculture and by exterminators contained 85–90% Diazinon and appear as a pale to dark brown liquid. Diazinon preparations sold in the past for home and garden use contained 1–5% Diazinon in a liquid or as solid granules. Diazinon was banned by the USEPA from retail sales in 2005 for all non-agricultural uses.

Diazinon seldom migrates below the top 1.3 cm (0.5 inch) of soil but can stay biologically available for six months under conditions of low temperature and low moisture. The average time for 50% degradation in soil is two to four weeks. Bacterial enzymes can speed the breakdown of Diazinon. The breakdown rate is also highly dependent on the acidity of water. At highly acidic levels, one half of the compound disappeared within 12 hours, while in a neutral solution, the pesticide took six months to degrade to one half of the original concentration (EXTOXNET, 1993).

Chlorpyrifos
Chlorpyrifos is an organophosphorus insecticide that has been widely used for residential and agricultural uses. Residential applications of Chlorpyrifos were used to control cockroaches, fleas, and termites; it has also been an active ingredient in some pet flea and tick collars.

Agricultural applications were used to control ticks on cattle and as a spray to control crop pests. In June 2008, the USEPA and Dow AgroSciences reached an agreement to stop the sale of Chlorpyrifos for home, garden, and lawn use because of its health risk to children (Beyond Pesticides, 2008). Toxicity to freshwater fish, insects, birds, and some plants has been linked to Chlorpyrifos detections in creeks, streams, and rivers (Beyond Pesticides, 2008). Chlorpyrifos is moderately persistent in soils. The half-life is usually between 11 and 180 days but can range from two weeks to over a year, depending on soil type, climate, and other conditions (American Bird Conservancy, 2008).

Malathion

Malathion is commonly used for the control of adult mosquitoes and many other insects including aphids, ants, ticks, and spiders. The US Department of Agriculture uses Malathion in many special control programs, including bollworm eradication efforts in the southern US, Mediterranean fruit fly control in California and Florida, and grasshopper control on federal rangelands. Malathion is used for the control of insects on many agricultural crops, and is formulated for use by homeowners on lawns and gardens. Over 7 million pounds of Malathion (active ingredient) are used, annually, in the US (American Bird Conservancy, 2008).

Synthetic Pyrethroid Pesticides (Bifenthrin, Permethrin, and others)

Synthetic pyrethroids are the current commercially available pesticide used primarily for ant, termite, and mosquito control. The synthetic pyrethroid compound class is the replacement for the previously banned organochlorine and organophosphate pesticides DDT, Chlordane, Diazinon, and Chlorpyrifos. Synthetic pyrethroids can have long degradation rates in the environment with half lives ranging from 39 days for permethrin in aerobic conditions to as long 425 days for Bifenthrin in anaerobic conditions. Synthetic pyrethroids are highly hydrophobic and have a strong affinity for binding to organic particulates.

Bifenthrin

Bifenthrin is the commonly detected synthetic pyrethroid pesticide found in urban runoff and has been directly linked to observed toxicity to the freshwater amphipod *Hyalella azteca* and the marine amphipod *Eohaustorius estuarius.* Bifenthrin has a very low solubility and high octonal water coefficient or tendency to bind to organic compounds. Bifenthrin is commonly found in home and garden products in both a liquid and granular form.

Permethrin

Similar to Bifenthrin, Permethrin is a synthetic pyrethroid used for control of adult mosquitoes, termites, roaches, ants, fleas, and other insects. Permethrin comes in many forms, including sprays, dusts, fogs, emulsifiable concentrates, and creams. Permethrin is widely used to control pests in cotton, corn, wheat, and alfalfa crops. Additionally, in 2003, the USEPA approved Permethrin-impregnated clothing for public use (Beyond Pesticides, 2008). Annually, over 100 million applications of Permethrin are made each year in and around US homes (Whitmore et al., 1992).

Polyaromatic Hydrocarbons

PAHs are one of the most widespread organic pollutants due to its collective natural and manufactured origins. PAHs are a class of very stable organic molecules made up of only carbon and hydrogen in fused aromatic ring structures formed mainly as a result of pyrolytic processes. PAHs may contain four-, five-, six- or seven-member rings, but those with five or six are most common. PAHs containing up to six fused aromatic rings are often known as small PAHs and those containing more than six aromatic rings are called large PAHs. Smaller molecules, such as benzene and naphthalene, are not formally PAHs, although they are chemically related and are called one-ring (mono) and two-ring (di) aromatics. Collectively, PAHs are a group of over 100 different chemicals that occur naturally in oil, coal, tar deposits and are formed during the incomplete combustion of petroleum products, garbage, and tobacco and even charbroiled meat. Different types of incineration yield unique distributions of PAHs in both relative amounts of discrete PAHs and in which isomers are produced, making these compounds potentially useful as source markers. PAHs are also manufactured in its pure form and used in medicines or to make dyes and plastics. PAHs have relatively low solubility in water but are highly lipophilic. Because of its lipophilic properties, PAHs in the marine environment are found primarily in the sediment and are one of the most widespread organic pollutants. When dissolved in water or adsorbed on particulate matter, PAHs can undergo photodecomposition when exposed to ultraviolet light from solar radiation and may also be degraded by some microorganisms in the soil.

As a pollutant, they are of concern because some compounds have been identified as carcinogenic, mutagenic, and teratogenic. PAHs toxicity is very structurally dependent, with isomers varying from being nontoxic to being extremely toxic. One PAH compound, benzo(a)pyrene, is notable for being the first chemical carcinogen to be discovered and is one of many carcinogens found in cigarette smoke.

Polychlorinated Biphenyls

Due to their chemical stability and nonflammable properties, PCBs are valuable as coolants and insulating fluids for transformers and capacitors, stabilizing additives in flexible PVC coatings of electrical wiring and electronic components, pesticide extenders, cutting oils, flame retardants, hydraulic fluids, sealants, adhesives, wood finishes, paints, aspirating agents, and in carbonless copy paper. PCBs are also inadvertently generated as a byproduct of certain combustion and chemical processes. First isolated in the 1880s from coal tar extracts, PCBs were commercially produced in the 1920s and were in widespread use throughout most of the 20th century.

PCB congeners are chlorine-substituted biphenyl compounds synthesized by chlorinating biphenyl with chlorine gas. Individual congeners are identified by the number and position of the chlorine atoms around the biphenyl rings. There are 209 possible PCB congeners, ranging from the mono-substituted 2-chlorobiphenyl to the fully substituted decachlorobiphenyl, although only approximately 130 of these were found in commercial PCB mixtures. The number and placement of the chlorine atoms on the biphenyl molecule determines how the congener is named and dictates its environmental fate and toxicity. PCBs generally occur as mixtures of congeners; the most common commercial mixtures were called Aroclors. The primary commercial manufacturer, Monsanto, marketed PCBs under the trade name Aroclor from 1930 to 1977. Aroclor names reflect the percent chlorine (by weight) of the mixture, with the more chlorinated mixtures generally being the most persistent and toxic. Commercial PCBs are known to be contaminated with levels of other significantly toxic compounds such as dioxins and furans through partial oxidation.

Like many other chlorinated hydrocarbons, PCBs associate with the organic components of soils, sediments, and biological tissues, or with dissolved organic carbon in aquatic systems. PCBs volatilize from water surfaces in spite of their low vapor pressure, and partly as a result of their hydrophobicity. The chemical properties of PCBs favor their long range transport, consequently PCBs have been detected in arctic air, water, and organisms. PCBs and other persistent halogenated aromatic hydrocarbons are linked to reproductive and immunotoxic effects in wildlife. In the 1970s, PCB production was banned in the US and regulations concerning the presence of PCBs in the environment were promulgated. PCBs are very persistent in the environment, and can be found in aquatic wildlife at concentrations a million times greater than the concentration in the surrounding water. PCB-contaminated sites and sediments account for the vast majority of PCB contamination affecting the food web and, thus, human and wildlife exposure.

4.0 SEDIMENT SAMPLING METHODS

4.1 Site Locations

A field reconnaissance was conducted to locate and identify the specific drainage areas for sampling. Considerations for choosing site locations included:

- Indication of recent deposition.
- No evidence of recent erosion and/or scouring.
- Proximity to targeted sampling areas.
- Representation of watershed.
- Historical site location.
- Minimal hazards, including traffic concerns and transient encampments.
- Accessibility.

A total of 24 sampling locations were inspected (Figure 4-1). The Switzer Creek Watershed was divided into four areas and sampling sites were chosen in each of the four areas based on storm drain size and land use. Many of the original sites visited were not sampled due to access issues and/or lack of sediment to sample. Figure 4-1 depicts sample sites inspected and the sites where sediment samples were collected.

The lower area (Area 1 (Downtown)), is the downstream section of the watershed which runs underneath downtown San Diego. Based on land use data, this area has the highest percentage of transportation (49.03%), commercial (6.61%), and industrial (5.45%) usage.

Area 2 (Balboa Park) is the day-lighted section of the creek that runs along Pershing Drive. In Area 2 (Balboa Park), the main land uses are open space preserve (38.81%), commercial recreation (20.54%), active park (12.34%), and public facility (12.01%). A section of this area is Balboa Park, which includes other public recreational uses (e.g., a golf course and disc golf course, tennis courts and archery. There is also a City of San Diego maintenance yard in this area of the watershed.

Area 3 (Residential) and Area 4 (Residential & El Cajon Blvd.) are the upstream sections of the watershed, where the creek runs underground in the MS4. Area 3 (Residential) is to the east and the highest land use in this area was residential (58.98%); the other major uses were transportation (27.82%) and open space preserve (8.44%). Area 4 (Residential & El Cajon Blvd.) is to the north and the main land use is residential (51.30%). There is also transportation (34.06%) and commercial (5.94%) uses. The majority of the commercial land uses are centered on El Cajon Boulevard and University Avenue.

Sample IDs, location, and GPS coordinates are presented in Table 4-1. A sampling location (Site SC-24) was chosen at the end of Switzer Creek, where it flows under Harbor Drive prior to draining into San Diego Bay. This sampling location is considered representative of conditions at the outlet to the bay.

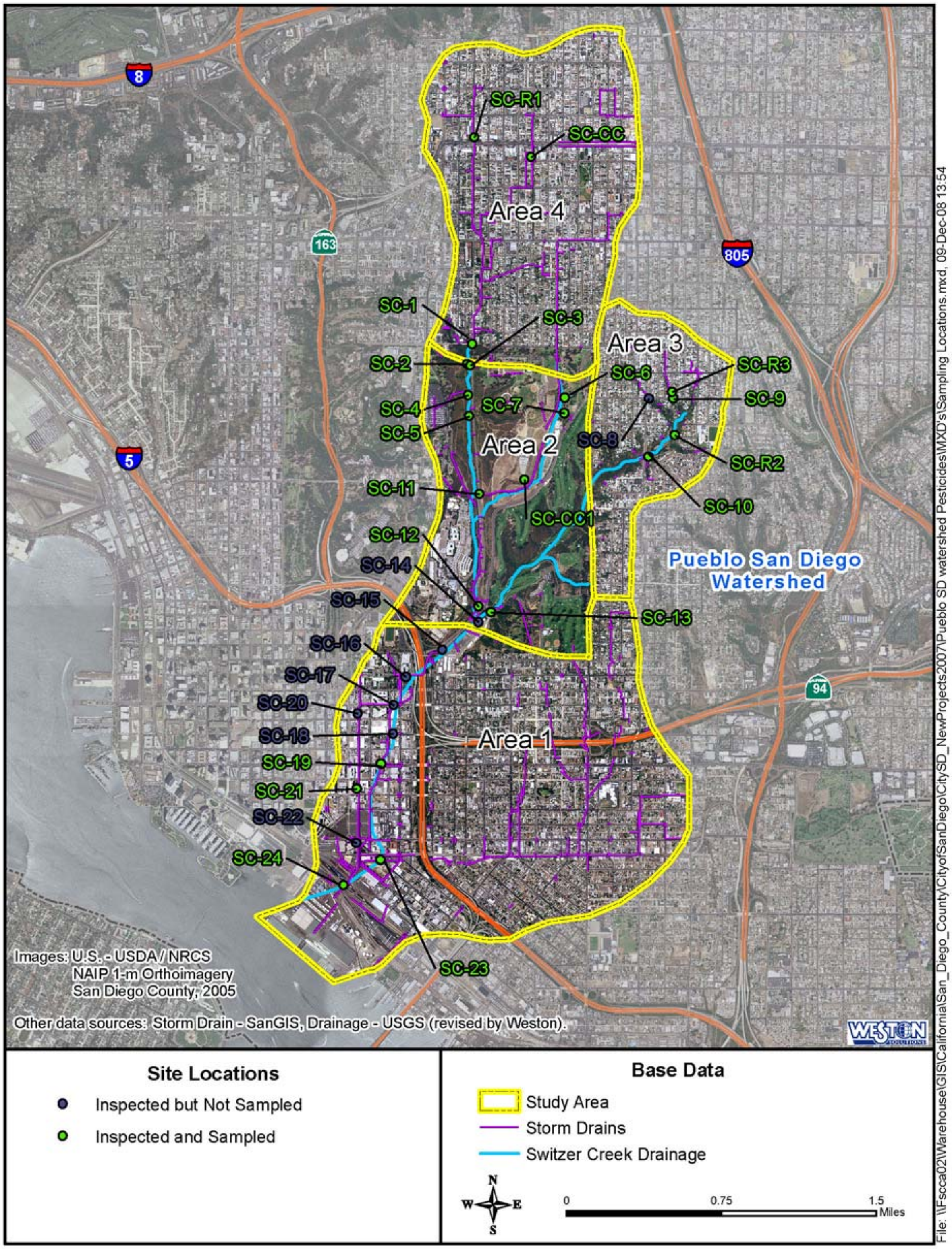


Figure 4-1. Switzer Creek Sampling Locations

Table 4-1. 2008 Switzer Creek Sediment Sampling Locations

Station ID	Location Description	Area	Latitude	Longitude
SC-1	Upas Street and Florida Avenue	4	32.741137	-117.143709
SC-2	Florida Ave and Morley Field (from creek flow under road)	2	32.739711	-117.144133
SC-3	Florida Ave and Morley Field (end of San Diego outlet)	2	32.739626	-117.143871
SC-4	San Diego outlet along Florida Avenue	2	32.737555	-117.144023
SC-5	Pedestrian bridge along Florida Avenue	2	32.736052	-117.143932
SC-6	Manhole on disc golf course	2	32.737440	-117.135981
SC-7	Manhole on disc golf course, south/west of pro shop	2	32.736335	-117.136026
SC-8	Redwood Street and 30th Street	3	32.737400	-117.129000
SC-9	Redwood Street and 32nd Street	3	32.737400	-117.127000
SC-10	End of Burlingame Drive	3	32.733300	-117.129000
SC-11	Florida Avenue, north of Zoo Place, at San Diego outlet	2	32.730600	-117.143000
SC-12	West of Florida Avenue, south of Pershing Drive	2	32.722700	-117.143000
SC-13	Pershing Drive and 26th Street	2	32.722300	-117.142000
SC-14	Concrete channel behind city yard (north side)	2	32.721600	-117.143000
SC-15	Concrete channel behind city yard (south side)	1	32.719600	-117.146000
SC-16	Near B Street and 16th Street (sample in underground creek)	1	32.717700	-117.149000
SC-17	D Street and 16th Street	1	32.715700	-117.150000
SC-18	15th Street and G Street	1	32.713700	-117.150000
SC-19	Market Street between 14th Street and 15th Street	1	32.711600	-117.151000
SC-20	13th Street, between D Street and E Street	1	32.715100	-117.153000
SC-21	Clean-out on 13th Street, south of Island Avenue	1	32.709800	-117.153000
SC-22	13th Street and National Avenue	1	32.706000	-117.153000
SC-23	Clean-out on National Avenue, north of 16th Street	1	32.704800	-117.151000
SC-24	Day-lighted section under Harbor Drive	1	32.703000	-117.154000
SC-CC	Texas Street and Howard Avenue	4	32.754300	-117.138940
SC-CC1	Pershing Drive, at the city yard	2	32.731640	-117.139270
SC-R1	Florida Avenue and El Cajon Blvd	4	32.755650	-117.143690
SC-R2	Palm Street and 31st Street	3	32.734850	-117.126810
SC-R3	End of 31st Street	3	32.737900	-117.127090

4.2 Sample Frequency

The sediment sampling survey was conducted in Switzer Creek during June 2008. The sample collection was done over the four days. The sites in Area 1 (Downtown) were sampled during the evening hours of June 24–25, 2008, (SC-16 through SC-24) due to traffic concerns. Samples in areas 2, 3, and 4 were collected on June 26, 2008. As previously mentioned, several of the original sites chosen were not sampled due to access issues and/or lack of sediment able to be sampled (Figure 4-1). Therefore, alternative sample locations were chosen and field scientists sampled these locations on June 30, 2008. Follow-up sampling was conducted at four sites on January 21, 2009 (SC-9, SC-CC, SC-R1, and SC-R3) to confirm pesticide detections at these locations.

4.3 Sample Collection

At each sampling location, the area was surveyed for a location representative of the mobile surface sediments. Sites where there was evidence of recent erosion or scouring were avoided. A minimum of 8 ounces was required to analyze the complete list of constituents.

Once the location was selected, the top 2 cm of material were collected to determine the surficial sediments likely to be mobilized during storm events. Surface samples were collected with a stainless steel spoon and then placed in a sample jar. In some cases a sampling pole with a scoop on the end had to be used for sample collection. At Site SC-24, a Ponar grab was used for sample collection. The Ponar sampler was lowered from the Harbor Drive bridge into the channel. Three equidistant grab samples were collected (one from the left, mid, and right portions of the channel). Samples were then composited in a stainless steel bowl and then transferred into the sample jar. Samples were transported under chain of custody, on ice, from collection in field and delivered to WESTON where they were frozen for delivery to the analytical laboratory.

A field data log was filled out for each site visited (Appendix A). The field data log included empirical observations of the site and sediment quality characteristics. Observations included parameters such as odor, color and general estimates of the sediment's geotechnical characteristics (e.g., percentage of silt and percentage of sand). The purpose of visual observations was to assess potential sources of sediments that may carry pesticides impacting Switzer Creek and included potential activities that may impact pollutant levels in the creek.

Samples were analyzed for the parameters listed in Appendix B-1, which shows the method, method detection limits (MDLs), reporting limits (RLs), and associated units. Sediment samples were also analyzed for sediment grain size distribution by WESTON's internal grain size laboratory. Chemical laboratory analyses were performed by CRG Marine Laboratories of Torrance, CA, a laboratory certified by the California Environmental Laboratory Accreditation Program (ELAP) to conduct the analysis of the constituents specified. Although the 2006 SWRCB Section 303(d) listings for the mouths of Switzer Creek, Chollas Creek, and Paleta Creek do not include synthetic pyrethroids, the analysis was included since there has been an observed shift in the use of pesticides from Diazinon to synthetic pyrethroids. This shift is likely a result of the USEPA ban on Diazinon for urban use on January 1, 2005, and consumer and increased professional use of available synthetic pyrethroid products. (Monitoring results from the Proposition 13 PRISM Grant and the 2005–2006 and 2006–2007 San Diego Municipal Storm Water Monitoring Program Reports support this finding).

4.4 Sample Handling

Sediments samples were placed in the glass sediment containers with 2 cm of headspace and labeled with the project name, sample identification number, site location, and date and time of collection. Samples were then stored frozen within 24 hours for delivery to the analyzing laboratory, following WESTON's chain-of-custody procedures. The laboratory also kept all samples frozen until analysis.

5.0 RESULTS AND DISCUSSION

There are three study questions that this project sought to answer.

1. **What is the spatial distribution of pesticides in sediment in Switzer Creek?**
2. **Are areas of Switzer Creek impacted in specific areas related to historical pesticide use?**
3. **Do sediment concentrations exceed published sediment guidelines or LC_{50}s for target species?**

The results and discussion section is organized into sections for each of the study questions to effectively answer them. A table of sample results compared to both freshwater and saltwater sediment benchmark criteria can be found in Appendix B-2. Follow-up sampling was conducted on January 21, 2009 to confirm and assess the concentrations of constituents from Area 3 (Residential) and Area 4 (Residential and El Cajon Blvd.). Results for the follow-up sampling are provided in Appendix B-3.

5.1 Spatial Distribution of Pesticides

5.1.1 Distribution between Areas and Land Uses

For sampling and analysis purposes, the Switzer Creek Watershed was divided into four different areas (Figure 4-1). Analyzing the results from these different areas will allow future watershed activities to focus on the sections of the watershed that had the highest concentrations of the COCs. The lower area (Area 1 (Downtown)) is the downstream section of the watershed which runs underneath downtown San Diego. Area 2 (Balboa Park) is the day-lighted section of the creek that runs along Pershing Drive. Areas 3 and 4 are the upstream sections of the watershed, where the creek runs underground in the MS4. Area 3 (Residential) is to the east and Area 4 (Residential & El Cajon Blvd.) is to the north.

One of the study questions was to determine if different land uses could be correlated to certain constituents. There were not enough samples collected in each of the different land use types to perform statistical analysis on the constituent distributions between land uses. Therefore, only a qualitative assessment was included. This involved a discussion of the differences in the spatial distributions between the areas and the land uses in those areas.

Based on the spatial distribution across the watershed, there was no area which was higher than all of the others for all of the COCs as a whole. However, for each of the analyte groups a different area was the highest, showing that the distributions of these COCs are due to different sources or use patterns, and therefore different areas of the watershed. For an example, average DDT isomers and Chlordane concentrations were highest in samples collected from Area 4 (Residential & El Cajon Blvd.) and lowest in Area 1 (Downtown) (Figure 5-1). This result ties directly to the idea that land uses or conditions in Area 4 (Residential & El Cajon Blvd.) have an impact on the distribution of these constituents and would be a priority for management action over other areas of the watershed. The graphs showing the spatial distribution of the all constituents analyzed can be found in Appendix C.

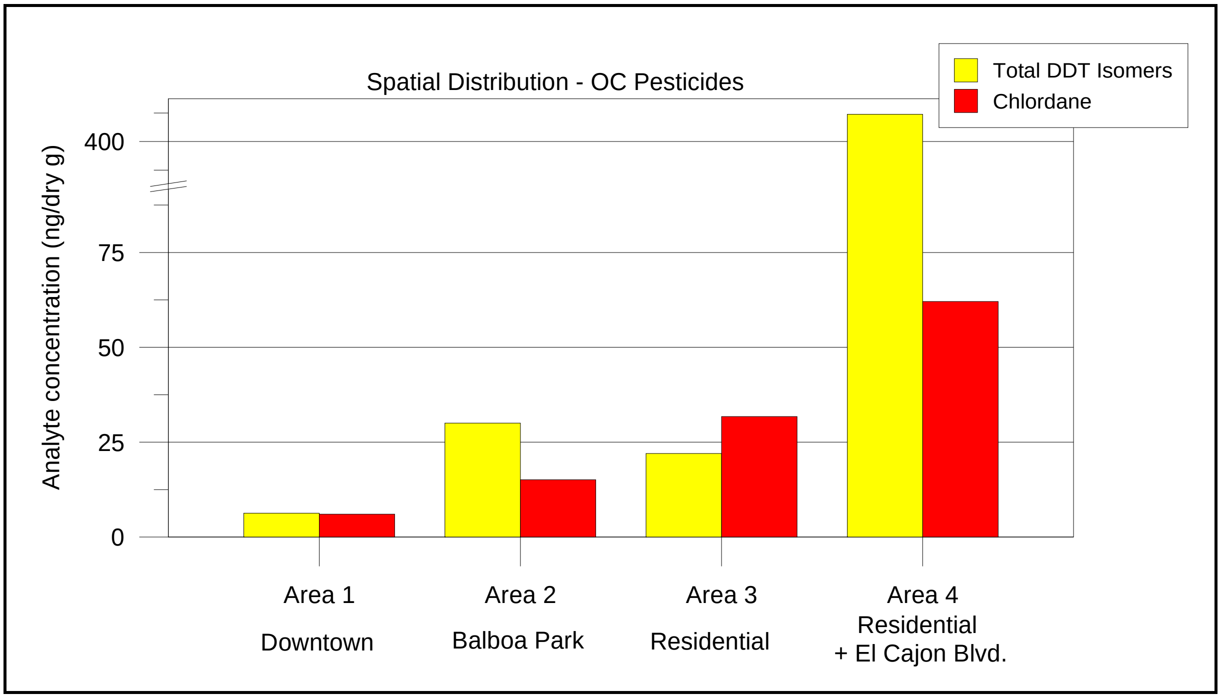


Figure 5-1. Spatial Distribution of Average Total DDT isomers and Chlordane Results in Switzer Creek

To further understand the distribution of constituents analyzed, each Area was examined individually. Area 1 (Downtown) had the highest levels of the cadmium, copper, and lead, and also had high levels of PAHs. The only Diazinon detection of the four areas assessed was found in Area 1 (Downtown). Based on land use data, this area has the highest percentage of transportation, commercial, and industrial usage. Results from an aerial deposition study in the City of San Diego indicate that transportation land use could be contributing to the high levels of metals, specifically copper from automotive brake pads and zinc from tire wear (WESTON, 2007b). Lead may be a result of industrial facilities in the area, along with elevated cadmium. Burn ash has also been frequently detected in the downtown areas of San Diego and is a know problem during soil excavations, demolition, and construction which has been occurring at a significant pace over the past 10 years in downtown San Diego.

Area 2 (Balboa Park) had high concentrations of PAHs and the highest levels of the synthetic pyrethroid Permethrin. This area of the watershed is the only natural-bottom section and runs along Balboa Park and a City of San Diego maintenance yard. Permethrin is primarily used in agricultural, but is also sold for commercial and residential uses.

Area 3 (Residential) was low in all constituents except Chlorpyrifos. The only detectable result of Chlorpyrifos was found in this Area. Chlorpyrifos is an organophosphate pesticide that was primarily used for termiticide applications and ant control, but was discontinued from urban uses in 2003. Detections of Chlorpyrifos coincide with land use information as this area has the most residential land use in the watershed.

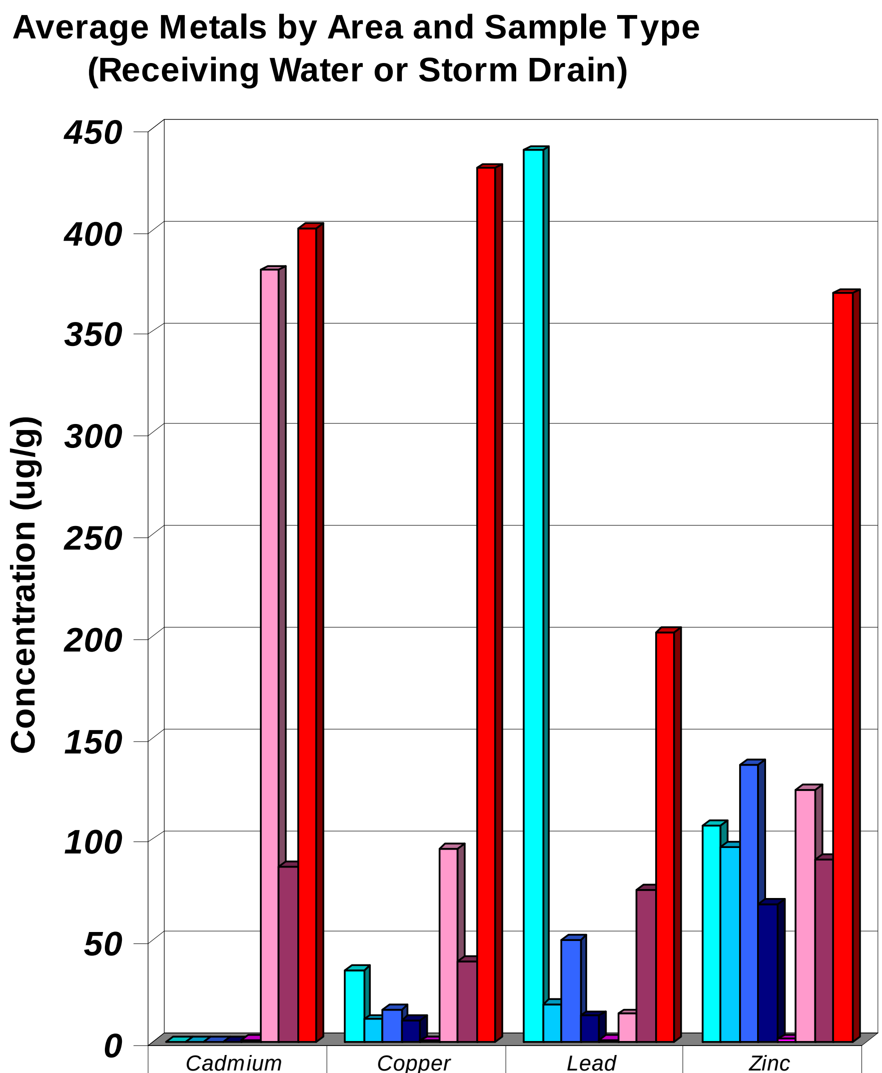
Area 4 (Residential & El Cajon Blvd.) was highest for zinc, Chlordane, Total DDT isomers, total PCBs, and Bifenthrin. Many of the highest single sample concentrations were also detected in this Area of the watershed. Total DDT isomers, Chlordane and Bifenthrin are all different forms of pesticides that have been used. DDT, an organochlorine pesticide, has been banned in the US since 1972, but was just recently banned in Mexico in 2000. Chlordane is also a banned organochlorine pesticide (and in Mexico in 1998). Bifenthrin, a synthetic pyrethroid, is still available for purchase today in the US. Sample locations in Area 4 (Residential & El Cajon Blvd.) were characterized as having high amounts of trash and sediment.

5.1.2 Distribution between Receiving Water and Storm Drains

To further answer the question related to the spatial distribution of the COCs, the secondary question was posed: How were the constituent concentrations distributed between the sites in the storm drains and the sites in the receiving water? To make this assessment, any sites which were within the City's MS4 were classified as storm drain sites and any sites in the natural-bottom portion of the creek were listed as receiving water.

Figure 5-2 shows the concentrations of cadmium, copper, lead, and zinc in the receiving water and the storm drains across the four areas of the watershed. Across the different areas, the storm drain samples were markedly higher for cadmium and copper for areas 2, 3, and 4. The low results for copper and cadmium in receiving waters suggests there is limited influence on the sediments from storm drains for these metals. Lead was highest in the receiving water in Area 1 (Downtown) at the daylight area near Harbor Drive. However, most other storm drain and receiving water samples were relatively low for lead. Zinc was similar in concentration between storm drains and receiving waters. The Area 4 (Residential & El Cajon Blvd.) storm drain samples were highest for cadmium, copper, and zinc, while the Area 1 (Downtown) receiving water was highest for lead. This may suggest a more localized source of lead in Area 1 (Downtown). Graphs of the remaining constituents can be found in Appendix D.

Total DDT isomers, Chlordane, and synthetic pyrethroids (Bifenthrin and Permethrin were highest in the storm drain samples from Area 4 (Residential & El Cajon Blvd.). Diazinon and Chlorpyrifos were generally low or not detected indicating these pesticides are not being used with any regularity or their degradation rates are relatively high in comparison to other pesticides. Total PCBs were generally low or not detected, but were highest in the Area 1 (Downtown) receiving water sample at Harbor Drive. PAHs were highest in Area 1 (Downtown) receiving waters and Area 2 (Balboa Park) storm drains.



	Cadmium	Copper	Lead	Zinc
Area 1 (Downtown) RW	0.237	35.41	439	106.6
Area 2 (Balboa Park) RW	0.1615	10.9875	18.62375	95.9575
Area 3 (Residential) RW	0.2975	16.04	49.99	136.49
Area 4 (Residential & El Cajon Blvd.) RW	0.218	10.72	12.76	68.01
Area 1 (Downtown) SD	0.9	0.5	0.7	1.5
Area 2 (Balboa Park) SD	380.0	95.1	13.8	124.2
Area 3 (Residential) SD	86.7	39.8	74.7	89.8
Area 4 (Residential & El Cajon Blvd.) SD	400.8	430.1	201.6	368.5

Analytes

RW=Receiving Water, SD=Storm Drain

Figure 5-2. Receiving Water Sediment and Storm Drain Sediment Metals Results in Switzer Creek Displayed by Area

5.2 Exceedance of Published Guidelines

5.2.1 Overview of Applicable Guidelines

There are a variety of established guidelines for freshwater and saltwater sediments which were used for evaluating the concentrations of sediments detected. Both freshwater and saltwater guidelines were used for different reasons. The freshwater guidelines are the appropriate guidelines for evaluating freshwater receiving waters within the watershed. However, the TMDL that is being developed for this watershed is for the mouth of the Switzer Creek in San Diego Bay, where saltwater guidelines are used. Therefore, to gain perspective on the potential impact that these sediments would have if they were to reach the mouth of the creek, saltwater guidelines were applied. Saltwater guidelines are generally more conservative and vary depending on the constituent compared.

The following is a description of the guidelines that were used during this study. The threshold effect level (TEL) represents the level below which concentrations are expected to have adverse effects only rarely (MacDonald et al., 2000). The second is the probable effect level (PEL). The PEL is the concentration above which there is expected to be adverse effects frequently (MacDonald et al., 2000). There were both freshwater and saltwater versions of this standard developed. Additionally, for both freshwater and saltwater, lethal concentrations of 50% of a testing population were developed (known as LC_{50}s).

There are other guidelines developed for saltwater. There is the effect range – low (ERL) and effect range – median (ERM) sediment guideline, which were developed by the National Oceanic and Atmospheric Administration using a database which compiled many different data sets. The results were organized from highest to lowest and then any study which reported adverse effects was identified. The ERL is the 10^{th} percentile of the results and the ERM is the 50^{th} percentile (NOAA, 1999).

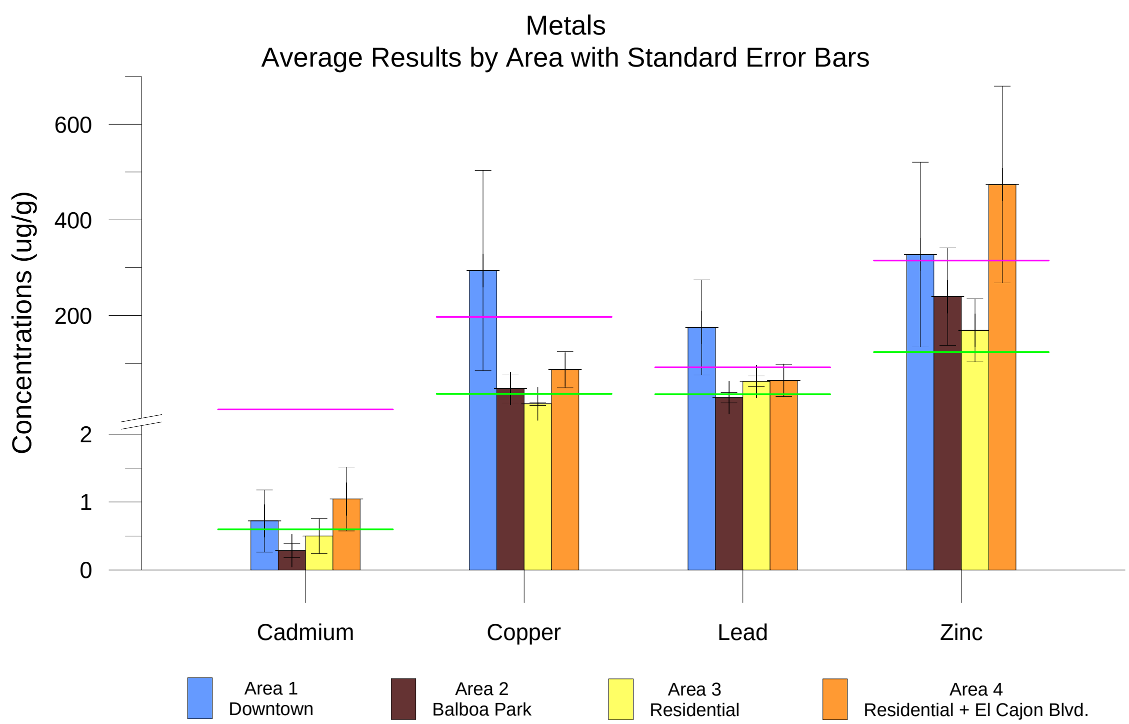
5.2.2 Results of Fresh Water Guideline Exceedances

When comparing all of the parameters to the fresh water guidelines, there were exceedances in all areas assessed. Most of these exceedances, especially in areas 4 and 3, were either organochlorine pesticides (Total DDT isomers and Chlordane) or synthetic pyrethroids (Bifenthrin, Permethrin, Cyfluthrin, and Cypermethrin). Areas 1 and 4 had the highest number of exceedances (Table 5-1).

Table 5-1. Number of Exceedances in Switzer Creek by Area for Each Fresh Water Guideline

Fresh Water Guideline	Area 1 (Downtown)	Area 2 (Balboa Park)	Area 3 (Residential)	Area 4 (Residential & El Cajon Blvd.)
TEL	6	4	4	6
LC_{50} – low *Hyalella azteca*	5	3	3	4
LC_{50} – high *Hyalella azteca*	4	3	2	4
PEL	3	2	2	3

In Area 1 (Downtown), the PEL exceedances were noted for copper in Area 1 (Downtown), lead in Area 1 (Downtown), and zinc in Areas 1 and 4. Cadmium was below the PEL in all areas (Figure 5-3). For the organochlorine compounds (Total DDT isomers and Chlordane), PEL exceedances were noted in Areas 2, 3, and 4, but not in Area 1 (Downtown) (Figure 5-4). Area 4 (Residential & El Cajon Blvd.) generally had the highest pyrethroid exceedances of the upper *H. azteca* LC_{50}. Bifenthrin was above the upper *H. azteca* LC_{50} in all areas. Permethrin was above the upper *H. azteca* LC_{50} in areas 2 and 4. Cyfluthrin was above the upper *H. azteca* LC_{50} in Areas 1, 2, and 4, and Cypermethrin was above the upper *H. azteca* LC_{50} in Area 4 (Residential & El Cajon Blvd.) (Figure 5-5).



Note: Error bars show standard error for the analyte concentrations for each area. Area 1 includes four (4) sites, Area 2 includes seven (7) sites, Area 3 includes four (4) sites, and Area 4 includes three (3) sites.

[1] Fresh water sediment benchmark

Figure 5-3. Freshwater Sediment Exceedances for Metals in Switzer Creek

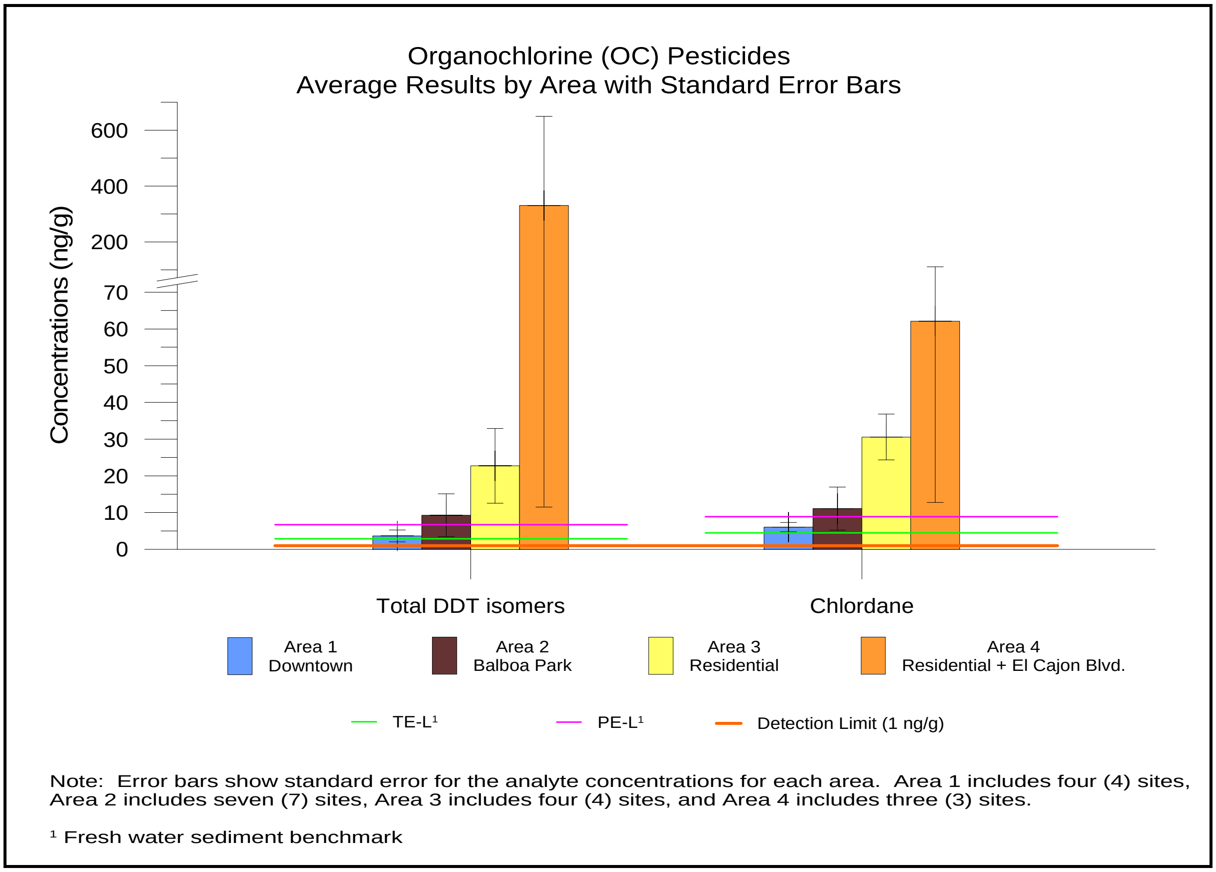


Figure 5-4. Freshwater Sediment Exceedances for Organochlorine Pesticides in Switzer Creek

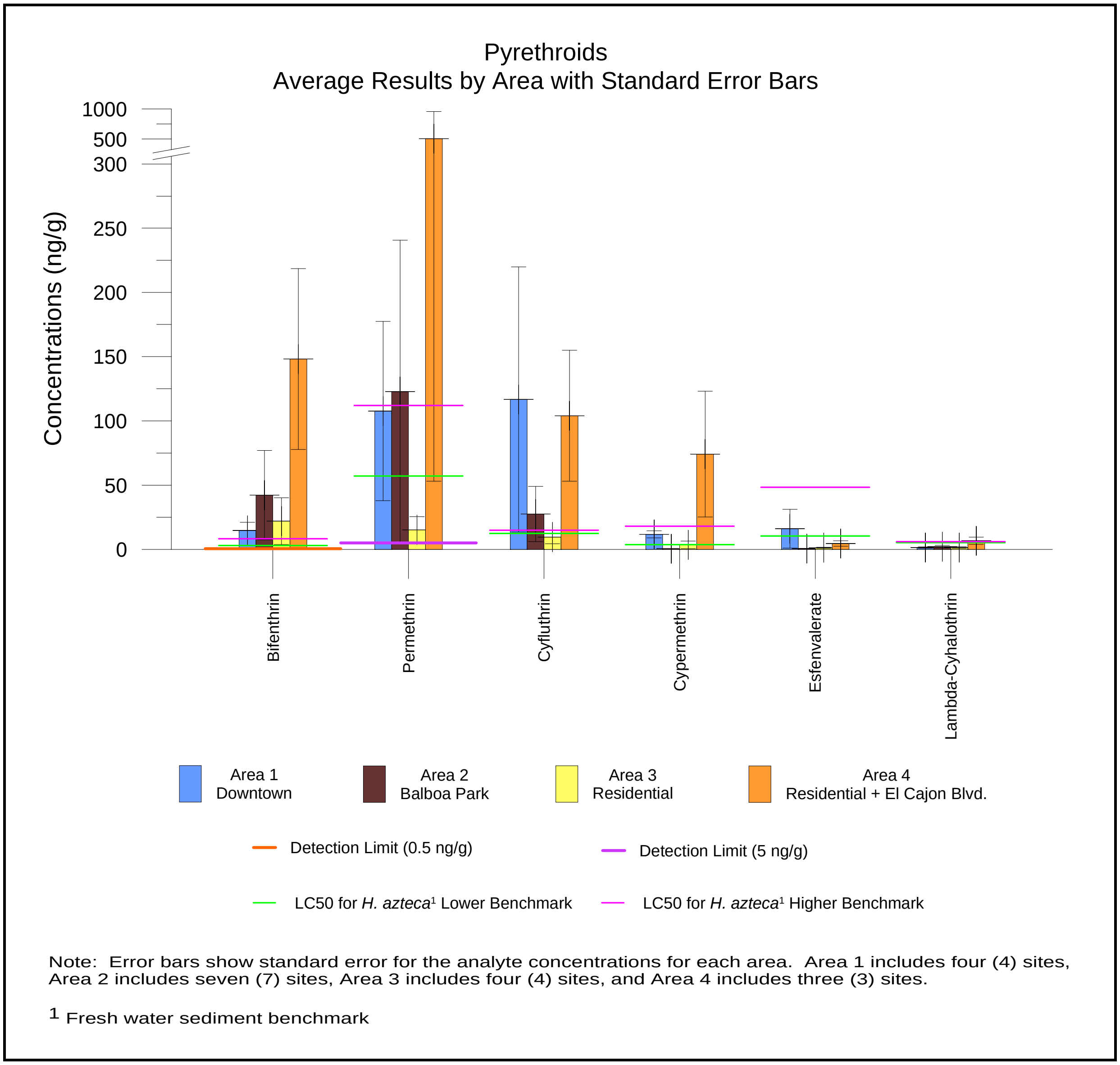


Figure 5-5. Freshwater Sediment Exceedances for Synthetic Pyrethroids in Switzer Creek

Copper concentrations were plotted and colored, showing the distribution of copper exceedances in Switzer Creek (Figure 5-6). The colored crosses show the constituent levels compared to freshwater sediment criteria and the circle is compared to saltwater sediment criteria. Maps such as this were generated for all of the groups of COC and are presented in Appendix E.

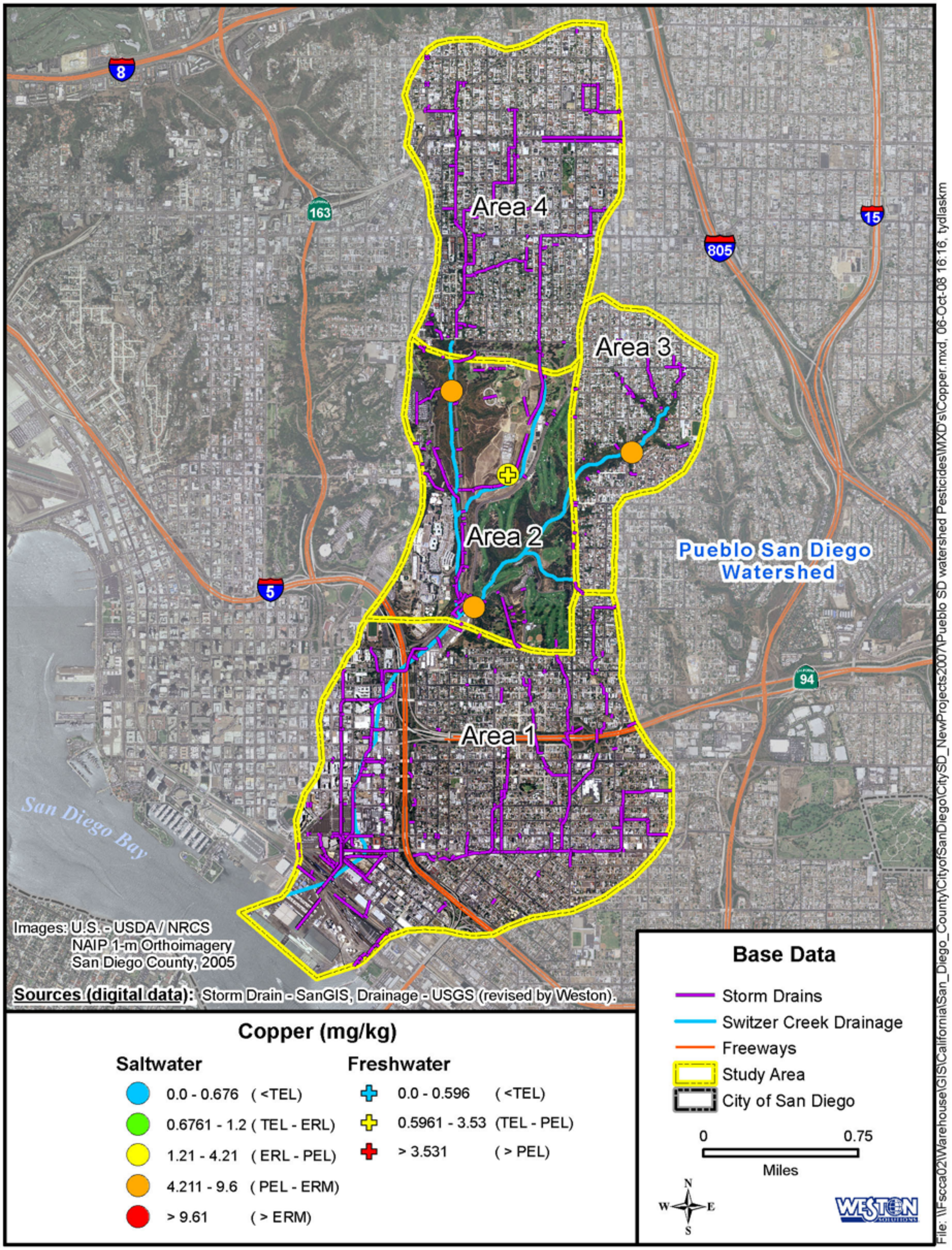


Figure 5-6. Map of Copper Exceedances

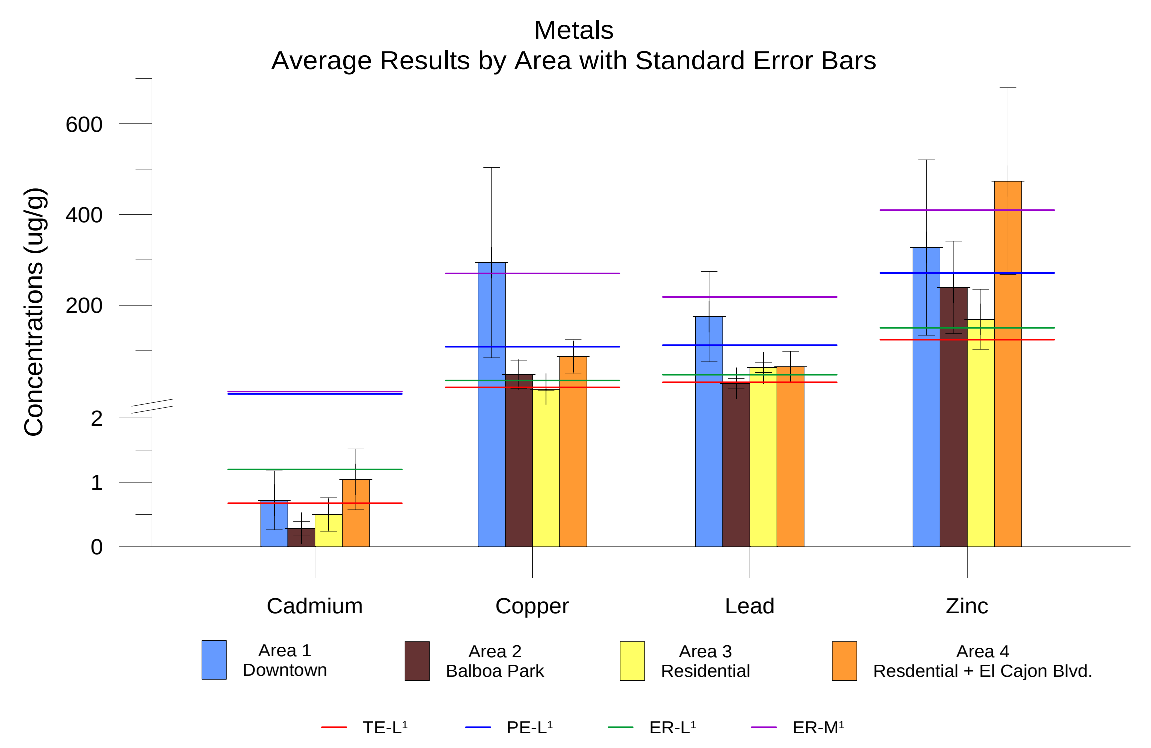
5.2.3 Results of Saltwater Guideline Exceedances

Saltwater exceedances were similar to that of freshwater exceedances. Areas 1 and 4 had the highest numbers of exceedances (Table 5-2). All areas had more exceedances in general when compared to the saltwater guidelines since they are more conservative.

Table 5-2. Number of Exceedances in Switzer Creek by Area for Each Saltwater Guideline

Saltwater Guideline	Area 1 (Downtown)	Area 2 (Balboa Park)	Area 3 (Residential)	Area 4 (Residential & El Cajon Blvd.)
TEL	7	5	4	7
ERL	6	5	4	5
PEL	4	2	2	3
ERM	2	2	2	3
LC50	2	2	1	2

In Area 1 (Downtown), many of the saltwater exceedances were a result of metals exceedances (Figure 5-7). Specifically, copper exceeded all four of the saltwater parameters. Zinc was very high in Area 4 (Residential & El Cajon Blvd.) and exceeded all saltwater guidelines.



Note: Error bars show standard error for the analyte concentrations for each area. Area 1 includes four (4) sites, Area 2 includes seven (7) sites, Area 3 includes four (4) sites, and Area 4 includes three (3) sites.

¹ Marine sediment benchmark

Figure 5-7. Saltwater Sediment Exceedances for Metals in Switzer Creek

Organochlorine pesticides were most prevalent in Area 4 (Residential & El Cajon Blvd.) and level of total DDT isomers and Chlordane were above the saltwater ERM guidelines (Figure 5-8). Levels were also high in Areas 3 and 2, where all of the saltwater guidelines were also exceeded.

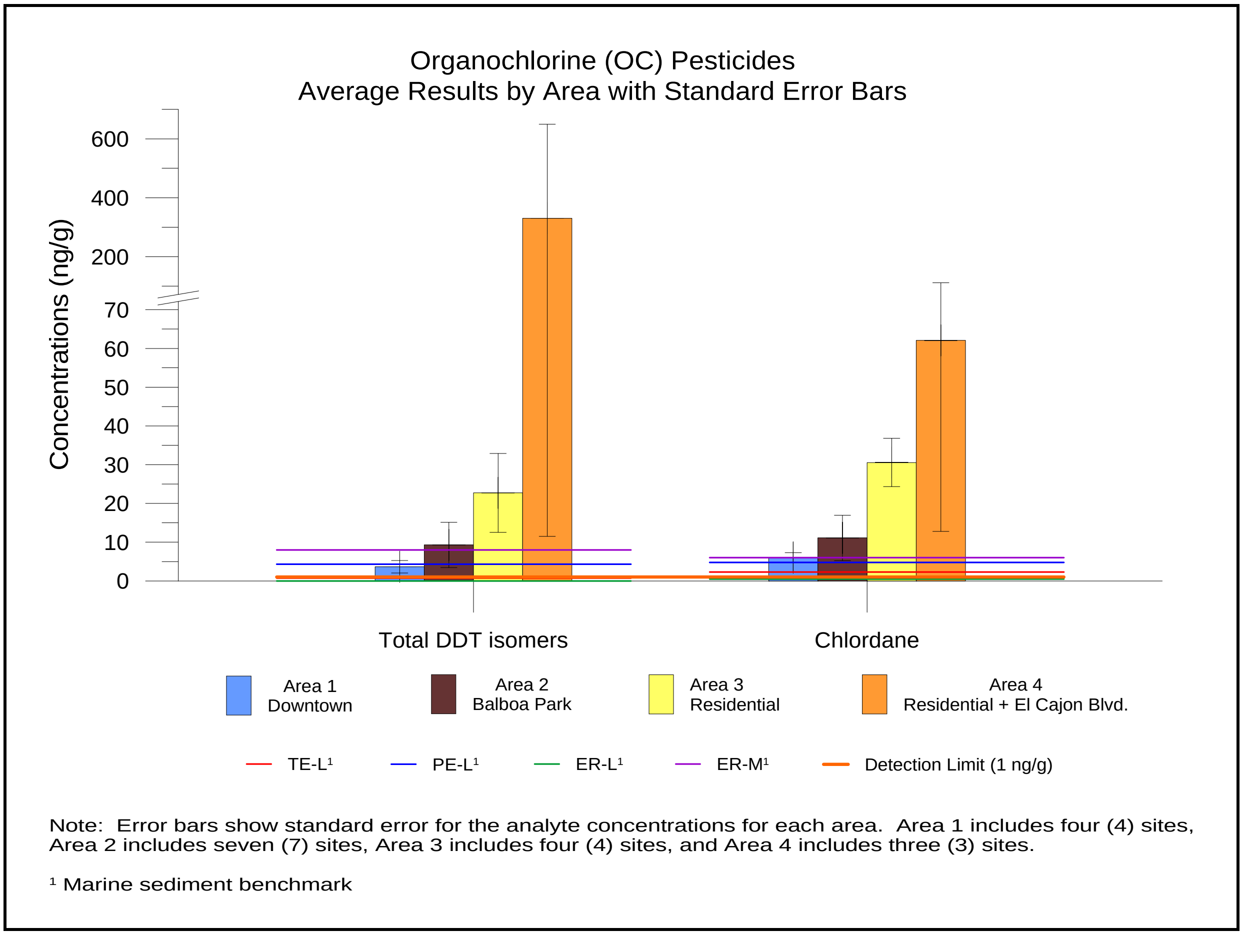


Figure 5-8. Saltwater Sediment Exceedances for Organochlorine Pesticides in Switzer Creek

The majority of the remaining exceedances were a result of elevated synthetic pyrethroid concentrations in Areas 1 and 4 (Figure 5-9). PAHs were all below the ER-M and below the PEL in all areas except one (Area 2 Balboa Park), while PCBs were below both the ER-M and the ER-L (Figure 5-10 and Figure 5-11 respectively).

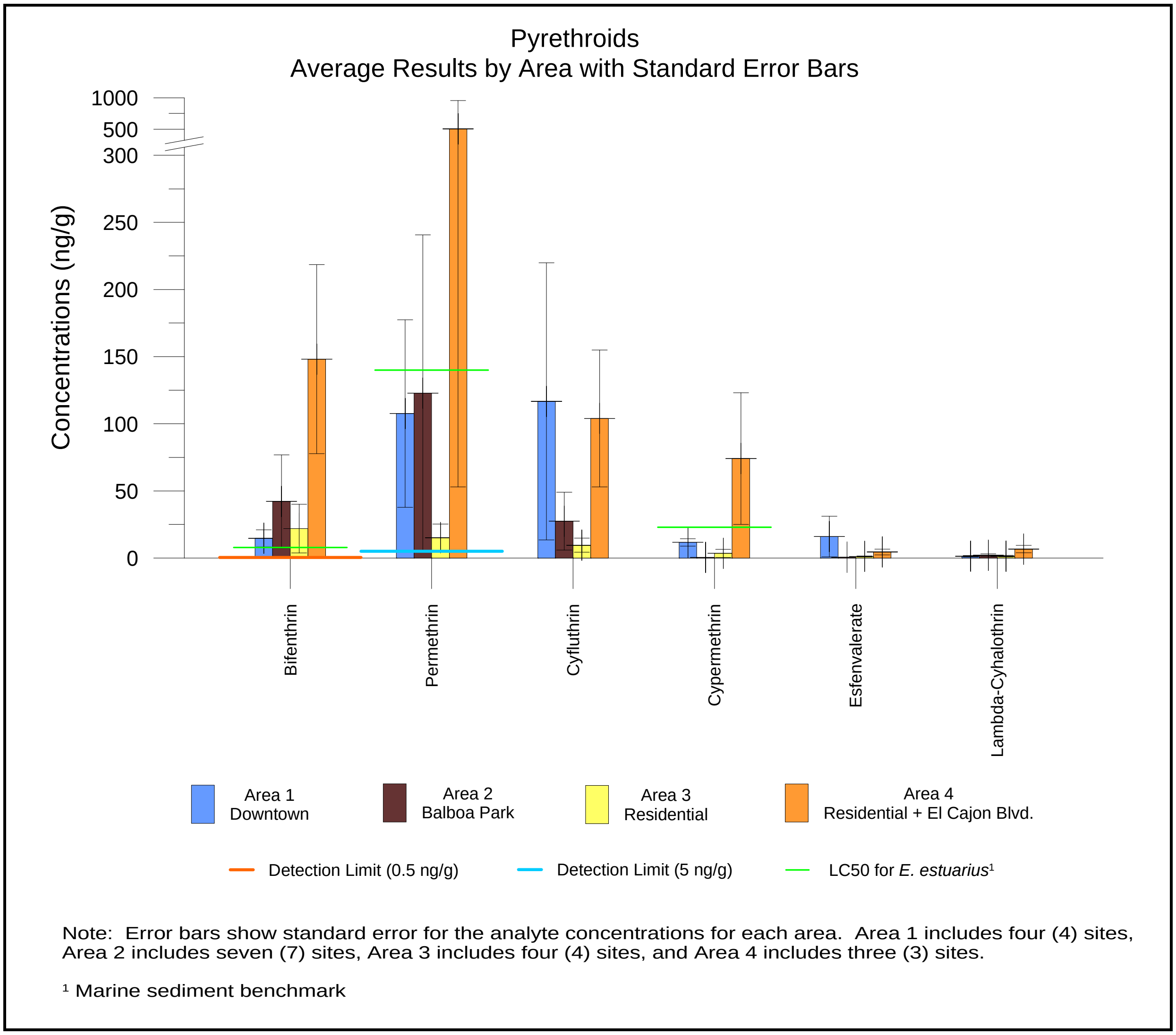
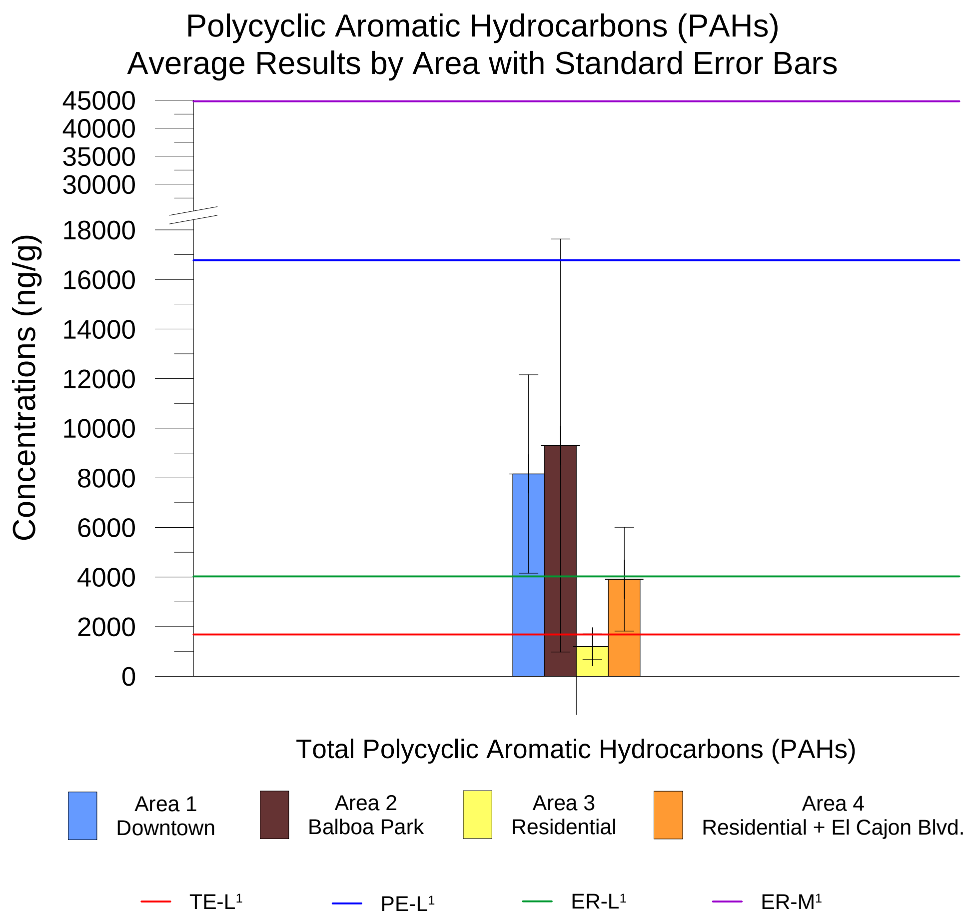


Figure 5-9. Saltwater Sediment Exceedances for Synthetic Pyrethroids in Switzer Creek



Note: Error bars show standard error for the analyte concentrations for each area. Area 1 includes four (4) sites, Area 2 includes seven (7) sites, Area 3 includes four (4) sites, and Area 4 includes three (3) sites.

[1] Marine sediment benchmark

Figure 5-10. Saltwater Sediment Exceedances for PAHs in Switzer Creek

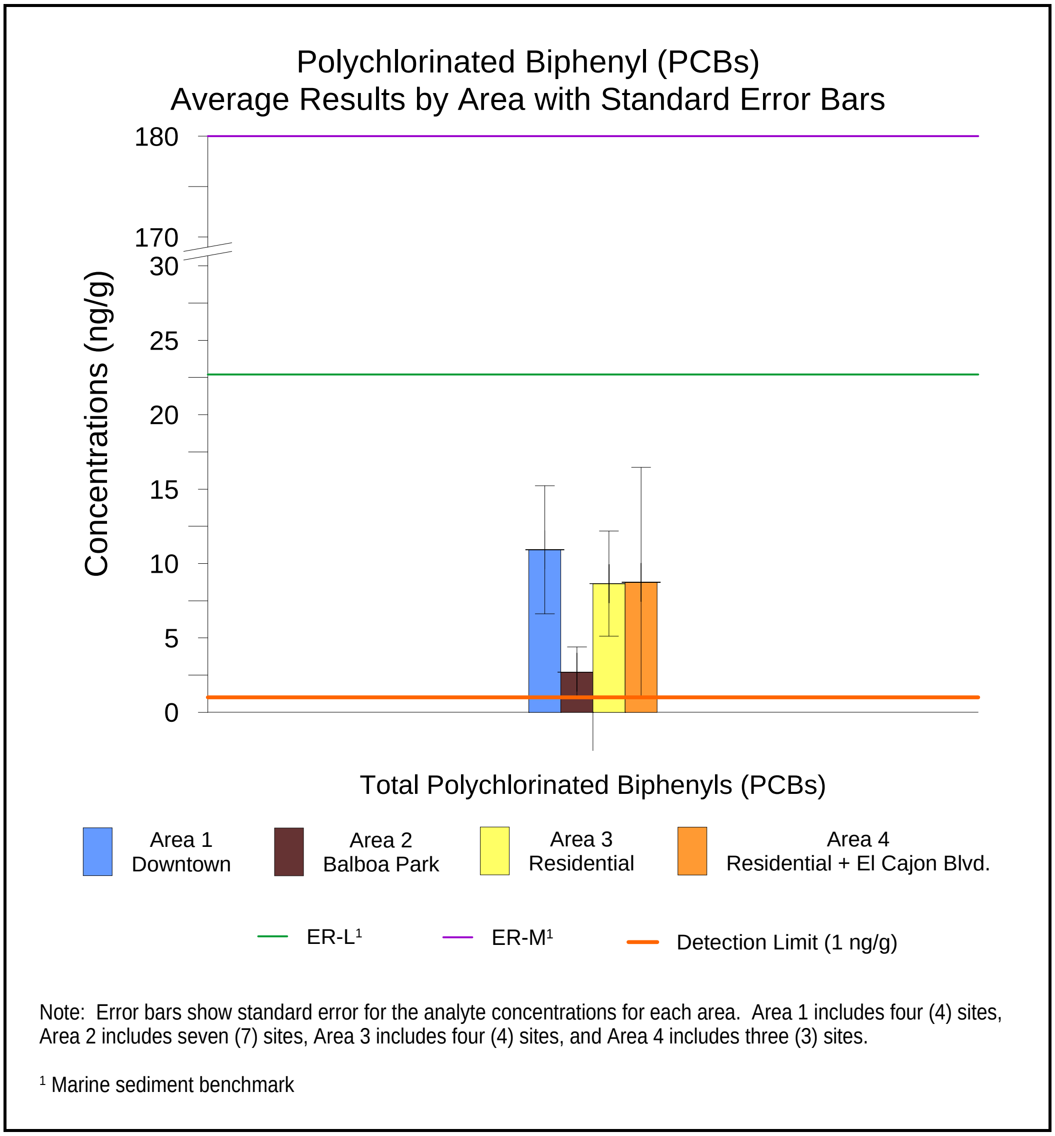


Figure 5-11. Saltwater Sediment Exceedances for PCBs in Switzer Creek

When all of the exceedances in the watershed were plotted, Areas 1 and 4 account for over half of all exceedances. Although the land uses in these two areas are different, the sediment in these two areas has been influenced the most by metals and pesticides. A comparison was also done between the exceedances in the storm drain samples versus those in the receiving water. As can be seen in Table 5-3, the storm drain samples had more exceedances in all areas of the watershed.

Table 5-3. Storm Drain Versus Receiving Water Exceedances in Switzer Creek

Total Exceedances	SW-TEL	SW-PEL	SW-ER-L	SW-ER-M
Receiving Water	25	13	25	10
Storm Drain	52	26	46	18

6.0 CONCLUSIONS AND RECOMMENDATIONS

The focus of this study was to characterize sediment pesticide concentrations in the Switzer Creek Watershed. The study was conducted to answer questions related to TMDLs for the mouths of Switzer, Chollas, and Paleta Creeks where elevated detections of the banned organochlorine pesticides Total DDT isomers and Chlordane were detected. Additionally, metals (copper, lead, and zinc), PAHs, organophosphate pesticides, and synthetic pyrethroids are known COCs in these watersheds.

Based on the sample results assessed, some conclusions are presented to answer the following study questions:

1. **What is the spatial distribution of pesticides and other relevant COCs in sediment in Switzer Creek?**

The pesticides Chlordane, Total DDT isomers, and synthetic pyrethroids were highest in and most frequently detected in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential) which coincide with residential and commercial land uses. Although DDT and its degradation isomers were detected, the concentrations are indicative of historical usage and not indicative of recent application. DDT isomers are generally persistent and have long half lives in soil. The compound 4,4-DDT was detected during the initial sample event, but was not detected during follow-up sampling which further confirms evidence of historical pesticide use and not recent application. Organophosphate pesticides were rarely detected and demonstrate that the USEPA ban on these pesticides is effective.

Copper and lead were highest in Area 1 (Downtown) while zinc was highest in Area 4 (Residential & El Cajon Blvd.). Cadmium was relatively low in comparison to copper, lead, and zinc. However, cadmium, copper, and zinc were highest in Area 4 (Residential & El Cajon Blvd.) and Area 2 (Balboa Park). Lead was highest in Area 1 (Downtown) receiving water locations. PAHs were highest in Area 1 (Downtown) and Area 2 (Balboa Park). PCBs were rarely detected.

2. **Are areas of Switzer Creek impacted in specific areas related to current and historical pesticide use?**

This question was answered by the elevated detections of Total DDT isomers, Chlordane, and synthetic pyrethroids in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential), which have primarily residential land uses. Synthetic pyrethroids were detected in all areas. However, organophosphate pesticides were rarely detected or were just above the detection limit. DDT isomers and Chlordane were historically used for pesticide control. Currently, synthetic pyrethroids are the most commonly used pesticides to control ants, termites, and mosquitoes. Because DDT and Chlordane are banned compounds, the elevated levels detected in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential) suggest that these pesticides were previously applied in areas not subject to environmental exposures until soil excavations, erosion, or building demolition occurred in recent years. Re-sampling of several sites in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential) to confirm detections of 4,4-DDT showed no detections of 4,4-DDT and generally lower concentrations of the breakdown products DDE and DDD.

Synthetic pyrethroids are the most readily available retail pesticides and it stands to reason that elevated detections of these compounds would be expected. However, their route to the storm drain network likely occurs through improper applications to impervious surfaces subject to washoff. Applications of these pesticides to impervious surfaces can occur through lawn and garden products, professional pest control operators (PCOs), and via broadcast spraying to control mosquitoes.

3. Do sediment concentrations exceed published sediment guidelines or LC_{50}s for target species?

Based on the data assessed, it is evident that Total DDT isomers, Chlordane, synthetic pyrethroids, and metals (copper, lead, and zinc), are being detected at levels above published sediment guidelines in the Switzer Creek Watershed. Although PAHs and infrequent detections of PCBs, Diazinon, and Chlorpyrifos were noted, these compounds were below the effects level expected to cause lethal effects to freshwater or marine organisms.

In conclusion, the results of this study demonstrate that Chlordane, Total DDT isomers, synthetic pyrethroids, copper, lead, and zinc should be classified as COCs in the Switzer Creek Watershed. Because the watershed is similar to many urbanized settings within the City and County of San Diego, it stands to reason that storm drain sediment results would likely be similar in other watersheds. Synthetic pyrethroids are a known issue on a statewide basis and have been detected in storm water runoff in most areas of San Diego County. The California Storm Water Quality Association (CASQA) Pesticide Subcommittee is actively working with the Department of Pesticide Regulation to provide information and recommendations during the pyrethroid re-registration process, with the ultimate goal of preventing these compounds form entering the MS4 or receiving waters.

Recommendations

Management actions focused in Area 4 (Residential & El Cajon Blvd.) and Area 3 (Residential) may help to reduce the use and detections of legacy pesticides in these areas. Increased education and outreach combined with household hazardous waste disposal events may help to eradicate stored sources of these pesticides. Promoting integrated pest management techniques may also be useful. Alternatively, promotion of ecowise certified PCOs (Ecowise, 2008) may help to influence other PCOs to operate in a more environmentally friendly manner. Additionally, pre-termiticide applications of these compounds are long lasting and may be a result of building renovations and soil excavations in older areas of the watershed and may be detected for some time. Enforcement of construction site erosion controls or BMPs may help to stabilize sediments from these activities. Because most of the COCs are associated with sediment transport, BMPs focused on controlling sediments from entering the storm drain system may be beneficial at reducing sediment concentrations of these compounds. The City of San Diego is currently evaluating the effectiveness of aggressive street sweeping in the Pueblo San Diego Hydrologic Unit with a focus in Chollas Creek. Mechanical street sweepers, vacuum assisted street sweepers, and regenerative air street sweepers are being assessed for their effectiveness at reduce pollutant loadings that include sediment, pesticides, metals, and other constituents. Lastly, efforts focused at removing sediment from storm drain catchments prior to the storm season will help to reduce the amount of sediment able to be mobilized during the wet weather season.

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